Geothermal Energy Basics

An Online Continuing Education Course for Engineers

Course Number: R-1002

Credit: 1 Hour / 1 PDH / 1 CPD

Geothermal Energy . . .
Power from the Depths

The Earth's crust is a bountiful source of energy—and fossil fuels are only part of the story. Heat or thermal energy is by far the more abundant resource. To put it in perspective, the thermal energy in the uppermost six miles of the Earth's crust amounts to 50,000 times the energy of all oil and gas resources in the world!

The word "geothermal" literally means "Earth" plus "heat." The geothermal resource is the world's largest energy resource and has been used by people for centuries. In addition, it is environmentally friendly. It is a renewable resource and can be used in ways that respect rather than upset our planet's delicate environmental balance.

Geothermal power plants operating around the world are proof that the Earth's thermal energy is readily converted to electricity in geologically active areas. Many communities, commercial enterprises, universities, and public facilities in the western United States are heated directly with the water from underground reservoirs. For the homeowner or building owner anywhere in the United States, the emergence of geothermal heat pumps brings the benefits of geothermal energy to everyone's doorstep.

U.S. geothermal power plants, such as this steam plant at The Geysers in California, have a total generating capacity of 2700 megawatts, enough to provide electricity for 3.7 million people.

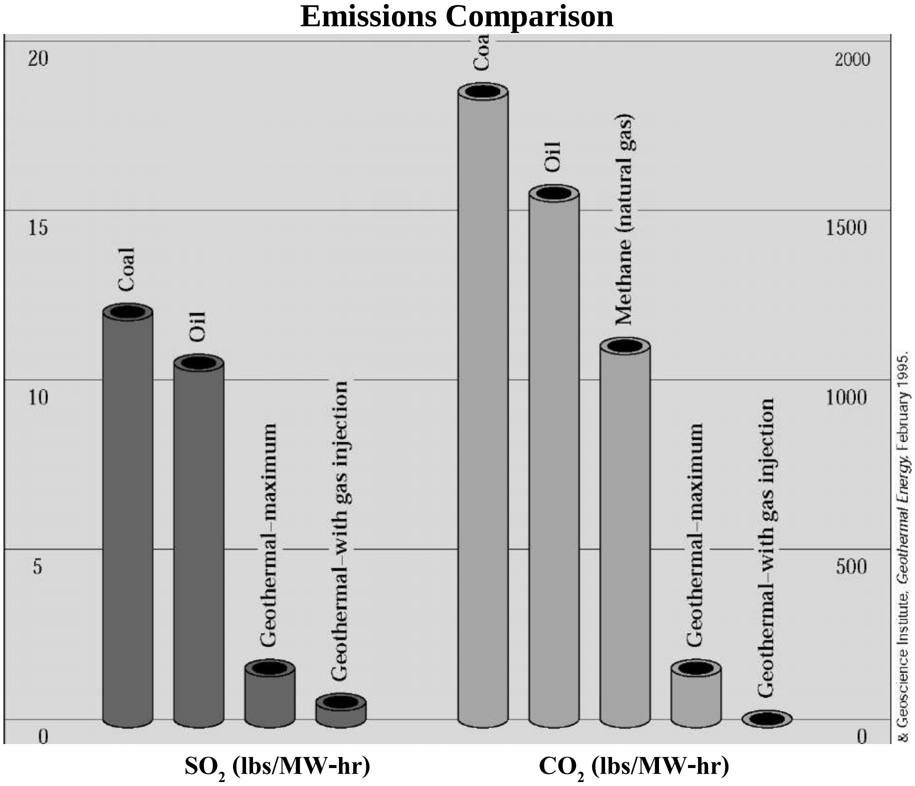
The Basics

There's a relatively simple concept underlying all the ways geothermal energy is used: The flow of thermal energy is available from beneath the surface of the Earth and especially from subterranean reservoirs of hot water. Over the years, technologies have evolved that allow us to take advantage of this heat.

