WAVE ENERGY GENERATION: HIGH EXPECTATIONS AND CURRENT REALITY IN THE UK

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INTRODUCTION

British people of a certain age may have fond memories of watching the Salter duck—a tiny wave device-bobbing up and down in a wave tank powering a small light bulb in the Tomorrows World studio on BBC1, no doubt murmuring sagely that it was the future of power generation for an Island nation such as the UK. (1)

Those same viewers may have visited a tidal power mill in the UK—such as Eling on the south coast—or gazed in awe at the power of the flood tide as it flows into a channel, or watched the waves as they crash onto our shoreline.

So where are we 25 years on from the Salter duck in harnessing the waves? How much further advanced are we than our ancestors who built the Eling tide mill? Are we significantly closer to realising the dreams of our forefathers who 100 years ago had plans to build a barrage across the Severn to harness the power of the second highest tidal range in the world? (2)

The Eling tide mill web site contains the following information;

"The ONLY regularly working tide mill IN THE WORLD—AND IT STILL PRODUCES FLOUR DAILY! See natural tidal power, harnessed in a centuries old (900 years) tradition, producing stone ground organic wholemeal flour from English wheat. The mill is open Wednesday to Sunday from 10.00 am—4.00 pm. For milling times visit: (3)

That the tide was being harnessed 900 years ago to produce one of the basics of the age—flour—is clearly a close analogy to our current desire for the tide to produce one of the most basic needs of our own time-electricity.

The drawbacks of tidal technology can be seen in the need to ask for milling times. The tide moves in and out and doesn't always have the capacity to generate power. Similarly those observers of the waves crashing on our shore will recognise that sometimes the sea is like a mill pond. So in some respects ocean power may suffer from the same inherent drawbacks as wind power, the variability of renewable power sources.

The proposed harnessing of the Severn estuary raises a further issue that has also bedevilled wind-that implementing the technology can cause great controversy and ironically creates a green dilemma. In the case of the estuary that the means needed to generate the power will fundamentally change the habitat and appearance of the estuary as we know it.

This article concentrates on wave power and examines the current state of the technology and the practical considerations of generating power from this renewable source.

THE DRIVE FOR RENEWABLES

The current European target is to source 20% of its energy-on average across its members-from renewables by 2020 in order to reduce CO_2 emissions and secure energy supplies. For the UK this is 15%. In this context energy includes heat and transport as well as electricity (4) Wave and tidal power is expected to make a significant but largely unspecified contribution to meeting these targets. The govt seem to want to exceed this aim with 35% by 2020 (5)

To date much of the UK's efforts has been directed towards increasing the renewables proportion by building additional controversial wind farms. The UK is Europe's windiest country (6) and much of that wind is found on some of the most beautiful upland areas of the country.

The raw material of wind, wave, solar, and tidal, demonstrates something of a 'goldilocks' syndrome, in as much to operate effectively the mix must be not too hot, not too cold but 'just right'. The difficulty in achieving this happy medium was illustrated by the severe downturn in wind power contribution during the 2008/9 winter (the coldest for 12 years) (7) when a high pressure sat over the UK. The resultant long windless spell during this intensely cold period occurred just when power was most needed.

Small wonder the Govt is looking at a range of other renewables to help meet its targets and that the UK with some 12500 km (7760 miles) of coastline (8) is anxious to harness the power of the sea.

WHAT IS WAVE ENERGY?

Ocean waves are created by the interaction of wind with the surface of the sea causing a movement of water, with the size of the waves determined by the wind (speed, period and distance), bathymetry of the seafloor (which can focus or disperse the energy of the waves) and currents. Waves contain a great deal of energy as water is a denser medium than air, in this it can be described as a more concentrated form of wind energy. According to wave consultancy Seabased of Uppsala Sweden the energy density per wave meter for 2 m significant wave height is about 10 times higher than the energy density of wind per square meter.

Generally, the stronger the wind and the longer the distance over which it travels, the larger the waves will be and the more energy they are likely to carry. Waves can travel great distances without significant losses of energy and act as an efficient energy transporter across thousands of miles. In deep water long waves travel faster than short ones, with velocity being proportional to the long ones.

Due to prevailing winds from the west, waves on the west coast of the UK tend to contain more energy than those on the east coast, as the wind can blow all the way across the Atlantic. As waves reach the shallower water near our coasts, they begin to lose energy through friction with the seabed and eventually break on the shore.

The power of waves that has travelled considerable distances as it arrives on an Atlantic facing coast can be seen in Cornwall which has some of the best surf in the UK. However, the offshore environment can be severe, so a wave energy device usually needs protection from stresses in a similar way that wind turbines need protection against high winds.

