Understanding and Evaluating Geothermal Heat Pump Systems

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New York State
Energy Research and
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Information for Evaluating Geoexchange Applications

prepared for the

New York State Energy Research and Development Authority (NYSERDA)

by the

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Introduction

This document describes the steps involved in evaluating a geoexchange, also known as ground source or geothermal, heating and cooling system. It describes the system and options and attempts to anticipate questions that building owners and designers might have about the technology. This document is designed to assist the layman in understanding the main concepts in geoexchange systems and in providing initial sources of information for the designer to pursue a specific project evaluation.

Geoexchange technology is not new. Geoexchange systems have successfully operated for decades in a variety of building types. While the basic technology has been around for more than fifty years, many improvements recently have been made, including types of materials used, design and installation methods, and the efficiencies of compressors, pumps and other equipment.

Geoexchange systems are applicable in both existing and new buildings. Their benefits are greatest in buildings with similarly sized annual heating and cooling loads and those desiring independent climate control of many rooms with the potential for heating and cooling different zones simultaneously.

Office buildings and schools are particularly good applications for geoexchange technology. They have relatively high occupancy, fluctuating usage schedules, and widely varying heating and cooling requirements within individual zones (offices and classrooms) that are difficult to meet efficiently with conventional systems. Further, efforts to improve the efficiency of conventional systems employ control strategies that add considerable cost and complexity to the systems, increase maintenance requirements, and often compromise occupant comfort.

Large open spaces, such as gymnasiums and theaters in schools can be comfort conditioned with geoexchange systems. The capital costs of combining multiple units can exceed the costs of larger conventional systems. In addition, the total energy requirements of these spaces are generally lower because of their infrequent occupancy. Large retail and warehouse applications that often favor the low first cost of rooftop equipment would, most likely, not realize the economic benefits of geoexchange systems.

In some instances, geoexchange systems can be installed for the same cost as conventional systems, but generally the added investment of installing the ground heat exchanger can cause initial cost of a geoexchange system to be higher than that of a conventional system. The lower energy and operating costs over the life of the system, however, often offset the added initial investment. Depending on building type, system design, operating parameters, and energy costs, the simple payback for the marginal cost of a geoexchange system usually falls between 2 and 8 years.

Replacement of a functioning HVAC system in a building with any type of alternative system requires a substantial capital investment. Replacing a functioning system that is providing adequate heating and cooling at a reasonable operating cost is typically not cost effective. The best time to consider installing geoexchange technology is when a new building is being planned, or when considering the replacement of an existing system that no longer meets the needs of the building or has reached the end of its useful life.

The environmental benefits of geoexchange are also an important consideration. Geoexchange systems can help facilities qualify as Green Buildings. Green Buildings incorporate practices that significantly reduce or eliminate adverse environmental impacts and increase the efficient use of energy, environmental, and human resources. Green buildings in New York State may qualify for a tax credit. See http://www.nyserda.org/green.html for more details.

This energy and environmental approach becomes clear when you consider that every million square feet of space conditioned with geoexchange technology results in a combined savings of more than 7.6 million kWh and 38,207 MMBtus of fossil fuel. The savings will obviate the need to import approximately 20,490 barrels of crude oil per year and result in an annual emissions reduction of about 1,525 metric tons of carbon equivalents. This is comparable to 1,200 cars off the highway, or planting 764 acres of trees. Most significantly, utilities will see a 2.5 megawatt demand reduction for each of the 20 years that the geoexchange system is in operation.

I. How Geoexchange Systems Work and What Makes Them Efficient

- Geoexchange systems couple the building to the local environment;
- The ground provides a nearly constant temperature source for efficient heating and cooling;
- Geoexchange systems are distributed systems rather than a central system; and
- Energy is moved around the building efficiently with water rather than air.

Basic Geoexchange Concept

Geoexchange technology transfers heat between the steady temperature of the earth and a building to maintain the building space conditions. Below the surface of the earth throughout New York the temperature remains in the low 50°sF throughout the year. This stable temperature provides a source for heat in the winter and a means to reject excess heat in the summer. In a geoexchange system, a fluid is circulated between the building and the ground loop piping buried in the ground. In the summer the fluid picks up heat from the building and moves it to the ground. In the winter the fluid picks up heat from the ground and moves it to the building. Heat pumps in the building make this transfer of heat possible.

Geoexchange systems exchange thermal energy between a building and the ground. When the building needs heating, the system extracts energy from the ground and pumps it into the building where it is concentrated by the heat pump. Conversely, when the building needs cooling, the heat from the building is concentrated by the heat pumps and the system removes heat from the building and pumps it into the ground. This exchange of thermal energy makes the system efficient. Rather than creating heat by burning a fuel on site, the geoexchange system moves thermal energy between the ground and the building, using heat pump technology.

The relatively constant temperature of the ground makes this energy transfer efficient throughout the year, even during the coldest weather. When the building needs cooling the system takes advantage of the relatively constant ground temperature that is often cooler than the outdoor air in the summer. Alternative systems must move energy from the building to the hotter outdoor air, while the geoexchange system gains efficiency by transferring the energy to the cooler ground.

Benefits of Geoexchange

Geoexchange technology has several benefits, including:

- *Low Operating Cost* - The efficiency of the heat pumps operating under moderate loop temperatures provides the basis for high efficiency and low operating cost. The cost to move energy around the building is also low, as heat pumps are placed at each space. There is no need to circulate large amounts of air around the building to transport energy, nor is there a need to reheat air to maintain comfort in certain areas of a building.

- ***Simplicity*** – The distributed nature of the system makes it easy to understand. A heat pump located at each space will provide independent heating and cooling. The operation of one heat pump does not affect any other heat pump. Control simply requires turning the unit on or off in response to the area that needs heating or cooling.

- ***Low Maintenance*** – The heat pump itself is a packaged unit no more complex than typical residential air conditioning equipment. The components are the same as those used for outdoor applications that have much wider operating ranges and exposure to the weather. Diagnosing problems has become easier due to the distributed nature of the system. Any problem is typically closely related to the equipment serving the particular space.

- ***No Supplemental Heat Required*** – Heat pumps can meet all of the space loads, including ventilation loads. Ventilation air can be tempered by separate heat pumps and/or conditioned with heat recovery equipment.

- ***Low Cost Integrated Water Heating*** – Heat pumps can be dedicated to meet hot water loads. These heat pumps become particularly attractive when there is a large cooling load relative to the heating load. By extracting some of the heat from the ground loop for water heating, the ground heat exchanger size and cost can be reduced.

- ***No Required Exposed Outdoor Equipment*** – The ground heat exchanger is buried and the heat pumps are located inside the building. Vandalism, noise, and visual screen problems are eliminated. Designers do not have to supply space on the roof for equipment, making options such as standing seam metal roofs or large sloped roofs possible.

- ***Low Environmental Impact*** – No fossil fuels need to be consumed on site. Pollution can be best mitigated at a central power plant where electricity is produced. As the efficiency of electricity production or renewable power generation increases, so does the environmental efficiency of the heat pump system.

- ***Level Seasonal Electric Demand*** – With winter heat pump operation displacing fossil fuel use, and summer heat pump operation occurring at moderate, more efficient loop temperatures, the electric demand is more consistent throughout the year so the average price of electricity is reduced.

- ***Longer Life Expectancy*** - Both the American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) and the Electric Power Research Institute have concluded, based on independent research studies, that the appropriate service life value for ground source heat pump technology is 20 years or more. This benchmark is the current industry standard.

Making the Ground Connection

The availability or lack of land for the ground heat exchanger can define the design options but need not exclude the use of a geoexchange system.

- There is a variety of ground loop options to suit specific project needs, vertical bores, ponds, and open well, to name a few
- The loop consists of long life high density polyethylene that is fused to provide a leak-tight, continuous loop of pipe
- The loop material may be warranted for 50 years
- Water with a benign additive to prevent freezing is often circulated within the loop

The unique aspect of geoexchange systems is the ground coupling. The ground loop provides the means of transferring heat to the earth in the summer and extracting heat from the earth in winter. Detailed design information is available from ASHRAE.[1]

Types of Ground Heat Exchangers

Closed-Loop vs. Open-Loop

Closed-loop systems are environmentally benign. They are sealed so that no fluid is exchanged with the environment. The fluid often includes an antifreeze solution to protect the heat pump equipment. Some alcohols or a food grade glycol additive are sometimes used to eliminate any potential impact due to spills or leaks. Leaks are rare, generally occurring because of a contractor cutting a buried pipe. The connection process heats the pieces of tubing and fuses them together, effectively becoming one continuous pipe. The high density polyethylene piping used in geoexchange systems is the same or higher grade of pipe used in cross country natural gas piping and often comes with a fifty year warranty.

Open-loop systems must deal with the discharge of water. Water can be re-injected into a well or discharged to surface water. Open systems may be buffered through a heat exchanger that protects the closed-loop within the building from water quality issues such as dissolved minerals, acidity, etc.

Closed-Loop Vertical Bore Ground Heat Exchangers

A popular configuration of the ground loop consists of several lengths of plastic pipe typically buried in vertical holes. This bore field is then covered with landscaping or a parking lot.

[1] Kavanaugh, S. P., et al, Ground-Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings, ASHRAE, 1997.

The vertical bore configuration is a popular choice for systems of all sizes because of its efficient use of space.

Each bore hole is four to six inches in diameter. A pipe is lowered to the bottom of the bore, makes a U-turn and returns to the top of the bore. The remaining space is filled with a grout to seal the hole from potential ground water penetration. Grout provides the means for thermal contact between the pipe and the surrounding earth.

Historically, the main purpose of grout has been to protect the ground water from surface run-off, so there was no consideration given to the grout's thermal properties. In fact, standard grout used in the water well industry acts like an insulating blanket around the pipes in the bore hole, requiring the installation of more bores. Standard grout can have as little as one-half to one-quarter of the ability of the surrounding soil to transfer heat.[2]

Newer grout mixtures are available that improve the ability of the grout to exchange heat with the surrounding ground. Thermally enhanced grout, developed for use in geoexchange systems, can double or nearly triple the ability to exchange heat with the ground by controlling the sand particle size used in the grout formulation.

Figure 1. Example of a Borehole

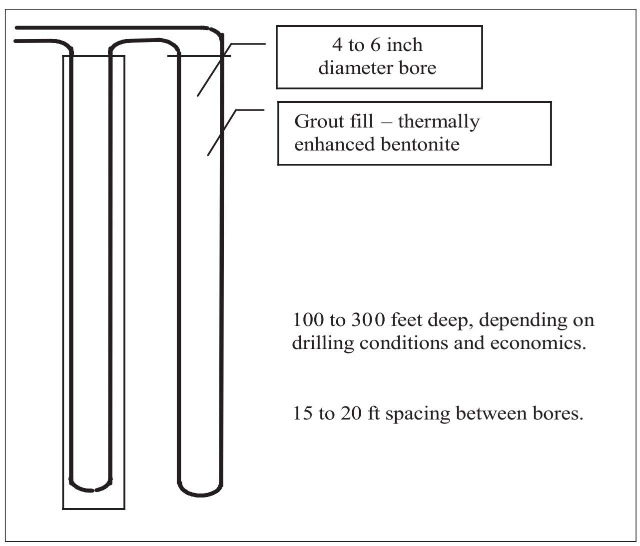


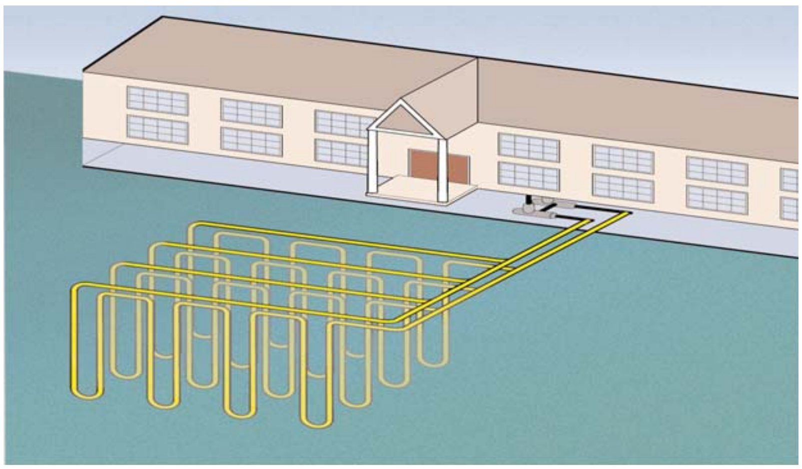
Illustration courtesy of CDH Energy Corporation.

