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Wave and Tidal Energy in the UK

Conquering Challenges, Generating Growth

February 2013

RUK13-008-8

Contents

Document Version:
Issue 2 - Feb 2013

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Executive Summary

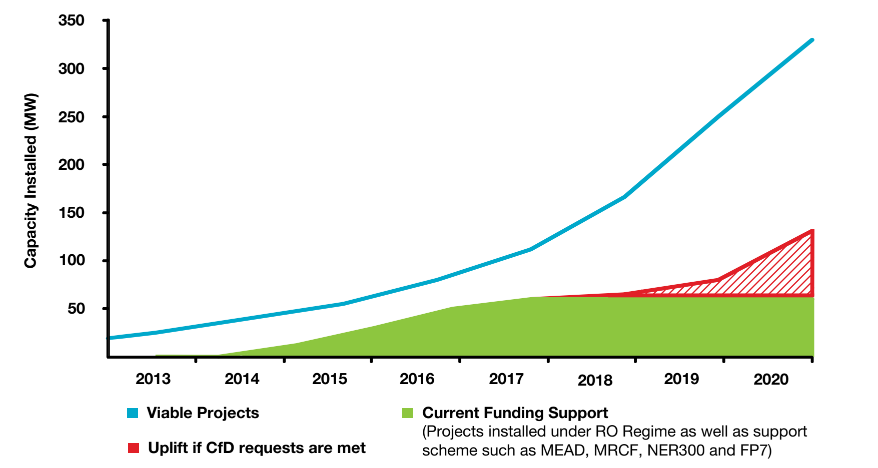
There is widespread understanding that the UK's wave and tidal energy is a strategic priority for our emerging green economy. We enjoy substantial natural resources, strength in depth in our technical capability, and an eye on the prize in terms of the scope of a future UK and global market in wave and tidal stream technology.

The potential benefits of wave and tidal energy development to the UK are well understood - the marine energy industry has been forecast to be worth £6.1 billion to the UK economy by 2035, creating nearly 20,000 jobs. With a burgeoning export market, the rewards could be greater still. The potential for predictable and consistent marine energy to moderate requirements for balancing plant can have a substantial impact on the cost of increasing the uptake of other variable renewables generation.

The wave and tidal energy industries are making rapid progress in delivering this goal as they move from single device demonstration to installing multi-device arrays in UK waters. Industry know-how, backed by a long term commitment from Government means that we now have world-leading technologies being built and demonstrated in the UK, by UK and international companies, utilising a UK supply chain delivering sustainable employment.

The last year has seen an immense amount of activity. There have been 12 large-scale prototype devices deployed or installed around the UK in the last year – more than the rest of the world combined, and seabed leases awarded for over 1.8GW of power production, including the first Northern Ireland leasing round. Major engineering firms such as Siemens, Andritz, Voith, Alstom and ABB are working hand in glove with major utilities such as SSE, E.ON, RWE Innogy, Vattenfall, EDF and ScottishPower Renewables to take our industry forwards, while UK is cementing its academic, testing and industrial pre-eminence. The UK and Scottish Governments have provided a consistent strong signal of commitment. Programmes such as the Marine Energy Array Demonstrator and Marine Renewables Commercialisation Fund, backed up by support from the Renewables Obligation have been introduced, and the plans for the first small arrays are being progressed.

Figure 1: Likely deployment for UK Wave and Tidal energy (based on current grant programs such as MEAD, MRCF, NER 300 and FP7)



Determining the deployment pipeline

One challenge facing the sector is clarity on expected levels of deployment over the next few years. Government and industry need to have a shared view of how wave and tidal will develop, as well as the costs and benefits of this support. To make sure that industry is basing its projections on realistic delivery scenarios, RenewableUK has worked closely with its members to update and agree authoritative deployment information. We have used the list of wave and tidal leases from The Crown Estate as a starting point before developing a pipeline of projects that are in a position to gain grid connection and consent approval in the relevant timeframe. These projects are shown as "Viable Projects" in the figure above.

Direct capital support from the UK Government, Scottish Government and European Union will facilitate the development of a small number of projects. These are identified in the scenario "Current Funding Support" in Figure 1. To date this is the best available forecast of anticipated deployment.

This progress has led to the wave and tidal sectors gaining significant momentum, and confidence in its ability to deploy technology and reduce cost over time. However, a critical junction looms. Between now and 2017 industry must deliver a first round of demonstration projects, and begin work on a first generation of multi-device arrays. However, between 2014 and 2017 industry will move from the Renewables Obligation (RO) into the new Contract for Difference (CfD) regime which underpins Electricity Market Reform (EMR). At the same time, delays in building out new infrastructure, and concerns over costs of transmission charging are adding risk, and frustrating the ability of developers to press ahead.

Perhaps the most significant unknown for the UK's burgeoning wave and tidal sector is the EMR process. Investment in wave and tidal energy projects is now focusing beyond 2017 and the end of the Renewables Obligation regime.

Correctly set up, EMR can be a springboard for successful delivery of wave and tidal across the second part of this decade into the next, when a second generation of commercial arrays will be in operation, delivering the job benefits and cost reductions sought. However, should the EMR regime not inspire confidence in the future of the UK wave and tidal sector, progress made to date will be threatened. The transition from the RO to the CfD falls in the middle of the delivery period for the first arrays. As such, this policy shift holds the potential to halt or catalyse the development of the industry.

To be this springboard, EMR needs to deliver the following:

- **An initial strike price of £280–300 per MWh for tidal stream energy and £300–320 for wave energy**, which is required to catalyse the industry and allow the necessary economies of scale and learning to be realised. The knock on effect of this initial pump priming will be increased deployment and lower strike prices for a 2nd generation of schemes.
- **Deferment of technology-neutral auctions**, as premature exposure to such mechanisms would be extremely detrimental to this maturing renewable energy source. Offshore wind will represent a good comparator in due course, and it has to be recognised that any new technology, by definition, requires time to become cost convergent.
- **Contracts of 20 years** are required to allow adequate investment return periods. The reduction of a 20-year Renewables Obligation period to a 15-year CfD period is a large risk for new technologies. CfD length for new technologies needs to be longer than that for established technologies. **Any reduction in the contract length would need to be offset by an appropriate uplift in Strike Price.**
- **Certainty of sufficient CfD capacity** within the Levy Control Framework through a specific allocation to marine technologies. This will be particularly important until cost convergence occurs, or the CfD mechanism will simply stifle market entry for any new technology.
- **Ability to guarantee a route to market** by ensuring generators can access the reference price is critical to success in the short to medium term whilst the industry reaches scale.
- **Index-linked strike prices** would contribute meaningfully to the development of the industry by addressing inflationary issues. Linking the strike price to the Consumer Price Index, as opposed to the Retail Price Index, would heighten requirements for revenue support.

The creation and implementation of a market system that will continue to provide certainty, durability and confidence to investors, developers and the supply chain will only serve to consolidate further the UK's position as the global leader in this emerging sector, and generate a local market, with key players capable of exporting technology and expertise.

Wave and tidal stream energy has one of the most compelling cases for rapid initial cost of energy reduction, so the high strike prices required to underpin the next stages of commercialisation must be viewed as a short-term feeder rather than a long-term provision. However, industry is very mindful of government's concerns about the overall cost to consumers and the constraints under the Levy Control Framework. Cost to the consumer can be managed as part of CfD design, or use of project caps similar to those used in the Renewables Obligation. Overall costs will be modest due to the moderate output in the initial phase of small-scale demonstration projects currently being developed. In addition, the long lead in times for larger-scale projects provides the visibility to enable the support levels to be fine-tuned as the industry moves to commercial-scale arrays.

Managing Risk Effectively

The second element of this work has to look at the risks faced by the wave and tidal sectors. Our analysis of the primary risks is summarised below.

Although the prize is big, wave and tidal developers face a number of hurdles in their journey to large scale deployment. These challenges relate to risks associated with securing finance, solving technology challenges, gaining connection and access to the UK's grid network, and managing consenting processes.

Management of these risks in an effective, timely manner will be important to ensure successful deployment, as well as to deliver rapid reductions in the cost of energy. An important point is that these risks are best managed by industry and government working hand-in-glove. In this way government will be able to manage costs to the consumer as well as maximise delivery of the benefits this sector offers to the UK economy.

For example technology risks can be managed through marshalling private sector innovation, academic expertise and public sector innovation funds such as the new Offshore Renewable Energy Catapult. Risks associated with grid can be managed by effective regulation,

RISKS				MITIGATION
Category	**The event**	**Likelihood of occurrence**	**Potential impact**	**Possible mitigation strategies**
Finance	Private sector investors lack confidence in EMR regime due to ongoing uncertainty	Mid – Issues around strike price, contract length, auctions and the route to market are yet to be resolved. DECC is still working on EMR details, so these concerns may yet be addressed.	Mid-high – Lack of clear long-term market leads investors/Manufacturers to pull out of wave and tidal. Without adequate revenue support, future projects will not be taken forward.	Ensure that the CfD strike price is in line with industry requirements based on evidence of costs. Address route to market concerns.
Finance	Divergence of development trajectories for wave and tidal	Mid – there is a perception that tidal stream technologies may be further down the cost curve and closer to array deployment than their wave counterparts.	High – tidal may benefit disproportionately from array funding, whilst wave is neglected.	More sophisticated design of public support schemes to ensure money is genuinely accessible to both sets of technologies.
Technology development	Wave and tidal cost reduction progression is slower than that of competing technologies	Mid-high – Cost trajectory highly uncertain due to nascent technology status.	High – Diverts attention and funding of both policymakers and manufacturers.	Ringfence a proportion of Levy Control Framework funding for wave and tidal and agree a targeted, long term research and development programme that promotes cost reduction.
Technology development	Survivability of devices remains a major technical challenge	High – most devices to date have been in the water for short periods (less than 1 year) so survivability data is limited.	High – reputational damage deters investors.	Learning from the first arrays.
Grid	Delays to grid connections	High – grid delays are now expected in provision of connections to Scottish islands.	High – delays of years to some projects. First small arrays may miss option for support through RO. Uncertainty may result in some projects being abandoned.	Implementation of special case of 'Connect and Manage' (C&M) for W&T arrays, i.e. with higher levels of generator curtailment in advance of provision of full connection capacity, along with consideration of RO-EMR transition measures.
Grid	Grid costs very high due to site location, compared to average for other technologies, e.g. onshore wind.	High	High – Could easily be ten times the cost per MWh for typical onshore wind sites.	Ensure these costs are understood in setting wave and tidal capital or revenue financial support.
Consenting	Unduly onerous requirements pre and post deployment deployment	High – the scientific impact is not well understood.	Mid – Punishes first movers. Causes delays because developers are unwilling to take on financial exposure before achieving consent. Can be costly to engage with complex procedures.	Frank and open discussion between industry and consenting bodies about where the burden of evidence should lie. Increase prominence of wave and tidal in the Offshore Renewable Energy Licencing Group
Consenting				Survey, deploy, monitor policy approach to be implemented pragmatically in face of application of precautionary principle by statutory consultees

timely provision of connection upgrades, and developers having sufficient confidence in a long term market to sign onto connection agreements.

We will use this risk analysis as part of ongoing partnership work between government and industry to manage risk and ensure successful deployment of wave and tidal generation over the next few critical years as the sector transitions from initial full scale demonstration to the larger scale deployment vital to realising the benefits of this new generation technology.