Changes in wind direction can smooth waves, whilst shelter from islands, bays and cliffs may also change their height and energy characteristics. There appears to be limited practical study as to the consequences of the removal of wave energy from the shoreline in terms of current, sediment deposition and the affect on wild life or leisure activities. That wave devices may also be a form of protection against severe wave action on such structures as sea walls and railway lines, whilst providing power, is also an area that does not appear to have been investigated in depth.

Whilst the greatest amount of energy is available in deeper well-exposed waters offshore, and on the westside of the UK, locations closer to the shore may also have worthwhile energy possibilties. These will generally be more compromised by leisure and commercial activity thereby creating practical difficulties and reducing generation capabilities, but conversely be more accessible.

The decision of the placement of a wave energy device is often related to design requirements concerning water depth, which generally increases with distance from shore, the energy content of waves-which is greater offshore—and appropriate access for deployment, retrieval, operation and maintenance. All devices no matter their location will need to be securely fixed and may be either bottom-mounted or floating. (9)

The device may often be working in hostile conditions so robustness and the corrosive nature of its working environment may be material considerations. Consequently technology, funding, environmental concerns and the political will are just a few of the jigsaw pieces that need to be in place for the industry to develop.

Wherever it is located, the wave device needs to transform energy from the wave and deliver it via the electricity grid to reach the end user-which can cause considerable logistical problems. (See section on Wave hub)

With relatively low oil prices-meaning other forms of energy were more attractive-and the political will to promote renewables largely lacking until recent years, it is unsurprising that working wave devices generating significant amounts of power are to this day very few and far between anywhere in the world. This is an industry still developing its technology for testing—not for the most part deploying it in actual commercial wave farms.

There has been one such device working on the island of Islay in Scotland since the early 1990s, producing 75 kW of electricity. (10)

Ian Fells of Newcastle University, through his own energy consultancy, has a telling point to make and describes the current state of the market as "very expensive and immature compared with other renewable resources because you have to over engineer it to cope with extremes of weather." He also asserts that "world wave power generates about 10 MW and it would need 10,000 wave power units to replace one nuclear power station." (11)

There is a brief run down of projects working and proposed later in this report.

BASIC PRINCIPLES OF WAVE POWER DEVICES

Energy from waves can be captured by various devices (Wave energy converters-WEC), that produce enough movement either of air or water to drive generators. The WEC need a system of reacting forces in order to extract energy efficiently. To create this, two or more bodies need to move relative to each other, while at least one body interacts with the waves. One approach is to allow one body to move freely with the waves, while another is held static (as in the case of a floating buoy reacting against the seabed). Alternatively, all of the bodies may be dynamic. Within the reaction system, a common requirement is to avoid situations where the relative motion is so large that destructively high forces occur between the bodies. So there needs to be enough movement to create the energy in the first place but not so much that the device is damaged. (12)

Testing—mostly in tanks or on computer modelling—has shown that there are a number of different devices capable of extracting energy from the shoreline out to the deeper waters offshore.

The European Marine Energy Centre (EMC) have identified six main types of WEC.

Attentuator An attenuator is a floating device which works perpendicular to the wave direction and effectively rides the waves. Movements along its length can be selectively constrained to produce energy. It has a lower area parallel to the waves in comparison to a terminator so the device experiences lower forces.

Point absorber A point absorber is a floating structure which absorbs energy in all directions through its movements at/near the water surface. The power take-off system may take a number of forms, depending on the configuration of displacers/reactors.

Oscillating wave surge convertor This device extracts the energy caused by wave surges and the movement of water particles within them. The arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves.

Oscillating water column An oscillating water column is a partially submerged, hollow structure. It is open to the sea below the water line, enclosing a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn compresses and decompresses the air column. This trapped air is allowed to flow to and from the atmosphere via a turbine, which usually has the ability to rotate regardless of the direction of the airflow. The rotation of the turbine is used to generate electricty.

Overtopping device This type of device relies on physical capture of water from waves which is held in a reservoir above sea level, before being returned to the sea through conventional low-head turbines which generates power. An overtopping device may use collectors to concentrate the wave energy.

Submerged presure differential These devices are typically located nearshore and attached to the seabed, the motion of the waves causes the sea level to rise and fall above the device inducing a pressure differential in the device. The alternating pressure can then pump fluid through a system to generate electricty.

Other This covers devices with 'novel' designs to more established types of technology or if the devices characteristics could not be determined. For example the wave rotor is a form of turbine turned directly by the waves. (13)

All these devices are strikingly different in appearance but much of the wave action—and hence much of the structure—takes place on or under water. Consequently the structures are relatively unobtrusive, especially compared with wind turbines. When connected in 'arrays' they are however noticeable if located close to the shore.

