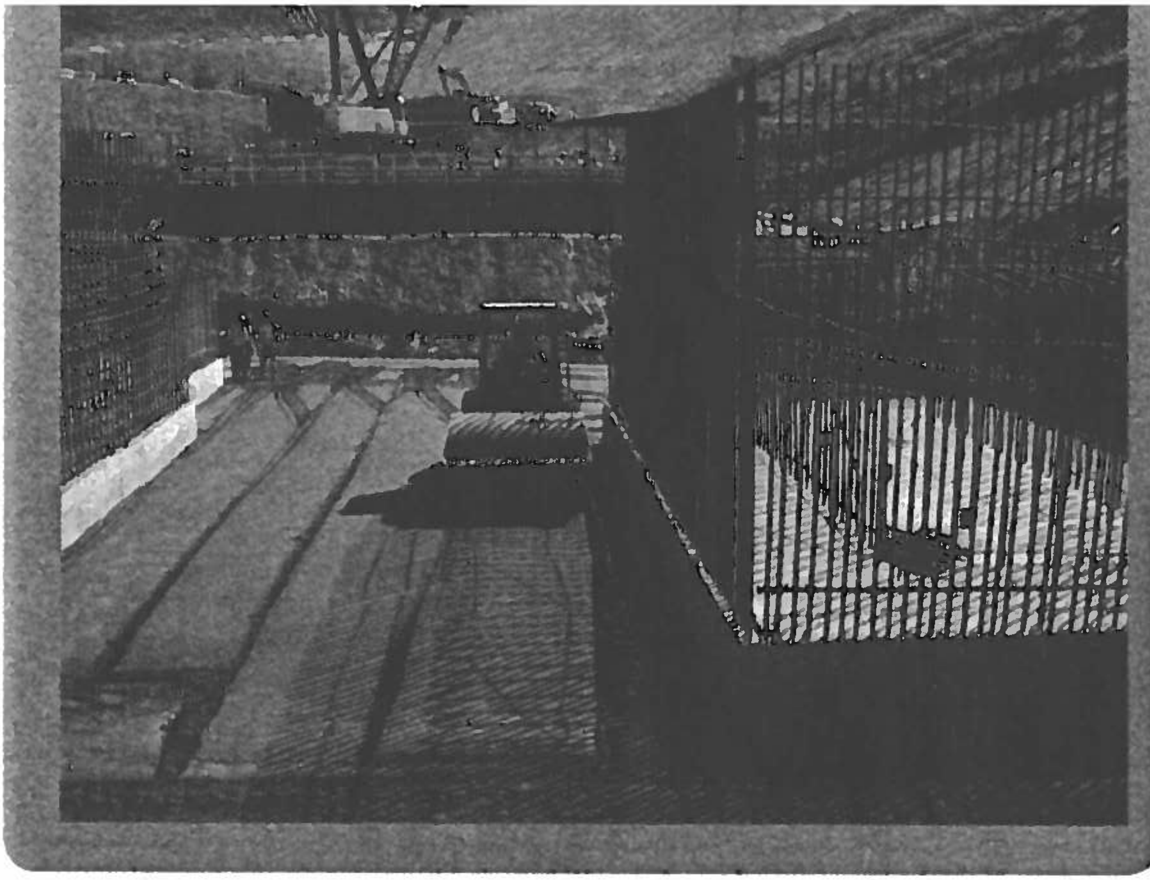


Cofferdam construction at Cannelton was completed by Kiewit Traylor Construction in June. All photos courtesy AMP.

Hydropower Takes Center Stage for AMP

By Lindsay Morris, Associate Editor

While renewable energy advocates have been pushing for solar and wind over the last few years, American Municipal Power Inc. (AMP), based in Columbus, Ohio, has chosen hydropower as its paramount renewable. AMP, a nonprofit electric cooperative, is moving forward with four developments along the Ohio River that will total more than 300 MW of generation for its member communities.

AMP CEO Marc Gerken said that hydropower been "largely ignored" in recent discussions about alternative energy. "Hydro is not a new, shiny, sexy technology," he said. "But it doesn't have to be."

It's true, hydropower is not new. Hydroelectric generation comprised approximately 40 percent of generation in the early 1900s, but that was over a century ago. In 2011, hydroelectricity accounted for 7 percent of all generation, according to the National Hydropower Association (NHA).

But hydropower is anything but tapped out. About 130,000 sites in the U.S. could be used to produce another 30,000 MW of hydropower, according to the Department of Energy (DOE). A study by the Electric Power Research Institute found at least 23,000 MW of additional capacity, including hydrokinetic and wave energy that could be brought on line by 2025. Under a best-case scenario, the study estimated possible maximum development of 95,000 MW.

Marc Gerken, CEO of AMP.

Gerken said AMP and its partners turned to hydroelectric partially because of how reliable the resource is. "I know what I'm going to get out of these units tomorrow. I can't do that with wind or solar."

Currently, 67 percent of domestic renewable generation comes from hydropower, according to NHA. In recent years, environmental groups have criticized hydro projects that require the construction of new dams. But all of AMP's hydro projects are being sited on existing U.S. Army Corps of Engineers locks and dams. In fact, the Corps' original intention was for run-of-river projects to be installed at the dams where AMP is now building, Gerken said.

