COLD CLIMATE HOUSING RESEARCH CENTER
CCHRC

Ground Source Heat Pumps in Interior Alaska

Lessons learned from installed systems

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Abstract

There is increased interest in ground source heat pumps in Interior Alaska as more residential systems are installed, but there are still questions about how heat pumps perform in cold climates. CCHRC surveyed about a dozen homeowners and property developers in the Fairbanks area to gain a better understanding of the GSHP installation characteristics, performance, reliability, and owner satisfaction. The final result of these surveys is a flow chart of basic questions to guide consumers interested in whether a GSHP is a potential heating option for them. While the surveys reinforced a prior conclusion that a long term study is necessary for definitive conclusions about GSHP long-term performance, they did provide some lessons for homeowners considering a GSHP.

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Acknowledgements

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Disclaimer: The research conducted or products tested used the methodologies described in this report. CCHRC cautions that different results might be obtained using different test methodologies. CCHRC suggests caution in drawing inferences regarding the research or products beyond the circumstances described in this report.

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Contents

Introduction

Installations of ground source heat pumps (GSHPs) have been steadily increasing over the past several years in Interior Alaska as homeowners and businesses explore alternative heating sources to combat the rising costs of fossil fuels. In 2011, the Cold Climate Housing Research Center (CCHRC) and the Alaska Center for Energy and Power (ACEP) conducted a preliminary assessment of GSHPs in Alaska (Meyer, et. al., 2011). The assessment identified uncertainties associated with the use of GSHPs in cold climates:

1. Longer-term studies of six to ten years are necessary to assess the efficiency of GSHPs over time in cold climate regions. Because GSHPs extract heat from the ground all winter, changes in the thermal regime of the ground are a major concern in Alaska. If there is not enough solar recharge during the summer to maintain a balance between heat gain and extraction, the heat pump performance will decline over time.
2. Hybrid GSHPs should be studied to assess advantages and disadvantages of using solar thermal panels to actively recharge the ground over the summer.
3. Better data is needed on the effectiveness of GSHPs as retrofit heating appliances.
4. Better information is needed on the installation costs of GSHPs.

CCHRC installed a GSHP in its Research and Testing Facility to address the first point, and partnered with the Fairbanks North Star Borough School District to study the second point. This document addresses the third and fourth points by gathering information on existing systems in Interior Alaska to provide homeowners and others considering a heat pump with examples of existing systems: system details, installation costs, operating costs, qualitative observations, and efficiency.

There are currently an estimated 40-50 GSHP systems in the Fairbanks area (A. Roe, personal communication, March 21, 2013). This report contains 13 case studies (chosen based on access and availability) that encompass different types of GSHP systems and provides lessons learned from those case studies and guidance for homeowners in Interior Alaska who are interested in GSHP as a heating option. The information on the surveyed systems comes almost entirely from the systems' owners and is used to provide basic information on Fairbanks installations and to discuss how homeowners feel their GSHPs are working relative to other heating systems. While these findings can help guide homeowner expectations for GSHPs in Interior Alaska, the lack of long-term studies (more than six years) makes the lessons and conclusions tentative.

Ground Source Heat Pump Technology

Unlike combustion heating appliances that create heat by burning oil, gas, or wood, a heat pump moves heat from one place to another, using electricity. A GSHP used for heating operates like a refrigerator in reverse; instead of moving heat out of the fridge and into your house, it employs a loop of piping in the ground to gather heat from the soil, and then uses a refrigeration cycle to step up that heat to a temperature that can be used inside a home. Figure 1 is a diagram of a heat pump working in heating mode. A freeze-protected fluid gathers heat from a piping loop in the ground and passes that heat to the refrigerant fluid cycling within the heat pump, which boils at low temperatures into a gas that can be compressed. A compressor concentrates the heat, which is passed on to the distribution system in a home. The cycle is completed as the refrigerant is condensed, ready to repeat the cycle and to collect more heat from the ground. Heat pumps require electricity to run the compressor, but the main source of heat is the heat energy gathered from the soil.

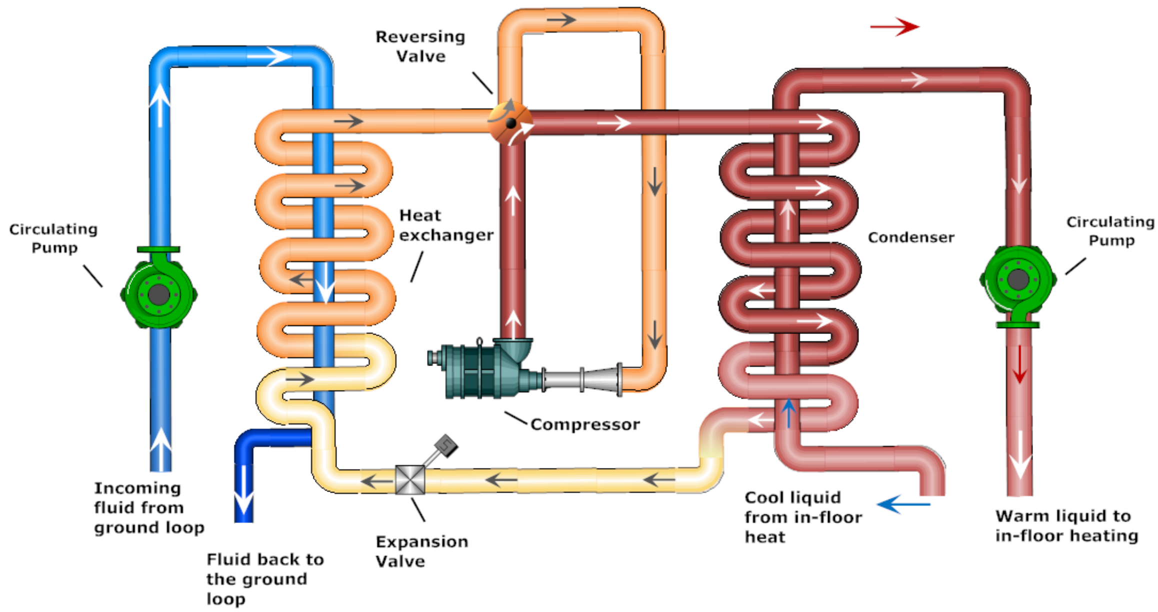

Figure 1. Heat pump schematic. The basic components of a ground source heat pump in heating mode. Some heat pumps can also be used for cooling by switching the reversing valve.

The pipes in the ground can be configured in different ways. In Interior Alaska there are horizontal loops and vertical wells. Horizontal loops are laid out in the ground at a specific depth usually in a "slinky" formation where the piping is coiled in an overlapping pattern. Horizontal slinky loops can also be sunk in a large body of water, such as a lake. Another horizontal ground loop configuration consists of straight pipes drilled into the ground horizontally, requiring less excavation. Vertical wells involve a series of deep wells that extract energy from a borehole that typically ranges from 100-250 feet. Figure 2 shows vertical and horizontal configurations.

Heat pumps are referred to in terms of “tons of cooling,” not in terms of heating. A ton of cooling is equivalent to 12,000 BTU/hr, so a 10-ton heat pump can remove up to 120,000 BTU/hr of heat from a space. A 10-ton system can provide slightly less or slightly more than 10 tons of heat depending on the entering ground loop fluid temperature. In general a system in Alaska will deliver less heat energy than the rated amounts due to lower fluid temperatures.

GSHP efficiency is often measured by calculating the Coefficient of Performance (COP). The COP is a ratio of the amount of heat delivered by the heat pump to the electrical energy that the heat pump uses to run the refrigeration loop. For instance, if a GSHP has a COP of 3, that means that for every 1 unit of electrical energy that the GSHP uses, it is able to deliver 3 units of heat energy to a home. The higher the COP, the more efficient the heat pump is at delivering heat to a home with a given amount of electricity. The COP of a heat pump is affected by the temperature of the soil around the ground loop. The higher the ground temperature, the higher the COP and thus the higher efficiency.

