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Geothermal Heat Pumps

If you're planning to build a new house, office building, or school, or replace your heating and cooling system, you may want to consider a geothermal heat pump (GHP) system. GHP systems are also known as GeoExchange[SM], ground-source, or water-source heat pumps (as opposed to air-source heat pumps). Regardless of what you call them, energy-efficient geothermal heat pumps are available today for both residential and commercial building applications.

A GHP system can be installed in virtually any area of the country and will save energy and money. According to the Environmental Protection Agency (EPA), GeoExchange systems are the most energy efficient, environmentally clean, and cost-effective space conditioning systems available (source: "Space Conditioning: The Next Frontier," EPA 430-R-93-004, April 1993).

While residential GHP systems are usually more expensive initially to install than other heating and cooling systems, their greater efficiency means the investment can be recouped in two to ten years. After that, energy and maintenance costs are much less than conventional heating and air-conditioning systems.

When GHP systems are installed in commercial buildings, the state-of-the-art designs are extremely competitive on up-front costs when compared with cooling towers and boilers, and they have lower energy and maintenance costs.

In addition to their cost effectiveness, GHP systems offer aesthetic advantages, quiet operation, free or reduced-cost hot water, improved comfort, and a host of other benefits.

What Is a Geothermal Heat Pump?

Geothermal heat pumps are viable nationwide. They use the Earth as a heat sink in the summer and a heat source in the winter, and therefore rely on the relative warmth of the earth for their heating and cooling production. Through a system of underground (or underwater) pipes, they transfer heat from the warmer earth or water source to the building in the winter, and take the heat from the building in the summer and discharge it into the cooler ground. Therefore, GHPs don't *create* heat; they *move* it from one area to another.

Warren Gretz, NREL/PIX06534

For a home of 1,500 square feet with a good building envelope and a geothermal heat pump, energy costs are about one dollar a day.

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Geothermal heat pumps can reduce energy consumption—and corresponding air pollution emissions—up to 44% compared to air source heat pumps and up to 72% compared to electric resistance heating with standard air-conditioning equipment.

(Source: EPA, 1993)

How Do They Work?

Simply put, a GHP works much like the refrigerator in your kitchen, with the addition of a few extra valves that allow heat-exchange fluid to follow two different paths: one for heating and one for cooling. The GHP takes heat from a warm area and exchanges the heat to a cooler area, and vice versa. The beauty of such a system is that it can be used for both heating and cooling—doing away with the need for separate furnace and air-conditioning systems—and for free hot water heating during the summer months. For a more detailed explanation of how GHP systems work, see the sidebar on page 5.

Benefits of a GHP System

Low Energy Use

The biggest benefit of GHPs is that they use 25-50% less electricity than conventional heating or cooling systems. This translates into a GHP using one unit of electricity to move three units of heat from the earth. According to a report by Oak Ridge National Laboratory, statistically valid findings show that the 4,003-unit GHP retrofit project at Fort Polk, Louisiana, will save 25.8 million kilowatt-hours (kWh) in a typical meteorological year, or 32.5% of the pre-retrofit whole-community electrical consumption. This translates to an average annual savings of 6,445 kWh per housing unit. In addition, 100% of the whole-community natural gas previously used for space conditioning and water heating (260,000 therms) will be saved. In housing units that were all-electric in the pre-retrofit period, the GHPs were found to save about 42% of the pre-retrofit electrical consumption for heating, cooling, and water heating.

Free or Reduced-Cost Hot Water

Unlike any other heating and cooling system, a geothermal heat pump can provide free hot water. A device called a "desuperheater" transfers excess heat from the heat pump's compressor to the hot water tank. In the summer, hot water is provided free; in the winter, water heating costs are cut roughly in half.

Year-Round Comfort

While producing lower heating bills, geothermal heat pumps are quieter than conventional systems and improve humidity control. These features help explain why customer surveys regularly show high levels of user satisfaction, usually well over 90 percent.

Design Features

Geothermal heat pump systems allow for design flexibility and can be installed in both new and retrofit situations. Because the hardware requires less space than that needed by conventional HVAC systems, the equipment rooms can be greatly scaled down in size, freeing space for productive use.

And, geothermal heat pump systems usually use the existing ductwork in the building and provide simultaneous heating and cooling without the need for a four-pipe system.

