



# postnote

January 2009 Number 324

## MARINE RENEWABLES

Britain has an EU mandated target to meet 15% of its energy requirements from renewable sources by 2020. The UK has the largest wave and tidal resources in Europe, so marine renewables are a candidate for contributing to this target. Around 15-20% of the UK's electricity could potentially be produced from marine renewable sources,<sup>1</sup> but the technology is not mature. This POSTnote considers the technologies available and the environmental, economic and technological challenges involved in their deployment.

### Background

#### Tidal Power

- 'Tidal stream' devices use the *flow* of water due to tides to generate electricity.
- 'Tidal range' devices use the *change in height* of water due to tides, using principles similar to a hydroelectric dam. There are only a few tidal 'barrages' (see Box 1). Tidal lagoons (structures built at sea to capture water at high tides) are also possible.

#### Wave Power

Wave devices use the motion of water caused by winds at the sea surface to generate electricity. While approaches are more varied than for tidal power, most devices fall into three main groups:

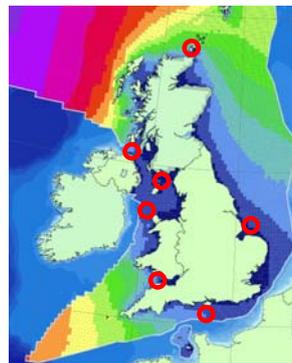
- Buoys, which move with the waves relative to an anchored structure below sea level;
- Segmented devices, where segments move relative to each other in the waves;
- Oscillating water columns, where the motion of the waves forces air out of a column through a turbine.

Other marine renewables which are not suitable for use in the UK,<sup>2</sup> and offshore wind, are not addressed here.

#### Location of marine resources

It is estimated that Britain has access to a third of Europe's wave and half of Europe's tidal power resources.<sup>3</sup> As Figure 1 indicates, UK tidal resources are concentrated in 7 main locations while wave resources are more extensive, both in the UK and worldwide. Prototypes have been tested in many countries, including the USA, China, Denmark and Portugal, but are not yet commercially viable. Marine renewables currently

account for less than 0.1% of the energy produced worldwide.



*Figure 1: Wave and Tidal Resources in the UK.<sup>2</sup> Coloured bands show wave resources, with purple denoting the greatest resource. Red circles show some of the most significant tidal power sites. Tidal resources are closer to shore than wave.*

### Government Support

The **Renewables Advisory Board (RAB)**, a government advisory body, suggests that to meet the EU target, 32% of UK electricity must come from renewables by 2020. The government has set a further target to cut carbon emissions by 80% by 2050. This has increased interest in all low carbon energy sources, including marine. The government supports marine renewables through a mix of market regulations and direct funding, for which around £160 million of public money has been allocated since 1999.<sup>4</sup> Funding is distributed by these sources:

- **SuperGen Marine Consortium:** £2.6 million over four years for collaborative academic research. Led by Edinburgh and Robert Gordon Universities;
- **Energy Technologies Institute (ETI):** A new body supporting energy technologies, including a few large marine projects, with up to £550 million of government-matched industry funding;
- **Marine Energy Accelerator:** £3.5 million from the Carbon Trust focused on measures to make marine renewables more cost competitive;
- **Marine Renewables Deployment Fund (MRDF):** £50 million for pre-commercial projects which have already shown three months continuous operation at sea.

Before the creation of the ETI in 2006, funding for device testing was also provided by the **Technology Strategy Board**. This may be reinstated after the ETI allocates its

first round of funding in early 2009. The Scottish government funds marine renewables through the £13 million **Wave and Tidal Energy Support Scheme**. They have also announced a £10 million **Saltire Prize** for one marine power project.

### Incentives

To encourage uptake of renewables, the **Renewables Obligation (RO)** requires UK electricity suppliers to source an annually increasing percentage of their electricity from renewables, currently ~9%. Under the 2008 Energy Act, it will reach 20% by 2020. The Act also introduced 'banding' within the RO to give extra support to emerging technologies such as marine. The Scottish government may choose to offer additional support for marine within this framework. More details about the RO can be found in POSTnote 315.

## From Research to Testing

### Device Concepts

There are over 80 marine renewables concepts at various stages of development. Government policy is to avoid 'picking winners', instead letting the market converge on the best approaches. Given the number of technologies already being developed, few researchers are looking for new ways to generate marine energy. Academic research (such as the SuperGen Marine Consortium) is focused on general issues such as moorings and control systems. Industrial research differs between devices. Almost all tidal stream devices involve turbines. Turbine technology is well understood, so the challenges lie in adapting to ocean conditions. Wave devices are based on technology which is less well understood. Research is more varied due to the many different types of device.

