Research and Development Initiative

Geothermal Heat Pump

OGE ENERGY CORP

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Authored by: Michael Ballard

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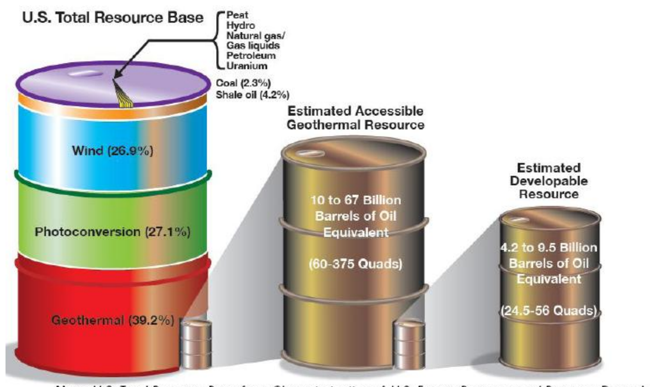
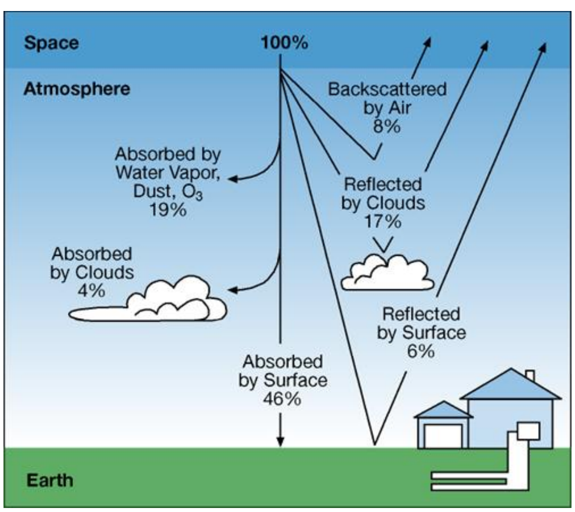
Overview

Geothermal heat pump is a generic term used to describe a variety of other names for this technology including geoexchange, ground-source or water-source heat pump, earth-coupled, etc. The engineering and scientific community tend to prefer the terms "geoexchange" or "ground-source heat pumps" because very little of the heat originates from true geological sources. Instead, these pumps draw energy stored in the ground that is heated by the sun in the summer. Genuine geothermal energy from the core of Earth is available only in places where volcanic activity comes close to the surface, and can usually be extracted without the help of a heat pump.[i]

Of all the energy resources available in the United States, the Department of Energy characterizes geothermal as the most plentiful with 39.2% of the total available energy. Within the geothermal category, capturing of the energy from geothermal heat pumps (GHP) is the most widely available geothermal resource in the country and the most easily accessed. GHPs constitute between 30 – 70% of developable geothermal resources.

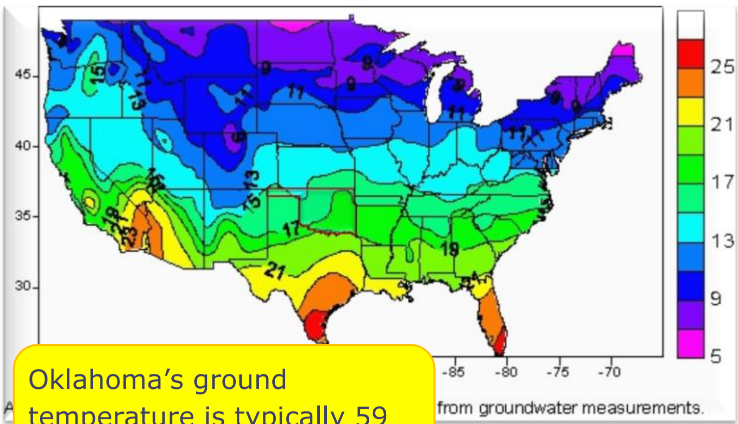


Note: U.S. Total Resource Base from *Characterization of U.S. Energy Resources and Reserves*, December 1989, U.S. Department of Energy, DOE/CE-0279.
Source: NREL/TP-840-40665, November 2006



A GHP is designed to provide central heating and cooling to a building by pumping or exchanging heat with the earth. In an average year, the earth absorbs roughly 46% of the energy delivered to its surface by the sun. This is 500 times more energy than we use in a given year and it is clean and renewable. GHPs tap into this source of renewable energy by exploiting the fact that the absorption of the sun's rays by the earth creates a near constant deep earth temperature throughout the year. [ii]

In other words, when outside air temperatures reach 100˚F or even when they fall to -25˚F, the temperature of the earth just a few feet below the surface stays nearly constant. The actual earth temperature varies depending on soil composition and yearly average air temperature but it is always cooler than the air temperature on the hottest summer days and warmer than the outside air temperature on the coldest winter days.[iii]



