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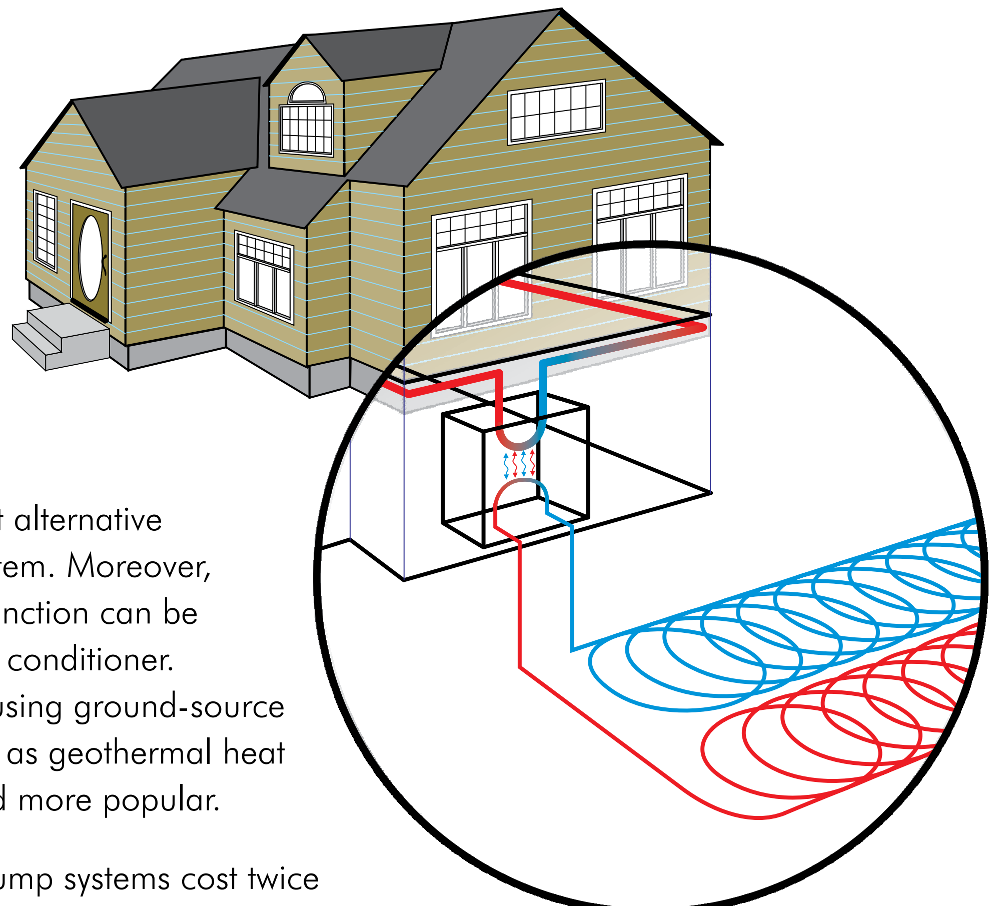
Ground-source Heat Pumps



Reviewed by

Kenneth Hellevang, Ph.D., P.E
Extension Engineer
and Professor

A heat pump can be an efficient alternative to a standard home heating system. Moreover, during the cooling season, its function can be reversed, and it becomes an air conditioner. Heating and cooling buildings using ground-source heat pump systems (also known as geothermal heat pumps) are becoming more and more popular.

Typically, ground-source heat pump systems cost twice as much as conventional heating and cooling systems as a result of the cost of the outside piping to install but cost three to four times less to operate.

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North Dakota State University
Fargo, ND

The Basics

To understand how a heat pump works, think about your refrigerator. It pulls heat from inside the refrigerator and releases the extracted heat to the area around the refrigerator, keeping food cool. The mechanical device that performs this function is a heat pump.

Heat pumps heat or cool a building by moving heat from one location to another. In the winter, they move heat from the air, ground or a water source into a building, where it is concentrated to provide heating. In the summer, the process can be reversed and the heat from a building is removed, cooling the building. For purposes of this publication, the information will concentrate mainly on the heating aspects of heat pumps.