PRACTICAL ASPECTS

A recent survey conducted by Seaview Sensing carried out in association with Wave Energy Today (14) has revealed some interesting insights into the wave energy market where 72% of the 246 participants thought they needed to learn more about waves, the reasons given including "Buoy data not extensive enough nor are data sets complete nor standardised, to optimise the weather window for installation activities", "Poor access to accurate data", "A whole host of reasons ranging from wave energy, wave shadowing, flood defence, coastal erosion", "to evaluate energy yield from sites we need wave data".

Whilst there is obvious self interest here, it seems common sense enough that before an expensive wave farm is commissioned-let alone deployed- as much data as possible needs to be collected to avoid an expensive mistake as there are numerous factors to consider.

POWER GENERATION CAPABILITIES OF WAVE DEVICES

To put the following figures in perspective a medium sized coal fired power station such as the highly controversial Kingsnorth proposed by E.ON would generate 1600 MW.

The UK is facing a major challenge according to EON. "We've got a third of our power stations closing in the next 10 to 20 years so we need to fill the gap so we can keep the lights on." (15)

The UK's electricity consumption is around 350,000,000,000 kilowatt hours (kWh) per year. (16) Britain needs 25 GW of new electricity generation over next few decades, around one third of todays energy capacity, and given the available resource, it is said that marine renewable energy could perhaps produce between 15 and 20% of this (17) so in itself could theoretically almost supply the 15/20% UK target for renewables set by the EU.

Before proceeding it should be noted that all figures relating to renewables-particularly the newer technologies such as wave power - should be taken with a very large pinch of sea salt. They are highly theoretical and should only be viewed as very broadly indicative. The bigger and more complex the project and the more untried the technology, the more any claimed figures require close scrutiny.

There are few real world installations on which calculations can be based, so theoretical figures are often based on performance in tanks and in computer models.

According to the Carbon Trust in deep water, the period of waves is proportional to the square root of the wavelength ($T \propto \sqrt{\lambda}$), and therefore the frequency is proportional to one over the square root of the wavelength ($f \propto 1/\sqrt{\lambda}$). It is sometimes more convenient to talk about frequency than wavelength because we can readily measure frequency. For example, if we were to place a floating body on the sea surface, we could count how often it heaved up and down during a certain time interval.

Getting devices from the tank into real situations to confirm the generating possibilities is one of the purposes of wave hub-described later in this paper.

Some estimates of wave power potential are made below.

Sea based of Sweden comment that estimates range from 10,000 to 15,000 TWh per year worldwide and that substantial amounts of wave energy resources are found in sheltered waters and calmer seas. (19)

Future Energy Solutions (20) highlight that global power potential has been estimated to be around 8,000–80,000 TWh/y (1000–10,000 GW) which is the same order of magnitude as world electrical energy consumption. The best wave climates, with annual average power levels between 20–70 kW/m of wave front or higher, are found in the temperate zones (30–60 degrees latitude) where strong storms occur. However, "the extent to which this will prove practical to harness will depend upon the successful development of both near shore and deep water technologies."

Able Technologies, L.L.C. is a research and development company based in the US with a patented technology that harnesses ocean waves. They claim that the present world demand for energy would be satisfied if less than 0.02% of the renewable energy available within the oceans could be converted to electricity. Able expect to sell 123,000 of their units, with a combined generating capacity of over 48,000,000 kW (48,000 MW). This is said to be equal to about 120 average sized U.S. fossil fuelled power plants. (400,000 kw average per plant) (21)

Energy analysts at Frost & Sullivan released a forecast for ocean energy on 10th November 2008 and suggest that "if ocean energy technologies continue to be supported, and achieve their predicted potential, approximately 3 gigawatts (GW) of installed capacity could be available in the EU by 2020." They continue that 'the Oceans are a predictable and abundant source of energy with the ability to supply approximately 10% of the world's electricity needs." (22)

F and S estimate the potential worldwide wave energy to produce electricity is between 10–50% of the world's yearly electrical demand. Also that the value of worldwide electricity revenues from wave and tidal stream projects could ultimately be between pounds sterling 60bn (euro 77.40bn) and pounds sterling 190bn (euro 245.10bn) per year. The United Kingdom is a clear leader both in terms of activity and in terms of support to the sector. It possesses 50% of Europe's wave energy potential. (23)

Whatever end of the various estimates turns out to be correct, it is evident that wave power offers enormous potential that is largely unrealised.

COST OF ENERGY

The Carbon Trust (24) state that 'Marine renewable energy has the potential to become competitive with other generation forms in future. At present, it is likely to be more expensive than other renewables and conventional generation until at least hundreds of megawatts capacity are installed. This capacity is equivalent to several offshore wind farms at the scale currently being constructed.'

They continue 'Some estimates on costs of Energy from wave energy farms have been between 12 p/kWh and 44 p/kWh, with central estimates for offshore wave farms in the sub-range 22 p/kWh to 25 p/kWh.'