Six to twelve individual bores are typically connected together to form a circuit. The circuit connects to a header through a shut-off valve so a circuit can be isolated.

[2] Standard Bentonite grout thermal conductivity is 0.43 Btu/hr-ft-°F, while soil thermal conductivity can range from 0.8 to 2.0 Btu/hr-ft-°F. Enhanced grouts can be configured to provide 0.6 to 1.0 Btu/hr-ft-°F.

The header combines the flow through all the circuits before going to the building portion of the loop. The header can be installed outdoors in a valve pit or all of the circuits can be brought into the building before being combined.

Figure 2. Closed-Loop Vertical Bore Ground Heat Exchanger



An alternative to a common ground loop is to serve each heat pump or small group of heat pumps with its/their own bore(s). This distributed ground heat exchange works best in single story buildings with small core areas – such as an elementary school – or when retrofitting an existing building. This configuration might require more total bores, but the system is simplified by eliminating the need for a central building piping system to accommodate the loop, central pumping, and heat pump shut-off valves. Instead, small cartridge pumps at each heat pump could circulate fluid directly between the operating heat pump and its dedicated bores.

System Operation

Water in the building loop piping is pumped through a heat exchanger in each heat pump. In the summer, the loop fluid absorbs heat from the refrigerant and carries it to the ground through the ground loop piping. In winter, it absorbs heat from the earth through the ground loop, and transfers that heat to the refrigerant. Loop temperatures are generally expected to be around 40ºF in the winter, and reach 90ºF in the summer.

The length of the ground loop is determined by the size of the heating and cooling loads and the ground thermal properties. The loads are defined by the size of the building, type of construction, use of the building, duration of the heating and cooling seasons, and climate.

The thermal conductivity of the soil directly impacts the size of the bore field needed. The drilling conditions at the site have a direct impact on the drilling cost. Knowing the drilling conditions allows drillers to better estimate the cost of vertical loop systems.

A thermal conductivity test requires completion of one or more bore holes to the projected design depth. The test circulates water through the bore loop while adding a constant amount of heat. The loop temperatures are measured over a 48 hour period and the thermal properties of the borehole can be derived from the temperature response over time.

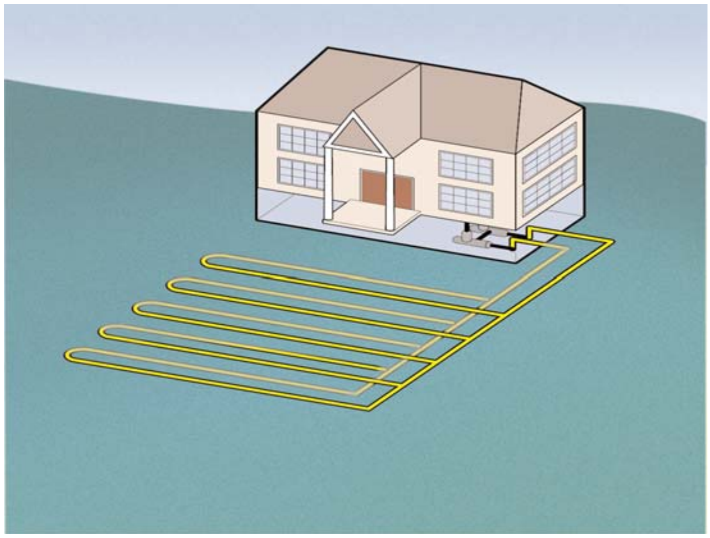
- Bore holes are typically 150 ft. to 450 ft. in length
- Typical systems require between 150 ft. to 200 ft. of bore per ton of peak block load
- At 20 ft. bore spacing, a shallow field of 150 ft. bores requires approximately 1 acre per 100 tons of peak block load
- Ground loop heat exchanger costs can vary from $1,200 to $2,000 per ton installed, depending on the drilling conditions and the size of the system

Closed-Loop Horizontal Ground Heat Exchangers

On smaller systems the placement of piping in horizontal trenches can reduce the installation cost of the ground heat exchanger because trenching is generally less expensive than drilling. Horizontal fields require more land area since they run near the surface, rather than straight down into the earth. They also require more piping because the temperature of the ground closer to the surface is subject to larger temperature swings associated with the weather. Due to the relatively large land requirements, horizontal loops are usually applied to systems less than 50 tons in capacity (about a 10,000 to 15,000 sq ft building).

A standard configuration would place pipes at the bottom corners of a six to eight foot trench, cover the pipes with two feet of soil, and return the pipes on top of the fill before backfilling the entire trench.

Figure 3. Closed-Loop Horizontal Ground Heat Exchanger



A slinky configuration would flatten a spiral of piping at the bottom of a wide trench or large scraped area. The slinky loops could be placed adjacent to each other in a large excavated area and then backfilled to a depth of six to eight feet.

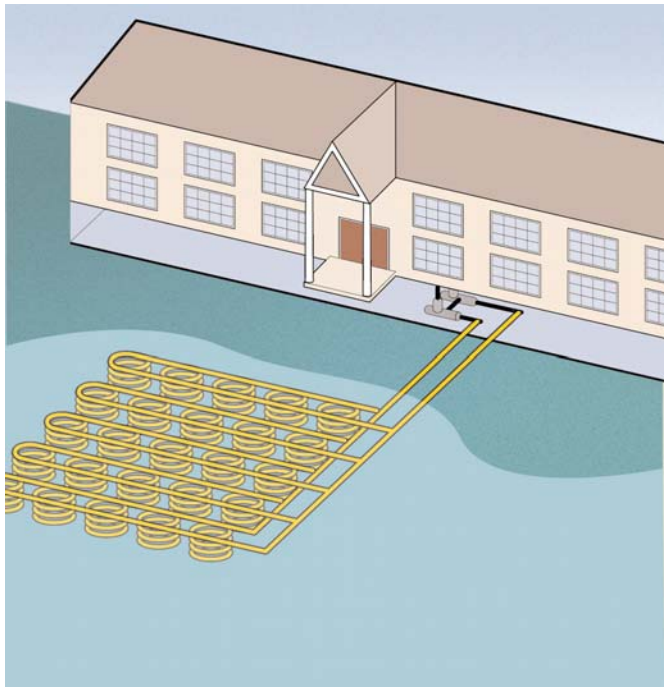
- Typical systems require 300 feet of two-foot-wide trench for two tons of peak block load
- With four foot spacing between trenches, a standard system would require one acre per 24 tons of peak block load
- Typical slinky configurations require 150 ft. of three-foot-wide area per ton
- A slinky configuration can require one acre per 90 tons of peak block load, but the entire area must be excavated or filled to a depth of six to eight feet
- Ground loop heat exchanger installation costs can vary from $800 to $1,500 per ton depending primarily on the excavation cost.

Closed-Loop Surface Water Ground Heat Exchangers

An existing pond or a pond created for a project may also be used as the heat source or sink. Loop fluid flows through pipes anchored at the bottom of the pond. Individual pipe coils are typically combined into a single circuit and attached to a frame. The frame can be floated on the pond to the desired location, filled with fluid and sunk. Concrete blocks anchor the frame to the bottom. The frame keeps the pipes slightly elevated above the bottom surface to promote circulation and to avoid sediment covering the pipes.

The loosely coiled piping allows water to flow across the bundle as a result of the buoyancy force created by the temperature difference of the pond water and the pipe fluid. Pond systems work in heating because the water is at its highest density at 39°F, so in a properly sized system the water around the pipes at the bottom of the pond is sufficiently above freezing for heat to be extracted easily.

Figure 4. Closed-Loop Surface Water Ground Heat Exchanger



- About one 300 foot coil of pipe is required for each ton of peak block load
- A pond depth of at least 12 feet is needed to supply heating in the New York climate
- Systems have been successfully operated with ponds sized at 60 tons of installed heat pump capacity per acre of pond at a 20 ft. depth
- loop heat exchanger costs can range from $500 to $1,000 per ton installed when an existing pond is used

ASHRAE design guidelines recommend detailed thermal analysis for densities above 10 tons of heating block load per acre or 20 tons of cooling block load per acre. A detailed thermal analysis will consider the energy flows in a pond such as solar influx, evaporation, surface convection, surface ice formation, flow in and out, ground conduction, and thermal mass of the water volume.

Open-Loop Heat Exchangers

Open-loop systems have been used on all sizes of systems and are some of the oldest systems installed, first appearing in the 1940s. These systems circulate water directly out of the ground to a heat exchanger which serves the heat pump loop in the building. Easy access to ground water, the amount of water available, and means to discharge the water are the main factors determining the feasibility of an open-loop system. Open water systems can provide the lowest initial cost when these factors are favorable.

An open system pumps water from an aquifer, changes its temperature and discharges the water. The configuration is basically a water well, and like any water well, the physical characteristics of the ground dictate how the well is completed. The production area of the well may contain a screen with gravel pack, screen only, perforated casing, or uncased.

Open-Loop Surface Discharge

A surface discharge system dumps used water into a pond or river. Surface disposal is the simplest approach, only requiring piping to the discharge point. Typical water requirements are 1.5 gpm per ton of block load.

Open-Loop Injection Well Discharge

An injection system might be considered due to local regulations, lack of suitable surface discharge, or the need to stabilize the aquifer. An aquifer may need stabilization if continuously removing water creates concern for a long-term draw down from extended use. No water is removed from the aquifer, since the injection system returns the used water to the aquifer. This assures that the groundwater resource will support the geoexchange system over its life.

As water is pumped from a well, the water level in the immediate area drops. This is known as the cone of depression. The radius of influence is affected by the production rate of the well. An injection well must be located far enough away from the supply well so that they do not affect each other.

Conventional mud rotary drilling is often avoided in drilling an injection well, as the thick drilling mud used for carrying away cuttings can penetrate the surrounding area and inhibit the ability of the well to accept water.

Fine particles that are extracted in the production well have the potential to plug the injection well. For this reason the screen lengths for injection wells are typically twice the size of production wells.

Standing Column Well Ground Heat Exchangers

A variation on an open-loop system is a standing column well that uses a few very deep wells (1,500 ft.) spaced about 75 feet apart. One 1,500 ft. well can often accommodate up to 40 tons of heating or cooling load.

In a standing column well, water is pumped from the bottom of the well and re-injected at the top. As water moves along the length of the well, it exchanges heat with the surrounding earth and often circulates with ground water. The capacity of the well can be increased by bleeding off up to 10% of the extracted water.

Standing column wells are often applied where little land area is available or the bedrock is close to the surface. Several geoexchange systems using standing column wells have been installed in the New York City area.

See page 21 of this report for information regarding the New York State Department of Environmental Conservation's regulations governing the drilling of water wells.

Open-Loop Surface Water

Geoexchange systems designed for the direct use of surface water are simple and can achieve the benefits of open wells without the need to drill to an aquifer. As with an open-loop well system it is good practice to isolate the surface water from the building loop through a heat exchanger. Water is usually extracted from the bottom of a lake and discharged back near the surface to minimize disturbance of the natural thermocline.

These systems are rarely used because:

- There is a potential for fouling the heat exchanger;
- Larger pumps may be needed to overcome elevation head; and
- System operation at near-freezing conditions may be difficult.

Hybrid Systems

Creative designers have placed ground heat exchangers within structural pilings of a building. Others have used effluent from a wastewater treatment plant as a means to couple the systems to the environment. Geoexchange systems can be creatively applied wherever there is a heat source or sink available at moderate temperatures (e.g. 40ºF to 90ºF).

Hybrid systems:

- Use the ground heat exchanger to meet only a portion of the load;
- Can minimize initial costs;
- Can minimize land space requirements; and
- Have added components with added complexity and maintenance.

The ground heat exchanger is most economical when its load factor is high in both heating and cooling modes (i.e. the summer heat rejection matches the winter heat extraction). In cases ground heat exchanger, it can be more economical to augment the loop design with a fluid cooler.

Sizing the ground heat exchanger for the heating requirements of the building and adding a fluid cooler to supplement the heat rejection can minimize first cost of the system. This helps preserve the economics of the geoexchange system. The use of a fluid cooler adds to the complexity of system controls and adds a piece of outdoor equipment, along with water treatment considerations. However, the potential cost reduction of the ground heat exchanger may justify this option in projects with cooling dominant loads.

