

# Geothermal Energy

## Introduction

Heat from the earth can be used as an energy source in many ways, from large and complex power stations to small and relatively simple pumping systems. This heat energy, known as geothermal energy, can be found almost anywhere—as far away as remote deep wells in Indonesia and as close as the dirt in our backyards. Tapping geothermal energy is an affordable and sustainable solution to reducing our dependence on fossil fuels, and the global warming and public health risks that result from their use.

In the Western United States and in other places around the world, geothermal energy produces electricity in large power plants. Today, geothermal energy provides about five percent of California's electricity, and 25 percent of El Salvador's.[1] In Idaho and Iceland, geothermal heat is used to warm buildings and for other applications. In thousands of homes and buildings across the United States, geothermal heat pumps use the steady temperatures just underground to heat and cool buildings, cleanly and inexpensively.

## The Geothermal Resource

Under Earth's crust, there is a layer of hot and molten rock called magma. Heat is continually produced there, mostly from the decay of naturally radioactive materials such as uranium and potassium. The amount of heat within 10,000 meters (about 33,000 feet) of Earth's surface contains 50,000 times more energy than all the oil and natural gas resources in the world.

The areas with the highest underground temperatures are in regions with active or geologically young volcanoes. These "hot spots" occur at plate boundaries or at places where the crust is thin enough to let the heat through. The Pacific Rim, often called the Ring of Fire for its many volcanoes, has many hot spots, including some in Alaska, California, and Oregon. Nevada has hundreds of hot spots, covering much of the northern part of the state.

These regions are also seismically active. Earthquakes and magma movement break up the rock covering, allowing water to circulate. As the water rises to the surface, natural hot springs and geysers occur, such as Old Faithful at Yellowstone National Park. The water in these systems can be more than 200°C (430°F).

## How Geothermal Energy Is Captured

Geothermal springs for power plants. The most common current way of capturing the energy from geothermal sources is to tap into naturally occurring "hydrothermal convection" systems where cooler water seeps into Earth's crust, is heated up, and then rises to the surface. When heated water is forced to the surface, it is a relatively simple matter to capture that steam and use it to drive electric generators. Geothermal power plants drill their own holes into the rock to more effectively capture the steam.

There are three designs for geothermal power plants, all of which pull hot water and steam from the ground, use it, and then return it as warm water to prolong the life of the heat source. In the simplest design, the steam goes directly through the turbine, then into a condenser where the steam is condensed into water. In a second approach, very hot water is depressurized or "flashed" into steam which can then be used to drive the turbine.

In the third approach, called a binary system, the hot water is passed through a heat exchanger, where it heats a second liquid—such as isobutane—in a closed loop. The isobutane boils at a lower temperature than water, so it is more easily converted into steam to run the turbine. The three systems are shown in the diagrams below.

The choice of which design to use is determined by the resource. If the water comes out of the well as steam, it can be used directly, as in the first design. If it is hot water of a high enough temperature, a flash system can be used, otherwise it must go through a heat exchanger. Since there are more hot water resources than pure steam or high-temperature water sources, there is more growth potential in the heat exchanger design.

The largest geothermal system now in operation is a steam-driven plant in an area called the Geysers, north of San Francisco, California. Despite the name, there are actually no geysers there, and the heat that is used for energy is all steam, not hot water. Although the area was known for its hot springs as far back as the mid-1800s, the first well for power production was drilled in 1924. Deeper wells were drilled in the 1950s, but real development didn't occur until the 1970s and 1980s. By 1990, 26 power plants had been built, for a capacity of more than 2,000 megawatts (MW).

Because of the rapid development of the area in the 1980s, and the technology used, the steam resource has been declining since 1988. Today, the Geysers has a capacity of 850 MW, which still meets nearly 70 percent of the average

electrical demand for California's North Coast region.[2] The plants at the Geysers use an evaporative water-cooling process to create a vacuum that pulls the steam through the turbine, producing power more efficiently. But this process loses 60 to 80 percent of the steam to the air, not reinjecting it underground. While the steam pressure may be declining, the rocks underground are still hot. Some efforts are under way to remedy the situation, including the Santa Rosa Geysers Recharge Project, which involves injecting treated wastewater from neighboring communities through a 40-mile pipeline.[3] Recharging the existing reservoirs is estimated to increase output by 85 MW, providing enough electricity for approximately 85,000 homes.

One concern with open systems like the Geysers is that they emit some air pollutants. Hydrogen sulfide—a toxic gas with a highly recognizable “rotten egg” odor—along with trace amounts of arsenic and minerals, is released in the steam. In addition, at a power plant at the Salton Sea reservoir in Southern California, a significant amount of salt builds up in the pipes and must be removed. While the plant initially started to put the salts into a landfill, they now reinject the salt back into a different well. With closed-loop systems, such as the binary system, there are no emissions; everything brought to the surface is returned underground.