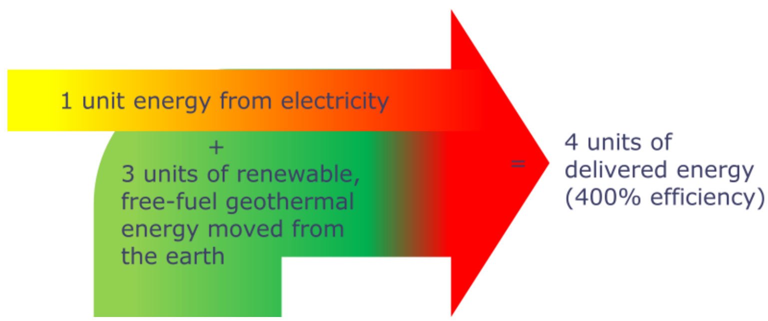
Oklahoma's ground temperature is typically 59 - 62 degrees F. (15 – 17 c)

Source: Geothermal Heat Pumps Geothermal Resources Council Bulletin 11(11), 3-8, 1982

The system works by utilizing the earth to act as a source of heat in the winter and a source of coolant in the summer. The ground temperature varies throughout the country, but in Oklahoma, the average temperature of the earth is approximately 59-62 degrees F. (15-17 C.) at the depths where ground-source loops are installed.

In a typical GHP system, the earth provides 3 units of energy for each 1 unit of electric energy needed to accomplish the heating and cooling goals. This yields an average of a 400% efficient system since energy from the earth is a renewable and free fuel source.

(Four units of total energy delivered divided by 1 unit of added electrical energy to pump or move the heat either to or from the building)



In theory, these heat pump systems work much like a refrigerator as they force the transfer of heat from one location to another. The key component of the heat pump is a loop of refrigerant that is pumped through a vapor-compression refrigeration cycle that moves heat. Like a refrigerator, a GHP simply transfers heat from one place to another. When a refrigerator is operating, heat is being carried away from the inside food storage area to the outside, your kitchen. Therefore, cooling is not being added to the inside; heat is being taken out.

Technology

In general, GHP systems consist of three components, (1) a ground (or water source) heat pump, (2) a heat sink/source (open or closed loop piping system) and (3) a distribution system (forced air ductwork or hydronic piping). The heat sink/source is obtained by placing a series of pipes underground or in the water of a well or pond. This is known as the ground or water loop. It functions as a heat exchanger that either extracts or adds heat to the ground. These systems come in several different configurations, each with its own strengths and weaknesses. The key system types are:

Open vs. Closed Loop

Open loop systems draw ground water directly into the building to heat/cool the heat pumps with it. The system requires sufficient ground water to meet the needs of the building. Ground water often has minerals and other contaminants in it that detrimentally affect the equipment. Open loop systems that use lake water are also available, but should use filtration equipment or secondary heat exchangers to deal with contaminates. Lake water, used in an open loop application, should be used in climates where the entering water temperature is above 40 degrees F. The ground must have the capacity to take open loop system discharge. These cannot be used below 40°F without the risk of freezing. In addition, open loop systems must allow for the increased pump head from the lake/ground water level to the heat pumps. Over a period of years, an open-loop system will require more maintenance because it is not sealed or pressurized, thus opening up the possible build-up of minerals or iron deposits.

Closed loop systems have a dedicated fluid loop that is circulated through the ground or pond in order to exchange energy. The ground/pond water and loop water do not mix. Closed loop systems are further broken down into loop types.[iv]

__Vertical Loops__ are used extensively where land area is limited or soil conditions prohibit digging the more economical horizontal loops. A pair of pipes with a special u-bend assembly at the bottom are inserted into a bore hole that averages between 150 to 250 feet deep per ton of HVAC equipment. These holes are then backfilled with a special grout solution to ensure good contact with the earth.

__Horizontal Loops__ are installed in areas where the soil conditions allow for economical excavation. Taking up more land area than any other loop type, they are used where space is not an issue. Trenches are normally about five feet deep with multiple pipes placed in the trench at different depths. Normally, several hundred feet of trench is required, but where space permits these loops are considered desirable.

__Pond Loops__ are usually very economical to install. If a pond or lake at least eight feet deep is available, pond loops can utilize the water (rather than soil) to transfer heat to and from the pond. A coiled pipe is placed in the water, which should cover about ½ acre. An average home would require about 900 feet of pipe. Reduced installation costs and high performance are characteristics of this type of loop.[v]

Water Heating with GHP: GHP and water-source heat pumps are able to heat, cool, and, if so equipped, supply the house with hot water.