In fact, electric power plants driven by geothermal energy provide over 44 billion kilowatt hours of electricity worldwide per year and world capacity is growing at approximately 9% per year. To produce electric power from geothermal resources, underground reservoirs of steam or hot water are tapped by wells and the steam rotates turbines that generate electricity. Typically, water is then returned to the ground to recharge the reservoir and complete the renewable energy cycle.

Underground reservoirs are also tapped for "direct-use" applications. In these instances, hot water is channeled to greenhouses, spas, fish farms, and homes to fill space heating and hot water needs.

Emissions Comparison



Geothermal power plants produce significantly less sulfur dioxide (SO2) and carbon dioxide (CO2) than do conventional fossil-fueled power plants.

Geothermal energy use extends beyond underground reservoirs. The soil and near-surface rocks, from 5 to 50 feet deep, have a nearly constant temperature from geothermal heating. Homes, as well as commercial and industrial properties can use the Earth as a heat source or heat sink with geothermal heat pumps. According to the U.S. Environmental Protection Agency (EPA), geothermal heat pumps are one of the nation's most efficient—and therefore least polluting—heating, cooling, and water-heating systems available. In winter, these systems draw on "earth heat" to warm the building, and in summer they transfer heat from the building to the earth, which ranges in temperature from 50° to 70°F (10° to 21°C) depending on latitude.

A Clear Advantage

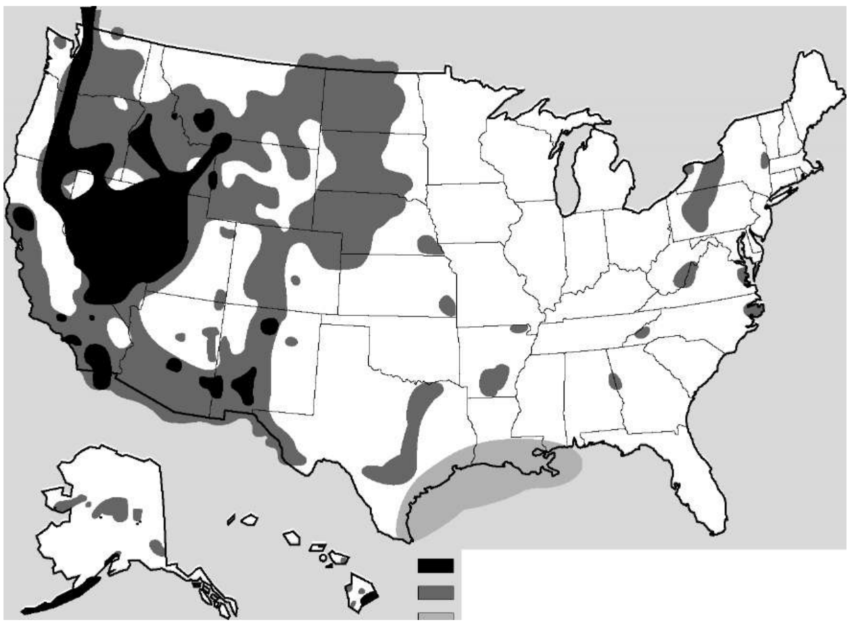
Geothermal energy delivers some powerful environmental and economic benefits. If you live in an area that uses geothermal resources for electricity production, you're quite fortunate. Consider Lake County, California, which is home to many of the geothermal power plants at our nation's best-developed geothermal resource, The Geysers. It's no coincidence that the Lake County air basin is the first and only one in compliance with all of California's stringent air quality regulations.

Companies with energy-intensive manufacturing processes can benefit the most from geothermal energy. For example, it's estimated that greenhouses can reduce heating costs by up to 80% using geothermal energy compared to traditional energy sources, resulting in savings about 5% to 8% in total operating cost.

So, by using geothermal energy sources, you're not only doing your part to help make the world a cleaner place to live and breathe, you're rewarded with low operating and maintenance costs, and, usually, lowest life-cycle costs.

