Over 20 companies developing technology

British Isles - powerhouse of wave energy

Surrounded by sea, the British Isles are ideally located to receive a continuous flow of renewable energy from waves. While offshore wind power is taking off, a new marine-energy industry - focusing on wave and tidal power - is emerging. With at least twenty companies involved, Britain is at the forefront of the development of wave power. Even technology from Scandinavia, the US, and Australia is being deployed and fine-tuned in British waters.

By Leen Preesman

Wave power is, in theory, a highly promising form of renewable energy. Yet, as the first commercial wave-power farms are appearing on the horizon, it is clear that this technology still has a long way to go. Most projects depend heavily on subsidies, and while it is too early to identify the successful designs, few companies can provide an estimate of the production costs.

Besides the technical challenge, the access to or the capacity of the grid are often problematic in areas where wave-power conditions are best. According to the International Energy Agency, a lack of cooperation between developers as well as the absence of guidelines and standards is slowing down developments. However, the IEA also observed a general increase in government funding for research and development.

The UK government has indicated that marine power is probably not going to play a major role in the energy supply. Nevertheless, experts agree that wave power can be a useful diversifier in the energy mix, and that its economics are getting better as fossil-fuel prices go up.

In this article we highlight the different technologies that are in an advanced stage of development.

Pelamis Sea Snake - the world's first wave-energy farm

The Pelamis Sea Snake is among the most promising technologies. It is a 160-meter long construction of linked floating tubes, and the wave-induced movement on the hinge points generates the power.

The Edinburgh-based manufacturer, Pelamis Wave Power (PWP), will soon switch on the 'world's first' wave-energy park off the coast of Portugal. The

Pelamis Sea Snake

three devices of the €8 million project - commissioned by Portuguese energy company Energis - are expected to produce 2.25 megawatt. The Portuguese government has guaranteed an index-linked price of 24 eurocent per kilowatt-hour during the next 15 years, as part of its plan to develop 550 megawatt of wave power, for which it has set aside 1.4bn.

The three Sea Snakes are meant to be the start of a much bigger project. According to Max Carcas, PWP's Business Development Director, Energis has signed a letter of intent for a 20-megawatt wave farm in Portugal. However, Carcas could not be more specific about the timescale. The interlinked multimachines will be connected to shore by a single sub-sea cable, PWP indicated. A typical 30-megawatt plant will occupy one square kilometer of sea surface.

In September, the Scottish government granted energy company Scottish Power planning permission for the 'world's largest' generating-capacity wave farm, consisting of four 750 kilowatt Sea Snakes. The floating generators will be positioned off the coast near the European Marine Test Centre on the Orkney Islands. The commercial wave farm is expected to start producing energy in the winter of 2008-2009.

The €10 million project has received a €6 million grant from the Scottish government. In addition, it will also benefit from the Renewable Obligation Certificate scheme, Carcas said. PWP's Business Development Director expects to have a technology that can compete with offshore wind power within four to five years, and with onshore wind technology within ten years.


Wave Dragon

Wavegen Limpet, six years of field testing

The Inverness-based company Wavegen - a subsidiary of Voith Siemens Hydro Power Generation since 2005 - has developed the world's first grid-connected wave-power generator. Its Limpet, which has been operational since 2000, is powered by an oscillating water column (OWC). The company has been testing two 250-kilowatt generators for up to six years. In more recent times, the Limpet trials have focused on 120-kilowatt turbines.

The shore-based Limpet is housed in a concrete shell against the rocky Atlantic shore off the Scottish island of Islay. An opening in the front of the installation allows the sea to rise and fall within a chamber, due to the action of the waves. This motion compresses and decompresses the enclosed volume of air. The energy generated from this pressure differential is then transformed into electricity with the aid of a Wells turbine and a generator. At the moment, the Limpet is Wavegen's testing site for the fifth generation of turbines.

Meanwhile, the company has developed a generator - also based on the OWC principle - that can be incorporated in breakwaters. Last summer, the Basque Energy Board commissioned Wavegen to build the world's first commercial breakwater-energy plant on the Spanish Atlantic coast. The new plant in Mutriku,

which is to become operational in the winter of 2008-2009, consists of 16 Wells turbines of 20 kilowatt each, integrated into a breakwater, which is being constructed by the local government. It must deliver green electricity for 250 local households.

'We don't know the costs per kilowatt-hour, because we are focusing on the supply side', Marketing Manager David Langston says. 'Our reason for the project is to identify the costs and ways to reduce them in the future', he adds. 'We hope to be competitive with wind power within five years.'

Together with Npower Renewables, Wavegen is also preparing a breakwater project on the Atlantic coast of the Outer Hebrides in Scotland. The Siadar project is aiming to incorporate up to thirty 100-kilowatt turbines into a new pier. The planning application for the 3-megawatt plant will be submitted early 2008.

