Tulsa, OK

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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.

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!"

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.

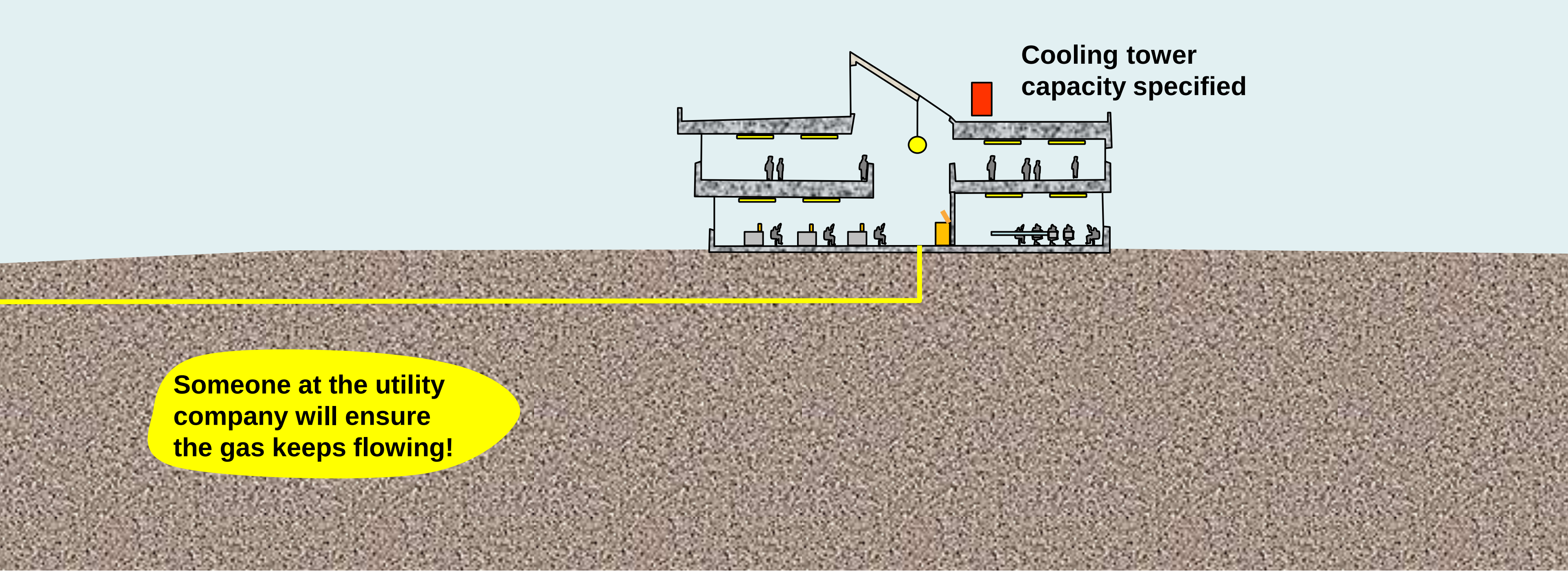
Too large and the client may not have the land area required or can't justify the cost.

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

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.



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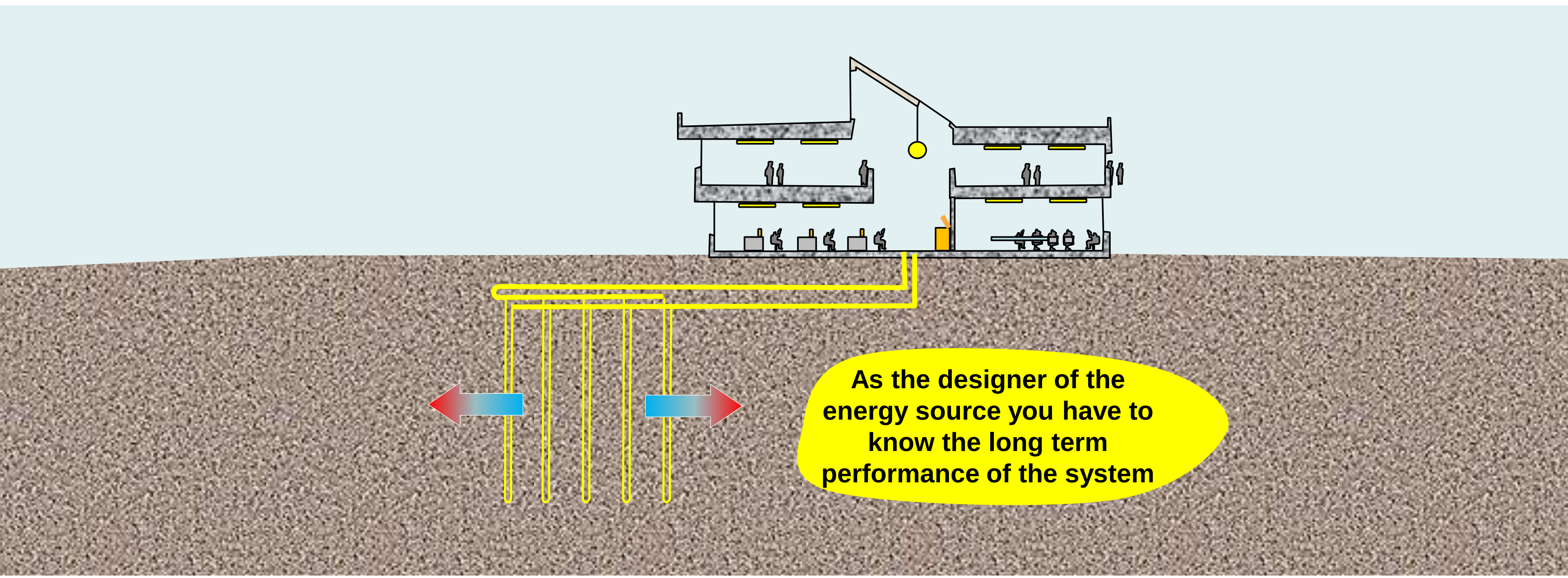
Design for geothermal system includes designing the energy source & tower

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.



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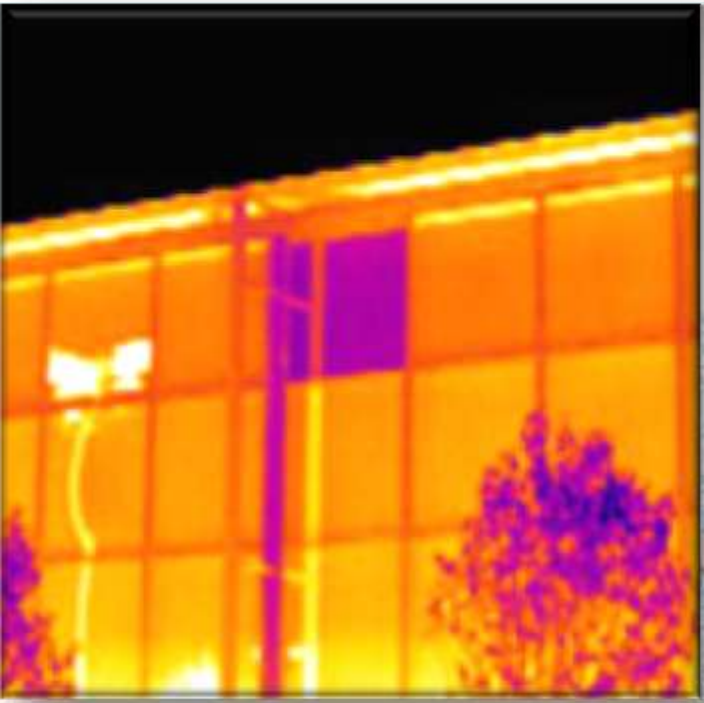
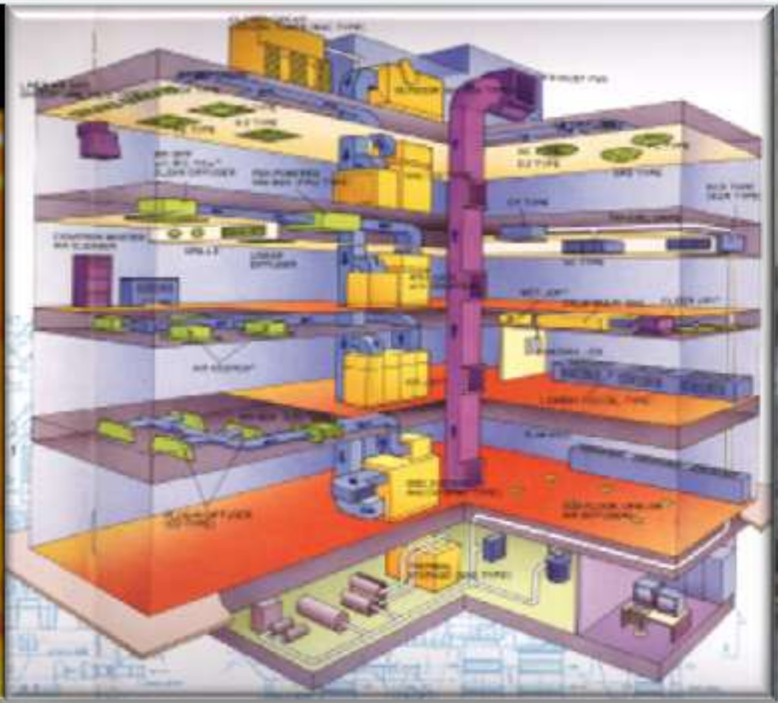
Requirements for design of geothermal system

