Federal Regulation

The **Federal Energy Regulatory Commission (FERC)** is the federal agency that has the authority to license non-federal hydropower projects on navigable waterways and federal lands. FERC issues initial hydropower licenses for periods of 30 to 50 years. When a license expires, one of three things happens:

- FERC relicenses the project;
- the Federal Government takes over the project; or
- the project is decommissioned.

FERC is charged with ensuring that all hydropower projects minimize damage to the environment. Many concerns about hydropower licensing or relicensing involve natural resource issues. Hydropower project operations generally alter natural river flows, which may affect fish populations and recreational activities, both positively and negatively. Project construction or expansion may also affect wildlife habitats, wetlands, or cultural resources. Land owners and communities downstream of the projects also want to be assured that the project dams are safe.

FERC staff prepares an environmental analysis of every hydropower proposal. This is done both for new projects (original license) and for existing projects (relicense). Before the environmental analyses are prepared, FERC staff may hold public meetings and may conduct site visits to the projects to identify issues relating to the construction or continued operation of projects. Citizens and interested groups have a number of opportunities to participate in the licensing process, to identify potential issues, and to share their views on how to address the effects of the projects on the natural and human environment.

Many hydropower projects built in the 1960s and 1970s are now applying for relicensing. It is the job of FERC to weigh all of the economic, environmental, and societal issues and grant or reject the relicensing applications.

With all non-federal hydropower projects, it is the primary responsibility of the owners to analyze existing conditions at the facilities and assess future environmental impacts, then prepare comprehensive reports for FERC.

Relicensing Issues

Supporters of increased hydropower argue that, unlike fossil-fueled electric power plants, hydropower projects do not pollute the air or increase emissions of greenhouse gases. Opponents have countered that hydropower can harm fragile aquatic environments.

Each group has its own set of issues concerning hydropower; those in favor of hydropower can encounter difficulties with relicensing authorities, while those who oppose hydropower may fight for dam removal. During the relicensing process, federal, state, and local groups may advocate for endangered or threatened species, as well as other region-specific issues.

There are many state and federal laws and regulations that must be followed during relicensing. Some of these laws include:

- Federal Power Act
- Energy Policy Act of 2005
- Clean Water Act (Section 401)
- National Environmental Policy Act
- Endangered Species Act

WILDLIFE

Image courtesy of U.S. Fish and Wildlife Service

The Federal Energy Regulatory Commission authorizes the initial construction of non-federal hydropower projects and reconsiders licenses every 30 to 50 years. The U.S. Fish and Wildlife Service conducts environmental reviews during relicensing.

- National Historic Preservation Act
- Federal Code of Regulations for Recreation

One of the most prominent issues facing the Pacific Northwest hydroelectric industry involves endangered fish populations and the Columbia River. The Columbia River basin is one of the largest water systems in North America. It stretches from Canada down into seven states. The Columbia River and its **tributaries**, including the Snake River, are well developed in terms of hydropower, with 31 federally owned projects. These hydro projects produce nearly 40 percent of the region's electricity.

However, the Columbia and Snake Rivers are home to endangered and threatened migrating salmon and steelhead populations that must pass up to eight dams. The dams were originally built with fish ladders that mature fish have been successfully navigating upstream to spawn. Hundreds of millions of dollars have been spent to improve fish passage for juveniles swimming downstream to reach the ocean.

The down river side of the Safe Harbor Hydroelectric Power Plant in southern Pennsylvania.

Advantages and Challenges of Hydropower

Using hydropower as an energy source offers many advantages over other sources of energy, but hydropower has significant disadvantages too because of the unique environmental challenges involved.

