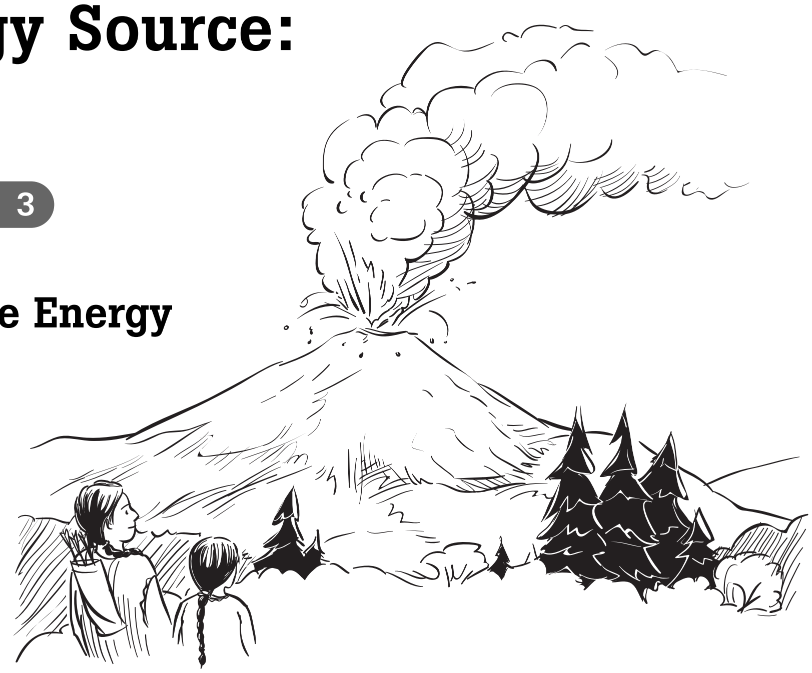
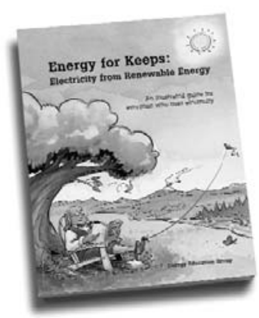
Renewable Energy Source: GEOTHERMAL



EXCERPT FROM CHAPTER 3

Energy for Keeps: Electricity from Renewable Energy



About *Energy for Keeps*

These pages about geothermal energy are taken from *Energy for Keeps*, an illustrated guide "for everyone who uses electricity." *Energy for Keeps* is a one-of-a-kind book. It covers all energy resources used for electricity generation, with an emphasis on renewables. It addresses energy history, technology, sustainability, and policy — all in easy-to-understand language.

First published in 2003, *Energy for Keeps* was updated and revised in 2005. Its new friendlier format, available in hard- or softcover, is 174 pages. The book includes an extensive glossary, an index, and further information resources. It's for home, office, and library shelves everywhere. Classroom support is free on the website and, on request, a free student activity CD comes with the book. See preview of entire book, reader comments, and ordering information at **www.energyforkeeps.org**.

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TERMS IN GLOSSARY

binary power plant
conduction
crust
dry steam power plant
fissure
flash power plant
fumarole
geothermal reservoir
groundwater
heat exchanger
hot dry rock
hydrogen sulfide
magma
mantle
modular
mud pot
porous
subducting
tectonic plates
wastewater

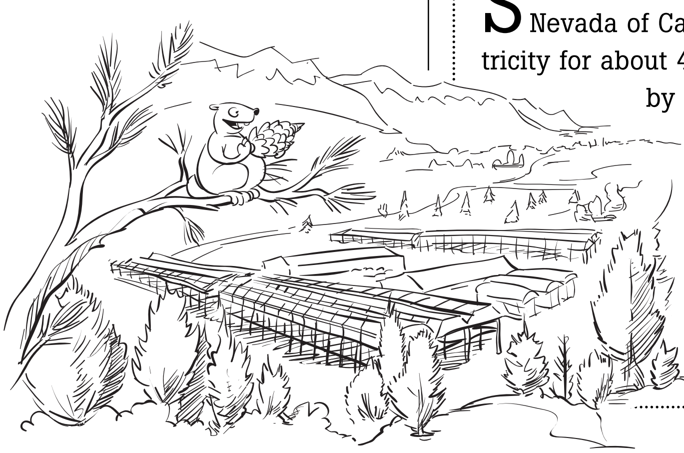
PEOPLE HAVE ALWAYS BEEN FASCINATED with volcanoes and their fiery displays of nature's power. Many ancient societies once thought volcanoes were homes to temperamental gods or goddesses. Today we know that volcanoes result from the immense heat energy — geothermal energy — found in Earth's interior. This heat also causes hot springs, steam vents (fumaroles), and geysers.