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





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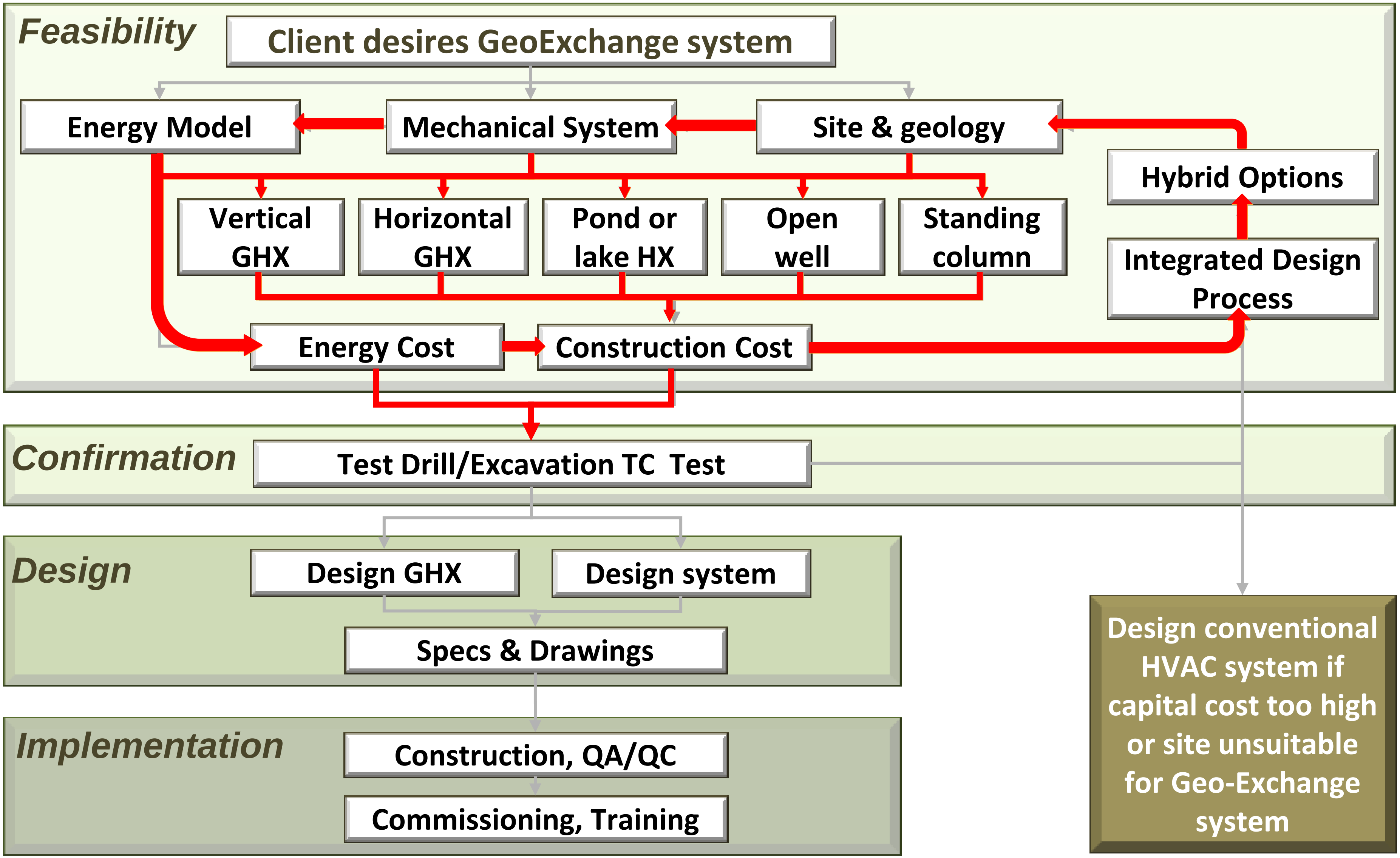
Developing a design process to optimize a geothermal system



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Example project

This apartment project totals approximately 34,000 square feet in area on four floors.

Private developers have generally not considered geothermal systems because of the additional cost to build the systems and they don't pay the energy bills…the tenant does. There has to be something in it for the developer.

- Marketing opportunities
- Opportunity to include heating & cooling in the rent

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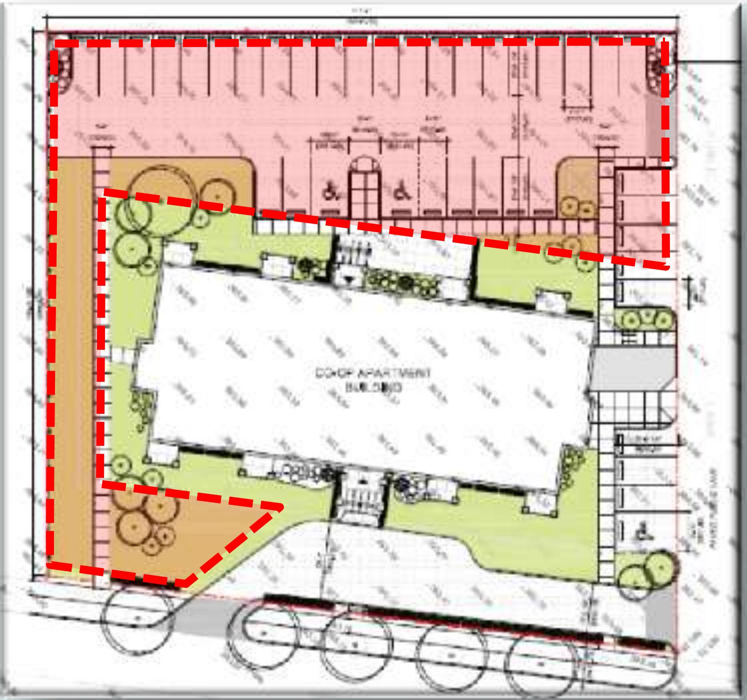
Land area for construction of GHX

The entire building site is approximately 39,000 square feet in area. The area available for construction of the GHX is approximately 17,000 square feet in area (outlined in red)

The geology of the area is:

- 0 - 65': glacial till (predominantly sand, silt, clay)
- 65' – 250': soft shale / mudstone
- Estimated average thermal conductivity: 0.80 to 0.90 Btu/hour * foot * °F



Drilling contractors in the region

Drilling with a wet auger drill rig is very cost-effective in the type of formation found in the region…ranging from $6.50 to $7.50 per foot including tie-in to the building.

The problem with the type of rig is a depth limitation of approximately 150’. Mud rotary is also very effective in this formation, but the cost ranges from $11.00 to $12.00 per foot – 50% to 60% higher in cost, but the drilling depths can be greater – to about 300’

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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". In this region typical "rules of thumb" would work out to be approximately:

- Peak heating load: 20 Btu/hour per square foot – 680 kBtu/hour
- Peak cooling load: 15 Btu/hour per square foot – 540 kBtu/hour

	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	0	0	0	680
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	540	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
	378000	**540**	**952000**	**680**
	EFLH	**700**	**EFLH**	**1400**

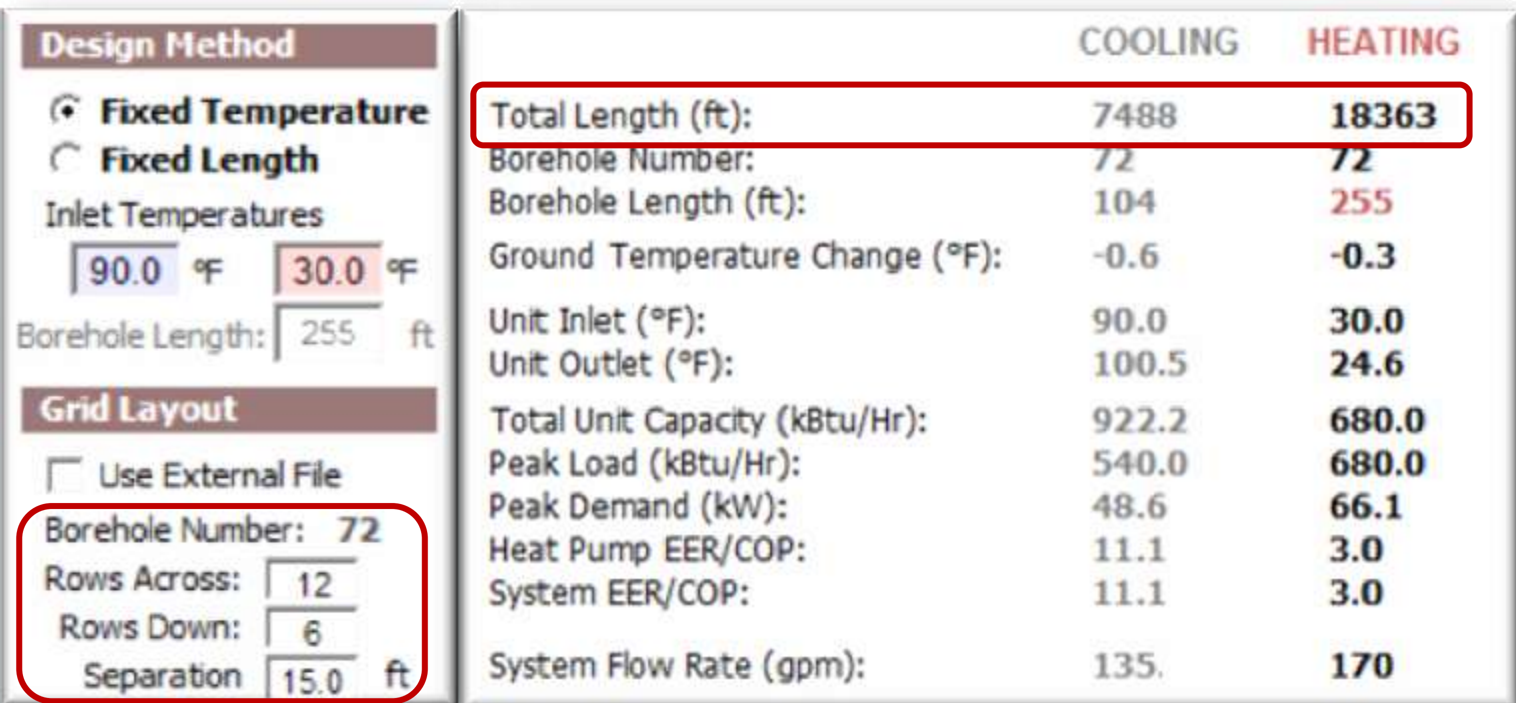
Equivalent full load hours are "guesstimates"

