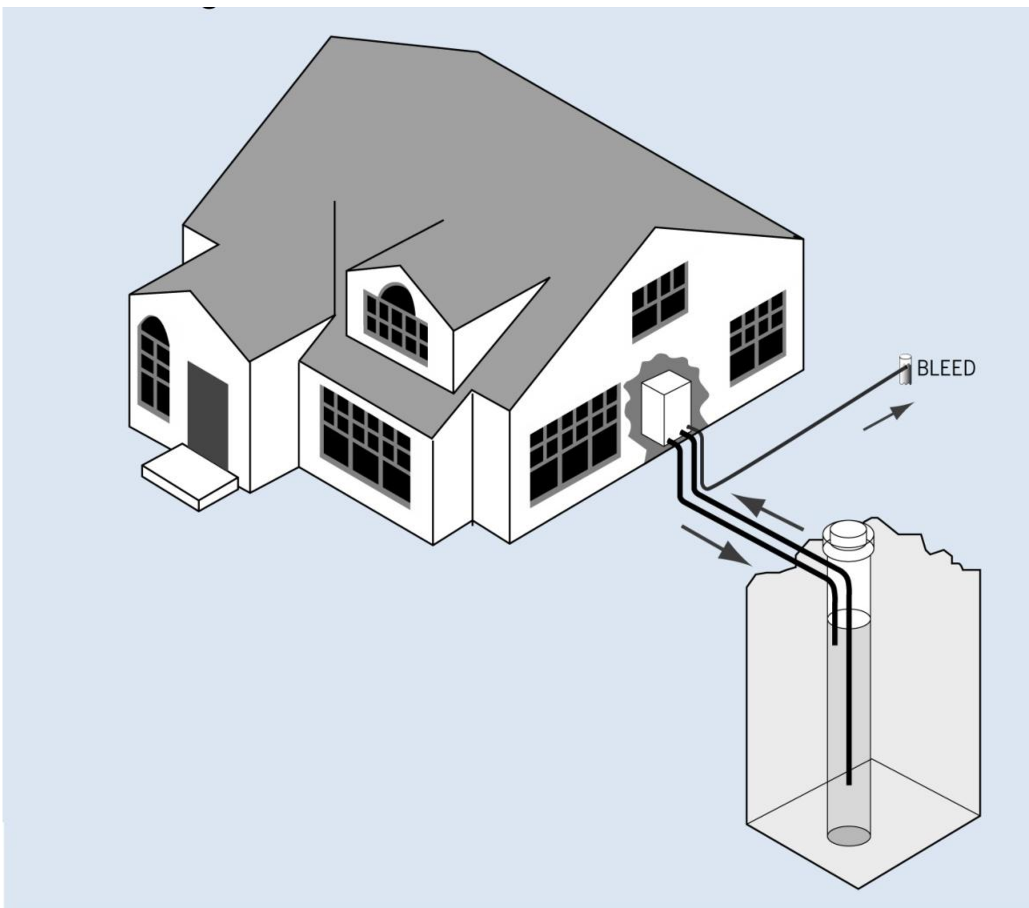
Heating Your Home or Business in Vermont with a Geothermal System



Modified by Green Mountain Geothermal, based on DOE diagram

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Comments and suggestions on this guide are welcome: Please send email to ben.luce@lyndonstate.edu.

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About the NVDA: Formed in 1950, at the same meeting where U.S. Senator George D. Aiken coined the term "Northeast Kingdom" to describe Caledonia, Essex and Orleans counties, the Northeastern Vermont Development Association has served the people, municipalities and businesses of this region as both the Regional Planning Commission and Regional Development Corporation.

As the Regional Planning Commission, NVDA assists municipalities, organizations, committees and individuals with a wide variety of planning and technical services. From assisting municipalities with regulatory options, to administering grants, creating maps, and implementing transportation and natural resource plans, NVDA is actively working with land use issues in the region.

As the Regional Development Corporation, NVDA works on infrastructure improvements, assists companies relocating to the area, helps existing businesses to grow, and administers revolving loan funds. NVDA also fosters key partnerships with the Small Business Development Center, the Northeast Kingdom Collaborative, the Northeast Kingdom Travel and Tourism Association, and the various Chambers of Commerce in the region.

Please visit www.nvda.net for more information.

Introduction to Geothermal/Ground Source Heat Pumps

Geothermal or "ground-source" heat pump systems can be used to heat and/or cool buildings. If equipped with a so-called "**desuperheater**", they can also contribute substantially (if not entirely) to domestic hot water heating.

Is a geothermal system right for you? This guide provides essential information in a step-by-step format for evaluating the feasibility of and for obtaining geothermal heating systems in Vermont. There are separate guides for wood stoves and pellet stoves in this series, as well as guides for obtaining power from photovoltaic and wind energy systems, and hot water from solar hot water systems. Please visit www.nvda.net to obtain these.

