Marine Energy Infrastructure Study :
Stage A - Industry Consultation and Concept Design

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Halcrow
A CH2M HILL COMPANY

BVGassociates

Llywodraeth Cymru
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Document history

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Executive Summary

The Marine Renewable Energy Industry has the potential to contribute to the Welsh Government's ambitions to reduce greenhouse gas emissions, reduce energy dependency and to promote sustainable economic growth and employment. Facing the Atlantic and the Irish Sea, Wales has enviable wave and tidal energy resources. In the global adaptation to the recognised affects of climate change, the greatest opportunities will fall to those regions that are able to access nearby energy resources quickly and efficiently, making use of existing local infrastructure and supply-chains wherever possible. Wales is in a good position to place itself at the leading edge of technology development through exploitation of its natural resources. Wales has important strengths and advantages that put it in a competitive position within the UK and Europe with regard to developing a marine renewable energy industry that can fully utilise local energy resources and develop technical expertise and manufacturing capability that could be exported. It has a rich industrial heritage, which means that Wales can offer ports and supply-chain infrastructure that may be adapted to meet the needs of this nascent industry.

In March 2011, the Welsh Government published the results of its Marine Renewable Energy Strategic Framework (MRESF) project. This was a three year study that collated and mapped a broad range of marine environmental data throughout Welsh Territorial Waters. The MRESF study found there to be extensive raw wave and tidal energy resources around the Welsh coastline that have the potential for development. There are powerful tidal streams in the seas around Anglesey and the Llyn Peninsula in North Wales, and at Pembrokeshire and the Bristol Channel in South Wales. Furthermore, a large wave energy resource exists off the south-west coast. The MRESF study estimated economically extractable wave and tidal energy resources equivalent to between 1.5 and 6.4GW of installed capacity, depending on the spatial and environmental constraints that may be assumed to apply.

The aim of this Marine Energy Infrastructure Study is to generate a development concept for wave and tidal energy generation in Welsh waters. This is based on researched industry requirements and taking into account the regional resource, constraints, infrastructure and potential economic benefits. This study will support Welsh Government's efforts to achieve their regional marine renewables energy objectives and to promote economic regeneration through the establishment of a new industry. The study complements the findings of the Marine Renewable Energy Strategic Framework (MRESF) study and makes clear recommendations for the Welsh Government to consider in supporting industry.

This study is being undertaken in two stages. This report covers Stage A, which has undertaken extensive industry consultation and developed independent non-site specific proposals to provide infrastructure in support of the marine renewable energy industry in Wales. Stage B will take the recommendations made in Stage A and present these in more detail. This will be in terms of preferred deployment zones, individual project descriptions, programmes and costs, method of delivery and organisations that may be well placed to carry the recommendations forward. The preferred development concept recommended for further consideration incorporates both physical shore-side infrastructure and improvements to the electrical distribution grid. However, it also includes site-specific marine surveys and targeted research and development activities to overcome key obstructions to large-scale development.

In coordination with the Welsh Government and our supply chain specialists, BVG Associates, Halcrow Group Ltd has undertaken detailed consultations with industry. These have given us an opportunity to really understand the ambitions of the emergent marine renewables sector,

but also given us insight into some of the frustrations and pitfalls to which it is exposed. The largest and most experienced device developers are looking to move from single prototype device testing to the first multi-megawatt arrays that will pave the way for full-scale commercial development. Large utilities and Original Equipment Manufacturer (OEM) organisations are starting to invest in the technologies and developers are looking forward to establishing bases of operations to build components and assemble generator devices. Wales is already established as a centre of excellence in energy production, and has a supply chain and ports ready to diversify and expand to meet the needs of energy generation projects. There is a vibrant academic community that is keen to assist industry in developing and testing emergent technologies and in understanding the marine environmental conditions in which they operate. Whilst much of the licensing of marine development is controlled by the UK government, Wales offers expert technical advice to both decision-makers and developers alike in helping them to best utilise the considerable energy resources whilst also protecting the unique marine environment.

The Welsh Government wants to support the industry on its journey from early prototype testing through to full commercial generation. In order to achieve this, the Welsh Government is uniquely positioned to assist the industry in overcoming acknowledged obstructions relating to consenting processes, a lack of detailed development site data, and risks associated with the provision of energy infrastructure. This report makes the following recommendations as to the next steps necessary to encourage and assist developers, ports, academics and consenting authorities in their work to exploit Welsh marine energy resources for the benefit of local communities.

High Priority Early/Immediate Recommendations (2012 to 2013)

- Make MRESF source data more widely available.
- Grid connection studies to investigate required grid upgrades to each of the primary resource areas.
- Obtain detailed site data and analysis for all potentially viable resource areas.
- Following-on research into likely interactions between full-scale arrays and the marine environment.
- Develop a clear ‘plan or programme’ for the development of the primary resource areas for arrays up to 30MW (the anticipated project-level limit on revenue subsidy), and make this the subject of a Strategic Environmental Assessment (SEA).
- Undertake a supply chain study to identify and encourage welsh suppliers who could adapt and expand into the marine renewable energy industry.

High Priority Medium-term Recommendations (2012 to 2017)

- Primary Resource Sites should be prepared for use by :
    - Obtaining and making available detailed site data relating to energy resources and environmental baseline
    - pre-consenting of deployment sites, where possible
    - Lobbying for, consulting, investigating and then procurement of grid connections to main resource areas. This will include shore-side works to upgrade the networks in certain areas.
    - Committing to provide financial support to technical and environmental monitoring
    - Inclusion of developments in local plans. Consultation regarding possible navigational Safety Zones.
- Network and cable route studies for National Grid upgrades in anticipation of full commercial arrays from 2017 onwards.

Wales benefits from both viable energy resources and strong supporting infrastructure, and this means that with the right governmental support, it will be in a good position to host a number of early multi-megawatt pre-commercial arrays within the next five years.

To reflect the First Minister's announcement of 14th March and the release of the Welsh Government's Policy Statement 'Energy Wales : A Low Carbon Transition', this report supports Wales' ambition to be 'open for business' with regard to the development of marine energy production.

Contents

1. Introduction

1.1 A Strategy for Marine Renewable Energy Development

The Welsh Government sees great potential in developing the marine energy resource around its coasts and strongly supports the development of a Marine Renewable Energy Industry in Wales. Facing the Atlantic and the Irish Sea, it has enviable Wave and tidal energy resources. A rich marine heritage means that Wales can offer ports and supply-chain infrastructure that may be adapted to meet the needs of this nascent industry. In March 2011, the Welsh Government published the results of its Marine Renewable Energy Strategic Framework (MRESF) project. This was a three year study that collated and mapped a broad range of marine environmental data throughout Welsh Territorial Waters. This included the available energy resources that could be extracted by current technologies, together with physical and environmental constraints that may apply to development. The project was led by consultants RPS on behalf of the Welsh Government with the information presented in a report and as a GIS mapping tool. Further information is available at http://mresf.rpsgroup.com.

On 14th March 2012 the Welsh Government released its Policy Statement 'Energy Wales : A Low Carbon Transition'. This sets out the Welsh Government's policy on the promotion and development of all forms of energy. It restated its commitment to the European Union's objective of reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990, with a consequent impact on increasing low carbon electricity generation. It describes the Government's ambition to 'create a sustainable, low carbon economy for Wales', together with its priorities and actions that it sees as necessary to promote good energy generation and management. Whilst promoting expansion across all energy sectors, it also encourages sustainable economic growth for the benefit of local communities. The statement stressed Government commitment to work in partnership with industry to achieve mutual objectives. On Pages 23 and 24 of the statement, consideration is given to marine energy, and the opportunities presented for industry, academics and developers to work together to successfully develop the impressive energy resources that exist in the seas around Wales.

1.2 Overview of this Marine Renewable Energy Infrastructure Study

To follow on from the MRESF, the Welsh Government has commissioned Halcrow Group Ltd (a CH2M Hill Company) to undertake this Marine Renewable Energy Infrastructure Study. An overall objective of the study is to indicate the direction of travel on the path towards the establishment of a new industry, including the identification of broad deployment zones. The MRESF study found that Wales benefits from a potentially valuable energy resource. However, there is a need to understand what additional steps could be taken by government to initiate large-scale deployments and associated industrial growth. The study has comprised a comprehensive review of all available data, and this has led to the preparation of a number of options for marine energy development and particularly the associated marine and shore-side infrastructure that needs to be provided. A key aspect of the study is consultation with device developers and other stakeholders.

The Infrastructure Study is being delivered over two phases:

- **Stage A (current stage)** - In coordination with the Welsh Government and our supply chain specialists, BVG Associates, we have engaged with stakeholders to identify industry needs. This has allowed us powerful insight into the needs of the various parts of the marine renewable energy industry and forms the basis of the recommendations made in Section 5 of this report.

- **Stage B (future stage) -** Having determined industry requirements and understood the appetite for provision of infrastructure and other intervention to support marine energy development, the second phase will consider the MRESF data in detail to allow us to find suitable sites for the short-listed development concepts within Welsh Waters. It is anticipated that the project will recommend one or several individual projects within specified deployment zones to be taken forward to more detailed feasibility studies and, where appropriate, construction. The Stage B report is scheduled for completion in August 2012.

Throughout this report, recommendations are summarised at the end of each relevant section, then collated into a comprehensive table at the end of the document.

Figure 1.1 below shows a simplified flowchart of the information and consultations used in the delivery of the study. A more detailed description of the study methodology is given in Appendix A.