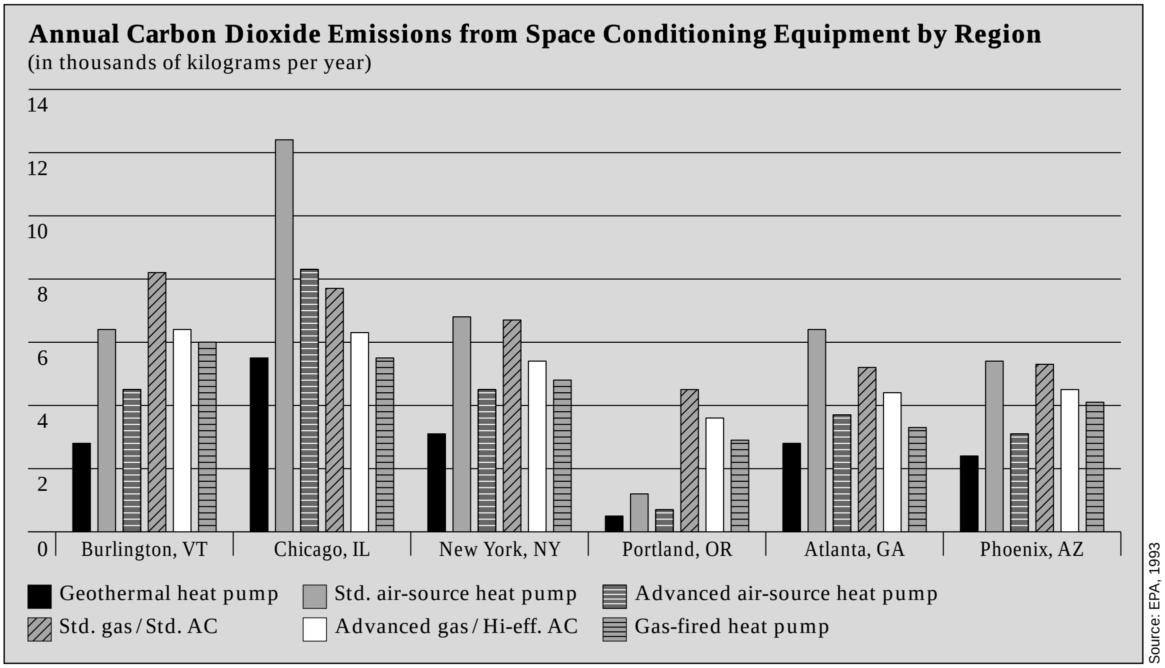
Improved Aesthetics

Architects and building owners like the design flexibility offered by GHPs. Historic buildings like the Oklahoma State Capital and some Williamsburg structures use GHPs because they are easy to use in retrofit situations and easy to conceal, as they don't require cooling towers.

GHP systems eliminate conventional rooftop equipment, allowing for more aesthetically pleasing architectural designs and roof lines. The lack of roof top penetrations also means less potential for leaks and on-going maintenance, and better roof warranties. In addition, the above-ground components of a GHP system are inside the building, sheltering the equipment both from weather-related damage and potential vandalism.

Low Environmental Impact

Because a GHP system is so efficient, it uses a lot less energy to maintain comfortable indoor temperatures. This means that less energy—often created from burning fossil fuels—is needed to operate a GHP. According to the EPA, geothermal heat pumps can reduce energy consumption—and corresponding emissions—up to 44% compared to air-source heat pumps and



GHP systems have the lowest carbon dioxide emissions of all the heating and cooling technologies.

A GHP system can be installed in virtually any area of the country and will save energy and money.

up to 72% compared to electric resistance heating with standard air-conditioning equipment.

Low Maintenance

According to a study completed for the Geothermal Heat Pump Consortium (GHPC), buildings with GHP systems had average total maintenance costs ranging from 6 to 11 cents per square foot, or about one-third that of conventional systems. Because the workhorse part of the system—the piping—is underground or underwater, there is little maintenance required. Occasional cleaning of the heat exchanger coils and regularly changing the air filters are about all the work necessary to keep the system in good running order.

Zone Heating and Cooling

These systems provide excellent "zone" space conditioning. With this, different areas of the building can be heated or cooled to different temperatures simultaneously. For example, GHP systems can easily move heat from computer rooms (which need constant cooling) to the perimeter walls for winter heating in commercial buildings. School officials like the flexibility of heating or cooling just auditoriums or gymnasiums for special events—rather than the entire school.

Durability

Because GHP systems have relatively few moving parts, and because those parts are sheltered inside a building, they are durable and highly reliable. The underground piping often carries warranties of 25 to 50 years, and the GHPs often last 20 years or more.