Similarly, if the heating load greatly exceeds the cooling load, it might be more economical to meet a portion of the heating load with a boiler and size the loop for the smaller cooling load.

Inside the Building

- Geoexchange systems are a distributed system rather than a central system.
- Energy is moved around the building efficiently with water rather than air.

The distributed nature of the geoexchange system contributes to its overall efficiency. Thermal energy is primarily transported throughout the building with a water loop. A heat pump in each space (zone) rejects or extracts heat from the loop to maintain the desired temperature.

Other systems circulate large volumes of air to provide space conditioning. A central system may supply cooled air to all spaces, with individual spaces reheating the air to maintain the desired temperature. Geoexchange systems often save on fan energy as they use many smaller fans to blow air through short ducts at low pressure (e.g. typical fan energy use rate of 0.3 W/cfm). Other systems use extensive duct systems that transport air greater distances at a higher pressure (e.g. energy use rate of 1.0 W/cfm).

In the schematic of a standard chiller/boiler variable air volume (VAV) system, each room or zone can be heated or cooled independently. Cold air is distributed throughout the building to each room. When room temperature is too warm, a damper allows more cold air into the space. When room temperature is too cold, the damper closes to its minimum position. If the space is still too cold, a heating coil reheats the air supplied to the room. When room temperature is at the desired level, some cold air is still introduced to provide ventilation since the dampers are at the minimal position. As less air is required in more rooms, the central fan slows to reduce the amount of energy used.

In an effort to reduce the amount of reheat at the zones, control systems often increase the supply air temperature so the damper in at least one zone is almost fully open, or the supply air temperature is reduced with lower outdoor temperature. The supply air temperature reset reduces reheat energy use at the expense of additional fan energy.

It is imperative that all the dampers operate well. Stuck dampers can drive the entire system into using excessive amounts of both fan energy and reheat energy.

The VAV system supplies hot water to each room or zone, and provides chilled water to each central air handler. Cold air that is circulated throughout the building supplies cooling. A minimum amount of fresh air is continuously introduced into the re-circulated air as the total air flow is reduced.

Figure 5. VAV Chiller/Boiler Schematic

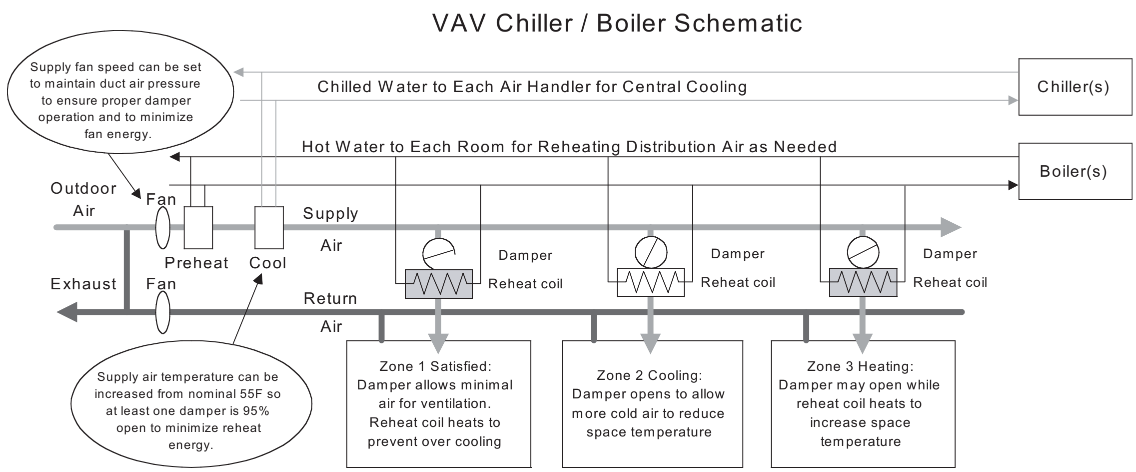


Illustration courtesy of CDH Energy Corporation.

The geoexchange system is less complicated than the VAV system. Heat pumps located in each room or zone simply heat or cool the space as needed by conditioning the air circulated between the heat pump and the space. A fluid loop connected to the ground heat exchanger circulates throughout the building, providing the heat pumps with a source or sink for heat. Stopping flow through heat pumps that are turned off, and reducing the speed of the pump, minimizes pumping energy on the ground loop.

Fresh air is often introduced through a dedicated outdoor air system. This system preconditions the outdoor air by recovering energy from the exhaust air stream through a heat exchanger. A heat pump tempers the ventilation air to a neutral condition before it is distributed to the heat pumps serving each room. Providing ventilation air via a separate system ensures that the proper amount of fresh air is delivered to each space. There is no mixing of fresh air with re-circulated air until it reaches the room heat pump.

This geoexchange air distribution system is smaller than the air system in a conventional system because it contains no re-circulated air. Only the required outdoor air is delivered to each space, as opposed to a central VAV system that often over-ventilates many zones. The fan energy is minimized because the air can be delivered at lower pressure, and there is no damper or coil to pass through in each room.

For the most part, the space conditioning of each room is independent of other rooms. The only common reliance is on the ground loop. Any problem with a heat pump only affects the room it serves and cannot impact upon the performance or energy use of the entire system.

Figure 6. Geoexchange System Schematic

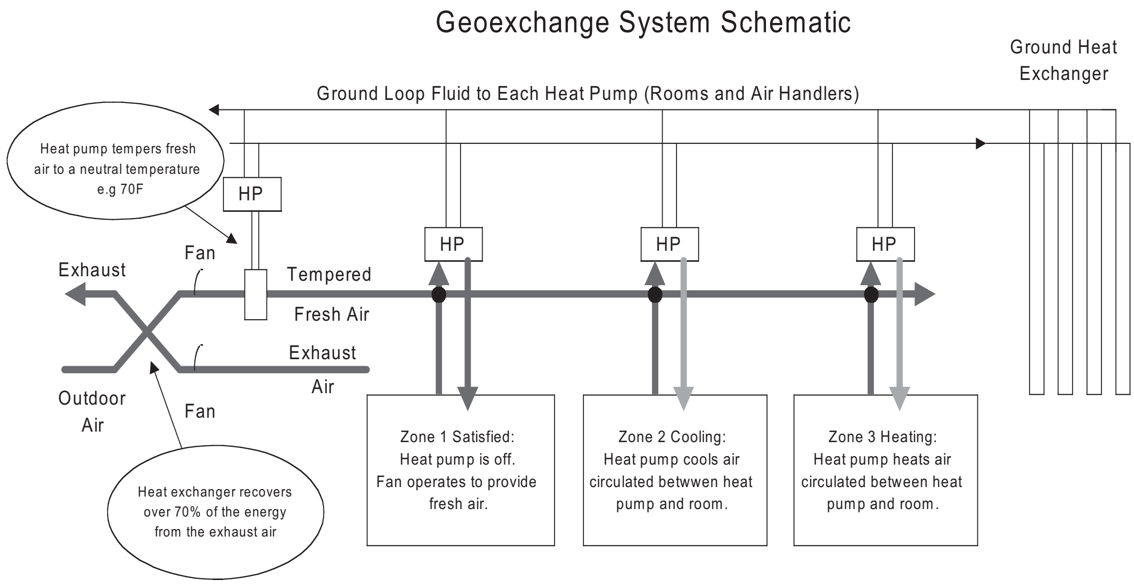


Illustration courtesy of CDH Energy Corporation.

Large Spaces

Large open spaces often require more heating and cooling capacity than a single heat pump can provide. In moderately sized spaces multiple heat pumps can meet the space needs. In larger spaces, systems often employ standard two-speed air handler units with heating and cooling supplied by water-to-water heat pumps. These heat pumps condition water rather than air. The water-to-water heat pumps come in larger sizes and can be ganged together to achieve larger capacities.

Figure 7. Geoexchange in Large Spaces

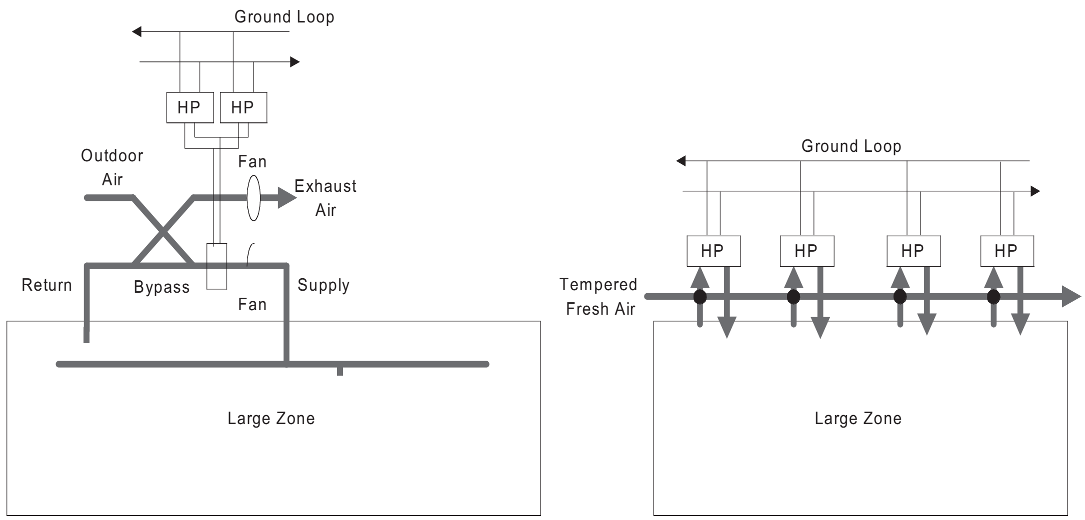


Illustration courtesy of CDH Energy Corporation.

Vestibules & Building Entrances

A vestibule acts as a buffer between the conditioned space and the outdoors. Designers often want to heat these spaces quickly with large capacity equipment to melt snow that is tracked in and to avoid drafts. While a typical heat pump can condition the vestibule space if provisions are made to maintain a minimum entering air temperature, an in-floor heating system can recover the space conditions faster and keep snow melted. A water-to-water heat pump can supply warm water to tubing within the concrete floor slab. The slab stays warm, and is able to melt snow even with frequent door openings. This type of system is also applied in garages or spaces with large overhead doors that would benefit from maintaining a warm, thermally massive floor.

Water Heating

A geoexchange system moves heat from the ground to heat the building. It is also possible for the geoexchange system to move heat from the ground to heat hot water to 125° F. Integrating water heating with a geoexchange system is particularly effective when the cooling load dominates the sizing of the ground loop. The need to reject heat to the ground can be reduced by using some of that energy to heat hot water.

The Ramada Inn in Geneva, New York, has an on site laundry and a full-service restaurant. All water heating is provided by the geoexchange system. By integrating water heating into the system the designers were able to reduce the total ground loop heat exchanger by 20%; approximately the cost of the water heating system. Extracting heat from the loop throughout the year equalized the annual heating and cooling loads on the loop.

Loop Pumping

The hydraulic system design and the selection of the pumping system can greatly impact upon the energy use of the entire system. During spring and fall months a poorly designed pumping system can use more energy than the heat pumps. An average system will use 75 W/ton of cooling capacity or more. The best systems use less than 50 W/ton because they minimize friction losses in piping and valves, select pumps to operate near their maximum efficiency point, and use high efficiency motors.

Variable frequency drives are vital to minimizing pumping energy during non-peak load periods. Equipping each heat pump with a normally closed valve, to automatically isolate it when the heat pump is off, allows the drive to slow the pump speed and reduce the amount of fluid circulated through the building loop.

Heat Exchangers

Heat exchangers are often needed in open-loop systems to protect the building loop from poor water quality. A heat exchanger isolates the ground or surface water from the loop water that circulates in the building among the heat pumps.

Both tube-in-shell and plate-frame heat exchangers are used in open-loop systems. Bolted plate frame heat exchangers can be easily disassembled and cleaned. Tube-in-shell heat exchangers often have brush systems, integrally installed, that merely require back flushing to operate.

Heat Pumps – It's Not Magic, It's Thermodynamics

Heat pumps:

- Use the principle that heat always flows from a hot area to a cold area;
- Use a refrigeration cycle to move heat from a colder to a hotter temperature, concentrating it; and
- Create a cold zone in the area where heat is to be extracted and a hot zone in an area where heat is to be dumped.

