CHAPTER 6

Ocean Energy

Few places overflow with life as generously as the Makah Bay, at the northwest tip of the continental United States near Olympic National Park. Soaked by as much as two hundred inches of rain each year, the temperate rainforests on this remote peninsula are so fertile and lush that even the cool, moist air seems green and alive. Immense, old-growth cedar trees climb down the mountains to the sea, laden with mosses that sometimes grow heavy enough to break branches; lichens, mushrooms, and ferns colonize every stone and fallen log; pink-orange bursts of salmonberries flash among the leaves. On the beach, the dock, and the pilings, bald eagles loiter like mere seagulls, a dozen at a time.

The waters off that beach hold more life still. Where enormous waves regularly pound this shore, wrecking hundreds of ships over the centuries and carving deep caves into the black cliffs, a sea otter has found a quiet corner and lolls on its back, snacking. In the shallows, thick with algae, a gray whale feeds, the arc of its speckled back and spouting blowhole marking its languid journey. Beneath the surface, where the continental shelf meets three offshore canyons, deep, nutrient-rich Pacific waters mix in the "Big Eddy" with the sediment-laden flow of the Fraser River, tumbling down from the Canadian Rockies, creating one of the most productive and diverse marine ecosystems in the world. An unmatched variety of seaweeds, algae, and invertebrates live here, as well as glass sponge and black and gorgonian corals. Among the foraging seabirds are the threatened marbeled murrelet, rhinoceros auklet, and tufted puffin. Elephant seals, harbor seals, and Steller sea lions mingle with the fifteen species of whales that migrate through, including humpbacks, orcas, and fins.

For several thousand years, this marine abundance has supported the Makah tribe, several hundred of whom live in the little town of Neah Bay, one of the very few towns scattered along this isolated coastline. Paddling as far as a hundred miles from shore in canoes hewn from single logs of cedar, dozens of generations of Makah have fished and hunted seals and whales for their meat and skins. When, in 1855, the tribe signed the Treaty of Neah Bay with the governor of the Washington territory, tribal leaders gave up three hundred thousand acres of the most valuable timberland in America to preserve the "right of taking fish and of whaling or sealing," which they considered then and now to be the core of their culture.

Though its population and culture declined precipitously during the century that followed, several events over the past thirty years have served to revitalize the tribe and its relation with the sea. In a 1974 ruling considered among the century's most important on Native American rights, U.S. District Judge George Boldt found that the Makah treaty guarantees them half the salmon and steelhead harvest in their “usual and accustomed” fishing grounds, covering five hundred square miles, and that the tribe had the primary authority to manage those fisheries. That decision, largely upheld by the Supreme Court in 1979, established the Makah as comanagers of the fisheries with the state and federal governments.

In that same decade, archaeologists unearthed the pre-Columbian Makah village of Ozette, a few miles south of Neah Bay, which like much of Pompeii had been perfectly preserved when it was buried—in this case by a mudslide. That discovery of some fifty-five thousand artifacts further reinvigorated the Makah’s sense of ancestral identity. After the gray whale was deemed sufficiently recovered to be removed from the endangered species list in 1994, the tribe determined to revive what it considers its most fundamental tradition. Eight men began the rigorous physical and spiritual training necessary to undertake the first whale hunt—in the traditional manner, with harpoon and canoe—in seventy years. Sustained protests against the 1999 hunt, some of them violent, made national news.

Today, the sea remains the center of Makah identity. Their tribal totem is a thunderbird holding a whale in its talons; in the summer evenings, war-canoe racers practice in the harbor. Fishing remains the tribe’s main source of income. In the spring, the town is flush, with thirty-five small boats landing mountains of halibut and salmon. As the days shorten, and unemployment climbs toward 70 percent, things get harder. A third of the town lives below the poverty line, many in dilapidated trailer homes; in the 2000 census, the median family income was $21,625 a year. As winter storms roll in, bringing hundred-mile-an-hour winds and fearsome blizzards, power lines go down and the heat and lights often go out. In 2006–2007 the village spent twenty-five days without power, in darkness and freezing cold.

in 2001 the makah tribal council found a new way the sea could sustain its people. They were visited by an energetic woman with a little start-up company that, she said, could turn the kinetic energy in their world-renowned waves into electricity.

Alla Weinstein emigrated from the Soviet Union in 1974. After twenty-two years at Honeywell Aviation designing navigational controls and installing systems on Russian airplanes, she became involved in wave energy in the fall of 2000, when she met Hans and Gören Fredrikson, sons of the man who had invented the technology she was offering to bring to the Makah. Her favorite expression, delivered with a twinkle, is “It’s all about the motion in the ocean.” The name of her company, fittingly: AquaEnergy Group.

