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ENERGY EFFICIENCY AND RENEWABLE ENERGY CLEARINGHOUSE

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.

Dave Parsons / NREL / pix 01045

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.

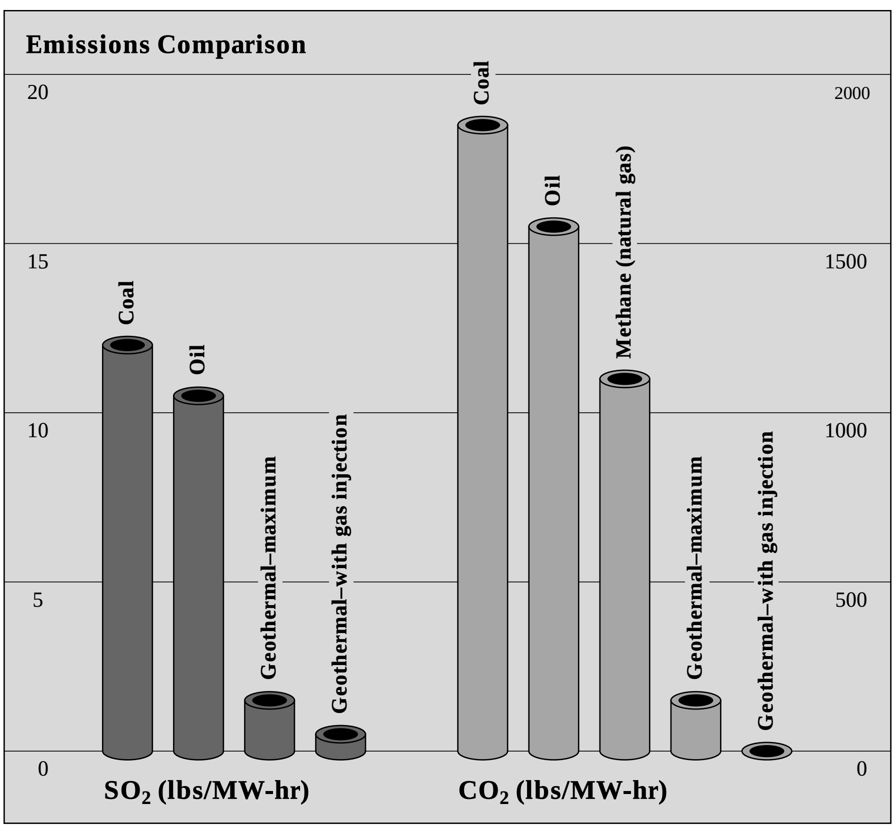
Geothermal energy use extends beyond underground reservoirs. The soil and near-surface rocks, from 5 to 50 feet deep, have a nearly constant temperature from geothermal heating. As a homeowner or business owner, you can use the Earth as a heat source or heat sink with geothermal heat pumps. According 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 house, and in summer they transfer heat from the house 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.

Perhaps you own a greenhouse and need to cut exorbitant energy bills in order to stay in business. If you are located near a geothermal resource, you should know that most greenhouse growers estimate that direct use of geothermal resources instead of traditional energy sources reduces heating costs by up to 80%. This can save about 5% to 8% in total operating cost.