The pumping or exchange of energy is done by heat pumps – a refrigeration device that works by the same concept as a refrigerator. Refrigerators, air conditioners and heat pumps all operate by pumping refrigerant through a closed loop in a way that creates two distinct temperature zones – a cold zone and a hot zone.

When a heat pump heats, fluid from the ground loop flows next to the heat exchanger tubes containing refrigerant that is colder than the loop fluid. Since a primary principle of heat transfer is that heat always flows from a higher to a low temperature, the refrigerant absorbs heat and evaporates within the tubing.

The cool refrigerant gas is then compressed and pumped to the high temperature section, which is often configured as a refrigerant coil with air blowing across it. Because the refrigerant becomes hotter than the air, when it is compressed, it gives up heat to the relatively cooler air from the space. As the refrigerant gives up heat to the air stream, it condenses into a liquid. The liquid passes through a restriction that maintains the pressure difference between the hot and cold zones. As the pressure of the liquid drops, it vaporizes and its temperature drops to the cold zone temperature where it begins the refrigerant process again.

Figure 8.

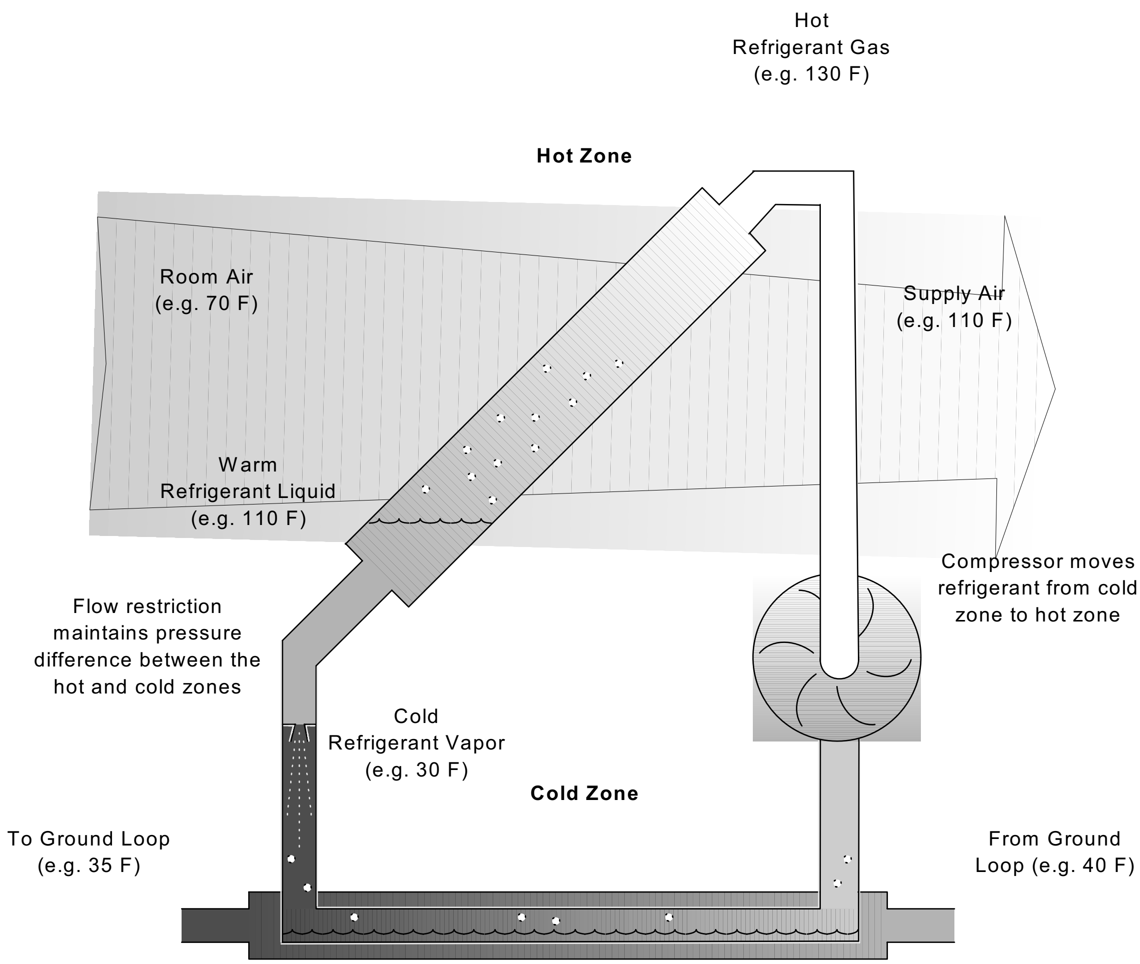


Illustration courtesy of CDH Energy Corporation.

To provide cooling, a heat pump has a reversing capability, so the hot zone and the cold zone can be swapped. With the zones reversed, heat is extracted from the indoor air and transferred to the ground loop.

Maintenance

Routine maintenance involves keeping the coil clean, by changing the filter in each heat pump. Heat pump maintenance requires no more specialized skills than servicing the equivalent of a residential air conditioner. Research has shown that with proper water and airflow along with regular filter replacement, the heat pumps should perform well for 20 to 25 years.

Additional noise insulation may be necessary in areas extremely sensitive to noise, however normal noise levels are generally acceptable. Placement in an insulated closet is also an option. One popular approach in single-story buildings with pitched roofs is to place the heat pumps above each zone and provide a catwalk for easy service access.

Regulations

While New York State does not explicitly regulate geoexchange bore fields, the industry has developed acceptable practices that must be followed. As for regulations, the New York State Department of Environmental Conservation, through its Division of Mineral Resources, regulates wells including geoexchange bores with depths greater than 500 ft. Registered water well drillers are required to notify the state of proposed water wells and provide a completion report. Closed loop geoexchange boreholes do not meet the legal definition of a water well (an excavation for the purpose of obtaining water). There are more than 400 registered water well drillers in the state.

II. Case Studies

Throughout New York State, there are numerous commercial and institutional buildings that are using geoexchange systems. Following are four case studies profiling the Kopernik Space Education Center in Vestal (Broome County); Sullivan County Community College in Loch Sheldrake; Holiday Inn Express in Albany; and the Saratoga Race Course in Saratoga Springs. (Please note that the information contained in the case studies was deemed accurate at the time of their development.)

Albany Molecular Research, Inc., Albany, New York

Background

Albany Molecular Research, Inc. has offices in Syracuse and Albany. The company decided to improve and expand an existing building located near Albany's Pine Bush Preserve. Albany Molecular placed considerable importance on completing this project in an environmentally friendly manner. The company contacted NYSERDA for assistance through the New York Energy $martSM New Consruction Program and the New York Energy $martSM FlexTech Program.

The original building consisted of 75,000 square feet and was constructed as office and warehouses space. Albany Molecular Research, Inc. expanded it to a a130,000-square-foot state-of-the-art pharmaceutical laboratory.

Albany Molecular Research, Inc. and its design team first contacted NYSERDA about conducting a study under NYSERDA's FlexTech Program. Through that program, Malcom Pirnie, P.E. evaluated the feasibility of installing a geothermal groundwater cooking-system at the site. As part of the assistance available through NYSERDA's New Construction Program, Science Applications International Corporation (SAIC) completed a detailed energy analysis of the entire building. Design parameters from Friedman-Fisher Engineers, the project engineering firm were used.

Recommendations

The analysis recommended the following equipment be installed:

- Variable air-volume and supply systems with direct digital controls (DDC);
- Run-around heat recovery for cooling-ventilation load reduction;
- Primary/secondary hot-water pumping; and
- Geothermal groundwater cooling system

Incentives and Results

NYSERDA cost shared $33,220 of the study cost and offered $400,000 to help offset the cost of installing these high-efficiency measures.

These measures will result in:

- A cost savings of $139,745 annually
- A 397,453 kWh reduction in energy use per year
- A payback period of three years
- Summer and winter peak electric demands will be reduced by 610 kW and 85 kW respectively

NYSERDA also is providing $9,320 to Albany Molecular to commission the installation and start-up of this equipment.

Tannery Pond Community Center, Johnsburg, New York

Background

The new Tannery Pond Community Center not only offers entertainment and meeting spaces, a catering kitchen, and office space for the Johnsburg Chamber of Commerce, but offers significantly lower energy costs as compared to most new buildings. To make the Center energy-efficient, the Town of Johnsburg, the owner of the 11,200-square-foot facility, received financial and technical assistance through the New York Energy $martSM New Construction Program.

To identify the most energy-efficient options, a design evaluation was completed through NYSERDA's technical assistance provider, Science Applications International Corporation (SAIC).

Recommendations
As a result of the evaluation completed at the Tannery Pond Community Center, the following measures were recommended:

- Geothermal heat pump system
- Super-insulated building shell
- High-efficiency windows
- Air-to-air heat recovery system

Incentives and Results
NYSERDA offered an incentive of $93,852 for installation of the above measures that resulted in:

- An estimated 140,733 kWh reduction in annual energy use
- A savings of approximately $24,000 in annual energy costs
- A payback of 3 years to the Town of Johnsburg on its energy-efficiency investment

Bard College, Annandale-on-Hudson, New York

Background
Bard College has been committed to economical and environmental construction projects. The college is located on 500 acres and, as part of an expansion effort, sought to construct a nine-building dorm complex. Continuing a cooperative relationship, Bard College requested design assistance and implementation support from NYSERDA. Bard's commitment to high-efficiency geothermal heating and cooling played an important role in the project design.

As part of the New York Energy $martSM New Construction Program, Bard College, Novus Engineering, P.C., and Reynolds Design Associates partnered with NYSERDA's technical assistance provider, Science Applications International Corporation (SAIC). A feasibility study was conducted evaluating energy-saving opportunities.

Recommendations
The technical assistance and design assistance recommended the following measures for the new dormitory complex construction:

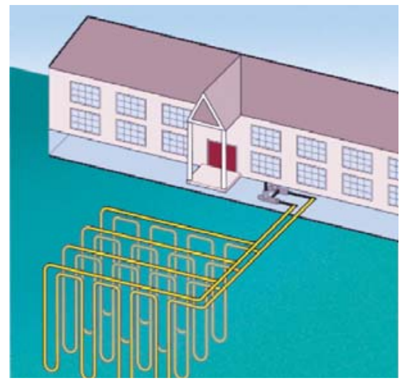
- Computer modeling
- Improved building envelope
- Horizontal-axis washing machines
- Variable-speed drives for the geothermal loop
- Building commissioning
- Air-to-air heat exchangers
- Geothermal heat pump system

Incentives and Results
NYSERDA provided Bard College with a $234,655 incentive that will help the college realize:

- Annual energy savings of $36,830 (387,180 kWh)
- 242.1 kW peak-summer demand savings
- Simple payback of 2.8 years
- Reduced emissions of over 171 tons annually

Indian River Central School District, Indian River, New York

Background
As part of a new 71,500 square foot elementary school building, Indian River Central School District undertook a preliminary study which indicated the overall cost of heating, ventilating, and maintaining the building could be lowered by using a geothermal heat pump system. Subsequently, the Indian River School Board requested the assistance of the New York State Energy Research and Development Authority (NYSERDA) to undertake a detailed analysis to determine the feasibility of a geothermal heat pump system to heat and cool the building.



Geothermal heat pumps, or geoexchange systems, tap the renewable energy available from the earth to provide efficient heating and cooling. In the winter, this is accomplished by a series of pipes buried beneath the earth that extract heat from the ground and carry it to a geoexchange unit. The process is reversed in the summer. Heat is drawn from the interior air and transferred to the ground. The systems are environmentally friendly, burning no fossil fuel and producing no greenhouse gases.

Recommendations
The goal of this Technical Assistance project was to compare the use of geothermal heat pumps to air-source heat pumps. Since the proposed building site is not serviced by natural gas, traditional fuel choices are limited to electricity and fuel oil. Both types of heat pumps would yield benefits. There would be no on-site combustion, combustion by-products, or fuel storage. The geothermal system, however, has the ability to transfer all of the schools heating and cooling loads from the earth to the building.

Results
While the air-source system has a lower initial cost, the potential energy maintenance savings of the geothermal system pays for itself.

- Annual Energy Savings: $11,300
- Incremental cost of the Geothermal Heat Pump System over the alternative Air Source Heat Pump: $178,750
- Total Operation and Maintenance savings over 20 year life cycle: $285,600
- Simple Payback: 12.5 years

Sullivan Community College

Creating a consistently comfortable environment is important to an educational facility. With the goals of both its students and faculty in mind, Sullivan County Community College (SCCC) took nothing for granted and decided that the best way to ensure a productive learning and working environment was to utilize geoexchange technology.