By understanding the risks impacting wave and tidal projects, the industry can work with other stakeholders to develop viable strategies for overcoming them. Only by engaging with the challenges together can they be conquered. In short, it is time to get real about risk. Our analysis has identified the primary risks facing the industry and suggested possible mitigations for them. This will help to educate the range of stakeholders on the activities they should engage in to move the industry forward.

The greater understanding of our current position and the potential risks is a sign of the growing maturity of the industry as we grapple with how best to progress. The growing sense of realism in our deployment and cost projections and greater engagement with the issues ensures that we are firmly on the pathway to commercialisation. With this shared vision, the industry can achieve the potential it promises and deliver meaningful amounts of electricity and the full range of economic and environmental benefits.

Introduction

As a generation sector, wave and tidal is one that attracts significant support and interest from the public, politicians and business community. There is a clear understanding that to deliver on the potential of this sector is required a long term programme with industry and government working closely together. However, to make this effective there is a need for certainty on both sides.

Government needs to have certainty on cost and levels of deployment. Industry needs certainty around the wider policy framework, so that it can focus on securing finance, deploying initial projects and solving technical challenges. Significant progress has been made in the last year with consent approvals for the leading array projects and the start of deployment of multidevice arrays.

However, despite the current momentum, there are uncertainties in the industry as to how some critical risks are managed. Risks can be best managed when shared between relevant parties who can control them, and to do this there needs to be a clear understanding of what these risks are.

One risk regularly commented on is Electricity Market Reform (EMR). This reform will be introduced at a crucial stage for wave and tidal as it gains confidence and takes deployment to the next level. The Renewables Obligation has provided a sound framework for the development of the technology to date, on the strength of increasing subsidy levels, but the long-term signals are still missing that are required for manufacturers to continue to invest the large amounts of R&D that are required to get the industry to commerciality. It is critical that early and clear signals are given that the sector will have a clear place within the EMR process and that appropriate provisions will be made in terms of an adequate volume of Contracts for Difference (CfDs) at an appropriate strike price.

The debate around EMR, and the support the industry requires from it, has focussed our minds on the current status of the industry. Engaging closely with industry, primarily through RenewableUK's Marine Strategy Group and the Marine Energy Programme Board's EMR subgroup, both formed of the industry's leading experts, we have sought to develop credible and realistic deployment and cost forecasts. Gathering all available evidence, including The Crown Estate's list of leases, consenting applications, grid contracts and data submitted through government grant programmes, we have developed authoritative evidence that can be relied upon by industry and policy makers.

This work has enabled us to gain a realistic understanding of the deployment pipeline and cost trajectory for the industry. Perhaps more importantly, it has enabled us to match our support request closely to what we need to create a thriving industry. Basing our policy asks on robust evidence of costs and deployment allows us to engage more effectively with policy makers and work with our government to develop the right policy for the industry.

Based on this work, we have been able to work with industry to frame a clear answer to the question of how we can make sure that EMR acts as the vital springboard to the next phase of this maturing industry. This report sets out how EMR – and in particular the CfD mechanism - can be responsive to the needs of wave and tidal generation.

However, while significant, EMR is only one of a number of risks faced by the wave and tidal sector. If we are to fully capitalise on our position and potential, it is vital that we develop a better understanding of the full range of risks we face. We have worked with our members to categorise and set out what industry sees as the key risks we face between now and 2017.

This report aims to set out how best Government and industry can best work together to manage risks, turning challenges into opportunities. It is also a demonstration of the maturity of the sector in facing up to these challenges by providing realistic, hard-headed analysis of what industry must do to play its part in overcoming them and delivering the wider benefits offered by this sector.

Health and Safety: Challenges & Opportunities

The rapid progress to commercial viability has rightly highlighted the critical importance of aiming for the highest health & safety standards for the wave and tidal sector. Health and safety is an integral linchpin in reducing risks and driving down costs for all technologies – whatever their state of development. In this context, embedding health and safety into the whole life cycle decision making (e.g. Safety through Design) of the development of wave and tidal projects is seen as a critical success factor in terms of safety and economics.

RenewableUK in partnership with key stakeholders has been at the forefront in raising health and safety standards by the development of global leading industry guidance, and enabling the development of relevant training and competence standards. However in such a rapidly developing sector it is acknowledged much more will need to be done.

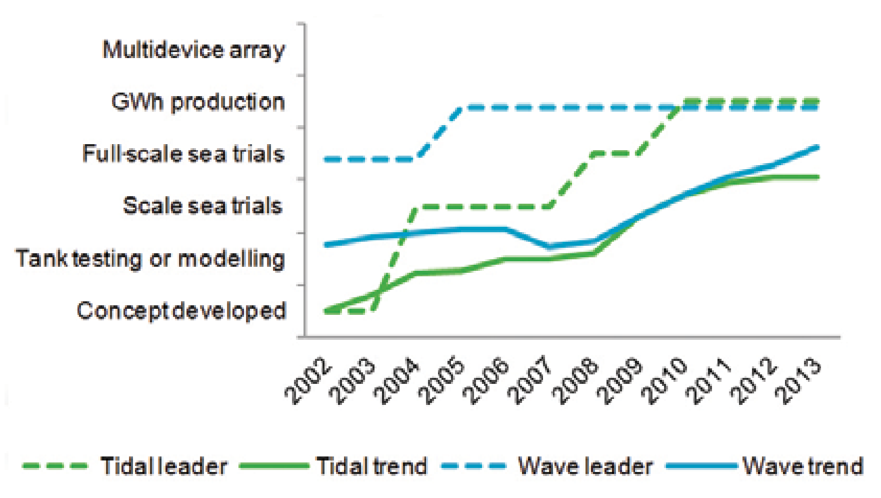
Responsibility for delivering health and safety standards resides with the duty holders throughout the wave and tidal supply chain. However, it is also self evident that greater clarity in the policy and revenue support mechanisms would enable earlier investment and decision making in key health and safety related matters, resulting in more significant cost and risk reduction measures being put in place at the earliest opportunity.

Current State and Potential of the Industry

The wave and tidal stream energy industries have continued to move towards commercial viability as an increasing number of devices move through the demonstration phase. We now have development plans for the first arrays and several world-leading projects in planning.

The expansion of the industry is thanks in no small part to the comprehensive package of support that the UK and Scottish Governments have provided to the industry. In particular, the consistent provision of 5 ROCs per Megawatt hour (MWh) of marine energy production has focused the industry on developing utility-scale projects since its introduction under the Marine Supply Obligation in 2008. This support has catalysed a large amount of activity in the industry and enhanced the attractiveness of first array projects to a range of investors, in parallel with setting the business and investment context for technology development and manufacturing. The result is a thriving and diverse wave and tidal energy industry in the UK, with the future potential to export this globally.

Figure 2: Device Deployment Milestones (Source, BVG Associates)



Deployment and the market

Between 2010 and 2012 The Crown Estate has licensed almost 40 wave and tidal sites throughout the UK. While the vast majority are in Scottish waters, sites are also being developed as far and wide as Falmouth in the south west of England and Torr Head in Northern Ireland. These sites mean that there is now a substantial pipeline of potential capacity, with likely deployment of 100 to 200MW of devices expected by the end of 2020.

What's more over the last few years it has been clear that a new development model for wave and tidal energy is emerging. There has been a significant shift towards project development, with more developers now taking on leases before agreeing a contract with a device developer. This step away from device developers taking the lead in both technology and site development us a sign that the sector is maturing and beginning to resemble that of the wider energy market.

The past year has seen an unprecedented investment into the sector, with large engineering firms taking controlling stakes in a number of manufacturers.

- Andritz Hydro acquired a majority share in Hammerfest Strøm, forming Andritz Hydro Hammerfest.
- Siemens is now the owner of Marine Current Turbines.
- ABB Technology Ventures invested £5 million in Scotrenewables Tidal Power. This complements ABB's investment in Aquamarine Power in 2011.
- Alstom acquired TGL from Rolls-Royce for £65 million.
- DCNS has stated that it intends to increase its holding in OpenHydro to 60%, at a cost equivalent to approximately £110 million.

This indicates that significant players have confidence that marine energy has the potential to become an important part of the energy industry.

The industry is preparing for GWh production and multidevice arrays, as can be seen in Figure 2, updated from previous work published by RenewableUK in 2012. Although power production has not yet moved significantly beyond that achieved by commercial demonstration projects, both technical and commercial development has continued with significant milestones being reached.

Larger projects are now being approved, including MeyGen's 10MW Phase 1 project, and utility developer ScottishPower Renewables (SPR) has obtained consent for the 10MW Sound of Islay Tidal Array, for which Andritz Hydro Hammerfest has been assigned as the preferred device supplier.

In 2012, wave projects have focused on improving device performance, by extending the "operating envelope" these machines will generate in. Both Aquamarine Power and Pelamis Wave Power, for example, have each been demonstrating device operation in increasingly challenging conditions, enabling them to accumulate more operating experience and increase investor confidence in the viability of their technology.

During the past year, the full-scale devices in Table 1 were installed or operating around the UK.

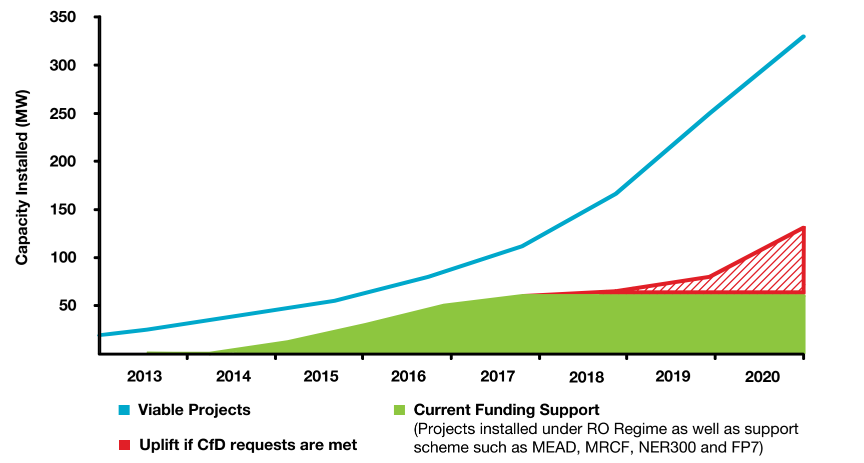
Table 1: Full Scale Devices Installed or Currently Operating in UK Waters

	Operator	Device	Location
Tidal	Andritz Hydro Hammerfest	HS1000	Fall of Warness, EMEC
	Marine Current Turbines	SeaGen	Strangford Lough, Northern Ireland
	Neptune Renewable Energy	Proteus	North Humberside
	OpenHydro	Open Centre turbine	Fall of Warness, EMEC
	Scotrenewables Tidal Power	SR250	Fall of Warness, EMEC
	Alstom	DeepGen 1MW	Fall of Warness, EMEC
WAVE	Aquamarine Power	Oyster 800	Billia Croo, EMEC
	E.ON	Pelamis P2	Billia Croo, EMEC
	Fred.Olsen	Bolt "Lifesaver"	FaBTest, Cornwall
	ScottishPower Renewables	Pelamis P2	Billia Croo, EMEC
	Seatricity	Oceanus	Billia Croo, EMEC
	Wello	Penguin	Billia Croo, EMEC

Future outlook

One challenge facing the sector is clarity on expected levels of deployment over the next few years. To make sure that industry is basing its projections on realistic delivery scenarios, RenewableUK has worked closely with its members to update and agree authoritative deployment information able to be relied upon by Government and industry. We have used the list of wave and tidal leases from The Crown Estate as a starting point before developing a pipeline of projects that are in a position to gain grid connection and consent approval in the relevant timeframe. These projects are shown as "Viable Projects" in Figure 1.

