Wave Energy

Can a mechanical snake that surfs the ocean squeeze enough watts from water?

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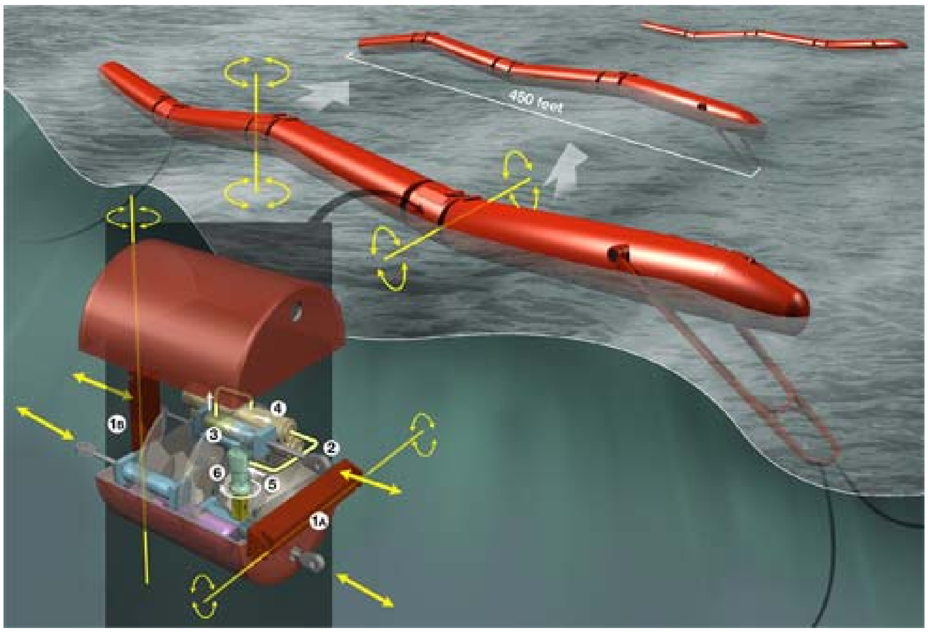
DISCOVER Vol. 26 No. 12 | December 2005 | Environment

VOLTS FROM A MECHANICAL SEA SNAKE

Pelamis is a segmented cylinder moored at both ends to the ocean floor. As a wave passes down the length of Pelamis, hinged joints on the power conversion modules allow the tubes to move up and down and side to side. The motion of the tubes relative to one another drives pumps that turn generators. The electricity flows via a cable to a shore-based grid. To access high-energy swells, Pelamis is designed for use about five miles offshore.



Graphic by Don Foley

HOW THE MODULE CAPTURES WAVE ENERGY: A horizontal hinge (1A) on one side of the module exploits up-and-down motion (heave). A vertical hinge (1B) on the opposite side exploits side-to-side motion (sway). The wave-induced motion forces the pistons (2) that connect the segments forward and backward through hydraulic chambers (3). The action pushes biodegradable fluid through accumulators (4) that smooth the flow and turn hydraulic motors (5). The revolutions drive generators (6), producing electricity.

The tsunami in the Indian Ocean last December that killed nearly 300,000 people and shattered the lives of millions also offered the world an indelible demonstration of how much energy a wave can carry. Geologists estimate the underwater earthquake that triggered the tsunami unleashed a force greater than all the explosives detonated in World War II. That much energy—6 trillion watt-hours—breaks on the world's coastlines every two hours or so. Capture it all and you could power 5 million American households for a year.

Offshore, even more free energy rolls in swells. Tony Trapp, managing director of Engineering Business Ltd. in England, calculates that capturing just 1 to 2 percent of global wave power—the share he considers recoverable—could supply 13 percent of the world's current demand for electricity.

The bonanza is so obvious that inventors have dreamed of harnessing ocean waves for more than two centuries. In 1799 a French father-and-son team tried to patent a giant lever attached to a floating ship, which would rock with the waves to drive shoreside pumps, mills, and saws. But steam power stole everyone's attention, and the dream languished on drawing boards. Two centuries later, oil embargoes once again spurred wave-power designs, but they passed into memory as gasoline prices slid downward. Now, as oil prices soar again, wave energy may finally be poised to deliver.

ENERGY FROM UNDULATION

Ocean Power Delivery

A Portuguese consortium backs the world's first commercial wave farm, located off the country's northern coast. The initial order is for three units of the wave-energy capture device known as Pelamis. The motion of the segmented structures will produce electricity for 1,500 households. If all goes well, the project may eventually include 40 such sea snakes.

Engineers at Ocean Power Delivery in Edinburgh, Scotland, can point to proof bobbing just off the stormy shores of Scotland's Orkney Islands. There, Ocean Power's sinuous, 450-foot-long cherry-red steel snake, called Pelamis after a sea snake, pumps 11,000 AC volts into a grid at the European Marine Energy Centre, an innovative test bed that can offer the sort of apples-to-apples performance measures of sea generators that investors and electric utilities crave.

Since its installation a little more than a year ago, Pelamis has performed so well that a Portuguese consortium, led by the renewable energy company Enersis, recently ordered three of the devices. If tests go well, the group intends to buy 30 more. Ocean Power engineers say that 40 of their sea snakes spread across 250 acres would supply enough electricity to feed as many as 20,000 households.

Pelamis's inventor, Richard Yemm—a tousled, big-boned mechanical engineer—is a lifelong sailor. His project development engineer, Andrew Scott, is an ardent surfer. Both got their sea legs in Scotland's rough, cold waters, and both have a healthy respect for the energy that waves carry. Designing a wave generator is "a very complex problem," muses Yemm, "an unusual marriage of physics and heavy-duty engineering in a dynamic environment."

