

# How Hydropower Plants Work

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## Inside this Article

1. [Introduction to How Hydropower Plants Work](#)
2. [The Power of Water](#)
3. [Pumped-Storage Plants](#)
4. [Hydrologic Cycle](#)
5. [Hydroelectric Footwear](#)
6. [Lots More Information](#)
7. [See more »](#)

[See all Energy Production articles](#)

Worldwide, hydropower plants produce about 24 percent of the world's electricity and supply more than 1 billion people with power. The world's hydropower plants output a combined total of **675,000 megawatts**, the energy equivalent of 3.6 billion barrels of [oil](#), according to the [National Renewable Energy Laboratory](#). There are more than 2,000 hydropower plants operating in the United States, making hydropower the country's largest renewable energy source.

In this article, we'll take a look at how falling water creates energy and learn about the hydrologic cycle that creates the water flow essential for hydropower. You will also get a glimpse at one unique application of hydropower that may affect your daily life.

[Hydropower Plant Image Gallery](#)



Photo courtesy U.S. Bureau of Reclamation

**Outflow during a test at the hydropower plant at the Hoover Dam, located on the Nevada-Arizona border. See more [hydropower plant pictures](#).**

## The Power of Water

### Simple Beginnings

Use of hydropower peaked in the mid-20th century, but the idea of using water for power generation goes back thousands of years. A hydropower plant is basically an oversized **water wheel**.

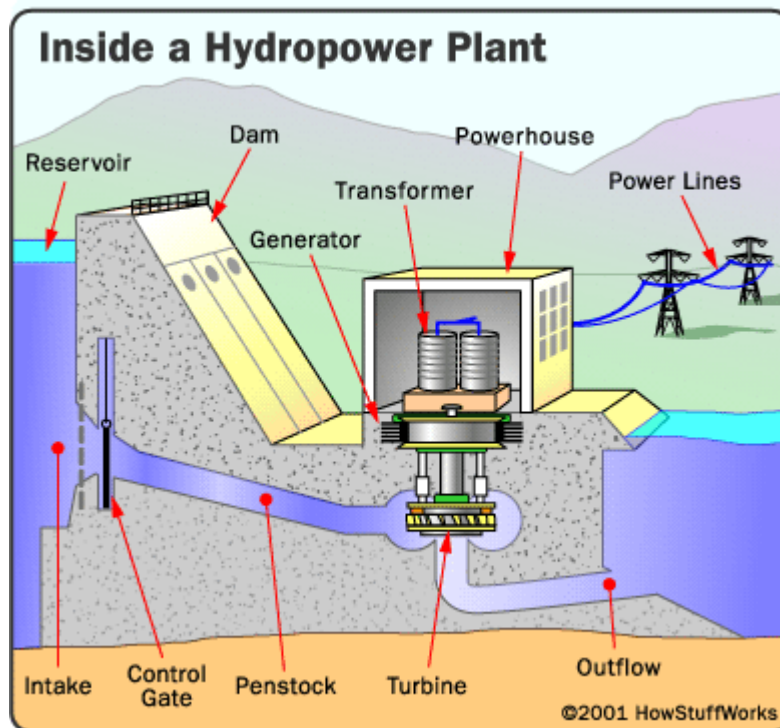
More than 2,000 years ago, the Greeks are said to have used a water wheel for grinding wheat into flour. These ancient water wheels are like the turbines of today,

When watching a river roll by, it's hard to imagine the force it's carrying. If you have ever been white-water rafting, then you've felt a small part of the river's power. White-water rapids are created as a river, carrying a large amount of water downhill, bottlenecks through a narrow passageway. As the river is forced through this opening, its flow quickens. **Floods** are another example of how much force a tremendous volume of water can have.

Hydropower plants harness water's energy and use simple mechanics to convert that energy into electricity. **Hydropower plants** are actually based on a rather simple concept -- water flowing through a dam turns a turbine, which turns a generator.

Here are the basic components of a conventional hydropower plant:

spinning as a stream of water hits the blades. The **gears** of the wheel ground the wheat into flour.



**Dam** - Most hydropower plants rely on a dam that holds back water, creating a large **reservoir**. Often, this reservoir is used as a recreational lake, such as Lake Roosevelt at the [Grand Coulee Dam](#) in Washington State.

**Intake** - Gates on the dam open and **gravity** pulls the water through the **penstock**, a pipeline that leads to the turbine. Water builds up pressure as it flows through this pipe.