Simply put, geothermal systems extract natural, low temperature thermal energy from the ground during colder months for heating, and transfer thermal energy from the building to the ground in warm months for cooling. Most of the heat provided by a geothermal system is actually **solar energy** that has diffused into the ground, and which is replaced quickly when removed by a heat pump. Thus heat pump systems can be considered a ***renewable*** energy source, except for the electrical energy needed to power them, which may or may not be renewable.

Will this harm the ground environment? Because solar energy diffuses in quickly to replace thermal energy removed by these systems, the ground environment will not be harmed by their operation. There are other environmental risks, which are discussed later, and which can be minimized if proper precautions are taken.

Note that the type of low temperature geothermal heat we are considered here should be clearly distinguished from the high temperature geothermal resources used to produce electrical power in some regions. High temperature geothermal energy is only economic to obtain where it's available close to the Earth's surface, which occurs only in some regions (e.g. Iceland), whereas low temperature geothermal heat is available essentially everywhere.

The "**heat pump"** itself, the heart of a geothermal system, is a device consisting of pipes, heat exchangers (which also serve as evaporators and condensers), and a compressor. These components are housed in a cabinet, typically cubic in shape, and a few feet on a side. Some "**water-to-air**" units also have an "**air handler**" attached, which produces hot air for distribution in a forced air distribution system (the heating ducts), while other so-called **water-to-water** systems produce hot water which is either supplied to an in-floor or radiant heating system, or to an air-handler placed elsewhere in a building's forced air distribution system.

These photos show what heat pumps actually look like. The first is a Climatemaster brand water-to-water heat pump (without an air handler) in a residential setting. This system feeds a radiant floor and also a hot water tank.

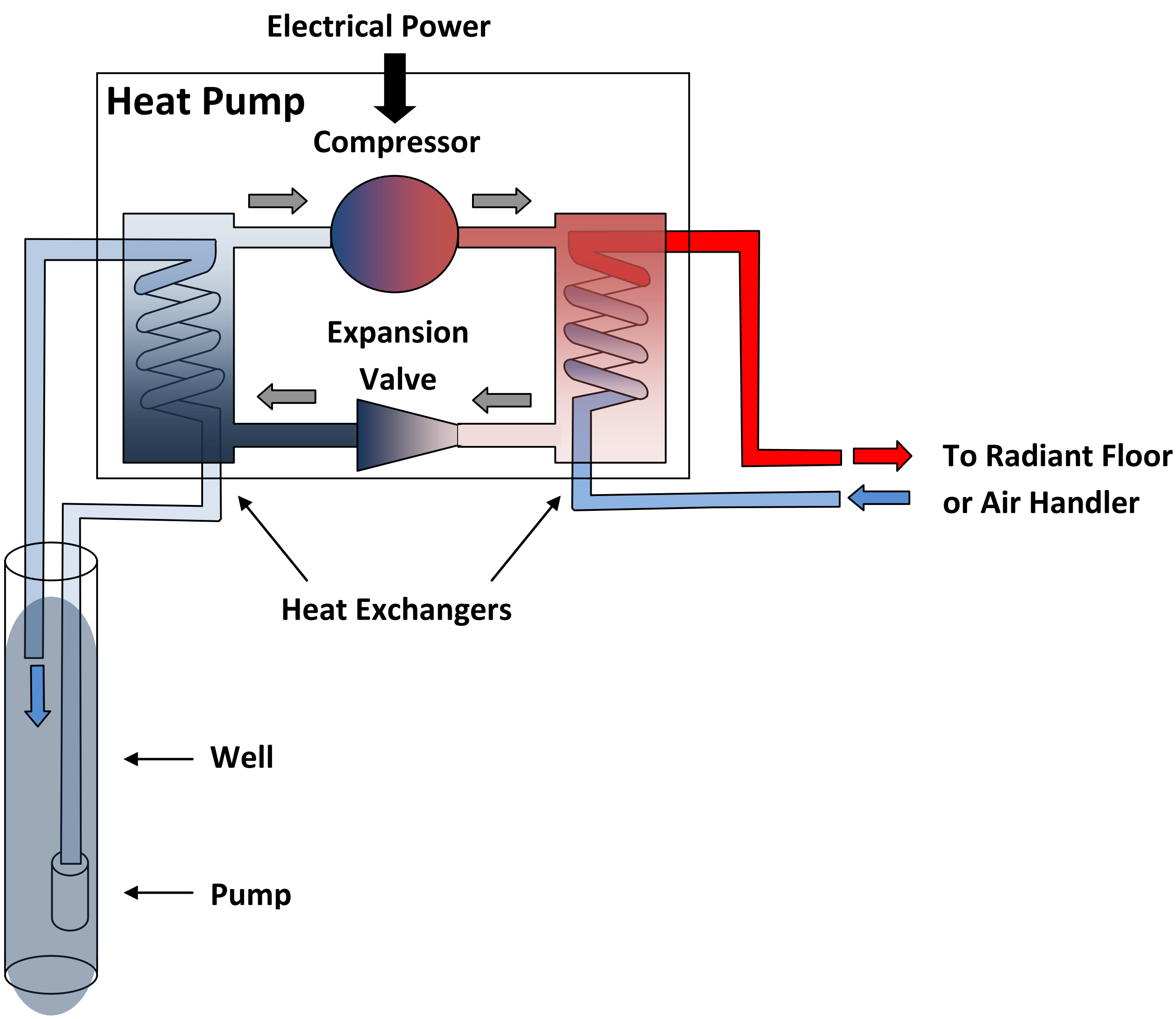
The next photo is a Climatemaster brand water-to-air heat pump (with an air handler) in a residential setting. Note the air duct coming out of the air handler on the top. The heat pump also provides domestic hot water heating.

