AN INFORMATION SURVIVAL KIT

FOR THE PROSPECTIVE GEOTHERMAL HEAT PUMP OWNER

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ABOUT HEATSPRING LEARNING INSTITUTE

HeatSpring Learning Institute is a clean energy education company offering training courses on geothermal heating and cooling systems for buildings. The company's geothermal course offerings range from system basics to advanced technical courses for building designers and system installers.

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INTRODUCTION

The fact that you are considering a geothermal (sometimes referred to as ground-source) heat pump system, places you among the best informed and most innovative homeowners in the country. Geothermal heat pumps (GHPs), although not a new technology, remain a small but growing player in the residential heating/cooling sector. Although somewhat higher in first cost, this technology can, in the right application, quickly repay this cost premium through savings in energy costs.

Despite all the positive publicity on GHPs, they are not for everyone. Like any other heating and cooling system, GHPs tend to fit well in certain circumstances and poorly in others. Familiarizing yourself with the factors that affect the feasibility of GHPs will assist you in making an informed decision as to their suitability for your home. It is the goal of this document to provide that information and to address some of the most frequently asked questions regarding the technology.

This document was originally published in 1997 and updated in 2001. As the GHP industry has evolved, changes in costs, equipment performance, refrigerants and applications render earlier versions of this document obsolete and inaccurate.

TERMINOLOGY

A sometimes confusing aspect of this technology is the wide array of terms used to refer to it. Names for different system types vary regionally and have evolved to some extent over time. The following figures outline the major residential system types and the various names used for each.

Terms such as geothermal heat pump (GHP), geoexchange (GX) and ground-source heat pump (GSHP) are used to refer to the industry in general. Specific types of systems are referred to by what we might call sub-terms.

Open loop or ground water heat pump systems (Figure 1) are the oldest GHP systems and have been in common use since the 1970's. These systems pump water from a well – often the same well used for domestic supply in rural homes – and deliver it to the heat pump. After passing through the heat pump the water flows to an injection well or to some surface body of water (lake, creek, river etc). Water volumes necessary for heat pump operation are normally well in excess of what can be handled by a septic system. Open loop systems, in applications in which the home's domestic water supply is served by a well, can be very economical. Water quality is a major consideration however. If very low pH (< 6) very hard water (>100 ppm as CaCO2) or hydrogen sulphide presence (rotten egg smell) characterizes the water, careful analysis should be done prior to its use in a heat pump. Water temperature delivered to the heat pump is always more favorable with open loop systems than closed loop systems. However, open loop systems have higher pumping power requirements. With moderate pumping requirements and careful design open loop systems offer similar energy efficiency to closed loop systems. Water requirements in most residential applications are in the 1.5 to 2.5 gpm per ton range with the exact figure determined by water temperature and pumping requirements.

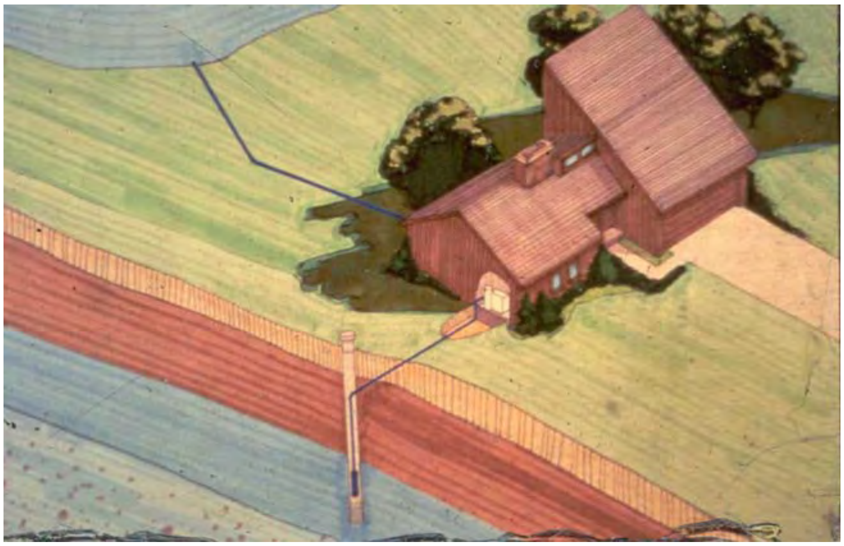

Figure 1

Open Loop Heat Pump System

Ground-coupled, or closed loop systems (Figure 2) have been widely used since the late 1980s and are the most common system in both residential and commercial markets. Currently both horizontal and vertical designs are used and the type installed depends on local practices and site conditions. Very small parcels tend towards vertical systems as ground surface requirements for vertical systems are much lower. Horizontal systems, both linear and spiral (or "Slinky") configurations tend to be somewhat less expensive than vertical loops in most areas. The length of pipe necessary (called loop length) is a function of system size, climate, soil/rock thermal characteristics and loop type.

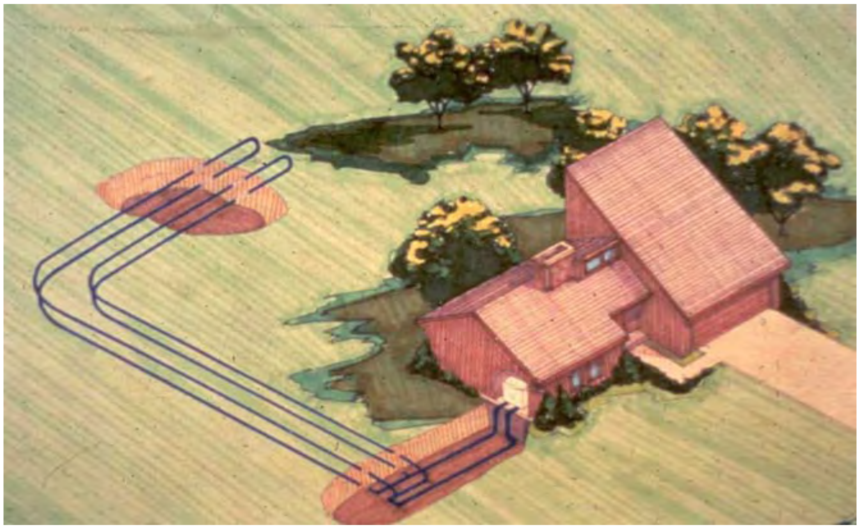

Figure 2

Horizontal Closed Loop Heat Pump System

This figure can range from 125 to 300 feet of trench per ton in horizontal systems and from 150 to 220 feet of borehole per ton for vertical systems. The energy efficiency of the system is dependant upon sufficient loop to produce favorable water temperatures for the heat pump. In addition to adequate loop length, individual trenches or boreholes also must be separated sufficiently to avoid thermal interference. An excellent reference on the design of residential closed loop systems can be found at http://www.geokiss.com/res-design.htm

Lake or pond loops (Figure 3) are the least common type of system in residential applications since far fewer homes are located on a suitable body of water and environmental concerns sometimes compromise use of natural lakes. Lakes are very effective heat rejectors and relatively poor heat producers. In fact heating mode heat pump entering water temperatures for lake loop systems are typically the lowest for any type of GHP at a given site in moderate to cold climates. In order to provide efficient operating temperatures, adequate lake depth (at least 12 ft) is required. Sufficient surface area is also necessary. At a loading of 10 tons per acre or less, the thermal impact of the loop on the lake is negligible. Commercial systems have been installed at densities of as much as 100 tons per acre but long term performance of these installations is not yet confirmed. Lake loops, provided a lake is available, can be a low cost option – on the order of 30% to 60% of the cost of a vertical or horizontal loop.