Figure 1: Likely deployment for UK Wave and Tidal energy (based on current grant programs such as MEAD, MRCF, NER 300 and FP7)



It is noted that financing is a primary constraint to the development of the industry. The current government capital support stream will facilitate the development of a small number of projects as identified in the scenario "Current Funding Support" in Figure 1. This is based on the projects that will benefit from Marine Energy Array Demonstrator (MEAD) and Marine Renewables Commercialisation Fund (MRCF) support. It also accounts for various European demonstration funding streams (e.g. NER300 and FP7). To date this is the best available forecast of anticipated deployment.

Crucially, the current investment environment is beset with uncertainty around the level of future revenue support that the industry can expect. There is a risk of a funding hiatus if the revenue support is not attractive enough to encourage project financers to take on the risk of the initial precommercial projects (planned for deployment in 2014–18).

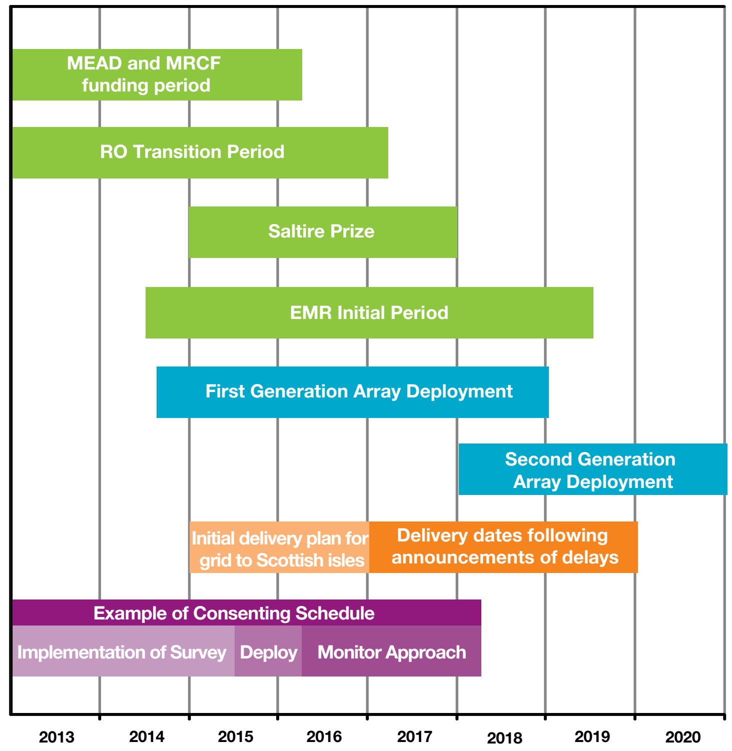
A significant factor in the viability of these projects are the series of decisions that Government will make over how to support wave and tidal projects under EMR. Any reduction in the support offered through CfDs would risk halting installation and jeopardising the UK's global lead.

Taking consideration of the various constraints and challenges currently facing the industry, a strike price of £280–300 per MWh for tidal stream energy and £300–320 per MWh for wave energy would be the minimum requirement to provide adequate returns for investors over a 20-year period and to maintain momentum in the sector. Any shortening of the contract length would need to be offset by an uplift in the strike price granted to the wave and tidal industries.

All things being equal, this should enable project developers to reduce costs and encourage the development of additional projects or increase generation capacity within specific projects. Without this, investor appetite for this novel sector could falter at such a critical time.

If an appropriate level of revenue support could be offered to marine energy, it is thought that the "actual" deployment could deliver a figure approaching full realisation of the "Viable Projects" scenario. Increased deployment will inevitably lead to increased innovation as well as decreased vulnerability to external factors.

Figure 3: Policy, Infrastructure and Delivery Timeline for Wave and Tidal Energy



When you examine the timescales of the various policy measures and infrastructural constraints against the deployment plans of the industry, it is clear that there is a high level of disruption to the plans of project developers. While there is the urgency on the part of developers to install projects before the cut-off date for the RO regime and the deadlines of the upfront capital support schemes, there are delays caused by lack of access to grid infrastructure and the length of the consenting process.

To ensure sustained deployment of wave and tidal devices, it is essential that stakeholders work together to eliminate inconsistencies and delays. In particular, the uncertainty around the provision and charging measures of transmission infrastructure needs urgent attention. Removing non-technical constraints to the development of the industry would enable a higher level of deployment and the full realisation of industry potential.

The Benefits of Developing Wave and Tidal in the UK

The wave and tidal energy sector in the UK is now on the verge of commercialisation and there is the potential for strong growth in the sector over the next decade, as the first small-scale arrays become operational in 2016/17. Sustained investment is required, however, for the UK to capitalise on its early R&D lead.

This chapter examines some of the current benefits to the UK resulting from the wave and tidal sector, and the potential benefits looking forward to 2020 and beyond.

Decarbonised energy system

The UK has legally binding carbon emission reduction targets, and the wave and tidal sector could have a significant impact on reaching 2050 targets.

Table 2: CO_2 displaced by wave and tidal sector in 2017 and 2020 under two deployment scenarios

Scenario	Year	Cumulative Capacity Deployed (MW)	CO_2 Displaced (tonnes/year)
Expected Deployment	2017	59	78,000
	2020	130	171,400
Viable Projects	2017	120	158,200
	2020	340	448,300

The total amount of wave energy in UK and Irish waters is estimated at 840TWh/year,[1] equivalent to approximately 50% of the total European wave energy resource. The tidal stream energy resource is estimated to be 95TWh/year.[2] The tidal range energy resource, both barrage and lagoon is estimated to be 121TWh/year,[3] equivalent to approximately 25% of the European tidal energy resource. Of this, some 50TWh/year of wave energy resource, 18TWh/year[4] of tidal stream energy resource and 30TWh/year[5] of tidal range energy resource has been assessed as being economically recoverable with today's technologies. To put these figures in context, current UK annual electricity demand is about 350TWh/year.

If the economically recoverable marine energy resource around the UK was fully exploited and displaced conventional fossil-fuel generation, this could reduce the carbon dioxide output from the UK's energy system by 42 million tonnes per year, using DECC's conservative carbon saving of 0.43kg of CO2 per kWh for wave and tidal electricity generating assets replacing combined cycle gas turbine (CCGT) power stations.

Two scenarios are given in Table 2 for deployment up to 2020, along with the resulting carbon dioxide displaced, given an assumed capacity factor of 35%.

Socioeconomic benefits

Over recent years the UK has developed a range of technologies to access the vast marine renewable energy resource off its coastline. The sector is already contributing to the UK economy, generating investment and jobs as well as low-carbon electricity.

Low-carbon economy: we have the opportunity to seize the first-mover advantage, building a strong marine energy sector, well equipped to supply not only UK projects but those overseas also.

The wave and tidal industry, as it matures, is supporting an increasing number of jobs. Scottish Renewables has calculated that the total full-time equivalent (FTE) employment in wave and tidal energy development and

1. *Wave Energy - Industry Response to the National Grid CfD for Strike Prices V5*, RenewableUK, 2013
2. *UK Wave and Tidal Key Resource Areas Project*, The Crown Estate, 2012 (available at www.thecrownestate.co.uk/media/355255/uk-wave-and-tidal-key-resource-areas-project.pdf)
3. Ibid
4. *Phase II UK Tidal Stream Resource Assessment*, Black & Veatch, 2005
5. Ibid

supply chain activities in Scotland alone is currently over 500.[6] It has been estimated that a similar level of additional full time jobs has been achieved in the rest of the UK. This is increasing as technology continues to be developed and more projects are announced.

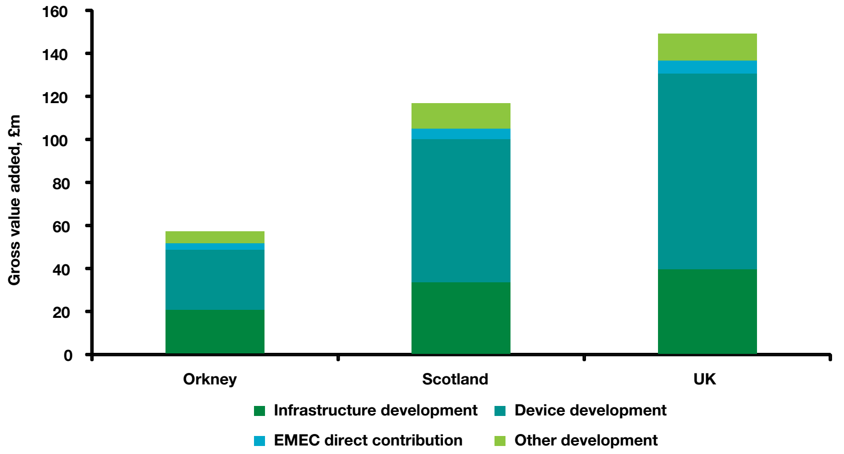
Nowhere is this more apparent than in Orkney, where early support has led to the establishment of a strong wave and tidal economy, with the European Marine Energy Centre (EMEC) contributing an estimated £149m to Orkney since 2003 and the sector currently employing 250 people (see text box). Many of these are highly skilled jobs, and the UK's expertise in marine energy is starting to be sought after globally.

The direct and indirect jobs supported in the UK and the benefits to the economy will increase as a UK-based supply chain establishes and the pace of installation increases. The leading wave device manufacturers estimate that the UK content of their capital spend is already over 50%. This demonstrates the positive steps being taken by wave and tidal stakeholders to nurture their supply chains in the UK.

Inward investment: the sector is now attracting global interest and inward investment, with a series of high-profile acquisitions of tidal players made last year. This investment from a number of large international engineering companies has energised the sector, enabling increased pace of development of technologies and a growth in numbers employed both directly and indirectly by the industry. Studies show that public sector investment has leveraged multiples of the amounts of private investment.

It is crucial at this time that investors have strong confidence in both the sector's capability to deliver and the UK Government's long-term commitment to developing the wave and tidal industries. The announcement of enhanced support under the Renewables Obligation (RO) scheme has had a notable impact on the industry.

Figure 4: Economic impact of EMEC, 2003 to 2012



EMEC opened in 2003 and is the world's only grid-connected, full-scale wave and tidal energy converter testing and accreditation facility in real sea conditions. It is a global centre of excellence and is widely credited with playing a significant part in accelerating wave and tidal energy development in the UK and further afield.

Founded with public money, it has been self-supporting since 2010. The investment attracted to Orkney alone by EMEC has far exceeded the initial investment in establishing the facilities and, when the entire UK is considered, the gross value added to the economy has been calculated to be 4.5 times the initial investment cost.[7]

Currently, EMEC employs 22 people directly and supports a further 250 people working in the marine renewables sector in Orkney. It has attracted developers and investment from all around the globe. EMEC has become a centre of expertise and is at the forefront of the development of international standards for the testing of marine technologies. Recently, EMEC has established a number of international collaborations with organisations in Canada, Japan, USA, South Korea and Taiwan.

The cumulative impact throughout the UK is extensive. The figures above are taken from the previously referenced report assessing the economic impact of the centre. It is clear that the establishment of a marine energy centre on Orkney has contributed to the creation of value in the national economy.

Employment and expertise has been created, and a new hub developing wave and tidal energy has been established in Orkney. The centre is likely to expand both its operations and capabilities, bringing ever greater benefits to Orkney, the UK and the marine renewables industry.