The college needed a reliable heating and cooling system for ten buildings (170,000 sq. ft.) that include classrooms, offices, kitchens, libraries and a faculty lounge. Aesthetics and environmental sensitivity were concerns, and lowering energy costs was an important factor.

The foremost goal SCCC had for its new system was to obtain a totally controlled environment. Special attention was needed for rooms containing 30 computer stations operated by students. The HVAC system did not allow separate classrooms to have individual thermostats, and this caused a great deal of discomfort for students and faculty who regularly felt either too hot or too cold.

Meetings were held over three to four years with consulting engineers Friedman Fisher Associates, who created the master plan with an alternative HVAC systems study. Various energy options and their corresponding costs were brought to light. Throughout the selection process geoexchange technology stayed at the top of the list.

SYSTEM SPECS

- 132 water-to-air and five water-to-water heat pumps
- Water-to-water heat pumps for ventilation system dehumidification and heating coils
- Air-to-air heat exchangers and water-to-water heat pumps in energy-efficient ventilation design
- Ground heat exchanger with 200 bores, 410 feet deep, 500 ton capacity
- Heating and ventilating systems for large culinary program kitchens
- All primary and secondary pumps housed with system piping manifold in a new pump house building

Total contract value: $10,500,000
Mechanical/Electrical/Geothermal contract value: $7,400,000
Project completion date: Oct. 2001

The installation, with phased construction, took two years. Disruption was minimized and budget considerations were accommodated. The system consists of 132 water-to-air and five water-to-water heat pumps (for ventilation system dehumidification and heating coils), supplied by a well field with 200 vertical bores dug 410 feet into the earth. All primary and secondary pumps are housed with system manifold piping in a new pump house building. The design included heating and ventilating systems for large culinary program kitchens.

The entire college, except for the gymnasium, took full advantage of the geothermal heat pumps by October 2001, and the total cost of the project was slightly over $4.4 million dollars. The total contract value was $10,500,000.

After concluding that the geoexchange system would save it more than 420,000 kWh per year, approximately the power needed to energize more than 70 homes annually, New York State Energy Research and Development Authority provided the school $250,000 to help offset the costs of the installation. The expected savings on the college's operating costs rounded out to approximately $74,000 a year.

Brad Fisher, President of Friedman Fisher Associates, recalls his experience with the SCCC Project: “It was great to work with a client who was knowledgeable and excited to reap the benefits of geoexchange technology.”

SCCC feels it made the best choice it could have for its facility. Faculty monitors the system monthly and has found that they have saved quite a bit of money using geoexchange technology.

“A lot of people, both homeowners and commercial property representatives, come out to our campus for tours of our facility,” said George Amaral. “They really like what we’re doing with our geothermal heat pumps.”

College officials have been so pleased that, with design help of Friedman Fisher Associates, they recently added another geoexchange system to serve its new 180-student dorms. The two, four-story buildings operate off their own loop field, using a ground coupled heat pump system and modular building construction. Since the installation was completed, college officials and those using the dorms have been pleased with both the totally climatized environment and the money saved by using renewable thermal energy rather than fossil fuels.

Project Participants:

Building Information
Sullivan County Community College
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(845) 434-5750

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Albany, New York

Electrical
Weisburgh Mechanical and
Electrical Corp.
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Facilities and Programs Coordinator
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Friedman Fisher Associates
Brad Fisher
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Geothermal
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Rochester, New York

Plumbing
Mechanical Construction
Poughkeepsie, New York

Building Supervisor
SCCC, George Amaral
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NYSERDA
Greg Lampman
518-862-1090 Ext. 3372

Holiday Inn Express, Albany, New York

Improved aesthetics, noise reduction, and energy cost savings are some reasons cited by owner Michael Hoffman and architect Henry Dennis to use geoexchange (geothermal) heating and cooling systems to heat and cool the new Holiday Inn Express in Albany, New York. The 125-ton geoexchange system installed in 1995 is the energy efficiency centerpiece of the hotel, that also includes R-19 wall insulation, R-30 ceiling insulation, and thermopane windows.

Quiet, Attractive, and Energy Efficient

The Holiday Inn Express has 126 rooms, a health club with an indoor pool, a great room adjacent to the lobby, and a guest business center. Architect Henry Dennis had to be concerned about the height of the building, since the community was averse to a tall building. The geoexchange system eliminated the need for rooftop condensing units, thus creating a lower and more attractive building silhouette. Owner Michael Hoffman was concerned about energy bills, since high energy costs can put a hotel out of business. He also needed quiet operation, a primary concern of hotel guests.

System Description

Each room has a console heat pump, while office areas have six ceiling-mounted heat pumps. No wall penetrations disrupt the building envelope. Two water-to-water units are installed in the pool area. Each heat pump has individual thermostat controls, and the five well pumps include an energy management system that responds to the interior water loop temperature.

The ground heat exchanger consists of five 1,500-foot standing column wells. Water is drawn from deep in the wells through a concentric inner pipe, used to heat or cool the building and then re-injected into the top of the well. A heat exchanger separates the building's interior water loop from the ground loop. Each well utilizes a 5-hp pump for operation. The interior water loop, driven by one 10-hp pump, feeds more than 130 heat pumps and is designed for a maximum loop temperature of 85ºF during cooling and a minimum temperature of 40ºF during heating.

Energy Cost Savings

The $178,000 installed cost of the system was offset by a $28,000 ($225/ton) rebate from the Niagara Mohawk Power Corporation, and with estimated energy cost savings of more than $38,000 a year, the system yielded a positive cash flow from the first month. The simple payback period for the geoexchange system is 3.8 years.

Michael Hoffman states that although the decision to use geoexchange was difficult, the considerations that led him to proceed with the geoexchange installation (cost-competitiveness and quiet operation) now make him pleased with his decision. The choice to use a geoexchange system has given him a substantial competitive advantage in his market, where energy costs can be as high as 20 to 22 percent of sales. Holiday Inn Express energy costs are running about 4.5 to 5 percent of sales, and Mr. Hoffman thinks they will be as low as 3 to 4 percent in the future.

Project Participants:

Owner/Operator
Michael Hoffman, Holiday Inn Express,
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Utility
David Abrey, Niagara Mohawk Power Corporation,
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Architect
Henry Dennis, Henry Dennis, Jr. Architects,
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Equipment Manufacturer
Roger Kerr, ClimateMaster
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Mechanical/Electrical Contractor
Donald Bronstein, Eastern Heating & Cooling, Albany, NY (518) 465-8878

Saratoga Race Course, Saratoga Springs, New York

Saratoga Springs, New York, is home to the most important historic racetrack in America. More than 130 years ago thoroughbred horses pounded around the 350-acre track with such enthusiasm that just one year later 10,000 people jammed the racecourse for the first four-day meet. Today, people from around the world visit Saratoga Race Track every summer, and the racing fever that began many years ago continues to thrive.

It was this history that Saratoga Race Course wanted to preserve when a renovation project began. Weathering and natural aging had deteriorated some buildings that the racecourse wanted to protect.

"Parts of the buildings on this property are nearly 100 years old," said George Hathaway, facilities manager of Saratoga Race Course. "It's a historic site."

Keeping in mind its ties to the past, the racecourse examined ways to improve upon its facilities, including a newly built jockey house. The improvements had to be made without disturbing the highly visible structures on the site. A new heating and cooling system had to provide 14,000 square feet of space with the necessary interior climate conditions.

"Our Jockey House was an outdated facility that didn't have air conditioning or the proper equipment for the jockeys," Hathaway said. "We wanted to offer a more state-of-the-art building, but we didn't want the building's HVAC system to detract from the grounds."

SYSTEM SPECS

- 50 ton, vertical closed loop ground heat exchanger
- Ground heat exchanger consists of 10 bores, 480 feet deep
- High efficiency, extended range heat pumps
- Elimination of requirement for exterior equipment to be installed in areas accessible to the public
- Minimal mechanical room space reduces building footprint

Total contract value: $1,600,000
Geothermal / HVAC contract value: $200,000
Project completion date: July 2000

Although the jockey house is only occupied for six weeks each year (late July to September), the racecourse wanted to heat and cool the building year-round to help preserve the finishes and equipment inside. Located in the middle of an area that is open to the public, the racecourse wanted to maintain the integrity of the facility without new equipment, pipes and registers detracting from the overall appearance. Noise levels presented a concern and a quiet system was preferred.

Once an energy analysis was performed and alternatives were on the table, a geothermal heat pump system was selected as the best energy option by the Saratoga Race Course.

The racecourse worked with consulting engineers Friedman Fisher Associates and NYSERDA to update its heating and cooling technology into a 50-ton, closed loop, vertical type ground heat exchanger system. The ground heat exchanger consists of 10 bores at 480 feet deep. Also installed was a ground coupled water source heat pump system using high efficiency, extended heat pumps to adequately support the expanded program and to air condition the jockey accommodations for the first time. The total cost of the system was $202,513, of which $57,203 was funded by NYSERDA to help offset the cost of installing a geothermal HVAC system instead of an alternative system.

The Jockey House was finished in July of 2000, and the Saratoga Race Course is pleased with the geoexchange system's performance, including the energy savings and multi-zone control geoexchange provides. The estimated savings per year are approximately $7,800 and the race-course looks forward to more savings over the next 20 years as its system continues to accrue additional operational savings.

Hathaway added, "I can tell you that we made the right decision to go with geoexchange, both from an economical and efficiency standpoint."

Project Participants:

Building Information
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General
BBL Construction Services
Albany, New York

Designing & Consulting Engineer
Friedman Fisher Associates, PC
Brad Fisher
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Geothermal
Geothermal Services
Mays Landing, New Jersey

Mechanical
Collett Mechanical
Albany, New York

NYSERDA
Greg Lampman
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Geoexchange Installation Inventory

The following table describes many of the geoexchange systems installed in New York State in recent years.

Table 1.
Geoexchange Installations in New York

Site Name	City	Year Installed	Building Size (sq. ft.)	System Size (tons)
1400 5th Avenue Condominium	Harlem	2003	225,000	643
148 Reed Street	New York			
150 Reed Street	New York			
152 Reed Street	New York			
156 Reed Street	New York			
349 West 86th Street	Manhattan	2000	11,000	30
360 Court Street	Brooklyn	1998	27,000	136
9 East 64th Street	Manhattan			
Adelphi University	Long Island	2003		
Adirondack Community College-Eisenhart Hall	Queensbury	2006	28,607	76
Adirondack Dental Implant Center	Queensbury	2002	6,000	
AIA Center for Architecture	New York	2003	14,000	40
Albanese Development Corp.	Battery Park City		36,000	103
Albany Medical Center	Albany			
Albany Molecular Research, Inc. Corporate building	Albany	2003		
Alternative Education Facility (Frontier CSD)	Hamburg	2002	40,373	140
April Asset Holdings, LLC	New York		12,000	34
Association for Preservation of the Adirondacks Headquarters	Colonie	2003	5,448	21
Atlantis Marine World	River Head	2000	52,500	150
Aztech Techhologies	Ballston Spa	2005	24,000	48
Bank of Greene County	Coxsackie	2005	4,175	10
Bard-Avery/Blum Arts Complex	Annandale-on-Hudson	2004	50,000	110
Bard Performing Arts Center	Annandale-on-Hudson	2002	110,000	520
Bard-Bathrick House	Annandale-on-Hudson	1997	1,800	4
Bard-Botstein House-Foreign Language Studies	Annandale-on-Hudson	1992	2,655	3
Bard-Campus Road Dorms	Annandale-on-Hudson	2005	14,400	28
Bard-Campus Road Dorms	Annandale-on-Hudson		14,400	28
Bard-Cruger Dormitory	Annandale-on-Hudson	1999	15,000	36
Bard-Henderson Computer Center	Annandale-on-Hudson	2000	4,800	14
Bard-North Village Dormitories I	Annandale-on-Hudson	2001	3,438	12
Bard-North Village Dormitories II	Annandale-on-Hudson	2001	3,438	12
Bard-North Village Dormitories III	Annandale-on-Hudson	2001	3,438	12
Bard-North Village Dormitories IV	Annandale-on-Hudson	2001	3,438	12
Bard-North Village Dormitories IX	Annandale-on-Hudson	2002	3,438	12