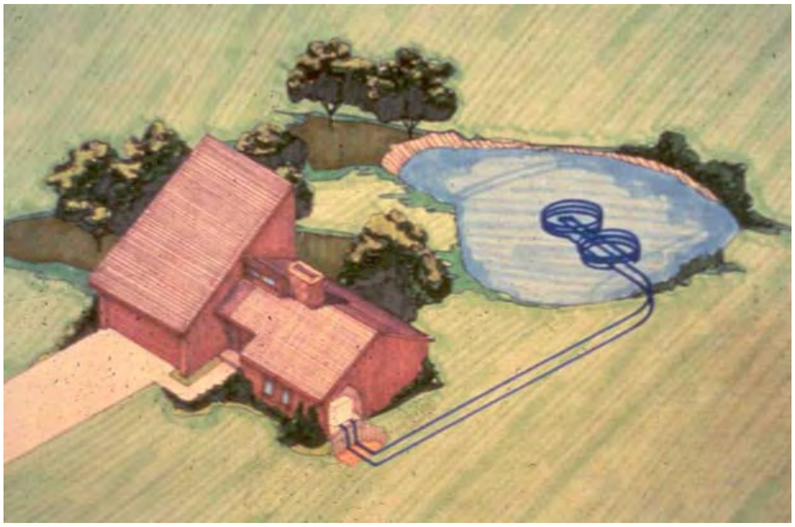

Figure 3

Lake Loop Heat Pump System

One system type not shown in the diagrams is the Standing Column system (sometimes referred to as an Energy Well System). In this arrangement water is pumped from a well, passed through the heat pump(s) and returned to the same well. Though the system uses ground water its heat transfer with the ground is more reflective of a closed loop system thus it is something of a hybrid of open loop and closed loop. In the peak heating and cooling seasons, it is usually necessary to Ableed@ a portion of the water flow to waste in order to prevent the well water temperature from rising to high or falling too low. There is insufficient data from existing systems to quantify the magnitude of this waste flow on an annual basis. These systems have been widely used in the Northeast US where the geology is typically hard rock formations which produce little water - a situation that compromises the ability to apply conventional open loop systems. The same water quality concerns apply to standing column systems as for residential open loop systems. Well depth requirements are in the range of 50 to 100 ft/ton.

HEAT PUMP FUNDEMENTALS

Heat naturally flows "downhill", from higher to lower temperatures. In order for a GHP system to function some means is necessary to raise the temperature of the heat naturally residing in the ground (at typically 45 to 70 F) to a level sufficient for it to be delivered to the home as useful heat (at typically 100+F). A heat pump is a machine which causes the heat to flow in a direction opposite to its natural tendency or "uphill" in terms of temperature. Because work must be done (energy consumed) to accomplish this, the name heat "pump" is used to describe the device.

In reality, a heat pump is nothing more than a refrigeration unit. Any refrigeration device (window air conditioner, refrigerator, freezer, etc.) moves heat from a space (to keep it cool) and discharges that heat at higher temperature to the room or the outside air. The only difference between a heat pump and a refrigeration unit is the desired effect--cooling for the refrigeration unit and heating for the heat pump. A second distinguishing factor of many heat pumps is that they are reversible and can provide either heating or cooling to the space.

One of the most important characteristics of heat pumps, particularly in the context of home heating/cooling, is that the energy efficiency of the unit and the power required to operate it are directly related to the temperatures between which it operates. In heat pump terminology, the difference between the temperature where the heat is absorbed (the "source") and the temperature where the heat is delivered (the "sink") is called the "lift." The larger the lift, the greater the power input required by the heat pump. This is important because it forms the basis for the efficiency advantage of the geothermal heat pumps over air-source heat pumps. An air-source heat pump, must remove heat from cold outside air in the winter and deliver heat to hot outside air in the summer. In contrast, the GHP retrieves heat from relatively warm soil (or groundwater) in the winter and delivers heat to the same relatively cool soil (or groundwater) in the summer.

As a result, a geothermal heat pump, regardless of the season is always pumping the heat over a shorter temperature distance than the air-source heat pump. This leads to higher efficiency and lower energy use. Beyond this GHP's do not need to periodically defrost in the heating mode as air source heat pumps do. The elimination of the defrost cycle increases both energy efficiency and service life of the equipment in comparison to ordinary air source heat pumps.

HEAT PUMP UNITS

The foundation of any GHP system is the heat pump unit itself. The most commonly used unit in these systems is the single package, extended range, water-to-air heat pump. All of the components are contained in a single enclosure, about the size of a small gas furnace and the unit is installed inside the home.

The heat pump includes a refrigerant-to-water heat exchanger, refrigerant piping and control valve, compressor, air coil (to heat air in winter, cool and dehumidify in summer), fan and controls. A typical vertical unit appears in Figure 4.

The single package design is a major advantage over the so-called "split" system used for air-source heat pumps (ASHP). The lack of an outside unit reduces the amount of refrigerant required and the potential for leaks--a major enhancement to reliability.

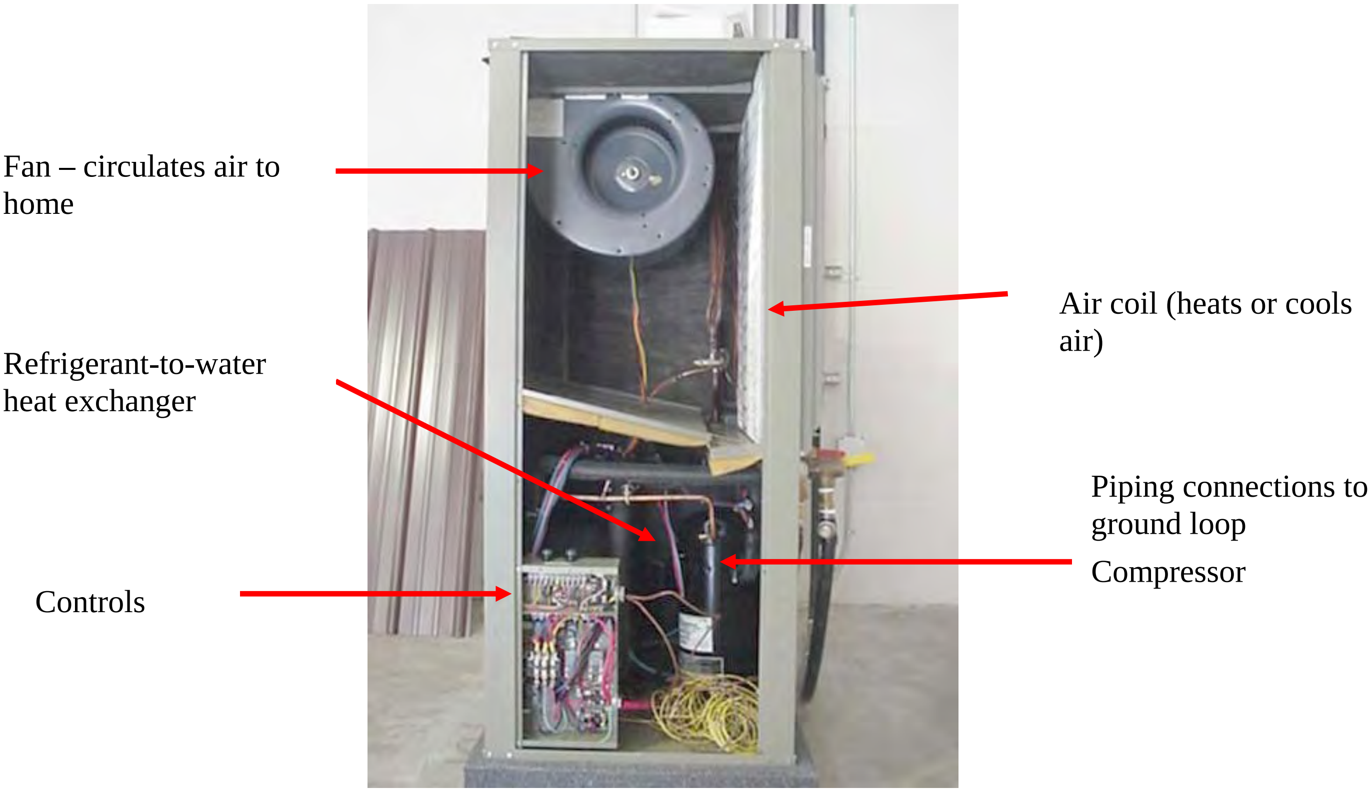

Figure 4
Typical Water-to-air Heat Pump Unit
(Kavanaugh, 2008)

