Quantum Geothermal

White Paper

Geothermal Heating and Cooling

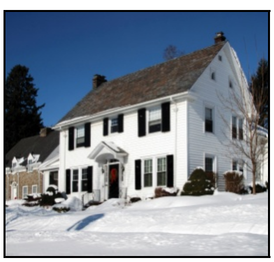
The fundamentals of a **geoexchange system** (geothermal heating and cooling system) are well understood and although many factors need to be considered when designing a system, overall the performance of a well engineered system is quite predictable.

In this **White Paper**, we provide a more detailed exploration of the functional thermodynamics that form the underlying physical properties of a **geoexchange system**.

Renewable Energy

Each year the earth receives hundreds of times more energy from the sun that we could possibly use. Some of this solar radiation is reflected back into space by the atmosphere and by clouds. Typically this reflected energy is about 25% of the total incoming solar energy and is of no practical use. Approximately another 25% of the total incoming solar energy is absorbed into the atmosphere and clouds, and typically **about 50% of the incoming energy is absorbed by the lands and oceans of the planet**. About 75% of the energy that is absorbed is later radiated back into space, which when combined with the energy reflected away by the clouds and atmosphere totals 100%. This keeps the temperature of the earth relatively constant, excluding any discussions about global warming.

It is the 50% of the total incoming solar energy that is absorbed into the lands and oceans that is of particular interest when we consider geothermal energy. This is a **vast renewable energy source** that we can tap into from virtually any location in Canada.



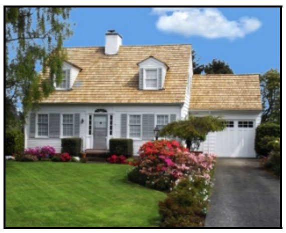
Ground Source Heating

In southern and central Ontario the ground below the frost line will maintain itself at a constant temperature of about 10 -11^{o}C. Local topography and geology, along with the soil type under your property, will have some bearing on the actual range of temperatures but overall there will be an **abundant supply of thermal energy available** throughout the winter months regardless of the specific location. **Properly sized and designed, a geoexchange system can provide all the heating requirements of a household for the heating season.**

Ground Source Cooling

Conversely, in the summer months the same **geoexchange system** can be operated in reverse mode and **can be used to cool your home** by dumping heat back into the ground using the same thermodynamic principles as your kitchen fridge. All heat pumps operate on the thermodynamic principles of this refrigeration cycle and they do so with very high thermal efficiencies.

The load capacity of the system will be designed for the annual heating requirements, which are always larger than the cooling requirements in Ontario. Consequently, a geoexchange system can provide abundant air conditioning during the summer months without any concerns about the ground loop size, additional installation costs, flow rates, pump size or load capacity. Better yet, it can do so for a small fraction of the cost of traditional air conditioning systems. This is what is meant when geoexchange cooling is referred to as “free”, **the only incremental cost of running the system for air conditioning is the electrical operating cost of running the compressor, pump and fan**.



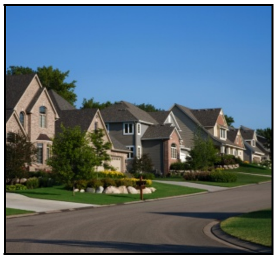
The Ground Loop

To bring the thermal energy stored in the ground up to the heat pump, a loop of piping is buried in the ground. This loop is, almost always, constructed of high density polyethylene (HDPE) piping formed into a continuous circuit or closed loop. The piping is assembled, pressure tested and then filled with a mixture of antifreeze and water. The one exception, an open loop system, is discussed below, but for our immediate purposes we will consider only closed loop systems.

The mixture of antifreeze and water serves as the carrier or heat exchange medium and is repeatedly circulated through the system. The ground loop feeds into a header and manifold which is buried below the frost line outside the home and then the piping is brought into the home and circulated through the heat pump. **A properly constructed ground loop should operate maintenance free with no loss of efficiency or deterioration for decades.**

Horizontal Closed Loop

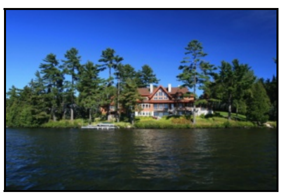
In rural locations or in a setting where a home sits on a large property, a horizontal loop may be installed. For this style of installation a trench is excavated to a depth of approximately 5-6 ft (1.5-2 metres) and the HDPE pipe is laid out in a loop or pattern. After pressure testing provides assurances that the integrity of the loop is intact, the trench is backfilled. **Horizontal loop systems require more accessible land but the cost of installation is generally less than vertical loop systems.**



Vertical Closed Loops

Most urban and suburban properties will not have a sufficient lot size to accommodate a horizontal loop. Instead, a series of vertical boreholes are drilled and a loop of HDPE piping is inserted into each hole. These vertical loops are brought together and joined into a header and manifold and then, common to all loop systems, the pipe is brought into the home and heat exchange liquid is circulated through the heat pump.