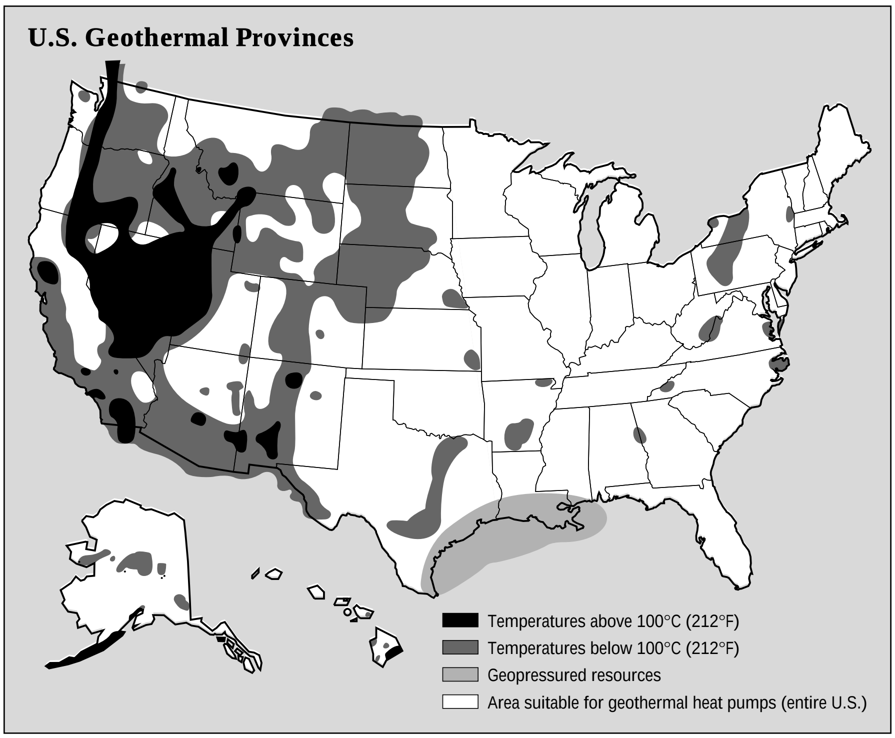
Assume you're a home or business owner who has installed a geothermal heat pump. You're not only doing your part to help make the world a cleaner place to live and breathe, you're rewarded with low operating and maintenance costs, and, usually, lowest life-cycle costs. (Life-cycle cost is the total cost of the equipment spread over the useful life of the equipment.) In practical terms, your heat pump investment may cost you $15 per month more in mortgage payments, but it may save you $30 per month on your electric bill.



Energy & Geoscience Institute, *Geothermal Energy*, February 1995.

Geothermal power plants produce significantly less sulfur dioxide (SO_2) and carbon dioxide (CO_2) than do conventional fossil-fueled power plants.

In all three of these cases, domestic, not foreign, resources are being used—a practice that has merits all its own. 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.



Energy and Geoscience Institute, *Geothermal Energy*, February 1995.

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 from 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 4¢ to 8¢ per kilowatt hour. The geothermal industry is working to achieve a geothermal life-cycle energy cost of 3¢ per kilowatt hour. And remember, this is clean energy produced from domestic resources.

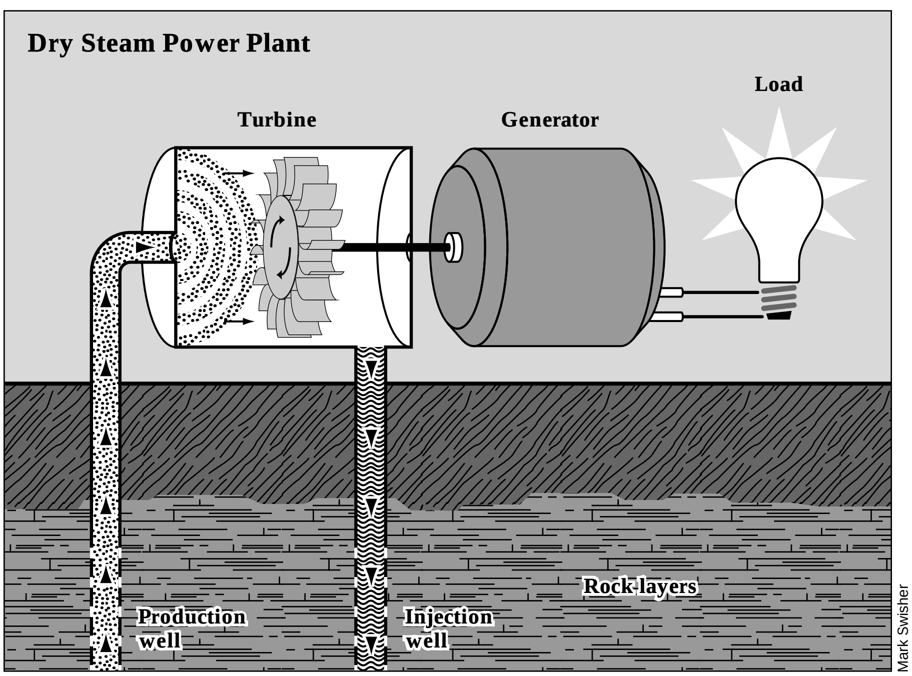
How clean? In terms of air emissions, geothermal power plants have an inherent advantage over fossil fuel plants because no combustion takes place. Geothermal plants emit no nitrogen oxides and very low amounts of sulfur dioxide—allowing them to easily meet the most stringent clean air standards. The 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 groundwater 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.