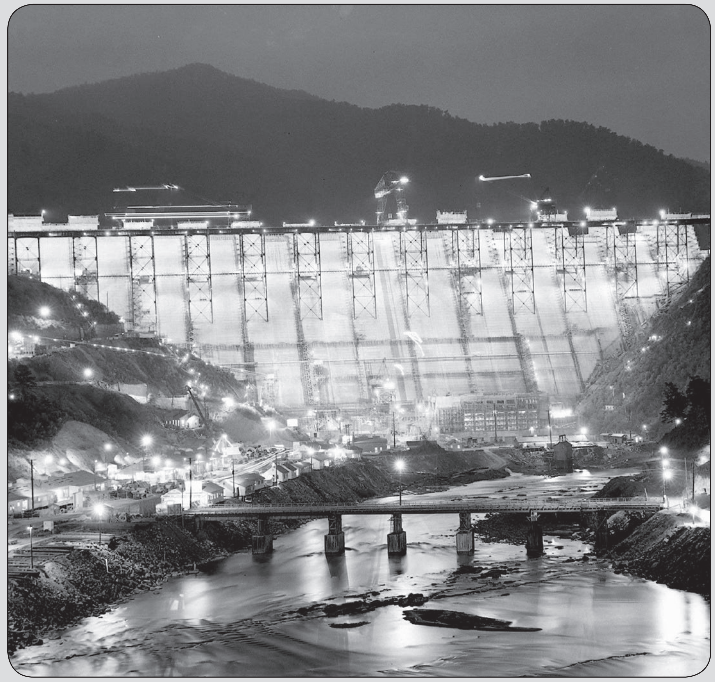
Advantages of Hydropower

- Hydropower is a clean energy source. It is fueled only by moving water, so it doesn't produce emissions. Hydropower does not increase the level of greenhouse gases in the atmosphere.
- Hydropower is a renewable energy source. It relies on the water cycle, which is driven by the sun. The total amount of water in a hydropower system does not change; the moving water is used to generate electricity and returned to the source from which it came.
- Hydropower is usually available when it is needed. Engineers can produce electricity on demand and control the amount of electricity generated.
- Hydropower is an established, proven, and domestic source of energy.
- Hydropower is an economical way to produce electricity. Maintenance costs of hydropower facilities are low. Once a plant is up and running, the water flow that powers it is free. The electricity generated by hydropower facilities is the cheapest electricity in the country.
- Hydropower is an efficient way to produce electricity. The average hydropower plant is 90 percent efficient at converting the energy in the moving water into electricity.
- Impoundment facilities create reservoirs that offer a wide variety of non-energy benefits to communities, such as recreational fishing, swimming, and boating. The reservoirs can also increase the property value of the adjacent land.
- Hydropower facilities can help regulate the water supply, providing drought and flood control. Many dams were designed primarily as flood control projects; the generating equipment was an additional benefit. During drought, the reservoirs provide a more reliable source of drinking water, as well as water for fragile downstream habitats.
- Hydropower dams are very safe and durable—built to last for hundreds of years.
- Hydropower is a flexible energy source in meeting electricity generating needs quickly. Hydropower plants can begin generating electricity within minutes of increased demand. Most hydropower plants can also provide reliable and dependable **baseload power**.
- Presently, less than three percent of existing dams in the U.S. contain generators. Without building any new dams, existing dams have the potential to generate 12,000 megawatts of power.

Challenges of Hydropower

- Hydropower plants are dependent on water supply. When there is a drought, for example, hydropower plants cannot produce as much electricity.
- A dam on a river can permanently change the ecology of a large land area, upstream and downstream, creating a different environment. When a dam is built, the resultant reservoir floods a large area of land upstream from the dam. The natural ecology of the river and adjacent land downstream is changed by a reduction in soil deposition.
- Hydropower facilities can impact water quality and flow. Reservoirs can experience low dissolved oxygen levels in the water, a problem that can be harmful to fish populations and downstream riparian (riverbank) habitats. Maintaining minimum flows of water downstream of a reservoir is also critical for the survival of riparian habitats.
- Some fish populations, such as salmon, migrate upstream to reach spawning grounds and then return to the ocean. Impoundment facilities block fish from completing this natural migration process. Fish ladders or elevators may be built to aid upstream fish passage. Downstream fish passage can be aided by diverting fish around the turbine intakes, by maintaining a minimum spill flow past the turbines, using screens or racks, and even underwater lights and sounds.
- Development of new hydropower reservoirs can be very expensive because dams have already been built at many of the more economical locations. New sites must compete with other potential uses of the land.

President Franklin D. Roosevelt signs the TVA Act in 1933.



The Fontana Dam in North Carolina as it nears completion in 1944.

The Tennessee Valley Authority: A Vision Born from Hydropower

The Tennessee Valley Authority (TVA) is a public utility established by Congress in 1933 as one of Franklin Roosevelt's solutions to the Great Depression. The Tennessee Valley was in bad shape in 1933. Much of the land had been farmed too hard for too long, depleting the soil. The best timber had been cut. TVA developed fertilizers, taught farmers how to improve crop yields, and helped replant forests, control forest fires, and improve habitats for wildlife and fish.

The most dramatic change in Valley life came with the advent of electricity generated by TVA dams that also controlled floods and improved navigation. Electricity brought modern amenities to communities and drew industries into the region, providing desperately needed jobs.

During World War II, the country needed more electricity and TVA engaged in one of the largest hydropower construction programs ever undertaken in the United States. At the program's peak in 1942, twelve hydropower projects and a steam plant were under construction at the same time, employing 28,000 workers. By the end of the war, TVA had completed a 650-mile navigation channel the length of the Tennessee River and had become the nation's largest electricity supplier.

Today, TVA's system consists of a mix of energy sources, including:

- 29 hydroelectric dams and 1 pumped storage plant;
- 11 coal-fired and 9 combustion-turbine power plants;
- 3 nuclear power plants;
- 16 solar power sites;
- 1 wind power site;
- 1 methane gas site, and
- 1 biomass cofiring site.

Right: The dedication of the Douglas Dam in Dandridge, TN, 1943.
Images courtesy of Tennessee Valley Authority

TVA operates a system of 49 dams and reservoirs on the Tennessee River and its tributaries, as well as managing 293,000 acres of public land. TVA manages the 41,000-square-mile watershed as an integrated unit to provide a wide range of benefits, including:

- year-round navigation;
- flood control;
- electricity generation;
- recreational opportunities;
- improved water quality; and
- a reliable water supply to cool power plants and meet municipal and industrial needs.

A Case Study in Improving Ecology at a Dam

Observers in the Grand Canyon of the Colorado River have noticed a decline in the number of sandbars used as campsites. This decline is attributed to Glen Canyon Dam, which controls the flow of the Colorado River through the canyon. Most of the sediment and sand now gets trapped behind the dam.

The rapids that make the Grand Canyon so popular with white-water rafters are created by debris fans—piles of rock fragments—that tumble down from tributaries during intense rainfall. The debris fans used to be cleaned out yearly by floods of water that flowed through the canyon during spring snowmelt in pre-dam years.

Rapids are caused by large boulders that get stuck on the river bed.

The dam dramatically reduced the flow of water through the canyon. This drop in water flow limits the ability of the river to move rock debris. The dam also decreased backwater habitats and lowered the overall water temperature of the main river, leading to the extinction of four native fish.

The U.S. Department of the Interior, Bureau of Reclamation, which operates Glen Canyon Dam, released an unusually high flow of water during the spring of 1996 to see if it could rebuild beaches and restore other habitats that have deteriorated since the dam's completion in 1963. Two other high flows were released in November 2004 and March 2008.

Scientists found that periodic flooding is successful at rebuilding the sandbars. However, there were no measurable positive outcomes for native endangered fish populations. Additional studies and adaptive management strategies will continue at the dam.

