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The Economic Impact of the Development of Marine Energy in Wales

A Report by Regeneris Consulting and the Welsh Economy Research Unit at Cardiff Business School

Welsh Government

The Economic Impact of the Development of Marine Energy in Wales

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Purpose of the Report

i. Regeneris Consulting and the Welsh Economy Research Unit at Cardiff Business School were appointed by the Welsh Government to undertake an assessment of the potential economic contribution of marine energy to Wales.

ii. The primary purpose of this study is to estimate the potential economic benefits for Wales from the future development of the sector. The analysis covers wave and tidal stream energy (it excludes tidal range) and examines the economic benefits for Wales from three illustrative timeline scenarios:

- A 30MW wave installation and a 30MW tidal stream installation;
- 300MW in marine energy capacity (two 30MW wave installations and eight 30MW tidal stream installations, reflecting the relatively advanced state of tidal energy);
- 1GW of marine energy capacity (250MW of wave and 750MW of tidal energy).

iii. For each scenario we consider the impacts arising from direct employment and expenditure, indirect expenditure via supply chain goods and services sourced within Wales and induced expenditure by employees supported through direct and indirect effects. As we explain in detail throughout the report, there is considerable uncertainty on the timing of these scenarios. As an indication, there is potential for Scenario 1 to be achieved in the next 3-4 years, scenario 2 in ten years and scenario 3 in the next two decades.

iv. The assessment has been informed by a review of existing economic impact and supply chain literature and consultations with project and device developers, policy and strategy leads in Welsh Government, and other industry experts and stakeholders (see Appendix B for a full list of organisations consulted with). We set out in more detail our approach to the economic impact assessment, along with the approach to dealing with uncertainty, in Section 2.

Overview of Marine Energy

v. The development of renewable energy technologies is driven by the need to de-carbonise the energy system, in order for the UK to meet climate change obligations. The Welsh Government has stated its strong commitment to marine energy and sees Wales as having the potential to be a world leader in this area. This includes a commitment to provide strategic leadership, maximise economic benefits and support innovation, R&D and commercialisation in the sector.

vi. The International Energy Assocation estimates that total global installed capacity could be as high as 210 GW by 2050. The UK has the largest wave and tidal resource in Europe. The Marine Renewable Energy Strategic Framework (MRESF), found a potential of 1.5 to 6.5 GW of installed capacity in Welsh waters.

vii. The costs of marine energy will need to fall considerably for the energy source to be competitive and to become viable without public subsidy. The Carbon Trust estimates the Cost of Energy will need to reduce by 50-75% by 2025 for marine energy to be competitive. To achieve this, significant levels of innovation and economies of scale are needed. We provide further details in Section 4.

viii. The UK Government has provided capital (e.g. the Marine Energy Array Demonstrator fund) and revenue (the Renewables Obligation) support for the industry. Electricity Market Reform (EMR) will determine the future subsidy available. Current plans are to replace ROCs with a Contract for Difference with a Feed in Tariff (CfD FiT) mechanism. Precise details on the level of support to be offered have yet to be announced and this is widely seen as a risk factor to the development of the industry at present.

Development of the Industry to Date

ix. Twelve large-scale prototype devices have been deployed in the UK at present, which is more than in the rest of the world combined. There is a great deal of uncertainty surrounding the future development pipeline however. Latest evidence suggests that there is potential for 200 MW of installed capacity in the UK by 2020. Beyond this, our consultations indicate that it is not possible to make a robust assessment of future capacity development given the range of uncertainties outlined above.

x. In Wales, there are currently a total of four pre-commercial (demonstration) projects proposed off the Pembrokeshire coast:

- Tidal Energy Ltd is in the process of installing a 1.2MW device, consisting of 3 horizontal axis tidal turbines, in Ramsey Sound, Pembrokeshire in 2013.
- E.ON in partnership with Lunar Energy Ltd also has plans to install a device in Ramsey Sound, which will consist of six turbines totalling 8MW.
- Wave Dragon Wales Ltd planned to install a temporary 7MW wave energy converter 2-3 miles off the Pembrokeshire coast to test its proprietary technology in 2011/12 with the aim of scaling up by a factor of 10 to a commercial size array; however the project has been delayed due to a lack of financing.
- Marine Energy Ltd has plans for a 10MW wave energy system. It is currently in the process of making applications and aims to install the device towards the end of 2013.

xi. In addition, Marine Current Turbines (MCT) Ltd has successfully developed and tested prototype tidal devices in Strangford Lough, Northern Ireland and aims to install its first full-scale tidal turbine array in Welsh waters by 2016.

The Marine Energy Supply Chain

xii. There are broadly five phases in the project lifecycle, which can be summarised as follows:

- Development and Consents: design and feasibility, surveys and monitoring (e.g. environmental), planning application.
- Device manufacturing: hydrodynamic, reaction, power take off and control systems.
- Balance of plant manufacturing: foundations, mooring, cabling, electrical equipment, onshore infrastructure.

- Installation and commissioning: port services, installation of electrical systems, installation of foundations and moorings, device installation,
- Operations and maintenance: monitoring, planned and unplanned maintenance, insurance, grid charges.

xiii. In section 5 we set out a detailed mapping of the potential marine energy supply chain in Wales. Given the current sectoral strengths of the Welsh economy, our analysis suggests that device manufacture may be concentrated outside of Wales, in other parts of the UK (Scotland in particular) and Europe. The greatest opportunities for the Welsh economy could be in terms of balance of plant manufacturing, and in supporting elements of installation, local assembly of imported products and maintenance. However, given the nascent nature of the marine energy sector, there is scope to capture elements of higher value device manufacture with carefully targeted SME support.

Potential Economic Benefits for Wales

xiv. Section 6 provides full details on the underlying assumptions for our economic impact modelling and the sources drawn upon. The results of our analysis are presented here. In addition to the uncertainties surrounding the estimates it should be noted that the realisation of these benefits is heavily dependent on continued capital and revenue support from Government and the ability of the industry to drive down costs through innovation.

Development and Installation

xv. From the available evidence we estimate that gross spending associated with tidal installations is currently around an average of £4.2m per MW and £5m for wave energy. After accounting for expenditure that leaks out of Wales (largely on specialised services and the manufacture of devices), we estimate the likely level of spend retained in Wales from tidal to be around two thirds and a half for wave.

xvi. After accounting for indirect and induced multiplier effects and cost-savings due to learning and scale effects (for the time periods in which the different scenarios might be realised), our estimate of the cumulative impact on Welsh GVA of our three Scenarios is presented below.

The Economic Impact of the Development and Construction of Marine Energy in Wales: Gross Value Added (£m, 2013/14 prices)

	Scenario 1 - 60MW			Scenario 2 - 300MW			Scenario 3 - 1GW		
	Tidal	Wave	Total	Tidal	Wave	Total	Tidal	Wave	Total
Manufacturing & Energy	16	14	30	98	25	123	240	87	327
Construction & Maintenance	8	8	16	56	15	71	152	61	213
Distribution, Transport & Communications	5	4	9	35	7	42	91	28	118
Professional & Public Services	9	8	17	52	14	67	128	53	181
Total	**38**	**34**	**72**	**241**	**62**	**303**	**611**	**229**	**840**
GVA/MW (£m)	*1.28*	*1.13*	*1.20*	*1.01*	*1.03*	*1.01*	*0.81*	*0.91*	*0.84*

Source: WERU Calculations
Note: Figures may not sum due to rounding.

xvii. The key points to note are as follows:

- Scenario 1 of development has the potential to support over £70m of GVA across Wales, with this including on- and off-site economic activity (based on total investment in Wales of the order of £150m in 2013 prices).
- Scenario 2 (300MW, with a preponderance of tidal) delivers just over £300m of GVA for Wales, with the economic impact per megawatt declining somewhat (from £1.2m in Scenario 1 to £1m) as cost reductions come further into play (based on total investment in Wales of over £500m in 2013 prices).
- The final, very substantial roll out of 1GW in wave and tidal delivers £840m of GVA impact on Wales (based on total investment in Wales of the order of £1.5bn in 2013 prices).

xviii. By this last Scenario, the economic impact per megawatt is slightly higher from wave than tidal due to the assumed slower cost reductions (in line with DECC sector development assessments). Given the level of uncertainty, however, over technological development and local sourcing, the differences reported between wave and tidal impacts are relatively minor and should be treated as indicative only.

xix. Employment effects are reported below.

The Economic Impact of the Development and Construction of Marine Energy in Wales: Person-Years of Employment

	Scenario 1 - 60MW			**Scenario 2 - 300MW**			**Scenario 3 - 1GW**		
	Tidal	**Wave**	**Total**	**Tidal**	**Wave**	**Total**	**Tidal**	**Wave**	**Total**
Manufacturing & Energy	370	310	680	2,250	580	2,830	5,500	2,000	7,500
Construction & Maintenance	340	350	690	2,310	630	2,940	6,260	2,520	8,780
Distribution, transport & comms	120	100	220	760	180	940	1,960	670	2,630
Professional & Public Services	230	210	440	1,420	380	1,800	3,430	1,420	4,850
Total	**1,060**	**970**	**2,030**	**6,740**	**1,770**	**8,510**	**17,150**	**6,610**	**23,760**
FTE person years of employment per MW	35	32	34	28	30	28	23	26	24

xx. For Scenario 1, we estimate a total of around 2,000 person-years of employment associated with development and installation. This rises to 8,500 person-years in Scenario 2 and for the large 1GW installation of Scenario 3 almost 24,000 person-years. It is important to note that the employment arising in Scenario 3 could be supported over a 10-20 year period, depending upon the time it takes to roll out this capacity. To put this into context, this compares to around 4,500 person years that would be generated for 1 GW of gas fired power station capacity.[1]

[1] See Cardiff University and Regeneris Consulting (2013) *Employment effects associated with regional electricity generation*. Note that the major driver of the large economic impacts from wave and tidal compared to other technologies is the cost of development and installation. As novel technologies, wave and tidal are more expensive to install and hence tend to support greater economic impacts.

Operational Phase

xlii. We estimate a gross operational cost currently of £165,000 per MW for tidal stream and £175,000 for wave, albeit with considerable uncertainty over these estimates. Unsurprisingly, as the table below shows, the operations-related impacts of marine energy installations are more moderate than those estimated for development/installation (although they accrue in every year of operation):

- In Scenario 1, with 60MW in operation, we estimate a total of £2m in GVA and 50 FTE jobs per annum would be supported across Wales throughout the period of generation.
- Economic impacts increase with the scale of installation. For the 1GW Scenario 3, we estimate that £20m of GVA and 440 FTE jobs per annum are supported across Wales through generation activities.
- We estimate that regional operational spend per MW will, by Scenario 3, be under a third of its current estimated level for tidal stream, and around 50% its current level for wave. Hence, whilst each MW of capacity in Scenario 1 supports 0.83 FTE jobs in Wales, by Scenario 3 each MW is supporting 0.44 FTE jobs.

The Economic Impact of Operations and Maintenance of Marine Energy in Wales: GVA and Jobs (FTEs)

	Scenario 1 - 60MW		**Scenario 2 - 300MW**		**Scenario 3 - 1GW**	
	GVA (£m)	**Jobs**	**GVA (£m)**	**Jobs**	**GVA (£m)**	**Jobs**
Tidal Stream	1.2	25	6.3	145	13.2	310
Wave	1.0	25	1.5	35	5.5	130
Total	**2.1**	**50**	**7.8**	**180**	**18.7**	**440**
Per MW	0.04	0.8	0.03	0.6	0.02	0.4

Note: Tidal-Wave split illustrative only

Conclusions and Recommendations

xxi. Our analysis indicates the potentially significant benefits to be gained for Wales from the development of marine energy. In interpreting the results, it should be borne in mind that there are a range of uncertainties underlying them. We have therefore sought to err on the side of caution throughout, triangulating the evidence from the different sources available to us to ensure robust estimates of economic impact within Wales.

xxii. Our mapping of the capabilities of the Welsh supply chain suggests that there is an existing presence of firms that could diversify to serve the sector, and that the strongest opportunities lie in balance of plant manufacturing and in supporting elements of installation, local assembly of imported products, and on-going maintenance.

xxiii. Our review of the development of the industry in Scotland has highlighted that it is developing an advantage in marine energy, moving from R&D, deployment and testing, and on towards commercialisation. In addition to its natural resources, this has been driven by a mixture of strong political support, significant revenue incentives and additional capital funding. Consultees have also pointed towards the typical length of the consenting process for energy projects in Wales being less favourable than in Scotland. We would note that whilst on the face of it these factors have served to provide confidence and galvanise the industry in Scotland, more evidence would be needed to understand the specific contribution of Scottish Government interventions to this progress.

xxiv. Welsh Government and other stakeholders have made progress in fostering the development of the marine energy sector in Wales, including developing the evidence base through research studies, growing the research expertise in collaborations between the HE sector and industry, and providing targeted grant assistance in support for on-going development of a number of devices. Whilst the impact of this assistance is not yet clear, there is the need to ensure that this investment can be built upon in an effective and appropriate manner. It is now critically important that devices are deployed in Welsh waters.

xxv. As also stressed in our parallel work on energy employment effects, high economic impacts are not necessarily a justification for further public sector intervention. A range of other factors need to be considered in making choices on interventions, including the prospects of achieving efficiency in the technology, environmental externalities surrounding these types of investments and the overall value for money they present in economic development terms.

xxvi. In Section 8 we provide a series of high level recommendations. These focus on:

- Communicating the nature of the opportunity Wales presents to developers;
- An investment focus on one or two marine hubs which will provide a focus on testing commercial scale devices;
- Targeted supply chain development, possibly underpinned by further supply side analysis;
- The provision of commercial development and growth finance for SMEs in the sector and the associated supply chain;
- Integration of these actions with existing area-based initiatives with an energy focus; and
- The development of an investment strategy which enables Welsh Government and project sponsors to access ERDF and other suitable resources to enable the delivery of these actions.

1. Introduction

1.1 Regeneris Consulting and the Welsh Economy Research Unit at Cardiff Business School were appointed by the Welsh Government to undertake an assessment of the potential economic contribution of marine energy to Wales.

1.2 Given the scale of wave and tidal stream resource in Wales and the existing capabilities of the Welsh business and HEI base, it is recognised that marine energy represents a significant opportunity for Wales. A number of studies have examined the potential nature and scale of economic benefits from marine energy at a global and UK level. However, to date there has not been a detailed assessment of the potential economic benefits for Wales.

1.3 Therefore, the primary purpose of this study is to estimate the potential economic benefits for Wales from the future development of installed generating capacity and the growth of the sector. In addition to the economic impact evidence, the report provides guidance on the types of interventions that could be pursued in order to maximise the benefits of the development of marine energy.

1.4 The scope of the analysis is as follows:

- The assessment covers wave and tidal stream energy (it excludes tidal range, which includes tidal lagoons and barrages).
- The analysis examines the economic benefits for Wales from three scenarios:
    - A 30MW wave installation and a 30MW tidal stream installation
    - 300MW in marine energy capacity (2 30MW wave installations and 8 30MW tidal stream installations, reflecting the relatively advanced state of tidal energy)
    - 1GW of marine energy capacity (250MW of wave and 750MW of tidal energy).
- For each scenario we consider the impacts arising from:
    - Direct employment and expenditure in Wales through planning and development work; manufacture of device components; construction and installation; and operations and maintenance
    - Indirect expenditure via supply chain goods and services sourced within Wales
    - Induced expenditure by employees supported through direct and indirect effects.
- The spatial focus of the assessment has primarily been upon Wales as a whole.
- The key indicators of impact used are Gross Valued Added (GVA) and Full Time

Equivalent (FTE) Jobs.

1.5 The focus of the study is on the core *economic* opportunities that would be created by the future development of the sector. It does not provide an assessment of the wider environmental or social impacts. Given the industry is only at an early stage in its development, there is more uncertainty and less of an existing evidence base to draw on than for other, more mature energy technologies. In Section 2 we explain the primary and secondary sources that have been drawn on in undertaking the assessment and how we have dealt with these uncertainties.

1.6 The remainder of the report is structured as follows:

- **Section 2:** sets out in detail the assessment approach, including the economic impact framework and the research methods used, and the approach to accommodating the considerable uncertainties associated with this nascent industry.
- **Section 3:** provides a brief discussion on the policy context for marine energy at the UK and Wales level.
- **Section 4:** provides a general overview of the marine energy sector, focussing on the resource available, development economics of the sector, the development of the industry to date, the types of wave and tidal technologies in development, nature of the supply chains, the types and scale of potential economic benefits, and experiences of other parts of the world in growing the sector.
- **Section 5:** provides a review of the sector in Wales, covering the resource available, the development of the sector to date, projects and support infrastructure, an analysis of relevant capabilities of the current Welsh supply side, and challenges and constraints going forward.
- **Section 6:** presents the results of the economic impact modelling for the different scenarios.
- **Section 7:** sets out our conclusions and recommendations.
- **Appendix A** provides details of the methodology used
- **Appendix B** summarises the organisations that were consulted as part of the study
- **Appendix C** provides details on marine energy projects currently in development in the UK
- **Appendix D** contains details on the marine energy supply chain.

2. Assessment Approach

2.1 In this section we set out the approach used to estimate the potential economic benefits of the sector for Wales. We provide an explanation of the economic impact framework and the various research strands undertaken.

Economic Impact Framework

2.2 At the centre of our assessment is an economic model that is designed to capture the potential economic impacts for Wales of future development of the marine energy sector. This is described below.

Sources of Impact

2.3 Each of the phases in the development of a wave or tidal stream installation supports economic activity through the capital investment incurred in designing, testing, developing and constructing the installation and the operational expenditure incurred in operating and maintaining it. In broad terms our modelling considers five phases:

1) **Development and Consents**: An extended period of work is required before any contracting for manufacturing and assembly. This covers the design and feasibility work, physical and environmental surveys and monitoring activities, and planning consent. Evidence from elsewhere suggests this could last for anything up to five years.

2) **Device manufacturing**: A range of different wave and tidal devices are in development and being tested. Across all device types the principles remain the same: a hydrodynamic system is required to interact with the water to extract energy from it; a reaction system holds the device in place; and a power take off system converts the energy extracted into electrical energy. A control system provides supervisory and closed-loop control. The manufacturing of these devices is a significant component of the overall capital cost associated with wave and tidal projects.

3) **Balance of plant manufacturing**: All components that are not part of the device itself but are required for its operation come under this header. This includes foundations, mooring, cabling, electrical equipment, and onshore infrastructure.

4) **Installation and commissioning**: Once the manufacturing phases are complete they need to be assembled onshore and installed offshore. Typical activities required include port services, installation of electrical systems, installation of foundations and moorings, and finally device installation.

5) **Operations and maintenance**: Once the installation becomes operational, various on-going activities are required to facilitate this, including monitoring, planned and unplanned maintenance, insurance, and grid charges.

2.4 As well as potentially benefitting from opportunities associated with the development of marine energy in Welsh waters, there are longer term opportunities for Wales to export its expertise in the sector to wider UK, European and global marine energy markets. These are outside the scope of the quantitative economic assessment, since it is not possible in a robustly assess these export benefits. However, we provide a qualitative commentary on this potential benefit.

Types of Impact

2.5 The core economic benefits have been assessed quantitatively through an economic impact model which estimates:

- **Direct Impacts**. This measure captures the economic activity that is supported directly through the construction, operation and maintenance of the installation. This covers staff directly employed on the development and all first tier supply chain expenditure relating to the construction of the installation.

- **Indirect Impacts**. This measures the impact of the additional output generated by companies in the supply chain supporting the tier one suppliers.[2] The additional economic activity in these companies is passed down through their supply chains and generates additional, indirect benefits for many other companies.

- **Induced.** This captures the knock on benefits that additional employment supported directly and indirectly has in the economy as salaries, earned by those employed in additional jobs are spent on goods and service elsewhere in the economy.

2.6 There are also wider economic benefits associated with the development of the industry in Wales, including:

- **Research expertise.** The development of the sector will require research, development and commercialisation expertise, which will reside in both higher education institutions and firms in Wales.

- **Sector development**. A pipeline of marine energy projects in Wales over the medium term could help to deliver lasting benefits by stimulating increased capacity in the overall renewables sector (e.g. as companies start up or diversify into other renewables activities to take advantage of new opportunities), and positioning local firms to access future opportunities in the sector both within Wales and further afield.

- **Employment and skills.** The growth of the sector will provide additional employment opportunities, many of which will be outside the main economic centres in Wales, which will need skills mostly at an intermediate and higher level.