They further state "that a wave device called SPERBOY™ devised by Embley Energy Ltd which took part in the Carbon Trust's Marine Energy Challenge provided in a study a best-case, cost-of-energy generation of 5 p/kWh that was calculated for a commercial wave farm. The planned design of this device will use a concrete structure has low maintenance requirements and a 40–50 year life expectancy."

Able technologies of the US state that "Cost per kilowatt is expected to be competitive and potentially cheaper than conventional energy." (25)

Whilst all figures are hypothetical at this stage, once a critical mass is obtained—as with most technologies- the cost of deployment and therefore of production could tumble. However we are a long way from that, and any substantial commercial scheme-or its initial development—is likely to require considerable subsidy and high level support for the foreseeable future.

REDUCTION OF EMISSIONS

The particular interest in renewables come from their lower CO_2 emissions compared to conventional-particularly coal fired-power stations. The pursuit of this technology is largely tied up with the stated need to reduce carbon emissions by 80% by 2050 (26)

The Carbon Trust calculate that for every kWh of power generated from waves and tidal streams, 430 grams of CO_2 emissions would be avoided. (27)

Able Technologies claim no hydrocarbon, particulate, CO, SO_2, or nitric oxide pollutant waste streams for their Generating Wave Pipe and similar technologies would also carry these benefits. (28)

CONNECTION TO THE GRID

How do you get power from all those wave devices -perhaps 20 miles off shore- on to the land and into the National grid, and thereby deliver electricity to the end user?

Transmission is a key element of the renewables proposition and is potentially a thorny issue, as siting of large machines in environmentally sensitive areas- whether on sea or land—will require the means to take that power to the consumer. This may typically involve the construction of sub power stations and heavy duty transmission lines carried on massive pylons with all the controversy that may bring. The CPRE have stated that 12 new power lines covering 170 miles are currently planned in conjunction with a £4.7 Billion project to modernise the electricity grid and are concerned over its impact on the countryside. (29) Unlike some other countries the UK generally carries its power lines overhead rather than bury them underground.

In the case of wave power the UK has come up with an innovative solution which serves several purposes-a test bed for various developers to try out their devices in actual ocean conditions, whilst providing the means to transmit that power into the National grid. In due course it is hoped that it may become a commercial wave farm in its own right, in this respect it is the logical step from a wave tank and computer modelling. The project is called Wave hub.

WAVE HUB

Wave hub is described as an electrical 'socket' which is located on the sea bed at a depth of some 50 metres. (30)

It has been decided that the best area for wave energy testing is close to the electricity grid off the north coast of Cornwall. Critical constraints for the location are the wave climate, grid connection and sea areas excluded by a variety of established users. Taking into account water depth, seabed condition, shipping lanes, the MOD practice area and following consultation with the fishing industry, the best place for the wave hub was found to be some 16 km off the coast, NNE of St Ives. The area of sea occupied by the devices and a safety (exclusion) zone around them would measure

4,000 m by 2,000 m. This area may also have a beneficial effect as a nursery ground for fish stocks.

The hub would consist of a main cable that splits at a TDU terminal and distribution unit resting on the sea bed. This is a sealed box about the size of a table whose weight will keep it on the sea floor. It is effectively a 'junction box' that allows four smaller cables, that will attach to the wave device arrays, to be connected to the main cable. All the underwater equipment is known technology and has been proven in the oil and gas industry.

From the underwater hub a 33 kv–20 mva cable runs to the shore, armoured where necessary against rocks, and buried as it enters St Ives bay, it remains buried as it passes under the beach close to Hayle and is then taken under the sand dunes to a sub station to be built on the former Hayle power station site, thence to existing power lines adjacent and into the National grid. It is said to be capable of powering 7500 average UK homes, in a local context that is some 3% of Cornwall's electricity power needs, it would be possible to upgrade by 50% to 30 MW.

With a capacity of up to 20 MW, it will allow the pre-commercial testing of wave energy devices in a well defined and monitored site on a significant scale, greatly simplify and shorten the legal consents process for developers, provide them with the next step towards commercial application of devices, and enable future financing of commercial projects. Four wave device developers are working with the South West Regional Development Agency (SWERDA) on the project, and up to 30 devices could be deployed, with each of the four device arrays being up to 5 MW capacity.

Numerous studies have been made of the locations suitability and environmental impact and consents obtained from the UK Government. (31) The environmental impact assessments includes the effects of laying the cable (most of which will be offshore) and the impacts of the likely arrays of wave energy devices on marine ecology, fisheries, recreational users and navigation. There will be very little terrestrial land-take, with only one cable coming ashore, terminating near the site of the disused power station at Hayle.

