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Power from the oceans: Blue energy

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14-18 minutes



Siemens

Marine Current Turbines' tidal-energy converter in Strangford Lough, UK, generates power with underwater blades that can be raised for maintenance.

Several kilometres off the coast near Perth in Western

Australia, hidden beneath the waves and out of sight of watchful boaters, three giant buoys will soon begin producing electricity as they bob to the rhythm of the Indian Ocean. At 11 metres wide and 5 metres tall, the squat orange floats look a bit like giant pumpkins. As waves pass by, the tethered buoys will drive hydraulic pumps on the sea bottom, converting the motion of the ocean into 720 kilowatts of electricity to power a nearby naval base.

Carnegie Wave Energy of North Fremantle, Australia, plans to have the system — the latest attempt at harvesting power from the sea — up and running by June. The pilot project will generate a lot of press, but veterans of the marine-energy field will watch warily to see how it fares. This industry has taken a slow road: none of the myriad devices designed thus far has proved its worth in the highly competitive energy market, and few have survived prolonged exposure to the harsh conditions in the sea. Despite an overall investment of around US\$735 million over the past decade by a dozen leading companies, marine power from tide and waves has yet to take off. In fact, it remains the most expensive form of power on Earth.

But the outlook has brightened for those hoping to tap this source of energy. In the past few years, several major industrial leaders have acquired start-up companies that harvest energy from tides, the easiest type of marine power to capture. In March, three projects were approved for Canada's Bay of Fundy, home to some of the largest tides on the globe. The wave-energy industry, which is targeting a much larger

but more elusive resource, has had a few setbacks, including a decision to scale back plans for an array off the coast of Oregon last month. But there is little doubt that both types of marine energy will eventually grow. Last year, the London-based consultancy Bloomberg New Energy Finance projected that up to 22 tidal projects and 17 wave projects generating more than one megawatt of electricity — enough to power around 250 homes — could be installed by 2020.

In theory, oceans could power the entire globe without adding any pollution to the atmosphere. And they could provide a more dependable source of electricity than the wind or sun. They are also geographically convenient: roughly 44% of the global population lives within 150 kilometres of the coastline.

Some nations have been using large, dam-like structures to block off inlets and draw power from tidal flow for decades, but the latest approaches are designed to be less intrusive.

Although the potential environmental impacts are still under investigation, many researchers say that the sea could turn out to be an even more benign source of power than wind.

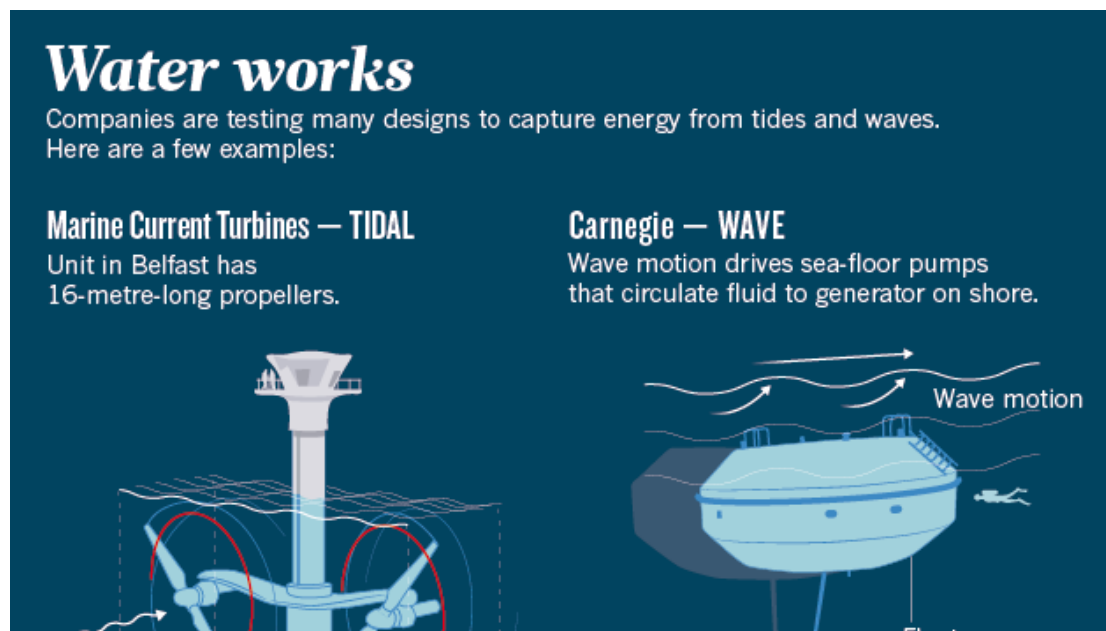
Indeed, energy experts envisage a day when the sea will deliver a significant amount of reliable carbon-free power to islands and burgeoning coastal cities around the world. “It has proved harder than people had expected at the start, but it has also proved possible,” says Neil Kermode, managing director of the European Marine Energy Centre, the leading test facility for wave- and tidal-energy devices in the Orkney Islands, UK. “We have shown that you can make electricity from moving