Over the ages, humans have benefited from Earth's geothermal energy by using the hot water that naturally rises up to the earth's surface. We have soaked in hot springs for healing and relaxation and have even used them as instant cooking pots. Hot springs have also been an important part of cultural life, especially in Japan and Europe.

Today we drill wells deep underground to bring hot water to the surface. We use this geothermal energy to heat buildings, to speed the growth of plants and fish, and to dry lumber, fruits and vegetables. We use the really hot water to generate electricity.

POWER SKETCH: Good Neighbor

Set amidst the open vistas and forests of the eastern Sierra Nevada of California, a power plant churns out enough electricity for about 40,000 homes. The natural setting is not marred by smoky emissions, because there are none. This geothermal power plant uses hot water resources from an underground geothermal reservoir to power its turbine generators. Many tourists and residents of nearby Mammoth Lakes don't even realize the power plant is there beside the main highway. Those who do say it is a good neighbor indeed.



Mammoth Lakes geothermal power plant

THE GEOTHERMAL RESOURCE

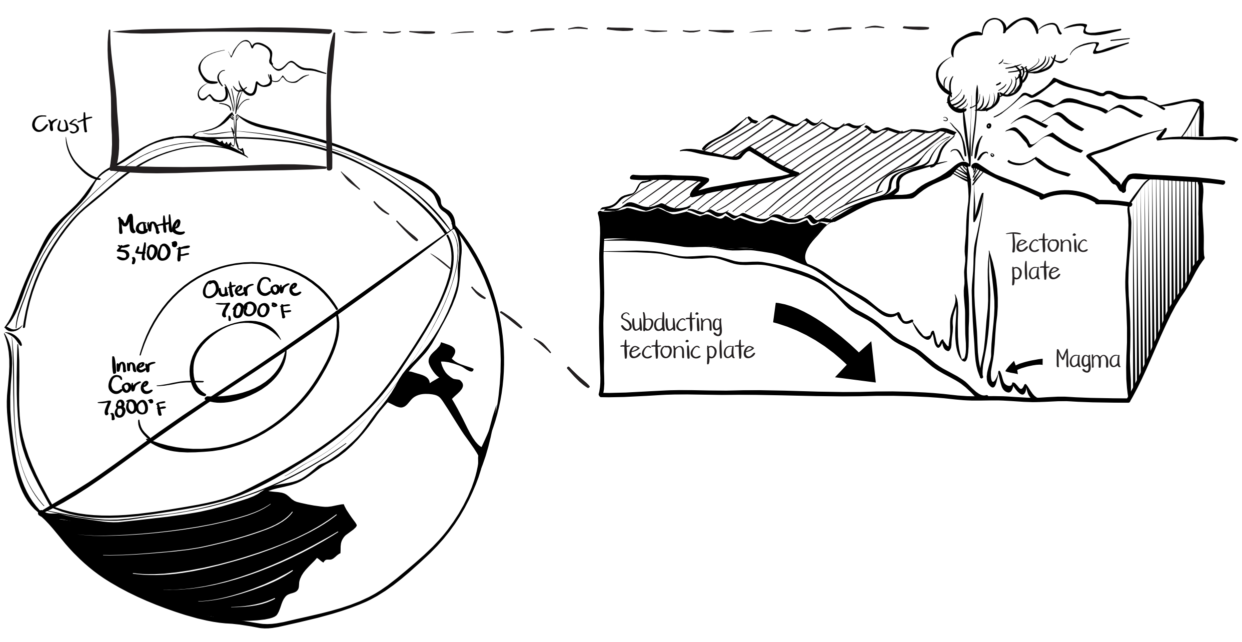
Geo means earth and *thermal* means heat. So geothermal energy is the heat energy of the earth.