About three miles out from shore, she told tribal leaders, a cluster of buoys would be moored loosely to the seafloor. Attached to the bottom of each buoy would be an eighty-foot steel cylinder, “an acceleration tube” submerged vertically in the water and open at both ends. In the middle of each cylinder would be a piston and, attached to the piston, two rubber marine hoses, one connecting to the top of the cylinder and the other to the bottom. As the buoy rose and fell on the waves, the piston would lag behind, slowed by the water in the cylinder, causing the hoses to stretch and relax in turn. Like a cow’s udder, or like the little Chinese fingertrap that you slip on and can’t pull off, each stretched hose would contract like a muscle, pumping water at continuous high pressure (the equivalent of a 650-foot waterfall) into a turbine and generator (preferably a centralized turbine, floating on a barge nearby). A standard submarine cable would then carry the electricity back to shore. The device would be durable, she assured them: hose pumps have no seals or moving parts, and are actually lubricated by saltwater. And in major storms, the slack mooring would allow the buoys to ride tsunami-size waves out at sea, rather than be crushed by them as they broke onshore. Most important, the modular design—with each buoy independently producing up to 250 kilowatts of electricity—would protect the power supply and simplify maintenance: if one failed, the company would not need to maintain it at sea but could simply lift it out and replace it.

Just four buoys, Weinstein told the five members of the tribe's leadership council, would provide a megawatt of electricity, enough for 150 Neah Bay homes. In time, when the pilot plant had proved itself and the company had optimized the technology, it could add sixteen more to meet the village's total electricity demand. The tribe could even make electricity to sell: an 80-megawatt plant, arrayed in a starfish configuration with ten buoys on each arm, would require a quarter of a square mile of the bay and supply half the electricity for the whole Olympic Peninsula.

Weinstein's timing was perfect. The tribe had recently determined to become energy self-sufficient and to diversify its struggling economy, and had begun investigating windmills and the use of wood waste as fuel. How much better to turn to the resource that had always sustained them? In 1994 the tribe had rejected another kind of energy development in its waters: when the U.S. Minerals Management Service began considering reactivating leases for offshore gas and oil development, the Makah supported the creation of the Olympic Coast National Marine Sanctuary within its treaty-protected waters. A 1991 fuel spill from the Japanese fishing vessel *Tenyo Maru* had damaged ecosystems all along the Washington coast, heightening the tribe's concerns about offshore production and oil transport. The Strait of Juan de Fuca, on the village's northern flank, is the second most active waterway in the world; every year, fourteen thousand vessels pass through into Puget Sound to the ports of Seattle, Portland, and Vancouver, many of them carrying oil from the North Slope.

AquaEnergy seemed amenable to an equal partnership. Tribal chairman Ben Johnson, a fisherman who over many decades had gained intimate knowledge—much of it passed down by his father—of the habits of various species and the seasonal patterns of the waves, pored over maps with Weinstein to choose the best spot for the buoys, making sure to skirt prime fishing areas. They discussed terms, with the tribe making clear that eventually they would switch from upland leaser to equity ownership.

Finding a buyer for the energy was easy. The Clallam County Public Utility District, eager to develop more diverse and stable energy supplies, agreed to purchase the electricity and deliver it through its grid to Neah Bay. If, eventually, the enterprise goes to commercial scale, an upgrade of transmission lines will be required. The feeder lines serving Neah Bay now handle just 14 megawatts, not the 80 megawatts AquaEnergy ultimately hoped to produce.

Securing the necessary permits—some fifteen in all, from state and federal fish and wildlife agencies, the U.S. Army Corps of Engineers, the state historic preservation officer, the Federal Energy Regulatory Commission (FERC), and the marine sanctuary, among others—has been a far more protracted affair. Part of the problem, especially at first, was AquaEnergy's lack of experience with the regulatory process, and its lack of money. Just as Weinstein was founding the company, the dot-com bubble burst and venture capital dried up. "Most of that money," she says "wasn't interested in infrastructure anyway." She found herself in a catch-22: without permits she couldn't get financing, and without financing she couldn't do the studies needed to secure the permits.

She might have given up were it not for a tragedy that fortified her determination to succeed. On December 11, 2001, Weinstein was in Neah Bay for a technical meeting with the tribe, awaiting the arrival of her brother and partner, Yury Avrutin, and company cofounder and chief technologist Bengt-Olov Sjostrom. The two men were in a small plane, scouting potential sites on the California and Oregon coasts along the way. They never arrived. From then on, says Weinstein, a warm and effusive woman, failure ceased to be an option. "Maybe events like that push you to do things you might not otherwise do. Why else would I put myself in this position; so much uncertainty, no income for six years? I need to get it done. Otherwise they lost their lives for nothing." In honor of their memory, she gave the device a new, superhero name—AquaBuOY—capitalizing the initials of her lost colleagues.