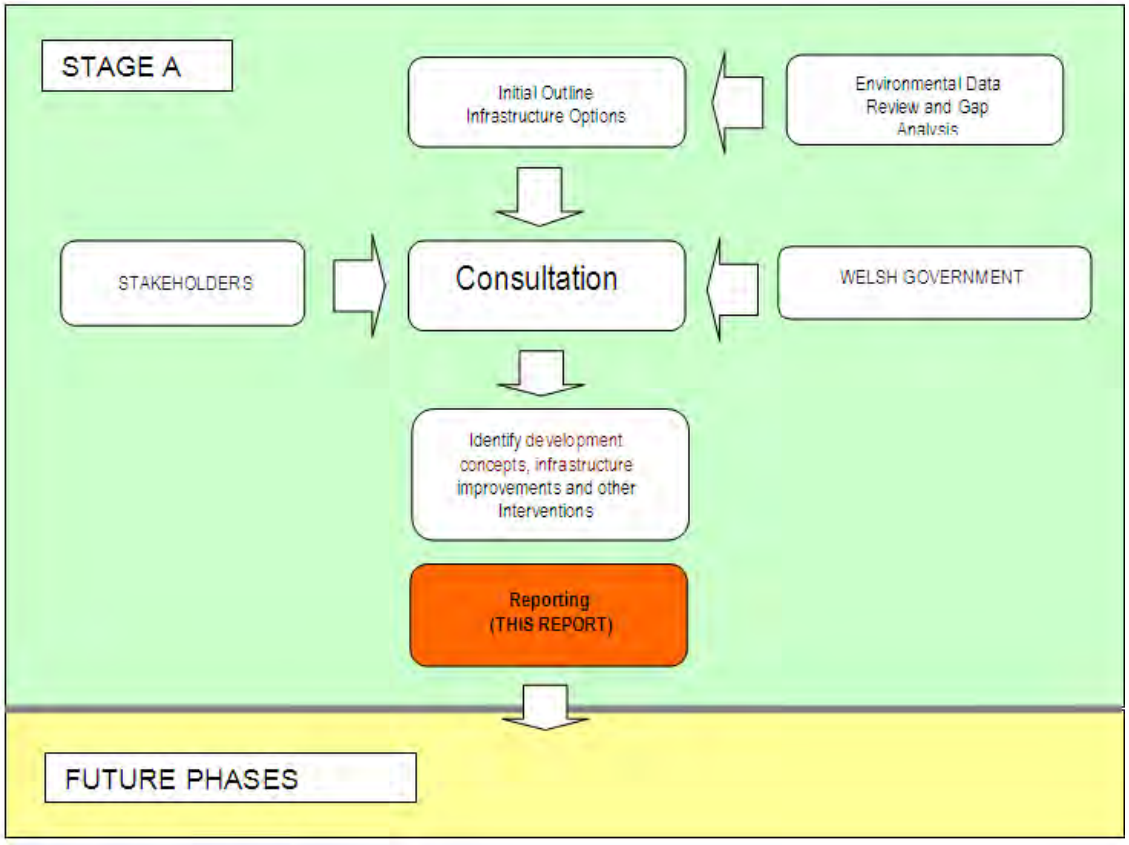

Figure 1.1 – Study Methodology

1.3 Concurrent studies

The preparation of this document in Wales has coincided with a number of concurrent studies into the future of marine energy development in the UK. These are summarised below, together with key results and recommendations where these are available. There appears to be broad agreement in the recommendations and conclusions of these separate high-level studies that have been reflected in our own detailed investigations and consultations in Wales

House of Commons Energy and Climate Change Committee. In February 2012, the UK government's Climate Change Committee published a report,entitled 'The Future of Marine Renewables in the UK'. The report makes the following key points.

- Fundamental to the development of a marine renewable energy industry in the UK and globally is the attraction of private investment.
- For this, a stable and consistent policy regime must exist.
- Investors are unwilling to act alone to take on risk presented by the emergent technology
- The priority over the next decade must be to focus on reducing the overall cost of marine renewable energy and incentive schemes such as the Renewable Obligation should be applied accordingly.
- If cost reductions are delivered successfully, more ambitious plans for the deployment of marine renewable energy projects can then be adopted.
- Key non-commercial barriers to development are grid constraints, environmental concerns, and a lack of clarity over the planning process

In Wales, developers have indicated that attracting private investment into marine renewable energy projects is important for projects to be successful. This would be encouraged by either direct Welsh Government or European funding of specific projects, or by public funding of activities that would benefit the wider industry. Our own Welsh stakeholder consultations also found challenges relating to grid connection, environmental and consenting processes.

The Crown Estate have commenced their UK Wave and tidal Energy Strategic Areas Project to map marine energy resources. It has sought advice and marine environmental data from developers and academics in order to construct a detailed hydrodynamic computer model of the UK coastline. Initial model outputs show that the development potential for commercial scale tidal strategic areas is largely driven by the available resource, and commercial scale energy resources occur in distinct pockets of opportunity around the UK. Wave opportunity has a less spatially defined footprint and covers a much larger areas. It is anticipated that the available energy resources in Welsh Waters will be found to be broadly in accordance with or even exceed the MRESF low constraints scenario (6.4GW, 14.4TWhrs/yr), and that overall availability of energy resources will not be found to be a barrier to development.

Recommendation - Depending on the timing of the two studies, the results of this Infrastructure Study should be fed into the Crown Estate study by providing constraints analysis and views on site selection.

Renewable UK have completed a State of the Industry report Wave and tidal Energy in the UK for 2012. This records achievements to date and looks forward to future developments. Renewable UK believes that the wave and tidal energy industry in the UK had reached a tipping point as it has decisively moved towards commercial viability through improvements in technology. Specifically, Renewable UK has asks the UK government to:

- Enable investment and cost reduction for a sustainable industry by providing urgent clarity and an appropriate strike price level in the Electricity Market Reform.
- Support the development of the first arrays with correctly targeted, coordinated and appropriate funding streams.
- Take positive and proactive action to minimise key project risks such as underwriting costs, grid infrastructure limitations and environmental constraints.
- Support innovation to ensure continued improvements in reliability and cost

DECC – Consultation. The UK Department for Energy and Climate Change (DECC) have undertaken a consultation on proposals for the levels of banded support under the Renewables Obligation for the period 2013-17 and the Renewables Obligation Order 2012. In its consultation document UK DECC acknowledged that the marine renewables industry 'will require both grant and market instrument support' in order to establish. Grants to a total value of £20M are already available through the Marine Energy Array Demonstrator (MEAD) fund, although DECC have indicated that further grants could be made available by the devolved regional governments. Revenue support for wave and tidal energy is due to be increased from 2 to 5 Renewable Obligation Certificates (ROC's) from April 2013. This level of support is due to continue to 2017, after which the Electricity Market Reform (EMR) will be established as the primary means for incentivising renewable energy production.

There are a number of common themes running through the above concurrent studies, and these can be seen to support the advice and recommendations that have arisen from our own investigations in Wales.

1.4 Learning from Offshore Wind

The emergent wave and tidal energy industry can benefit from its predecessor, offshore wind, and it is useful to reflect on the conditions required to allow the offshore wind industry to be self sustaining in terms of attracting private investment. The Crown Estate's Round 1 offshore wind leasing was for developments of up to 30 turbines, which is comparable to the limit to be set by DECC in its proposed ROC banding for the period to 2017. The complex requirements for site selection, difficult access and infrastructure provision are broadly similar to those of Wave and tidal energy. It was necessary for early offshore wind technology to be proved in terms of reliability, efficiency and cost of energy prior to being able to attract the investments necessary to develop large arrays. In this way, it could be presumed that the Wave and tidal industry would require government support until it reaches a similar stage of development.

However, the development of wave and tidal technology remains at a disadvantage in relation to offshore wind due to the following:

- suitable energy resources are located in discrete, remote areas
- the marine environmental conditions at those sites are very aggressive
- grid capacity is often limited
- Wave and tidal energy devices do not have an on-shore equivalent technology from which to gain experience

It is for these reasons that a higher level of governmental intervention may be required in order to establish an offshore marine renewable energy industry, at least up to the point where large commercial scale (>30MW) arrays are common-place. An example of this is the Marine Energy Array Development (MEAD) fund that has already been established by UK DECC. In Wales, a number of device developers have benefitted from funding contributions from the Welsh Government for research activities, including Tidal Energy Ltd's demonstrator project at Ramsey sound.

Recommendation – If Wales is to establish a lead in the growth of the marine energy industry, it should allow for some level of capital funding of marine energy projects, in addition to the revenue support provided by the Renewable Obligation or future Feed-in Tariffs.

2. Power from the Oceans

2.1 Marine Power Generation Technology

In the context of this study, the term 'marine renewable energy' refers to energy generation that draws from the power of the sea itself, namely wave and tidal current devices. To give context to the contents of this report, and to help the reader to visualise the technology that could be constructed and deployed in Wales, information is provided in Appendix B on the types of equipment that can be used to extract energy from the sea. This Marine Renewable Energy Infrastructure study only directly considers the opportunities presented by Wave and tidal Stream energy developments, as it is this that represents a unique opportunity for Wales to expand into this new sector.

2.2 Physical Infrastructure

In considering the extraction of energy from the sea, the energy generation devices are only part of the necessary development. To operate generators effectively over long periods and transmit the energy to shore, a number of additional items of equipment and facilities are required. The following Marine Energy Infrastructure is critical to the effective development of energy projects.

- Foundations / moorings
- Electrical cables
- Electrical hubs
- Navigational marks / lights & navigational Safety Zones
- Communications / data-links
- Cable landfall
- Shore station / sub-station
- Electrical grid upgrades
- Port facilities
- Land transport links

It is common for the scale of the engineering works necessary to achieve the required infrastructure to be comparable with or even greater than that of the actual generation equipment. It is the provision of this infrastructure, and other potential supporting actions, that this study is considering. On the following page Figure 2.1 shows a conceptual drawing of a notional marine renewable energy deployment site, with key items of infrastructure shown.