HIGH FLOW

Image courtesy of U.S. Geological Survey

A Case Study in Removing a Small Dam—When the Costs Outweigh the Benefits

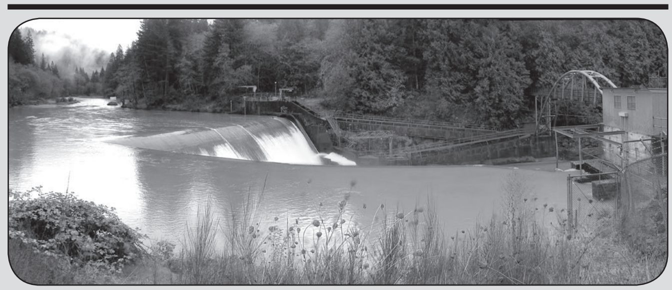
In May 1999, Portland General Electric (PGE) announced plans to decommission, or tear down, its 95-year-old hydropower project on the Sandy River in Oregon. The project eliminated expensive maintenance costs to the power plant, and avoided the cost of bringing fish protection up to today's standards. The project consisted of dismantling the following:

- the 47-foot-high Marmot Dam;
- a concrete-lined canal that took water from Marmot Dam to the Little Sandy River;
- the 16-foot-high Little Sandy Dam;
- a 15,000-foot-long wooden flume (artificial water channel); and
- a 22-megawatt powerhouse.

Marmot Dam was removed in 2007, restoring the Sandy to a free-flowing river for the first time in nearly a century. Within hours the Sandy River looked like a natural river. Torrents of water carried sediment downstream, helping create natural bends, bars, and logjams. The Little Sandy Dam was removed in 2008.

PGE is giving about 1,500 acres of land to the Western Rivers Conservancy. This land will form the foundation of a natural resource and recreation area in the Sandy River Basin. Covering more than 9,000 acres, the area will be owned and managed by the U.S. Department of the Interiror, Bureau of Land Management.

BEFORE DEMOLITION



DURING DEMOLITION

Images courtesy of U.S. Geological Survey

New Hydropower Initiatives

The U.S. Department of Energy (DOE) Water Power Program researches, tests, evaluates, and develops innovative technologies capable of generating renewable, environmentally responsible, and cost-effective electricity from water resources. This includes hydropower as well as marine and **hydrokinetic** energy technologies.

Modernizing Existing Facilities

The Water Power Program's conventional hydropower activities focus on increasing generating capacity and efficiency at existing hydroelectric facilities, adding hydroelectric generating capacity at non-powered dams, and reducing environmental effects.

In 2009, the DOE awarded over $30 million in American Recovery and Reinvestment Act funding to modernize hydropower projects. The investment has created and continues to create jobs and increase renewable electricity generation without building any new dams. The projects will produce an estimated 187,000 megawatt-hours of electricity per year, which is enough to power 12,000 homes. The hydropower projects focus not just on installing or upgrading turbines, but also include generators, transformers, wiring, maintenance equipment, and fish and wildlife habitat improvements.

- Alabama Power Company—Mitchell, AL. Up to $6 million will be used to replace turbines installed in the 1940s and 1960s. Four new high-efficiency turbines will maximize the use of the limited water available at the three sites. Generation will increase by over 36,000 megawatt-hours each year.
- Alcoa, Inc.—Robbinsville, NC. Up to $13 million was awarded for replacing four 90-year-old turbines. New turbines, generators, and transformers will increase generation by 95,000 megawatt-hours annually, which is a 23 percent increase. In addition, the project improves environmental conditions at the plant by removing lead and asbestos and reduces the potential for oil spills into the river by replacing water-cooled transformers.
- City of Tacoma, Department of Public Utilities—Potlatch, WA. Just under $5 million was awarded to add two turbines to increase generation by 23,500 megawatt-hours per year. This project also focuses on improving wildlife conditions in the river by incorporating an upstream fish collection pool that will allow for the reintroduction of native fish species above the dam for the first time since the 1920s.
- City of Boulder, CO. To upgrade a 100-year-old facility, about $1.2 million was awarded. Two older turbines will be replaced with a single unit that operates more efficiently under variable conditions. Annual generation is expected to increase 30 percent, or 11,000 megawatt-hours.
- Incorporated County of Los Alamos, NM. In April 2011, a project at the Abiquiu Hydroelectric Plant was the first hydropower project funded by the American Reinvestment and Recovery Act to be completed nationwide. Using $4.5 million, a new low-flow

FISH-FRIENDLY TURBINE

FISH BYPASS

Images courtesy of Grant County Public Utility District

At the Wanapum Dam on the Columbia River, a fish-friendly turbine bypass that is designed to help salmon smolts pass through the dam without injury is being tested.

turbine/generator was installed. This high-efficiency turbine operates at flows above and below the older turbines, increasing annual generation 22 percent. Environmentally, the project will improve dissolved oxygen content of the water downstream.

- North Little Rock Electric Department—Little Rock, AR. This project will install an automated maintenance device to clear debris obstructing the intake using $450,000. Cleaning away the debris will allow the facility to operate consistently near peak efficiency.

These projects and many other research projects are in various stages of completion, and are funded through grants and congressionally directed funds. For more information, visit the U.S. Department of Energy, Energy Efficiency and Renewable Energy's Wind and Water Power Technologies Office report entitled Hydropower Projects.

Advanced Turbine Systems

The Department of Energy also supports research into new technologies. Current hydropower technology, while essentially emission-free, can have undesirable environmental effects, such as fish injury and mortality from passage through turbines, as well as detrimental changes in the quality of downstream water. Advanced hydropower turbine technology could minimize the adverse effects yet preserve the ability to generate electricity from an important renewable resource.

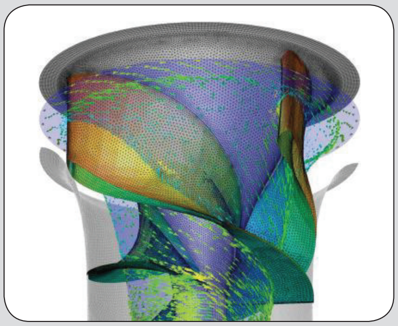
The goal of DOE's Advanced Hydropower Turbine System (AHTS) Program is to develop technology that will allow the nation to maximize the use of its hydropower resources while minimizing adverse environmental effects. Conceptual designs of environmentally friendly hydropower turbines have been completed under the DOE-industry program. Potential fish injury mechanisms caused by turbine passage have been identified.