Reduced Vandalism

GHPs usually have no outdoor compressors or cooling towers, so the potential for vandalism is eliminated.

Installation

Because of the technical knowledge and equipment needed to properly install the piping, GHP system installations are not a do-it-yourself project.

To find a qualified installer, call your local utility company, the International Ground Source Heat Pump Association (IGSHPA—see *Source List*), or the Geothermal Heat Pump Consortium (GHPC—see *Source List*) for their listing of qualified installers in your area. Installers should be certified and experienced. Ask for references, especially for owners of systems that are several years old, and check them.

How GHPs Are Labeled

GHP efficiency is rated in two ways. The Coefficient of Performance, or COP, and Energy Efficiency Rating, or EER, are measures of heating and cooling efficiency, respectively.

Manufacturers of high-efficiency geothermal heat pumps voluntarily use the EPA ENERGY STAR® label on qualifying equipment and related product literature. If you are purchasing a geothermal heat pump and uncertain whether it meets ENERGY STAR® qualifications, ask for an efficiency rating of at least 2.8 COP or 13 EER.

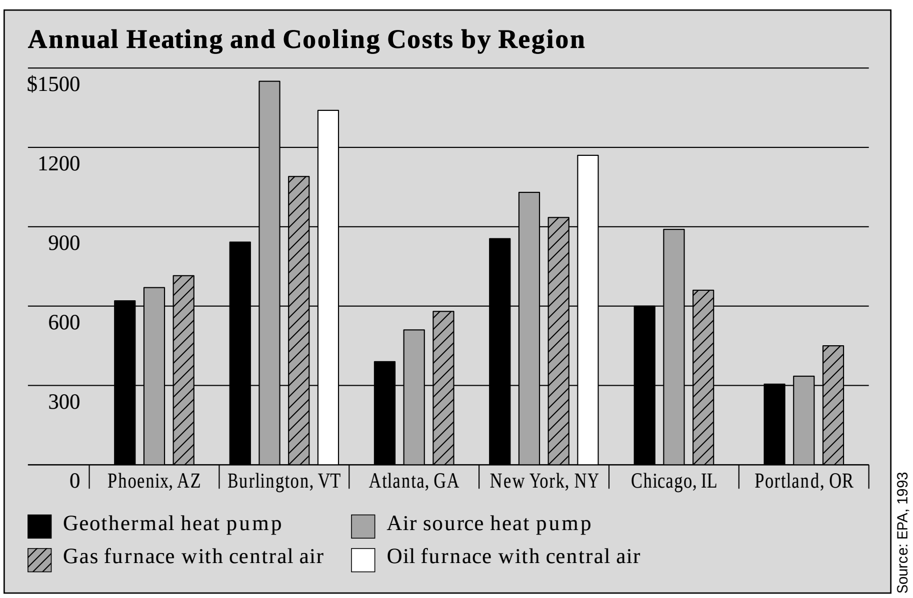
GHP systems have average total maintenance costs ranging from 6 to 11 cents per square foot, or about one-third that of conventional systems.

Financing a GHP System

Many geothermal heat pump systems carry the U.S. Department of Energy (DOE) and EPA ENERGY STAR® label. ENERGY STAR®-labeled equipment can now be financed with special ENERGY STAR® loans from banks and other financial institutions. The goal of the loan program is to make ENERGY STAR® equipment easier to purchase, so ENERGY STAR® loans were created with attractive terms. Some loans have lower interest rates, longer repayment periods, or both. Ask your contractor about ENERGY STAR® loans or call the ENERGY STAR® toll-free hotline at 1-888-STAR-YES for a list of financing options.

Homeowners should check with their utility and ask if they offer any rebates, financing, or special electric rate programs. Another way to help finance the purchase of a GHP system is to roll the cost into an "energy-efficient mortgage" that would cover this and other energy-saving improvements to the home. Banks and mortgage companies can provide more information on these loans.

These mortgages can create positive cash flow from the start. Say that installing a geothermal heat pump system adds $25 per month to the mortgage. However, because a GHP system is so efficient, it will save more than $30 per month in energy costs.



A GHP system can lower heating and cooling costs in all areas of the country.

