Ground Source Heating & Cooling Symposium

Earth Rangers Centre
the Living City Campus at Kortright,
Woodbridge, ON

2011-11-03

Ed Lohrenz, B.E.S., CGD

204.255.5959

ed@geoxergy.com

Ground source heat pump systems – It's all about the Money!

Institutional projects

A high percentage of commercial geothermal projects are institutional:

- Schools
- Churches
- Prisons
- Government offices, etc.

Several designers have told me that 60% to 80% of their work is institutional.

Ground source heat pump systems – It's all about the Money!

Private developers install geothermal system based on economics

Almost all private developers base their decision to install a geothermal system on economics. They may want to install a geothermal system because of the environment or whatever…but ultimately it's the money.

When he was running to be president Bill Clinton said, "It's the economy stupid!"

Ground source heat pump systems – It's all about the Money!
The ground heat exchanger (GHX) is the difference

The difference in cost to build a conventional HVAC system compared to a GeoExchange system is typically about the cost of the ground heat exchanger.

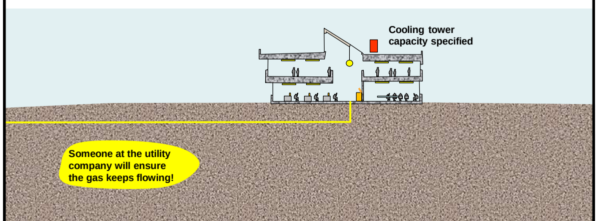
Too large and the client may not have the land area required or can't justify the cost.

Too small and you run the risk of the system not working.

Ground source heat pump systems – It's all about the Money!
Design process for conventional HVAC system

The design process for a conventional HVAC system does not include designing the energy source.

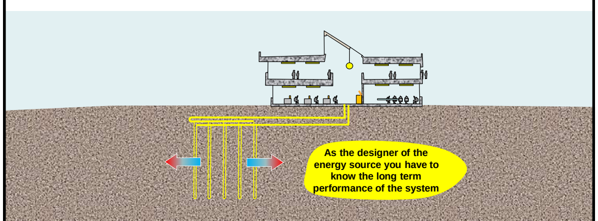
The gas line and cooling tower are sized on peak loads.



Ground source heat pump systems – It's all about the Money!
Design for geothermal system includes designing the energy source & tower

Detailed hour by hour energy model of a building is the only way to determine:
- Peak heating & cooling loads
- Monthly heating & cooling energy loads
- Determine energy balance between heating and cooling

An accurate energy model allows you calculate energy cost & GHX…and economics.



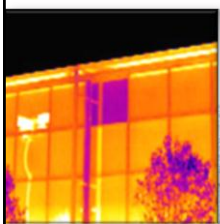
Ground source heat pump systems – It's all about the Money!
A ground heat exchanger is not an infinite energy supply

Designing a geothermal system is somewhat like designing a heating system for a building in a remote community where fuel can only be delivered once a year.

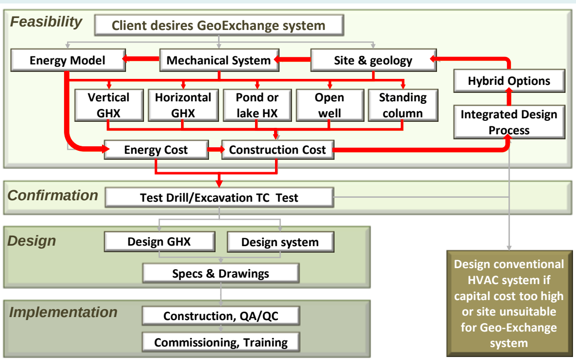
The designer needs to know how much energy the building will require through the whole year. Annual energy loads are required.

Ground source heat pump systems – It's all about the Money!
Requirements for design of geothermal system

Three requirements before you design a geothermal system:
- Understanding of the building construction & use
- Understanding of building system design
- Understanding of the building site and geology



Ground source heat pump systems – It's all about the Money!
Developing a design process to optimize a geothermal system



Ground source heat pump systems – It's all about the Money!
Example project

This retail project includes 7 typical retail box stores in a strip mall with a total area of 178,000 square feet.

