Five Striking Concepts for Harnessing the Sea's Power

Sea "snakes," special buoys, and mechanical carpets are aimed at making wave energy viable.

February 21, 2014

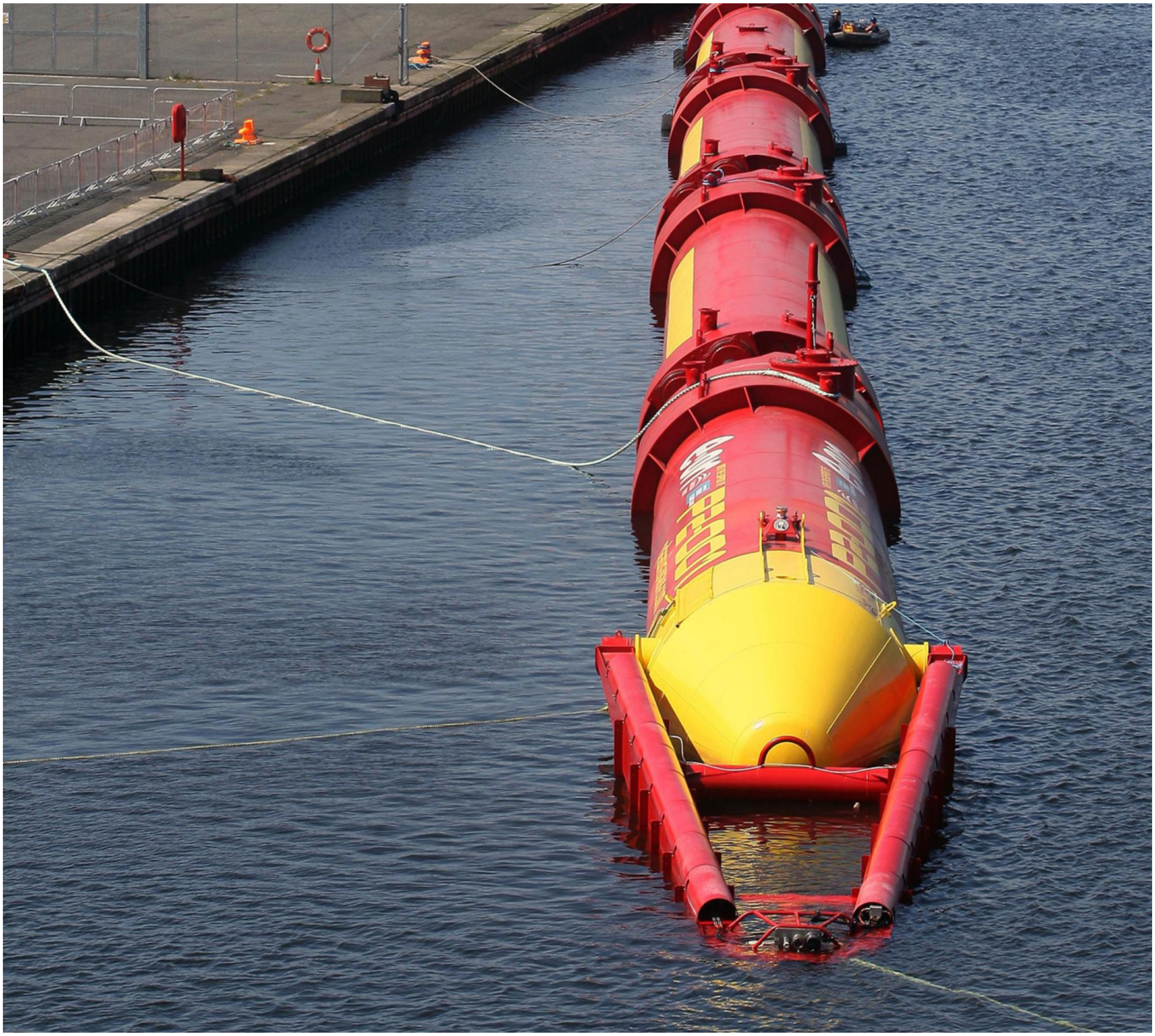
Off the southern coast of Australia, a new effort is under way to capture the energy embedded in ocean swells. Special buoys will be used to convert the sea's waves into a maximum of 62.5 megawatts (MW), or enough to power 10,000 homes, according to an announcement this week from project partners Lockheed Martin and Victorian Wave Partners Ltd. Touted as the world's largest wave energy project, the Australia buoys are still just a drop in the bucket for wave power potential.