DOE Spreads the Word about GHPs

In 1994, DOE, working closely with the Environmental Protection Agency, Edison Electric Institute, Electric Power Research Institute, International Ground Source Heat Pump Association (IGSHPA), National Rural Electric Cooperative Association, and industry, helped to create the Geothermal Heat Pump Consortium (GHPC). The GHPC launched the National Earth Comfort Program, designed to foster the development of a fast-growing, self-sustaining, national GHP industry infrastructure. DOE has also supported research and development activities, especially through IGSHPA; the American Society of Heating, Refrigeration, and Air-Conditioning Engineers; the National Ground Water Association; and DOE's national laboratories. The work has targeted several areas of GHP technology, lowering the cost of ground heat exchangers, and developing advanced design software.

In partnership with the GHPC, DOE's Office of Geothermal Technologies seeks to increase annual installations of GHP systems to about 400,000 by 2005 and reaching about 2 million installed (cumulative) that same year. Achieving the goal of 400,000 annual installations by 2005 will save consumers over $400 million per year in energy bills and reduce U.S. greenhouse gas emissions by over 1 million metric tons of carbon each year.

Install a GHP and Forget about High Energy Bills

With a geothermal heat pump system, you'll experience greater indoor comfort, lower energy bills, and a system that provides heating, cooling, and hot water for many trouble-free years to come.

How Does a GHP System Work?

The ground heat exchanger in a GHP system is made up of a closed or open loop pipe system. Most common is the closed loop, in which high density polyethylene pipe is buried horizontally at 4-6 feet deep or vertically at 100 to 400 feet deep. These pipes are filled with an environmentally friendly antifreeze/water solution that acts as a heat exchanger. In the winter, the fluid in the pipes extracts heat from the earth and carries it into the building. In the summer, the system reverses and takes heat from the building and deposits it to the cooler ground.

The air delivery ductwork distributes the heated or cooled air through the house's duct work, just like conventional systems. The box that contains the indoor coil and fan is sometimes called the air handler because it moves house air through the heat pump for heating or cooling. The air handler contains a large blower and a filter just like conventional air conditioners.

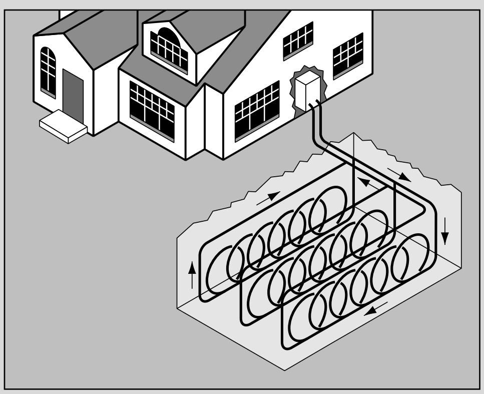
Installation Options

The installation of a GHP system is not for the do-it-yourselfer. Contact local utilities, IGSHPA (see *Source List*), and the GHPC (see *Source List*) for references on licensed and experienced installers. In addition, many states have Heat Pump Councils which may provide additional referrals.

There are four basic types of ground loop systems. Three of these—horizontal, vertical, and pond/lake—are closed-loop systems. The fourth type of system is the open-loop option. Which one of these is best depends on the climate, soil conditions, available land, and local installation costs at the site. All of these approaches can be used for residential and commercial building applications.

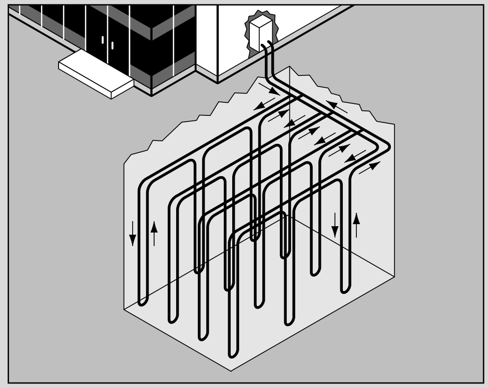
Closed-Loop Systems

Horizontal



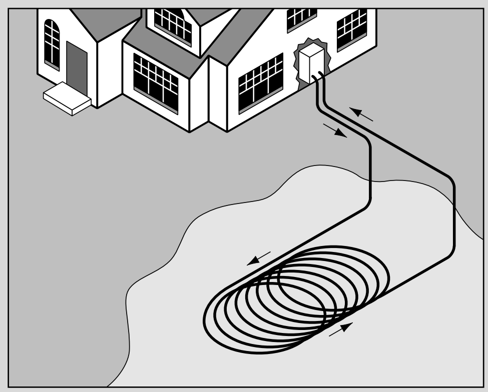
This type of installation is generally most cost-effective for residential installations, particularly for new construction where sufficient land is available. It requires trenches at least four feet deep. The most common layouts either use two pipes, one buried at six feet, and the other at four feet, or two pipes placed side-by-side at five feet in the ground in a two-foot wide trench. Or, the Slinky™ method (shown) of looping pipe allows more pipe in a shorter trench, which cuts down on installation costs and makes horizontal installation possible in areas it would not be with conventional horizontal applications.

