Sustainable Engineering Worldwide

Scottish Government - Marine Energy Group

Marine Energy Supply Chain Survey

SUMMARY:

A brief survey of the marine energy supply chain has been conducted, based on information obtained directly from wave and tidal energy technology developers through consultation. The methodology used for the study was specified by the Scottish Government Marine Energy Group.

Three deployment scenarios have been considered in this study. Based on a capital cost learning curve and using the retention factor derived from the consultation, this study evaluates the supply chain and economic impacts of marine energy deployment in Scotland and internationally, including the impacts on expenditure, value added and direct, indirect and induced employment up to but excluding the operational phase.

Uncertainties and risk factors associated with the development of marine energy projects in Scotland are highlighted.

CLIENT: **Scottish Government - Marine Energy Group**

CONTACT: **Sian McGrath and Richard Yemm**

DISTRIBUTION :

Client:

Sian McGrath, Richard Yemm

Marine Energy Group

SgurrEnergy: Grégory Dudziak, John Simmons, Ian Irvine

IPA: Alice Waltham, Colin Barnes

	Name	Job Title	Signature
Prepared by	Grégory Dudziak Alice Waltham Colin Barnes	Senior Renewable Energy Consultant Consultant Economist	 AW CB
Checked by	John Simmons	Senior Renewable Energy Consultant	J. E. Simmons
Authorised by	Ian Irvine	Technical Director	
Date of Issue	8th July 2009	**Classification:**	Confidential

CONTENTS

EXECUTIVE SUMMARY 4
1 INTRODUCTION 5
2 LITERATURE REVIEW 5
3 CONSULTATION 7
3.1 Consultation documents 7
3.2 Consultees 8
3.3 Results 8
4 ANALYSIS AND DISCUSSION 9
4.1 Supply Chain Requirement 9
4.2 Expenditure 9
4.3 Employment 13
4.4 Scenario Analysis 17
4.5 Uncertainties and Risks 22
5 CONCLUSIONS 24
APPENDIX A – REFERENCES 26
APPENDIX B – CONSULTATIONS DOCUMENTS 27
APPENDIX C – SUPPLY CHAIN REQUIREMENTS FOR MARINE ENERGY PROJECTS 28
APPENDIX D – COMBINED CONSULTATION SPREADSHEET 30
APPENDIX E1 – MARINE ENERGY DEVELOPMENT IN SCOTLAND, EXPENDITURE AND EMPLOYMENT (STRETCH MEG SCENARIO) 31
APPENDIX E2 – MARINE ENERGY DEVELOPMENT IN SCOTLAND, EXPENDITURE AND EMPLOYMENT (DOWNSIDE MEG SCENARIO) 32

LIST OF FIGURES AND TABLES

FIGURES

Figure 1: Breakdown of Cost Items for a 50MW Plant up to Construction Phase 10
Figure 2: Expenditure by Country 10
Figure 3: MEG Scenarios to 2020 17
Figure 4: Capital Cost Learning Curve 18
Figure 5: Employment in Scotland under the three MEG Scenarios (pre-operational only) .. 21
Figure 6: Cumulative Capital Expenditure in Scotland under the three MEG Scenarios (pre-operational only) 21

TABLES

Table 1: Summary of Results from the Consultation Exercise with Companies in the Marine Energy Sector 14
Table 2: Marine Energy Development in Scotland, Expenditure and Employment (Base Case MEG Scenario) 20
Table 3: Uncertainties and Risk Factors 23

EXECUTIVE SUMMARY

SgurrEnergy and IPA Energy + Water Economics have been appointed by the Marine Energy Group (MEG) to perform a brief survey of the marine energy supply chain. The methodology used for the study was specified by the Scottish Government Marine Energy Group. This survey is based on information directly obtained from wave and tidal energy technology developers through consultation. These developers were selected in order to include companies who have had direct experience in the procurement process and construction of full scale marine energy devices, ideally in Scotland.

This study briefly evaluated the supply chain and economic impacts, including the impacts on expenditure, value added and direct, indirect and induced employment up to but excluding the operational phase, therefore including, planning, design, construction and commissioning. The scope of this study excluded the operational and decommissioning phases of the lifecycle of marine energy projects.

The analysis considered three potential marine energy development scenarios in terms of installed MW capacity in Scotland for the period 2009 – 2020, namely:

- “Base case” – 1,000 MW installed by 2020
- “Stretch” – 2,000 MW installed by 2020
- “Downside” – 500 MW installed by 2020

These marine energy development scenarios were specified by the Scottish Government Marine Energy Group.

A capital cost learning curve based on a 12.5% learning rate and on a capital cost of £3 million/MW in 2014 was adopted.

Based on the consultation, a 53% overall retention of capital expenditure has been estimated for the Scottish supply chain. The creation of around 20 jobs per MW of installed capacity has also been adopted.

Using the base case scenario as a reference, this study concludes there is the potential of significant expenditure of the order of £2.4 billion towards the development of marine energy projects in Scotland out to 2020. Of this, £1.3 billion could be retained in Scotland and could create over 2,600 jobs in Scotland alone (not including a significant number of longer term operations and maintenance jobs, or employment generated in Scotland by capacity installed in the rest of the UK and worldwide). This finding is subject to the assumptions used in this study and the associated qualifications which we have summarised in our conclusions.

To achieve the benefits from marine energy development, the supply chain will require stimulation and strong commitment from the companies involved in the development of the technology, in turn supported by project developers, financiers commitment and sufficient economic support, while technical, skills, regulatory, financial and commercial risks will need to be addressed or mitigated, and strong political support maintained.

1 INTRODUCTION

SgurrEnergy and IPA Energy + Water Economics have been appointed by the Scottish Government Marine Energy Group (MEG) to perform a survey of the marine energy supply chain. This survey is based on information directly obtained from wave and tidal energy technology developers through consultation. These developers were selected in order to include companies who have had direct experience in the procurement process and construction of full scale marine energy devices, ideally in Scotland.

This study is concerned with the supply chain and economic impacts, including the impacts on expenditure, value added and direct, indirect and induced employment pre the operational phase of wave and tidal projects. It therefore includes, planning, design, construction and commissioning, but excludes the operational and decommissioning phases of the lifecycle of marine energy projects, which may be considered in the scope of a subsequent study and survey.

One of the key factors in terms of the contribution of incremental value added and employment created within the Scottish economy will be retention of these variables in the Scottish economy. Equipment, technologies and skills will almost certainly need to be sourced from other parts of the UK, other European countries or internationally

Scotland has some experience of developing marine energy projects and facilities in Islay and Orkney and has a critical mass of research and development institutions which form a strong base for the development of marine energy. They include the European Marine Energy Centre (EMEC) in Orkney and a number of Scottish universities including Aberdeen, Edinburgh, Heriot-Watt and Strathclyde universities amongst others.

2 LITERATURE REVIEW

A number of reports have assessed the significant potential of the marine resource and the economic impact of marine renewable energy in Scotland and more widely in Europe and worldwide.

Studies on marine energy in the UK (the Severn Barrage, South West England Wave Hub[1] [1], Northern Way Offshore Wind Energy [2]) have also demonstrated the regional economic development impacts of the marine energy sector and associated projects including the impacts on regional value added/gross domestic product (GDP), direct, indirect and induced employment and other factors.

Studies in Ireland [3a, 3b, 3c] have estimated the economic gains resulting from electricity generation, avoided emissions, security of supply, regional economic development impacts and knowledge creation. The value for regional development based on planning, construction and operation and maintenance (O&M) employment where ocean energy is developed was estimated at €4,030 per MW per year (£2,742)[2] and 45 construction jobs per MW per year installed (although this employment figure is an order of magnitude higher than other studies suggest). It is likely that the retained economic impacts of the marine energy sector in

[1] The Arthur D Little study on the wave hub project in Cornwall estimated that the wave hub could generate 20MW and 100 direct jobs by 2010 with indirect benefits of 450 jobs in 2010 with an associated increase in gross value added of £15 million in 2010 of which 20-40% would be retained in Cornwall with more retained in the South West and the UK. The total capital expenditure for the wave hub project was estimated at £13.84 million.

[2] Based on an exchange rate of 1.42 Euro to the GB pound in 2005.

Scotland will be relatively higher than in Ireland and the South West region of England, given the substantial engineering, construction and research and development bases which already exist in Scotland.

