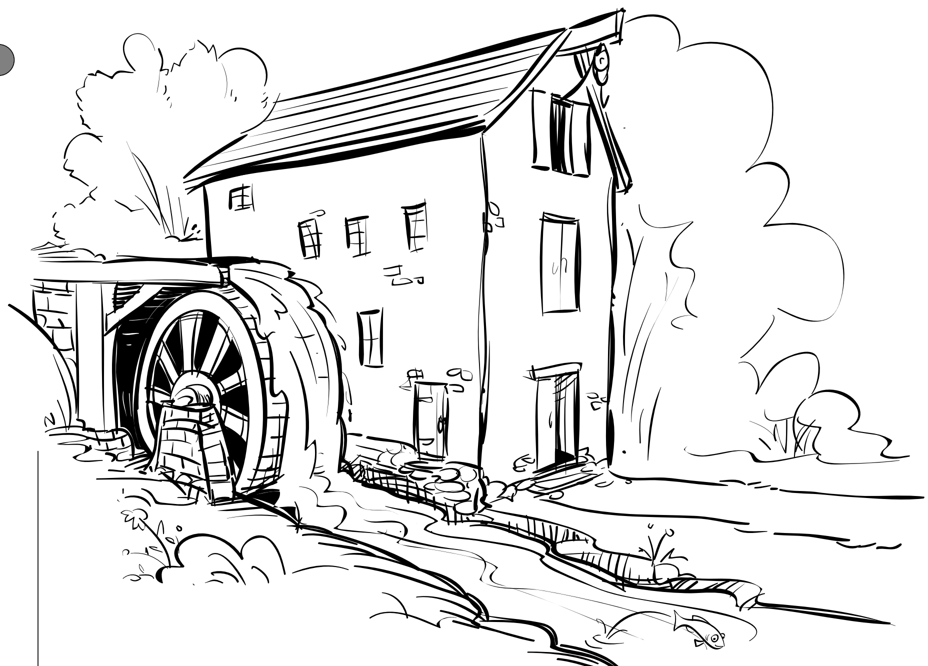
Renewable Energy Source: HYDROPOWER

VOCABULARY

- flow
- head
- horsepower
- impoundment
- penstock
- pumped storage
- run-of-river (diversion)
- tailrace
- water cycle



FLOWING WATER is one of nature's most powerful forces. Humans began harnessing this energy force several thousand years ago. By the first century B.C., waterwheels were working in many parts of the world, including Greece. In fact, the term hydro comes from an ancient Greek word for water. For centuries waterwheels provided the energy to grind grain and saw lumber. By the 1700s, more than 10,000 waterwheels were hard at work in colonial New England alone.

During the Industrial Revolution, waterwheels were also used to run textile mills and other factories. By the mid-1800s water turbines were driving a new device – the generator – to produce electricity. In 1878, the world's first commercial water-driven electrical station opened at Niagara Falls, New York, and the era of hydroelectric power was born.

THE HYDROPOWER RESOURCE

The hydropower resource is the energy in flowing water, provided to us naturally by the earth's water cycle and by gravity. Moving water has a great deal of force. In fact, the force of the flow of a medium-size river is equal to several million horsepower. (One million horsepower, if converted to electricity, would equal the power of 746 MW.) You can imagine how easily this much force can be put to work driving waterwheels or water turbines.