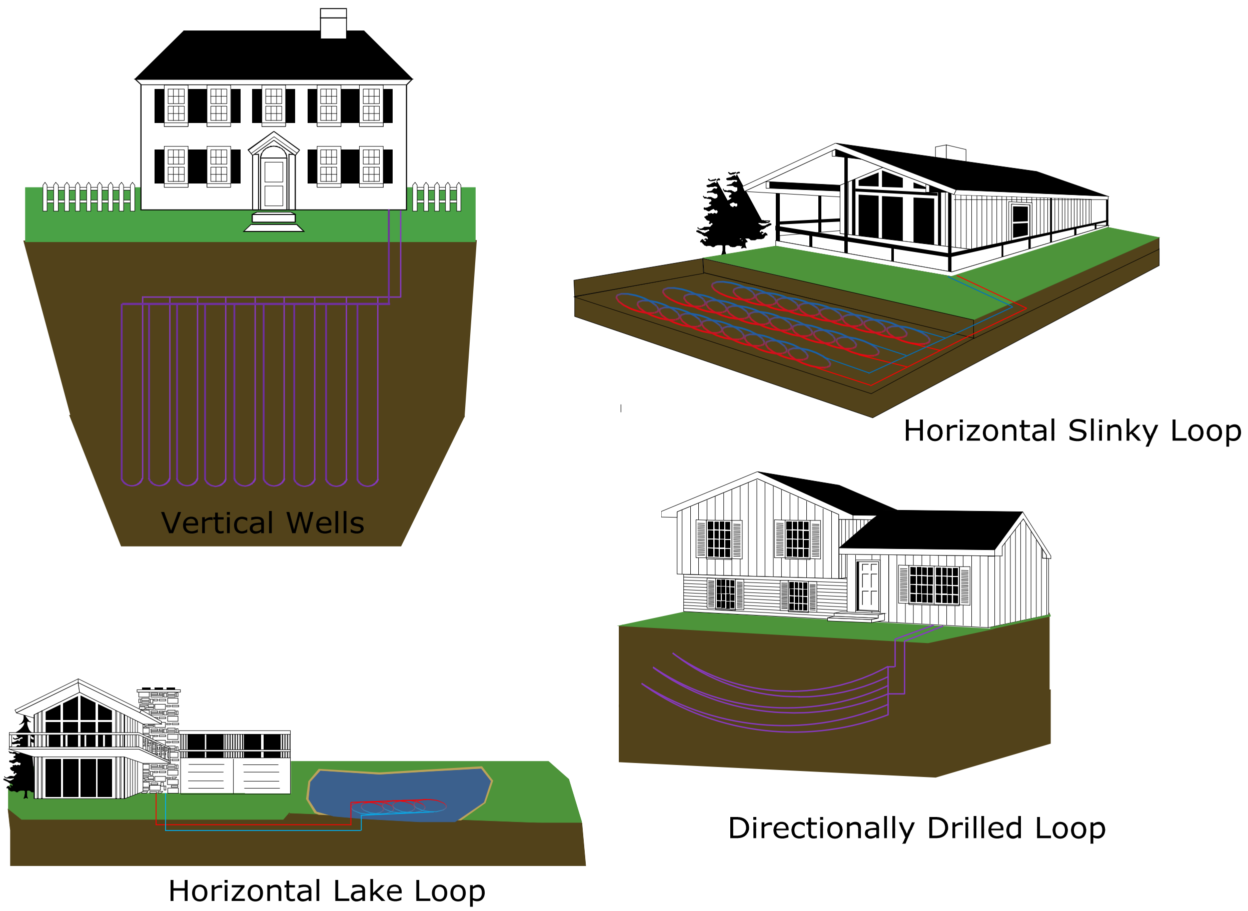

Figure 2. GSHP ground loop configurations. The most common ground loop configurations in Fairbanks.

For more information on how heat pumps work please see “Ground Source Heat Pumps in Cold Climates” at cchrc.org/ground-source-heat-pumps.

Selected GSHPs in Interior Alaska

Thirteen GSHPs located in the Fairbanks area are summarized in Table 1. Twelve of the systems are currently functioning and in use. The information on each system comes from interviews with homeowners, installers, and property developers. In some cases, detailed records were available, and in other cases interviewees only know basic system information. The full case studies are located in the Appendix. The systems listed are identified by ground loop type and installation date. Five systems were installed in new buildings and the remainder were retrofits replacing oil-fired systems. Each system is designed for its specific locations, thus sizes and distribution systems vary.

Table 1. Ground source heat pump case studies.

System Case Name	Ground Loop	Load	Distribution	Installation	HP size
Lake Loop 2008	Ten coils sunk 12 ft. down in a lake	House 3500 ft^2	In-floor hydronic	Retrofit	10 ton
Lake Loop 2012	Ten coils sunk in a lake	House 5000 ft^2	In-floor hydronic	Retrofit	10 ton
Condominium Vertical Wells 2012	Ten 200-ft. deep wells	7900 ft^2 3-unit condo	In-floor hydronic	New construction	10 ton and 4 ton
Habitat for Humanity Vertical Wells 2012	Five 135-ft. deep wells	House 1400 ft^2	In-floor hydronic	New construction	4 ton
Commercial Vertical Wells 2012	Ten 150-ft. deep wells	Office and apartment building 5000 ft^2	In-floor hydronic	New construction	10 ton
Ft. Wainwright Vertical Wells 2009	Three 250-ft. deep wells	Design load 32,000 Btu/hr	In-floor hydronic and baseboard	Retrofit	6 ton
Fox Horizontal Loop 2009	Eight 105-ft. long horizontal slinky loops on a south facing slope	House 2800 ft^2	In-floor hydronic	Retrofit	7.25 ton
McGrath Horizontal Loop 2010	Three 150-ft. long horizontal slinky loops at 8 ft. deep just above the permafrost	House 2400 ft^2	Under floor hydronic and baseboard	Retrofit	4-5 ton in conjunction with a boiler
Horizontal Loop 2011	Horizontal slinky loops 11 ft. deep	House 3000 ft^2	In-floor hydronic and baseboard	Retrofit	8 ton with back-up boiler
Weller Horizontal Loop 2013	Six 100-ft. long horizontal slinky loops at 8 and 12 ft. deep on a south facing slope	Elementary school make-up air	Forced air	Retrofit	5 ton
CCHRC Horizontal Loop 2013	Six 100-ft. long horizontal slinky loops at 9 ft. deep	Office space 5000 ft^2	In-floor hydronic	Retrofit	6 ton
North Pole Horizontal Loop 2010	Ten horizontal slinky loops at 8 ft. deep	House 5200 ft^2	In-floor hydronic	New construction	8 ton with back-up boiler
Directionally Drilled Loop 2013	Eight 130-ft. long directionally drilled loops at 8 to 10 ft. deep	House 1000 ft^2	Forced air	Retrofit	4 ton

Lessons Learned

The 13 systems surveyed provided lessons in regards to compatibility of heat delivery systems, favorable site conditions for the ground loop, cost estimates for installation and operation, and owner satisfaction.

Heat Delivery Systems

Common residential heat delivery systems include hot water (hydronic) or forced air ducting. For hydronic heat, energy is delivered via hot water either to pipes embedded in a concrete floor or pipes attached to the underside of a floor (commonly referred to as radiant floor heating). Hydronic heating also includes pipes that run around the edge of a room (called baseboard). In a forced air system heat is delivered throughout the house via warm air that is blown through metal ducts.

GSHPs provide a lower-temperature heat than combustion appliances. Thus, heat pumps work well with hydronic in-floor and forced air delivery systems, because they only require an air or water temperature of 90 to 120°F. Baseboard heat emitters, on the other hand, require fluid temperatures of 140 to 180°F, so heat pumps are not a good match for these distribution systems. Under-floor hydronic systems can be viable depending on the type of floor coverings used and other design factors.

Three of the 13 units surveyed have baseboard emitters on the second floor. Two of the homes with baseboard have a back-up boiler that boosts the temperature of the delivery fluid to accommodate the baseboard. The Ft. Wainwright system had baseboard on the second floor but no back-up boiler. Its failure stemmed from the inability of the heat pump to deliver higher-temperature fluid to the baseboard on the second floor. The system was a retrofit where the baseboard heat delivery system was designed for delivering heat via a higher-temperature heat source. The resident complained that the second floor was too cold and maintenance personnel changed the setting on the heat pump to deliver warmer fluid. The heat pump was unable to complete this delivery and the compressor failed.

Retrofitting a house to use a heat pump can be successful, as demonstrated by many of the surveyed systems. However, detailed planning and designing need to go into a retrofit to ensure that the GSHP interfaces with the home's heat distribution system. Five of the 13 units studied were part of new construction. Designing the heat delivery system from the start so that low-temperature fluid from a heat pump can be used most effectively will allow for a more appropriately sized heat pump system. Another consideration for GSHP installations is the need for domestic hot water. In most of the case studies, homeowners had a separate system (such as an electric water heater) or the GSHP provided part of the domestic hot water and the system had a back-up boiler to boost the water temperature.

Site Conditions

A GSHP in Interior Alaska is more likely to function successfully if the ground loop location is well exposed to solar input; in other words, on south-facing hillsides. Based on the case studies, these conditions can be achieved by a diverse range of subsurface environments, ranging from ground with shallow groundwater to lakes to dry upland locations.

With the exception of three sites, all of the systems surveyed are situated in the alluvial valley environment around Fairbanks and North Pole that typically has shallow groundwater. Many of these lowland horizontal systems are either located in lake water or in ground water, which allows for a fairly consistent temperature heat source during the winter. The lowland soils are mostly moist silt and have relatively high thermal conductivity, which allows for better heat transfer to the in-ground piping and greater ability for passive solar recharge in the summer.

The horizontal systems in the hills are not in ground water but are usually on a south-facing slope. The Weller Elementary loop is on a well-exposed south-facing slope in dry silt derived from the underlying fractured schist bedrock. It is unique in that the piping is buried at alternating depths of 8 and 12 feet deep. The report "Hybrid Ground Source Heat Pump at the Weller Elementary School in Fairbanks, Alaska" discusses the soil thermal regime at Weller in more detail (Garber-Slaght & Keays, 2014). The McGrath horizontal loop system is in a well-exposed area on a southwesterly slope. The loop is installed at approximately 8 feet deep, directly above permafrost; unfortunately there is no information on ground temperatures or heat pump performance for this installation.

None of the systems studied were on north-facing slopes or in heavily shaded areas. This is probably due to concern that there is not enough solar heat gain in the summer to recharge the subsurface around the ground loops.