The constantly churning oceans that cover most of the Earth offer an inexhaustible source of clean energy. The amount of recoverable energy embedded along the continental shelf of the United States, for example, amounts to almost a third of all the electricity the country uses in one year, according to estimates from the Electric Power Research Institute,

"It's emission-free power and it's located close to where most of the population lives," said Sean O'Neill, president of the Gaithersburg, M-based Ocean Renewable Energy Coalition (OREC).

But the process of harnessing all of that energy, still in its infancy, isn't an easy one. "At this stage, putting equipment in the sea and getting it to work reliably, consistently, during severe storms, is a huge challenge," said Aquamarine Power CEO Martin McAdam. "If anyone tells you otherwise, they haven't done it yet." (See related pictures: "Immense, Elusive Energy in the Forces of Nature.")

Precisely how such a feat could take shape is an open question still to be answered, in the most literal sense: What designs and mechanisms will work best? Beyond "PowerBuoys" in Australia, wave energy proponents are now testing diverse and intriguing ideas for power generators that can even pull double duty for desalination, maritime surveillance, and other exciting applications.



A serpentine power-generation device from Pelamis is set to be deployed in the United Kingdom and Portugal.

PHOTOGRAPH BY DAVID CHESKIN, PA WIRE/AP

Slithering Scottish "Sea Snakes"

Scotland-based Pelamis Wave Power produces an offshore wave energy converter that looks like a colorful sea snake—and is in fact named for the species Pelamis platurus. But this snake's bite lies in its ability to produce power. (See related pictures: "Nature Yields New Ideas for Energy and Efficiency.")

Anchored 1.25 to 6.2 miles (2 to 10 kilometers) from shore, the Pelamis can naturally spin on a chain to face wave direction like a flag changes orientation on a flagpole. Five floating tube sections are linked by universal joints that flex in two different directions as waves roll down the machine's serpentine length. Each joint houses cylinders that resist the wave-driven movements and pump hydraulic fluid to power onboard generators, sending electricity to shore via underwater cables. The Pelamis can handle dangerous storm swells much like a surfer paddling out to a favorite break: When big waves roll in, it simply passes through and under them.

Pelamis has produced six full-scale machines so far, each rated at 750 kW. Over the past 15 years they have logged more than 10,000 hours at sea while connected to real electrical grids, notably at the European Marine Energy Centre (EMEC), off the west coast of the Orkney mainland.

The company plans to debut its technology commercially with Farr Point Wave Farm, a ten-machine project off the Sutherland coast that is set to produce power by 2017. Pelamis has several other plans currently on the drawing board.

The UK energy supplier E. ON and ScottishPower Renewables each own a Pelamis machine currently in sea testing at the EMEC. Each company has ambitions to develop a wave farm, E.ON's in waters north of EMEC and Scottish Power Renewables' off Marwick Head in Orkney. These operations could link as many as 66 machines each and produce 50MW of power at each location. Pelamis has also partnered with Vattenfall to develop a 10MW wave farm, using up to 14 machines, off the Shetland Islands and is planning another 10MW facility off the west coast of Lewis in the Outer Hebrides. And in Aguçadoura, Portugal, past site of a three-machine Pelamis farm, Companhia da Energia Oceânica SA (CEO) might install as many as 26 machines with a target capacity of 20MW.

Pelamis is one of five competitors vying for the £10 million ($16.6 million) Saltire Prize, offered by the government of Scotland to the first company able to create a viable green energy system that taps the energy constantly churning offshore. (Terry Garcia, National Geographic executive vice president for mission programs, chairs the Saltire Prize committee.) Scotland has some of the world's most promising wave and tidal energy resources and has led the way in promoting their development. (Related: Ocean Energy Teams Compete for $16 Million Scotland Prize.)