GHP units have used refrigerant R-22, an HCFC, until very recently. R-22 is considered a transition refrigerant and has an ODP (ozone depletion value) of 0.05--only 5% of the most damaging CFC type refrigerants R-11 and R-12. Though this refrigerant is not scheduled for phase out in new heat pumps until 2020, most manufacturers now use, or are in the process of transitioning to the non ozone depleting refrigerants developed to replace R-22. The most common of these is R410A – sometimes referred to as AZ-50, Puron or SUVA 9100. Additional information about R-22 and its replacement refrigerants can be found on the Environmental Protection Agency's web site at: http://www.epa.gov/ozone/title6/phaseout/22phaseout.htm

Domestic hot water heating capability can be added to most GHP units. The components are typically installed in the cabinet as a factory option by most manufacturers. The domestic hot water heating components consist of a refrigerant-to-water heat exchanger and a small circulating pump. Field installed piping connects this unit to your domestic hot water heater or to an intermediate storage tank. Referred to as a "desuperheater" this option provides a portion of the heat pump's capacity for hot water heating. Some units can also be configured for full water heating capacity as well.

High efficiency water-to-air units generally contain a high efficiency compressor (usually scroll or rotary type) larger air coil, higher efficiency ECM fan motor, and sometimes, a larger refrigerant-to-water heat exchanger. The higher efficiency lines of larger manufacturers are also typically the earliest ones to be converted to the use of non ozone depleting refrigerants.

Manufacturers also offer split systems, water-to-water heat pumps, multi-speed compressors, dual compressor, and rooftop versions of this equipment to suit various applications. The variable speed or two speed units offer some performance and operating features over single speed units but this comes at the expense of higher cost and greater unit complexity. In high humidity climates, adequate dehumidification capacity should be verified for multi-speed units. Use of this equipment should be carefully considered in the context benefits vs costs.

EQUIPMENT PERFORMANCE RATINGS

Equipment performance ratings are the numbers we use to compare one manufacturer's product to another – much as we use EPA gas mileage ratings to compare one car to another. Like gas mileage ratings, equipment performance values do not always (actually almost never) reflect true installed-in-the-home performance. Rather they are best used to compare similar equipment (furnace to furnace or GHP to GHP) of one manufacturer to another. Unfortunately, the ratings used for different types of equipment (furnaces, ASHP, GHP) are not comparable, making direct comparisons between different types of equipment difficult. Ratings for all types of equipment are arranged such that higher values indicate more efficient equipment. The major difference between GHP and ASHP ratings is that ASHP values are intended to reflect seasonal performance and GHP values are the results of tests carried out at a single set of specific laboratory conditions.

For an expanded discussion of equipment ratings see the Equipment Ratings section at the end of this document.

Table 1

Residential Heating and Cooling Equipment Rating Summary

Equipment Type	Rating	Typical Range*	Comments
GHP Heating	COP	3.0 to 4.0	Coefficient of Performance laboratory conditions, 32 F entering water
GHP Cooling	EER	12.0 to 18.0	Energy Efficiency Ratio laboratory conditions, 77 F entering water
ASHP Heating	HSPF	5 to 9	Heating Seasonal Performance Factor calculated seasonal value
ASHP Cooling	SEER	10 to 15	Seasonal Energy Efficiency Ratio calculated seasonal value
Fossil Furnace	AFUE	78 to 97	Annual Fuel Utilization Efficiency calculated seasonal efficiency, no fan electricity included

*Values for GHP and ASHP equipment are for single speed units. Two speed, "dual capacity" or variable speed equipment is available and in low speed exhibits much higher ratings values. This equipment is not suitable in all applications however.

FREQUENTLY ASKED QUESTIONS

1. What does it cost to install?

The best way to begin this answer is to say that it will cost more than a conventional system. How much more depends, among other things, on where you live, which type of GHP system you use and the level of contractor availability (and competition) in the area.

For closed loop systems (both horizontal and vertical), cost varies with the number of available contractors. In locations where the technology is not well established, the lack of competition results in higher, sometimes substantially higher, prices. Open loop systems, because they do not require specialized contractors are less affected by this problem but this option is often not offered to the customer, particularly by contractors who specialize in closed loop installations.

Much of the following information is based on a 1995 study of GHP costs done by Dr. Steve Kavanaugh and others at the University of Alabama for the Tennessee Valley Authority entitled "*Cost Containment for Ground-Source Heat Pumps*." The cost data in the report have been updated to 2008 values using the construction industry historical cost index published in a widely used construction cost estimating reference (Means, 2007). The original Kavanaugh report addressed only ground-coupled systems. Groundwater (GW) system values were added by the author of this publication in 1997 and have been similarly updated.

The following data are believed to reflect costs in areas of the country where a high level of competition exists and the technology is well established resulting in relatively low capital cost to the homeowner. In regions where these favorable conditions do not exist, costs could approach twice the values shown here. Updated cost information will be added here as it becomes available.

Figure 5 summarizes the cost of the ground loop portion of the system only. This could be considered the "outside" the home costs for the system. Vertical closed loop (GC Vert) installations tend to be the highest cost partly due to the high cost of the drilling equipment relative to backhoes or small excavators used in horizontal loop (GC Horiz, GC Slinky) installations. For groundwater systems (GW), the costs shown include the cost of a larger well pump, tank, piping to and from the house, and a 50' disposal well. For ground-coupled systems, the costs include the trenching or boring, pipe installation and headers up to the home. The decreasing cost for the open loop installations with increasing capacity occurs due the use of the same well for disposal of water from all system sizes. With the same cost for the disposal well, the cost per ton decreases with system size.

