The Future of Marine Renewables

Response from the *Engineering the Future* alliance to the Energy and Climate Change Committee

The response has been prepared by the following institutions:

- The Royal Academy of Engineering
- The Institution of Engineering and Technology
- The Institution of Civil Engineering

It is also supported by the following institutions:

- The Institution of Chemical Engineering
- The Engineering Council

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Engineering the Future is pleased to have the opportunity to input into the Committee's inquiry into the future of marine renewables. As the alliance of the UK professional engineering institutions, *Engineering the Future* can draw upon a wide range of expertise in the energy field. The UK has a large resource of marine energy that it could potentially exploit, contributing significantly to a secure and low-carbon future energy system as well as a successful UK supply chain. There are, however, many challenges to overcome before full commercialisation of any of the various technologies is realised. The engineering realities of large-scale adoption of new technologies should not be underestimated and it is hoped that this response will help bring to light some of the relevant issues.

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Engineering the Future is a broad alliance of the engineering institutions and bodies which represent the UK's 450,000 professional engineers.

We provide independent expert advice and promote understanding of the contribution that engineering makes to the economy, society and to the development and delivery of national policy.

The leadership of *Engineering the Future* is drawn from the following institutions: The Engineering Council, EngineeringUK, The Institution of Chemical Engineers, The Institution of Civil Engineers, The Institution of Engineering and Technology, The Institution of Mechanical Engineers, The Institute of Physics and The Royal Academy of Engineering.

Executive summary

- There are large potential resources of marine renewable energy available to the UK. In this, we are better placed than any other European country so, if any country is likely to make a success of marine renewables, it is the UK and we should therefore take the initiative. This is not the case for other renewables such as solar PV where countries such as Spain and Germany already have a lead.

- There is the possibility of a large and successful UK supply chain, as there is in the oil and gas sector, but it will not happen without a clear, integrated plan and the relevant support for it.

- None of the various marine technologies will be cheap when measured on a £/MWh basis. However those based on tidal motion have the benefit of predictability and in the future this may be more important than the price per unit of electricity that has been used in most of the assessments up to now.

- Tidal barrages have far lower technical uncertainties than for other marine renewables and they supply power predictably, but at a higher cost per MWh than can be obtained from a wind turbine. Proposed barrage structures also often encounter public opposition due to their impact on the local region adding extra risks and costs, as evidenced by the Severn Estuary proposals. However, as the UK is so favourably placed in terms of tidal range resource the government should continue to research developments in this technology, targeting more flexible generation over both ebb and flow tides, and multi-use options such as bridges or flood defences, along with lower costs and less environmental impact.

- Tidal flow turbines have been demonstrated in prototype numbers and represent a promising technology that is applicable to certain areas of coastline, particularly around Scotland. They are visually unobtrusive and unlikely to be damaged by storms. We strongly recommend support for further demonstration and development projects.

- Wave energy is at an early stage of development. There are challenging technical and logistical problems to be solved and, at this stage of development, it is not clear that these can be overcome at an acceptable price. Wave energy converters are, by necessity, massive structures at the sea surface where they would impact commercial and recreational use of the sea and would be subject to the full force of storms.

- Overall, the development of marine renewables will be challenging and, because of the need to test large machines in inhospitable conditions far from urban centres, will be expensive. However, they include some of the very few renewable technologies that have the potential to provide predictable power that is not dependent on the weather. To meet the targets of the 2008 Climate Change Act, marine renewables are likely to become an important ingredient in the generation mix. As with all the low-carbon energy options, there are technical and political risks in deployment - and some may fail. It is, therefore, vital to carry forward a range of potential choices.

- We would urge that a systems view of marine renewables is taken in evaluating costs and benefits versus other options. This is vital as the future energy system will be a complex network made up of many interdependent parts. No single technology should be assessed in isolation.

1. What are the potential benefits that marine renewables could bring to the UK and should Government be supporting the development of these particular technologies?

The main aims for the future UK energy system are security of supply, affordability and reduced emissions of greenhouse (mainly CO_2) gases. Marine energy could potentially benefit in two of these areas:

a) Energy security

Marine renewables could help meet peak electricity demands in an energy system relying heavily on renewable energy from wind:

- Tidal energy has the benefit that it is predictable. It is possible to predict the output of a tidal energy device decades in advance. The timing of tides also varies at different locations meaning a smoother supply from devices if distributed around the coast. In this, it is quite unlike wind energy that can sink to almost zero for a week or more during a settled anticyclone, such as has occurred in the last two winters.

