An IEA *OPEN Energy Technology Bulletin*[1] Article
Issue No. 64, December 2009

Tapping the Energy of Waves and Tides

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The power of the world's oceans could make massive contributions to energy security and mitigation of CO_2 emissions. The most familiar forms of ocean energy are waves and tides. It is estimated that harnessing their forces could yield more than four times the amount of electricity obtainable from today's global power generation capacity. How are the technologies advancing to give ocean waves and tides a stronger role in fuelling the world's economies? What can be done to accelerate progress?

At some point in the future, all energy consumed on the earth will be derived from renewable sources. The timeframe for this fundamental move from fossil to sustainable fuels is debatable, but the end result is not. It will occur for two reasons, one being environmental concerns and the ongoing effort to counteract climate change. The second reason is that, simply put, the rate of use of the world's fossil fuel resource outstrips its replenishment by a factor of millions. The life expectancy of oil is estimated to be decades; for coal, it is a few centuries. Reserves of coal, oil, and gas will simply run out.

Many alternatives to fossil fuels exist, and in amounts that greatly exceed the current rate of human energy consumption. Perhaps the most under-explored, and certainly the most under-utilised, is ocean energy. It is commonly estimated that the power in the

[1] The IEA *OPEN Energy Technology Bulletin* is a free, web-based periodical newsletter published by the International Energy Agency (IEA). Views expressed in *OPEN Bulletin* articles do not necessarily reflect the views or policies of the IEA Secretariat or of all its individual member countries.
[2] The Ocean Energy Systems Implementing Agreement (OES IA) is one of 42 international energy technology collaborative programmes operating within the framework of the IEA.

ocean, in all its myriad forms, surpasses present human usage by a factor of more than five thousand-fold.

There are many vastly different forms of possible ocean energy that contribute to this potential. Here we shall focus on recent developments with waves and tides. A recent *National Geographic* magazine article estimated the annual global electricity generation potential of wave and tidal energy alone to be more than 91 000 TWh (source: Ecofys). Contrast this with the world's current annual electricity generation capacity of around 20 000 TWh.

Harnessing the waves

Waves alone (more correctly, surface gravity waves of the type we see breaking on the shoreline) have the theoretical potential, based on the estimates above, to provide more than four times the world's current power usage. However, the vast majority of this power is dissipated on beaches and headlands. If just a small percentage of this power were harnessed effectively, it would play a meaningful role in global energy production.

One of the unique aspects of wave energy is the diversity of technology types for converting it into electricity. Devices range from pneumatic to hydraulic in terms of power off-take, and from fixed to floating in terms of their mooring. Technologies for basic operation range from buoyancy to pressure to gravity. No two devices seem to look the same. Indeed, some are as different as a hairdryer is different from a lawn mower.

One similarity, however, is that peak output per device is generally limited to the order of 1 MW or so. This is because most wave energy technologies rely on some degree of resonance or "tuning" to the length scales of the waves. It is not possible to scale up individual wave energy devices indefinitely, due to the physical constraints of the waves' period and length, and the need to attain resonance and avoid the destructive interference of the waves with one another. But scale-up to any desired capacity can be achieved very simply by using multiple devices.

It is because of the scale-up question that the wave energy industry has found development of full-scale prototypes difficult and costly. The wind energy industry, on the other hand, started with small quasi-commercial versions, gradually scaling devices into larger and larger turbines to obtain ever increasing commercial viability.

Conversely, open-ocean wave devices cannot be too small, for the same reasons that they cannot be too large – their physical size needs to "match" the waves. Building a cheaper "small-scale" version of a wave energy technology in the real ocean would simply result in a device which operates well below its optimum. Small-scale wave energy devices in real scale oceans do not even operate effectively as demonstration units, let alone commercial installations.