So far, Npower has funded the Siadar project itself. However, it said it will be looking to secure funding from an appropriate mechanism, such as the Marine Supply Obligation or the Marine Renewables Development Fund.

Wave Dragon - a floating giant

The Wave Dragon design stands out among the wave-power technologies. This large floating device consists of two wide-open arms, which deflect the incoming waves into a reservoir above the sea surface. The draining water directly drives the turbines at the bottom of the structure. The turbines contain the only moving objects of the plant.

According to the Wave Dragon company, the Wave Dragon produces energy in a similar way as a low-head hydropower station. It considers the absence of new technology as a major advantage of the concept.

After twenty years of preparations and four years of prototype testing, the Danish company expects to launch a full-size 7-megawatt demonstration plant this year. It is meant as the first step to a 70-megawatt wave-power farm in 2010.

The Wave Dragon's 120-meter long arms span a total opening of 300 meters. The incoming waves are directed to a 140-meter ramp. Including the concrete ballast to keep the generator stable, its total weight is 33,000 tons.

The generator will be moored between three and five kilometers off the Welsh coast, near Milford Haven. It will be connected to the local grid by means of a sub-sea cable. Although there was still no clarity on the available grid capacity in November, Wave Dragon Chairman Hans Christian Sorensen does not expect this to be a major problem.

The same goes for the chosen site, a Special Area of Conservation (SAC). 'Our device will only be there for testing for three to five years,' Sorensen says.

Wave Dragon has taken environmental aspects into account by replacing all hydraulic oils with water hydraulics. In addition, it has refrained from using anti-fouling paint. The visibility of the structure will be limited to a height of seven meter maximum, the company stressed.

The total costs of the demonstration project are estimated at €25 million, of which €2.4 million will be covered by the EU and over €7 million by a grant from the Welsh government. Sorensen cannot estimate the cost of Wave Dragon electricity. 'We need to have more devices running first,' he says. The Chairman expects that his technology will become competitive with offshore wind power after he has sold between fifty and a hundred Wave Dragons with a capacity of between 4 and 7 megawatt. Wave Dragon has formed a project-development company which aims to develop a 50-megawatt wave-power farm in Portuguese waters. The firm - Tecdragon, in which Portuguese and German investors participate - aims to have the project up and running by 2010.

Archimedes Wave Swing - an underwater bobber

The Archimedes Wave Swing is a totally submerged cylindrical buoy, which responds to the changing water pressure of waves passing overhead. The waves move an air-filled upper casing against a lower cylinder, which is fixed to the seabed. The relative movement between the floater and the lower part is converted into electricity through a hydraulic system and a motor-generator set.

According to the Wave Swing manufacturer - Scottish-based AWS Ocean Energy - the generator avoids large and potentially damaging waves, because it will be constructed at least six meters below the surface.

In 2009, the company aims to launch its 250 kilowatt 'pre-commercial demonstrator' in 50-meter deep water at the European Marine Energy Centre (EMEC) in Orkney. The project has been granted a €3 million contribution from the Scottish Executive. AWS Ocean Energy says it also expects financial support from the Carbon Trust, a government-funded green consultancy.

The company already claims that its low maintenance design and the high ratio of produced energy will result in the cheapest electricity from wave power. It also rates its environmental credentials highly, because of the absence of a visual impact and noisy equipment.

Ocean Energy Buoy - another OSW device

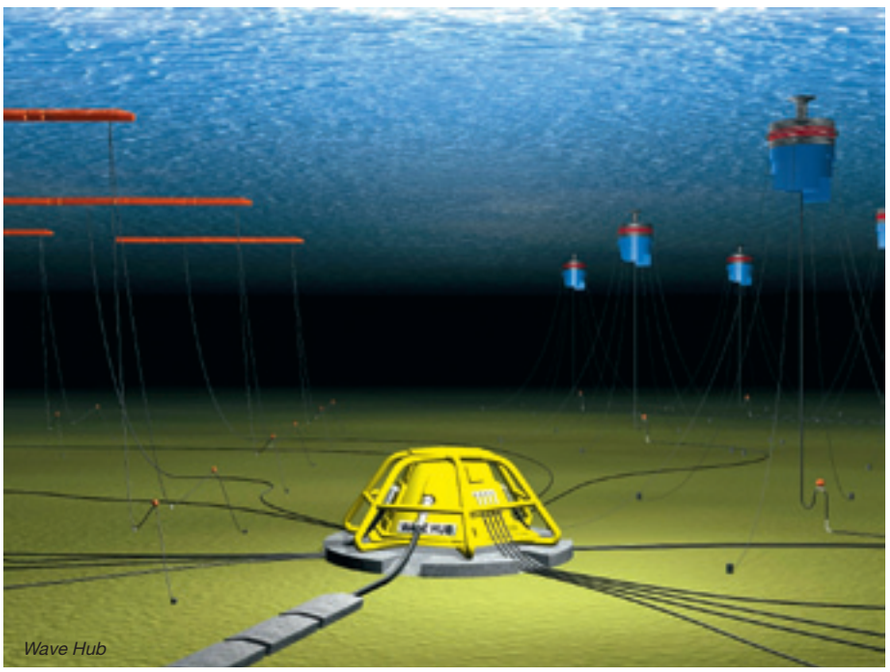
The wave-power generator developed by the Irish private entrepreneur Michael Whelan is, like the Wavegen, based on the oscillation water principle. His device is a floating L-shape lying on its back, with an open front. The wave-induced air movement inside the chamber is being harnessed by a Wells air turbine high up in the vertical part, which turns the air flow into a continuous one-way rotation.