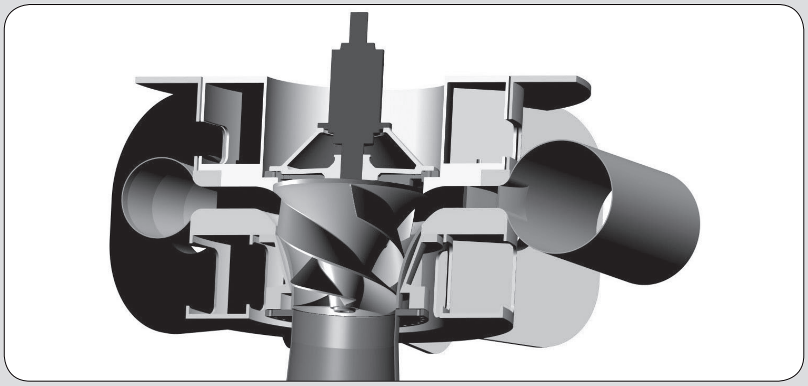
Potential benefits of advanced turbine technologies include:

- Reduced fish mortality: Advanced turbine technology could reduce fish mortality resulting from turbine passage to less than two percent, in comparison with turbine-passage mortalities of five to 10 percent for the best existing turbines and 30 percent or greater for other turbines.
- Improved water quality: Advanced turbine technology would maintain a downstream dissolved oxygen level of at least six milligrams per liter, ensuring compliance with water quality standards.
- Reductions in carbon dioxide emissions: The use of environmentally friendly turbine technology would help reverse the decline in hydroelectric generation and reduce the amounts of CO_2 and other greenhouse gases emitted by consumption of fossil fuels.

Alden Lab

Founded in 1894, Alden Lab is the oldest hydraulic laboratory in the United States and one of the oldest in the world. Alden has developed a new hydraulic turbine runner to reduce fish injury and death as part of the DOE Advanced Hydropower Turbine System (AHTS) program. Results of pilot-scale tests indicate a 90.5 percent efficient turbine with fish passage survival of 94-100 percent.





Top Left: Milling the blade of the turbine.

Top Right: A 3D model of the turbine.

Bottom: A cross-section of a fish-friendly turbine.

Images courtesy of Alden Lab

Marine and Hydrokinetic Technologies

The ocean is in constant motion and contains energy that can be harnessed. Some devices harness the energy in the changing tides to generate electricity. Others harness the energy in the waves, while others rely upon underwater currents.

Tidal Barrage

A tidal power plant, or **tidal barrage**, is built across an **estuary**, the area where a river runs into the ocean. The water here rises and falls with the tides. A tidal barrage has gates and turbines at its base. As the tide rises, the water flows through the barrage, spinning the turbines, then collects in the estuary. When the tide drops, the water in the estuary flows back to the ocean. The water again turns the turbines, which are built to generate electricity when the water is flowing into or out of the estuary.

Tides are caused by the interaction of gravitational forces between the Earth, moon, and sun. The force from the moon is much more powerful since it is closer to the Earth. The moon pulls on the ocean water that is closest to it. This creates a bulge in the surface of the water, called a **tidal bulge**. Because the Earth is rotating, the water on the opposite side of the Earth also forms a tidal bulge. These bulges produce high tides. The influence of the sun is apparent when it is aligned with the moon and the tides become higher than at other times.

Between the tidal bulges are lower levels of water that produce low tides. The tidal bulges move slowly around the Earth as the moon does. Halfway between each high tide is low tide. Most shorelines have two high and two low tides each day. The Gulf of Mexico only experiences one high and one low tide each day because of its geographic location.

On most of the U.S. coast, the tidal range, or the difference between high and low tides, is only about three to six feet. When a high tide flows into a narrow bay where the water cannot spread out, the tidal range can be very large. These areas are potential locations for harnessing tidal power. The Bay of Fundy in Canada, near Maine, has the highest tides in the world, sometimes rising over 50 feet.

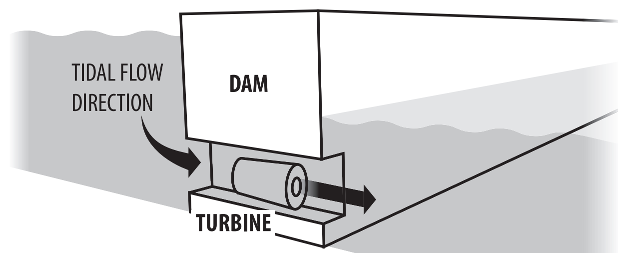
The main challenge with using **tidal power** (barrages, fences, and turbines), is geographical. There are few parts of the world with significant enough tides to support tidal power stations. Countries that currently use tidal power include Canada, China, France, Netherlands, New Zealand, Russia, South Korea, Sweden, the United Kingdom, and the United States. Tidal barrage systems are expensive to build, and their construction may harm local wildlife habitats.

Tidal Fences

Building large-scale tidal barrages is less likely than alternative methods of harnessing tidal power. One option is a **tidal fence**. Tidal fences are similar to tidal barrages in that they stretch across narrow areas of moving water. Unlike tidal barrages, tidal fences do not dam water, but allow it to flow freely. This makes them cheaper to install as well as having less impact on the environment. However, tidal fences may inhibit the movement of large marine mammals and ships.

