ED02360

Additional Support for Marine Electricity Generation in Scotland

Volume 1 – Summary Report

AEA Technology & Pöyry Energy Consulting for the Scottish Executive

October 2006

ED02360

Additional Support for Marine Electricity Generation in Scotland

Volume 1 – Summary Report

AEA Technology & Pöyry Energy Consulting for the Scottish Executive

October 2006

Title	Additional Support for Marine Electricity Generation in Scotland Volume 1
Customer	Scottish Executive
Customer reference	
Confidentiality, copyright and reproduction	This document has been prepared by AEA Technology plc in connection with a contract to supply goods and/or services and is submitted only on the basis of strict confidentiality. The contents must not be disclosed to third parties other than in accordance with the terms of the contract.
File reference	EV73257362
Report number	AEAT/ENV/R/ 2260
Report status	Volume 1 - Issue 1 - 19 October 2006

AEA Technology
Glengarnock Technology Centre
Caledonian Road
Lochshore Business Park
Glengarnock
KA14 3DD
Telephone 0870 190 6191
Facsimile 0870 190 5151

AEA Technology is the trading name of AEA Technology plc
AEA Technology is certificated to ISO9001 and ISO14001

	Name	**Signature**	**Date**
Author	John Simmons		19/10/06
Reviewed by	Colin McNaught		19/10/06
Approved by	Colin McNaught		19/10/06

Executive Summary

This study examines in detail the economic benefits and costs of a potential revenue support mechanism to encourage the growth of Marine Energy in Scotland. The mechanism is designed to work within the legislation that underpins the existing Renewables Obligation, which is bringing forward significant renewable energy capacity and output. The scope of the study is described in Box 1 below and the main elements of the support mechanism are shown in Box 2 overleaf.

Box 1: Scope of the project and our reports

The focus of this project was the objective analysis of the level and form of ***revenue support to marine power projects*** needed to attract private capital investment, the impacts of the supported growth of marine renewables on the renewable electricity market and other renewables, and the wider impacts on the Scottish economy.

In parallel with our analysis, the Scottish Executive developed proposals for a Banded Marine Obligation and issued its first consultation paper. Our study considers how support would be awarded to projects through this mechanism, but not the detail of how the support would be sourced through the Obligation on electricity suppliers.

The UK Government's report on the Energy Review was published after the analysis which underpins our reports was completed. Therefore we do not consider the outcomes of the UK Energy Review in this study.

Our reports comprise this Summary Report (Volume 1) and the Main Report (Volume 2). The Summary Report provides a brief overview of the methodology used in our analysis, presents the headline results and our general conclusions. The Main Report describes our analysis in detail, presents the full range of results, and describes our detailed findings. Both reports are primarily intended to inform decision-making by the Scottish Executive, in parallel with the statutory consultation. They relate specifically to the additional support to marine projects, and are not intended to be a wider guide on support for renewables, Renewable Obligations, or to inform investor decisions in marine technologies.

Carrying through the development of any technology from early demonstration to commercial viability is a major challenge. Revenue support has been successful in promoting such development, but the considerations in setting up effective mechanisms are inevitably complex, and this is reflected in the contents of our reports.

Many of the terms we use have specific meanings in the context of this report, and to aid understanding we provide a Glossary of terms after the Executive Summary.

Box 2: Main Elements of the Support Mechanism

- Provides revenue support for Marine Energy (wave & tidal) in the form of an additional payment per MWh of qualifying generation output.
- Would require electricity suppliers in Scotland to purchase specified amounts of Marine Energy, with these amounts increasing from a small initial level through a number of phases.
- Would be designed to give a high level of support (high £/MWh) to early projects, with the support level falling as the size of projects increase and the costs of generation fall.
- The level of support would be fixed at the start of an individual project's life and continue until the end of the project life or 2027 (whichever is the earlier date).
- The support level is designed to provide investors the rate of return required to bring forward projects.
- The level of the generation output target and the timing of changes in the support level is designed to change in a series of steps over the period 2007 to 2027.

A key point is that this study does not forecast or predict the growth of marine energy capacity or output. Rather it considers in detail the economic benefits and costs for several distinct growth scenarios. The costs of marine energy used are based on discussions with 14 developers with cross checking of information with recent analysis by the Carbon Trust.

Hence we believe the estimates to be robust and credible - for the growth scenarios considered.

During the period of this study the DTI undertook a major Energy Review, the conclusions of which were published in July[1]. The Review includes proposals for changes to the Renewables Obligation which are intended to support emerging renewable energy technologies including offshore wind, biomass and marine. The DTI intends to consult on these proposals later in 2006 with a view to introduce the resulting changes in 2009. Hence there are parallels with the Energy Review proposals and the support mechanism studied.

Marine energy has the potential to make a significant contribution to Scotland's renewable energy portfolio. Marine energy potentially offers substantial economic rewards, in terms of manufacturing jobs and export market opportunities, to the country that successfully demonstrates and hosts commercial scale systems. Scotland has a number of world-class companies active in this area and there is a concern that without further support the economic benefits will be reaped elsewhere.

Market mechanisms are already in place to support renewable electricity generation from a number of sources, including the Renewables Obligation (Scotland) and the DTI Marine Renewables Deployment Fund. The principle of providing different levels of support for different renewable sources is included in the UK Energy Review. However, to realise the potential represented by Scotland's engineering and technical expertise in marine energy, as well

[1] The Energy Challenge, Energy Review Report 2006; Department of Trade and Industry; July 2006

as the physical resource, a further support mechanism that will elevate marine energy to a similar level of investment opportunity as wind energy is required.

Thus in September 2005 the Scottish Executive, announced its intention to provide further support which would enable the marine energy sector to move beyond the pre-commercial stage. It was envisaged that this could be achieved by unlocking the funds required to develop marine energy on a substantial commercial scale and so create a market in which marine technologies can compete.

Future Energy Solutions (FES), in partnership with Pöyry Energy Consulting (formerly ILEX Energy Consulting), undertook this study to investigate in detail the key questions around the scale, scope and structure of this support mechanism for marine energy projects.

Methodology

To provide the level of data and analysis required to inform the Executive's decisions we have:

- Developed scenarios on the potential growth of marine energy capacity (MW) and output (MWh) in Scotland.
- Estimated the cost reduction for marine energy as the market grows.
- Developed a project appraisal model that calculates the rate of return for investments in marine energy, based on current costs and performance.
- Discussed the costs and performance of marine energy technology with 14 developers of wave and tidal stream devices.
- Discussed views on investment risks and required returns with a spectrum of investors, ranging from venture capital funds, technology funds through to utilities.
- Established levels of support which would give attractive, but not excessive rates of return from projects, phasing the reduction of the support with the reduction in project costs.
- Rationalised the number of support phases over which different levels of support would be provided to projects, and incorporated this revenue stream in the project appraisal models.
- Aggregated the investment, generation, and cost of the support through the Marine Obligation, for projects commissioned between 2008 and 2027.
- Considered how the support to projects could be provided through the Marine Obligation, and outlined the essential elements for the structure of the support mechanism.
- Undertaken renewable energy market analysis to assess potential impacts on other renewables, for example, displacement of offshore wind.
- Undertaken indicative analysis of the wider economic impacts and net benefits from provision of the support, for example increase in electricity costs to consumers and jobs created.

The main opportunities for the deployment of marine energy in Scotland on a substantial scale[2] are for offshore wave and tidal stream technologies. The scale of development for nearshore wave and shoreline wave will be limited by the availability of economically viable sites.

[2] By substantial in the context of this report, we mean a scale of development comprising multiple marine projects in each year, each project being of comparable capacity (MW) to typical onshore windfarms, and aggregate development which would make a noticeable contribution to meeting Scotland's 40% renewables by 2020 aspiration. In our analysis this is represented using the growth scenarios described in our reports.

The analysis includes a great deal of detailed information, which is presented in two reports. Volume 1, this report, summarises the main results of the study and is published alongside Volume 2, which provides detailed results. The specific details of the costs and performance of each marine energy device are commercially sensitive, hence our analysis aggregates these into several groups.

Analysis Results

The study concludes that:

- Projections of the costs and performance of marine energy systems cover a broad range due to the limited operational experience to date, with only a handful of devices having been tested at any scale. This leads to uncertainty in the future generating costs when devices are manufactured, deployed, and operated in arrays in full-scale power projects. The early stage of development also means that the practical issues, such as planning requirements and installation timescales are not certain. Our analysis includes a range of build rates and technology costs.
- While the future costs of marine energy are uncertain, our analysis shows that a high level of revenue support is required to support the initial projects. The level of additional[3] support that is required to provide rates of return which should be attractive to investors range from £210/MWh for offshore wave to £105/MWh for tidal stream in the early stages, reducing to £60/MWh for the duration of the existing ROS. We describe the derivation of these levels of support in our Main Report, Sections 5, 6, and 7, and Appendix 1. So that the baseline cost estimates are valid we have used information from those developers who have the most operational experience and hence the most robust view of likely costs. Our models for specific technologies show early generating costs within the lower central ranges given by the Carbon Trust in their Future Marine Energy report.
- The growth of marine energy capacity and output will be dependent upon the scale of support provided, the size of the obligation, and the response of the industry to grow investment and deliver capacity. To address this we have developed two growth scenarios for marine. These are both based on a review of the energy resource, our views on the likely order in which different types of marine generation will be deployed (from early projects through to the long-term), and the capacity of the industry to develop and install devices. Hence the scenarios recognise issues such as the early development of tidal stream in shallow water sites leading to the development of sites in deeper water, and the long-term opportunity for offshore wave on a large scale.

  However, we have also recognised the need to support the range of technologies sooner rather than later in order to maximise the opportunities and that there may be benefits from supporting a diversity of devices, at least in the short term.

  A successful support scheme needs to balance the need to provide a mechanism that promotes competition between devices, against the higher cost needed to support some of the devices that are further from practical deployment. Rather than using revenue support, there may be alternative means of assisting devices in the latter category. We anticipate that

[3] The revenue support awarded to electricity suppliers by the MWh generated by a project, , additional to that received through the existing Renewable Obligation, Levy Exemption Certificates and wholesale power price. The level of the support received by marine project developers will be reduced below that received by the electricity suppliers, according to the factors included in the Power Purchase Agreement (PPA). Please see Glossary for further definition of the terms used in this report.

market competition and commercial returns will lead to consolidation of the industry and a focus on a few successful devices, as has happened with the wind industry.

The scenarios take different views on the level of marine generation that can be supported taking into account the costs of the support in the long term. The Support Cost Constrained scenario assumes a high early increase in build rate to maximise the benefits of early investment in marine and the ensuing unit cost reductions, but constrains the supported build rate in the medium term, in order to constrain the build up of costs and potential adverse impacts. In the long term, our analysis indicates that some form of support additional to the basic electricity revenue may be required for the financial viability of marine projects commissioned beyond 2020 and 2027. Hence it may not be practicable to extend the MO for new build beyond 2020 within the existing ROS and its cessation in 2027. The Support Cost Constrained scenario results in a total installed capacity of 330 MW in 2020.

Two variations of the High Sustained Growth scenario assume support for increasing build rates up to 2020 or 2027, to achieve further economies of scale, and support a sustained growing marine industry. This results in a total installed capacity of 650 MW in 2020, which is consistent with the anticipated contribution from marine to meet the Scottish Executive's aspiration of 40% or electricity generation from renewables by 2020[4].

- The recommended structure for a support mechanism within the ROS could operate through a number of phases (potentially two, three, or four). In the early phase(s) a high level of support is needed to encourage deployment.This falls significantly in the mid phase. Long-term support is dependent upon whether the ROS is extended beyond 2027. While the level of support is high in the early phase(s), the total amount of support to be claimed in the early phase(s) is expected to be modest, because there is likely to be a relatively low installed capacity.

  In 2015 the cost of support for the Support Cost Constrained scenario is around £51 million, and under the High Sustained Growth scenario it is around £65 million. The provision of support for later projects of much greater aggregate capacity will drive the costs and impacts of the support, the cost of the support peaking in the long-term due to commitments made for projects implemented in the mid term.

  In 2020 the cost of support for the Support Cost Constrained scenario is around £74 million, and under the High Sustained Growth scenario it is around £127 million. For an indicative comparison, the annual projected costs of the ROS as it stands at present are £78 million in 2007/8, rising to £104 million in 2010/11 and to £155 million for 2016-27[5].

  These costs exclude proposed changes to the buyout price and increase in the obligation above 15.4%, and also exclude the marine proposals. In total the amount of additional support is assessed to be a little over £1 billion under the Support Cost Constrained scenario and around £1.7 billion under the High Sustained Growth scenario, in both cases for a Marine Obligation increasing up to year 2020. This compares with an estimated private capital investment in the supported marine projects of £450 million and £910 million respectively under these two growth scenarios, further measures for comparison being given in our Main Report.

  For an indicative comparison, the total projected cost of the ROS as it stands at present is £2.75 billion, and the total value of electricity used in Scotland up to 2020 has been

[4] Please see Section 3 of this report.

[5] Poyry projection.

estimated as £18 billion. Please see Box 3 overleaf for a basic explanation of the form of support provided through the proposed Marine Obligation.

- The Support Cost Constrained scenario would not impact significantly on the development of other renewables. As such we project that under the Support Cost Constrained scenario the Marine Obligation would induce an additional 300 MW of renewable capacity generating over 10 TWh of renewable generation over the period to 2027, a potential carbon saving[6] of 4 $MtCO_2$. The High Sustained Growth scenario could reduce investment in offshore wind projects from 2015, perhaps substituting up to 500MW of offshore wind capacity. Taking account of the additional marine capacity deployed under this scenario we do not envisage any significant net reduction in renewable generation.
- There will be significant wider impacts in terms of the jobs created and the pass through of costs to electricity consumers in Scotland. The analysis estimated creation of up to 2,340 direct, indirect and induced jobs. For our indicative analysis we have established the maximum costs to consumers by assuming that full costs of the support are passed on to consumers in Scotland only. In order to establish the cost increases to customers that could result from additional support to marine energy projects, a forward view of electricity prices without any additional marine support has been taken. This forms a baseline projection of electricity prices. The increases in electricity costs for domestic customers of up to 7.3% and for industrial consumers of up to 13.9% in 2027 are therefore increases attributable to the additional support, above the baseline projection. The additional cost increases year-on-year as the quantity of marine generation supported by the Marine Obligation increases. Hence the maximum increase is in 2027 if the size of the Marine Obligation continues increasing up to 2027.

[6] Assumes a carbon saving from the displacement of conventional power generation of 430kg of CO_2 per MWh of renewable generation. Reference DEFRA: Environmental Reporting: Guidelines for Company Reporting on Greenhouse Gas Emissions (2001).

Box 3: Characteristics of power project economics and revenue support

Power projects are generally characterised by high capital costs and long pay-back periods. Furthermore, marine power projects will have relatively high operation and maintenance costs. The return received by investors will be determined by the balance of revenues and costs over the long-term, which will be highly dependent upon the project being installed and commissioned within the budgeted costs and timescales, the actual performance and power generated by the project, and actual operation and maintenance costs. External influences will also have major effects on the financial success of the investment, including interest rates and power prices. The potential variation of all these factors over long pay-back periods presents major risks to successful investment in marine power projects, and investors will seek sufficient prospective rewards to give the desired risk-reward balance.

The support provided through both the existing Renewables Obligation (RO) and the proposed Marine Obligation (MO) is characterised:

- It is a revenue support mechanism which is received over the operating life of the project (or other defined period), on a £/MWh basis. Receipt of the support depends upon the power generated by each project in each year;
- This support is designed to raise the value of electricity generated to a sufficient level to give an attractive rate of return on the capital investment;
- Prior to commissioning a project and commencement of electricity sales, there is no support from the RO or MO. The capital cost is funded solely by the private investment (and other capital forms of support);
- Irrespective of the mechanism used to provide the support, the cash flow received by projects under the support must come from somewhere. Since under the proposed arrangements, there is no change in the total Renewable Obligation, the cost must be borne by the electricity suppliers on which the Obligation is placed. This cost will ultimately be transferred to electricity consumers.
- The revenue support provided through the RO or MO is not equivalent to capital support or public funding.

In this study support for marine projects through a Marine Obligation is considered additional to the existing support these projects would receive under the existing Renewables Obligation. All values given in our reports are for the additional element only, unless otherwise stated.

For this study it is required to consider the economics of projects commissioned year-on-year, and the aggregate cash flows for these projects. All cash flows used in our analysis and reported herein are present values.

The following table summarises the key results of the analysis for two scenarios.

	Support Cost Constrained Increasing Obligation up to year 2020	High Sustained Growth Increasing Obligation up to year 2027
Capacity in year 2020 (MW)	330	650
Annual output in year 2020 (MWh)	821,970	1,571,500
Total cost of Support (£ billion to 2027)	1.1	2.0
Peak support (£ Million)	78 in 2020	226 in 2027
Net Jobs created or maintained in year 2020	630	2,340
Peak impact on domestic electricity prices (%)	2.5% in 2021	7.3% in 2027
Peak impact on industrial electricity prices (%)	4.7% in 2021	13.9% in 2027
Private Sector Capital Investment (£ Million)	450 to 2020	1,590 to 2027

Table 1 Summary of key results for two growth scenarios

A comparison of the overall costs and revenues from our analysis of the Support Cost Constrained scenario is presented in Figure 1. This includes the aggregate cost and revenue elements over the projects life, for the mix of wave and tidal projects commissioned up to 2020. This shows the size of the market opportunity and the cost of the support as values to projects. External cash flows such as project returns to investors are shown costs, and cash flows to the electricity supply industry are shown as both revenues and costs to balance the total revenues and costs. From the project perspective, the reduction in value of the power generated from market wholesale and ROC prices can be seen as a cost as it reduces the project returns, but this cost provides a revenue to the electricity supply industry.

