Geothermal

Geothermal at a Glance, 2010

Classification:
- renewable

Major Uses:
- heating, electricity

U.S. Energy Consumption:
- 0.21 Q
- 0.2%

U.S. Energy Production:
- 0.21 Q
- 0.3%

What is Geothermal Energy?

Geothermal energy comes from the heat within the Earth. The word geothermal comes from the Greek words *geo*, meaning *earth*, and *therme*, meaning *heat*. People around the world use geothermal energy to produce electricity, to heat homes and buildings, and to provide hot water for a variety of uses.

The Earth's **core** lies almost 4,000 miles beneath the Earth's surface. The double-layered core is made up of very hot molten iron surrounding a solid iron center. Estimates of the temperature of the core range from 5,000 to 11,000 degrees Fahrenheit (°F).

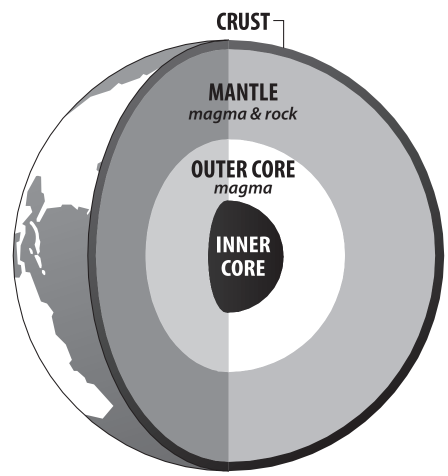
Surrounding the Earth's core is the **mantle**, thought to be partly rock and partly **magma**. The mantle is about 1,800 miles thick. The outermost layer of the Earth, the insulating **crust**, is not one continuous sheet of rock, like the shell of an egg, but is broken into pieces called plates.

These slabs of continents and ocean floor drift apart and push against each other at the rate of about one inch per year in a process called plate tectonics. This process can cause the crust to become faulted (cracked), fractured, or thinned, allowing plumes of magma to rise up into the crust.

This magma can reach the surface and form volcanoes, but most remains underground where it can underlie regions as large as huge mountain ranges. The magma can take from 1,000 to 1,000,000 years to cool as its heat is transferred to surrounding rocks. In areas where there is underground water, the magma can fill rock fractures and porous rocks. The water becomes heated and can circulate back to the surface to create hot springs, mud pots, and fumaroles, or it can become trapped underground, forming deep geothermal reservoirs.

Geothermal energy is called a **renewable** energy source because the water is replenished by rainfall, and the heat is continuously produced within the Earth by the slow decay of radioactive particles that occurs naturally in all rocks.

The Earth's Interior



History and Uses of Geothermal Energy

Many ancient peoples, including the Romans, Chinese, and Native Americans, used hot mineral springs for bathing, cooking, and heating. Water from hot springs is now used worldwide in spas, for heating buildings, and for agricultural and industrial uses. Many people believe hot mineral springs have natural healing powers.

Today, we drill wells into geothermal reservoirs deep underground and use the steam and heat to drive turbines in electric power plants. The hot water is also used directly to heat buildings, to increase the growth rate of fish in hatcheries and crops in greenhouses, to pasteurize milk, to dry foods products and lumber, and for mineral baths.

Where is Geothermal Energy Found?

Geologists use many methods to find geothermal reservoirs. They study aerial photographs and geological maps. They analyze the chemistry of local water sources and the concentration of metals in the soil. They may measure variations in gravity and magnetic fields. Yet the only way they can be sure there is a geothermal reservoir is by drilling an exploratory well.

The hottest geothermal regions are found along major plate boundaries where earthquakes and volcanoes are concentrated. Most of the world's geothermal activity occurs in an area known as the **Ring of Fire**, which rims the Pacific Ocean and is bounded by Indonesia, the Philippines, Japan, the Aleutian Islands, North America, Central America, and South America.

High Temperature: Producing Electricity

When geothermal reservoirs are located near the surface, we can reach them by drilling wells. Some wells are more than two miles deep. **Exploratory wells** are drilled to search for reservoirs. Once a reservoir has been found, production wells are drilled. Hot water and steam—at temperatures of 250ºF to 700ºF—are brought to the surface and used to generate electricity at power plants near the production wells. There are several different types of geothermal power plants:

▪ Flash Steam Plants

Most geothermal power plants are **flash steam plants**. Hot water from production wells flashes (explosively boils) into steam when it is released from the underground pressure of the reservoir. The force of the steam is used to spin the turbine generator. To conserve water and maintain the pressure in the reservoir, the steam is condensed into water and injected back into the reservoir to be reheated.