Systems installed in and around Fairbanks (with the exception of the Ft. Wainwright system) are performing to the satisfaction of the owners thus far. The lack of data on soil temperatures or long-term GSHP efficiency prevents further conclusions from being drawn. The longest running system started in 2008 and has been operating 6 years; however, this system consists of a ground loop placed in a lake, and the impact of the heat extraction on the lake is difficult to gauge. The COP of the lake-loop system has not shown signs of declining over time, indicating that heat extraction from a surface water body may provide a viable ground loop option for long-term GSHP operation in Interior Alaska. The long-term operation of the other lake loop GSHP system installed in 2012 should help further evaluate this option. The 2009 retrofit in Fox has been running for five years and thus far the owner has not noticed any change in performance based on his electricity bills. While this may indicate that the ground temperature is remaining relatively stable from year to year, there is no direct evidence available in terms of GSHP efficiency or ground temperature. The owners of the 2013 retrofit GSHP with a directionally drilled ground loop system reported declining energy savings over the course of the 2013 - 2014 winter. They estimated that by April 2014, the cost of heating with the GSHP was equivalent to their historical oil heating cost. Even though their savings degraded over the course of the winter their annual savings stayed the same. This is based on a rough comparison of utility bills, including electricity use for the whole house instead of a dedicated meter specific to the heat pump, so no detailed conclusions can be drawn about the system efficiency. None of the other systems CCHRC surveyed offer performance data over time, although some of them have been running for 3 or 4 years.

Based on the survey findings, the ground loop locations commonly chosen in Interior Alaska allow for functioning GSHPs in the short term. Uncertainty exists whether efficiency will decline for GSHPs operated more than five years (the longest running GSHP in soil in this survey) due to thermal degradation in the ground loop, however, CCHRC did not identify any direct evidence indicating a decline in system performance over time for the systems surveyed.

Costs

Installation costs for the 13 heat pump systems studied in this survey ranged from $17,000 to $45,000, depending on the size of the system installed and the installation circumstances. Costs range so widely primarily due to the varied nature of the ground loop designs (vertical, horizontal, directionally drilled) and the size of the system. In this survey, the average cost for a single-family home using an installation contractor was $32,000. Most of the owners applied for and received the 30% federal residential renewable energy tax credit for installing a heat pump, which was not factored into these costs. This personal tax credit, in place until December 31, 2016 rebates 30% of the installation costs of qualifying Energy Star-rated GSHPs. More information about the renewable energy tax credit can be found here: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US37F

Table 2 provides an overview of estimated savings from heat pump owners who have kept records of utility bills. All of the homeowners with retrofit GSHP systems report saving money over their previous oil-fired appliance. The savings are highly variable, depending on the size of the building, the system being replaced, and many other factors. All costs savings information comes directly from homeowners, as CCHRC did not independently assess costs in this survey.

Table 2. Estimated costs and savings.

System Case Name	Estimated Heating Cost	Estimated Savings
Lake Loop 2008	$2,587 per year	Estimated $2,134 saved per year when compared to oil heat
Lake Loop 2012		Estimates a 50% cut in energy costs
Condominium Vertical Wells 2012	$6,000 per year Highest bills for the heat pump are $1,200/month in November and December	New construction-no data available
Habitat for Humanity Vertical Wells 2012		Estimated 50% reduction based on modelling results
Commercial Vertical Wells 2012	$3,539 for electricity in 2013-14 winter	New construction-no data available
Fox Horizontal Loop 2009	$400 per month for 4 months	
McGrath Horizontal Loop 2010		Estimates $1,000 a year savings compared using 100% oil
Horizontal Loop 2011		Estimates $2,000 a year savings compared to oil heat
Directionally Drilled Loop 2013		Estimates an average $200 savings a month compared to oil heat

Owner Satisfaction

The surveyed homeowners reported that their heat pumps are generally meeting their expectations. Many respondents noted substantial energy savings over using oil heat. Additionally, homeowners felt that the low maintenance requirements of the heat pump are an advantage, likening it to a refrigerator. Other noted advantages include not relying on the fluctuating prices of fuel, no on-site combustion, and no on-site fuel storage.

Discussion

The success of surveyed systems in the Fairbanks area indicates that Interior Alaska has the potential for efficient GSHP operation, although long-term performance is still unknown. For those considering installing a GSHP in a new or existing building, there are a few specific questions that can help guide the decision. Figure 3 presents a flow chart with preliminary questions. If a building uses traditional baseboard heat delivery, it is not a likely candidate for a GSHP; the higher-temperature delivery fluid required by baseboard is not readily attainable with a GSHP and the cold ground temperatures in Interior Alaska. Location is the next big question; a GSHP ground loop in Interior Alaska needs to be somewhere with ample solar input in order to run efficiently. It is unknown whether north-facing or heavily shaded areas will allow for GSHP operation.

If a site meets the location requirements, the final consideration is the cost of energy. If heating fuel is inexpensive or electricity is expensive, a heat pump will not be cost-effective. The estimates in the flow chart are based on an AFUE-rated 90% efficient boiler or furnace and a GSHP with a COP of 2.5. This is just one example; different efficiencies will yield different results. Additionally, the flow chart does not address installation costs or pay back, which will require further discussion with a local GSHP expert and a home energy rater who can evaluate all the potential energy saving options for a specific home.

Conclusions

Based on interviews with owners, installers, and property developers of 13 GSHP systems in the Fairbanks area, GSHPs have become an option for residential and light commercial building space heating in Interior Alaska, if properly designed. All owners interviewed were generally satisfied with their heat pumps, and roughly half reported significant energy savings as compared to heating with oil. The most significant factors of a successful GSHP installation relate to the system design, primarily ensuring compatibility between the heat pump and heat delivery system. The only documented GSHP failure resulted from a mismatch between a heat pump and a heat delivery system. The operating GSHP systems had a diverse range of ground loop environments, from vertical well fields to lake bottoms to horizontal loops in soil. These findings and the documented costs for GSHP installation and operation can help guide the expectations and decisions of homeowners and businesses considering installing a GSHP.

The relative newness of heat pump installations in the Interior makes it difficult to state more detailed conclusions about GSHPs in Interior Alaska. Currently, the major question about GSHPs in Interior Alaska is whether they can maintain long-term efficiency or if they degrade the ground temperature over time, thereby losing efficiency. One GSHP system with a lake loop has operated for six years with no declines in efficiency, indicating that lake ground loop systems may provide a viable option for long-term GSHP operation in Interior Alaska. The longest-running ground loop installed in soil in this study has run for five years with no direct monitoring of the ground loop or performance of the system beyond anecdotal testimony. To address this uncertainty, CCHRC began a project in Fall 2013 studying the effects of ground temperature on long-term heat pump performance with a GSHP installation at CCHRC's Research and Testing Facility. Findings from this study as well as continued documentation of the operation of other GSHP systems in Interior Alaska will provide more insight into long-term GSHP performance and efficiency.

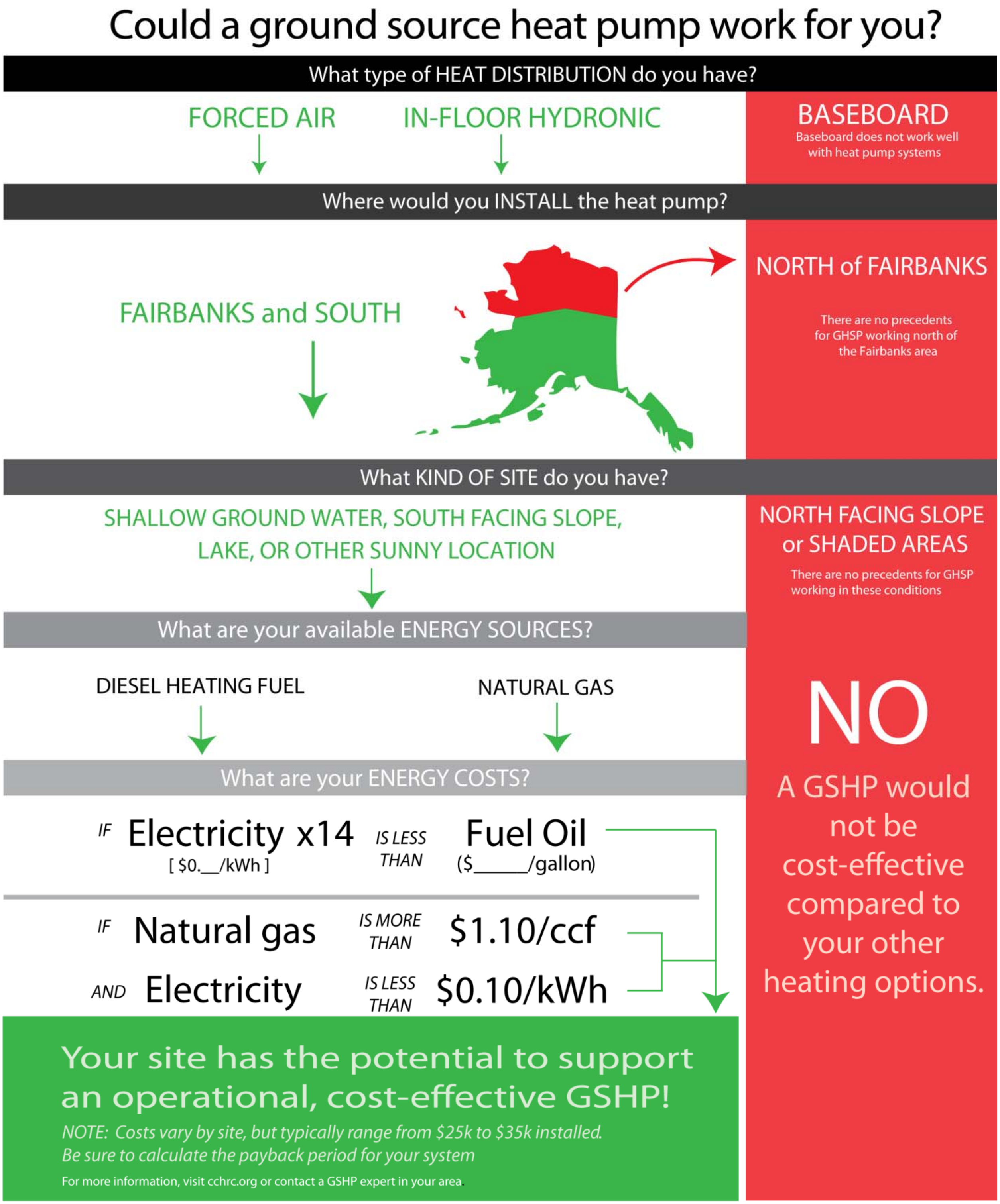

Figure 3. Preliminary steps to inform a decision about installing a ground source heat pump. If a site meets these requirements there are further questions to bring to a local expert. This is a conservative estimate using an oil boiler with an AFUE of 90% and a heat pump with a COP of 2.5; different efficiencies will produce different results. This assessment does not account for the cost of installation.