While the wind energy industry saw a reasonably rapid convergence of technological varieties into essentially one commercial style – the three-bladed, horizontal axis turbine – the wave energy industry is yet to experience such a convergence. Some even say that the same level of convergence as that seen by the wind industry will not occur with wave energy, due to certain fundamental differences in the resource. Time will tell. At all events, such considerations have been no discouragement to numerous companies with the knowledge and the motivation to innovate and advance.

Activity in the wave energy industry has been expanding for well over a decade now. The past year or so has seen more proposed and real development occurring than ever before. Some of this activity has been rather less successful than might have been hoped, but occasional setbacks are a necessary part of the learning experience required if an industry is to move ahead. Some 100 projects at various stages of development have been identified recently and there is no evidence that the number is falling, as new concepts and technologies replace or outnumber those abandoned.

Several companies are now nearing commercialisation of their wave energy technologies. The majority of these organisations reside in Europe and North America, although there are prominent exceptions. For example, Australia is home to five separate wave energy companies. Although the technologies of some of these companies are quite similar, it is the dissimilarity between technologies which dominates.

Pelamis wave farm, tested in Portugal, August-November 2008
Photo courtesy of Pelamis Wave Power

Wave energy technology Powerbuoy,tested in Santoña (Spain) in 2008
Photo courtesy of Ocean Power Technologies

One of the more high-profile events in the wave energy industry over past months has been the Pelamis deployments in Portugal (photo above), with development of the next generation P2 unit. This technology draws energy from the relative oscillating motion between two bodies. Pelamis is the first grid-connected wave farm worldwide. Another major project is the Ocean Power Technologies project under development in northern Spain (photo above). This exploits the heaving motion of a slack-moored axisymmetric buoy reacting against the inertia of another body.

Meanwhile, Australia has seen the decommissioning of Oceanlinx' Port Kembla unit (photo right) to make way for the imminent commissioning of the next version of its demonstration wave energy project technology at the same site. Full grid interconnection is envisaged.

Oceanlinx device at Port Kembla, Australia

Photo courtesy of Oceanlinx

The many wave energy project development plans in various stages of fruition around the world at present are too numerous to list here. Progress is extremely encouraging. Wave power is clearly seen as an energy source of the future. It is to be hoped that the maximum number of projects make it into the water over the coming year so that the industry can benefit from the experience generated.

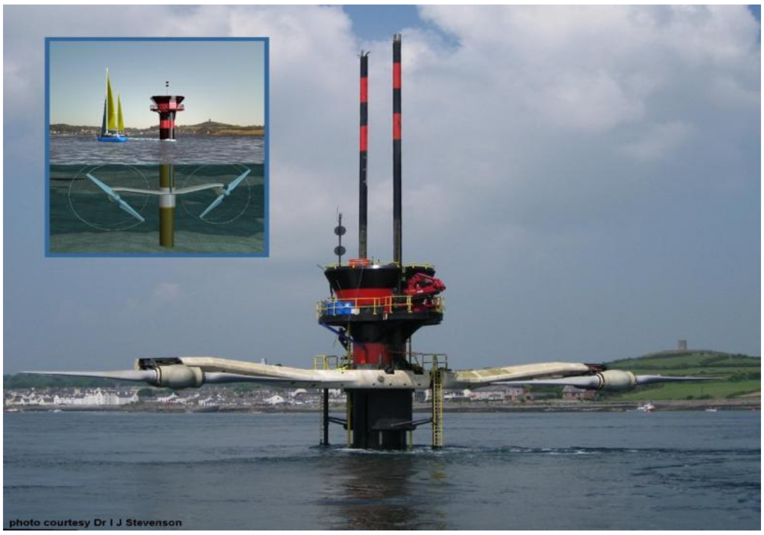
Capitalising on tidal forces

The story for tidal energy is somewhat similar. While tidal technologies have been in commercial existence for many decades, the emergence of a widespread industry remains elusive. The tidal resource is estimated to be about one-tenth that of the wave energy resource, but this still equates to more than 25% of current global power usage. And the tidal energy resource can be accurately predicted centuries in advance.