To build consensus around the project, she began meeting with commercial and recreational fishermen, local environmental groups, the marine sanctuary advisory committee, the Surfrider Foundation, the Northwest Energy Coalition, and any other group that voiced interest or concern. In 2003 she went to the Clallam County Fair and collected one thousand signatures from citizens in support of the project, which she delivered to the state of Washington's congressional delegation.

As FERC considered the license application, the public comment period brought hundreds of responses. An association of Oregon crabbers expressed concern about the possible loss of access to productive grounds. But its was the sole unambivalent objection, according to sanctuary superintendent Carol Bernthal; others urged only that the project be managed with the utmost care. Many, she says, were simply fascinated by the technology. Environmental Defense Fund weighed in, with a letter signed by marine biologist Rod Fujita and representatives from four other conservation groups voicing concerns about impacts on the marine habitat and erosion of sanctuary rules, and urging that a full environmental impact statement (EIS) be required.

Things sped up in 2006, when Finavera Renewables, a Canadian company with roots in Ireland, purchased AquaEnergy. Finavera hired a lawyer with permitting experience and brought in SAIC, an $8 billion engineering firm (its core business is national defense) with an aquatic environmental team of two hundred marine biologists, oceanographers, water and sediment quality experts, cultural resource archaeologists, and hydrodynamics scientists with thirty years of experience doing environmental assessments and monitoring. In November 2006, Finavera applied for the nation's first preliminary permit for an offshore wave energy plant. In April 2007 it was granted.

As of this writing, one of the hurdles remaining was securing the permit from the marine sanctuary, which has found itself in the difficult position of assessing an industry that has almost no track record and a technology that is not yet fully designed. "We are having to rely on analogy," says Bernthal. "And not knowing, in a place of national significance, has pretty high stakes."

A primary sanctuary mandate is to protect the seafloor, so sanctuary officials are paying particular attention to the anchors that will secure the buoys and transmission cable. If the cable traverses bedrock, where creatures attach and create the three-dimensional habitat structure critical to fisheries, anchors could do serious harm. The sanctuary and tribe have already been burned once. In 1999, the high-flying company Global Crossing buried sixty-six miles of a fiber-optic cable that links the United States with Japan within the sanctuary—carelessly: unmoored stretches of cable ended up obstructing access to the tribal fisheries. Then Global Crossing went bankrupt and left the mess behind; only in 2006 was the cable finally repaired and reinstalled. To insure against a repeat of that experience, the sanctuary will consider bonding this time around.

If FERC's final environmental assessment fails to address all of its concerns, the sanctuary will do its own supplemental assessment. "Our level of scrutiny is high compared to FERC, which normally deals with large-scale hydroelectric projects," says Bernthal. "They may issue a license without final engineering, and speculate on the impacts. We need more than that." If the sanctuary does issue a permit, it will be for only the five-year pilot project, with the assumption that the buoys will then be decommissioned and removed. Because a larger-scale project may have additional impacts, such as disruption of local circulation patterns critical for transport of larvae and nutrients, a decision to pursue a commercial-scale project will require the tribe and the company to start the permitting process again. Throughout the pilot project, the sanctuary will require rigorous monitoring, "so that five years from now we'll be able to say whether in fact these projects are benign." What is most important, says Bernthal, is that "we not greenwash this stuff, but have a real, honest dialogue about the trade-offs."

Finavera's engineers have continued revising the design to address environmental concerns. They have reshaped the AquaBuOY to avoid tempting seabirds or sea lions to perch. Although their hydraulic circuit uses water, not petroleum-based fluids that could hurt marine mammals and sea birds if spilled, they have sealed it so fish cannot be trapped inside. They have found a path for the cable entirely on soft bottom, where large movements of sediment prevent any creatures from taking up residence (the sand moves so quickly, in fact, that several of the devices they laid down to measure currents have already vanished). When told that the mooring chains from the concrete anchors they planned to use might sweep across the floor and hurt the "benthic community"—the crabs, sponges, snails, and other small organisms that live in bottom sediments—they proposed a switch to "vertical launch anchors," recently developed for offshore oil-drilling platforms. The broad, flat anchors, resembling sting rays, are embedded beneath the seafloor, reducing their surface footprint to the thickness of the cables connecting to the buoys, and can also be unlatched and retrieved. Since the design is not yet complete, Finavera will try to persuade the sanctuary to provide a contingent permit, revocable should the company fail to provide a satisfactory solution.

The tribal leadership bristles at mention of the sanctuary's role. "If it weren't for us the sanctuary would not be there," says Johnson, who as chairman is shown the deference awarded the hereditary chief before the treaty abolished the traditional leadership system. "They say we have fishing rights in the sanctuary. But the sanctuary is in our territory. We were here thousands of years before them, and allowed them to come into our waters. The designation document for the sanctuary has a savings clause, protecting our economic interests."