6. *Creating an Industry*, Scottish Renewables, 2012
7. *EMEC Economic Impact Assessment May 2012*, Steve Westbrook, 2012

Inward investment attracted in the last year has included:

- Significant investment in device development by major industrials such as ABB, Alstom, Andritz Hydro, DCNS, Siemens and Voith.
- Utility companies SSE, E.ON, Vattenfall, RWE, EDF, GDF Suez and ScottishPower Renewables developing marine renewable power projects in UK waters.

These factors have attracted interest from several of the biggest companies involved in the energy sector. Local studies, such as those conducted by EMEC and Highlands and Islands Enterprise, suggest that the industry is currently achieving a fivefold return on public investment. It is expected that, as investors become more accustomed to marine energy projects and the technology matures, the cost of capital will reduce and new classes of investor will enter the sector.

Export potential: the UK's wave and tidal sector is gaining global recognition and attracting international attention. The expertise of a number of established organisations, such as the testing capabilities at EMEC in Orkney, is being sought from around the world. The generating capacity of devices installed at EMEC last year, predominantly developed in the UK, is more than that of the rest of the world put together.

While the current UK focus is rightly on deploying wave and tidal devices around our coastline, success here should bring us a lead in a longer term world market. Countries around the world have conducted resource studies and feasibility studies into marine energy. The World Energy Council has conservatively estimated the market potential for wave energy alone to be in excess of 2,000TWh/year, representing a capital expenditure of more than £500 billion,[8] assuming 2007 costs.

Global Activity in the Wave and Tidal Sector

Canada
Canada's Marine Renewable Energy Technology Roadmap sets out the path to the commercialisation of marine energy in Canada. This is supported by funding via the ecoENERGY Innovation Initiative. The Fundy Ocean Research Centre for Energy (FORCE) in Nova Scotia acts as an industry incubator similar to EMEC.

China
A national project has been started to construct a pilot zone and offshore test sites.

France
Brittany, the French Government and the EU have all contributed to a project deploying four 2MW tidal turbines off the coast of Paimpol-Bréhat to create the world's largest tidal array exporting power into the electricity grid.

Japan
Marine energy research and development has been allocated a total budget of the equivalent of approximately £50m for the years 2011 to 2015.

New Zealand
The Marine Energy Deployment Fund was set up in 2007 with the aim of bringing forward the development of marine energy in New Zealand by supporting the deployment of devices. Grants to the equivalent of approximately £2.1 million were allocated in four annual rounds between 2007 and 2011.

Portugal
The Portuguese Marine National Plan has been published, aimed at ensuring the sustainable use of marine resources by a variety of users.

South Korea
The government has set a target that 11% of the national energy demand comes from new and renewable energy by 2030. Ocean energy, including wave and tidal is targeted to contribute 4.7% to the new and renewable total.

Spain
The Spanish Government's Renewable Energy Plan 2011–2020 includes a target for an annual installation rate for marine energy of 20–25MW between 2016 and 2020. The plan states that 100MW is expected to be installed by 2020, producing 220GWh/year by then.

USA
The United States Government Water Power Program is currently assessing the opportunities associated with ocean energy resources. This is anticipated to inform the establishment of aggressive national goals for marine energy technology deployment.

Additionally, Australia, Belgium, Denmark, Germany, Ireland, Italy, Mexico, Norway and Sweden also have an active interest in marine energy and are members of the Ocean Energy Systems Implementing Agreement (IEA-OES).

8. *Survey of Energy Resources,* World Energy Council, 2007 (available at www.worldenergy.org/publications/survey_of_energy_resources_2007)

UK marine energy devices have already been installed in projects around the world. For example, British tidal devices have been installed in the Bay of Fundy in Canada, a number of different wave devices have been installed off Portugal and site development is progressing in India for a project utilising British technology.

Given the huge global resource and the increasing activity in many separate markets (see info box), the export potential is clear as long as lessons are taken on board from other countries and other sectors about how to maximise this potential.

Security of energy supply

Further diversifying the UK portfolio of electricity-generating assets through wave and tidal energy generation offers benefits in terms of security of supply.

Wave and tidal electricity generation does not require imported fuels, with associated price volatility and risks of unavailability.

Tidal power has the benefit of being highly predictable, meaning that both the level and timing of generation can be planned in advance. Wave energy, while being a form of stored wind energy, counter-correlates with wind energy. Counter-correlation means that it will peak at different points to wind energy, as waves will move more slowly towards a coastline than an advancing wind front. Wave power also has the advantage of being less variable on an hourly basis than an equivalent amount of wind power. Increased predictability and diversity in our low carbon electricity supply will have a significant positive impact on the cost of providing transmission upgrades and balancing capacity for our energy system.

Affordability of energy

Capital costs of marine energy projects are currently relatively high compared with offshore and onshore wind. Nevertheless, there are good reasons for expecting these costs to fall significantly as devices are developed and manufacturing and installation processes industrialised. For the immediate future, although the cost per megawatt hour is likely to remain high, the total cost to consumers will be low, as the installed capacity is small.

Costs are anticipated to fall for three reasons:

- Industry learning (doing the same things better due to experience).
- Technical innovation (finding new ways of doing things).
- Industrialisation (doing things faster and cheaper by doing them on a larger scale).

There is still a significant variation in the technology approaches being taken by different device manufacturers in each sector. This suggests that there is still significant opportunity for further cost reduction. In addition, supply chain and financing costs are likely to fall as volumes increase and risks are better understood and mitigated.

The Current Policy Framework

The benefits to the UK of wave and tidal energy are clearly illustrated in terms of price stability, export opportunities and security of supply. To achieve this, we need to ensure that the policy framework enables continued development. The progress of the sector to date has been driven by a coherent package of support provided by government and other stakeholders but it is essential that policy continues to underpin a high level of growth in the industry.

Financial mechanisms

Public sector funding is focused on supporting manufacturers and developers through their first array deployments, to encourage the commercialisation of the sector. During the past year there have been a number of initiatives.

The **Marine Energy Array Demonstrator (MEAD)** scheme is a £20m capital grant fund from DECC to support two projects testing devices in arrays. The application process closed in June 2012 and awards will be made in spring 2013.

The Scottish Government's **Marine Renewables Commercialisation Fund (MRCF)**, administered by the Carbon Trust, is an £18 million initiative to support two projects of commercial-scale arrays in Scottish waters. The application process closed in August 2012 and conditional awards will be made in spring 2013.

The Crown Estate announced in January 2013 that it could invest up to £20 million in two wave and/or tidal stream array projects (multiple devices with installed capacity of 3MW or greater) with final investment decision by March 2014.

The Technology Strategy Board's Marine Energy: Supporting Array Technologies (MESAT) is a £10.5 Million competition being run with Scottish Enterprise and the Natural Environment Research Council. Successful applicants were Brunel University, IT Power, Mojo Maritime, SSE, Tension Technologies International, TGL and Tidal Stream. The funding is supporting the development of vessels for high-flow tidal installation and O&M, antifouling and corrosion prevention projects, and subsea electrical hub design.

The Saltire Prize, offered by the Scottish Government, is a £10m fund that will be awarded to the owner of the commercial wave and tidal project in Scottish waters that produces the most energy over a continuous two-year period between 2012 and 2017. The minimum hurdle of 100GWh must be exceeded. Current competitors are Aquamarine Power, MeyGen, Pelamis Wave Power and ScottishPower Renewables.

WATERS2, the second funding round run by the Scottish Government, Scottish Enterprise, and Highlands and Islands Enterprise, has allocated £7.9 million funding to five marine energy developers to support the testing of new wave and tidal energy prototypes in the seas around Scotland. The recipients are AlbaTERN (£0.6 million), AWS Ocean Energy (£3.9 million), Nautricity (£1.4 million), Oceanflow Energy (£0.75 million) and Scotrenewables Tidal Power (£1.2 million).

The Scottish Government's **Renewable Energy Investment Fund (REIF)** has £103 million available in loans, equity investments and guarantees (not grant funding) for projects, including those to accelerate the growth of the marine renewable energy sector in Scotland.

The Energy Technologies Institute has run a number of investment rounds in the marine energy sector, including investment in wet-mate connector technology, tidal resource modelling and Tidal Energy Converter System Demonstrator and Wave Energy Converter System Demonstrator projects that apply a system and through-life approach to technology commercialisation. Other ETI initiatives including the Performance Assessment of Wave and Tidal Array Systems (PerAWaT) project have delivered a commercial software tool to assist in marine energy yield prediction. The Reliable Data Acquisition Platform for Tidal (ReDAPT) project has assisted with installation of a 1MW tidal generator at EMEC in January 2013 to deliver detailed environmental impact and performance information.

Finance is also available from the European Commission in the form of the European New Entrants Reserve

(NER) 300 Fund and via the Marine Renewables Infrastructure Network (MARINET).

These schemes need to be continued to allow access to finance. In addition, whilst electricity generation from marine energy was not listed as a priority sector for the **Green Investment Bank (GIB)**, 20% of the bank's funds to 2015 are to be invested in "green sectors", and we urge priority is given towards wave and tidal energy.

Testing and demonstration facilities

The UK has a range of world-leading testing facilities to support technologies through different stages of development. It has succeeded in attracting overseas clients and investment, and in capitalising on the depth and breadth of UK experience to export knowledge to the rest of the world.

A number of new UK facilities support the proof-of-concept and scaled tank-testing stages of technology development. FloWave TT (a subsidiary of the University of Edinburgh) is scheduled to complete construction of an onshore tank test facility in 2013 and has made an agreement with EMEC to facilitate the sharing of site data, to be able to replicate sea conditions in the tank. This will enable device manufacturers to test their concepts at a small scale, with representative site conditions. In 2012, Plymouth University opened its test tank, the Coastal Ocean and Sediment Transport (COAST) laboratory, which replicates wind, wave and current conditions.

Following tank testing, facilities are available to support the first deployment of a device in testing locations such as EMEC and Wave Hub.

EMEC has purpose-built, accredited open-sea testing facilities and offers independent research and consultancy services. During the past year, it has reached capacity with all 14 wave and

The Strategic Initiative for Ocean Energy

At the European level, the Strategic Initiative for Ocean Energy (SI Ocean) has been conceived to strengthen Europe's wave and tidal energy networks. It will enhance collaboration across research and development and build on existing knowledge of technological, financial and policy barriers to identify solutions that will accelerate deployments of wave and tidal technologies.

The 2012-2014 project, funded by Intelligent Energy Europe, is being led by the European Ocean Energy Association and brings together a range of expertise from the European Commission's Joint Research Centre, the UK's Carbon Trust, University of Edinburgh, Danish Hydrological Institute, Portugal's WavEC Offshore Renewables and RenewableUK.

The project focuses on the high resource areas of the 'Atlantic Arc' region, spanning the western facing Atlantic coastline and the northern area of the North Sea, encompassing the territorial waters of Denmark, France, Ireland, Portugal, Spain and the UK. Investigations of the wave and tidal stream resources, technology challenges, policy landscape and market conditions that exist within this region are key components of SI Ocean.

Key SI Ocean deliverables are:

- Resource assessment encompassing both near and longer term projections for future energy generation across the Atlantic Arc;
- Strategic Technology Agenda outlining actions for overcoming technological challenges and supporting commercialisation of wave and tidal devices;
- Market Deployment Strategy which will integrate all resource, technology, policy and market information to deliver a strategy for uniting Europe's wave and tidal sectors behind a common agenda for commercialisation.

tidal berths filled and is now looking to expand. This UK-based organisation has become a global exporter of knowledge, supporting test centres worldwide, and has now signed collaboration agreements with organisations in Taiwan, Japan, China and South Korea, as well as UK-based organisations such as FloWave TT.