- Wave energy is less predictable than tidal energy and also suffers from being, to some extent, correlated with wind energy. Waves tend to be larger during storms, when the wind is also strong, and to be of lower amplitude during calm weather (although in some conditions strong winds many hundreds of miles away can result in large waves on a calm day).

b) Contribution to UK CO_2 emission reduction

This will depend on the level of deployment of marine energy but has the potential to make a significant contribution. The figure of 61Mt of CO_2 from wave and tidal stream by 2050 given in the Marine Energy Action Plan appears to be a reasonable estimate.

Marine energy could also potentially help in the following areas:

c) Industrial opportunities

It is estimated that Britain has access to a third of Europe's wave and half of Europe's tidal power resources[1]. Because our natural resources are so suitable, we are well placed to be a first-mover, bringing industrial export opportunities should we be successful and others follow.

First-mover advantage and technological leadership are not sufficient, however. There is still a long way to go in terms of commercial realisation. Different technologies are at different stages. Tidal barrage technology is essentially mature but at least one major UK company has a new turbine design that may reduce costs and environmental impacts. Tidal stream technology is less mature but devices are now being refined by world class major companies in the UK and elsewhere. Wave energy is the least mature, but Scotland appears to be well advanced in terms of construction and testing at full scale.

[1] Atlas of UK Marine Renewable Resources, DTI, Dec 2004

d) Public acceptance

Given the widely-reported public resistance to deployment of wind turbines (envisaged as the largest source of renewable energy in the next 10-15 years), it may prove that much less visible tidal stream and wave devices will encounter fewer objections when going through the planning application process. Although this remains to be tested (and large scale marine power will often still require unpopular onshore infrastructure), a smoother passage through planning applications should reduce the financial risks for prospective investors. Tidal barrage projects have more major public acceptance issues because they involve building large civil engineering structures in river estuaries, however they can generate local public benefit, for example from new river crossings and associated economic regeneration opportunities.

Marine renewables have been estimated to offer a contribution to the UK's electricity supply of 15 - 20%[2] (excluding contributions from tidal range which could provide a similar amount). However, this is probably the upper bound and would not be realised until around 2050 as the technology is largely at prototype and proving stage. In the more foreseeable future – to 2020 – when the UK needs to achieve around one-third of its electricity supply from renewables, it is not expected that marine power will make a significant contribution. However, if the government continues to pursue an 80% reduction in CO_2 emissions by 2050, a balanced portfolio of low-carbon technologies will be needed and that will include marine energy. Anything which has peak output at different times to wind power could make a valuable contribution to the generation mix and reduce demand for peaking plant that is less environmentally sound.

These benefits will not happen without public support because marine is an emerging technology and the initial costs and risks are too high. However, the experience in Scotland demonstrates that with the right form of government support for initial stages, the transition from cottage industry scale to "initial mature" industry is possible for leading designs.

The engineering realities of achieving significant levels of marine technology should not be underestimated. In the case of tidal barrages, the technology is not new but its development to reduce costs and environmental impact is, and the risks of mass manufacture and deployment into one of the very large potential projects such as the Severn Barrage may be beyond the private sector alone. Tidal stream power devices are becoming more robustly engineered, with more effort needed on deployment, anchoring and maintenance recovery.

For wave power, devices fall into two categories – resonant devices that float on the surface and extract energy from a narrow frequency of waves or stationary structures anchored to the seabed or shoreline that funnel energy from all waves into a turbine or hydraulic mechanism. The floating devices are subject to all the rigours of a marine environment and hundreds of kilometres of plant would be needed to replace the equivalent of large thermal power plants. Stationary wave devices have high levels of embedded energy, are visually intrusive and are yet to demonstrate a favourable return of energy.

The engineering challenge to build, install, connect, operate and maintain, and ultimately replace - all at a scale that would contribute significantly to the UK's electricity supply - is considerable. If the government is to push these technologies it would be advisable to carry out a serious engineering appraisal of the risks and costs associated with a long-term, large-scale marine renewable industry, considering the different challenges of tidal barrage, tidal stream and wave energy separately. A market appraisal, including comparison with alternatives and consideration of overseas commercial opportunities, is also required.

[2] The Path to Power, BWEA, June 2006

2. How effective have existing Government policies and initiatives on marine renewables been in supporting the development and deployment of these technologies?

Scotland has so far been markedly more effective than the rest of the UK in supporting the development and deployment of marine renewables. The Scottish Renewables Obligation rules give a higher subsidy to marine renewables than the equivalent UK system, recognising the fact that the technology is worthwhile but at early stage.