Seafloor "Magic Carpet" For Power, Desalination, and Coastal Protection

Reza Alam, a UC Berkeley engineer and expert at wave mechanics, has created a power-producing "magic carpet" that serves as an artificial ocean bottom with multiple applications.

"Mud is known to very strongly dampen ocean waves. Within a distance of a couple of hundred yards even very strong waves can be completely dampened out," he said. "So we were inspired to wonder if a synthetic carpet could respond similarly to the action of waves and absorb that same amount of energy."

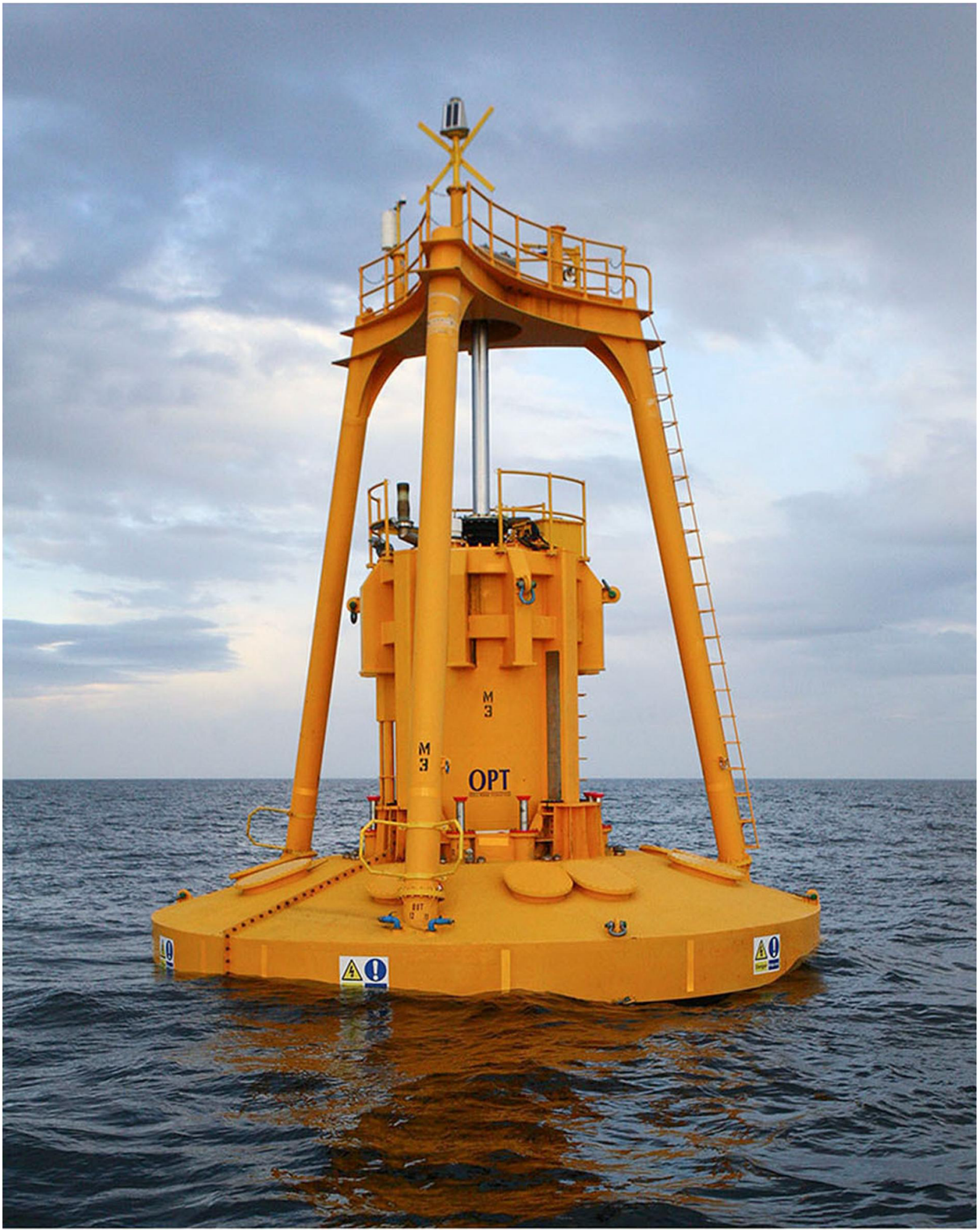
The device features a thin rubber or elastic composite carpet stretched across across a grid of cylinders and double-action piston pumps. The carpet adopts the up and down wave motion of its waters and subsequently moves the attached piston pumps to produce hydraulic pressure with multiple applications.