The Rance tidal barrage has operated in France for 40 years, so this technology is established, though there are few other barrages worldwide. Box 1 outlines the issues surrounding the proposed Severn barrage. Scale is a key issue. Tidal barrages are large, one-off projects. Wave and tidal stream devices, however, are small units which, when deployed in numbers, comprise an energy 'farm', similar to wind turbines. This means individual units can be deployed and tested. It is also likely that tidal barrages will require more extensive government involvement than modular devices, to be viable.

### Testing Facilities

Most modular marine devices are undergoing or preparing for testing. The UK has developed several testing facilities, largely through government funding:

- **New and Renewable Energy Centre (NaREC), Northumberland:** provides testing and research facilities for a range of renewables including marine. This centre is used for initial small scale prototype testing in sheltered waters.
- **European Marine Energy Centre (EMEC), Orkney:** Opened in 2003, this provides for full scale testing at grid-connected open sea sites. Orkney was selected for its large wave and tidal stream resource and challenging test conditions. EMEC verifies device performance, monitors the environment and helps to develop industry standards.

- **WaveHub, Cornwall** is designed to be a pre-commercial wave testing site. It will offer grid connected berths for 'plug and play' device testing.

Denmark also has a grid connected wave energy test site, and Ireland has a small-scale prototype facility. Other countries including Portugal, Spain, France, and Canada are developing similar facilities. Though not essential, they can make the testing process easier and quicker.

### Box 1. Severn Barrage

Many studies have considered a tidal barrage in the Severn estuary, which has the world's second largest tidal range. Under one proposal this could supply ~5% of UK electricity for 120 years.<sup>5</sup> Smaller barrages could be constructed at other UK locations and these options are also being explored. The Sustainable Development Commission (SDC) supports a Severn Barrage provided certain criteria are met:<sup>4</sup>

- **Construction of compensatory habitat.** The area is designated a Special Protected Area under the EU Directive on Birds and Habitats, and new sites would have to be constructed to replace those lost.
- **Public ownership.** Though the SDC supports private investment, it says that the project is so large (~£15 billion) that "the Government effectively underwrites the project". If it were privately led, "taxpayers and consumers could end up with all the risks but none of the benefits". The SDC also suggests that public leadership will "ensure long term sustainability".<sup>4</sup>
- **Development of other renewables.** A Severn barrage can provide only 1% of the UK's energy, so could not meet the EU targets on its own. But as the project is so large, there are concerns it could affect support for other renewables needed to meet the EU targets.

### Issues in Research and Testing

There are few published data on the performance characteristics of many marine technologies. This is largely due to the limited number of devices tested. Also, developers are concerned about compromising intellectual property (IP). This restricts information sharing, and can make it hard for funders to establish the characteristics of devices, and allocate funding. IP concerns can make developers reluctant to collaborate, limiting knowledge transfer from, for example, the oil and gas industry. However, there have been some notable collaborations: for example Marine Current Turbines (Box 2) announced in early 2008 that they would work with the utility company 'npower' on their next project. Funding bodies such as the ETI have also tried to foster collaboration. However, this has led to questions about how any resulting IP will be managed.<sup>6</sup>

Only two devices, Pelamis (Box 2) and Open Hydro (a tidal stream device), have been tested at EMEC. This is due to the challenges involved in moving from laboratory to open water testing. Some developers attribute the delay to lengthy contract negotiations, while the Renewables Advisory Board suggests developers may have been over optimistic in earlier estimates of their state of development. It also thinks the gap from initial testing at NaREC to full-scale testing at EMEC is too wide and an intermediate facility would aid progress.

## From Testing to Deployment

### Deployment and Maintenance

As shown by recent problems with the deployment of SeaGen (Box 2), it can sometimes be difficult to access suitable vessels, as ships are not designed for installing the devices. Access for maintenance is also difficult, particularly sub-sea, and often requires the return of the device to shore. Many companies are considering developing bespoke equipment for such purposes.

#### Box 2. Technology Case Studies

##### Pelamis

Pelamis is one of the wave energy devices that has undergone open sea testing. It consists of hinged segments which move relative to each other due to wave motion, generating power. Following testing at EMEC, the Pelamis company is building its first wave farm in Portugal, where 'feed-in tariffs' (page 4) are attractive. Three devices have been installed in the first stage, giving a total capacity of 2.25MWe. If tests are successful, the site will be extended to create a 22.5-30MWe wave farm. For comparison, the UK's Sizewell B nuclear plant has an output of 1180MWe.