Councilman Micah McCarty sees a parallel with the struggle the tribe faced over the resumption of whaling. "We are an ancient society that still has a living relationship with our ancestral fishing and hunting grounds. By continuing to sustain ourselves from these resources, we keep the breath of our ancestors alive. It has spiritual meaning. But we repeatedly run up against a belief that nature should be viewed without touching it, kept pristine. I understand where that view derives—it comes from people who live in a wholly altered environment, see a devastating human impact, and overcompensate for that devastation. But it winds up disenfranchising the people who depend on the land."

makah bay is a kind of crucible, within which all the tensions around the emerging new-energy economy are distilled. Though here the tensions are heightened by the exceptional value of the ecosystem, the jurisdictional complexities, and the acute need for economic development and reliable energy, none of the new carbon-cutting technologies will be without environmental impact. All will require vigilance and a balancing of competing environmental values. Weinstein argues that warming and acidification of the oceans from business as usual and continued climate change will do far more damage to northwest Pacific ecosystems than her cables and anchors.

Carol Bernthal wonders whether a marine sanctuary, one of only fourteen in the entire country, is the best place to undertake this experiment. She also recognizes that the Makah are tied to their traditional waters and cannot do the project elsewhere, and that the energy that will be displaced comes from immense hydroelectric dams, which—even though they emit no carbon—have destroyed most of the salmon habitat in the Northwest by changing water temperatures, flows, and bottom habitat. The sanctuary is already stretched beyond its resources, and cannot itself assess the impact of this project. But where better to hold this new industry to the highest standards?

One member of the Makah tribe, fortunately, is extraordinarily well equipped to reconcile these many tensions. A graduate of the George Washington University Law School, Robert

Martin spent twenty-three years in Washington, D.C., leading an association of tribes managing mineral-rich lands, representing tribes in environmental fights, and, finally, serving three administrations as an independent ombudsman at the U.S. Environmental Protection Agency (EPA). His job was to investigate public complaints against the agency, and he became, in that position, something of an icon: in her 2003 book, *Bushwhacked*, the late Molly Ivins devoted an entire chapter to him. Describing him, aptly, as “a bear of a man” who with his long ponytail and rumpled clothes sometimes “looks like an unmade bed,” she told the story of his 1992 victory helping small-town newspaper publisher Marie Flickinger stop the EPA from incinerating 245,000 tons of toxic sludge at a Texas superfund site. Though Flickinger had been petitioning the EPA for five years without success, within a few months after Martin’s arrival the agency had sealed the site, mandated that the water be treated, and evacuated a contaminated elementary school and 677 homes nearby. As Ivins put it, he used his first big case “to expand and define the powers of an office that was almost an experiment when he drew his first paycheck.”

In 2006 Martin returned to Neah Bay to help his tribe pursue its energy plans and additional opportunities he sees emerging in a carbon-constrained world. In the tribe’s forests, for instance, it might do “carbon farming”: growing and preserving timber to store carbon, then selling those “offsets” in the carbon market. Martin’s environmental credentials remain sound: he is on the board of the Natural Resources Council of America, a group of more than eighty-five environmental groups that includes Ducks Unlimited, the Humane Society of the United States, the Ocean Conservancy, and the Woods Hole Research Center. He sees the permitting issue with the sanctuary and other agencies “not as obstacles, but as necessary conversations.”

the makah project has a number of important allies. The Clallam County Economic Development Council strongly supports the program, calling support for innovation “the basis of rural development.” The council estimates that of the $4 million it will cost to complete the Makah Bay pilot project, half will stay in the community. Given its maritime history, the county has the local suppliers and most of the marine engineering capability needed to assemble, install, and maintain the buoys.

Many in the Northwest share the view that the development of ocean energy offers the best opportunity to rebuild coastal communities and maritime trades that declined along with the fishing, shipbuilding, and logging industries. Not surprisingly, much of the political leadership in the region is working to accelerate that rebuilding. Democratic U.S. Senators Maria Cantwell and Patty Murray of Washington, Ron Wyden of Oregon, and Daniel Akaka of Hawaii and Republican Senator Lisa Murkowski of Alaska are pressing, along with Democratic Representatives Jay Inslee of Washington and Darlene Hoorley of Oregon, for legislation that would provide hundreds of millions of dollars in funding for wave energy research and development, as well as tax credits and loans. In 2006 Oregon state legislators put wave energy at the top of their economic development agenda and passed a generous investment tax credit; for Finavera, that credit will equate to a refund of 25 percent of expenditures.