This photo shows a commercial heat pump installation. Multiple heat pumps combine to create a system large enough to heat the entire building.

How Geothermal Systems Work

Heat pumps function much like a refrigerator: A refrigerant cycle inside the heat pump cabinet, driven by a compressor powered with electricity, accomplishes the heat transfers between the various fluids coming into and out of the cabinet. The following schematic illustrates the basic process in detail for an open loop system:

Schematic Diagram of an Open Loop Geothermal System in Heating Mode



Here, well water is pumped through a heat exchanger, where heat flows from the well water into the cold refrigerant. The refrigerant is then compressed, which greatly raises its temperature. The refrigerant, which is now hot and vaporized, then loses it heat in the second heat exchanger to water which is then circulated either under a radiant floor or into an air handler.

Types of Ground Source Heat Pumps

There are two basic categories of geothermal systems, **closed loop and open loop systems**:

Open Loop Systems: These include "Standing Column Well" and (open) "Pond" systems

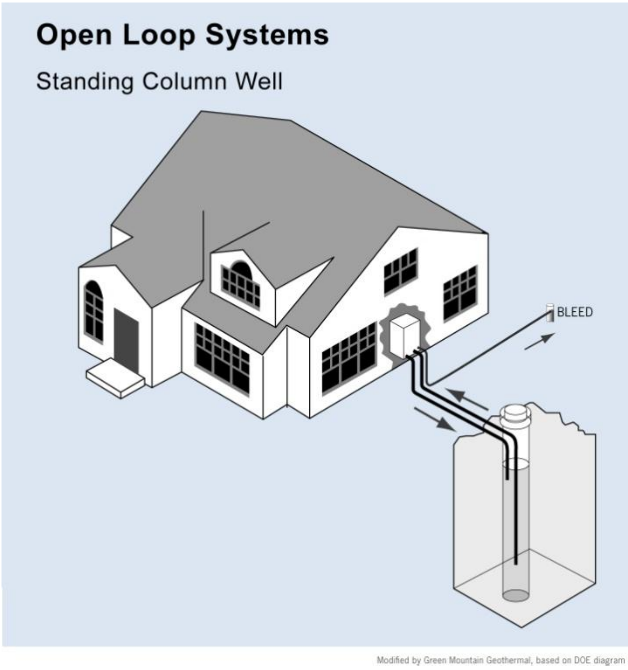
- In **Standing Column Well Systems**, water is drawn from the bottom of a deep rock well, and and returned to the top of the well. As the returned water travels downwards, it exchanges heat with the surrounding bedrock. Water can also be returned to a **recharge well**, or in some cases **discharged on the surface**. Surface water, such as a pond, can also be used and returned to the same water body or discharged elsewhere.
- Standing column well systems often employ a "**bleed**" whereby a (small) percentage of the well water is diverted and discharged to the surface, which causes other groundwater to diffuse towards the well, which hence increases the temperature in the well. This increases the efficiency of the system, and also helps prevent freezing (there is no anti-freeze in these systems).
- The well water thus diverted can also be used in the domestic water supply for the building. See diagrams below.

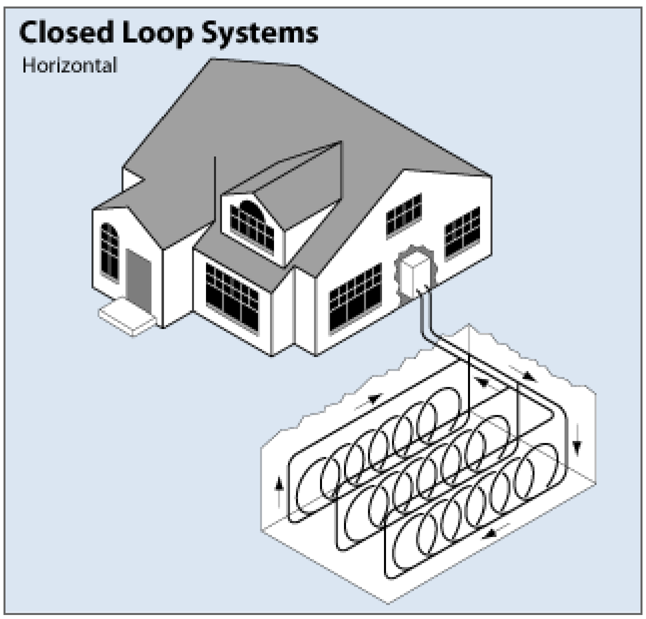
Closed Loop Systems: These include "Horizontal", "Vertical", (closed) "Pond", and "Direct Exchange" systems.