"The first idea was desalination, near the device or onshore, because high-pressure water is something we need for that," Alam explained. The system can also be customized to deliver compressed air, rather than water, for offshore aquaculture, where it could be used to move cages and oxygenate water.

And of course the system could generate electricity—perhaps in surprising quantities. In recent wave tank tests, it absorbed more than 90 percent of incoming wave energy. With that kind of results, Alam estimated, a single square meter (11 square feet) of carpet system on a seafloor could power a pair of U.S. homes. A 100-square-meter (1,076-square-foot) patch on the California coast would equal the power production of a 6,400-square-meter (68,889-square-foot) solar panel array.

The ocean wave energy converter is meant to be set in 60 feet (18 meters) of water, where it's protected from storm damage by the water column above and would be largely invisible to those on shore. It must be carefully sited to avoid sensitive areas for marine life, like reefs, as well as recreational areas like surf breaks. But because the system greatly reduces wave impacts by absorbing their energy, it could also be strategically deployed to create "safe zones" near coastlines, protecting harbors or slowing erosion. "The idea first was producing power," Alam explained, "but when we presented it in conferences, the feedback I got was that protecting harbors was probably a more immediate application of this idea. Then you don't even need a pump, just the material to absorb the energy of the waves."

The carpet is currently undergoing wave tank tests and should move to open ocean trials by 2016, Alam said.



Specially designed buoys can use the rise and fall of ocean waves to generate energy.

PHOTOGRAPH BY PR NEWSWIRE/LOCKHEED MARTIN/AP

Buoys Boost Energy, Thwart Pirates, Perform Sea Surveillance

The buoys being installed for the large wave energy project off the coast of Victoria, Australia, might also be able to make the seas safer.

Ocean Power Technologies (OPT) PowerBuoys are anchored to the ocean floor but move freely up and down with the ocean swells, driving an onboard piston-like structure to power a generator and produce electricity sent to shore via subsea cable. They boast sensors that monitor their own performance and the ocean's movement, able to switch off power production when waves are too large and strong.

The buoys may avoid one challenge that offshore wind turbines have faced: At 38 feet (11.5 meters) high, the buoys present a far lower profile than offshore wind turbines, which can tower more than 440 feet (135 meters), and according to an OPT fact sheet, they are not highly visible at a distance of 3 miles (5 kilometers) from shore. Some offshore wind projects have sparked opposition because of their potential to disrupt ocean views. (Related: Cape Wind Deadline: Headwinds for Offshore Turbines.)

The buoys are anchored with a proprietary system to avoid seafloor ecosystem damage, and could even provide some benefits to marine animals by serving as an artificial reef, said Charles F. Dunleavy, chief executive officer of OPT.

In addition to delivering power to the grid, the buoys can power themselves at a remote location and support a flexible suite of sensors and equipment for maritime security and monitoring off the grid.

The U.S. Navy's Littoral Expeditionary Autonomous PowerBuoy (LEAP) program tested a smaller, totally autonomous version of the PowerBuoy with acoustic sensors, communications systems and signal processing. The equipment might be deployed someday as maritime surveillance, protecting sensitive areas or equipment and tracking illegal ship traffic.

Floating Pumps "Surf" on Wave Energy

Aquamarine Power's Oyster is a simple design, just as its makers intended, that basically functions as a wave-powered pump. The floating system features a large, hinged flap anchored in 33 to 50 feet (10 to 15 meters) of water in the near-shore zone, some .3 miles (.5 kilometers) out. The flap moves with wave motion, driving attached pistons that push high-pressure water through an underwater pipeline. That water is funneled to shore, where it powers a standard hydroelectric turbine—the design keeps complicated moving parts out of the ocean and on dry land where they can be more easily maintained.