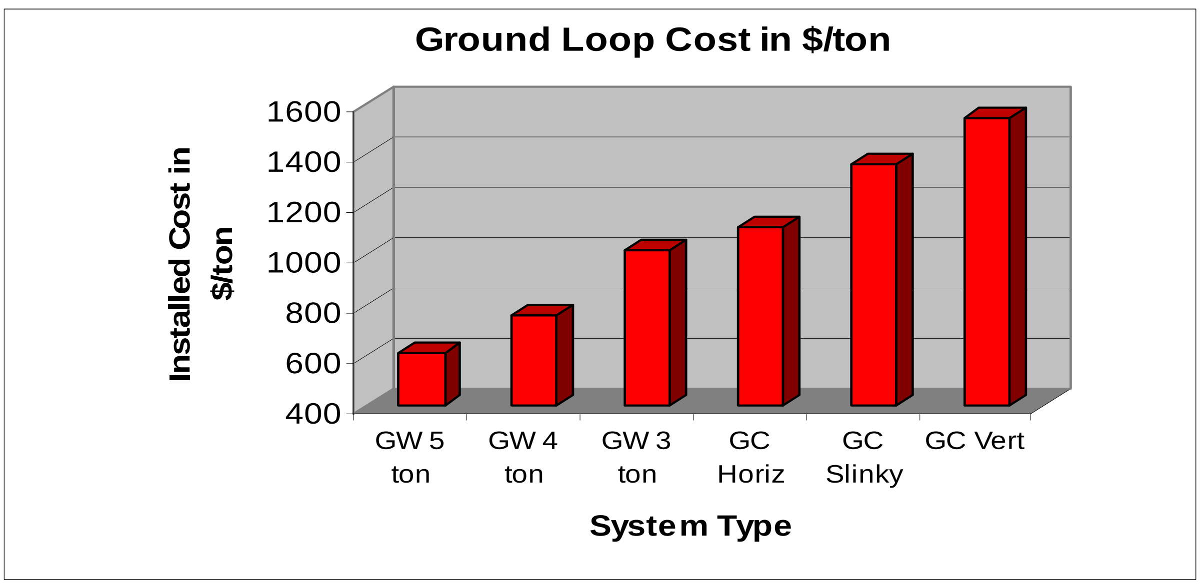

Figure 5

Ground Loop Cost per Ton

Figure 6 shows total installed cost for 3-ton systems including both inside (ductwork, heat pump unit, controls etc) and outside (ground loop, piping, excavation and/or drilling).Open loop system costs are based on the assumption that the home would be served by a well for domestic water supply. As a result incremental costs for a larger pump are included along with piping and the injection well. Open loop costs for a home connected to a municipal water system would be higher than those portrayed in the figure.

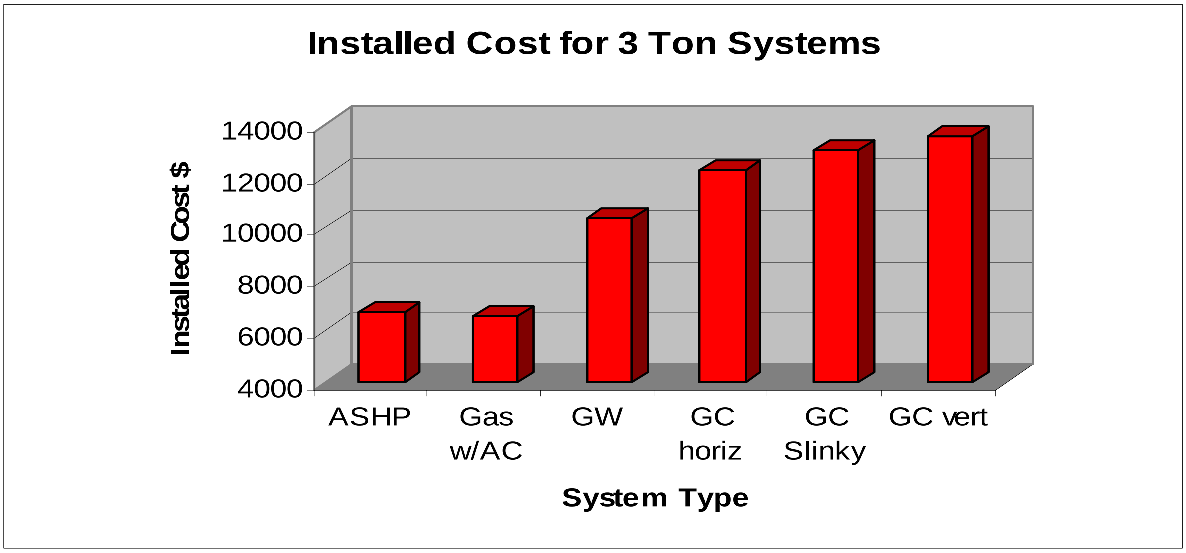

Figure 6
Total System Installed Cost

2. How does the cost of heating with a GSHP compare to other heating methods?

This has a great deal to do with your local rates for electricity and other fuels. The comparison involves the efficiency of the device, the type of fuel used and the cost of that fuel.

Commonly used heating fuels have the following approximate heating content:

Fuel oil	- 138,000 Btu/gal
Propane	- 90,000 Btu/gal
Natural gas	- 100,000 Btu/therm (1,000 Btu/ft^3)
Electricity	- 3,413 Btu/kWh

A common index of the cost of heat is "dollars per 1,000,000 Btu of useful heat." In order to calculate useful heat (heat actually delivered to the house), it's necessary to adjust for the efficiency of the heating device and the cost of the fuel. The following equations can be used for this purpose

Fuel oil	(7.25 x $/gallon) / efficiency
Propane	(11.1 x $/gallon) / efficiency
Natural gas	(10.0 x $/therm) / efficiency
Electric Resistance	293 x $/kWh
ASHP	(1000 x $/kWh) / HSPF
GHP	(293 x $/kWh) / COP

Efficiency for the furnace calculations can be assumed as follows: older furnaces (25+years) 0.65, newer standard efficiency furnaces 0.78, newer moderate efficiency furnaces 0.84, newer high efficiency furnaces, 0.92. For air source heat pumps in warmer climates an HSPF of 2.3 can be used, for colder climates 1.8. For GHP's in colder climates a COP of 3.2 is appropriate and warmer climates 3.9.

As an example, let's look at a location in a moderately cold climate when the fuel costs are as follows: Electricity, $0.08/kWh; fuel oil, $3.50/gal; propane, $2.25/gal; and natural gas, $1.30/therm. This would result in the following useful heat costs:

$ per Million Btu

Fuel Oil	30.21 (0.84 eff)
Propane	29.73 (0.84 eff)
Natural Gas	15.48 (0.84 eff)
Electric Resistance	20.51
ASHP	10.90 (2.15 COP)
GHP	6.70 (3.5 COP)

Obviously, it is necessary to know the total amount of heat required for the year to calculate total annual space heating cost. Annual heating requirements are a function of climate and one index used to reflect this is the Heating Degree Day total or HDD for the location. The colder the climate the higher the annual HDD. Minneapolis for example has an annual HDD of approximately 8400, Boston 5600, Kansas City 4700 and Atlanta 2900. For a more complete listing of HDD for other US locations see the table at the end of this document. Annual heating energy is also a function of the size of the home and its quality of construction (insulation level).

Table 2 provides some calculated annual space heating cost data for a variety of climates from very cold to warm for various heating system types.

Table 2
Annual Space Heating Costs – 2200 sq ft "Average" Home

	ANNUAL HEATING REQUIREMENT (HDD)						
	8000	**7000**	**6000**	**5000**	**4000**	**3000**	**2000**
GHP	$516	$438	$364	$295	$229	$167	$109
ASHP	$1,179	$963	$774	$573	$413	$295	$179
NAT GAS	$995	$870	$817	$681	$545	$440	$293
FUEL OIL	$1,941	$1,698	$1,594	$1,329	$1,063	$858	$572
PROPANE	$1,913	$1,674	$1,571	$1,310	$1,048	$846	$564

Notes: based on 0.08 $/kWh, 3.50 $/gal fuel oil, 2.25 $/gal propane, 1.30 $/therm natural gas.
Assumes use of gradually increasing furnace efficiency from warm to cold climates as follows:
Oil, gas and propane 78% efficiency @ 2000 HDD to 93% efficiency at 8000 HDD. Assumes the use of gradually lower performance in heat pumps with colder climates (due to lower soil/water temperatures) as follows: ASHP HSPF at 8000 HDD = 4.8, HSPF @ 2000 HDD = 7.8, GSHP COP 3.2 @ 8000 HDD and 3.8 @ 2000 HDD.

The table is based on an "average" 2200 sq ft home. According to US Energy Information Administration data (US EIA, 2001) the average heating energy requirement for all US homes is approximately 4 Btu/sq ft per HDD and this value was used as the basis for Table 2 calculations. Obviously new, very well insulated homes would have somewhat lower, and older poorly insulated homes somewhat higher costs than those in the table.