References

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Appendix – Ground Source Heat Pump Case Studies

There are approximately 40 to 50 GSHPs operating in the Fairbanks area (A. Roe, personal communication, March 21, 2013). The following case studies are a sampling of these heat pumps, meant to give interested homeowners an idea of the installation process, the components of a heat pump system, and costs. Most information reported is anecdotal. The opinions expressed in these case studies are those of the heat pump owners or property developers, and based on their interaction with their personal heat pump systems.

The Weller Horizontal Loop 2013 case study is presented in a separate document, "Hybrid Ground Source Heat Pump at the Weller Elementary School in Fairbanks, Alaska" (Garber-Slaght & Keays, 2014).

Lake Loop 2008

Chena Pump Rd in west Fairbanks, Andy Roe, homeowner and installer

Building	System Information	Performance
o 3,500 ft^2 house o 2 stories, built in 2004 o R-21 walls, R-48 ceiling o Occupied by a family of 6	o $20,000 to install o 10 ton Econar Geosource2000 o Hydronic in-floor distribution o Ten in-lake horizontal loops o 20% methanol mixture in lake loop o Retrofit system replacing an oil fired boiler	o COP of 3.1 o Estimated $2,587 in electricity per year compared to $4,720 per year in oil

The heat pump was installed by the homeowner, a professional heat pump installer, in 2008. The installation cost were approximately $20,000, not including labor. As it was the first heat pump he had installed, there was some trial and error during the first year to adjust the water temperature and flow rates in the radiant floor for optimal efficiency. After the first year, the heat pump has worked smoothly.

Previously, the house was heated by an oil-fired boiler, which still provides a portion of the domestic hot water and acts as the back-up heating system. The heat pump currently provides all of the space heating and 65% of domestic hot water for the house. At design temperatures, the heat pump runs approximately 75% of the time, pumping a methanol-water solution 27 gallons per minute through the lake loop collector. There are 3 pumps that circulate water through 13 heating zones in the home.

The loop field consists of 10 coils of pipe in a lake behind the home. Three houses have collector loops in the lake, which has a surface area of about 12 acres. The loops rest 12 feet deep about 40 feet from the shore. The lake temperature at that depth is generally around 50°F at the end of summer, and drops to just above freezing in the winter. A chain link fence covers the 30 ft. by 30 ft. loop field area so it does not float or get caught on a boat.

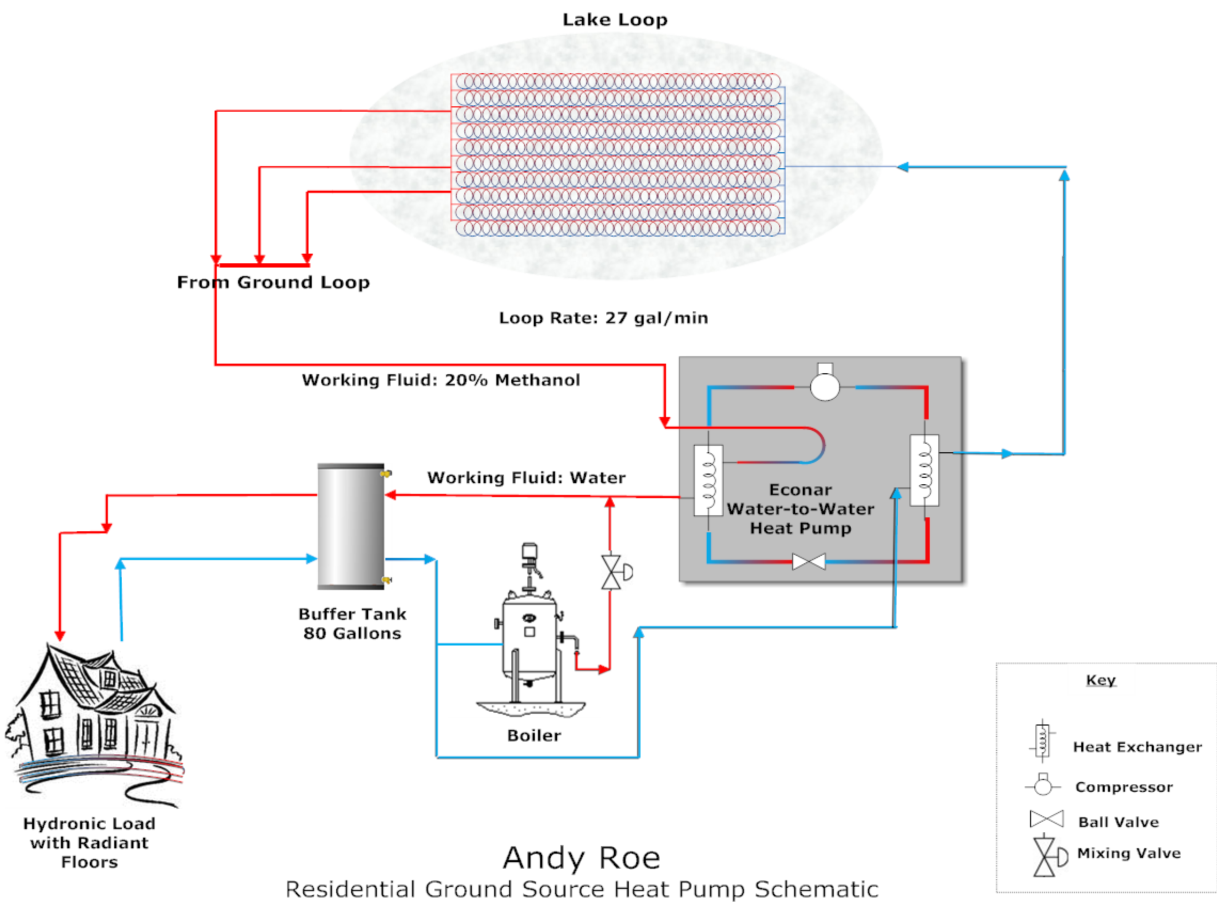
Water is circulated at 105°F through the concrete foundation slab. There is an 80-gallon buffer tank between the heat pump and the distribution system. The system is controlled by thermostat settings of 70°F in the home and 72°F in the bathrooms.

The homeowner monitors the efficiency of the heat pump system with one electric sub meter and two hydronic energy meters. The electric sub meter measures the electrical input to the heat pump while the hydronic energy meters measure the heat produced by the heat pump. Mr. Roe estimates that the average COP for the 6 years that the heat pump has operated is about 3.1, which is slightly lower than the manufacturer specified COP of 3.5.

Mr. Roe's estimate of annual heating costs comes from the electric sub meter. The yearly electric energy usage for 2010 was 11,141 kWh or about $2,339 at today's electricity rate ($0.21/kwh) and for 2011 usage was 12,317 kWh or $2,587. The house also uses about 200 gallons of fuel oil annually for the boiler to provide domestic hot water. The total annual energy use would be equivalent to 1,180 gallons of heating fuel, which would cost $4,720 at $4 per gallon with an 80% efficient boiler. Based on these assumptions, the heat pump saved approximately $2,134 for 2011. To date, there have been no maintenance costs. The heat pump came with a warranty on parts (5 years for some, 10 years for others) but the homeowner has yet to replace any.

The homeowner has been very happy with the GSHP because of the energy cost savings and low maintenance. The noise levels of the heat pump are similar to a boiler. However, Mr. Roe notes that newer heat pump models are quieter.

Mr. Roe first learned about heat pumps while studying for an engineering degree. After some Internet research, he decided to install one when oil prices rose sharply in 2008. If he could have done anything differently, he would have installed a heat pump model capable of both heating and cooling.



Andy Roe
Residential Ground Source Heat Pump Schematic

Lake Loop 2012

Chena Pump Rd. in west Fairbanks, Greg Milles, homeowner

Building	System Information	Performance
o 5,000 ft^2 house o 2 stories, 3400 ft^2 o Heated 800 ft^2 garage	o $32,000 to install o 10 ton Econar o Hydronic in-floor distribution o In-lake horizontal loop o Used for heating and cooling	o 50% savings in energy bills o Estimates a 5 to 7 year payback

The heat pump was installed by Andy Roe of Alaska Geothermal, LLC., in 2012, replacing a Viessmann Vitola 200 oil-fired boiler that previously provided space heating and domestic hot water for the home. The Viessmann still acts as a back-up heating appliance and also boosts the temperature of the water tank for domestic hot water. The heat pump is used for both heating and cooling.

The loop field consists of 10 loops of pipe in a lake located behind the home. The pipe is filled with a methanol-water solution. The heating system uses in-floor hydronic tubes to distribute heat to the 5 zones of the home. The heat pump also heats a tank for domestic hot water, although the boiler is used to further boost the temperature of water in the tank. For cooling, the heat pump is used to pump cool fluid through the hydronic floor loop.