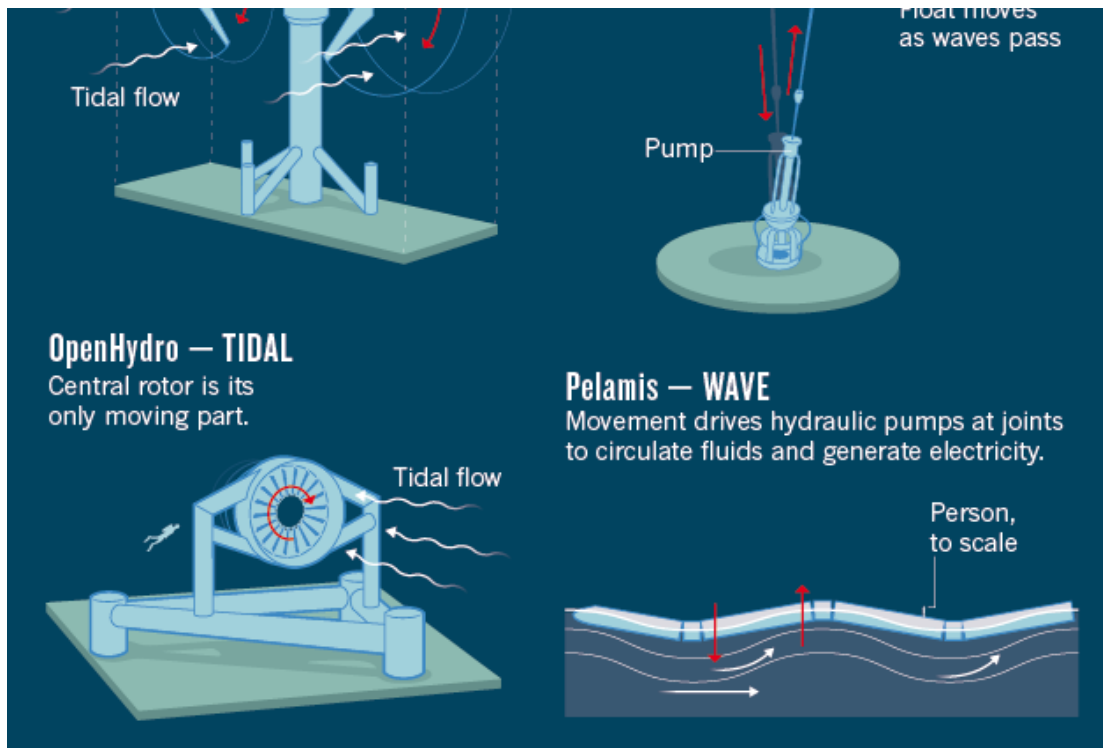
sea water, and that's a huge step forwards.”

Shifting tides

Twice a day, some 350 million cubic metres of tidal water flows through a narrow strait into Strangford Lough — a small inlet southeast of Belfast, UK — and then back out to sea. With each trip, it passes a pair of 16-metre-long propellers attached to a central tower that is anchored to the floor of the channel. The force of the water, equivalent to a wind blowing at 555 kilometres per hour, spins the propellers at up to 15 revolutions per minute, generating 1.2 megawatts of electricity.