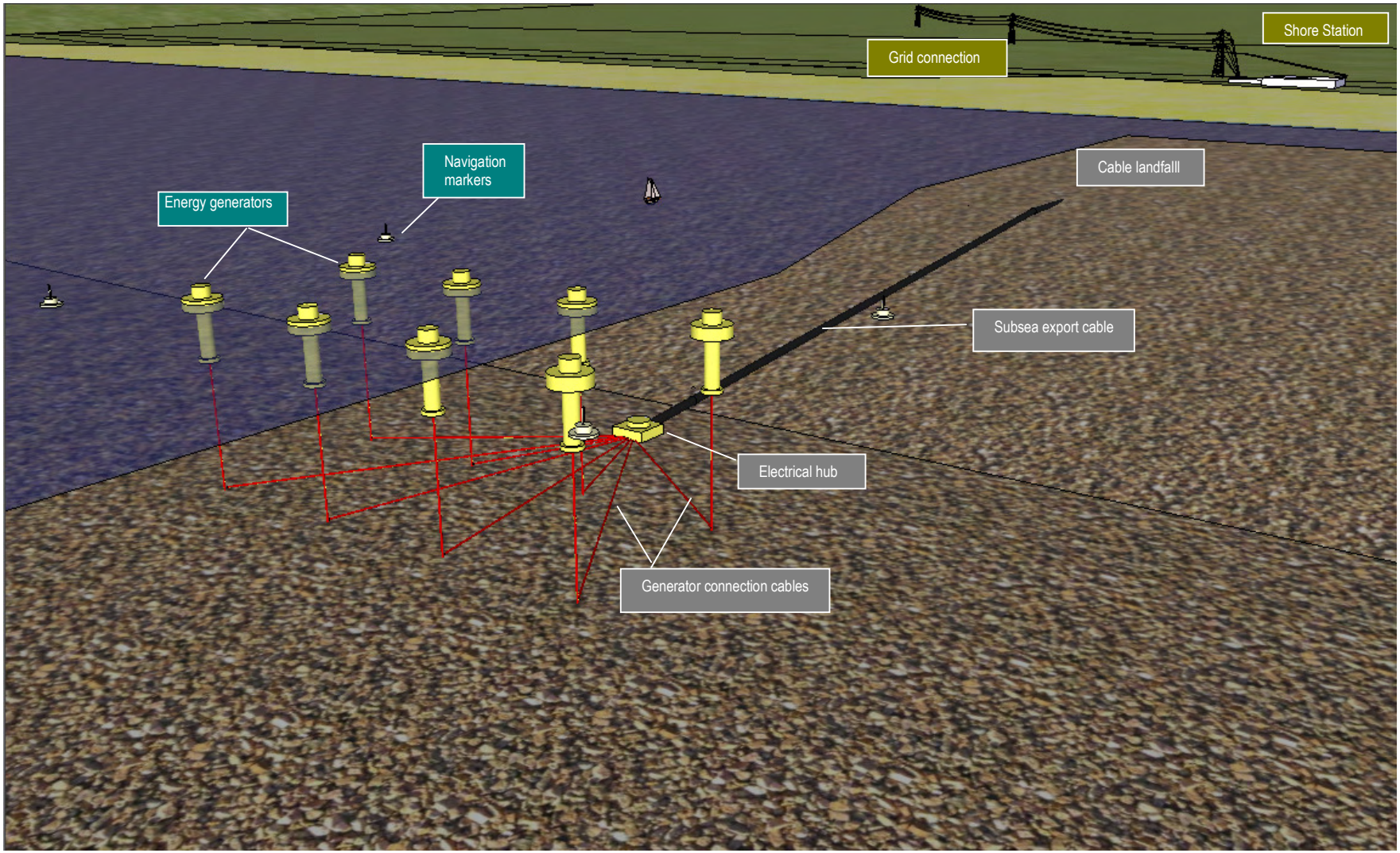

Fig 2.1 - Marine Energy Deployment Site

2.3 Energy Resources

Strong wave energy resources are distributed throughout the world's oceans, but particularly in the Southern Ocean, Pacific, and North Atlantic, whereas the strongest tidal energy resources are concentrated at a small number of sites in Western Europe, Canada, and south-east Asia. However, much of the global energy resource is difficult to extract due to the practicalities of working in remote locations at sea. The UK, and Wales in particular, has an advantage in having energy resources close to centres of population and industry. Within Wales, the MRESF study identified extractable resources equivalent to an installed generation capacity of 1.5 to 6.4GW (3.4 to 14.4TWhrs/yr) of wave and tidal development. In the development of the global marine renewable energy industry, the greatest opportunities will fall to those regions that are able to access nearby energy resources quickly and efficiently, making use of existing local infrastructure and supply-chains wherever possible. Wales is in an enviable position to place itself at the leading edge of technology development through exploitation of its natural resources. Leading developers have already shown considerable interest in Wales, and the following key development activities are planned.

- Marine Current Turbines (MCT) – a 10MW array of SeaGen-type devices in the Skerries tidal race off the coast of Anglesey
- Tidal Energy Ltd (TEL) – a 1.2MW single demonstration device to be installed at a grid-connected test site at Ramsey Sound, Pembrokeshire. This will be a precursor to a larger 10MW project at St David's by Tidal Energy Developments South Wales Limited (TEDSWL)

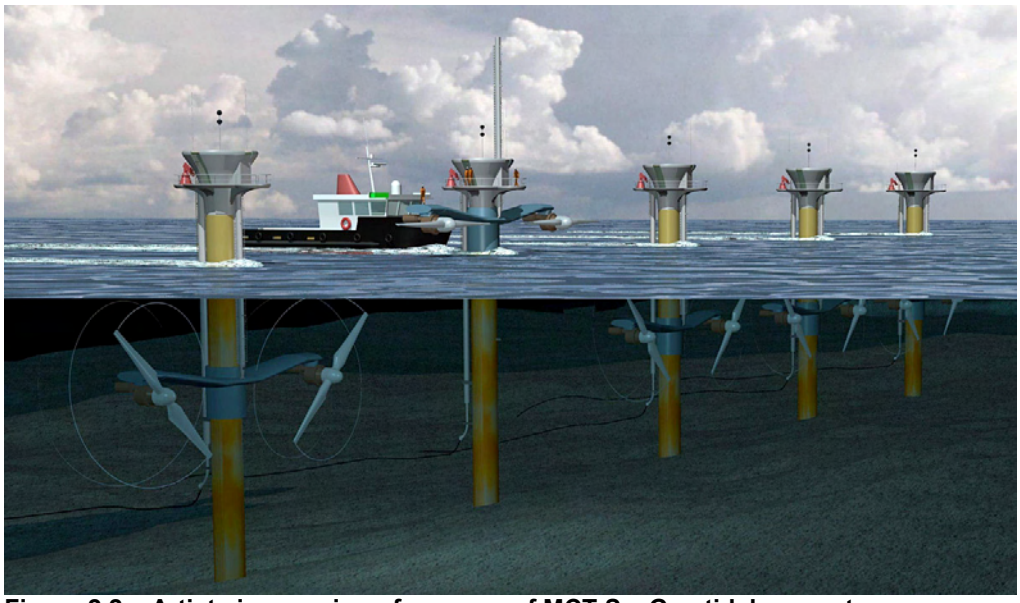

Figure 2.2 – Artists impression of an array of MCT SeaGen tidal generators

2.4 Key challenges and opportunities for Wales and UK

Globally, the marine renewable energy industry has not expanded and developed as fast as initially hoped. Despite the fact that the raw energy resources are effectively 'free', the costs and risks associated with collecting that energy are high in relation to fossil fuel based generation. The size and weight of the equipment necessary to harvest relatively small amounts of energy, and the need to transport and deploy devices at offshore sites, presents considerable challenges to existing energy companies and supply-chains seeking to adapt into marine renewables. This report discusses a number of challenges that face this emergent industry, relating to grid connectivity, financial support, marine environmental data, legislation, environmental impact assessment and marine engineering. Whilst there are difficulties, Wales has a unique opportunity to overcome these challenges through its proximity to easily accessible energy resources, academic expertise, ports, industrial capability and potential for governmental support.

2.5 Introduction to Development Options Considered

The marine energy industry has made significant steps over recent years with the development of EMEC, Wave Hub, FabTest and NAREC as demonstration and testing facilities. It is also an industry that attracts both intellectual and financial support from the UK Government bodies such as the Carbon Trust and DECC, and private organisations such as the ETI. Most recently the Crown Estate has offered leases within the Pentland Firth and has commenced a resource assessment with a view to similar leasing rounds elsewhere in the UK. However, it is still apparent that there is a gap in the defined route from prototype technology through to fully developed commercial scale installation.

In advance of the consultation phase of this study, it was considered that opinion could be most effectively canvassed through the presentation of a number of non-site-specific development concepts. These were presented to stakeholders as potential infrastructure projects that could assist in the development of the marine renewables industry. The following development concepts were considered for both wave and tidal generation devices:

A Single Device Test Site

There are a number of existing test facilities in the UK. There are open-water facilities for both wave a tidal device testing at EMEC, and for wave devices at Wave Hub. Furthermore, pool and flume test facilities exist at NAREC for scale model prototypes, and these are supplemented with full-scale drive-train testing at the same site. A sheltered but non-grid-connected open-water facility exists at Falmouth, known as FabTest. Even with this level of provision, a number of developers have successfully developed their own grid-connected test sites, demonstrating some residual level of demand. Therefore, we presented a development scenario that would provide an additional facility. It was considered

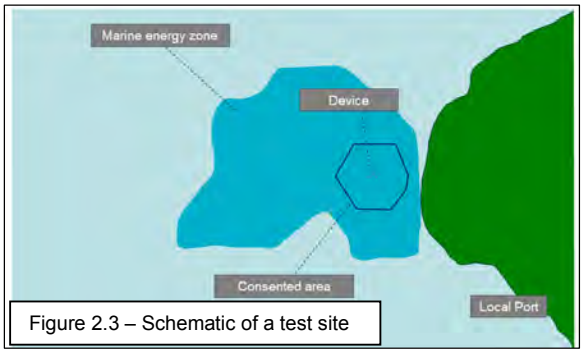

Figure 2.3 – Schematic of a test site

that such a facility should be developed at minimal cost, with an emphasis on finding a site (or sites) free from spatial or environmental constraints. It should be within a fairly gentle energy resource, and close to a port for easy access. The objective would be that devices could be deployed for short periods and then returned to port for modification and adjustment prior to redeployment. There would be opportunities to test a variety of alternative component designs quickly, with elements such as turbines, blades, floats, power take-off and mooring assemblies being swapped in order to optimise designs. Initially, such a site need not be grid-connected, and power production could be demonstrated through use of a floating or device-mounted load cell.

A Multi-Device Test Site

The Wave Hub site in Cornwall has attracted developers into two of its four available berths, and has interest in a third berth for use with an experimental floating wind turbine. The Wave Hub is design for testing of groups or 'arrays' of wave energy converters, with a capacity of 4-5MW in each. Whilst there may appear to be saturation in the market for wave energy device testing, with tidal developers looking to expand towards multi-device arrays, there may be demand for a grid-connected, multi-device tidal stream test site (a "Tide Hub"). Several developers would be able to deploy and simultaneously assess the performance of and interaction of multiple devices, making use of shared infrastructure such as cable, electrical hubs and navigation marks. Furthermore, much of the risk and cost of consenting would be removed, with developers required only to provide information and assessment of device-specific impacts.

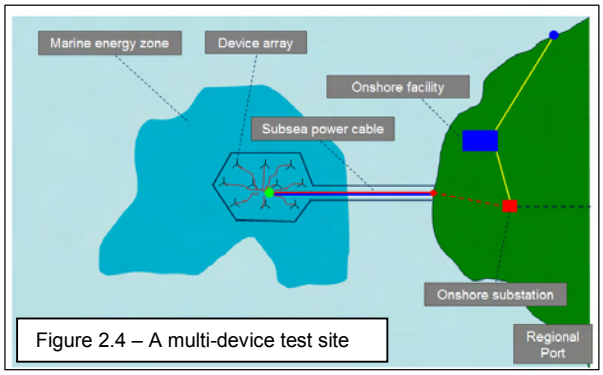

Figure 2.4 – A multi-device test site

Single-Developer Small Array

Leading developers are reaching a point where they are seeking to expand towards larger arrays (typically up to 10MW). However, they are concerned about the cost and risk associated with such an expansion. Key areas of risk relate to availability of site data, uncertainty regarding environmental impacts, fisheries, cable and landfall arrangements and onshore grid reinforcement. Therefore, developers are seeking support from government in managing these risks, and this could be provided through provision of physical infrastructure for a particular project and management of environmental impact assessment and consenting.

Full-sized Commercial Array

As developers become more confident through the successful delivery of small arrays, it is likely that they will seek to expand further. It is known that DECC is seeking to link the provision of

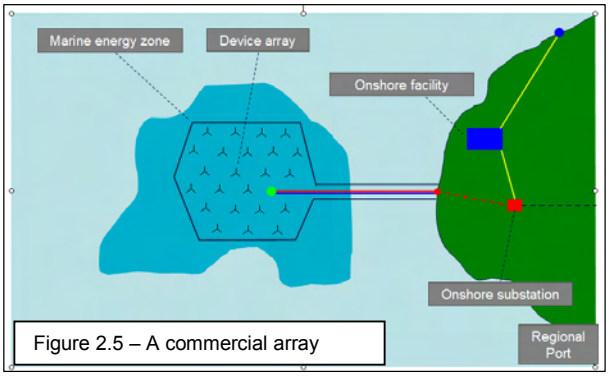

Figure 2.5 – A commercial array

subsidies in all areas of renewable energy development with observed reductions in the cost of energy to the consumer over time. It is likely that this could only be achieved through standardisation of designs and mass-production leading to arrays of towards 30MW. Even if there were confidence to scale up in this way, developers may still require assistance in strategic planning of deployment zones, shared onshore grid infrastructure and landfall arrangements, and with individual project consent applications.