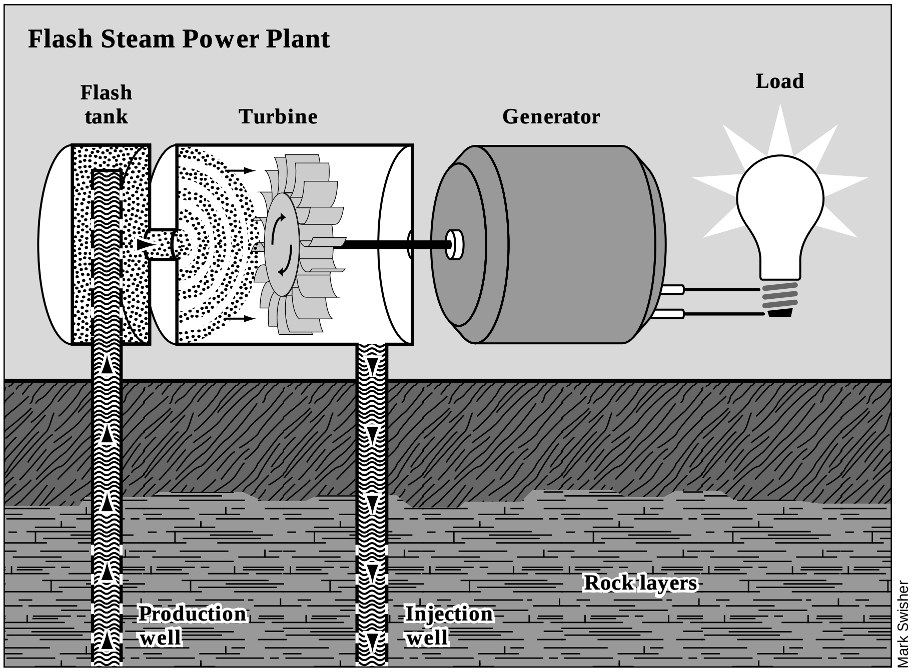
All U.S. geothermal power plants are located in the states of California, Nevada, Utah, and Hawaii—home to some of the most majestic scenery on Earth. It's fortunate, then, that these plants consume only a small amount of land, and can coexist with numerous other land uses, including agriculture, with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

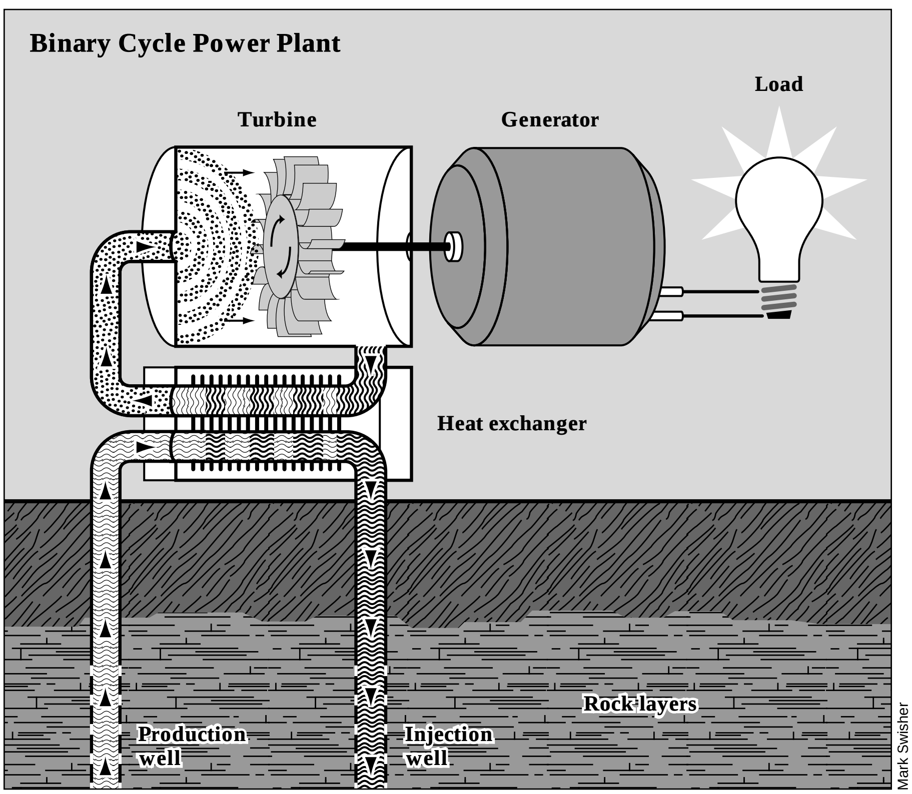
Dry Steam Power Plants were the first type of geothermal power plant (in Italy in 1904). The Geysers in northern California, which is the world's largest single source of geothermal power, is also home to this type of plant. These plants use the steam