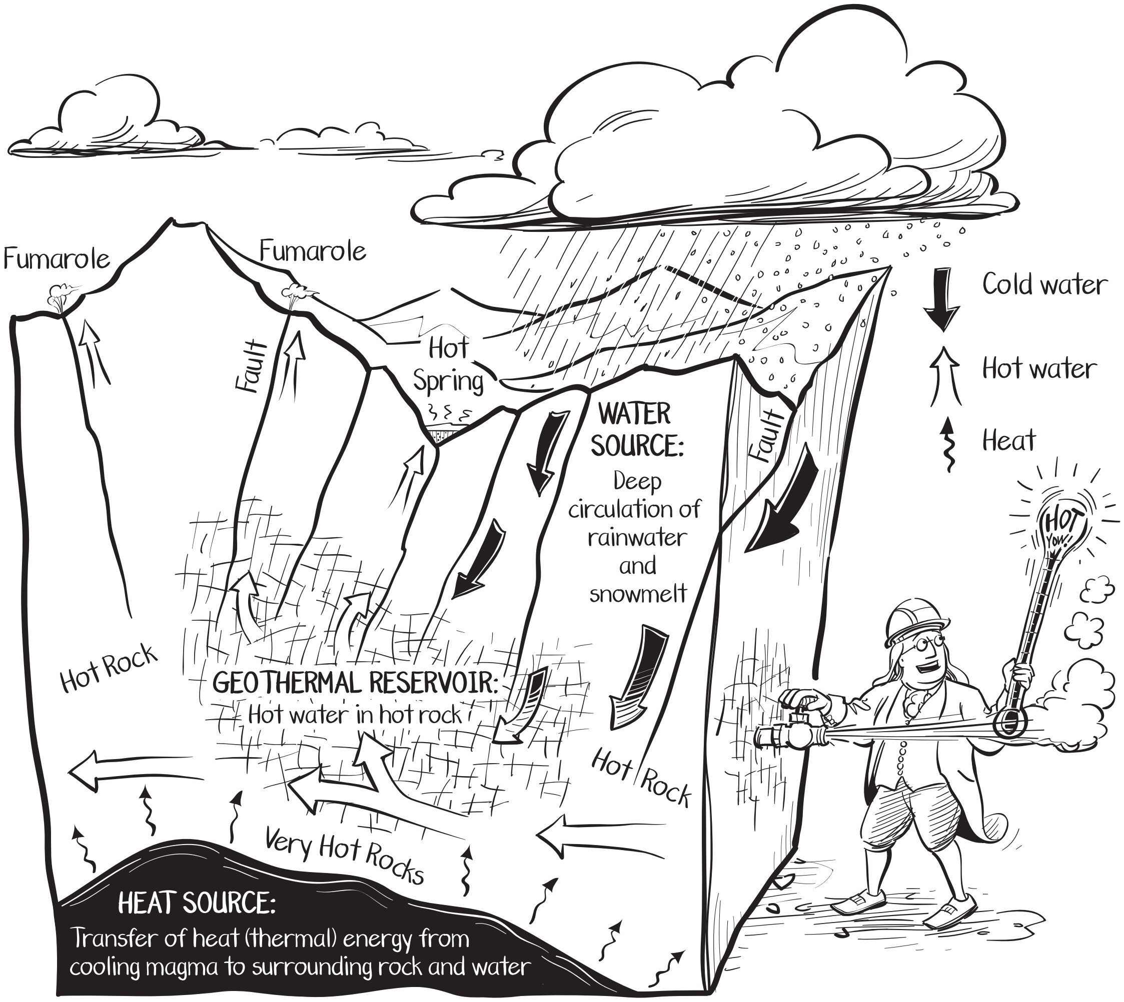
The Inner Earth: Hot, Hot, Hot!

Billions of years ago our planet was a fiery ball of liquid and gas. As the earth cooled, an outer rocky crust formed over the hot interior, which remains hot to this day. This relatively thin crust "floats" on a massive underlying layer of very hot rock called the mantle. Some of the mantle rock is actually melted, or molten, forming magma.

The heat from the mantle continuously transfers up into the crust. Heat is also being generated in the crust by the natural decay, or breakdown, of radioactive elements found in all rock.

The crust is broken into enormous slabs — tectonic plates — that are actually moving very slowly (about the rate your fingernails grow) over the mantle, separating from, crushing into, or sliding (subducting) under one another. The edges of these huge plates are often restless with volcanic and earthquake activity (see page 36, Hot Locations). At these plate boundaries, and in other places where the crust is thinned or fractured, magma is closer to the surface than it is elsewhere. Sometimes the magma emerges above ground — where we know it as lava. But most of it stays below ground where, over time, it creates large regions of hot rock.





A geothermal reservoir is a large underground area of hot permeable rock saturated with superheated water.

Geothermal Reservoirs: Earth's Natural Boilers

Rainwater and melted snow can seep miles below the surface, filling the pores and cracks of hot underground rock. This water can get really hot. It can reach temperatures of 500°F (260°C) or higher — way above boiling.

Sometimes this hot water will work its way back up (hot water is less dense than cold and so tends to rise). If it reaches the surface it forms hot springs, steam vents (fumaroles), mud pots, or geysers. If it gets trapped deep below the surface, it forms a "geothermal reservoir" of hot water and steam. A geothermal reservoir is an underground area of cracked and porous (permeable) hot rock saturated with hot water. The water and steam from these superheated reservoirs are the geothermal resources we use to generate electricity.