California has become particularly active on the issue, attracting big companies with money and muscle, thanks in large measure to the strict caps on global warming emissions passed by the state legislature in 2006. PG&E, for instance, has applied for FERC licenses to build two 40-megawatt wave farms by 2010. In 68 square miles off Fort Bragg in Mendocino County and 136 square miles off Humboldt County near Eureka, the utility will spend $3 million testing technologies. In late 2007 it signed a 2-megawatt power purchase agreement with Finavera.

Oregon Iron Works (OIW), a sixty-five-year-old metal fabricator with more than four hundred employees, is already benefiting from this emerging industry. In its sheds in Clackamas, near Portland, the company built the prototype buoy for Finavera and is building a second prototype for a competitor, New Jersey–based Ocean Power Technologies. OIW does a range of prototypes and production runs, many for the U.S. military, including boats, hydroelectric dams, fish screens, containment vessels for nuclear waste, the launch complex for Atlas and Delta rockets, and an electric streetcar. Its experience building for the unique challenges of marine environments—forces and torques far more powerful than those endured by windmills, corrosive saltwater that eats at welds—has proved useful in developing these wave energy devices, says vice president Chandra Brown; OIW knows, for instance, how to create seals with super-close tolerances that remain tight under extreme water pressures.

Although it performed as hoped for two months, the first test AquaBuOY, deployed in August 2007, came to a bad end. Just one day before it was to be removed, it sank to the bottom of Makah Bay. Finavera explained that a few days before it sank, the buoy began taking on water—then its bilge pump failed. The company pronounced the test a success, nonetheless; all through its deployment, the buoy had been supplying valuable data that will be used in developing the next model.

Beyond ensuring that the next generation stays afloat, the fabricators face two additional challenges. First, OIW needs to help Finavera optimize the AquaBuOY's performance. In projecting the output of the four demonstration buoys planned for Makah Bay—1,500 megawatt-hours per year—Finavera assumed that they would produce electricity at just 18 percent of capacity; the goal for optimized production installations is 40 to 50 percent capacity. The second challenge is to cut costs, which for the prototype now come to about 25 cents per kilowatt-hour. "It took wind twenty-five years to get from 30 cents to 7 cents," says Brown. "We plan on a much quicker learning curve." If OIW succeeds, and lands contracts to mass-produce buoys for the two companies, it could quickly become a key player in the wave energy industry. "We've intentionally stayed a small business," says Brown, "but we are now talking about kicking off a new division. We believe the ocean is one of the biggest untapped resources. We also believe that U.S. manufacturing needs to be alive and well. We don't want to be outsourcing; we want to be in-sourcing. Keeping those skills sets, and developing domestic renewable energy sources, are both security issues. We can't depend for our infrastructure on China, and we can't depend for our power on foreign sources."

though the financing and development of ocean energy have lagged beind solar power and biofuels, recognition of its potential is growing. A 2005 report from the International Energy Agency notes that energy exists in the oceans in several different forms, the most important of which are marine currents, caused by variations in salinity and temperature, and waves, which are generated by surface winds.[1]

Because the best waves are created by the steadiest, strongest winds, the wave resource is largest on western seaboards between 40 and 60 degrees latitude. Prime areas are found off the densely populated Pacific Coast from northern California to Alaska, Europe's Atlantic coasts, western Australia, and the southwest coasts of South America and Africa. (At some specific sites, such as Makah Bay, the shape of the shoreline and underwater features serve to concentrate the wave energy, making them especially attractive for development.) The Electric Power Research Institute (EPRI) estimates that wave power could eventually meet 10 percent of total U.S. demand; similar estimates are made for the global potential. Advances in technology may expand the regions in which the resource can be used, as they have for wind. While the early-stage systems will require good wave structure and big waves, eventually the industry may be able to harvest energy from Atlantic swells.

though its total potential is likely only a fraction of solar's, ocean energy does have several distinct advantages. One is consistency. Waves steadily pound the coasts because the ocean serves as a big energy storage system. It does not matter where in the Pacific the wind is blowing: once generated, waves are preserved and can cross the entire ocean without losing much energy.

A second advantage is predictability. Data buoys all over the ocean provide several days' notice of when waves are going to hit the coast, allowing grid managers to plan accordingly. Mariners rely on the National Oceanic and Atmospheric Administration (NOAA) forecasts, Wavewatch III; in 2007, EPRI began a study to refine correlations between deep ocean buoys and ones nearer to shore.

A third advantage is energy density. Waves are a third-order power source: the sun produces winds (by differential heating of the earth); winds in turn transfer that energy to the water, which is eight hundred times denser than air. At each step the energy gets more concentrated. So while the maximum solar energy per square meter is about 1,000 watts and the maximum wind energy is 10,000 watts, the maximum for waves is as high as 100,000

[1] A third potential way to make energy from the ocean would use the temperature difference between warm surface water and the cold depths much as the Chena, Alaska, geothermal power plant uses the difference between cold creek water and hot springs (see chapter 7). It remains unclear whether this "ocean thermal energy conversion" technology will make a major contribution to the future power mix.

watts, higher still during storms.