The sea is indeed cruel. Storms have wrecked pioneering wave generators in Norway and Britain and badly damaged a European Union experiment in the Azores Islands of Portugal. The genius of Pelamis is that it avoids storm destruction because its segmented body is designed to rock and roll with the waves. As its hinged joints heave and fold, they pump hydraulic pistons, which in turn spin high-pressure fluid generators. The system uses off-the-shelf technology, and the current travels by cable to shore. The cable also works like a boat's anchor and chain, holding Pelamis in place while allowing enough play to keep it positioned head-on into the wind and waves.

The design allows Pelamis to withstand storm waves that rise 10 times as high as average waves and pack 100 times as much power. As waves get steeper and uglier, Pelamis dives through them like a surfer ducking through a breaker. "People in the wave field looked from the start for efficiency; you have to start from survivability," says Max Carcas, director of business development for Pelamis.

Like oil, wave power is unequally distributed and a matter of lucky geology. Because Earth rotates eastward, and winds come mostly from the west, waves tend to be strongest at latitudes distant from the equator and at the eastern ends of long fetches, such as the western coasts of continents. Waves off Western Europe and the Pacific Northwest can generate a hefty 40 to 60 kilowatts per yard width of wave front. West of Ireland and Scotland, the average wave power rises to 70 kilowatts. But on the east coasts of Asia, Africa, Australia, and the Americas, waves average just 10 to 20 kilowatts per yard.

Inevitably, people trying to understand the potential of wave energy try to compare it with wind power. But wind, though capricious, is a relatively simple phenomenon, and efforts to capture its energy quickly settled around standard aerodynamics that reverse the principles of powering a propeller plane. On a tower, a prop pushed by wind spins a shaft connected to a generator. Capturing waves is much more complex, forcing engineers to contrive a head-spinning assortment of designs. A wave can drive a pump, a piston, and a turbine. Each can produce either mechanical motion or fluid pressure, which in turn can drive a generator. Nearly two dozen wave-energy systems are in development, and most are striking in their differences, not their similarities.

POTENTIAL SOURCES OF SEA POWER

WAVES
HOW TO HARNESS: Floating or shoreside devices capture wave energy to produce electricity (or, in the future, hydrogen or desalinated water)
UPSIDES: Large, widespread resource; promising economics; environmentally benign; readily scalable
DOWNSIDES: Variable intensity (though much more predictable and consistent than wind); hazardous conditions; many designs are untested for long-term survivability; navigation and sea-space concerns
PROSPECTS: Good in the medium and long term; uncertain for the short term

TIDAL CURRENTS
HOW TO HARNESS: Rotary turbines and other collectors capture energy in underwater tidal streams
UPSIDES: Extremely dense energy source; highly predictable; promising economics; scalable
DOWNSIDES: Daily slack intervals; underwater devices difficult and costly to service; less widespread than waves
PROSPECTS: Good

OCEAN CURRENTS
HOW TO HARNESS: Devices capture in-stream energy in the same way as tidal-current collectors but operate in monodirectional, heat-driven oceanic "rivers," such as the Gulf Stream
UPSIDES: Dense, large-scale, predictable; constant resource
DOWNSIDES: Limited number of sites; technical challenges; uncertain impact on ocean circulation patterns
PROSPECTS: Promising in the long run; big payoff once issues are resolved

ESTUARINE TIDES
HOW TO HARNESS: Dams impound flows behind gates and release them through hydroelectric turbines
UPSIDES: Proven, reliable technology; low operating costs
DOWNSIDES: Major environmental impacts; high capital cost; limited number of sites
PROSPECTS: Unlikely

Waves originate when air and water surface temperatures are not the same. The heat of the sun causes air to rise, and the rising air produces wind, which pushes the water into waves. But the particles in a wave do not travel far like the molecules in wind. Instead, wind-stirred water particles begin rotating, nudging the particles ahead of them, which in turn start to revolve and nudge those ahead of them, and so on, sometimes for thousands of miles. Although the particles mostly return to their original positions, the wave travels onward.

Waves are also more concentrated than wind. Although winds reach higher velocities, waves tend to be more powerful because water is 832 times as dense as air. Once a wave gets moving, it packs a heavier punch.

Waves—and tides—offer other advantages over wind. Winds are notoriously fickle, rising, gusting, and diminishing, sometimes within minutes. Waves keep rolling once they build momentum and can be forecast as far as three days away. Tides are so regular they can be forecast for decades.

Finally, wave machines hold another edge: They're more discreet. In areas like Cape Cod, noisy, view-blocking, bird-whacking wind towers have sparked a backlash. Wave generators, says engineering professor Stephen Salter of the University of Edinburgh, are "quite nice to have around, just like big, friendly whales."

Most make little noise. Rotating parts are either self-contained or so slow moving that marine animals should be able to avoid them. Wave farms don't interfere with aviation or radar, like wind towers, and they require far less space than wind farms. They must, however, be sited outside sea-lanes and marked well.

Recently, the Electric Power Research Institute, an industry-supported think tank based in Palo Alto, California, judged Pelamis the only wave-energy system advanced enough for use in trials scheduled for the waters of Maine, Washington, Oregon, and Hawaii. One can only imagine the sight—40 red serpents undulating in the sea, churning out 12 megawatts of power.

To pioneers like Yemm, generating electricity is just the beginning. He looks forward to a day when the same technology will be used to desalinate water or produce hydrogen: "Wave is new. It has the potential to be really big."