A typical vertical loop installation in southern Ontario will have several 6 in (15 cm) diameter boreholes drilled to a depth of approximately 180 ft (60 m). Many homeowners are surprised to learn of this technique but it is well established and proven technology and results in excellent thermal transfer properties for the loop. A typical residential drilling operation will be completed in 1 or 2 days with minimal impact or disruption to the property. **Each year thousands of vertical loop installations are completed in southern and central Ontario alone.**



Lake Loop Systems

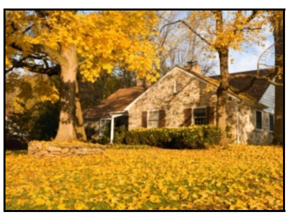
When a property is located next to a large pond or a lake we can extract the thermal energy of the water through a style of closed loop system known as a lake loop. As any swimmer or diver knows, once you venture deeper than a few feet below the surface of a lake the temperature of the water quickly cools. The basic thermodynamics and heat exchange principals are the same as we encounter with ground source geoexchange systems, except we are extracting energy from the thermal mass of the water instead of from the earth itself. The pipe loop is assembled into an array that is moved into position and then sunk to the bottom of the lake near shore.

In the case of cottages and some recreational properties special consideration must be given to any impact the loop may have on the shoreline, as many municipalities and cottage associations have restrictions on modifications that change the natural shoreline. Ice movement during spring break up and the risk of damage from recreational boat anchorage are other issues that may require consideration when designing and locating a lake loop system. **Despite these factors, the number of lake loop installations completed each year is growing. The thermal efficiencies that can be achieved are quite favourable.**

Open Loop Systems

As noted above, closed loop systems are the most common design form but there is an alternative way to configure a geoexchange system in some circumstances. Occasionally, a property under consideration may have access to a suitable underground aquifer. Water is drawn up and circulated through the heat pump to provide the heating and cooling energy source. These systems are referred to as open loop systems—no HDPE pipe is required—and they rely on an abundant supply of ground water.

Open loops can be cost effective to construct in locations where the geology and water table can support the flow rate requirements. The system is effectively comprised of two wells, a supply well where ground water is drawn up and passed through the heat pump, and a return well where the spent water is returned to the aquifer. However, open loop systems present some unique operating and maintenance challenges and environmental concerns that are beyond the scope of this discussion. Before deciding upon an open loop system, the homeowner would be well advised to become thoroughly informed on all aspects of their construction, operation and maintenance. Significantly less than 1% of all the geoexchange systems installed in Ontario are open loops.

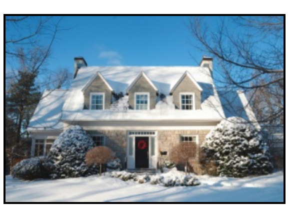


Seasonal Heat Pump Systems

Another alternative design is an air-to-air heat pump. These systems are installed above ground, typically located near an exterior wall of the house at a location where one would typically locate the exterior components of a traditional air conditioning system. Air-to-air systems extract energy from the ambient air and can be used during the spring and fall months for supplementary heating. These air exchange systems cannot be operated during the winter once temperatures approach the freezing point and are therefore not effective as the primary heating system.

For further information on any of these topics the federal government has published an extensive guide located here:

Heating and Cooling with a Heat Pump Information Booklet



Heat Loss Calculation

An important initial step in the proper design of any ground source heating and cooling system is to conduct a heat loss/heat gain study and determine what size of loop and geoexchange system is required to meet your home comfort requirements. The Canadian Geoexchange Coalition (CGC) working in conjunction with the Canadian Standards Association (CSA) has established standard factors to calculate the heat loss and heat gain through the various elements of a residential structure. A software modelling program is used to determine the insulation value of the walls, windows and roof of the house, while also considering the number of occupants, energy use patterns, geographical location and exposure of the property. **With a heat loss/heat gain analysis completed it is then possible to determine the optimum size and design of the ground loop and heat pump system.**

Consideration is given to the locale of the home and the historical weather data for the area to determine the seasonal outdoor temperature range and to establish the coldest winter temperature at which the heat pump can fully meet all the anticipated heating requirements of the household. This is referred to as the balance point. When the outside air temperature is above the balance point the heat pump will routinely cycle on and off to meet the heating requirements. During a severe cold snap, the heat pump will run continuously and the programmable controller may activate an auxiliary heater to supplement the demand. The auxiliary heater is an electric resistance heating element mounted in the plenum of the heat pump.

Once the heat loss calculation is completed, best design practices and economic considerations will determine the appropriate size and capacity of the system.

For more information on geothermal heating and cooling, please refer to the following websites:

Residential Earth Energy Systems: A Buyer's Guide

Environment Canada Weather Office

Canadian GeoExchange Coalition – Information Centre