Vertical GHX based on "rule of thumb" building loads

A common "rule of thumb" used to design a vertical GHX is 200' to 250' of borehole per ton. The heating load is 850 kBtu/hr, or 71 tons, so the GHX needs to be:

71 tons x 250' = 17,750', or 72 boreholes to a depth of about 250'

Using software and adjusting the equivalent full load hours (EFLH), the conductivity and the grout conductivity, the numbers can be made to appear reasonably close.



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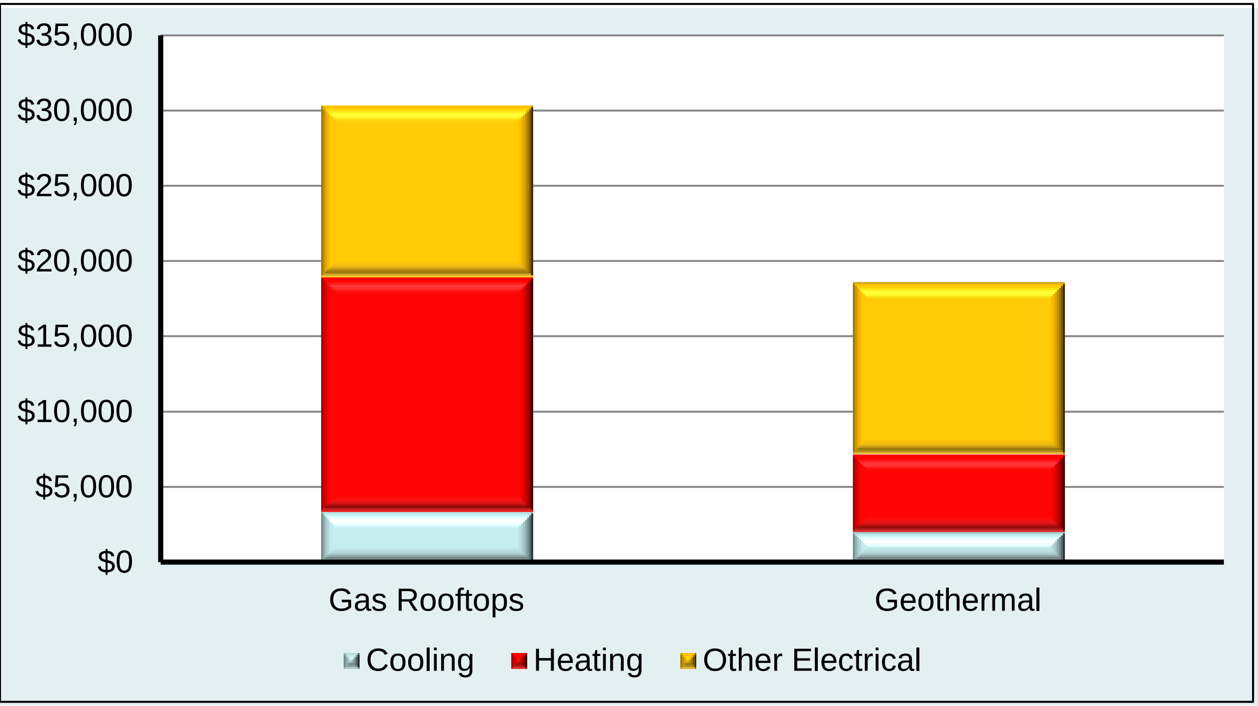
Simple payback of system based on "rule of thumb" calculations

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 $211,000.

Simple payback = $211,000 / ($30382 - $18,631) = 18.0 years



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First energy model loads

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: 13.6 Btu/hour per square foot – 463 kBtu/hour
- Peak cooling load: 12.3 Btu/hour per square foot – 418 kBtu/hour

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

	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	2726	17	184620	463
Feb	2761	28	126606	444
Mar	5057	72	83124	393
Apr	12450	163	32702	239
May	27981	185	13120	82
Jun	47856	282	2648	32
Jul	77404	418	355	18
Aug	67348	316	621	26
Sep	29097	290	3898	37
Oct	11115	103	14084	147
Nov	4066	42	78662	372
Dec	2917	17	149818	430
	290779	**418**	**690256**	**463**
	EFLH	**695**	**EFLH**	**1492**

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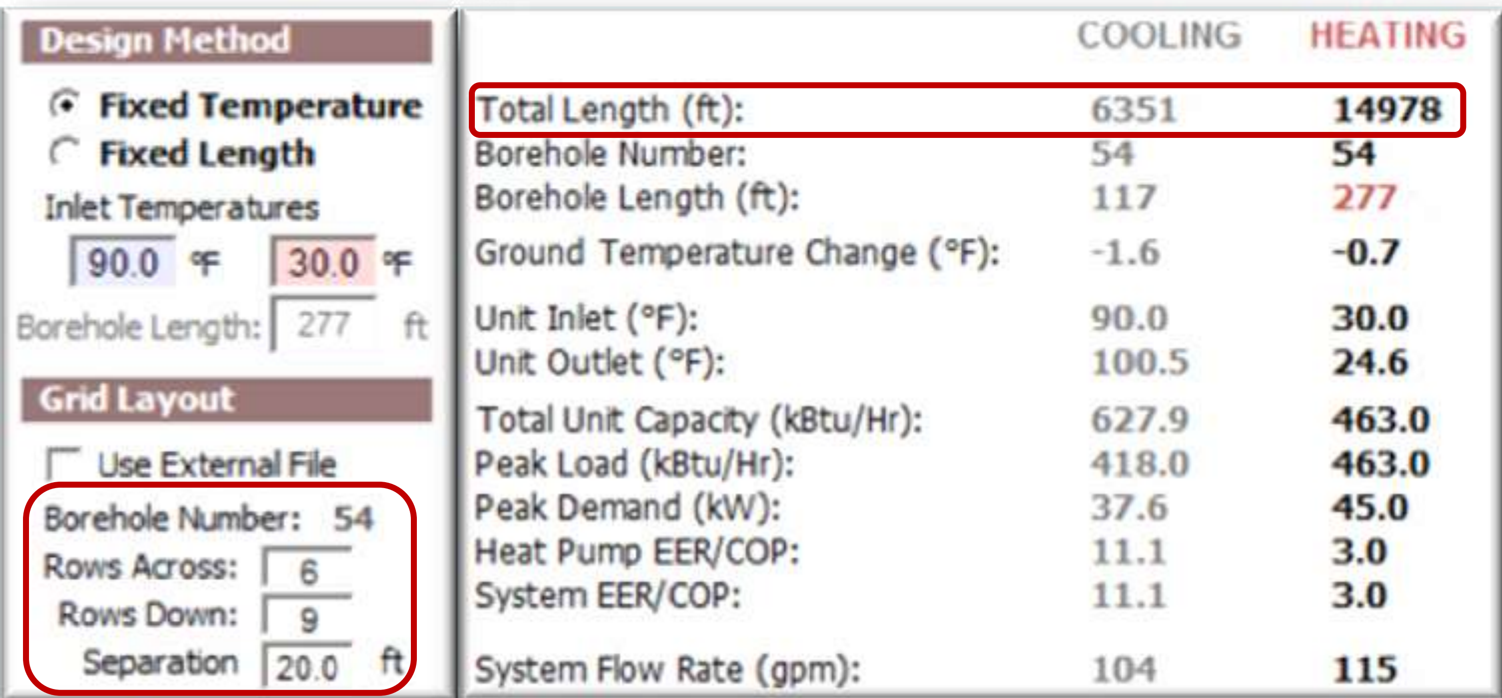
GHX required for first energy model loads – deep boreholes (<300' depth)

The first energy model for this building reduces the amount of drilling required to slightly less than 15,000'.

Approximately 16,000 square feet of land area is needed to construct this GHX.