Wave Hub is the largest, grid connected site for the testing and development of marine energy devices. This £42 million facility provides shared offshore infrastructure for the demonstration and testing of arrays of wave energy devices. Located 16km off the North Cornish coast, Wave Hub is a 20 MW capacity electrical socket in the seabed to which arrays of wave energy devices can be connected. Wave Hub has four 5 MW berths and the excess capacity on the cable for up to 50 MW. Two of the four berths on Wave Hub have now been reserved for wave energy developers and the potential for a demonstration facility for floating wind technology is being investigated. Wave Hub is linked to the UK's electricity grid via a purpose built substation next to the new Hayle marine renewables business park. The control and monitoring of devices at Wave Hub is performed remotely from the substation using data transmitted via fibre optic cables within the main subsea cable.

Manufacturers have also continued to bench-test their devices. The National Renewable Energy Centre (NaREC) has completed testing in the past year on devices such as the Atlantis Resources Corporation AR1000 using their Nautilus drivetrain test rig.

These testing facilities should continue to be supported to allow the development of technology.

Frameworks and collaborative initiatives

There are a number of frameworks in place across the UK to encourage clustered and collaborative technology development, and investment in the sector.

The South West Marine Energy Park (from Bristol to Cornwall and the Isles of Scilly) was launched in January 2012. Likewise, the Pentland Firth and Orkney Waters Marine Energy Park was launched in July 2012. Each aims to create a positive business environment that will foster collaboration, attract investment and accelerate the commercial development of the marine energy sector.

The Energy Technology Institute (ETI) runs the Marine Energy Programme to invest in key technologies for marine energy. Investment is guided by the Marine Energy Programme Board (MEPB), and the programme aims to increase investor confidence by targeted investment in key technologies from the sector.

The Scottish Government's Marine Energy Group is a similar forum to the MEPB. It published the Marine Energy Action Plan in June 2012, an update to the Marine Energy Road Map published in August 2009. Key recommendations include the need to consider support beyond the WATERS2 programme, which is now closed, and to include marine renewable energy devices in the Energy Technology Criteria List, enabling a first-year capital write down allowance of 100%, as opposed to the current level of 10%.

The Sustainable Power Generation and Supply Initiative is a collaborative research programme run by the SuperGen UK Centre for Marine Energy Research (UKCMER).

Moving Industry Forward— The Pathway to Commercialisation

Wave and tidal energy has built up significant momentum and has made clear progress on the pathway to commercialisation, giving us a world leading industry, based on British skills and resources. The industry has also worked hard to understand deployment pipelines and cost trajectories to make sure that Government has reliable evidence to use in its assessments.

Clarity on costs and deployment is vital as wave and tidal approaches a critical junction. We have the opportunity to consolidate our lead and establish a fully commercial industry. Our focus here is how to use Electricity Market Reform (EMR) as the springboard to sustained growth of the wave and tidal sector.

As demonstrated in the preceding chapters of this report, wave and tidal energy has built up significant momentum and has made clear progress on the pathway to commercialisation. We've seen supportive policies put in place due to the potential of the industry to create a range of benefits to the UK.

We now have a world leading industry, based on British skills and resources. However, a critical junction looms. We have the opportunity to consolidate our lead and establish a fully commercial industry if we manage to eliminate uncertainty in the market through a clear and consistent message from all stakeholders. If we fail to provide this comfort, the industry could falter and the progress we have made to date will be undone.

Electricity Market Reform and its Implications for Marine Energy

EMR will fundamentally alter the policy landscape for wave and tidal stream energy at a crucial time for this industry's development. Done correctly, EMR has the potential to be the springboard into an important new phase of development for this important sector. However, to realise the immense potential – both domestically and through exports - of the industry, it is imperative that EMR and the associated Energy Bill are shaped with the wave and tidal industries in mind.

The creation and implementation of a market system that will continue to provide certainty, durability and confidence to investors, developers and the supply chain will only serve to consolidate further the UK's position as the global leader in this emerging sector, and generate a local market, with key players capable of exporting technology and expertise.

The transition to a Contract for Difference (CfD) regime falls in the middle of the delivery period for the first arrays. As such, this policy shift holds the potential to halt or catalyse the development of the industry. Taking consideration of the objectives of the EMR, a strike price of £280–300 per MWh (for a 20-year contract) is essential to catalyse growth in the tidal energy industry, whilst the various factors impacting wave energy mean a strike price of £300–320 per MWh (for a 20-year contract) is required to maintain the UK's global lead in wave and tidal energy. In addition, these strike prices should be index linked, to address inflationary issues, preferably to the Consumer Price Index.

A number of key variations between the ROC and CfD impact the level of support required by the industry:

- **The shortening of the contract length from 20 years under the RO to 15 years under the FiT CfD** has a significant impact on the rate of returns expected from projects, heightening the required support level by around 16% under a 15-year contract. **Thus a reduction in contact length to 15 years would necessitate uplift of the strike price to £325 - £350 per MWh for tidal stream energy and £350 - £375 per MWh for wave energy.**

- **Exposure to technology-neutral auctions** could prove extremely harmful to the industry. Whilst the industry is working hard to reduce costs and could feasibly compete on price terms with offshore wind by the end of the next decade, the 2020s should be dedicated to scaling up the industry, and it is unlikely that this developing industry will reach the cost point of more mature technology by the mid-2020s.
- **Certainty of sufficient CfD capacity.** It is essential that adequate allocation of capacity for marine technologies under the Levy Control Framework ensures availability of a CfD at the right strike price at the time the projects are to deliver. Providing adequate capacity through the Levy Control Framework would provide some level of comfort to investors, but it would be beneficial if further certainty could be granted to the industry.
- **A clear route to market.** It is essential that marine technologies have a route to market and can access the market reference price either through a competitively priced PPA or by selling power directly into the market. The CfD is a purely financial mechanism and does not take account of the risk inherent in any novel energy technology, and therefore it is expected that a power offtake agreement through a PPA would be required.

If the appropriate level of support is granted to the marine energy industry, EMR could be beneficial as it will provide a high level of price certainty. Under the RO regime, investment decisions were often based on the lowest possible value of ROCs, leading to undervaluation of projects. The CfD approach enables decisions to be based on a certain revenue stream, which should reduce risk and enable sustained growth of the industry.

Achieving Viability—Cost Reduction Potential

To understand the costs of wave and tidal energy in comparison to other types of generation, we need to think about the Levelised Cost of Energy (LCoE). LCoE is the primary measure of cost effectiveness used in the energy industry. It defines a unit cost for electricity by dividing total energy production by the costs involved in developing projects. Wave and tidal projects are subject to a high level of technology and novelty risk, as well as policy risks including level of support granted to projects, timely and affordable access to grid and the onerous requirements of the consenting process.

The true LCoE for marine energy is yet to be confirmed, due to the lack of full-scale arrays. However, the submission of data in application for the MEAD and MRCF has crystallised the current position on LCoE and its trajectory up to 2020. The data we have gathered represent the most current thinking on LCoE and broadly agrees with data in the established publications such as the Carbon Trust's Marine Energy Accelerator[9], the Energy Technology Institute's Marine Energy Technology Roadmap and DECC's own Technology Innovation Needs Assessment (TINA)[10].

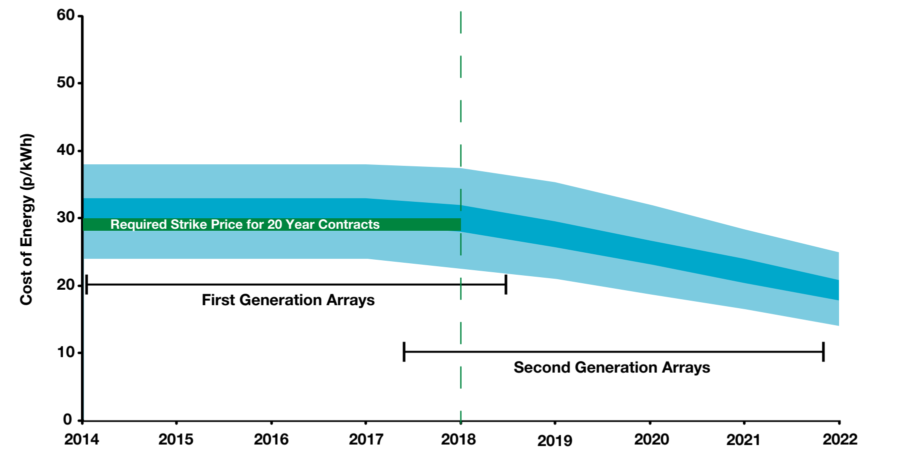
Whilst the timing of the end of the RO regime is far from ideal for the wave and tidal industries, the review period for the initial phase of EMR fits more closely with their development cycles. The first generation of arrays, for which we have robust data for the cost of energy, are planned for the period 2014–18. Following the commissioning of the first generation of arrays up until 2018, we will have a clearer picture of the cost of second-generation arrays and will be able to help determine the revenue support the industries will require to continue flourishing.

9. *Accelerating Marine Energy*, Carbon Trust, 2011 (available at www.carbontrust.com/media/5675/ctc797.pdf)
10. *Technology Innovation Needs Assessment* (TINA), Marine Energy Summary Report, August 2012 (available at www.carbontrust.com/media/168547/tina-marine-energy-summary-report.pdf, accessed January 2013)

Tidal Stream Energy – Focus on the first Arrays

We have seen a high level of activity in the tidal stream sector as utilities, industrials and project developers focus their attention on prototype demonstration prior to the first arrays. We now have a group of credible projects, using technologies which are demonstrating significantly improved performance over that of earlier prototypes and are planned for the next few years. Moreover, the number of applications for the MEAD and MRCF capital support schemes has helped solidify the LCOE position and give confidence to investors and policy makers:

Figure 4: Anticipated levelised cost of energy for tidal stream energy based on recent data submissions.



A large proportion of the current array deployment funds (MEAD, MRCF and NER300) are likely to go to tidal projects as they are well positioned to gain funding, grid and consenting in the required timeframes. While we envision that most of these leading tidal stream projects will be installed under the RO regime, there is still a need for certainty around future support mechanisms and it is essential that the CfD strike price set for tidal stream energy sends out the right market signal.

In addition, the first phase of the EMR period should catalyse additional growth to enable continuous project development and consequent cost reduction. It is also critical that market competition is allowed to develop.

This requires technologies that are prototyping today but have their demonstrations arrays delayed by the revised grid dates in Orkney and Pentland Firth waters.

The strike price we have requested aligns closely with LCoE estimates, catalysing deployment of the most cost effective projects and encouraging those with higher costs to work more cost efficiently. In addition, this level of support will encourage continued investment while ensuring value for money, allowing the tidal stream industry to maintain engagement with policymakers and investors while retaining a positive public image.

Wave Energy – Closing the Financing Gap:

The challenges for wave developers are not significantly different to those for tidal, however Original Equipment Manufacturer investment in the sector so far has been predominantly in tidal. There are a number of reasons for this including familiarity ("looks similar to wind turbine"), a consensus on technology, generation predictability and site access. But it is important to recognise that while tidal can deliver 95TWh/year of energy into the UK grid wave has the potential to deliver many times that - in the region of 840TWh/year. So long as the necessary level of stakeholder and financial support levels are maintained then investment will be maintained and indeed increased as confidence grows in the sector. Success with early tidal projects will naturally encourage investment in wave.