Feedback received from stakeholders during the initial stages of consultation indicated that, whilst the provision of physical infrastructure as described above would be valuable in supporting growth, there were a number of other measures that could also be taken to improve confidence and accelerate growth in the industry.

- Identification and promotion of preferred deployment zones
- Provision of detailed resource and engineering data for those areas
- Assistance with Environmental Impact Assessments, environmental surveys and monitoring
- Consenting, or pre-consented deployment sites
- Provision of on-shore grid connections and grid upgrades
- Establishment and training of supply-chain
- Provision of deployment and recovery vessels

Together with the proposed infrastructure provisions, these additional measures were presented to stakeholders in order to understand how these would encourage growth. A full list of the organisations involved in the production of this study is given reporting Appendix D.

3. The Welsh Opportunity

3.1 Introduction

There is a big opportunity for Wales in using its marine energy resources, academic expertise, and industrial capability to capture the economic benefits from encouraging the growth of this nascent industry,

3.2 Energy Resources

The MRESF study has indicted that Welsh territorial waters contain impressive wave and tidal energy resources that could be exploited by a new world-leading industry. Whilst not yet published, it is anticipated that the ongoing Crown Estate Strategic Areas Project will broadly support the conclusions of MRESF and this will strongly support the view that, subject to application of appropriate environmental constraints, the energy resources will be sufficient to encourage commercial development with a deployed capacity of 1.5 to 6.4GW (3.4 to 14.4TWhrs/yr). The strongest tidal energy resources exist in Pembrokeshire, Anglesey the Llyn Peninsula and in the Severn Estuary and the study indicated a technically viable wave energy resource off Pembrokeshire. The two charts shown below have been provided by the MRESF study. These show the highest energy in the brightest coloured areas.

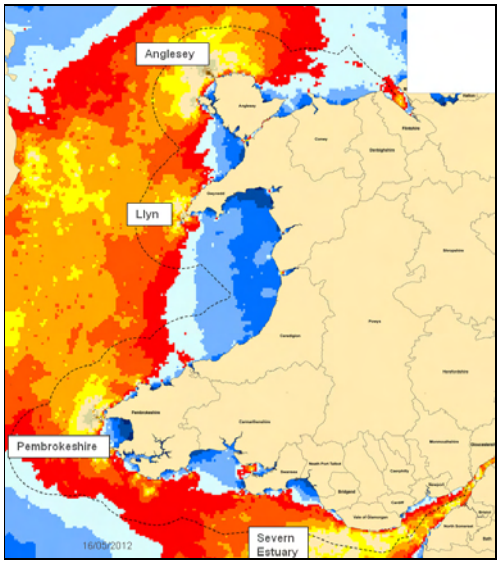

Fig. 3.1 -Tidal Energy (Mean-Peak-Spring Velocity)

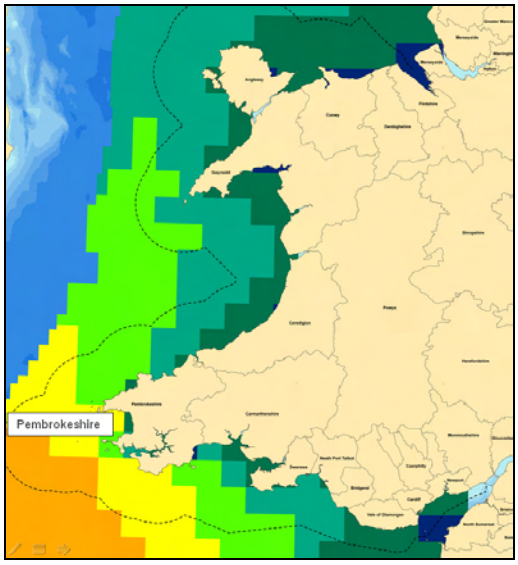

Fig. 3.2 - Wave Energy (Annual Mean Wave Energy)

All of the four identified resource areas (Anglesey, Llyn, Pembrokeshire and Severn Estuary) have extensive areas of sea with mean-peak Spring tidal velocities above 2.0m/s and Pembrokeshire has an annual average wave energy resource of 20kW/m length of wave crest. Whilst, on their own, these raw statistics are insufficient to justify deployment at any particular site, they give a strong indication that a viable energy resource exists at each of the main target resource areas.

Our consultations with developers have allowed us to understand that theoretical or hydraulically modelled resource assessments can be very useful in gaining a strategic understanding of potential energy resources, particularly if used in combination with practical field-based surveys. However, if considered in isolation, they can be misleading when applied to the siting of individual energy developments. An indication of a strong raw energy resource does not guarantee that a suitable extractable resource exists that can be used as the basis of development. In order to prove the viability of a site, detailed and site-specific marine surveys must be undertaken to record the energy resource over time. Developers have indicated that the provision of such surveys by the Welsh Government, and using standardised methodology and equipment, would do much to reduce risk to the early stages of projects. This would follow on from the work already commenced in Pembrokeshire by the Low Carbon Research Institute.

Recommendation – Undertake detailed resource surveys of primary resource areas

3.3 Proximity of Resources to Population

It is understood that a key constraint to development of renewable energy technologies is the proximity of energy resources to both centres of population and transport links. Wales has an advantage in that the highest densities of population and industry lie along the north and south coasts. This broadly coincides with the locations of strongest energy resources. Therefore, the good transport links that exist (road, rail and sea) will act to serve offshore developments with components and a workforce, as well as residential and commercial markets for the energy produced. The key energy resource areas are listed below.

- Pembrokeshire (pop. Approx. 120,000)
- Anglesey (pop. Approx. 70,000)
- Llyn Peninsula (pop. Approx. 15,000)
- Severn Estuary (pop. Approx. 700,000)

Existing Industrial Capability

Wales has a rich heritage in energy production and manufacturing. The consultation phase of this study has engaged with device developers, ports and key suppliers to existing related industries. Whilst Wales benefits from its existing capacity in oil and gas industries, there is an understanding amongst suppliers that energy production will change in the next decade, with a movement away from fossil fuels towards low-carbon technologies. For example, the Oil & Gas sector already has a highly skilled and closely regulated workforce focussed on high-value, low-volume activities. The establishment of mass-production facilities capable of continuous output of generator devices over several years would provide some relief from the short periods of very intense 'shut-down period' workload that engineering companies currently experience. Evidence from the consultation suggests that companies, such as Pembrokeshire-based engineering firm Jenkin and Davis, are looking to diversify into renewables. This presents an opportunity to anchor economic growth in Wales from this emerging industry.

> "Shut-down work won't last forever. We are looking to diversify into renewables" – Jenkin & Davis

Recommendation - Further and ongoing consultation with developers and supply-chain should be undertaken allow us to find out how developers plan to manufacture their devices. This will allow integration of device development with supply-chain capability and port operations to reduce the cost of mass-produced units.

3.4 Grid infrastructure

> "There are no generalities that apply to the assessment of grid connections; each project must be considered on its own" – Western Power Distribution

The urban and industrial areas of Wales, located along the north and south coasts, are supported by good connections to the National Grid, which operates a transmission network at voltages above 275kV. Large power stations connect directly to this High Voltage network. At lower voltages, local Distribution Networks Operators (DNO's) manage connections to the National Grid, together with those of small scale private electricity generators and distribution of electricity to domestic and commercial users. It is this local distribution network to which early commercial arrays of 10-30MW would need to connect at either 33kV, 66kV or 132kV. Discussions with DNO's and a review of the grid network information contained in the MRESF indicates that whilst there is substantial National Grid transmission capacity, and there are suitably sized local networks in the vicinity of likely shore-connections from marine renewable energy sites, these are not continuous along the coastline. Furthermore, the introduction of large new generators to the end of a distribution network that was previously designed and used to transmit electricity to users can cause local difficulties in voltage regulation. For these reasons, it is difficult to infer the feasibility and cost of necessary grid upgrades purely by inspecting the network plan, and detailed consultations are required with the local DNO in order to determine the feasibility of each proposed connection. It is likely that some small degree of reinforcement will be required to achieve the necessary grid capacity in every situation. Whilst it will be possible to connect early arrays to the local distribution networks, shore-connections capable of handling generation from multiple commercial arrays of capacities greater than 30MW would require direct connection to the National Grid, and for this to occur, extensions of the existing high voltage transmission network would be required.

Discussions with developers have indicated that the first multi-device marine renewable energy array projects would benefit from government involvement in establishing grid connections to deployment zones, together with shared shore-side infrastructure. Advice from the DNO's shows that the suitable connection points and upgrades can only be identified in coordination with grid connection studies.

Recommendation – Undertake grid connection studies to identify connection and upgrade works necessary to connect primary resource areas.

3.5 Port infrastructure

> "It is our responsibility as a port to adapt to changes in the energy industry. We are really committed to the renewable energy markets, and have already invested in changes to support this." – Milford Haven Port Authority

It is recognized that ports have an important role in supporting development of the UK's energy mix. This is reflected in the DECC UK offshore Wind Ports Prospectus (May 2009). The port requirements of the wave and tidal energy industry are broadly similar. Good ports infrastructure will enable developers to establish a base of operations for access to deployment zones throughout the life of a project. It will allow transport of components, but also manufacturing and assembly of devices and foundations. During operation of an offshore array, ports that are near to the deployment site will provide berthing for support vessels and maintenance crews. Through consultation with both developers and port authorities, this study has understood the great opportunity that the development of marine renewable energy could be for the ports sector, and that Welsh ports have both desire and potential to meet the challenge of supporting the Welsh Government's growth targets.

Typical port requirements necessary to support assembly and deployment of wave and tidal energy devices are:

- Cranes with a heavy lift capacity of up to 1000 tonnes;
- Large lay-down and storage areas of several hectares to enable assembly of components and rapid deployment of devices. Ideally, the facilities should be dust-free and include both covered and uncovered areas;
- Suitable space for final assembly adjacent to the quayside;
- Dry and potentially wet commissioning of electrical parts;
- Sufficient quay length for loading activities that could exceed 200m, or a wide (30-40m) slipway;
- Good road infrastructure access;
- Supply of support vessels and personnel. During installation of an individual project phase up to six vessels and several man years of support are required on site; and
- Sufficient draft and beam to facilitate movement of vessels and devices at a range of tides.

Wales has a number of major ports close to the identified energy resources in both North and South Wales. These are at Mostyn, [Holyhead],Milford Haven, Swansea and Port Talbot. Of these, many are already expanding or interested in expanding into renewable energy and have development space available within or close to the ports to enable an increase in provision to the offshore wind industry (Round 3 sites) whilst simultaneously looking to diversify into wave and tidal energy. Together, the ports have an estimated 55 hectares of available area that is either already available or could be quickly converted for wave and tidal developments.

Dockside port areas are at a premium and developers are encouraged to work innovatively with potential suppliers and port authorities to establish manufacturing and assembly procedures that can be implemented remotely from the actual dockside, and using Abnormal Indivisible Load techniques and specialist moving equipment to transport heavy components or even whole devices to the dockside for loading onto vessels.