Developers for retail space have generally not considered geothermal systems because of the initial cost and they do not pay the energy bills…the tenant does. First cost is the primary concern.

Ground source heat pump systems – It's all about the Money!
Land area for construction of GHX

The land area available for construction of a GHX is the parking lot area for the stores…approximately 230,000 square feet. The geology of the area is:

- 0 - 50': lacustrine clay
- 50 – 400': limestone

Ground source heat pump systems – It's all about the Money!
Using "rules of thumb" to estimate building loads

Designers and/or mechanical contractors often simply estimate the peak heating and cooling loads of this type of project based on "rules of thumb":

- Peak heating load: 25 Btu/hour per square foot – 4,450 kBtu/hour
- Peak cooling load: 34 Btu/hour per square foot – 6,096 kBtu/hour

	Building Loads – "Rule of Thumb"			
	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	0	0	0	4450
Feb	0	0	0	0
Mar	0	0	0	0
Apr	0	0	0	0
May	0	0	0	0
Jun	0	0	0	0
Jul	0	6096	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Oct	0	0	0	0
Nov	0	0	0	0
Dec	0	0	0	0
	0	6096	0	4450
	EFLH	700	EFLH	1400

Note: Equivalent full load hours are an estimate

Ground source heat pump systems – It's all about the Money!

Vertical GHX based on "rule of thumb" building loads

A common "rule of thumb" used to design a vertical GHX is 200' of borehole per ton. The cooling load is 6,096 kBtu/hr, or 508 tons, so the GHX needs to be:

508 tons x 200' = 101,600' or 254 boreholes to a depth of 400'

Using software and adjusting the equivalent full load hours (EFLH), the numbers are pretty close.

	COOLING	HEATING
Total Length (ft):	96767.	97560
Borehole Number:	240	240
Borehole Length (ft):	403.	406.5
Ground Temperature Change (°F):	+2.7	+2.7
Unit Inlet (°F):	90.0	30.0
Unit Outlet (°F):	100.3	24.8
Total Unit Capacity (kBtu/Hr):	7699	4450
Peak Load (kBtu/Hr):	6096	4450

Design Day Loads

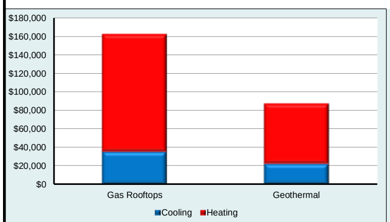
Time of Day	Heat Gains (kBtu/Hr)	Heat Losses (kBtu/Hr)
8 a.m. - Noon	0.0	0.0
Noon - 4 p.m.	6096.0	0.0
4 p.m. - 8 p.m.	0.0	0.0
8 p.m. - 8 a.m.	0.0	4450.0
Full-Load Hours:	700	1400

Ground source heat pump systems – It's all about the Money!

Simple payback of system based on "rule of thumb" calculations

Energy costs are calculated by multiplying the estimate of the equivalent full load hours (EFLH) by the estimated peak load and the energy rates. Cost of installing GHX is estimated at $1,651,000.

Simple payback = $1,727,000 / ($162,200 - $87,000) = 23.1 years



Ground source heat pump systems – It's all about the Money!

Standard construction - 8,760 hour energy model

Taking the time to model the building, using 8,760 hourly weather data and accurately scheduling the use of the building results in much different heating and cooling loads.

- Peak heating load: 17.3 Btu/hour per square foot – 3,077 kBtu/hour
- Peak cooling load: 19.8 Btu/hour per square foot – 3,523 kBtu/hour

8,760 hourly loads also provides monthly peak & energy loads for heating and cooling and calculates the annual equivalent full load hours.

Standard Construction Building Loads

	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	0	0	660361	3010
Feb	0	0	474200	2903
Mar	244	60	295273	2324
Apr	52371	1536	42589	1344
May	201580	1834	1135	107
Jun	373272	2585	0	0
Jul	546625	3523	0	0
Aug	482079	3033	0	0
Sep	194717	2880	394	69
Oct	58748	1327	29420	1220
Nov	3671	451	272568	2419
Dec	0	0	558306	3077
	1913308	3523	2334245	3077
	EFLH	543	EFLH	759

Ground source heat pump systems – It's all about the Money!