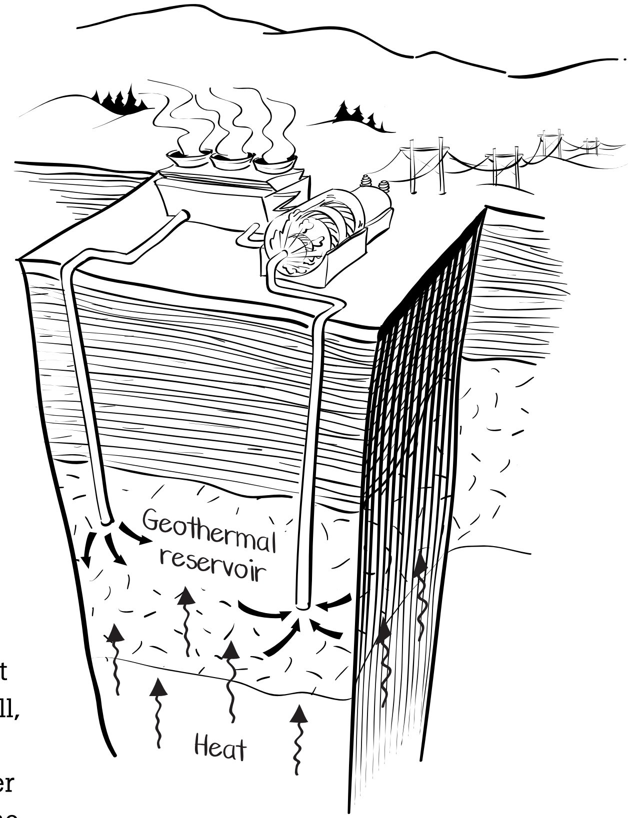
GENERATING ELECTRICITY FROM GEOTHERMAL RESOURCES

Geothermal reservoirs can be found from a few hundred feet up to two or more miles below Earth's surface. We drill wells to reach them. After the wells are drilled, steel pipe (casing) is inserted. Now with an open passageway to the surface, the hot geothermal water or steam shoots up the well naturally or is pumped to the surface. From here it's piped into a geothermal power plant.

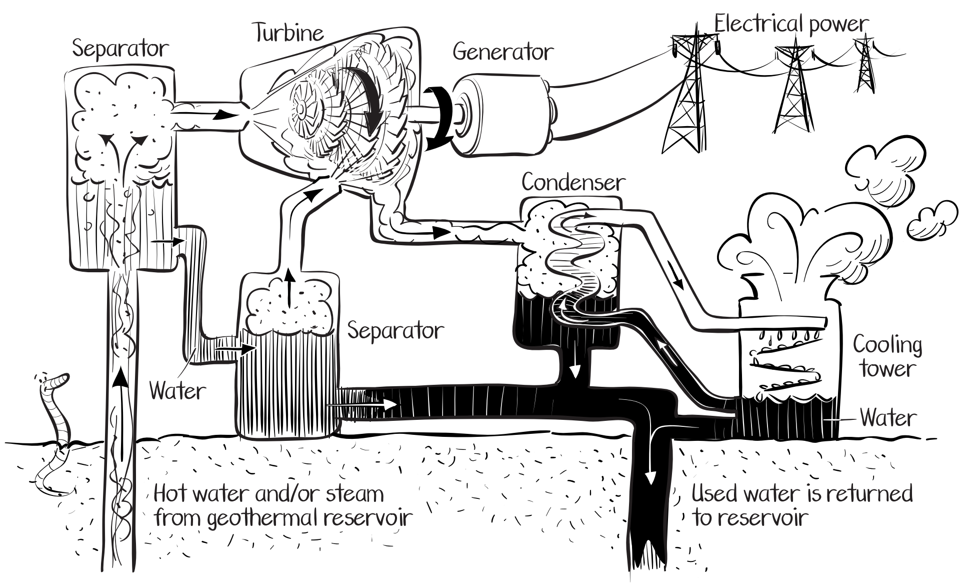
Geothermal Power Plants

There are different kinds of geothermal power plants, because there are different kinds of geothermal reservoirs.

Flash Steam Power Plants. Flash steam plants use really hot geothermal reservoirs of about 350°F or higher. From the well, high-pressure hot water rushes up pipes into a "separator," where the pressure is reduced. This causes some of the water to vigorously "flash" to steam, the force that drives the turbine-generators. After the steam does its work, it is condensed back into water and piped back down into the geothermal reservoir so it can be reheated and reused. Most geothermal power plants in the world today are flash plants.



Hot water or steam from deep underground shoots up a geothermal well, spins the turbine-generator, and is returned to the reservoir.