There have been a number of economic studies on renewable electricity generation in the Scottish economy, including a study by the Institute of Mechanical Engineers [4] and notably by Allan et al [5]. This latest reference is based on the use of input-output tables for the Scottish economy which are limited by their date of publication (2000). However, this provides an historic snapshot of the contribution of the electricity generation sectors to the Scottish economy. Findings in relation to the marine generation sector may be summarised as follows:

- The share of total inputs which are intermediate inputs sourced in Scotland are relatively high at 65% when compared with other generation sectors including nuclear (5.5%), coal (46.9%), hydro (44.5%) and gas (44.5%).
- The direct employment/output coefficient (jobs per £ million output) is high for marine energy (36.22 jobs) when compared with nuclear (2.55 jobs) and coal (1.21 jobs)

Allan et al [5] show that the average Scottish share of installation expenditure to be 68.5% with 95% Scottish share in concrete structures, structural metal products and overall construction. This relatively high capital expenditure retention in Scotland may need to be treated with caution. The paper is based on a hypothetical wave device and the authors recognise the need to establish the backward linkages to the regional economy i.e. Scotland. In another paper, Allan et al [6] consider that the development of tidal energy in Scotland can potentially deliver a significant benefit to the country with their central case scenario produced a present value of discounted GDP change of £5.5 billion over the period 2005 – 2105. However, as they point the employment and value added/GDP benefits will depend on the phasing of construction and the number, location and type of marine energy devices installed.

The Forum for Renewable Energy Development in Scotland (FREDS) estimated that 1,300MW of marine power could be installed by 2020 [7], creating 7,000 direct jobs.

The Carbon Trust Future Marine Energy report [8] evaluated the capital costs, cost of energy, and potential growth of the wave and tidal energy industry based on information provided to the participants to the Marine Energy Challenge initiative.

The reports on the analysis which underpinned the Marine Supply Obligation (MSO) [9, 10] give results derived from previous consultations with marine technology developers and the Carbon Trust combined with detailed economic analysis. Similar to this study, the methodology was based on different marine energy development or growth scenarios, economic analysis of projected marine power projects at various stages in the learning curve, calculation of aggregate cash flows, and evaluation of wider economic impacts including job creation. Consistent with the importance of the MSO this included in-depth analysis, verification, and validation as far as could be taken with the stage of development of leading technologies and marine power project experience existing in 2006.

The MSO study includes many detailed findings. Some of the findings pertaining to this study include:

- Marine energy development or growth scenarios were analysed with 330MW and 650MW cumulative installed capacity in 2020;
- Projected installed costs for offshore wave technologies ranged from £3.3m/MW at demonstration stage, through £2.3m/MW at 50MW scale, to £1.2m/MW in 2020;

- Projected installed costs for tidal technologies ranged from £1.9m/MW at demonstration stage, through £1.3m/MW to 1.5m/MW at 50MW scale, to £1.0m/MW to £1.3m/MW in 2020.
- The 650MW growth scenario included £88m expenditure in 2020 (we will see that this is less than predicted in our study due to the lower installed cost (£m/MW), lower cumulative growth (MW), and earlier distribution of marine energy development in the MSO study than is used in our study);
- The employment factor for direct, indirect, and induced jobs was 17.4 jobs/£m capital invested at the installation stage (calculated from commonly used factors for a range of standard industrial classifications);
- The calculation of net jobs created allowed for operational phase jobs, jobs created in the energy supply companies, finance and insurance, but also displacement of other renewables and the costs of the economic support mechanism to the wider Scottish economy. Marginal economic analysis indicated that there would not be significant displacement of other renewables under the 330MW growth scenario but that significant displacement could be expected for the higher growth scenario;
- The 650MW growth scenario predicted 2,340 jobs net in Scotland in 2020;
- The 330MW growth scenario predicted 630 jobs net in Scotland in 2020. However the number of jobs predicted was falling from a peak around year 2015 as the build rate stabilised and the economic support (£/MWh or ROCs multiple) is reduced for later projects. This indicated the importance of maintaining sufficient economic support to maintain continuing construction of marine energy projects in the long term.

Finally, figures compiled at European level for the wind industry indicate that 15.1 jobs are created in the EU for every MW installed [11].

The consultation and analysis performed here differs from previous studies by:

- Focusing on the marine energy development to take place in Scotland and their impact on the Scottish, rest of UK, European and rest of the world supply chains;
- Being based on the direct input from wave and tidal technology developers with real experience in the procurement and construction of full scale devices;
- Including current information which was not available in 2006, the date of the last consultation and study which covered this scope, particularly from recent experience from demonstration projects and the participation of some new leading marine technology developers.

3 CONSULTATION

3.1 CONSULTATION DOCUMENTS

A template spreadsheet to be used for the consultation had been prepared and provided by the MEG. Following internal review and further discussions and clarifications with the MEG, a slightly modified version of this template spreadsheet was finalised. An introduction letter was also prepared for the benefits of the consultees, in order to:

- Introduce SgurrEnergy and IPA to the consultees, provide background on the rationale behind the consultation and invite consultees to take part;
- Explain the format of the quantitative information required (consultation spreadsheet);
- Ask a supplementary set of six qualitative questions in order to support the economic analysis.

A template spreadsheet and introduction letters are provided in Appendix B – Consultations documents.

The categories defined in the spreadsheet are based on the generic CADMID model for product lifecycle (Concept, Assessment, Demonstration, Manufacture, In-service, Disposal). As indicated in the introduction, the operation (in-service) and decommissioning (disposal) phases were not part of the scope of this initial study. Supply chain requirements of a marine energy project can also be assessed using the generic flow chart of marine power project development given in the guidelines compiled by the European Marine Energy Centre (EMEC) [12], as part of EMEC's Marine Renewable Energy Guides.

A short description of the typical supply chain requirement to be expected for a multi-MW wave or tidal energy project is given in Appendix C – Supply Chain Requirements for Marine Energy Project.

Consultees were asked to provide input on the supply chain requirement for a 50 MW project based on their respective technologies, as well as other supporting information such as research and development spending, primary material used, skills required, and estimate of induced jobs creation, if available.

The key input obtained from consultees was the supply chain source breakdown, first by company (in-house or external) and second by country of origin (Scotland, other UK, Europe, rest of the world).

3.2 CONSULTEES

A total of ten consultees have been approached. These consultees were initially selected to fulfil the following criteria:

- Wave or tidal energy technology developers;
- Having already constructed full scale prototypes or commercial devices, or being in the corresponding procurement stage;
- Based in Scotland or known to have interests in developing projects in Scotland and therefore having current or potential future impact on its marine energy supply chain.

A total of six consultees responded fully or partially to the consultation, being composed of four wave and two tidal technology developers. Three consultees declined to contribute on the ground of confidentiality. The final consultee could not commit to a response in the required timescales.

In accordance with the Marine Energy Group brief for this study, consultation of the wider supply chain was not undertaken.

3.3 RESULTS

As agreed in the scope of work and in order to preserve the confidentiality of the information provided, the individual responses from the consultees (spreadsheets and supplementary questions) are not available within this report.

Numerical responses from the individual spreadsheets have been combined into a composite spreadsheet by taking the average on a cell by cell basis. The results are presented in Appendix D – Combined consultation spreadsheet. We initially considered the use of weighting factors between technologies in order to possibly take into account factors such as the relative fraction of wave and tidal energy projects expected to be deployed, or the potential market share of the various technologies. However, it became clear that the introduction of such factors would be highly subjective and could introduce some fundamental biases and unnecessary sources of errors within this study. Therefore, despite its limitations, the direct averaging of the consultees' figures was selected as the best and simplest method to combine the individual numerical responses.

Responses to the consultation supplementary questions were also combined in order to build a view representative of the marine energy industry.

4 ANALYSIS AND DISCUSSION

4.1 SUPPLY CHAIN REQUIREMENT

A short description of the supply chain required for a multi-MW wave or tidal energy project is given in Appendix C – Supply Chain Requirements for Marine Energy Projects.

Installation covers equipment transportation, offshore site preparation, device positioning and connection. Scotland has traditionally had a strong offshore-contracting industry to support the oil and gas sector. However, translating these resources to the marine renewables industry will be a challenge. The operating conditions (such as wave regime and tidal flows) for oil and gas technology are typically very different from those seen in marine renewables. Also, the project revenue streams, uncertainties and risks, and the potential scale of the market (particularly the market with a visible pathway for development including the required economic support) are different in marine renewables to the oil and gas sector. Marine technology developers who participated in the consultation stated that aligning oil and gas technical skills and resources to marine renewable requirements and costs will be critical to successfully installing marine energy devices using Scottish companies. In addition we observe that transfer of skills and resources from other marine sectors and the offshore wind sector will also be necessary contributors.

4.2 EXPENDITURE

The breakdown of expenditure identified in the survey is given in Figure 1.