As with wind power, the Europeans are ahead of the United States in developing the new hydroelectric technologies, supporting them with subsidies and infrastructure assistance and, most important, setting caps on carbon emissions. For its project in Portugal, Finavera Renewables secured a 1.3-million-euro grant from the European Commission, the executive body of the European Union. Portugal also pays 40 cents (American) per kilowatt-hour for wave energy. That above-market rate—called a "feed-in tariff" since the government is giving rather than taking the tariff—will decline over time. The South West of England Regional Development Agency (SWERDA) is spending $43 million to build a wave hub off the coast of Cornwall: a high-voltage cable that will run from the electrical grid to a point ten miles out at sea, allowing companies installing wave energy systems easy access to the grid.

OIW's Chandra Brown is frustrated by the lag. "Why did Vestas [a Danish company that is the world's biggest maker of windmills] and all the other European companies get out ahead? Because they were subsidized early and got a corner on the market. Here research hasn't been funded. For the next generation of renewables, we'd like the U.S. to at least be in the game. There will be markets for this stuff when there's a cap on carbon and emissions trading."

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the innovations that are in the works fall into three broad categories. Each technology carries its own mix of advantages and potential environmental impacts. And most illustrate, once again, the importance of scale in evaluating renewable-energy technologies. A pilot project—whether Finavera's experiment at Makah Bay or Wave Dragon's demonstration project off the Welsh coast, described below—may seem to have a small impact when compared to existing technologies. But a single, 1-megawatt coal plant would not have a large environmental impact either. The concerns emerge at commercial scale, as the combined impact of many generator units potentially affects important ecological processes. Ultimately, alternative technologies must be judged on their impact at the scale of the conventional energy-generating operations they hope to replace.

Shoreline and near-shore devices are relatively easy to install and maintain and do not require underwater cable, but the waves they tap are less powerful because their energy has diminished as they come close to shore, absorbed by the seabed and dissipated through turbulence and friction. A leader in this category is Wavegen, which has operated a grid-connected wave energy plant near its home base in Scotland since 2000. Wavegen was purchased in 2005 by the German water energy joint venture Voith Siemens Hydro Power Generation. Called Limpet (an acronym for "land-installed marine-powered energy transformer"), Wavegen's power plant is centered on a capture chamber—the first was excavated directly out of a rocky shoreline; others have been built into man-made breakwaters. As waves enter the chamber, they compress a pocket of air, which is forced through a turbine at the back; as they leave, they suck the air back out through the turbine, which is specially designed to capture the flow in both directions to create electricity. Using air instead of the moving water itself to spin the turbine blades keeps corrosive saltwater away from the moving parts. This method of capturing energy with rising and falling water is called an "oscillating water column." There is no need to lay a seabed cable—eliminating worries about the impact on bottom habitats and organisms. On the other hand, these facilities have a footprint on coastal lands, where many different kinds of environmental pressures often collide.

Wave Dragon, a Danish-born company that moved to Wales in 2007, uses a completely different technology. The Wave Dragon is a seaborne hydroelectric dam, a large floating barge that stretches out collector arms toward oncoming waves to guide 330 yards of wave front up long, curved ramps; after climbing the ramps, the water flows over the top of the barge and into a reservoir, then drops down through turbines as it returns to the sea. With an expected capacity of 4 to 7 megawatts, the Wave Dragon is the largest onshore wave energy plant in development.

Offshore plants exploit the more powerful waves in deep water. The one AquaBuOY has to beat is the Pelamis from Scotland's Ocean Power Delivery, an articulated "sea snake" that floats partially submerged in the ocean, moored with weights that swing it to face oncoming waves. As its sections are moved to and fro by the waves, hydraulic rams in the joints pump oil to drive generators; a five-hundred-foot snake makes 750 kilowatts of power. Ocean Power Delivery has operated a pilot in the North Sea since 2004 and built its first commercial-scale project (2.25 megawatts) in Portugal; it will add a 3-megawatt project in Scotland in 2008. Since 2002 the company has secured more than $50 million from European venture capitalists, the U.K. government–funded Carbon Trust, and, most recently, GE. Even so, its path, like that of all these new energy ventures, has not been entirely smooth. Soon after installation, the generators in Portugal had to go back for retrofitting and repair. According to Finavera and less-biased observers, its immense scale and complexity may prove its Achilles heel.