J P Kenny, part of international energy services company John Wood Group PLC, has been appointed as engineering and management contractor. Construction could take place in the spring of 2010, completed by August, with the first power generated by the end of 2011.

An independent economic assessment (32) has calculated that Wave hub could create 1800 jobs and inject £560 million into the UK economy over 25 years, around 1000 of these jobs and £332 million could be generated in the South West.

(Note: Good diagram of the wave hub power transmission plus photos of the hub itself on wavehub.co.uk))

The siting of Wave hub is particularly interesting, combining as it does the wave energy devices in an optimum location offshore, with a convenient access onshore to the National grid, thereby obviating many of the inherent problems associated with siting and transmission. Whether the wave hub itself can be a template for future developments elsewhere will require further study, as a site and transmission point juxtaposed to each other may not arise in many places. In the UK most transmission and distribution networks are along the centre of the country—not near the coastline (33)

INTERNATIONAL GRID CONNECTION

The problem of Britain losing its renewables capability due to the vagaries of the weather has already been discussed. However, if the renewables net is spread much wider the likelihood of power still being generated elsewhere in Europe at any time increases considerably. That is the premise behind two schemes whereby power could be spread amongst Europe through an international grid. This is proposed by the European Commission in its strategic energy review Nov 2008. It made far reaching proposals in energy efficiency investments, a shift to alternative fuel vehicles to end oil dependence in transport, and more aggressive deployment of energy and carbon capture and storage to "decarbonise" the EU electricity supply.

Figuring prominently among its first six "priorities essential for the EU's energy security" are the *North Sea offshore electric power supergrid* and the *Mediterranean Ring electric interconnection of Europe and North Africa* The strategy sees the MedRing as a component of a larger supergrid through Europe and into the Mediterranean and via Iraq into the Middle East and also Sub-Saharan Africa. The review makes a number of assumptions in that by 2020 total energy demand will drop from the 2005 equivalent of 1811 metric tons of oil to 1672 MTOE in 2020. It is expected that renewables demand such as wind, solar and hydro will increase in real terms from 123 to 274 MTOE, with their share of total demand more than doubling from 6.8% to 16.4%. Imported renewables that would use the MedRing—mostly consisting of North African solar and wind power—increases some 10 times from the 2005 figure of 0.8% to 8.8% by 2020.

The report suggests that the current staples of generation, Oil, gas, coal and nuclear, will all decline as a share of European energy demand. Natural gas drops the most—although 'low' carbon—from 25% to 21%. This decline appears to be for geo political reasons connected with concerns over Russian gas supply. Nuclear's share is set to drop the least, from its current 14% of demand to just under this figure. This makes the assumption that plans to phase out nuclear production—particularly in Germany, are followed through, as reported by Energywise (34).

The problems of such a grid are manifold, but the concept is interesting as renewables become an ever more important part of the mix. Spreading the risk amongst countries with a variety of weather systems is probably the best we can hope for, unless someone can come up with an innovative idea on energy capture and storage. Considerable investment and political support is needed to turn the International grids- and the shift to renewables—into reality, and raises other concerns discussed in the summary as the report highlights assumptions being made on conventional power sources, and puts into context the current dash for renewables, whether or not they may always be the best option.

CURRENT AND PROPOSED WAVE PROJECTS

SeaGen technology will be instrumental in developing a commercial tidal farm, of up to 10 MW in UK waters, within the next three years. 'With the right funding and regulatory framework, we believe we can realistically achieve up to 500 MW of tidal capacity by 2015 based on this new SeaGen technology," said Martin Wright, managing director of Marine Current Turbines. (35)

Aquamarine Power Ltd of the UK has signed a Development Agreement with Airtricity, the renewable energy development division of Scottish and Southern Energy ("SSE"), aimed at developing sites capable of hosting 1,000 MW of marine energy by 2020. (36)

The World Wave & Tidal Market Report 2009–2013", forecasts installation of 86MW wave and tidal capacity between 2009–2013 worldwide and say; "The past five years have been characterised by small-scale and full-scale deployments from a wide number of technology developers. The next five years will, however, see commercial-scale activity increasing significantly." (37)

The report forecasts a total of 135 units will be deployed over the next five years with some 74 being commercial-scale units –55 percent of the total. The UK is expected to be the biggest market, and is expected to install 51 MW of the total capacity (60 percent). Westwood says the UK is so dominant due to three main factors; the excellent wave and tidal resources around the coastline; the market mechanisms and funding in place, which are comparatively strong and give more investor confidence than in other countries; and thirdly, the UK is home to a large number of wave & tidal device developers, including some of the early market leaders. The report expects the USA to be the second largest market, with 11 MW (12 percent) of overall capacity. Portugal with 9 MW (10 percent) and Canada with 6 MW (7 percent) are the other most significant countries. The report confirms the industry faces many challenges, which include "survivability and reliability, cost reduction, attracting private investment, supply chain stimulation, and development of market mechanisms to support deployment and development activities".