##### SeaGen

This 1.2MWe tidal stream device was recently installed in Strangford Lough, Northern Ireland. This followed testing of a 0.3MWe prototype, SeaFlow, at Lynmouth, Devon. The concept, developed by Marine Current Turbines (MCT), has two key features:

- It is not completely submerged, so the turbines can be raised above the sea for maintenance.
- Its blades can be pitched through 180° to permit generation on both the ebb and the flood tides.

Installation of SeaGen was delayed as the company had problems finding a suitable ship for deployment. The device had to be redesigned for a different ship. Following this testing, MCT hopes to be the first to qualify for the MRDF. Their next proposed project is a 10.5MWe array in Wales.

### Durability

Devices have to withstand storms, high seas and corrosive salt water. Both wave and tidal stream devices require anchoring to the seabed, which is technically challenging. How these issues are dealt with varies between devices. All require extensive testing to prove their durability before deployment.

### Environmental Impact

Environmental impact varies depending on the type of device and location. Tidal barrages potentially have the most significant impacts (Box 1). Little environmental research has been conducted, as few devices have been deployed, but a strategic environmental assessment (SEA) has taken place in Scotland.<sup>7</sup> This reviewed the impact of marine renewables on the environment, landscape and other sea users and highlighted a range of issues (some are outlined below). Following the SEA, the Crown Estate called for tenders for marine power projects in the Pentland Firth, in north Scotland. There has been no such study elsewhere in the UK but there is industry pressure for the government to review this position.

### Planning

Deployment can be delayed by lengthy planning inquiries. Developers claim that UK planning procedure is slower than in other countries. This contributed to Pelamis' decision to deploy its first wave farm overseas

(Box 2). The British Wind Energy Association (BWEA) suggests a more proportional approach, so small projects can be assessed rapidly. The 2008 Planning Act will not be relevant to marine renewables, as it covers only deployments in excess of 100MW offshore.

The Scottish SEA found that conflict with other sea users may be a significant issue. The forthcoming UK Marine Bill includes proposals for the creation of a Marine Management Organisation in England and Wales which may handle such issues. Natural England suggests that marine renewables could be deployed in "Marine Protected Areas" (see POSTnote 310, "Marine Conservation Zones"). This would reduce conflict with other sea users who are excluded from these zones.

### Grid Connection

Most UK marine resources are located off the north and west coasts of the British Isles (Figure 1). These areas are far from regions of high population density. Transmitting electricity from marine renewables located in these locations would require significant development of the grid network, which raises many issues such as public acceptability, cost, and the length of time the development would take. Delays could disadvantage early developers who may have to bear additional costs. Plans to improve grid access for renewables are outlined in the Transmission Access Review.<sup>8</sup> For further details, see POSTnote 280, "Electricity in the UK".

### Variability of Supply

Electricity from marine sources is not produced continuously. For example, tidal stream devices produce zero electricity at high and low tide, with peaks between. Though completely predictable, this variation makes grid flexibility important, particularly for large scale production such as a Severn Barrage (Box 1). Wave behaviour is less variable from hour-to-hour<sup>9</sup> (placing fewer demands on the grid) but also less predictable, as it depends on weather patterns. However, it can be forecast fairly accurately several days in advance using modelling. Predictability is important as it allows the grid to adjust to ensure demand is met. Wave energy is well matched to current seasonal demand. Around half of UK wave energy is produced over winter when demand is high.

To maintain consistency of supply, marine renewables would be best used as part of a mix. For example, wave and wind are not directly correlated and a 50:50 mix minimises variability.<sup>10</sup> Using a range of locations can also help to limit variation in supply, but would require measures to encourage development at less profitable sites, which would however benefit the whole network.

### Policy Challenges

Government policy is to allow the marine renewables market to converge on the best of the many approaches being developed. Views are mixed about whether this stage has been reached and, if so, whether the policy should be reviewed. The Renewables Advisory Board (RAB) suggests funding more general projects such as grid connection and mooring (such as through the SuperGen Marine Consortium) rather than specific device development.

## Public Funding

Many developers consider the range of funding sources too complex and inconsistent. The BWEA criticises inflexibility in many application criteria, though the Scottish Wave and Tidal Energy Scheme is praised for its more flexible approach. No devices have qualified for the Marine Renewables Deployment Fund because technologies are not sufficiently developed to meet the criteria. The reasons for this are disputed. Some suggest the delays are due to unforeseen technical and engineering challenges of the marine environment. The RAB also points to over-optimism amongst some developers. Despite the lack of uptake, it has recommended the MRDF remain, as some technologies are now close to qualifying.<sup>3</sup> The Carbon Trust suggests another problem might be a funding 'gap' between research and development and the MRDF. Another issue is that the Energy Technologies Institute (page 1) will fund only a handful of large marine projects, while the Technology Strategy Board, a potential source of funding for other marine projects, has not issued a call for Marine Energy research since the ETI was set up.