The current Oyster 800 is has been at sea two and a half years—longer than any other mobile wave energy device. The device's location near the shoreline and its design are both aimed at mitigating one of wave power's top challenges-surviving the sometimes brutal conditions in locations like the Scottish coast.

"Survivability is one thing that we think differentiates Oyster, and it can really stay out there in big storms," said CEO Martin McAdam. "It's designed to spill excess wave energy over the top of the machine in storm conditions, because the machine actually ducks under the water and excess energy cascades across the back of the wave."

Oyster has withstood several storms with waves of 26 feet (8 meters) and more. (See it in action with this video.) Because of its location in shallow (40 to 50 feet, or 12 to 15 meters) water, McAdam said the machine shouldn't encounter waves much above 33 feet (10 meters).

The Oyster system is designed for increased scale, so that pipelines could connect several hundred devices to a single onshore plant producing electricity. The company, also chasing Scotland's Saltire Prize, has permits for a 40MW farm off the Isle of Lewis and plans to begin producing power there within four years.

Underwater Turbines Tap Tidal Power

Waves aren't the ocean's only motion. The gravitational pull of the sun and moon causes sea levels to rise and fall reliably, typically twice a day. This horizontal flow of ocean waters offers a regular and predictable energy source that's being targeted by several companies, including Saltire Prize competitors MeyGen, ScottishPower Renewables, and West Islay Tidal.

In September of last year, MeyGen was given a permit to install Europe's biggest tidal turbine array in part of Pentland Firth, the fast-moving channel between the northeast tip of the Scottish mainland and the island of Stroma (map). In a recent study, engineers from Oxford and Edinburgh Universities estimated that underwater turbines in the larger Firth could produce 43 percent of Scotland's electricity needs—up to 1.9 gigawatts. The MeyGen project would be the first commercial tidal turbine operation in Scotland.

To tap tidal power, MeyGen is testing seafloor-anchored turbines from two different manufacturers, Atlantis Resources Corporation and Andritz Hydro Hammerfest. Unlike their wind-driven counterparts, these would be largely invisible from above and benefit from the fact that seawater is 832 times more dense than air. For this reason, a 5-knot ocean current packs more kinetic energy than a 217 mph (350 km/hr) wind, according to MeyGen statistics.

Other Saltire Prize competitors seek to tap the power of tides. ScottishPower Renewables, a division of wind energy giant Iberdrola, is developing (though not yet constructing) a Demonstration Tidal Array in the Scottish Sound of Islay. Ten Andritz Hydro Hammerfest HS1000 turbines will be anchored to the seafloor between the islands of Islay and Jura. The test is preparation for development of a 95 MW tidal energy project at the Ness of Duncansby, on Pentland Firth waters.

West Islay Tidal is also promoting a project, a 0.8-square-mile (2-square-kilometer) tidal stream array in 100 feet (30 meters) of water off the West Islay coast. Here, tides are not only strong but also biodirectional, meaning that the ebb and flow run conveniently (for turbines) almost 180 degrees opposed to one another. West Islay Tidal hopes to see installation begin in 2015 and 30 MW capacity complete by the end of 2016

But for all of ocean power's plans and potential, it also poses great challenges. Systems have to be built to avoid injury to marine mammals and other ocean life. They have to be robust enough to survive the rough weather that is common in places with the potential for high ocean energy. Conflicts can arise between use of the ocean for energy and other activities, such as fishing, shipping, and recreation. And not least are the financial challenges of producing energy at competitive rates, and raising investment dollars for new and relatively unproven technologies.

Like his European counterparts in the field, Sean O'Neill of the OREC believes all this can be overcome with a vision of clean energy that won't run out. He also sees a need to speed development of the technology, which will drive innovations that make it cheaper and better.

"We have polluted the oceans for decades, and here we have a new use," he said, "so there is some fear of the unknown, and we do need to make certain of wave and tidal power's impacts and monitor them.

"If there are any negative effects we need to mitigate them, and we'll probably discover some unintended benefits as well. But most of all, we need to get these technologies and projects into the water." (See related interactive map: "The Global Electricity Mix.")

This story is part of a special series that explores energy issues. For more, visit The Great Energy Challenge.