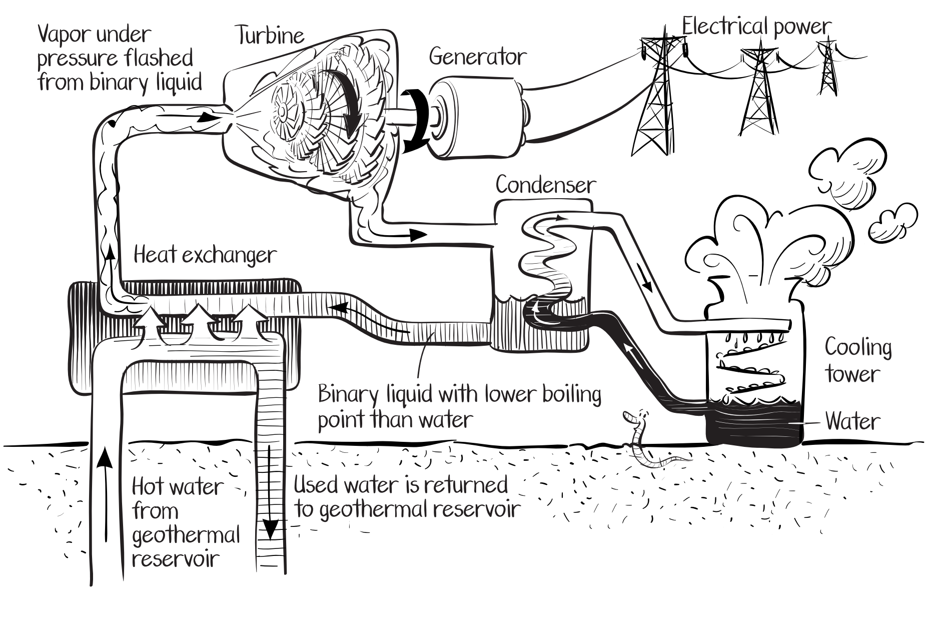


Flash steam plants can include one steam/water separator or, more commonly, two separators (shown here).

Dry Steam Power Plants. A very few geothermal reservoirs are filled naturally with steam, not water. This means that the wells will produce only steam. The power plants that run on this steam are called "dry steam" power plants. Here, the steam blasts right into the turbine blades (they do not need separators), then is condensed to water and piped back into the reservoir. Though dry steam reservoirs are rare, they have been important to the development of geothermal power, especially in California, Italy, and Japan.

Binary Power Plants. In some geothermal reservoirs, the water is hot (over 200° F, or 93°C), but not hot enough to produce steam with the force needed to efficiently turn a turbine-generator. Fortunately, we can generate electricity from these "moderate temperature" reservoirs, using binary power plants.

In the binary process, the geothermal water is used only for its heat, not to produce steam. In a heat exchanger (see sidebar, this page), the heat transfers to a second liquid. This second liquid flashes to vapor and drives the turbine. Once used, the geothermal water is pumped back into the reservoir. Moderate-temperature reservoirs are more common than high-temperature reservoirs, so the use of binary power plants is expanding worldwide.



Binary power plant

HEAT EXCHANGERS

Heat exchangers are used in electricity generation when the heat source is hot, but not quite hot enough to bring water to a boil to create forceful steam.

A heat exchanger transfers heat (thermal energy) from a hotter liquid to a cooler one by conduction. The heat is conducted from the first (hotter) liquid into the second liquid through metal pipes or plates that keep the two liquids separated.

The second liquid is usually one with a lower boiling point than water, so it vaporizes, or "flashes" to vapor, at a lower temperature. Sometimes — such as in certain solar thermal power plants, where the first liquid is oil or another material (see page 63) — the second liquid can be water.

The force of the rapidly expanding vapor or steam spins the turbine blades that drive a generator. The steam or vapor can then be condensed back to a liquid and used over and over again.

All Shapes and Sizes

Geothermal power plants come small (300 kW to 10 MW), medium (10 MW to 50 MW), and large (50 MW to 100 MW and higher). A geothermal power plant usually consists of two or more turbine-generator "modules" in one plant. Extra modules can be added as more power is needed.