▪ Dry Steam Plants

A few geothermal reservoirs produce mostly steam and very little water. In dry steam plants, the steam from the reservoir shoots directly through a **rock-catcher** into the turbine generator. The rock-catcher protects the turbine from small rocks that may be carried along with the steam from the reservoir.

The first geothermal power plant was a dry steam plant built at Larderello in Tuscany, Italy, in 1904. The original buildings were destroyed during World War II, but they have since been rebuilt and expanded. The Larderello field is still producing electricity today.

The Geysers dry steam reservoir in northern California has been producing electricity since 1960. It is the largest known dry steam field in the world and, after 50 years, still produces enough electricity to supply a city the size of San Francisco.

▪ Binary Cycle Power Plants

Binary cycle power plants transfer the heat from geothermal hot water to other liquids to produce electricity. The geothermal water is passed through a **heat exchanger** in a closed pipe system, and then reinjected into the reservoir. The heat exchanger transfers the heat to a working fluid—usually isobutane or isopentane—which boils at a lower temperature than water. The vapor from the working fluid is used to turn the turbines.

Binary systems can, therefore, generate electricity from reservoirs with lower temperatures. Since the system is closed, there is little heat loss and almost no water loss, and virtually no emissions.

▪ Hybrid Power Plants

In some power plants, flash and binary systems are combined to make use of both the steam and the hot water. The Puna Geothermal Venture Facility produces 30 megawatts of power, or 20 percent of the electricity needed by the big island of Hawaii.

Low Temperature: Direct Use or Heating

Only in the last century have we used geothermal energy to produce electricity, but people have used it to make their lives more comfortable since the dawn of humankind.

▪ Hot Spring Bathing and Spas

For centuries, people have used hot springs for cooking and bathing. The early Romans used geothermal water to treat eye and skin diseases and, at Pompeii, to heat buildings. Medieval wars were even fought over lands for their hot springs.

Today, many hot springs are still used for bathing. And around the world, millions of people visit health spas to soak in the mineral-rich water.

▪ Agriculture and Aquaculture

Water from geothermal reservoirs is used in many places to warm greenhouses that grow flowers, vegetables, and other crops. Natural warm water can also speed the growth of fish, shellfish, reptiles, and amphibians. In Japan, aqua-farms grow eels and alligators. In the U.S., aqua-farmers grow tropical fish for pet shops. Iceland hopes to raise two million abalone, a shellfish delicacy, each year through aquaculture.

▪ Industry

The heat from geothermal water is used worldwide for dying cloth, drying fruits and vegetables, washing wool, manufacturing paper, pasteurizing milk, and drying timber products. It is also used to help extract gold and silver from ore. In Klamath Falls, OR, hot water is piped under sidewalks and bridges to keep them from freezing in winter.

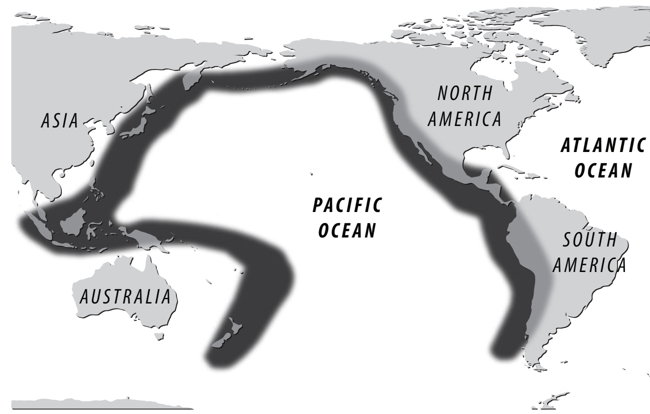
▪ Heating

The most widespread use of geothermal resources—after bathing—is to heat buildings. In the Paris basin in France, geothermal water from shallow wells was used to heat homes 600 years ago. More than 150,000 homes in France use geothermal heat today.

Geothermal **district systems** pump hot water from a reservoir through a heat exchanger that transfers the heat to separate water pipes that go to many buildings. The geothermal water is then reinjected into the reservoir to be reheated.

The first district heating system in the U.S. was built in 1893 in Boise, ID, where it is still in use. There are many other systems in use in the country today. Because it is clean and economical, district heating is becoming increasingly popular. In Iceland, almost 90 percent of residents use geothermal energy for heat and hot water. In Reykjavik, Iceland, a district heating system provides heat for 95 percent of the buildings.

Ring of Fire



Geothermal

Geoexchange Systems: Heating and Cooling

Once you go about twenty feet below the Earth's surface, the temperature is remarkably constant year round. In temperate regions, the temperature stays about 52 degrees Fahrenheit. In tropical regions, it can range as high as 65 to 70 degrees Fahrenheit, while certain arctic regions stay near freezing all year.