In addition to the traditional propeller, tidal-power companies have experimented with contraptions such as corkscrews, hydrofoils and underwater kites. The device used in Strangford Lough, however, is leading the way. Built by Marine Current Turbines in Bristol, UK, the design has generated more than 90% of the industry's power to date, according to the company.





Nik Spencer/*Nature*

The achievements attracted the interest of engineering giant Siemens in Munich, Germany, which took control of the company in 2012. Marine Current Turbines is now preparing to deploy its first array of five 2-megawatt machines — each costing roughly £9 million (US\$15 million) — off the coast of Wales by 2016. As well as boosting the size of the machines, the company added a third blade to reduce vibrations and make the machines more durable, says chairman Kai Kölmel. But he cautions that progress is likely to be incremental. “I think some of the venture capitalists are disillusioned, but this is not a quick-buck industry,” he says. “The wind industry didn't start up rapidly either.”

Even with major companies such as Siemens entering the game, the biggest challenge remains attracting the money needed to do the engineering and build prototypes, says

Christopher Sauer, chief executive of Ocean Renewable Power Company, based in Portland, Maine. Sauer's company has developed and deployed, albeit briefly, a unique device off the coast of Maine that looks a bit like the spinning blades of a combine harvester. The company is now working on a second-generation device that should be ready for deployment as early as 2015. "We're doing the best that we can with the money we have," he says.

Waves of energy

The power of waves is vast, but developing machines that can reliably extract that energy and withstand the often-punishing environment represents a wholly different kind of challenge. Companies have explored designs ranging from swinging flaps to gyroscopic devices that convert the rocking of a ship into a circular motion to drive an onboard generator. Each has its advantages, but the idea behind Carnegie Wave Energy's bobbing buoys in Australia was to escape the rough battering of waves at the surface. The submersion has the added advantage of keeping the devices out of sight and avoiding the debates over aesthetics that have arisen with wind farms.

As the waves carry the buoys up and down, the sea-floor pumps circulate fluid through a closed loop that extends roughly 3 kilometres to an onshore generation facility (see ['Water works'](#)). Operating like a bagpipe, the system accumulates pressure and then releases it gradually to generate a constant flow of electricity. Each of the three devices can generate up to 240 kilowatts of energy.

“This is obviously not a commercial project, but there's not a commercial wave-energy facility in the world at the moment,” says Carnegie's chief operating officer Greg Allen.

Nonetheless, it represents progress, he says: each device generates three times more power than the version that was tested in the same waters in 2011. Allen says that the first commercial projects could come as early as 2018. To gain a foothold in the market, the company aims to compete with diesel-fired power generators on islands.

“The sea could turn out to be an even more benign source of power than wind.”

Pelamis Wave Power, based in Edinburgh, UK, has taken a different approach. It uses a set of five connected buoys that float on top of the ocean and wriggle in the waves like a snake. The segments move independently, and hydraulic pumps at each of the joints use the motion to drive fluids to an on-board generator. The company is currently testing a pair of 750-kilowatt machines at the Orkney Islands testing site. One of these is operated through a partnership with Scottish Power Renewables, a utility based in Glasgow. New components have helped to reduce internal wear and tear in the hydraulic system, and the company is now working on algorithms that will allow the device to adjust each of its 16 hydraulic pumps individually and maximize energy production as it rides the waves.

The company hit some rough waters last year when the German energy firm E.ON pulled out of a partnership after a

three-year project to test one of the devices in the Orkney Islands. Founder and chief executive Richard Yemm remains optimistic, and says that the device is still in the water and producing power. But he acknowledges that the company needs to strengthen its bonds with the industrial energy sector. “We need the big industrial skills that the big companies have,” he says.

One reason that wave energy has attracted less commercial interest is that no one has yet managed to produce machines that can withstand the rough and tumble of the seas and produce electricity around the clock for sustained periods, says Angus McCrone, chief editor at Bloomberg New Energy Finance. “These companies have gone through a lot of money,” he says, “and now the industry finds that it is going to have to spend significantly more to get the devices to commercialization.”