The 28-ton prototype - measuring 12x4x4 meter - was recently fitted with a 16 kilowatt Wells turbine. This was after it had spent eight months in Galway Bay, on Ireland's west coast, which has the largest wave-power potential in Europe. Over there, the body of the Ocean Energy Buoy survived one of the worst storms in 20 years. If the combination is successful,

From above to below:
Fred Olsen's multipoint absorber rig
Oceanlinx Unit
Ocean Energy Buoy prototype
Fred Olsen's multipoint absorber

Whelan says he will soon make a decision on building a full-scale 650-ton prototype of 40x20x16 meter, fitted with two 750 kilowatt generators. In Whelan's vision, the Ocean Energy Buoys are to be moored in groups in water depths of 30-50 meters, delivering their power onshore through a submarine cable.

The Irish wave-power pioneer expects to be building commercial devices by 2011. 'Given the recent price developments, the gap between fossil energy and wave power is narrowing quickly,' he comments. So far, the government-funded agency Sustainable Energy Ireland has contributed 45% of the €2 million project. The Irish Marine Institute has also given financial support to the research on the Ocean Energy Buoy.


Wave Hub

Wave Hub - a giant socket for wave-power generators

A relatively new development within the wave-power generation industry is the Wave Hub, an underwater hook-up for an array of devices. The big socket on the seafloor - including transformers and circuit breakers - will be constructed 16 kilometers off Cornwall's Atlantic coast, where waves measure six meters or more.

With a capacity of up to 20 megawatt, hook-up points for 30 devices, and an available sea surface of eight square kilometers, the Wave Hub is being advertised as 'the world's first large-scale wave farm'. It is scheduled to become operational in 2009.

The produced wave power will be brought ashore by a 25-kilometer cable, buried more than two meters under the seabed. The green electricity will be fed into the grid through a new 33-kilovolt substation onshore. The €42 million project has been commissioned by the South West of England Regional Development Agency (SWRDA). The national government will contribute €7 million, whilst approximately €15 million of funding is expected from the EU Regional Development Fund

According to the SWRDA, an environmental impact assessment has shown that the negative effects of the Wave Hub on fisheries, flora, birds, and sea mammals will be minimal. However, the British Surfers' Association has voiced concern about the expected reduction of up to 13% of the waves rolling ashore.

Four companies have secured connections on the Wave Hub:

• **Power Buoy**. The US-based company Ocean Power Technologies (OPT) has secured four connections on the Wave Hub for its 150-kilowatt Power Buoys. It plans to use the facility to expand to a wave farm of 30 generators within four years, a spokeswoman indicated.

The (floating) Power Buoy generates electricity through a piston-like structure, driven by the rising and falling movement of the waves. According to OPT, the technology has been tested in the US since 2004, both in the Atlantic and in the Pacific. OPT claims that the generating costs of its green power can be as low as 3.4 eurocents per kWh.

• **Oceanlinx**. Australian company Oceanlinx will deploy approximately four devices of its OSW technology at the Wave Hub site, where they are to produce 5 megawatt. Its generator - a 1.5-megawatt type is its standard - is driven by Oceanlinx' own turbine technology; a two-way turbine with a variable pitch blade in combination with a slower rotational speed and a higher turbine torque.

The company said that a full-scale unit has already been tested successfully in Australia during the past two years. It claims to be at an 'advanced permitting stage' for the installation of 18 units in Portland, Australia.

• **Fred Olsen**. Fred Olsen's multiple-point absorber is also set to hook up a device to the Wave Hub. Originally a shipping firm, the Norwegian company has expanded into offshore energy and renewables. The company has developed a 'multiple-point absorber system', which consists of a number of floating egg-shaped buoys underneath a floating platform. The technology has been tested since 2004 on a 1:3-prototype in Norwegian waters. The full-scale device to be attached to the Wave Hub is expected to generate over 2.5 megawatt. Olsen aims at a cost of 2.8 eurocent per kWh.