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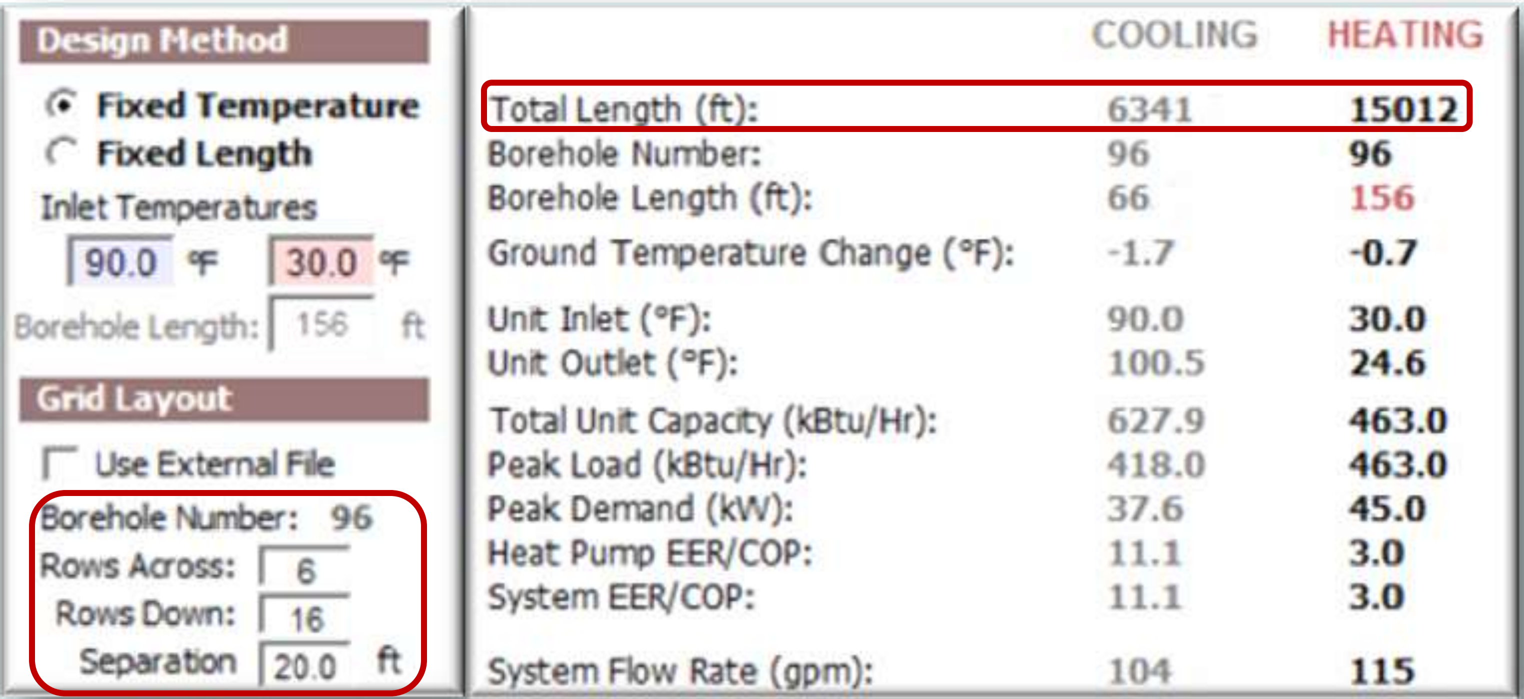
GHX required for first energy model loads – shallow boreholes (<150' depth)

Approximately 30,000 square feet of land area is required to build this GHX.

This GHX cannot be built on this site because there is not enough area.



	COOLING	HEATING
Total Length (ft):	6341	15012
Borehole Number:	96	96
Borehole Length (ft):	66	156
Ground Temperature Change (°F):	-1.7	-0.7
Unit Inlet (°F):	90.0	30.0
Unit Outlet (°F):	100.5	24.6
Total Unit Capacity (kBtu/Hr):	627.9	463.0
Peak Load (kBtu/Hr):	418.0	463.0
Peak Demand (kW):	37.6	45.0
Heat Pump EER/COP:	11.1	3.0
System EER/COP:	11.1	3.0
System Flow Rate (gpm):	104	115

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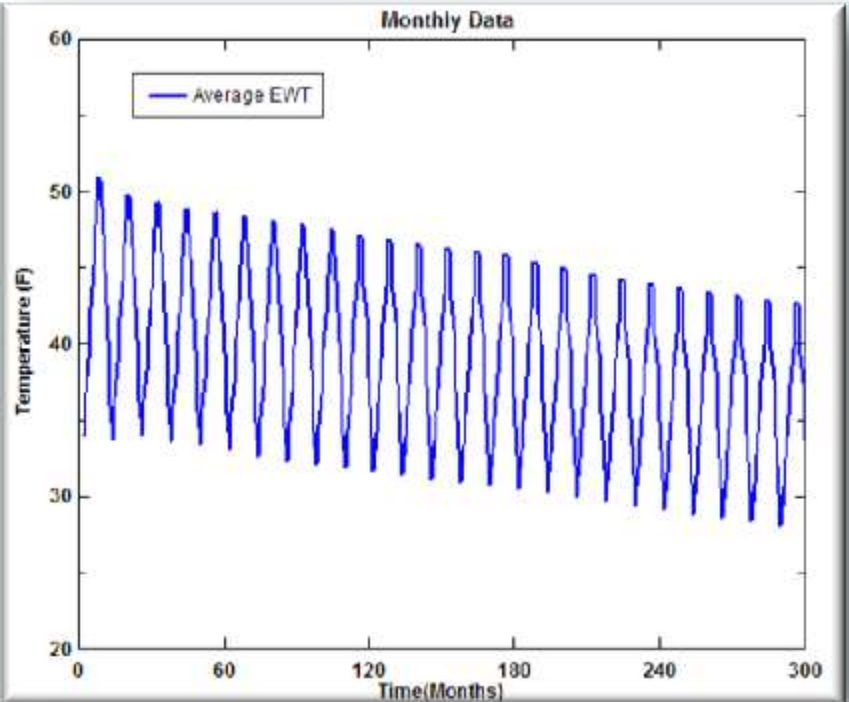
First energy model – predicted long term operating temperatures

The first energy model is heating dominant. More energy is extracted from the ground than rejected to the ground. Over 25 years the minimum average temperature of this GHX can be expected to drop to about 27°F.

The system heating efficiency will gradually deteriorate.



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With HRV & 0.27 SC Glass (coated to reduce solar gains)

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.

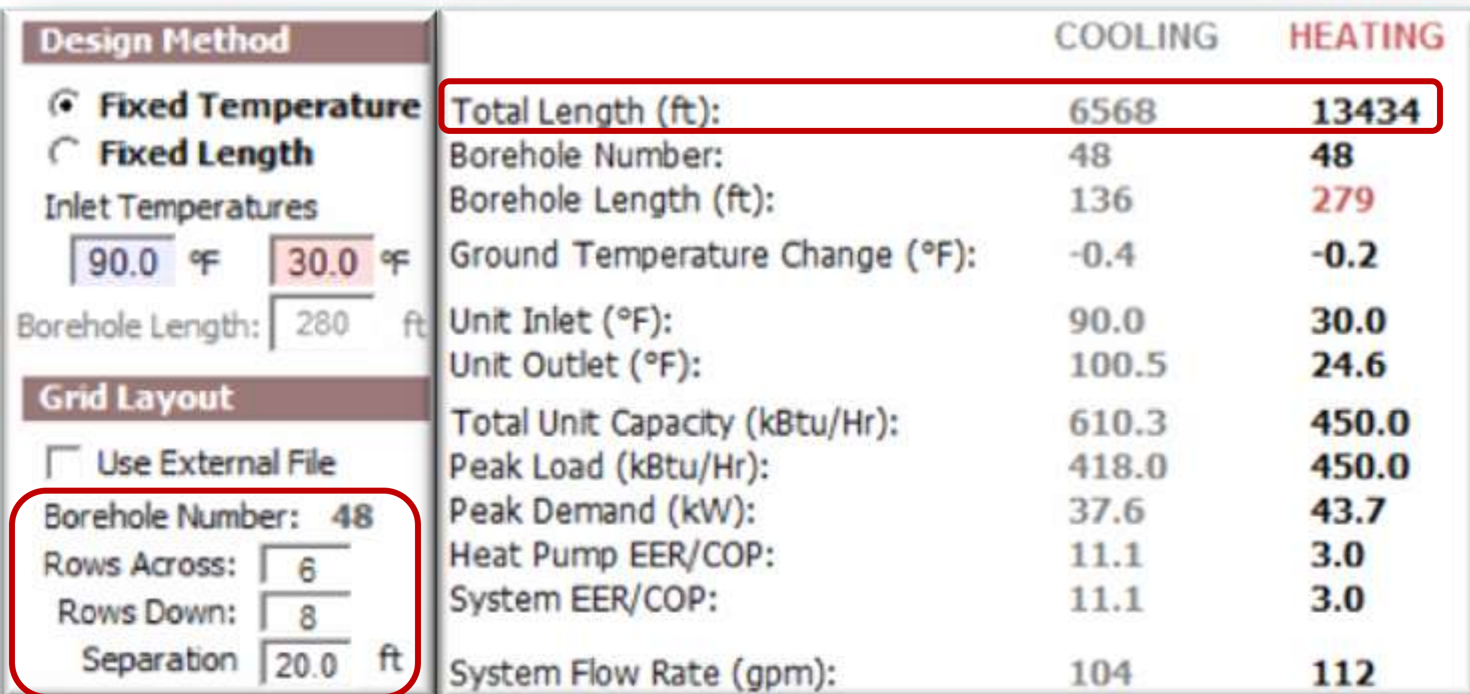
- Peak heating load: 13.2 Btu/hour per square foot – 450 kBtu/hour
- Peak cooling load: 12.3 Btu/hour per square foot – 418 kBtu/hour

	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	2752	18	160473	450
Feb	2701	18	110156	420
Mar	4575	72	72242	365
Apr	11903	165	29078	212
May	27934	186	11881	72
Jun	47978	281	2373	22
Jul	77415	418	303	11
Aug	67206	315	453	12
Sep	28798	290	3273	35
Oct	10565	104	12115	114
Nov	3870	42	66830	344
Dec	2922	18	127657	420
	288619	**418**	**596834**	**450**
	EFLH	**690**	**EFLH**	**1326**

GHX for HRV & 0.27 SC glass – deep boreholes (< 300' depth)

Adding heat recovery to the ventilation air makes this GHX somewhat less heating dominant.