Green machines

The marine-energy industry has also encountered wary regulators who are well aware of controversies surrounding bird deaths caused by wind turbines. Before Marine Current Turbines was allowed to start testing, it had to place seal spotters atop its turbines, who would hit an emergency cut-off button if any seals approached (which did not happen). And fears that seabed-mounted turbines designed by OpenHydro in Dublin, Ireland, could turn orcas into whale sushi nearly killed a proposal to test the devices in the Puget Sound near Seattle, Washington.

Gayle Zydlewski, a fish biologist at the University of Maine in Orono, says that she was able to capture only limited data on fish moving around and through Ocean Renewable Power's tidal unit in Maine. Fish mostly seemed to avoid the turbine, she says, but she wonders: "What happens when you have another one next to it?" Her team is still collecting baseline data, and her goal is to improve her models and understand how much fieldwork will be needed to determine potential impacts.

Others are busy in the lab. Biologists with the US Department of Energy have shot fish through turbines and exposed them to electromagnetic fields similar to those that surround the cables that transport the power back to shore. Neither seemed to cause any permanent damage, according to the department. In the case of the orcas in Puget Sound, energy-department researchers at the Pacific Northwest National Laboratory in Richland and Sandia National Laboratories in Albuquerque, New Mexico, studied a worst-case scenario: what if a curious orca stuck its head inside one of the turbines? The teams scoured the literature, tested various rubber materials as surrogates for whale skin and built a model to understand the potential impact of a blade strike (see go.nature.com/aaptn2). When a dead whale washed up onto the shore near Seattle last year, the scientists performed a computed tomography scan on the skull to look at skin and blubber thickness and used the information to improve their models. They also took some whale skin and tested its strength in the lab.

The upshot of the study, released in January, was that an orca that got struck on the head by a turbine blade would probably swim away with little more than a bruise, says biological oceanographer Andrea Copping from Pacific Northwest National Laboratory, who led the effort. “When whales hit a ship, it's the jawbone break that causes the death, but there wasn't enough force for that to happen,” she says. The proposal to test the turbines in Puget Sound was approved by the Federal Energy Regulatory Commission on 20 March.

Copping is also heading an international collaboration that is pulling together all the environmental research on tidal- and wave-energy development. The goal is to determine the most likely impacts and concentrate the research on those.

Its first report, issued in January 2013, focused on three areas: animal interactions, turbine noise and the effect of taking energy out of the marine system and slowing down the flow of water. Thus far, the team reports, there is no evidence that there would be significant effects on marine animals or water flow, although the influence of large arrays is difficult to project.

The issue of sound could be more difficult to resolve.

Researchers have taken detailed measurements of individual devices, and blasted fish at volume levels that the animals would experience if they were effectively strapped to the turbines for 24 hours. Apart from some tissue damage, equivalent perhaps to what a teenager would experience at a rock concert, Copping says that the fish seem to be okay. But

the broader effects of an array of devices in an environment that is already saturated with sound from the motion of water as well as the loud drone of ships are hard to forecast. A little noise might help the animals to avoid the machines, but too much could trouble whales and other animals that use sound to communicate. “Many or all of these projects are going to need a good deal of monitoring,” Copping says. “The oceans are everybody's backyard.”

Developers, researchers and environmentalists all agree on one thing: to understand both the economics and the environmental impacts, the industry needs to put more machines in the water. Bloomberg's McCrone says the projections for wave power are likely to drop in their next assessment, owing to declining industrial interest and the cancellation of some projects. But he also believes that both sectors will eventually mature.

One of the current hot spots is Canada's Bay of Fundy, which will soon host three projects, including a 4-megawatt installation featuring two devices from OpenHydro that will produce enough power for 1,000 homes by 2015. If all goes well, the company hopes to expand the array to eventually generate 300 megawatts. Although that would equal just one small coal-fired electricity plant, it would be a significant step forward for marine power.

“It will take off eventually,” McCrone says. “There's a lot of energy in the sea.”