Site Name	City	Year Installed	Building Size (sq. ft.)	System Size (tons)
Bard-North Village Dormitories V	Annandale-on-Hudson	2001	3,438	12
Bard-North Village Dormitories VI	Annandale-on-Hudson	2002	3,438	12
Bard-North Village Dormitories VII	Annandale-on-Hudson	2002	3,438	12
Bard-North Village Dormitories VIII	Annandale-on-Hudson	2002	3,438	12
Bard-Public Relations Dept/Formerly Annandale Hotel Converted	Annandale-on-Hudson	1998	2,500	3
Bard-Residential Dorms I	Annandale-on-Hudson	2000	30,000	70
Bard-Residential Dorms II	Annandale-on-Hudson	2000	30,000	70
Bard-Residential Dorms III	Annandale-on-Hudson	2000	30,000	70
Bard-Walter's Cottage	Annandale-on-Hudson	1997	1,800	4
Barden Homes	Tully	2004	16,632	38
Bear Mountain Inn Renovation/Restoration	Harriman	under construction	80,000	316
Bethlehem Lutheran Church	Delmar	1990	8,750	25
Black Rock Forest Center	Black Rock Forest	1999	9,000	26
Blue Point Condo Association	Blue Point	1990	105,000	300
BOCES Broome-Tioga	Binghamton	2000	4,000	8
BOCES Broome-Tioga	Binghamton	2005	250,000	400
BOCES Westchester	Rye Lake		24,500	70
Botanical Gardens	Queens			
Bridge Street Properties	Irvington	2004	24,000	100
Bridges World Financial Center	New York		14,000	40
Brockport Central School District	Brockport	1998	293,000	300
Bronx Zoo, lions' house	Bronx			
Brooklyn Children's Museum	Brooklyn	under construction		
Camphill Village	Copake		7,000	20
Cayuga Community College	Auburn	2002	33,000	94
Caster Well Drilling (Shop & Office)	Chautauqua	2002	10,000	39
Cobleskill-Richmondville CSD-Golding MS	Cobleskill	under construction	125,000	200
Cobleskill-Richmondville CSD-Ryder ES	Cobleskill	under construction	125,000	200
Columbia Greene Community College	Hudson	1998	164,500	470
Colvert Street Townhouses	New Castle		11,200	32
Corning Area School District	Corning	under construction	380,000	1,000
Crossroads Educational Center	Buffalo	under construction	50,000	

Site Name	City	Year Installed	Building Size (sq. ft.)	System Size (tons)
Culinary Institute of America – Student Townhouse #1	Hyde Park	2003	23,000	83
Culinary Institute of America – Student Townhouse #2	Hyde Park	2003	23,000	83
Culinary Institute of America – Student Townhouse #3	Hyde Park	2003	23,000	83
Culinary Institute of America – Student Townhouse #4	Hyde Park	2003	23,000	83
Darling Center	Schenectady		14,000	40
Discovery Health Center	Monticello		28,000	80
Dooley Square Complex	Poughkeepsie			
Dutchess County Community College - Browne Hall	Poughkeepsie	2005	27,414	22
East Irondequoit Middle School	Rochester	2003	143,000	409
Ellenville School	Ellenville	1993	10,500	30
Elmira Gove House	Wellsburg			
Empire State College Foundation	Saratoga Springs	2004	52,000	90
Esquire Building	Brooklyn		120,000	343
First Americans IGA Supermarket	Akwesasne	2005	50,000	75
Foundation House-9 East 64th Street	New York City	1997	20,000	60
Fox Street LLC	Poughkeepsie			
Front Street project	Manhattan			
GEICO Office Complex	Woodbury	1995	250,000	400
Geneva Lakefront Hotel	Lake Geneve		77,000	220
Great Oaks Office Park	Albany	1994	98,000	280
Hamilton College	Clinton	2003		58
Hawthorne Valley School	Ghent		65,000	186
Hewlitt Woodmere High School	Nassau	2003	40,000	114
High Point Condominiums	Troy		16,800	48
Hilltop House	Chestnut Ridge	2004	10,000	115
Holiday Inn Express	Albany	1995	43,750	125
Hospice and Pallative Care of St. Lawrence Valley	Potsdam	2006	8,983	32
HS800	Brooklyn-planned			
Ice Cream Head Office - Phase 1	Saratoga			
Indian River CSD-IR Intermediate	Philadelphia	2003	34,515	210
Indian River CSD-Theresa Elementary	Theresa	2002	71,545	204
Ithica Youth Bureau Recreation Center	Ithica	1995	20,650	59
Kaatsbaan Internation Dance Center	Tivoli	2004	3,206	19
Kadimah School of Buffalo	Getzville	2005	34,000	
Kensington Library	Brooklyn			
Kupernik Space Education Center	Vestal	1993	8,000	24
LeMoyne College	Syracuse	2002	35,000	60
Living Word Worship Center	East Syracuse		84,000	240

Site Name	City	Year Installed	Building Size (sq. ft.)	System Size (tons)
Long Island Aquarium	Riverhead		100,000	
Long Island Bird Sanctuary	Long Island	1999	6,500	19
Long Island Lighting Company	Garden City	1995	7,000	20
Long Island Lighting Company	Brentwood	1990	63,000	180
Long Island Power Authority	Brentwood	1990	64,583	185
Long Island Power Authority	Garden City			
Long Island Power Authority	Hewitt			
Long Island Power Authority	River Head			
Marriott Court Yard	Lake Ronkonkoma		95,200	272
Mark IV Construction - Corn Hill Landing	Rochester	2005	187,000	339
Massry	Albany		8,400	24
Mazza Chautauqua Cellars	Mayville	2005	5,667	
Medical Arts Building - 227 Alexander LLC	Rochester	2005	70,000	174
Memorial City Hall	Auburn	2003	26,768	70
Midwood High School	Brooklyn	under construction	55,000	157
Milkhause Veterinary Lab	Albany		3,500	10
Montgomery Row Phase II	Rhinebeck	2004	28,000	98
Mother of Perpetual Help	Esopus		18,000	
Museum of the Earth	Ithaca	2002	18,000	55
Nature Conservancy #1	Cold Spring Harbor		5,950	17
Nature Conservancy #2	East Hampton		5,250	15
New Testament Church	Greece	2002	12,098	40
Newark Valley CSD - Nathan T. Hall Elementary School	Tioga	2004		299
Newark Valley CSD - Newark Valley High School	Tioga	2004	26,200	134
Newfane CSD	Newfane		66,000	189
NFA Office Building	Syracuse		5,250	15
Notre Dame	Cannindaigua	1999	40,000	100
NYNEX Telephone Switching buildings	8 locations	1994	2,450	7
NYRA	Saratoga Springs	2000	12,500	33
Octagon Park	Roosevelt Island		350,000	1,000
Office Project	Albany			

Site Name	City	Year Installed	Building Size (sq. ft.)	System Size (tons)
Orange County Pet Hospital	Middletown	1992	5,950	17
Ossing Public Library	Ossing		46,000	
Our Mother of Perpetual Help	Esopus	2001	16,000	41
Oyster Bay Western Waterfront	Long Island			
Peconic Landing	Long Island		80,000	200
Pequenakonck Elementary School	No. Salem	1998		
Post Road School	White Plains			
Precision Contractor of Dutchess Inc.	Poughkeepsie	2005	49,179	108
Presbyterian House	Chautauqua		14,430	22
Putnam Valley Middle School	Putnam Valley	1998	127,000	200
Ramada Inn Geneva Lakefront	Geneva	1996	122,500	350
Redemptorist Convent	Esopus		18,550	53
Regency Park Development	Guilderland		454,300	1,298
Rhinebeck Performing Arts Center	Rhinebeck	1997	14,000	40
Righteous Babe Records	Buffalo	2004	29,000	60
Roosevelt Science Center	Jones Beach		12,000	
Rosendale Recreation Center	Rosendale	2003	10,500	30
Roth School	South Hampton	under construction	60,000	
Sagamore Resort	Lake George	1983	400,000	567
Sara Lawrence College	Bronxville			
Saratoga Springs Race Course-Jockey House	Saratoga Springs	2000	17,500	50
Seneca Nation	Irving		25,000	71
South Folk Natural History Museum	Bridgehampton		10,500	30
Southampton College (LIU)	Southampton		31,500	90
Southampton Village Police Station	Southampton		14,700	42
Sprout Creek Farm	Poughkeepsie		12,000	34
Statue of Liberty - Concession Building	NYC			
Sullivan County Community College			172,200	492
Tanglewood Nature Center and Museum	Elmira	2002	7,000	15
The Esquire Buildling, LLC	Brooklyn	2001	120,000	265
The Gerry Homes	Greenhurst		45,000	129
The Greenhouse Studio	Garrison	2002	1,300	10

Site Name	City	Year Installed	Building Size (sq. ft.)	System Size (tons)
The Harbor at Blue Point	Blue Point	1995	132,000	377
The Inn at Fox Hollow	Woodbury	2001	71,750	205
The Queens Botanical Garden - Administration Building	Queens		16,000	
The Weston Charitable Foundation	Ossining		15,000	43
Theodore Roosevelt Science Center	Long Island		12,000	34
Tompkins County SPCA	Ithaca	2003	8,779	35
Town of Kent - Library	Carmel	2004	13,084	44
Town of Kent - Police Station	Carmel	2004	8,436	23
Town of Kent - Town Hall	Carmel	2004	14,445	50
Town of Rosendale	Rosendale	2002	6,400	17
Triangle Fire Department	Triangle	1991	7,000	20
Trolley Barn	New York		80,000	150
Tuckohoe School District	Hamptons		25,200	72
Unadilla Valley Central School	New Berlin	2003	260,000	743
USDA	Waverly	1996	2,450	7
Vanderbuilt Mansion	Hyde Park	2000	42,000	120
Vassar College	Poughkeepsie	2002	21,000	56
Webster CSD Ross J. Willink Middle School	Webster			
Webster-Monroe County School	Rochester			
Weeksville Heritage Center	Brooklyn			
Wendys	Kingston	1996	10,500	30
West 86th Street	NYC		15,000	
Westchester Country Club	Westchester County	2002	210,000	600
Whispering Pines New Lodge	Cattaraugus		4,076	16
Woodbury Suites Hotel	Long Island	2002	110,000	314

Data partially compiled by the Geothermal Heat Pump Consortium

III. Feasibility Studies

The purpose of a feasibility study is to estimate and compare the cost and benefits of alternatives. The study should go beyond a simple first estimate of cost and benefits. It should attempt to describe and quantify the main differences, in operation and performance of the alternative systems, to a level of detail that will support a decision on a system choice. It should also identify obstacles and issues associated with the choices. The approach to completing a feasibility study varies by the available schedule, budget, tools, and the investigator's skill and experience.

Study Scope
The purpose of a feasibility study is to assess the benefits and costs of a geoexchange system relative to the base or alternative system. The first step in such a study is to define the scope of the study, the level of detail required to support decisions, and the mechanical systems to be considered.

Generally speaking, the level of detail required for the feasibility study should match the rigor of the decision making process. A relatively low-cost, even no-cost, study can be performed using "rules of thumb" for typical cost components, current energy costs, system operating parameters, full load hours, building hours of use, etc. It can be completed in a matter of days and is best suited for situations where the decision rests with a handful of individuals who are empowered to make the final decision. Often, however, the level of confidence in the assumptions made and conclusions reached might only be enough to help decide whether or not a detailed feasibility study should be commissioned.

Such a study begins with a detailed hourly energy use model of the proposed building, using construction details, operating schedules, and detailed energy costs that include energy and demand charges from provider tariffs, etc. It could also include HVAC equipment performance data and detailed estimates of equipment procurement and installation costs.

The study might also strive to identify any technical hurdles or advantages to the use of geoexchange. The lack of outdoor equipment, integrated water heating, reduced floor-to-floor height, and reduced mechanical space might have appeal in a particular project. The amount of available land or existence of difficult drilling conditions at the site could pose barriers.

Heating and Cooling Loads
The first element in the HVAC system analysis is to define the heating and cooling loads. Unlike traditional HVAC systems that consider only peak heating and cooling loads, sizing calculations for a GX system also factor in the annual duration of these loads. Methods for estimating loads include: using data from other buildings, estimations from utility bills, generic estimates from full-load hour values, heating and cooling load line development from peak loads along with bin weather data, and detailed hourly building energy simulations. The type of analysis (seasonal, bin or hourly) determines the effort needed to estimate the building's heating and cooling loads.