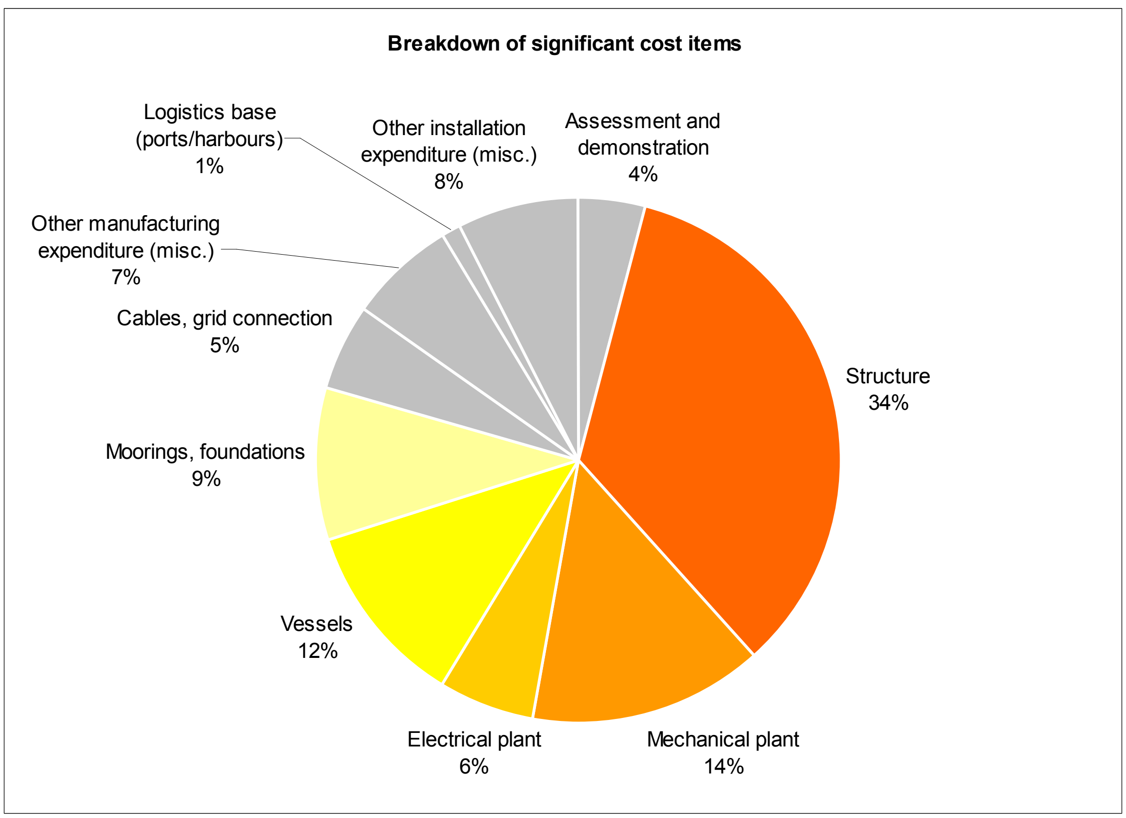

Figure 1: Breakdown of Cost Items for a 50MW Plant up to Construction Phase

The largest items of expenditure include the structure, mechanical plant (e.g. hydraulics, turbines), electrical plant (e.g. generators, switchgear), vessels, foundations and moorings. Steel and concrete have been quoted as the primary structural materials to be required.

This does not include the project financing costs, which especially for early commercial high risk projects will use a large proportion of the revenue generated by the project. Nor are operating costs such as insurance and transmission charges included in this analysis.

Retention of Capital Expenditure in Scotland

The results of the survey identified the amount of capital expenditure that was expected to be retained in Scotland. An overview is given in Figure 2.

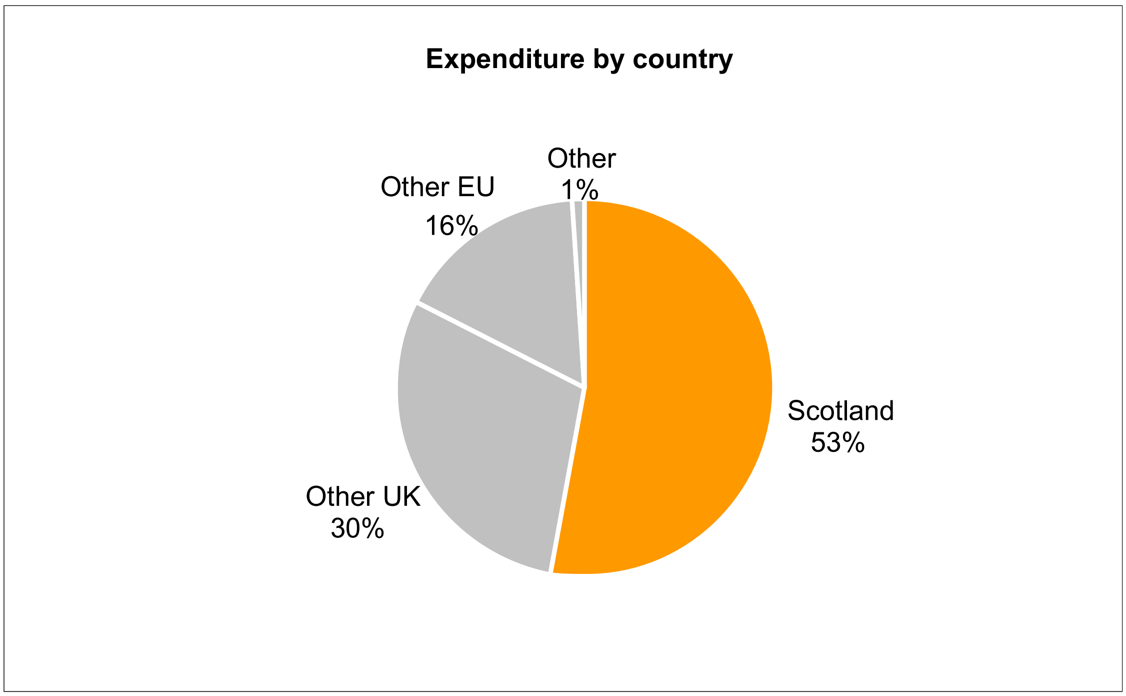

Figure 2: Expenditure by Country

The notable areas of significant expenditure (more than 5% of the total cost of a 50MW plant) where the contribution from the Scottish economy and supply chain is expected to be relatively low included (see Appendix D:

- Mechanical plant (e.g. hydraulics, turbines): 11% Scotland;
- Electrical plant (inc. generators, switchgear): 29.3% Scotland;
- Cables, umbilicals and communications, grid connection: 31.5% Scotland;
- Installation vessels (jackups, lift barges): 36.7% Scotland.

Most marine energy technology developers want to assemble their devices using proven, reliable, “off the shelf” sub-components purchased from established suppliers. Unlike the wind turbine manufacturing industry there is (as yet) no real vertical integration and few companies who have opted for the development of subcomponents dedicated to marine energy technologies. The supply chain categories highlighted above may include significant imports from Europe or even farther afield, consequently these could be the areas to focus on in order to increase the Scottish share of the supply chain market. This would typically be through development of expertise in marine energy technologies and supporting infrastructure.

However, as the marine energy industry progresses from the demonstration to the commercial phase and procurement grows in scale, there will be increased pressure and opportunity to source components at the lowest cost from a wide supply base. Review of long term retention figures through comparison with other industries was beyond the scope of the brief for this study.

We consider a few of the significant areas of the supply chain qualitatively below.

Mechanical Plant

At present, the facilities are not in place in Scotland to produce the specific hydraulics subsystems required for marine energy devices. Germany and Switzerland have been mentioned as the main sources for hydraulic components. Where there are bespoke items such as steel or concrete structures, then the skills exist for these to be fabricated in the UK. Some of the sub-components such as bearings, seals and ballasting valves would need to be sourced from the rest of the UK. Assembly is anticipated to be done in Scotland.

Electrical Plant

Generators: The market for generators is characterised by a number of very large companies making generators for the renewables industry as a small part of their overall business in electrical machinery. New supply capacity is emerging in China, with the leading suppliers increasing their production facilities around the world and there are currently no signs of a shortage in this area. Demand for more advanced and/or tailored applications may change this, but such concepts are likely to be designed in partnerships between generator suppliers and marine device manufacturers.

Hydraulic Power Converters: The market is characterised by a number of large European companies who together should be capable of meeting most of the demand from the marine energy industry. With new facilities being established around the world by the leading suppliers and new entrants, there is no sign that power converter supply will constrain growth. Information from both the supply and demand sides suggests there is currently pressure for increased converter supply, but that suppliers are confident that they can meet this.