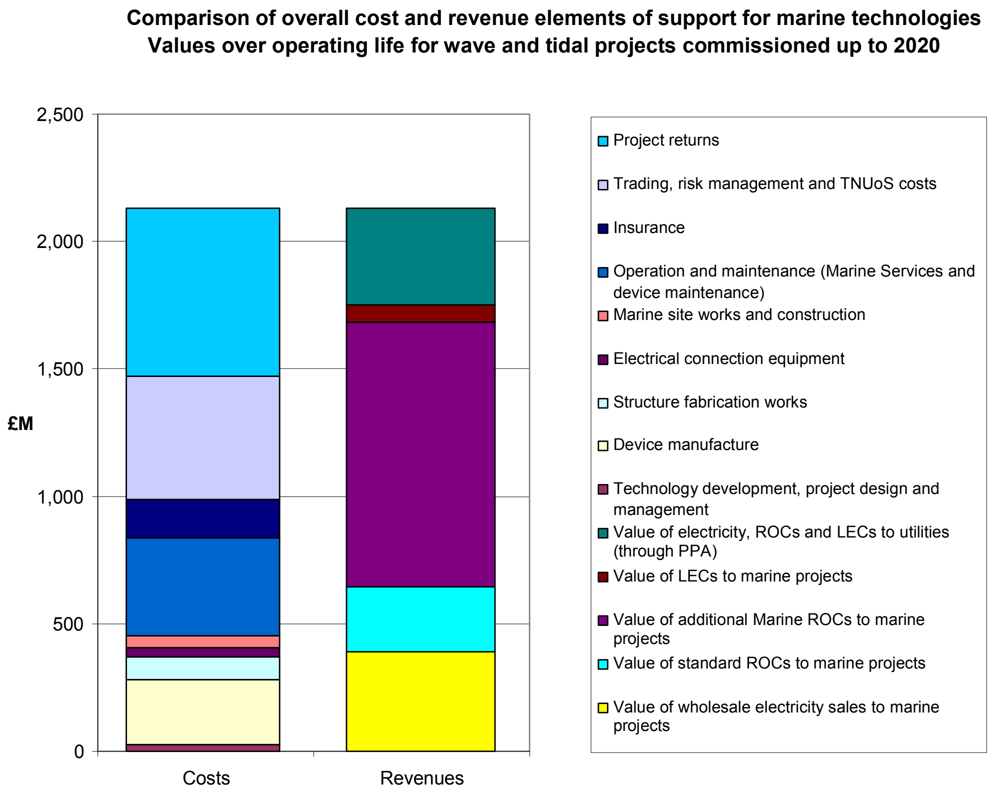


Figure 1 Comparison of cost and revenue elements for marine projects

The corresponding average costs and revenues for the range of projects included in our aggregate model are presented in terms of £/MWh in Figure 2.

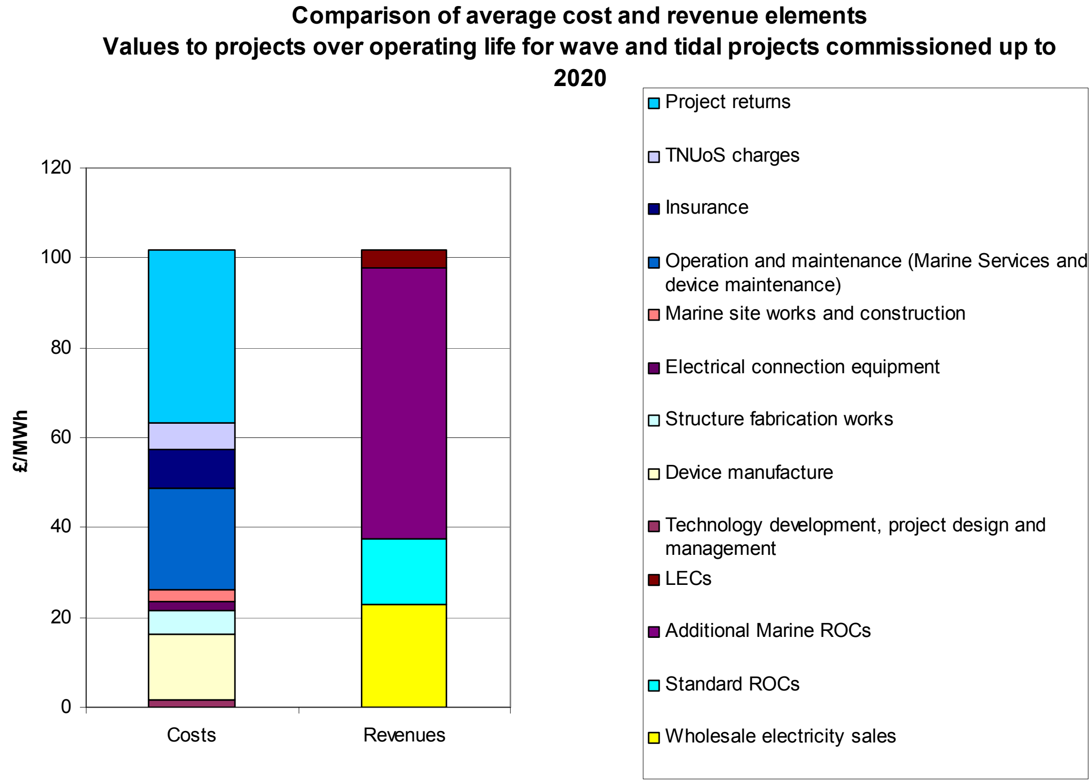


Figure 2 Comparison of average cost and revenue elements per MWh for marine projects

A substantial proportion of the additional support needed to attract private investment, is required to share the risks of investment in the first large scale commercial marine projects, and to provide a visible pathway for development of marine renewables from small scale demonstration of device performance to an established means of renewable generation. Uncertainties include technology costs which will be achieved and the timescale for development, especially for substantial cost reductions due to design improvements and economies of scale, and for successful demonstration of full-scale projects on a commercial basis. Other influences which will affect the widespread take up of marine renewables include permitting processes and grid constraints. In setting the level and phasing of the additional support, strategic decisions are required on the level of risk to the success of the support mechanism in stimulating marine renewable development on a substantial scale.

Hence the support scenarios presented in our reports should not be taken as final recommendations. Rather, the results of our analysis are intended to be used to inform further assessment and decisions for the future direction of support for marine renewables in Scotland.

Next Steps

In May, the Scottish Executive issued a consultation paper to obtain views on the potential mechanisms that could be used to deliver revenue support for marine energy projects in Scotland. This report and the companion Volume 2 are intended to present a detailed and objective analysis to inform decision making by the Scottish Executive on the extent and form of support to marine projects through a Marine Obligation, which will be required to attract investment in marine projects on a substantial scale. This report and the companion Volume 2 are therefore being used in parallel with the current consultation to inform the options to be carried through for Statutory Consultation. The overall aim of the Scottish Executive is to put the support mechanism in place for April 2007.

Glossary

Definitions
Definitions of the main terms and phrases used in this report are as follows:

Additional Support / Support: The revenue support required for, or provided to marine generation, awarded on the power (£/MWh) exported to the Grid in Scotland. This is additional to the basic power price, the value of Climate Change Levy Exemption Certificates, and the value of the standard Renewable Obligation. The net revenue received by a marine generation project through the Power Purchase Agreement will be less than the sum of these elements.

Aggregate power project appraisal model / Aggregate model: The aggregate model shows the cumulative installed capacity, generation, cash flows and rate of return across all the projects installed up to a given year. The aggregate model includes life cost models representing the application of the leading technologies in anticipated power projects within a number of time bands. These are aggregated to display the results by the main resource or technology category type, and the grand total.

Allowed cost: This is a generating cost value for each of the main technology groups, used in this study to represent potential costs. It is used in determining levels of support which allow for some uncertainty in actual project performance and costs, and also support some diversity of technologies within each technology type. It is the greater of the second lowest technology cost, and the lowest technology cost with factors to allow for reductions in project performance or real project costs above those estimated by the technology developers. The rationale and derivation is described in Volume 2, Appendix 1 of our report.

Availability factor: This allows for downtime due to maintenance, and hence is a function of the reliability of the plant and the time to repair. Typical availability factors for proven technologies are in excess of 95%.

Bankability: This relates the degree of certainty over the future income stream for a project. Banks typically offer relatively cheap finance in return for low risk. Lenders to power projects typically take a conservative view of the future value of revenue streams, in order to ensure that the project will be able to continue to meet its debt repayments even in a low-income case. For a renewable support scheme to be bankable it must provide a secure income stream with a minimal degree of uncertainty – largely isolated from market regulatory or political risk.

Buy-out Fund: The sum of buy-out price payments made by suppliers. The Buy-out Fund is recycled back to suppliers each year in proportion to the number of ROCs each supplier has redeemed. The process increases the value of ROCs in years where a substantial Buy-out Fund has accumulated. This report considers a number of alternative mechanisms for recycling buy-out payments made in relation to the Marine Obligation.

Buy-out price: Under the Renewables Obligation, licensed electricity suppliers are set a target for the amount of electricity they need to purchase from renewable sources. Accredited renewable electricity generators are issued with ROCs for every MWh they generate. Suppliers can either present enough certificates to match their target, or they can pay a 'buy-out price' for any shortfall. Under the present RO the buy-out price is £33.24/MWh for the year 2006/7 and will rise in line with inflation in each to 2015. Under the MO the buy-out price would be higher, to provide the additional support identified as required by Marine renewable projects.

Capacity factor: This combines the variation of incident wave energy or energy due to tidal stream velocity over a year, with the device's response characteristic and rated capacity, to express the energy predicted to be extracted from the array over the year, as a proportion of the rated capacity of the array. This may typically be around 30%. It is a major driver in power project economics, and is increased by sizing the device for the location, so that energy is not fully exploited from the higher energy waves or maximum tidal velocities. This is equivalent to the term Load Factor used for conventional power generation, but in the later case, load factors are generally much higher as the plant is intended to be operated at or near its full capacity whenever there is load demand, and the plant is not undergoing periodic maintenance or repair.

Commercial scale: A commercial power project would need to have a capacity typically in excess of 10 MW.

Common schemes capped for wave and tidal: A Marine Obligation structure or mechanism which does not distinguish between wave and tidal projects. The level of support would be capped within affordability constraints, or designed to support lower cost resource or technology type projects. It would not necessarily be designed to provide sufficient support for the higher cost resource or technology type projects.

Deeper water tidal: Extraction of energy from tidal streams at sites deeper than 30 metres.

Discount rate: This is used in two ways, for generating cost calculations and lifecycle costings. For generating cost calculations it is similar to the interest rate on a loan, being used in the same way to calculate annual repayments of an investment. For lifecycle costings, it represents depreciation in the value of money over time, since the money could be invested elsewhere giving a return. It represents the cost of capital at present values, and hence excludes inflation.

Diversity of investors and Weighted Average Cost of Capital: Different types of investor may consider investing in marine power projects at various stages of the development of these technologies. Potential investors include electricity utilities, venture capitalists, private equity funds, investment banks, energy majors, industrial conglomorates, independent energy developers and project finance houses. Such investors will have differing strategic reasons for investing in marine power projects, and consequently different investment decision criteria, specifically relating to the balance of risk versus reward. Since the balance of risk and reward will change substantially as marine power projects progress from the demonstration phase, the types of investor interested in investing in marine projects, and the rates of return each type requires will change over time. The weighted average cost of capital (WACC) will change over time depending upon the development status, and the mix of investors at that time. Encouraging a greater diversity of investment will offer more financing options to developers.

Diversity of technologies: Within each technology type, the level and structure of the support may be designed to support the lowest cost technology, or may be designed to support a greater diversity of technologies. Although the former option will give the lowest support cost in the short-term, there is a risk that the lowest cost technology will fail either through lower performance or higher costs than estimated. Also learning factors and learning rate effects may be different for specific technologies so that the lowest cost technology in the early stages is not necessarily the lowest cost technology in the longer term. Furthermore, competition between technologies may be desirable to encourage improvements in design and production. This suggests that supporting technologies above the lowest estimated cost in the early stages should be considered.

Diversity of technology types: The level and structure of the support may be designed to support the lowest cost technology type (expected to be shallow water tidal initially), or may be designed to support a greater diversity of technology types. Although the former option will give the lowest support cost in the short-term, greater diversity of technology types may offer long-term advantages in terms of potential growth (including export markets), technology development and exploitation of renewable resources. Such factors may combine so that the cost of technologies may converge in the long-term. This suggests that supporting a diversity of technology types at higher cost in the early stages, to realise greater potential benefits in the longer term, should at least be considered.

Fixed Price Contract: Reflects the typical value a supplier (or other third party) would be willing to offer a risk averse generator (and its financiers), by providing a perfect hedge against the volatility of the electricity and ROC markets (subject to the credit worthiness of the offtaker). However, this comes at the price of a substantial loss of value. The limited number of suppliers in the market, most of which have substantial generation assets of their own, allows suppliers to extract the lion's share of value under these contracts. Given this, coupled with suppliers' concerns over their future market share of consumers, we consider that fixed price contracts are likely to be set at a value close to the Low price projection, with no chance of the developer upside in the event that outturn prices are higher than this.

Floored Price Contract: is characterised by a floor price plus a sharing of any upside above this level in the outturn annual electricity and ROC prices. This contract form provides the surety of a guaranteed minimum value, with the potential to share in the upside for prices above this level. The value of this contract will vary depending on the level of outturn prices. This form of contract tends to offer a degree more risk than a fixed-price contract (as the floor price would typically be below the fixed price), but greater potential upside, should outturn prices be closer to Pöyry Energy Consulting's Central or High scenario than their Low.

Generation: This is the annual electrical output of the array of devices in a project (MWh/yr), calculated from the product of the installed capacity, capacity factor, availability factor and operating hours in a year. The electricity exported to the grid will be equal to this value less transmission losses between the generators and the grid connection point, and self-loads of the scheme.

Generating cost: This is the specific cost of generation (£/MWh), including repayment of the initial capital costs over the specified design life of the project at a specified annual discount rate, ongoing operation and maintenance costs. It is calculated from the sum of the annualised costs divided by the annual generation.

Grid connection: Connection from the array of marine devices to the grid connection point on the nearest mainland or island.

Grid / Network: The national grid which may be extended or upgraded to provide a grid connection point on the nearest mainland or island (for example the major islands of the Western Isles, Orkneys and Shetland). This study considers marine projects connected to the Grid in Scotland.

High Sustained Growth scenario: A scenario for the build up of marine installed capacity in Scotland up to 2020 and possibly 2027, and the ensuing marine generation and costs, as described in detail within this report. Note that this refers to the level of marine generation supported by the Marine Obligation, under this scenario. It is not necessarily the limit on total marine capacity and generation.

Installed capacity: The maximum generating output (MW) of the project when the incident wave energy or tidal stream velocity is sufficient for all the devices in an array of "farm" to operate at their rated capacity. Hence it is calculated for a project from the product of the number of devices and the rated capacity of each device. In our aggregate model we cumulate the installed capacity of all the projects in Scotland.

Installed Cost: The capital cost for each project expressed relative to the installed capacity (£/MW).

Internal Rate of Return: This is the rate of return from an investment over a specified return period. It is calculated by determining the discount rate which yields zero Net Present Value in the year equal to specified return period.

Learning factor: Improvements in energy capture performance, or cost reductions achieved through design improvements. These may apply between each development phase rather than applying to volume increases.

Learning rate: A measure of the anticipated or achieved economies of scale, quantified by the percentage reduction in cost from each doubling of the cumulative build of an item, in this case usually based upon the cumulative installed capacity of a technology.

Lifecycle Costing or Whole Life Costing, and Net Present Value: This form of financial analysis is essential for long-term projects such power projects. This is a year-by-year analysis of the cash flows for a project, including the capital cost (-ve value usually in year zero), and operating costs (-ve values) and revenues (+ve values) in subsequent years, for the design life of the project. The balance of costs in each year are calculated and discounted at a discount rate (see below) to allow for the time value of money. This yields the Net Present Value (NPV) in each year, which represents the profit made by the project. This will be negative in the early years and, for an economically viable project, will become positive before the end of the project life. This gives a much better indication of the predicted economic viability of a project than simple payback.

Main resource or technology category type: Offshore wave / Nearshore wave / Shallower water tidal / Deeper water tidal.

Marine Energy / Marine: Electricity generation from the energy in waves and tidal streams. Marine energy is often abbreviated to 'Marine' in this report.

Marine Obligation: The 'Banded Obligation' specifically for marine generation, proposed for inclusion within the ROS as outlined in the Scottish Executive's consultation paper. This is an additional support mechanism for marine renewable projects in Scotland. The proposed mechanism is to offer support via modification of the Renewables Obligation Scotland (ROS). The MO will place an obligation on licensed electricity suppliers to purchase a specified proportion of the electricity they supply to consumers in Scotland from accredited marine renewable generators. Suppliers can meet their obligation by either redeeming Marine Renewable Obligation Certificates (MROCs) or by paying a buy-out price. Support is provided to marine renewable generators through the price that suppliers are willing to pay for MROCs, in order to avoid paying the buy-out price and in order to receive payments from the Buy-out Fund. Hence the support is offered indirectly to marine energy projects and hence to the project developers the investors and ultimately the technology developer and equipment suppliers. Throughout the report we will refer to support via the ROS for marine projects – this should be taken to read support though suppliers who have been incentivised via the ROS/MO to purchase output from marine projects at a premium price. Where we state values of the Marine Obligation in £ or £/MWh this refers to values for the Additional Support as defined above.

Marine Renewable Generator: Electricity generation projects utilising wave or of tidal stream technologies.