Savings are also generated during domestic hot water heating and cooling. These will be small compared to the heating savings in all but southern climates. See the next question for some examples.

3. How much will it save when air conditioning and domestic water heating are considered?

As mentioned in the above question, this depends upon the particulars of your case and for an exact answer requires a sophisticated computer simulation. To provide a guide, the following data was developed (Kavanaugh, 1992a; Kavanaugh, 1992b) for three U.S. locations with widely differing climates. The comparison addresses only heat pump systems – typically the lowest energy cost options available in most climates. The values shown are annual electricity consumption (kWh) for the different system types assuming a newly constructed, energy efficient, moderate sized (1700 sq ft) home. Only GHP units are assumed to be equipped with a desuperheater for domestic hot water consumption. The balance of hot water heating is assumed to be provided by electric hot water heaters.

Atlanta, GA (2900 HDD)

	Cooling	Heating	DHW	Total
ASHP	3,409	7,396	4,120	14,925
ASHP (variable speed)	2,499	5,540	4,120	12,159
GHP (std. eff.)	2,599	4,236	2,620	9,455
GHP (high eff.)	2,079	3,510	2,509	8,098

Spokane, WA (6800 HDD)

	Cooling	Heating	DHW	Total
ASHP	773	11,475	4,120	16,458
ASHP (variable speed)	435	9,295	4,120	13,850
GHP (std. eff.)	451	5,562	3,150	9,163

Portland, OR (4300 HDD)

	Cooling	Heating	DHW	Total
ASHP	513	6,666	4,120	11,299
ASHP (variable speed)	285	4,706	4,120	9,111
GHP (std. eff.)	337	3,549	3,468	7,354

It is apparent from the data that even as far south as Atlanta, annual savings are heavily dominated by the heating mode and secondarily by domestic hot water heating.

The U.S. EPA report, "Space Conditioning: The Next Frontier" by L'Ecuyer and others (EPA 430-R93-004) also contains savings information.

4. How much of the job can I do myself?

Very little. The performance of a ground-coupled heat pump system is determined by the quality of the installation. Assuring that proper backfilling is done around the pipe, fusing of the polyethylene piping, flushing the system and purging air from it, all require skills, tools and equipment only available to properly trained contractors. Ground loops are not do-it-yourself projects.

5. What about domestic hot water heating?

Most GHP units can be equipped (optionally) with a device called a desuperheater to partially heat domestic hot water (DHW). In the summer, this device uses some of the "waste" heat from the air conditioning to heat hot water. As a result, during the cooling season, this heat is essentially free since it would otherwise be rejected to the ground or ground water. In the winter, some of the capacity of the heat pump is diverted from space heating to heat domestic hot water – while not free the heat is produced for less cost than conventional methods. It is important to understand, however, that with a desuperheater the heat pump only produces domestic hot water when it is running for either space heating or cooling purposes. As a result, only a portion of the annual domestic hot water heating needs are met by the desuperheater. As suggested in the annual energy use data appearing under FAQ #3 the annual savings varies from about 15% (Portland, OR) to 39% (Atlanta, GA).

The percentage of annual DHW heating needs met depends upon the run time of the heat pump and DHW use patterns in the home. The largest savings occur in applications where the heat pump runs a large number of hours in the cooling mode and where alternative water heating is by electric resistance.

For an average family size (3.5 persons), with a 3-ton heat pump, the annual savings on domestic hot water would be in the range of 15% (colder climates) to 50% (warmer climates), or about $100 - $150 per year at $0.08/kWh. Since desuperheater capacity is directly related to heat pump capacity, the savings from a 4- or 5-ton system would be greater than the 3-ton savings cited above.

6. Should I use vertical, horizontal or open loop?

This is a tough question to answer. Let's look first at whether to go open loop or closed loop.

Open loop systems are best applied in situations where the house is, or will be, served by its own water well. A slightly larger well pump is installed to provide for the water required by the heat pump. A major consideration is the disposal of the water. Existing systems have used ponds, lakes, rivers, irrigation ditches, and return (or injection) wells. Surface disposal is obviously the least expensive option; but, even if a disposal well is required, the capital cost is likely to be much less than the cost of a closed loop ground coupling. Water quality is also an important issue. Since the water is used directly in the heat pump, the issue of corrosion and/or scaling can be a problem. If the water is hard (>100 ppm) or contains hydrogen sulphide (rotten egg smell), a closed loop system could be a better choice. If the water is of good quality and the house is to be served by a well for domestic water, serious consideration should be given to the open loop approach. Contractors will often suggest a cupro-nickel heat exchanger as a way to address water quality problems in open loop systems. It is a rare occasion when this is an effective strategy. Cupro-nickel is effective for salt water applications. For most of the commonly encountered water quality problems (carbonate scale, iron and hydrogen sulphide) cupro-nickel construction is of little if any value. See the costs section of this report for capital costs for the open loop system.

If the system is to be a closed loop design, the choice between vertical and horizontal system is sometimes a difficult one to grapple with. The major advantage of the vertical design is that it places the loop in a much more thermally stable zone. Soil at 100 ft is not subject to temperature fluctuations as soil at a 4 or 5 ft depth is. While soil and rock at depth remains at a constant temperature, shallower soil may fluctuate as much as 10F above deep ground temperature in the summer and 10 F below in winter. As a result, the vertical design offers the potential of supplying the heat pump warmer water in winter and cooler water in summer resulting in higher energy efficiency.

Contractor availability will be the dominant factor in determining which type of ground coupling is used for many projects. In most areas of the country, the availability of contractors is still somewhat limited. As a result, if the local contractors only install horizontal systems, that is what you get.

The thermal advantages of the vertical over the horizontal are less of a factor in moderate climates. The more extreme the climate, either in heating or cooling, the greater the advantage of the vertical system from a performance standpoint – particularly in cooling.

7. Who makes the best equipment?

This is a lot like asking who makes the best car. All major manufacturers produce quality products and what is "under the hood" on most products of comparable quality is surprisingly similar. Larger manufacturers usually have more than one line of heat pumps and energy efficiency can be substantially different between models.

One way to compare equipment is by the rated performance. This information is published periodically in the ARI (Air Conditioning Refrigeration Institute) Directory and is available on their web site at: http://www.ahridirectory.org/ahriDirectory/pages/wbahp/defaultSearch.aspx

The information in the following table addresses only 3 ton capacity, water-to-air units from the manufacturers currently listed in the ARI Directory. Performance varies with heat pump unit capacity and the 3 ton unit values appearing here should not be taken as representative of other size units. Note that many manufacturers have multiple models with sometimes substantially different performance. Ratings appearing here are for closed loop rating conditions under which testing is done at 77 F entering water temperature in cooling and 32 F entering water temperature in heating. These models could be applied to open loop, closed loop or lake loop applications.