Another benefit of geothermal energy is that it uses domestic, not foreign, resources. Nearly half of our nation's annual trade deficit would be obliterated if we could displace imported oil with domestic energy resources. A nation's trade deficit represents a permanent loss of wealth for the citizens of that nation. Keeping the wealth at home translates to more jobs and a robust economy. And not only does our national economic and employment picture improve, but a vital measure of national security is gained when we control our own energy supplies.

U.S. Geothermal Provinces



Temperatures above 100°C (212°F) Temperatures below 100°C (212°F) Geopressured resources
Area suitable for geothermal heat pumps (entire U.S.)

Much of the western United States has geothermal resources suited to power production (above 100°) and direct uses (from 20°C and 150°C). The Gulf Coast region contains geopressured resources, and the entire country is suitable for geothermal heat pumps.

Types of Geothermal Resources

The center of the Earth is 4000 miles (6400 kilometers) deep. How hot is this region? Our best guess is 7200°F (4000°C) or higher. Partially molten rock, at temperatures between 1200° and 2200°F (650° to 1200°C), is believed to exist at depths of 50 to 60 miles (80 to 100 kilometers).

Heat is constantly flowing the Earth's interior to the surface. Most types of geothermal resources—hydrothermal, geopressured, hot dry rock, and magma— result from concentration of Earth's thermal energy within certain discrete regions of the subsurface.

Hydrothermal resources are reservoirs of steam or hot water, which are formed by water seeping into the earth and collecting in, and being heated by fractured or porous hot rock. These reservoirs are tapped by drilling wells to deliver hot water to the surface for generation of electricity or direct use. Hot water resources exist in abundance around the world. In the United States, the hottest (and currently most valuable) resources are located in the western states, and Alaska and Hawaii. Technologies to tap hydrothermal resources are proven commercial processes.

Geopressured resources are deeply buried waters at moderate temperature that contain dissolved methane. While technologies are available to tap geopressured resources, they are not currently economically competitive. In the United States, this resource base is located in the Gulf coast regions of Texas and Louisiana.

Hot dry rock resources occur at depths of 5 to 10 miles (8 to 16 kilometers) everywhere beneath the Earth's surface, and at shallower depths in certain areas. Access to these resources involves injecting cold water down one well, circulating it through hot fractured rock, and drawing off the now hot water from another well. This promising technology has been proven feasible, but no commercial applications are in use at this time.

Magma (or molten rock) resources offer extremely high-temperature geothermal opportunities, but existing technology does not allow recovery of heat from these resources.

Earth energy is the heat contained in soil and rocks at shallow depths. This resource is tapped by geothermal heat pumps.

Geothermal plants emit minimal amounts of carbon dioxide—1/1000 to 1/2000 of the amount produced by fossil-fuel plants.

Geothermal Power Plants—from Water to Light

Flip a switch and light up a room—what could be easier? Push a button on the TV remote control and be entertained. It all seems so simple that we are often unaware of the true environmental and social cost of these conveniences—and who would want to give them up even if we had to account for every penny?

But rather than thinking in terms of giving things up, let's think positively: in the United States, right now, the installed generating capacity for geothermal stands at about 2700 megawatts. That's the equivalent of about 58 million barrels of oil, and provides enough electricity for 3.7 million people. The cost of producing this power ranges from 44 to 84 per kilowatt hour. The geothermal industry is working to achieve a geothermal life-cycle energy cost of 34 per kilowatt hour. And remember, this is clean energy produced from domestic resources.