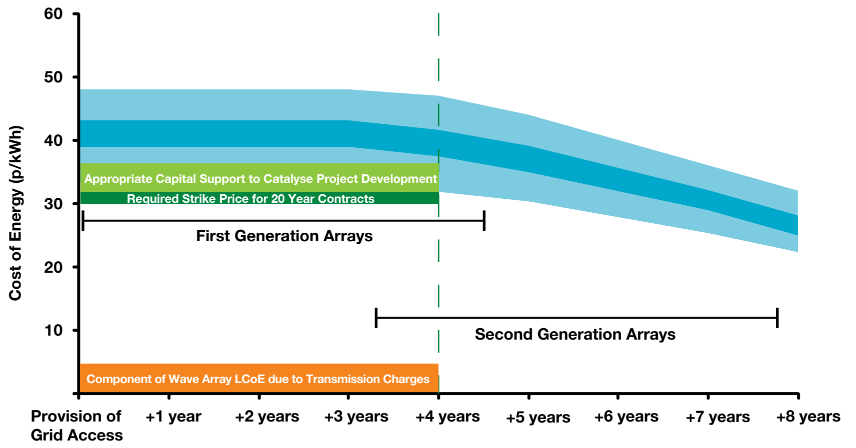
It is important to note that several of the primary sources of costs are beyond the control of developers and wave projects should not be penalised for factors that are under the influence of other stakeholders. A primary example of this is the high transmission charges that wave projects will be subjected to simply due to the location of the sites.

When assessing The Crown Estate's list of marine energy leases, it becomes clear that 92% of wave energy projects are located off the Scottish islands and will be subject to heightened islands transmission charges, which could be as high as £100 per kW per year (equivalent approximately to an extra £50 per MWh for renewable plant, compared to equivalent plant on the Scottish mainland). This factor needs to be considered when determining the CfD strike price.

A further major source of uncertainty is access to the grid, with the announcement by SHETL that transmission infrastructure for the Scottish islands will be delayed and the work programme will not meet the contracted dates, as previously stated. Due to this uncertainty, Figure 5 demonstrates array deployment, and consequent cost reduction, in relation to grid provision rather than particular years.

It is clear that these delays have pushed the delivery plans for wave projects out beyond the cut-off dates for the current array capital support schemes and the

Figure 5: Anticipated levelised cost of energy for wave energy based on recent data submissions.



Wave energy – The strategic investment proposition

We have seen a variety of industrials and utility companies involved in the sector and, given the discrepancy between cost and revenue, it may be queried why this is the case. The answer lays in the strategic significance of wave energy and the opportunity it presents to provide large quantities of clean electricity. Wave energy is found across the World's seas and oceans, is clean and renewable and is one of the last renewable energy forms which mankind has yet to harness, and its potential is huge. In summary, the advantages that wave energy holds for investors are as follows:

- The total global wave energy resource has been estimated at up to 80,000 TWh/year, which is one hundred times the scale of the estimated tidal stream global resource.
- Research has shown that, with conservative economic and environmental constraints, wave energy technologies could be capable of capturing around 2.5% of this global resource satisfying over 10% of the current annual global electricity consumption of approximately 18,000 TWh.[11]
- The wave sector provides the opportunity to scale up rapidly once the optimal technological solutions are confirmed. This will happen on both the individual device scale and at the array scale, where wave is particularly flexible.
- The technology has the potential to make large efficiency and energy capture improvements not available to other forms of low carbon generation. This situation is analogous with the Solar PV technologies that have recently improved their energy capture from ~17% to ~30%.

These factors have attracted interest from several of the biggest companies involved in the energy sector and encouraged them to retain an interest whilst making a loss on the initial arrays. Support through the Electricity Market Reform is essential to ensure we generate growth in this strategically important sector which is based on British ingenuity and maritime engineering ability.

11. *A Brief Review of Wave Energy*, UK DTI Report, TW Thorpe
12. *Government response to the consultation on proposals for the levels of banded support under the Renewables Obligation for the period 2013-17 and the Renewables Obligation Order 2012*, Department of Energy and Climate Change, 2012 (Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42852/5936-renewables-obligation-consultation-the-government.pdf)

RO regime. The risk that wave energy projects will not benefit from these support schemes further necessitates a CfD strike price that will drive investment in the industry.

From Figure 5 we can see that the level of support the industry has requested through the EMR process will not meet project costs. A major driver for the LCoE of wave energy is the need to develop projects in areas that are energetic enough to ensure a high level of output but that will result in extreme transmission charges, especially when compared to other forms of energy generation.

Previous DECC analysis, in support of the Renewables Obligation of 2011 suggests that, even with capital support grants at a level of 25% of project costs, "wave demonstration projects at central costs would need 6.6 ROCs/MWh"[12], which is significantly higher than the 5 ROCs provided to the industry thus far and the strike price requested by the industry.

Given these factors, it is essential that an appropriate level of revenue and capital support is provided to ensure that the wave energy industry can move from the development phase to full commercialisation. With the right mix of capital and revenue support, the UK can retain its world leading status and solidify its position as the best place in the world to develop wave energy projects.

Key activities for reducing costs

- **Device power uprating:** following the wind industry pathway, wave and tidal energy devices will increase in size, improving output.
- **Multiple generators per foundation:** foundations make up a significant proportion of marine energy projects, and structure innovation can reduce project costs significantly.
- **Reliability and maintainability:** experience leads to improving availability schedules and maintenance strategies.
- **Supply chain and production:** deployment will enable the supply chain to scale up and enable innovation, and the establishment of specialist production facilities will reduce manufacturing costs.
- **Installation:** lessons and scale from offshore wind, as well as specific innovations in device installation methods and equipment, will reduce installation costs.
- **Offshore grid:** grid remains a barrier to the development of the industry but improved access, innovation and scale can aid project development.
- **Device access:** innovative deployment and recovery systems, offshore marine operations innovation and scale all contribute to reduced costs.
- **Offshore wind:** exploiting synergies in manufacturing, supply chain, grid and operation and maintenance logistics lowers costs.
- **Higher-capacity factor sites:** higher-capacity sites become accessible with experience on more benign sites, thus improving output.
- **Reducing cost of capital:** discount rates applied to projects reduce as investors become more accustomed to marine energy projects and the technology matures, reducing novelty and technological risk.
- **New types of investors:** as the risk profile of marine energy changes, so does the type of investor. Debt funds and equity will become more involved once the first proving arrays have been commissioned.
- **Reduced insurance costs:** as deployments increase, international standards are applied and confidence is established.

Targeting cost

The industry has developed its own set of detailed cost reduction plans, and the leading developers are pursuing an aggressive cost reduction programme to ensure that cost can fall to a level that will encourage investment and catalyse development. The best plans combine both high-level aspirations for cost reduction with detailed proposals for specific engineering work to reduce costs.

The primary focus of the leading manufacturers is to prepare for array-scale deployment by improving deployment and recovery methods, reliability and O&M practices. These are becoming key differentiators between device manufacturers.

Many of the leading manufacturers are now designing or deploying more production-ready, full-scale devices. The accessibility requirements of these devices have now changed as there is less need to access devices regularly for testing purposes and more need to make the deployment, O&M and retrieval operations as efficient and safe as possible. As a result, diverse O&M strategies are emerging. Manufacturers of different devices use a variety of deployment and recovery techniques. Devices are typically separated into permanent and detachable sections. Some concepts just have foundations on the seabed with the full device detachable; others use a substantial fixed structure with just a detachable power take-off module. A considerable amount of investment has been allocated to technologies that reduce the challenges in this area, such as research into wet-mate connectors funded by the Energy Technologies Institute.

Substantial work is also being undertaken by the sector to improve reliability of devices and understanding of their through-life operation. This is being achieved partly through implementing learning from real-life operations at test centres such as EMEC, and component testing under controlled conditions such as at NaREC.

Historically, vessels used for wave and tidal applications have been adapted from other sectors. In the case of the tidal sector, the vessels have not been designed for high tidal flow and as such are often utilised at the limit of their capabilities. The sector is now seeing significant investment from third-party installation providers who are designing generic solutions, rather than device manufacturers and project developers who have previously created project-specific solutions. Public funding has been allocated towards the development of solutions such as improved dynamic positioning systems, and these activities will increase the operating windows of vessels, hence lowering costs and reducing risk.

Risks and Mitigation Strategies for Wave and Tidal Development

Although the prize is big, wave and tidal developers will encounter a number of hurdles in their journey to large scale deployment – spanning finance, technology development, the grid, consenting and more. As the industry matures there is a real responsibility to engage with risks and work to manage and reduce them. In the following chapter GL Garrad Hassan identifies the primary risks facing the industry out to 2017 – and proposes mitigation strategies to address them.

Finance

As capital-intensive technologies, when wave and tidal energy converters scale up from prototypes to small arrays, their financing needs will scale up too. Total public funding, as delivered by various acronymic funding pots – MEAD, MESAT and NER300 amongst others – remains small compared with, say, the £1bn Commercialisation Programme for carbon capture and storage. Yet a strong revenue incentive in the form of 5 ROCs/MWh has helped compensate for constrained public sector capital support. The result has been to attract the interest – and equity – of Original Equipment Manufacturers (OEMs) and utilities. The latter have invested in both wave and tidal energy converters, in recognition that the potential exists for both.

Risks

In the transition from capital grants to revenue-based support, the availability of debt or "debt-like" finance will be critical. With the technical risks of marine energy too high for conventional lenders, the industry was particularly disappointed to hear last year that the Green Investment Bank (GIB) did not consider marine energy as a priority for its investments. Continuing its proactive support for the industry, The Crown Estate aims to help compensate for the GIB's conspicuous absence in the sector: in January it announced plans for investing up to £20m in the construction of two wave and/or tidal stream arrays. Whilst this investment is not to be underplayed, it remains uncertain that £20m will be sufficient to bridge the funding gap for wave and tidal projects.

Financing risks may be particularly high for wave projects. Early indications and suggest that tidal projects may benefit disproportionately from the MEAD and MRCF. If so, there could be a risk that the allocation of public funds does not fully reflect the longer-term potential of wave energy technologies – such as the high potential to export technology globally, bearing in mind the vast global wave resource. Insufficient funding could have a large detrimental impact at this critical stage of development for wave technologies.

A further risk is that uncertainties around CfDs introduced by EMR will shake the commitment of OEMs and utilities to wave and tidal technologies. If the funding mechanism post-2017 is viewed as flawed, this will inevitably undermine confidence in the long-term market for wave and tidal. Specific concerns about CfDs relate to the politics of and mechanism for setting the strike price, the lack of a clear route to market for independent developers, and the post-2020 plans for technology-neutral auctions. Since investors and the supply chain require clear visibility of a long-term market, such policy uncertainties have the potential to threaten interest in these technologies in the present.

Mitigations

- **Provide clarity on Electricity Market Reform:** reassure investors of the long-term market for wave and tidal energy in the UK.
- **Unlock the latent potential of the Green Investment Bank for wave and tidal projects:** emulate the achievements of Germany and Denmark, who have successfully stimulated offshore wind deployment through providing low-cost capital via government-backed banks.
- **Ensure appropriate distribution of funding between wave and tidal projects:** ensure that the delivery of public funding adequately reflects differing technology development trajectories, so that support is genuinely accessible to both groups of technologies, rather than merely *de jure* technology neutral.