So there is a huge gap between what is estimated to be the total potential from waves, the number of schemes currently in operation, and those planned. Whether funding problems or robustness issues—amongst others—will reduce expectations remains to be seen but it is clear that high level support is vital if the industry is to develop to its full potential.

It is generally accepted that the UK has a lead in the development of these technologies but others are catching up fast, and that wave power is ten years behind wind power in its commercial deployment.

SUMMARY OF ADVANTAGES OF WAVE ENERGY

This is a non-polluting source of energy. Minimal/no emissions.
Largest waves generally occur round the UK in winter when power is most needed.
Virtually unlimited potential
Wave turbines are relatively quiet to operate and do not affect wildlife
The UK has a world lead and numbers some of the leading players in the industry
By reducing wave energy hitting the shore WEC's could be considered as a form of flood defence—depending on their array.
Commitment and enthusiasm by many agencies, companies and individuals
Costs will reduce as the industry reaches a critical mass.

DISADVANTAGES

It is a very new technology
The turbines can be unsightly if located close to shore in large arrays.

Wave heights vary considerably, so they would not produce a constant supply of energy. The amount of power generated will vary according to weather conditions.
WEC's would reduce the wave energy reaching the shoreline with possible effects on ecology, current, sedimentary distribution and human activities.
Development and funding issues mean that a commercially viable industry is some way off and financial, practical and political support will be needed for some time.
Potentially subject to disruption from harsh environment (some similarities to North Sea oil production)
Up to ten years development lag behind wind power
High costs of generation

COMMENT

A picture is emerging of an industry that has evolved relatively little over the last 25 years as cheaper and easier power sources were available. It is now gearing up to recover ground lost to other renewable sources.

Seaview Sensing (38) has revealed some interesting additional insights through a study into the wave energy market.

"Participants (in the study) were from all over the world with the US ranking as the country with the most wave energy interest, closely followed by Continental Europe and the UK. In terms of industry issues, funding is seen to be the biggest issue. Interestingly 35 respondents thought political will was the biggest issue. Respondents listing this issue were based predominantly in the US and UK with other respondents from across the World including Spain, The Netherlands, Pakistan, Portugal, Holland and Denmark. A number of participants pointed out that uncertainty in the industry is the biggest issue. Political will was very closely followed by grid connection. Contacts listing grid connection as the main issue were also based predominantly in the UK with others in the US, Italy, Canada, The Netherlands and Taiwan."

All these issues and more have a part to play in the development of the industry. Its relative weakness was emphasised during the writing of this report as wave energy leader-Pelamis of Edinburgh—was reported nationally as having serious robustness problems with its WEC, (since denied) rendering its link up with E.ON in some doubt, (39) whilst a major project relating to the Severn tidal scheme reportedly had concerns—expressed in the Western Morning news in March 2009—over its ability to proceed, citing a variety of reasons including funding and development issues.

That the industry has enormous potential in harnessing an endlessly renewable resource that is unlikely to be as contentious as on shore wind farms is apparent. With the technology largely geared towards large scale developments however, it lacks the potential of community involvement afforded by solar and wind, which even individual households can utilise—albeit probably not cost effectively. Little work seems to be occurring for small-scale robust wave units that can be placed close offshore for community needs-nor for combined wave/tidal units although there may be many practical reasons for this. Similarly the potential of WEC's as a potential defence against waves striking vulnerable structures seems unrealised. For example a three mile stretch of rail running along the coast between Dawlish and Teignmouth in

South Devon is said to be the most expensive to maintain in the country, with wave ingress stopping trains at times. A problem it has suffered since being built 150 years ago with subsequent calls to re route the railway in land, with all the infrastructure costs and effect on the local economy that would entail. The cost of protecting this by WEC's could be offset by power generation, thereby removing infrastructure and social costs related to rerouting.

If the industry is to fulfil its role as a significant source of energy, it needs a step change in the amount of help it receives-both in terms of support, advice and funding from the private sector, and as it is driven by political agenda, by the governments involved. This is not to diminish in any way the sterling efforts and enthusiasm of a variety of agencies, companies and individuals in the UK at what is an exciting time for the industry. However the potential may be difficult to realise unless a greater focus is given to ensure the industry is given a leg up to the next level—getting more units to a real world testing situation, and subsequently facilitating developments proven to be capable of producing worthwhile amounts of power. From that it will need an even greater step up to developing an industry capable of delivering worthwhile amounts of power at a competitive price. The author would observe that those wishing to be involved with the technology have to negotiate many hurdles before getting to the starting gate, and the ultimate prizes may not go to the best, but those with the greatest stamina or deepest pockets.