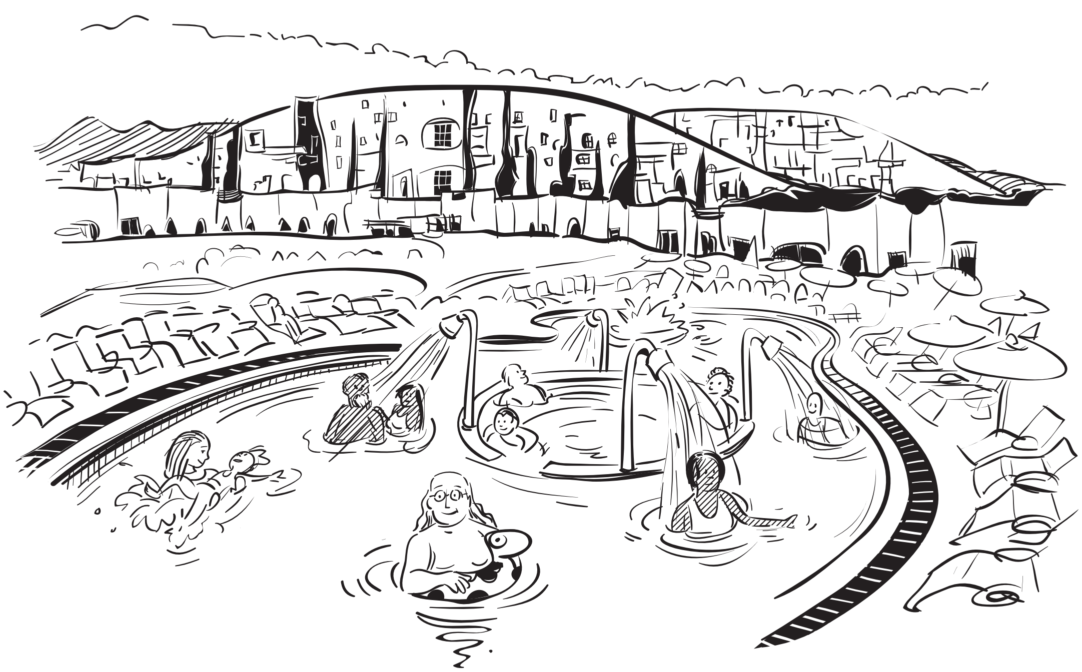
Binary plants are especially versatile because they can use relatively low reservoir temperatures. Small binary modules can be built quickly and transported easily. These little power plants are great for use in remote parts of the world, far from transmission lines. One interesting plant is installed in the rugged mountains of Tibet (People's Republic of China). At a soaring 14,850 feet (4,526 meters), it is the highest geothermal power plant in the world.

Small binary plants are also popular for hot spring spas and health resorts. They add the convenience of electricity while maintaining an environmental and healthful appeal. For example, an artistically designed hot springs resort in Austria is using a small binary geothermal power plant for its power.

REMINDER

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

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



This unique hotel and hot springs resort in Austria is powered by geothermal energy.

Geothermal at Work around the Globe

So far, the U.S. produces more electricity from geothermal energy than does any other country. Four states have geothermal power plants. California has the most, followed by Nevada, Utah, and Hawaii — and more are planned in these states and in Idaho. The U.S. Department of Energy's "GeoPowering the West" program seeks to expand the use of geothermal resources in 19 western states.

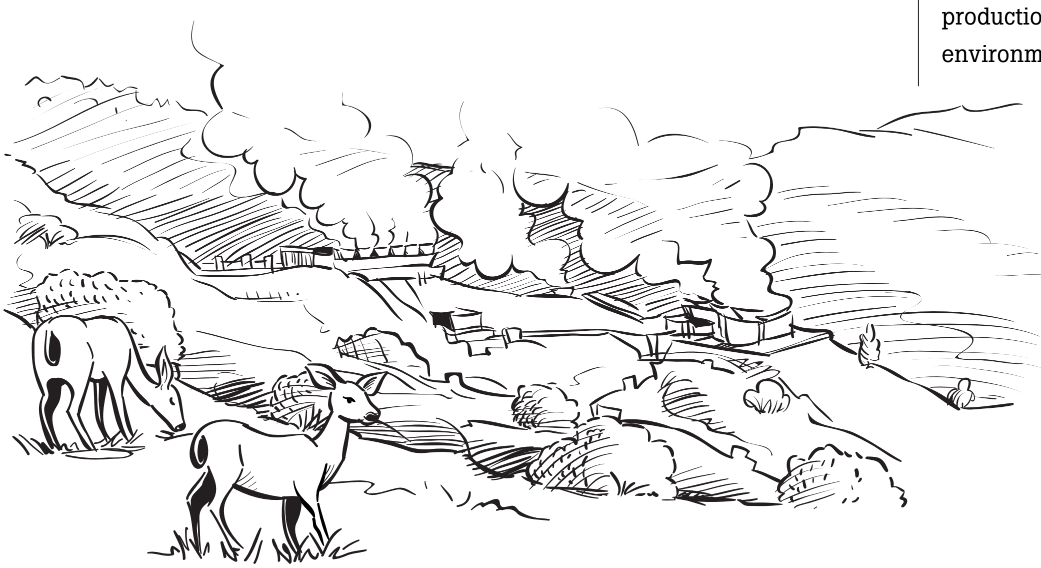
U.S. plant types vary widely. One little 300kW geothermal powerhouse in northern California runs all by itself and automatically radios an operator when it needs maintenance. At one of Nevada's geothermal plants, the heat from geothermal water is used to dry onions and garlic before it is injected back into the reservoir. Hawaii's geothermal plants provide over 20 percent of the electricity used on the Big Island. And the world's largest single geothermal power plant, 185MW, is nearing construction near southern California's Salton Sea.

The Philippines and Indonesia have abundant geothermal resources. Geothermal generates about one-fourth of the electricity in the Philippines, making this country the second largest user of geothermal electricity in the world (after the United States). Italy was the site of the first geothermal power development. Its beautiful dry steam field of Larderello, developed in 1904, is still generating electricity today. Other places with large geothermal power developments include Mexico, Iceland, New Zealand, Japan, and several Central American countries.