Marine renewables are not currently cost competitive. It is hard to analyse their economics as devices are at an early stage of development and vary significantly. Cost will depend on many factors such as maintenance charges, grid connection and construction materials. These differ between devices and are likely to change as the technologies develop. Whether prices are competitive will depend on the cost of other electricity generation sources.

The Carbon Trust predicts that prices will need to be in the range 2.5-8 pence per kilowatt-hour (p/kWh) to be competitive. They estimate current costs to be in the range 22-25p/kWh for wave and 12-15p/kWh for tidal stream power.<sup>1</sup> It is possible that these costs will decrease through economies of scale, increased efficiency, reduced maintenance costs and increased lifespan as the devices develop. Similar technologies, such as wind, have seen cost reductions of 10-15% with every doubling of deployed capacity. Through comparison with these technologies and analysis of devices currently being developed, the Carbon Trust predicts that marine renewables should show similar rates of cost reduction. It is too early to say whether marine renewables will be cost competitive and when that might be. However, the Carbon Trust suggests they are unlikely to be competitive "until at least hundreds of megawatts capacity is installed".

## Private Sector Funding

As in other high level technologies, investment in marine renewables is risky. As technological approaches converge, risk decreases. Complex planning processes and policy uncertainty also contribute to investment risk. As technologies are not yet cost competitive, investors require evidence of long term support through measures such as the Renewables Obligation. Increased support as proposed in Scotland is welcomed by the industry. However, most would also prefer consistency across the UK market rather than different parts of the UK acting independently. Discussion between Holyrood and

Westminster are ongoing. Alternatives, such as 'feed-in tariffs', would allow distributors to charge a higher rate for electricity from renewable sources. A feed-in tariff (of €0.26/kWh) was significant in the decision to deploy Pelamis in Portugal rather than the UK (Box 3).<sup>11</sup>

## The Future

Marine renewables contribute ~1MWe to UK current electricity capacity. It is unlikely that they will be major contributors to the 2020 targets. They may be a better prospect in the medium term once the technology has matured. Energy Technologies Institute targets for marine renewables are 2000MWe by 2020 and 30,000MWe by 2050. A recent government consultation on UK renewable energy strategy considered many options including a Severn barrage. A finalised strategy will be published in spring 2009.

## Overview

- The UK has significant wave and tidal resources;
- A range of technologies is being developed to harness these resources, but most are immature;
- Initial deployment has been slower than expected - one reason is that the ocean environment poses a considerable engineering challenge;
- The current grid network would need significant modification to accommodate marine sources, which tend to be in remote locations;
- Marine renewables could ultimately supply up to 20% of UK electricity.

## Endnotes

- 1 *Future Marine Energy*, The Carbon Trust, January 2006.
- 2 This includes Ocean Thermal Energy Conversion (OTEC) which is effective only in the tropics.
- 3 *Atlas of UK Marine Renewable Energy Resources*, Department for Trade and Industry (now BERR), December 2004.
- 4 *Marine renewables: Current status and implications for R&D funding and the Marine Renewables Deployment Fund*, Renewables Advisory Board, January 2008.
- 5 *Turning the Tide: Tidal power in the UK*, Sustainable Development Commission, October 2007.
- 6 House of Commons Innovation, Universities, Science and Skills Committee, fifth report of session 2007-8, *Renewable Electricity Generation Technologies*, HC 1063, para 15.
- 7 *Scottish Marine Renewables: Strategic Environmental Assessment*, Faber Maunsell and Metoc PLC, March 2007.
- 8 *Transmission Access Review*, Ofgem and BERR, June 2008.
- 9 *Variability of Marine Resources*, The Carbon Trust, July 2005.
- 10 *Diversified Renewable Energy Portfolios for the UK*, Graham Sinden for the Carbon Trust, October 2005.
- 11 House of Lords Committee on Economic Affairs, fourth report of 2007-8, *The Economics of Renewable Energy*, HL 195-I, Memorandum by Mr Neil Kermod.

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology.

POST is grateful to Sue Kirk for researching this briefing, to the Institute of Physics for funding her Parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact Dr. Chandrika Nath, at POST.

Parliamentary Copyright 2009

The Parliamentary Office of Science and Technology, 7 Millbank, London, SW1P 3JA; Tel: 020 7219 2840; email: [post@parliament.uk](mailto:post@parliament.uk)

[www.parliament.uk/parliamentary\\_offices/post/pubs2009.cfm](http://www.parliament.uk/parliamentary_offices/post/pubs2009.cfm)