Heat pumps are available in two types for home heating and cooling: air source and ground source. An air-source heat pump extracts heat from the air, concentrates it (even when that air is cool) and transfers it to the indoors or outdoors, depending on the season. These units generally are more suited to mild climates for heating because their capacity is limited. Air temperatures fluctuate considerably, but the temperature just a few feet underground is very stable. A ground-source heat pump extracts heat from this more consistent source of heat.

Ground-source heat pumps often are equipped with a desuperheater, which uses excess heat to produce domestic hot water (Figure 1).

Figure 1. Forced-air heat pump with desuperheater.

Components

Ground-source heating systems generally require three main components: the heat exchanger (ground loop), a heat pump (condensing unit) and a distribution system such as air ducts or in-floor tubing (Figure 2).

The heat exchanger or loop is simply a length of tubing placed underground and used to transfer the heat from the ground to the heat pump. The heat pump concentrates the heat using a condensing unit. In the winter, that heat is transferred to the distribution system and released through the building's air ducting systems or in-floor hot water (hydronic) heating system. The process can be reversed for cooling.

A water-antifreeze mixture is used as the transfer medium between the heat source (the ground) and heat pump. The heat pump concentrates the heat and disperses it into the home. Household air is never in direct contact with the heat source (air, soil or water).

Other names

People often confuse geothermal energy, ground-source heating systems and geothermal/ground-source heat pumps. Geothermal simply means "earth heat" (geo earth, thermal - heat). So geothermal energy is energy produced from an earth-based source, such as when underground steam supplies are used to convert heat energy to electricity. Ground-source heat pumps do not create energy but simply move heat energy from one location to another, such as moving heat in the ground into a home. Geothermal/ground-source heat pumps are the actual condensing units in the home that concentrate