The installation cost was $32,000, including the heat pump, lake loop, and labor. Mr. Milles applied for the federal energy tax credit to regain 30% of the installation cost. To date, no maintenance has been needed on the system and the homeowner estimates that his heating bill has decreased by approximately 50%, even with the 150 gallons of oil he uses over the winter for the domestic hot water.

The homeowner, Mr. Milles, is satisfied with the GSHP. In addition to the savings in heating costs and low maintenance requirements, he likes that the home's carbon footprint has been reduced, and that the appliance can provide both heating and cooling. He decided to install the heat pump because of the cost savings and to reduce the environmental impact of his home.

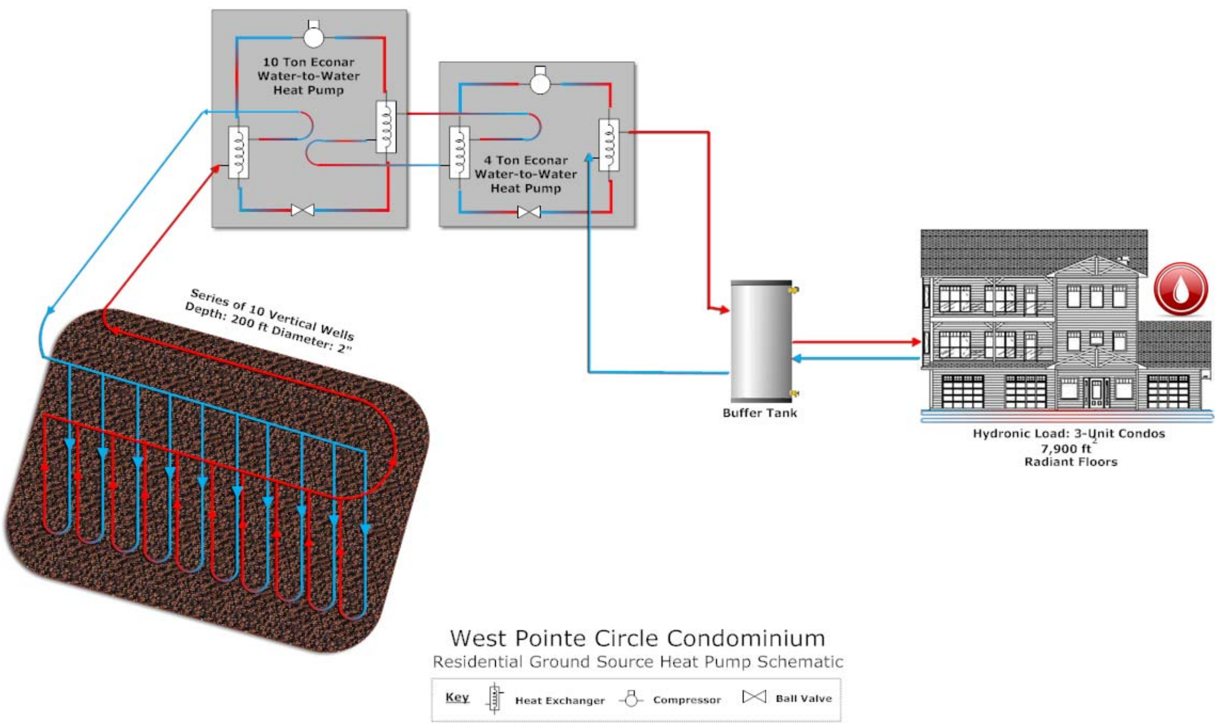
Condominium Vertical Wells 2012

Chena Pump Rd in west Fairbanks, Darrell Russell, condominium developer

Building	System Information	Performance
o 3 unit condo o 7,900 ft^2 in 3 stories o Walls are R-22 insulated with fiberglass	o $45,000 to install o 10 ton and 4 ton Econar o Hydronic in-floor heat distribution o Ten 200 ft. deep vertical wells	o $6,000 annual operating costs o Estimates a 2-year pay back

The heat pump system was installed by Alaska Geothermal, LLC in 2012. Alaska Geothermal installed the ground loop and heat pump along with pipes leading to the manifold for the hydronic in-floor heat distribution. The mechanical contractor for the building installed the distribution system. There is no back-up space heating system. The heat pump can also provide cooling.

Two Econar heat pumps, one 10-ton and one 4-ton, provide heat for the building. The larger heat pump works at temperatures down to -20°F, and the smaller heat pump is activated at colder temperatures. A Tekmar controller interfaces between the heat pumps and thermostats in each unit. The loop field consists of a closed loop of 10 200-ft vertical wells next to the building. The soils around the wells consist of wet gravel. The site has a high water table and no permafrost.



The heating system uses hydronic in-floor tubes within the concrete slab to heat five zones in each condo. There is a buffer tank between the heat pump and each condo. Domestic hot water is provided by separate electric hot water heaters in each unit, which are controlled by occupants.

The installation cost was $45,000, which was paid by the condo owners. Before installing the heat pump units, the installer used software to estimate savings over oil for occupants, who are eligible to apply for the federal residential energy tax credit and will benefit from the energy savings. The building developer had already sold two of the units in the condo when he made the decision to install a GSHP instead of a boiler, after learning that Alaska Geothermal had the capacity to drill vertical wells. The buyers agreed to install the GSHP system in spite of the rise in price of the condo (each unit became $15,000 more expensive).

Current annual operating costs are around $6000 for the building. During November and December 2013, the combined electricity used by the heat pumps cost $1,200 per month.

Mr. Russell believes that GSHPs are a viable heating option in Fairbanks because they are not subject to the price fluctuations of fuel oil, require no tuning and very little maintenance, and have no on-site emissions He also appreciates the in-floor distribution system because the floor retains heat for a while even in the event of a power outage, preventing the home from cooling quickly.

Habitat for Humanity Vertical Wells 2012

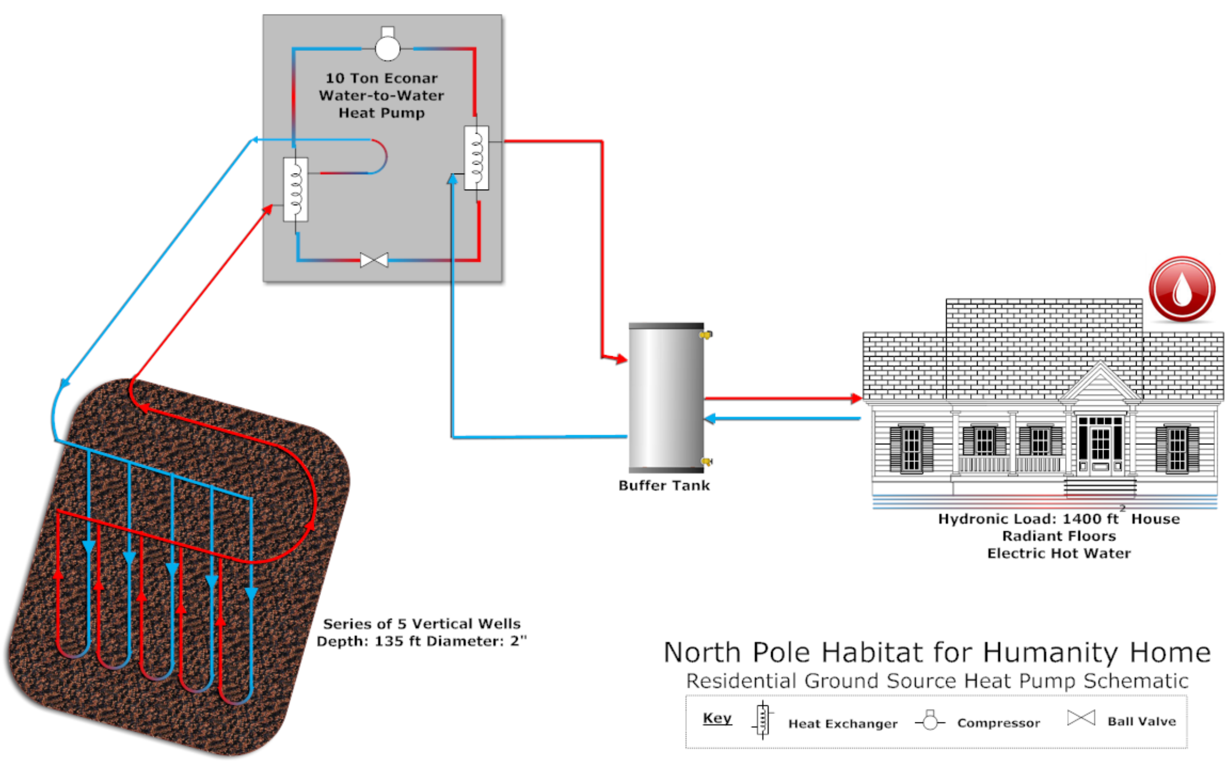
North Pole, Darrell Russell, Habitat for Humanity board member

Building	System Information	Performance
o 1,400 ft^2 one-story house o R-30 walls o Occupied by a family of 4	o 4 ton Econar o Hydronic in-floor heat distribution o Five 135 ft. deep vertical wells	o Estimated 50% savings over oil

The heat pump was installed by Alaska Geothermal, LLC in 2012. There is no back-up heating appliance. The 4-ton Econar heat pump can also provide cooling. The loop field consists of five 135-ft vertical wells in the soil near the house. The soil consists of wet gravel. There is no permafrost and there is a high water table.

The heating system uses in-floor hydronic tubing to distribute heat to the zones of the house. A buffer tank provides heat to the slab, and a Tekmar controller is used with the system. The domestic hot water is provided by the GSHP but there is an electric hot water heater that can be activated as a back-up if needed.