Marine Renewable Obligation Certificates: Under the proposed banded Marine Obligation, MROCs would be awarded to marine renewable generators for each MWh of eligible generation, in a similar manner to the award of standard Renewable Obligation Certificates (ROCs) for other renewables. Specific differences in the award of MROCs to ROCs are described in our reports. Award of MROCs would qualify the project for support under two separate markets: firstly, the market for standard ROCs including all eligible renewables; and secondly, the market for fulfilling the banded element arising from the Marine Obligation, from eligible marine generation. We anticipate that the value of an MROC will be set at a suppliers avoided buy-out payments plus an anticipated recycling from the Buy-out Fund.

Nearshore wave: Extraction of energy from the waves at sites typically shallower than 40 metres and deeper than 15 metres.

Offshore wave: Extraction of energy from the waves at sites typically deeper than 40 metres.

Power project: A project designed to generate and export power to the grid, and thereby return revenue from electricity sales on a commercial scale.

Power Purchase Agreement / Power Purchase Agreement Factors: Please see Text Box 15 in our Summary Report for a brief description on Power Purchase Agreements. Factors are applied to projections for the wholesale electricity price, and the standard ROC price, to estimate the value of these elements which would be received by the marine generator under a long-term contract. These factors will depend upon the contractual arrangements and risk sharing between the Generator and the Network Operator.

Practicable Extractable Resource: Terms variously used in resource literature include Technically Extractable Resource, Practical Resource, Practicable Resource, Accessible Resource. Definitions included in the SPICe briefing for Wave and Tidal Power[7] include:

- **Available resource** refers to the total amount of different forms of renewable energy available for extraction e.g. the energy in ocean waves.
- **Technical potential** (also referred to as accessible resource) refers to the amount of energy that might be extracted from the available resource, using known technologies (the paper noted that the technical potential for renewable resources is very large, exceeding UK primary energy consumption several times over).
- **Practicable potential** (also referred to as practicable resource) refers to the amount of the technical potential that might reasonably be accessed, taking into account various technical and physical limiting factors such as competing land (and ocean) use and often includes further limitations, such as electricity grid and system constraints.
- **Economic potential** refers to the amount of accessible potential that is economically viable, given current technology, or with future, better (and cheaper) technologies.

We have therefore used the term "Practicable Extractable Resource" to describe the resource which is both technically and practicably extractable using theoretically possible extraction efficiencies, and taking into account identified economic and environmental constraints such as lower thresholds of wave energy or tidal velocity for effective deployment of devices. Wave power is calculated from the average power per length of wave front (kW/m) multiplied by the available length of wave front. There is the potential for double counting between offshore and shoreline / nearshore wave, but this effect will be small since the total available length of wave front for shoreline / nearshore wave is a small proportion of that for offshore wave. For tidal stream, the practicable resource takes into account reductions on tidal velocity due to the energy extracted in turbine arrays. Note, that the practicable extractable resource figures we quote do not allow for limiting factors on use of the sea bed or surface, actual power extraction and transmission efficiencies, economic viability, or grid constraints. Economic viability is likely to impose higher thresholds on minimum energy density for viable deployment of devices, and constrain their effective operating range. Grid connection costs may limit the distance offshore for wave projects, and hence their placement in the most energetic wave environments.

Present values: Used for lifecycle costings, present values exclude inflation effects. All values presented in our report are at present values.

Project commissioning. The time following project construction, when the plant is first brought into operation and exports power to the grid commensurate with its installed capacity. We have assumed that the major capital costs occur in the year leading up to project commissioning, and that revenue from power generation from the project commences in the year following the capital expenditure.

Project development phases: This refers to the upward trend in the build rate and scale of individual projects, as preceding projects are demonstrated to be technically and commercially successful, and uncertainties and risks to investors are reduced. Early developments are likely to include a small number of devices, with a combined output for each project of < 10MW (< 5MW for some early projects). As the technologies mature, the size of a typical marine energy project will increase to multiple 10's of MW with associated reductions in specific costs. The specific cost of a typical project is linked to the size and number of devices produced and the

[7] http://www.scottish.parliament.uk/business/research/briefings-04/sb04-09.pdf

learning rate for the technologies. Transition from more accessible sites, to more energetic and demanding sites will also be reflected in the project development phases. In this study we use up to 5 phases of project size over the period to 2027.

Project implementation: Activities involving project planning, design, permitting, and construction, leading to project commissioning and power generation. Requires major commitment on the part of the developer and major capital investment.

Project permitting: The process of undertaking environmental impact assessments, obtaining regulatory approvals, and crown leases, in order that a project may proceed.

Return period: This is the period over which a project is required to return of profit, i.e. to yield a positive Net Present Value. It therefore represents the maximum acceptable payback period and must not be greater than the design life of the project, if the project is to ever make a profit. Often the required return period will be less than the design life, for example being determined by the duration of the Power Purchase Agreement (see below)

Separate schemes for wave and tidal: A Marine Obligation structure or mechanism designed to provide different levels of support to wave and tidal projects, at least in the early support phases.

Shallower water tidal: Extraction of energy from tidal streams at sites shallower than 30 metres.

Shoreline wave: Extraction of energy from the waves at the shoreline, typically at sites shallower than 15 metres. Devices may be installed in a structure such as a breakwater or causeway, or make use of natural topographical features.

Standard Renewable Obligation / Standard Obligation: The existing Renewables Obligation incorporating a 15% target for renewables in 2015 extending to 2027[8].

Support Cost Constrained scenario: A scenario for the build up of marine installed capacity in Scotland up to 2020, and the ensuing marine generation and costs, as described in detail within this report. Note that this refers to the level of marine generation supported by the Marine Obligation, under this scenario. It is not necessarily the limit on total marine capacity and generation.

Support phases: The mechanism for providing additional support for marine energy will have several stages of support. The level of buy-out price, and hence the income for generators, will be set a different levels over the duration of the support mechanism. The buy-out price will be highest in the early stages, to provide the support needed for the first commercial scale projects, falling in several stages to lower levels.

Support Structure / Mechanism: The arrangements by which additional revenue support is awarded to projects through the Marine Obligation.

[8] The UK Energy Review (2006) states the intention to raise the target up to amaximum of 20% renewables under a headroom approach, if renewable generation approaches the present 15% obligation. However, the analysis for this study was undertaken before the UK Energy Review was published, and is based upon the 15% target continuing from 2015.

Transmission Network Use of System Charges: These are annual charges levied by NGC on generators and suppliers for the use of the transmission grid, and are intended to reflect the cost of maintaining this capacity. Charges for capacity are based on the Transmission Entry Capacity (TEC) of a project. Charges vary by region, the rate being higher for locations remote from the demand centres. However, the rate may be capped to reduce the disadvantage to generation from renewables at very remote locations. The schedule of rates is agreed with Ofgem.

Visibility: Visibility relates to the transparency and certainty of support for renewable projects over the life of the renewable investment. Power projects are long-term infrastructure investments with high up-front capital costs. Investors require transparency and a degree of certainty over the future level of the income stream to projects. Where additional support is required for investments in renewables, the commitment of that support will need to extend over the return period for projects (typically 20 years) commissioning over a prolonged period of time. The present RO only provides support to 2027 and up to 20% of the energy supplied in the UK. Given that marine projects are unlikely to reach commercial scale before 2020, and that return periods will be of the order of 20 years, visible support through the Marine Obligation will be required for marine projects beyond the life of the existing Renewables Obligation).

Weighted cost of capital: This is the average discount rate for an investment taking into account the mix of investors and the returns they require. The latter we be governed by alternative investments which are available, and which meet their investment criteria.

Abbreviations

IRR: Internal Rate of Return

LEC: Levy Exemption Certificate, the award of which gives exemption from the UK Climate Change Levy

MO: Marine Obligation

MRDF: Marine Renewables Deployment Fund (introduced by the DTI in 2005)

MROCs: Marine Renewable Obligation Certificates (awarded under the MO)

PPA: Power Purchase Agreement

RO: Renewable Obligation

ROCs: Renewable Obligation Certificates (awarded under the standard RO)

ROS: Renewable Obligation (Scotland)

SBOF: Scottish Buy-out Fund

TNUoS: Transmission Network Use of System (charges)

Contents

1 INTRODUCTION

Box 4: Pathways for marine power projects development

We anticipate a technical-economic pathway for the successful commercialisation of marine technologies would need to entail the following stages of progression:

1. Demonstration of the performance of near full-scale prototype devices through sea trials;
2. Pre-commercial demonstration of the construction and operation of small grid connected arrays of devices (wave or tidal "farms");
3. Demonstration of power project economics through successful operation over a sufficient period to reliably indicate the long-term returns;
4. Implementation of projects on a progressively larger scale, thereby achieving economies of scale;
5. Achieving generating costs competitive with the lowest cost rival technology, for example offshore wind.

Revenue support mechanisms have proven the most effective means of support for establishing renewable energy, since they directly reward the renewable generation achieved, and provide the incentive for successful long-term operational performance of power projects. Demonstration of operational performance will be critical for the development of marine energy. However it will be necessary to attract substantial private investment in marine projects, to take this form of renewable energy from the demonstration of prototype devices to commercially competitive power projects. This requires that there is a visible pathway for commercially viable development, with a clear commitment to provide the necessary levels of financial support at each stage.

Marine generation costs are high at present, a major factor in this being the small-scale of early development. The levels of revenue support required in £/MWh will be high in the early stages, but should be substantially reduced once economies of scale have been achieved. Clear commitments on the phasing of this reduction, and specifically the eligibility of projects for certain levels of support, will be critical in attracting private investment.

A banded Marine Obligation, combined with the provision of sufficient but phased reductions in the level of support through the Marine Obligation market mechanism, would provide strong drivers for marine development. However, this form of support will not be visible beyond 2027, when the existing Renewable Obligation will cease. This precludes support beyond 2027 under the envisaged Marine Obligation arrangements, and provides a driver for supporting a rate of marine development which maximises the prospects of it achieving full cost competitiveness by 2027.

Planning, permitting and leasing arrangements, and the resolution of grid connection constraints, must also be visible and perceived by investors as manageable, if investment in marine projects on a material scale is to occur.

The focus of this study is an analysis that will assist the Scottish Executive to decide on the details of a mechanism that will financially support renewable electricity generation from marine projects. In this context 'marine' comprises wave and tidal stream technologies. The Executive's policy objective is to encourage additional electricity generation from marine sources, which will help deliver its commitment to tackle climate change, and at the same time assist the growth of a new Scottish industry in the development and deployment of marine energy projects. This study was undertaken by Future Energy Solutions (FES), with Pöyry Energy Consulting (formerly ILEX Energy Consulting).

The aim is to stimulate investment in marine electricity generation projects on a substantial scale. In accordance with the brief, the scope of this study focuses on the required support for marine projects to achieve this, rather than how the support may be funded.

The additional support for marine will be in the form of revenue support for the renewable electricity generated, i.e. on a £/MWh basis. While this is similar to the existing Renewable Obligation Scotland (ROS) and other tariff support mechanisms, unlike these, the level of support will be phased commensurate with the anticipated reduction in marine generation costs. Incorporation in the ROS will provide a long term visible pathway for investment in marine technologies. Substantial cost reductions are expected between now and 2027, hence the mechanism will be designed to follow these reductions.

The Scottish Executive has developed proposals for how the funding for this support could be sourced, as described in a recent consultation paper[9]. This study considers support through a 'Banded Obligation' for marine within the ROS, termed the Marine Obligation (MO) in this report.

The scope of this report includes:

1. Establishing the levels and phasing of support required to:
    - Attract investment in marine projects.
    - Achieve substantial renewable electricity generation from marine projects.
    - Achieve substantial economies of scale.
    - Achieve a Scotland-based marine renewables industry which is cost-competitive in renewables export markets.

2. Outlining some of the key elements required for the structure of the support mechanism that will be essential for it to be a success.

3. Determining the cost of the support and undertaking an indicative assessment of the wider economic impacts.

[9] Supporting wave and tidal energy in Scotland – a consultation on amending the Renewables Obligation (Scotland) Order – 2006

Box 5: Timescales for provision of support

In our study we have considered the timescale for provision of additional support to deliver marine capacity up to 2027, since:

1. Likely timescales for early development are longer than have been anticipated by some recent studies, for example the MEG report;
2. It is unlikely that cost convergence with conventional sources or the lowest cost renewable sources of generation will be achieved by 2015. Our analysis shows that additional support will be necessary for projects commissioned beyond 2015;
3. The provision of additional support beyond 2015 will incur a major proportion of the total cost commitment for additional support;
4. The continued development of marine is necessary to maintain the benefits from growth of the industry and employment. Indeed, early curtailment or insufficient long-term support will result in job losses from those previously created in the marine energy industry.

However, the existence of the Renewable Obligation (of which the envisaged Marine Obligation would be a part) beyond 2027 is uncertain, as are long-term marine cost projections. Hence, prediction of long-term marine project costs, the likely need for a form of long-term support for marine, the costs of this support, and how this support might be provided, are beyond the scope of this report. In the latter context, long-term is beyond 2020, after which support under the existing Renewable Obligation arrangements (ceasing in 2027) is unlikely to be effective for new projects.

However, we do provide some indicative projections of the cost of the support up to 2027, if this continued at pre-2020 levels, to represent the case where a form of long-term support is required to maintain the marine industry.

2 METHODOLOGY

Box 6: Overview of analytical models used for this study

At the core of this study is an objective analysis of the extent of additional support required to attract investment in marine power projects, and analysis of the impacts of the provision of this support.

In our reports we present the results from the two analytical models we have developed:

1. Aggregate marine power project appraisal model: This focuses on the provision of additional ***support to projects***, not the mechanism by which the support is obtained. It incorporates whole life cycle costings for power projects utilising various leading marine technologies, at different stages in the development and growth of marine energy. Different levels and phasing of the additional support are input in this model to give attractive rates of return for the projects utilising the desired diversity of both wave and tidal technologies. A mix of these projects is then aggregated to give possible overall growth scenarios, total private investment, electricity generation and support costs for marine energy.
2. Renewable Energy markets model: This looks at how the support would be provided to projects through the banded ***Marine Obligation*** mechanism, the necessary size of the Marine Obligation consistent with the growth scenarios derived in the first model, and buy-out prices and phasing arrangements to give the required support to projects determined from the first model. It determines the costs of the support through the Marine Obligation mechanism, and the effects of the size of the Marine Obligation on the uptake of other renewables.

Both models therefore give profiles of the cost of the support. We used the first model in undertaking an indicative analysis of the wider impacts of the provision of the support, since this model includes all the investment and operating cash flows which yield jobs from investment in the marine industry and other areas. We also used the first model to calculate increases in electricity costs to the consumer.

The use of these models is described in our reports, including the cases where differences arise between the growth scenarios used in each model, and the consequent costs of the support.

In undertaking this study we have:

- Developed scenarios on the potential growth of marine energy capacity (MW) and output (MWh) in Scotland. These growth scenarios are needed in order to estimate the additional contribution to Scotland's renewable energy target, the cost of the revenue support that could be claimed and to assess the rate of cost reduction in marine energy projects. The growth scenarios are outlined in Section 3 of the Summary Report and described in more detail in Sections 3 and 5 of the Main Report.

- Estimated the cost reduction for marine energy as the market grows. This is assessed using the learning rate, expressed as the % reduction in cost for every doubling of installed capacity. The projected cost reductions are summarised in sections 4 and 6 of this report and described in greater detail in our Main Report: sections 3, 4, 5 and Appendix 1.
- Developed a project appraisal model that calculates the rate of return for investments in marine energy, based on phased performance improvements and reductions in costs. This is described in Appendix 1 of the Main Report. In order to maximise the prospect of the support being bankable to each project, we recommend a mechanism where the level of support for which a project is eligible, is determined by its commissioning date, and is maintained at that level for the life of the project. Visibility and bankability issues are considered in sections 7 and 8 of the Summary Report, and sections 6 and 9 of the Main Report.
- Discussed the costs and performance of marine energy technologies and planning for future projects with 14 developers of wave and tidal stream devices. This is described in Appendix 1 of the Main Report.
- Discussed views on marine power project investment risks and required returns with a spectrum of investors, ranging from venture capital funds, technology funds through to utilities. This is described in Section 7 of the Summary Report and Section 6 of the Main Report.
- Established levels of support which would give attractive, but not excessive rates of return from projects at each development phase, phasing the reduction of the support with the reduction in project costs. The headline results are presented in Section 7 of the Summary Report. The detailed analysis and results are presented in Section 7 and Appendix 1 of the Main Report.
- Rationalised the number of support phases over which different levels of support would be provided to projects, and incorporated this revenue stream in the project appraisal models. The proposed support structure is described in Section 8 of the Summary Report, and Sections 7, 8, and 9 of the Main Report.
- Aggregated the installed capacity, generation, and cash flows from the project appraisal models, for the range of marine technologies over the project development phases. The methodology is described in Appendix 1 of the Main Report. The results are presented in Section 8 of the Summary Report, and Sections 8 and 10 of the Main Report.
- Calculated the aggregate annual investment in marine projects and contribution from the Marine Obligation, i.e. the cost of the support. This costs of the support are presented in Section 8 of our Main Report, and investment figures are given in Section 11 of our Main Report. Note that up to this point we have focused solely on the ***support to projects***.
- Considered how the support to projects could be provided through the ***Marine Obligation***, and outlined the essential elements for the structure of the support mechanism. The proposed support structure is described in Section 8 of the Summary Report, and Sections 7, 8, and 9 of the Main Report. The end of the Renewable Obligation in 2027 means that the support will cease to have value beyond 2027, and that it may not provide sufficient revenue support for projects commissioned beyond 2020. In different sections of our reports we consider the cases where projects commissioned up to 2027 are supported, or where the Obligation and support do not increase beyond 2020. This will be explained further in the relevant sections of our reports.