**Turbine** - The water strikes and turns the large blades of a turbine, which is attached to a generator above it by way of a shaft. The most common type of turbine for hydropower plants is the Francis Turbine, which looks like a big disc with curved blades. A turbine can weigh as much as 172 tons and turn at a rate of 90 revolutions per minute (rpm), according to the [Foundation for Water & Energy Education](#) (FWEE).

**Generators** - As the turbine blades turn, so do a series of magnets inside the generator. Giant magnets rotate past copper coils, producing **alternating current** (AC) by moving electrons. (You'll learn more about how the generator works later.)

**Transformer** - The transformer inside the **powerhouse** takes the AC and converts it to higher-voltage current.

**Power lines** - Out of every power plant come four wires: the three phases of power being produced simultaneously plus a neutral or ground common to all three. (Read [How Power Distribution Grids Work](#) to learn more about power line transmission.)

**Outflow** - Used water is carried through pipelines, called **tailraces**, and re-enters the river downstream.



Photo courtesy U.S. Bureau of Reclamation

### **The shaft that connects the turbine and generator**

The water in the reservoir is considered **stored energy**. When the gates open, the water flowing through the penstock becomes **kinetic energy** because it's in motion. The amount of electricity that is generated is determined by several factors. Two of those factors are the volume of **water flow** and the amount of **hydraulic head**. The head refers to the distance between the water surface and the turbines. As the head and flow increase, so does the electricity generated. The head is usually dependent upon the amount of water in the reservoir.

## **Pumped-Storage Plants**

There's another type of hydropower plant, called the **pumped-storage plant**. In a conventional hydropower plant, the water from the reservoir flows through the plant, exits and is carried down stream. A pumped-storage plant has two reservoirs:

**Upper reservoir** - Like a conventional hydropower plant, a dam creates a reservoir. The water in this reservoir flows through the hydropower plant to create electricity.

**Lower reservoir** - Water exiting the hydropower plant flows into a lower reservoir rather than re-entering the river and flowing downstream.

Using a **reversible turbine**, the plant can pump water back to the upper reservoir. This is done in off-peak hours. Essentially, the second reservoir refills the upper reservoir. By pumping water back to the upper reservoir, the plant has more water to generate electricity during periods of peak consumption.

### **The Generator**

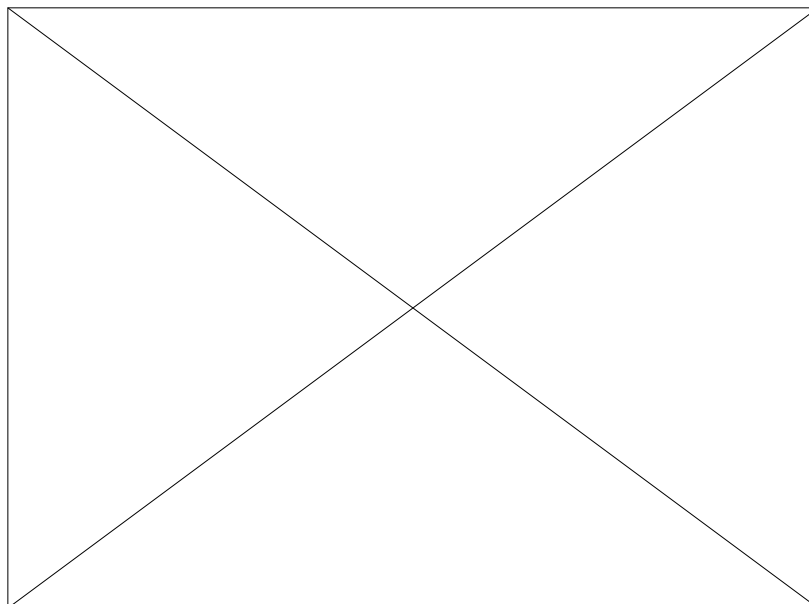
The heart of the hydroelectric power plant is the generator. Most hydropower plants have several of these generators.



Photo courtesy U.S. Bureau of Reclamation

**The giant generators at Hoover Dam produce more than 2,000 megawatts.**

The generator, as you might have guessed, generates the electricity. The basic process of generating electricity in this manner is to rotate a series of magnets inside coils of wire. This process moves electrons, which produces electrical current.



**Inside a hydropower plant generator**



The Hoover Dam has a total of 17 generators, each of which can generate up to 133 megawatts. The total capacity of the Hoover Dam hydropower plant is 2,074 megawatts. Each generator is made of certain basic parts:

**Shaft**  
**Excitor**  
**Rotor**  
**Stator**

As the turbine turns, the **excitor** sends an electrical current to the rotor. The **rotor** is a series of large **electromagnets** that spins inside a tightly-wound coil of copper wire, called the **stator**. The magnetic field between the coil and the magnets creates an electric current.