REMINDER

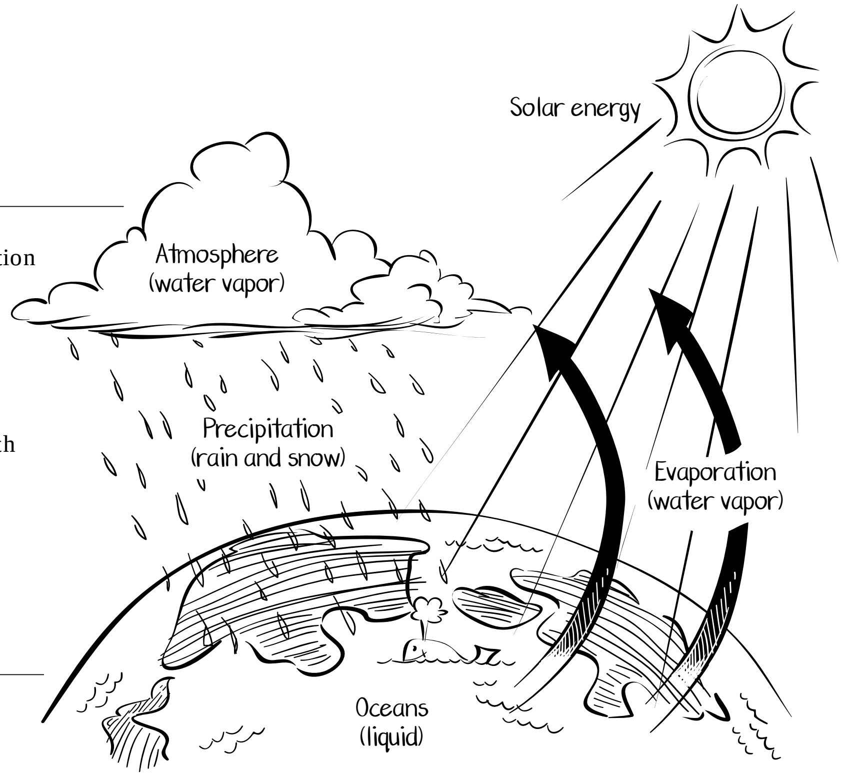
W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt serves about 1,000 homes in the United States.

DISCUSSION

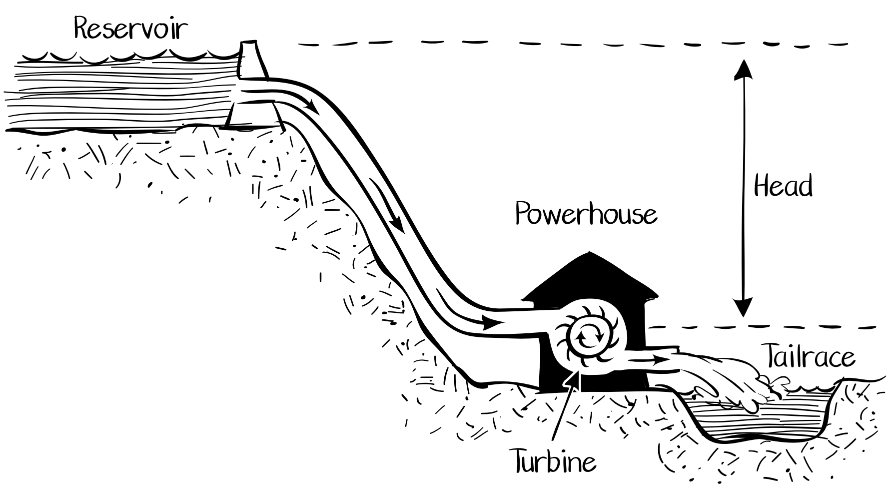
THE WATER CYCLE

Energy from the sun causes evaporation of water from the land and from the oceans, rivers, and lakes. This puts water vapor into the atmosphere where it can condense to form clouds, which then return the water to the earth as rain, snow, and ice. Water runoff is pulled down by gravity to form streams and rivers, which flow to lakes and to the sea. The cycle of evaporation and precipitation is continuous.



The Steeper the Better

The amount of force that water can impart depends on two factors: the head, the vertical distance the water falls; and the flow, the volume (amount or mass) of the water. The greater the head and the flow, the more water energy is available. So hydropower systems work best with a steep drop (high head) and a large flow. One gallon (3.8 liters) of water falling 100 feet (30 meters) per second can generate about 1 kW of electric power. No wonder waterfall areas, with their naturally steep drops, were chosen as the sites for the world’s first hydroelectric power plants.