On completion of large arrays, local ports will be used for a rolling programme of maintenance throughout the life (normally assumed to be 25 years) of the devices.

Fig. 3.3 - Pembroke Dock – (photo – Copyright Mark Richards – www.photowales.com for Milford Haven Port Authority)

3.6 Environmental and Consenting Expertise

Consenting bodies are knowledgeable of marine renewable energy technologies and, where sufficient data and analysis exists, they are able to provide robust advice on potential impacts. CCW is the Welsh Government's statutory advisor on nature conservation, landscape and recreational matters throughout Wales and Welsh waters out to 12nm of the coast. In the context of energy generation, CCW's role is to provide independent, evidence-based advice to Government, regulators and developers on the potential impact of strategic policy, plans and programmes and individual developments on natural heritage and it contributed widely to the MRESF study. CADW is the Welsh Government's historic environment service working for an accessible and well-protected historic

> "CCW supports initiatives which expand generation from low carbon sources while minimising unnecessary impacts on natural heritage. To better understand the environmental risks associated with marine renewables CCW believes there is a need to maximise and make widely available the learning from demonstration projects to help confirm or eliminate potential impacts and begin to address issues associated with larger scale wave and tidal stream arrays." - CCW

environment for Wales. The Marine Consents Unit (MCU) acts as a "one stop shop" for marine licensing in Wales, including marine energy projects up to a generation capacity of 1MW. It issues licenses under the Marine and Coastal Access Act 2009. Like CCW, both CADW and the MCU are active in understanding and supporting marine renewable energy projects in the management of potential environmental impacts, and have been consulted in the delivery of this study.

From 2013, it is expected that the Welsh Government will merge the functions of a number of departments and statutory authorities into a Single Body that will manage all environmental licensing activities. It is anticipated that this will act to streamline the consultation and consenting processes applicable to marine energy projects.

Following completion of both the MRESF by the Welsh Government, and the Offshore Energy Strategic Environmental Assessment (OESEA2) by DECC in 2011, we are at a critical stage in the consenting of future marine renewable energy projects. In particular, the MRESF demonstrates that, after collecting and analysing large amounts of environmental data, the key energy resources that are suitable for exploitation using currently available technology are located in discreet locations around the coast. It is important that developers and consenting organisations alike recognise the value of this step in that it should dramatically simplify future decision-making and assessments in relation to EU Habitats, Birds and Environmental Impact Assessment Regulations. However, the overall extent of marine renewables development considered by OESEA2 in the Scoping Document (DECC March 2010) was not identified (ie. a target capacity was not set) due to the early stage of technological development of the industry. OESEA2 refers to projects of up to 30MW (anticipated to be the project-scale limit of revenue subsidy for projects commenced before 2017 – see DECC consultation on the Renewables Obligation Banding Review – October 2011), but does not reflect on likely deployment zones within the time horizon of the Assessment, which is only five years. A more detailed and updated SEA that specifically assesses the impacts of marine renewable energy projects in Wales would further simplify the provision of project-specific EIA's that will be used to gain consent for individual projects. To determine the scope of further strategic assessment work, it will be necessary to liaise closely with stakeholders and statutory authorities during Stage B of this study.

Recommendation - Undertake a Strategic Environmental Assessment (SEA) of development of primary resource areas in Welsh waters

In its recent policy statement Energy Wales : A Low Carbon Transition, the Welsh Government described how it will make further improvements in the planning and consenting regimes. In particular, it will continue to seek repatriation of the consenting of offshore energy projects greater than 1MW capacity, together with onshore electrical transmission projects. Furthermore, it seeks to establish a Single Environmental Body to manage all environmental regulation and advice at a single point of delivery, and this will improve both efficiency and consistency of approach across specialisms.

3.7 Research partnerships

Wales benefits from an active academic sector that wishes to support the establishment of the marine renewable energy industry. There are two exciting research partnerships that operate in Wales, with good linkages and sharing of expertise and experience between these groups, which are part-funded by Welsh and European governmental grants.

> "Yes, we want to let developers have use of our research so they can start to develop plans for these sites, but not just that; we want this to be the start of a long and mutually beneficial relationship between developers and academics that will help the industry to grow." - LCRI

The Low Carbon Research Institute (LCRI) was set up to unite and promote energy research in Wales to help to deliver a low carbon economy. The multidisciplinary group aims to support the energy sector in Wales, UK and globally, and provides research into low carbon generation, storage, distribution and end use technologies. Members include universities and other research establishments from across Wales, including the Universities of Cardiff, Glamorgan, Swansea, Aberystwyth and Bangor.

SEACAMS (Sustainable Expansion of the Applied Coastal and Marine Sectors) is a new strategic initiative to integrate and expand research and business opportunities in the marine sector. SEACAMS is led by the Universities of Bangor, Swansea and Aberystwyth and welcomes new collaborative links with industrial partners to support growth in the marine renewable industry.

Welsh academics understand that for their research to be of maximum value, it must be targeted at areas of interest to developers. In particular, they are seeking to learn more about the main energy resource areas, and have already collected high resolution bathymetry and tidal current data for some of the most promising deployment sites.

Recommendation – Continue surveys and prioritised research into primary resource areas in order to facilitate the engineering design and environmental consenting of marine renewable energy projects

3.8 Community Engagement

Our engagement with stakeholders has shown that communities are very enthusiastic about the opportunities presented by an expansion of the marine renewable energy industry in Wales. There is an understanding that developments can offer economic benefits in terms of attracting investment, education and employment opportunities, whilst also reducing carbon emissions. Alongside this, there is a high level of environmental awareness. Communities are concerned about the known environmental impacts associated with all energy production methods, and see the expansion of the marine renewables sector as an opportunity to produce energy without damaging the unique marine environments that they enjoy.

The public and stakeholder organisations are ready for involvement much earlier in the project planning and design development process. Two key stakeholder groups have formed, comprised of developers, port authorities, academics, environmental specialist organisations, and local government. These are Marine Energy Pembrokeshire, based in Milford Haven and Energy Island, Anglesey. These organisations play an important role in gathering and distributing information and hosting numerous public and stakeholder events to promote the marine renewable energy industry.

It is important to learn from the positive experiences of the wind energy industry in the encouragement of community ownership of developments. Community engagement and ownership has the potential to address local concerns at an early stage, will reduce the risk of objections, and gives local communities opportunities to benefit from projects.

Recommendation – Continue to promote the marine renewable energy industry through stakeholder groups such as Marine Energy Pembrokeshire, and Energy Island, Anglesey.

4. Capturing the Industry

4.1 An Expanding Industry

The Welsh Government's Energy Policy Statement of March 2010 indicated the potential for an installed marine energy generation capacity of 4GW, and this was supported by the previous MRESF study. For this to be achieved there would need to be a rapid expansion of the industry and the generator technology on which it is based. Whilst the overall available energy resource does not present an obvious constraint to development, there are a number of challenges that are faced by the Marine Renewable Energy Industry, as it grows from single-device prototype deployments through the commercial-scale arrays, as follows:

- The best energy resources exist in the most technically challenging locations
- Strong tidal energy resources are mostly in areas of high environmental sensitivity and protection
- For the full potential for growth to be realised, it would be necessary to prove that contemporary generating equipment did not cause any unacceptable environmental impacts to the marine environment and could be used throughout the primary resource areas
- To develop towards fully commercial developments that could be funded primarily through private investment, the level of confidence in current technologies would need to be increased. For this, it would be necessary for any technical difficulties that were uncovered during the development of device technology to be resolved quickly.
- All necessary supporting infrastructure, from manufacturing supply-chain and ports, to on-shore grid capacity, would need to expand at a similar pace to the development of the generator technology.
- The cost of energy during initial expansion would be high in relation to conventional fossil fuel-based generation, and therefore current high levels of subsidy would need to continue until the industry had reached full-production capacity.

These potential challenges apply equally to any region of Europe. Wales has a number of strengths and advantages that put it in a competitive position within the UK and Europe with regard to developing a marine renewable energy industry that can fully utilise local energy resources and develop technical expertise and manufacturing capability that could be exported.

Major developers are already testing single full-sized prototype generators throughout the UK, including Wales. But these are individual devices, and the industry wants to grow quickly after these initial test periods are completed over the next two to three years. A number are looking to deploy multi-device arrays in order to properly understand interactions between devices and also to gain a better understanding of the impacts of multiple devices on the marine environment. This first round of expansion is expected to commence from 2015 and we should expect to see several 10-12MW arrays in Welsh waters by 2017, assuming developers are able to follow through on their current plans. From that point, major developers that can show that their current technology can be adapted to multi-MW deployments will seek to expand quickly to 30MW arrays. In

order to benefit from the next round of UK Government Renewable Obligation incentives, wave and tidal developments would need to be deployed by 2017.

From our discussions with device developers, and in consideration of the critical steps that need to be taken in order for the current technology to develop to full commercial array deployment, we can suggest the following growth scenarios to 2017 for Wales.

Scenario	Estimated deployed capacity (MW)	Assumptions / Conditions
Low	100	Difficulties in applying public funding to marine renewable projects (eg. if found to conflict with EU State Aid rules) Technology needs further R&D and adaptation to allow upscaling into array deployments Some deployment sites found to be unsuitable in terms of energy resource or sea-bed conditions First arrays subject to onerous adaptive environmental monitoring procedures, leading to periods of low energy productivity.
Medium	300	Public funding of projects is found to be successful. Energy device technology suffers only minor technical difficulties when applied to array deployments. Majority of deployment sites found to be viable. Early arrays indicate no unacceptable impacts. DECC do not apply a cap to the total ROCs available to marine renewables
High	500	Public funding stimulates enthusiastic response from private investors. No technical difficulties in application of device technologies to array deployments All development sites found to be suitable Early arrays indicate no unacceptable impacts. DECC do not apply a cap to the total ROCs available to marine renewables

Table 4.1 – Growth Scenarios

It is likely that developers will wish to establish projects at key large high-energy sites using a phased approach to project planning. This will commence through the first multi-MW arrays, which will be closely monitored to ensure a good understanding of the engineering and environmental performance of technologies employed. If successful, these early arrays will expand further into the resource areas.

Developers have indicated that, beyond 2017, some level of financial support will be required to allow the marine renewable energy industry to be viable in competition with fossil fuels. It is expected that, in line with the approach taken to subsidies for offshore wind, these will reduce over time and in proportion to the expansion of the industry. However, if new second-generation generation technologies are to be developed, these will continue to require an enhanced level of subsidy.

Assuming that sufficient incentives remain in place, first-generation developers would seek to expand further, with the deployment of much larger arrays (50-100MW). It may be assumed that after 2017, developers will be equally attracted to Wales, with its energy resources, infrastructure, and industrial capability, as to other development zones in Europe. If the technology can be shown as having no unacceptable environmental impacts, and adequate revenue funding were to continue beyond 2017, it could be expected that deployment could expand further to utilise a large proportion of the overall potential energy resources identified by the MRESF study.

Recommendation – Encourage UK Government to commit to providing adequate revenue support to projects beyond 2017.