Policy in Scotland has also been more effective in encouraging private industry to become involved. For example, the Wave Hub project in Exeter is only attracting very small scale investment from private industry at a "cottage industry" level, whereas in Scotland the greater government support has encouraged significant levels of investment and a local supply chain to develop. In addition, the Scottish Government's £10 million Saltire Prize for technological advances in wave and tidal energy is one of the biggest international innovation prizes in existence.

Government policies in England and Wales have been much less effective in supporting development of these technologies. The level of public sector resources being devoted to the development of marine power (eg the recently announced £20m DECC fund) seems rather modest. Only a small number of projects are being supported, and the level of central direct support is much less than was available via the Marine Renewables Deployment Fund which has been discontinued.

The reasons for the inadequate UK-wide support for marine energy include:

a) UK policy has tended to see marine as a relatively small contributor to national annual energy needs rather than more appropriately seeing it as the solution of choice for particular coastal regions both in the UK and abroad.

b) The planning and regulatory regimes for marine renewables have been complex and uncertain, with conservation and community obligations and priorities not always reconciled with power generation ambitions. The Scottish Government and others have identified issues about the cost of connection to the national electrical transmission system as having potentially perverse incentives. We are aware that work is underway to address conservation and grid issues but the final outcomes remain to be assessed.

c) There has been a policy over the years of evaluating renewable energy in terms of price per MWh without a proper assessment of the predictability of the output. If one takes a systems view of energy, the requirement of the electricity supply system is not to provide so many units of electrical energy over the course of a year but to provide particular power loads minute by minute. Viewed from this perspective, predictable energy, such as provided by tidal power devices, is more valuable than intermittent bulk energy units and should be evaluated against other predictable renewable options such as biofuels, electrical storage or demand control.

While R&D financing in the UK has produced a plethora of experimental designs, the funding has not been available for consolidation to take place.

Testing at scale is a vital but expensive part of the R&D phase because small scale tank-based water experiments do not provide a guide to the behaviour of the marine environment. The commitment to undertake large scale trials and deployment has until recently been lacking.

Support for the development of marine renewables could be argued to be “too little, too late”. The UK government is committed to massive investment in (particularly offshore) wind in order to meet European 2020 renewable energy targets. Insufficient development to date means that marine power is unlikely to contribute much towards these targets. With a fleet of new nuclear power stations also being planned in England, and a number of gas fired facilities also in planning or delivery, it is unclear how much demand there is likely to be for marine energy in the 2020s. One clear window of opportunity has been missed, the next is uncertain and that is not a good basis for confidence and long-term investment. However the challenge of decarbonising energy is massive and some currently promising options may fall by the wayside, meaning that having a range of choices is important. It is hoped that the current Electricity Market Reform will provide sufficient incentive to potential investors in marine renewables alongside other low-carbon technologies.

3. What lessons can be learnt from experiences within the UK and from other countries to date in supporting the development and deployment of marine renewables?

UK government (particularly England and Wales) support for marine R&D has been too short-term, too fragmented and too focused on pre-commercialisation research. For example, the recent EPSRC-funded SuperGen Marine 2 wave energy research programme is valued at £5.5 million over four years and is divided between four universities. This will enable some theoretical studies and testing at 1:100 scale in wave tanks. It will not enable building and testing of working machines, even at one quarter full-scale. Unless a serious intention to reach full commercialisation is shown and the technology development and additional sectoral requirements are driven forward, the sector can stagnate and nascent companies struggle to stay afloat.

Future public funding should concentrate on development and demonstration. The route to full commercialisation of any new technology is long, expensive and high risk, so there is no point starting if there is no clear strategy to reach the end.

The UK government’s latest energy Whiter Paper[3] on Electricity Market Reform moves policy closer to the Scottish model for technology-banded ROCs, which is a good move, but Scotland fears a lowest common denominator outcome and wishes to retain the right to set its own levels for ROCs.

Many of the lessons for marine renewables grid connection and transmission are similar to those faced by offshore wind. Some of the anchorage issues faced by offshore wind turbines may also have lessons for marine power, although devices that are floating freely rather than anchored to a foundation may present additional technical difficulties as is the case for some wave and tidal stream devices.

Other countries may offer generic lessons in industrial development, particularly in how best to develop good ideas into national industrial strengths. Denmark and Germany may be specifically relevant for their development of strong wind power industries and Portugal has invested in marine energy test beds.