Standard construction - 8,760 hour energy model

The first iteration of the vertical GHX is less than half the size of the GHX based on "rule of thumb" peak loads.

	COOLING	HEATING
Total Length (ft):	42700	**43620**
Borehole Number:	108	**108**
Borehole Length (ft):	395	403
Ground Temperature Change (°F):	+3.8	**+3.7**
Unit Inlet (°F):	90.0	**30.0**
Unit Outlet (°F):	100.3	**24.8**
Total Unit Capacity (kBtu/Hr):	5324	**3077**
Peak Load (kBtu/Hr):	3523	**3077**

Design Day Loads

Time of Day	Heat Gains (kBtu/Hr)	Heat Losses (kBtu/Hr)
8 a.m. - Noon	177.1	3077.0
Noon - 4 p.m.	3523.0	449.7
4 p.m. - 8 p.m.	177.1	449.7
8 p.m. - 8 a.m.	177.1	449.7
Full-Load Hours:	543	759

Ground source heat pump systems – It's all about the Money!

Adding heat recovery to ventilation - 8,760 hour energy model

Working with the mechanical designer to incorporate heat recovery to the ventilation air results in significantly lower heating loads and a small reduction in cooling loads.

- Peak heating load: 12.9 Btu/hour per square foot – 2,296 kBtu/hour
- Peak cooling load: 18.4 Btu/hour per square foot – 3,277 kBtu/hour

Addition of Energy Recover Ventilation

	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	0	0	455895	2296
Feb	0	0	337253	2160
Mar	708	66	220935	1589
Apr	60276	1618	36105	1265
May	216143	1836	926	93
Jun	385450	2384	0	0
Jul	545955	3277	0	0
Aug	481097	2898	0	0
Sep	204237	2690	353	49
Oct	67160	1403	24106	1160
Nov	5086	551	206274	1690
Dec	0	0	398810	2204
	1966111	**3277**	**1680657**	**2296**
	EFLH	**600**	**EFLH**	**732**

Ground source heat pump systems – It's all about the Money!

Adding heat recovery to ventilation - 8,760 hour energy model

Adding heat recovery to the ventilation air makes this GHX cooling dominant. The spacing between boreholes is increased to 25' from 15' to compensate. The size of the GHX is reduced by 11% by adding HRV.

	COOLING	HEATING
Total Length (ft):	**38823**	33592
Borehole Number:	**96**	96
Borehole Length (ft):	404	349.9
Ground Temperature Change (°F):	**+1.8**	+2.0
Unit Inlet (°F):	**90.0**	30.0
Unit Outlet (°F):	**100.3**	24.8
Total Unit Capacity (kBtu/Hr):	**3972**	2296.
Peak Load (kBtu/Hr):	**3277**	2296.

Design Day Loads

Time of Day	Heat Gains (kBtu/Hr)	Heat Losses (kBtu/Hr)
8 a.m. - Noon	225.2	2296.0
Noon - 4 p.m.	3277.0	276.1
4 p.m. - 8 p.m.	225.2	276.1
8 p.m. - 8 a.m.	225.2	276.1
Full-Load Hours:	600	732

Ground source heat pump systems – It's all about the Money!

Using high-efficiency lighting - 8,760 hour energy model

Working with electrical engineers and architects to reduce lighting intensity and improved lighting efficiency reduces cooling loads. Heating loads are slightly *increased* as internal gains from lighting are reduced.

- Peak heating load: 17.9 Btu/hour per square foot – 3,182 kBtu/hour
- Peak cooling load: 17.2 Btu/hour per square foot – 3,058 kBtu/hour

	Addition of High-Efficiency Lighting			
	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	0	0	810702	3107
Feb	0	0	608758	2989
Mar	0	0	432297	2410
Apr	12073	1012	117015	1478
May	78193	1244	11730	524
Jun	217831	2041	0	0
Jul	379150	3058	0	0
Aug	316316	2543	0	0
Sep	83190	2438	11969	995
Oct	11692	816	103348	1414
Nov	0	0	401200	2545
Dec	0	0	703838	3183
	1098446	3058	3200856	3182
	EFLH	359	EFLH	1006

Ground source heat pump systems – It's all about the Money!