The annual cost savings for this house was modeled at 50% over an oil-fired boiler. The family living in the house reportedly likes the GSHP, and Habitat for Humanity plans to install a GSHP in another house in the future.



Commercial Vertical Wells 2012

South Fairbanks, Aaron Welterlen, builder and owner

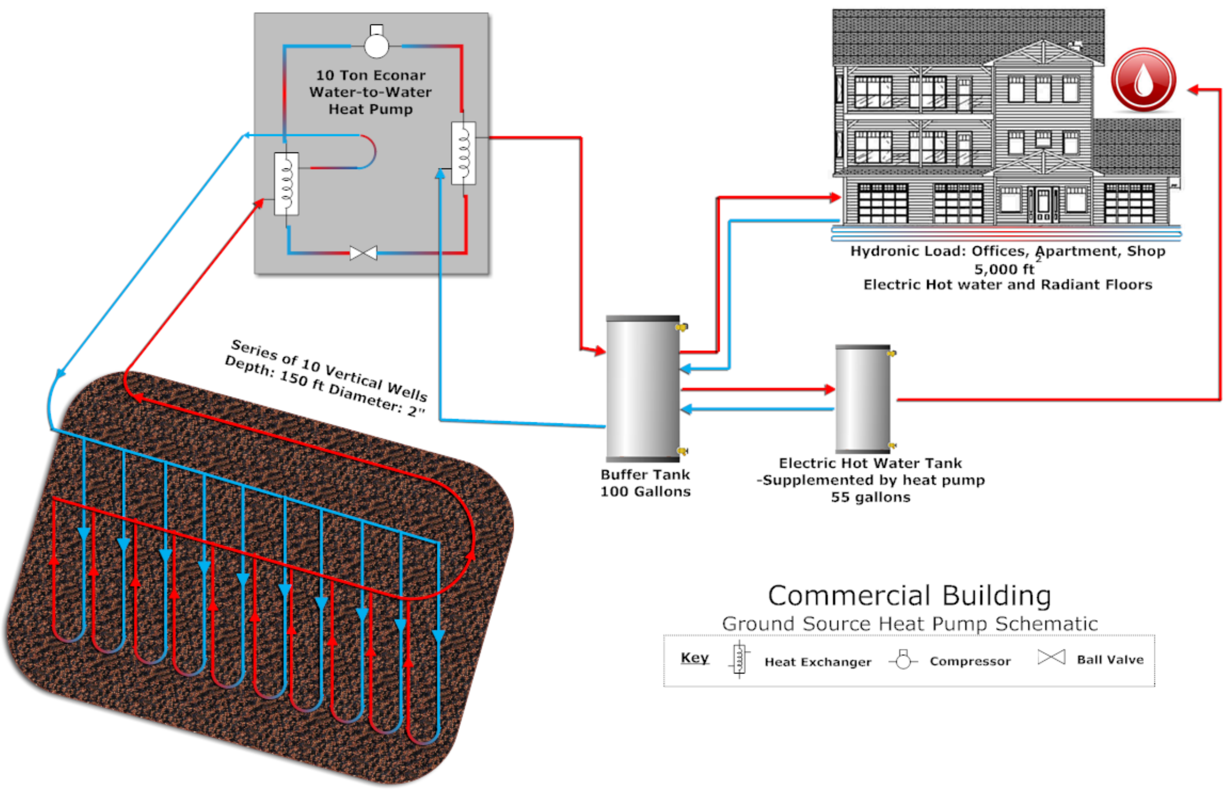
Building	System Information	Performance
o 5,000 ft^2 commercial building o 1,200 ft^2 is an apartment with 3 occupants o 1,200 ft^2 is office space o 2,600 ft^2 is a shop	o $36,000 for installation o 10 ton Econar o Ten 150 ft. vertical wells of 2 inch pipe, water and methanol solution o In-floor hydronic heat distribution	o Estimated $450/month to operate o 16,850 kWh in the second winter, $3,539 in electricity

The heat pump was installed by Alaska Geothermal, LLC. The vertical wells were installed in August 2012, and the heat pump was used for the first time in October 2012. It is a new installation, and there is no back-up system. The heat pump came with a 5-year warranty on the installation and a 10-year warranty for parts. Mr. Welterlen applied for the Federal Residential Tax Credit for 2012. After the system was installed, there was one maintenance issue: more methanol had to be added to the ground loop. This was fixed at no cost.

The heating system uses in-floor hydronic tubes in wooden spacers to distribute heat throughout the apartment and office zones. The shop also has in-floor hydronic tubes embedded in a 6-inch concrete slab, which is insulated from the ground by 12 inches of foam board. The apartment temperature is set at 75°F, the offices at 60-70°F, and the shop at 60°F. A buffer tanks sits between the heat pump and the in-floor distribution. A Tekmar control system is used to monitor the interaction between the heat pump, buffer tank, and distribution system. There is an electric hot water heater that provides domestic hot water to the building, and the heat pump supplements the electric hot water heater.

Mr. Welterlen installed an electric meter on the heat pump, which cost approximately $300, on January 22, 2013 in order to monitor electrical consumption. Mr. Welterlen estimates monthly energy costs at roughly $450 during the winter, which includes heat and DHW. The heat pump consumed approximately 6,000 kWh from January to April 2013. During its second winter the heat pump used approximately 16,850 kWh, or $3,539 in electricity.

Mr. Welterlen likes the GSHP because it allows him to heat without being tied directly to the price and schedule of delivered fuel oil, and the lack of combustion reduces the possibility of fire. Also, the small maintenance requirements and the fact that fuel can't be stolen makes GSHPs even more attractive. If he could change anything, he would install a monitoring system to measure the efficiency of the GSHP.



Ft. Wainwright Vertical Wells 2009

Ft. Wainwright, Trison Construction Inc, Oklahoma City, Geothermal and HVAC contractor

Building	System Information	Performance
o 2 story unit on the south end of a 4-plex o The design heat load is about 32,000 BTU/hr	o 6 ton ClimateMaster Tranquility o Three 250 ft. vertical wells with a 20% methanol in water solution o In-floor hydronic and baseboard heat distribution	o Entering water temperatures from the ground loop, 32.6°F into January o This system failed its first winter and was not re-engaged

The Ft. Wainwright system was installed to demonstrate the potential of vertical loop ground source heat pumps for a future housing project on the Army base. The system was designed and installed by Trison Construction Inc. of Oklahoma City, OK. Trison contracted with a local well driller to install the ground loops and did all the in-building installation themselves. Prior to the installation of the system, Trison conducted a thermal conductivity test of the soils using a 200-foot well. The drilling revealed ground water at 30 feet deep. The thermal conductivity of the borehole was 1.55 BTU/hr ft °F. Once installation was complete, the system was monitored for several months. There were temperature sensors on the entering and leaving fluid to the ground and the entering and leaving water to the building. When the system was running, the entering water temperature from the ground wells was approximately 32.6 °F.

This system was set up in a building that used steam for the hydronic distribution system. The hydronic supply temperature downstream of the steam heat was 120°F. The heat pump was initially set to supply 110°F water to the floor and the baseboard. In January 2010 the occupant complained that the house was too cool. Maintenance staff adjusted the aqua stat (on the heat pump entering water temperature) to 120°F. Four hours later the heat pump shut down and failed to restart. Alaska Geothermal, LLC. was contracted to replace the compressor in May 2010. The heat pump still did not start, until it was discovered that a capacitor had broken. The capacitor was replaced and the heat pump functioned, but the homeowners decided not to use the heat pump again and instead relied on the steam heat system.

Fox Horizontal Loop 2009

Fox, 10 miles north of Fairbanks, Michael Edmunds, owner

Building	System Information	Performance
o 3-story, 2,800 ft^2 home	o $30,000 to $40,000 to install o 7.25 ton Econar o Hydronic in-floor heat distribution o Eight 105-ft. long horizontal slinky loops	o About $400/month to operate

The heat pump was installed by Alaska Geothermal, LLC in October 2009 with no back-up system, although the homeowner has plans to install a wood stove in the future. The heat pump was a retrofit installation, replacing an oil-fired boiler and wood stove that were stolen while the house was on the market.

The loop field consists of slinky coils of pipe arranged in horizontal rows in the front yard of the house. The loop is in fractured schist on a south-facing slope. To install the loop field, the contractor excavated one large hole and then arranged the pipe in 8 slinky loops, each 105 feet long and perpendicular to the direction of the slope. The loops are connected to the heat pump by two 140-foot header pipes.