Some other wider issues also raise their heads. Renewables—expected to produce 20% of the UK's electricity generation- are generally considered to be more expensive (40) than from conventional sources at present. As far as can be judged from the lack of firm data on wave power, if stripped off all subsidies they would be very much more expensive, and that position is likely to continue for some years.

20% of renewable power that is significantly more expensive will have a notable effect on the cost of the other 80% that is subsidising it, and the public probably don't realise they are paying for it. Consequently from several points of view the renewables target is something of a double edged sword. For as well as being more expensive, if that 20% of supply falters during unfavourable weather conditions it will be significant enough to cause severe supply problems for consumer and industry.

The likely lack of any significant input from wave power over the next decade causes a problem when set besides the UK renewables target of 35% by 2020. It perhaps indicates that the govt has two stark choices.

Vastly expand the provision of on and off shore wind turbines-likely to be highly unpopular where they are located on shore, and/or find another renewable source capable of generating a reliable, calculable, and significant amount of power. The possible answer to that brings us full circle to the medium employed used by the Eling tide mill. The potential is indicated in this report.

"The World Offshore Renewable Energy Report 2002–2007, released by the DTI, suggests that while 3000 GW of tidal energy is estimated to be available, less than 3% is located in areas suitable for power generation. Tidal current energy is therefore very site specific, optimised only where tidal range is amplified by factors such as shelving of the sea bottom, funnelling in estuaries and reflections by large peninsulas. However, tidal power has the distinct advantage of being highly predictable compared with some other forms of renewable energy which makes tidal eneregy development an attrractive resource option."

In the UK context, according to the sustainable Development Commission 'at least 10% of the Uk's electricity—if fully exploited'—could be supplied by tidal stream and tidal range resources—half from each.

This 'site specfic' aspect explains why the Govt is looking at the Severn estuary so keenly, as it is estimated to be capable of generating the lions share of the 5% of Britains total electricity needs that could be achieved through tidal range power (SDC).

It is a site with considerable implications for the environment, as ironically the drive for green power generation will have an enormous impact on the intenationally famed estuary environment (and whether it can supply power to the grid by 2020 must be highly debatable). One very large and highly controversial power source from tidal range or many hundreds of smaller ones from wind power? A battle ground is forming that is likely to range green group against green group and place the govt in a considerable dilemma.

Much of the foregoing would seem to suggest that realistically a reliable base load of conventionally generated cheap and reliable power is needed, with urgent action necessary to plug the UK's projected energy gap that will not be achieved through renewables. That is not perhaps a popular message as that infers greater use of conventional power stations in the short and medium term. Clearly that is a conundrum as both the EU strategic energy plan and the UK Govt assume a lesser overall importance for conventional power plants, thereby making renewables even more important within the projected overall energy mix. Green aspirations seems to be striding ahead of reality and the practicalities of generating power from renewables in the amounts required needs to be better recognised.

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Much current and useful information is available from Waveenergytoday.com

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Listing of companies with an involvement in wave power
With kind permission from EMEC

Company	Technology	Device Type	Country Base
Able Technologies L.L.C.	Electric Generating Wave Pipe	B	USA
Applied Technologies Company Ltd	Float Wave Electric Power Station	B	Russia
Aqua Energy/Finevara Renewables	Aqua Buoy	B	USA
Aquamarine Power	Oyster	C	UK
Atmocean	Atmocean	B	USA
AW Energy	Waveroller	C	Finland
AWS Ocean Energy	Archimedes Wave Swing	F	UK
Balkee Tide and Wave Electricity Generator	TWPEG	B	Mautitius
BioPower Systems Pty Ltd	bioWave	C	Australia
Bourne Energy	OceanStar ocean power system	G	USA
Brandl Motor	Brandl Generator	B	Germany
Caley Ocean Systems	Wave Plane		UK/Denmark
Checkmate Seaenergy UK Ltd.	Anaconda	G	UK

(Continued)