There are other marine energy concepts that could be explored which may be of interest. For example the Dutch 'Energy Island' that offers bulk storage[4]. This has been developed with government support in The Netherlands through basic feasibility stages.

[3] http://www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/emr_wp_2011.aspx
[4] http://www.kema.com/services/consulting/utility-future/energy-storage/large-scale-storage.aspx

4. Is publicly provided innovation funding necessary for the development of marine technologies and if so, why?

Public funding will be needed if tidal stream and wave energy at least are to be commercialised because they are high-risk developments that require large (and expensive) trials. For water-based technologies, results from small scale prototypes cannot be scaled up on paper. The physical properties of water mean that small-scale prototypes in tanks do not behave in the same way as larger prototypes or full-scale models at sea.

For this reason we support the Marine Energy Action Plan's recommendation to provide funding for first and second generation sea trials. Also, government needs to appreciate that some publicly funded projects will result in failure. It cannot be assumed that potential failures have already been weeded out at this stage.

For wave and tidal stream devices, it is important to research the effectiveness of arrays of multiple units not just single examples. This is because:

- Any such device placed in the water creates waves of interference which affect the power and direction of waves reaching nearby devices. By utilising multiple technology types it is possible to increase the efficiency of an array because different types of devices capture different forms of wave.
- If different types of device are placed in the same array, systemic problems may arise in part, or all, of the array that were not observed in individual devices.
- It is necessary to test a range of different mooring methods with different strains on them in order to find optimal solutions for different areas of seabed which vary widely in composition and angle.

5. What non-financial barriers are there to the development of marine renewables?

Reputation – there has been a great deal of progress on wave power in the last five years. In Scotland, wave energy has now reached a stage in its development where mainstream commercial companies such as SSE and ABB are sufficiently confident to invest. Despite this, it is difficult to shake off the received wisdom that wave energy research has been around since the 1960s (eg Salter's Duck) and we are little nearer now to a workable and economically viable device than we were then. The key to this reappraisal lies in seeing successful marine power designs as the solution of choice in particular locations in the UK where there is a natural resource at a suitable scale for either local distributed use or to be fed into the national electrical transmission system.

Technical challenges – there are technical issues that still require solutions, although this is to be expected for any developing technology. Many of the issues relate to installing and operating machinery in a hostile environment and include mooring techniques, durability and maintenance. Grid connections represent a serious challenge although this is also being dealt with in offshore wind.

Regulatory - governments have, in the past, changed policy and programmes at short notice, without always fully considering the implications. The recent changes (regardless of whether they were right or wrong) to solar feed-in tariffs is a case in point. The uncertainty created makes private investment and commitment more difficult to secure. The current reform of the electricity market is a chance to provide stability and certainty and, as such, is critical to give investors the confidence to engage with marine energy.

Planning - the UK's spatial planning and conservation regimes should ensure pro-active and co-ordinated planning of energy infrastructure. Marine power priorities must be clearly considered alongside shipping and conservation issues, while onshore planning also needs to be made more certain and efficient. The proposed approach of the new Marine Management Organisation is encouraging in this respect, promising detailed analyses underpinning its off-shore planning and integration with associated on-shore planning, as well as coordination with Scottish and Welsh processes. However, it has not yet completed its first plans so its ability to deliver remains to be demonstrated. Smaller on-shore developments, such as substations and other overhead lines, can also be difficult to secure permission for – the more so as renewable energy is often generated in areas which have not previously had generating facilities (the same issues apply to wind power).

Skills – the UK renewable energy industry faces a general shortage of suitably skilled workers in both technical and commercial disciplines and faces stiff competition for talent with other industries, particularly offshore oil and gas and other major construction sectors. Relying on talent from those sectors or importing labour from abroad will not be sufficient.

Port capacity – major port facilities and related infrastructure will be required if marine renewables are to be installed at sufficient levels to contribute meaningfully to the UK's low-carbon electricity supplies. Serious thought needs to be given to these issues and not simply the offshore structures, particularly with regard to how they will interact with the growing offshore wind industry.

Environmental impact – whilst this is probably modest for tidal stream and wave energy (though impact on marine life would need to be studied) it is significant for tidal barrage schemes. More work is needed to maximise the potential of new technology to minimise this.

Other – there is the possibility of difficulties arising from other industries and services that will share the same space as marine renewables such as fishing, marine conservation, shipping and leisure services.

6. To what extent is the supply chain for marine renewables based in the UK and how does Government policy affect the development of these industries?