Table 3
Selected ARI Performance Values for 3 ton Water to Air Heat Pumps

Manufacturer	Model #	EER	COP

Bard Manufacturing	GSVS361	17.5	3.5
Carrier	50PSV036	19.2	3.9
	50RVR036	14.7	3.4
	50RVS036	16.4	3.4
	50YCV036	17.2	3.5
	50YEV036	19.2	3.9
Climate Master	GRV36	14.7	3.4
	GSV36	16.4	3.4
	TSV36	19.2	3.9
Cold Flow Air Conditioning	CFX041	13.1	3.0
Econar	GH360	14.6	3.3
	GV380	16.0	3.9
Enertech Manufacturing	GS030	18.5	3.7
Fedders	HGY036	14.9	3.5
FHP Manufacturing	EC036	14.2	3.2
	EM036	15.3	3.4
	ES036	17.2	3.8
	EV036	17.4	3.4
	GS036	18.7	3.6
	GT036	17.0	3.5
Geosmart Energy	GS036	19.6	4.0
Heat Controller	HRV036	14.7	3.4
Hydo delta	HE036	15.0	3.4
	MT036	13.9	3.8
Hydron Module	H030	18.5	3.7
Loop Group	ES036	19.0	3.5
	GT036	17.0	3.6
	EV036	17.4	3.4
Marvair	VWI40	17.0	3.7
McQuay	WCCH1036	16.0	3.4
	WCCH2036	17.7	3.6
Northern Heat Pump	RVHF36	13.7	3.1
Trane	GEHP036	14.5	3.25
	WPVJ036	17.3	3.9
Waterfurnace	GS036	19.6	4.0
	NSV036	19.6	4.0
	P034	16.9	3.2

Though it is possible using the data above to identify the manufacturer with the highest EER and or COP, it is not always the best approach to proceed with a rigid requirement that the contractor install only that brand of heat pump. The reason for this is that contractors tend to handle only one or two brands of equipment on a regular basis. They develop a relationship with a particular manufacturer and as a consequence often benefit from preferential pricing from that manufacturer. Requiring a contractor who represents one brand of equipment to install a brand he does not regularly handle may result higher cost and potentially delays in delivery. An effective strategy is to identify which brands of heat pumps are represented among your local contractors and choose the most efficient among that group.

8. How do I find a contractor?

Selection of a contractor for a geothermal heat pump system is very important, particularly for ground-coupled systems. There are several places to look for information:

Local utilities often have promotional and/or certification programs for both ASHP and GHP contractors. The utility may maintain a list of approved contractors to which they can refer you.

Manufacturers (see list below) of heat pump equipment can direct you to one of their dealer/contractors in your area.

HeatSpring Learning Institute offers a directory of contractors and building professionals who have been through their training programs. The listings are searchable by location and available on their website: http://www.heatspring.com

The International Ground Source Heat Pump Association (IGSHPA) maintains a list of contractors on their web site at:
(http://www.okstate.igshpa.edu). The list is organized by state.

The search for a groundwater system contractor is somewhat simpler. In this case, most general heating and air conditioning contractors can handle the installation without special training and no certification programs are currently in place for open loop installation. It is necessary for the heat pump contractor to coordinate with the well pump contractor to assure that an adequately sized well pump and tank are installed however.

9. Who makes the heat pump units?

The following manufacturers currently appear in the ARI ratings document:

Airedale North America	www.airdaleusa.com
Bard Manufacturing	www.bardhvac.com
Carrier	www.carrier.com
Climate Master	www.climatemaster.com
Cold Flow Air Conditioning	www.coldflow.net.au
Econar	www.econar.com
Enertech Manufacturing	www.geocomfort.com
Fedders	www.fedders.com
FHP Manufacturing	www.fhp-mfg.com
Geosmart Energy	www.geosmartenergy.com
Heat Controller	www.heatcontroller.com
HTS Engineering	www.htseng.com
Hydo delta	www.hydroheat.com
Hydron Module	www.hydronmodule.com
Loop Group	www.loop-group.com
Mammoth	www.mammoth-inc.com
Marvair	www.marvair.com
McQuay	www.mcquay.com
Northern Heat Pump	www.northernheatpump.com
Whalen	www.whalencompany.com
Trane	www.trane.com
Waterfurnace	www.waterfurnace.com

10. What do I look for in a contractor?

EXPERIENCE! The contractor should be able to provide documentation of prior installations with customer names and contact information. A proven track record of several years in the GHP business is advisable. If your contractor's experience consists of installing one 5 years ago for his brother-in-law…keep looking.

Certification of contractors has been provided for many years by the International Ground Source Heat Pump Association (IGSHPA). Don't be afraid to ask to see proof of certification. Some contractors are certified by other organizations for pipe fusion expertise and this with sufficient experience in GHP installation is acceptable.

Certification is not provided at this time for open loop installations. In all likelihood an open loop system will involve a heating and air conditioning contractor for the heat pump and sheet metal work inside the home and a well drilling and/or pump contractor for the well pump related work. Again experience is the key.

11. Can GHP systems be used in conjunction with hot water space heating?

Yes and no. Heat pumps are available from several manufacturers that produce hot and chilled water rather than hot and cold air. These units (referred to as water-to-water heat pumps) can be connected to some types of hot water heating equipment. The limitation in the heating mode is temperature. Conventional hot water radiators and base-board type elements are designed to operate at temperatures of 160ºF and above (older systems as high as 215ºF). Unitary heat pumps are limited to producing supply water temperatures of a maximum of about than 125ºF. Operating an existing hot water system, designed for 180 F at 115F will result in a reduction of approximately 70% in heating capacity. As a result, on a retrofit basis (a home with existing hot water radiator or baseboard), the prospects are not favorable.

The best hot water systems to connect to a GHP are radiant floor (or hydronic radiant slab) systems. This design, in which plastic tubing is installed in the floor slab, operates at water temperatures typically much lower than radiator type systems. In order to minimize the required water temperature, the home should be well insulated and use minimal floor coverings. This type of system is more complex, in terms of equipment and controls than a standard water-to-air system and requires careful design.

In general, complete space cooling cannot be accomplished in humid climates with a floor system since condensation would occur on the floor surface. As a result, this system generally must be coupled with some sort of fan coil unit to provide cooling and dehumidification if the climate is such that dehumidification is necessary.

In addition the number of contractors necessary is greater than in a typical GHP system as it is usually necessary to engage a plumbing contractor for the floor piping and circulating pumps, a heating and air conditioning contractor for the heat pump and a loop contractor for the ground loop (or well contractor for the water wells).

12. Can snow melting be done?

Snow melting can be accomplished with GHPs; but, there are serious cost impacts on the residential side. Snow melting has been successfully incorporated into some commercial GHP systems serving gas stations/convenience store operations. The advantage here is that the store contains a great deal of refrigeration equipment which continually produces waste heat used for the snow melting system. Melting of snow using this waste heat is very low cost and in fact is beneficial to the system's operating temperatures in the cooling season by reducing the heat buildup in the ground that would otherwise occur in these applications.

Due to the nature of snow melting, a separate system must be installed to serve the load. This results from the requirement for the circulation of an antifreeze fluid through the melting system, instead of the warm air supplied by water-to-air heat pumps. Beyond this, since the requirement for snow melting coincides with the need for space heating, additional ground loop may be necessary to serve the capacity of the snow melting system.

Although GHPs produce heat less expensively than most other systems, because of the substantial quantities of heat required by snow melting systems, the annual cost remains high. The high energy cost is a result of the way snow melt systems are operated. Most systems are allowed to "idle" at a low heat output during the winter season. This allows the paved surface to quickly come up to temperature when snow fall occurs. The energy consumed by this idling operation, because of the number of hours over an entire season, is substantial. Because of the thermal mass of the paved surface, simply turning the system on when snow fall occurs results in a long time lag (several hours to one day) between start up and snow melting. This can result in incomplete snow removal and a "corduroy" effect on the surface.

The high energy cost is compounded by the need for high water temperatures to produce the necessary output required for adequately rapid snow melting. These temperatures, in areas where heavy snow occurs, are far in excess of what would be produced by available unitary heat pump equipment. Finally the capital cost of heat pump heating capacity (in Btu/hr) is approximately 7 times that of equivalent capacity in a boiler. This in conjunction with the larger loop length requirement tends to erode the overall economic attractiveness of GHP snow melting systems.