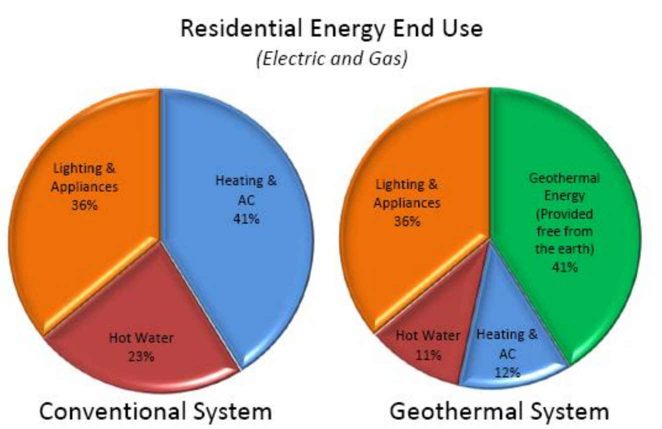
There are two types of hot water systems that work in conjunction with GHP's:

Full condensing units assign the total capacity of the compressor when required. These systems offer output comparable to a fossil fuel water heater, with water heating electricity use to be about 1/3 as great as with a resistive water heater. These are typically high-end products.

Desuperheaters are small heat exchangers between the compressor and the primary condenser. They utilize the heat normally generated in the heat pump's high-pressure vapor coil to heat water. A water line connects the desuperheater to the building's hot water heater where it is then then pumped into the bottom of the water heater's storage tank. In the summer, this improves performance, but it is a small additional load in the winter. A desuperheater system costs several hundred dollars, but is expected to offset about half of the annual electricity that would otherwise be consumed by a traditional resistance water heater. The principal drawback of the desuperheater approach is that it only heats water when the heat pump unit is operating to heat or cool the building.

Documented Benefits

According to the Department of Energy, in the West-South Central Region, which includes OG&E's service territory, approximately 64% of household energy (including both electricity and gas) is used for heating, air conditioning, and water heating.[vi] The Department of Energy estimates that with a Geothermal Heat Pump (GHP) system, energy costs can be reduced by 25%-50%. An example comparing a conventional and GHP system is shown in the figure to the right. In this example, the earth provides geothermal energy for approximately 40% of the energy needs, which reduces the AC, heating and hot water needs down from 64% from the conventional system to only 23% of total energy consumed with the GHP system.



Source: Data from Department of Energy – Energy Information Administration – South West Region
(Graphics by OGE Strategy Dept.)
http://www.eia.doe.gov/emeu/recs/recs2005/c&e/detailed_tables2005c&e.html
ClimateMaster Fort Polk Case Study

Edison Electric Institute evaluated and commented on the benefits and value of GHP systems as follows:

- "They provide the highest levels of efficiency for heating and cooling. In fact, the U.S. Environmental Protection Agency performed a study and concluded that GeoExchange systems provided the lowest operating costs and best environmental performance, even when compared to advanced fossil fuel systems.

- They can save homeowners 30 - 70 percent on their heating bills and 20 - 50 percent on their cooling bills, when compared to standard heating and cooling systems.

- There are now a large number of builders and contractors who have experience with the installation of these systems, along with hundreds of thousands of satisfied homeowners."[vii]

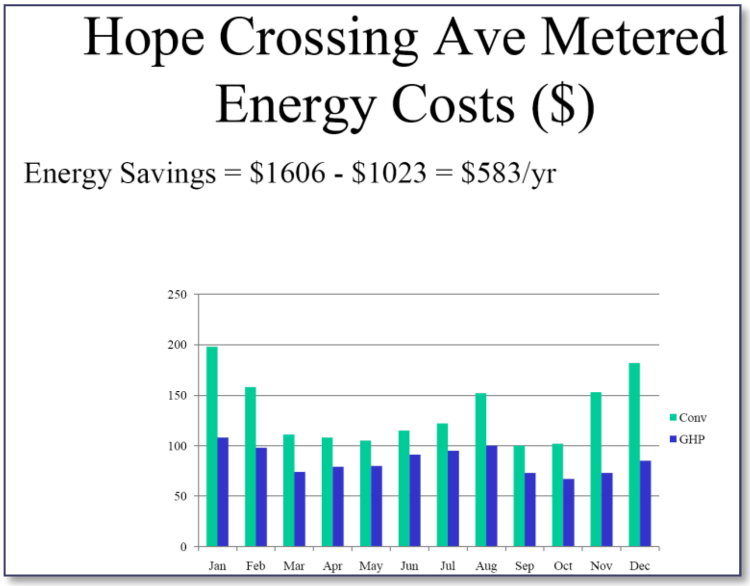
The energy saving benefits of GHPs are well documented. Many independent sources have published results of case studies that clearly show the summer peak reduction benefits as well as reduced costs for the customer in the winter as well.