- Undertaken renewable energy market analysis to assess potential impacts on other renewables, for example, displacement of offshore wind. Our findings are summarised in Section 9 of this report, and our analysis described in Section 10 and Appendix 2 of the Main Report.
- Undertaken indicative analysis of the wider economic impacts and net benefits from provision of the support, for example increase in electricity costs to consumers and jobs created. Headline findings are presented in Section 9 of this report. The detailed analysis is described in Section 11 and Appendix 3 of the Main Report.

3 MARINE DEVELOPMENT SCENARIOS

Box 7: Determination of growth in marine power projects

The achievable growth in marine will be dependent upon a range of factors including: progress with the successful demonstration of early power projects; grid connection; planning, permitting, and leasing processes; the capacity of the industry to address these issues, construct and operate projects. The profile of growth in marine, and especially whether the growth is sustained, will have a major effect on realising the potential economic benefits, for example from job creation.

It would be unreasonable to impose an Obligation on suppliers which is not practicable or achievable. Conversely, it would not meet the aims of the support, if the growth of the marine energy sector was insufficient to make a material contribution to meeting renewable generation aspirations, or the economies of scale necessary to take marine substantially towards commercial competitiveness. Therefore we have established upper and lower bounding growth cases for our analysis.

Our investigations (see Box 14) indicate that the uptake of marine projects will depend upon a range of factors:

- The balance of risk-reward as perceived and estimated by investors;
- Qualitative factors, especially bankability, arsing from the structure of the support and eligibility mechanisms;
- Go – no go investment decisions arising from investors cost and revenue projections, and specifically the level and phasing of the support;
- External factors facilitating or constraining the growth rate.

Hence, there is not a proportional or readily quantifiable relation between the level of revenue support (£/MWh) and growth. The structure of the support and size of the Marine Obligation will be major driving factors.

The aggregate cost of the support through the Marine Obligation must also be considered. Hence we have defined two target growth scenarios representing substantially different policy outcomes, lying between the bounding cases.

We have used each predefined scenario in our detailed analysis to determine:

- Build rates for projects using the range of leading marine technologies which could contribute to the aggregate growth scenario;
- Size of the Marine Obligation being analysed;
- Aggregate cost and benefits of the support through the Marine Obligation.

The results of the analysis for each scenario can then be interrogated to inform policy decision-making on the form and size of the Marine Obligation. Please note that we do not make a judgement on the marine growth which will be supported, or which will actually be achieved.

Due to the low level of operational marine energy projects and the difficulty in projecting growth rates accurately we have developed two growth scenarios upon which we have based our analysis:

1. Where the long-term cost of the support is limited (Support Cost Constrained).
2. Where higher growth is sustained up to 2027 (High Sustained Growth).

These two growth scenarios are shown in Figure 3.

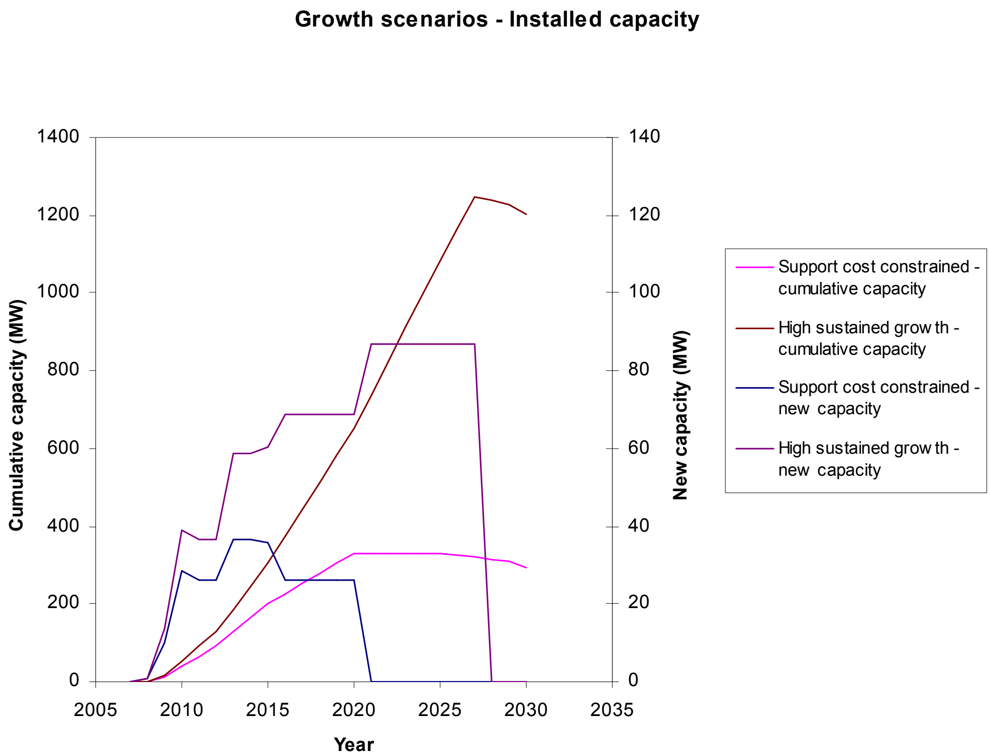


Figure 3 Growth Scenarios – Installed Capacity

The High Sustained Growth scenario is consistent with the anticipated contribution from the range of renewable sources, required to meet the Scottish Executive's aspiration of 40% electricity generation from renewables by 2020[10]. It provides for substantial economies of scale

[10] The major contributors to achieving this aspiration are likely to be onshore wind and offshore wind. Growth of onshore wind will depend upon the progress of applications through the planning process. Growth of offshore wind will depend upon achieving cost effective installations and performance at Scottish offshore locations, economically attractive returns, site permitting and crown leases. The total growth of wind in the UK, and the contribution of Scottish wind projects to the 40% aspiration will depend upon the incentive for growth under the Renewables Obligation, and the proportion of Scottish to UK electricity demands. Other renewable sources such as eligible hydro, may also contribute to achieving the 40% aspiration. The balance of renewable generation required from wave and /or tidal projects to meet the 40% aspiration may be relatively low, and sensitive to variations in the wind generation achieved. Due to uncertainty on these aspects there are no definitive estimates of the marine generation required to meet long-term renewables targets. The Marine Energy Group Report 2004: "Harnessing Scotland's Marine Energy Potential", and the Scottish Renewables Forum Report: Delivering the New Generation of Energy: A Route Map to Scotland`s Renewable Future; June 2006, suggest that 3.4 TWh/yr could be generated from 1300 MW marine installed capacity in Scotland by 2020. This is probably a higher bounding estimate for the quantity of marine generation which would be required to meet the 40% aspiration, or which could be practicably achievable within this timescale.

and sustained marine energy industry growth. We have considered various factors in determining the achievable build rate for this scenario as described in our detailed report.

We have compared the costs and impacts under these two scenarios, comparing the effects of long term costs of the support with the benefits of sustained growth of the marine industry.

We have only incorporated new build up to 2020 or 2027 in our models, since the growth scenarios approaching and subsequent to 2027 will be dependent on whether the standard ROS is extended. In Figure 3, the 'cumulative capacity' curves show the theoretical reduction in capacity beyond 2027, when the early installations reach the end of the projects' life and come off line.

Note, however, that we do not judge in our scenarios whether investment and the target growth will actually occur under the support provided. Rather we have proposed levels of support and support arrangements which should attract investment in a range of target technologies depending upon the support scenario. As explained in Box 7 and Box 14, there is not a direct quantitative relation between the level of support and growth. Therefore, for each growth and support scenario, we present the range of IRR projected values for the various technology types, and costs of the support. Comparison of projected IRR with both the target IRR for attracting investment, and the projected IRR for competing technology types, will indicate the potential diversity of investment in technologies.

Policy decisions can be considered in further developing the support arrangements, setting the size of the Marine Obligation and buy-out prices, which govern the levels and phasing of the support. Such policy decisions will include balancing the following:

- The degree of risk which is acceptable to the success of the additional support in stimulating marine renewableson a substantial scale;
- The desired growth and diversity of technology types and specific technologies;
- The desired diversity of investment;
- The prospects for sustained marine industry growth and job creation;
- The cost of the support and wider impacts.

An optimum support arrangement may draw on a combination of features from the different scenarios we have presented in our reports.

4 PROJECTED COST REDUCTIONS

Box 8: Generating Cost and Internal Rate of Return (IRR)

In our analysis we have followed normal practice for power projects to establish the generating cost, and in the use of project life costing to establish IRR.

The generating costs include annual repayment of the capital costs and the annual operating costs. The interest rate or discount rate used in capital repayment calculations may be 8% for comparison of the baseline technology costs with conventional generation (for example as quoted in the Carbon Trust's Future Marine Energy report), or 11% to reflect the likely weighted cost of capital for marine renewables in the medium term. The generating costs presented in our reports are calculated using an 11% discount rate, unless stated otherwise.

The IRR calculation does not include the repayment of capital costs, and hence is independent of discount rates. Instead the IRR should be sufficient to provide a return on the initial capital investment, and will generally need to be higher than the cost of capital in order to cover risks to the developer or investor of investing in an emerging technology.

The IRR is calculated from the balance of operating revenues and costs in each year over the return period as defined by the developer or investor. The return period may be linked to the duration of the Power Purchase Agreement (PPA) and will not be greater than the design operating life of the plant. In our analysis we assume a return period of 15 unless stated otherwise. Please see Text Box 15 on revenues and PPA's.

In summary, the sum of the predicted electricity price and revenue support elements must be greater than the baseline generating costs in order to cover:

- Investment risks and the consequent difference between the required rate of return and cost of capital. This applies unless the cost of capital and quoted generation cost allows for the risk of the project not performing as designed;
- The difference in the value of electricity generated at source and to electricity suppliers, especially offsetting the risk of differences between actual prices over the long term and market predictions made at the outset of the project. This includes variations in value of fulfilment of the Renewable Obligation,

Investors will balance the prospective risks and rewards before investing in a project, and will only accept total risks up to a certain level. Where high risks arise from the unproven performance of the technology, investors are likely to seek to minimise their exposure to risks from external market conditions. This can be achieved by the generators accepting lower prices from electricity suppliers for the electricity generated, thereby transferring some of the risk associated with external market conditions to the electricity suppliers.

The case for marine renewables depends on substantial economies of scale being achieved. Figure 4 shows the range of costs for the various forms of marine generation, the anticipated cost reductions, and illustrates how economies of scale are forecast by learning rate. We have used a 5 stage project development model to allow for the learning rate to feed through to generating costs.

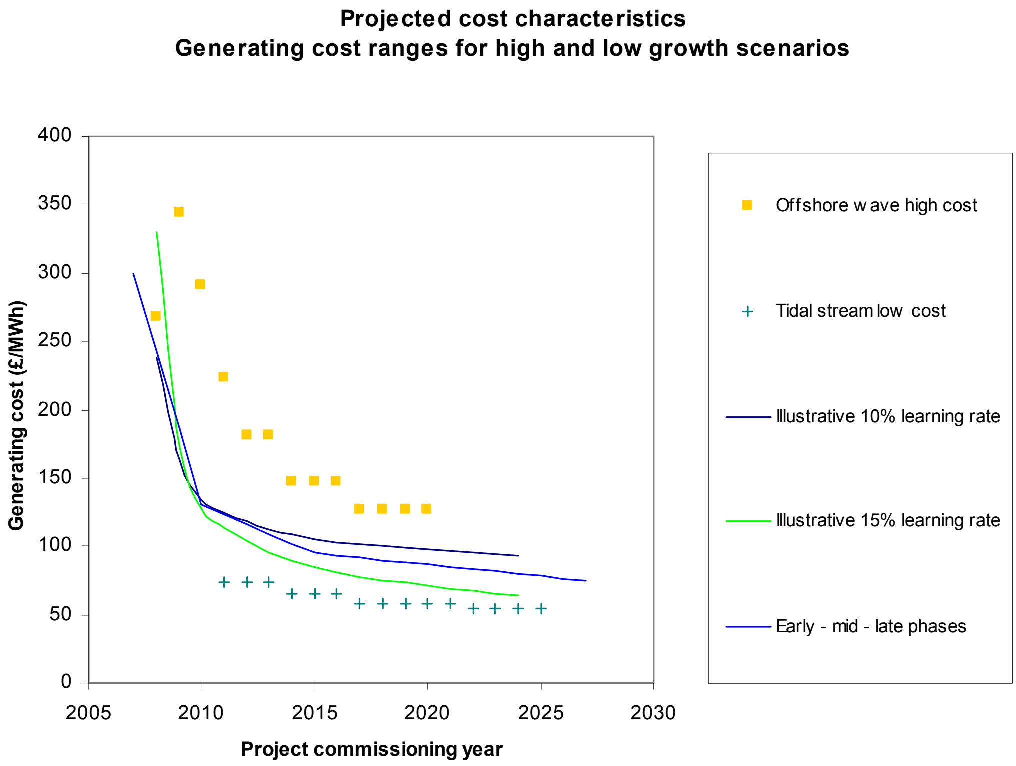


Figure 4 Projected Cost Characteristics – High & Low Growth Scenarios

Figure 4 shows illustrative characteristic cost reduction curves, together with results from our analysis for the highest and lowest cost technologies from the range of technologies we have considered, encompassing the range of technology types[11]. Further results for each technology type, derived from the detailed analysis and cost projections for power projects undertaken in this study, are presented in Section 6 of this report , and sections 3, 5, and Appendix 1 of our detailed report.

Cost reductions arise from both design improvements and learning rate effects due to economies of scale. The cost reduction or learning curve characteristic follows the progression of marine energy towards maturity, comprising the development phases:

1. Early phase development comprising transition from pre-commercial technology demonstration to commercial scale power project implementation. Early costs are very high and will require a high level of support (£/MWh). However the installed capacity and

[11] The maximum costs for offshore wave increase between years 2008 and 2009, due to the inclusion in our analytical model of a leading lower cost offshore wave technology which is first deployed in a Scottish project in 2008, and a higher cost technology which is first deployed in a Scottish project in 2009.

aggregate cost commitment for the support (£M/yr) for early phase projects is relatively low.

2. Mid phase commercial scale power project developments, establishing leading marine technologies and marine projects in the renewable energy market, albeit on the basis of additional financial support. Substantial cost reductions have been achieved by the beginning of this phase. A substantial build rate is achieved during this phase, together with further substantial cost reductions. The level of support and actual capacity achieved during this phase is critical. A medium level of support (£/MWh) is combined with substantial installed capacity to give high aggregate cost commitment for the support (£M/yr).
3. Later phase supported power project developments, consolidating marine in the renewable energy market with the aim of achieving cost competitiveness with mainstream renewables such as wind. By the end of this phase the level of additional support required for marine power projects should be zero, if it is to be viable as a self-sustaining cost-competitive source of renewable energy in the long term. This study considers how the support required during this phase relates to the current horizon for the ROS of 2027.
4. In the long run, marine renewable power projects, in common with other renewable sources, would be expected to have to compete on a level playing field with conventional generation sources, without any form of renewables support. Pöyry estimates that the long-term wholesale electricity price (beyond 2025) could be around £35/MWh under central assumptions for fuel and carbon costs.

The actual cost characteristics for each technology will depend upon:

1. The entry costs actually achieved, comprising the full costs for early projects.
2. Achievement of design improvements which improve energy capture performance, allow deployment in more demanding sites, and reduce generating costs. Some time is required for these improvements to be realised between projects.
3. Achievement of cost reductions correlated to volume manufacture and larger site developments;
4. The actual build rate or growth in capacity. This will determine the correlation between volume cost reductions and timescale.

The projected growth and cost characteristics have clear implications for the support required:

1. To balance marine investment needs and affordability constraints, the level of support must be phased commensurate with the achieved growth, predicted marine project costs, and predicted total cost of the support mechanism.
2. Wave and tidal marine power projects have significantly different early phase costs, and potential economies of scale. This strongly suggests that different levels of support would be appropriate, at least for the early phase(s), to encourage diversity of supply and realise maximum long-term benefit.
3. To allow for the steepness of the learning curve, and associated level of uncertainty, there must be the facility to adjust or control the level or extent of the support which will be provided during mid and later phase development. Adjustment would depend upon the installed capacity or generation achieved, and revisions to project cost predictions in the

light of experience. Whilst the legislative Order which implements a Marine Supply Obligation may set in place the support period and levels of different phases, consideration should be given to keeping the arrangements under regular review, as they are currently for the Renewables Obligation (Scotland).

4. The duration for the early phase could be less than the duration for planning and implementing marine projects. This is because the duration for planning and implementation is not yet known. This presents a challenge for setting appropriate levels or extent of the support for the mid phase, with sufficient visibility to attract investment in marine.
5. This study has identified a potential need for ongoing support to marine energy beyond 2027.

The high levels of uncertainty regarding cost projections based on the information available now, presents major challenges for initiating support through a RO mechanism at the current stage of marine development. The desirability of being able to adjust the level of support in the light of experience conflicts with:

- Simplicity and visibility of the support to projects for long-term decisions by investors.
- Visibility of the 'Banded Obligation' targets and buy-out prices for long-term decisions by Scottish electricity suppliers.
- Established principles of the existing ROS.

The "established principles" of the existing ROS are not currently delivering marine energy projects so a new policy mechanism to support this area is appropriate. Any policy support mechanism introduced should seek to minimise conflicts between the efficiency of the policy design and its visibility.

Setting of the phases and level of support to marine power projects, and the visibility to investors, are major aspects considered in this study.

In the context of the scale of development being considered in this study, the opportunities for economically attractive development of shoreline or nearshore wave in Scotland on a significant scale appear limited since indicative costs are often above those of offshore wave. Shoreline and nearshore wave costs are highly site specific, however, and some projects may be of lower cost than offshore wave. In determining the levels and phasing of support for large scale development we have focused our analysis on offshore wave and tidal stream. This is described further in Section 5 of our Main Report.