Tidal energy technologies come in two forms: tidal barrage and tidal stream. Tidal barrage systems have been in place in some parts of the world for hundreds of years. Such systems involve letting the tide fill either a natural or artificial basin, then blocking the "opening" at full tide with a barrage. Once the tide has retreated to form a head (the difference between the water level inside the basin and that outside the basin), the barrage is opened and the resulting "waterfall" is used to drive a standard low head turbine.

At low tide, the system works in reverse, with the ensuing waterfall running in the opposite direction. Such a system has been operating successfully at La Rance on the northern coast of Brittany (France) since the 1960s, with a 240 MW tidal barrage and a 22 km2 reservoir. A much larger project was mooted for the Kimberley region of Western Australia, but it was rejected due to environmental concerns relating to the twice-daily flooding and drying of the inter-tidal zone.

Tidal stream technologies, for their part, are quite different again. These technologies are only just now being commercialised, although none is fully commercial yet. A tidal stream technology essentially operates like an underwater wind turbine. In fact, much of the development process for tidal stream turbines has called upon the knowledge and lessons learned from the wind industry.



Installed in Strangford Lough (Northern Ireland), the commercial demonstrator operating SeaGen tidal turbine, powering 1000 homes.

Photo courtesy of Marine Current Turbines Ltd.

Several companies, including Marine Current Turbines (MCT – photo left) and Verdant have turbines operating in the northern hemisphere. Some of the more recent global activity in this area includes that of Open Hydro, Pulse Tidal, and Atlantis Corporation. Much of the present tidal energy activity is occurring in the United Kingdom (UK), with the European Marine Energy Centre (EMEC) leading the charge. This is the case for the Open Hydro device, which, like SeaGen, recently became a pioneer tidal stream technology generating electricity that feeds into the UK grid.

Survival of the fittest technologies

As in any new industry, there are many hurdles for ocean energy technology to overcome on its way to general acceptance and use. Inevitably, there will be technical issues to resolve. No pioneering idea is without its teething problems in this regard. Most new technologies also have commercial barriers to market entry that need to be tackled.

Luckily for wave and tidal technologies – and indeed for any renewable energy technology – the only significant commercial issue that needs to be addressed is price: the unit cost of electricity produced. The appetite and demand for renewable energy is of such magnitude that, in relation to supply, its ultimate competitiveness depends simply on the technology's ability to be relatively cost effective versus fossil fuel sources. And this is fundamentally a technical issue anyway.

Technical problems are overcome via a combination of funding and experience. With proper funding comes the opportunity to implement real projects in the real ocean. This opportunity results in the valuable learning experience needed to integrate modifications and improvements in the development process and ensure that any technical issues and problems are solved along the way. The multitudes of marine energy test centres springing up around the world bear ample witness to the willingness of authorities to "lend a hand" in overcoming these issues.

A new industry like the marine energy industry will initially attract interest, followed by funding, followed by experience. Such experience inevitably includes some disappointments, which can dampen initial enthusiasm when taken at face value. The result can be a potential funding gap at a crucial stage in the technology's technical and commercial development. The strong technology options can of course bridge this gap and the road to success becomes much smoother. Those that cannot bridge the gap will disappear in a process of natural selection. That is why the projects in operation at the moment are so important. Equally important to foster the innovation process is circulation of information through international collaboration, which is what we do in the IEA Ocean Energy Systems Implementing Agreement (OES IA).

The survival or demise of a technology is a tenuous thing. For any new technology with potential, it is vital that funding does not dry up at the critical time when lessons have already been learned and mistakes corrected. A few wave and tidal technologies are at the point of reaching this fork in the road, which will guide them either to successful commercialisation or to an untimely end through lack of support. Once commercialisation is attained, the road will quickly become a highway, leading to benefits for all stakeholders and to major contributions to protection of the earth's climate and the health and wellbeing of its populations.