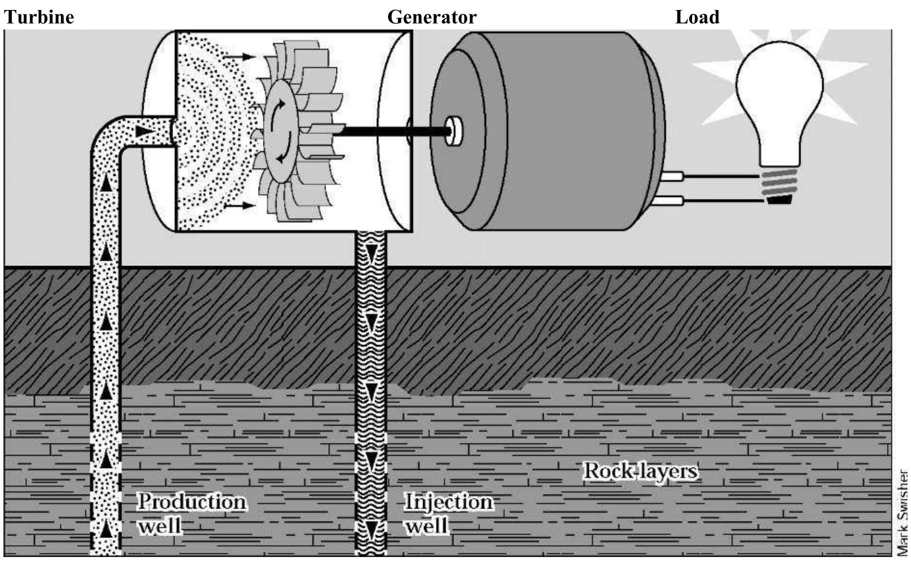
How clean? In terms of air emissions, geothermal power plants have an inherent advantage over fossil fuel plants because no combustion takes place. Geothermal plants emit no nitrogen oxides and very low amounts of sulfur dioxide—allowing them to easily meet the most stringent clean air standards. The steam at some steam plants contains hydrogen sulfide, but treatment processes remove more than 99.9% of those emissions. Typical emissions of hydrogen sulfide from geothermal plants are less than 1 part per billion—well below what people can smell. The low levels of air emissions produced are mostly carbon dioxide, which many people believe acts as a greenhouse gas to trap heat within Earth's atmosphere. Even so, geothermal plants emit minimal amounts of carbon dioxide—1/1000 to 1/2000 of the amount produced by fossil- fuel plants.

Geothermal water sometimes contains salts and dissolved minerals. In the United States, the geothermal water is usually injected back into the reservoir from where it came, at a depth well below ground-water aquifers, after its heat energy has been extracted. This recycles the geothermal water and replenishes the reservoir. However, some geothermal plants also produce some solid materials, or sludges, that require disposal in approved sites.

All U.S. geothermal power plants are located in the states of California, Nevada, Utah, and Hawaii—home to some of the most majestic scenery on Earth. It's fortunate, then, that these plants consume only a small amount of land, and can coexist with numerous other land uses, including agriculture, with minimal impact on the surrounding beauty.

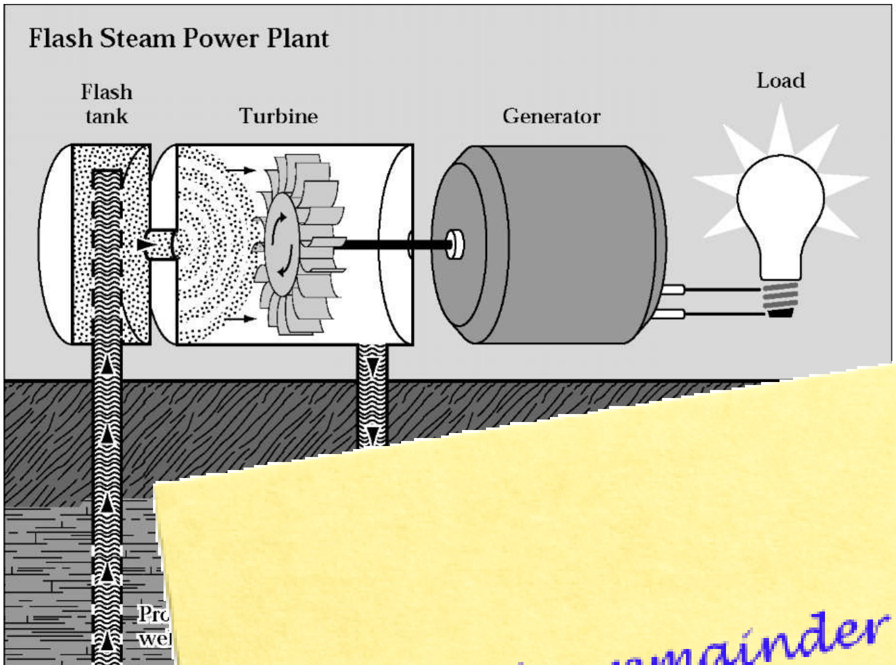
They're reliable and efficient, too. Taken as a group, geothermal power plants are available to generate power 95% or more of the time; they are seldom off-line for maintenance or repair. And, they have the highest capacity factors of all types of power plants. Capacity factor is the ratio of the amount of electricity a plant produces to how much electricity it is capable of producing.