AMP's run of river approach—generating power from the natural flow and elevation of a river without a large impoundment of water—achieves capacity factors of 55 to 60 percent.

"Hydro power is not a new, shiny, sexy technology. But it doesn't have to be."

That percent is high in comparison to other renewable forms of energy. Wind in the Midwest has a capacity factor in the 20 to 30 percent range. And the capacity factor of solar is in the 15 to 18 percent range, Gerken said.

In 2006, AMP commissioned a study by MWH of 10 undeveloped projects along the Ohio River. Based on the results of the study, AMP sought and gained licenses from the Federal Energy Regulatory Commission for three projects: Cannelton Locks and Dam, Smithland Locks and Dam and Willow Island Locks and Dam. AMP also has a co-license with its partner community of Hamilton, Ky. for a fourth project at Captain Anthony Meldahl Locks and Dam.

These four are not the first of AMP's hydro developments. AMP commissioned its first hydro project along the Ohio River in 1999: the 42-MW Belleville hydro plant. Since that time, AMP has completed two other member-owned hydro plants along the Ohio River at Greenup and Hannibal.

All four projects currently under construction are expected to be completed in 2014 or 2015.

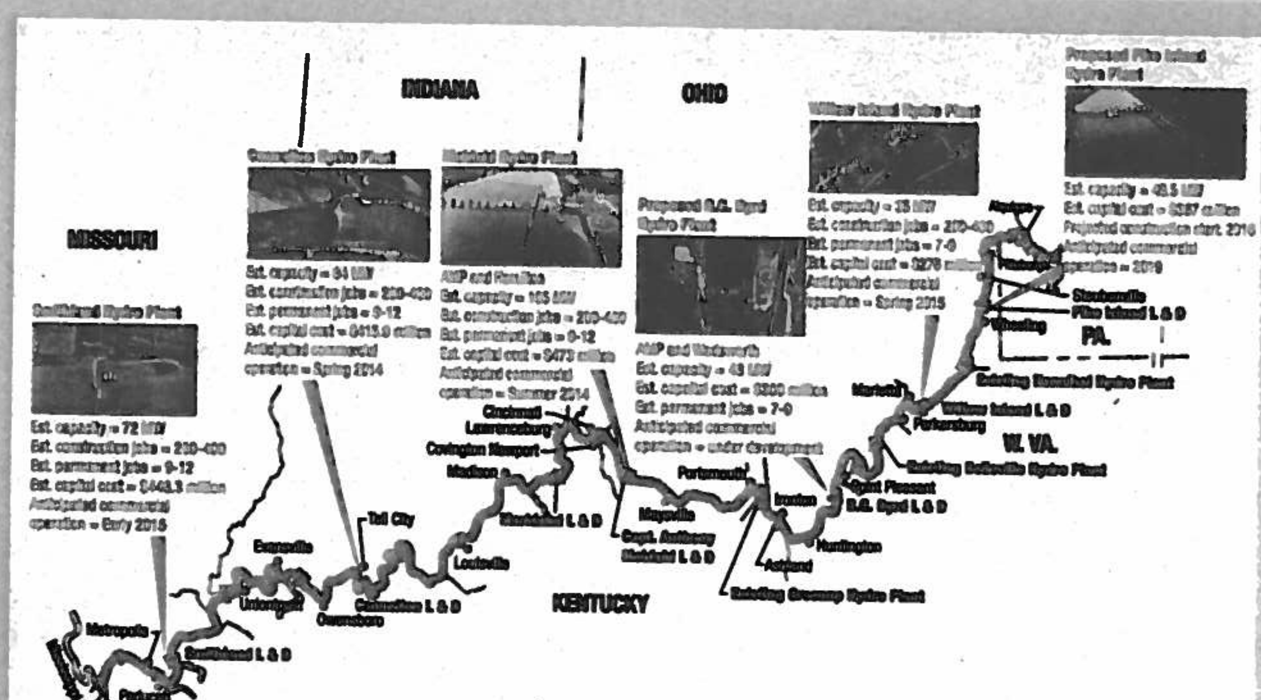
Cannelton

The 84-MW Cannelton project, located in Hawesville, Ky., was the first of the four projects to break ground on Aug. 5, 2009. Project costs are projected at $416 million. Cannelton is expected to be the first project finished, with completion aimed at spring of 2014.

The Cannelton project will divert water from the existing Cannelton Locks and Dam through bulb turbines to generate an average gross annual output of approximately 458 million kilowatt-hours. The site will include an intake approach channel, a reinforced concrete powerhouse and a tailrace channel. The powerhouse will house three horizontal 29.3-MW bulb type turbine and generating units at a gross head of 25 feet. A 1,000-ft-long 138-kV transmission line interconnection is planned to connect to MISO.