The major developers are forming into consortia, to bring specialist expertise and capabilities together. These are starting to look for bases of operations for large-scale manufacture and in doing so they intend to get costs down by scaling up. Major developers are looking for all future deployments to be profitable. There is now some fatigue with investment in research for its own sake, and they are looking to make those investments start to produce rewards. Developers have expressed a preference to manufacture and assemble devices close to the best energy resources, but they are also interested in capturing the best economic conditions in each area with regard to local or regional government investment. It is unlikely that developers would find multiple assembly sites at remote locations to be economic. Presently, developers are holding a ‘pipeline’ of potential projects in various stages of development and planning, with a view to accelerating particular projects towards deployment and completion when device technologies are ready, and when economic and consenting conditions are optimal.

Developers often seek the most energetic sites, as these would appear to have the potential for the highest returns. However, this must be balanced against the challenges presented by the aggressive marine environmental conditions found at such sites, the durability of the device technology in question and the difficulties of access.

It is important to note that, against the background of plans for growth of current technologies, new innovative techniques for extracting energy from the sea are in development. A number of emergent technologies are in development that may be directed at lower energy wave and tidal resources that are less likely to interfere with protected landscapes, species and habitats. These include a high-efficiency tidal turbine by Swansea-based Swan Turbines, a tidal kite by Minesto, and a low energy wave device by Vertlabs. Furthermore, Pulse Tidal are seeking to make use of shallower depth sites with their oscillating hydrofoil technology. Second-generation technology developers such as these will need small test sites to enable sea-trials in more sheltered marine conditions, ideally close to ports. The development of such devices to multi-MW arrays is unlikely to be achievable in the timescales necessary to contribute to the Welsh Government's ambitious energy targets. However, the overall area of sea that can be utilised with low-energy or shallow-depth devices is much larger than for the current round of devices, and in the longer term they may allow far higher targets to be achieved. Therefore, the needs of smaller developers that are in the early stages of testing should also be considered in developing an overall strategy for supporting renewable energy production.

> "Known test sites are less risky than those that you know nothing about, even if they might have a less promising energy resource" – Pulse Tidal

Recommendation – Develop proposals for test sites for prototype devices that can operate effectively in low-energy or reduced-depth resource areas.

Recommendation – Investigate extentions of consents and re-use of existing known test sites.

4.2 Addressing Known Constraints to Development

Plans for growth in the marine renewable energy sector are extremely ambitious in relation to the small scale of currently planned developments. However, they are achievable if some of the existing constraints to development can be understood and overcome. This chapter identifies the key obstacles that were identified through the stakeholder consultation, and identifies recommended courses of action that should be considered.

Working in technically challenging locations

It is clear that major developers want to deploy in the most powerful resources, as they finally want to see financial return after spending a long time in prototype development. However, the sites with powerful resources experience difficult access for installation and maintenance. Some elements of the supply chain are undergoing significant change as they adapt technology from offshore wind into marine renewables. For example, device and cable deployment vessels are required by the marine renewables industry to adapt to operations in more aggressive marine conditions and using shorter operational windows. This will create additional demand for high-specification Dynamic-Positioning or Jack-up vessels that may already be committed to extensive offshore wind projects. Therefore, developers should try to work with ports and marine contractors to

> "We need to consider using small, bespoke vessels for deployment and recovery" – Pulse Tidal

develop new deployment and recovery systems that avoid the need for expensive high-specification vessels.

Recommendation – encourage coordination between marine contractors, ports and device developers to establish cheap and efficient means of deployment and recovery of generators.

Working in areas of high environmental sensitivity

Consenting bodies are knowledgeable of marine renewables technology and, where sufficient data and analysis exists, they are able to provide good advice on potential impacts. For example, CCW have prepared a comprehensive list of the research and development tasks that would, if completed, provide greater understanding of the impact of devices on the marine environment (see data report Appendix C). Both developers and environmental advisors alike have complained that decisions on the suitability of potential schemes are obstructed by a lack of knowledge regarding impacts on mobile species such as birds, seals and cetaceans. Historically in the UK, environmental assessment has been required to follow the 'precautionary principle', which encourages assessment of worst-case-scenarios in our efforts to understand environmental impacts of complex and innovative projects. This, together with an industry-wide lack of understanding of the likely environmental performance of multi-device arrays, has led to a 'deploy-and-monitor' approach to consenting. Under these principles, initial single-device deployments are permitted and monitored for a number of years, after which a phased deployment process may follow at each site. Following MCT's extensive monitoring of it's SeaGen project at Strangford Lough, such investigations are now being led by Welsh projects, such as Tidal Energy Ltd's deployment of it's Deltastream device at Ramsey Sound in Pembrokeshire. This will incorporate specialist detection and monitoring equipment that will record the behaviour of marine mammals in proximity to the device. It is anticipated that through collaboration between developers and environmental stakeholders, we can actively build consensus amongst regulators and advisors about the extent to which findings from one site or region are transferable to another.

> "Despite the considerable uncertainty about the environmental impacts of wave and tidal devices it is possible to deploy in sensitive areas under some circumstances. Evidence for this comes from the recent approval for a tidal stream device in Ramsey Sound off the West Wales coast. The deployment site is of high importance to species and habitats protected under the Habitats Directive, but by adopting an adaptive management approach to deployment, crucial data and information on close-scale interactions between an operating device and marine mammals will be provided for the first time anywhere in the world." – CCW

Understandably, consenting organisations and their environmental advisors want carefully phased and well-monitored projects with good baseline information. With good management, parts of large deployment zones can be used as test sites without blighting future development opportunities.

Developers should continue to seek to expand their knowledge of a zone during prototype or small array testing, with a view to larger deployment phases taking place in the vicinity of the test site. Whilst this approach can seem painfully slow for developers who are eager to expand quickly to multi-device arrays, the industry does need further extensive investigations into the potential impacts of multi-device arrays on both the overall marine energy resource and collision risks to mobile protected species. For example, greater understanding is required on the viability of protected populations in the face of potential losses from all causes, including collision risk with boats and renewable energy devices. It is hoped that, if appropriately prioritised, this research may lead to uncontested conclusions that the current generation of devices can be deployed and operated without causing unacceptable impacts to the marine environment. In turn, it is anticipated that this could lead to speedy, yet robust, consenting decisions in favour of large arrays.

Recommendation – Baseline surveys of environmental conditions throughout the primary resource areas.

Recommendation – Undertake further prioritised research into likely impacts of multi-device arrays to assist in consenting of marine renewable energy projects

It is clear that not all developers fully understand the environmental assessment and consenting processes, and this has the potential to obstruct projects. Furthermore, a number of developers expressed concern over the uncertainty associated with the cost and timescales of environmental investigations that are necessary to support consent applications, and these present one of the largest risks to projects in their early stages. Support from government with regard to the interpretation and management of environmental impact assessments would be welcomed, as would assistance in the delivery of project specific environmental investigations and monitoring.

In considering the application of government intervention in the development of projects, questions may arise as to the potential for a conflict of interests to arise between the roles of developer and regulator. However, discussions with statutory authorities and prior experience of the consenting of marine renewable energy projects has demonstrated that authorities are able to treat applications from government-led projects in a robust and impartial manner, and that good evidence-based determinations can emerge.

Recommendation - Encourage and support the existing Marine Energy Pembrokeshire business plan objective to define the consenting regime in an easily understood manner to developers.

Recommendation – Provide technical assistance to developers in the preparation of Environmental Impact Assessments for Marine Renewable Energy projects.

Fig 4.1 – Common Dolphin (photo – Mandy McMath CCW)

Availability of site-specific Data

Prior to committing to developing at a particular site, a developer must satisfy himself that he fully understands the energy resource available, the sea-bed conditions, and numerous other potential technical and environmental constraints. This level of confidence in the site conditions is necessary not only in order to attract project funding, but also to obtain the necessary consents and licenses. It is in these early stages of development that projects are most likely to fail, and any investment made in procuring information and analysis to support the project may be lost. Until consents are awarded, and in a competitive market, there is considerable risk that several developers could undertake surveys of the same area of sea, leading to duplicated work.

Our consultations with developers, academics and environmental advisors have indicated the benefits that a single publicly available and free dataset would bring to the industry. This should follow on from previous work undertaken within the MRESF and contained within The Crown Estate's MARS database, but with greater focus on the most likely deployment sites that contain the primary energy resources.

Recommendation - The following data should be collected and made freely available.

- **Existing source data for MRESF**
- **For tidal energy sites, bed-mounted ADCP surveys of the primary resource areas, supported by over-board vessel-based ADCP surveys and the construction of detailed hydro-dynamic modelling.**
- **For wave energy sites, surveys of wave heights and direction using waverider buoys**
- **High resolution bathymetric, side-scan, magnetometer and sub-bottom profiling**
- **Environmental classification surveys, where these are not already completed and available.**

In order for the primary resource areas to be taken forward into formal deployment zones that could be the subject of a Crown Estate Leasing Round similar to that undertaken in the Pentland Firth, this information will be required. It is considered that the value of this information will be recovered through the avoidance of duplication and through the early abandonment of non-viable sites. This presents a good opportunity for appropriately prioritised academic research and data gathering to directly meet the needs of the industry. Furthermore, there are opportunities to forge better links between academia and developers for the benefit of the wider industry.

Working with the Supply Chain

The following key components and services are required in the development of wave and tidal energy sites:

- Cable Manufacture (for both in-array and export cables)
- Seabed electrical infrastructure (hubs, connectors)
- Electrical engineering design and manufacture (generators, seabed infrastructure, control equipment)
- Device superstructure
- Foundations
- Blades, floats
- Turbine hubs and nacelles
- Bearings, Gearboxes, power take-off
- Deployment and recovery vessels
- Cable-lay vessels, together with rock-dumping/mattressing protection vessels
- Material source for rock-dumping/ mattressing cable protection
- Deep-water port with lay-down and covered assembly areas
- Operation and Maintenance port facilities
- Surveys, monitoring and other environmental services
- Professional / consultancy services

During the current round of prototype development, assembly and deployment, major developers are procuring the services of many separate companies through separate contracts. As these are 'one-off' contracts, with little opportunities

"When working at sea it is important to ensure that significant planning and risk mitigation measures are in place. Recovery of a device can be an expensive operation" –TEL

for additional orders in the short-term, this represents value for money for developers, but carries a high programming risk and administrative burden. As devices are proven at sea, and then in small arrays, developers will seek to make larger orders. As projects move into full commercial production, contracts will last for several years, with components produced for assembly of devices on production lines that could produce at a rate of up to one device every two weeks. In these circumstances, it is likely that developers will seek to appoint Single Contract Suppliers that would be contracted to manage all parts of the supply chain. In this way, risks are passed to the supply chain and for large projects, this is likely to present the best value of money.

Whilst small local suppliers may be attractive to developers during prototype development, there may be some reluctance to use them on larger contracts for the following reasons.

- Small suppliers may not be able to offer quality management systems that will be demanded by developers and their 3rd party technical accreditors.
- They are less likely to have the financial backing or be able to raise the insurance cover required.
- If large contracts are funded by government, then they are subject to EU procurement rules and must be advertised and managed in accordance with strict procedures. This can place an administrative burden on small suppliers that can deter them from involvement.