Company	Technology	Device Type	Country Base
College of the North Atlantic	Wave Powered Pump		Canada
Columbia Power Technologies	Direct Drive Permanent Magnet Linear Generator Buoy/Permanent Magnet Rack and Pinion Generator Buoy/Contact-less Force Transmission Generator Buoy	B	USA
C-Wave	C-wave	A	UK
Daedalus Informatics Ltd	Wave Energy Conversion Activator	C	Greece
Delbuoy	Wave Powered Desalination	B	USA
DEXA Wave UK Ltd	DEXA Wave Energy Converter	A	USA
Ecofys	Wave Rotor	G	Netherlands
Ecole Centrale de Nantes	SEAREV	B	France
Edinburgh University	Sloped IBS Buoy	A	UK
Embley Energy	Sperboy	B	UK
Energias de Portugal	Foz do Douro breakwater	D	Portugal
Float Inc.	Pneumatically Stabilized Platform	B	USA
Floating Power Plant ApS (F.P.P.)	Poseidon's Organ	C	Denmark
Fobox AS	FO3	B	Norway
Fred Olsen & Co./ Ghent University	SEEWEC	B	Norway / EU
GEdwardCook	Syphon Wave Generator	F	USA
GEdwardCook	Floating Wave Generator	A	USA
Green Ocean Energy Ltd	Ocean Treader WEC	A	UK
Greencat Renewables	Wave Turbine	A	UK
GyroWaveGen	GyroWaveGen	G	USA
Hydam Technology	McCabe Wave Pump	A	Ireland
Independent Natural Resources	SEADOG	B	USA
Indian Wave Energy Device	IWAVE	B	India
Ing Arvid Nesheim	Oscillating Device	B	Norway
Instituto Superior Tecnico	Pico OWC	D	Portugal

Company	Technology	Device Type	Country Base
Interproject Service (IPS) AB	IPS OWEC Buoy	B	Sweden
JAMSTEC	Mighty Whale	E	Japan
Joules Energy Efficiency Services Ltd	TETRON	B	Ireland
Lancaster University	PS Frog	B	England
Langlee Wave Power	Langlee System	C	Norway
Leancon Wave Energy	Multi Absorbing Wave Energy Converter (MAWEC)	D	Denmark
Manchester Bobber	Manchester Bobber	B	UK
Martifer Energia	ONDA 1		Portugal
Motor Wave	Motor Wave	B	Hong Kong
Muroran Institute of Technology	Pendulor		Japan
Neptune Renewable Energy Ltd	Triton	C	UK
Neptune Systems	MHD Neptune	G	Netherlands
Norwegian University of Science and Technology	CONWEC	B	Norway
Ocean Energy Ltd	Ocean Energy Buoy	D	Ireland
Ocean Motion International	OMI Combined Energy System	B	USA
Ocean Navitas	Aegir Dynamo	B	UK
Ocean Power Technologies	Power Buoy	B	UK/USA
Ocean Wave Energy Company	OWEC	F	USA
Ocean Wavemaster Ltd	Wave Master	G	UK
Oceanic Power	Seaheart		Spain
Oceanlinx (formerly Energetech)	Denniss-Auld Turbine	D	Australia
Offshore Islands Limited	Wave Catcher	G	USA
Offshore Wave Energy Ltd	OWEL Energy Converter		UK
ORECon	MRC 1000	D	UK
OWWE (Ocean Wave and Wind Energy)	Wave Pump Rig	B	Norway
Pelagic Power AS	PelagicPower	B	Norway
Pelamis Wave Power	Pelamis	A	UK
Renewable Energy Holdings	CETO	B	AUS/UK
Renewable Energy Pumps	Wave Water Pump (WWP)	D	USA
Sara Ltd	MHD Wave Energy Conversion (MWEC)	G	USA

(Continued)

Company	Technology	Device Type	Country Base
SDE	S.D.E	C	Israel
Sea Power International AB	Streamturbine		Sweden
Seabased AB	Linear generator (Islandsberg project)	B	Sweden
Seawood Designs Inc	SurfPower	B	Canada
SEEWEC Consortium	FO3 device, previously as Buldra	B	UK
SeWave Ltd	OWC	D	Faroe Islands
Sieber Energy Inc	SieWave		Canada
SRI International	Generator utilizing patented electroactive polymer artificial muscle (EPAMT) technology		USA
Swell Fuel	Lever Operated Pivoting Float	B	USA
SyncWave	SyncWave	B	Canada
Trident Energy Ltd, Direct Thrust Designs Ltd	The Linear Generator	B	UK
Union Electrica Fenosa of Spain	OWC	D	Spain
University of Edinburgh	Salter's Duck	A	N.A.
Vortex Oscillation Technology ltd	Vortex oscillation	A	Russia
Wave Dragon	Wave Dragon	E	Wales/Denmark
Wave Energy	Seawave Slot-Cone Generator	E	Norway
Wave Energy Centre (WaVEC)	Pico plant	D	Portugal
Wave Energy Technologies Inc.	WET EnGen™	B	Canada
Wave Energy Technology	(WET-NZ)	B	New Zealand
Wave Power Group	Salter Duck, Sloped IPS	A	UK
Wave Star Energy ApS	Wave Star	B	Denmark
Waveberg Development	Waveberg	B	Canada
WaveBob Limited	Wave Bob	B	Ireland
Wavegen (Siemens)	Limpet	D	UK
Wavemill Energy	Wavemill		Canada
WavePlane Production	Wave Plane	E	Denmark
WindWavesAndSun	WaveBlanket	G	USA

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