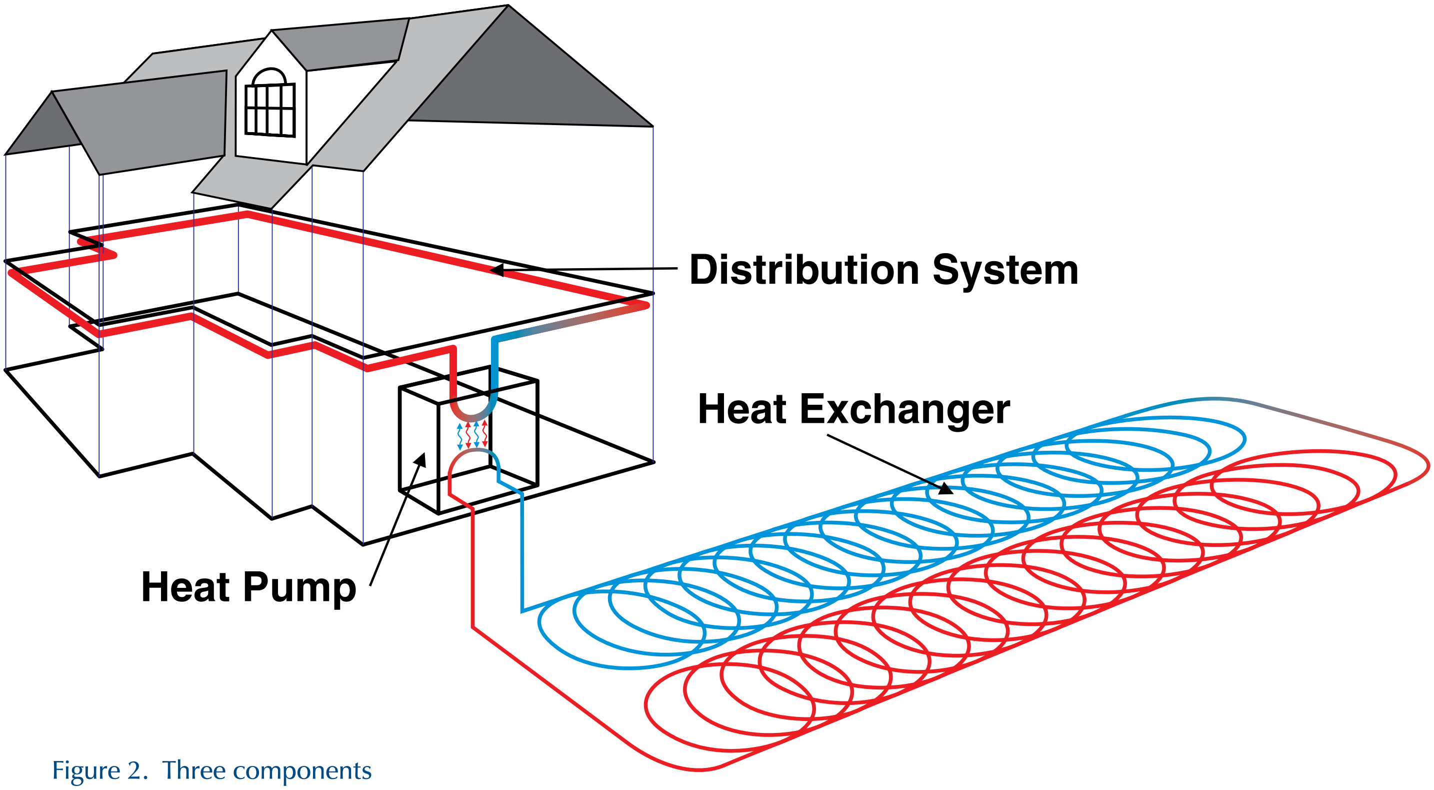

Figure 2. Three components

the heat. Ground-source heating systems also are known by a variety of other names. Some of the other names you could see include ground-coupled heat system, GeoExchange and earth energy systems.

Installation

Ground-source heat exchangers can be installed in a variety of ways. The majority of installations are closed-loop that involves the installation of a sealed loop of piping through which a liquid solution is circulated to exchange heat (Figure 3). Some open-loop systems circulate water from a lake, pond, stream or well. Open-loop systems are limited due to the lack of water and problems related to the pipe clogging. In either application, the piping is used to transfer the heat. For closed-loop systems, the pipes can be installed either