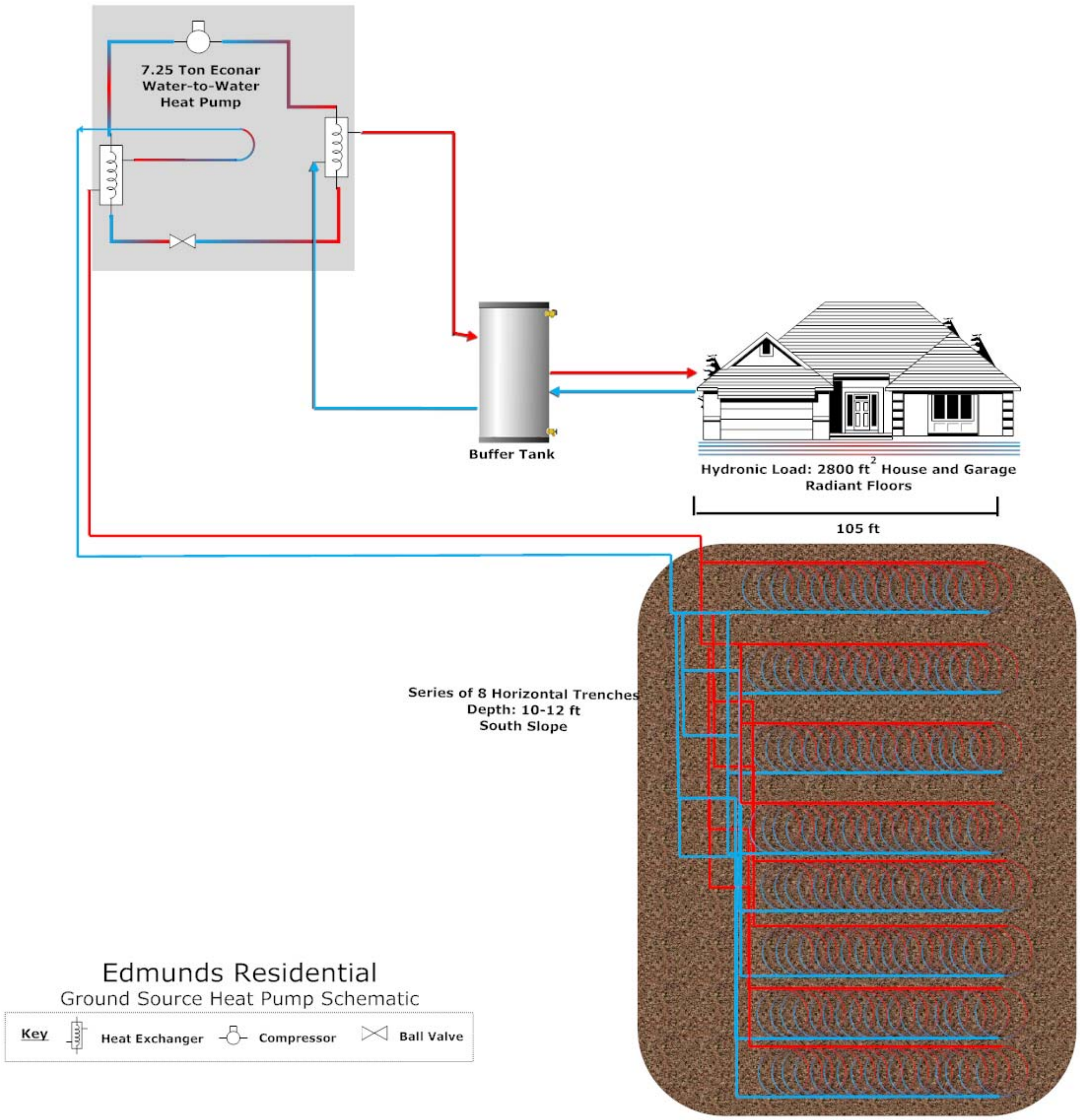
Most of the house is kept at 68°F, with the third floor set to 65°F. The heat pump does not provide cooling or domestic hot water.

Since installation, there have been no maintenance costs, although the homeowner contacts the installer about the heat pump approximately once a year.

The heat pump does not have a separate sub-meter, so Mr. Edmunds does not know exactly how much electricity is used to run it. However, he monitors his electrical bills throughout the year. By examining the difference between the electric bills in the summer, when the heat pump does not run, and the winter, he estimates that it costs approximately $400/month to run the heat pump from November to February.

The homeowner, Mr. Edmunds, first learned about heat pumps while researching heating systems. He attended a presentation at the Fairbanks home show to learn more, and decided to install one for the cost savings. He was one of the first 10 people to install a GSHP in Fairbanks.

He is very happy with the system: the in-floor distribution system provides warm floors. The heat pump operates cleanly, and he doesn't have to worry about oil leaks or the theft of his heating oil. Downsides include the high capital cost, but the only thing he would do differently would be to install a vertical ground loop instead of horizontal (vertical drilling was not an available in 2009).



McGrath Horizontal Loop 2010

Northeast Fairbanks, Bruce Delbridge, homeowner

Building	System Information	Performance
o 2,400 ft^2 with a 600 ft^2 addition o 2 story home o Double wall construction o Occupied by 3 people o On pilings in a permafrost area	o $17,000 to install o 4 to 5 ton Water Furnace o Under floor and baseboard heat distribution o Three 150 ft. long horizontal slinky loops, 60% methanol mixture, 8 ft. deep just above permafrost	o Saved about $1,000 the first year

The heat pump was installed during the summer of 2010 by Mr. Delbridge with the help of Chuck Renfro, a professional heat pump installer from Energy Efficiency Associates in Anchorage. It is capable of producing domestic hot water. The heat pump is intended to work with the home's other heating appliance, an Energy Kinetics System 2000 boiler.

The heating system uses under-floor hydronic tubes to distribute heat to the first floor of the home, so the temperature of the fluid needs to be around 130°F-140°F, higher than for a typical in-floor heat system. The second floor has a baseboard distribution system. The thermostat set point temperatures range from 70°F to 80°F, depending on the zone.

The heating system is unique because the heat pump cannot produce the water temperatures necessary for the under floor and baseboard distribution systems efficiently. Thus, the system is designed to allow the GSHP and the boiler to work together to produce heat in an efficient and cost-effective manner. There are two 40-gallon buffer tanks in the mechanical room. A staging control is used to allow the GSHP to heat the tanks to 115°F, which the heat pump can do efficiently. Then, the stage control prompts the boiler to turn on to boost the fluid up to the temperature required to heat the home. This system allows Mr. Delbridge to use the GSHP to provide the majority of his heating needs, and the boiler boosts the water tank the last few degrees.

The installation cost was $17,000 before the Federal Residential Tax Credit. This included $10,000 for the heat pump, $5,000 for the piping, and $2,500 to rent equipment to dig the trenches. There were no labor costs because he installed the system himself.

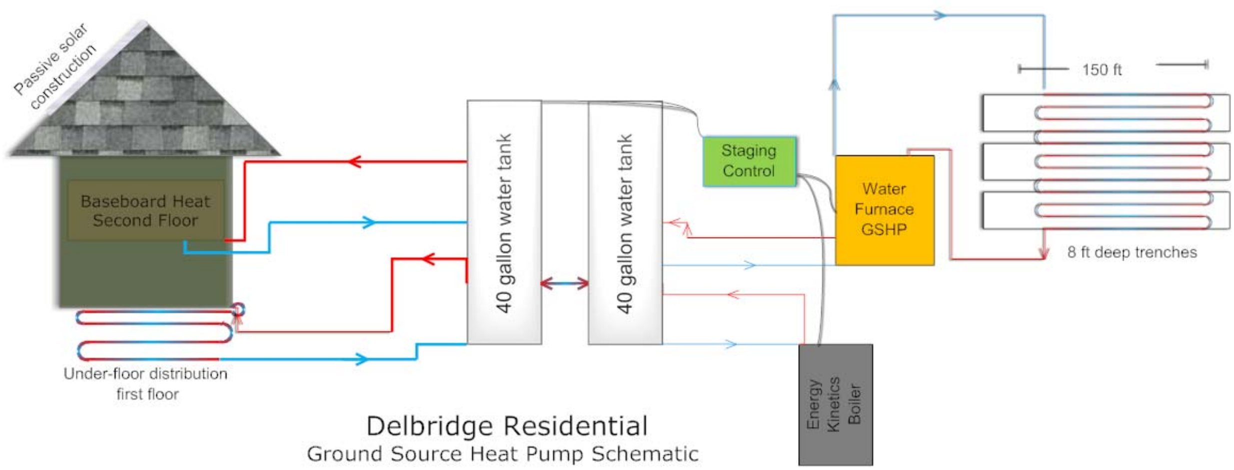
The homeowner has run into several maintenance problems. He had to replace an external circulating pump and the heat pump experienced some problems shutting off at higher water temperatures. Mr.

Delbridge cleaned the heat exchanger because it was fouled, and believes that solved the issue. He performs his own maintenance, so has not had extra maintenance costs.

Mr. Delbridge does not have a separate electric meter for the heat pump and thus does not know exact operating costs. He estimates he saved around $1,000 in heating costs the winter of 2010-2011 by reducing oil use. During the 2012-2013 winter, his savings were less because the staging control has not been working properly.

Mr. Delbridge first learned about heat pumps at an installer training session. He researched them at home shows and speaking to friends that were heat pump installers. He likes his system because he has a built-in back-up appliance if either the heat pump or boiler stops working, which is especially nice for periods when he is out of town. He thinks lower electrical prices would make GSHPs more attractive in Fairbanks. He feels his system works well, especially during the spring and fall when the house does not require high temperature water. If he could start over, he would install a heat pump capable of producing higher water temperatures so that he could avoid problems with the staging control.

The soil temperatures, measured by Mr. Delbridge, are typically around 35°F in late summer and fall to 31°F during the winter.



Horizontal Loop 2011

Chena Pump Rd. in west Fairbanks, Brian Barney, homeowner

Building	System Information	Performance
o 3,000 ft^2 with a 525 ft^2 garage o 2 story home	o 8 ton Econar with boiler back-up o Horizontal loop field 11 feet deep o In-floor hydronic and baseboard	o Estimated COP of 3 o Estimated 7 year pay back o Estimated $2,000 per year savings

The ground source heat pump was installed during the winter of 2010-2011 by the homeowner. Andy Roe of Alaska Geothermal, LLC, a GSHP installer located in Fairbanks, helped design and size the system and provided installation support as needed. The heat pump is used for heating, cooling, and 90% of domestic hot water needs. The house was originally heated by a boiler, which remains in the house to provide supplemental heat to the upstairs zones and domestic hot water. The system is controlled by a Tekmar controller.