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.



A flash steam power plant draws hot water from a hydrothermal production well to a flash tank where a drop in pressure "flashes" the water to steam. The steam turns a turbine/generator that generates electricity. The steam is then condensed and, with any hot water not flashed to steam, returned to the geothermal reservoir via an injection well.



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 "flash" into steam. The steam is then used to power the turbine / generator. The remaining hot water and condensed steam are injected back into the reservoir.

Binary Cycle Power Plants operate on the lower-temperature waters, 225° to 360°F (107° to 182°C). These plants use the heat of the hot water to boil a "working fluid," usually an organic compound with a low boiling point. This working fluid is then vaporized in a heat exchanger and used to turn a turbine. The geothermal water and the working fluid are confined to separate closed loops, so there are no emissions into the air.

Because these lower-temperature waters are much more plentiful than high-temperature waters, binary cycle systems will be the dominant geothermal power plants of the future.

Developing and commercializing geothermal power technologies contributes not only to a cleaner environment, but to a healthy U.S. industrial base, as well. Around the developing countries of the world, demand for electric power is burgeoning—and nearly half of these countries have geothermal resources. These markets have proven particularly receptive to clean energy produced with indigenous resources, creating attractive export options for geothermal technologies and expertise. In fact, U.S. geothermal companies have signed contracts worth more than $6 billion in the past few years to build geothermal power plants in some of these developing countries.

Direct Use of Geothermal Energy

If you've ever soaked in water from a natural hot spring, you're one of the millions of people around the world who has enjoyed the direct use of geothermal energy. And while this naturally occurring hot water may be the perfect tonic for frayed nerves and sore muscles, it's capable of much more.


Geo-Heat Center / pix 03705

The Milgro Nurseries' greenhouse near New Castle, Utah, is one of approximately 40 greenhouses nationwide that benefit from the direct use of geothermal energy.

The consumer of direct-use geothermal energy can reduce fuel costs by as much as 80%, depending on the application and the industry.

In the United States alone, direct geothermal applications (not including geothermal heat pumps) have an installed capacity of 500 thermal megawatts, which is roughly equivalent to saving half a million barrels of oil per year. This includes approximately 40 greenhouses, 30 fish farms, 190 resorts and spas, 125 space and district heating projects, and 10 industrial projects.

The resource required for these applications is widespread across the western third of the United States. This is water in an underground reservoir, at low-to-moderate temperatures usually ranging from 68° to 302°F (20° to 150°C). The consumer of direct-use geothermal energy can count on savings in energy costs—as much as an 80% reduction from traditional fuel costs, depending on the application and the industry. Direct-use systems typically require a larger initial investment, but have lower operating costs and no need for ongoing fuel purchases, therefore reducing life-cycle costs.

In a typical application, a well brings heated water to the surface; a mechanical system—piping, heat exchanger, controls—delivers the heat to the space or process; and a disposal system either injects the cooled geothermal fluid underground or disposes of it on the surface.

The direct use of geothermal energy offers some heartening possibilities. Imagine an entire community of people having their homes heated geothermally. Sound like something way off in the future? Not at all. In 1893, the citizens of Boise, Idaho, put their pioneering spirit to work and built the world's first geothermal district heating system by piping water from a nearby hot spring. Within a few years, the system was providing heat to 200 homes and 40 downtown businesses—and the system continues to flourish today.

There are now 18 district heating systems in the United States (including one in Klamath Falls, Oregon, that melts snow from the city's downtown sidewalks), and the potential for more is tremendous. A recently updated resource inventory of 10 western states identified 271 communities located within 5 miles (8 kilometers) of a geothermal resource.