Kiewit Traylor Construction was awarded the contract for the design-build cofferdam and excavation, which was completed in June of 2010. Walsh Construction Group was awarded a $192 million contract for the general construction of the powerhouse and appurtenances. The Walsh contract also includes the construction of the three-unit bulb turbine type powerhouse adjacent to the existing Cannelton Locks and Dam. Walsh has mobilized

Figure 1 AMP OHIO RIVER PROJECTS UNDER DEVELOPMENT



horizontal 35 MW bulb type turbines at a gross head of 30 feet. If interconnected to MISO, an eight-mile-long 138 kV transmission line planned. If interconnected to PJM, a five-mile-long 345 kV transmission line is planned.

The $473 million facility is located near Hamilton, Ohio. A contract is being completed with the AMP member community of Hamilton, meaning the city will maintain 51 percent ownership of the project.

Angelo Iafrate Construction has been chosen as the contractor for the Meldahl cofferdam. Alberici/Baker was awarded the contract for the powerhouse.

"If the environment became such that we had clear regulations that provided adequate time to capture and recover costs, I think hydro would be far superior to coal or even nuclear."

Beyond the Quad

In addition to the four projects that already have permits, AMP and its member community Wadsworth, Ohio are also pursuing the development license for a 48 MW project at the Robert C. Byrd Locks and Dam on the Ohio River. A sixth Ohio River development is proposed at Pike Island with AMP member community Oberlin, near Cleveland.

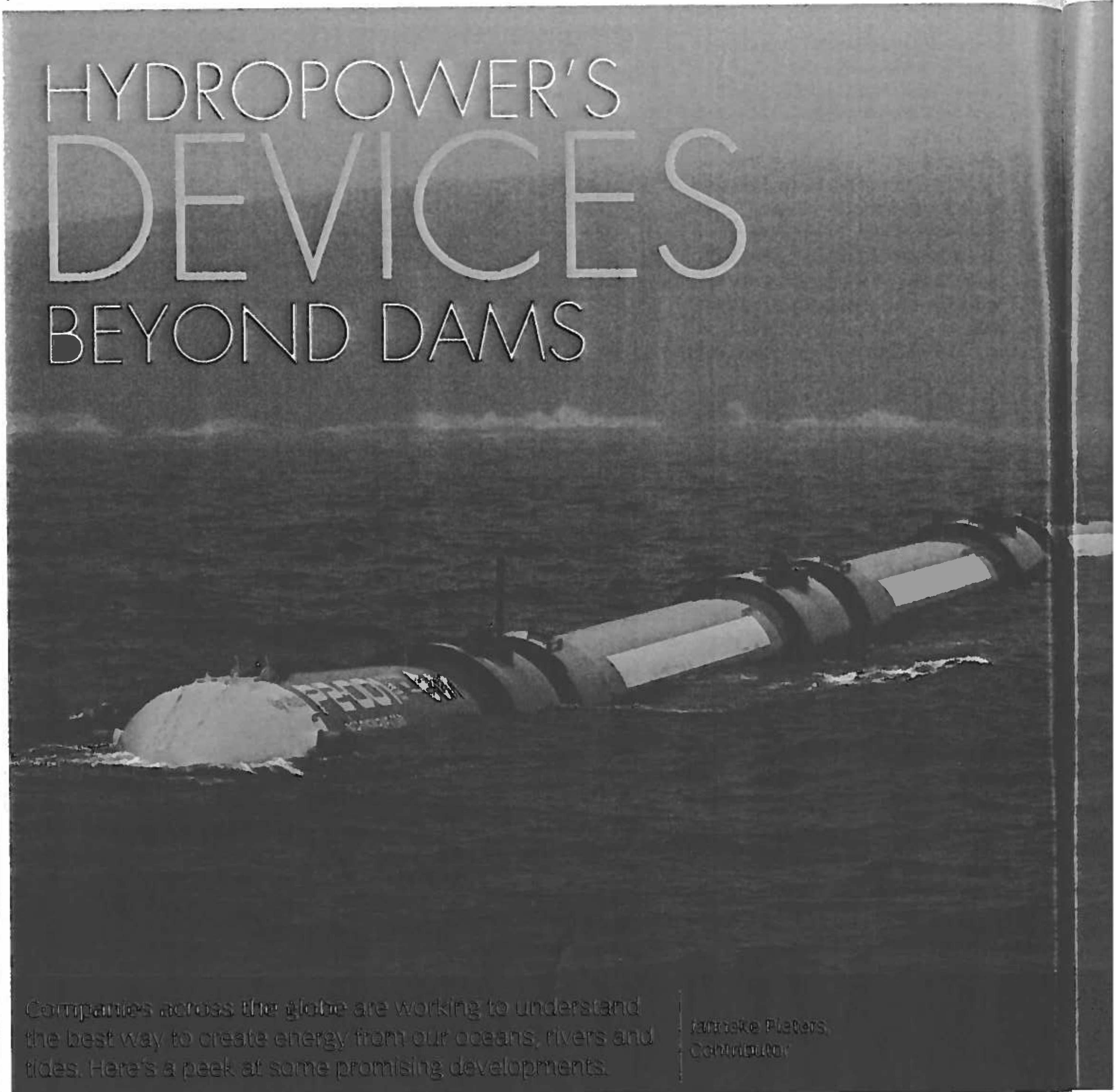
Gerken said these two projects will trail behind the other four by about three years. "We need to go through more permitting and licensing."