"THE GEYSERS"

A geothermal area in northern California is named "The Geysers" (even though it has never had any geysers — only fumaroles). It once was the site of a famous resort — attracting the likes of Jack London and Teddy Roosevelt. Today it is the world's largest single source of geothermal electrical power. Even its reservoir is unique, being one of the few in the world to produce steam (rather than mostly water). After over 40 years, The Geysers' 21 power plants still reliably generate enough electricity to power a city the size of San Francisco — about 900 MW.

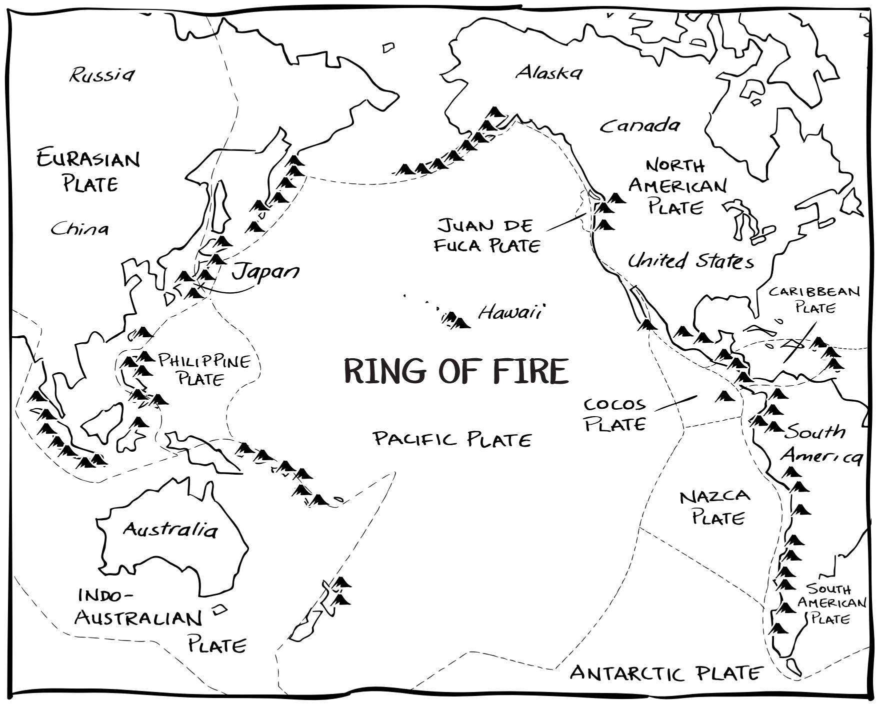
To top it off, cities in Lake and Sonoma Counties are piping their cleaned wastewater many miles to The Geysers and injecting it deep into the geothermal reservoir. Doing so is helping to sustain the productive life of the reservoir for electicity production and is providing an environmentally safe way to dispose of wastewater.



Geothermal power plants at The Geysers in California

HOT LOCATIONS

The edges of the continents that surround the Pacific Ocean (the Pacific "Ring of Fire") are prone to earthquakes and volcanoes and have some of the best geothermal resources in the world. This includes the western part of North, Central, and South America; New Zealand; Indonesia; the Philippines; Japan; and Kamchatka (eastern Russia). These countries all have coastlines that sit on or near the boundaries of tectonic plates (see page 30). Some of the other prime geothermal locations include Iceland, Italy, the Rift Valley of Africa, and Hawaii.



This map shows the edges of the tectonic plates (they all have names) that form the "Ring of Fire." Most countries in this area have lots of geothermal energy.