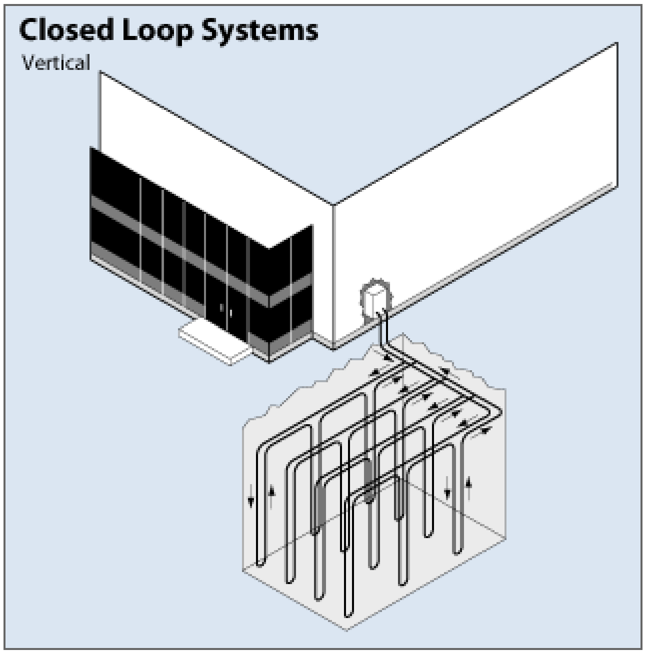
- Water, **with or without antifreeze**, is circulated in a closed loop underground or in a pond to collect geothermal heat in cold months and disperse heat to the ground in warmer months. The underground piping can be laid out **horizontally** in trenches at least four feet deep, often in a coiled or "**slinky**" fashion so as to make maximum use of the trenches, or the piping can be laid out **vertically** in holes 100-400 feet deep, with **U-joints** at the bottom, spaced roughly 20 feet apart. Piping can also be placed in **ponds**, if such a water body exists nearby. See diagrams below.
- In so-called "**Direct Exchange**" or **"DX"** closed loop systems, the refrigerant is circulated directly in the ground in copper or steel pipes, which enables a high efficiency (but requires lots of refrigerant and metal piping).

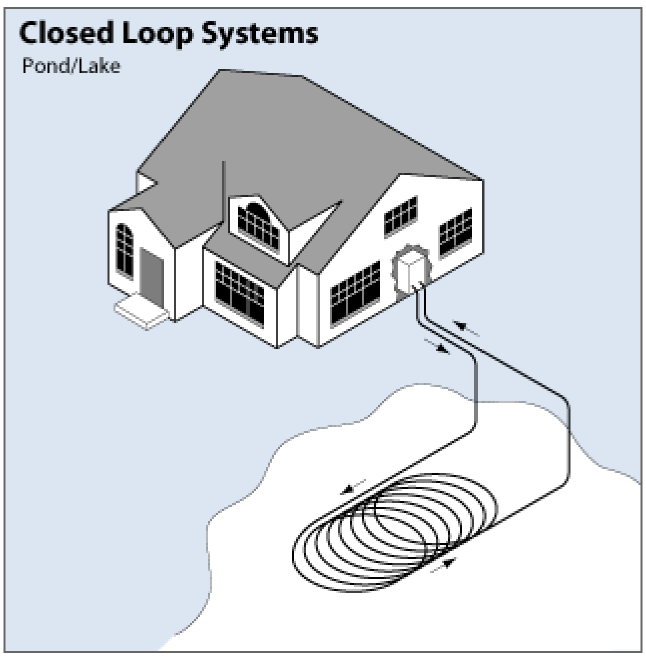
In general, for reasons explained below, open loop systems are more efficient than (non DX) closed loop systems, and are often cheaper to install because they require less piping and excavation. Moreover, standing column wells can be constructed virtually everywhere in Vermont. But not all sites can accommodate open systems, for example due to hydro-geological reasons, and in some ways closed loop systems can be simpler to install, for example because hydro-geological assessments are not needed. <u>In any case, open loop systems should be considered first, closed loop systems second.</u> This is contrary to the general trend in the Southern US, where many closed loop systems are installed for mainly cooling purposes.