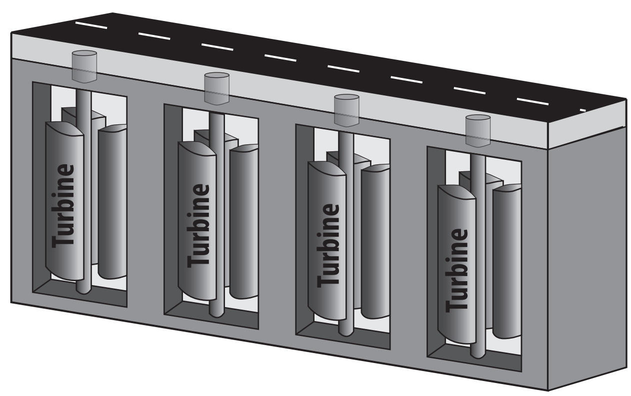
Tidal Bulge

Tidal Barrage



Tidal water is captured at high tide behind a dam. When the tide turns, the water is released to the sea, passing through a set of turbines.

Tidal Fence with Bridge



Tidal Turbines

Another source of tidal power relies on strong and steady underwater ocean currents that can be harnessed to generate power. This technology is known as hydrokinetic or tidal stream power. Underwater turbines work like submerged windmills, but are driven by flowing water rather than air. They can be installed in the ocean in places with high tidal current velocities or in places with fast enough continuous ocean currents. A major advantage of this energy resource is that it is as predictable as the tides, unlike wave energy, which relies on the weather.

Marine Current Turbines has developed the world's largest grid-connected tidal stream system, known as SeaGen S. SeaGen S is a 1.2 megawatt commercial demonstration project. A single SeaGen S device began operation in Strangford Lough (a shallow bay situated on the east coast of Northern Ireland) in 2008.

SeaGen S is able to generate clean and sustainable electricity equivalent to the average needs of approximately 1,500 homes.

SeaGen S turbines can be raised above sea level to allow maintenance from small service vessels. This is an important feature because underwater maintenance by divers or remotely operated vehicles (ROVs) is difficult in locations with the strong currents needed for effective power generation.

Environmental impact studies report that this technology does not offer a serious threat to fish or marine mammals. The rotors turn slowly, a maximum of 14 **revolutions per minute**. The risk of impact from the rotor blades is extremely small, considering that most marine creatures that swim in areas with strong currents and have excellent perception and agility, giving them the ability to successfully avoid collisions with slow-moving underwater obstructions.

OpenHydro, an Irish energy technology company, has designed a different style of **tidal turbine**—one with an open center. These tidal turbines are designed to be installed on the ocean floor, with no portion of the structure above the water level. The blades of the turbine turn in both directions, producing electricity during both ebb and flow tides.

The open-center turbines are designed to minimize environmental impacts. For example, the open center allows for safe passage of fish. The machine uses no oils, grease, or other lubricating fluids, eliminating potential pollutants. The blade tips are enclosed in the unit, preventing injury to large and small marine animals. Also, data gathered from the turbines show that the units produce low levels of sound.

In 2012, Maine deployed the country's first commercial, grid-connected tidal power system. This system, operated by the Ocean Renewable Power Company, is located in The Bay of Fundy and is projected to eventually power approximately 2000 homes.

TIDAL TURBINE

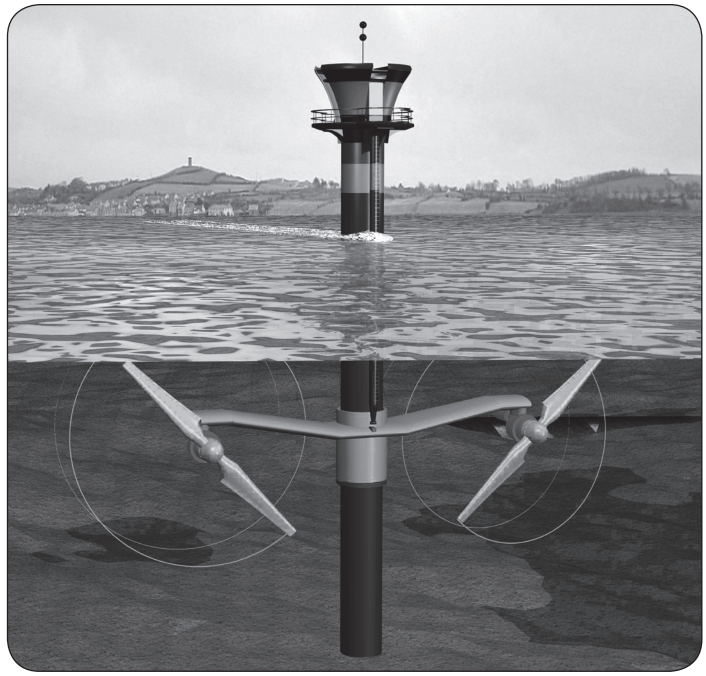


Image courtesy of Marine Current Turbines

An artist's rendering of the SeaGen S tidal turbine system. The SeaGen S consists of two large rotors, each driving a generator with a gearbox. The twin rotors—each 14-20 meters in diameter—are mounted on wing-like extensions on either side of a three-meter wide tubular steel monopile that is set into a hole drilled in the sea floor.

OPENHYDRO TIDAL ENERGY SYSTEM

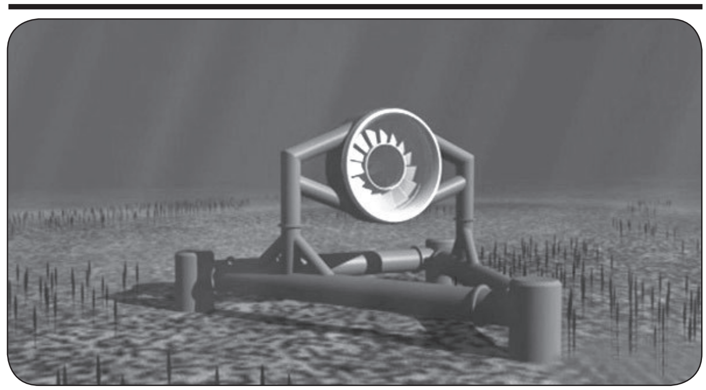


Image courtesy of OpenHydro

OpenHydro currently has tidal power projects planned in Europe, Canada, and in Admirality Inlet off the coast of Whidbey Island in Washington State.