Vertical



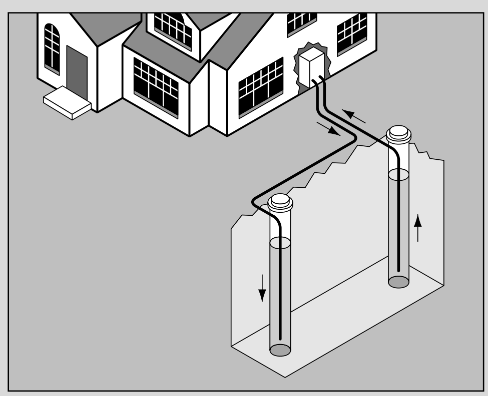
Large commercial buildings and schools often use vertical systems because the land area required for horizontal loops would be prohibitive. Vertical loops are also used where the soil is too shallow for trenching, and they minimize the disturbance to existing landscaping. For a vertical system, holes (approximately four inches in diameter) are drilled about 20 feet apart and 100 to 400 feet deep. Into these holes go two pipes that are connected at the bottom with a U-bend to form a loop. The vertical loops are connected with horizontal pipe (i.e., manifold), placed in trenches, and connected to the heat pump in the building.

Pond/Lake



If the site has an adequate water body, this may be the lowest cost option. A supply line pipe is run underground from the building to the water and coiled into circles at least eight feet under the surface to prevent freezing. The coils should only be placed in a water source that meets minimum volume, depth, and quality criteria.

Open-Loop Systems



This type of system uses well(s) or surface body water as the heat exchange fluid that circulates directly through the GHP system. Once it has circulated through the system, the water returns to the ground through the well, a recharge well, or surface discharge. This option is obviously practical only where there is an adequate supply of relatively clean water, and all local codes and regulations regarding groundwater discharge are met.

In Lincoln, Nebraska, not only is the school district benefitting from the savings of GHP systems, but the taxpayers are, too. With cooperation from Lincoln Electric Systems and Lincoln Public Schools, four elementary schools recently installed GHP systems. The heating and cooling costs are about $144,000 a year less (for 1996–1997) than they would have been if those schools installed more traditional heating and cooling systems. These savings will reach about $3.8 million over just 20 years, allowing for other capital improvements to be realized.

Compared to natural gas HVAC systems (air-cooled, variable air volume systems) that were installed in two other schools at the same time, the schools had a total energy cost savings of 57%. There were also 42% and 20% reductions in electrical demand and electrical energy consumption, respectively. Not only will the school district taxpayers save about $3.8 million over the next 20 years, but the GHPs also help reduce peak demand for electricity compared to alternative systems.

PIX06649

Cavett Elementary School in Lincoln, Nebraska, is one of several Lincoln schools that saves money and energy with GHP systems.

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 Avenue, SW
Washington, DC 20585-0121
(202) 586-5340
http://www.eren.doe.gov/geothermal/

Sponsors research to improve GHP technology, and works closely with industry to develop design tools and advanced technologies, and provides technology transfer.

The Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048
Merrifield, VA 22116
(800) DOE-EREC (363-3732)
Fax: (703) 893-0400
http://www.eren.doe.gov/consumerinfo/
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 GHPs to consultants, developers, potential users, and the general public; information has been developed through extensive research and first-hand experience with hundreds of projects. Publishes a quarterly bulletin. The center's resources are available to the public through the auspices of DOE.

Geothermal Heat Pump Consortium, Inc. (GHPC)
701 Pennsylvania Avenue, NW
Washington, DC 20004-2696
(888) ALL-4-GEO (255-4436)
http://www.geoexchange.org/

Provides extensive information regarding geothermal heat pumps, including consumer brochures, technical reports, and a database of installers. The Web page contains case studies, published articles, list of equipment suppliers, and workshop schedules and locations. The GHPC has broad-based support and participation from DOE, the utility sector, and geothermal associations and manufacturers.

International Ground Source Heat Pump Association (IGSHPA)
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. Provides a list of equipment manufacturers, a state-by-state list of installers, and numerous design manuals and brochures for contractors, homeowners, students, and the general public.