No significant supply chain constraints have been identified for the manufacture/assembly of the power take-off (PTO) sub-station (housing the hydroelectric converter, control systems, power electronics and generator). All equipment is established technology available at the appropriate scale in other industries however the expertise to deliver this equipment is typically only available in Europe.

Transformers: In an individual marine energy device, a power transformer would typically step up the generator output voltage from low voltage (LV - typically though not exclusively 690V) to medium voltage (MV - normally 11kV or 33kV in the UK). A number of devices can then be linked together in an MV cable network. For smaller installations (e.g. tens of MW), closer to shore, this MV cable network can connect directly to an onshore substation. Alternatively, the MV cables can be marshalled at a subsea substation and the voltage increased (e.g. from 11kV to 33kV as planned at the Wave Hub project).

For larger installations farther from shore, then offshore platform substations will be required to transform the voltage to 132kV or greater for transmission to the shore via a higher voltage transmission subsea cable.

These substations are complex and require skilled design and engineering. Key plant items located on these platform substations will include:

- Transformers (33/132kV, 33/245kV[3] are the most likely voltages);
- 33kV switchgear;
- Higher voltage switchgear (132kV, 245kV);
- Reactive compensation, back-up generators, control and protection equipment.

Manufacturers of this equipment are largely limited to the large electrical engineering companies: ABB, Siemens, Alstom and General Electric. There are also a few specialist manufacturers who produce large transformers and higher voltage switchgear, e.g. Tamini in Italy. Most large manufacturers have facilities to manufacture plant in more than one location and although manufacturing timescales for such plant can be quite long (e.g. 18+ months for a 33/132kV transformer, making timely ordering essential). It is unlikely that demand will be high enough to create significant supply problems in the short term.

The supporting structures for offshore substations are similar in terms of supply chain capability to a turbine foundation or a *Minimum Facilities Platform* as commonly used in the UK oil and gas industry.

All onshore works, including slab preparation and substation construction would normally be completed by local contractors in the region of the wave or tidal farm.

Cables

Subsea Cables: MV subsea cables take the power from a wave generator directly to an onshore connection point (for smaller, close to shore wave farms) or to an offshore platform substation for transformation to a higher voltage such as 132kV (for larger, more distant wave farms). A transmission subsea cable would then export power to the onshore grid.

Manufacture of subsea power cables is a specialist activity. At present there are four prominent subsea cable manufacturers in Europe or close proximity to Europe. They are:

- Nexans;
- AEI (TT Electronics);
- ABB;
- Prysmian (formerly Pirelli).

All the above companies are relatively large multi-national operations with offices and manufacturing facilities throughout Europe, and all specialise in the manufacture of power cables (ABB also manufacture a wide range of other transmission and distribution equipment).

The specialised manufacturing requirements and the need to be able to manufacture cables with a high integrity in very long continuous lengths (several or tens of kilometres) means that manufacturers tend to have one specific manufacturing facility rather than multiple facilities in different locations.

Potentially high volume demand for subsea cable (for example due to the UK ‘Round 3’ offshore wind projects) may stretch existing manufacturing facilities for both MV subsea cables and transmission subsea cables which would be used for turbine interconnection and export to the onshore grid.

[3] 245kV is the highest voltage for which subsea three core transmission cables have been developed.

New entrants to the market for transmission subsea cables are unlikely as two suppliers (Prysmian and Nexans) dominate the sector and new specialist players are finding some difficulty in accessing the market. Typical lead times for subsea cables greater than 33kV exceed 18 months.

There is a consistent message coming from cable suppliers that the bottleneck is not strictly factory capacity but lead times both for raw materials and for setting up production runs for product variations. The supplier's view is that standardisation of cables across the industry would bring lead time and capacity benefits, as would the change from AC transmission systems to HVDC systems as these dramatically reduce the amount of conductor material required. However, as a rule of thumb, HVDC subsea transmission only becomes preferable over AC technology at distances of the order 80 – 100km from shore, or for very large capacities (in the hundreds of MW range).

Installation Vessels

Installation vessel requirements and deployment strategies are likely to be initially very diverse as a consequence of the range of technologies under development and of the range of deployment locations (offshore, nearshore, shoreline) and seabed conditions.

Some technology developers have decided to build or design vessels dedicated to their technology (OpenHydro Installer), while others such as MCT have used crane barges typically employed by the offshore wind industry to deploy their devices. Installation requirements are likely to be less onerous for floating devices and structures which can be towed to the deployment location.

Given the strength of the Scottish and UK shipbuilding and naval architecture industry, there are opportunities for the design and at least some manufacturing components of this supply chain to be retained.

4.3 EMPLOYMENT

The results of the consultation exercise are summarised in Table 1. It should be recognised that the sample of companies that responded is limited to six technology developers and that a number of companies active in the field of marine energy declined the invitation to respond. The first phase of the supply chain review therefore has a limited sample and cannot provide a statistically robust response. There are a number of other issues which make it difficult to extrapolate from the consultation exercise. These include the following:

- The marine development scenarios as defined by the Marine Energy Group give no indication of the deployment split to be expected between different types of marine energy – wave and tidal energy;
- Commercial full-scale marine power generation projects have yet to be completed and the performance of various aspects demonstrated. Commercial performance and actual employment which will be created therefore remains uncertain at this stage;
- Long-term economic support mechanisms sufficient for marine energy are yet to be established. The scale of development which will be supported in the long term is currently uncertain;
- The economics of marine energy will change in the future with changes in technology, energy pricing and regulation as well as with changes in the prices and availability of construction materials, machinery and equipment;

- Jobs per MW installed will change with learning rate effects and installed cost reductions (£/MW), particularly during scale-up of project developments, i.e. until the industry reaches maturity;
- Employment predictions, particularly of indirect and induced jobs may be difficult before supply chains are established based on continuing business, i.e. until the industry reaches maturity.

Table 1: Summary of Results from the Consultation Exercise with Companies in the Marine Energy Sector

ITEM	RESPONSES	OTHER COMMENTS
Availability of skilled labour and associated skills	There is pool of skilled labour in Scotland but there may be a need for training or transfer of skill for working in the offshore working environment.	The same skills will be required whether this is a demonstration or commercial project. Scotland has developed a pool of labour with skills developed in the offshore oil and gas sectors.
Job creation	Limited input. See text	Main areas of job creation would be manufacture, installation and infrastructure in the pre operational phase. Additional jobs may also be created in the field of research and development.

Estimates of job creation are difficult without validated cash flow information, and, as we saw in the literature review, very wide ranges have been quoted. Estimates of direct, indirect and induced employment creation with the development of marine energy have been given by a number of companies who replied to the consultation exercise. In some cases these relate to the design and construction phase while in other cases estimates are given at full commercial development of 50 MW. It is likely that direct, indirect and induced employment multipliers may produce more jobs than those provided by consultees. This will be particularly the case if and when Scotland develops expertise and a cluster of marine energy industries including design, construction, maintenance, refitting and or decommissioning as well as the ancillary activities of:

- Feasibility studies (engineering, environmental, economic and financial analysis);
- Planning (permits, insurance, finance and legal services);
- Testing and certification;
- Research and development[4].

[4] The development of the marine energy sector will reinforce the research and development activities in marine and other sources of renewable energy in universities (for example Strathclyde on economics and engineering, the University of Edinburgh and other universities as well as public and private research centres in Scotland).

While some of the jobs will be created in Scotland, for certain specialised items it is clear that there will be some leakage of direct, indirect and induced jobs outside Scotland. However, with the development of expertise in marine energy technologies and infrastructure up to 2020, technology developers expect job retention in Scotland to increase.

The installation and subsequent maintenance of the devices will create both direct and indirect employment opportunities. Consultees have suggested that 10 to 25 jobs (both on and offshore) will be created related to the ongoing maintenance of the 50MW project. These will be permanent jobs, whereas construction jobs are only during the installation phase. The use of local port facilities will support the on-going development of the harbour and underpin the economic security of the wider area. These effects will continue for the duration of the project. However, this longer term input is not part of the remit for the current study, which only considers project phases up to and including construction.

Allan et al [5] suggests that while marine electricity generation in Scotland could create up to 1,710 jobs, there would also be a job displacement impact of 923 jobs as skills and labour are transferred from other sectors of the economy. Job creation and displacement at the level of the Scottish economy are likely. This includes potential displacement of other sources of energy (including renewables) with the potential expansion of market share of marine energy. Although it is likely that the development of marine energy will be complementary with existing and other potential energy sources in Scotland.

The MSO analysis [8, 9] suggests that a high marine energy development scenario (650MW cumulative capacity in 2020) could create 4,660 jobs (direct, indirect and induced), but that this would be offset by 2,316 job losses in other renewables and in the wider Scottish economy due to the cost of support for marine energy, this giving net jobs created in Scotland of 2,340. The equivalent figure for the 330MW scenario was 630.