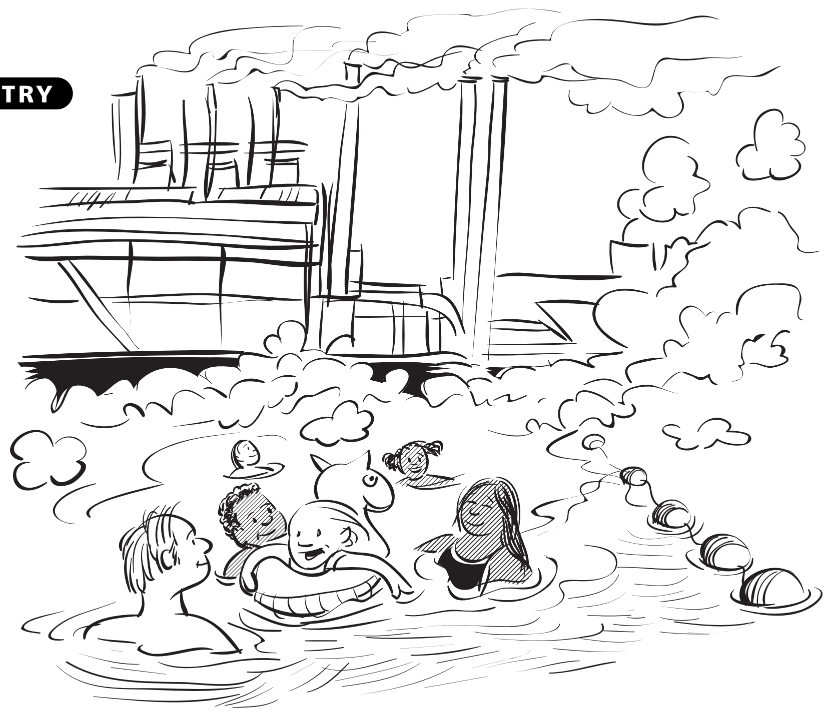
New Energy from "Engineered" Reservoirs

There are many places underground where the rock is really hot but doesn't naturally contain much water. Researchers are working on ways to pump water down into the hot rock, creating "engineered" geothermal reservoirs. Sometimes called "hot dry rock," this method involves drilling a well down into the hot rock and injecting high-pressure cold water to make cracks (fractures) in it. Then more water is pumped down into the fractured rock. The heat from the rock transfers to the water, and the now-hot water is pumped up a separate well to generate electricity in a binary power plant.

A U.S. project at Los Alamos, New Mexico, first demonstrated that hot dry rock power plants can work. Japan, France, Germany, Switzerland, Australia, and other countries are also working on this method. In the United States and elsewhere, similar processes are being adapted to boost the production of already-developed natural geothermal reservoirs.

HOT ENERGY FOR A COLD COUNTRY

Iceland is such an active geothermal area that hot springs occasionally bubble up right into people's living rooms! People in this cool-weather country make really good use of their abundant geothermal energy resource. They use it for everything from heating homes, offices, and greenhouses to warming swimming pools and generating electricity. In the middle of winter, it is not uncommon to see people soaking in the steamy hot pool found right outside a geothermal power plant.



Some spas in Iceland are located right next to geothermal power plants.

CONSIDERATIONS

- Geothermal power plants have no smoky emissions. What comes out the top of a geothermal plant cooling tower is steam (water vapor) with only trace amounts of natural minerals and gases from the geothermal reservoir. Flash and dry steam plants produce only a small fraction of air emissions compared to fossil fuel plants. Binary power plants have virtually no emissions.
- Geothermal power plants use very little land compared to conventional energy resources and can share the land with wildlife or grazing herds of cattle. They operate successfully and safely in sensitive habitats, in the midst of crops, and in forested recreation areas. However, they must be built at the site of the geothermal reservoir, so there is not much flexibility in choosing a plant location. Some locales may also have competing recreational or other uses.
- Geothermal wells are sealed with steel casing, cemented to the sides of the well along their length. The casing protects shallow, cold groundwater aquifers from mixing with geothermal reservoir waters. This way the cold groundwater doesn't get into the hot geothermal reservoir and the geothermal water doesn't mix with potential sources of drinking water.

(continued)

CONSIDERATIONS (continued)

- Geothermal water contains varying concentrations of dissolved minerals and salts. Sometimes the minerals are extracted and put to good use. Examples are zinc (for electronics and for making alloys such as bronze and brass) and silica. At reservoirs with higher concentrations, advanced geothermal technology keeps the salty, mineralized water from clogging and corroding power plant equipment.
- Most geothermal reservoirs contain varying amounts of dissolved gases such as hydrogen sulfide. This gas smells bad (like rotten eggs) and is toxic at high concentrations. Modern geothermal technology ensures that geothermal power plants capture these gases before they go into the air. The gas removal processes can produce sulfur for use in fertilizers.
- Geothermal reservoirs must be carefully managed so that the steam and hot water are produced no faster than they can be naturally replenished or supplemented.
- Geothermal power plants run day and night, so they provide reliable baseload electricity. Most geothermal power plants can increase their output of electricity to provide more power at times of greater demand. But geothermal power plants can't be used exclusively for peaking power; if geothermal wells were turned off and on repeatedly, expansion and contraction (caused by heating and cooling) would damage the wells.

Geothermal Facts*

United States

- Geothermal resources suitable for electricity production in the U.S. occur mostly in the western states.
- The U.S. has about 2,800 MW of geothermal power plants — currently more than any other country.

Worldwide

- Around the world there are about 11,000 MW of geothermal power plants in 22 countries, including the U.S., Italy, the Philippines, Japan, Indonesia, New Zealand, and Mexico.
- Geothermal experts have identified 39 countries that could be powered 100 percent by geothermal energy.

*Data available in 2004. See www.energyforkeeps.org for state-specific information about Geothermal energy use.