Measures of Impact

2.7 The assessment uses two key measures to quantify the nature and scale of economic impacts:

[2] Tier One suppliers are at the top of the supply chain, supplying directly to the Prime Contractor.

- **Gross Value Added (GVA).** GVA is the commonly accepted measure of wealth creation for an economy. It is what is left of gross output once bought in goods and services have been paid for. This residual output is then available for distribution as profits, wages and salaries and capital investment costs.

- **Employment**. This is the number of jobs that are created within Wales. We express these both as Full Time Equivalents, a measure that converts full- and part-time jobs into a common currency (where one PT job is equivalent to half a FT job) and, for temporary construction impacts, as person years of employment.

Uncertainty and Scenarios

2.8 Given that marine energy is at an early stage in its development, there are several sources of uncertainty, which make any assessment of its future economic contribution challenging:

- **Future development pipeline**: Whilst we have identified and consulted with the Welsh projects that are in development, the future pipeline of marine energy projects is uncertain and the longer term trajectory is unclear. RenewableUK has concluded in its most recent publication that it is not possible to make a robust assessment of future capacity post 2020 (see section 4 for more details). Therefore, our study makes use of three scenarios for future capacity:

    - A 30MW wave installation and a 30MW tidal stream installation

    - 300MW in marine energy capacity (2 30MW wave installations and 8 30MW tidal stream installations, reflecting the relatively advanced state of tidal energy)

    - 1GW of marine energy capacity (250MW of wave and 750MW of tidal energy).

- Whilst it is difficult to judge when this capacity may come forward, it is quite likely that it could take another decade for 300MW capacity, the second scenario, to be installed in Welsh waters. Based on other assessments, the 1GW scenario might not be achieved for two decades. Implicit in these scenarios is the need for the capital and operational costs to have fallen sharply to ensure that the roll-out of these much higher levels of capacity is economically and financially viable.

- **Capital and operational costs**: the early stage of the industry means there is a relative lack of evidence on costs associated with the development and operation of marine energy projects, since no projects have been developed at commercial scale to date. This is complicated by the fact that it is not possible to predict the future mix of technologies (both between and within wave and tidal stream) that will successfully come forward, or over what period (costs vary to some degree with technology). However, our desk review has highlighted several sources of generic cost information based on intelligence from developers. We have made use of this information and supplemented it with consultations with device/project developers in Wales in order to arrive at reasonable estimates. In doing so we have erred on the side of caution.

- **Cost reductions**. Coupled with the uncertainty on baseline costs, it is not known in advance the extent to which the industry will be able to reduce its cost of energy over time through learning, economies of scale and innovation. However, detailed studies on feasible cost reduction pathways have been completed recently, and these provide a useful indication of potential cost reductions. We have made use of these studies, again erring on the side of caution. This is discussed in more detail in section 6.

- **Sourcing from Wales.** The final key source of uncertainty centres on the extent to which Welsh industry is able to benefit from the opportunities generated by marine energy projects on Welsh waters. This depends on a range of factors, including the procurement approach pursued by developers, the current capabilities of the Welsh supply side, its ability to form strategic alliances in order to bid for large packages of work, and so on. Since no projects have yet been developed there is a paucity of existing evidence to inform judgements on these matters. We have therefore made use of the following sources to arrive at a reasonable view on sourcing:

    - Structured consultations with device/project developers to understand their procurement routes and their views on the availability of suitable goods and services in Wales.

    - A detailed review of the current supply side in Wales, mapping the general marine energy supply chain against current Welsh capabilities using data on employment and business units in relevant sectors, and drawing on the knowledge of our team. This analysis is set out in Section 5.

    - Evidence from other economic impact studies on marine energy (e.g. in Scotland), where sourcing evidence is available, to provide comparator information.

2.9 The analysis of Welsh capabilities set out in Section 5 uses Standard Industrial Classification (SIC) codes along with data on employment and business units. As such it is subject to a number of caveats:

- The analysis is based on historical data. There may be new inward or domestic investment in the future to supply the needs of these sectors which are poorly represented in terms of current SIC codes.

- Whilst a basic Location Quotient (LQ) analysis may suggest some Welsh specialisation in particular sectors and a presence of skills relevant to the marine renewable industry, these sectors may not have the capacity or willingness to grow or diversify into this type of business.

- There is no guarantee that the firms contributing employment in Tables D-2 and D-3 have the expertise or willingness to work with the marine renewable industry. Rather this is a broad brush means of identifying where there could be the capabilities to develop and serve the sector in the future. Equally, there could be firms not identified as contributing employment in the selected SIC codes which could also later diversify to serve the needs of this emerging sector.

- Jordan FAME (Financial Analysis Made Easy) data for units of activity may overstate the underlying activity because one firm could have multiple trading addresses. We also note that there are a few cases where the FAME data on maximum employment in firms in the sector conflicts with information from the Business Register and Employment Survey. This may be due to firms classifying activity differently in their accounts from where they are completing official surveys.

Research strands

2.10 A number of research strands have been pursued in order to inform the assumptions of our economic model:

- **Desk research**: this has comprised several elements:
  - A review of relevant policy and research documents at the UK and Wales level, including publications from HM Government, Welsh Government and RenewableUK, and the Carbon Trust.
  - A review of the existing literature on the economic impact of wave and tidal energy development, focussing on studies at the UK level and for regions within the UK.
  - Analysis of the existing capabilities of the supply side of the Welsh economy, mapped against the marine energy supply chain.
  - A review of the development of the industry in other locations, filtered down to focus on Scotland.
- **Consultations**: we have consulted with a range of relevant stakeholders in the course of the study (see Appendix B for a list of consultees), including:
  - Device/project developers in Wales, in order to understand latest plans for the development of their projects, and to gain views on any plans for sourcing of goods and services from Wales, constraints, opportunities, support needs and the future development of the sector in Wales. This took the form of structured interviews as well as the use of a proforma to gather data on costs and sourcing.
  - Industry experts and stakeholders, including RenewableUK (the trade body for the renewable energy sector), and support organisations in Wales.
  - Policy and strategy leads in Welsh Government, DECC and Scotland, to gain their perspective on the potential development of the sector, and the support currently on offer and planned.

3. Priorities for Marine Energy

3.1 This section of the report provides a brief overview of the policy and strategic drivers for marine energy. To set Welsh policy in its context we first provide an outline of the wider UK policy drivers.

Climate Change and Low Carbon Technologies

3.2 The Climate Change Act of 2008 commits the UK to reduce its greenhouse gas emissions by at least 80% by 2050. As part of this drive, carbon budgets have been developed, which specify the legally binding limits on the level of emissions in specific five-year periods. These carbon budgets require emissions to be reduced by 34% by 2020, and by 50% by 2027 (compared to the same base year).

3.3 The Carbon Plan sets out how the UK Government plans to meet these targets, covering strategies for the whole range of sectors. Alongside energy efficiency measures decarbonising the energy system is a fundamental imperative that must be achieved in order to meet the emission reductions targets. The power sector accounts for around 27% of all emissions and this will need to be close to zero by 2050. Whilst a variety of low carbon technologies are likely to contribute towards the UK's energy mix in coming decades, it is expected that 15% of all energy demand will be met from renewable sources by 2020.

3.4 This will therefore require considerable development of new low carbon electricity generating capacity. The mix of technologies contributing to this is of course uncertain and will depend on relative rates of innovation, technology development and cost reduction. The broad aspiration is that low carbon technologies will compete on cost by the 2020s.

Marine Energy

3.5 Compared to other low carbon and renewable sources such as nuclear and onshore wind, marine technologies are at a much earlier stage in their development and have not been deployed at commercial scale to date. Nonetheless, the UK is at the forefront of marine technology development, given its wave and tidal resources and the concentration of relevant R&D currently occurring and engineering expertise. The Renewable Energy Roadmap, published in 2011 (and updated in 2012) sets out an expectation for around 200-300 MW of installed marine capacity in the UK by 2020.[3] Given the level of uncertainty in the development trajectories of the various renewable technologies, the view of the UK Government is that it is premature to set targets beyond 2020.

Renewables Policy in Wales

3.6 The Welsh Government is committed to decarbonising energy production and maximising the economic opportunities that this brings. The stated ambition within the current Programme for Government (2011-16) is *to create a sustainable, low carbon economy for*

[3] This was a very significant reduction on the previous figure contained in the Marine Energy Action Plan, published in 2010, which set out a figure of 1-2 GW. It was felt that the felt the previous target was unrealistic.

Wales.

3.7 *Energy Wales: A Low Carbon Transition* provides the latest statement of Welsh Government policy with respect to the energy sector and restates the commitment to ensure the transition to the low carbon economy, by:

- Providing leadership and a clear and consistent framework for investors and regulators, other stakeholders, as well as necessary infrastructure.
- Maximising the economic benefits at every stage of development of new low carbon energy infrastructure and ensuring that communities see a long term benefit.
- Supporting innovation, R&D and commercialisation of the most promising technologies.

3.8 At the time of writing the Welsh Government is considering establishing a Renewable Energy Delivery Board. The purpose would be to co-ordinate government, industry and regulators.

3.9 The Welsh Government has stated its strong commitment to marine energy and sees Wales as having the potential to be a world leader in this area. It has funded a £1 million study – the Marine Renewable Energy Strategic Framework[4] – to examine in detail the potential marine resource available to Wales (the results of which are discussed in detail in Section 5), along with studies into the industry's infrastructure requirements[5] and R&D potential.[6] It has also supported Marine Energy Pembrokeshire, a collaborative public-private partnership to develop a marine Centre of Excellence[7]. In addition, the Welsh Government has set up seven Enterprise Zones across the country, offering business support and a range of incentives for businesses locating there, including reduced business rates. The Enterprise Zone at Anglesey complements the existing Energy Island Programme (EIP), which seeks to drive growth and development in renewable energy. Haven Waterway Enterprise Zone, located in Pembrokeshire, also has an energy focus.

3.10 The range of actions that the Welsh Government will take in the current Government term to promote the development of the marine energy sector are summarised in the Box below.

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[4] RPS for Welsh Assembly Government (2011) *Marine Renewable Energy Strategic Framework*

[5] Halxrow and BVG Associates (2012) *Marine Energy Infrastructure Study*

[6] Carbon Trust (ongoing) *Wales low carbon R&D strategy*

[7] Funding for MEP was agreed on an annual basis for a 3 year period beginning 2010, with the following organisations all contributing: the Welsh Government, the Crown Estate, the Park Authority, Pembrokeshire CC and the National Park.

Key things we will do in this Government term
• Lead the drive to develop a competitive marine energy sector in Wales by stimulating collaboration between business, academia and the public sector – working with local delivery groups such as Marine Energy Pembrokeshire – and ensuring Wales' energy infrastructure is responsive to the marine sector's needs. • Complete our marine energy infrastructure project in order to identify strategic sites for wave and tidal stream developments and the wider actions that will be needed to support them. • Work with The Crown Estate and industry to bring forward a marine energy leasing round for Welsh waters as soon as possible. • Continue to support institutions like the LCRI and SEACAMS to develop world class academic expertise and innovative technologies to meet the growing global demand for marine renewables. • Provide robust and timely information and guidance to the emerging marine renewable energy sector on the nature of the opportunities in Welsh waters. • Work with partners to promote Wales as a centre for marine renewables. • Investigate mechanisms for advancing the deployment of marine energy arrays. • Gear up training providers to ensure capacity exists to deliver a future workforce with the necessary skills required to support the commercial deployment of marine energy investments. • Continue to press the UK Government hard for both a fair resolution to the current situation that sees Wales lose out under the Renewables Obligation in comparison with other parts of the UK and, a longer term solution under the Electricity Market Reform (EMR) that provides a more equitable and stronger support mechanism for marine energy in Wales.
Source: Energy Wales: A Low Carbon Transition.

4. The Marine Energy Sector in the UK

4.1 In this section we provide a general overview of the marine energy sector. The purpose is to set out the key issues before focussing on the industry in Wales in section 5. We cover:

- The global marine resource
- Development economics of marine energy
- Development of the sector to date and future prospects
- The marine energy supply chain
- Experience from elsewhere.

4.2 Our review has been informed by desk research and consultations with industry stakeholders.

The Global Marine Resource

4.3 Numerous estimates have been made of the potential wave and tidal resource at the global level. These estimates all take account of:

- **Theoretical resource**: an unconstrained top-level estimate of the potential marine energy.
- **Technically extractable resource**: the proportion of the theoretical resource that can be exploited using available (and envisaged) technology and within certain economic constraints, without causing 'excessive' impact on the underlying 'tidal hydrodynamic environment'.
- **Economically Extractable (Practical) resource:** the proportion of the technically extractable resource that can be extracted whilst taking account of significant external constraints to extraction such as access to the grid and related infrastructure, impacts on fishing and shipping etc.

4.4 The range of factors influencing the wave and tidal stream resource are summarised in Box 1 below.

4.5 At a global level, the IEA estimates that total installed capacity could be as high as 210 GW by 2050. Wave is forecast to be the larger contributor to the marine market, with higher deployment levels reflecting greater known wave resource versus tidal. Theoretical global resource estimates are in the region of 100,000 TWh/year. The European Ocean Energy Association estimates that the European wave resource is 45,000 TWh/year and the tidal resource is 2,200 TWh/year.[8]

[8] European Ocean Energy Association, cited in SQW (2010) *Economic Study for Ocean Energy Development in Ireland*

4.6 As the latest report by the Energy and Climate Change Committee on the marine energy sector states, the UK has the largest wave and tidal resource in Europe, due to its exposure to Atlantic winds which serve to boost the wave resource, and as a result of the presence of headlands and islands which concentrate tidal flows[9]. Specific estimates of the UK's marine resource are subject to significant uncertainty surrounding tidal resource estimates and location specific environmental conditions:

- The practical **wave resource** has been estimated at between 40 and 70 TWh/year[10]
- The practical **tidal stream resource** is subject to much greater uncertainty and has been variously estimated at between 12 and 29 TWh/year.

4.7 The Carbon Trust estimates that the economically exploitable resource is approximately 70 TWh/year – 40-50TWh/year for wave, and 20-30 TWh/year for tidal. 70 TWh/year is equal to c.20% of current UK electricity demand, or 10% of forecast 2050 electricity demand[11].

[9] Energy and Climate Change Committee (2012) *The Future of Marine Renewables in the UK,* Eleventh Report on the Session 2010-12.

[10] Energy and Climate Change Committee (2012) *The Future of Marine Renewables in the UK,* Eleventh Report on the Session 2010-12., Carbon Trust – *Accelerating Marine Energy*, The Offshore Valuation Group 2010, Carbon Trust - UK wave energy resource report (2012)

[11] Carbon Trust (2012) *Technology Innovation Needs Assessment*

Box 1: Factors Determining the Marine Energy Resource

Wave

The amount of available wave energy resource depends on numerous factors including the nature of device interactions, the level of spacing between devices and their cumulative impact[12]. Natural factors influencing the extraction potential are the wind speed, duration and fetch[13] and the distance from and characteristics of the sea-bed, including any possible diffraction effects from obstacles. There is also considerable seasonal variation in the wave power level of an area.

Wave power is conventionally measured in terms of average annual power per metre of wave crest width parallel to the shoreline (kW/m). Energy exploitation is economically viable when wave levels are greater than 15-20 kW/m[14].

Wave resource depends on the coastline's orientation to the ocean and the location's latitude. The UK is especially suited for wave energy, especially along the North West of Scotland and Ireland (Wales' resource seems to be greatest in the South West).

Tidal

Tidal energy is more predictable than wave energy (and tidal range is more predictable than tidal stream). The amount of available tidal stream energy resource depends on the same factors as for wave energy[15]. Similar to wind energy, the amount of energy captured is a function of the flow speed and the area intercepted by the turbines, however because water is denser than air, a smaller device is required to capture the equivalent amount of energy.

The Significant Impact Factor (SIF) describes the maximum amount of energy extractable at a site without causing significant environmental or economic impacts. The Carbon Trust assume a SIF of 20% in their assessment of the current UK tidal resource based on preliminary analysis by Black & Veatch[16]. However the SIF only accounts for environmental issues that arise directly from energy extraction at a site and does not take into account site-specific environmental and practical constraints such as competing sea uses and difficult grid access. In addition, SIFs will vary substantially by location and therefore the 20% figure is an indicative average.

[12] Ernst & Young (2010) for DECC, *Cost of and Financial Support for Wave Tidal Stream and Tidal Range in the UK*.

[13] Distance of open water that the wind blows over.

[14] http://www.aquaret.com/en/elearningtool/technologyselection/4-wave-/42-energy-source-and-location-/421-level-2-

[15] Ernst & young (2010) for DECC, *Cost of and Financial Support for Wave Tidal Stream and Tidal Range in the UK*.

[16] Black & Veatch (2005) for Carbon Trust, *UK Tidal Stream Energy Resource Assessment*

Development Economics of Marine Energy

4.9 The extent to which the available resource can actually be exploited commercially is determined by the development economics associated with extracting energy from it. The various factors are outlined below.

The Cost of Marine Energy

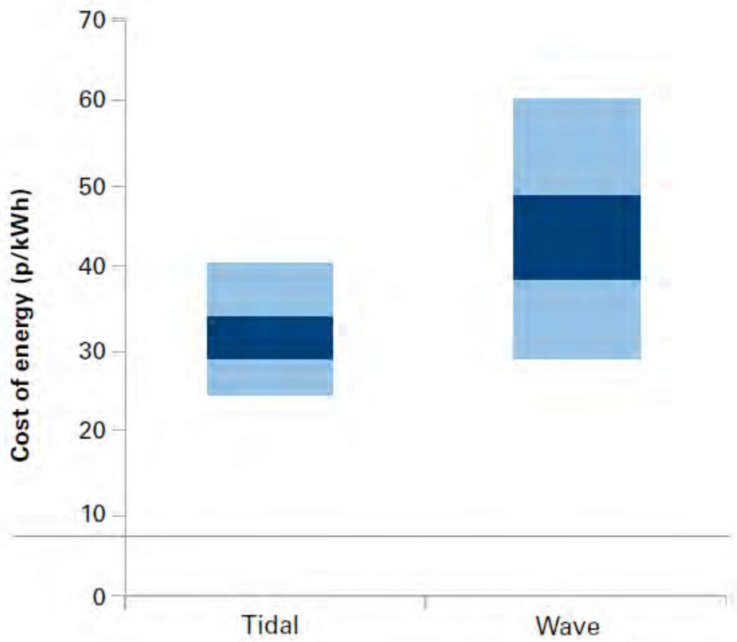
4.10 Calculating a comparable cost of energy for a particular technology is challenging as costs vary depending on the device type, stage of development and deployment location. In 2006 the Carbon Trust developed a cost estimation methodology which has been used in subsequent technology assessments by themselves and other research bodies. Their model calculates a consistent and comparable cost figure based on the discounted present value[17] of critical parameters such as the capital cost, operation and maintenance costs, decommissioning costs and energy production in order to generate a cost of energy (CoE) figure.

4.11 The Carbon Trust estimated in 2011 that the baseline costs of marine energy are 38-48p/kWh for wave and 29-33p/kWh for tidal – see Figure 4-1.[18] The wider range for wave is explained by the greater uncertainty on the energy capture methods compared to tidal stream devices.

[17] The discount rate is a product of the considered risk of the investment. Lowering the risk lowers the discount rate and consequently the cost of energy. The Marine Energy Challenge used a range of discount rates between 8 and 15%, depending on whether the technology was new and theoretically proven, or established and practically proven.

[18] Carbon Trust (2011) *Accelerating Marine Energy*. Total capex and opex costs. Uses a 15% discount rate. These are 'first farm' costs assumed to have a capacity of 10MW.

Figure 4-1: Current Cost of Energy for Tidal and Wave Energy



Source: Carbon Trust (2011) *Accelerating Marine Energy*
Note: The dark bars demarcate the cost of energy at medium energy (upper bound) and high energy (lower bound) sites. The outer bars add to this optimistic and pessimistic cost and technical assumptions to these limits.

4.12 We discuss the breakdown of capital and operating costs later in this section under the *Marine Energy Supply Chain*. Notable points are that:

- **Capital expenditure** includes construction (c.90%), electrical systems infrastructure, pre-development costs and insurance. Also included are installation costs, foundations and moorings, and grid connections. The cost of a grid connection includes shore-based facilities to join the energy output to the land-based electricity grid, cables, transformers and switchgear. Costs depend on the distance from the shore, the nature of the seabed and the quantity of energy being transmitted[19].

