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Groundwater Heat Pump: An Efficient Way to Heat and Cool Your Home

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GROUNDWATER HEAT PUMP

An Efficient Way to Heat and Cool Your Home

Engineers at the Utah Water Research Laboratory and the Mechanical Engineering Department at Utah State University have looked into the economic feasibility of groundwater heat pumps for residential heating and cooling in the Utah climate. They have found that this type of system conserves energy and may cost less than conventional heating systems. By using a heat pump, thermal energy can be taken from groundwater and can be used to heat homes in the winter and cool them in the summer. If you are a Utah homeowner in an area where the groundwater heat pump system is economical, you may wish to take advantage of groundwater as an abundant (and often overlooked) indirect source of solar energy.

What Is a Heat Pump?

A heat pump operates in a manner similar to a household refrigerator which pumps heat from inside the refrigerator to the outside. The major difference between the two systems is that a heat pump can either deliver heat to or remove heat from a space by simply reversing the flow direction of the refrigerant. For this reason, heat pumps are sometimes called "reversed-cycle refrigerators."

There are several different types of heat pumps identified by their heat source (substance from which heat is removed) and heat sink (substance to which heat is delivered) respectively. The most common types are air-to-air, water-to-air, and water-to-water. A groundwater heat pump for residential use can be of the water-to-air or the water-to-water type.

How Does a Groundwater Heat Pump Work?

In Figure 1, a groundwater heat pump extracts heat energy from incoming groundwater and delivers heat energy (H_h) into your home. When the heat pump is operating as an air conditioner, however, heat energy (H_c) is removed from your home and carried away by the outgoing groundwater, which is usually discharged back into a second water well drilled some distance from the source well.

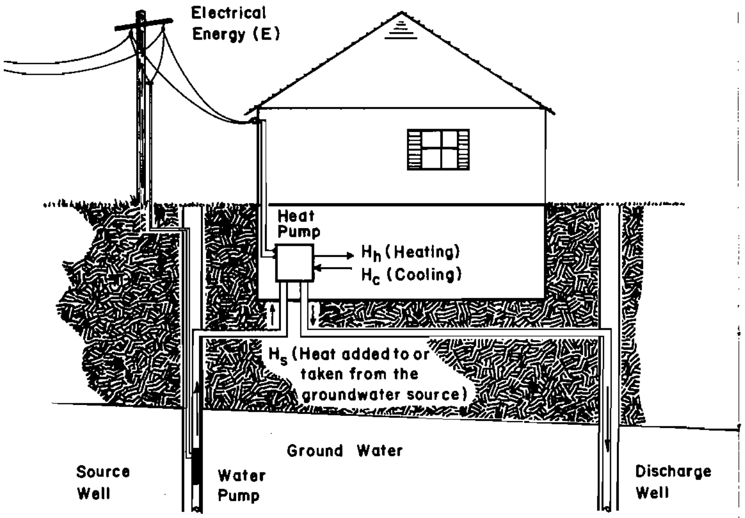

Figure 1. How a groundwater heat pump works.

Now let's examine the heat pump cycle itself. When the heat pump is operating in the heating mode, as shown in Figure 2, valve (1) directs a gaseous refrigerant from compressor (2) to the air-refrigerant heat exchanger (3). Heat is removed from the groundwater and delivered into the house by blowing air over the heat exchanger. This causes the hot gas to condense to a warm liquid. The warm liquid refrigerant then enters the expansion device (4) where the pressure decreases and part of the liquid refrigerant vaporizes, becoming chilled. It passes through heat exchanger (5) where it absorbs heat from the groundwater, causing the rest of the liquid refrigerant to evaporate. The gaseous refrigerant then enters the reversing valve, and the cycle is repeated.

When the heat pump is operating in the cooling mode, as in Figure 3, the position of valve (1) is reversed. The compressor pumps hot refrigerant to the heat exchanger (5) where the gas condenses to a warm liquid giving up heat to the groundwater. The warm liquid flows through the expansion device where the pressure decreases causing the liquid to expand into a chilled gas. Hot air blowing over the heat exchanger (3) gives up heat to the refrigerant, and cool air is blown into the house. The gaseous refrigerant is directed by valve (1) into the compressor, and the cycle is repeated.