a third category of renewable ocean energy—tidal energy—got a big boost in 2007. While several companies had been working on tidal projects on a small scale, Voith Siemens Hydro announced a quantum leap: the planned construction of a 600-megawatt plant in the South Korean province of Wando. A series of bridge-like structures will suspend turbines, much like underwater windmills, into the current; twice a day, they will rotate to capture the flow direction of both high and low tides. According to Voith Siemens, the jump in scale is made possible by advances in the computer modeling of tides, which enable engineers to do site-specific assessments of different turbine designs and differing arrays of those turbines without having to build or install real equipment. The turbines will be capable of producing 1 megawatt each, an enormous amount compared with other wave energy systems, despite their intermediate size (blades fifty feet in diameter). The reason for the high energy output is location: Wando, whose many small islands create constrictions where ocean water must flow rapidly, has among the fastest currents in the world. Jochem Weilepp, head of ocean energies at Voith Siemens, cautions that the technology is new and challenging; while the company is striving for minimum environmental impact, including an oil-free design, he says the company will not be able to eliminate all problems simultaneously. Plans call for three prototypes to be lowered into the water in 2009, with gradual scale-up to the 600-megawatt installation by 2018. Other companies are considering similarly large-scale tidal generators suspended in the powerful Gulf Stream off the southeast coast of the United States.

The recent advances in tidal energy have triggered a kind of land rush, with companies vying to lock up FERC permits for sites ahead of the competition. Chevron planned to apply to FERC to use tidal power for its offshore platforms in Alaska's Cook Inlet, but Alaska Tidal Energy got to FERC first. Eventually, FERC made them share: each company received a preliminary three-year study permit, and each had to reduce its study area so that the tests would not overlap. In New York City, a fiercer fight has unfolded over the East River between New York–based Verdant Power and Washington, D.C.–based Oceana Energy, which is, as it happens, Alaska Tidal's parent company.

Verdant's cofounder, William "Trey" Taylor, has worked for more than a decade to commercialize tidal turbines. He and his partners first prototyped a design by Philippe Vauthier, an erstwhile jeweler once commissioned by Tiffany & Co. to make a chalice for Pope John Paul II; though they sank $500,000 of personal savings into the effort, a falling out with Vauthier forced Taylor and his partners to move on. They found another design by Dean Corren, a former New York University scientist who in 1986 had figured out how to pitch and twist the watermill blades to overcome one of the knottiest problems in tidal energy: keeping the turbines from stalling as the current slows. Corren had let his patent lapse, but Taylor pulled it and its inventor back into action. In 2002 he built a prototype and a $100,000 catamaran to drag the prototype through the Chesapeake Bay, simulating tides. On the first test, someone forgot to put in a 50-cent cotter pin and the rotor sank to the bottom.

Undeterred, Taylor's team moved its computers and controls into motor homes under the Roosevelt Island Bridge and put their turbines into the East River—a tidal strait—where they continue to operate. Having burned through their own money, they got backing from Matt Klein, who had made an Internet fortune and retired at age thirty-one; he in turn introduced them to Paul Tudor Jones, a billionaire hedge fund manager and chairman of the National Fish and Wildlife Foundation, who invested $15 million. By 2007 they had six turbines in the river, were powering a grocery store on Roosevelt Island, and had spent $2 million on fish sensors to prove their turbines "don't turn local striped bass into sashimi." Using twenty-four sophisticated "hydroacoustic beam transducers" and an ultrasound system, the sensors monitor the movement of fish—and sometimes birds—as they move through the water. The evidence so far suggests that fish swim around the turbines; next, they plan to test what happens in a larger field of thirty turbines, where fish may not be able to avoid the turbines entirely, but will have to swim between them.

Verdant's rival, Oceana, is at first glance a far more elegant affair. Operating out of a Beaux-Arts building in Washington, D.C., that was once home to banker Andrew Mellon, it is chaired by William Nitze (son of NATO architect Paul Nitze), a Harvard-educated lawyer who spent fourteen years at Mobil Oil before going to work for the Reagan State Department and the Clinton EPA. In 2005 Nitze invested $250,000 in Oceana in return for 20 percent equity. John Topping, president of the Climate Institute, joined him as cofounder.

The Oceana engineering team is a bit more rough and tumble. Ned Hansen, the company's chief engineer, has worked on bunker-busting nuclear weapons at Sandia National Laboratories and on Screaming Squirrel roller coasters. Herbert Williams, who designed the beta version of the turbine, was an Alaska crab-boat captain and served four and a half years in federal prison for conspiracy to distribute cocaine after he designed a fast boat for a Colombian smuggler.

The rival companies have taken very different approaches. Verdant focused first on refining its technology. To answer environmental concerns and secure the permits needed to put its turbines in the water for testing, the company designed a rig that could quickly lift those test turbines out of the water if any problems cropped up. Sure enough, within a few days of putting their turbines into the East River, the blades began to break. Verdant pulled them out for a redesign, using stronger materials and constructing the turbines around a more rigid internal frame. Engineers also redesigned the base that holds the turbines to the riverbed, to afford more resilience against horizontal pressures and greater flexibility in moving turbines from place to place to optimize power output and minimize their impact on fish. After testing at the National Renewable Energy Laboratory, the newest generation of blades was scheduled to be back in the East River in February 2008. Verdant's turbines are much less powerful than those planned for Korea; because of the slower currents and shallower waters in New York, each is capable of producing only 35 kilowatts, about one-thirtieth of Voith Siemens' projected turbine output. But Taylor says the smaller size will make testing and repairs much easier.