- **Operational costs** include operation and (planned and unplanned) maintenance (c.60%), overhaul costs (servicing), insurance and licensing, monitoring, de-commissioning, plus Crown Estate rent, transmission network use of system (TNUoS) and national grid charges. Decommissioning costs are small compared to initial capital costs and because they are discounted heavily, the marginal effect is low.

4.13 Both capital and operating costs depend on specific devices and locations and operating costs can vary year by year. The velocity of the tide has a particular impact on the cost of energy. Whilst sites with higher velocity tidal streams have the potential to be more economic, greater velocity can also increase the costs of designing, installing and operating

[19] Grid connection costs do not take account of any potential upgrades to the distribution and transmission network as these will vary by location. The significance of these costs will vary depending on how remote the site is the level of pre-existing capacity in the grid, and the strength of the grid infrastructure.

farms in these areas. Operating costs are subject to greater levels of uncertainty than capital costs due to the scarcity of operational marine energy systems, although inference has been drawn from similar offshore wind and oil and gas developments.

4.14 A distinction can also be made between the current and future cost of energy. First generation technology costs are based on proven technology without learning and therefore represent the costs of developing initial commercial farms (demonstration farm cost premiums and early financial premiums are excluded). Second generation costs include learning effects after the development of first generation sites.

Potential for Cost Reduction

4.15 Costs are currently very high compared to other energy generation methods, will need to fall considerably to be competitive and in due course to become independent of public subsidy. The Cost of Energy is lowered by either reducing the costs of construction and operating the device, or increasing the device's energy production, or a combination of the two. The CoE is therefore lowered as technology and processes become more efficient as experience is gained.

4.16 The latest commonly accepted work on potential cost reductions in marine energy is the Technology Innovation Needs Assessment (TINA), published by the Low Carbon Innovation Coordination Group in August 2012.[20] This work updated its estimates on the current costs of marine energy, stating that they were around £350-400/MWh for wave and £200-300/MWh for tidal.[21] The key findings are **that the CoE will need to reduce by 50-75% to around £100/MWh by 2025** for marine energy to be competitive (current offshore wind costs are in the order of £140-180/MWh and offshore wind power has a target of £100/MWh by 2020 in the UK Government's Renewables Roadmap).

4.17 To achieve this, significant levels of innovation and economies of scale are needed, which will require large scale (>200MW) arrays to be operational, alongside supply chain optimisation and sufficient financing. Technology innovation can steepen the learning curve, or start the curve at a lower level, through reductions in capital or O&M spend (per kWh of output), or improvements in device performance (increasing reliability or efficiency increases the kWh per unit of capital and operating spend). The greatest cost reductions come from capital costs.

4.18 Before this happens, demonstration devices need to be deployed (1-5 MW), in order to prove that multiple single devices work in various locations, to optimise control systems and therefore energy yield, and to assess the potential for cost savings in construction and installation. The TINA's assessment is that **initial deployment of first arrays must be completed by around 2015, the first commercial multiple device arrays (10-15MW) by 2017, and fully commercial farms (c.50 MW) by 2019/2020.**

4.19 Possible cost reduction pathways are shown below for wave and tidal, with three scenarios:

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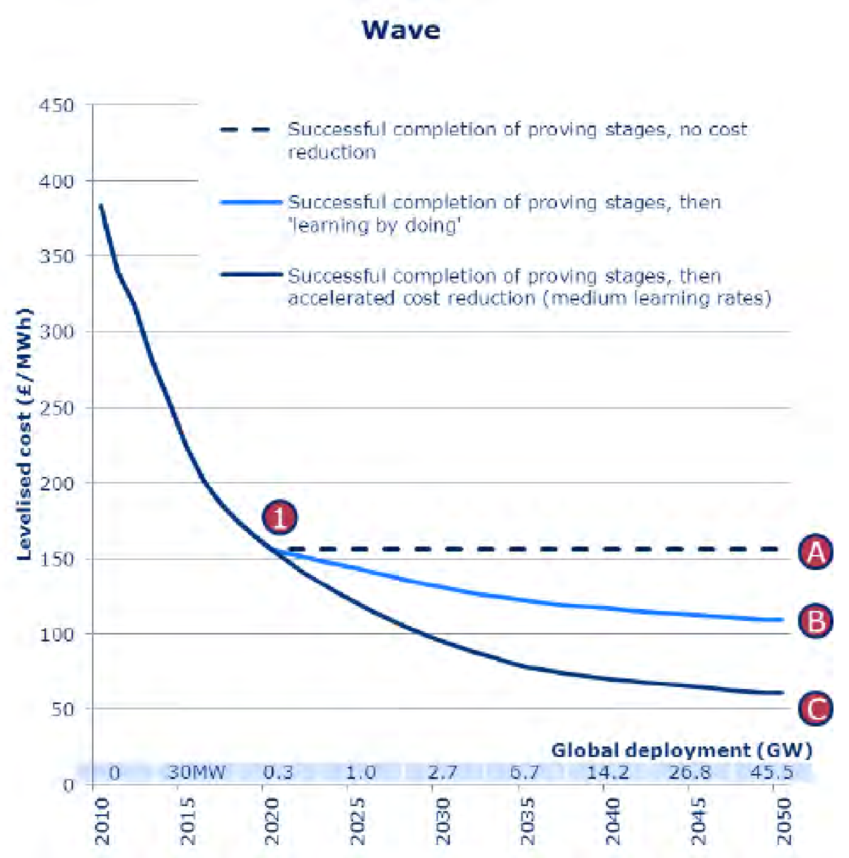
[20] More recent work by RenewableUK on the cost of marine energy largely accords with these findings.

[21] i.e. 30-40p per KWh for wave and 20-30p per KWh for tidal stream.

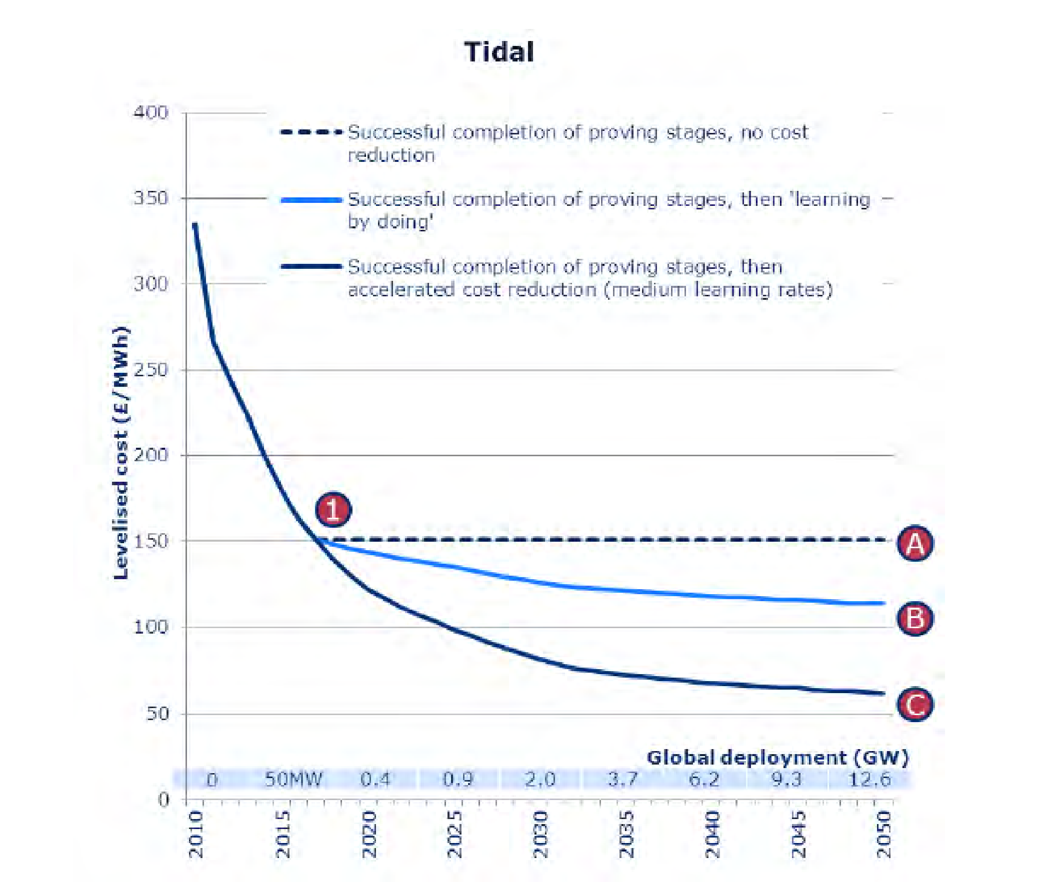
- A: no further reduction is considered beyond the point of first commercialised costs
- B: costs continue to fall in line with the expected improvements of alternative technologies e.g. offshore wind
- C: costs fall in line with additional technology innovation.

Figure 4-2: Potential Cost Reduction Pathways for Wave Energy



Source: Taken from Carbon Trust (2012) *Technology Innovation Needs Assessment*

Figure 4-3: Potential Cost Reduction Pathways for Tidal Energy



Source: Taken from Carbon Trust (2012) *Technology Innovation Needs Assessment*

Capital Support

4.20 The considerable capital costs outlined above are currently too high, and the potential returns too uncertain, for private investors alone to be able to finance the development of marine energy projects. The UK Government has therefore recognised that given this market failure and the potential future benefits from the development of the industry, there is a need for the public sector to share some of this risk and to provide early stage capital funding.

4.21 A number of different funding streams have been in operation in the UK. The main ones are as follows:

- The £50m Marine Renewables Deployment Fund (MRDF): established in 2006 to support demonstration of pre-commercial wave and tidal energy devices. No rewards for demonstrations were made, since developers found it more difficult than anticipated to develop, deploy and test prototypes at full scale.[22] The Fund was closed in March 2011.

[22] Energy and Climate Change Committee (2012) *The Future of Marine Renewables in the UK,* Eleventh Report on the Session 2010-12.

- The £22m Marine Renewable Proving Fund: designed to assist the industry to move to large scale prototype deployment and testing (and therefore to be ready for MRDF funding). Six grants were made to developers for full-scale prototype devices ranging from 0.8 to 1.2MW in size.

- The £20m Marine Energy Array Demonstrator (MEAD) fund: This was introduced by the Department of Energy and Climate Change (DECC) in 2011, funded by its Low Carbon Innovation Fund. The aim of the MEAD fund is to help developers to move from single to multiple device projects and to develop the first pre-commercial arrays. In 2013, £10m was awarded to the Skerries Tidal Stream Array (MCT)[23] and £10m to MeyGen[24].

- The £18 million Marine Array Commercialisation Fund (MRCF) is capital support offered to wave and tidal stream developers by the Scottish Government which is intended to support the Pentland Firth and Orkney Waters leasing round. The fund may also be used to support innovative enabling technologies or infrastructure that will de-risk future arrays. The aim is to support at least two developers in Scottish Waters with technologies that are proven at full-scale.

- European New Entrants' Reserve (NER) 300 Fund: this EU fund provides finance for innovative low carbon technologies.

Revenue Support

4.22 Revenue support is currently required to incentivise and support the development of the industry, given the high costs of energy from marine compared to other established energy sources using mature technologies. Revenue support provides a framework in which investors and developers can plan and provides a market signal to investors.

4.23 The key source of public subsidy is the Renewables Obligation, which supplements the revenue received by renewable energy generators from selling electricity to the grid. This works through Renewables Obligation Certificates (ROCs). Wave and tidal stream energy in England and Wales were previously eligible for 2 ROCs per MWh of electricity generated. Following DECC's Renewables Obligation Banding Review, this was increased to 5 ROCs per MWh, putting England and Wales in line with Scotland, which was already offering 5 ROCs per MWh. This move was widely welcomed by the industry and seen as an indication of the Government's commitment to the industry.

4.24 The ROC regime is due to continue until 2017, at which point the RO will be closed to new entrants. Electricity Market Reform (EMR) was introduced in 2010 and will determine the future subsidy available. Current plans are to replace ROCs with a Contract for Difference with a Feed in Tariff (CfD FiT) mechanism. This would set a price for electricity generated from wave and tidal power (the Strike Price), linked to the cost of energy. This would incentivise and reward cost reductions as a margin between the actual cost and the strike

[23] The array is located close to the port of Holyhead, off the north-west coast of Anglesey in North Wales and will consist of five SeaGen 2MW tidal stream turbines.

[24] a joint venture between Morgan Stanley, International Power and tidal technology provider Atlantis Resources Corporation. The array will be located in the Pentland Firth in Scotland.

price would develop. However, precise details on the level of support to be offered have yet to be announced and this is widely seen as a risk factor to the development of the industry at present. RenewableUK's latest analysis recommends a strike price of £280-300 per MWh for tidal stream and £300-320 per MWh for wave energy.

Development of the Industry to Date and Future Prospects

4.25 Clearly, the marine energy industry is at an early stage in its development, and marine energy technologies are not yet at a full commercial stage. Figure 4-4 provides a generic summary of the stages in the development of a wave and tidal installation. The Marine Energy TINA states that only two wave and four tidal technologies have so far moved to a full scale demonstration stage, with a further three devices expected to join them over the next year (1 wave, 2 tidal). Between 10-17 developers are identified as being at early demonstration/scale testing stage, with a further 25-35 developers at the applied research stage (completing tank testing).[25]

4.26 Nonetheless, significant progress is being made. RenewableUK's latest publication on marine energy in February 2013 notes that twelve large-scale prototype devices are being deployed in the UK at present, which is more than in the rest of the world combined.[26]

Figure 4-4: Stages in the Development of a Marine Energy Installation

Source: Carbon Trust (July 2011) *Accelerating Marine Energy*

Wave Technologies

4.27 A range of different device technologies are currently being developed and tested using full-scale prototypes as developers move towards developing commercially deployable devices. The emphasis is shifting from Proof of Concept towards improving reliability achieving cost savings. Recent work by the Carbon Trust summarises the current state of development as follows:

"Designs for wave energy have not yet converged. There are a variety of device concepts including oscillating water columns, overtopping devices, point absorbers, terminators, attenuators as well as flexible structures."[27]

"A number of very different wave devices are under development, and little design convergence has taken place, although the leading developers are demonstrating full-scale

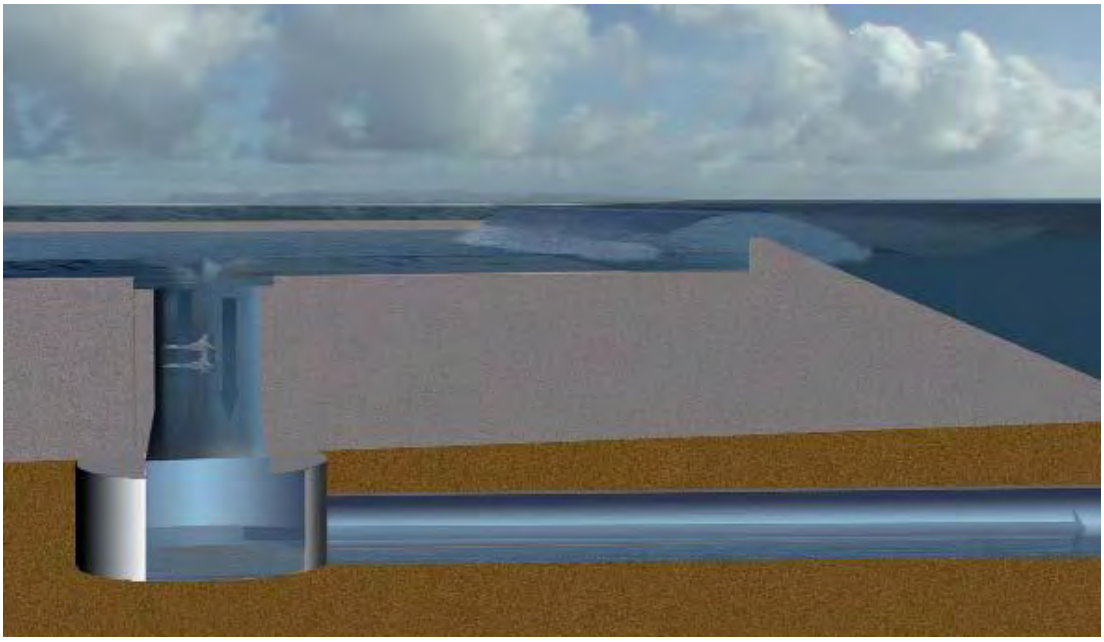
[25] Carbon Trust (2012) *Technology Innovation Needs Assessment*

[26] RenewableUK (February 2013) *Wave and Tidal Energy in the UK, Conquering Challenges, Generating Growth*

[27] Carbon Trust (2012) *Technology Innovation Needs Assessment*

devices."[28]

Figure 4-5: Example of an Overtopping Wave Device



Source: BVG for Crown Estate (2011) *Wave and Tidal energy in the Pentland Firth and Orkney Waters: How the projects could be built*

4.28 Wave devices can be categorised depending on their deployment location. Offshore wave converters are designed for deep waters (in the region of 20-50m) whereas near shore converters are placed in shallow waters. The technologies underpinning each device type are significantly different and hence the extent to which learning and refinement of the technologies can be shared between device types is limited[29].

Tidal Stream Technologies

4.29 Tidal devices are very similar to wind energy generating devices and much of the technology, components and knowledge can be drawn from 30 years of wind-turbine development. Sea water is 800 times denser than air and flow rates are around one fifth those of air meaning that tidal turbines are typically half the diameter of wind turbines.

4.30 Though most devices have a superficial resemblance to wind turbines, there is currently no consensus on the form and geometry of the conversion technology used[30]. Possible variants include horizontal axis turbines, vertical axis turbines, oscillating hydrofoil machines and venturi-based devices. Fundamental design options include the method of fixation and shrouding.

[28] Carbon Trust (2011), *Accelerating Marine Energy*

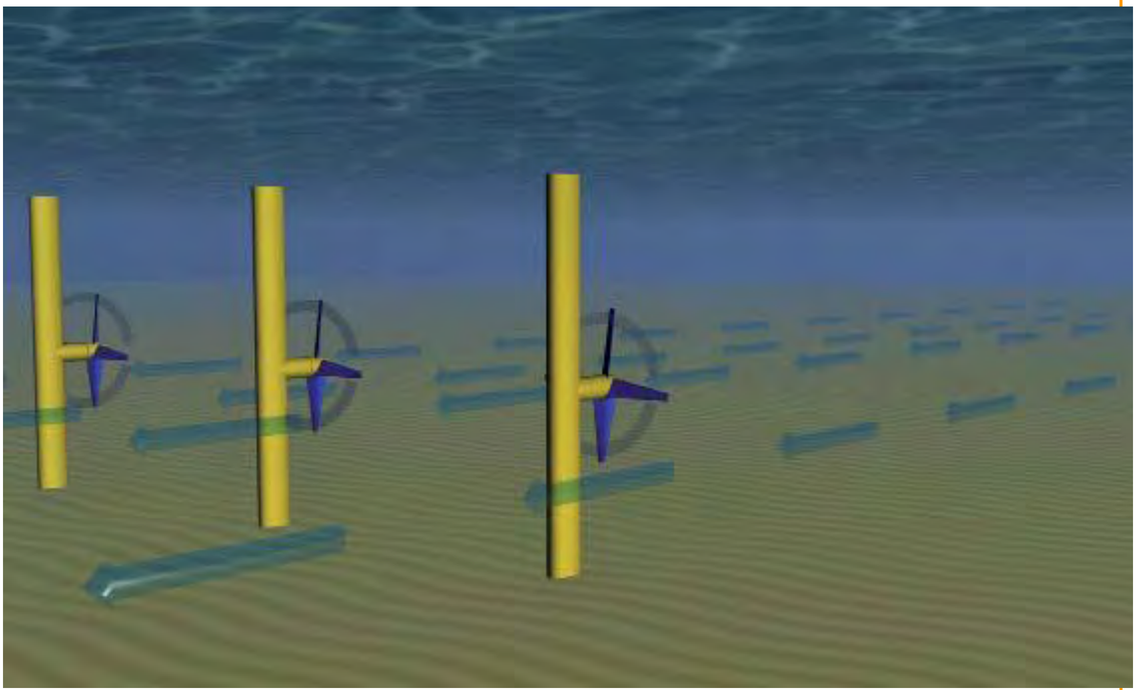
[29] Ernst & Young (2010) for DECC Cost of and Financial Support for Wave Tidal Stream and Tidal Range in the UK.