The following diagrams of ground source heat pumps are from the Dept. of Energy (http://www.energysavers.gov):


Open Loop Systems
Standing Column Well
BLEED
Modified by Green Mountain Geothermal, based on DOE diagram


Closed Loop Systems
Horizontal





How efficient are geothermal systems?

Ground systems generally deliver between 3 to 5 times more heat than the electrical energy they consume, depending on the type of system and other details. They are more efficient than heat pumps that utilize outside air instead of ground heat, because ground source systems can take advantage of the nearly constant and relatively warm ground temperature below the frost line, which remains at a fairly constant temperature of 45-60 degrees Fahrenheit. Note that this is roughly the *annual* average of the air temperature on the surface. This fairly constant temperature is directly due to the downward diffusion of solar heat into the ground. In general, the warmer the ground, the more efficient the system: It takes less energy to move thermal energy from a colder environment to a warmer one if the temperature difference is smaller, which is a basic fact of thermodynamics.

The *heating* efficiency of a heat pump is specified by the system's **"Coefficient of Performance", or "COP"**, which is the ratio of the rate of heat delivery by the system divided by the electricity required to run the unit, where both measures must be in the *same units*, such as BTUs per hour, so that the COP itself has no units (is a pure ratio). So, for example, the electrical wattage of the unit must be converted to BTUs per hour. For a given model, manufacturer's specifications usually include COP ratings for each type of system a unit will be used in (see example below). But note that these do not include the pumping loads, because these depend on the particular installation, so the actual COP of a system will generally be somewhat lower than the COP of the heat pump itself. Open systems will generally have higher pumping loads, but their COPs will often still be higher for reasons given below. Also note that COPs will vary depending on whether the unit is running at full or partial capacity, the temperature of the ground at the time, etc.

COPs of Closed Loop vs. Open Loop Systems: Well designed and well installed closed loop systems using water in plastic pipes for heat collection typically have *total* COPs (that is, with pumping loads included) in the neighborhood of 3-4, whereas open loop systems, with pumping loads included in the electrical consumption, typically have higher COPs, ranging from about 3.5-5, and DX (Direct Exchange) systems can have COPs exceeding 5. Some units bear the ENERGY STAR® label, which indicates a heating COP of 2.8 or greater. Note that this is well below what is achievable today.

The *cooling* efficiency of geothermal systems is indicated by the **Energy Efficiency Ratio (EER)**, which is the ratio of the heat removed, in BTUs per hour, to the electricity required (in watts) to run the unit. The ENERGY STAR® label indicates an EER of 13 or greater, whereas high performing systems have EER ratings upwards of 20.

The following table shows a typical set of manufacturer's specifications. Note how the COPs and EERs of ground loop systems (closed systems) are everywhere lower than the COPs for ground water systems (open systems).

Model	Capacity	Water Loop Heat Pump				Ground Water Heat Pump				Ground Loop Heat Pump			
		Cooling 86°F		Heating 68°F		Cooling 59°F		Heating 50°F		Cooling 77°F		Heating 32°F	
	Modulation	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP	Capacity Btuh	EER Btuh/W	Capacity Btuh	COP
TTS/P026	Full	25,800	15.60	28,100	5.00	29,200	23.40	25,100	4.70	26,600	17.70	20,000	4.00
	Part	19,800	18.80	22,200	6.20	22,700	31.70	18,900	5.40	21,400	26.20	16,600	4.70
TTS/P038	Full	37,300	15.40	44,500	5.30	41,500	22.40	36,900	4.80	37,600	17.00	28,400	4.00
	Part	27,000	17.80	31,700	6.10	30,300	29.80	26,200	5.10	28,600	24.80	22,700	4.50
TTS/P049	Full	47,600	14.80	59,500	5.20	52,300	21.50	48,600	4.80	48,100	16.50	37,600	4.00
	Part	35,700	16.20	44,500	6.20	40,100	26.70	36,100	5.30	37,800	22.30	31,400	4.70
TTS/P064	Full	58,900	14.00	71,700	4.70	64,100	20.30	60,100	4.20	60,400	16.00	45,800	3.50
	Part	45,000	16.10	53,900	5.40	51,200	27.10	42,800	4.40	48,100	22.40	37,200	3.90

Why these differences? Although open systems generally have higher pumping loads, in a closed loop system with plastic pipes, heat must conduct from the ground through the walls of the piping to the fluid. In this case, the low thermal conductivity of the plastic piping means that the temperature difference between the ground and the circulating water needs to be substantial, which means that the circulating water needs to be quite cold, which requires the heat pump to work harder, which tends to lower the COP significantly. Open loop systems simply draw in ground water directly and extract heat from that water, so the heat pump does not have to work as hard.