Many developers have avoided investing in hydroelectric generation in the past due delays in permitting and high capital investment. Gerken said that despite the delays, hydropower is worth installing because it is a zero carbon footprint alternative with inherent reliability. On average, a hydroelectric project costs about the same per kilowatt hour as a nuclear project, but entails less construction risk and no fuel costs, Gerken said.

But will hydropower be used to fill some of the generation gap that is expected as a result of coal-fired retirements in coming years? Over the short term, Gerken said he predicts natural gas generation will be used to fill the gap. Run-of-river hydropower, however, could play more of a role in terms of long-term generation.

"If the environment became such that we had clear regulations that provided adequate time to capture and recover costs, I think hydro would be far superior to coal or even nuclear."

For the near future, hydropower will likely continue to take a back seat to other forms of generation. But for AMP and its member communities, it will take center stage on the Ohio River. **pe**



HYDROPOWER'S DEVICES BEYOND DAMS

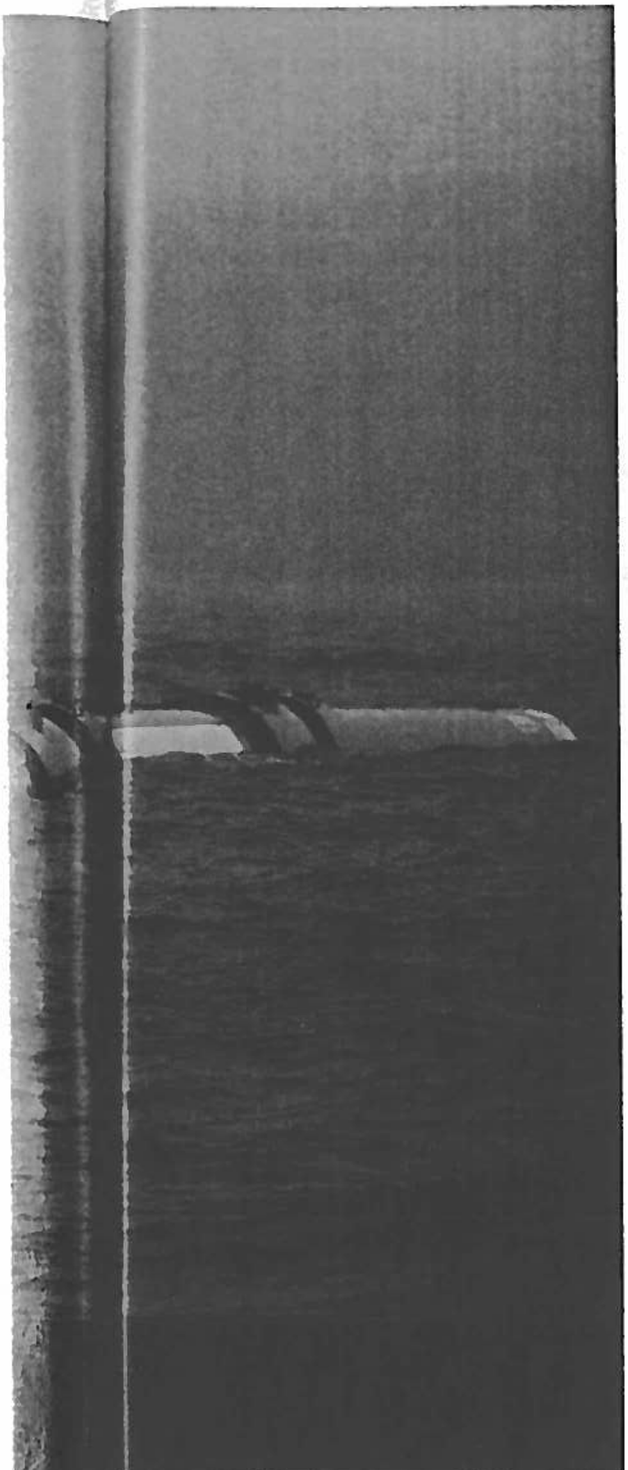
Companies across the globe are working to understand the best way to create energy from our oceans, rivers and tides. Here's a peek at some promising developments.