Greenhouse operators are taking advantage of geothermal direct use in growing numbers, with nearly 40 greenhouses (many of which are several acres in size) producing vegetables, flowers, houseplants, and tree seedlings in eight western states. Operators of fish farms are profiting from the lower energy costs and improved fish growth rates that geothermal energy delivers. Other industrial and commercial applications that match well with geothermal direct use include food dehydration, laundries, gold processing, milk pasteurizing, and swimming pools and spas.

The Heat Pump Solution

The geothermal heat pump doesn't create electricity—but it greatly reduces consumption of it. If you would like to reduce the cost of heating and cooling your home, you might want to consider installing a geothermal heat pump, an economical and energy-efficient technology for space heating and cooling and water heating. Nationwide, more than 350,000 of these systems are in operation in homes, schools, and businesses. And the geothermal heat pump industry expects to be installing 40,000 systems per year by 2000.

In winter, heat pump systems draw thermal energy from the ambient temperature of the shallow ground, which ranges between 50° and 70°F (10° to 21°C) depending on latitude. In summer, the process is reversed to a cooling mode, using the ground as a sink for the heat contained within the building. The system does not convert electricity to heat; rather, it uses electricity to move thermal energy between the building and the ground and condition it to a higher or lower temperature according to the heating or cooling requirements. Consumption of electricity is reduced 30% to 60% compared to traditional heating and cooling systems, allowing a payback of system installation in 2 to 10 years. And these low-maintenance systems have long lives of 30 years or more. Some systems are also capable of producing domestic hot water at no cost in summer and at small cost in winter.

An analysis by the EPA found these systems to be among the most efficient space-conditioning technologies available—with the lowest environmental cost of all that were analyzed. But this might be the most compelling statistic: Surveys show that the number of satisfied geothermal heat pump customers stands at 95% or higher.

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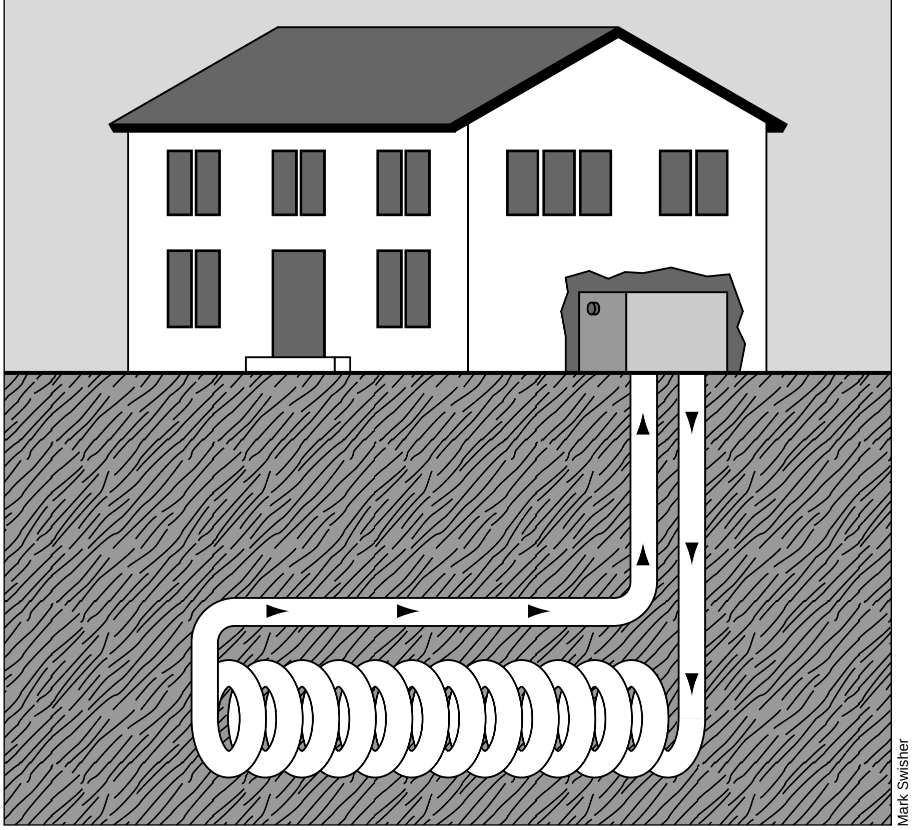
Geothermal Heat Pump



Geothermal heat pumps use the stable temperature of the shallow ground as a heat source to warm buildings in the winter and as a heat sink to cool them in the summer.