Direct use of geothermal heat. Geothermal springs can also be used directly for heating purposes. Hot spring water is used to heat greenhouses, to dry out fish and de-ice roads, for improving oil recovery, and to heat fish farms and spas. In Klamath Falls, Oregon, and Boise, Idaho, geothermal water has been used to heat homes and buildings for more than a century. New housing developments in Reno, Nevada, are also using geothermal heat from a well for home heating.

In Iceland, virtually every building in the country is heated with hot spring water. In fact, Iceland gets more than 50 percent of its energy from geothermal sources.[5] In Reykjavik, for example (population 115,000), hot water is piped in from 25 kilometers away, and residents use it for heating and for hot tap water.

Hot dry rock. Geothermal heat occurs everywhere under the surface of the earth, but the conditions that make water circulate to the surface are found only in less than 10 percent of Earth's land area. An approach to capturing the heat in dry areas is known as "hot dry rock." The rocks are first broken up by pumping high-pressure water through them. Water is then pumped from the surface down through the broken hot rocks. After the water heats up, it is brought back to the surface through a second well and used to drive turbines for electricity or to provide heat.

Researchers at the Los Alamos National Laboratory in New Mexico have studied hot dry rock since 1974. An experimental facility was built in Fenton Hill, New Mexico, involving a well drilled 11,500 feet into rock at 430°F to demonstrate the feasibility of hot dry rock technology. Water pumped down the well at 80°F returned to the surface at 360°F. Although the Fenton Hill facility was decommissioned in 1996, the plant produced as much as five megawatts of power, proving that energy from hot dry rock can be extracted for practical applications.[6] Research and development is continuing in the United States as well as in Australia, France, Germany, and Japan in an effort to make hot dry rock technology commercially feasible. Though several technical hurdles remain, Europe and Australia are currently working toward the establishment of the first commercially viable hot dry rock system.

Ground-source heat pumps. A much more conventional way to tap geothermal energy is by using geothermal heat pumps to provide heat and cooling to buildings. Also called ground-source heat pumps, they take advantage of the constant year-round temperature of about 50°F that is just 5 to 10 feet underground. Either air or an antifreeze liquid is pumped through pipes that are buried underground, and recirculated into the building. In the summer, the liquid moves heat from the building into the ground. In the winter, it does the opposite, providing pre-warmed air and water to the heating system of the building.

In the simplest use of ground-source heating and cooling, a tube runs from the outside air, under the ground, and into a house's ventilation system. More complicated, but more effective systems use compressors and pumps—as in electric air conditioning systems—to maximize the heat transfer.

In regions with temperature extremes, such as the northern United States in the winter and the southern United States in the summer, ground-source heat pumps are the most energy-efficient and environmentally clean heating and cooling system available. A study by the U.S. Environmental Protection Agency found that they are as much as 72 percent more efficient than electric heating and air conditioning systems.[7] The U.S. Department of Energy found that heat pumps can save a typical home hundreds of dollars in energy costs each year, with the system paying for itself in 2 to 10 years.[8]

By the end of 2005, more than 600,000 ground-source heat pumps were installed in the United States, with new installations occurring at a rate of 50,000 to 60,000 per year.[9] While this is significant, it is still only a small fraction of the U.S. heating and cooling market, and several barriers to greater penetration into the market remain. For example, despite their long-term savings, geothermal heat pumps have higher up-front costs. In addition, installing them in existing buildings can be difficult, since it involves digging up the yard around a house (provided it has a yard). Finally, many heating and cooling installers are just not familiar with the technology.

Ground-source heat pumps are catching on in some areas though. In rural areas without access to natural gas pipelines, homes must use propane or electricity for heating and cooling. Heat pumps are much less expensive to operate, and

since buildings are widely spread out, installing underground loops is not an issue. Underground loops can be easily installed during construction of new buildings as well, resulting in savings for the life of the building.

### The Future of Geothermal Energy

Geothermal energy has the potential to play a significant role in moving the United States (and other regions of the world) toward a cleaner, more sustainable energy system. It is one of the few renewable energy technologies that—like fossil fuels—can supply continuous, base load power. The costs for electricity from geothermal facilities are also declining. Some geothermal facilities have realized at least 50 percent reductions in the price of electricity since 1980. New facilities can produce electricity for between 4.5 and 7.3 cents per kilowatt-hour, making it competitive with new conventional fossil fuel-fired power plants.[10]

The U.S. Geological Survey estimates the geothermal resource base in the United States to be between 95,000 and 150,000 MW, of which about 22,000 MW have been identified as suitable for electric power generation.[11] Unfortunately, only a fraction of this resource is currently utilized, with an installed capacity of 2,800 MW (worldwide capacity is approximately 8,000 MW).[12] But thanks to declining costs and state and federal support, geothermal development is likely to increase. Over the next decade, new geothermal projects are expected to come online to increase U.S. capacity to between 8,000 and 15,000 MW. As hot dry rock technologies improve and become competitive, even more of the largely untapped geothermal resource could be developed. In addition to electric power generation, which is focused primarily in the western United States, there is a bright future for the direct use of geothermal resources as a heating source for homes and businesses everywhere.