New York City's East River Project

The city and state of New York have partnered with Verdant Power to harness the energy in the ebb and flow of the tides in Manhattan's East River. The Roosevelt Island Tidal Energy (RITE) Project is the first grid-connected (non-commercial) array of tidal turbines in the world. After completing a successful demonstration phase with six turbines that generated 70 megawatt-hours of electricity, the project received the first U.S. commercial license for tidal power. The next step is for the project to build out to one megawatt capacity with 30 tidal turbines.

Image courtesy of Verdant Power

Free Flow System turbine being installed in East River, NY.

Waves

The main cause of surface ocean waves is wind; although, they can also be affected by tides, weather conditions, and underwater events. The size of waves depends on the speed of the wind, wind duration, and the distance of water over which the wind blows, known as the fetch. Usually, the longer the distance the wind travels over water, or the harder it blows, the higher the waves. A strong breeze of 30 miles per hour can produce 10-foot waves. Violent storm winds of 65 miles per hour can produce 30-foot waves.

As the wind blows over the water, there is friction between the wind and the surface of the water. The wind pulls the surface water in the direction it is going. The water is much denser than the air and cannot move as fast, so it rises and then is pulled back down by the force of gravity. The descending water's momentum is carried below the surface, and water pressure from below pushes this swell back up again. This tug of war between gravity and water pressure creates wave motion.

Ocean waves are, therefore, the up and down motion of surface water. The highest point of a wave is the **crest**; the lowest point is the **trough**.

The height of a wave is the distance from the trough to the crest. The length of a wave is the distance between two crests. Small waves may have lengths of a few inches while the crests of large storm waves may be several football fields apart. Waves usually follow one another, forming a train. The time it takes two crests in a train to pass a stationary point is known as the **period** of a wave. Wave periods tell us how fast the waves are moving.

In deep water, waves do not move water in the direction of the wind. With each up and down movement, the water rises to a crest, turns a somersault into a trough, and returns to about the same spot where it began. Near shore, the ocean becomes shallow; some somersaults hit the bottom and drag. The water at the top continues to somersault. The crests crowd together and get top heavy, tumbling over and rushing toward the shore, allowing for surfing and bodyboarding.

Harnessing Wave Energy

The energy in waves can be harnessed to generate electricity. There are two main types of wave energy generation devices, fixed and floating. Fixed generating devices are built into cliffs along a coast.

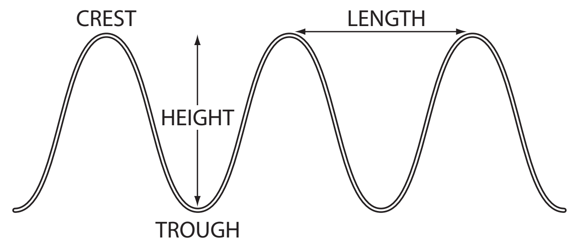
One **fixed device** is the **oscillating water column**. The column, or chamber, is partially submersed in the water. As the waves flow in and out of the chamber, the air inside the chamber is compressed and decompressed. The forced air spins a turbine. The generator attached to the turbine produces electricity.

Another fixed generating device is a tapered channel system known as a **TAPCHAN system**. It consists of a channel connected to a reservoir in a cliff. The channel gets narrower as it nears the reservoir, causing the waves to increase in height.

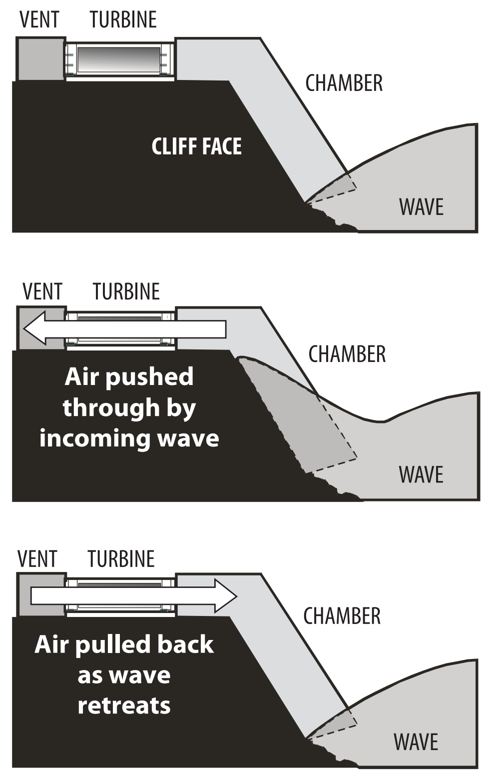
When the waves are high enough, they spill over the top of the channel into the reservoir. The stored water in the reservoir flows through a turbine, generating electricity.

A TAPCHAN system is not usable in all coastal areas. Ideal locations have consistent waves, good wave energy, and a tidal range of less than one meter.

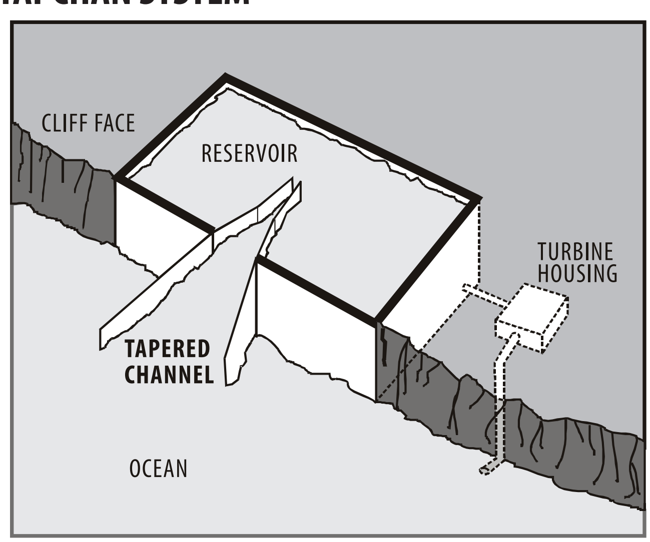
Wave Measurements



Oscillating Water Column



TAPCHAN SYSTEM



Several floating wave energy generation devices are under development. They generate electricity as they are moved by the waves. One open-ocean method uses **Salter Ducks**—tethered cams that bob up and down with the waves on the surface of the water.