For most areas, this means that soil temperatures are usually warmer than the air in winter and cooler than the air in summer. Geothermal exchange systems use the Earth's constant temperatures to heat and cool buildings. These heat pumps transfer heat from the ground into buildings in winter and reverse the process in the summer.

A geothermal exchange system doesn't look like a traditional furnace or air conditioner. For one thing, most of the equipment is underground. A liquid—usually a mixture of water and antifreeze—circulates through a long loop of plastic pipe buried in the ground. This liquid absorbs heat and carries it either into or out of the building.

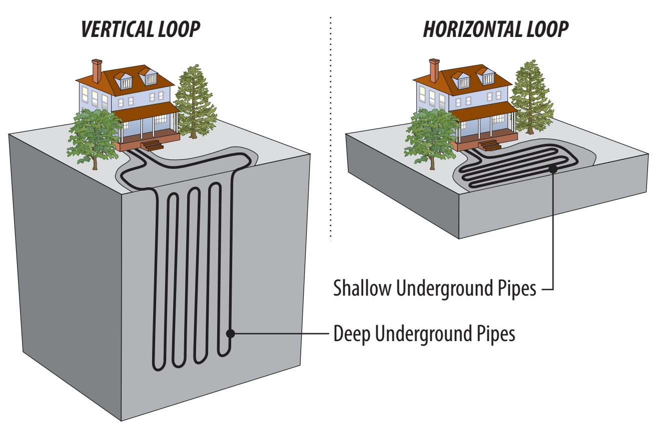
One advantage of a geothermal exchange system is that it doesn't have to manufacture heat. The heat is free, renewable, and readily available in the ground. The only energy this system needs is the electricity to pump the liquid through the pipes and deliver the conditioned air to the building. The pump itself is usually a small unit located inside the building.

The geothermal exchange pipes can be buried in several ways. If space is limited, holes for the pipe can be dug straight into the ground as far down as 300 feet. In very rocky areas, this method might not be an option.

If there is land available, the pipes can be buried horizontally in shallow trenches four to six feet underground, where the ground remains at approximately the same temperature all of the year. Once the pipes are in place, the surface can be used as a front lawn, football field, or parking lot. The pipes are very durable and should last up to 50 years without maintenance.

If a large lake or pond is nearby, the pipes can be buried in the water. The water must be at least six feet deep, though, or the temperature of the water will change too much. Deep, flowing water provides especially good heat exchange for a geothermal system.

Residential Geoexchange Units



Geothermal systems cost more to install than conventional heating and cooling systems. Over the life of the system, however, they can produce significant cost savings. They can reduce heating costs by 30–70 percent, and cooling costs by 20 to 50 percent. If the cost of the installation is spread out over several years, users see savings from the day they begin using the system. In addition, there is a Federal Tax Credit incentive of up to 30 percent of the cost for homeowners that install qualified ENERGY STAR geothermal heat pumps by the end of 2016.

Geothermal systems are low maintenance and should last twice as long as conventional systems. The pumps should last 20 years, since they are located inside, away from the weather. And most of the energy they use is free. Electricity is used only to move the heat, not to produce it.

Today, more than a million homes and buildings in the United States use geothermal heat exchange systems. They are an efficient, economical alternative to conventional heating and cooling systems. The U.S. Environmental Protection Agency has rated geothermal heat pump systems among the most efficient heating and cooling technologies.

Geothermal Production

Geothermal energy is put to work in many places around the world. The best-known geothermal energy sources in the United States are located in western states and Hawaii.

Geothermal power plants operate in California, Nevada, Utah, Hawaii, and Idaho. Today, the total installed capacity of geothermal power plants in the United States is around 3,000 megawatts (MW). There are currently 123 projects in development in 12 states that could add over 1,600 MW to geothermal's capacity.

In 2010, geothermal energy produced about 15.7 billion kilowatt-hours (kWh) of electricity, or 0.38 percent of the electricity used in this country. This is enough to serve the electricity needs of over three million households. California gets more electricity from geothermal energy than any other state.

Geothermal Economics

Geothermal power plants can produce electricity as cheaply as many conventional power plants. Operating and maintenance costs from one to three cents per kWh at a geothermal power plant, while the electric power generated sells for three to five cents per kWh. In comparison, new coal-fired and natural gas plants produce electricity at about four cents per kWh.

Initial construction costs for geothermal power plants are high because geothermal wells and power plants must be constructed at the same time. But the cost of producing electricity over time is lower because the price and availability of the fuel is stable and predictable. The fuel does not have to be imported or transported to the power plant. The power plant literally sits on top of its fuel source.

Geothermal power plants are excellent sources of **base load power**. Base load power is power that electric utility companies must deliver all day long. Base load geothermal plants can sell electricity any hour, day or night.