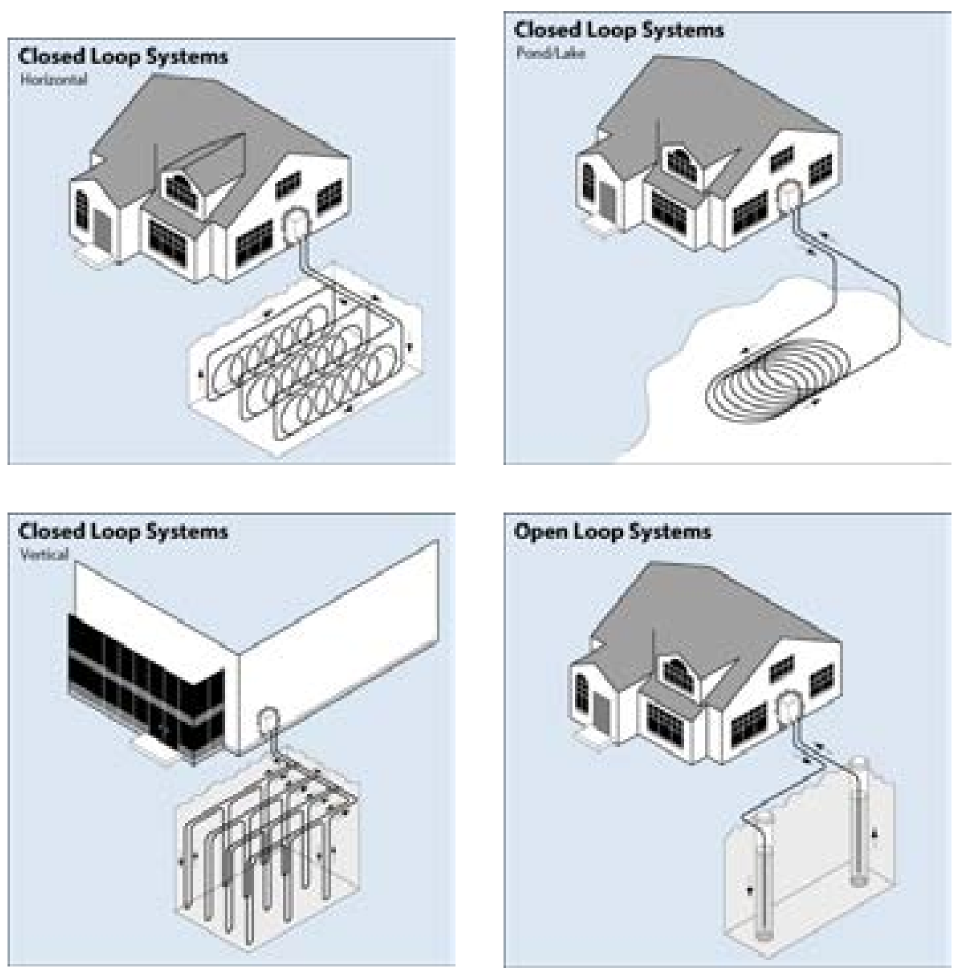

Figure 3. U.S. Department of Energy

horizontally or vertically in the ground or in a pond or lake.

If the building is on a large lot, the tubing can be installed in a horizontal trench. The trench depth varies depending on the frost line in your area. In North Dakota, depths of 6 to 10 feet are typical. Trenches are dug and pipe of the correct diameter is installed. The compaction of the soil around the pipe is critical to ensure efficient heat transfer between the pipe and the ground.

Overlapping the piping, such as installation in a "slinky" configuration, will reduce the efficiency of the heat exchanger but may be a necessary tradeoff to take advantage of available space (Figures 4 and 5).

For installations where the land area is not available, vertical bore holes are used and the pipe is installed in the vertical bore holes or wells. The wells are generally around 200 feet deep in North Dakota and are placed approximately 15 feet apart.

The vertical pipes are connected in parallel to make the flow loops essentially equal. Grout is used in the bore holes to ensure good heat transfer between the pipe and the ground.

For horizontal and vertical installations, the buried pipe is connected to a manifold of larger diameter pipe and runs into heating equipment in the building.

Vertical ground-source heat exchange installations can be seen in Figures 6 and 7.

Figure 4. Horizontal "slinky" system installation (before)

Figure 5. Horizontal ground loop (after)

Figure 6. Drill rig installing vertical ground loop

Figure 7. Installed vertical ground loop

Advantages

Ground-source heating systems have numerous advantages over other types of heating systems. The efficiency is the main advantage. Ground-source heat pumps simply pump heat from one area to another and, as a result, use considerably less energy than other systems. Since they are using less energy, they can be considerably more economical to operate.

Reliability is another important advantage. The systems have few moving parts that can wear out, so the mechanical parts typically have warranties of up to 10 years, and the ground loop piping can be warranted for up to 50 years.

Another advantage is that these systems have no mechanical parts outside of the home, so they are not subject to the weather or physical damage from vandalism or poorly driven lawnmowers.

Ground-source heat systems are able to provide heat as well as cooling for a building simply by reversing the direction of flow within the heat pump. The ability of the units to provide warm or cool air also allows for zone temperature control in larger buildings. These systems can heat one portion of a building and provide cool air in another.

Excess heat from the ground-source system also can provide domestic hot water to a building. Generally this is most efficient in the summer, when buildings have excess heat.