- **The Department of Energy:** "The biggest benefit of GHPs is that they use 25%-50% less electricity than conventional heating or cooling systems. This translates into a GHP using one unit of electricity to move three units of heat from the earth. According to the EPA, geothermal heat pumps can reduce energy consumption-and corresponding emissions-up to 44% compared to air-source heat pumps and up to 72% compared to electric resistance heating with standard air-conditioning equipment."[viii]
- **Oklahoma State University – International Ground Source Heat Pump Association:** "The GHP is one of the most efficient residential heating and cooling systems available today, with heating efficiencies 50 to 70% higher than other heating systems and cooling efficiencies 20 to 40% higher than available air conditioners. That directly translates into savings for you on your utility bills. A GHP can be a combination heating/cooling and hot water heating system. Using a desuperheater, some GHPs can save you up to 50% on your water-heating bill by preheating tank water."[ix]
- **Oak Ridge National Laboratories – Fort Polk Geothermal Case Study:**
    - *Energy Savings* – The energy retrofit reduced overall electrical consumption in Fort Polk family housing by 26 million kWh per year (33%) while eliminating altogether annual natural gas consumption of 260,000 therms. This overall 33% reduction in electricity use was achieved even though electric-powered GHPs replaced natural-gas-fueled furnaces and water heaters in 20% of the apartments.
    - *Peak Demand* – Summer peak electrical demand was reduced by 7.5 MW (43%) – equivalent to a decrease of almost 2kWh per house.
    - *Load Factor* –Electrical energy savings and reduction of peak demand have dramatically improved the annual electric load factor —from 0.52 to 0.62— which may allow the Army to negotiate lower rates for the entire base.
    - *Cost Savings* – Fort Polk saves about $345,000 annually for 20 years (the life of the contract). After the contract expires, the Army continues to reap the benefits of the GHPs' energy efficiency—about $2.2 million per year—during any remaining GHP service life. The proportion of total energy savings attributable to the new GHPs—through the heat pumps themselves and

through the desuperheaters for water heating—was a whopping 66% in 200 apartments on Feeder 1 that were all-electric before the retrofit.

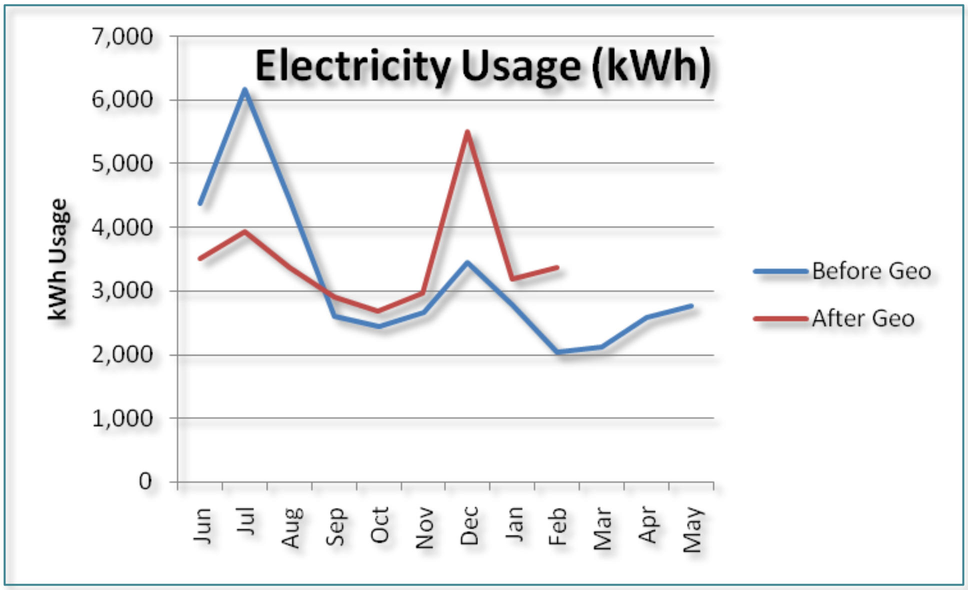
- *Cleaner Air* –CO_2 emissions are reduced by 22,400 tons per year.[x]

- **Hope Crossing Case Study – Habitat for Humanity – Oklahoma City, OK**
  - OG&E helped sponsor the construction of these energy efficient homes and has metered data showing the benefits of the geothermal systems. The average metered energy costs per home were reduced from $1,606 per year to $1,023 per year for an annual savings of $583.