Common descriptive building elements for energy modeling include:

- Floor Area and space designations
- Ventilation levels
- Wall insulation level
- Ceiling insulation level
- Exterior wall area
- Exterior glass area
- Uncontrolled ventilation level (infiltration)
- Heating and cooling setpoints
- Occupancy levels and schedule
- Lighting power density
- Equipment power density
- Representative weather data

HVAC Systems
The next element of the study is definition and description of the systems. Along with providing a conceptual overview of each system, the descriptions include detail about the main system characteristics and features that will be included in the analysis. This section also describes assumptions about how the system will be operated over a typical year: boiler/chiller shut down, seasonal schedules, ventilation air control, etc.

Energy Prices
The remaining background in the study defines energy prices. Considering actual utility rates is ideal, since the rates often have a significant demand component. Using average prices does not necessarily consider differences in peak demands that can be significant.

Because of the system's high efficiency and elimination of the fossil fuel heating components, a geoexchange system typically levels the seasonal electric demand – lowering the summer demand and increasing the winter demand. The overall impact usually results in a lower effective energy price on a $/kWh basis.

Assumptions
The study should use as much supporting information as possible to minimize the influence of assumptions. A sensitivity analysis on parameters expected to have a significant impact on the loads can show the impact of uncertainty in ventilation rates, lighting heat gains, occupancy and schedule. These parameters along with building size and construction details are the main elements that can be customized for a specific feasibility study.

Energy Results
The results from the energy simulations concentrate on heating and cooling loads, energy use, and energy cost. Monthly presentation of these values helps show the seasonal variation and provides demand information of interest to the electric utility. Seasonal efficiencies of the heating and cooling systems derived from total loads and energy use provide a means for a rough check on the results. Breaking the results into end-uses helps highlight the source of differences between the systems (primary or secondary, pumps, heating, cooling, etc).

Design Elements
Several software tools are available to size the ground loop heat exchangers for geothermal heat pump systems. The Geothermal Heat Pump Consortium web site provides an extensive comparison of these tools at www.geoexchange.org. These specialized tools generally incorporate ground-loop sizing calculations based on methods developed at the University of Alabama or line-source algorithms developed by the University of Lund in Sweden.

A study at Oak Ridge National Laboratory compared these software tools and sizing approaches in a series of technical papers.[3] GCHPCalc, a DOS based tool, appears to be the most widely used program in the US. The calculation methods used by GCHPCalc and several of the other tools are described in the ASHRAE Design/Data Manual for Closed-Loop Ground-Coupled Heat Pump Systems (1997).

Table 2. List of Geothermal System Loop Sizing Software

Name	Organization and Web Site	Description	Platform
ECA	Elite Software, Bryan, TX www.elitesoft.com	Geothermal loop sizing / heat pump design tool	Windows
GCHPCalc	University of Alabama, Dept. of Mechanical Engineering, Birmingham, AL www.bama.ua.edu/~geocool/Software.htm	Geothermal loop sizing / heat pump design tool	DOS
GLHE-PRO	Oklahoma State University, Stillwater, OK www.igshpa.okstate.edu	Geothermal loop sizing / heat pump design tool	Win
GL-Source	DynCorp, Overland Park, KS www.geoexchange.org	Excel-based Geo loop sizing tool	Excel
GS2000	Caneta Research Inc., Mississauga, Ontario, Canada www.greenbuilding.ca/gs2k-1.htm	Sizes geothermal heat pump systems	Win
Right-Loop	Wrightsoft Corp., Lexington, MA www.wrightsoft.com	Geothermal loop sizing / heat pump design tool	Win

Several packages of a building energy model based on DOE-2 are available, including geoexchange system modeling and ground heat exchanger performance. This type of model is useful in comparing annual energy use and cost of various systems.

The DOE-2 model does not include pond coupling so a custom approach is needed to model ponds. A simple model developed from an approach outlined in a design guide published by the American Society of Heating Refrigerating and Air-Conditioning Engineers can be assembled.

Test Boring and Thermal Conductivity

The thermal conductivity of the soil where the geoexchange system ground loop is going to be installed is the determining factor in the total length (number of bores and optimal depth) of the bore field needed to meet the heating and cooling requirements of the building. Generally, soil conductivity tests are conducted on systems that exceed 20 tons in size, as design variations in loop sizing assumptions do not have a significant impact on installed costs for smaller systems.

The answer to the question of when is the proper time to make a test bore and conduct a soil thermal conductivity test is naturally, “When you’re ready.” But since the cost of taking this s

[3] Thornton et al (1997) and Shonder et al (2000) carefully compared the performance of these loop sizing tools.

step is between $6,000 and $11,000 this decision needs to be made with due consideration.

A reasonably comprehensive feasibility analysis can be conducted using alternative methods of estimating soil conductivity without investing in a test bore and a soil conductivity test. Test data from a nearby geoexchange installation can be used where soil conditions are known to be homogeneous. Alternatively, representative data on drilling conditions from local drillers, or well logs from nearby water wells, could yield soil composition, water table, and bedrock information that could provide the designer general information for estimating the expected range of soil conductivity values.

Regardless of the estimation methodology, the designer's report should reveal the estimated value used in the analysis and loop sizing calculations, the basis for the soil conductivity estimate, and the range of soil conductivity values that could be expected at the site. The analysis should also include an assessment of the impact on total field length (number of bores, and depth) and the cost of anticipated variations from the chosen conductivity value.

Armed with this information, the decision makers will be able to assess the impact on the installed cost and economics of the geoexchange system should the soil conductivity and corresponding loop length need to be adjusted by ±15% or more. If the economics of the system are considered acceptable, the decision may then be made to proceed with the test which will provide a wealth of information on final loop design, optimal depth, and total length and drilling conditions that may impact the cost of the loop field.

Capital Cost

Estimates for capital costs typically come from previous comparable projects or published cost-estimating guides. The lack of previous geoexchange installations can inject more uncertainty into the analysis, but can be countered by comparing estimates with gross costs from regional projects.

The most important point about costs comparisons is maintaining consistency in sources of information among the alternatives. A comparison of different systems between an actual project and a cost estimating guide will inherently include the uncertainty in the guide's applicability to the local conditions and any unique conditions of the real project.

The new cost item for most designers is the ground heat exchanger. This cost not only depends on the building loads, but also on the geology of the site. Nearly any formation can be drilled cost-effectively with the proper equipment. The depth to bedrock is often a design factor that can greatly increase cost for drillers who are prepared only to drill through a consistent overburden. Local well drillers often have limited experience installing large commercial projects, so their cost structures may be extrapolated from single water well experiences and are typically—perhaps two to three times—higher than those seen in other projects. Depending on the size of a project, experienced drillers often travel from other areas. A list of drillers is included in the Appendix.

Open loop and pond systems are generally less expensive to install than vertical bore fields. Costs range from $500 to $750 /per ton. Vertical bore field loop costs depend on the driller experience, capability, site conditions and design. Complete costs typically range from $1,200 to $2,000 per ton ($8+/ foot of bore).

The integration of the geoexchange system within the total project might result in additional cost savings. For instance, with the reduced size of duct work previous projects have found that floor-to-floor height can be reduced, resulting in lower construction costs. The reduced need for mechanical space with a geoexchange system can also reduce construction costs or add more useable floor area. How one views the cost benefit of less mechanical space can influence how one views the geoexchange system cost.

A 403,000 sq ft High School in Wisconsin was able to install a 720 ton system using pond loops for the total project budget that was already in place for a VAV chiller/boiler system. Cost savings in building construction and mechanical space traded-off against the added cost of creating a pond loop. It is important to consider the impact of the choice of a geoexchange system on the project cost in its entirety.

The selection of an HVAC system is often not a question of energy efficiency, but one of economic feasibility. While the costs of system components and the energy costs are quantifiable, other factors such as maintenance costs,[4,5,6] comfort and productivity levels are less easily defined. Studies of maintenance costs have suggested 20%-30% lower costs with geoexchange systems due to simplicity of the equipment and less specialized skills needed in servicing the heat pumps over more complex chillers, boilers, and VAV controls. Productivity and comfort issues are not totally system dependent, but rely on the degree of control given to the occupant as opposed to centralized control of space conditions.

Decision Makers

A geoexchange system often requires additional effort on the part of the owner and engineer. This cost must be justifiable by operating cost benefits and/or occupant satisfaction and other factors important to the owner. Time is required to investigate and make the case to choose the geoexchange system because the general lack of experience with geoexchange often adds an element of uncertainty.

[4] Cane, D., et al, Survey and Analysis of Maintenance and Service Costs in Commercial Building Geothermal Systems, ASHRAE, RP-024 10-1997.
[5] Shonder, J.A., et al, Estimated Maintenance Cost Savings From a Geothermal Heat Pump Energy Savings Performance Contract at Fort Polk, Louisiana, ASHRAE Trans., 1997, vol. 103, part 2, #BN-97-11-2, pg 757-766.
[6] Martin, M.A., et al, Comparing Maintenance Costs of Geothermal Heat Pump Systems with Other HVAC systems in Lincoln, NB Public Schools: Repair, Service and Corrective Actions, ASHRAE Trans., 1999, Vol. 105, Part 2, #SE-99-20-04, pg 1208-1215.

The level of expertise of the decision makers should be considered when defining the scope of the study. Some projects will rely on the designer for ultimate recommendations, others will rely on operating staff, and still others may rely on people with little knowledge of HVAC systems, like a school board, planning committee, etc. The background of the decision makers will likely dictate the issues that are of primary importance (operational ease, environmental impact, ownership cost, occupant satisfaction, etc).

The main hurdles remain the willingness of designers to consider the system, the decision process for system selection, and availability of local expertise in designing and installing ground heat exchangers. Addressing these hurdles will allow the geoexchange system to be chosen or rejected on its own merits for specific applications.

Commissioning

Commissioning is the process of ensuring that the system operates to the design intent decided upon by the owner and designer. The commissioning process incorporates functional testing and system integration testing into the building process. Commissioning and Preventative Maintenance topics are discussed in an ASHRAE publication. The guide provides discussion on acceptance of ground-loop piping, building-loop piping, pumps, heat recovery equipment, heat pumps, chemical treatment, air and water flow balancing, and controls. As in any construction project, the delineation of responsibility for the various component parts of the geoexchange system is vital to the overall project's success.

IV. Avoiding Potential Problems

The simplicity of geoexchange systems reduces the potential for problems; however, care must still be exercised with the system details. The design and installation of an efficient, cost effective, reliable HVAC system rests on the skill of the designer, the quality of the installation, and education and skill of the building operator.

Ground-Loop Sizing

The most critical issue in the design phase is proper sizing of the ground heat exchanger. Calculation tools exist to assist in predicting ground heat exchanger performance, and the extreme seasonal temperatures that the system can expect. The tools mainly focus on vertical and horizontal systems.

[7] Commissioning, Preventative Maintenance, and Troubleshooting Guide for Commercial Ground-Source Heat Pump Systems, ASHRAE, SP-94, 2002.

The fundamental principals of pond-loop system are described in the ASHRAE design guide and recent ASHRAE research has focused on standing column well design issues.

The ground thermal conductivity is a critical parameter influencing the ground heat exchanger size. Regardless of the system configuration, an understanding of the ground thermal properties must be developed. The best way to establish local ground conditions for a vertical bore field is to perform a soil conductivity test. A conductivity test requires installation and completion of a single (or sometimes multiple) bore to the most likely depth. By applying a constant amount of heat to the bore and recording the resulting temperature response, the thermal properties of the bore and ground can be derived.

A conductivity test should also include a detailed drill log that gives potential loop contractors valuable data about the actual drilling conditions on the site. Having the drill log for the test bore can remove much of the uncertainty that would otherwise be priced into the bid to complete the bore field.

Ground-Loop Configuration

A vertical bore field needs to consider the long-term impact of seasonal load imbalances. Frequently the cooling load exceeds the heating load, leading to a potential long term heating of the ground in cases where there is minimal ground water flow. Increasing the spacing between bores can alleviate much of the potential for long-term heat buildup.