[30] http://www.aquaret.com/en/elearningtool/technologyselection/32tidalstream/33-technology-types-/331-level-2-

4.31 Tidal devices have converged to a greater extent than wave devices, with most designs now based around horizontal axis turbines, which share some similarities to wind turbines. There are some earlier stage designs still looking at the potential for vertical axis turbines, hydrofoils and Venturi-effect devices, in some case for niche applications.[31]

"Tidal devices are approaching a convergence of design, with most concepts based on a bottom-mounted horizontal axis turbine"[32]

Figure 4-6: Example of a Horizontal Access Turbine Tidal Stream Device



Source: BVG for Crown Estate (2011) *Wave and Tidal energy in the Pentland Firth and Orkney waters: How the projects could be built*

4.32 Unlike wave, shallow (<40m) and deep (>40m) tidal stream devices can benefit from learning from one another as the two forms of extraction only differ in terms of the structure, foundation and moorings used; not the principal technology. Shallow sites are currently the easiest and most economical to deploy[33]. The maximum amount of energy that can be extracted from the tidal stream is 59% of the theoretical resource (the Betz Limit).

Future Pipeline

4.33 There is a great deal of uncertainty surrounding the future development pipeline both globally and in the UK. This is in turn driven by inter-related uncertainties on the rate of technological development, the ability of the industry to reduce costs and move away from public subsidy, the availability of public and private finance, the future policy framework as

[31] Carbon Trust (2012) *Technology Innovation Needs Assessment*

[32] Carbon Trust (2011) *Accelerating Marine Energy*

[33] Ernst & young (2010) for DECC *Cost of and Financial Support for Wave Tidal Stream and Tidal Range in the UK.*

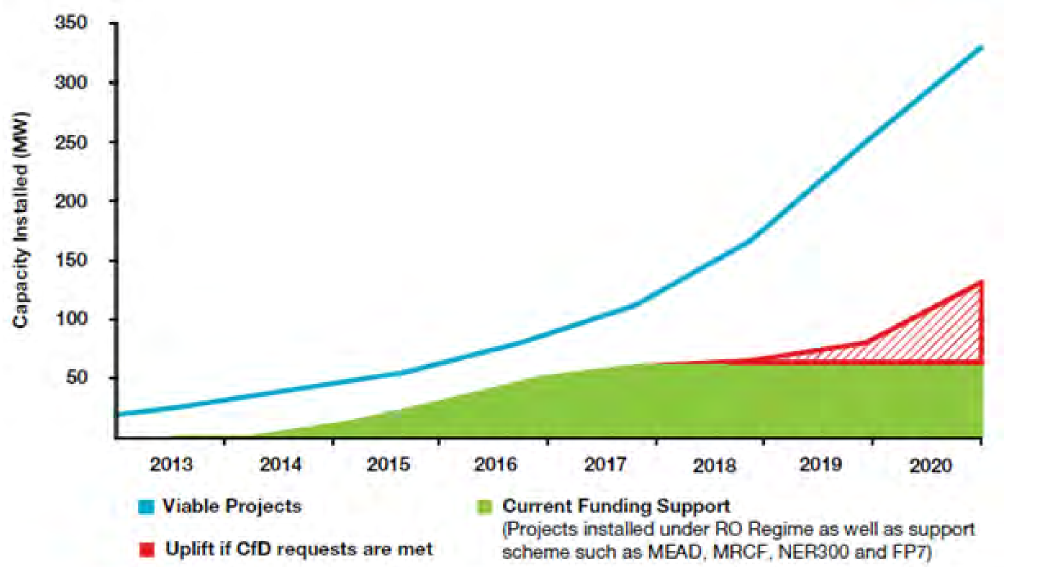
well as the relative status of other low carbon energy technologies.

4.34 However, RenewableUK has worked extensively in recent months to provide a realistic assessment of this pipeline. This has been done by taking the list of wave and tidal leases as a starting point and from here mapping out the projects that are in a position to connect to the grid and to gain consent up to 2020. These projects amount to in excess of 300 MW of installed capacity. Given the importance of finance to fund the capital investment required to develop and deploy these projects, RenewableUK concludes that the most accurate and realistic development pipeline is given by those projects that are currently in receipt of public sector support (from the UK and Scottish Governments as well as EU sources). These projects could collectively account for 100-200 MW of installed capacity by 2020 (within this, Welsh projects account for 10MW – the pipeline of projects in Welsh waters is discussed in more detail in Section 5). This is summarised in Figure 4-7 and chimes with other analyses – for example, the UK Energy and Climate Committee concluded that

"[Marine renewables'] very high cost at their present state of development means they are unlikely to make much, if any, contribution before 2020."[34]

4.35 Beyond this, our consultations indicate that it is not possible to make a robust assessment of future capacity development, given the range of uncertainties outlined above. In particular, the successor to the ROC regime - which expires in 2017 – and Electricity Market Reform is a particular "known unknown" and potentially a risk to future development. This is confirmed by RenewableUK, who state that until there is more certainty on the future subsidy it is not possible to robustly project forward capacity for the UK.

Figure 4-7: Potential Future Development Pipeline



Source: RenewableUK (February 2013) *Wave and Tidal Energy in the UK, Conquering Challenges, Generating Growth*

4.36 Further to this, we have mapped out the various projects that are in development in the UK,

[34] Energy and Climate Change Committee (2012) *The Future of Marine Renewables in the UK,* Eleventh Report on the Session 2010-12.

based on the information available to us. This is provided in Appendix C.

The Marine Energy Supply Chain

4.37 Whilst there are no commercial scale arrays at present, with a consequent lack of evidence on marine energy supply chains, our consultations and desk review have enabled us to draw out in detail the typical supply chain associated with wave and tidal projects, from planning and development through to operations and maintenance. A particularly useful source is the Crown Estate's recent work on the projects within the Pentland Firth and Orkney waters.[35] This maps out how and when these projects could be built, and the goods and services required at each stage in development, based on work with the developers. There are broadly five phases in the project lifecycle, which can be summarised as follows:

- **Development and Consents**: design and feasibility, surveys and monitoring (e.g environmental), planning application.
- **Device manufacturing**: hydrodynamic, reaction, power take off and control systems.[36]
- **Balance of plant manufacturing**: foundations, mooring, cabling, electrical equipment, onshore infrastructure.
- **Installation and commissioning**: port services, installation of electrical systems, installation of foundations and moorings, device installation.
- **Operations and maintenance**: monitoring, planned and unplanned maintenance, insurance, grid charges.

4.38 There is considerable variation in the supply chains as between wave and tidal energy projects, and within each of these, as between different device technologies (e.g. depending on the depth at which they are to be deployed). There are also multiple options on the materials to be used (e.g. concrete versus steel). However, allowing for this variation, the Crown Estate has mapped out in detail the typical goods and services that are expected to be required for marine energy projects at each broad stage in the lifecycle. We provide a summary of these detailed findings in Appendix D.

4.39 In Section 5 we map these requirements against the current set of capabilities in Wales.

Economic Benefits

4.40 A number of studies have attempted to quantify the potential future economic contribution from marine energy at the global and UK level. The methods used range from top-down assessments that estimate the future size of the market and extrapolate the associated jobs

[35] BVG for Crown Estate (2011) *Wave and Tidal energy in the Pentland Firth and Orkney waters: How the projects could be built*

[36] The hydrodynamic system is the system that interacts with the water to extract energy from it; the reaction system holds the device in place; the power take off system converts the energy extracted into electrical energy; and the control system provides supervisory and closed-loop control.

and GVA, to more bottom-up estimates for particular locations that use average capital and operational cost estimates to estimate future investment and thus jobs and GVA. Examples of studies include:

- *The Offshore Valuation* (2010) by the Public Interest Research Centre: This sets out three scenarios for total wave and tidal stream capacity in the UK by 2050 (4 GW to 35 GW),[37] and uses DECC's central electricity price scenario to estimate associated costs. Consequent economic impact estimates range from 4,000 jobs to 23,000 jobs in the UK in 2050.

- *Channelling the Energy* (2010), RenewableUK. This uses the offshore valuation above plus a survey of leading technology developers to estimate the future project cost breakdown for a hypothetical 30 MW Project. It then uses Scenario 3 from the Offshore Valuation for deployment and market retention estimates to project value of the industry. From this, it is estimated that there will be £800m in GVA and 19,500 employees by 2035, and £770m GVA and 19,000 employees by 2050.

4.41 Our review has highlighted several examples of studies at a more local level. Notable examples include:

- PMSS (2010) *Offshore Renewables Resource and Development – South West Economic Impact Assessment* PMSS: This work took in all offshore renewables (i.e. including offshore wind). Based on available marine resources, future capacity development in the South West was estimated to be 9.2 GW, of which 7.7 GW was estimated to be operational by 2030. Capital and operational cost data was taken from desk research and three scenarios for expenditure retention in the South West were constructed. Over the period 2015 to 2030, tidal stream development is estimated to support a total of £475m in GVA and 12,200 FTEs in the South West, with wave contributing £820m GVA and 22,000 FTEs.

- Sgurr Energy and IPA for Scottish Government Marine Energy Group (2009) *Marine Energy Supply Chain Survey*: This study used three scenarios for marine capacity in Scotland by 2020, ranging from 500 MW to 2,000 MW. Consultations with developers were used to estimate capital costs (operations and maintenance was excluded). The study estimated that 53% of capital expenditure would be retained in Scotland and in the base case 2,600 FTEs could be supported in Scotland.

4.42 The University of Strathclyde has also undertaken recent work on the economic impacts from wave and tidal stream development at Pentland Firth and Orkney waters up to 2020. This work is currently in draft form.

[37] It should be noted that these deployment scenarios for the UK are optimistic. The Carbon Trust estimates that global deployment could be around 60 GW by 2050.

Experience Elsewhere

Global Activity

4.43 We saw earlier that the UK is relatively advanced in developing and testing marine energy prototypes. To put this into context it is worth noting the activities being undertaken in other locations. RenewableUK's latest publication on the sector provides a useful summary of developments in other countries. We reproduce this in the box below.

Box 2: Summary of Global Marine Energy Activity
Canada Canada's Marine Renewable Energy Technology Roadmap sets out the path to the commercialisation of marine energy in Canada. This is supported by funding via the ecoENERGY Innovation Initiative. The Fundy Ocean Research Centre for Energy (FORCE) in Nova Scotia acts as an industry incubator similar to EMEC. **China** A national project has been started to construct a pilot zone and offshore test sites. **France** Brittany, the French Government and the EU have all contributed to a project deploying four 2MW tidal turbines off the coast of Paimpol-Bréhat to create the world's largest tidal array exporting power into the electricity grid. **Japan** Marine energy research and development has been allocated a total budget of the equivalent of approximately £50m for the years 2011 to 2015. **New Zealand** The Marine Energy Deployment Fund was set up in 2007 with the aim of bringing forward the development of marine energy in New Zealand by supporting the deployment of devices. Grants to the equivalent of approximately £2.1 million were allocated in four annual rounds between 2007 and 2011. **Portugal** The Portuguese Marine National Plan has been published, aimed at ensuring the sustainable use of marine resources by a variety of users. **South Korea** The government has set a target that 11% of the national energy demand comes from new and renewable energy by 2030. Ocean energy, including wave and tidal is targeted to contribute 4.7% to the new and renewable total. **Spain** The Spanish Government's Renewable Energy Plan 2011–2020 includes a target for an annual installation rate for marine energy of 20–25MW between 2016 and 2020. The plan states that 100MW is expected to be installed by 2020, producing 220GWh/year by then. **USA** The United States Government Water Power Program is currently assessing the opportunities associated with ocean energy resources. This is anticipated to inform the establishment of aggressive national goals for marine energy technology deployment. Additionally, Australia, Belgium, Denmark, Germany, Ireland, Italy, Mexico, Norway and Sweden also have an active interest in marine energy and are members of the Ocean Energy Systems Implementing Agreement (IEA-OES).
Source: Taken from RenewableUK (February 2013) *Wave and Tidal Energy in the UK, Conquering Challenges, Generating Growth*

Developments in Scotland

4.44 Our review of the development of the industry in other locations – along with our consultations with the marine energy industry - has pointed towards the strong progress made by Scotland. Our review and consultation has therefore focussed in more detail on what has been happening there and the key explanatory drivers.

4.45 The Scottish government has repeatedly demonstrated its support for the sector through a number of funding initiatives, supportive messages and high tariffs, to aid its ambition of generating 100% of its electricity from renewable sources by 2020. Scotland's main assets are its natural resources and its transferable oil and gas expertise.

Resource available and developments to date

4.46 Like Wales, Scotland is endowed with significant marine energy resources. The Scottish government states that the country has up to 25% of Europe's tidal power resources and 10% of its potential wave resource.[38] The coastlines around Shetland, Orkney, the Outer Hebrides and Argyll experience strong winds and currents and therefore have plentiful marine energy resources, estimated to have a potential capacity of 1.6GW, in addition to an estimated 112 MW elsewhere in Scotland.

4.47 More than 25 marine energy leases have been awarded by the Crown Estate. Six wave and five tidal schemes – with the potential to generate 1.6 GW of marine energy – will be developed off Scotland's north coast, in the Pentland Firth and Orkney Waters, by 2020. In addition, Scotland has the world's largest consented tidal stream project, a 10 MW project near Islay, developed by ScottishPower Renewables using Andritz Hydro Hammerfest technology.

4.48 An indication of the level of interest and confidence in the sector in Scotland is given by the fact that global engineering and energy groups such as Rolls-Royce, Siemens and Alstom have been acquiring pioneering firms. Developers located in Scotland include Pelamis Wave Power, Aquamarine Power, Voith Hydro Wavegen, AWS Ocean Energy and Scotrenewables.

Policy and strategy, partnership arrangements

4.49 The Scottish Government has been very vocal about its support for renewables in general, and marine energy in particular. The Marine Energy Roadmap (2009) sets out the key challenges for the sector and recommendations for overcoming barriers relating to planning, finance, supply chain, grid connectivity and support from Europe. Progress has since been measured against these 5 elements, and this has subsequently been updated in the form of the Marine Energy Action Plan (2012).

4.50 The key partnership charged with delivering the Government's aspirations for the sector is the **Marine Energy Group (MEG),** a collaboration between wave and tidal developers, key public sector organisations, the Crown Estate and the European Marine Energy Centre (EMEC – see below for details). The MEG exists to:

'To create the world's leading marine energy industry, one that will provide a substantial contribution to the sustainable economy and environment of Scotland.'[39]

[38] Scottish Development International, *Wave and tidal energy in Scotland*

[39] Marine Energy Group (2012) *Marine Energy Action Plan*

Funding

4.51 In addition to the strong statements of political support and partnership work, an important factor supporting the development of the industry in Scotland has been the availability of additional capital and revenue funding, over and above what has been made available in England and Wales. Scotland negotiated with DECC to establish Renewables Obligation Certificates (Scotland) bands as 3 ROCs/MWh for tidal stream and 5 ROCs/MWh for wave. This compared at the time with 2 ROCs/MWh offered in England and Wales. This has subsequently been equalised, with both England and Wales and Scotland offering 5 ROCs /MWh for both wave and tidal (although Scotland has not imposed a 30 MW limit for the receipt of ROCs). This provided a strong additional incentive for the industry in Scotland, as well as a powerful signal of the Government's support for the industry.

4.52 Alongside this revenue support the MEG has consistently reinforced the need for public sector capital investment in order to mitigate the risk faced by private sector investors at the high risk, prototypical and demonstrator stages in the technologies' lifecycle. Scotland has offered a number of capital funding streams in recent years, in addition to that offered by DECC for the UK:

- In 2009, a £13m support package was introduced for Scottish marine energy developers funded by the Scottish Executive, which aimed to establish Scotland as a world leader in marine energy.
- The Scottish Government's £18m Marine Renewables Commercialisation Fund (MRCF) was launched in summer 2012 with the aim of providing capital support to at least two developers[40] installing commercial-scale arrays of multiple devices[41], or enabling technologies that have the potential to de-risk arrays. The investment is part finance scheme, whereby the developer must provide at least 75% of the total project cost. The money has yet to be awarded but will be distributed by March 2015.
- Most recently, the £103m Renewable Energy Investment Fund (REIF), announced in October 2012 and financed by the Fossil Fuel Levy Fund, aims to provide loan guarantees and equity finance alongside co-investment partners to renewable energy investments. Though the fund is not exclusively allocated to marine energy, up to three quarters of the financing could be allocated to the marine sector. This money has to be committed by 2015.
- Scottish government's WATERS 2 (Wave and Tidal Energy: Research, Development and Demonstration Support) scheme has provided £7.9m to 5 Scottish companies in 2012 to further develop the testing of wave and tidal prototypes in the seas around Scotland. This followed a first round of funding (£6.9m) in 2010 distributed to 4 companies. The companies rewarded under the WATERS 2 scheme are:

[40] A maximum of £9m will be distributed to any individual array project.

[41] To be eligible, the arrays must include at least 3 devices, have a total capacity of more than 2MW (3 – 10 MW preferred), use wave or tidal stream devices that are proven at full scale, and have a planned completion date before March 2017.

- Scotrenewables Tidal Power — £1.2m towards a project to design, construct and install a 2MW SR 2000 commercial-scale floating tidal turbine
- AlbaTERN — £617,000 towards the deployment of a WaveNET demonstrator array comprising six SQUID 7.5kW wave energy converters
- AWS Ocean Energy — £3.9m towards a scheme to design, build and launch stages of a project to prove the AWS-III WEC device at full scale
- Nautricity — £1.4m towards the building and testing of a full-scale, pre-commercial CoRMaT 500kW tidal turbine
- Oceanflow Development — £750,000 towards a project to build and field-test a quarter-scale prototype twin-turbine tidal energy converter, Evopod TE70

4.53 The introduction of the Scottish Government's **Saltire Prize**, the world's largest prize for technological advances in marine energy, has arguably raised the profile of Scotland's marine renewables industry. The £10m Saltire Prize is intended to incentivise competition and encourage the development of marine energy devices. The challenge is to produce the greatest volume of electricity (100 GWh) from Scottish waters over a continuous two-year period by 2017. Four British companies entered (Tidal – MeyGen and Scottish Power Renewables, Wave – Pelamis and Aquamarine). Though arguably the prize is insignificant compared to the potential revenues from a commercially successful technology, the main objective is to publicise and promote the industry which may help to stimulate further private sector investment.

4.54 In February 2012, the Technology Strategy Board (TSB), Scottish Enterprise (SE) and the National Environmental Research Council (NERC) together launched a £10.5m Marine Energy: Supporting Array Technologies (MESAT) competition on common technology challenges associated with marine energy device array deployment and operation. The money has been allocated to seven projects that are developing supporting technology, which can used be used across the industry to solve common problems. The companies leading the TSB-funded projects are CC Hydrosonics, IT Power, Mojo Maritime, SSE Renewables, Tension Technology International, Tidal Generation, TidalStream

Test Facilities: EMEC

4.55 The European Marine Energy Centre (EMEC) based in Orkney was established in 2003 as the world's first purpose-built, accredited open-sea testing facility for marine energy developers. The location benefits from abundant natural resource, good grid connectivity, harbour facilities and the relevant expertise that exists in the local area. EMEC currently has 14 berths leased, with 6 operation devices, 5 devices undergoing installation and 3 scheduled to arrive in the next 2 years. More full-scale devices are deployed at the European Marine Energy Centre on Orkney than at any other site worldwide. So far, 4 devices have produced electricity for sustained periods (days).

4.56 There is a continued demand from developers for test and demonstration sites. Developers are looking beyond EMEC to other sites around the coast that also offer attractive benefits. The Crown Estate, which operates the leasing process, is offering sites to the west, north west and other areas, not just EMEC. Developers are looking for sites that have less vigorous seas and winds for testing newer technologies. Wave developers are attracted to locations along the west coast and Shetland.

Infrastructure

4.57 The MEG and Scottish government view grid connectivity as a critical factor determining the future of the industry. Progress has been made on increasing connectivity and upgrading power lines, and reducing transmission charging in certain areas.

4.58 Other infrastructure investments have been made to advance the industry: The Orkney Islands Council has pledged £15m for the development of its 3 Ports Strategy, investment by Highlands and Islands Enterprise (HIE) together with EU funding is supporting the construction of development areas at Hatson for tidal energy companies to access the Eday test site, and Scrabster Harbour is receiving £25m in funding for development, in part from the HIE (£5m) and Scottish Government (£3m). In addition, a network of test and demonstration facilities called the Scottish Energy Laboratory (SEL) which includes a test tank (FLOWTT) developed at the University of Edinburgh has been created. The North and East of Scotland have been designated low carbon/renewables Enterprise Areas by the Scottish Government which will offer incentives for businesses to relocate (enhanced business rates relief or capital allowances).