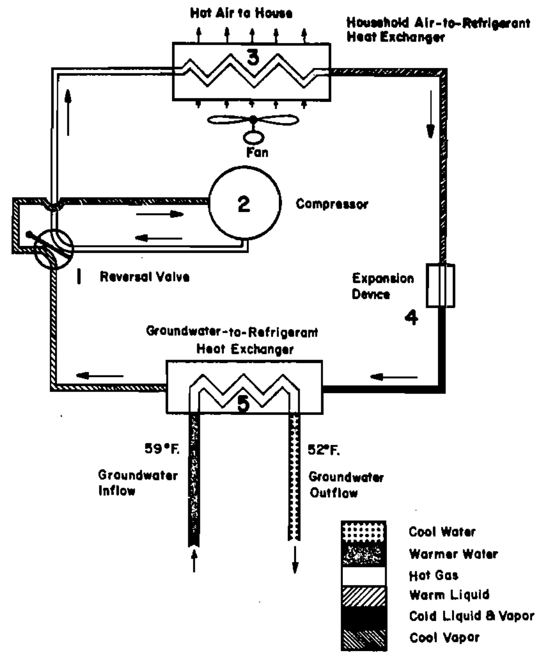

Figure 2. Heating mode water-to-air heat pump.

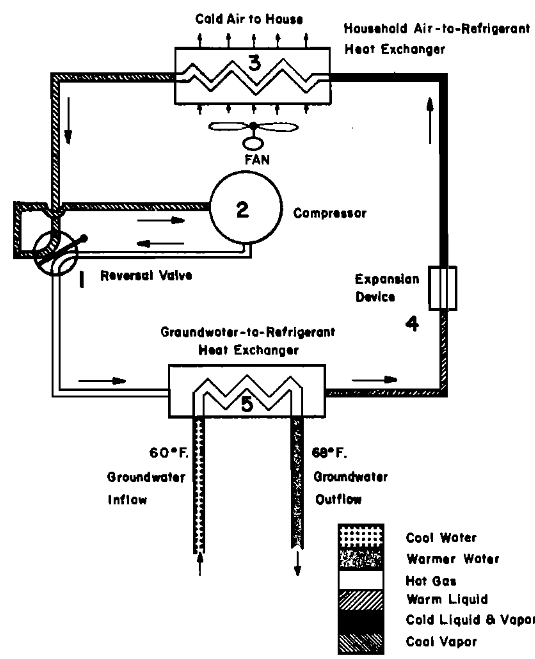

Figure 3. Cooling mode water-to-air heat pump.

Why Use Groundwater?

Groundwater heat pumps have two basic advantages over heat pumps which use air as the heat source. First, water has the highest specific heat of any common substance. Its specific heat is four times greater than that of air. In other words, a given mass of water can store four times as much heat energy as an equal mass of air and the water occupies a much smaller space. Second, groundwater temperatures in Utah are fairly constant the year around, with annual temperature changes from 10 to 20°F in shallow groundwater. The temperature variation for deep groundwater is even less. Air temperatures, however, are usually too low for economical use in the winter when heat is needed and too high in the summer when cooling is needed. When an air-to-air heat pump operates in these extreme temperatures its efficiency is reduced, and a greater quantity of electricity is consumed.

What Is the Coefficient of Performance?

The coefficient of performance (COP) is a measure of heat pump efficiency; the higher the COP, the more efficient the heat pump. By definition, the coefficient of performance is the heating or cooling output divided by the electrical energy input. Referring to Figure 1, the COP may be written as:

$COP = H_h/E$ for the heating mode and
$COP = H_c/E$ for the cooling mode.

Conventional heating systems using natural gas, coal, and electric resistance have COPs of 0.75, 0.70, and 0.95 respectively. Heat pumps, on the other hand, normally have COPs greater than 1. Table 1 compares the COPs of each of these heating systems. The fact that heat pumps have COPs greater than 1 seems to contradict the laws of nature since more energy comes out of the heat pump than we put in! Actually, this is not so because a heat pump merely utilizes electrical energy to remove "free heat" energy from the groundwater. The average COP for a groundwater heat pump is around 3.2, which means, for example, that a heat pump will deliver 320 BTUs (units) of heat for every 100 BTUs of electrical energy it consumes. Note that the average COP of a groundwater heat pump is somewhat higher than the air-to-air heat pump.

Table 1. Comparison of performance of heat pumps and conventional systems.

System	COP	Energy* Input	Energy* Output
Coal	0.70	100	70
Natural gas	0.75	100	75
Electric resistance	0.95	100	95
Air-to-air heat pump	2.0	100	200
Groundwater heat pump	3.2	100	320

*Arbitrary units

How Reliable Are Heat Pumps?

Heat pumps have been commercially available since 1952. The reliability of many of the early models left something to be desired; poorly designed compressors experienced stresses which frequently caused failures, valves often did not operate properly, and installation and maintenance were generally poor. Consequently, the heat pump sales volume was low. But during the past decade, heat pump components have been vastly improved, making the reliability of today's heat pumps equal to that of conventional heating systems and boosting national sales to over 500,000 units in 1978. Modern heat pumps require no more maintenance than conventional heating systems.