The nodding motion of the cams compresses oil in pistons inside the devices. The pressurized oil is released through a hydraulic motor that converts 90 percent of the harnessed energy into electricity.

A Scottish company, Pelamis Wave Power, has developed a floating wave energy converter known as Pelamis, named after the scientific name of a sea snake.

Each device is a series of five semi-submerged tubes that are linked to each other by hinged joints. Passing waves cause each tube to rise and fall like a giant sea snake. The motion tugs at the joints linking the segments. The joints act as a pumping system, pushing high pressure oil through a series of hydraulic motors, which in turn drive the electrical generators to produce electricity. The wave energy converters are anchored to the sea floor by moorings and then connected to the grid via subsea power cables.

In 2008, Pelamis Wave Power and the Portuguese utility Enersis built the world's first wave farm off the coast of Portugal. Three first-generation Pelamis machines had an installed capacity of 2.25 megawatts and generated sustained power to the electric grid. However, the project ended later that year, with the Pelamis machines being towed back into harbor, due to the financial collapse of Enersis' parent company.

In 2009, Portuguese electric companies EDP and Efacec purchased Enersis' share in the wave farm and have plans to install up to 26 second-generation Pelamis wave energy converters with an installed capacity up to 20 megawatts.

In the summer of 2012, FERC approved the construction of a grid-connected 1.5 MW wave power farm, to be placed off of the Oregon coast. This farm will utilize computer-equipped buoys over 100 feet long that were deployed by Ocean Power Technologies. It is the first wave power station permitted in the U.S.

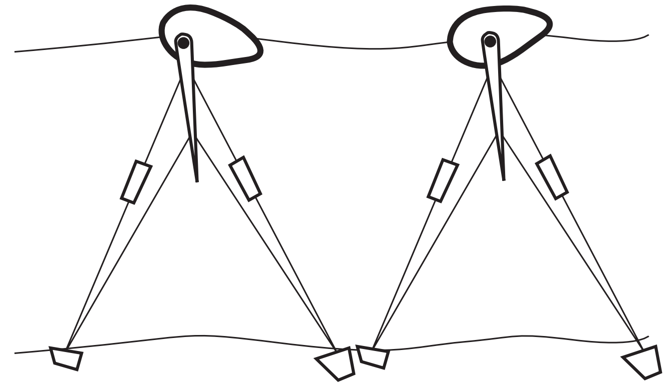
Osmotic Power Plant

In 2009, a Norwegian energy group, Statkraft, opened the world's first osmotic power plant. **Osmotic power** is based on the natural process of osmosis—the diffusion of molecules through a semi-permeable membrane from a place of higher concentration to a place of lower concentration. It is a clean, renewable energy source.

In an osmotic power plant, seawater and freshwater are separated by a semi-permeable membrane—freshwater can move through the membrane but saltwater cannot. The salt content of the seawater draws freshwater through the membrane to dilute the salinity, increasing pressure on the seawater side of the membrane. The increased pressure is used to spin a turbine to generate electricity.

The first prototype of the osmotic power plant in Norway is generating up to four kilowatts of electricity. The next phase is to improve the efficiency of the membrane and open a one to two megawatt pilot facility. A 25 megawatt plant could be operating by 2015.

Salter Duck



The Salter Duck generates electricty offshore using the movement of the waves to bob up and down on the surface of the water.