It is difficult to forecast at this stage of industry development the extent to which job creation will be driven by project size, although it is clear that it is likely to differ across the project stages:

- **Design and Development Jobs:** little change with project size;
- **Manufacturing and Assembly Jobs:** expected to be related to the MW to be installed. However, unit cost reductions as represented by learning rates would be partly achieved through reductions in labour required per MW and result in reduction in the number of jobs per MW factor;
- **Installation Jobs:** Operations teams and vessel crew – installation staff numbers would be dependent on the number of devices to be deployed, however, it would be likely that the same team would carry out a number of installations;
- **Operations:** On site operations and remote operations teams. Engineering support. This will be ongoing throughout the life of the project. The numbers of staff required would be dependent on the size of the development.
- **Infrastructure:** Grid connections, cable installations, port upgrades – these jobs will not relate to the size of developments and will be created on a strategic basis to service a number of projects.

Where employment per MW is used as metric, this factor can be expected to reduce with leaning rate effects applying to all the above activities.

It should be noted that our study does not undertake analysis of jobs created in the energy supply companies and financial institutions which will benefit from the operating returns from marine energy projects over and above the value of their initial investment.

After having considered all the available information from the consultation and the literature, we have decided to adopt for the marine energy industry a figure of 20 jobs created per MW of installed capacity.

Location of Jobs

For their internal operations, the companies surveyed expect to source most positions locally, with the overall breakdown similar to the financial breakdown shown in Figure 2.

In particular, the following areas of work may well have a relatively high local employment component, although the balance is likely to change as the industry matures:

- Permitting and consenting;
- Vessel hire;
- Divers and ROV surveys;
- Environmental and geotechnical monitoring;
- Maritime operations consultancy;
- Fabrication and final assembly;
- Underwater substation pod;
- Cable installation (directional drilling, connection to substation);
- Installation of telecommunications to shore station;
- O&M;
- Port facilities.

Skills

Skilled staff will be required for engineering and technical support during the development, design and construction phases of a 50MW project. Once the project is constructed and commissioned, operations support staff would then be required.

Required skills include: researchers, hydrodynamic analysts, commercial analysts, planning specialists, oceanographers, metocean modellers, marine operations experts and engineers from various disciplines (mechanical, hydraulic, control, structural, electrical power engineering, offshore installation engineers, QA, inspection).

The sector also needs high calibre marine operations staff. There are a large number of skilled individuals in the power, oil and gas and offshore sectors in Scotland. However, attracting these people to work in marine renewables is a challenge due to the perceived risks of a developing industry and in some cases a disparity in salaries that are offered. The only way that this can be overcome is through the successful and sustained growth of marine renewables into a stable long-term industry, a process that can only occur in the presence of appropriate, unambiguous policy and the necessary long-term economic support mechanisms to incentivise marine energy.

Training

The following areas of study were specifically cited by consultees as potentially useful as part of PhD / industry alliance programme:

- Naval Architecture;

- Hydrodynamics;
- Offshore Engineering (with wave/tidal bias);
- Marine Operations (with wave/tidal bias).

It was also highlighted that EMEC are introducing an Acoustic Doppler Current Profiler (ADCP) deployment vocational course, which will be useful for staff involved in marine operations.

4.4 Scenario Analysis

MEG Scenarios

Our analysis has used the three marine energy development scenarios in terms of installed MW capacity in Scotland that have been developed by MEG for the period 2009 – 2020, namely (see Figure 3):

- "Base case" – 1,000 MW installed by 2020
- "Stretch" – 2,000 MW installed by 2020
- "Downside" – 500 MW installed by 2020

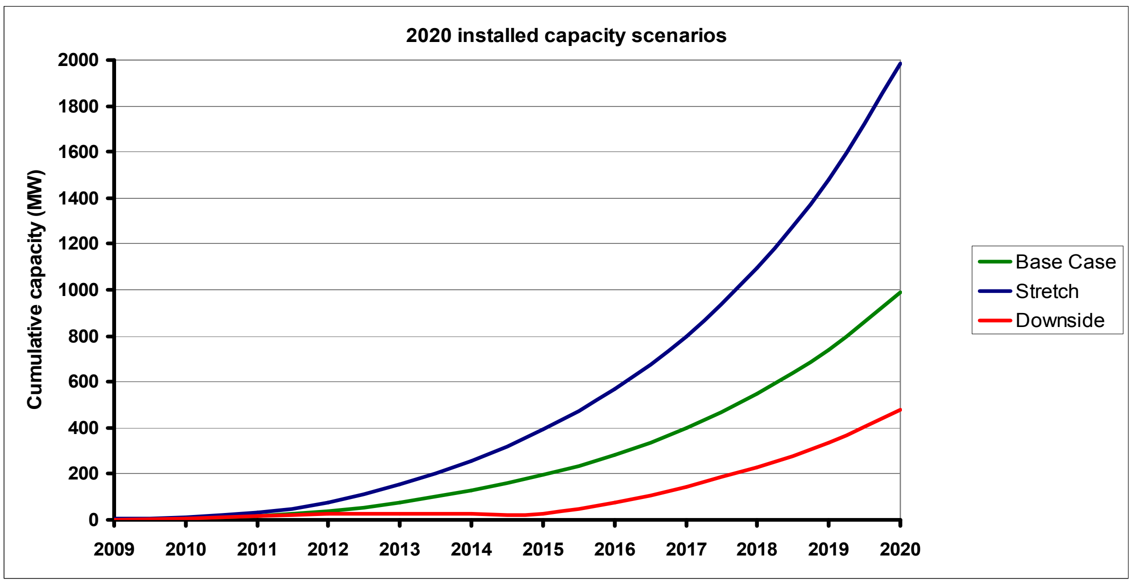

Figure 3: MEG Scenarios to 2020

Each of these will have different implications for the development of year on year and cumulative electricity production capacity and value, value added, employment and displacement on other electricity generation sectors.

Again, as this initial phase of the study is only concerned with the pre operational phase (Concept + Assessment, Demonstration, Manufacture, Installation), value, value added and employment deduced from this work are likely to be lower estimates.

Capital Costs and Learning Curve Assumptions

A capital cost value of £3.7m/MW has been deduced from the consultation based on the average value provided by consultees for a typical 50MW wave or tidal farm. However, using a constant capital cost figure over a 10 year period appeared unrealistic. Therefore, capital costs were estimated using a cost learning curve and assumptions believed to be appropriate for the marine energy sector.

Based on input from the MEG, and other information such as the reports included in the literature review, a cost learning curve was adopted based on a 12.5% learning rate and on a capital cost of £3m/MW in 2014 (see Figure 4).

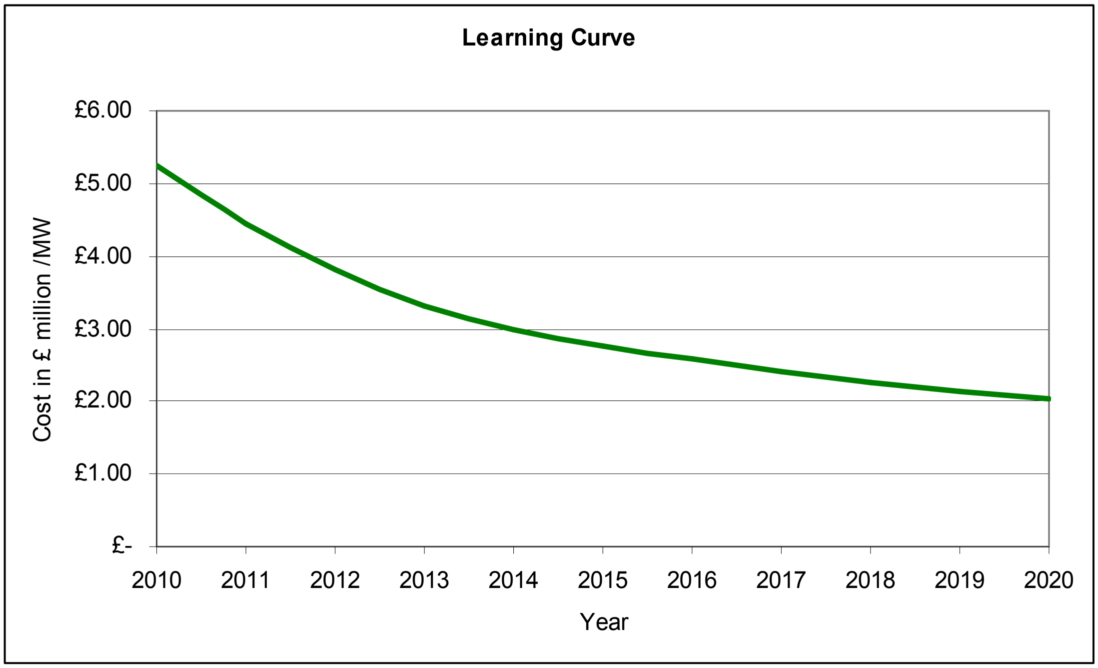

Figure 4: Capital Cost Learning Curve

Employment Creation and Expenditure

Initial estimates for employment creation and expenditure including retention in Scotland are summarised in Table 2 for the base case scenario. Estimates for the "stretch" and "downside" scenarios are provided in

Appendix E1 – Marine Energy Development in Scotland, Expenditure and Employment (Stretch MEG Scenario).