4.59 Recommendations of the MEG include identifying potential 'pinch-points' in grid availability and effectively underwriting the cost of new grid connections[42].

Marine Energy Park (MEP)

4.60 Pentland Firth and Orkney Waters were designated as UK Marine Energy Parks (MEP) by DECC in July 2012. It is hoped that this will help stimulate investment in the sector, and strengthen links between university researchers and private companies, leading to the successful commercialisation of technologies. Pelamis, together with E.ON and ScottishPower Renewables, is developing 200MW of wave farm projects within the new Marine Energy Park.

4.61 In February 2013, the Scottish MEP joined forces with the South West MEP[43] to exchange knowledge and best practice, with the ultimate goal of accelerating commercial development of the marine energy sector. The Scottish government also announced further investment of £4.1m in EMEC; £3m for a new grid-connected testing-berth and a £1.1m project to develop support vessels.

Supply Chain and Skills

4.62 There are a number of companies in the north of Scotland with expertise in the Oil and Gas sector which have direct relevance to the wave and tidal industry. There are also a number of construction companies in the Highlands and Islands areas with experience of offshore

[42] Marine Energy Group (2012) *Marine Energy Action Plan*

[43] http://www.wavehub.co.uk/wp-content/uploads/2012/02/Marine-Energy-Park-prospectus.pdf

infrastructure for oil, gas and wind.

4.63 SE and HIE are in the process of producing a Marine Supply Chain portal; an online interactive tool which will allow developers to search for the relevant supply chain companies that can assist them in the various stages of development. A similar directory currently exists for the offshore wind energy industry[44].

Consenting

4.64 A number of consultees have pointed towards the swifter consenting process in Scotland, with one stating that the consenting process takes an average of 6-9 months, whereas in Wales the decision making process can take 18-24 months.

[44] http://www.scottish-enterprise.com/your-sector/energy/offshore-wind/companysearch.aspx

5. Marine Energy in Wales

5.1 In this section we provide a summary of the marine energy sector in Wales. We cover the following:

- The marine resource in Wales
- The marine energy sector in Wales
- The potential supply chain for marine energy in Wales
- Challenges and constraints.

The Marine Resource in Wales

5.2 The Marine Renewable Energy Strategic Framework (MRESF)[45] was published in 2011 and provides an assessment of the marine resource available in Wales (both theoretical and practical). Overall the assessment concluded that there was potential for a total of **1.5 to 6.5 GW of installed capacity in Welsh waters**, equivalent to 3.4 to 14.4 TWhr per year. These resources were found to be concentrated in Anglesey, Llyn Peninsula, Pembrokeshire and Glamorgan. Underlying these figures is a complex assessment process, the key features of which we summarise below.

5.3 In order to estimate the potential generation capacity within Welsh waters, areas were assessed and ranked on a scale of 1 to 5 according to the amount and significance of constraints limiting the potential for extraction. Constraints were grouped into the following six categories:

- **Practical limitations** (e.g. financing, sourcing of materials, grid connection);
- **Device specific issues** (e.g. resource availability, water depth, distance from shore);
- **Support** (ranging from local interest to government level and including issues such as financing, research);
- **Legislative considerations** (e.g. SEA, sustainability, consenting and nature conservation legislation);
- **Existing use** (i.e. existing human use such as shipping, fisheries and MOD); and
- **Data requirements** (e.g. quantity and quality of available data, ownership issues and cost of acquisition).

5.4 The overall conclusion of the report is that Wales has significant wave and tidal stream energy potential, which is constrained by existing interests in the resource areas. Shipping, commercial fishing and ecology/wildlife are common constraints. Energy generation

[45] RPS (2011) Marine Renewable Energy Strategic Energy Framework Stage 3

scenarios depend on the level of these constraints. Higher energy yields assume development in areas with more (level 4) constraints – defined as *"significant issue/constraint: probable delay and could possibly stop the project"* - which will be problematic to achieve:

- **The Low energy yield scenario** excludes any potential areas that have identified constraints of level 4 or above.
- **The Medium energy yield scenario** is divided into two alternative outcomes: scenario A estimates the potential energy when areas constrained by **a single rank 4 data layer** are included, and Scenario B includes areas constrained by **up to two rank 4 data layers.**
- **The High energy yield scenario** relies on development in level 4 areas (areas with "considerable challenges for developers and the consenting authorities"). It is made clear that for development to be acceptable in these areas, a significant number of barriers would have to be overcome by effective discussion and negotiation with affected parties to minimise impacts on existing sectoral uses and the environment.

5.5 The results from these scenarios are summarised in the table below:

Table 5-1: Summary of MRESF Scenarios

Scenario		Constraint Layers	Variable	Tidal	Wave	**Total**
Low energy yield: Areas ≤ constraint rank 3		35	Potential Installed Capacity (GW)	~0.1	~1.6+	**1.5**
			Area (km2)	23	466	487
Medium energy yield: Some areas with constraint rank 4	Scenario A	52	Potential Installed Capacity (GW)	-	-	**3.7**
			Area (km2)	-	-	1,139
Medium energy yield: Some areas with constraint rank 4	Scenario B	59	Potential Installed Capacity (GW)	-	-	**5.1**
			Area (km2)	-	-	1563
High energy yield: Areas ≤ constraint rank 4		63	Potential Installed Capacity (GW)	~0.6	~6.1	**6.4**
			Area (km2)	161	1713	1,875

RPS (2011) Marine Renewable Energy Strategic Framework Stage 3
Numbers may not sum due to rounding. Blanks indicate data not available. The figures for potential installed capacity include a number of assumptions and hence are subject to a degree of uncertainty.

The Marine Energy Sector in Wales

5.6 As we saw in Section 3, the Welsh Government is committed to capturing the marine resource in Wales and maximising the benefits from the development of the industry. To date, development and testing has been focussed in Pembrokeshire, which has a large amount of the practical resource in Wales and offers research centres, port facilities and good grid connections.

5.7 Below we review the key partnerships and projects that have developed.

Academic Collaborations & R&D

5.8 Wales has a number of research establishments that are active in marine renewables.

The Low Carbon Research Institute

5.9 The Low Carbon Research Institute (LCRI) is a collaboration of leading renewable energy related Research and Development departments at universities in Wales, which aims to develop capacity and facilities around existing areas of low carbon energy expertise in Wales, enabling the Welsh Government to meet its renewable energy policy objectives whilst promoting low carbon energy development, helping to attract international research funding. Its stated aims are

"to support the energy sector, UK and globally, to develop low carbon generation, storage, distribution and end use technologies, and to offer policy advice."[46]

5.10 LCRI is supported by grants from the Higher Education Funding Council for Wales (HEFCW), as well as contracts from the Research Councils, Industry and Government. In 2010 LCRI secured £19 million from the Welsh European Funding Office, a contribution to a £34 million programme to enable Wales and its industry partners to lead the way in research to cut carbon emissions, as part of the European Research Development Fund's Convergence, Regional Competitiveness, Employment programmes and the ESF programme. LCRI's research fund portfolio now exceeds over £80 million.

5.11 The LCRI Marine project is funded by ERDF and focusses specifically on supporting the marine energy sector in Wales by providing SMEs that are located within a Convergence Area of 15 local authorities with a variety of free enterprise and R&D support including delivering technical advice, appraising technology or project sites, collecting and analysing data, helping SMEs develop new technologies, and conducting assessments of technologies' associated environmental impacts.

5.12 The LCRI Marine project is composed of six academic research institutes:

- **Cardiff University,** includes the Cardiff Marine Energy Research Group (CMERG), The School of Earth and Ocean Sciences established and the Hydro-environmental Research Centre.

[46] http://www.lcri.org.uk/about

- **Swansea University.** The Marine Energy Research Group (MERG), part of the Civil and Computational Research Centre at Swansea University.

- **Swansea Metropolitan University.** The Coastal and Marine Research Group (CMRG) is located within the School of Built and Natural Environment at Swansea Metropolitan University. The CMRG team specialises in coastal and marine management strategies from physical and cultural environment perspectives.

- **Bangor University.** The Centre for Applied Marine Sciences (CAMS) examines the oceanographic impacts of marine energy. The School of Ocean Sciences (SOS) at Bangor University is one of the largest university Marine Science departments in Europe, a multidisciplinary department located on the shores of the Menai Strait in North Wales.

- **Aberystwyth University.** The Centre for Research into Environment (CREH) and Health is part of the Institute of Geography and Sciences at Aberystwyth University. CREH will examine effects on sea water quality.

- **Pembrokeshire College.** The Coastal Zone and Marine Environment Research Unit has a focus on projects "relevant and appropriate to current and likely future activities on the coast, in particular the Pembrokeshire and West Wales area."

SEACAMS (Sustainable Expansion of the Applied Coastal and Marine Sectors)

5.13 This is a new partnership between Bangor, Swansea and Aberystwyth Universities, which aims to develop the marine energy sector in Wales by combining expertise in marine and environmental science and policy and transferring this knowledge to commercial organisations. It also offers sea vessels, laboratories and field equipment.

5.14 **MCRI Marine** is also working with Welsh Energy Sector Training (WEST) to deliver funded training courses in the higher education and professional development sectors in order to develop the skills and education of the Welsh marine supply chain[47].

Support Organisations

- **Marine Energy Pembrokeshire (MEP)** is a partnership between technology developers, the supply chain, academia and the public sector working together to establish Pembrokeshire as a centre for excellence for sustainable marine energy generation by providing information about marine renewables projects in Pembrokeshire and promoting the facilities that the area offers such as research institutes, ports and grid connectivity. MEP also lists the services required for the development of marine energy projects - based on information provided by Tidal Energy Limited relating to their development of the DeltaStream project at Ramsey Sound – and supplies links to an Off Shore Wind Supply Chain Directory as the two technologies require similar services and components[48].

[47] http://westproject.org.uk/content/marine

[48] MEP had intended to produce a specific supply chain database for marine developers. This project is currently on hold. In the meantime, MEP stores contacts referred by current marine developers.

- **The Bridge Marine Science Group** in Anglesey is an independent, not for profit, maritime cluster providing marine science expertise. The group is a combination of over 200 small medium enterprises (SMEs), universities, local government, national government, selective further education institutes, non-government organisations and social enterprises based in Wales and provides marine and environmental consultancy services to businesses with an interest in the marine sector. It also offers research and commercial placements to prospective marine science specialists.

- **Pembrokeshire Science and Technology Park** has an innovation and incubation centre to provide academic and technical support and networking opportunities to start-up and nascent businesses.

5.15 In addition, the Welsh Government has set up seven Enterprise Zones across the country, offering business support and a range of incentives for businesses locating there, including reduced business rates. The Enterprise Zone at Anglesey complements the existing Energy Island Programme (EIP), which seeks to drive growth and development in renewable energy. Haven Waterway Enterprise Zone, located in Pembrokeshire, also has an energy focus.

Early Stage Projects

5.16 There are currently a total of four pre-commercial (demonstration) projects off the Pembrokeshire coast, which are outlined in the table below.

Table 5-2: Marine Energy pre-commercial devices in Wales

Sector	Developer	Location	Size	Installation
Tidal	Tidal Energy Ltd	Ramsey Sound, Pembrokeshire	1.2MW	2013
	E.ON/ Lunar Energy	Ramsey Sound, Pembrokeshire	8MW	waiting for SEA
Wave	Wave Dragon Ltd	Pembrokeshire Coast	7 MW	seeking finance
	Marine Energy Ltd	Pembrokeshire coast	10MW	Q3 2013

- Tidal Energy Ltd is in the process of installing a 1.2MW device, consisting of 3 horizontal axis tidal turbines, in Ramsey Sound, Pembrokeshire in 2013. The turbine blade technology was developed at Cranfield University. The project has received £7m from ERDF, and an ERDF project evaluation is being commissioned at the time of writing. UK firm DesignCraft is supplying the rotors; GE Energy the generator and electrical systems and Siemens the gear systems.

- E.ON in partnership with Lunar Energy Ltd also has plans to install a device in Ramsey Sound, which will consist of six turbines totalling 8MW, but is currently awaiting the results of a Strategic Environmental Assessment.

- Wave Dragon Wales Ltd planned to install a temporary 7MW wave energy converter 2-3 miles off the Pembrokeshire coast to test its proprietary technology in 2011/12 with the aim of scaling up by a factor of 10 to a commercial size array; however the project has been delayed due to a lack of financing. Swansea University assisted the project by conducting environmental modelling. The company is currently testing a 1.5MW device at a test centre in Denmark.

- Marine Energy Ltd has plans for a 10MW wave energy system also off the coast of Pembrokeshire. It is currently in the process of making applications and aims to install the device in towards the end of 2013. The technology has been developed at the University of Uppsala in Sweden.

- Marine Current Turbines (MCT) Ltd has successfully developed and tested prototype tidal devices in Strangford Lough, Northern Ireland and together with its partner RWE npower renewables (together forming SeaGeneration Wales Ltd) aims to install its first full-scale tidal turbine array in Welsh waters by 2016. Five turbines with a total capacity of up to 10MW will be located 1km off the coast of Anglesey between Skerries and Carmel Head, providing up to 20% of the Island's power at a cost of £70m. £10m of investment came from the Marine Energy Array Demonstration (MEAD) award granted by DECC. MCT intends to use the local port facilities at Holyhead for installation, operations and maintenance of the array. A major breakthrough for marine energy in Wales, it is hoped that this project will spur future development in the area.

Potential Marine Energy Supply Chain in Wales

Methodology

5.1 In section 4 we set out a summary of key features of the marine energy supply chain, subject to the considerable uncertainties on the precise requirements of the industry going forward in terms of services and manufactured goods. This is also set out in detail in Appendix D. Using an analysis of the Welsh supply side we now outline the extent to which industries in Wales might form part of this future supply chain. In undertaking this exercise it is noted that some elements of the supply chain to the electricity generation sector in general will support marine renewables (wave and tidal) particularly the limited regional supply chain that supports offshore wind development.

5.2 The analysis has been structured as follows:

- **Mapping the marine renewables supply chain**: we begin by examining the different types of activity (see Table 5-3) that are involved in the process of development and gaining planning consents, device manufacturing, and installation and commissioning and then operations and maintenance phases. This subdivision of activity was derived from material in Appendix D of this report, which also includes some description of the underlying activity and needs. Each category of activity in Table 5-3 has been coded alphabetically.

- **Mapping activities to SIC codes**. We then seek in the two tables in Appendix D to match with Standard Industrial Classifications (2007). Due to the large number of industries we separate out manufacturing and related categories (Table D-2) from other industries (Table D-3). We stress that these are where there are possible connections between a marine renewable supply chain and a SIC code. Although we adopt a fine level of disaggregation here (5 digit SIC codes) each industry code can still embrace a great deal of variation.

- **Analysing existing capacity**. We then collate information on existing Welsh capacity in these industries, setting out:

- Employment in Wales in each identified SIC code from the ONS Business Register and Employment Survey for 2011.

- Simple location quotients (LQs) for each identified industry in Wales. This is based on the Welsh share of GB employment in the industry as compared to the Welsh share of all GB employment and is a simple measure of relative specialisation in the sector (for comparative purposes here we also include an LQ figure for Scotland in these same sectors).

- An estimate of the number of firms operating in Wales at the current time from the Jordan FAME database. The data presented here represents cases where firms have a primary trading address or registered office address in Wales and which list the SIC codes as their primary activity. The final column shows the highest employment in the units identified on the FAME database. There is no means of gaining employment population for all the firms identified here on FAME because many of the entries relate to smaller firms which have reporting exemptions.

• **Understanding wider Welsh linkages**. The final part of the analysis uses the identified SIC codes and the Welsh Input-Output tables to reveal the potential wider employment and GVA effects[49] for Wales from growth of these sectors.

[49] That is, taking in indirect and induced effects.

Table 5-3: Main Elements in Wave and Tidal Stream Development		
Development	**Category**	**Estimated proportion of Capital expenditure**
Design and feasibility	a	0.3
Physical surveys	b	0.4
Environmental surveys	c	0.4
Meteorological and resource monitoring	d	0.2
Applications and consents	e	0.4
Device manufacturing		
Hydrodynamic system	f	19.0
Reaction system	g	17.0
Power take-off system	h	12.0
Control system	i	3.0
Balance of plant manufacturing		
Foundations and mooring	j	9.0
Cabling	k	4.0
Electrical equipment	l	4.0
Onshore infrastructure	m	3.0
Installation and commissioning		
General installation	n	0.0
Port services	o	3.0
Installation of electrical systems	p	7.0
Installation of foundations and moorings	q	7.0
Installation of marine energy device	r	11.0
Total capital spending		**c.100.0**
Operations and maintenance categories	s	na

5.3 In interpreting the analysis that follows it is important to bear in mind the caveats set out in Section 2.

Analysis: Manufacturing sectors

5.4 Our analysis of the supply chain has shown that an estimated 50% of total capital expenditure required to bring forward wave and tidal projects is accounted for by:

- Category (f): hydrodynamic system (precision fabrication of blades, moulding and finishing of composites, casting of metal structures),
- Category (g): the reaction systems (moorings, marine structures, large scale steel and concrete structures, wires and chains etc), and then

- Category (h): the power take-off system.

5.5 These activities are mapped onto the SIC codes in the second column of Table D-2. The third column reveals that there is already significant employment within sectors that have related activities in Wales. Whilst many of these firms will be small scale, the raw employment numbers provide an indication of the skill supply side in these areas. For example, i**n 2011 there were around 15,000 people in Wales employed in firms whose principal SIC codes would align them partially with categories relating to the manufacturing of devices**. The Jordan FAME data suggests over 600 business units involved in these same categories. The strong showing in some of these categories suggests that a number of firms here already serve elements of the oil and gas, chemicals and electricity generation sector. For example, the manufacturing of metal structures (SIC 25110) includes firms such as Rowecord, Unit Engineering, Ledwoods and Mainport, which provide services to some of Wales' largest manufacturing industries.

5.6 In terms of current levels of specialisation, the LQ information in Table D-2 suggests relatively higher levels of activity (compared to the GB average) in sectors such as casting of steel (SIC 24520) and light metals (SIC 24530), manufacture of metal structures (SIC 25110), manufacture of other fabricated metal components (SIC 25990), treatment and coating of metals (SIC 25610), and manufacture of electrical wires and cables (SIC 27320). Indeed Wales has over 10,000 employees in these same sectors. Given that selected firms in these sectors are currently serving industries in Wales that are in longer term decline, the potential to diversify into new areas might be welcome. However, currently the volumes of business likely to be offered in developing 10-30MW of wave and tidal stream capacity in Wales might discourage these firms from targeting new business opportunities in marine renewables, at least in the short term.

5.7 Finally, it is worth reflecting on the wider effects for Wales of expansion in these industries. Here we base estimates on information within the Input-Output tables for Wales. For this exercise we group the sectors in Table D-2 into 4. This grouping reflects different parts of the supply chain, but then also very different types of activity within the Welsh Input-Output tables:

- Group 1 includes activity in manufacturing concrete products.
- Group 2 activities focus on manufacturing groups allied to metals and metal structure production.
- Group 3 are industries linked to electrical and electronic engineering.
- Group 4 focuses more on mechanical engineering.
- Group 5 sectors are those identified as relating more to on site construction and installation.
- Group 6 includes business and professional services that support renewable generation through development to final operations.

5.8 The Group 1 sectors are associated with average GVA multipliers of around 1.42, and employment multipliers of around 1.59.[50] For Groups 2, 3 and 4 GVA multipliers are an estimated average of 1.58, 1.48 and 1.44 respectively, and employment multipliers are 1.87, 1.54 and 1.47 respectively. This analysis reveals the relatively strong indirect economic effects in Wales of increases in activity in the Group 2 metal/ metal structures industries. Put simply, should these industries be willing and able to serve the marine industry, there would be significant employment multiplier effects for Wales.

Analysis: Non-Manufacturing elements

5.9 Activities under the umbrella of construction and installation are expected to comprise close to 30% of total capital spending. There are particular problems in mapping the supply chain in Wales here largely because while there is expected to be capacity for onshore installation and electrical work connected to marine renewables, installation at sea would be expected to involve specialist contractors, particularly where larger arrays are to be developed. Here there could well be synergy with an emerging supply chain to serve the offshore wind industry.