The following evaluation of a snow melt system for a residence in Michigan points out some of the limitations.

> "In your area, a snow melting system would be designed for an output of about 165 Btu/hr per square foot, under melting conditions. For a 12 ft wide 100 ft long driveway, this would amount to 198,000 Btu/hr or the equivalent of about a 20-ton heat pump. This is about six times the size heat pump required for the average house.
>
> For snow melting conditions below 30°F and wind speeds above 5 mph, required water temperatures in the snow melt loop are in excess of 130°F. This is higher than the average heat pump can produce.
>
> Because the snow melting system requires the circulation of hot water, a

water-to-water heat pump is required. Most homes with a geothermal heat pump use a water-to-air heat pump.

Snow melting requires a substantial amount of energy on an annual basis. In your area, a residential system would consume about 133,000 Btu/yr per square foot of driveway. Supplying this from a geothermal heat pump, at a COP of 3.5, would require an electrical input of 11 kWh/sq ft of driveway. For a driveway of 1200 sq ft (100 ft x 12 ft), this would be about 13,200 kWh/yr or $924 per year at $0.07/kWh."

It is possible with very carefully configured controls and the acceptance by the owner of reduced performance of the system, that annual energy requirements could be substantially reduced relative to the above example. The moral of the story in general though is that snow melting can be done with residential GHP systems if money is no object. For most folks though, it's much more economical to hire the neighborhood kid to shovel the driveway.

13. Can I heat my pool?

Pools can be heated with a GHP and in very warm climates, this makes a good match with a space conditioning GCHP. In cooling dominated climates, the space conditioning heat pump rejects much more heat to the ground than it absorbs from the ground on an annual basis. As a result, there is the potential for a gradual increase in ground temperature to occur over a period of years, where a ground-coupled system is used. Removing this excess heat and delivering it to a swimming pool reduces (or eliminates) the problem.

Pool heating will require a separate heat pump for the pool. Beyond this, the heating capacity of the heat pump will likely be less than that of a typical gas-fired heater in the same application. This is a result of the fact that heat pumps cost about five to seven times what gas-fired pool heaters do per unit of heating capacity. The smaller heat pump would not affect the ability to maintain pool temperature, but would result in a longer time required to bring the pool temperature from cold up to usable temperatures at the beginning of the season.

The pool heating unit would be of the water-to-water type rather than the water-to-air design used for home heating and air conditioning. The impact of the pool heating upon required loop length would depend upon the size of the pool and the amount of the year it is in operation.

14. I currently have a propane (or oil or gas) furnace and I am thinking about changing to a GHP. What should I be aware of?

First of all, there will be a major difference in the air temperature from the supply registers. Heat pumps, regardless of the type, produce lower temperature air than fossil fuel furnaces. Air-source heat pumps produce the coolest air 90ºF to 95ºF. GHPs produce air of 95ºF to 105ºF, a small but very noticeable improvement.

Another issue is the ductwork. If the house was not originally equipped for air conditioning, the ductwork may be undersized for the heat pump. Both central air conditioning and heat pumps require more air flow than fossil fuel furnaces. Be sure to have your contractor evaluate this issue. Undersized ductwork results in noise and lower system efficiency due to the greater fan power necessary to force the air through the ductwork.

15. Are there any substantial improvements in efficiency on the horizon?

There are always improvements to be made in mechanical devices like heat pumps. This is not a reason to put off the installation of a GHP system, however. Most of the substantial efficiency gains in heat pump units have been made over the past 15 years. Remaining improvements will likely be small in comparison to what has been achieved. As an example, the average performance of five manufacturer's equipment found in the 1987 and current ARI Directories has shown an average of 41% improvement in EER and 27% improvement in COP. The 2000 year changes in the ratings system for water-to-air heat pumps did result in a rise in the EER and COP rating values. In general this is not the result of a general improvement in the equipment itself but rather modifications to the ratings system that improve the numbers.

Although periodically new closed loop buried piping configurations are attempted, the basic vertical and horizontal approaches used currently have proven to be an excellent solution to high efficiency, reasonable capital cost and superior reliability.

16. I am planning a large home. Should I use one large unit or two smaller ones?

There are several reasons why it may be advisable to use multiple smaller units than one large one in large homes. The use of two or more small units is referred to in the HVAC trade as "zoning." Generally a separate zone is established if one or more of the following criteria apply: the area has a specific use distinct from the rest of the home (mother-in-law's apartment), the area is maintained at a distinct temperature (basement), a separate level of the home (2nd floor bedrooms).

An additional reason for using two systems is that the equipment of many manufacturers falls off in performance above four to five tons. As a result, the use of two 3-ton units is likely to yield a higher performance than a single 6- or 7-ton unit. This performance difference when it exists is marginal and by itself is not sufficient to justify the additional cost of the 2-system design.

Multiple smaller units can reduce costs associated with ductwork and loop piping in many applications, as smaller, shorter pipe and duct length is associated with a multiple unit installations.

17. Is the system's antifreeze a potential environmental problem?

In residential applications, the commonly used antifreeze solutions pose little to no environmental hazard. Each state regulates the types of antifreeze fluids used in GHP systems. The most commonly used solutions are propylene glycol, and methanol. Propylene glycol is a non-toxic fluid which poses no hazards to the environment, humans or animals, and in fact, is used in food processing.

Methanol (or alcohol) is potentially flammable, but not in the concentrations used in GHP systems. It is similar to the antifreeze solution used in automotive windshield washer systems.

The key issue with respect to antifreeze solutions is that they are contained in a fused piping system with equal or greater integrity than that used for distribution of natural gas. Given this and the small volume of low concentration (typically less than 20%) of the antifreeze, potential environmental risk is extremely small. Open loop systems do not use antifreeze solution.

18. I have heard of a system where air is circulated through large diameter pipes buried in the soil and then supplied to the building for heating or cooling purposes. Is this possible?

Anything is possible. It's just that some things work better than others. Due to limitations in heat transfer and equipment, this is one of those ideas that doesn't work too well. The following is an excerpt from a response we recently sent to a farmer in Minnesota. He had 42ºF soil and wanted to heat some new barns.

> "In order to transfer heat from a source (like the soil) to a fluid (like air), two things are necessary: a temperature difference and some surface area across which the heat will be transferred (the pipe). Because a temperature difference is required to drive the heat out of the soil, across the pipe and into the air, the temperature of the air leaving the buried pipe will always be less than the temperature of the soil. The closer you try to get the leaving air temperature to the soil temperature, the more pipe (surface area) it takes. For argument, let's figure that a 10ºF difference is required (close to what ground-source heat pumps are designed for). This means that the air exiting the pipe will be 32ºF in the coldest part of the year. In order for this air to deliver heat to the building to be heated, a temperature difference between

the air exiting the pipe and the air in the space is required. The smaller this temperature difference is, the more air that must be circulated to meet the heating load. The problem is that these two temperature differences, combined with the temperature of the soil result in the ability to maintain only very low temperatures in the "heated" buildings. If we used another 10ºF temperature difference between the space and the pipe exit air, this would result in the ability to maintain only 22ºF maximum in the space. The above assumes that the soil would remain at the undisturbed temperature of 42ºF minimum. This would not be the case since the removal of heat would cause the decline in the soil temperature, thus reducing the temperatures used above.

This type of system has some possibilities in the cooling season but, as you can see, it's pretty limited in the heating season. In the cooling mode similar temperature and temperature difference constraints exist limiting the application to non conventional space cooling applications. Other issues with respect to air quality (development of molds in the buried pipe in humid climates) also tend to limit applications.

The soil is an excellent heat source and sink but practical use of it requires a heat pump in the system to "amplify" the heat to usable levels for normal space heating or cooling.