The keys assumptions which have been used are:

- Creation of 20 jobs per MW of installed capacity;
- Capital expenditure retention factors of 53% for Scotland, 30% for other UK, 16% for other EU, and 1% for the rest of the world (RoW). These factors were directly obtained from the consultation.

Based upon these assumptions our forecast for the employment and expenditure in Scotland under each of the three scenarios devised by the MEG group is shown in Figure 5 and Figure 6.

In order to estimate the impact of marine energy we assumed a total of 20 jobs per MW in the pre-operational phases, based literature references and on the responses from the consultees. This will only apply to new capacity being installed[5] and does not allow for the impact of learning rate effects.

We assumed a 53% overall retention (capital expenditure and jobs) in Scotland based on consultees responses.

We did not include R&D expenditure required to bring plant to the level where 50MW facilities could be installed. This expenditure was estimated at an average of £30 million per company.

It should be noted that these figures are uncertain and are based on a limited sample of consultees and literature. The employment creation effects in particular will depend on the general economic climate, availability of labour and skills in Scotland and competition from abroad and other sectors in particular oil and gas. It is likely that the availability of such skills will improve over the time period 2010 to 2020 with experience and increased investment in skills and training. Other risks and uncertainties are highlighted in section 4.5, which could have a positive or negative impact on these figures.

[5] Later jobs in the operational phase seem likely to be around 0.5 jobs per MW and will last for the whole operational life of the project.

Table 2: Marine Energy Development in Scotland, Expenditure and Employment (Base Case MEG Scenario)

Year	Capacity (MW)		Employment (Jobs)					Expenditure (£ million cumulative)				
	Per annum	Cumulative	Total	Scotland	Other UK	Other EU	RoW	Total	Scotland	Other UK	Other EU	RoW
2010	5	7	**100**	53	30	16	1	**26**	14	8	4	0
2011	10	17	**200**	105	60	32	2	**71**	37	21	11	1
2012	20	37	**400**	211	120	65	5	**147**	77	44	24	2
2012	40	77	**800**	422	239	129	10	**279**	147	84	45	3
2014	52	129	**1,040**	548	311	168	12	**435**	230	130	70	5
2013	68	197	**1,360**	717	407	220	16	**624**	329	186	101	7
2016	87	284	**1,740**	917	520	281	21	**848**	447	254	137	10
2014	115	399	**2,300**	1,213	688	372	28	**1,125**	593	337	182	13
2018	148	547	**2,960**	1,561	885	479	35	**1,461**	770	437	236	17
2015	193	740	**3,860**	2,035	1,155	624	46	**1,875**	989	561	303	22
2020	251	991	**5,020**	2,647	1,501	812	60	**2,383**	1,257	713	385	28

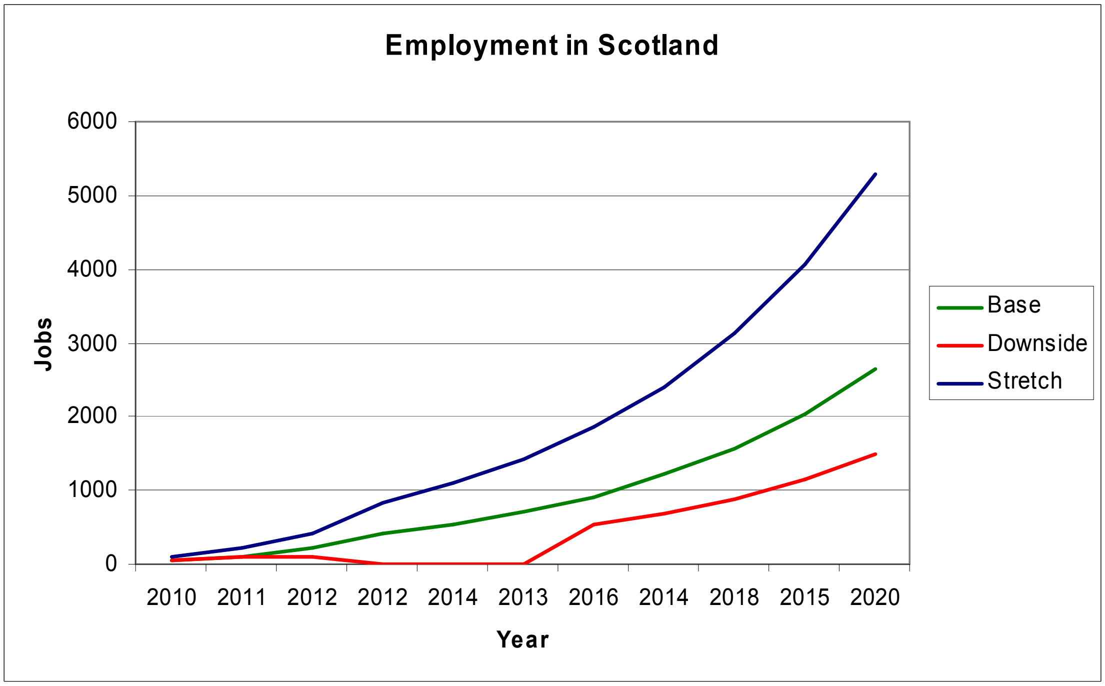

Figure 5: Employment in Scotland under the three MEG Scenarios (pre-operational only)

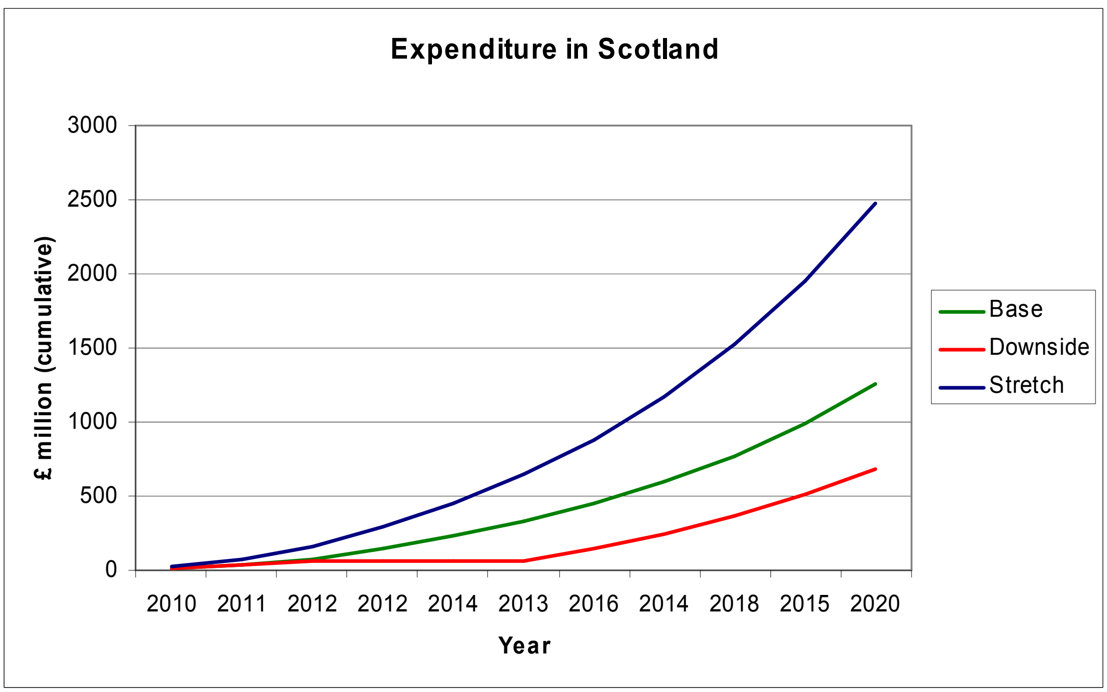

Figure 6: Cumulative Capital Expenditure in Scotland under the three MEG Scenarios (pre-operational only)

4.5 UNCERTAINTIES AND RISKS

As well as the obvious uncertainty in the assumptions used above, there are a number of risk factors associated with the development of marine energy projects in Scotland. While this has not been factored into this phase of the study the key issues which could either increase or reduce the economic impact and jobs created are identified in Table 3.