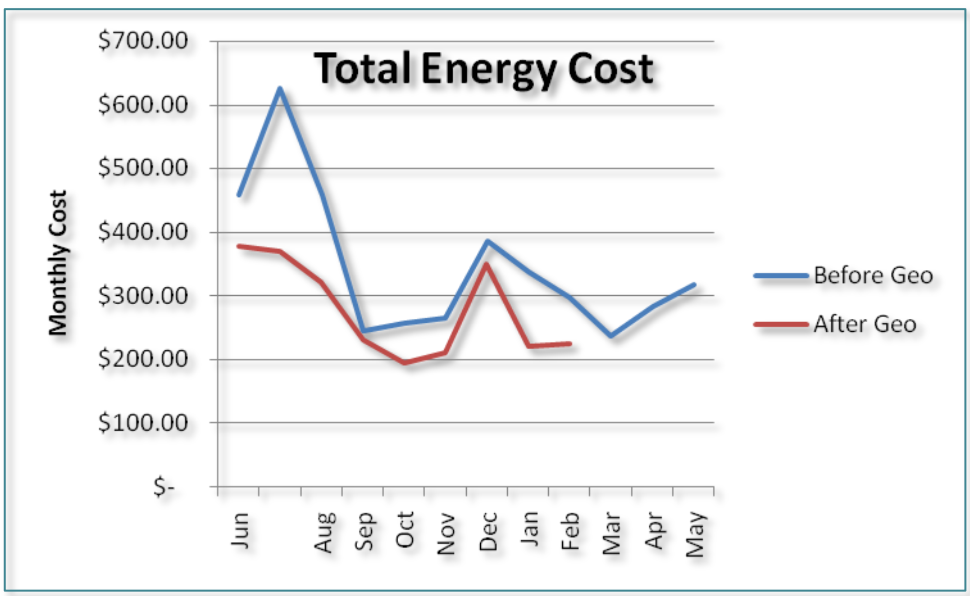


- **OG&E Employee Case Study A**
  - 3200 ft^2 home - Built 2000
  - **HVAC Before:**
    - 4 ton 12 SEER A/C - Natural Gas Furnace – Downstairs
    - 3 ton 12 SEER A/C - Natural Gas Furnace – Upstairs
  - **Water Heating Before:**
    - 50 gallon - Natural Gas – Downstairs
    - 50 gallon - Natural Gas – Upstairs
  - **HVAC System - Geothermal:**
    - ClimateMaster Tranquility 27 split units installed (EER Rating 27 - Partial Load)
    - 4 ton unit for main floor
    - 3 ton unit for upstairs
    - Geothermal system operational - June 11, 2009
    - Natural Gas backup heat
  - **Water Heating System - Geothermal:**
    - Electric hot water heater replaced natural gas unit - June, 2009, adding to electric load

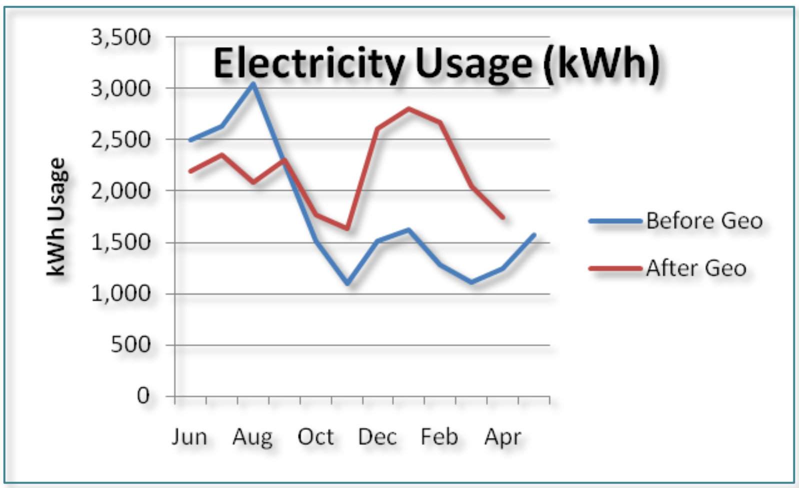
The electricity usage graph clearly illustrates the kWh was lower during the summers months with a gain in the winter. The winter gain is attributable to the home being heated with geothermal energy and the required electricity to run the heat pump. There was an overall gain in kWh due to the home converting from Natural Gas water heating to electric.



The next graph illustrates that although there was a gain in electricity usage in the winter months, and the hot water heater was converted to electric, the overall cost of energy was less in both the summer and the winter. This is due to the efficiencies attributed to the use of free geothermal energy that is stored in the ground and moved by the geothermal system. In addition, approximately 50% of the hot water needs can be generated with the geothermal heat pump.