Box 9: Benefits of supporting wave and tidal steam technologies

Early costs for shallow water tidal stream projects are predicted to be substantially less than for most wave and deep water tidal stream technologies. Hence, it could be suggested that the additional support should be set at a level which would attract investment in shallow water tidal stream projects. This would minimise the cost of the support.

However, offshore wave offers much greater potential resource and long term growth worldwide, which provides potential long-term benefits of greater renewable generation, sustained growth of the industry, and potential economies of scale. The latter must be realised, possibly at a higher learning rate than predicted, to give long term cost competitiveness . This suggests that higher levels of support should be offered to wave projects, at least in the early stages, to see if costs can be reduced such that the long-term benefits could be realised at an affordable cost. The analysis presented in our Main Report shows that if the level of support offered to wave and tidal converges in the medium and later development phases, the overall cost of the support in the long-term is not much greater, proportionally, than support determined from shallow water tidal costs.

Similar arguments apply, but to a lesser extent, for differentiating between shallow and deep water tidal.

We describe in our Main Report how the marine resources and sites in Scotland provide natural advantages for deep water tidal and offshore wave, which are more distinct to Scotland than for shallow water tidal and nearshore or shoreline wave.

In summary, the potential long-term advantages from providing differential in the support to wave and tidal stream, and possibly deep and shallow water tidal, are:

- Diversity of renewable energy supply;
- Sustained growth of marine energy industry;
- Natural advantage more distinct to Scotland.

Potential disadvantages of differentials in the support are:

- Higher cost of the support, constrained by converging levels of support for mid and later phase projects;
- Sufficient cost reductions for wave and deep water tidal may not be achieved to realise long-term benefits at affordable cost of the support
- May be perceived as reducing competition between marine technologies and hence the competitiveness of the marine renewables sector overall;
- Impacts on the Marine ROC market caused by perceptions of complexity;
- Administrative effort and costs to monitor projects under separate streams.

The inclusion in the 2006 UK Energy Review, of differentials in the support for the various types of renewables, suggests that some of the latter disadvantages may be lesser drawbacks, since the envisaged type of arrangements may become more widely understood and supported.

5 UNCERTAINTIES

Box 10: Uncertainties and risk

Due to the current status of wave and tidal development, there is at present, a paucity of information from experience and near-stage planning, on which to base reliable predictions for commercial power project economics.

This has the following implications for our analysis, interpretation of the results, and decisions at this stage on the level, phasing, and form of additional support:

1. There is significant uncertainty on the actual generating costs which will be achieved by early projects, and especially the achievement of projected cost reductions for subsequent projects;
2. This sets a challenge in setting support levels, and phased reductions in the levels of support at this stage.
3. However, it will be required to commit to support levels and phases in advance of performance and cost predictions based upon experience being available, since:
    a. Visibility is required for strategic investment in marine energy;
    b. It is necessary to close the cash flow gap for technology developers;
    c. The support is required to be bankable for investment in specific projects together in advance of the timescale for planning and implementing projects.
4. The set levels and phasing of support may result in insufficient returns, or the returns from marine projects which may be perceived as excessive being achieved. However, the set levels and phasing of support should give a reasonable prospect of sufficient returns in order to:
    a. Attract investment in marine projects utilising the leading lowest cost marine technologies, as a minimum cost option;
    b. Attract investment in the desired diversity of marine technologies, to reduce reliance on the lowest estimated cost technologies, or realise the long-term benefits of greater diversity;
    c. Reduce risks of project failures, especially in the early stages where a failure could prevent subsequent investment.

A wide range of uncertainties has been identified which will affect the achievable growth in capacity and costs per MWh for marine power projects. This in turn affects the extent of the support required to attract investment to the sector. These uncertainties will also influence the cost of the support, and the net benefit to the wider Scottish economy.

Major uncertainties have been identified and addressed in this study as follows. Due to the immature nature of commercial marine development, there is a paucity of information on which to undertake objective analysis of uncertainties. It has therefore been necessary to make judgements as to whether and how we can address each area of uncertainty in our analysis. We describe uncertainties and the means of addressing them in greater detail in Section 4 and subsequent detailed sections of our Main Report.

- Marine technology development status, power project development phases and timescales[12]: To date there has been limited testing of marine devices over extended operating periods, and no technologies have been tested in the more demanding environments where the greatest available resource lies, for example offshore wave off the Western Isles, or deep water tidal in the Pentland Firth. No marine power projects have been built to test arrays of devices, or the return of power to the grid on a commercial basis. Success in each stage of development is a prerequisite for progression to the next stage

  We have assumed that demonstration of the leading technologies is successful and leads progressively to the successful implementation and operation of commercial-scale power projects, broadly in accordance with the leading technology developer's plans or expectations.

  However, the timescale for achieving commercial scale project developments may be longer than anticipated, and this could severely affect cash flows for the leading technology developers. In determining the phased reduction in the levels of support, we have allowed for some delay in implementation of projects compared with technology developers' plans so that early projects may still receive the higher levels of support, once they are commissioned. Under a revenue support scheme it is not possible to directly compensate technology or project developers for cash-flow gaps due delays in commissioning projects. However, injection of the necessary capital into technology and project developers can be made an attractive proposition to others, by providing high levels of support for early projects, and a visible pathway for investment in projects into the longer term.

  There is the potential that failure of early projects could prevent investment in subsequent projects. The occurrence and effects of this on investor decision-making cannot be predicted on an objective basis. Hence we have not covered this eventuality in our analysis.

- Achievable growth: This will be constrained by practicable timescales for project planning and implementation. Grid connection will be a major constraint until the provision of sufficient capacity to the requisite locations is resolved. Overall affordability of the support mechanism will be a major consideration.

  In determining the high growth scenario we have considered project developments over a number of phases, and the likely number of projects and installed capacity that could realistically be expected to be developed within each phase. We have also taken into account likely grid constraints. Where appropriate, we have modified technology developer's projections for specific technologies to be consistent with the aggregate growth scenarios presented herein, and recalculated the learning rate effects accordingly. We have substantially reduced high growth projections by some of the technology developers which have less developed technologies.

- Marine generation costs: There has been some deployment of devices at test sites. However, no marine power projects of significant capacity have been built or operated for long periods. Total installation and operating costs are very uncertain, and it has not been demonstrated whether costs are reducing, or whether there will be increases in costs before the projected cost reductions can be achieved.

---

[12] Please see definition of 'Project Development Phases' in the Glossary.

We have compiled representative marine power project life cycle models for projects using a range of wave and tidal stream technologies, based upon information from the Carbon Trust's Marine Energy Challenge and leading technology developers. We have used a consistent model format to ensure all major anticipated cost elements and revenue reduction factors are included. We have also allowed for moderate reductions in output, and moderate increases in installed costs, on the lowest cost wave and tidal technologies.

We have determined levels of support which would give viable rates of return for a range of leading technologies, and the lowest cost technologies with contingencies, rather than determining a level of support based only on the lowest cost technology estimates. Supporting diversity of technologies reduces the risk to growth of the marine sector, from failure of the lowest cost technologies, or actual costs for the lowest cost technologies being greater than estimated. Basing the levels of support on estimates for a range of technologies brings in the widest range of state-of-the- art cost predictions.

- Attracting investment in marine renewables: The primary concerns are the rate of return which will be achievable versus the exposure to risk for marine power projects; the management of cash low within the industry; visibility of the support and bankability aspects.

  Through consultation with potential investors, we have identified sources of investment, and minimum target rates of return to attract investment at each marine development phase, thereby providing a pathway for investment in marine.

  Visibility aspects and the bankability of the support to each project will be critical to the effectiveness of the support scheme. In the light of rapid but uncertain projected cost reductions, there are obvious conflicts between simplicity of the support structure, and one which balances and adjusts the levels and phasing of the support against project return criteria within affordability constraints.

  We consider options for the support structure that provide transparent arrangements for the support to projects. We balance the preference for simplicity and the requirement for manageability, with the complexity of phasing of the support suggested by project return v. affordability calculations. We present this analysis for three representative support scenarios.

- Achieving competitiveness: Our central estimates indicate that a form of support additional to standard ROCs will be required for marine projects commissioned up to and potentially beyond 2020, and that some form of support additional to basic electricity sale revenue will be required beyond 2027. Marine is unlikely to become competitive with conventional sources of generation without ongoing support.

  Long term cost projections are highly uncertain and we have not compared marine with other renewables such as offshore wind. However, given the high entry costs for marine, and limiting factors on the cost reductions which will be achievable, it should not be assumed that marine will become fully competitive with other renewables within the timeframe of the RO. In the longer term, pressures on security of supply and the need to achieve large scale CO_2 reductions will alter judgements over the acceptable costs of new forms of renewable energy generation. However, without support now there is absolutely no possibility that a viable self-sustaining marine industry can be achieved. The potential cost of the support versus sustaining the jobs and other wider economic benefits that marine may bring need to be carefully considered.

- Reliance on export markets: The global market opportunity for marine will be constrained by the viability of marine energy under other marine resource and economic regimes; practical drivers on where project activities will be undertaken and the most-cost effective locations for device manufacture; provision of additional support for marine abroad and the conditions associated with this support.

  Given the extent of the support required for marine established in this study, and the question on long term self-sustainability, it is not certain that other countries will provide support for marine development on a similar scale to that proposed for Scotland. However, Portugal has already taken steps to provide tariff and several forms of capital support for marine energy. As with the Scottish mechanism, these may only be introduced elsewhere if they too are expected to offer their economies an early lead in the global marine energy marketplace.

  In estimating learning rate cost reductions we have as a default, allowed for the building of capacity worldwide at the same rate as assumed for Scotland, i.e. the Scottish market drives the learning rate. In undertaking the assessment of net economic benefit we have assumed that imports and exports for marine power projects in Scotland and elsewhere balance. The basis for these assumptions is further described in Section 11 and Appendix 3 of our main report.

  As explained in the detailed text, some cost elements are readily transportable and other elements such as site construction and maintenance work are determined by location and preclude export or import. Our aggregate analysis for the range of technologies indicates that overall, initial device manufacture and equipment costs will be of the order of 15% of total outgoings over the life cycle of the projects. Hence the wider economic impacts will be less sensitive to the balance of imports and exports of devices and equipment than might at first be envisaged.

- Provision of long-term support: The cost and affordability of the support long-term will require a major ongoing commitment, firstly to support projects commissioned during the mid and later phases, and possibly to sustain the marine industry post 2027.

  In our indicative analysis we have made the 'worst case' assumption that all the support costs are ultimately transferred to electricity consumers. Our analysis therefore shows the maximum costs to consumers. However, under the banded Marine Obligation mechanism, and the recycling options being proposed[13], we do not foresee that the costs to consumers would be substantially less than the maximum costs presented.

  The degree of commitment required for projects in the mid phase, may cause investors to question the bankability of the support. We have considered two growth scenarios in this study, the support cost constrained scenario may be perceived as more realistic by the wider range of stakeholders.

[13] The mechanisms being proposed under this study do not include the 'Headroom' arrangements subsequently proposed in the statutory consultation, and as proposed in the UK Energy Review (2006).

Box 11: Sensitivity analysis

We present the results of our analysis for different cases, through:
1. Scenario models representing substantially different growth and support scenarios;
2. A hierarchy of uncertainties and their effect on attracting investment in marine projects;
3. An indicative sensitivity analysis for one selected growth and support scenario.

We present the hierarchy of uncertainties and the indicative sensitivity analysis in Section 7 of our Main Report. These present the uncertainties and sensitivity analysis results with respect to the effect on marine project returns, and hence whether investment in wave and tidal power projects is likely to be attractive.

This shows that there is not a proportional or readily quantifiable relation between the level of revenue support (£/MWh) and uptake of marine, in MW of capacity built or MWh generated, but rather that the level of support will affect diversity, both of technologies providing viable returns, and of investors prepared to invest.

A full analysis taking into account all the uncertainties identified in our study presents the following challenges in the analysis, how meaningful it would be, and in its interpretation:
- There is a wide mix of qualitative and quantitative factors, with varying mechanisms by which they interact and influence real investment decisions;
- There is a paucity of available objective information on which to determine sensitivity ranges. This arises from the early status of the industry and lack of relevant project experience;
- A central case is a prerequisite for a quantitative sensitivity analysis, and is normally set by precedent or accepted norms. For this study a central case has been selected from one of the scenarios we have considered. However, this should not be taken as a recommendation for the final support scenario. The scenarios presented in this report represent widely different options for the level and diversity of marine development which could be supported. Any of these support scenarios, or another option could be selected in the light of the findings of this study, related studies commissioned by the Scottish Executive, the consultation, and outcomes of the UK Energy Review.

We can however conclude that:
- The delivery of MWh of marine generation in the foreseeable future would be driven by the size of the banded Marine Obligation, with the proviso that the level of support provided by the buy-out price is sufficient to give attractive rates of return v. risk;
- In order for investment to occur, the support for each project must be both visible and bankable. This requires clear commitments that the Marine Obligation mechanism will provide a set level of support over a set period for each project. The growth of marine that is supported through the size of the Marine Obligation will have greater effect on the overall costs of the support than changes to the phasing or duration of support to individual projects (where the support gives similar rates of return for each case);
- The uncertainty and sensitivity effects of marine generation costs are likely to be greater than those of long-term power and ROC prices. However, the reduction of estimated risks through successful construction, operation, and economic performance of preceding marine power projects, will be key to project developers or investors being able to access greater value from long-term power and ROC prices (see Box 15 on Power Purchase Agreements).

6 FORECASTING THE COST OF MARINE RENEWABLES

Box 12: Marine power project costs

Marine power projects will usually comprise the following major cost elements. Indicative costs over the project lifecycle for the mix of offshore wave and tidal technologies included in our analysis are expressed as ***percentages of the capital costs***.

Capital costs:

- Development and manufacture of devices (62%);
- Fabrication of structures for mounting and accessing devices on the seabed or shoreline. Alternatively procurement of moorings (20%);
- Electrical connection to the shore, and thence to the nearest grid connection point. Note that we have not included the cost of grid upgrades or extensions in our analysis, other than through an allowance for TNUoS charges (8%);
- Site installation and commissioning, including the cost of installation vessels and labour in laying subsea foundations or moorings, installing structures and devices (10%);

Operating and Maintenance costs:

- Routine servicing and repair in-situ, including cost of service vessels and labour. Periodic maintenance and repair involving return of devices to the shore for refurbishment, repair, or replacement, including the cost of installation vessels and labour, and a proportion of the device manufacture costs (85%);
- Insurance (33%).

For nearshore and shoreline wave projects, the civil engineering cost will generally be higher than the device costs, but may be shared when the power project is incorporated in a harbour development, or reduced when natural topographical features are utilised. Hence nearshore and shoreline wave project costs are highly site specific.

We have undertaken extensive consultation with the Carbon Trust and marine technology developers and our own independent analysis to establish 'state of the art' projections for the development of marine projects and their costs.

We have incorporated the data in life cycle models representing each technology and project development phase, ensuring that all major cost elements are included in a consistent manner. This may give higher all-in costs than other predictions.

We have applied our own forecasts of electricity and ROC prices, Power Purchase Agreement factors, and transmission system charges in order to determine the cash flows and rates of return achieved under different additional support scenarios. Previous assessments of the extent of support required, or the competitiveness of marine, may not have allowed real reduction factors or taken into account the levels of risk on marine power project economics.

The cash flows from each technology and phase model have been aggregated to calculate the total installed capacity, power generated, and cost of the additional support in each phase.

Our models for specific technologies show early generating costs within the lower central ranges given by the Carbon Trust in their Future Marine Energy report. For cost reduction projections we have assigned practicable cost reduction factors or learning rates according to the nature of the cost item and potential improvements, or where available, evidence of planned cost reductions from the technology developers. Where technology developers have used their own market growth estimates to assess future technology costs, we have adjusted these to be consistent with the growth scenarios presented in this study.

However, no information has been available on planned project costs for specific sites in Scotland, and as identified above there is very little actual project experience. Entry costs could be adjusted up or down before the projected cost reductions commence, despite the cautious approach we have adopted in our analysis. Hence there is still a fairly high level of uncertainty on costs at all stages.

Figure 5 shows the ranges of generating costs for some of the main technology types included in the aggregate model.

The technologies are grouped:

- The least cost tidal stream technologies.
- The deeper water tidal stream technologies – lower and higher cost range.
- The offshore wave technologies – lower and higher cost range.

These show a rapid cost reduction, especially for the higher cost technologies as their deployment increases in the early and mid phases[14] of development.

[14] Please see Glossary, Section 4 and Figure 2 for the definition of the project development phases.