Finance Risk Register

RISKS			MITIGATION			
The event	**Likelihood of occurrence**	**Potential impact**	**Possible mitigation strategies**	**Proposed lead actor(s)**	**Benefit of mitigation action**	**Cost of mitigation action**
Private sector investors lack confidence in EMR regime due to on-going uncertainty	Mid – Issues around strike price, contract length, exposure to technology neutral auctions and the route to market are yet to be resolved. DECC is still working on EMR details, so these concerns may yet be addressed.	Mid–high – Lack of clear long-term market leads investors/OEMs to pull out of Wave and Tidal. Without adequate revenue support, future projects will not be taken forward.	Ensure that the CfD strike price is in line with industry requirements based on evidence of costs. Address route to market concerns.	DECC, informed by Marine Energy Programme Board (MEPB)	Increased clarity on EMR regime reassures investors that CfD is appropriately designed for wave and tidal	No direct cost, except DECC and industry's time to refine design for wave and tidal
Divergence of development trajectories for wave and tidal	Mid – there is a perception that tidal stream technologies may be further down the cost curve and closer to array deployment than their wave counterparts.	High – tidal may benefit disproportionately from array funding, whilst wave is neglected.	More sophisticated/ prescriptive design of future public support schemes to ensure money is genuinely accessible to both sets of technologies	DECC, with support from MEPB and RenewableUK	Ensure appropriate distribution of public funds to wave and tidal technologies	N/A
			Implement MEAD/ MRCF "Round 2" that is genuinely accessible to wave energy technologies	DECC/Scottish Government	De-risking of pre-commercial multi-unit deployment for wave industry	~£20m in total (based on funding of current MEAD programme)
Funding gap for W&T emerging in the mid-2010s	High – there has already been substantial discussion of a funding gap for offshore wind.	Mid – slows pace of development, so the first arrays may miss out on ROCs and current capital support schemes.	Allocate 5% of Green Investment Bank's budget to wave and tidal projects	Green Investment Bank	Increase the funding pool – replicating the success of offshore wind support in Germany and Denmark	Opportunity cost of £150m to other green technologies (5% of £3bn)
			Launch targeted publicity initiative on the risk–reward profile of wave and tidal technologies	RenewableUK and/or MEPB	Reduce gap between perceived and actual risk profile – to attract more investors in longer term	~£10–100k (based on costs of previous campaigns)

Technology development

Risks

The technology development of wave and tidal devices will be shaped by both engineering and cost pressures. Perhaps the most significant risk in technology development is (non-)survivability: any significant failures could be make or break for leading device developers, through detrimental impacts on investor confidence. This is a challenge that applies to all ocean energy projects, although the loads resulting from harsh environments are perhaps more obvious for wave devices than their tidal counterparts.

The difficulty in finding cost-effective solutions for the installation of devices in harsh and difficult-to-access marine environments is a significant risk, and is particularly challenging for projects operating in fast tidal flows. Historically, most offshore and maritime operations have avoided the very areas where the emerging tidal stream industry now seeks to install and operate machinery. The windows of opportunity for installation are relatively short (often less than one hour), which means major operations need to be extremely quick or be able to continue in high tidal flows. This challenge is compounded by the supply chain risk that vessels and installation equipment are diverted to larger-scale, higher-margin areas of the energy industry – such as oil and gas, or offshore wind. This could push up the costs and lead times associated with installation (and maintenance), thus acting as a brake on wave and tidal technology development.

Understanding of the likely energy production of wave and tidal generators is still developing due to limited empirical testing and data. There are two issues at stake here. First, industry needs to understand the resource, and its impact on power output and energy capture. Second, industry needs a better understanding of the reliability of devices themselves. Various research programmes are seeking to address one or both issues: for instance, the ReDAPT project, funded by the Energy Technologies Institute, is helping to improve understanding through a comprehensive data collection system on an innovative 1MW tidal generator. Although significant progress is being made, the risk remains that the first small arrays will have lower load factors than predicted. Moreover, technical problems hampering load factors could be difficult to address given the challenges of maintaining technologies in the marine environment.

Cost pressure for all renewable energy technologies is expected to increase this year with the publication of CfD strike prices. If other technologies, such as floating wind or photovoltaics, are deemed to have greater cost reduction potential than wave and tidal devices, this could divert the attention – and associated funding – of both policymakers and OEMs. Indeed, if there is a divergence in the cost trajectories for wave devices and tidal devices, this could lead to investors favouring one set of technologies over another. Starved of resources, the rate of technology development of neglected devices would be constrained.

A further risk is that short term cost pressures force convergence on technology designs which, although effective for one-off prototypes, are suboptimal in the long-term. The result may be to create technology lock-in which inhibits future step-change innovations. However, this risk should not be overstated; industry cannot afford to wait for a magical ‘optimum’ solution to appear, and in any case the optimum will only become apparent through demonstration and deployment. The priority is to have operating units in the field, and to learn from these.

Mitigations

- **Ringfence funding:** ensure marine energy projects get an appropriate share of funding under the Levy Control Framework and that policy supports the needs of wave and tidal as they follow different paths with different requirements.
- **Continue targeted and consistent R&D effort**: improve survivability, installability and availability via public–private partnerships, to better understand the resource and device behaviour (both individually and in arrays).
- **Communicate benefits with realism**: make clear the long-term and additional benefits of wave and tidal energy to policy-makers and investors, whilst at the same time demonstrating realism and openness about the risks and returns.

Technology Development Risk Register

RISKS			MITIGATIONS			
The event	**Likelihood of occurrence**	**Potential impact**	**Possible mitigation strategies**	**Proposed lead actor(s)**	**Benefit of mitigation action**	**Cost of mitigation action**
Wave and tidal cost reduction progression is slower than that of competing technologies	Mid–high – cost trajectory highly uncertain due to nascent technology status	High – diverts attention/funding of policy-makers and OEMs (Government under pressure to adopt least-cost path to decarbonisation)	Ring-fence a proportion of Levy Control Framework funding for wave and tidal	DECC/Treasury	Reassurance that wave and tidal will get its intended share of funding	N/A – merely guarantees that funding intended for wave and tidal goes to the industry
			A targeted, long term R&D programme that promotes cost reduction. This needs to be coordinated to leverage learning from the first arrays, and could be informed by a neutral party that would collect cost data	Energy Technologies Institute, Technology Strategy Board, DECC, Scottish Government, The Crown Estate	Improved techniques and modelling will inform device and process design. Promotes collaboration between industry and academia to further knowledge	£8–13m for 4–5 year in-depth research programme similar to WATERS 2 and WATES
Survivability of devices remains a major technical challenge	High – most devices to date have been in the water for short periods (less than one year) so survivability data is limited	High – reputational damage deters investors Mitigations for these risks are connected	Learning from the first arrays	Industry	Gain empirical data to improve understanding of how devices operate in the marine environment	Wave and tidal companies that have moved through the development cycle and conducted scale testing, numerical modelling and device demonstration have sold for ~£50m
Load factor is lower than expected.	Mid – data is currently limited. Some devices have ~1 year of data	Mid – increases risk associated with the move to generation-based support	Continued R&D programmes (e.g. PerAWaT II) to better understand and model the wave and tidal resource and its interaction with devices. This needs to be coordinated to leverage learning from the first arrays, and could be informed by a neutral party that would collect reliability data	Energy Technologies Institute, Technology Strategy Board, DECC, The Crown Estate	Improved scientific understanding and modelling will inform device design. Promotes collaboration between industry and academia to further knowledge	£8–13m for 4–5 year in-depth research programme similar to PerAWaT and ReDAPT. More specific projects have lower cost: <£500k, based on Engineering and Physical Sciences Research Council (EPSRC) projects
Delayed and costly installation and maintenance	High for tidal – due to challenges of fast tidal races, and limited availability of vessels and installation equipment	High – slows development and increases cost of installation and maintenance	On-going design refinements to optimise installation (and maintenance) strategy	Industry	Improved design will enable installation and maintenance in a broader range of weather and sea conditions	Costs will be device-specific. Improved R&D (see above) and scientific understanding will help to minimise costs
			Conduct study into availability of vessels and installation equipment, in context of competition with other industries	RenewableUK, devolved bodies, Scottish Enterprise	Better understand vessel/equipment availability; advertise opportunities for diversification into wave and tidal to vessels industry	~£30–50k, based on cost of previous similar studies
Convergence on suboptimal technical solution	High for wave – industry under pressure to converge to prove maturity to investors Low–mid for tidal	Low–mid – early lock-in reduces scope for later step-change innovations that cut costs	Use funding such as European NER300 Round 2 and FP7 to demonstrate range of devices	Industry, with support from DECC	Demonstrate a range of technologies to prevent premature convergence	Effort required to submit applications for NER300 Second Call expected to be similar to First Call

Grid

Risks

Grid connections for marine devices have similarities to offshore wind, though in the near and medium terms the arrays will be close enough to shore to avoid offshore substations and high-voltage subsea transmission. There are additional risks with reliability and cost of connections to marine devices, particularly in locations with high tidal currents and rocky seabeds. These risks are external to the devices but are properly "technology" rather than "grid" issues, and are not covered in the table below. However, they represent a high generic risk to the emerging industry that should not be ignored.

The proposed sites for wave and tidal arrays to 2017 are notable for their location on the fringes of the existing electricity system, and distance from major centres of electricity demand. There is therefore a substantial risk that grid costs will be particularly high, both for the upfront costs of connection and reinforcement, and for on-going costs for use of the distribution and transmission systems. This is especially the case on the Western Isles, Orkney and Shetland.

Currently, there are several formal decision-making processes in train on charging mechanisms, which will affect these costs for wave and tidal generators. In particular, on-going debates about the transmission capacity required for renewables with low capacity factors, and how this should be charged for, could have a significant impact on optimisation of the design of wave and tidal devices and arrays. In addition, current aims to harmonise electricity markets across Europe could result in a radical change to UK grid charging mechanisms within a few years. If there is a move away from the current UK principle of including a strong element of locational charging, this could have a beneficial effect on generators on the periphery of the networks.

As well as high costs for connections, the developer also has to commit in advance to substantial financial liabilities to cover the capital costs of the electricity network operators. This is required well ahead of connection, when the project is still subject to considerable risks such as consenting, and before the project's finances are known in detail. Because of the greater uncertainties for wave and tidal projects, this is a specific disadvantage compared to mature technologies such as onshore wind.

Apart from the cost issues, there is a further substantial risk for wave and tidal projects: that of long delays in providing the connection, particularly due to delays in consenting and constructing transmission reinforcement. A prime example is the recent announcement by Scottish Hydro Electric (SHE) Transmission of substantial delays in several transmission projects, affecting a large number of generation projects across the Highlands and Islands.

A specific instance of this risk may apply to the first arrays: the Renewables Obligation (RO) closes to new projects on 31 March 2017. The first small arrays plan to be operational by that time to claim ROCs, and grid connection delays could risk projects losing the RO option. DECC has proposed a limited "grace period" for projects affected in this way, but this is understood to be no more than six months, which is insufficient to provide confidence to project developers and investors.

Mitigations

- **Rapidly resolve current grid cost uncertainties:** timely decisions by Ofgem, National Grid and DECC are required.
- **Compensate for the specific risks and costs of wave and tidal grid connections:** reallocate the risks implied by substantial financial down payments via an industry consortium or government, and consider compensating for higher grid costs via higher ROCs or CfDs.
- **Address the delays to grid connection:** consider implementing a special case of "Connect and Manage" for wave and tidal arrays.