Key issues for consideration therefore include:

- Success of the technology at demonstration phase and when scaled up to commercial levels, particularly the actual cost of early commercial projects and cost reductions achieved through learning;
- Energy price projections;
- The economic support mechanism provided for marine energy, including the number of ROCs or £/MWh and ROC prices, the phasing and duration of the support, or limits on installed capacity eligible for the support;
- The comparative economics of energy production from other sources in Scotland including other renewables, oil, coal and gas and nuclear energy, including raw material prices;
- Provision of grid connection;
- Changes in the regulatory environment for electricity generation and marine projects;
- Technology transfer from universities and R&D institutes to the private sector in Scotland in the field of marine energy;
- The availability of private finance for project development in the marine energy sector;
- The availability of public sector funding to support project development, research, development and training;
- The presence of Scottish companies that can meet the construction, engineering and infrastructure requirements necessary to support the development of marine energy in Scotland;
- Evolution of the marine energy planning regime, marine energy industry and project developments such that production of marine energy devices and project construction may be maintained on a continuing basis. Otherwise the jobs created will be lost or intermittent.
- The long-term affordability of an economic support mechanism for marine energy. The economic support mechanism will need to provide sufficient long-term support to incentivise continuing build of marine energy projects, and provide a visible pathway for commercialisation and the scale-up of marine energy to achieve sufficient cost reductions for ongoing economic viability. The cost of this support mechanism and impact on jobs will partially offset the jobs created in the construction and operation of the marine energy projects.

Table 3: Uncertainties and Risk Factors

Reduces positive economic impact or jobs created in marine energy in Scotland	**Increases positive economic impact or jobs created in marine energy in Scotland**
General economic climate. Reduced energy prices, constraints on costs of economic support mechanism and low availability of private finance constrain marine energy development below previous projections. Constraints on public or private expenditure may limit training or creation of supporting infrastructure.	General economic climate. Shift from near full employment to high unemployment could remove labour availability constraint, for example if it encourages re-skilling. Reduced oil and gas prices might encourage some transfer of skills and technical resources from the oil and gas sector.
Development of sufficient renewables capacity to meet government targets and commercial obligations using other renewable energy sources at lower cost or risk. Marine energy contribution not seen as significant.	Government renewables targets and commercial obligations combined with constraints on development of other renewables sources, and relative costs of alternatives, demands significant contribution from marine energy.
Marine energy development scenarios not supported by sufficient economic support mechanism (due to high actual project costs or affordability constraints on the support).	Successful commercial demonstration combined with a sufficient and visible economic support mechanism, and long-term energy price projections provides for large scale commercial developments continuing in the long term.
Marine energy development scenarios not achievable technically or with project development and implementation timescales.	Successful technical demonstration combined with effective project development and planning regime enables rapid development
Lack of grid connection infrastructure to prospective sites, or insufficient grid capacity.	Grid connection infrastructure provided, removing this constraint on large scale marine power generation project developments.
Spasmodic technology or project development (for example due to site development and planning constraints, or business failures) results in intermittent development and loss of jobs previously created.	Supported marine energy development scenario with project developments continuing into the long term enables competitive marine energy industry and supply chains to be established and sustained. Direct, indirect and induced jobs are created and sustained.
Transfer of manufacture to lowest cost regions worldwide with full commercialisation, up-scaling, and increasing availability of suitable suppliers overseas.	Establishment of technology, knowledge and skills base, and supporting infrastructure in Scotland.
	Export markets for marine energy technology. However this will be subject to sufficient economic support mechanisms being implemented in other countries without conditions for local supply preventing import.
Lack or technical and commercial knowledge and skills transfer hinders practical and commercially viable development and project implementation.	Successful transfer of technical knowledge, skills and resources from offshore wind, offshore oil and gas, or other marine sectors.

Jobs per MW installed reduce with learning rate effects and with the level of economic support.	Cost-competitiveness or marine energy increases the greater the learning rate. Long-term affordability of economic support mechanisms and the long-term sustainability of marine energy are increased if the required levels of economic support are reduced.
No public support for R&D or demonstration projects.	R&D jobs (not included in this study)
Marine power generation projects not commissioned.	Operational phase jobs (not included in this study).
Overselling of marine technologies or marine energy projects resulting in losses to investors. High insurance claims.	Marine energy project returns to energy supply companies and the financial sector exceeding investment costs, creating wealth and employment (not included in this study).
Marine energy industry and supply chains not established or sustained.	Indirect and induced jobs (not fully included in this study)

5 CONCLUSIONS

The socio-economic benefits from the development of marine energy in Scotland will include the generation of full time and part time employment during the planning, design, construction and operational phases of marine energy in Scotland. The development of marine energy will together with vocational training, research and development in Scotland on marine energy increase the skills base of the country in marine energy and the socio-economic benefits will be felt at different levels of the supply chain and in the supporting services to the marine energy sector.

Using the base case scenario as a reference, this study concludes there is the potential of significant expenditure of the order of £2.4 billion towards the development of marine energy projects in Scotland out to 2020. Of this, £1.3 billion could be retained in Scotland and could create over 2,600 jobs. This figure does not include a significant number of longer term operations and maintenance jobs. This figure only relates to employment generated by projects installed in Scottish waters, and therefore does not include the potentially significant number of jobs that could be generated within the Scottish supply chain by marine energy deployments taking place in the rest of the UK and worldwide (export potential).

The methodology and level of analysis used for this study was defined by the Marine Energy Group. The findings of this study are based upon assumptions and should be qualified as follows:

- The marine energy development scenarios used in this study were specified by the Marine Energy Group.
- The breakdown of project installed costs or capital costs and particularly the capital expenditure retention figures are based on consultation responses from a limited number of technology developers.
    - Validation has not been undertaken through detailed scrutiny of consultees' underlying information.

  - Consultation has not been undertaken with other elements of the supply chain for example project developers, component suppliers, or construction companies.
  - Validation has not been undertaken through review and comparisons with other industries.
- The consultation and analysis in this study is based upon a nominal 50MW installed capacity project, combined with forward projections using the Marine Energy Group marine energy development scenarios.
  - We have not quantified the change in capital expenditure retention with time which could be expected as the industry matures and up-scales, and progresses from the demonstration to the commercial phase.
  - Jobs created will be dependent upon learning rate effects and predictions using the jobs / MW installed capacity metric should be treated with caution particularly when applied over the early up-scaling period.
- R&D, operational phase jobs and jobs in the energy supply companies and financial sector have not been included. These jobs and further indirect and induced jobs could increase the total jobs created substantially.
- Displacement of other renewables and costs of the economic support which will be necessary to achieve the marine development scenarios and impacts on jobs have not been quantified in this study. This will partially offset the derived job creation figures.

Furthermore, to achieve the investment and job creation as indicated by this study, the supply chain will require stimulation and strong commitment from the companies involved in the development of the technology, in turn supported by project developers, financiers commitment and sufficient economic support, while technical, skills, regulatory, financial and commercial risks will need to be addressed or mitigated, and strong political support maintained.

While there will be a number of synergies with the supply chain requirements for the offshore wind industry, there will be a requirement to coordinate activities with those of offshore wind to ensure that suppliers are available, and also take specific measures to encourage transfer of skills and resources from the offshore oil and gas and other marine sectors.

While there may be some displacement of employment in Scotland in the short term as skilled labour is drawn from other sectors, this will inevitably be linked to the skills and labour market situation in Scotland. In the longer term it is expected that a more skilled labour force with experience in marine energy will be created, provided that progressions from demonstration to commercialisation is adequately supported and is successful.

APPENDIX A – REFERENCES

[1] Arthur D Little (2005). Wave Hub. Summary Business Case. Report to South West of England Regional Development Agency.

[2] Joint IPA – SgurrEnergy review of offshore wind supply chain and economic opportunities – Client confidential (2008)

[3a] Denny, E. (2009). The economics of tidal energy. Energy Policy 37, pp 1914 – 1924

[3b] Shields, Y., O'Connor, J., and O'Leary, J. Ireland's Ocean Economy and Resources. A briefing document. Marine Foresight Series No. 4. Marine Institute/Foras na Mara

[3c] Marine Institute and Sustainable Energy Ireland (2005). Analysis of the Potential Economic Benefits of Developing Ocean Energy in Ireland

[4] Institute of Mechanical Engineers (2008). Marine Energy – more than a drop in the ocean?