The steeper the drop, the greater the force of falling water

GENERATING ELECTRICITY FROM HYDROPOWER RESOURCES

All hydropower plants, large or small, use a water turbine and a generator to produce electricity. The water turbine is at the heart of any hydroelectric system. Resembling its cousin, the waterwheel, it is far more streamlined and spins much faster. The first model, the Francis turbine (also called a Pelton wheel), is still in wide use. Its curved paddles are enclosed in a shell into which the water flows. Today's water turbines are designed for maximum efficiency. They come in many shapes and sizes to work with varying conditions of head and flow. Hydropower generators resemble those found in many other types of electric power plants.

Most hydropower systems use some type of water passageway, pipe, or channel, to send the water to a turbine. The passageway not only directs the water where it is needed, but also concentrates the water's force by increasing the volume in a specific area of flow.

Most have a powerhouse enclosing the turbine(s) and/or generator(s) to protect the equipment and to make maintenance possible. Water leaving the turbines is channeled back to the river downstream of the power facility.

HARD-WORKING WATER

The ambitious Big Creek hydropower project in California, begun in the early 1900s, now sends the water of Big Creek through a series of dams, lakes, tunnels, and powerhouses — all built into the steep mountainsides of the Sierra Nevada between Yosemite and Sequoia national parks. Nine powerhouses have been added, which altogether generate over 1,000 MW of electricity, prompting some to call this river system the "hardest working water in the world."

POWER SKETCH: Power in Paradise

Members of a family living in the hilly rainforest many miles from Quito, Ecuador, have always treasured their lush, natural environment. After many years of roughing it, they wanted to enjoy a few conveniences that required electricity. But they lived far from power plants and transmission lines. They solved this dilemma by installing a small hydroelectric system near the waterfall on their property. This "run-of-river" system does not disrupt the flow of the river feeding the waterfall and pool below. It does generate enough electricity to run a small refrigerator and electric lights. It even provides power to run a computer, which is used for their exotic plant-seed business. The forest has almost covered the power-generating equipment with foliage, so they enjoy the convenience of electricity without disturbing the beauty of their little piece of paradise.

Two Common Hydropower Systems

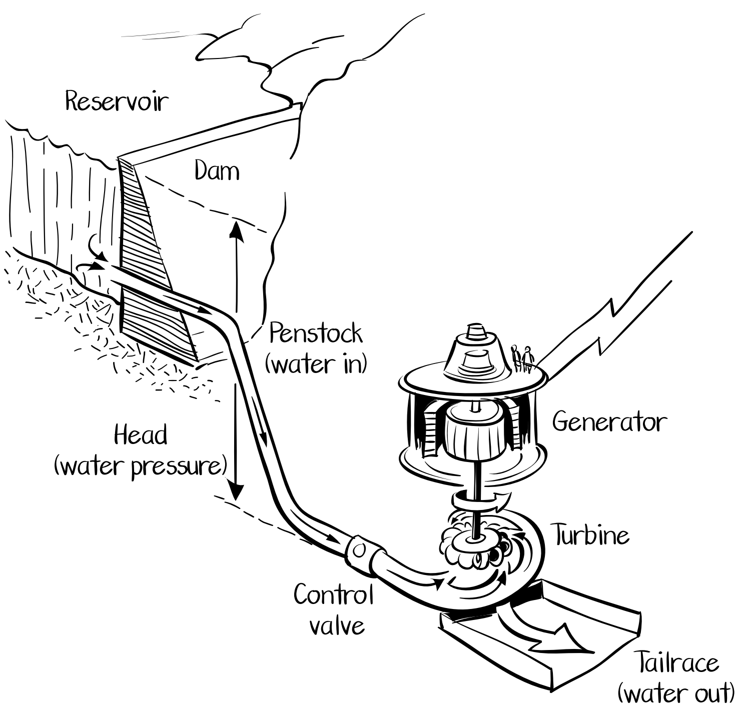
There are basically two ways that hydropower facilities use the force of flowing water.