Source List

The following organizations serve as excellent resources for information on geothermal energy and its various applications.

U.S. Department of Energy (DOE)
Office of Geothermal Technologies, EE-12
1000 Independence Ave., S.W.
Washington, DC 20585-0121
(202) 586-5340
http://www.eren.doe.gov/geothermal/

Sponsors research to develop geothermal science and technology, and works closely with industry to develop advanced technologies and help commercialize research discoveries. Publishes brochures and newsletters focused on geothermal energy and applications.

Energy and Geoscience Institute
423 Wakara Way, Suite 300
Salt Lake City, UT 84108
(801) 581-5126
http://www.egi.utah.edu/

Conducts applied geoscience research pertaining to geothermal resources, fossil fuels, minerals, and environmental assessment; works cooperatively with universities, government agencies, national energy companies, and a global network of collaborating scientists. The institute has a professional staff of more than 40 scientists and engineers.

The Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048
Merrifield, VA 22116
(800) DOE-EREC (363-3732)
E-mail: doe.erec@nciinc.com

Provides free general and technical information to the public on the many topics and technologies pertaining to energy efficiency and renewable energy.

Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601-8801
(503) 885-1750
http://www.oit.osshe.edu/~geoheat/

Provides technical information regarding direct-use geothermal energy to consultants, developers, potential users, and the general public; information has been developed through extensive research and firsthand experience with hundreds of projects. Publishes a quarterly bulletin. The center's resources are available to the public through the auspices of DOE.

Geothermal Education Office
664 Hilary Drive
Tiburon, CA 94920
(800) 866-4GEO
http://geothermal.marin.org

Focuses on helping students learn about geothermal energy. Provides K-12 teachers and other interested parties with free booklets, posters, global statistical maps, and reference material. A grade school video, activity-packed curriculum , and a high school video with curriculum supplement are available at cost.

Geothermal Energy Association
122 C Street, N.W., Suite 400
Washington, DC 20001
(202) 383-2676
http://www.geotherm.org

Serves as the trade association for U.S. companies that support the use of geothermal resources worldwide. Assists the U.S. geothermal industry in the export of goods and services; interacts with federal entities, the financial community, and environmental and other renewable energy groups; and provides education, outreach, and publications about geothermal energy.

Geothermal Heat Pump Consortium, Inc.
701 Pennsylvania, NW
Washington, DC 20004-2696
(202) 508-5500
http://www.ghpc.org/

Provides extensive information regarding geothermal heat pumps. Web page contains case studies, published articles, list of service providers, and workshop schedules and locations. The consortium, established under President Clinton's "Climate Change Action Plan," has broad-based support and participation from DOE, the utility sector, and geothermal associations and manufacturers.

Geothermal Resources Council
2001 Second Street, Suite 5
Davis, CA 95617-1350
(916) 758-2360
http://www.demon.co.uk/geosci/grcdoc.html

Publishes a monthly bulletin (11 issues a year); provides videos, maps, and posters. Develops and convenes special meetings, workshops, conferences, courses, and symposia on a full range of subjects pertaining to geothermal exploration, development, and use. Periodically schedules a basic introductory course on geothermal energy.

International Geothermal Association
c/o Institute of Geological and Nuclear Sciences
Wairakei Research Centre, Private Bag 2000
Taupo, New Zealand
64-7-374-8211
http://www.demon.co.uk/geosci/igahome.html

Publishes the "IGA News" (quarterly). Provides information about geothermal industry associations worldwide. Encourages the development and use of geothermal resources worldwide through the compilation, publication, and dissemination of scientific and technical data and information. Organizes the international geothermal congress every five years.

International Ground-Source Heat Pump Association
490 Cordell South
Stillwater, OK 74078-8018
(405) 744-5175
(800) 626-4747
http://www.igshpa.okstate.edu/

Established in 1987 to advance geothermal/ground source heat pump technology on a local, state, national, and international level. Publishes "The Source," a bimonthly newsletter. Sponsors the annual Geothermal Heat Pump Technical Conference and Expo. Offers numerous booklets and brochures for contractors, homeowners, students, and the general public.