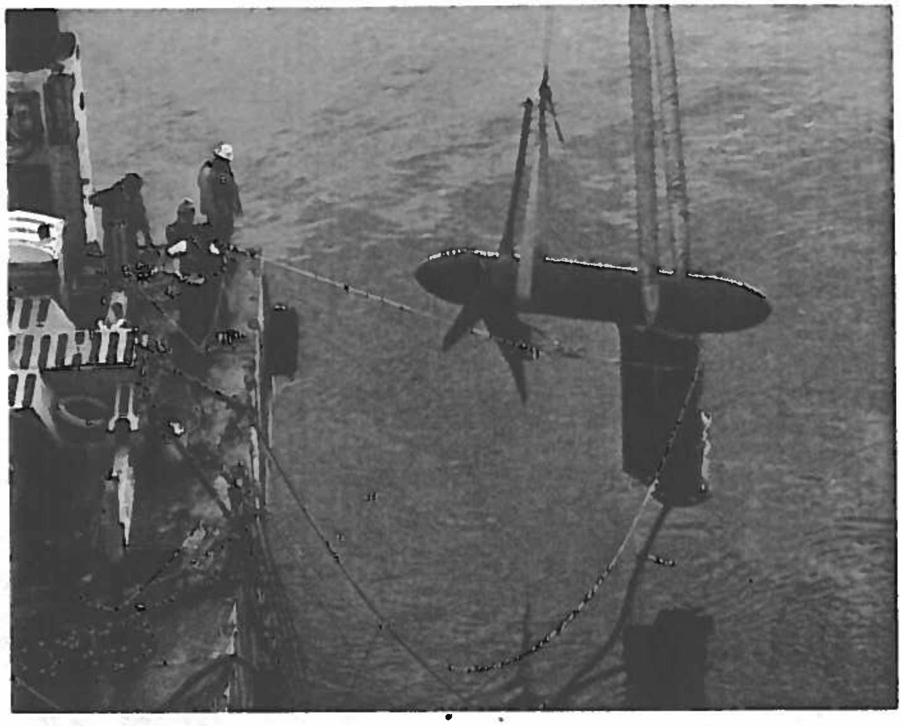
Janneke Pieters, Contributor

Compared to other renewable energy technologies, the sheer multiplicity of wave, tidal and hydrokinetic power devices indicates that the potential for generating power from the world's oceans and rivers is considerable. There are more than 100 different marine and hydrokinetic devices currently being developed, tested and deployed by various companies, according to a recent Pike Research report, and the Ocean Renewable Energy Coalition estimates that as much as 10 percent of U.S. power needs could be met from these unconventional hydropower resources.

Point Absorbers

Several kinds of devices can generate electricity from wave energy and in most cases,





Left The Pelamis Sea-snake. Courtesy Pelamis Wavepower.

Above Verdant Power's free-flow kinetic hydropower system. Courtesy Verdant Power.

undersea power cables carry the energy to shore. A point absorber is a floating device with parts that move relative to each other in response to wave motion and can use hydraulic, pneumatic or direct-drive systems. A direct-drive permanent-magnet generator device built by Columbia Power Technologies (CPT), located in Virginia, is an example. Built of fiber-reinforced plastic that doesn't corrode in harsh sea conditions, CPT's prototype SeaRay is designed to work with the least number of moving parts, thereby increasing efficiency and reducing the chance of parts that can break, according to CEO Reenst Lesemann.

"In its simplest form, there are two wings, forward and aft, and a cell in between. Each wing is directly connected to a generator. Each wing and cell move independently of each other," describes Lesemann. "We are trying to exaggerate the motion of the device." The SeaRay's average output is hundreds of kilowatts (kW), and the peak output is a megawatt (MW). One of its advantages, Lesemann said, is that the parts are modular: "If a piece goes bad, it doesn't have to bring the whole device down." The company's next step is to build a utility-scale model of the SeaRay that is seven times larger, called the Manta.

Ocean Power Technologies' (OPT) PowerBuoys are another example of point absorbers. The 150 kW PB150 generates power by bobbing up and down with the motion of the waves. The mechanical motion drives a generator inside the buoy. Built of steel, the buoys' sizes range from the PB150 up to the PB500 (maximum capacity of 500 kW). Currently, OPT, which is based in Pennington, N.J., is in the final planning phases of a 1.5-MW wave power park 2.5 miles off the coast of Reedsport, Ore. It will be the first commercial project off the west coast of the United States, and will feature ten PB150 buoys, an undersea substation, and a submarine cable. The company expects deployment of the buoys to begin in mid-2012.

Sea Snake

Another type of wave power device — an attenuator — floats on top of the water and in parallel to the direction of the waves. Several segments are connected like a long sea-snake. Pelamis Wavepower (named for the Pelamis platura, a sea snake), based in Edinburg, Scotland, has engineered a steel attenuator device built of five segments that flex in two directions. As the joints flex in response to waves, the motion is converted via hydraulic power take-off systems inside each joint. The device is rated at 750 kW with a target capacity factor of 25 to 40 percent.

In 2008, Pelamis built the world's first wave farm off the northwest coast of Portugal and the company currently has 170-MW worth of projects underway in UK waters, including projects for utility customers E.ON and Scottish Power Renewables. The company doesn't have any projects in the United States or Canada yet, but envisions that it will move into that market in the long term, especially given the "huge potential for generating electricity from the waves around North America," Deborah Smith of Pelamis said.

> RIGHT NOW, ORPC IS LAUNCHING THE FIRST GRID-CONNECTED U.S. TIDAL ENERGY SYSTEM IN COBSCOOK BAY, MAINE

Harnessing Tidal Currents

Instead of waves, tidal energy devices use the movement of tides to generate power. According to the Ocean Energy Council, the total world potential for ocean tidal power has been estimated at 64,000 MW-equivalent. Since water is more than 800 times as dense as air, tidal devices (which often look like wind turbines) can generate an equal amount of energy as wind turbines, but on a much smaller technological scale and at slower water current speeds.