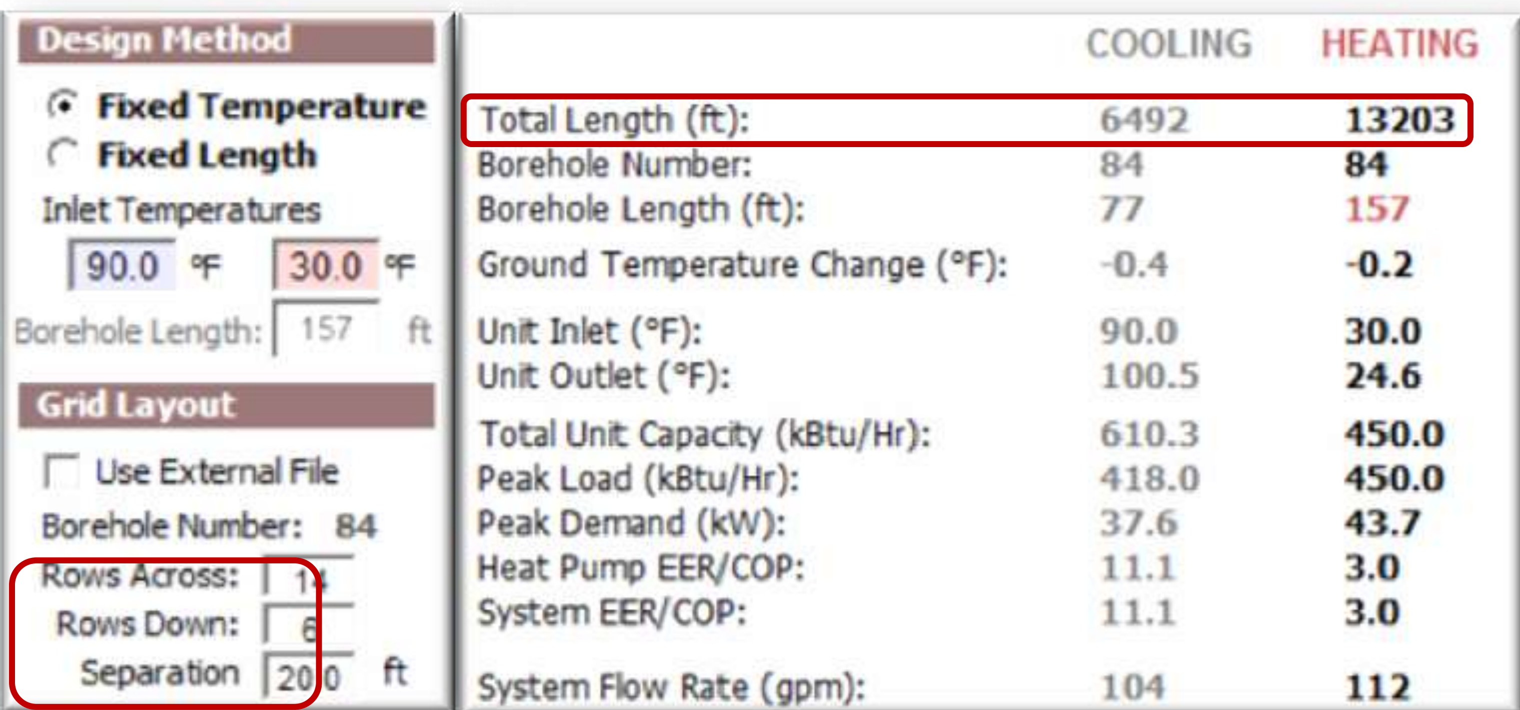
Approximately 14,000 square feet of land area required to build GHX at $11.50 / foot drilling cost.



GHX for HRV & 0.27 SC glass – shallow boreholes (< 150’ depth)

With this energy model, shallow boreholes, less than 150’ require more land area than is available.

Approximately 26,000 square feet of land area required to build GHX at $7.00 / foot drilling cost.



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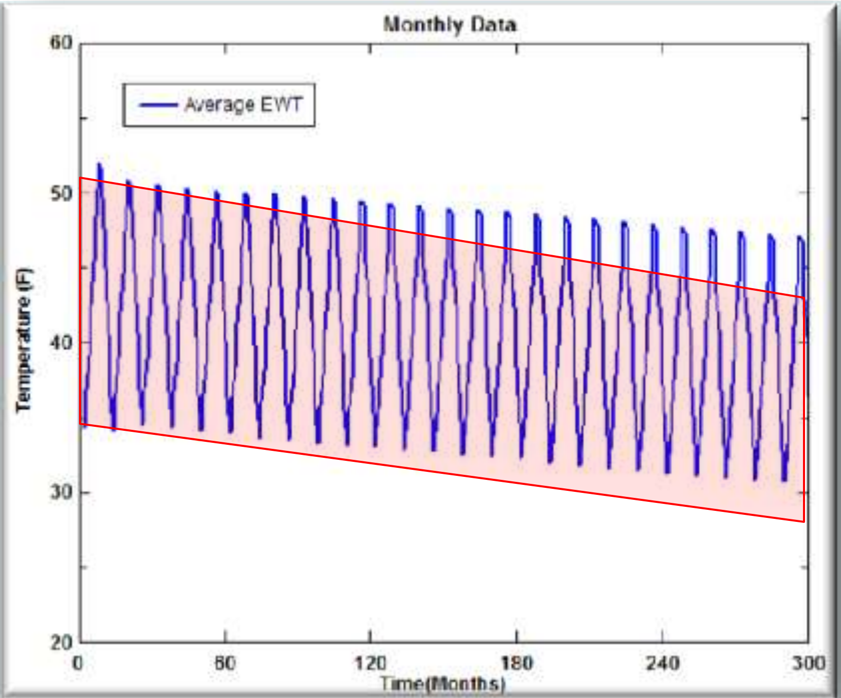
Long term predicted operating temperature with HRV

Adding heat recovery for the ventilation air reduces the energy imbalance to the ground. The minimum average temperature after 25 years is expected to drop to 31°F.




Temperature predictions for first energy model


Temperature predictions for HRV & 0.27 SC Glass

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Heat recovery ventilation plus 0.70 SC glass (clear glass to increase heat gain)

Working with the architect to change the glass specifications increased annual cooling loads while reducing annual heating loads. This reduces the energy imbalance to the GHX:

- Peak heating load: 11.9 Btu/hour per square foot – 406 kBtu/hour
- Peak cooling load: 13.1 Btu/hour per square foot – 445 kBtu/hour

	Cooling		Heating	
	kBtu	kBtu/hr	kBtu	kBtu/hr
Jan	3556	26	126138	406
Feb	4032	47	83983	382
Mar	9236	122	54573	279
Apr	20964	214	23281	127
May	41005	265	8943	53
Jun	61456	319	1728	36
Jul	91862	445	178	21
Aug	80477	380	335	20
Sep	39000	321	2548	25
Oct	17178	117	9559	79
Nov	5804	58	51741	283
Dec	3641	21	101251	370
	378210	**445**	**464257**	**406**
	EFLH	**850**	**EFLH**	**1142**

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HRV & 0.70 SC Glass – deep boreholes at 20' spacing

Installing glass that increases solar gains to the building increases cooling loads and at the same time decreases the heating loads *(more solar gains)*. The loads to the GHX become less heating dominant and decrease the size of the GHX by about 29%.

Approximately 8,400 square feet of land area are needed to construct this GHX using deeper boreholes.

Design Method

- (•) Fixed Temperature
- ( ) Fixed Length

Inlet Temperatures: 90.0 °F | 30.0 °F

Borehole Length: 298 ft

Grid Layout

[ ] Use External File

Borehole Number: 32
Rows Across: 4
Rows Down: 8
Separation: 20.0 ft

	COOLING	HEATING
Total Length (ft):	7849	9527
Borehole Number:	32	32
Borehole Length (ft):	245	297
Ground Temperature Change (°F):	+2.6	+2.1
Unit Inlet (°F):	90.0	30.0
Unit Outlet (°F):	100.5	24.6
Total Unit Capacity (kBtu/Hr):	550.6	406.0
Peak Load (kBtu/Hr):	445.0	406.0
Peak Demand (kW):	40.0	39.4
Heat Pump EER/COP:	11.1	3.0
System EER/COP:	11.1	3.0
System Flow Rate (gpm):	111	101

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HRV & 0.70 SC Glass – shallow (< 150' depth) boreholes at 20' spacing

With this energy model, shallow boreholes, less than 150' depth, requires more land area than is available.

Approximately 18,000 square feet of land area required to build GHX at $7.00 / foot drilling cost.