Disadvantages

Depending on the installation, ground-source heating systems will have a higher initial installation cost than other types of heating systems. They should make up for the extra initial investment through operational savings through time if designed and installed properly

The air supplied to the home from a heat pump is generally at a lower temperature than a gas forced-air furnace or electric-resistance heater requiring a higher amount of air to be circulated through a building. If the building was not constructed efficiently, the system may not be able to supply enough heat to the structure unless the system is oversized, which can add considerable installation cost.

Proper home air sealing and insulation is essential to ensure a return on investment for ground-source heat pumps, as with any other heat source.

Sizing

Sizing of the systems is done by determining the heating or cooling loads that are needed for the building. Homeowners have a variety of ways to do this. Energy experts highly recommend that heating and cooling load calculations be done by a qualified professional. Simply sizing the system on the square footage of the building is not satisfactory and could result in comfort and efficiency issues. For far northern climates, units often are sized based on the heating needs, while in southern, warmer climates, the units are sized for air conditioning and humidity removal.

Depending on the climate of an area and the design of the building, backup heating systems can be installed to provide supplemental heat when the temperature drops below certain levels, which can add to the cost.

Cost

The total cost for an outdoor ground loop, indoor heat pump and distribution system can range from about $15,000 to $30,000 for residential installations. Federal and state tax incentives in addition to local utility rebate programs can reduce this cost by about one-third.

How much money can you save with a ground-source heating system? Individual results will vary, but savings of 25 percent to as high as 60 percent are not unusual when compared with a conventional electrical-resistance furnace or electric baseboard heat.

For climates with a moderate heating load, choose ENERGY STAR-rated systems. In colder climates, heaters exceeding ENERGY STAR performance criteria will be justified economically.

The payback time depends on a number of factors such as the cost of electricity, equipment and installation costs, as well as the number of incentives and rebates used to reduce the initial cost.

Efficiency

A ground-source heating system's efficiency is reported in a unit called the coefficient of performance (COP). As an example, if a unit has a reported COP of 3.0, this means the heat pump moves three times the amount of heat energy into the building as the electrical energy required to operate to the system. The heat pump effectively would have an efficiency of 300 percent, compared with electric-resistance heat. Typically COPs range from 3.0 to as high as 5.0. COPs of installed systems would be lower depending on a variety of factors such as proper sizing of equipment, quality of installation and thermal conductivity of the ground.

Resources

For a list of qualified contractors, consult the International Ground Source Heat Pump Association accredited installers, designers and contractors directory.

www.igshpa.okstate.edu

The U.S. Department of Energy has created a Database for State Incentives for Renewables and Efficiency to help find assistance in your state.

www.dsireusa.org

ENERGY STAR also has provided information for federal tax incentives for efficient heating systems.

www.energystar.gov

Ground-source heat pump case study: Bismarck, N.D.

House description:

- 2,200-square-foot rambler with no basement built in 2005 (Figure 8)
- Triple-pane windows and 2- by 6-inch exterior wall construction with spray foam insulation

Heating and cooling equipment installed: Dual-fuel forced-air heating system

- Four-ton forced-air ground-source heat pump (primary heating and cooling)
- Natural gas forced-air furnace backup (has not been needed)

Qualifies for off-peak electric winter heating rate:

- Average $.04 per kilowatt

Average monthly heating costs:
$32 per month
October to April

Installation cost in 2005:

- $19,000 for equipment and installation, $5,000 for the four heat-exchanger wells

Estimated comparable cost in 2018:

- $25,000 for equipment and installation, $7,000 for four heat-exchanger wells

Figure 8. Bismarck home with ground-source heat pump

While these numbers may be considered "typical" for the climate zone, each individual situation needs to be considered separately. Factors such as building construction, homeowner lifestyle and local energy costs can affect heating expenditures considerably.

For more information about energy from the NDSU Extension Service:

www.ndsu.edu/energy

This publication was authored by Carl Pedersen, former Energy Educator

Contributor/Reviewer: Joe Ponessa, Ph.D.
Reviewer: Randy Mathern, Bismarck, N.D.
Based on AE-918, "Ground Coupled Heat Pumps," authors Lambert Vogel and Harvey Hirning

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