5.10 With this important caveat there are over 16,000 people employed in Wales in 2011 in sectors including machinery and equipment installation (SIC 33200), construction of other civil engineering projects (SIC 42990) and electrical installation (SIC 43210). The latter category is made up of a large number of smaller firms. Table D-3 reveals that employment numbers linked to construction of water projects and utility projects for electricity are low but this is misleading because larger civil engineering firms with the capability to undertake these works are unlikely to list these as their prime activity.

5.11 We conclude that with respect to construction and installation it is very difficult to draw any firm conclusions. Nonetheless, Wales' strong gateway port infrastructure, combined with the fact that a number of the UK's largest civil engineering contractors maintain teams in Wales should guarantee that even if managing contracts were to be awarded externally, local construction firms and installers should gain opportunities. At the same time, where larger wave and tidal arrays are developed it is likely that specialist barges and installation equipment will be required and that this equipment will be managed by firms outside of Wales (i.e. a similar pattern to the vessel requirements for offshore wind), but still leaving opportunities for local subcontractors. In this respect it is unlikely that the pattern would be materially different from other strategic capital projects in Wales.

5.12 In the services sector (which includes design and feasibility, physical, environmental and resource surveys etc.) we expect that there is already expertise in the region to undertake this work, and our industry consultation suggests that expertise is available locally at competitive rates. Many larger UK professional consultancies in engineering and planning have offices within Wales, and have the scope to draw on the capacity of the larger organisation. Notwithstanding this, the analysis reveals that in many professional and business services categories Wales is relatively (compared to GB average) poorly represented despite the large number of companies in these same sectors.

[50] In other words for every £1m of GVA generated in Group 1 activities a further £0.42m of GVA is supported in other parts of the regional economy through supply chain and household spending effects. Moreover, every FTE job in the sector is connected to a further 0.6FTE jobs Wales; again supported through supply chain and household effects.

5.13 The services sectors in Table D-3 largely relate to development and consents, and some parts of the operations and maintenance phases. In the former it is estimated that this would make up around 2% of the total capital spending. Going forward and following the pattern in other renewables sectors we expect the propensity for local sourcing in the majority of the identified services sectors to be strong.

5.14 In terms of multiplier effects, the Group 5 industries that focus around installation and construction activity would, according to the Welsh Input-Output tables, be associated with GVA multipliers of around 1.64 and an employment multiplier of 1.47. The services sectors in Group 6 generally feature lower multipliers because of their pattern of regional purchases and higher labour intensities. Typical multiplier values here would be 1.42 (GVA) and 1.41 (employment)

Conclusions

5.15 The supply chain assessment for wave and tidal is complicated by the early stage of the technology and uncertainty about the nature of devices going forward. Nonetheless our analysis suggests that it is unlikely that the highest value components in devices would be produced in Wales and the greatest opportunities could instead be in terms of balance of plant manufacturing, and in supporting elements of installation, local assembly of imported products and maintenance.

5.16 We summarise our conclusions in the table below.

Table 5-4: Conclusions on Potential Welsh Supply Chain

Development Phase	Category (links to Tables D-2 and D-3)	Estimated proportion of Capital expenditure	Conclusions
Development and Consents			
Design and feasibility	a		• Strong scope for purchasing services from firms in Wales recognised by developers. • Potential for some elements of survey work to be carried through into operational phases. • Elements of detailed design expected to be centred around where devices are manufactured. • Selected providers able to capitalise on prior expertise in offshore wind development.
Physical surveys	b		
Environmental surveys	c		
Meteorological and resource monitoring	d		
Applications and consents	e		
Total Development and Consents		**2%**	
Device manufacturing			
Hydrodynamic system	f		• Supply chain impacts in Wales might be increased where devices are finally assembled close to final destinations. • Some evidence from consultations that Scotland gaining expertise and that while cutting edge research being
Reaction system	g		
Power take-off system	h		
Control system	i		

Table 5-4: Conclusions on Potential Welsh Supply Chain

Development Phase	Category (links to Tables D-2 and D-3)	Estimated proportion of Capital expenditure	Conclusions
			undertaken in Wales in terms of device design, placement, and monitoring, limited evidence that device. manufacture will take place in locally. • Device manufacturing expected to be associated with high relative wages and greater indirect and induced effects in Wales were region to successfully gain facilities.
Total Device Manufacturing		**50%**	
Balance of Plant Manufacturing			
Foundations and mooring	j		• Stronger scope for involvement of regional suppliers. Some commonalities with supply chain for other renewable particularly offshore. • Issue on whether small initial volumes would attract interest from Welsh suppliers. • Issue that device manufacturers may select solutions to balance of plant proximate to where they are based during early development.
Cabling	k		
Electrical equipment	l		
Onshore infrastructure	m		
Total Balance of Plant Manufacturing		**20%**	
Installation and commissioning			
General installation	n		• Installation of some tidal stream devices expected to require specialist plant and barges. • Strong expectation that if technology moves to greater scale that pattern of purchasing during installation phase parallels that in offshore wind. • Opportunities for Welsh contractors in servicing needs of managing contractors. • Regional effects here linked to where gateway port is located.
Port services	o		
Installation of electrical systems	p		
Installation of foundations and moorings	q		
Installation of marine energy device	r		
Total Installation and Commissioning		**30%**	
Operations and maintenance categories	s	na	• Inspection and monitoring provides potential opportunities for firms in Wales. • Maintenance contracts potentially reside with device manufacturer. • Potentially greater employment effects through operations compared to other land based renewable due to environment in which devices sit.

Table 5-4: Conclusions on Potential Welsh Supply Chain			
Development Phase	**Category (links to Tables D-2 and D-3)**	**Estimated proportion of Capital expenditure**	**Conclusions**
Source: WERU analysis Note: Proportional breakdown of capital spend does not sum due to rounding.			

Challenges and Constraints for Sector Development in Wales

5.17 There are a range of challenges and constraints to the development of the marine energy industry in Wales, both in terms of the development of installed capacity on Welsh waters and the extent to which the Welsh economy is able to derive benefits from this development. Some of these challenges are global in nature and apply regardless of geography (notably, the need for the industry to prove technologies and reduce the cost of energy in order to be viable in the long run without Government subsidy). Others are primarily national (i.e. the future revenue subsidy regime in the UK). Some of these more general challenges were outlined in section 4. Other challenges are specific to, or particularly acute in, Wales.

5.18 The recent report by Halcrow on infrastructure requirements of the industry[51] provides the latest and most comprehensive discussion on the key challenges for Wales, based on extensive consultation with industry stakeholders. Many of the messages set out here have been confirmed and re-iterated in our own consultations. The key challenges highlighted are as follows:

- Performance in technically challenging environments: potential sites with the greatest amount of wave and tidal power also tend to be those that are the most challenging from the point of view of device survival, given the tough conditions that they need to withstand. Furthermore, these sites can also be difficult to access for installation and maintenance. This increases the risks and costs of operating these sites.

- Working in environmentally sensitive areas: at present there is a lack of knowledge on the potential impacts of marine energy installations on marine life and the marine environment generally. This currently acts as a constraint to consenting large multi-device arrays.

- Site specific data needs: detailed data on sea-bed conditions and energy resource availability are required in order for a developer to understand fully the conditions of the site.

- Supply chain development: we highlighted above the potential marine supply chain in Wales. As projects move to commercial scale they are likely to require Single Contract Suppliers and contract requirements for production capacity, quality management systems, technical accreditation and insurance will tend to favour

[51] Halcrow (2012) *Marine Energy Infrastructure Study*

larger firms. For small Welsh suppliers to benefit, they need to be engaged at an early stage so that they can plan, collaborate and form Joint Ventures as appropriate. The Welsh Government is currently scoping out a supply chain study.

- Shore-side infrastructure: various infrastructure is required in order for projects to connect to the Grid. In the absence of a co-ordinated approach to the planning and funding of this infrastructure, it is not often not economical to develop.

- Grid connection: the need for grid reinforcement and connection poses a risk factor for developers, who need to accept the risks of non-use of upgraded assets and to incur the costs associated with the consenting process.

6. Potential Economic Benefits for Wales

6.1 Here we present the results of our quantitative modelling of the potential economic impacts (in terms of jobs and Gross Value Added) from marine energy development in Wales. We present the results in two sets:

- Development and construction phases: The impacts for these phases are taken together and presented as person-years of employment and total cumulative GVA, to represent the 'one off' impact of the associated capital expenditure.
- Operations and maintenance: Impacts are presented as FTE jobs and GVA supported in each year of operation.

6.2 The results presented below combine direct, supply chain (indirect) and personal expenditure (induced) effects.

6.3 Within each of these phases we present the results according to the three scenarios set out in section 2:

- A 30MW wave installation and a 30MW tidal stream installation
- 300MW in marine energy capacity (two 30MW wave installations and eight 30MW tidal stream installations, reflecting the relatively advanced state of tidal energy)
- 1GW of marine energy capacity (250MW of wave and 750MW of tidal energy).

6.4 As discussed in Section 2, it should be noted that the profit element of GVA will be gathered in highest proportion by non-Welsh companies, given ownership patterns in the sector.

6.5 In addition to the uncertainties surrounding the estimates it should be noted that the realisation of these benefits is heavily dependent on continued capital and revenue support from Government and the ability of the industry to drive down costs through innovation. In Section 7 we provide recommendations on steps that can be taken to maximise the opportunity for Wales.

Key Assumptions

6.6 Our model uses assumptions on expenditure and sourcing from Wales, drawn from a range of primary and secondary sources.

Expenditure and sourcing from Wales

6.7 As set out in section 2, whilst the novelty of the technologies precludes our ability to extrapolate from previous experience, we have drawn on a number of sources to help develop an estimate of the current spend per MW for both wave and tidal stream technologies. Assessing the extent to which this expenditure is likely to be retained in Wales is more complex. However, we have drawn on our primary research, which includes interviews with key stakeholders in this area, and questionnaires returned from developers detailing their expectations on potential spend in Wales. In addition we have used our analysis of the supply side provided in Section 5 and our research team's deep knowledge of the Welsh economy, including to some extent its flexibility to respond to new opportunities.

6.8 It should be noted that these scenarios represent our best estimate at the current most likely level of local sourcing. This potential may increase (or indeed prove optimistic) as the sector develops, and these potentials are discussed qualitatively.

6.9 We are, of course, aware of the potential for bias with a relatively small number of interviews and questionnaires, especially where impacts are likely to vary between technology types *within* wave or tidal themselves. We have therefore at all stages pressure tested primary survey responses with wider data where available, and indeed with reference to unpublished work undertaken within the wider engaged academic community.

The Potential for Cost Reductions

6.10 Our model uses the latest available evidence on the potential for cost reduction from the Carbon Trust/ DECC. This provides guidance on how far the financial efficiency of production will reduce as capacity increases. The Carbon Trust provides some indication of electricity cost savings (per MWh generated), as a result of learning, economies of scale and innovation. We have examined Carbon Trust/DECC assumptions on savings by cost centre for each technology and applied these to the within-Wales spend categories for wave and tidal developed for this report. These are set out in Table 6-1.

Table 6-1: Cost Reduction Assumptions (Percent of Current Baseline Cost of Energy)

Tidal			
Modelled Elements	Scenario 1	Scenario 2	Scenario 3
Development & consent	72%	52%	38%
Device Manufacture	77%	60%	46%
Other Equipment & electrical	76%	57%	43%
Installation & commissioning	92%	78%	67%
Wave			
	Scenario 1	Scenario 2	Scenario 3
Development & consent	85%	72%	66%
Device Manufacture	83%	69%	62%
Other Equipment & electrical	86%	75%	70%
Installation & commissioning	96%	87%	84%

Source: Carbon Trust (2012) TINA and WERU analysis
Note: This effectively assumes that Welsh capacity doubles at the same rate as in the Rest of the World/UK

6.11 As Table 6-1 shows, we assume that significant cost savings are associated even with a move to 60MW installed from today's experimental arrays. It should of course be remembered that an increased level of financial efficiency will assist commercial viability but work to reduce regional economic impact per megawatt installed (given the lower expenditure per MW of capacity developed).

Expenditure Assumptions

6.12 From the available evidence we estimate that gross spending associated with tidal installations is £4.2m per MW and £5m for wave energy, with these decreasing by around 20% and 10% respectively to Scenario 1 – see Table 6-2.

Table 6-2: Estimated Gross Baseline Capital Expenditure per Installed Megawatt (£000s, 2013/14 prices)

	Tidal Stream	Wave
Development & consent	170	220
Device Manufacture	2,390	2,580
Other Equipment & electrical	460	1,110
Installation & commissioning	1,180	1,090
Total	**4,200**	**5,000**
Note: excludes pure R&D expenditure		

6.13 A similar process to the above has resulted in our estimate of operational expenditure for wave and tidal stream – again per MW – although here there is potentially more uncertainty over the size and direction of spending. Table 6-3 presents our estimates of gross spending, again (notionally) for current installations and subject to some cost savings as in the development phase.

Table 6-3: Estimated Gross Baseline Operational Expenditure per Installed Megawatt (£000s, 2013/14 prices)

	Tidal Stream	Wave
Maintenance	95	85
Insurance	25	40
Other inc. Grid	45	50
Total	**165**	**175**
Note: other includes seabed lease and grid related costs		

Economic Impact: Development and Installation

6.14 After accounting for expenditure that leaks out of Wales (largely on specialised services and devices) we estimate the current likely level of spend in Wales from tidal at £2.75m and wave at £2.35m per MW (despite the fact wave is rather more expensive in gross terms, there is greater leakage). Hence we estimate that in the development and installation phase, 35% of all tidal expenditure and just over 50% of wave expenditure is likely to leak out of Wales.

6.15 After accounting for indirect and induced multiplier effects and cost-savings due to learning and scale, our estimate of the cumulative impact on Welsh GVA of our three scenarios is presented in Table 6-4.

Table 6-4: The Economic Impact of Marine Renewables in Wales: Development and Installation (Gross Value Added, £m, 2013/14 prices)

	Scenario 1 - 60MW			**Scenario 2 - 300MW**			**Scenario 3 - 1GW**		
	Tidal	**Wave**	**Total**	**Tidal**	**Wave**	**Total**	**Tidal**	**Wave**	**Total**
Manufacturing & Energy	16	14	30	98	25	123	240	87	327
Construction & Maintenance	8	8	16	56	15	71	152	61	213
Distribution, transport & comms	5	4	9	35	7	42	91	28	118
Professional & Public Services	9	8	17	52	14	67	128	53	181
Total	**38**	**34**	**72**	**241**	**62**	**303**	**611**	**229**	**840**
GVA/MW (£m)	*1.28*	*1.13*	*1.20*	*1.01*	*1.03*	*1.01*	*0.81*	*0.91*	*0.84*

Source: WERU Calculations
Note: Figures may not sum due to rounding.

6.16 The key points to note from our analysis are as follows:

- Scenario 1 has the potential to support over £70m of GVA across Wales, with this including on- and off-site economic activity (based on total investment in Wales of the order of £150m in 2013 prices). In Scenario 1, with an equal split of installed capacity between wave and tidal, slightly more of the economic impact (53%) comes from tidal than wave, driven by the somewhat higher potential for local sourcing reported by developers.

- Scenario 2 (300MW, with a preponderance of tidal) delivers just over £300m of GVA for Wales, with the economic impact per megawatt declining somewhat (from £1.2m in Scenario 1 to £1m) as cost reductions come further into play (based on total investment in Wales of over £500m in 2013 prices).

- The final, very substantial roll out of 1GW in wave and tidal delivers £840m of GVA impact on Wales (based on total investment in Wales of the order of £1.5bn in 2013 prices).

6.17 In this final scenario, the economic impact per megawatt is slightly higher from wave than tidal due to the assumed slow cost reductions (these are taken from the DECC documentation). Given the level of uncertainty, however, over technological development and local sourcing, the differences reported between wave and tidal impacts are relatively minor and should be treated as indicative only.

6.18 The economic activity and GVA in Wales set out above is of course associated with employment effects. These are reported in Table 6-5. For Scenario 1, we estimate a total of around 2,000 person-years of employment associated with development and installation. This rises to 8,500 person-years in Scenario 2 and for the large 1GW installation of Scenario 3 almost 24,000 person-years. To put this into context, this compares to around 4,500 person years that would be generated for 1 GW of gas fired power station capacity.[52] It is important

[52] See Cardiff University and Regeneris Consulting (2013) *Employment effects associated with regional electricity generation*. Note that the major driver of the large economic impacts from wave and tidal compared to other

to note that the employment arising in Scenario 3 could be supported over 10-20 year period, depending upon the time it takes to roll out this capacity.

Table 6-5: The Economic Impact of Marine Renewables in Wales: Development and Installation (Person-Years of Employment)

	Scenario 1 - 60MW			Scenario 2 - 300MW			Scenario 3 - 1GW		
	Tidal	Wave	Total	Tidal	Wave	Total	Tidal	Wave	Total
Manufacturing & Energy	370	310	680	2,250	580	2,830	5,500	2,000	7,500
Construction & Maintenance	340	350	690	2,310	630	2,940	6,260	2,520	8,780
Distribution, transport & comms	120	100	220	760	180	940	1,960	670	2,630
Professional & Public Services	230	210	440	1,420	380	1,800	3,430	1,420	4,850
Total	**1,060**	**970**	**2,030**	**6,740**	**1,770**	**8,510**	**17,150**	**6,610**	**23,760**
FTE/MW	35	32	34	28	30	28	23	26	24

6.19 For each scenario, the largest employment impacts are those involving construction-type activities, and in manufacturing and energy – with the latter focussed on ancillary devices and electrical and cabling materials. Together these sectors account for around two thirds of employment (in each scenario). Distribution and transport account for around 10% of employment impacts, with much of this in ports and transport services (but of course with this fungible with the construction sector). The remainder of employment arises around the consenting process, and in the professional services involved with initial surveying, etc.

6.20 Following the pattern established for GVA, the per-MW impact on Welsh employment associated with development declines from 34 FTEs in Scenario 1 to 24 FTEs in the 1GW scenario 3.

Economic Impact: Operational Phase

6.21 As Table 6-3 indicates above we estimate a gross operational cost currently of £165,000 per MW for tidal stream and £175,000 for wave, albeit with considerable uncertainty over these estimates.

6.22 Much of this spend is on grid connection, seabed leasing costs and insurance - an estimated 42% for tidal and 52% for wave. In the current devolution and energy regulation context, and with specialist insurers located elsewhere, there is very limited scope for Wales to benefit directly from any of this spending. There is of course the potential for that money to re-enter Wales via spending by national organisations such as Crown Estate Trust and National Grid, although this is at an uncertain scale and hence not modelled here.

6.23 Unsurprisingly, as Table 6-6 shows, the operations-related impacts of marine renewables installations are more moderate than those estimated for development/installation. In Scenario 1, with 60MW in operation, we estimate a total of £2m in GVA and 50 FTE jobs per

technologies is the cost of development and installation. As novel technologies, wave and tidal are more expensive to install and hence tend to support greater economic impacts.

annum would be supported across Wales throughout the period of generation.

6.24 Economic impacts increase with the scale of installation. For the 1GW Scenario 3, we estimate that £20m of GVA and 440 FTE jobs per annum would be supported across Wales through generation activities.

Table 6-6: The Economic Impact of Marine Renewables in Wales: Operations and Maintenance

	Scenario 1 - 60MW		Scenario 2 - 300MW		Scenario 3 - 1GW	
	GVA (£m)	Emp (FTE/yr)	GVA (£m)	Emp (FTE/yr)	GVA (£m)	Emp (FTE/yr)
Tidal Stream	1.2	25	6.3	145	13.2	310
Wave	1.0	25	1.5	35	5.5	130
Total	**2.1**	**50**	**7.8**	**180**	**18.7**	**440**
Per MW	0.04	0.8	0.03	0.6	0.02	0.4

Note: Tidal-Wave split illustrative only

6.25 The economic impacts of operational activities on Wales are moderated, as capacity increases, by the cost saving that will be necessary to make the generated power commercially viable. Drawing on the carbon trust analysis and survey returns, we estimate that regional operational spend per MW will, by Scenario 3, be less than a third its current estimated level for tidal stream, and around 50% its current level for wave. Hence, whilst each MW of Scenario 1 capacity supports 0.83 FTEs in Wales, by Scenario 3 each MW is supporting 0.44 FTEs.

7. Conclusions and Recommendations

Conclusions

7.1 Through consultation with the industry, a review of the available evidence and input-output modelling our analysis has tested the potential economic impacts for Wales from the development of the sector under three scenarios. Our analysis indicates that there are potentially significant benefits that could be secured in Wales from the development of marine energy: should 1GW of capacity be developed in say the next two decades, this could support a total of:

- £840m of GVA and 24,000 person years from construction and installation; and
- £20m in GVA per annum and 440 FTE jobs over the operational period.