DX or "Direct Exchange" systems circulate a refrigerant directly into the ground in copper pipes. Because copper has high thermal conductivity, and because one less heat exchange step is required in the heat pump itself, these systems tend to have COPs higher than either water based closed loop or open loop systems. On the other hand, these systems require large amounts of copper pipe and refrigerant, and the refrigerant has some chance of leaking into the ground.

Potential Environmental Issues with Heat Pumps

In closed loop systems, anti-freeze is often added to prevent freezing in the ground loop, especially for systems designed for heating. Food grade propylene glycol is most commonly used today, although some systems in the US still use denatured alcohol or methanol. Many states only allow propylene glycol. Even though propylene glycol is non-toxic, and even though all of these can biodegrade in principle, it is still important that the antifreeze not be released into the ground, and there is always some risk that this can happen with such systems.

The refrigerants currently utilized in heat pumps, such as R410-A, are now generally ozone safe, thanks to the Montreal Protocol. Direct exchange systems use much more refrigerant and refrigerant circulates directly underground in these systems, so there is a risk of accidental release of refrigerant into the environment with these systems.

With open systems it is possible for biological contamination of the inside surfaces of the piping (including inside the heat pump) to contaminate ground water, and precautions should be taken to guard against this. Also, if water is discharged to the surface, for example if a system utilizes a "bleed" to prevent freezing and to maintain efficiency, then groundwater can potentially be depleted. Open loop systems therefore needed to be carefully designed to be compatible with hydrogeology of the site.

Excavation and drilling processes can also introduce contamination into the ground, and precautions should be taken here to avoid this.

Sizing of Heat Pump Systems, and Building Thermal Efficiency

To understand the sizing of geothermal systems, one must first understand the basic unit of capacity that is used:

"Tonnage" of a Geothermal System: The heat delivery rate of heat pumps is often measured in "tons" of capacity, where one ton means a heat delivery rate of 12,000 BTU per hour:

$$1 \text{ ton} = 12{,}000 \text{ BTU/hour}$$

The heat pumps used in homes typically have capacities of 3-5 tons (with more than one unit being used in larger homes).

The precise capacity of a heat pump system for your home or business depends entirely upon how large your structure is, and how well it is insulated, including what the air leakage rate of the structure is. These factors should be thoroughly understood before a heat pump system is designed.

Geothermal systems are fundamentally different from conventional high temperature/high capacity heating systems in certain ways. Heat pumps are capable of delivering a steady, low temperature source of heat that is adequate to entirely heat a building. Unless grossly over-sized, however, they are not capable of delivering extremely high rates of heating that might be needed, say, in a grossly under-insulated and leaky structure during the coldest days of the year.

For this reason any building that is a candidate for a geothermal system should be as well insulated as reasonably possible, and in general, if funds are limited, improving the thermal efficiency should take precedence. There are additional reasons for putting efficiency first when it comes to geothermal systems. Geothermal systems will usually significantly increase the electrical energy consumption of a building, because even with a COP of 4, a full quarter of the heat must still ultimately derive from electricity. For the economics to work out favorably, it is important to minimize the potential increase in electrical consumption of the heat pump as much as possible. Geothermal systems will also cool the ground somewhat, and there is a limit to how much heat and/or water (in the case of open systems with a "bleed" capability), that can be withdrawn from the ground without either causing freezing and/or decreasing the COP of the system. Excavation and well drilling are also expensive, so it important not to oversize systems for this reason. Finally, heat pump systems are capital intensive. So buildings should be reasonably thermally efficient, and ideally very efficient, before a geothermal thermal system is considered.

How much do geothermal systems cost?

The heat pump unit itself, fully installed, and *not* counting drilling or excavation costs and the external piping, will cost approximately $2500 per ton of capacity, depending on installation details. So for example, the heat pump for a home with a 3 ton will cost approximately $7500.

Drilling or excavation costs tend to run anywhere between about $10,000 to $30,000 depending on the design capacity of the system, the type of system, the geology of the site, and the hydrogeology of the site.

If you have an existing well that is suitable for a geothermal system, then a geothermal will be very economical for you.

In general, vertical closed loop systems in general require somewhat more and/or deeper boreholes than do open, standing column well systems, due to the relatively low thermal conductivity of the plastic piping through which heat must conduct in a closed system. For example, a closed system with a 3 ton capacity might require one to three 300 ft boreholes, whereas an open system might do the same drawing from a single well with a 300 foot standing water column.

Likewise, horizontal closed loop systems, at least those utilizing plastic pining, require very significant lengths of piping, again due to the relatively low thermal conductivity of the plastic piping. This implies significant excavation and piping costs. For example, a 3 ton system might require 600 feet of piping (200 ft/ton). Excavation for horizontal systems tends to cost roughly half of what drilling for vertical systems cost per foot, so a horizontal system may be preferable over a vertical closed loop system where adequate land area with soil at least 4 feet deep is available. The cost of horizontal systems can also be lowered in many cases by using a trencher instead of an excavator.