Using high-efficiency lighting - 8,760 hour energy model

Adding high-efficiency lighting reduces the cooling loads and at the same time increases the heating loads *(less internal gains)*. The loads to the GHX become very heating dominant and increase the size of the GHX by about 44%.

	COOLING	HEATING
Total Length (ft):	31704.	62662
Borehole Number:	160	160
Borehole Length (ft):	198	391
Ground Temperature Change (°F):	-1.1	-0.5
Unit Inlet (°F):	90.0	30.0
Unit Outlet (°F):	100.3	24.8
Total Unit Capacity (kBtu/Hr):	5507	3183
Peak Load (kBtu/Hr):	3058.	3183

Design Day Loads

Time of Day	Heat Gains (kBtu/Hr)	Heat Losses (kBtu/Hr)
8 a.m. - Noon	0.0	3183.0
Noon - 4 p.m.	3058.0	671.0
4 p.m. - 8 p.m.	0.0	671.0
8 p.m. - 8 a.m.	0.0	671.0
Full-Load Hours:	359	1006

Ground source heat pump systems – It's all about the Money!

Heat recovery ventilation & high-efficiency lighting – 8,760 hourly loads

Designers and/or mechanical contractors typically estimate the peak heating and cooling loads of this type of project.

- Peak heating load: 13.5 Btu/hour per square foot – 2,405 kBtu/hour
- Peak cooling load: 15,8 Btu/hour per square foot – 2,805 kBtu/hour

Detailed hourly load profile not typically done.

	Addition of High-efficiency Lighting & Energy Recovery			
	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	0	0	580178	2405
Feb	0	0	439112	2234
Mar	0	0	320159	1699
Apr	13954	1044	102991	1138
May	84743	1229	9979	407
Jun	225037	1842	0	0
Jul	374247	2805	0	0
Aug	310616	2428	0	0
Sep	85145	2242	10130	946
Oct	13730	848	91383	1118
Nov	41	41	307024	1803
Dec	0	0	506148	2293
	1107512	2805	2367104	2405
	EFLH	395	EFLH	984

Ground source heat pump systems – It's all about the Money!

Heat recovery ventilation & high-efficiency lighting – 8,760 hourly loads

Adding both HRV and high-efficiency lighting reduces overall energy consumption, but loads to the GHX are still fairly heating dominant. The GHX is still slightly larger than the model that includes heat recovery alone.

	COOLING	HEATING
Total Length (ft):	30166	44838
Borehole Number:	112	112
Borehole Length (ft):	269	400
Ground Temperature Change (°F):	-0.2	-0.1
Unit Inlet (°F):	90.0	30.0
Unit Outlet (°F):	100.3	24.8
Total Unit Capacity (kBtu/Hr):	4161	2405
Peak Load (kBtu/Hr):	2805	2405

Design Day Loads

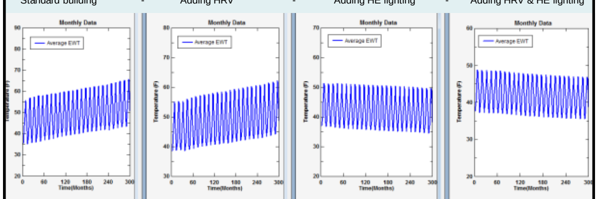
Time of Day	Heat Gains (kBtu/Hr)	Heat Losses (kBtu/Hr)
8 a.m. - Noon	42.6	2405.0
Noon - 4 p.m.	2805.0	454.8
4 p.m. - 8 p.m.	42.6	454.8
8 p.m. - 8 a.m.	42.6	454.8
Full-Load Hours:	395	984

Ground source heat pump systems – It's all about the Money!

Long term temperature of different energy model / GHX iterations

Adding heat recovery ventilation, high-efficiency lighting, or both to the building systems has an impact on the long term temperature of the GHX. The standard building system and the system with only the HRV results in a cooling dominant GHX. The temperature will gradually climb over 25 years. Adding high-efficiency lighting reduces the cooling loads and results in a more stable GHX that will change little over time.