Grid Risk Register

RISKS			MITIGATIONS			
The event	**Likelihood of occurrence**	**Potential impact**	**Possible mitigation strategies**	**Proposed lead actor(s)**	**Benefit of mitigation action**	**Cost of mitigation action**
Delays to grid connections	High – see recent SHE Transmission statement, citing delays due to lead times for subsea cabling, consenting of transmission reinforcement, and outages	High – delays of years to some projects. First small arrays may miss option for support through RO (ends March 2017, with possible "grace period" of only six months). Uncertainty may result in some projects being abandoned	Implementation of special cases of "Connect and Manage" (C&M) for wave and tidal arrays, i.e. with higher levels of generator curtailment in advance of provision of full connection capacity, justified because project value is not just energy generated, but also experience gained	DECC	Delay removed or reduced. Will not be relevant on all connections, depending on reasons for delay	Curtailment costs (generator is reimbursed for lost production when curtailment is caused by insufficient connection capacity). Cost could be limited by application only to projects where the cost is acceptable for the benefits gained. Under present C&M arrangements, cost of curtailment payments is 'socialised' over all electricity customers: for early W&T arrays, cost could instead by met by Government.
Grid costs very high due to site location, compared to average for other technologies, e.g. onshore wind	High	High – could easily be ten times the cost per MWh of typical onshore wind sites	Ensure these costs are understood in setting wave and tidal capital or revenue financial support	DECC, Ofgem, Scottish Government	Resolves current disadvantage without need for "special treatment" in grid charging mechanisms, particularly in view of possible further radical change within a few years	Not quantifiable until current discussions on grid charging are resolved. Assuming costs for wave and tidal are ten times higher than for onshore wind in the southern UK, cost per MWh would be greater than 1ROC
Uncertainty about grid connection costs for renewables with lower capacity factors than conventional thermal plant	Mid – esp. in remote areas and islands. Industry debates are intended to reach resolution shortly	High – delay to projects with a chance of some projects being abandoned	Ensure issues currently in formal decision processes are resolved on planned timescales	Ofgem, National Grid, DECC	Risk removed	Insignificant
Substantial financial commitments (down payments or bonds) required by network operators in advance of energising the connection	High for some projects, low for others, depending on relative timing of other critical steps such as achieving consents.	High – Developer may need to sign up to financial commitments before consents and financing are in place, i.e. risk of sunk costs. Wind projects are likely to be able to commit earlier than marine projects. Some marine projects may not proceed, or may be forced to delay the grid connection process until consents are obtained, resulting in substantial overall delay.	Project developers in an area form a consortium. Consortium agrees to share risk (proposed by the Energy and Climate Change Committee (ECCC))	Marine Energy Project Board and/or RenewableUK to lead discussion within industry	Risk is shared across the consortium. Also, the combined approach may result in cheaper network connection for all	Management and legal costs to consortium members. May be non-financial "costs" in aligning consortium members' timescales.
			Government to underwrite all or part of financial commitments (proposed by ECCC)	DECC	Risk reduced or removed entirely for project developers	Cost for any single event could be high (possibly £1m+), but as few such events are likely, total cost may be acceptable in relation to total wave and tidal capacity

Consenting

To date, wave and tidal projects have largely been concentrated in specific test centres, most notably EMEC in Orkney and Wave Hub in the South West, which has minimised consenting challenges. This will change with the transition to small arrays, although devolution will lead to differentiated impacts across the UK.

Risks

A key risk is a general lack of preparedness amongst statutory consultees – such as Scottish Natural Heritage, the Joint Nature Conservation Committee and Natural England – in addition to the Marine Management Organisation and Marine Scotland. Wave and tidal energy devices are an evolving and diverse set of technologies, with the implication that their assessment will require substantial specialist expertise. If organisations lack appropriate capabilities, they will have limited means to assist developers at the pre-application stage, and when applications are received, there will be long lead times for their assessment. This risk is widely known, and efforts are being made to address it, such as mentioned by The Scottish Short Life Energy Planning and Consenting Task Force. Nonetheless, in the context of limited resources, organisations may decide to focus their activities on offshore wind deployment (of GW scale in total), at the expense of wave and tidal technologies (of MW scale).

Although its aspirations are laudable, the obligations for maintaining biodiversity under the European Union's Habitats Directive may cause further difficulties in deployment. Since marine energy technologies are new, their impact on marine wildlife – such as marine mammal collision and the obstruction of migration routes – is not yet scientifically well understood.

To compound the problem, baseline data on the status of biodiversity in UK waters is typically limited. Wave and tidal projects are subject to a similar level of scrutiny as offshore wind, despite their project capacity being on a much smaller scale. Also, some of the questions asked of developers are not easily answerable, with it being fundamentally difficult to prove the absence of an effect.

The result is that pre deployment evidence gathering and post deployment monitoring requirements could take up a disproportionate part of project costs. As the recent DEFRA consultation into the Habitats and Wild Bird Directives acknowledges, at heart the challenge is to strike a balance between the precautionary principle and a pragmatic approach. The risk is that the balance is struck in the wrong place, with the burden of evidence largely resting with developers. When combined with the high grid liabilities highlighted in the previous section, the effect on projects could be suffocative.

A further, previously underexplored, risk is that of a potential backlash to wave and tidal technology deployment in the public debate – for instance, questioning technology cost, local impacts on the marine environment or the visual impact of onshore elements. This risk has rightly been highlighted by the Energy and Climate Change Select Committee as an area requiring further attention. The SOWFIA (Streamlining of Ocean Wave Farms Impact Assessment) project co-ordinated by Plymouth University has highlighted limitations in the community and stakeholder consultation process to date. Industry cannot afford to be complacent.

Mitigations

- **Equip key statutory consultees:** ensure that statutory consultees have sufficient resources to provide specialist input, guiding developers rather than being a roadblock to deployment.
- **Bring wave and tidal specific issues to the fore**: go beyond the experiences of offshore wind to consider consenting issues that hit wave and tidal particularly hard, examining this at devolved, national and European levels.
- **Engage with public debate**: continue to communicate the technologies' benefits and publicise environmental impact findings from EMEC, to build trust and maintain the public's on-going support for wave and tidal technologies.

Consenting Risk Register

RISKS			MITIGATION			
The event	**Likelihood of occurrence**	**Potential impact**	**Possible mitigation strategies**	**Proposed lead actor(s)**	**Benefit of mitigation action**	**Cost of mitigation action**
Unduly onerous requirements pre-deployment (survey & baseline evidence gathering) and post deployment (monitoring)	High – the scientific impact is not well understood	Mid – punishes first movers. Causes delays because developers are unwilling to take on financial exposure before achieving consent. Can be costly to engage with complex procedures	Frank and open discussion about where the burden of evidence should lie. Industry needs to openly discuss with consenting bodies what the true environmental risks are – to help focus the assessment process and avoid unanswerable questions	On-going efforts by regulators and MEPB consenting working group, with support from RenewableUK	Reallocate the burden evidence to the bodies best placed to bear it. Focus environmental assessments on the real risks, to make them more meaningful and targeted	N/A – an on-going effort amongst established groups
			Survey, deploy and monitor policy to be implemented by regulators			
			Increase prominence of wave and tidal in The Offshore Renewable Energy Licensing Group (ORELG) forum	Offshore Renewable Energy Licensing Group	Bring wave- and tidal-specific issues to the fore, e.g. the disproportionate cost of monitoring requirements	None, except opportunity cost to offshore wind of dedicating less time to offshore wind-specific issues
			Engage with European Ocean Energy Association (EU-OEA) to both explore how other Member States are applying EU policy for ocean energy and also potentially influence EU policy.	RenewableUK to lead industry effort, feeding ideas to DECC via MEPB	Facilitate knowledge-sharing across Europe about different solutions to environmental monitoring	No direct cost – but requires focused effort by RenewableUK and MEPB
Statutory consultees underprepared for wave and tidal	Low–mid – has delayed offshore wind, but there are signs that the resource problem is now recognised	Mid – causes delays	Provide statutory consultees with sufficient funding to recruit/train staff to assist at both the pre-application stage and the assessment stage	On-going efforts by MEPB consenting working group	Statutory consultees will be better able to guide developers pre-application and assess applications swiftly	Unknown – financial needs would need to be estimated by the statutory consultees themselves
Potential backlash in public debate	Low–mid – based on experiences of campaigns on visual impact of onshore wind and costs of offshore wind	Mid – could make consenting more difficult if locals object to projects	Initiative to publicise the range of benefits offered by wave and tidal, and to get environmental data from EMEC in the public domain. Could focus on relevant coastal communities	RenewableUK to lead industry effort, perhaps in collaboration with regional bodies and green groups	Anticipates concerns that might emerge (e.g. cost, environmental impact, visual impact), by engaging public at early stages	£10–100k (based on costs of previous campaigns)
			Consider and implement relevant recommendations by SOWFIA and similar projects on the community/stakeholder consultation process	Industry	Builds trust through open and fair consultation process	N/A – relates to the way consultations are run rather than the money invested

Conclusions

The wave and tidal stream energy industries hold great potential for producing meaningful amounts of clean electricity. The industries have made significant progress to realising this potential by preparing for the installation of the first generation of arrays. There is a very real opportunity to capitalise on the progress of the industries in the UK and build a world beating industry able to deliver jobs, inward investment and export revenue to the UK economy. Yet challenges remain and it is essential that risks are addressed to ensure we deliver on our potential and the industry does not stagnate while awaiting certainty.

The industry remains dependant on support from government and it is essential that policy makers respond by sending a strong market signal to investors and project developers. Long term certainty of support at a level that will catalyse project deployment is an essential element of the policy package that industry needs to flourish. The development of the industry is thanks in large part to the policy support that industry has been granted in the past. However, current uncertainty threatens this progress and places the UK industry at risk of surrendering its world leading position.

Project and technology developers recognise that they are attempting some of the most technically challenging projects in the history of the energy industry at a time of extreme fiscal and financial pressure. As a result, there is a responsibility to temper policy requests with realism and the industry has furnished evidence to determine a realistic timeline for deployment and a cost reduction trajectory to underpin its deployment strategy.

It is important to bear in mind that the wave and tidal energy industries are dependent on a number of variables beyond their control. RenewableUK's analysis has pointed towards grid issues that have delayed projects, fiscal policy uncertainty that requires a strong response from government and a consenting regime that is unduly onerous as issues that need resolving. These risks make up a significant component of the project costs and are hampering the accelerated deployment the industry had previously touted.

Right now, the UK's wave and tidal industry stands poised to move from single device demonstrators to the installation of multi-device arrays. To successfully complete this step, industry will need to work closely with government, with both parties working hand in glove to manage many of the inherent risks. This joint working is important to (a) manage cost to the consumer and (b) ensure that the economic and environmental benefits offered by this sector accrue to the UK.

Right now the key risk facing industry is the transition from the RO to the CfD. However, if implemented correctly, Electricity Market Reform could act as the springboard needed by the wave and tidal industries. It offers long term stability and certainty, provided the CfD regime is structured in such a way that takes account of the particular needs of this emerging, exciting industry.

The greater understanding of risk and the future development of the industry, which remain very much interlinked, should give heightened confidence to policy makers and investors. By targeting the risks that will have the greatest impact on costs, and consequently deployment, the UK can conquer the challenges it currently faces and generate a level of growth that will ensure that it captures its rightful share of the potentially massive global market.

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Our vision is for renewable energy to play a leading role in powering the UK.

RenewableUK is the UK's leading renewable energy trade association, specialising in onshore wind, offshore wind, and wave & tidal energy. Formed in 1978, we have a large established corporate membership, ranging from small independent companies to large international corporations and manufacturers.

Acting as a central point of information and a united, representative voice for our membership, we conduct research, find solutions, organise events, facilitate business development, advocate and promote wind and marine renewables to government, industry, the media and the public.

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