In the Hoover Dam, a current of 16,500 amps moves from the generator to the transformer, where the current ramps up to 230,000 amps before being transmitted.

## Hydrologic Cycle

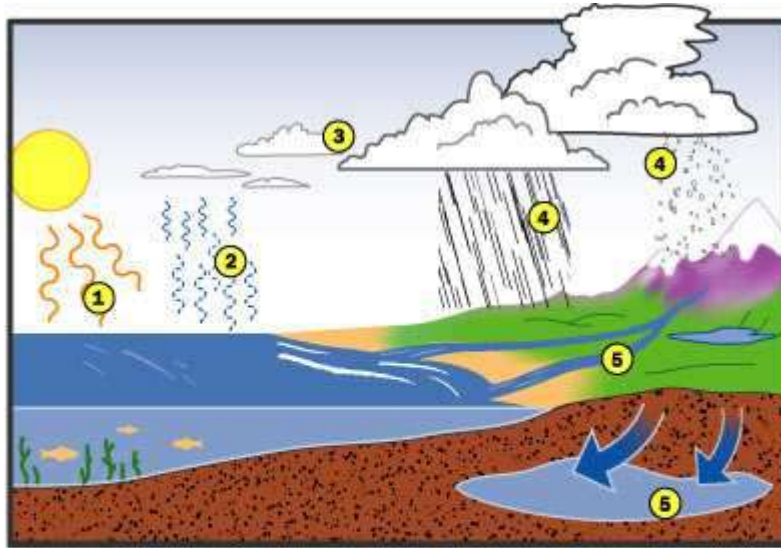
Hydropower plants take advantage of a naturally occurring, continuous process -- the process that causes rain to fall and rivers to rise. Every day, our planet loses a small amount of water through the atmosphere as ultraviolet rays break water molecules apart. But at the same time, new water is emitted from the inner part of the Earth through **volcanic activity**. The amount of water created and the amount of water lost is about the same.

At any one time, the world's total volume of water is in many different forms. It can be liquid, as in oceans, rivers and rain; solid, as in glaciers; or gaseous, as in the invisible water vapor in the air. Water changes states as it is moved around the planet by wind currents. Wind currents are generated by the heating activity of the **sun**. Air-current cycles are created by the sun shining more on the equator than on other areas of the planet.

Air-current cycles drive the Earth's water supply through a cycle of its own, called the **hydrologic cycle**. As the sun heats liquid water, the water **evaporates** into vapor in the air. The sun heats the air, causing the air to rise in the atmosphere. The air is colder higher up, so as the water vapor rises, it cools, **condensing** into droplets. When enough droplets accumulate in one area, the droplets may become heavy enough to fall back to Earth as **precipitation**.

### Did You Know?

- The largest hydroelectric power plant in the world is the **Itaipu power plant**, jointly owned by Brazil and Paraguay. Itaipu can produce 12,600 megawatts.
  - The second largest hydroelectric power plant is the **Guri power plant**, located on Caroni River in Venezuela. It can produce 10,300 megawatts.
  - The largest U.S. hydroelectric power plant is the **Grand Coulee power station** on the Columbia River in Washington State. It can produce 7,600 megawatts and is currently being upgraded to produce 10,080 megawatts. (NREL)
- Sources: U.S. Bureau of Reclamation and the National Renewable Energy Laboratory



- ① The sun heats the ocean.
- ② Ocean water evaporates and rises into the air.
- ③ The water vapor cools and condenses to become droplets, which form clouds.
- ④ If enough water condenses, the drops become heavy enough to fall to the ground as rain and snow.
- ⑤ Some rain collects in groundwells. The rest flows through rivers back into the ocean.

### The hydrologic cycle

The hydrologic cycle is important to hydropower plants because they depend on water flow. If there is a lack of rain near the plant, water won't collect upstream. With no water collecting up stream, less water flows through the hydropower plant and less electricity is generated.

## Hydroelectric Footwear

The basic idea of hydropower is to use the power of a moving liquid to turn a turbine blade. Typically, a large dam has to be built in the middle of a river to perform this function. A new invention is capitalizing on the idea of hydropower on a much smaller scale to provide electricity for portable electronic devices. Inventor **Robert Komarechka** of Ontario, Canada, has come up with the idea of placing small hydropower generators into the soles of shoes. He believes these micro-turbines will generate enough electricity to power almost any gadget. In May 2001, Komarechka received a patent for his unique foot-powered device.