If Wales is to fully benefit from involvement in all stages of large project delivery, local companies should be engaged at an early stage to ensure that potential suppliers are able to plan for new market opportunities. It is understood that industrial expansion can only follow actual orders for generation equipment and associated infrastructure, and this will come only when project developers start procurement for their projects. However, training and supplier information events should be provided by the Welsh Government in the manner of the Crown Estate's previous work with the offshore wind supply chain in advance of the Round 3 Leases. This work should build upon the current WEFO funded Wales Energy Sector Training (WEST) project. Stakeholder groups such as Marine Energy Pembrokeshire already hold extensive information about the potential supply chain and could be engaged to coordinate such events.
Further to this, to encourage the involvement of small local firms in large contracts, suppliers should be encouraged to come together to form Joint Ventures that could provide a complete vertically-integrated service to developers. These could provide a range of services including design, component manufacture, assembly, deployment, scientific monitoring, operation & maintenance, legal services and finance. In this way, local communities can maximise their opportunities for local economic regeneration.

Recommendation - Local companies should be engaged at an early stage to ensure that potential suppliers are ready to upskill and upsize to meet the needs of the industry. Suppliers should be encouraged to come together to form Joint Ventures, such that they remain competitive in seeking large contracts.

Figure 4.2 below shows an artist's impression of the Tidal Energy Ltd (TEL) Deltastream device. TEL are currently procuring components and services for their demonstrator project at Ramsey Sound, Pembrokeshire.

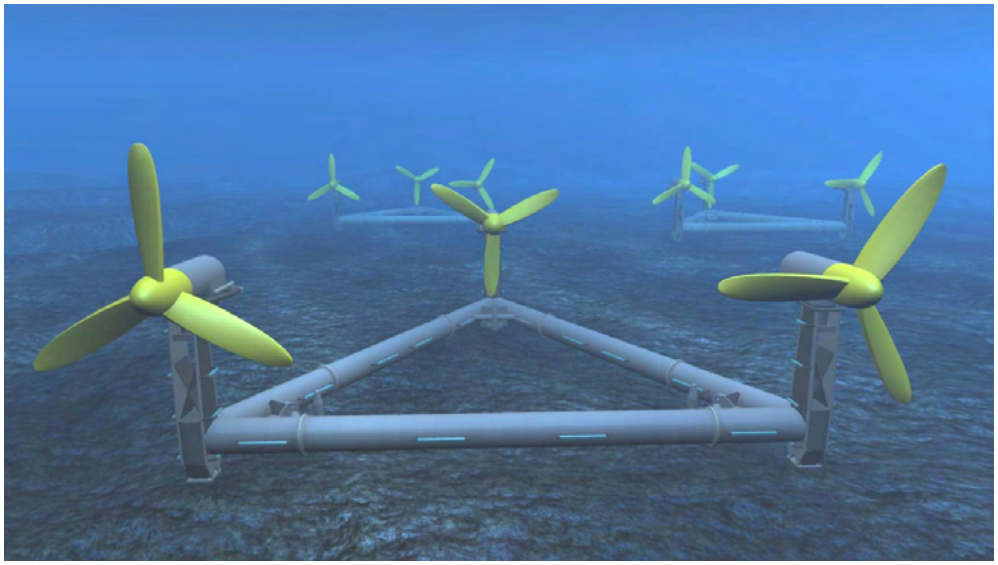

Figure 4.2 – Artist's Impression of Tidal Energy Ltd's (TEL) Deltastream tidal generator.

Grid Connection

Developers have found the procurement of grid connections for prototype deployments and the planning of early arrays to be difficult to achieve, physically, administratively and financially. Prior to receiving planning consent and investment funding for a project, this is one of the most risky aspects. This is due to the heavily regulated nature of the DNO's, which means that they cannot take any risks or incur any unrecoverable costs on behalf of energy developers. Grid reinforcement and connection arrangements must be paid for by the individual projects wishing to connect. Developers are required to cover for the risk of non-use of upgraded assets that are shared with other energy developers. Development of early arrays would be encouraged by the Welsh Government or a private infrastructure organisation procuring grid upgrades and connections to the primary resource areas on behalf of energy developers. The provision of electrical infrastructure into the resource areas would demonstrate a strong commitment to marine energy that would encourage developers to expand.

> "We are not allowed to speculatively develop the network without a commitment that upgrades will be used" – Western Power Distribution

Recommendation – Network and connection studies. Lobby for, consult, investigate and then procure grid connections to main resource areas, including shore-side works to upgrade the networks in certain areas.

4.3 Management of Risk

A common theme that arose from our investigations was that all activities were subject to considerable risk (financial, legal, environmental and reputational), and it was this that forced participants into a cautious approach to planning for deployment of renewable energy devices in Welsh waters.

Key risks to project developers are:

- Device output performance. Uncertainty regarding how much energy will be produced by each device at a particular site. Also, impact of multi-device arrays on local tidal/ wave climate, and device performance.
- Device reliability and survivability. Uncertainty about the methodology and cost of operation and maintenance tasks.
- Regulatory approach. Uncertainty regarding the costs and timescales required to achieve consent; also regarding conditions that may be applied to developments during operation.
- Costs of environmental monitoring
- Changing value of energy produced and financial support from government. Risk that Renewable Obligation could be removed.
- Short periods of access to the site (operational windows within weather and tidal constraints)
- Proximity and quality of access to local ports, labour, infrastructure
- Changing technology costs, components, assembly
- Damage to sub-sea infrastructure from vessels, anchors, etc.
- Requirement for warranties
- Availability of appropriate project insurance

Against this, it should be recognised that other parties, particularly government and regulatory authorities are at risk from pressure to award consent to development without sufficient knowledge of the likely outcomes. These bodies are legally responsible for protecting our marine environment, and any loss of reputation could lead to control of consenting being withdrawn and re-centralised.

Risk management is a technical specialism within the financial, health and safety and engineering professions. It is commonly accepted practice to aim to defer risk to those parties most able to manage or control it. Therefore, risks relating to device manufacture, deployment, reliability, survivability and energy production are best managed by device developers. Other site-related risks such as grid connection and reinforcement, collation of marine energy resource and environmental data, environmental assessment and monitoring are considered by developers to be less within their control and could be better managed through government intervention.

Recommendation – To maximise private investment in marine energy projects, Welsh Government should seek opportunities to de-risk projects by direct involvement in procurement of grid connection, shore-side infrastructure, together with site data collection and environmental impact assessments.

4.4 Approach to Investment

Whilst the anticipated forthcoming rise in Renewable Obligation payments for wave and tidal energy is welcomed, there remains considerable nervousness with regards to expansion. This is due to the risks associated with the early stages of technology development and consequential difficulties in attracting private funding. There is much that the Welsh Government can do to become involved in de-risking the marine renewable energy sector to encourage growth. To achieve the potential deployment capacities (indicated in table 4.1), the level of confidence in current technologies would need to be increased dramatically. Device developers would need to expand rapidly from the existing round of single-device test deployments through successful multi-device demonstrator arrays up to full commercial deployment. Any interventions from government should be targetted at this early phase of growth, when projects are for test sites and pre-commercial arrays up to 30MW. However, government should avoid an over-enthusiastic response that provides too much physical deployment of marine infrastructure in anticipation of demand.

Commitments should be sought from prospective users of shared onshore infrastructure (see section 4.5) in advance of the Welsh Government making investments.

> "This study, and any subsequent investment, should seek to partner the development process, and should be developer-led." – Atlantis

It is anticipated that after technologies have been proved at smaller scales (10 to 30MW arrays), then commercial-scale arrays (greater than 30MW, after 2017), will be largely self-financing with regard to meeting the capital costs. At this later stage, rather than trying to pay for such major projects directly, Government should invest in de-risking those projects. In this way, confidence will increase and private investment will be mobilised for larger fully-commercial arrays.

If the current ambitious plans for growth are to be met, government should plan for the creation and support of several clearly identified deployment zones, each capable of accommodating a number of 30MW arrays. Sites should be prepared by :

- Obtaining and making available detailed site data relating to energy resources and environmental baseline
- Providing on-shore grid connection infrastructure that could benefit a number of projects
- Following on from research into likely interactions between full-scale arrays and the marine environment, the pre-consenting of deployment sites, where possible
- Holding a leasing round with the Crown Estate, based on good site information
- Committing to provide financial support to technical and environmental baseline data collection and post-deployment monitoring. This may be through provision of grant funding or through direct commissioning of surveys

> "Whatever you do to encourage growth, you need to get buy-in, up-front, from all the different government departments." – Milford Haven Port Authority

Many of the early actions would be investigatory in nature, and would not require significant early capital investment. Until actual development sites are defined and allocated within each zone, the work should not unfairly favour any particular developer or technology. Therefore, these enabling actions could be supported from a single overall fund to support the whole industry or a number of smaller funds that could be targeted at each of the primary resource areas.

It is understood that all governments struggle with involvement in potentially risky projects, especially if money is coming from an external source, such as EU convergence funding. However, it is clear that if investment in marine renewable energy projects wasn't risky, then industry would have grown already, and there would be no need for any intervention to achieve the potential deployment capacity.

There are a number of ways in which the Welsh Government can support physical infrastructure projects where private funding cannot fully cover the costs.

- Grants – These are direct payments to organisations wishing to develop projects. Whilst there will be strict conditions as to the way in which grant money is spent, the Welsh Government would not expect to see any direct financial return. However, it may expect to see evidence of job creation or economic growth for the region, community or industry to which the grant was applied.
- Low Interest Loans – Like grants, these may be subject to conditions, but unlike grants, the Government could expect the money to be repaid.
- Public-Private Partnership (PPP) – The Government can take a stake in an organisation that provides all or part of a renewable energy development. Together with the other partners, the Government would contribute directly to the costs of a project, and would share ownership of the infrastructure. The PPP could also obtain grants, or loans, from other sources.
- Provision of advice and services to a project at reduced or no cost. Examples include paying for surveys, technical and legal advice, supply-chain development, training, consenting and EIA's

For expansion in the marine renewables industry to be successful, it will be necessary for any industry-scale technical difficulties that are uncovered by the development of device technology to be resolved quickly. Government will have an important leadership role in this, and should be prepared to take swift action to provide any necessary research or other support to assist. Welsh Government are in a unique position to unlock the perceived consenting obstructions to development as it can liaise between departments as well as academia and industry to reduce the risk of early-stage project failure. Concurrently, government should remain alert to the risk that overly-targetted investment could lead to localised and fruitless displacement of economic benefit from one Welsh region to another. Therefore to avoid this, investment should be market led and in response to developer's real needs.

4.5 Recommended Development Concept

Infrastructure

In reflecting on the results of the stakeholder consultations, there remains widespread enthusiasm for ongoing public funding to the industry, and this is considered necessary in order to achieve expansion to fully commercial (>30MW) projects. Whilst the provision of physical infrastructure would be welcomed by developers, we were cautioned that investment in offshore infrastructure such as electrical export cables and hubs carries greater risks than onshore measures, specifically:

- Technical requirements for offshore infrastructure will vary with the technology being deployed. There is a risk that marine infrastructure will be tailored to particular technologies and sites that, if found to fail, could mean that any associated infrastructure may not be easily re-used for other technologies,
- Procurement of offshore infrastructure is subject to long lead-in times, weather and marine environmental risks, and large items are normally imported from markets that are not accessible to local suppliers.