[5] Allan, G.J, McGregor. P. G., Swales, J.K. and Turner, K. (2007). Impact of alternative electricity generation technologies on the Scottish economy: an illustrative input-output analysis. *Proceedings I. Mech. E Vol. 221 Part A: J. Power and Energy.*

[6] Allan, G.J., Bryden, I., McGregor, P. G., Stallard, T., Swales, J.K., Turner, K. and Wallace, R. (2008). Concurrent and legacy economic and environmental impacts from establishing a marine energy sector in Scotland. *Energy Policy 36, pp 2734 – 2753.*

[7] FREDS Marine Energy Group report – Harnessing Scotland's Marine Energy Potential. Scottish Executive publications (2004)

[8] Carbon Trust. Future Marine Energy (2006). Results of the Marine Energy Challenge: Cost competitiveness and growth of wave and tidal stream energy.

[9] AEA Technology and Poyry Energy Consulting for the Scottish Executive - Additional Support for Marine Energy Generation in Scotland, Volume 1 – Summary Report (2006)

[10] AEA Technology and Poyry Energy Consulting for the Scottish Executive - Additional Support for Marine Energy Generation in Scotland, Volume 2 – Main Report (2007)

[11] Wind at work – Wind Energy Creation in the EU – European Wind Energy Association 2008

[12] EMEC (2009) – Guidelines for Project Development in the Marine Energy Industry. www.emec.org.uk

APPENDIX B – CONSULTATIONS DOCUMENTS

See documents:

- MEG Consultation Introduction Letter B2
- MEG Supply Chain - Consultation Spreadsheet B2

APPENDIX C – SUPPLY CHAIN REQUIREMENTS FOR MARINE ENERGY PROJECTS

Pre Construction:

1) Identification of potential sites
2) Survey and assessment for geotechnical and environmental appraisal of sites e.g.
    a. Vessel hire: workboats, and survey vessels
    b. Divers and ROV (Remotely Operated Vehicle) surveys
    c. EIA (Environmental Impact Assessment)
    d. Environmental monitoring (mammal surveys, acoustic assessment, oceanographic modelling etc)
    e. Geotechnical: includes IEA's, bathymetric seabed and land surveys, Geomorphology, Benthic Ecology, Geophysical, Metocean analysis, ADCP, sedimentology and core sampling).
3) Maritime Operations: advisory on maritime operations
4) Consultations
5) Permitting and Consenting
6) Legal and Power Purchase Agreement
7) Device certification

Design and Project Management:

A significant proportion of this work would be completed in-house however appropriate consultants and specialists will be utilised as required. There is a strong skill base for these outsourced design services already existing in Scotland and the UK.

Manufacture and Assembly:

The typical elements of a wave or tidal device that must be fabricated, sourced and assembled are described below. This list is not intended to be exhaustive given the wide range of wave and tidal technologies designs currently existing or under development.

1) Main structural components (depending on the device this could include nacelle, hub, blade, tubes, "flaps", buoy, concrete caissons, etc)
2) Hydraulics & Control System: Where there are bespoke items such as cylinders then the skills exist for these to be fabricated in the UK. Assembly is anticipated to be done in Scotland.
3) Sub-components (gearbox, generator, bearings etc). Some of the sub-components such as bearings, seals and ballasting valves would need to be sourced from the rest of the UK.
4) Substructure manufacture and assembly could be carried out in Scotland.

Construction and Commissioning:

1) Foundations: Supply chain studies show no constraints based on the range of materials identified (steel, concrete or hybrids of these); there is a strong existing base for the supply of these large structural items within Scotland. If drilling and piling operations are required for the final foundation design then there are also contractors within Scotland that can perform these activities.
2) Vessel suppliers / Installation contractors – there will be a requirement for the use of vessels during the installation. It is likely that vessels would be required to be available over a period of several months.

3) Moorings for floating structure – procurement of mooring system, mooring jewellery, mooring lines and bespoke connection fittings for tugs, workboats and multicats, divers, ROV, ribs
4) Port
    a. Marker Buoys and navigational lighting procurement
    b. Dockside facilities with appropriate depth, craneage and storage.
5) Electrical connection to the mainland grid system, including:
    a. Grid connection upgrades
    b. Power Conditioning Equipment – converters, generators etc.
    c. Underwater Substation Pod – procurement of transformers, switchgear.
    d. Cabling / electrical contractors: LV Dynamic cable and MV Static Cable (with fibre optics) – procurement, storage and testing
    e. Subsea cable armouring / burial vessels and skills
    f. Procurement of bespoke winches and drums for cable
    g. Cable laying vessels
    h. Pipelines: directionally drilled from shore out to the location of wave energy devices, an operation that requires specialised drilling equipment. There are sufficient directional drill contractors in Scotland to support a 50MW farm. Assuming that pipelines are constructed from carbon steel, then these would likely be fabricated and coated in the UK but could be assembled and welded by local Scottish companies.
6) Onshore structures: onshore substation, control building (at site itself[6] or remote[7]). All onshore works, including slab preparation and substation construction would completed by local contractors in the region of the wave farm.
7) SCADA system
8) Testing – over various components, also pressure testing.
9) Installation of telecommunications to shore station
10) Project certification

Operation and Maintenance (out of scope of this study)

1) Inspection vessels (ROV's and Divers)
2) Storage for replacement parts / PTO systems
3) Dedicated O&M staff and control centre
4) Planned retrievals using tugs and workboats
5) Port facilities with craneage, storage and laydown areas, waste disposal facilities
6) General marine engineering skills for offshore and onshore maintenance work

Decommissioning (outside the scope of this study)

As construction and commissioning

[6] Planned by Wavegen for Siadar project

[7] For example the Pelamis control room in Edinburgh for a Portuguese wave farm

APPENDIX D – COMBINED CONSULTATION SPREADSHEET

See document “Combined MEG Spreadsheet B1”

APPENDIX E1 – MARINE ENERGY DEVELOPMENT IN SCOTLAND, EXPENDITURE AND EMPLOYMENT (STRETCH MEG SCENARIO)

Year	Capacity (MW)		Employment (Jobs)					Expenditure (£ million cumulative)				
	Per annum	Cumulative	Total	Scotland	Other UK	Other EU	RoW	Total	Scotland	Other UK	Other EU	RoW
2010	10	13	**200**	105	60	32	2	**53**	28	16	9	1
2011	20	33	**400**	211	120	65	5	**140**	74	42	23	2
2012	40	73	**800**	422	239	129	10	**291**	154	87	47	3
2012	80	153	**1,600**	844	479	259	19	**553**	292	165	89	7
2014	104	257	**2,080**	1,097	622	336	25	**861**	454	257	139	10
2013	135	392	**2,704**	1,426	809	437	32	**1,230**	648	368	199	15
2016	176	568	**3,515**	1,853	1,051	568	42	**1,676**	884	501	271	20
2014	228	796	**4,570**	2,409	1,367	739	55	**2,220**	1,170	664	359	27
2018	297	1,093	**5,941**	3,132	1,777	961	71	**2,885**	1,521	863	467	34
2015	386	1,480	**7,723**	4,072	2,310	1,249	92	**3,701**	1,951	1,107	598	44
2020	502	1,982	**10,040**	5,293	3,003	1,624	120	**4,703**	2,480	1,407	761	56

APPENDIX E2 – MARINE ENERGY DEVELOPMENT IN SCOTLAND, EXPENDITURE AND EMPLOYMENT (DOWNSIDE MEG SCENARIO)

Year	Capacity (MW)		Employment (Jobs)					Expenditure (£ million cumulative)				
	Per annum	Cumulative	**Total**	Scotland	Other UK	Other EU	RoW	**Total**	Scotland	Other UK	Other EU	RoW
2010	5	7	**100**	53	30	16	1	**26**	14	8	4	0
2011	10	17	**200**	105	60	32	2	**71**	37	21	11	1
2012	10	27	**200**	105	60	32	2	**111**	59	33	18	1
2012	0	27	**0**	0	0	0	0	**111**	59	33	18	1
2014	0	27	**0**	0	0	0	0	**111**	59	33	18	1
2013	0	27	**0**	0	0	0	0	**111**	59	33	18	1
2016	50	77	**1,000**	527	299	162	12	**277**	146	83	45	3
2014	65	142	**1,300**	685	389	210	16	**468**	247	140	76	6
2018	85	227	**1,690**	891	505	273	20	**696**	367	208	113	8
2015	110	336	**2,197**	1,158	657	355	26	**970**	511	290	157	12
2020	143	479	**2,856**	1,506	854	462	34	**1,302**	687	390	211	16