7.2 It is worth noting that the marginal economic impacts for Wales of developing more than 1GW will fall somewhat, given the need for continued cost reductions. It should be noted that the realisation of the economic benefits outlined in this report is heavily dependent on continued capital and revenue support from Government and the ability of the industry to drive down costs through innovation.

7.3 In interpreting these results, it should be borne in mind that there are a range of uncertainties underlying them. Given the early stage of the industry it is not possible to draw on previous experience of completed developments in order to estimate costs and the retention of construction and operational expenditure within Wales. Hence there is significant uncertainty on the costs of marine energy development going forward and the extent to which the Welsh supply chain will be able to meet the needs of developers. We have therefore sought to err on the side of caution throughout, triangulating the evidence from the different sources available to us to ensure robust estimates of economic impact.

7.4 Ultimately the major source of uncertainty revolves around the development path of the industry and the status of other energy technologies, with which marine energy is to some extent competing. The development of the marine industry is heavily dependent on continued capital and revenue support from Government and the ability of the industry to drive down costs to compete with other technologies. Consequently, the economic benefits cannot be seen as given. It is not possible to say in a robust way how long it may take for the impacts in our latter two scenarios to materialise. The achievement of 1 GW of capacity in Wales could take multiple decades, although it could occur much quicker than this.

7.5 It is important to stress that economic impacts associated with tidal stream and wave devices in the future could be connected to whether or not tidal range devices and other marine renewables are developed at scale. This includes barrage schemes being considered for Swansea and Colwyn Bay. For example, there may be scope for common supply chain development, and selected skills serving tidal range could be used to serve the wider marine sector. Similar conclusions relate to off shore wind where there are expected to be supply chain and skills commonalities. Inevitably, real care needs to be taken in examining a set of technologies in isolation from more general industry development. In consequence future development in other renewables could have implications both positive and negative for wave and tidal stream technologies in the future.

7.6 Our mapping of the capabilities of the Welsh supply chain suggests that there is an existing presence of firms that could diversify to serve the marine energy sector, and that the strongest opportunities lie in balance of plant manufacturing and in supporting elements of installation, local assembly of imported products, and on-going maintenance. There is some evidence from consultations that Scotland is gaining expertise and that while cutting edge research is being undertaken in Wales in terms of device design, placement, and monitoring, there is a high likelihood at the moment that device manufacture (one of the highest value added aspects of the construction) will in practice take place outside of Wales.

7.7 In addition to the capabilities of the Welsh supply chain, the extent to which Welsh firms benefit from opportunities will depend on the developers' procurement approaches. Large multinational engineering and energy developers are increasingly operating in this area and they typically have established supply chains and networks outside the UK (or at least Wales) that may disadvantage Welsh firms.

7.8 Our review of the development of the industry in Scotland has highlighted that it is developing an advantage in marine energy, moving from R&D, deployment and testing, and on towards commercialisation. In addition to its natural resources, this has been driven by a mixture of strong political support, significant revenue incentives and additional capital funding. Consultees have also pointed towards the more lengthy consenting process for energy projects in Wales compared to that in Scotland. We would note that whilst on the face of it, these factors have served to provide confidence and galvanise the industry in Scotland (and there appears to be a consensus amongst consultees on this), more evidence would be needed to understand the specific contribution of Scottish Government interventions to this progress.

7.9 Welsh Government and other stakeholders have made progress in fostering the development of the marine energy sector in Wales, including developing the evidence base through research, studies, growing the research expertise in collaboration between the HE sector and industry, and providing grant assistance in support for on-going development of a number of devices. Whilst the impact of this assistance is not yet clear, there is a need to ensure that this investment can be built upon in an effective and appropriate manner. While these initiatives have slightly different objectives and major on different elements of technology and technological problems, there is a potential issue of how far initiatives directly (or indirectly) supported by Welsh Government are working together and the extent to which there are positive spillovers between the initiatives. This is important because the industry is at a critical stage and with financing very limited.

7.10 Another emerging issue from the report is that the successful development of marine renewables will contribute to a changing geography of energy generation in Wales. The period to 2025 could see more of Wales' electricity generation capacity on the south and north western fringes of the region. While this presents challenges in terms of developing appropriate grid infrastructures, there could also be subtle economic development benefits. For example, prototype wave and tidal devices are destined for Anglesey and Pembrokeshire. These same areas are among the most deprived in Wales, and in both cases have been subjected to significant structural decline resulting from the loss of large scale industrial facilities. Were these same areas to become hubs for marine renewables this would represent one means of industrial diversification, and a means of providing some new skilled employment opportunities to the Welsh periphery. We return to this issue in our recommendations with respect to integration hub concepts with area based initiatives.

7.11 Leading from the above is that this report on wave and tidal, when taken in parallel with current Welsh Government funded research on onshore wind and general Energy Sector Employment Effects, also raises questions about how precisely Wales will benefit from future expansion in renewables. It is accepted that wave and tidal are at a very early stage. However, our report provides nothing to suggest that the pattern of development in wave and tidal will be markedly different from that in onshore and offshore wind. While research being undertaken in Wales is undoubtedly informing the development of wave and tidal devices, it is unclear how far Welsh firms and institutions will benefit from a future roll out of the technology at scale.

7.12 This issue would seem to be particularly pertinent to cases where the Welsh Government is actively financing development and fine-tuning/testing of devices. In providing financial support to overcome perceived market failure, there is a need to consider the scope and scale of economic returns to Wales. Our review suggests that there is a real risk that much of the high value added device design and manufacturing activity from future development will accrue to firms outside of Wales. In Scotland there seem to be proactive steps being taken to maximise the regional effects of technologies proceeding at scale.

7.13 There is an associated challenge here to capitalise on the research skills and research infrastructure that already exists across the higher and further education colleges of Wales (for example, LCRI and CMERG). While government and EU monies have helped to kickstart research and prototype development and testing, there is now the opportunity to harness the expertise across Wales' universities and work towards marketing the resource in terms of consultancy expertise in development and testing, and the encouragement of spin-outs.

7.14 As is also stressed in parallel work on energy employment effects[53], high economic impacts are not necessarily a justification for further public sector intervention. A range of other factors need to be considered in making choices on interventions, including the prospects of achieving efficiency in the technology, environmental externalities surrounding these types of investments and the overall value for money they present in economic development terms.

Recommendations

7.15 A number of other studies on marine energy have been recently or are currently being undertaken in Wales. These studies include recommendations on their respective thematic areas (infrastructure, R&D etc.) and have provided Welsh Government and its partners with a good evidence base on which to take forward further work and potential interventions to support the sector. We understand that Welsh Government is in the process of appraising options for intervention with respect to infrastructure investment.

7.16 We discuss the key areas for intervention and provide our high level recommendations

[53] WERU and Regeneris Consulting (2013)

below:

- **Communication**. It is vital that Wales is able to promote itself effectively to potential marine energy developers, suppliers and other stakeholders. It has devoted a lot of effort to a range of research and strategy studies, but now it needs to focus on clearly communicating its strategy and underpinning plans to the industry. This is important if it is to improve its competitive offer to developers and investors. As noted elsewhere, demonstrating devices in Welsh waters is a very important part of this.

- **Marine Hubs**. A key concept emerging from this work is that of a hub for marine energy in the North West of Wales, with the possibility of a further hub in South West Wales. We understand that this revolves around the provision of testing facilities and related support, designed to provide the environment for developers to accelerate the development of multiple arrays. In so far as this can provide the infrastructure that is required to encourage developers to deploy and test their multiple device arrays in Welsh waters, we endorse this approach and recommend that these plans be progressed.

- **Integration with Area Based Initiatives**. There may be scope to integrate the proposed Hub concept with the emerging Enterprise Zone initiatives – for example, Anglesey Energy Island – providing EZ-type incentives to encourage businesses to locate there. We recommend that these be explored. The potential contribution of other EZs, such the advanced manufacturing EZ in South East Wales, should also be explored due to their potential to grow relevant parts of the manufacturing supply chain.

- **Supply Chain Development.** A key recommendation emerging from the Halcrow study was on the need to engage with the supply chain in order to understand capabilities and support needs. We agree that this is an essential next step and that this work should be progressed as a priority. There may be scope to combine this exercise with an analysis of the offshore wind supply chain in order to understand where commonalities and potential synergies exist. In due course, this work will need to provide evidence to inform future Welsh Government support for the supply chain, including understanding:

  - the readiness of the supply chain to respond to opportunities in wave and tidal energy

  - opportunities for firms in related sectors to diversify or switch their activities into this area

  - potential opportunities to target inward investment in selected areas, e.g. through the provision of inward investment grants and other incentives.

  We understand that this work is more advanced in Scotland and that a Supply Chain Portal has been developed there.

- **Development and Growth Finance**. The provision of public sector backed commercial finance can play a key part in encouraging developers to test and deploy their devices in Wales, in turn delivering much of the economic benefit locally. To date, support has been provided in grant form to device developers in Wales to manufacture and deploy their devices (for example, through the European Structural Funds). The general principle going forward should be to use repayable finance rather than grant, which provides a sensible basis for the sharing of risk and reward between the public and private sectors. We recommend that the Welsh Government explores options for the provision of development and expansion finance, which could be delivered through a specific fund or integrated into a successor to the current JEREMIE fund. There are advantages and disadvantages to both approaches.

- **Building on Previous Investment.** The Welsh Government has already provided significant support to the sector, including for SEACAMS, the LCRI and the Deltastream project. At this stage it may be appropriate to take stock of these interventions, to understand what progress has been made and how effective the support has been. We recommend that the Welsh Government consider evaluating these activities together, identifying any lessons which need to be drawn and whether there is a strategic case for on-going support in some limited instances.

- **Detailed Investment Planning**. In terms of delivery mechanisms, the next round of European Structural Funds provides an important opportunity to deliver support to the marine energy sector, and emerging work by WEFO highlights marine energy as an important priority. There is now a need to build on this, with a detailed investment plan.

Appendix A Economic Impact Assessment Methodology

1. In analysing the economic significance of any industrial activity (actual or proposed), it is important to distinguish direct, indirect (and then induced) economic effects. The direct effects are associated with the activity itself. Here direct effects might be understood in terms of the initial expenditure injection in Wales associated with the future development/construction and then operation of wave and tidal devices.

2. However, to provide a complete analysis of economic effects the research required an assessment of the economic benefits for Wales deriving from local procurement during wave and tidal stream device development and operation. For example, the development scenarios outlined in the report differ significantly in terms of scale, and with higher levels of direct spending creating greater economic effects in Wales through supply chain and household spending. Wales is a small and open economy and the scale of effects is determined by how far device developers, installers and operators are (will be) able to procure goods and services in the Welsh economy (see below).

3. We were fortunate in the research to gain inference of expected regional spending patterns from wave and tidal device developers that were surveyed. This told us much about the direct spending on the range of required goods and services by developers and operators through development, operations and maintenance and estimates of their potential payments to labour. This was a difficult exercise because in most cases we were asking developers to consider what they believed they could purchase in Wales in the future.

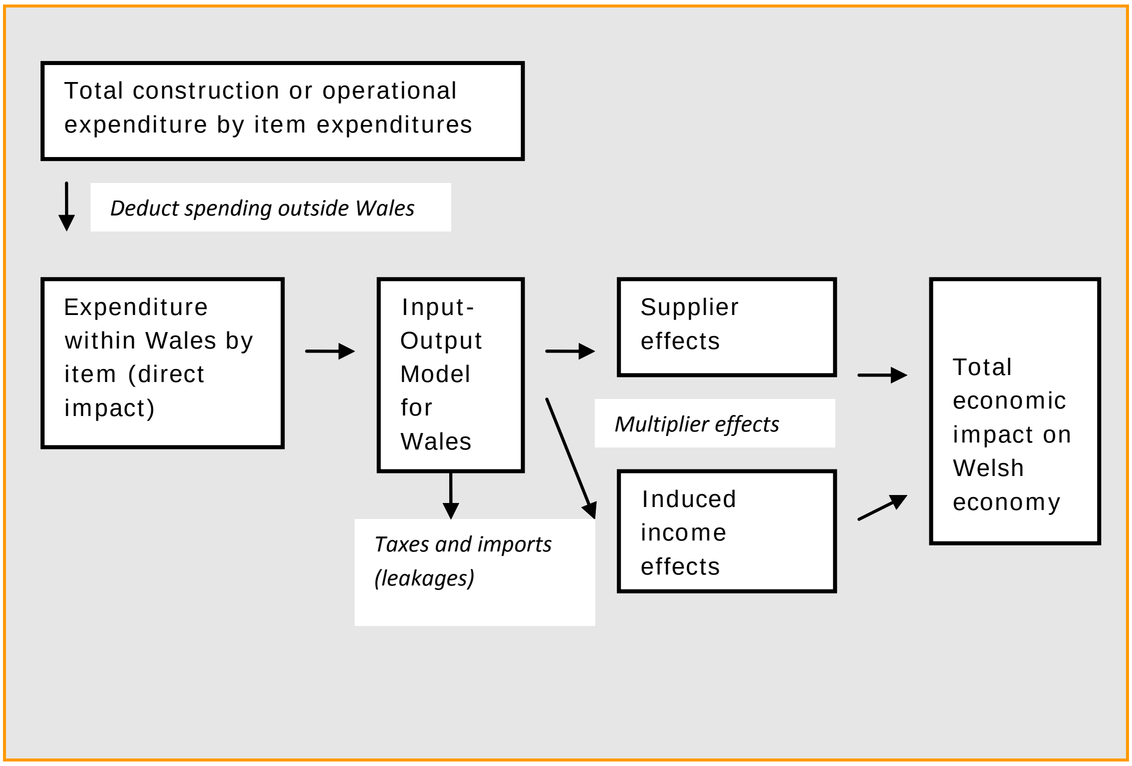
4. Notwithstanding these difficulties, this was an important step in moving on to consider the wider supply chain effects linked to this expected spending. For example the spending of the wave and tidal device developers would support economic opportunities in local and Welsh suppliers. However, these same suppliers would also spend monies in the local economy that support further economic output and employment. Furthermore employees of the developers and their suppliers would also spend money in the local economy that would support further economic output and jobs. These effects through the supply chain and household sector are termed indirect and induced effects respectively.

5. The scale of indirect effects is largely determined by how far developers and their suppliers of goods and services purchase goods and services in Wales as opposed to outside of Wales. Similar arguments apply to the employees of the developers. This analysis requires care. For example an employee of a tidal stream or wave device developer may spend within local shops and restaurants etc., however, the majority of the products could have been made outside of the locality. In this case the retail 'margin' would be a local spend whereas the spending relating to the product itself would 'leak' out to the rest of the UK or overseas. Similarly, construction firms may purchase large amounts of diesel within Wales, but much of this is a leakage outside of Wales in terms of taxes to UK government.

6. Consequently once in possession of direct spending estimates for projected developments and operations, it is necessary to subtract spending which is likely to be outside of Wales, to give the Welsh direct spending impact. These expenditures, by item, are then an input into a modelling process which allows the indirect and induced effects to be estimated. Adding the direct to these indirect and induced effects gives an estimate of the total economic impact on the Welsh economy of development and operations of tidal stream and wave devices.

7. To estimate these indirect and induced effects a picture of the local economy that specifies how the various Welsh industry sectors 'fit together' in terms of their trading relationships is a key requirement. This then allows the effects of spending and employment activity connected to future wave and tidal stream scenarios to be traced through the entire Welsh economy.

8. A comprehensive picture of the Welsh economy in these terms is an Input-Output table, which is essentially a spreadsheet detailing transactions between different sectors of the Welsh economy and beyond. As well as being an important descriptive tool, the Input-Output tables can be used for economic modelling and for impact assessment. Input-Output Tables for Wales are the product of a continuing research project at the Welsh Economy Research Unit to develop a comprehensive picture of the Welsh economy, and the way it is changing over time (see Bryan et al., 2004).



Appendix B Consultees

1. A list of organisations that have been consulted with as part of this study is set out below.

- Welsh Government
- DECC
- RenewableUK
- Carbon Trust
- The Crown Estate
- Scottish Enterprise
- Marine Current Turbines/Siemens
- Tidal Energy Ltd.
- Marine Power Systems
- Marine Energy Pembrokeshire
- University of Swansea

Appendix C UK Marine Energy Projects

Tidal Energy Projects

Developer	Location	Tech	Description	Supply Chain	Date
Marine Current Turbines (MCT)	Strangford Lough, Northern Ireland	1.2MW prototype	The SeaGen device is a horizontal axis turbine comprising twin axial flow rotors of 16m diameter, each driving a gearbox and generator. The structure is surface piercing so that the drive trains can be raised clear of the water for easier maintenance access.	The Strangford Lough device was assembled and tested at Harland and Wolff and blades were supplied by Aviation Enterprises. O&M support has been provided since installation through local vessel operators and technicians. Mojo Maritime have provided ongoing advice on offshore operations and methodologies.	2008
Marine Current Turbines (MCT)	Lynmouth, Devon	300kW 11m diameter turbine prototype	The location was selected because of its 5+ knot spring tide tidal streams and easy accessibility		Aiming for deployment in 2015 with a test installation in summer 2014.
Marine Current Turbines (MCT)	**Between Skerries and Carmel Head – 1km off coast of Anglesey**	**2MW tidal stream turbines – which will be secured to the seabed**	**The first proven full-scale commercial tidal turbine developed by MCT**	**Will make use of the local port facilities at Holyhead for the installation and operations and maintenance**	**2016**
Open Hydro	European Marine Energy Centre (EMEC) in Orkney	prototype Open-Centre Turbine tidal, 0.25MW	The Open-Centre tidal stream turbine is a seabed mounted device that consists of a rotor, duct, stator and generator. Water passes through the duct to the slow moving rotor with a hole designed to enable marine life to pass through. This is the only moving part. The permanent magnet generator is housed in the duct around the rotor.	Local companies that were contracted for the project include Orkney Towage and Isleburn. OpenHydro has stated that the UK will be able to meet most of its supply chain requirements with the exception of specialist items such as magnetic materials.	2006

Open Hydro	Fundy Ocean Research Centre for Energy (FORCE)	1MW test device			
Pulse Tidal	River Humber Estuary	0.1MW, Pulse Stream 100	Pulse-Stream is an oscillating hydrofoil tidal stream device. It extracts power from tidal currents using horizontal blades which move up and down. This movement drives a gearbox and generator through a crankshaft.	This project was successfully completed by a number of UK-based companies including: IT Power (engineering), Senergy Econnect (electrical), Corus (construction), Humber Work Boats (construction and installation) Briggs Marine (operations) and Designcraft	2009
Andritz Hydro Hammerfest	Falls of Warness, EMEC, Orkney	HS1000, 1MW	Horizontal axis, pitch regulated, three bladed turbine, installed in line with the flow with no yawing system. The device is seabed mounted using a gravity based foundation.	Local content has been used on this project, including using Arnish Yard, near Stornoway, Lewis, for the construction of the substructure. Converteam supplier of key electrical systems.	
Scotrenewables Tidal Power	Fall of Warness, EMEC, Orkney	0.25MW SR250	The SR250 is a floating tidal stream turbine. The main structure comprises a cylindrical tube to which horizontal axis rotors are attached via hydraulically retractable legs. The system's compliant mooring system allows installation in water depths of around 100m.	Scotrenewables is based in the Orkney Islands and is a majority locally owned company. The SR250 device was manufactured by Harland and Wolff Heavy Industries in Belfast.	2011
Tidal Energy Ltd	**Ramsey Sound, Pembrokeshire, South West Wales**	**1.2MW, DeltaStream hree separate horizontal axis turbines – proven technology.**	**The project will utilise the 1.2MW full scale DeltaStream device that consists of three horizontal axis turbines positioned on a common frame and gravity foundation.** **initial research funding from a sustainable development fund, administered by Pembrokeshire Coast National Park on behalf of the Welsh Assembly Government.** **blade technology developed at Cranfield University**	**Tidal Energy Limited is carrying out a comprehensive procurement process to source the design, supply of components and contractors to fabricate and install the demonstration device. Contracts have been awarded to Atkins for design integration, UK based DesignCraft for rotor supply, GE Energy for generator and electrical systems and Siemens for the gear system. Tenders for the fabrication contract have been received and the preferred contractor will be identified in the near future. The first phase of onshore preparatory work was**	**2013 – the device is currently ready for a 1 year deploy and monitor, and the developer has a signed agreement with the Crown Estate.**

				completed in February 2012 by Raymond Brown.	
Tidal Generation	Fall of Warness, EMEC, Orkney	0.5MW, DeepGen III	The TGL Deep Gen III device is a 500kW three-bladed upstream tidal turbine that extracts energy during both flood and ebb tide using an active yaw system. The nacelle is attached to a tripod foundation which is pinned to the seabed.	The turbine is supported from Hatston Quay in Orkney. In 2008 and 2009, the device was assembled at Rolls-Royce facilities in Dunfermline, drawing on in house engineering expertise extensively. Mojo Maritime and Ramboll have been commissioned to develop foundation concepts.	
Voith Hydro Ocean Current Technologies	Fall of Warness, EMEC, Orkney	1MW, Hy Tide 1000-13	The Voith HyTide device is a seabedmounted horizontal axis tidal stream turbine. The three symmetrical blades capture energy from the tidal stream on the ebb and the flood flow without pitch and yaw requirements	Cooperation partner BAUER Renewables manufactured and installed the foundation. Installation of the mono pole foundation is completed, using the offshore construction vessel North Sea Giant. Mojo Maritime conducted an operational installation and O&M study for Voith Hydro to outline options and methods for use at EMEC.	2012
E.ON/ Lunar Energy	**Ramsey Sound, Pembrokeshire**	**Rotech Tidal Turbine (RTT) x 6**	**site selection study involved the use of tidal resource models developed by RPS and GIS-based mapping to identify potential deployment sites - MRESF**		**Currently waiting for the results from the SEA to be published before taking the next steps with the project**