Storage Hydropower Systems. The hydropower plants we're most used to seeing are called "storage" hydropower plants. These plants use a dam, an impoundment that holds water back to create an artificially steep drop (high head). The dam is placed across a river, causing it to back up into a reservoir or lake. The water is held back until it is needed. When released, it falls down through pipes, or penstocks, to turbines in the powerhouse far below. Once used, the water usually flows through tailraces (pipes or channels) to the downstream river.

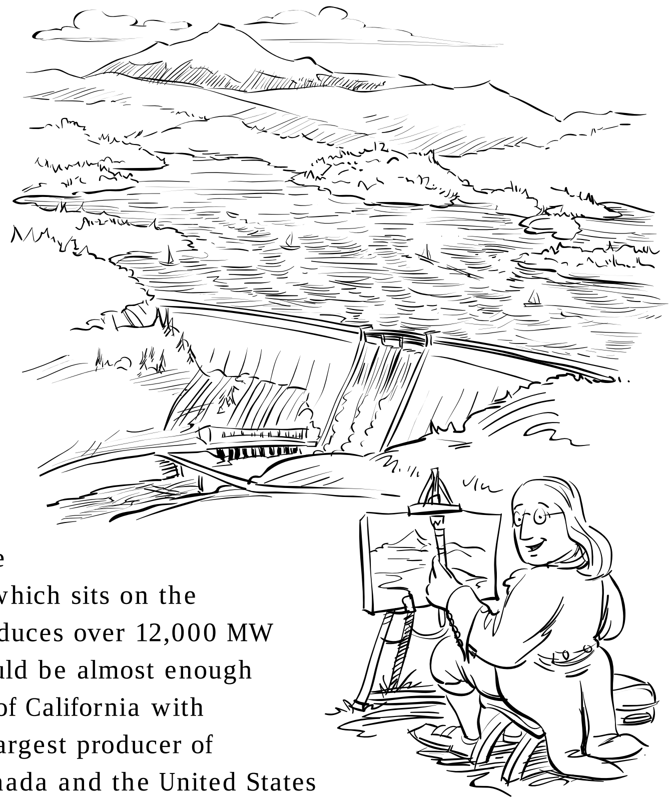
In 1887, California hosted the first hydropower plant in the western states, the High Grove Station in San Bernardino. A number of other pioneering hydro plants were built in California, including Folsom Dam, which began generating electricity from its powerhouse in 1895. After several upgrades, the Folsom Dam is still in operation today. As with a number of other hydropower projects, Shasta Dam was originally planned as an irrigation and flood control project. It began generating electricity in 1944 and is still a significant source of hydropower in California.

STORE NOW, USE LATER

Some dams use a pumped storage system to move water between an upper and a lower reservoir. During times of high demand (great need) for electricity, water is released from the upper reservoir to generate electricity and ends up in the lower reservoir. When electricity is plentiful, and this plant is not needed, the electricity is used to pump the water back to the upper reservoir. An example of this type of system is the Eastwood powerhouse in the Sierras of California.