Ocean Renewable Power Company (ORPC), based in Portland, Maine, developed a turbine-generating unit (TGU) — a gearless device made of corrosion-resistant composite materials. The TGU can be configured modularly. For example, in small rivers, the RivGen system combines a TGU with a support frame that rests on the riverbed. In deep ocean waters, the OCGen system stacks several TGUs on top of one another in a bouyant array that takes full advantage of ocean currents. According to Chris Sauer, president and CEO, the company is planning a prototype model of the OCGen system this fall, and plans to build a 1-MW module off the coast of Florida in the Gulf Stream by 2014.

Right now, ORPC is launching the first grid-connected U.S. tidal energy system in Cobscook Bay, Maine. "This is a huge step forward for the U.S. industry," Sauer said. "We will be breaking water on our first device in March — a 180-kW, single device power system that we hope to have connected to the grid to Bangor Hydro's system in June." The company gradually will add more modules in Cobscook Bay, Kendall Head, and West Passage, building up to a 29-device, 5-MW installation by the completion of Phase 3.

Verdant Power, based in New York, NY, has developed a free-flow kinetic hydropower system with a rotor and three blades. The turbines rotate at about 35 RPM, generating motion that then drives a speed increaser, which in turn drives a grid-connected generator. Verdant's device also features fully bidirectional operation on both ebb and flood tides.

Last January, the Federal Energy Regulatory Commission issued a pilot commercial license for Verdant's Roosevelt Island Tidal Energy (RITE) Project in the East Channel of the East River in New York City, making it the first commercially-licensed tidal energy plant in the United States. The plant will have 30 turbines that have a generating capacity of up to 1 MW.

Verdant Power Canada also is seeking to tap into the estimated 15,000 MW of hydrokinetic capacity in Canada via its Cornwall Ontario River Energy (CORE) project. At completion, the project will convert the currents of the St. Lawrence River into energy. It's estimated that as much as 15 MW of generating capacity will be able to be harnessed.

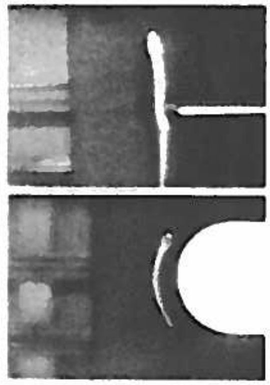
Tapping into Dams

Though it doesn't use waves or tides, HydroGreen of Westmont, Ill., has developed hydrokinetic technology that piggybacks on existing low-head hydropower sites. The technology, which the company calls a "plug and play" modular hydropower solution, is a run-of-river turbine with a capacity factor of 55 to 90 percent.

A 2009 Navigant Consulting report estimated there are 74,000 MW of this kind of hydrokinetic potential in the United States, mostly at non-powered dams. Combined with the waves and tides that surge over much of the Earth's surface, the non-conventional hydropower industry, with commercialization within arm's reach, is poised to tap into a vast supply of renewable energy.

Janneke Pieters has been writing about energy and electricity issues for the past five years.

Original Alden turbine runner. Photo courtesy Alden Research Laboratory.



Demonstration of the relationship between turbine leading edge blade shape and fish survival. Photo courtesy Alden Research Laboratory.

Final model turbine runner with band. Photo courtesy Alden Research Laboratory.

Turbine technology of the future

By Lindsay Morris, Associate Editor

The history of hydropower turbines has been associated with a high demand for maximum power generation. Over the last two decades, however, a focus on decreasing fish mortality has become increasingly important. Turbines are available and in continued development to offer solutions to some of hydropower's biggest issues – particularly the safe downstream passage of fish through turbines and increases in generation through reductions in spill.

In the early 1990s, turbine entrainment was as high as 2,500 fish per hour, according to the Federal Energy Regulatory Commission. This alarming number of fish injuries and mortalities was in part due to the pressure placed on the hydropower industry to operate at peak efficiency – plus or minus 1 percent – even during fish passage season.

One of the main solutions to downstream fish passage protection issues has been to implement direct spillage, which in turn has resulted in significant generation loss. Another technique to lower fish mortality numbers has been explored through turbine manufacturing. While turbines have historically become smaller and faster over the yeras, Alden Research Laboratory, one of the leaders in turbine innovation, has moved in the opposite direction – making its turbines bigger and slower.

Alden turbine's history

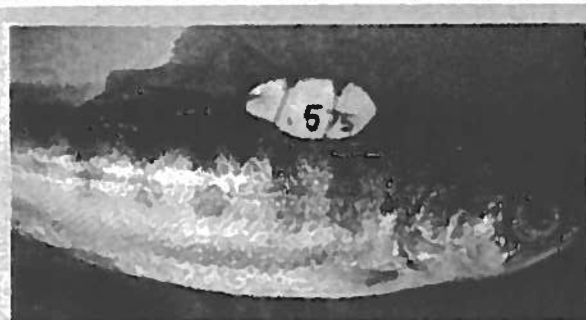
Efforts to develop a more fish-friendly turbine started in the '90s with efforts by the U.S. Army Corps of Engineers' Turbine Survival Program and the U.S. Department of Energy's Advanced Hydropower Turbine Systems Program. The joint effort kicked off with a financial contribution of $500,000 from the Electric Power Research Institute and a coalition of industry supporters. The DOE matched this contribution and solicited proposals from the industry to develop environmentally-enhanced hydropower turbine technologies that were also efficient for generating hydropower.