Design Method

- (•) Fixed Temperature
- ( ) Fixed Length

Inlet Temperatures: 90.0 °F | 30.0 °F

Borehole Length: 156 ft

Grid Layout

- [ ] Use External File

Borehole Number: 60
Rows Across: 6
Rows Down: 10
Separation: 20.0 ft

	COOLING	HEATING
Total Length (ft):	7905	9356
Borehole Number:	60	60
Borehole Length (ft):	131	155
Ground Temperature Change (°F):	+2.9	+2.5
Unit Inlet (°F):	90.0	30.0
Unit Outlet (°F):	100.5	24.6
Total Unit Capacity (kBtu/Hr):	550.6	406.0
Peak Load (kBtu/Hr):	445.0	406.0
Peak Demand (kW):	40.0	39.4
Heat Pump EER/COP:	11.1	3.0
System EER/COP:	11.1	3.0
System Flow Rate (gpm):	111	101

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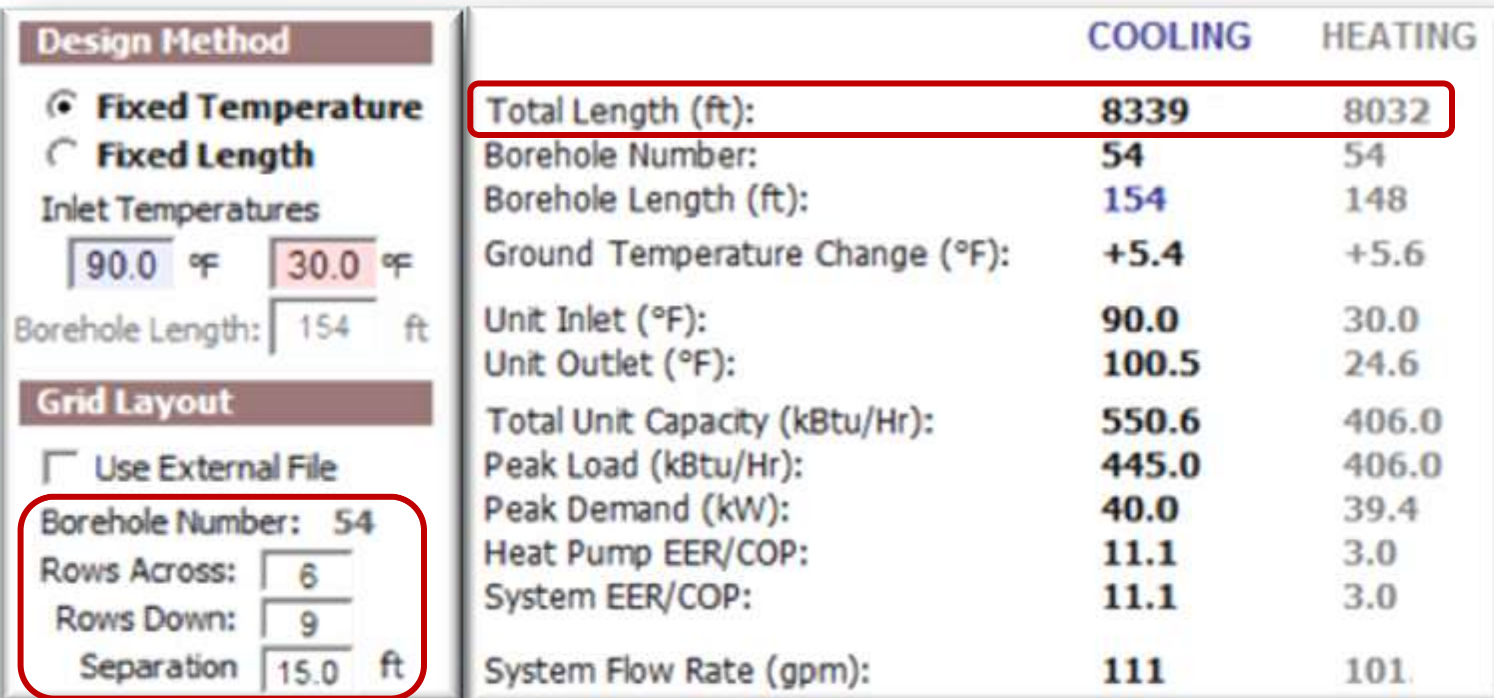
HRV & 0.70 SC Glass – shallow (< 150’ depth) boreholes at 20’ spacing

The more balanced energy loads in the building with heat recovery ventilation and increased solar gains using clear glass, allows us to reduce spacing between the boreholes to 15’.

Approximately 9,000 square feet of land area required to build GHX at $7.00 / foot drilling cost.



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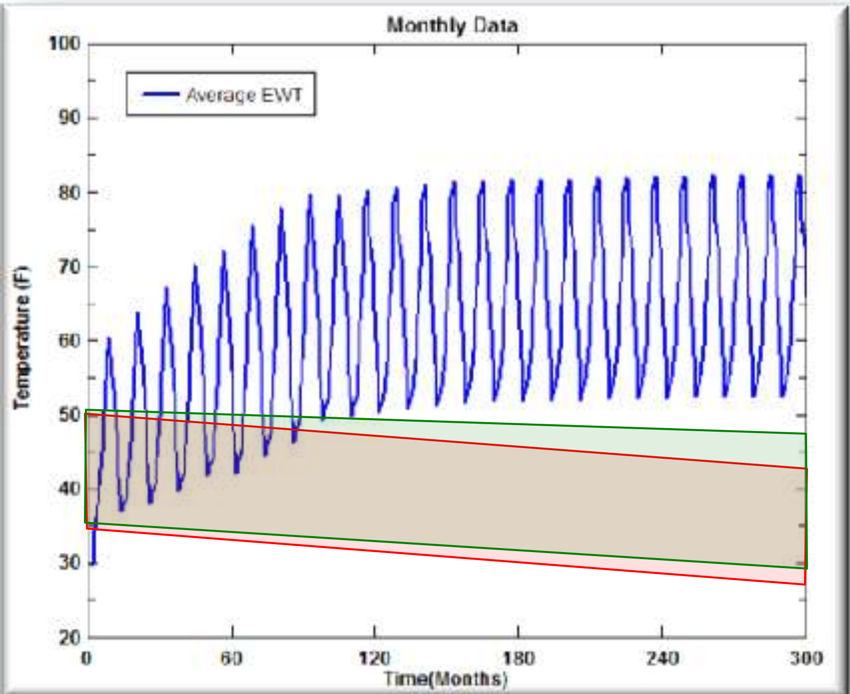
Long term GHX temperatures predictions – with HRV & 0.70 SC glass

Selecting glass that increases solar gains to the building increases the long term stability of the GHX. Minimum temperature from the GHX stabilizes at approximately 52°F after 10 years, making the system significantly more efficient in heating the building.



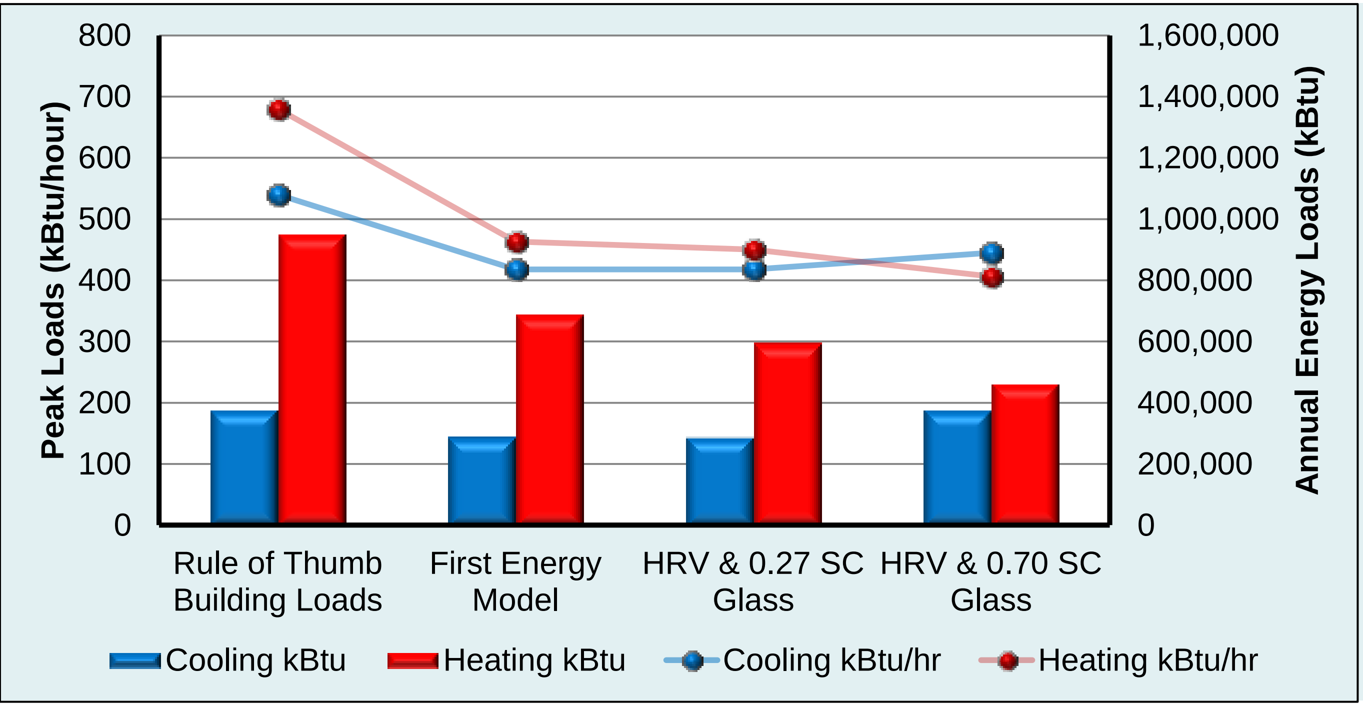
Temperature prediction for first energy model

Temperature predictions for HRV & 0.27 SC Glass

Temperature predictions for HRV & 0.70 SC Glass

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.