The marine renewables sector is currently too immature for a sustainable UK supply chain. Currently, the focus is on test units with no integrated plans to develop the full system that is required to deliver the technology to the seabed and the power to the land. However, compared with the wind sector, there is a much stronger element of UK ownership and control in the nascent marine renewables industry. Plus, a lot of what would be needed does exist in UK but it is not recognised as a marine energy supply chain. There is the possibility of a large and successful UK supply chain, as there is in the oil and gas sector, but it will not happen without a clear, integrated plan and the relevant support for it.

There are a number of successful examples in the UK and abroad, such as:

- In Scotland companies such as Aquamarine (a Dundee firm which built the Oyster 2 prototype) have diversified from the oil and gas industry. Aquamarine has a policy of investing in local capacity and building up the local supply chain, for example the European Marine Energy Centre (EMEC) testing facility in Orkney, and local consultancy firms for the purpose of obtaining the necessary consents.

- Norwegian tidal-power developer Hammerfest Strøm has placed contracts worth £4m to construct the first of their advanced HS1000 tidal turbines in Scotland using Fife-based Burntisland Fabrication Limited (BiFab) for the fabrication of the sub-structure. These will also be tested at EMEC.

Civil servants are naturally cautious and require a track record of success in order to minimise risk. In marine energy research this is a barrier because it is not until a model is scaled up to full size that its behaviour in a marine environment can really be tested. It is an iterative process since, as explained above, results at a small scale will not accurately predict how a device will interact with the marine environment at a larger scale.

However, capability has increased rapidly in the last five years, to the extent that commercial investors are now putting money into certain marine renewables. The situation in Europe has also improved with the EU Strategic Energy Technology Plan being amended to include marine renewables and calls for funding applications are being made.

It is important that the UK takes advantage of these opportunities for investment and follows the examples of best practice in order to develop a successful national supply chain and gain the maximum economic benefit from any potential marine renewables industry.

7. What approach should Government take to supporting marine renewables in the future?

The general approach from government towards marine renewables, as laid out in the Marine Energy Action Plan 2010 is sound. There is, however, a concern that the plan is good on intentions and aspirations but light on concrete actions. For example, it highlights the multiple stakeholders in the area but simply calling for better synergies across these bodies will not necessarily achieve that aim.

There is clearly a need to review the plan. A review was due to be completed by DECC in spring 2011 but is yet to be published. However, in the time since the original plan was completed a number of the stakeholder bodies, such as the RDAs, have been closed down. Some of the more important recommendations have also not been followed. The Marine Renewables Deployment Fund, which the plan called on to be extended, has now been withdrawn. As noted in the answer to question 2, this has reduced the amount of funding available and will undermine attempts to implement the rest of the plan’s recommendations.

Government should be bolder in the delivery of support for marine renewables. Policy should focus on creating critical mass not widespread subsidies. What is needed is a plan to deliver a certain amount of installed capacity by a set date and to put the right incentives in place to make it happen. This could include paying or part paying for development of robust test units and port infrastructure (which may also have benefits for offshore wind). We would not encourage increasing public support for research into new designs of marine device as this would merely add to the plethora of untested models.

Subsidy is required to de-risk the demonstration at scale stage for the most promising designs. A sliding scale of subsidy is needed over a number of years which is high initially then decreases over time.

8. Are there any other issues relating to the future of marine renewables in the UK that you think the Committee should be aware of?

The current Electricity Market Reform process will be vital in setting out the future incentives for renewable energy. Appropriate arrangements to supersede the current Renewables Obligations will be vital if the UK is to realise the full potential of its renewables opportunities. Marine power is perhaps not at the level of maturity where mainstream support through Contract for Difference feed-in tariffs are the most appropriate mechanism – government support is still needed but must be mindful of the transition between the types of support when developing and reviewing bandings.

On a more general level it may be worth reviewing the overall risk/cost/benefit profile to see which marine renewables are viable technologies, taking into account the future costs of other technologies and constraints on the availability of other renewable and non-renewable resources. Wave resource might ultimately give a total of 3GW, and tidal stream the same, so roughly 10% of today's peak electricity demand. This is not negligible, but equally only 10%, and by our earlier estimate perhaps 15% of total renewable energy. Tidal range technologies could provide equivalent amounts of energy but this will depend on which of only a small number of potential sites are developed. This analysis should consider costs and timelines to reach deployment at scale, and the costs and contributions (eg MWh, predictability) in a future energy world including smart grids and sophisticated demand management, possibly electric vehicles and a wide portfolio of renewable, nuclear and low-carbon fossil fuel sources.