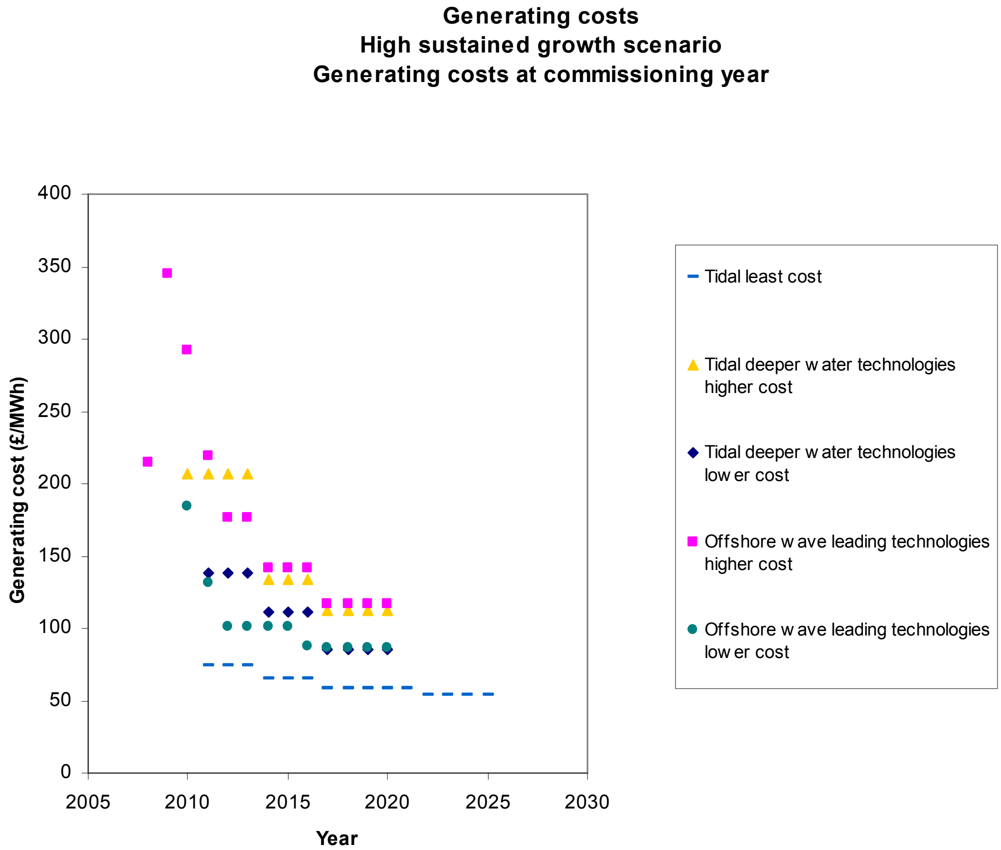


Figure 5 Generating Costs Leading Technologies – High Sustained Growth Scenario

7 ATTRACTING INVESTMENT IN MARINE RENEWABLES

Box 14: Focus on the investor's perspective and investor's decision making
Consistent with the project brief, our study focuses on the analysis and definition of the market pull required to lever in private capital investment for development of marine generation capacity on a material scale.

However, there is not a simple relationship between anticipated returns from projects and investment in projects, or stated another way, there is not a proportional relationship between the level of support (MWh) and build rate. Rather, in an open investment market, potential investors will make a go / no go decision as to whether to invest in marine projects, based upon their decision criteria for balancing risks and rewards. Below a certain level of anticipated reward there will be no investors who will be prepared to invest. Different investors will have different decision criteria, and above this threshold higher rewards v. risks will increase the diversity of investors who wish to invest. In setting the level of support, it is therefore necessary to consider the desired diversity of investment.

Once sufficient support is in place for positive returns to be anticipated, the high levels of uncertainty and risk will be the primary constraint on the diversity of investors in early marine power projects. Consultation with a range of investors and marine technology developers indicates that initial project investments are likely to be by the major utilities on a speculative basis, drawing on their cash resources and managing risk through their technical expertise and a staged development strategy. The underlying rationale for the Utilities is a risk balance, commencing development of marine as a hedge against the risk of not being able to meet their Renewable Obligations by other means (and also as a means of publicly demonstrating corporate responsibility for sustainability). Successful initial marine power projects are essential to demonstrate reductions in uncertainties and risks, establish attractive investment and hence open up investment from more diverse sources.

Experience of the Renewable Obligation shows that a further prerequisite for material investment, is that the Renewable Obligation and the Marine Obligation provide both:

- A visible pathway for successful strategic investment and growth in returns from marine projects;
- A firm commitment on the minimum level of support that will be received by each project over its return period, which will be bankable with investors.

Consistent with the focus on the investors' perspective we present the results of our analysis on graphs of IRR for the range of technologies under different growth and support scenarios. We are however, restricted in presenting results for specific technologies due to confidentiality constraints.

Once attractive investment is established, the volume of investment will depend upon the volume of available projects to invest in. This will depend primarily upon factors such as grid connection; planning, permitting, and leasing processes; the capacity of the industry to address these issues, construct and operate projects; and capacity or generation limits on eligibility for the support which may be determined by the size of the Marine Obligation.

The prospects for returns from marine power projects will have to be sufficient to attract investment in the development of both marine technologies and marine projects. For development on a substantial scale, the latter will require the largest investment, and is the focus of this study.

At present, Utilities are interested in investing in marine to cover the risks of not being able to meet the Renewable Obligation using other lower cost renewables. The introduction of a specific Marine Obligation at a sufficient buy-out price would provide a more powerful stimulus for investment by utilities. For wider investment, the prospects for returns from marine projects will have to be sufficient to attract other forms of investment, which means that marine projects compete with other investment opportunities.

Investment uncertainties and risks will decrease from very high levels in the early phase, possibly to levels commensurate with offshore wind in the later phase. This requires that full cost-competitiveness is achieved, or if not, that there is a visible means of ongoing support.

There is consensus that until the success of marine projects on a commercial scale has been demonstrated, the range of uncertainties and level of risk will preclude private equity or venture capital investments. Early investment in pre-commercial projects, and the immediate follow-on commercial projects, will be led by the electricity utilities, accepting relatively low rates of return. Hence there is a high reliance on the major utilities to kick start investment in marine.

Subsequently, high rates of return will be required to cover the remaining uncertainties and high levels of risk, in order to attract investment on a fully commercial basis. In the later phase, rates of return converging with established renewables may be sufficient to attract investment.

In determining the level and phasing of support required for marine projects, we have therefore used target rates of return:

- Pre-commercial projects and the immediate follow-on commercial projects (investment by utilities up to 10 MW): 8% to 12%.
- Early and mid phase fully commercial power projects: 15%.
- Later mature phase fully commercial power projects: 12%.

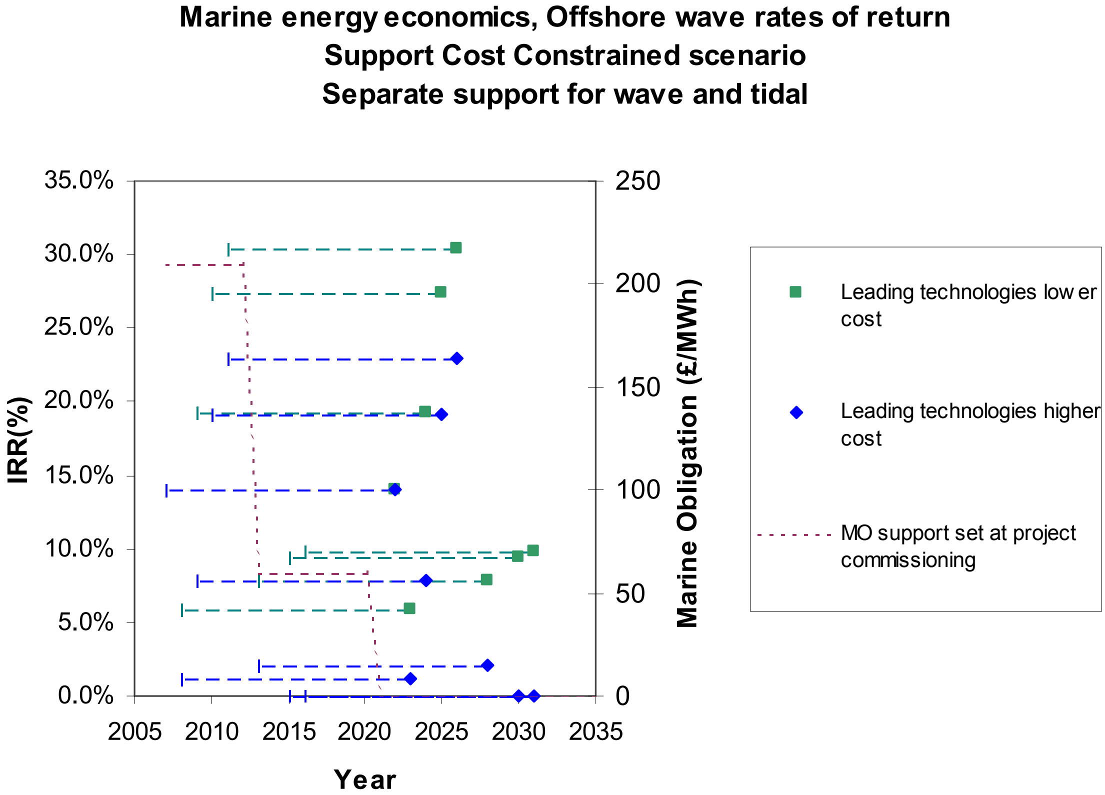
Figure 6 and Figure 7 show the range of rates of return achieved in our models for the main technology types. The range of returns arises from:

- The different leading technologies included in our model, which have different generating costs for different commissioning years (as shown in Figure 5 for example);
- How the generating costs for each technology at each development phase compare with the level of support for which they are eligible under the MO phasing arrangements.

As described in Box 3, project returns only follow from successful operation (performance as designed and generation output as predicted) of the power project over the return period. Hence the returns lag project commissioning by the return period, which is typically 15 years.

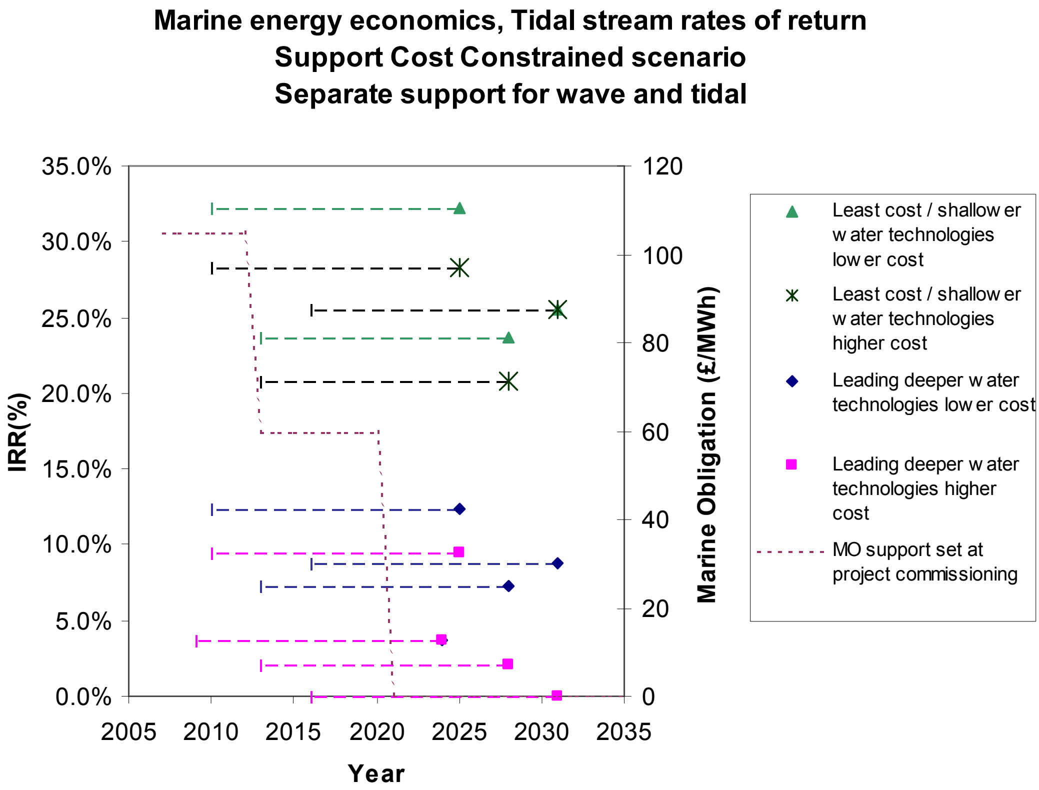
The Marine Obligation (or MO) values presented here are the level of additional support received by projects through the Marine Obligation, maintained from their commissioning date to the end of the return period, or 2027 if this is sooner. These values are likely to be similar to the set buy-out prices, the relation between the two being described in Section 8 of this report, and Section 9 and Appendix 2 of the Main Report.

We present the results for a defined support scenario incorporating different early levels of support for wave and tidal. In our Main Report, Appendix 1, we present similar graphs for 3 defined support options / scenarios.



1. IRR are shown for projects commissioned in development phases, the first phase commencing in 2007, and the final phase for commissioning ending in 2020;
2. IRR are shown for projects using the least cost and highest cost leading technologies in each development phase;
3. IRR results shown for a 15 year return period after project commissioning;
4. Projects shown with zero return give zero or negative return;
5. The support through the Marine Obligation (£/MWh) is the additional support for marine and will be approximately equal to the buy-out price for the specific marine element of the Marine ROC;
6. Eligibility for a certain level of support or Marine ROC buy-out price for each project is set by its commissioning date, this level of support being maintained for the life of the project;
7. Transition years from one phase of support to the next shown by step(s) in "MO support set at project commissioning" line. Each transition would occur at a single date.

Figure 6 Offshore Wave Project Rate of Return – Support Cost Constrained Scenario with Separate Support Schemes for Wave and Tidal



1. IRR are shown for projects commissioned in development phases, the first phase commencing in 2007, and the final phase for commissioning ending in 2020;
2. IRR are shown for projects using the least cost and highest cost leading technologies in each development phase;
3. IRR results shown for a 15 year return period after project commissioning;
4. Projects shown with zero return give zero or negative return;
5. The support through the Marine Obligation (£/MWh) is the additional support for marine and will be approximately equal to the buy-out price for the specific marine element of the Marine ROC;
6. Eligibility for a certain level of support or Marine ROC buy-out price for each project is set by its commissioning date, this level of support being maintained for the life of the project;
7. Transition years from one phase of support to the next shown by step(s) in "MO support set at project commissioning" line. Each transition would occur at a single date.

Figure 7 Tidal Stream Project Rate of Return – Support Cost Constrained Scenario with Separate Support Schemes for Wave and Tidal

The rate of return is calculated at the expiry of the Power Purchase Agreement (PPA), this is assumed to be 15 years after project commissioning. In order to maximise the prospect of the support being bankable to each project, we recommend a mechanism where the level of support for which a project is eligible, is determined by its commissioning date, and is maintained at that level for the life of the project, or until the end of the ROS system. The results presented in this report are for such a scheme.

It can be seen from Figure 6 and Figure 7 that the levels of support required are quite high, especially in the early phase, for the leading low-central cost technologies to achieve the target IRR. The early additional support for offshore wave is £210/MWh, and the mid-term level of support is £60/MWh. These values for the additional support to projects through the Marine

Obligation compare with projected ROC prices decreasing from current levels of around £48/MWh to around £37/MWh beyond 2009[15].

Even with these levels of support some of the rates of return appear quite low, partly because we have used cautious forecasts of power prices, standard ROC prices, and PPA factors in our model. In this analysis, the leading high cost technologies fail to achieve the target IRR at many stages in their development with the input levels of support. We have also undertaken analysis for higher revenue factors and present this in Volume 2 of our report.

At the levels of support suggested for offshore wave, high rates of return could be achieved by shoreline or nearshore projects, given favourable specific site characteristics at a few locations. However, as described in our Main Report, such developments would have relatively little effect on the aggregate capacity, power generated, or cost of the support.

The case shown is for a support structure including 2 phases over which different levels of support may be set. This is because in this model, the Marine Obligation ceases to have value when the ROS ceases in 2027. To achieve attractive rates of return from projects commissioned beyond 2020, it transpires that some form of support additional to the basic electricity price is required. Hence we have assumed that the MO phases for commissioning of new build cease in 2020. Clearly the form and level of the support required for subsequent build would depend on whether and how the standard ROS was extended beyond 2027.

The wide spread of IRR shows how sensitive project returns are to balance between the cost of the project, and revenue through the level of support provided. Further presentation of our analysis of 3 support scenarios, and a sensitivity analysis is given in our Main Report.

Due to the high learning rate effect, the achieved rate of return will be very sensitive to the time of project construction and commissioning relative to the phased reduction in the support, especially for early phase projects. Because projects commissioned in the same phase will receive the same incentive over their lifetime, projects commissioned at the beginning of a support phase will tend to achieve lower rates of return than projects commissioned towards the end of a support phase. The end dates for eligibility for higher levels of support will therefore drive progress. Provided that development of marine projects is achievable within the phased reduction of the support, this is a powerful positive feature of the proposed support structure. We provide further explanation in our Main Report, Section 7, and consider means of adjusting the levels and phasing of the support under the sections on the Marine Support Structure.

A support structure with more phases for the level of support, or ramped reductions rather than step changes in the level of support, would enable the support to be more closely matched to project forecast cost reductions. This would reduce the spread of IRR, especially in the early phases of project development when learning rate effects are most abrupt. We present the IRR results for a 3/4/5 phase support model in our Main Report, Appendix 1. However, such a support framework may be perceived as too complex by investors and project developers, and would be more complicated to administer, especially with respect to the tie-in between the

[15] Indicative comparisons based on values of the additional support to projects through the Marine Obligation and projected ROC prices of show that the additional support of £210/MWh is equivalent to an additional 4.5 x ROCs, and that the mid-term level of support of £60/MWh is equivalent to an additional 1.5 x ROC, or 2.5 ROCs total.

changes in the set Marine Obligation buy-out price, the effective incentive to invest, and the level of support awarded to projects.

It can also be seen that the rates of return are quite variable between different specific technologies within a technology group. Hence, the level of support for each technology type will determine the diversity of both technology types and specific technologies within each technology type, which are likely to be economically viable. This will be an important strategic policy consideration when deciding on desirable levels of support. However, it will remain up to the marine industry and investors to pick winners, progress projects on a commercial basis, and manage strategic investment between the support stages.

Figure 8 shows the aggregate rates of return achieved in the 2-phase, separate support model for wave and tidal stream, using a mix of leading technologies for which information was available. In this case the cash flow across all supported projects is aggregated over the project development phases, thereby showing the long-term or strategic investment potential in the range of marine technologies. The results are presented with cash flow aggregated separately for offshore wave and tidal stream projects, and across all marine projects. The derivation and meaning of the IRR plots on this graph is described further in Volume 2 of this report.