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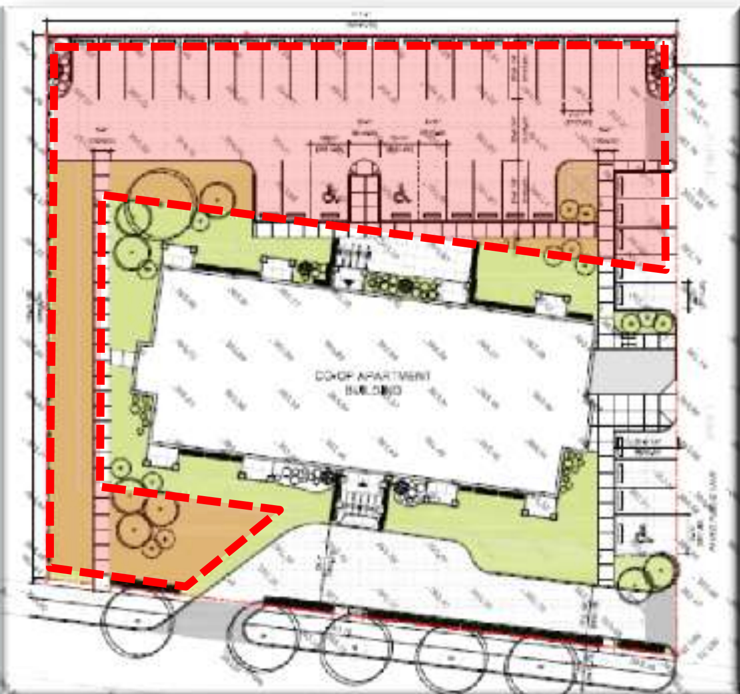
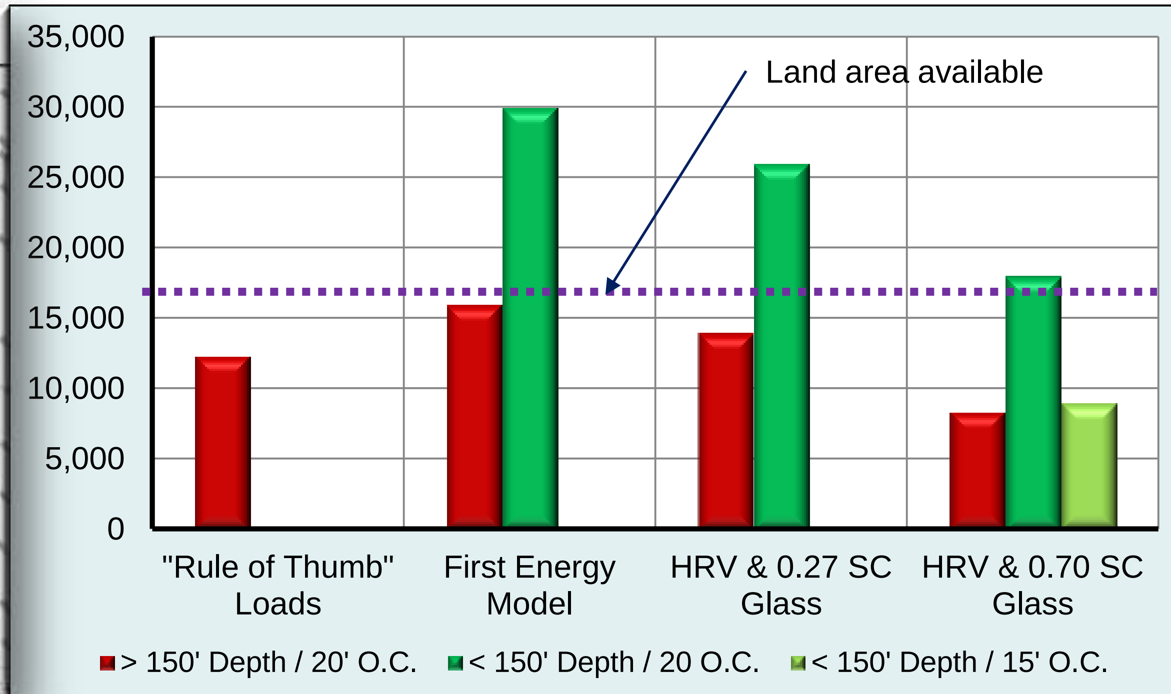
Land area required for GHX

Approximately 17,000 square feet of land are available for construction of the GHX. Space is available to install a GHX for each energy model with boreholes drilled to 250` or greater, but only by installing heat recovery for ventilation air and specifying clear glass can the owner take advantage of boreholes of 150`or less.

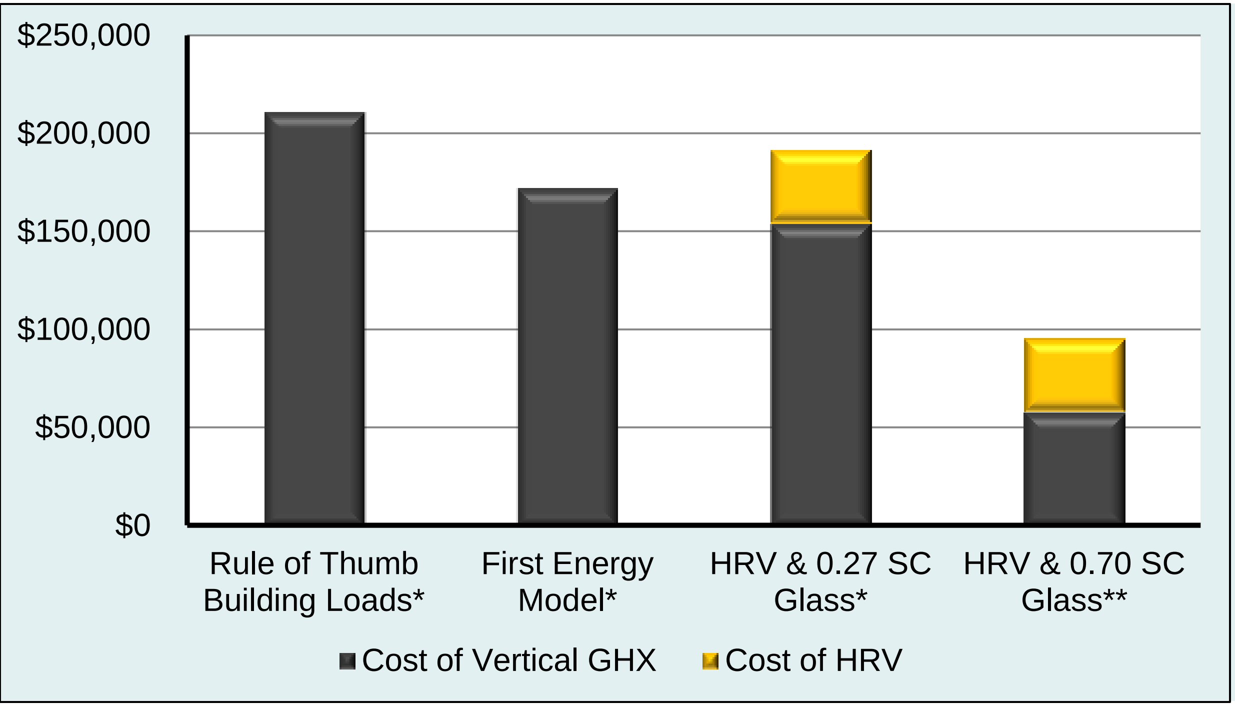




First cost of different energy models

The additional cost of constructing a geothermal system is typically the cost of the GHX.

The design team was asked to add heat recovery to the ventilation air for two of the possible system designs and to change the glass specifications to allow more solar gains. Adding the cost of the HRV increased the cost of the system about $1.00 / sq. ft. Changing the glass specifications slightly reduced the cost.