The standard bentonite grout has a very poor thermal conductivity of around 0.42 Btu/hr-ft at best. Thermally enhanced grouts can typically reach values of 0.8 to above 1.0 Btu/hr-ft, allowing a 20% reduction in the total bore length. Depending on the relative costs of grout and sand, and shipping the materials to the site, the higher cost of thermally enhanced grout ($12 to $15 per bag) over standard bentonite grout ($5 to $7 per bag) can have a small impact on the cost per foot of completing the loop. The difference is the total savings in drilling costs brought about by reducing the loop depth and/or the number of bores required by the system due to the improved earth connection.

Ground-Loop Pumping

Good design practice will minimize loop pumping by designing the loop field for a total head loss of 20 ft., with reverse return piping to eliminate balancing valves, providing for shut off valves for circuits in valve pits, minimizing threaded couplings and properly selecting a variable speed loop pump to accommodate partial or low flow at design loop static pressure. Intelligent design might also involve dividing the ground-loop into more sections or circuits to help reduce fluid velocity and total pump head, thus reducing the required pump horsepower of the system.

[8] Spitler J. D., S.J.Rees, Z. Deng, A. Chaisson, C.D. Orio and C. Johnson. 2002. R&D Studies Applied to Standing Column Well Design, ASHRAE 1119-RP Final Report. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

Geoexchange Maintenance
A critical issue with heat pumps is allowance for maintenance access. The filters must be changed regularly to extend the useful life of the unit, so simple access must be provided. Intelligent design may call for installing heat pump units in closets; others have located filters remotely at return air grilles. There must also be accommodations for access to replace/repair the unit should it be called for. When units are installed above a drop ceiling, coordination of the heat pump placement with ceiling system rails can facilitate ease of whole unit access should the need arise. Some installations may call for installation of catwalks to facilitate routine maintenance and repairs.

Condensate
Provision for condensate removal must be made. Many codes as well as the International Mechanical code require secondary drain pans for over ceiling installed equipment. The accommodation for secondary drains pans while still allowing removal for maintenance must be considered.

Geoexchange Controls
Interface of the heat pump to the control systems can sometimes pose issues of coordination of trades. Generally the heat pumps should have automatic valves to isolate the unit from the loop when the unit is off, so loop pumping power can be minimized.

The valves need to be interlocked to the unit so the compressor cannot operate unless the valve is open. The valve electronics must be compatible with the heat pump controls. Problems have occurred when slow acting valves starved flow to the unit during compressor operation, or incompatibility between the heat pump controls and valve electronics caused control failures.

Some have addressed this coordination issue by specifying manufacturer-supplied shut off valves integrated into the heat pump controls. Others have carefully detailed the coordination responsibilities of the mechanical contractor and controls contractor in the design specifications and followed-up on compliance.

Designing for normally closed valves is a simple method of ensuring that loop pump energy does not needlessly increase if the valve should fail. A failed valve will keep a unit from operating, drawing attention to the problem immediately.

Air Removal
Air in the ground loop can cause imbalances in loop flow rates, and affect heat absorption from, and/or rejection to, the surrounding earth. It is important to purge air from the system at startup and prevent air from accumulating in the system during operation. Standard practice may involve employing one or more of the following measures:

- Ensuring adequate horsepower is employed in the initial purging of the system (gener ally employed in smaller systems);
- Installing air vents to allow removal of air that tends to accumulate at the top of rises in system piping, and/or;
- Installing an air separator in the pump room.

There have also been cases of algae growth caused by air which was trapped in the loop system. These are easily corrected through water treatment techniques similar to those employed in other HVAC systems, but the best preventive measure is to eliminate the air that facilitates these problems.

Geoexchange Commissioning

Good commissioning practice will verify proper water and air flow through each heat pump and will verify the heat pump capacity and efficiency. Individual unit operation parameters should also be checked to be certain the units are appropriate for the intended application. Some units can be used in open or closed loop systems. The open application requires protection from loop freezing of pure water, so units are often shipped with the most restrictive safety limits. In a closed loop system the inadvertent setting of the safety switches can cause unexplained and annoying lockouts when the loop temperature approaches design values.

Air Distribution

Good design practice will place the thermostat away from interior air flows and will consider the need for multiple diffusers to disperse the supply air without causing drafts. In systems that constantly circulate air for ventilation, the designer must consider occupant comfort while the compressor is cycled off.

Noise

With a motor and compressor operating in close proximity to the occupied space, consideration for noise abatement must be made. Manufacturers offer added noise insulation packages. Some designers have used lined ducts, installed units in insulated closets or remote spaces that are highly critical to noise levels. Standard equipment offerings often provide acceptable noise levels.

Ventilation Air

The distributed nature of geoexchange systems facilitates the use of dedicated ventilation systems. The ability to duct known amounts of ventilation air to each space is a fundamental feature of dedicated ventilation systems. Simply delivering ventilated air into an above-ceiling plenum might negate the ability to circulate fresh air throughout the building.

Ventilated air is often tempered to neutral values so as not to pose problems at design conditions with air that is outside the return temperature limits of the heat pump. Tempering ventilated air also allows ventilation ductwork to remain un-insulated.

As in any building project, the best design is worthless if not followed. A commissioning process based on design intent, education to all parties, and functional performance testing will ensure that the system meets expectations.

V. Next Steps

Once a successful feasibility study is complete, the next step in proceeding with a geoexchange project is to compile the site and design information to proceed with the final design, and to select the preferred delivery method for the installation.

At this stage, the delivery method for the Geoexchange portion of the project can be considered. The indoor and outdoor portions of the project are often handled by separate contractors. These may include the standard mechanical system designer, loop field designer, and bore field driller. The responsibilities may be undertaken by separate parties, or combined under a single contractor. The delivery method of the project will dictate when certain parties become involved in the project and their responsibilities.

Regardless of the contractor arrangement, the responsibility for the size and design of the ground heat exchanger must be clearly defined. Simplicity of this organization is preferred; the fewer parties involved, the more clear these responsibilities become. Since more than traditional design loads are required to properly size the ground heat exchanger, someone must take responsibility for the annual loads used by the loop designers. In some cases the mechanical system designer might also be the loop field designer. A loop installer might be asked to "design" a loop field, but the design is often tied directly to design and annual load estimate provided in the feasibility study performed by the mechanical systems designer. A loop contractor might be willing to guarantee the performance of a loop within a temperature range for a given loading, but this assurance depends on the anticipated loads being representative of actual loads.

The size of the project, along with past contracting methods used by the owner will generally dictate the appropriate project delivery arrangement. The two main project delivery methods are bid-spec and design-build.

In bid-spec the owner assumes responsibility that the design is correct and complete, and that contractor(s) who meet the specification with the lowest possible cost will likely be awarded the project.

In design-build the owner chooses a contractor based on qualifications and negotiates a price to design and install the system. The contractor assumes responsibility for the completeness and correctness of the system design. This method requires good communication skills among the team members and a high level of trust. Often when the mechanical contractor is hired in a design-build arrangement to design and build the interior system, it is most expedient to bid the exterior portion of a geoexchange system installation to firms specializing in drilling and bore field installation.

Summary

Geoexchange systems couple a building to the surrounding environment. The movement of heat from the ground to the building for heating or from the building to the ground for cooling is the basis for the high efficiency offered by the systems. The ground provides a very stable temperature source or sink for exchanging energy between the building and the environment.

Numerous configurations of the ground heat exchanger are possible to meet the needs of many different project characteristics. Systems can use ground water directly to minimize land use, or incorporate a network of sealed piping to transfer heat with the ground. Lakes, ponds and rivers can also provide a means for geoexchange.

The distributed nature of the geoexchange system provides simplicity in operation and maintenance as well as contributing to the lower energy use of the system. Moving heat around the building with a water loop adds to the efficiency of the system compared with moving heat around the building with an air distribution system.

With all of its advantages, geoexchange is becoming the space conditioning system of choice for commercial and government installations where owners or managers desire maximum comfort for their customers and employees as well as low monthly energy costs, and long-term value.

Additional Sources of Information

NYSERDA
17 Columbia Circle
Albany, NY 12203-6399
Phone: 518-862-1090
Email: info@nyserda.org
Website: http://www.nyserda.org/programs/geothermal/default.asp

Geothermal Heat Pump National & International Initiative (GEO-NII)
1615 M. Street, NW
Suite 800
Washington, DC 20036
Email: info@geo-nii.org
Website: www.geo-nii.org

Geothermal Heat Pump Consortium
1050 Connecticut Avenue, NW
Suite 1000
Washington, DC 20036
Website: www.geoexchange.com

International Ground Source Heat Pump Association (IGSHPA)
374 Cordell South
Stillwater, OK 74078
Phone: 405-744-5175
Email: igshpa@okstate.edu
Website: http://www.igshpa.okstate.edu/

Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601
Phone: 541-885-1750
Email: geoheat@oit.edu
Website: http://geoheat.oit.edu

U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585
Phone: 1-800-342-5363
Email: The.Secretary@hq.doe.gov
Website: http://www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12640

Long Island Power Authority (LIPA)
333 Earle Ovington Blvd.
Uniondale, NY 11553
Phone: 800-490-0025
Website: http://www.lipower.org/cei/geothermal.html

Central Hudson Gas & Electric Corporation
284 South Avenue
Poughkeepsie, NY 12601
Phone: 800-527-2714
Email: marketing@cenhud.com
Website:
http://www.cenhud.com/products_services/geothermal_heat_pumps.html

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Appendix

Resources

The following resources were used for this publication:

Kavanaugh, S. P., et al, Ground-Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings, ASHRAE, 1997.

Thornton et al (1997) and Shonder et. al. (2000) carefully compared the performance of these loop sizing tools.

Cane, D., et al, Survey and Analysis of Maintenance and Service Costs in Commercial Building Geothermal Systems, ASHRAE, RP-024 10-1997.

Shonder, J.A., et. Al., Estimated Maintenance Cost Savings From a Geothermal Heat Pump Energy Savings Performance Contract at Fort Polk, Louisiana, ASHRAE Trans., 1997, vol. 103, part 2, #BN-97-11-2, pg 757-766.

Martin, M.A., et al, Comparing Maintenance Costs of Geothermal Heat Pump Systems with Other HVAC systems in Lincoln, NB Public Schools: Repair, Service and Corrective Actions, ASHRAE Trans., 1999, Vol. 105, Part 2, #SE-99-20-04, pg 1208-1215.

Spitler J. D., S.J.Rees, Z. Deng, A. Chaisson, C.D. Orio and C. Johnson. 2002. R&D Studies Applied to Standing Column Well Design, ASHRAE 1119-RP Final Report. *American Society of Heating, Refrigerating and Air-Conditioning Engineers*, Inc., Atlanta, GA.

Commissioning, Preventative Maintenance, and Troubleshooting Guide for Commercial Ground-Source Heat Pump Systems, ASHRAE, SP-94, 2002.

Geoexchange Analysis/Design/Construction Resources

The following list shows firms that have experience with geoexchange heating and cooling systems. While most are located in New York, some are located in other states but, have done work in New York. The list is arranged by project function: feasibility study, system design, loop construction and mechanical contractor.

Feasibility Studies

Aiello Enterprises, Inc.
210 – A Laurel Rd.
Northport, NY 11768
631-262-1444
www.heatgreen.com
Commercial and Residential Services

AirMasters Environmental Services, Inc.
20 Newhard Place
Hopewell Junction, NY 12533
845-226-1695
Commercial and Residential Services

Altren Consulting & Contracting, Inc.
P.O. Box 396
Rifton, NY 12471
845-658-7116
Commercial and Residential

Anthony Sacco Building Corp.
271 North Ave.
Suite 702
New Rochelle, NY 10801
914-654-8100
Commercial and Residential Services

Beardsley Design Associates Architects and Engineers
64 South Street
Auburn, NY 13021
(offices also in Syracuse and Malone)
315-253-7301
www.beardsley.com
Commercial Services

Black Rock Roofing
2064 Niagara Street
Buffalo, NY 14207
716-875-5138
www.blackrockroofing.com
Residential Services

Buro Happold
100 Broadway
23rd Floor
New York, NY 10007
212-334-2025
www.burohappold.com
Commercial Services

CDH Energy Corporation
P.O. Box 641
Cazenovia, NY 13035
315-655-1063
www.cdhenergy.com

Crosby Brownlie, Inc.
100 Nassau Street
Rochester, NY 14605
585-325-1290
www.crosbybrownlie.com
Commercial Services

D.J. Heating & A/C
P.O. Box 700
Marlboro, NY 12542
845-236-4436
Commercial and Residential Services

D. Silvestri Sons Inc.
173 Old Route 9
Suite 1
Fishkill, NY 12524
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