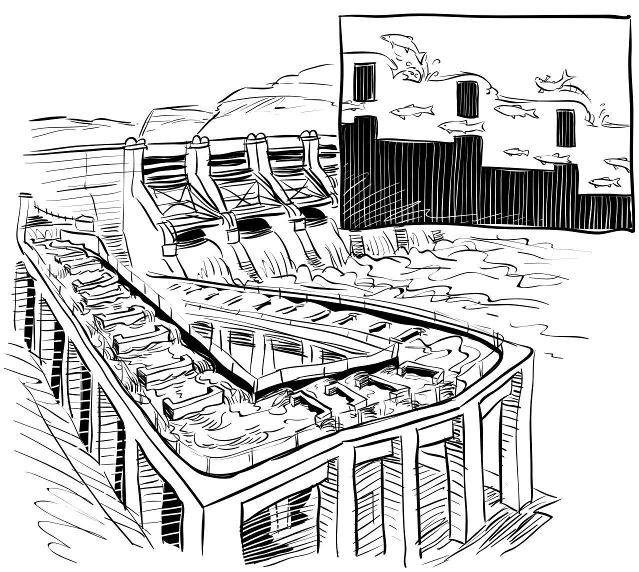


Inside a storage hydroelectric plant



The largest storage hydroelectric facilities in the United States are located along the Columbia River in the Pacific Northwest. These include the Chief Joseph, John Day and Grand Coulee Dams. In fact, the Grand Coulee is the largest dam in the United States and the third largest in the world. It produces over 6,000 MW of power and holds back a lake 150 miles (241 kilometers) long.

The largest hydropower plant in the world is the Itaipú hydropower plant, which sits on the border of Brazil and Paraguay and produces over 12,000 MW of power. (The power it generates would be almost enough to supply about one third of the state of California with electricity!) In fact, Brazil is the third largest producer of hydroelectricity in the world. Only Canada and the United States generate more. China, India, Malaysia, and Vietnam are planning large-scale hydro projects. China has begun a huge hydropower project on the Yangtze River that will control flooding while producing an anticipated 18,200 MW of electricity. Europe, Japan, and Russia are also top hydropower producers.