Conversely, on-shore infrastructure, such as grid upgrades, grid connections, shore-stations and landfall arrangements can be procured from local suppliers and may be used to serve multiple generation technologies. Whilst there is growing enthusiasm amongst developers to manage the marine engineering components of their projects themselves, many would benefit from public funding being directed towards onshore infrastructure.

Therefore, the recommended development concept incorporates all elements necessary to form a 'shore-to-grid' connection. The concept allows for connection, at a single point, of both pre-commercial (up to 30MW) and related small-scale test installations. The concept allows for the pre-consenting of deployment zones attached to the connection. Grid connection studies and the physical infrastructure provided should allow some flexibility in anticipation of future upgrades at the same site to fully commercial arrays. Stage B of this study will identify actual marine energy deployment zones and suitable connection and landfall sites within each of the primary resource areas. It will also clearly specify the infrastructure required at each site.

Other Actions

The consultation exercise recorded strong support for a number of non-infrastructure related measures that could be taken to de-risk projects and encourage growth in the industry. These include collation and publishing of site-specific resource and environmental data relating to key deployment areas, assistance with EIA and consenting, grid connection studies and ongoing assistance with environmental monitoring. Given the current pre-commercial state of the marine renewables industry, it is appropriate that research and technology development activities should be embedded within the overall development concept and supported by the academic community. It is recommended that all of these items, listed in Section 5 of this report, should be considered as integral to the development concept to be taken forward to Stage B of this study.

Programme

The following indicative programme has been prepared for use in the planning of projects to encourage growth in the primary energy resource areas. The programme assumes that both shoreside infrastructure (most likely to be part-funded by the Welsh Government) and offshore components (to be taken forward by energy device developers), would be taken through project planning, consenting, manufacture and construction concurrently. It also assumes that a SEA can be taken forward concurrently with baseline surveys and other non-project specific environmental investigations.

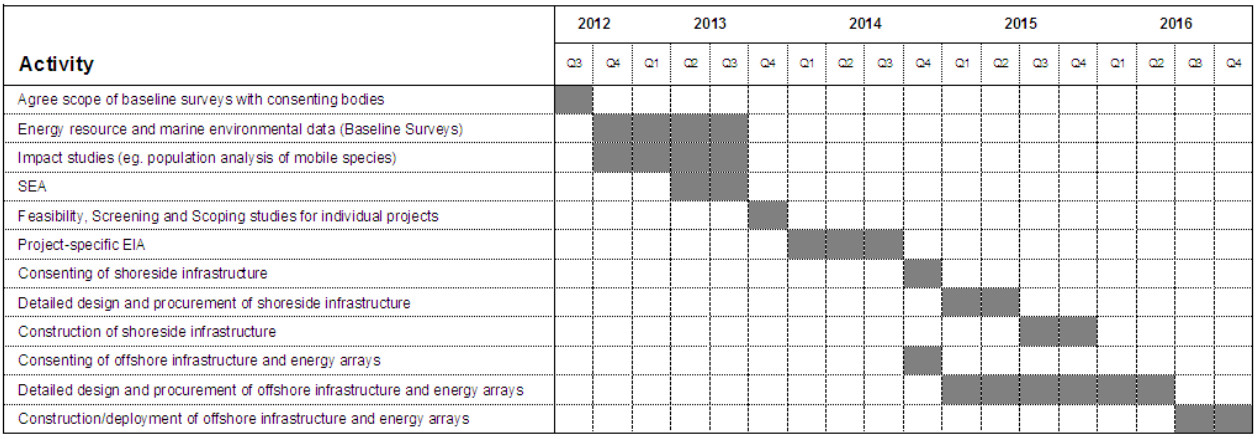

Fig. 4.3 – Indicative programme for project development

The above programme would allow participating developers to access the proposed ROC revenue support mechanism to 2017. Beyond 2017, it is difficult to predict the programme for projects following the initial pre-commercial deployments. However, it is clear that if the marine renewable energy industry is to progress beyond this point, then the following conditions should be met:

- It will be clearly demonstrated that the prevalent technologies do not cause unacceptable environmental impacts
- A stable mechanism will be in place for revenue support until the cost of energy from marine renewable sources reaches parity with that from fossil fuels
- Early arrays will have demonstrated that there are no significant difficulties with the construction, deployment and operation of generators and their associated marine infrastructure.

5. Conclusions and Recommendations

The study has found there to be extensive raw wave and tidal energy resources around the Welsh coastline. There are powerful tidal streams in the seas around Anglesey and the Llyn Peninsula in North Wales, and at Pembrokeshire and the Bristol Channel in South Wales. Furthermore, a large wave energy resource exists off the south-west coast. Our consultations have given us an opportunity to really understand the ambitions of the emergent marine renewables industry, but also given us insight into some of the frustrations and pitfalls to which it is exposed. Major wave and tidal energy developers are looking to establish bases of operations for large-scale manufacture and assembly of generator devices. They hope to get unit costs down by scaling up, and this presents enormous opportunities for Welsh ports and associated industries.

To achieve the identified potential deployment capacity, the level of confidence in current technologies would need to be increased dramatically. Device developers would need to expand rapidly from the existing round of single-device test deployments through successful multi-device demonstrator arrays up to full commercial deployment within 5 years. Any interventions from government should be targetted at this early phase of growth, achieving the first commercial arrays by 2017. It is considered that the scale of development planned after this time, both in Wales and elsewhere, will mean that revenue-based subsidies such as the Renewable Obligation or Feed-in Tariff, should be better placed to ensure the financial viability of the marine renewables industry, as it should have reached a level of maturity comparable with that of offshore wind.

The study has concluded that support should be given to the first multi-device arrays to ensure that these are successful and act to stimulate investor confidence. Concurrently, support is required for test sites for emergent technologies that could be capable of operating effectively in low-energy resource areas. Whilst the provision of physical infrastructure through direct government investment is welcomed by developers, there is equal merit in providing other kinds of support, including overcoming perceived consenting constraints and a lack of detailed deployment site data. There is an important role for government in coordinating and encouraging the supply-chain to upskill and upsize to meet the needs of an expanding industry. In this way the full potential for economic growth can be captured, and the value of the energy that is present in Welsh waters may be returned to local communities.

There is potential for a second generation of tidal energy devices to be developed that can access lower energy resource areas. However, such devices are some way off even a physical prototype stage and, as yet, there is no certainty that such devices are technically viable or practical to assemble and deploy. There appears little chance that the Welsh Government's current renewable energy capacity figures could be reached without use of currently available technology that requires access to high-energy sites. Therefore, the industry must prove that marine renewable energy devices are not inherently harmful to legally protected landscapes, species and habitats. If it cannot achieve this, then there is a risk that the industry could be constrained from accessing the only currently viable energy resources.

The study has identified a number of early 'easy-win' tasks that can be implemented without delay and for little cost, and also some longer term objectives, as shown in the following tables. Priority scores (ranked 1 to 3) are shown for each of the recommendations. These have been provided to reflect importance of each measure as shown in the feedback from stakeholders, but also based on our understanding of the critical activities necessary to achieve sustainable development. A score of 1 is assigned to the highest priority tasks that are considered to be of greatest benefit to growth in the industry.

Early/Immediate objectives (2012 to 2013)	
Priority	**Recommendation**
1	Complete Stage B of this study to identify and prioritise marine energy deployment zones and describe specific projects in each zone that will be necessary to deliver the **preferred development concept** as described in Section 4.5.
1	Grid connection studies to investigate connection opportunities, feasibility and cost for all of the primary energy resource sites in relation to local distribution networks.
1	Make MRESF source data available to all, whilst reinforcing links between the data and Welsh expertise. Encourage its use as a marine consenting and environmental scoping tool.
1	Obtain detailed site data and analysis for all potentially viable resource areas. Improve the quality and resolution of resource models. Surveys should include wave-rider buoys, seabed-mounted ADCP, vessel-based surveys, modelling, all to be linked to produce a single 'library' of public information. Making all the data freely available will avoid duplication of effort. Data will act to support ongoing strategic research and development, but also both the engineering design and the environmental consenting of projects.
1	Undertake environmental characterisation surveys of key resource areas, where existing sea-bed condition and habitat mapping is not complete. Surveys should include bathymetry and sub-bottom profiling, grab-sampling and geological surveys. This will support both the engineering design and the environmental consenting of projects.
1	Following-on research into likely interactions between full-scale arrays and the marine environment. Make best use of currently planned test sites in sensitive areas to prove no significant effect. Study population-level impacts to help to manage risks.
1	Develop a clear 'plan or programme' for the development of the primary resource areas for arrays in Welsh waters up to 30MW and with a time horizon of 2017, and make this the subject of a Strategic Environmental Assessment (SEA). Interface with other Marine Spatial Planning activities such as the creation of Marine Protected Areas and Marine Spatial Plans (table continued overleaf…..)

Early/Immediate objectives (2012 to 2013)	
Priority	Recommendation
1	Undertake a supply chain study to identify and encourage welsh suppliers who could adapt and expand into the marine renewable energy industry. Provide help in terms of training on device assembly, networking, communication, procurement, 3rd party certification. Encourage establishment of Joint Ventures to provide vertically integrated local services.
2	Feed into the Strategic Areas project and encourage the Crown Estate to plan for a Leasing Round in Welsh Waters that is based on good site information and associated environmental scoping advice.
3	Maintain and encourage existing stakeholder groups. Broaden their remit to sell Welsh renewable energy potential outside of Wales. Encourage their involvement in the coordination of supply-chain and training events, using existing training facilities.
3	Provide assistance to currently planned early array developments by providing environmental impact assessment, surveys and monitoring
3	Encourage and support the existing Marine Energy Pembrokeshire business plan objective to define the consenting regime in an easily understood manner to developers. This will allow consenting risk to be managed in a mature manner and be less of a burden.

Table 5.1 - Early/Immediate objectives (2012 to 2013)

Medium term Objectives (2012 to 2017)	
Priority	Recommendation
1	Network and cable route studies for Local Distribution and National Grid upgrades in anticipation of full commercial arrays from 2017 onwards.
1	Procurement of grid connections to main resource areas, including preparatory consultations and investigations and construction of landfall, shore-station works and local grid upgrades
1	Pre-consenting of deployment sites
1	Commit to provide financial support to technical and environmental monitoring
1	Public awareness, education and inclusion of developments in local plans. Consultation regarding possible navigational Safety Zones.
3	Publish information to engage stakeholders and the public in discussion about the potential for growth in the marine renewable energy industry to achieve Welsh Government's energy targets. Encourage an open and mature approach to associated necessary onshore and offshore infrastructure upgrades.
3	Provide advice and coordination regarding purchase and operation of deployment vessels, and establishment of common deployment and recovery processes.
3	Consider providing home port services for deployment vessels and taking weather risk.
3	Establish small test sites for low-energy wave and tidal devices.
3	Promote device development and evolution that have potential to be less harmful to the environment.

Table 5.2 - Medium term Objectives (2012 to 2017)