How Much Will It Cost?

Two separate costs must be considered in the economic evaluation of a groundwater heat pump system. First, there is the initial cost of the equipment and its installation. This cost can vary widely depending on the size and construction of your home. A small home which is not energy-efficient may require a heat pump which costs more than a heat pump installed in a larger, energy-efficient home. This emphasizes the importance of installing a lot of insulation. weather-stripping, caulking, and employing other energy-saving construction features. Table 2 shows the approximate average prices for a groundwater heat pump system. The base cost of the wells in Table 2 includes two 20-foot deep wells with 6-inch casings, an installed water pump, sanitary protection and well screens. You can expect to pay around $24 per additional foot that the wells must be drilled to reach the groundwater. Initial costs of conventional heating systems are included in Table 2 for comparison.

Table 2: Average initial costs for heating and cooling systems.

	System					
	Groundwater Heat Pump	Air-to-Air Heat Pump	Natural Gas Furnace	Electric Resistance	Electric Furnace	Propane
Heating	$3,000	$3,000	$ 800	$ 400	$1,000	$ 800
Cooling			$1,300	$1,100	$1,100	$1,300
Ductwork	$ 400	$ 400	$ 300		$ 400	$ 300
Chimney			$ 75			$ 75
Storage Tank						$ 150
Water Well	$2,300					
Plumbing	$ 300					
Total	$6,000	$3,400	$2,475	$1,500	$2,500	$2,625

The second cost which must be considered is the annual operating cost. The current low natural gas prices in Utah give this heating method a decided economic advantage over the use of all other heating fuels in the state. This is reflected in the fact that about 98 percent of Utah residences are natural gas customers. However, a groundwater heat pump having a good coefficient of performance gives natural gas heating keen competition. Table 3 compares annual heating costs (excluding water heating) for a typical 1500 square foot Utah home in four representative Utah cities having insulated walls constructed of 2 x 4 inch studs, 6 inches of ceiling insulation and double glazed windows. In St. George propane is used for comparison since this area is not serviced by natural gas.

As shown in Table 3, a groundwater heat pump must have a COP of about 3.4 in Salt Lake City and Logan and 3.2 in Moab to be cost-competitive with natural gas heating. Electric resistance heating is more expensive in all four cities than either natural gas or a groundwater heat pump. In St. George, a groundwater heat pump having a COP of 1.4 or greater is more economical than propane heating. All quality groundwater heat pump systems on the market today have COPs equal to or exceeding those needed to achieve a cost savings in the State of Utah.

Table 3. Annual operating costs for space heating.

Area	COP	Ground-water Heat Pump	Natural Gas	Electric Resistance*
Logan	3.2	$240	$228	$808
Av. G.W.	3.4	$225	$228	$808
Temp. =	3.6	$213	$228	$808
54°F	3.8	$202	$228	$808
Salt Lake	3.2	$213	$208	$718
Av. G.W.	3.4	$200	$208	$718
Temp. =	3.6	$189	$208	$718
58°F	3.8	$179	$208	$718
Moab	3.0	$177	$170	$560
Av. G.W.	3.2	$166	$170	$560
Temp. =	3.4	$156	$170	$560
63°F	3.6	$147	$170	$560
St. George	1.4	$267	$271	$394
Av. G.W.	2.0	$187	$271	$394
Temp. =	2.6	$144	$271	$394
66°F	3.2	$117	$271	$394

*Electric resistance baseboard heating or radiant heating.

In the cooling modes, Table 4 shows that a groundwater heat pump is much more economical than a conventional refrigeration unit (air-to-air heat pump) with the usual COP = 2.0. The lower cooling costs are particularly attractive to those who live in the southern portion of Utah where air conditioning is needed nearly half of the year.

As a result of the annual cost savings over electric resistance or propane heating, a groundwater heat pump will eventually pay for itself. If you live in Logan the payback period is about seven years. For Salt Lake City, Moab and St. George the payback periods are 8, 10, and 14 years respectively compared to electric resistance heating. The payback period is about 16 years compared to propane heating if you live in St. George. Each of these payback periods will be two or more years less if you already have at least one water well for your groundwater heat pump.

Table 4. Annual cooling costs.

Area	COP	Groundwater Heat Pump	Air-to-Air Heat Pump
Logan	2.0	$33	$33
	2.4	$28	$33
	2.8	$24	$33
	3.2	$21	$33
Salt Lake City	2.0	$53	$53
	2.4	$44	$53
	2.8	$38	$53
	3.2	$33	$53
Moab	2.0	$87	$87
	2.4	$72	$87
	2.8	$62	$87
	3.2	$54	$87
St. George	2.0	$117	$117
	2.4	$97	$117
	2.8	$83	$117
	3.2	$73	$117

Alternate Uses of Groundwater

The homeowner who has a groundwater heat pump has other potential advantages besides just an efficient and economical heating and air conditioning system. In certain areas of the state, where water can still be appropriated for consumptive use, it may be possible to use the water from the ground for other purposes. However, in these instances it will be necessary to discuss this possibility with the Utah Division of Water Rights. Possible uses include irrigation, drinking water, hot water use, and various other outdoor applications.