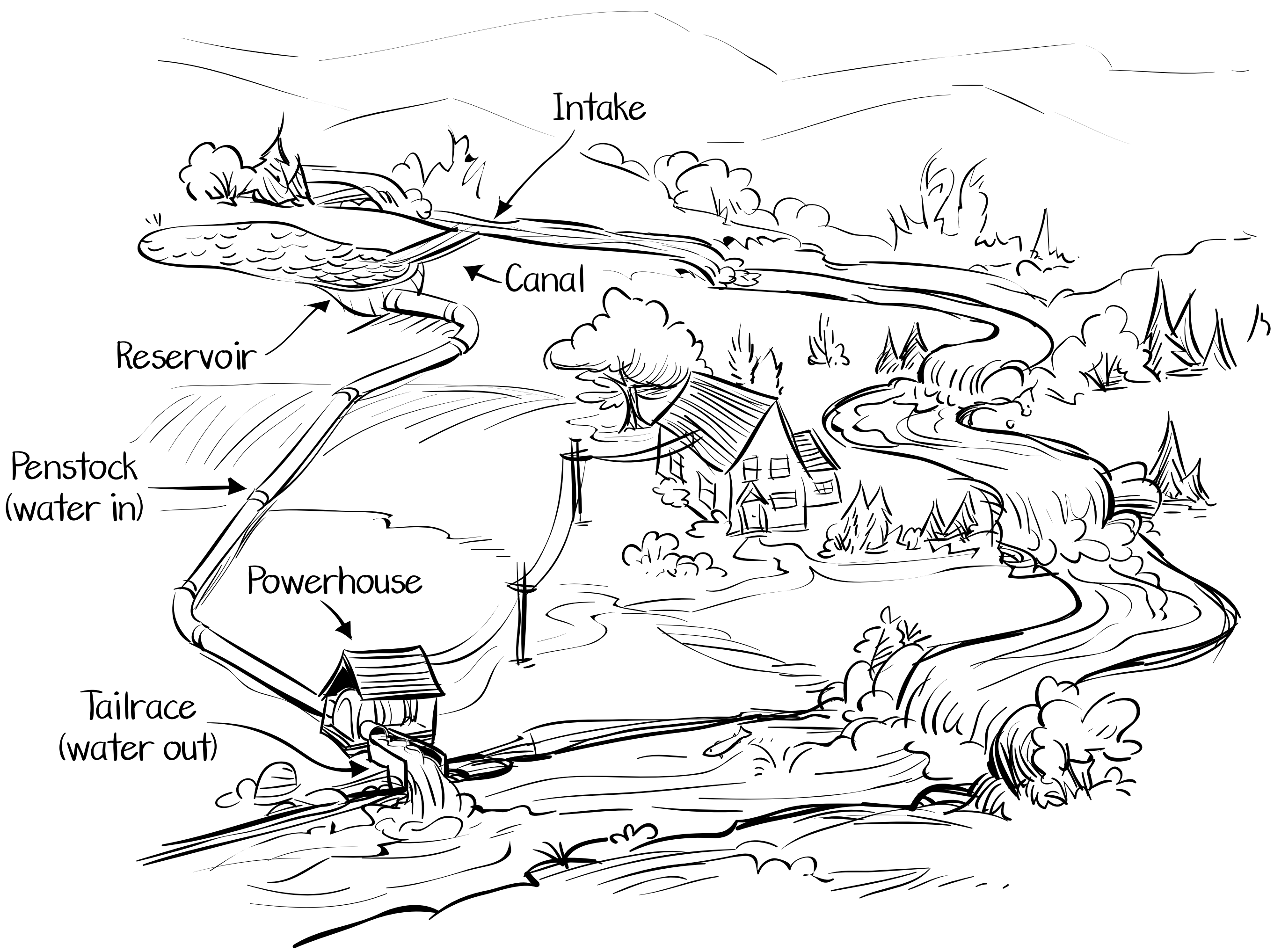
CHUTES AND LADDERS

There are a number of ways to avoid damage to fish caused by large storage hydropower plants. Innovative methods include fish ladders for adult salmon migrating upstream to spawn, flashing lights to alert night-migrating fish, screens to shield turbines, and surface collectors that guide juvenile fish through chutes that go around the project.

Run-of-River (Diversion). Run-of-river systems are today's hydropower systems of choice, because they are designed to maintain the natural flow of a river and are fish-friendly.

With these systems, the river generally continues to run its natural course while some of its water is directed off, or diverted, through a pipe or channel and often is held (usually for a short period of time) until needed. Once the diverted water has done its work, it is sent back to join the river through a tailrace. There are a number of ways this is accomplished.

In one type of facility, a pipe runs down an upriver slope to a downriver powerhouse at a lower elevation. In another system, water is diverted from a river into a small holding bay and then channeled down to a powerhouse as needed.



A diverted run-of-river system

A third method creates a channel through rock that runs alongside a steep drop. Nothing on the surface is disrupted as most of the system is placed underground. The Tazimina Hydroelectric Project near Anchorage, Alaska, was installed in a steep gorge that has turned a tumbling river into a 120-foot (37-meter) waterfall. Some of the upper river's flow is diverted through a vertical pipe installed in the cliff alongside the waterfall. The water rushes down the pipe to turbines in a powerhouse below and then it rejoins the river's main flow.

Run-of-river hydropower is useful in many places. It limits disturbance to the natural setting. Also, it can provide electrical power for people living far from transmission lines.

In the Gold Rush country of California's Calaveras County, there is a small run-of-river power plant called Murphy's Powerhouse, on Angels Creek. The name of the powerhouse refers back to Murphy's Camp, where water was originally diverted to assist the miners who were washing gravel to look for gold.

Sometimes storage and run-of-river systems are combined. For example, at Bishop Creek Hydropower Project in California's Eastern Sierra Nevada, spring runoff from melting snow is collected in two reservoirs, built to prevent flooding of the Bishop Creek area below. Throughout the year, a moderate amount of water is released into Bishop Creek, where it eventually spills through four run-of-river powerhouses. These were originally built to provide electrical power for gold and silver mining in the early 1900s and still provide plenty of electricity today.