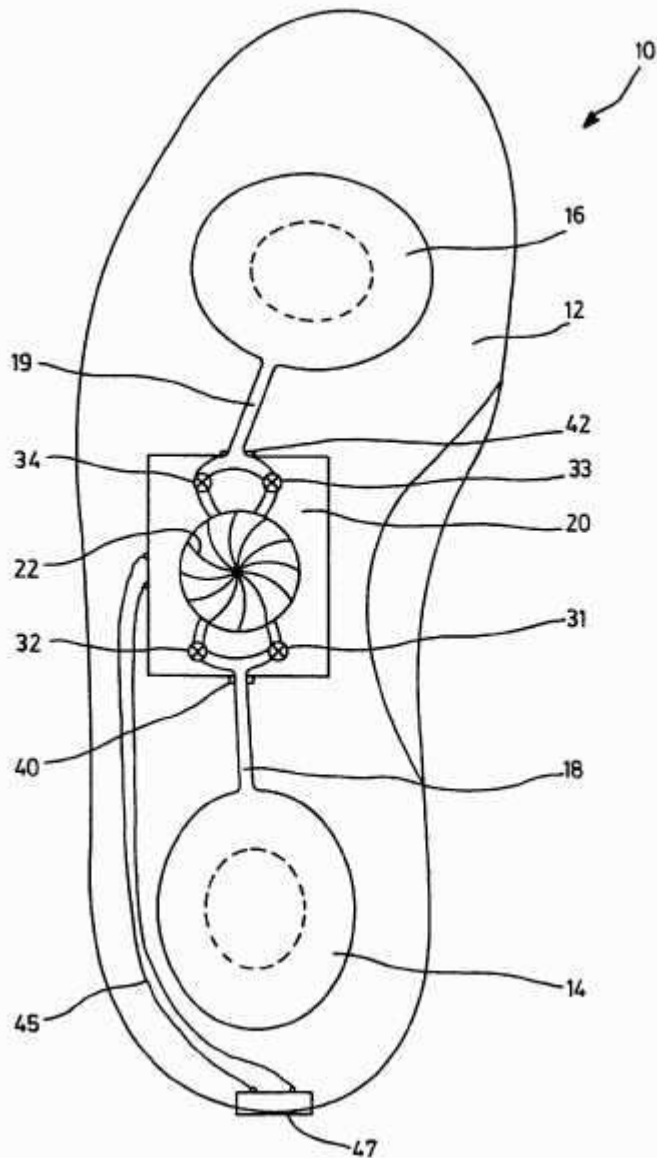


Photo courtesy U.S. Patent and Trademark Office

**Image from patent No. 6,239,501:**

### **Footwear with hydroelectric generator assembly**

There's a very basic principle to how we walk: The foot falls heel-to-toe during each step. As your foot lands on the ground, force is brought down through your heel. When you prepare for your next step, you roll your foot forward, so the force is transferred to the ball of your foot. Komarechka apparently noticed this basic principle of walking and has developed an idea to harness the power of this everyday activity.

There are five parts to Komarechka's "footwear with hydroelectric generator assembly," as described in [its patent](#):

**Fluid** - The system will use an electrically conductive fluid.

**Sacs to hold the fluid** - One sac is placed in the heel and another in the toe section of the shoe.

**Conduits** - Conduits connect each sac to a microgenerator.

**Turbine** - As water moves back and forth in the sole, it moves the blades of a tiny turbine.

**Microgenerator** - The generator is located between the two fluid-filled sacs, and includes a **vane rotor**, which drives a shaft and turns the generator.

As a person walks, the compression of the fluid in the sac located in the shoe's heel will force fluid through the conduit and into the hydroelectric generator module. As the user continues to walk, the heel will be lifted



and downward pressure will be exerted on the sac under the ball of the person's foot. The movement of the fluid will rotate the rotor and shaft to produce electricity.

An exterior socket will be provided to connect wires to a portable device. A power-control output unit may also be provided to be worn on the user's belt. Electronic devices can then be attached to this power-control output unit, which will provide an steady supply of electricity.

"With the increase in the number of battery-powered, portable devices," the patent reads, "there is an increasing need to provide a long-lasting, adaptable, efficient electrical source." Komarechka expects that his device will be used for powering [portable computers](#), [cell phones](#), [CD players](#), [GPS receivers](#) and two-way [radios](#).

For more information on hydropower plants and related topics, check out the links on the next page.