How much can a geothermal system save?

A geothermal system in Vermont can save roughly $1000 to $2000 per year in heating costs, and have a "simple payback time" of between 10-20 years.

To understand the trade-offs involved better, consider the following example. Suppose that heating oil costs average out to $3.00/gallon during the lifetime of the system (an assumption which may prove to be very conservative), and that a $30,000 geothermal system 1000 therms (where 1 therm = 100,000 BTU) per heating season. This is a reasonable ball park figure for a moderately well insulated, 2000 square foot home in Vermont.

Heating oil has about 139,000 BTU/gallon, so the system will save approximately 1000 x 100,000/139,000 = 719 gallons of oil per year, or $2157 in oil costs.

Assuming the system has COP of 4, then the system also consumed 1000/4 = 250 therms of electricity. Assuming the electricity costs $.13/kWh, and using the fact that 1 kWh = 3412 BTU, the total cost to run the system per year is 250 x 100,000/3412 x $.13 = $953.

So the net savings of the system is $1204. With the 30% Federal Tax Credit included, this implies a "simple payback time" of 17 years.

If heating oil instead averages out to $4.00/gallon, then the payback time drops to about 11 years.

Note that although the system really does produce a significant net savings, the monthly electrical bill will increase, in this case by roughly $100/month during winter months.

How much can a geothermal system decrease my CO2 emissions?

Relative to heating with oil, a geothermal system in Vermont today can decrease CO_2 emissions by at least 45%, even when the emissions associated with the increased electricity use of the system is factored in, and much more if a renewable electricity source is also utilized.

According to the Dept. of Energy, the mission rate for Heating Oil is 16.1 lbs CO_2 /therm[1]. It follows from this that a system that provides 1000 therms of heat per year, relative to oil consumption, will avoid emissions of 16,000 lbs of CO_2, not counting emissions that might be created by electricity use.

The Vermont Public Service board has established that increasing electrical consumption during off-peak times in Vermont creates approximately 1.046 lb of CO_2 emissions per kWh[2]. It follows from this that a system with a COP of 4 will create additional emissions from electricity consumption of 1000 x 100,000/(4 x 3412) x 1.046 = 7664 lbs.

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[1] *www.**eia**.doe.gov/oiaf/1605/excel/Fuel%20EFs_2.xls*

[2] See page 233 (6-72) of http://psb.vermont.gov/docketsandprojects/eeu/avoidedcosts/2009.

Overall then, the geothermal system will have decreased emissions by a net 52%, or 8335 lbs per year.

Types of piping for closed loop systems

Either PEX (cross linked polyethylene) or HDPE (High Density Polyethylene) may be used. PEX is generally pricier than HDPE and exerts more drag on the flow than HDPE, which means a higher pumping cost (assuming same lengths and diameters). PEX is more resistant to compression, however.

How Long do Geothermal Systems Last?

The Department of Energy estimates system life at 25 years for the inside components and 50+ years for the ground loop. There are at least roughly 50,000 geothermal heat pumps installed in the United States each year.

Step 1: Evaluate Your Building's Thermal Energy Efficiency

The first question to answer is whether you should invest first in thermal and electrical energy efficiency first, or move on to arranging for the installation of a geothermal system.

If you are unsure of how efficient your building is, a thorough energy audit is highly advised. Those who may qualify for low-income assistance should first check the eligibility requirements posted on the Vermont Weatherization Program website: http://dcf.vermont.gov/oeo/weatherization. Eligible households include any whose incomes are at or below 60 percent of Vermont's median income, based on household income and size.

Low-income energy services in the Northeast Kingdom of Vermont are provided by the Northeast Employment and Training Organization (NETO) in St. Johnsbury, who can be contacted at 802-748-8935.

Another source of energy services for all homeowners and businesses in Vermont is Efficiency Vermont (www.efficiencyvermont.com), Vermont's "energy efficiency utility". Efficiency Vermont offers up to $2,500 in incentives per household to help Vermonters pay for energy efficiency home improvements completed by a certified Home Performance with ENERGY STAR contractor.

A full energy audit should at very least involve a "blower door test" to ascertain air leakage rates, a review of past energy bills, a thorough inspection of the building, and possibly addition measures such as infrared imaging of the building on a cold night.

Today it is quite possible to build or retrofit a building's thermal energy efficiency such that it's extremely efficient, even in comparison with building codes. This is certainly highly advised, to the greatest extent that is reasonable for you to do, for a number of reasons, not the least of which is that it will minimize the capacity and cost of a geothermal system.

If you tighten up your building such that the air leakage rate is very small, such as under one quarter of an air change per hour, it is possible today to install an "air-to-air" heat exchanger, which will replenish indoor air, while keeping energy losses to a minimum. Other important measures to consider which are relatively new are insulating the basement floor and walls.