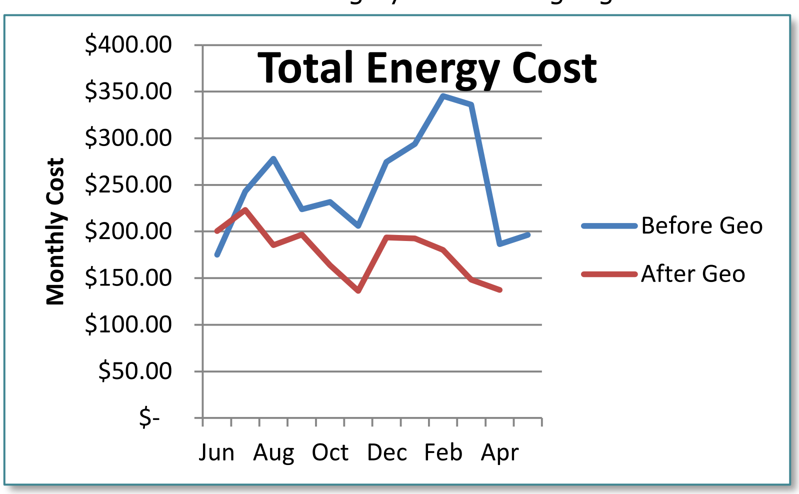


- **OG&E Employee – Case Study B**
    - 3700 ft^2 home - Built 1995
    - **HVAC Before:**
        - 4 ton 12 SEER Air Heat Pump - Propane Gas Furnace – Downstairs
        - 3 ton 12 SEER Air Heat Pump - Propane Gas Furnace – Upstairs
    - **Water Heating Before:**
        - 80 gallon - Propane
    - **HVAC System - Geothermal:**
        - ClimateMaster Tranquility 27 split units installed (EER Rating 27 - Partial Load)
        - 4 ton unit for main floor
        - 3 ton unit for upstairs
        - Geothermal system operational - May 25, 2009
        - Propane backup heat
    - **Water Heating System - Geothermal:**
        - Electric hot water heater replaced propane gas unit - May, 2009Case



Study B shows the same pattern as seen in Case Study A, where summer electricity usage is lower while the winter is higher.

The total cost of energy for the home is also lower in both the summer and the winter. This home also converted the propane water heater to electric, so a major electrical load was added in both the winter and the summer; however, the total energy cost remains lower in all months of the year. Case study B was also compared to ClimateMaster's GeoDesigner software that calculates and compares total energy for various HVAC and Water Heating systems using algorithms from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) handbook. The results of that analysis closely mirror the actual results from this case study.



Barriers to Adoption

A December 2008 Oak Ridge National Laboratory report entitled "Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoptions, and Actions to Overcome Barriers," states that "The key barriers to rapid growth of the GHP industry, in order of priority (1 being the most important barrier), are the following:

1. High first cost of GHP systems to consumers
2. Lack of consumer knowledge and/or trust or confidence in GHP system benefits
3. Lack of policymaker and regulator knowledge of and/or trust or confidence in GHP system benefits
4. Limitations of GHP design and business planning infrastructure
5. Limitations of GHP installation infrastructure
6. Lack of new technologies and techniques to improve GHP system cost and performance."[xi]

Upfront Costs: The high initial cost of GHPs is the principal barrier to greater adoption. The heat pump/compressor and air handler equipment costs in a GHP system are comparable to high-efficiency air-source heat pump equipment. But, depending on the complexity of the drilling, the incremental costs associated with the ground source heat exchange (drilling, ground loop piping, and headering) are in the range of $1,600 - $2,000/ton for individual residential applications. The average residential HVAC size is approximately 3 tons, so the additional cost burden ranges approximately $5,400. These loop costs are the primary driver of the cost differential between GHPs and other HVAC systems.

Currently, the upfront costs are mitigated with Federal Tax Credits and with rebates through OG&E's DSM program. The American Recovery and Reinvestment Act of 2009 provides a 30% uncapped credit to taxpayers who install a GHP system before 2016. This tax credit reduces the cost barrier of GHP systems but does not totally mitigate the differential between GHPs and other HVAC systems. With the OG&E $350.00 per ton rebate the upfront cost differential is effectively brought into parity with a high-efficiency air-source heat pump system.

Since the Geothermal Heat Pump energy savings to the customer and peak load benefits are so significant, it is important to identify technologies, tools and methods that will allow for an effective transition from a subsidized market to a sustainable business model whereby this technology will continue to be more adopted and utilized, even after the tax credits and rebates expire. Therefore, we propose that the primary purpose of this Research and Development project be focused on mitigating the most significant barriers to adoption – namely the "High first cost of GHP systems to consumers" and "Lack of new technologies and techniques to improve GHP system cost and performance."

Proposed Plan

As the above quoted Oak Ridge National Laboratory report indicates, the largest barrier to greater adoption of GHPs is the high first cost to the consumer and another barrier is a lack of new technologies and techniques to improve GHP system costs and performance. We propose the purpose of this research and development be aimed at applying new technologies and techniques to reduce the upfront costs. If this project proves new methods and technologies are able to reduce the cost, the possibility of having more consumers realize the benefits of GHPs will be the anticipated and desired outcome.

Since horizontal loop installations need a considerable amount of available and accessible land and ground water loop installations require an accessible pond, the most versatile of the options is the vertical loop design. Since the vertical loop design touches the broadest population, our focus will be on reducing the costs associated with this type of design.

Since the primary differential cost element between GHPs and other HVAC systems is associated with the ground-source loop, it is proposed that we focus our research and development efforts on reducing the cost impact of this particular part of the system. An itemization of the loop costs reveals the following breakdown:

- Drilling - 49%
- Piping materials - 17%
- Grout - 10%
- Trenching - 5%
- Headering - 19%

Since drilling-depth related items (drilling & piping) represent 66% of the total loop cost, it would provide a substantial benefit if new designs and technologies could help alleviate this cost burden.

Two technologies that have the potential of having a positive impact in reducing the overall depth of the drilling and thus the costs are 1) thermal grout and 2) advanced thermal piping. Both of these technologies could reduce the drilling depth needed to obtain the appropriate thermal exchange between the pipe loop and the earth.