• **Pelamis Sea Snake WestWave**. A partnership of renewables developer Ocean Prospect and Eon, the UK's largest integrated energy company, will deploy seven Pelamis Sea Snakes of 750 kilowatt each. ■

European Marine Energy Centre

Since early 2004, a test centre for wave-power technology has been operational on the Orkneys' island of Eday. The European Marine Energy Centre (EMEC) claims to be the world's first facility of its kind. It comprises four test berths at a depth of 50 meters at a distance of two kilometers offshore.
EMEC offers developers the opportunity to test their prototypes in waters with a wave-power potential which is among the highest in Europe. Offshore energy converters can be connected to the national grid via seabed cables.According to EMEC, its site offers a wide range of sea and weather conditions with 'comprehensive round-the-clock monitoring'. In 2004, the Pelamis Sea Snake was the first marine-energy converter that delivered waves from EMEC's test site to the grid.

At present, EMEC's test site is empty, but at least three companies are expected to test their technologies on Orkney next summer. Four Pelamis Sea Snakes will be deployed, as well as the piston-driven Power Buoy of Ocean Power Technology.
The Oyster of British company Aquamarine Power is also expected on the test site. The Oyster is fixed to the seafloor, and produces energy by swinging back and forth on the wave motion. According to EMEC's spokeswoman Edwina Cook, the test centre is also negotiating with several other companies that are interested in trials for short periods. A second test site for tidal-power devices is being set up near Stromness on the Orkneys.

The experts' views

The lobby organization

At this stage, it is very hard to judge the various wave-power technologies. Peter Madigan is Head of Offshore Renewables of the British Wind Energy Association (BWEA) - since 2004 also the advocate of wave and tidal stream energy. He commented, 'To me there are no clear winners yet. And no commercial projects have started yet either. The range of devices is very diverse and aimed at capturing different energy profiles. Therefore we will probably end up with different wave-power generators for different conditions,' he points out.
Madigan believes that wave and tidal-stream power could contribute 3% to 4% to the UK's energy production by 2020. 'It could play a useful role in the required energy mix, and for that reason it does not need to compete with offshore wind power,' he says.
However, the development of wave and tidal power will depend on financial support mechanisms, Madigan stressed. He has high hopes of a positive outcome of the present review of the Renewable Obligations Certificate scheme. 'If wave and tidal power will indeed be reclassified as 'emerging energy', they will get a higher priority than wind power,' he explains. 'This will mean a boost for the emerging industry, and it will support the shift from research and development to commercial projects.' On 28 February, the BWEA will hold its wave and tidal energy conference, 'BWEA Marine 08', in Edinburgh.

The sceptic

Although he acknowledges that wave and tidal energy could help to reduce carbon emissions, Professor Ian Fells remains sceptical about its impact. 'It is not going to save us,' he stresses. 'If you consider that the load factor for wave-power generators is 50% at best, you can calculate how many devices you need to produce the equivalent of a 1,200-megawatt nuclear-power station,' he explains. 'Based on the two generators in commercial production, Wavegen's Limpet and the Pelamis Sea Snake, we will need several thousands of them to match that output.'

Professor Fells is the founder and former Chairman of the New and Renewable Energy Centre in Blyth.
The commercial institute is an initiative of the regional development authority in Northumberland. Nowadays, Fells runs a consultancy on energy and environment.
In his opinion it is much more cost effective to build more nuclear capacity than to focus on renewables. 'In 2007 alone, the government paid €1.5 billion through the Renewables Obligations Certificate scheme to get 3% of the national electricity produced from renewables. For twice that amount you can build a nuclear power station,' he argues.
Tidal power, especially tidal currents, has the best potential for generating marine energy, Professor Fells believes. 'However, the best option is the proposed barrage in the estuary of the river Severn to harvest the power of the large tidal difference,' he says. 'The Severn Barrage could generate 5% of the UK's power needs.'

The Carbon Trust

According to the Carbon Trust - a government-funded company with a mission to accelerate the UK's move to a low-carbon economy - offshore wave energy has the greatest potential for the UK. It estimates the amount of energy, carried by offshore waves and which is practically convertible into electricity, at approximately 50 TWh a year. This is roughly one-seventh of the current electricity consumption in the UK.
However, the potential near-shore and shoreline wave energy is estimated at 7.8 TWh/y, and therefore niche, it says in its report 'The Marine Energy Challenge'. The potential for tidal stream power is 18 TWh/y, it adds.
The Carbon Trust expects wave and tidal-stream energy to become competitive with other renewables and combined-cycle gas turbines (CCGT) when at least hundreds of megawatts of capacity - equal to several large-scale wind farms - have been installed. 'But given the rise of fossil-fuel costs, it is prudent to continue investing in alternative technologies to create a deployment option if the technology becomes economically viable,' it says.