Step 2: Determine if Geothermal Heating is Compatible with Your Building

If and when you determine that you have a building that is suitable for geothermal heating, the next step is to determine whether a geothermal system is compatible with your buildings heating system.

As discussed in the introduction, a geothermal system provides a steady supply of low temperature heat, quite unlike the high temperature heat provided by boiler systems. Most boiler supplied baseboard and radiator heat delivery systems will not be compatible with heating systems because the lower temperature heat provided by geothermal cannot be delivered rapidly enough by these systems (which are sized for high temperature boiler heat).

In some cases, if a building's thermal energy efficiency has been improved dramatically, an existing baseboard system *may* be adequate to deliver geothermal heat. A professional installer or other competent professional should ultimately make this final determination based on direct calculation of heat delivery rates under the operating temperatures expected with the geothermal system.

Geothermal systems can also supply "air handlers" retrofit into existing forced air distribution systems (duct work). It may also be possible to leave the original furnace intact for back up heat, if you are concerned about having backup. Caution should be taken however to ensure that the ductwork is of adequate cross-sectional area. There are specific rules governing this that a professional installer can follow, and it can be well worth investing in improvements to the duct work itself.

It is also essential to ensure that any duct work that is not strictly within the "thermal envelope" of the building is very well sealed and insulated. Existing insulation may very well not be adequate. Significant losses in the duct work can greatly compromise a geothermal system because geothermal heat is generally delivered in a steady way, that is, the system is delivering much of the time, so that significant losses will be able to have a significant adverse effect.

In some buildings, especially small structures with few rooms, it may make sense to have an air handler simply deliver hot air to the building right at the location of the air handler, without duct work. Keep in mind however that the heat pump itself, specifically the compressor, can produce significant sound output, and should generally be well isolated from living space.

Step 3: Determine what type of geothermal system you should install

As discussed in the introduction, open systems (standing column wells, ponds, etc), should be considered first, and then closed loop systems. Standing column well systems are particularly convenient where bedrock is at or close to the surface and/or where land area is limited.

Information on existing wells in Vermont is now provided on the Vermont Renewable Energy Atlas (http://www.vtenergyatlas.com).

A standing column well system is typically not appropriate in locations where the geology is mostly clay, silt, or sand. More specifically, if the bedrock is deeper than 200 feet from the surface, the cost of the well casing needed may become prohibitive. Likewise, if the water table is at a depth of 100 feet or more, then pumping loads may become prohibitive for systems that will utilize a significant level of “bleed”, that is, discharge to the surface to help maintain groundwater temperatures.

Water quality is also an issue: Limescale may build up on the inside walls of the piping and require periodic acid cleaning. If the water contains especially high levels of minerals, salts, iron bacteria or hydrogen sulfide, a closed loop system is usually preferable.

As a rough rule of thumb, approximately 100 feet of standing water column is needed per ton of capacity. The precise value of your site must be determined from an evaluation of the geology at your site. The thermal conductivity of the bedrock in particular is a critical parameter.

How much of a “bleed” a standing column well system will depend on the production capacity of your well. Generally speaking, bleeds rates of about 5% to 15% of the system’s flow rates can be desirable for maintaining temperatures. Each ton of heat pump capacity will require roughly 3-5 gallons per minute (gpm) of flow, which implies bleed rates of .2-.6 gpm. So, for example, a 3 ton system would require a bleed rate of between about 1-2 gpm. If the system is running continuously, and is utilizing bleed say, 50% of the time, then this would result in the withdrawal of 700-1400 gallons per day. Your well must be able to easily support this level of withdrawal for significant durations during the heating season (if you are going to utilize bleeding).

A 3 ton closed loop horizontal system might require 600 feet of piping (200 ft/ton). Excavation for horizontal systems tends to cost roughly half of what drilling for vertical systems cost, so a horizontal system may be preferable over a vertical closed loop system where adequate land area with soil at least 4 feet deep is available.

Step 4: Make sure your systems performance can be monitored easily

The best way to insure that your system can be monitored effectively is to have “P/T Ports”, that is, pressure-temperature ports, installed where the ground loop water enters and leaves the heat pump. This will allow “stab-in” type pressure and temperature gauges to be quickly inserted, from which the rate of heat delivery can be easily determined.

Step 5: Finance your geothermal System

Federal Tax Credit: There is currently a 30% federal tax credit for geothermal heat pumps placed in service in homes before December 21, 2016.

Step 6: Some Does and Don’ts

- It is strongly advised that you avoid having a “heat pack” installed with your system, which is an electrical heating unit that is designed to supplement the geothermal heat with additional electrical heat. These can significantly decrease the COP (efficiency) of your system. A well designed system in an adequately weatherized building should not require this.
- Insist that your well pump be sized appropriately, so that it can produce the right pressure at the heat pump input. Oversized pumps, or pumps that are variable but for which the minimum pumping rate is still too high, can significantly decrease the efficiency of your system.