Oceana's first efforts were aimed at securing potential test sites. Without at first revealing much about the technology it wanted to test, the company applied to FERC for permission to study a number of prime tidal energy sites, including the currents under the Golden Gate Bridge and a fast-flowing section of the East River, directly upstream from Verdant's Roosevelt Island pilot site. Since FERC's three-year study permits were granted on a first-come, first-served basis, Oceana's were won without a great deal of scrutiny, under the names of seven local-sounding subsidiaries, including Maine Tidal Energy Company and Golden Gate Energy Company.

In September 2006, Senator Orrin Hatch of Utah, where Oceana planned to manufacture its turbines, had written to FERC, urging the agency to grant the company's permits. Oceana asked Utah's other senator, Robert Bennett, to get $1 million into the 2008 federal budget for testing Oceana turbines at the Carderock Division research center in West Bethesda, Maryland, where the U.S. Navy tests model ships in a pool more than a half-mile long. The federal funding did not come through, but the testing was scheduled, nonetheless, for late 2007.

Oceana's innovation is an "open center turbine," based—not surprisingly, given the career of chief engineer Ned Hansen—on linear motor technology borrowed from the roller coaster industry. The open center of the turbine means that aquatic life can swim right through the turbine, and need contend only with the slowly rotating blades near the outer rim. The Oceana turbines feature only one moving part—the rotor itself—and thus are highly resistant to corrosion or mechanical failure. The prototype is just six feet in diameter, although much larger versions are planned for deployment. Compared with other designs, Oceana claims, its turbine is more scalable; the size and shape of its blades are easily varied.

First, however, the engineers want to test and deploy small turbines in tidal inlets in San Francisco Bay, at sites off Maine, Oregon, and Alaska, and in New York's East River. When Verdant discovered that Oceana had applied for a test site adjacent to its own East River turbines, the team was furious. Calling Oceana "claim jumpers," Taylor had Verdant's lawyer file a protest with FERC; it likened Oceana to "dot-com exploiters who seized domain names and held them for ransom." (FERC approved Oceana's test site, despite the protest.) Oceana's general counsel told Bloomberg News that he understood why it might look like Oceana was trying to corner the market, but that in fact it needed to study lots of sites.

Oceana's strategy paid off in San Francisco. In the summer of 2007 the city signed an agreement to collaborate with the company and with PG&E on developing the energy potential of the tides under the Golden Gate Bridge. The utility also announced that it would invest $1 million in Oceana's local subsidiary.

of all the frontiers being explored and staked by the new-energy prospectors, the oceans and tidal straits may be the most untamed. From Makah Bay to the East River, the regulatory framework is lagging behind the boom. In April 2007, Doug Rader, principal scientist for oceans and estuaries at Environmental Defense Fund, testified before the House Committee on Natural Resources on the need to fix the "fractured system of ocean governance." Two months later, Finavera CEO Jason Bak echoed that argument to the Senate Committee on Energy and Natural Resources. The Minerals Management Service in the Department of the Interior had challenged FERC's hydropower licensing authority on the outer continental shelf, a prime location for ocean power development because the waves are powerful and there is less competition with commercial fishing. Bak urged the committee to confirm FERC's authority, both because his industry had already spent millions complying with its licensing process and because Makah Bay was demonstrating that the FERC process worked even in fiercely protected natural areas. Jurisdictional uncertainty, he told the senators, is "creating substantial regulatory risk for the ocean wave energy industry."

That risk made financing close to impossible to secure. Money rarely flows where the regulatory hurdles are too great. "Getting the technology right is the smallest part of it," says

Alla Weinstein, who moved from day-to-day operations for Finavera on to its board of directors, then in early 2008 left the company. “It’s the context we’re operating in that really matters.”

The best way to get the context right, Rader told the House Committee on Natural Resources, is to create a lead regulatory entity that will work with scientists, local communities, and companies to produce comprehensive and predictable rules. Ocean energy can contribute a great deal toward the protection of our atmosphere—without damaging marine ecosystems that are equally vital to the planet’s future.

*A third potential way to make energy from the ocean would use the temperature difference between warm surface water and the cold depths much as the Chena, Alaska, geothermal power plant uses the difference between cold creek water and hot springs (see chapter 7). It remains unclear whether this “ocean thermal energy conversion” technology will make a major contribution to the future power mix.