* Additional cost of geo system based on cost of $11.50 per foot

** Additional cost of geo system based on cost of $7.00 per foot

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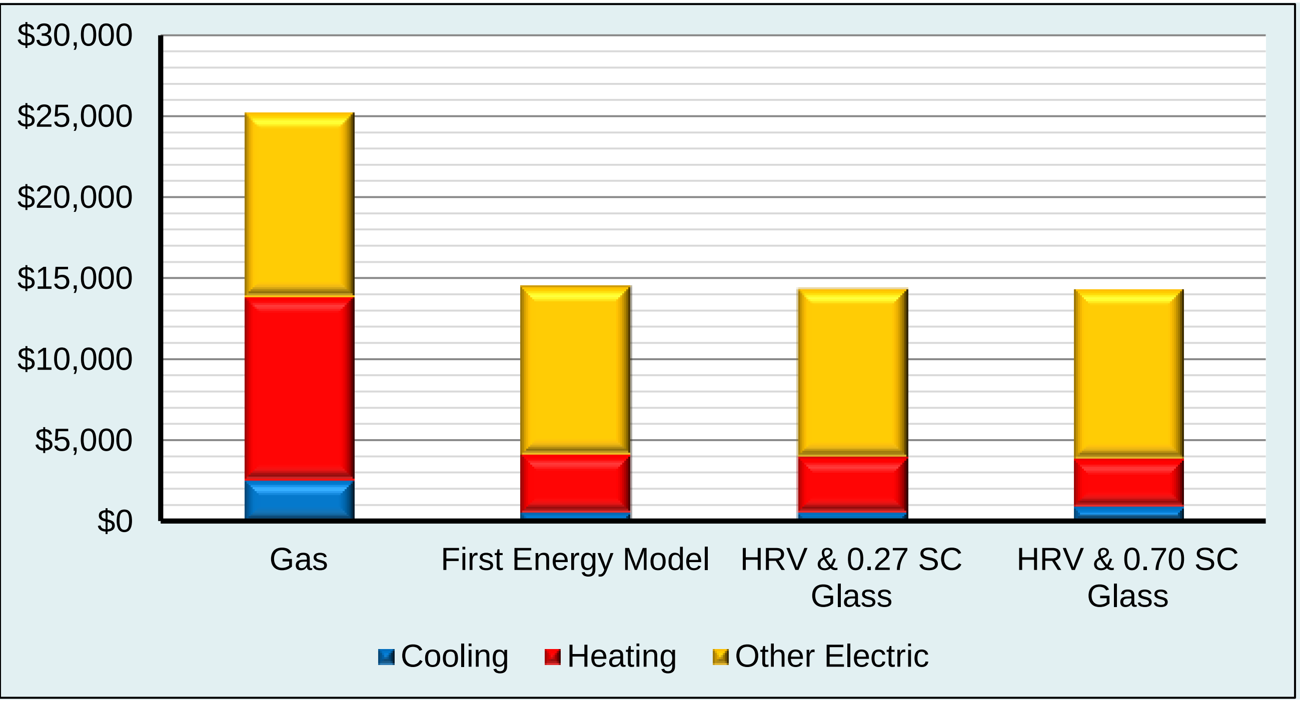
Energy cost for heating, cooling & other electrical loads based on energy models

Total energy costs for three geothermal alternative systems are similar, and show energy cost savings of approximately $11,000 annually compared to the gas system. The geothermal alternative with the HRV & 0.70 SC glass shows higher heating costs and lower cooling costs.

This has an impact on the energy balance and the size & cost of the GHX, and ultimately the payback of the system.



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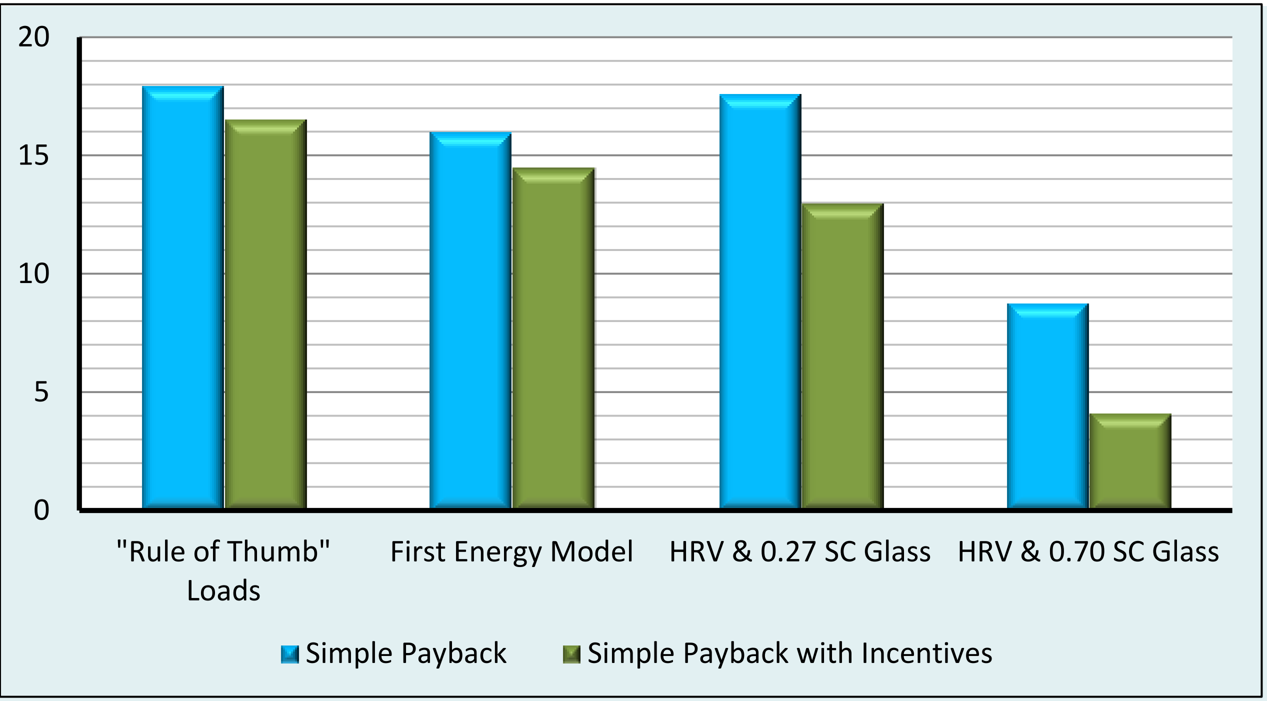
Simple payback of geothermal system with & without incentives

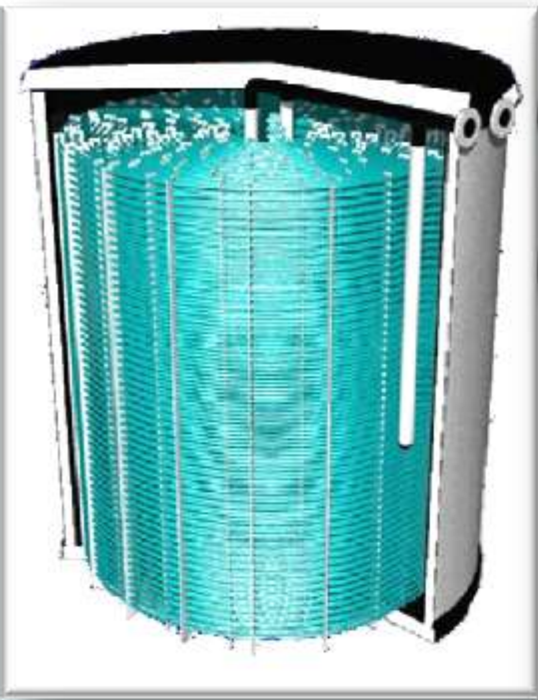
The project can achieve a simple payback without incentives of less than 9 years.

Government and utility incentives reduce the simple payback to approximately 4 years.



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



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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

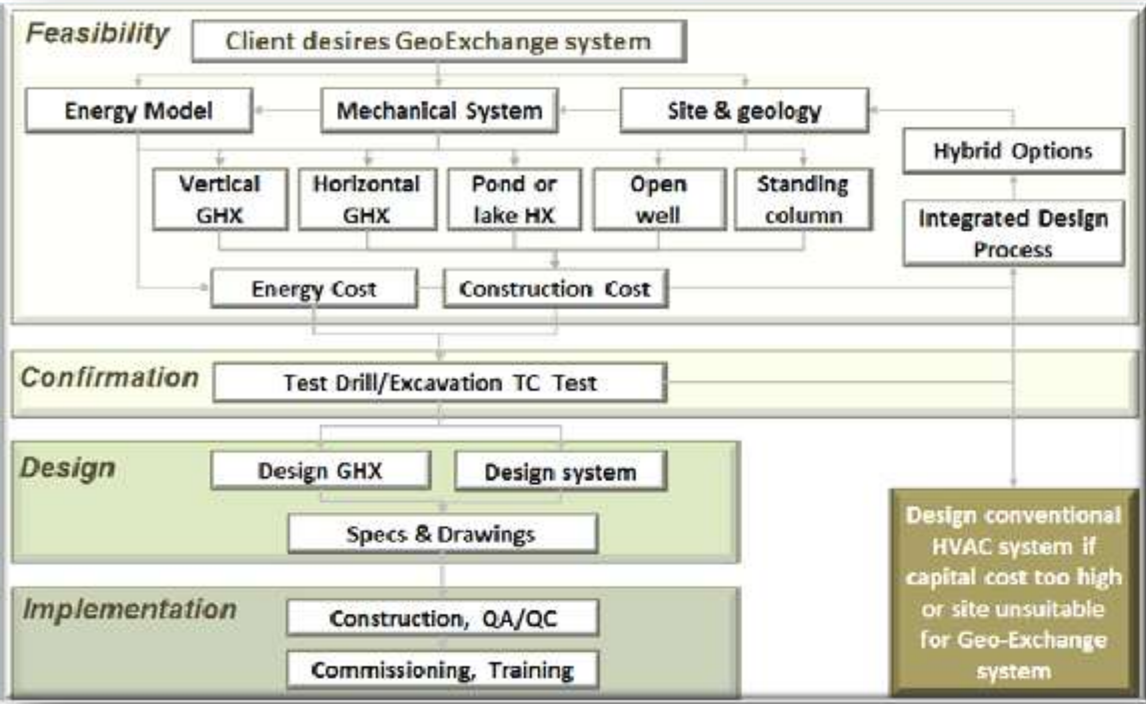
Conclusions

- 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 and working with available contractor resources can result in a GHX that is less expensive to construct and in a much shorter payback for the client

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.



IGSHPA
Down to Earth Energy

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