There are a number of run-of-river projects in the United States. Many are hailed for preserving a river's flow while providing electrical power. One project is located just off the Mississippi River near Vidalia, Louisiana. It maintains the flow of the "Mighty Mississippi" (a main artery for transportation), helps control flooding, and supplies electricity. A project on the Quinebaug River in Connecticut has recently been awarded a coveted "low impact" certification for producing hydropower without disturbing the local environment. Several other facilities have also received this award, including one at Falls Creek, in the Willamette National Forest of Oregon.

Worldwide, there is great interest in run-of-river projects for both remote areas and for grid-connected localities. For example, mountainous Nepal, criss-crossed with over 6,000 rivers, is interested in using these systems to provide rural villages with electricity. China has plans to provide up to 75 million people with diversion projects. Many hilly areas in Europe are already dotted with run-of-river hydro systems.

Project Size

Today's hydropower systems range from those that provide energy for one home to mammoth, multi-megawatt installations. In California, a large-scale hydropower facility is considered any project that generates more than 30 MW of electricity. Most large-scale hydropower installations use a storage system, which creates the greatest environmental concerns (See Considerations).

Small-scale hydropower projects are often divided into small-scale hydro and micro-hydro. Small-scale projects range from 100 kW to 30 MW, while micro-hydro projects usually produce 100 kW or less. Small-scale projects can be run-of-river or storage-type facilities. Most, but not all, small-scale hydropower systems are run-of-river, considered easier on the environment.

Most experts say that our hydropower facilities in the future will be small-scale and/or run-of-river facilities. Many potential locations exist for these types of power producers. Also, some older small-scale hydro projects that were shut down in the 1960s and '70s have recently been reopened. For example, a small hydro facility operated by Cornell University at Fall Creek in Ithaca, New York, was recently reopened after a 30-year shut-down. It is once again supplying 2-4 MW of power to the university, a small but eloquent testimonial to the value of using a local, renewable energy resource.

CONSIDERATIONS

- Hydropower produces no air pollution. It is very efficient, reliable, and — once installed — inexpensive. Hydropower systems can provide both baseload and peaking power. Run-of-river systems, especially, can be turned on and off very quickly.
- The main drawback of run-of-river systems is that the flow in the rivers and streams fluctuates by season, and in low rainfall or drought years, less electricity can be produced. Low rainfall can also lower electricity output of storage systems.
- Run-of-river hydropower systems are considered by many to be the preferred hydropower technology because they are easy on the environment. Run-of-river projects could contribute a significant amount of electricity worldwide.
- Large-scale storage hydropower projects are expensive to build, but can provide many megawatts of electricity to an area.
- The installation of a dam across a river for a large-scale storage project can cause the river water to back up over hundreds of acres, swallowing up towns and fertile land. There are also impacts to water quality, fish, and wildlife. The flooding can also ruin important cultural, religious, and archeological sites. Flooding an area can displace hundreds or even thousands of people. For example, the large Yangtze project in China will create a lake 400 miles (644 kilometers) long and will require the relocation of 1.2 million people.
- Currently, a number of large projects around the world have been canceled or placed on hold due to public concern about the environmental impacts of the dams. In recent years, some consideration has been given to removing dams in highly sensitive areas. For example, some smaller, older dams in sensitive areas of the U.S. Pacific Northwest have already been removed.

DATA FILE: Hydropower

California

- California has over 380 hydroelectric facilities that can produce more than 14,000 MW of electricity.
- About 19 percent of California's electricity comes from hydropower.

United States

- The United States gets between 7 and 12 percent of its electricity from hydropower.
- Washington, Oregon, California, and New York are the states producing the largest amount of hydroelectricity.

Worldwide

- One-fifth of all the world's electricity is generated by hydropower.
- Twenty-four countries get about 90 percent of their electricity from waterpower, including Norway, Brazil, Paraguay, Ethiopia, Ghana, and Zambia.

Data available in 2003