Other technologies that have the potential of reducing drilling costs are advanced drilling methods such as sonic drilling, slurry drilling and angular drilling. Since these methods can drill faster than traditional drilling techniques, and drilling costs are in part a function of the amount of time it takes to drill the holes, methods that can speed up the process have the potential to reduce overall drilling costs.

Thermal Grout:

Each vertical bore hole must be backfilled with grout to provide an aquifer seal and anchoring of the pipes. The most common type of grout is a bentonite mixture that performs well to seal the aquifer; however, its ability to transfer heat is limited. The main function of the pipe loop going into the ground is to act as a thermal exchange between the heat pump and the earth. In order to optimize this thermal exchange, the grout material should have at least the same thermal conductivity as the earth. Otherwise, the grout material could actually provide a thermal barrier or insulator, thus limiting the thermal exchange with the earth.

The typical thermal conductivity of standard bentonite grout is 0.42 Btu/hr-ft-F. The thermal conductivity of the earth is generally dependent on density, moisture content and mineral content. To understand the thermal conductivity of the earth at a potential site, an in-situ analysis can be performed. Another alternative is to sample certain areas and geographies and understand the thermal conductivities in these regions. Generally, the thermal conductivity of the earth in the central part of Oklahoma is 1.2 – 2.0 Btu/hr-ft-F, based on the composition being a combination of sandstone, clay and shale.

There are commercially available grouts that have a silica sand additive that enhances the thermal properties of standard bentonite grouts. The higher the concentration of silica sand, the higher the thermal conductivity. The bentonite remains an important constituent of the mix and should not be considered for elimination due to its sealing properties for the aquifer and its binding properties with the pipe loop. Therefore, a mixture of bentonite and silica is prepared to bring the thermal conductivity up to a level equal to the surrounding earth.

Since the current bore hole depth/ton is calculated based on the thermal exchange using standard bentonite grout, it is hypothesized that by using thermally enhanced grout, it would allow the bore hole to be drilled shallower; thus saving on bore drilling expense and pipe length expense. The incremental cost of the grout is considered to be less than the cost of the additional depth needed with standard bentonite grout.

Oklahoma State University conducted a study to test the potential performance benefits of thermally enhanced grout. Their study concludes, "For a number of years, the most commonly used borehole design in North America has been the single high-density polyethylene U-tube grouted with bentonite grout. This design protects aquifers from contamination as is very reliable. However, it leaves much to be desired from a heat transfer performance standpoint, as the grout is a significant thermal resistance. Some work has been done to investigate higher conductivity grouts (Remund 1999), (Kavanaugh and Allan 1999), and (Smith and Perry 1999) and several varieties are commercially available in North America." The results of their tests indicate that "thermally enhanced grout and spacer clips can allow a 30% reduction in the total borehole length, compared to the standard installation."[xii] Their conclusion was based on the variance of the loop temperature between the standard pipe and grout configuration and the thermally enhanced grout and spacer clips. This study did not actually drill a shallower borehole and test the recommendation, it only evaluated the temperature performance benefits associated with thermal grout and standard grout using equal depth boreholes.

The Kavanaugh and Allan 1999 study previously referenced was supported by the U.S. Department of Energy/Office of Geothermal Technologies. It indicates, "This research program has designed, evaluated and demonstrated improved cementitious grouts for completing vertical boreholes used with geothermal heat pumps (GHPs). Reduction of required bore length and more efficient performance of GHPs can be achieved through enhancement of grout thermal, physical and mechanical properties. The optimized grout formulation (Mix 111) has a thermal conductivity up to three times higher than that of bentonite and neat cement grout. Bore length reductions may be up to 22 to 27% based on calculations performed in FY97 and depending on bore diameter, soil type and other variables." This study concludes by stating, "Further field testing is desirable to monitor long-term performance."[xiii]

Even with these university/DOE studies, there is a lack of field data available to validate the conclusions that shallower bore holes can be drilled if thermally enhanced grout is used. Due to a lack of actual field validation of these studies, geothermal contractors are reluctant to risk trying this technology with their customers. Their concern is if the system does not achieve the performance indicated in the university studies, they would then be liable to rectify it at their expense. Therefore, we recommend establishing a study in conjunction with local geothermal contractors whereby they can observe first hand if the theoretical benefits of thermally enhanced grout are equal to the published results. To effectively compare the difference, a design of experiment study would be established to compare a base case to a statistically valid number of installations using a thermally enhanced grout design. The proposal of the experiment, how to evaluate and where to conduct the study will be presented later in this proposal.

Advanced Heat Exchange Piping:

The purpose of the heat-exchange piping is to transfer energy into and/or out of the home and into the earth via a heat pump. For instance, in the summer, the heat pump absorbs heat from the air in your home and transfers it to water circulating in the piping loop where it is absorbed by the earth. As this hot water flows through the pipe in the borehole, the heat energy flows out of the pipe and into the earth, leaving behind cooler water. This cooler water is then pumped back into the heat pump where the cycle of transferring heat from the home and into the water begins all over again. In the winter, water circulating in the piping loop absorbs heat from the earth and carries it to the heat pump, where it is concentrated and sent as warm air throughout the home.