From this solicitation, awards were made for the design of fish-friendly hydro-turbines to two teams: one led by Voith Hydro, and the other by Alden Research Laboratory. The Voith concept focused on modifying an existing Kaplan runner design, while the Alden concept focused on a radical new runner design created specifically for safely passing fish.

The Alden turbine, which features a helical-shaped runner with only three blades, is intended for new units in smaller rivers and fish bypasses. Original DOE laboratory tests with the Alden turbine demonstrated that fish survival, when scaled to a full-size field installation, would be over 98 percent for many fish species. Following initial proof-of-concept testing, an optimized conceptual design of the Alden turbine with boosted power density to be competitive with existing designs was conducted.

Once the conceptual design was finished, EPRI and DOE funded Alden and Voith Hydro to enhance the turbine's performance through modification of the hydraulic passageways, including the spiral case, distributor, runner and draft tube. The final stage of the Alden turbine design effort included a model test at Voith Hydro's hydraulic laboratory in York, Penn., in addition to the updated mechanical and balance of plant equipment sizing necessary for actual field installation. Model testing indicated a maximum prototype efficiency of almost 94 percent at conditions corresponding to a prototype net head and flow of 92.0 ft and 1,504 cubic feet per second.

The Alden turbine is currently undergoing a field demonstration project. Toward that goal, EPRI in 2010 launched an industry solicitation for potential demonstration sites. After applications were received, sites were ranked numerically until one site, Brookfield Renewable Power's 38 MW School Street Project in Cohoes, N.Y., was chosen as the preferred location for development of the demonstration program. An alternate site, Electricite de France's 8 MW Pebernat project, was identified in the event that the preferred site could not be developed.



A tagged fish after a balloon tagging test, prior to release. Photo courtesy Pacific Northwest National Laboratory.

Doug Dixon, senior program manager for EPRI's Fish Protection Program, said a power purchase agreement is expected to occur in the summer of 2012, and installation is expected to start in about two years. EPRI also received a $1.5 million grant from DOE in September that must be matched by EPRI and the hydropower industry.

In 2009, EPRI received an award from the DOE to conduct a multi-year program to continue the turbine's development and bring it to full-scale deployment. Utilities also are supporting the project to help make sure the turbine's potential is fulfilled. South Carolina Electric & Gas, Puget Sound Energy, Dairyland Power, Southern Co. and Electricité de France along with the New York Power Authority, the New York State Energy Research and Development Authority and Brookfield Renewable Power are funding the project to augment the DOE grant EPRI received. The 2009 funding supported the preliminary engineering design, which included Computational Fluid Dynamics (CFD) modeling, efficiency improvements and hydraulic model testing.

Designing a Difference

The Alden turbine incorporates a number of modifications from traditional turbines. For one, the number of blades was reduced. Whereas a Francis turbine has 12 to 16 blades and a Kaplan turbine has five or six blades, the Alden turbine has only three. The speed of the turbine was also decreased by reducing the number of blades. Because speed – revolutions per minute – is decreased by making the unit larger in diameter, reducing the number of blades diminishes the probability of strike.

An example of a sensor used during sensor fish testing. Photo courtesy Pacific Northwest National Laboratories.

Another deviation from the traditional turbine is the bluntness of the Alden's blades. The blade is far blunter, because "mortality decreases proportionality as the blade becomes blunter," Dixon said.

The shape of the blade was also scrutinized. Tests revealed that as the ratio of the diameter of the leading edge of the turbine blade and fish length increased, survival decreased. Essentially, rounded and wide leading edge blade shapes reduce fish injury and increase survival. To meet the desired design criteria, the Alden turbine is larger than conventional turbines for the same operational application.

Apart from the special hydraulic design, the Alden turbine power unit is similar to conventional turbine technology. The power unit is a vertical shaft arrangement with three bearings: an oil guide bearing above the generator, a combined thrust/guide bearing below the generator and a water bearing above the turbine.

The turbine spiral case is a rectangular cross section, concrete lined, full spiral case (see figure on pg. 64). Fixed stay vanes support the embedded stay ring. The wicket gates are adjustable with pressurized oil moving two, single acting servomotors. As the water discharges from the Alden runner, energy is recovered in the concrete lined, elbow type draft tube.

In addition, typical hydropower turbines have gaps between the blades and the turbine hub where fish can get caught. These turbines are designed to be small and spin fast to extract the most energy at the lowest initial cost.

The Alden turbine, by contrast, looks like a corkscrew. It has three blades, no gaps, is big and rotates more slowly. However, the design compensates so energy production doesn't suffer. With this design, fish move down a smooth channel with a few blades that are turning more slowly than traditional hydro turbines, resulting in less chance for injury.