PELAMIS WAVE ENERGY CONVERTER

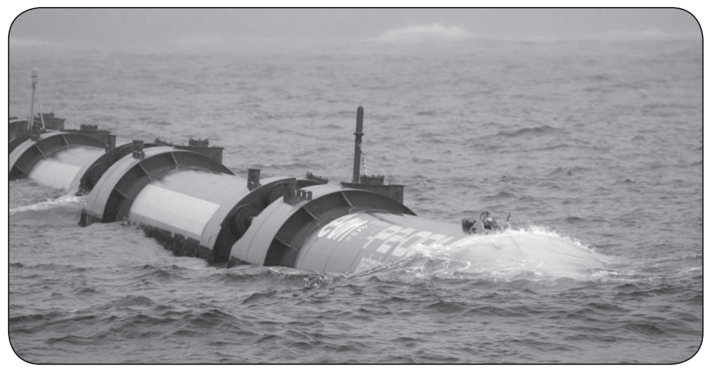


Image courtesy of Pelamis

Osmotic Power Plant

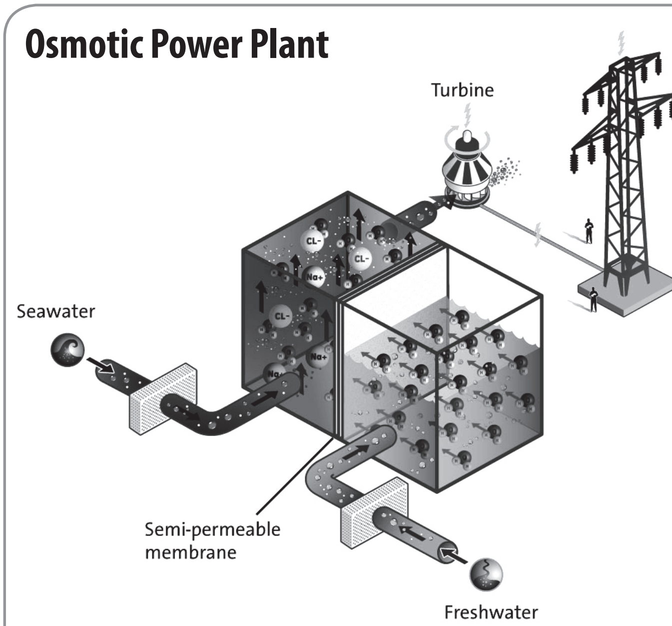


Image courtesy of Statkraft

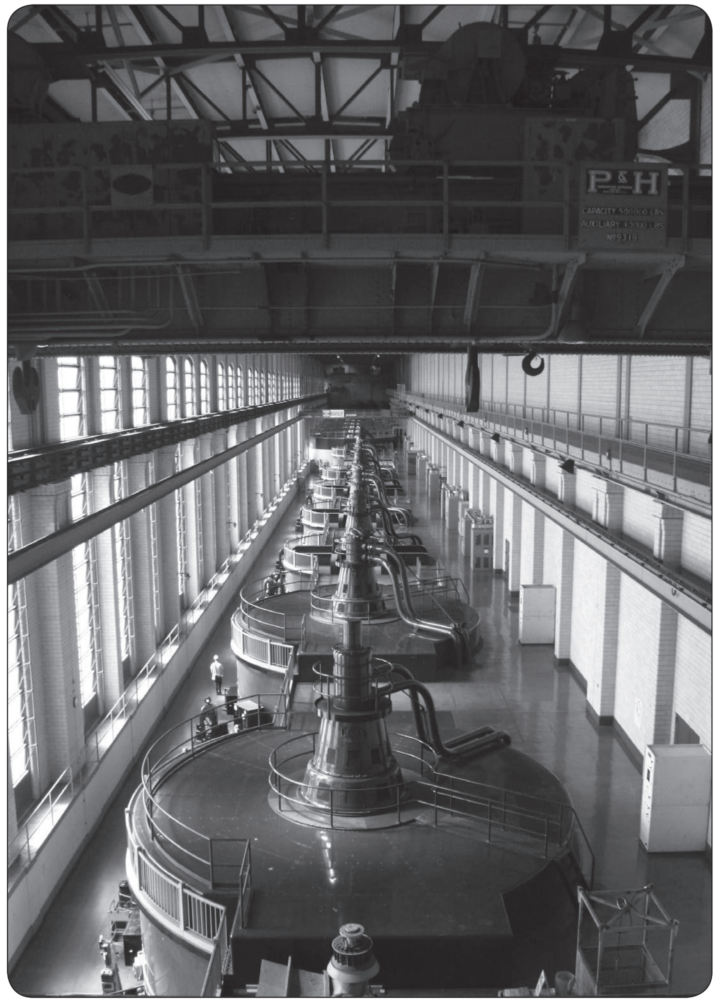
Future of Hydropower

The future of hydropower includes both challenges and opportunities, and will continue to be a major part of the U.S. and global energy mix for many years. As the nation and the world develop strategies to deal with global climate change, hydropower will play a significant role by producing clean, economical electricity without carbon dioxide emissions.

Advances in turbine design and other mitigation strategies will continue to reduce the impact of conventional hydropower facilities on fish populations, water quality, and the environment. New technologies will also allow facilities to become more efficient and generate more electricity. The addition of power plants to existing dams will increase the overall capacity of the hydropower industry.

The development and implementation of technologies that harness the power of moving water, whether it is from free-flowing streams, the tides, ocean currents, or waves, will also contribute to the future of hydropower in the United States and around the world.

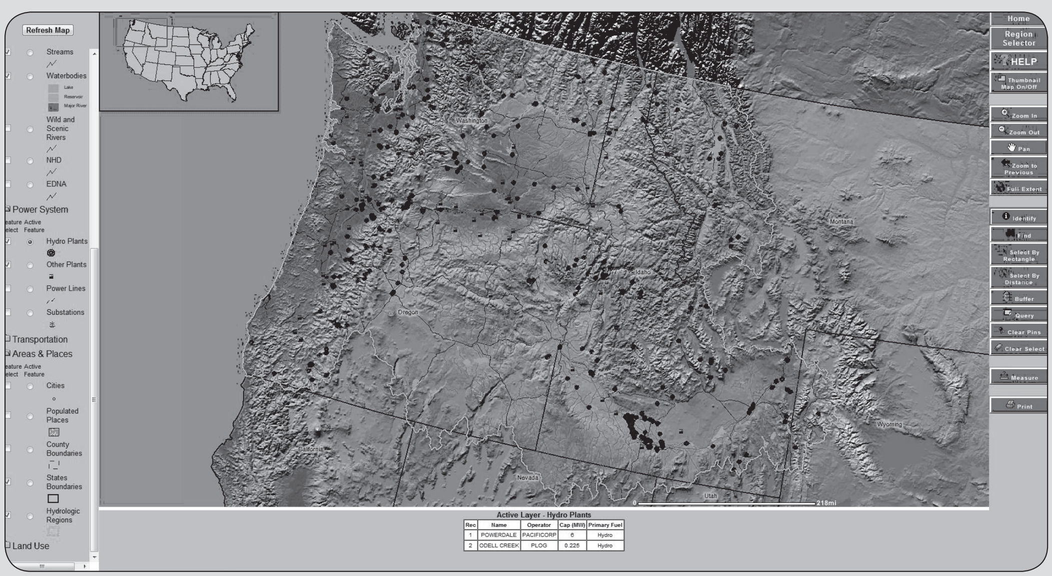
TURBINE ROOM AT SAFE HARBOR



Virtual Hydropower Prospector

Developed by the Idaho National Laboratory, this online geographic information system tool is designed to assist in locating and assessing natural stream water energy resources in the United States. Users can view data regarding hydropower projects across the United States including:

- Water Energy Resource Sites
- Potential Projects
- Hydrography
- Power Systems
- Transportation
- Areas and Places
- Land Use



The Virtual Hydropower Prospector: http://gis-ext.inl.gov/vhp/