Obtaining a Well Permit

It is necessary to obtain a well permit for a groundwater heat pump system. To acquire the well permit (water right) the home owner must file an application with the Utah Division of Water Rights and receive approval of the application. The normal processing period for such an application is about 120 days.

Where water rights are not being permitted for consumptive purposes, no uses such as irrigation could be made from those wells drilled for the groundwater heat pump.

How Far Apart Must the Wells Be?

Spacing the supply and injections wells 100 feet apart is satisfactory for most locations. For good aquifers this spacing might be as small as 25 feet while a larger spacing would be more efficient for poor aquifer conditions.

What About Remodeling?

Although the initial installation costs of groundwater heat pump systems described in this brochure are for new homes, you may want to install a groundwater heat pump in an older home. The additional cost you will pay by replacing your present heating system with a groundwater heat pump depends upon the age and size of your home and several other factors as well. Contact your local heating contractor for information on the cost of making the necessary modifications.

Where Is Groundwater Available?

The groundwater needed to operate a heat pump is available in many areas of the state. However, the occurrence of groundwater may be highly variable in an area. If you are not sure of the availability of groundwater, the depth to groundwater, or the drilling conditions, you should obtain information and advice from publications, from groundwater professionals, and from well drillers.

Heating Assistance from Solar Energy

There are two basic types of solar heating systems: active and passive. Depending on what kind of fluid is used to collect and/or distribute the solar energy, active systems may be further classified as liquid or air installations. Active designs usually use pumps and pipes or fans and ducts to transfer energy from the collectors to the living space; the term active is used because the pumps and/or fans must be actively driven with external power (usually electric). Conversely, passive designs use only natural convection circulation to transfer the energy through the living space.

As of 1979, energy prices are such that an active solar design has a very long payback period for a typical American city. However, passive solar design concepts may be incorporated in a new home design at very little extra cost. Passive design features include: south-facing glass; heat storage in containers filled with water, masonry walls and floors, etc.; summer shading of glass using facade overhangs, grills, awnings, or trees; shutters; earth berming natural ventilation with external breezes; passive solar homes are always well insulated, caulking, and weather stripped. For further passive design details, consult the appropriately titled reference listed at the end of this booklet.

What Do I Do Next?

1. Discuss groundwater heat pump with your architect and/or contractor.
2. Select the heating subcontractor, discuss the heat pump system and help him complete the design.
3. Obtain permits for the supply and injection wells.
4. Select the well driller.

A Few Energy Conservation Tips

The efficiency and cost savings of a groundwater heat pump system will be greatly enhanced by implementing energy conservation measures in your house itself. Here are some ideas that will help:

1. Plenty of insulation in walls and ceilings. Recommended R values are R-19 for walls and R-38 for ceilings.
2. Weather stripping and caulking around doors and windows.
3. Open drapes on sunny winter days letting the sun warm you naturally.
4. Close drapes at night to help keep heat inside.
5. Turn off all electric appliances when not in use.
6. Set thermostat at 65°F during the day and 55°F at night. During summer set cooling thermostat at 80°F or higher.
7. Install storm doors and windows.
8. Open and close outside doors and windows as seldom as possible.
9. Replace tungsten light fixtures with fluorescent light fixtures.
10. Use hot water sparingly.
11. Insulate hot water pipes.
12. Set hot water heating thermostat to 120°F.

Summary

In summary, this study has shown that a groundwater heat pump is more economical to operate in Utah homes than heating systems using electric resistance, propane, or air-to-air pumps. Compared to electric resistance heating, a groundwater heat pump can reduce your annual electric heating bill by as much as 70 percent. A 58 percent annual savings over propane heating can be achieved, and a 37 percent annual savings is possible over an air-to-air heat pump. However, the current low price of local natural gas gives a groundwater heat pump the strongest competition, and a significant savings is not possible. Nevertheless, if your area is not serviced by natural gas, a groundwater heat pump is still the next most economical alternative. Furthermore, if natural gas prices increase significantly in the future, the groundwater heat pump may be the best system.

For more information on groundwater heat pumps you may contact the Utah State University Extension Service (1-801-752-4100 Ext. 7511) or Utah Water Research Laboratory (1-801-752-4100 Ext. 7821).

Additional References

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