The most commonly used design of heat exchange piping involves drilling a borehole large enough in diameter to accept two polyethylene pipes connected at the bottom of the borehole with a u-shaped coupling – commonly referred to as a vertical u-tube design. In this configuration, water flows out of the heat pump and down one of the pipes and returns to the heat pump via the other pipe. The borehole is designed to ensure that there is ample depth to allow for proper exchange of energy between the point where the water leaves the heat pump to when in enters back in. The more efficiently the pipe can exchange either hot or cold energy with the earth, the shallower the borehole can be.

An alternative to the vertical u-tube design is a coaxial flow pipe design. This configuration is essentially a smaller pipe diameter inserted in a larger pipe diameter. In this configuration, water flows down the smaller diameter center pipe and back up through the larger diameter pipe. Some configurations of the coaxial pipes include designs that cause a turbulent water flow within the pipe that helps break up a boundary layer of water that collects on the surface of the inside diameter of the pipe. This boundary layer prevents some of the water from effectively exchanging heat energy with the earth, since it is prevented from getting close to the surface of the pipe where the energy is exchanged. Since the thermal exchange is improved in this turbulent-flow design, the depth of the borehole could potentially be decreased and still obtain the desired performance of the system. The coaxial design also allows for smaller diameter boreholes, which means less overall volume of thermal grout. The smaller diameter hole also provides a benefit of less drilling time since it is faster to drill a smaller diameter hole.

These coaxial designs are not commonly used as contractors are reluctant to try a technology that has little field experience and whose claims are largely theoretical in their minds. Their business models are designed to take low risk with the loop field since any remediation of an underperforming field is very time consuming, costly and damaging to their reputation. This risk aversion leaves new technologies largely untested in the field and uncommercialized.

Our proposal is to involve local contractors and utilize a coaxial pipe design so they can observe the results and confirm whether or not they would be comfortable utilizing this technology if field testing proves to offer the expected performance, system cost reductions, installation, and time benefits.

R&D Experiment Design

The above technologies have theoretical benefits; however, actual field studies quantifying their respective benefits are limited. To that end, it is proposed that we develop a design of experiment to specifically prove these benefits, relieve the risk of failure from the geothermal contractors, and if successful, provide an impetus towards further commercialization of these technologies. The main objective is to apply technology to the loop part of the geothermal system to be able to lower the upfront cost and bring geothermal systems into closer cost parity with other types of HVAC systems.

If the R&D from this proposal successfully proves that these technologies are able to lower the initial cost barrier, all customers would be beneficiaries by helping to commercialize these solutions and provide further optionality for the consumer.

This R&D experiment is proposed with the following elements:

- Install new loops with the previously discussed technologies at Habitat for Humanity homes that already have geothermal heat pumps. This would provide a set of geothermal homes that have existing kWh data to use as a baseline in the experiment. The experiment would be to use new technologies and monitor the results of using various loop combinations.
    - Utilize thermal grout and drill shallower holes
    - Utilize enhanced pipe design and drill shallower holes
    - Utilize advanced drilling methods and record total on-site drilling and installation time
- Provide an incentive to the owners of participating homes for allowing this experiment to take place on their property. The proposed incentive would offer a landscaping makeover. This will help to mitigate the inconvenience of drilling on their property and the effect on their landscaping. As part of the landscaping makeover it is proposed that we collaborate with the Oklahoma Department of Agriculture, Food and Forestry in an initiative they are promoting to evaluate the overall building thermal load benefit of selective tree placement at residential sites
- If an adequate base of existing geothermal homes cannot be obtained, then the alternative would be to install these R&D geothermal loops in newly constructed Habitat for Humanity homes of the same construction envelope, energy efficiency and design as the baseline homes
- Remotely monitor the incoming and outgoing water temperature of baseline and R&D systems
- Monitor the energy differential between the baseline and R&D systems
    - Use smart grid meters and technology to monitor energy in each home
- Monitor and compare the results of the baseline vs. R&D systems through at least 4 seasons
- Success would be determined by evaluating if the efficiencies measured by water temperature variances and energy usage variances are essentially the same between the baseline and R&D systems. This would be considered a success because if the loops can be drilled shallower, yet offer the same efficiency, then the potential exists of reducing the upfront system costs without degradation to performance.

References

[i] Rafferty, Kevin (April 1997), "An Information Survival Kit for the Prospective Residential Geothermal Heat Pump Owner", *Geo-Heat Centre Quarterly Bulletin* (Klmath Falls, Oregon: Oregon Institute of Technology) **18** (2): pp 1–11, ISSN 0276-1084

[ii] http://www.geoillinois.com/geo.cfm

[iii] (http://www.geoconnectionsinc.com/aboutGeo/howGSHPsWork.htm)

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