Source: Taken from RenewableUK. *Marine Energy in the UK State of the Industry Report 2012*

Wave Energy Projects

Developer	Location	Technology	Description	Supply Chain	Date
Aquamarine Power	EMEC	prototype 315kW Oyster 1 machine			2009
Pelamis Wave	Billia Croo, EMEC, Orkney	750KW P2 device (for Eon)	The Pelamis P2 is a second generation device; it is a semi-submerged floating device that faces into the direction of the waves. Five tube sections are joined by universal joints which allow flexing in two directions with identical, independently operating hydraulic power take-off systems in each joint. (See device case study)	The tubular modules were fabricated in Fordoun near Stonehaven by Neptune Deeptech. Final assembly and testing was carried out at Pelamis Wave Power's Leith facility. The P2 was designed to utilise standard hydraulic and electrical equipment throughout the machine wherever possible.	2010
Pelamis Wave	EMEC	P2 device (for Scottish power)			planned
Atlantis Resources Corporation	Fall of Warness, EMEC, Orkney	AR1000, 1MW	The AR1000 is a 3-bladed fixed pitch horizontal axis turbine with active yaw mechanism and direct drive permanent magnet generator, variable speed drive and export via medium voltage (3.8kV) cables to an onshore substation.	The nacelle and major power train components were fabricated, assembled and commissioned at the SMD facilities in Wallsend, Newcastle. Final assembly took place at Invergordon. Design analysis of the AR platform was contracted to Lockheed Martin. Around 75 per cent of spend on development of the AR1000 device has been in the UK.	2011
Wello	Billia Croo, EMEC, Orkney	0.6MW, Penguin	The Penguin is a floating asymmetric vessel which houses an eccentric rotating mass. The device is shaped so that waves passing it cause the mass to rotate on a vertical shaft and this motion is converted to electricity	Cooperation Partners of the Penguin are: EMEC, VEO, The Switch, Hydac, J+S, Riga Shipyard, INA FAG Schaeffler Group and Seaproof Solutions. The device has been built in the Riga Shipyard in Latvia and the entire deployment programme of the project at EMEC is managed by Orkneybased companies. The team is led by Stromness-based consultancy Aquatera	2012

Developer	Location	Technology	Description	Supply Chain	Date
				and new marine operations management company, Orcades Marine.	
Aquamarine Power	Billia Croo, EMEC, Orkney	three connected ~800kW devices - Oyster 800 - (further 1.6MW planned)	Oyster is a near shore wave powered pump which pushes high pressure water to drive an onshore hydro-electric turbine. The pump is a buoyant hinged flap which is almost entirely underwater and pitches back and forth due to wave motion.	To date, Aquamarine Power has worked with over 40 companies in Orkney during the installation of Oyster 1 and Oyster 800 and has spent over £3m directly in the Orkney economy. Local partners have included environmental consultants Xodus Aurora based in Kirkwall and Heddle Construction who carried out onshore construction. In addition, Aquamarine Power's Oyster 1 and Oyster 800 have both been fabricated in Scotland, by Isleburn and Burntisland Fabrications respectively.	2011 – 2013-14
Voith Hydro Wavegen	Islay	0.5MW Limpet	The Limpet device is a shore-mounted oscillating water column which has been tuned to capture energy from annual average wave intensities of between 15 and 25kW/m. It comprises an air chamber with an opening below the water and two counter-rotating Wells turbines.	Voith Hydro Wavegen made successful contracts with many UK-based companies during construction and operation of the device. They have also succesfully exported their technology from the UK to, for example, the Mutriku breakwater project in Spain. Partners and contractors included Charles Brand, Scottish Hydro-Contracting, Queen's University Belfast, IST Portugal and Kirk McClure Morton	2000
Wave Dragon Ltd	**off the Pembrokeshire Coast**	**7 MW device. Based on hydropower technology.**	**The demonstration project is being supported by the Welsh European Funding Office under the Objective 1 initiative. The device is intended to be tested for 3-5 years, whereupon it will be removed from the site and the site decommissioned. Wave Dragon will only remain in place for three to five years, covering an area of approximately 0.25 km2, before being removed; hopefully to join ten other units further (ten to twelve miles) out to sea, to form**		**Had planned to deploy in 2011/12, but is currently seeking venture capital. Testing a 1.5 MW device at Denmark test centre**

Developer	Location	Technology	Description	Supply Chain	Date
			Britain's first wave energy farm. The company has been testing devices since 2008/9 elsewhere such as Denmark and Portugal.		
Marine Energy Ltd	**off the Pembrokeshire coast**	**10MW pre-commercial wave energy power park**	**independently raising all required financing** **The technology has been developed over 7 years of research at the Division for Electricity Research at the University of Uppsala in Sweden.**		**in the process of making applications Q3 2013. A scoping doc has been produced.**
Source: Taken from RenewableUK. *Marine Energy in the UK State of the Industry Report 2012*					

Appendix D Marine Energy Supply Chain

1. Here we provide a detailed summary of the information on the marine energy supply chain (taken from BVG for Crown Estate (2011) *Wave and Tidal energy in the Pentland Firth and Orkney waters: How the projects could be built)* and a mapping of Welsh capabilities. Detailed discussion on this is provided in Section 6.

Generic Marine Energy Supply Chain

Table D-1: Marine Energy Supply Chain

Broad Phase in Lifecycle	Specific Phase	Indicative Activities
Development and Consents	Design and feasibility	Development of device arrangements; routing of sub-sea array cables; engineering design of balance of plant (mechanical, electrical, structural); marine logistics studies; financial analysis. **Relevant skills and capabilities**: Organisations with marine environment track record (e.g. through oil and gas or offshore wind, fishing, marine aggregates extraction) Some elements done in- house.
	Physical surveys	Coastal process surveys: potential subsea cable routes and landfall sites for cables. Seabed surveys: • geophysical surveys – depth, sediment cover • geotechnical surveys – sampling from boreholes, characterising soil conditions to determine load bearing capacity Survey results then used in the design of subsea components e.g. foundations and moorings. **Relevant skills and capabilities**: Geotechnical engineering, supply of specialised vessels. Overlap with offshore wind again.
	Environmental surveys	Benthic, fish, marine mammal, bird and onshore surveys (at the location of onshore equipment and cable laying routes). Some tasks undertaken alongside physical surveys, others use simple vessels. **Relevant skills and capabilities**: supply of vessels, local technical and species knowledge, supply of specialist surveying, trawling and imaging equipment for deployment of vessels, aerial surveying. Generally all contracted out by developer.
	Meterological and resource monitoring	Sensors are deployed at an early stage to measure meterological conditions. Data is used to inform project design by understanding mechanical loads that equipment will experience. **Relevant skills and capabilities:** supply of meteorological instruments, operational of vessels for installation and management of wave rider buoys; Technical consultancy to interpret data.
	Applications and consents	EIA statement, application for and negotiation of electrical grid connection conditions including modelling of device and array power quality output, stakeholder engagement, PR etc.

Table D-1: Marine Energy Supply Chain

Broad Phase	Specific Phase	Indicative Activities
Device Manufacturing	Hydrodynamic system	This is the system that interacts with the water to extract energy from it. • Tidal devices – this is typically blades or hydrofoils • Wave devices – this is the component that reacts to the oscillating wave motion. Components may be from steel, composites, concretes or other materials. **Relevant skills and capabilities**: • Hydrodynamic and structural design of large structures • Precision fabrication of blades and hydrofoils where steel/other metals used • Moulding and finishing of composites • Casting of metal structures used in providing buoyancy • Assembly of components with fasteners, welding etc. • Experience in design and production of pressure vessels for marine environment • Provision of coatings and treatments to control corrosion • Workshop testing and verification
	Reaction system	This holds the device in position. May consist of: • A mooring arrangement • A gravity base foundation or • A foundation fixed to sea bed via piles, suction bucket etc. These components likely to be made of steel or concrete. **Relevant skills and capabilities:** • Design of dynamic structures in marine environment • Procurement, fabrication and handling of large scale steel and concrete structures of up to 1,000 tonnes • Design, manufacturing and installation of wire ropes, chains and anchors in mooring systems • Expertise in corrosion and marine growth prevention • Local knowledge of marine conditions
	Power take-off system	This converts the energy extracted into electrical energy. • For oscillating systems, this could use hydraulic actuators that pump oil into a pressurised reservoir, where it drives a hydraulic motor connected to an electric generator, or linear electrical generators • For rotating systems, energy can be extracted most simply by a constraining movement via speedup gearboxes and electric motors or direct drive electric motors without gearboxes. To interface the generator to local electricity grid, may use a transformer, switchgear and subsea electrical connectors. Depending on device type, may need additional elements such as bearings to support hydrodynamic systems as well as cooling and lubrication systems. **Relevant Skills and capabilities**:

Table D-1: Marine Energy Supply Chain

Broad Phase	Specific Phase	Indicative Activities
		• Application of electrical and hydraulic knowledge in marine environment • Production of gearboxes, bearings and power transmission components in marine environment • Subsea connectors from devices to inter-array cabling
	Control system	This provides supervisory and closed-loop control. **Relevant skills and capabilities**: • Specialist sensors and data collection systems related to marine environment • Experience in design of SCADA systems • Hydraulic actuators, valves or other equipment • Bearings and actuation components for yawing and pitching • Design and production for high reliability applications
Balance of plant manufacturing	Foundations and mooring	Provide anchoring of the device to the seabed. Their design depends strongly on the device type. Possible arrangements include: • Steel space frames pin-piled into the seabed • Concrete gravity bases lowered into position on seabed • Multipoint mooring systems with steel anchors inserted into seabed **Relevant skills and capabilities:** • Large scale concrete structure production of length in excess of 50m • Fabrication of steel frame structures weighing up to over 500 tonnes • Expertise in the design of dynamic structures for the marine environment • Corrosion and marine growth prevention products
	Cabling	Covers array cables to connect strings of devices to an offshore substation. Then higher voltage cables to connect substation to onshore grid connection point. Cable lengths depend on exact site layouts and separation distances between devices as well as method of connection between devices. Note that there is high demand for subsea cables for offshore wind. May be capacity constraints depending on level of demand from marine sector. This is a specialist market serviced by existing players: • Dedicated large scale, high precision cabling extrusion and assembly equipment • Expertise in production of insulation for cables to provide thermal and electrical protection • Cable armouring products – to withstand extreme forces of 25 year life • Detailed electrical design knowledge
	Electrical equipment	Transformers likely to be required to step up from low to high voltage at offshore substation. Monitoring, protection and switchgear will be needed at each stage. Whether offshore electrical equipment is surface or subsea mounted will influence design requirement and capex/opex.

Table D-1: Marine Energy Supply Chain

Broad Phase	Specific Phase	Indicative Activities
		Relevant skills and capabilities: • Understanding design requirements of distributed generation • Experience in manufacture of offshore electrical solutions.
	Onshore infrastructure	e.g. cabling, substation and buildings to house electrical equipment, control centres, office space, spares.
Installation and commissioning	*General*	In general across this phase, there are not yet any broadly defined methods of installation across device types. Tidal devices: may require specialist dynamic positioning vessels to overcome tidal currents. Wave devices: may be more straightforward if can be towed to site and moored using standard methods. Large companies likely to deliver T1 activity – specialist activity and strong balance sheet needed. Small firms can, however, compete for sub-contracts due to need for local knowledge, understanding of conditions and access to labour.
	Port services	Final assembly likely to take place at quayside due to risks and costs of doing this offshore. **Relevant skills and capabilities**: • Marine logistics • Mechanical and electrical fit out • Commissioning and testing
	Installation of electrical systems	Installation of on- and offshore substations and cabling required.
	Installation of foundations and moorings	Installations methods dependent on device design. Gravity structures require minimal site preparation or post installation activities. Methods involving piling will require several stages to deployment and use of specialist installation tooling. **Relevant skills and capabilities:** • Specialist vessels to carry out complex installation procedures • Supporting vessels locally sourced for construction and monitoring support • Supply and operation of specialist tooling
	Installation of marine energy device	**Relevant skills and capabilities:** • Supply, fit-out and manning of specialist installation vessels using local knowledge of port facilities and marine work environment • Manufacture of specialist tooling • Marine logistics planning with knowledge of local conditions and constraints
Operations and Maintenance	*General*	Anticipated that in early years, core O&M services may be led by staff employed locally and employed by device manufacturers – this will aid feedback of design improvements to improve next generation devices. As industry matures, more third parties can be expected to enter the market.

Table D-1: Marine Energy Supply Chain

Broad Phase	Specific Phase	Indicative Activities
	Operations	Activities include: • Monitoring condition and performance of devices and balance of plant • Planning and management of maintenance activities • Managing and monitoring ongoing environmental impact of project
	Maintenance	25 year design life but some parts need to be exchanged several times within this. Devices and balance of plant subject to loading. • Planned maintenance: major refurb often needed after 5 years. • Unplanned maintenance: due to failure of equipment. For activity requiring return of device to port, need an O&M port facility available.
	Grid charges, insurance and related	**Covers** • Grid charges to cover access and use of electrical distribution and transmission networks • Insurance to cover risks related to ongoing operation of the project • Land-related costs for both onshore and offshore leases.

Source: BVG for Crown Estate (2011) *Wave and Tidal energy in the Pentland Firth and Orkney waters: How the projects could be built*.

Analysis of Welsh Capabilities

Table D-2: Analysis of Potential Supply Chain: Manufacturing Groups

Industry	Link to Marine renewables supply chain	Wales		Scot	Wales Firm no	Wales Highest
		emp number	LQ	LQ	indicator	emp
Group 1 Concrete and non-metal products						
23430 : Manufacture of ceramic insulators and insulating fittings	g,k,	-	0.0	0.0	0	na
23610 : Manufacture of concrete products for construction purposes	g,j,	546	0.8	0.8	16	132
Group 2 Activity related to metal/metal structure production						
24200 : Manufacture of tubes, pipes, hollow profiles and related fittings, of steel	f,g	223	0.6	1.2	5	na
24510 : Casting of iron	f,	<100	0.0	0.5	0	na
24520 : Casting of steel	f,g,j	241	1.8	0.4	1	na
24530 : Casting of light metals	f,g,j,	574	2.5	0.2	3	245
24540 : Casting of other non-ferrous metals	f,g	<100	0.6	0.6	2	na
25110 : Manufacture of metal structures and parts of structures	f,g,j	4,569	2.0	1.3	190	594
25290 : Manufacture of other tanks, reservoirs and containers of metal	f,g	211	1.0	1.4	6	1,051
25500 : Forging, pressing, stamping and roll-forming of metal; powder metallurgy	f,g	342	0.4	0.3	12	55
25610 : Treatment and coating of metals	f,g,j,k,	1,075	1.2	0.7	11	55
25910 : Manufacture of steel drums and similar containers	f,	<100	0.3	0.7	0	na
25990 : Manufacture of other fabricated metal products nec	f,g	2,031	1.6	0.8	278	341
Group 3 Activity related to electrical electronic industries						
26110 : Manufacture of electronic components	f,h,i	1,899	2.7	1.5	40	982
26511 : Manufacture of electronic instruments and appliances for measuring, testing, and navigation, except industrial process control equipment	f,h	874	0.5	1.0	24	520
26512 : Manufacture of electronic industrial process control equipment	h,l,	173	0.8	0.8	20	137

Table D-2: Analysis of Potential Supply Chain: Manufacturing Groups						
Industry	**Link to Marine renewables supply chain**	**Wales**		**Scot**	**Wales Firm no**	**Wales Highest**
		emp number	**LQ**	**LQ**	**indicator**	**emp**
27110 : Manufacture of electric motors, generators and transformers	h,l,	529	0.8	0.6	11	384
27120 : Manufacture of electricity distribution and control apparatus	h,l,	990	1.1	0.5	9	339
27320 : Manufacture of other electronic and electric wires and cables	k,m,	1,015	2.6	1.8	11	207
Group 4 Other machinery and products						
28131 : Manufacture of pumps	h,	<100	0.2	0.9	4	5
28140 : Manufacture of other taps and valves	i,	393	0.9	0.6	4	214
28150 : Manufacture of bearings, gears, gearing and driving elements	h,i	155	0.4	1.1	3	na
30110 : Building of ships and floating structures	f,	376	0.4	3.1	7	52
		16,361			657	
Source: Derived from ONS, BRES; Bureau van Dijk, Jordan FAME, and research team analysis						

Table D-3: Analysis of Potential Supply Chain: Non-Manufacturing Sectors

	Link to Marine renewables supply chain	Wales		Scot	Wales Firm no	Wales Highest
		emp number	LQ	LQ	indicator	emp
Group 5 Construction and installation						
33150 : Repair and maintenance of ships and boats	f,q,s	273	0.9	1.5	15	624
33200 : Installation of industrial machinery and equipment	n,p,q,r,s	905	1.3	0.9	102	209
42220 : Construction of utility projects for electricity and telecommunications	n,p,r	<100	0.1	0.2	24	93
42910 : Construction of water projects	n,r	<100	1.3	1.9	33	na
42990 : Construction of other civil engineering projects nec	m,n,r	6552	1.3	1.3	594	329
43130 : Test drilling and boring	b,n	<100	0.9	1.6	15	na
43210 : Electrical installation	p,r,s	9223	1.1	0.9	727	226
50200 : Sea and coastal freight water transport	b,n,o,q,s	132	0.6	0.9	39	295
52101 : Operation of warehousing and storage facilities for water transport activities of division 50	n,p,q,s	<100	0.5	0.2	2	na
Group 6 Services						
65120 : Non-life insurance	s,	4559	1.5	0.4	97	5324
70210 : Public relations and communication activities	s,	385	0.6	0.4	65	na
70229 : Management consultancy activities (other than financial management)	e,	7517	0.6	0.6	2060	265
73110 : Advertising agencies	e,	723	0.2	0.3	163	221
73120 : Media representation	e,	113	0.2	0.7	64	na
71121 : Engineering design activities for industrial process and production	a,b,h,l,j,k	787	0.4	0.9	85	na
71122 : Engineering related scientific and technical consulting activities	a,b,h,l,j,k	2392	0.9	2.3	212	157
71200 : Technical testing and analysis	a,b,f	1427	0.7	0.8	139	14
74901 : Environmental consulting activities	c,d,e	227	1.0	0.7	144	438

Table D-3: Analysis of Potential Supply Chain: Non-Manufacturing Sectors						
	Link to Marine renewables supply chain	Wales		Scot	Wales Firm no	Wales Highest
		emp number	LQ	LQ	indicator	emp
74902 : Quantity surveying activities	a,	556	0.8	0.9	105	na
77320 : Renting and leasing of construction and civil engineering machinery and equipment	all	950	0.7	1.4	119	235
77342 : Renting and leasing of freight water transport equipment	n,p,q,	n/a	n/a	1.2	1	4
77390 : Renting and leasing of other machinery, equipment and tangible goods nec	all	688	0.5	1.4	125	127
80200 : Security systems service activities	s,	477	1.3	0.9	83	36

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