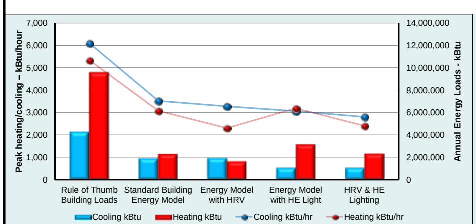
Standard building - Adding HRV - Adding HE lighting - Adding HRV & HE lighting



Ground source heat pump systems – It's all about the Money!

Energy load summary

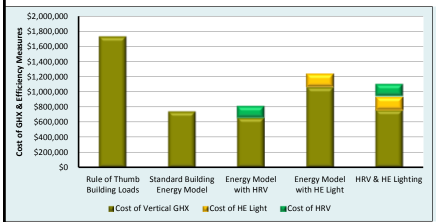
Graph compares the peak heating and cooling loads and annual energy loads estimated using "rules of thumb" with different iterations of the energy model.



Ground source heat pump systems – It's all about the Money!

Construction cost difference for a geothermal system with vertical GHX

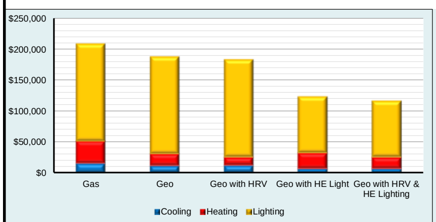
The cost of constructing a geothermal system is typically the cost of the GHX. We've asked the design team to add HRV's to the ventilation air to 2 scenarios and high-efficiency lighting to 2 scenarios. The graph shows the cost of adding a vertical GHX to the building as well as the additional cost of improved lighting and ventilation systems.



Ground source heat pump systems – It's all about the Money!

Energy cost for heating, cooling & lighting based on energy models

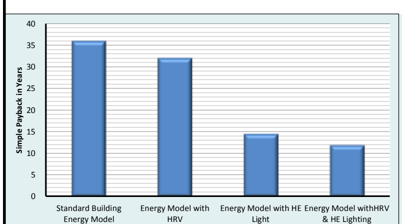
Energy costs for the building vary considerably. The graph shows the standard building with gas rooftop units compared to the same building with geothermal. The additional iterations show the energy cost of the geo building with the addition of HRV, high-efficiency lighting and the impact of both.



Ground source heat pump systems – It's all about the Money!

Simple payback of geo system with vertical GHX compared to gas system

The decision of which HVAC system will be installed is almost always based on economics. This chart shows the simple payback of the geo system compared with a standard gas rooftop system. It also shows the comparison geo with HRV, high-efficiency lighting and both compared with the standard gas rooftop system.



Ground source heat pump systems – It's all about the Money!

Alternative GHX configurations

A vertical GHX is most commonly used for commercial applications since it requires smallest land area. Most retail sites have ample parking lot areas that can be used to install a horizontal GHX. Some methods of installing a large horizontal GHX include ploughing, trenching, large excavations and horizontal directional drilling (HDD).

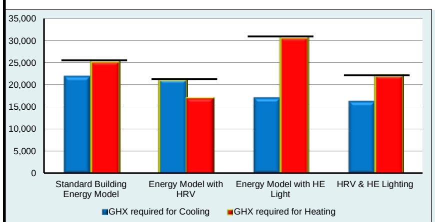
Pipe can be installed at depths up to 30' below the surface, and can be installed in several layers.

Ground source heat pump systems – It's all about the Money!

Comparative size of horizontal directionally drilled GHX

This graph illustrates the relative size of a horizontal GHX for each of the energy models. Note that the more balanced heating and cooling loads result in the shortest GHX length.

The energy model with only HE lighting results in a GHX that is *longer* than the model that uses only an HRV or that takes advantage of both.

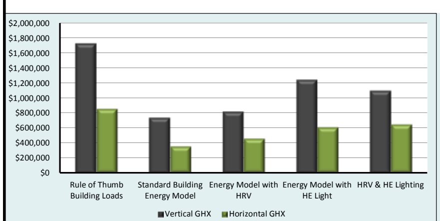


Ground source heat pump systems – It's all about the Money!