19. Where can I go for more information?

Energy Information Services http://www.geokiss.com
Excellent design guide for small GHP systems, extensive design information for large commercial applications. Outside the Loop newsletter for commercial designers.

HeatSpring Learning Institute http://www.heatspring.com
Geothermal training organization with seminars ranging from introductory topics to advanced design and installation courses.

Geo-Heat Center http://geoheat.oit.edu
Primarily a Direct Use Geothermal information clearinghouse with some GHP information. Older out-of-date version of the this publication.

International Ground Source Heat Pump Assn. (IGSHPA)

http://www.igshpa.okstate.edu
Provides training for contractors, directory of certified contractors

Geothermal Heat Pump Consortium Inc. http://www.ghpc.org
A variety of publications and information generally promotional in nature

Canadian GeoExchange Coalition http://www.geo-exchange.ca/
Provides training for contractors, and a variety of publications and information generally promotional in nature

National Rural Electric Corporative
http://www.webplus.net/nreca/homepage.htm1

Your local electric utility

Your state energy office

20. I am an engineer, where can I go to find more detailed information for large commercial applications?

AHSRAE is the primary source of design information for HVAC systems in commercial buildings. Through it's website you can access the ASHRAE bookstore where you will find design manuals, special publications and the semi-annual Transactions which contain the most current technical papers on the technology. Chapter 32 in the ASHRAE Handbook of Applications covers design issues associated with closed loop, open loop and lake loop GHP systems for commercial applications. ASHRAE also publishes a design manual for GHP systems and numerous papers can be found in the Transactions on all aspects of GHP design.

HeatSpring Learning Institute offers a variety of technical courses and seminars on all major GHP system types for residential and commercial designers. Details schedules and course descriptions can be found on
www.heatspring.com

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Appendix 1 - EQUIPMENT PERFORMANCE RATINGS

Equipment performance ratings are the numbers we use to compare one manufacturer's product to another – much as we use EPA gas mileage ratings to compare one car to another. Like gas mileage ratings, equipment performance values do not always (actually almost never) reflect true installed-in-the-home performance. Rather they are best used to compare similar equipment (furnace to furnace or GHP to GHP) of one manufacturer to another. Unfortunately, the ratings used for different types of equipment (furnaces, ASHP, GHP) are not generally comparable, making direct comparisons between different types of equipment difficult. As a result, it is useful to know a little about what the ratings values include and what they don't.

All heat pumps are rated by the Air Conditioning and Refrigerant Institute (ARI). Results are periodically published in the *Directory of Certified Applied Air Conditioning Products (for GHPs)* available on the organization's web site at:
http://www.ahridirectory.org/ahriDirectory/pages/wbahp/defaultSearch.aspx
Air source heat pump performance data is published in the ARI *Directory of Certified Unitary Products.*

One caution with respect to both air source and GHP heat pump ratings is the issue of two speed or variable speed unit ratings in comparison to single speed equipment ratings. Equipment with the ability to operate at more than one speed often has very high performance ratings in low speed. When full speed is required however (in very hot or very cold weather) the same equipment may actually have *lower* performance than single speed equipment under the same conditions. In addition, in humid climates, dehumidification capacity in low speed may be less than required in some applications. These issues in conjunction with the higher cost and complexity of variable speed heat pumps suggest that their use be carefully considered by the homeowner.

GHP Ratings

The ratings format for water-to-air heat pumps was changed as of January 2000. Prior to this date, ratings for GHPs were published under two different standards: ARI 325 (open loop or groundwater heat pumps) and ARI 330 (closed loop or ground-coupled heat pumps). The new rating is ISO 13256-1. Under all rating systems for water-to-air heat pumps cooling performance is reported as EER (Energy Efficiency Ratio) and heating performance as COP (Coefficient Of Performance). These are not seasonal values (as in the case of the air source heat pump SEER and HSPF values) but laboratory test results carried out under a specific set of conditions.

For water-to-air heat pumps EER is defined by the cooling affect produced by the unit (in Btu/hr) divided by the electrical input (in watts) resulting in units of Btu/wattXhr. The higher the EER, the more efficient the unit. Heating performance, COP, is the heating affect produced by the unit (in Btu/hr) divided by the energy equivalent of the electrical input (in Btu/hr) resulting in a dimensionless (no units) value. Again, the higher the COP value, the more efficient the unit.

Under the ISO 13256-1 standard, performance values (EER and COP) are provided at different temperatures to reflect performance in different system types. The ratings are divided in to three parts: water loop (WLHP), ground water (GWHP) and ground loop GLHP) of which the most useful for GSHP systems is the GLHP values. This information can be used to compare the products of one manufacturer to another for either open loop, closed loop or lake loop systems. Heat pumps are tested for performance at entering water temperatures of 32 ºF in the heating mode and 77 ºF in the cooling mode under the GLHP conditions.

Air Source Heat Pump Ratings

The major difference between ratings for ASHPs and GHPs is that the air source values are intended to reflect seasonal performance. The cooling performance index is the Seasonal Energy Efficiency Ratio or SEER. Its units are seasonal cooling provided, in BTU, divided by seasonal electrical energy consumed, in watts, for seasonal Btu/watt. The Heating Seasonal Performance Factor or HSPF is similarly calculated. The total heating energy provided, in BTU is divided by the seasonal electrical energy required to run the heat pump, resulting in HSPF units of Btu/watt. For both SEER and HSPF, the higher the value, the greater the energy efficiency of the unit.

ASHPs are rated under ARI standard 210/240. In order to simplify the process, a number of assumptions are made regarding operation of the heat pump. The rating is based on a moderate climate (Washington, DC) and as a result, is not reflective of either very cold or very warm areas of the country. As with the GHP ratings, values published for two speed or variable speed ASHP equipment may be substantially higher than single speed units. The suitability of this equipment for a given application should be carefully considered however.

Furnace Ratings

Furnaces are rated by an index known as AFUE or annual fuel utilization efficiency. This is intended to reflect the annual heat energy supplied divided by the energy content of the fuel consumed to supply that heat. The major drawback is that the electricity required to operate the fan in the furnace (and the combustion air fan if so equipped) is not included in the rating. As a result the AFUE gives a somewhat less than complete picture of annual energy requirements of the equipment.

Appendix 2 – Average Annual Heating Degree Day Totals for Selected US Locations (McQuiston and Parker, 1977)

Tuscaloosa, AL	2371
Anchorage, AK	10864
Tucson, AZ	1800
Little Rock, AR	3219
Sacramento, CA	2226
Denver, CO	6283
Bridgeport, CT	5617
Wilmington, DE	4930
Washington, DC	4224
Tallahassee, FL	1485
Atlanta, GA	2916
Honolulu, HI	0
Boise, ID	5809
Chicago, IL	6639
Indianapolis, IN	5699
Sioux City, IA	6951
Wichita, KS	4620
Louisville, KY	4660
Shreveport, LA	2184
Caribou, ME	9767
Baltimore, MD	4654
Boston, MA	5634
Lansing, MI	6909
Minneapolis, MN	8382
Jackson, MI	2239
Kansas City, MO	4711
Columbia, MO	5177
Billings, MT	7049
Lincoln, NE	5864
Las Vegas, NV	2709
Hanover, NH	7331
Atlantic City, NJ	4812
Albuquerque, NM	4348
Syracuse, NY	6756
Charlotte, NC	3191
Bismarck, ND	8851
Cleveland, OH	6351
Stillwater, OK	3725
Klamath Falls, OR	6916
Pittsburgh, PA	5987
Providence, RI	5954
Charleston, SC	2033
Milwaukee, WI	7635
Casper, WY	7410