Geothermal Energy and the Environment

Geothermal energy is a renewable energy source that does little damage to the environment. Geothermal steam and hot water do contain naturally occurring traces of hydrogen sulfide (a gas that smells like rotten eggs) and other gases and chemicals that can be harmful in high concentrations.

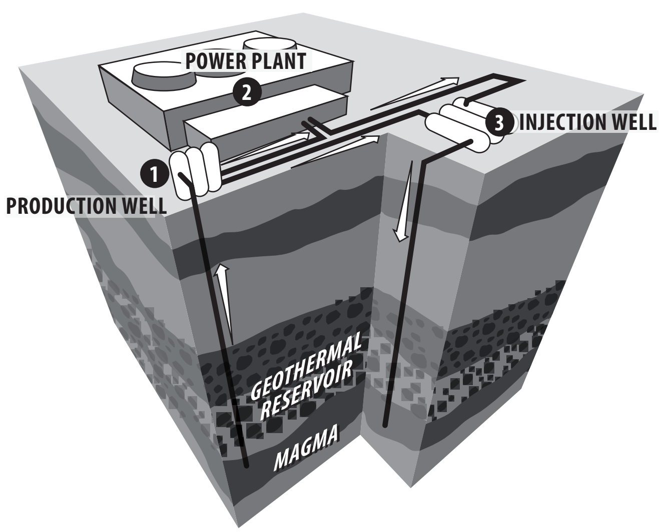
Geothermal power plants use **scrubber systems** to clean the air of hydrogen sulfide and the other gases. Sometimes the gases are converted into marketable products, such as liquid fertilizer.

Geothermal power plants do not burn fuel to generate electricity, so their emission levels are very low. They release less than one percent of the carbon dioxide emitted by comparable fossil fuel plants.

Emissions of sulfur compounds from vehicles and fossil fuel plants also contribute to acid rain. Geothermal power plants, on the other hand, emit only one to three percent of the sulfur compounds that coal and oil-fired power plants do. Well-designed **binary cycle power plants** have no emissions at all.

Geothermal power plants are compatible with many environments. They have been built in deserts, in the middle of crops, and in mountain forests. Development is often allowed on federal lands because it does not significantly harm the environment. Geothermal features in national parks, such as geysers and fumaroles in Yellowstone and Lassen Volcanic National Parks, are protected by law, so geothermal reservoirs are not tapped in these areas.

Geothermal Power Plant



1. **Production Well:** Geothermal fluids, such as hot water and steam, are brought to the surface and piped into the power plant.
2. **Power Plant:** Inside the power plant, the geothermal fluid turns the turbine blades, which spins a shaft, which spins magnets inside a large coil of wire to generate electricity.
3. **Injection Well:** Used geothermal fluids are returned to the reservoir.

Geothermal Reserves

The Earth has no shortage of geothermal activity, but not all geothermal resources are easy or economical to use. Geothermal energy comprises four percent of the total U.S. domestic energy reserves, an amount exceeded only by coal (83 percent) and biomass (five percent).

Because energy sources are considered energy reserves only when they are economical to develop, the amount of geothermal reserves will increase as the price of other fuels increases. Improvements in technology will make it easier to capture geothermal resources. This will also bring costs down and increase geothermal reserves.

In 2010, there were geothermal power plants in 24 countries, generating 63.9 billion kilowatt-hours of electricity. Direct uses of geothermal reservoirs amount to over 50,000 megawatts of thermal energy in 78 countries.

Future Geothermal Resources

Today, geothermal power plants use hydrothermal resources (*hydro = water*, *therme = heat*). Three other kinds of geothermal resources—hot dry rock, magma, and geopressured—are often called near-future geothermal resources. Researchers from the U.S. Department of Energy are studying ways to develop these resources for electricity production.

Hot Dry Rock Geothermal Resources underlie much of the world's surface. The U.S. is especially rich in these resources. Some scientists believe the resource base of hot dry rock in the U.S. far exceeds worldwide fossil fuel resources. Using hot dry rock resources to produce electricity requires drilling holes deep into the rock, pumping in cold water at high pressure to fracture the rock, and then accessing the heated water and steam from an adjacent well. The water can be used repeatedly, and there are no emissions into the air. This process has been successfully demonstrated by research projects in the United States, Japan, and Europe.

Magma Geothermal Energy has been called the ultimate energy source. A magma power plant would use a process similar to hot dry rock—water would be injected directly into the magma, cooling and hardening the rock around the well. The resulting steam would be pumped out through a pipe in the well.

Geopressurized Resources are reservoirs of hot water and natural gas (primarily methane) locked in deep sedimentary rocks, under great pressure from the overlying sediments. The heat, pressure, and natural gas can be used to produce electricity. In the U.S., geopressured resources occur along the Texas and Louisiana coasts.