The loop field consists of horizontal trenches located in the backyard in soil made up of sandy gravel. The trenches are 11 feet deep in a loop field approximately 100 by 50 feet. The home is also located near a lake, and the sprinkler system for the lawn uses lake water to water the grass during the summer. Since the lake water is around 70°F during this time, the homeowner thinks this added heat acts to recharge the loop field. The insulated supply and return lines run underneath the driveway to the garage.

The home is divided into 3 upstairs zones and 3 downstairs zones. Downstairs, the distribution system is in-floor hydronic tubes. Upstairs, the distribution system consists of hydronic baseboards which line the entire perimeter of the floor. The house was built with extra baseboard because the homeowner planned to run the boiler (the original heating system) at a low temperature, around 140°F.

The system uses a buffer tank to increase the efficiency of the heat pump. The domestic hot water is stored in a separate tank. The hydronic distribution system for the first floor pulls water directly from the buffer tank. For the upstairs, a 3-way mixing valve allows the boiler to boost the temperature of the water going to the baseboards. The boiler also boosts the temperature of the domestic hot water in the separate tank.

The homeowner installed the system himself and received the 30% federal energy tax credit for installation costs. His initial estimate was that it would have a payback of 7 years. Since then, he estimates that he saves approximately $2,000 per year by heating with the GSHP instead of with the boiler alone. During a cold month (with extended temperatures of -40°F) energy costs are approximately $700 for electricity, which includes electrical use from all appliances in addition to the GSHP, plus around 30 gallons of heating fuel.

The installation of the system went smoothly, but Mr. Barney had to modify the system in the first year. He was able to heat the upstairs to the set point temperature of 70°F with the GSHP and baseboard distribution system when the outside temperature was above 10°F, but the GSHP could only maintain an ambient temperature of around 65°F at colder outdoor temperatures. The installation of the three-way mixing valve to supplement the upstairs heating with the boiler allowed the set point temperature of 70°F to be maintained at any outdoor temperature.

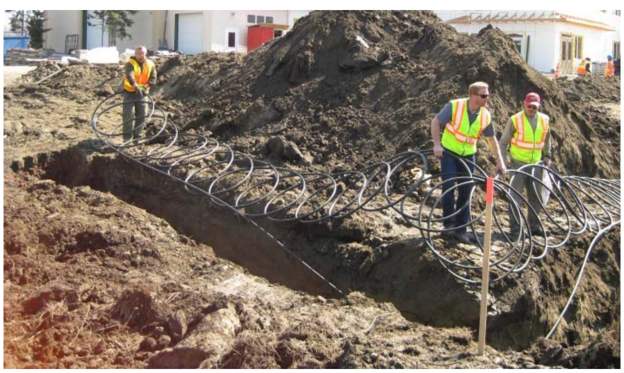
Mr. Barney is a heating contractor and the president/owner of NLC General Contractors. He was familiar with GSHPs before installing one and is LEED AP certified. He chose to install a GSHP for the cost savings and has been very happy with this decision. In fact, he plans to build an addition onto his home next year, and during the construction will retrofit the upstairs with hydronic in-floor heating so that he can use the GSHP exclusively. The boiler will remain in the home as a back-up heating device. The addition will be heated with the GSHP, and he plans to add another GSHP to a separate shed behind the house at that time as well. Also, NLC General Contractors is currently building a new office in Fairbanks, which will feature a GSHP.

CCHRC Horizontal Loop 2013

Fairbanks St. in west Fairbanks, Cold Climate Housing Research Center

Building	System Information	Performance
o 5,000 ft^2 2 story office space o Heats 1/3 of the Research and Testing Facility	o $47,000 for installation o 6 ton Geosource o Six 100-ft long loops 9 feet deep o In-floor hydronic distribution	o Estimated COP of 3.7 o Estimated $1,100 per year savings o Entering water temperature at the end of the first season declined by 3°F

This system was designed to study a GSHP on marginal ground for a long-term period. The goal is to learn whether the long-term performance of a GSHP is stable in a severe cold climate and to thoroughly characterize its efficiency over multiple heating seasons. The study will evaluate if thermal degradation of the ground loop field is a fundamental challenge for adoption of the technology in cold climates and examine the significance of practical and affordable ground surface treatments to maximize energy capture in the ground.



The loop field consists of six 100-foot horizontal loops buried 9 feet deep. There is a total of 4800 lineal feet of tubing. The fluid in the loop field tubing is 20% methanol and 80% water.

CCHRC is monitoring the efficiency of the system and its impact on ground temperatures. A full report on the project will be published in 2016.

This system cost $27,517 for the design and ground loop installation. The heat pump and in-building installation cost $19,686. The total cost was approximately $47,000. The COP of the heat pump averaged 3.7 the first season. CCHRC estimates a savings of $1,100 a year over the replaced oil-fired boiler.

The heat pump came online in November 2013 and provided heat to the building without any problems until late January. A faulty contact on the compressor and the control panel failed. The parts were under warranty and replaced quickly. The heat pump has been functioning smoothly ever since.

For more information on this heat pump visit, www.cchrc.org/ground-source-heat-pump-demonstration-cchrc

North Pole Horizontal Loop 2010

North Pole, Homeowner and installer interviewed in 2010, and a plumber interviewed in 2013. Names are withheld because the original homeowner has moved out-of-state and no longer has contact with the GSHP system.

Building	System Information	Performance
o 5,000 ft^2 home o 5-star energy rated	o $35,000 for installation o 8 ton Econar o Ten horizontal slinky loops 8 feet deep o In-floor hydronic heat distribution	o Ground loop temperatures ranging from 33°F in May to 48°F in September.

The house is heated and cooled using a GSHP system. There is also an oil-fired boiler for back-up heat and domestic hot water. The heat pump began operating in May 2010.

The heat pump is an Econar 8-ton system. The manufacturer's rated COP is 3.3 with an entering water temperature of 36°F. For cooling, the heat pump is bypassed and fluid from the ground loop is run directly to the floor tubes using a pump.

The ground loop is on one half-acre of land near the house. Loops are buried 8 feet deep, which puts them in the water table. Close to the house, where the pipes come up higher to connect to the manifold, there is insulation on top of the loops. A total of 10 loops (8 main loops and 2 back-up loops) were installed. The ground loop fluid is pumped at 22 gallons/minute. One of the main loops has a kink, so the system is currently running 8 loops + 1 backup. Fluid is 75% water and 25% methanol. The homeowner was able to monitor the return temperature from the ground loop. He reported ground loop temperatures ranging from 33°F in May to 48°F in September.

The heat pump maintains the temperature of a buffer tank of water. The pump turns on when the water temperature falls to 90°F. It heats the water up to 106°F, which is then distributed through the house using hydronic in-floor distribution.

The electric bills from 2010 were $180 in the summer and $310 in October. Not including the distribution system, installation prices were $20,000 for the boiler and $35,000 for the heat pump system; $12,000 for the heat pump and $1,500 for the water tank. The homeowner received a federal tax credit for 30% of system price.

Directionally Drilled Loop 2013

East Fairbanks, Mike and Crystal Timmcke, homeowners

Building	System Information	Performance
o 1,000 ft^2 home o Occupied by 2 people o Next to the Chena River	o $24,800 for installation o 4 ton Geocomfort o Eight 130 ft. horizontal straight loops 8 to 10 feet deep o Forced air heat distribution	o Estimated average $200 seasonal monthly savings

The heat pump was installed by Alaska Geothermal, LLC. in 2013 and provides heating, cooling, and domestic hot water for the house. It was a retrofit installation, replacing an oil-fired furnace that was at the end of its life. There is no back-up heating system. The GSHP uses the forced air distribution system previously used with the oil-fired furnace.

The ground loop field is in saturated gravel and is below the Chena River's natural level. The ground loop is in an area with substantial summer sunshine and extends to the high water mark of the Chena River, and is likely in an area with significant ground water movement.

The installation cost was $24,800 for the horizontal directional drilling, heat pump, and labor. This did not include the installation of the distribution system, which was already in place. The homeowners are applying for the Federal Tax Credit for the system, which will total $7,440. As the house required a new heating appliance when the heat pump was installed, the homeowners also consider the amount they would have paid for a new furnace as a deduction (approximately $8,000), leaving the incremental cost of installing a GSHP at $9,360.

The homeowners estimate the average monthly electrical costs at approximately $400 during the winter, which includes the heat and DHW along with the electrical use from other appliances. The homeowners have been tracking electric and fuel bills for the house since 2010 and estimate that the heat pump is saving them an average of $200 per month in energy costs during the heating season. They noticed a decrease in the savings per month as the winter progressed down to a net zero savings in April 2014. To date there have been no maintenance issues.

The homeowners first considered installing a GSHP in 2013 for several reasons. The oil-fired furnace in the home was more than 30 years old and no longer functioning. While installing a replacement furnace was one option, the house is located on a lot that receives substantial sunshine during the summer months. The sunshine can heat the house to high temperatures, sometimes near 90°F, so they wanted to have a heating system that could also provide cooling. Additionally, the flue from the existing furnace passed through the kitchen wall, and they desired a heating system without a flue in that location to accommodate future renovations. The GSHP was attractive because it has no flue and can provide air conditioning. Also, there was room for the loop field in an exposed area near the river. Furthermore, the installer was able to use a horizontal directional drill to install the ground loops. Horizontal directional drilling requires excavation only for the pipe headers, which resulted in fewer disturbances to the yard than a traditional horizontal slinky loop installation. So far, the homeowners are happy with their decision to install the heat pump.