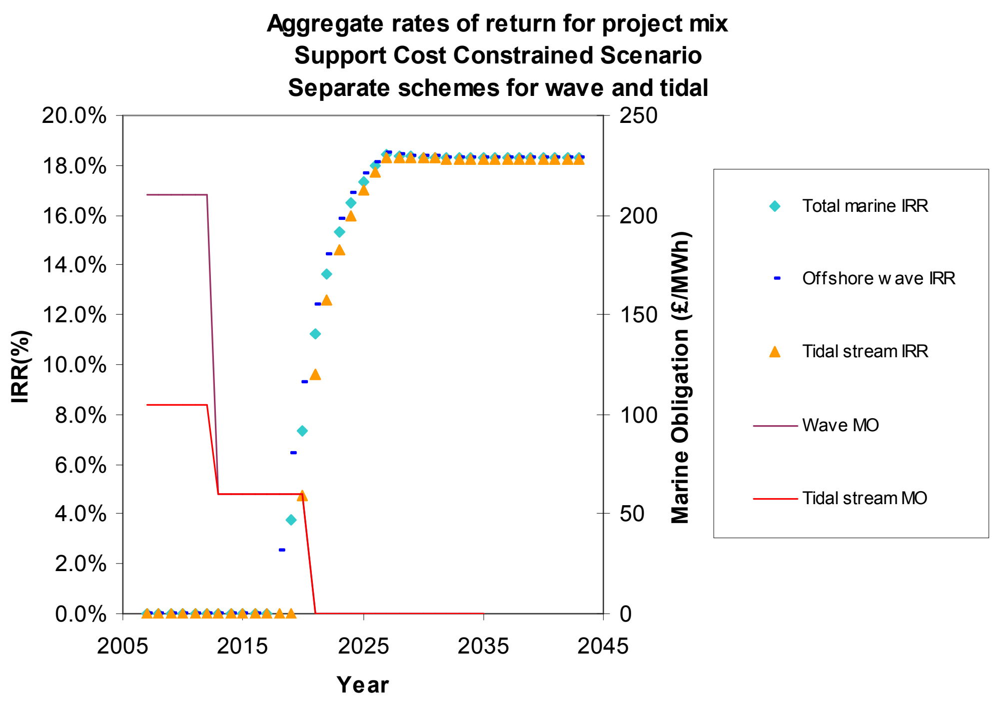


Figure 8 Support Cost Constrained Scenario with Separate Scheme for Wave and Tidal - Rate of Return for Project Mix

Based upon discussions with the utilities and potential investors, we consider that the proposed levels of support would attract a combination of utilities, lending and equity investment to provide a pathway for marine through the development phases, subject to the following provisos:

- There is sufficient investment in technology development and design improvement to achieve the required performance levels and cost reductions. As described in our Main

Report, we allow for a contribution to this from marine device sales, in determining the technology costs.

- Early marine projects are successful in terms of design, planning and the permitting process, implementation timescale and cost, operation and revenue returned. This is essential to pave the way for subsequent larger scale development. In addition permitting and grid connection barriers must be perceived as being manageable;
- The target levels of return are seen as achievable.
- The levels of support are adjusted to take into account revised cost projections based upon actual experience of implementing and operating commercial scale power projects. Whether through managed adjustment or through the Marine Obligation market mechanism, this must limit the cost to the consumer. In our analysis, and consistent with the objective to attract investment, we have tended towards technology cost estimates and levels of support above the minimum, in order to avoid the need for future increases in the level of support.
- The marine industry is able to manage cash flows in the early stages for technology development and design improvement, and establishing project planning, implementation and operating capability.
- The marine industry is able to manage cash flows associated with differences in project costs and the levels of support received by specific projects over the phases of the support. For example, those projects commissioned at the beginning of particular support phase would tend to have higher costs and make lower returns than projects commissioned towards the end of the same support phase.
- Long-term commitment to the support is visible to investors, and the support is seen as being affordable in the long term, so that investors have confidence in its continued provision. This commitment needs to extend at least to 2020 for commissioning of new projects and to 2027 for ongoing support, consistent with the existing Renewables Obligation.
- The support structure is visible and understood by investors.
- The level and duration of the support which will be received by each project is known at the time of early project planning and in advance of project implementation.

Box 15: Revenue and Power Purchase Agreements (PPA)

The source of revenue from a power project is electricity sales, calculated from the product of the power generated (MWh/yr) and rate (£/MWh) received by the project from the following:

- Value of electricity on the wholesale electricity market;
- Value of standard Renewable Obligation Certificates (ROCs) at market price;
- Value of the additional support for marine as proposed in this study;
- Value of Climate Change Levy Exemption Certificates (LECs);
- Deductions on the above through the Power Purchase Agreement (PPA).

Power Purchase Agreements (PPA) provide a long-term commitment by utilities or electricity suppliers to purchase the electricity generated by a project at certain rates (£/MWh) in accordance with conditions specified in the PPA. Hence PPA, combined with validated energy yield predictions, provide the visible and bankable predictions of revenue, which are necessary to obtain investment in the project.

PPA are a form of risk sharing between the generator and the electricity supplier, in which risks from long-term variations in market power and ROC prices, from those predicted at the outset of the PPA, are shared between the supplier and generator. In the early stages of commercial marine development, investors or developers will already be exposed to high levels of risk through uncertainties on project costs, energy yield, and availability. They will therefore seek to minimise other uncertainties effecting the return on investment, and will tend to opt for PPA which apportion most of the risk from external changes in the electricity and renewables markets to the electricity suppliers. However, this will invoke substantial reduction factors being applied between predicted electricity supply market prices and the rates received by the project, such that projects typically receive around 60% of the market price.

Where the investors or project developers are major utilities, development of marine projects may form part of their wider risk management strategy and it is possible that PPA reduction factors may be such that projects receive circa 90% of the market price.

In our reports we identify and consider the standard forms of PPA which are likely to be applied at the different stages of marine projects development. PPA reduction factors have been included in our calculations of IRR accordingly.

8 MARINE PROJECT SUPPORT STRUCTURE

Box 16: Requirements for a successful support structure

In order to meet the aim of achieving growth in marine energy, the support must provide a visible pathway for development and strategic investment, and must be bankable for each project. This requires a clear commitment on the levels, phasing, and provision of support to projects in the early, mid, and late marine development phases. Strategic policy decisions, design of the form of support, and the administrative arrangements, will need to cover the following elements:

- Definition of support for wave and tidal stream projects by site resource or technology type. The Marine Obligation is intended to provide a differential in the level of support to marine, above that received by established lower cost renewables. Differentials in the levels of support to different renewables is recognised in the 2006 UK Energy Review as necessary for the future development of renewables. This concept can be extended to provide differentials in the level of support between wave and tidal stream, and possible deep and shallow water tidal stream (see Box 9);
- Definition of the scope of the Marine Obligation. We consider the case where projects connected to the Grid in Scotland are eligible for the award of Marine ROCs, and the Marine Obligation is placed on suppliers of electricity in Scotland;
- Number of phases and transition dates for the phased reduction in the levels of support through the Marine Obligation;
- Size of each part of the Marine Obligation;
- Buy-out prices for each part of the Marine Obligation;
- Accreditation of projects to phases and duration of the accreditation for each project, giving eligibility for award of Marine ROCs under each part of the Marine Obligation;
- Mechanism for the adjustment of the level and / or phasing of the support. This may be managed adjustment or self-adjustment through the Marine ROCs market response to actual costs and growth. Managed adjustments would have to be made with a notice period at least as long as the time to plan and implement projects. This is 3 years minimum, with 5 years being preferred;
- Timescale for operation of the Marine Obligation as constrained by the ROS. We show that operation of the Marine Obligation for projects commissioned beyond 2020 would be dependent upon extension of the ROS beyond 2027;
- Other administrative arrangements, especially how the Marine Obligation will fit within the ROS.

The Scottish Executive is proposing to support the development of wave and tidal stream generation projects though a new Marine Obligation on suppliers in Scotland. The Marine

Obligation would form part of the existing Renewables Obligation (Scotland) (ROS), with suppliers obligated to source a proportion of the electricity supplied to consumers in Scotland from marine generation.

It is envisaged that eligible marine projects would be awarded Marine Renewable Obligation Certificates (MROCs) on their generation. Suppliers would be able discharge their Marine Obligation and ROS by redeeming MROCs. Alternatively suppliers can meet their Marine Obligation by paying a marine buy-out price. The avoided cost of this buy-out price will determine the value of the additional support provided to marine projects.

Our recommendations for the support structure are that:

1. There is the facility to set reducing levels of support over two or three phases. By splitting the Marine Obligation into phases, a higher level of support can be targeted at early stage developments, by setting differing buy-out prices in each phase.

Level of support (nominal)	Support phase (nominal dates)		
	2007 - 2012	2013 - 2020	2021 - 2027
	£/MWh	£/MWh	£/MWh
Wave	210	60	Dependent upon extension of ROS
Tidal stream	105	60	Dependent upon extension of ROS

Table 2 Support phases

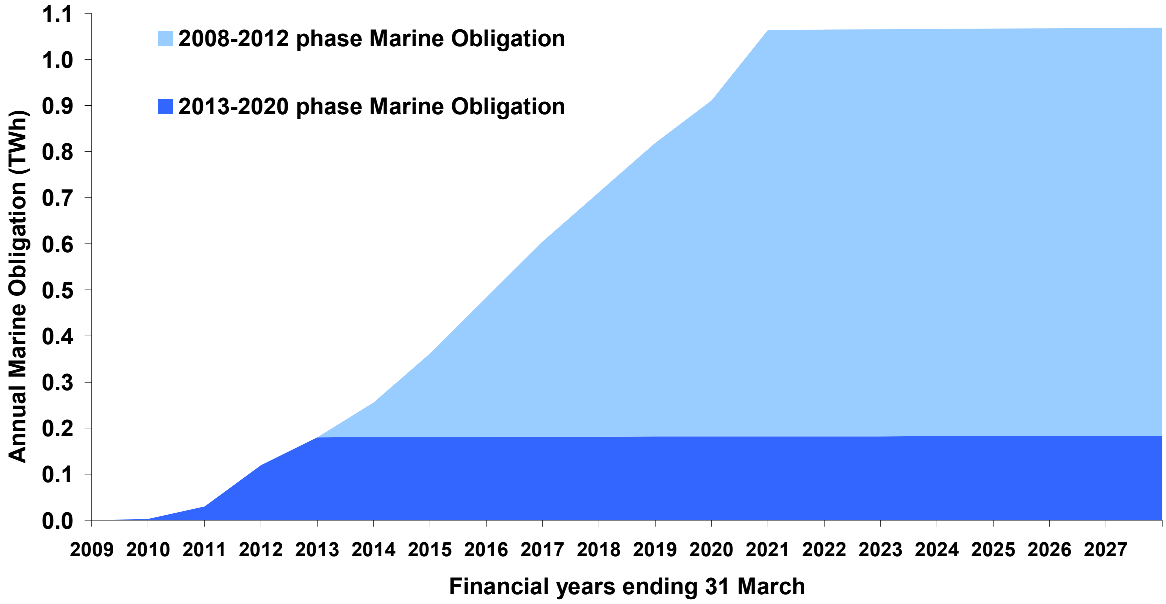
The table above shows the value of the support required to attract investment in projects as previously described in this report.

Due to cessation of the RO in 2027, implementation of new build marine projects beyond 2020 may not be financially viable. Hence it may not be practicable to extend the MO for new build beyond 2020 within the existing ROS. Neither of the supported growth scenarios presented in this section have an increasing MO beyond 2020.

2. Suppliers' obligations under each phase would be maintained until the end of the obligation. Suppliers can only satisfy their obligations in each phase by redeeming MROCs.

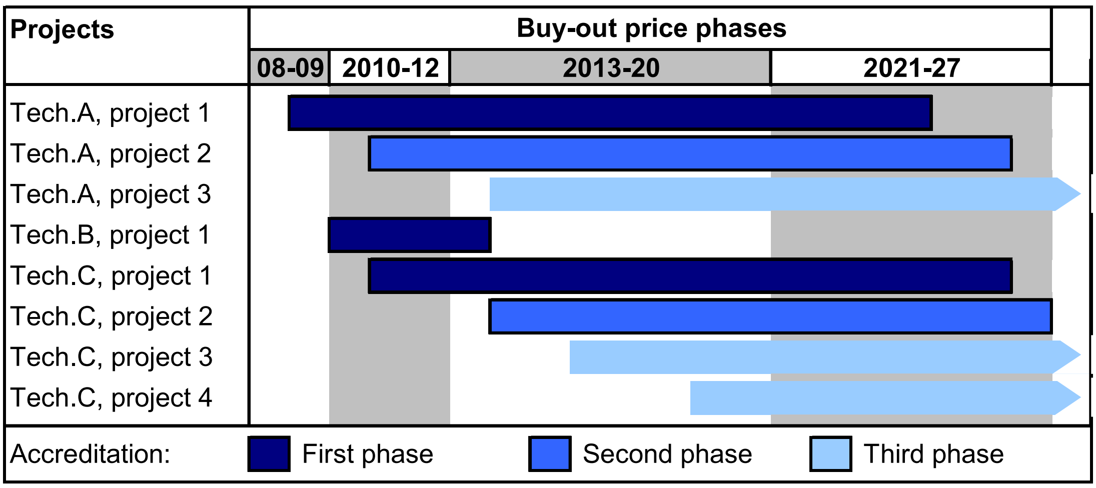
   Figure 9 shows the growth of the Marine Obligation for the Support Cost Constrained growth scenario, separately identifying the volume of the obligation in each of the two buy-out price phases. We have shown the aggregate wave and tidal obligation.

Figure 9 – Support Cost Constrained Marine Obligation by buy-out price phase



3. Marine projects should be accredited against a specific phase of the Marine Obligation. Their MROCs could then only be redeemed against that and subsequent phases of the obligation. The accredited obligation phase, the buy-out price and hence the level of support derived through the MROCs market, would be determined prior to, or at the projects' commissioning date, and would be maintained for the project life or until the Marine Obligation ceases to have value (in 2027 under the current ROS). Further explanation of this mechanism is provided in our detailed report, Volume 2.

Figure 10 – Marine generator accreditation phases based on design criteria



The case shown by Figure 10 above illustrates a mechanism where projects are accredited to a specific Obligation phase in advance of the project commissioning date. Hence projects commissioned at the same time can be accredited to different phases.

4. There is the facility to set different levels of support for wave and tidal developments. Nearshore and shoreline wave projects should be eligible for the same support as offshore

wave. Consideration should be given to different levels of support for deep and shallow water tidal projects, for the reasons given later in this report. However, this option has not been subject to detailed analysis.

Bearing in mind the different entry costs for wave and tidal projects we recommend the option to set different levels of support to stimulate diversity of supply and maximise long-term benefit, despite the relatively small differences in costs of the support. Otherwise, under a competitive market, early investment could be expected to focus on the lowest cost technologies offering the greatest returns. The full results of our analysis for common and separate support for wave and tidal projects, and our comparison of the support structure options to achieve diversity of supply are presented in Volume 2 of our report.

5. Provision of the support through a Marine Obligation requires that the marine targets and buy-out prices are fixed at the outset of the support mechanism, if the overall mechanism is to be consistent with the principles of the existing ROS. Suppliers and potential investors also have major concerns on the complexity, visibility, and uncertainties with variable levels or phasing of support.

6. However, there are considerable uncertainties over the future level of support that will be required, given the limited experience with these technologies to date, together with other uncertainties within the electricity and carbon markets. We have considered the option for the mechanism to adjust the extent of support to projects in the light of achieved installed capacity and costs, and revisions to growth and cost projections. This could be undertaken through one of two mechanisms:
    - Future levels of support or buy-out price are adjusted for phases with predetermined and fixed transition dates;
    - Future phase transition dates are adjusted for changes between predetermined and fixed levels of support or buy-out price.

    Key principles of the ROS to date have been that buy-out prices will not be reduced, that eligible projects will retain eligibility and that support phases for existing and developing projects will not be curtailed. Consistency with these principles may hamper the ability to provide flexibility over the level of support. The Scottish Executive will not want to underwrite future cost risk by guaranteeing that buy-out prices would be raised to ensure future viability of marine projects, as this could expose Scottish consumers to an unlimited liability.

7. Control of the support provided to projects, its costs and impacts, will be provided through fixed 'Banded Obligation' targets and buy-out prices. This may result in two scenarios:
    - If marine project and generation costs are less than those anticipated when setting the buy-out price, the buy-out price will drive high level compliance with the target, which will effectively form a constraint on the volume of generation supported;
    - If marine project and generation costs are greater than those anticipated when setting the buy-out price, there will be low level compliance with the target.

    Hence the use of cautious estimates for achievable marine costs appears appropriate for designing support intended to simulate the market for marine, without uncontrolled costs.

9 WIDER COSTS AND IMPACTS OF THE SUPPORT

Box 17: Identification of impacts and impact mechanisms

We identify the following potential impacts arising from the provision of additional support to marine through the proposed Marine Obligation mechanism:

1. Impacts within the electricity supply industry, including:
   a. The displacement of other renewables, namely offshore wind. Marginal cost effects suggest there will minimal displacement from a smaller size obligation, but that under a larger size obligation displacement effects could substantially reduce the net gain in renewable generation.
   b. Cash flows arising from fulfilment of the Marine Obligation. We anticipate that the additional costs of Marine Projects will ultimately be passed to the consumer, and that deadweight costs of the Marine Obligation will be recycled back into the industry. Returns will be balanced against exposure to risk;
2. Impacts outside the electricity supply industry arising from the transfer of costs of the Marine Obligation to electricity consumers. These include:
   a. Increased energy prices to industrial consumers. Since large scale consumers will be paying the lowest tariffs, the percentage increases will be greatest for them effecting their operating costs and possibly industrial competitiveness;
   b. Increased energy prices to domestic consumers. This will have social impacts on domestic consumers either within, or close to the fuel poverty criteria;
3. Job creation, displacement, and socio-economic impacts from the sustained growth, or otherwise of an indigenous marine renewables industry.