Biological Testing

"Fish passage survival is truly the measure of success of the Alden turbine," said Tim Hogan, fisheries biologist for Alden. In order to ensure lower rates of fish mortality, the Alden turbine is continually undergoing a number of studies during its demonstration phase. Already, the Alden turbine has completed intense CFD analysis to refine its design over the course of its development, Hogan said. CFD simulations serve as a framework into which biological data from the laboratory and field, as well as data on the physical and behavioral characteristics of fish, can be integrated.

The Alden turbine will also go through balloon tagging and sensor fish technology testing during the remainder of the demonstration phase.

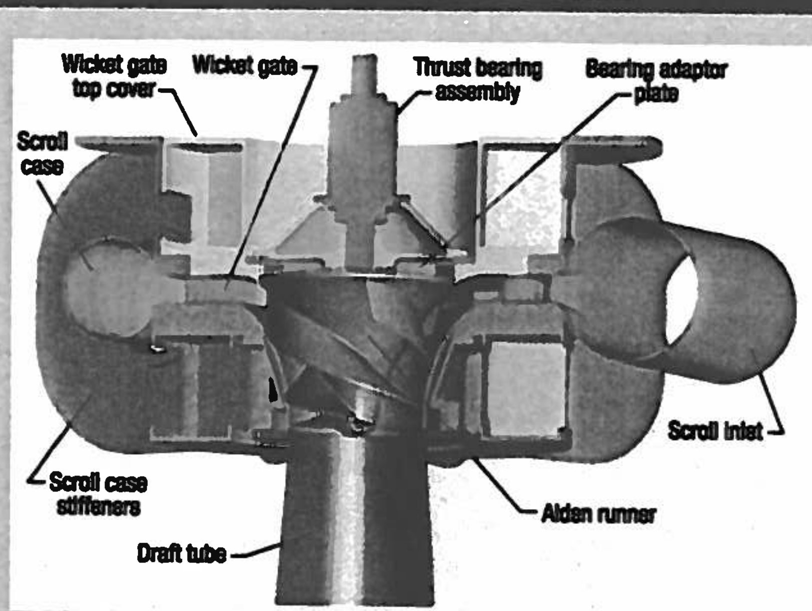
Balloon tagging allows the fish to be recovered immediately following turbine passage. As the fish is recovered, its condition – alive, dead, injured or uninjured – is determined, as well as the types of injuries it has sustained. The fish are tracked as they pass through arrays of receivers at locations downstream through radio or acoustic tracking technology.

Another method, known as sensor fish technology, was developed by Pacific Northwest National Laboratories to record pressures and accelerations experienced as the fish passes the turbine. This method has been used to develop a better understanding of the relationships between injuries, hydraulic conditions and the approximate location where the injuries may be occurring.

Several species of fish have been studied through the Alden turbine tests, including rainbow trout, alewife, smallmouth bass, coho salmon, American eel and white sturgeon. The range of pilot-scale survival rates for American eels and white sturgeon have been remarkably higher than would be achieved by other turbine designs at many sites. With typical turbines, survival rates among American eels are typically lower than they would be with a smaller fish, but with the Alden turbine, American eels had the highest survival rate.

Among the fish tested, eels were the largest, measuring up to 18 inches. Within an hour of testing, all the eels that passed through survived. When latent mortality rates were factored in, such as 96-hour post-passage survival, the smaller eels had 100 percent survival rate; the 18-inch eels had about 99 percent total survival rates.

ALDEN TURBINE CONFIGURATION



Brookfield Renewable Power's 38 MW School Street project in Cohoes, N.Y., was chosen as the preferred location for development of the demonstration program for the Alden turbine. Photo coutesy Alden Research Laboratory

Benefits

Once demonstration tests have been completed, the Alden turbine will likely discover its greatest demand to be at small hydro projects, where the highest gains in fish survival and additional power production can be achieved.

Based on estimates of downstream passage or minimum flow release requirements at developments licensed by FERC and non-federal developments under FERC's jurisdiction, plus potential projects, as many as 1,000 projects exist where the Alden turbine could be applicable.

According to the DOE, 21,000 MW of generating capacity can be added at existing dams in the U.S.

By using the Alden turbine instead of screening, spillage or other practices for downstream fish passage, generating capacity is expected to increase, while O&M costs for downstream fish passage facilities are expected to decrease.

The Alden turbine continues to improve fish passage numbers, with over 98 percent survival expected. "We're looking at very high survival," Hogan said. "I think the public would see that as environmental stewardship."

Although the Alden turbine may have a higher upfront cost, the payback is in increased generation with flow that is otherwise wasted. "Use of the turbine may also preclude the need for expensive screening systems and downstream bypasses," Hogan said.

Norm Perkins, senior civil engineer with Alden, said that the Alden turbine and technologies like it will help keep hydropower's name of being a clean, renewable technology. While Renewable Portfolio Standards have been under scrutiny for hydro developments in recent years, Perkins said that advancements like the Alden turbine "could continue hydro's ability to being considered for RPS in the U.S." pe