Dry Steam Power Plant



A dry steam power plant draws steam from a hydrothermal production well and sends it to a turbine/generator. The steam turns the turbine to generate electricity and is then condensed and returned to the geothermal reservoir via an injection well.

Dry Steam Power Plants were the first type of geothermal power plant (in Italy in 1904). The Geysers in northern California, which is the world's largest single source of geothermal power, is also home to this type of plant. These plants use the steam



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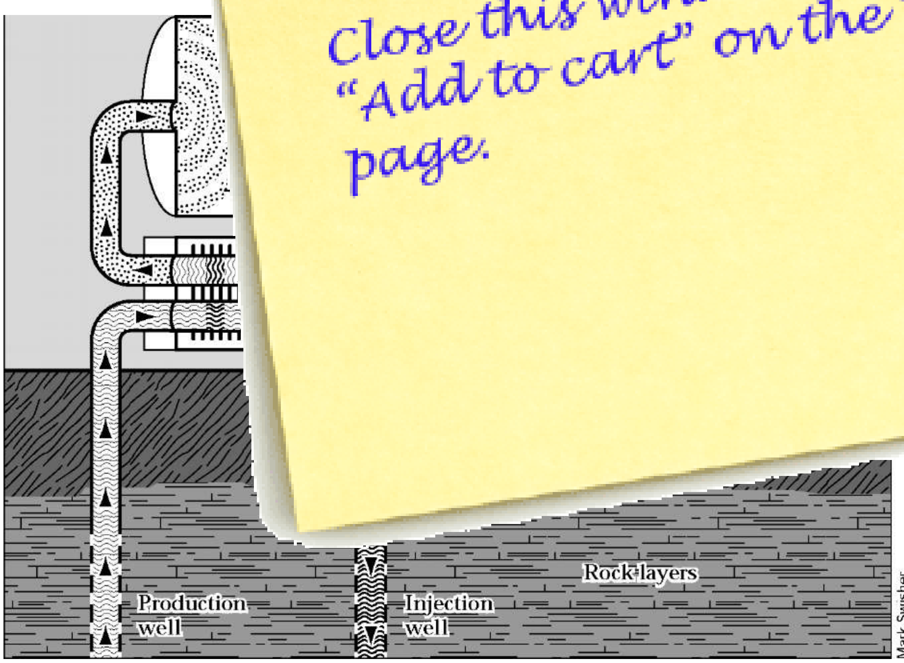
Binary Cycl



Using two closed loops, a binary cycle power plant pumps hot water from a hydrothermal production well to a heat exchanger where the geothermal water is used to boil a working fluid. The resulting working-fluid vapor turns a turbine/generator that generates electricity. After passing through the heat exchanger, the geothermal water is returned to the reservoir via an injection well, and the working-fluid vapor is condensed and recirculated through the working-fluid loop.

as it comes from wells in the ground, and direct it into the turbine/generator unit to produce power.

Flash Steam Power Plants, which are the most common, use water with temperatures greater than 360°F (182°C). This very hot water is pumped under high pressure to equipment on the surface, where the pressure is suddenly dropped, allowing some of the hot water to "fl..." into steam. The steam is then
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