Figure 11 shows the total cost of the Marine Obligation for the Support Cost Constrained and High Sustained Growth scenarios. The additional cost of providing the Support Cost Constrained scenario peaks at £80M per year from 2020 and would cost £1.1bn from 2008 to 2027. For the Sustained Growth to 2020 scenario annual cost of the marine obligation would peak at of £140M per year and would total £1.7bn to 2027.

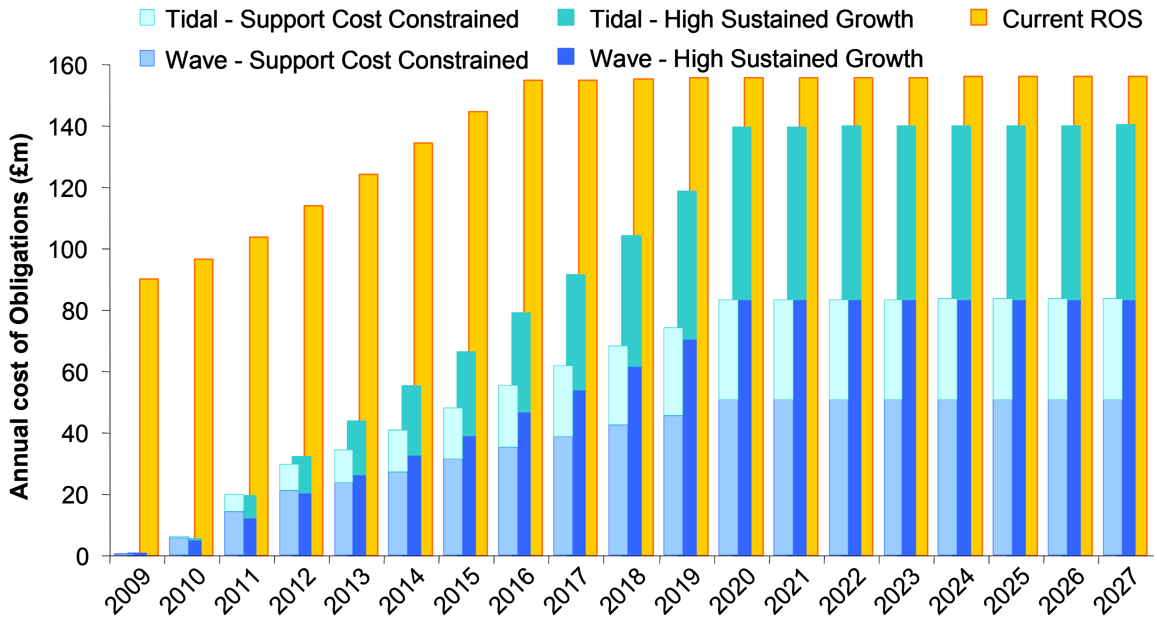


Figure 11 Projected annual costs of the Marine Obligation (separate for Wave and Tidal) and comparative cost of the ROS (£m in 2006 prices)

For the High Sustained Growth scenarios, the differences in costs between separate support for wave and tidal and a combined marine obligation is relatively low, as any differential between the technologies is applied to projects in the early phase, when the aggregate obligation is small. For the combined obligation under the Support Cost Constrained scenario we have capped the buy-out price at the lower level available to tidal projects in the early years. This scenario, discussed in more detail in Volume 2 of this report, has peak annual costs for the Marine Obligation of £72M and a total of £0.9bn to 2027.

Table 3 Comparative Costs of Separate and Combined Marine Obligations (£m in 2006 prices)

Financial year ending	Support Cost Constrained		High Sustained Growth	
	Separate wave and tidal	Combined marine*	Separate wave and tidal	Combined marine
2009	0.6	0.3	0.8	0.8
2010	6	3	6	6
2011	20	13	20	22
2012	29	19	32	37
2013	34	23	44	48
2014	40	30	55	59
2015	48	37	67	71
2016	55	44	79	84
2017	61	51	92	98
2018	68	57	104	112
2019	73	63	119	128
2020	83	72	140	151
2021	83	72	140	151
2022	83	72	140	151
2023	83	72	140	151
2024	83	72	140	151
2025	83	72	140	151
2026	83	72	140	152
2027	83	72	140	152
Total	1,097	919	1,738	1,876

* Combined buy-out price capped at level of separate tidal obligation

It is clear that the extent of support required to attract investment and achieve the scale of marine development considered by this study would entail a major financial commitment over a sustained period.

It is also apparent that the high early levels of support are not the major determinants of the peak costs of the support. The peak costs are due to the greater obligation at lower buy-out prices in the mid and later phases.

Alternative options for the duration of support could be envisaged, that might see the early phase obligations restricted to a shorter number of years – but providing greater upfront value to marine generators through higher buyout prices – which would redistribute allocation of costs between years. The total cost of these alternatives would be similar to those illustrated, though by front-loading the support to marine projects, exposure to risk could be reduced perhaps leading to cost savings that reduce the amount of support required. Further consideration of such options is outside the scope of this report.

Impact on other renewables

The additional volume of marine generation brought on through the Marine Obligation could depress ROC prices – potentially to the detriment of investment in other marginal renewable technologies – typically dedicated biomass plant and offshore wind. The extent to which the Marine Obligation could affect other renewables will be determined by the size of the Marine Obligation and the level of compliance with it. Whilst additional marine generation will depress ROC prices, a shortfall in marine ROCs could increase recycling payments partially, or fully offsetting this effect. In Volume 2 of our report we present an assessment of the magnitude of the potential impact and assess the degree of additionality and substitution that the Marine Obligation could create – against scenarios for the size of the obligation, level of compliance and recycling mechanisms adopted.

Our analysis suggests that only in the High Sustained Growth scenario would there be any material impact on ROC prices and substitution between marine and other renewables. Even then, only if there was a high level of compliance with this scenario, or no recycling of marine buy-out payments to standard ROCs, would ROC values be significantly reduced – by up to £3/MWh. In this worst-case scenario, the reduction in ROC values could be sufficient to dissuade investment in some offshore wind projects from 2015 onwards. We calculate that around 500 MW could be displaced. Taking account of the growth in marine generation, there could be a net loss of around 300 GWh of renewable generation in the period to 2027. This is immaterial, set against total renewable generation over the period or around 700 TWh. In all other scenarios considered, the impact would be less than £1/MWh, and could potentially be positive in some years, with additional recycling credits exceeding the dilution effect on ROC values. Under these scenarios the Marine Obligation would barely lead to additional renewable development.

Wider economic impacts

It is likely that the full costs suppliers incur in complying with their Marine Obligation will be passed on to consumers. Experience from the Renewables Obligation to date suggests that suppliers pass through the full cost of the buy-out price on a relevant proportion of the consumers demand, corresponding to the annual level of the obligation. With the Marine Obligation, suppliers will only incur the additional costs in respect of sales within Scotland. We have assumed that all these costs will be recovered from consumers in Scotland, as competition is likely to prevent suppliers cross-subsidising between regional markets[16]. In Figure 12 we assess the annual costs of the support mechanism and the impacts on energy costs to consumers in Scotland, for the constrained support cost scenario. Increases in electricity costs to consumers arsing from the additional support are presented as percentages of projected baseline power prices in each year without the additional support. The additional cost increases year-on-year as the quantity of marine generation supported by the Marine Obligation increases. Hence the maximum increase is in 2027 if the size of the Marine Obligation continues increasing up to 2027.

[16] Although there is a single wholesale electricity market and transmission system in Great Britain, there are in effect 14 regional retail markets, reflecting the 14 Distribution Network Operator (DNO) zones – each of which sets separate distribution tariffs. As electricity suppliers currently differentiate their charges by region to reflect local cost variations, we believe this will continue under the Marine Obligation, thereby potentially increasing charges to consumers in Scotland above those in England and Wales.

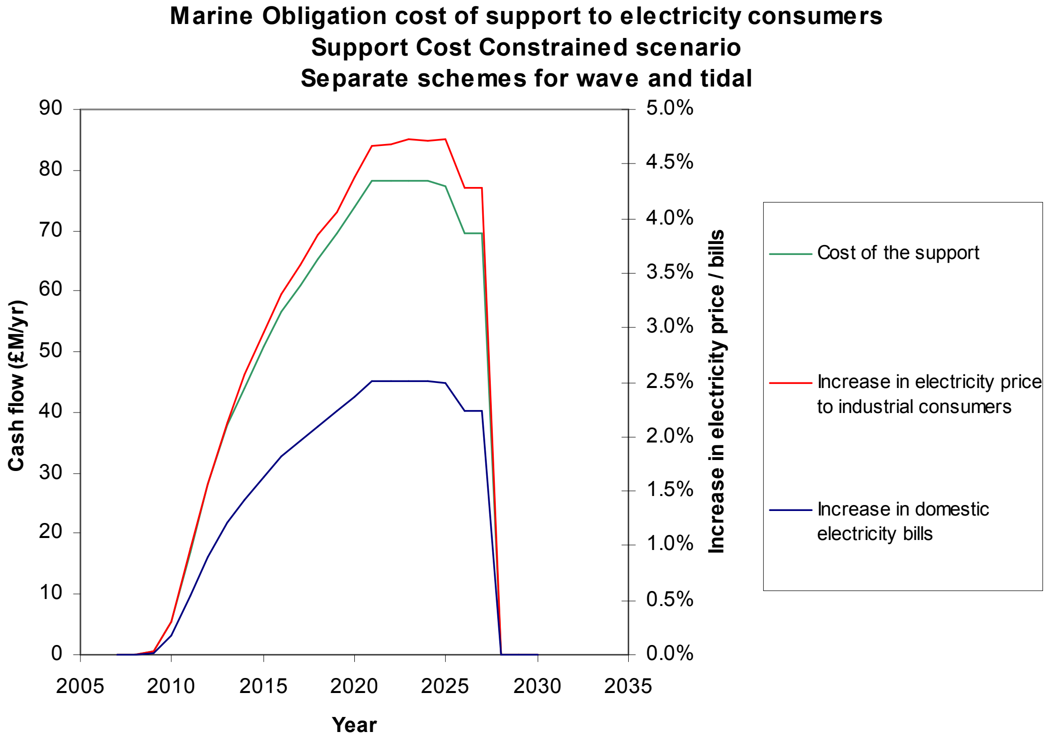


Figure 12 Increase in electricity prices – Support Cost Constrained Scenario with Separate Schemes for Wave and Tidal

While electricity prices have risen in recent months by more than these amounts, it can be seen that the additional cost to electricity consumers should not be considered insignificant. The cost increases presented are for the additional support for marine only. They do not allow for the cumulative impact of the additional support and the standard ROS, or how the latter may increase in the future.

10 CONCLUSIONS

Our detailed conclusions and recommendations are presented in Volume 2, our detailed report. In this summary report we conclude that:

- Estimates of the costs and performance of marine energy systems cover a broad range due to the limited operational experience to date, with only a handful of devices having been tested at any scale. This leads to uncertainty in the future costs of the devices when manufactured and deployed in arrays in full-scale power projects. The early stage of development also means that the practical issues, such as planning requirements and installation timescales are not certain.

- Although the future costs of marine energy are uncertain, our analysis shows that a high level of revenue support is required to support the initial projects. The level of support that is required to provide rates of return which should be attractive to investors range from £210/MWh for offshore wave to £105/MWh for tidal stream in the early stages, reducing to £60/MWh in the mid phase remaining under the existing ROS. So that these estimates are robust we have used information from those developers who have the most operational experience and hence the most robust view of likely costs. Our models for specific technologies show early generating costs within the lower central ranges given by the Carbon Trust in their Future Marine Energy report.

- The growth of marine energy capacity and output will be dependent upon the scale of support provided, the size of the obligation, and the response of the industry to grow investment and deliver capacity. To address this we have developed two scenarios for growth of marine. These are both based on a review of the energy resource, our views on the likely order in which different types of marine generation will be deployed (from early projects through to the long-term), and the capacity of the industry to develop and install devices. Hence the scenarios recognise issues such as the early development of tidal stream in shallow water sites leading to the development of sites in deeper water, and the long-term opportunity for offshore wave on a large scale.

  However, we have also recognised the need to support the range of technologies sooner rather than later in order to maximise the opportunities, and that there may be benefits from supporting a diversity of devices, at least in the short term. Such benefits include reducing the reliance on the growth of marine generation as a whole on the success of specific devices, supporting devices which in the longer term may be of lower cost than the early leaders, supporting technologies which provide potential for sustained growth of the marine sector and greater exploitation of marine renewable resources.

  A successful support scheme needs to balance the need to provide a mechanism that promotes competition between devices, against the higher cost needed to support some of the devices that are further from practical deployment. Rather than using revenue support, there may be alternative means outside the mechanism investigated in this report of assisting devices in the latter category. We anticipate that market competition and commercial returns will lead to consolidation of the industry and a focus on a few successful devices, as has happened with the wind industry.

Scenarios were developed which take different views on the level of marine that can be supported taking into account the costs of the support in the long term. The Support Cost Constrained scenario assumes a high early increase in build rate to maximise the benefits of early investment in marine and the ensuing unit cost reductions, but constrains the supported build rate in the medium term, in order to constrain the build up of costs and potential adverse impacts. In the long term, our analysis indicates that some form of support additional to the basic electricity revenue may be required for the financial viability of marine projects commissioned beyond 2020 and 2027. Hence it may not be practicable to extend the MO for new build beyond 2020 within the existing ROS and its cessation in 2027. The Support Cost Constrained scenario results in a total installed capacity of 330 MW in 2020.

The High Sustained Growth scenario assumes support for increasing build rates up to 2027 to achieve further economies of scale, and support a sustained growing marine industry. This results in a total installed capacity of 650 MW in 2020, which is consistent with the anticipated contribution from marine to meet the Scottish Executive's aspiration of 40% or electricity generation from renewables by 2020.

- The recommended structure for a support mechanism within the ROS could operate through a number of phases (potentially two or three). In the early phase a high level of support is needed to encourage deployment; support falls significantly in the mid phase. The need for long-term support will depend on whether the ROS is extended beyond 2027. While the level of support is high in the early phase, the total amount of support to be claimed in the early phase will be modest – both through scheme design, and because there is likely to be a relatively low installed capacity. The provision of support for later projects of much greater aggregate capacity will drive the costs and impacts of the support, the cost of the support peaking in the long-term due to commitments made for projects implemented in the mid term. In total the amount of additional support is assessed to be a little over £1 billion under the Support Cost Constrained scenario and around £1.7 billion under the High Sustained Growth to 2020 scenario. The latter figure increases to £2.0 billion if the further supported growth was to be extended to 2027.
- The Support Cost Constrained scenario would not impact significantly on the development of other renewables. As such we project that under the Support Cost Constrained scenario the Marine Obligation would induce an additional 300 MW of renewable capacity generating over 10 TWh of renewable generation over the period to 2027, a potential carbon saving[17] of 4 $MtCO_2$. The High Sustained Growth scenario could reduce investment in offshore wind projects from 2015, perhaps substituting up to 500 MW of capacity. Taking account of the additional marine capacity deployed under this scenario we do not envisage any significant net reduction in renewable generation.
- There will be significant wider impacts in terms of the jobs created and the pass through of costs to electricity consumers in Scotland. The analysis estimated creation of up to 2,340 direct, indirect and induced jobs. In order to establish the cost increases to customers that could result from additional support to marine energy projects, a forward view of electricity prices without any additional marine support has been taken. This forms a baseline projection of electricity prices. The increases in electricity costs for domestic customers of up to 7.3% and for industrial consumers of up to 13.9% in 2027 are therefore increases attributable to the additional support, above the baseline projection, assuming that the costs

[17] Assumes a carbon saving from the displacement of conventional power generation of 430 kg of CO_2 per MWh of renewable generation.

are only passed on to consumers in Scotland. The additional cost increases year-on-year as the quantity of marine generation supported by the Marine Obligation increases. Hence the maximum increase is in 2027 if the size of the Marine Obligation continues increasing up to 2027.

The following table summarises the key results of the analysis under both scenarios:

	Support Cost Constrained Increasing Obligation up to year 2020	**High Sustained Growth Increasing Obligation up to year 2027**
Capacity in year 2020 (MW)	330	650
Annual output in year 2020 (MWh)	821,970	1,571,500
Total cost of Support (£ billion to 2027)	1.1	2.0
Peak support (£ Million)	78 in 2020	226 in 2027
Net Jobs created or maintained in year 2020	630	2,340
Peak impact on domestic electricity prices (%)	2.5% in 2021	7.3% in 2027
Peak impact on industrial electricity prices (%)	4.7% in 2021	13.9% in 2027
Private Sector Capital Investment (£ Million)	450 to 2020	1,590 to 2027

Table 4 Summary of results for two growth scenarios

Some policy decisions will be necessary in developing the form of the additional support, and establishing the levels and phasing of the support going forward. Such policy decisions will include balancing the following:

- The degree of risk which is acceptable to the success of the additional support in stimulating marine renewables on a substantial scale;
- The desired growth and diversity of technology types and specific technologies;
- The desired diversity of investment;
- The prospects for sustained marine industry growth and job creation;
- The cost of the support and wider impacts.

Specific items to be confirmed include the following:

- The size of the Obligation;
- The buy-out prices;
- The number of phases and transition dates:
- The arrangements for accreditation of projects to projects, and the duration of the accreditation for each project;
- Whether there will be separate Obligations for wave and tidal, or other means of assigning support between wave and tidal technologies or sites. Whether this concept will be extended to distinguish between deep and shallow water tidal;
- Whether there will be managed adjustment or a Marine ROC market response to actual costs and growth;

- Headroom arrangements;
- The recycling option to be adopted;
- Whether there is scope for extension of the ROS beyond 2027.