Capital cost comparison of vertical & horizontal GHX

This graph compares the cost of installing a system with a vertical GHX with the cost of installing a horizontal directionally drilled GHX. The additional cost of adding an HRV and/or high-efficiency lighting is included in each iteration.

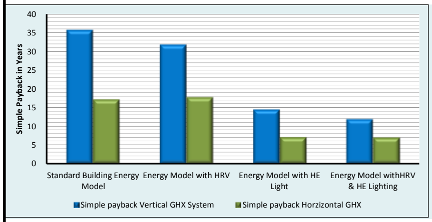
The construction cost of a geothermal system using a horizontal GHX is approximately 45% to 55% lower than a with a vertical GHX.



Ground source heat pump systems – It's all about the Money!

Simple payback comparison

The simple payback of a system using a horizontal GHX is significantly better than a system using a vertical GHX, ranging from 7 - 18 years versus 12 – 36 years for a vertical GHX.

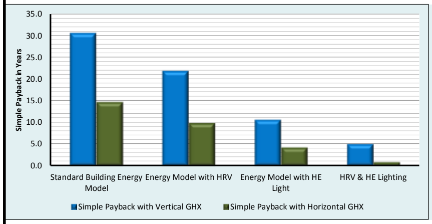


Ground source heat pump systems – It's all about the Money!

Simple payback after utility & government incentives are included

The project is located in an area where both the government and electric utility provide incentives to the owner. Incentives are greater if the building is more efficient, making the incentive larger for a building with high-efficiency lighting and HRV.

This project, built with a horizontal GHX, high-efficiency lighting and HRV, has a simple payback less than 1 year.



Ground source heat pump systems – It's all about the Money!

Conclusions

- Detailed energy modeling is a critical component in designing a GeoExchange system.
- It is important to work with the rest of the design team to look at methods to reduce the heating and cooling loads (peak and annual energy loads)
- Balanced heating and cooling loads result in a more stable GHX temperature and a system that will perform well over the long term
- Balanced heating and cooling loads result in a less expensive overall system and greatly improves the payback of the system for the client
- Looking at all GHX options can result in a GHX that is less expensive to construct and in a much shorter payback for the client

Ground source heat pump systems – It's all about the Money!

Other options that can help reduce heat flow to the GHX

- Ice storage tanks reduce peak cooling loads
- CO2 sensors reduce peak and annual energy loads
- Snow melt absorbs heat that would normally be rejected to the GHX
- Domestic hot water absorbs heat that would normally be rejected to the GHX

Ground source heat pump systems – It's all about the Money!

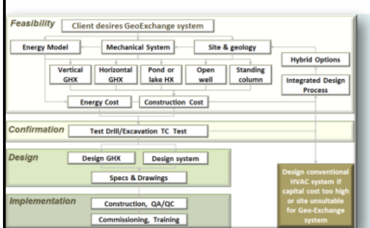
Other options that can help reduce heat flow to the GHX

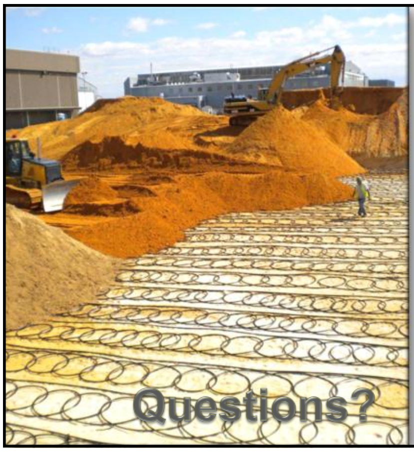
- CO2 sensors reduce peak and annual heating energy loads
- Refrigeration loads in the building can reject heat to the GHX
- Heat removed from server rooms can be added to the GHX

Ground source heat pump systems – It's all about the Money!

Geothermal must be designed as a system

We've found we can add more value to our services by developing and using this design process to optimize the *system* design for our clients, by working with the owner and their entire design and construction team.





Ground Source Heating & Cooling Symposium

Earth Rangers Centre
the Living City Campus at Kortright, Woodbridge, ON

2011-11-03

Ed Lohrenz, B.E.S., CGD
204.255.5959
ed@geoxergy.com