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Playtime Community Centre - Toronto, ON

About the project

The proposed Scarborough Community Centre, located at Sheppard Avenue and Conlins Road in Toronto, ON, includes an indoor swimming pool, gymnasium, multi-purpose rooms and administrative offices. The City is considering a geothermal heat pump system in place of a conventional gas heating / cooling system in order to meet the City's CO2 emission reduction targets. The installation of a geothermal heat pump system will eliminate the use of fossil fuels on site. This report provides guidance to the City and design team to optimize the size and performance of a ground heat exchanger (GHX) for the system and the impact of energy efficiency measures to the design of the system.

Executive Summary

This report provides an organized comparison of three buildings: a default ASHRAE 90.1 structure with conventional heating and cooling, an energy efficiency optimized structure with conventional heating and cooling, and the same energy efficiency optimized structure with a ground source heat pump system. This report enables decision makers to rationally select an appropriate energy efficiency solution for a particular building.

Table I summarizes the comparison results. It includes the cost of installing the HVAC systems in the three different buildings with the selected energy efficiency measures and any estimated incentives that may be available. Table I also provides energy cost comparisons, and the overall economics associated with the three building configurations.

Table I: Financial and Environmental Summary

Description	Standard ASHRAE 90.1 Building	Optimized Building with Gas Heating	Optimized Building with GSHP
Base System Cost	$2,400,000	$2,400,000	$2,400,000
GHX System Cost	---	---	$432,000
Exhaust Energy Recovery Cost	---	$160,000	$160,000
Upgraded Glass Cost	---	$80,000	$80,000
Total Cost	**$2,400,000**	**$2,640,000**	**$3,072,000**
INCREMENTAL COST	---	**$240,000**	**$672,000**
Heating and Cooling Costs			
Cooling Cost	$51,865	$51,482	$27,317
Heating Cost	$58,362	$22,259	$20,186
Total Heating and Cooling Cost	$110,227	$73,741	$47,502
ANNUAL COST SAVINGS	---	**$36,486**	**$62,725**

Financial Analysis			
Return on Investment [20 years]	---	**18.5%**	**11.3%**
Net Present Value [20 years]	---	**$439,876**	**$496,811**
Simple Payback	---	**6.6 years**	**10.7 years**

CO_2 Reductions			
CO_2 Emissions Produced	**459 tonnes**	**266 tonnes**	**136 tonnes**
Percent CO_2 Emissions Reduction	---	**42%**	**70%**

NOTE: The economics of this project are based on an hourly energy model similar in area and use to the proposed building using Toronto, ON, weather data. The size and cost of the GHX are based on the comparable energy model. By working with the architectural and engineering design teams, other energy efficiency measures may be found that can be integrated to further optimize the design and performance of a GSHP system for this building. This can only be done with an accurate hourly energy model of the specific building and site.

Estimated Energy Consumption

Energy consumption in the facility will vary based on building construction and selected mechanical systems. Changing insulation values, type of glass, lighting, ventilation strategy, etc. will change heating and cooling energy consumption and peak heating and cooling loads. This has an impact on the size and cost of the mechanical system and a larger impact on the size and cost of a ground heat exchanger (GHX).

The estimated energy consumption and peak heating and cooling loads of the proposed facility shown in Figure 1 and Figure 2 are based on a similar community center building that has been re-calculated using Toronto weather data and adjusted to match the size of the proposed building.

NOTE: Developing an accurate hourly energy model of the proposed project requires architectural and engineering drawings and specifications along with building occupation information. The building modifications in this report represent some potential changes and their impact on the size and cost of a GHX required to meet the needs of the building. An experienced designer working closely with your architectural and engineering design team may use iterative energy modeling to further optimize the building GSHP system.

The base energy model for the selected building is built to ASHRAE 90.1 standards for the location. If energy efficiency measures are implemented in the proposed building, heating and cooling loads change. The measures included in this building include:

- Exhaust air energy recovery
- Glass with higher insulating value and lower solar heat gain

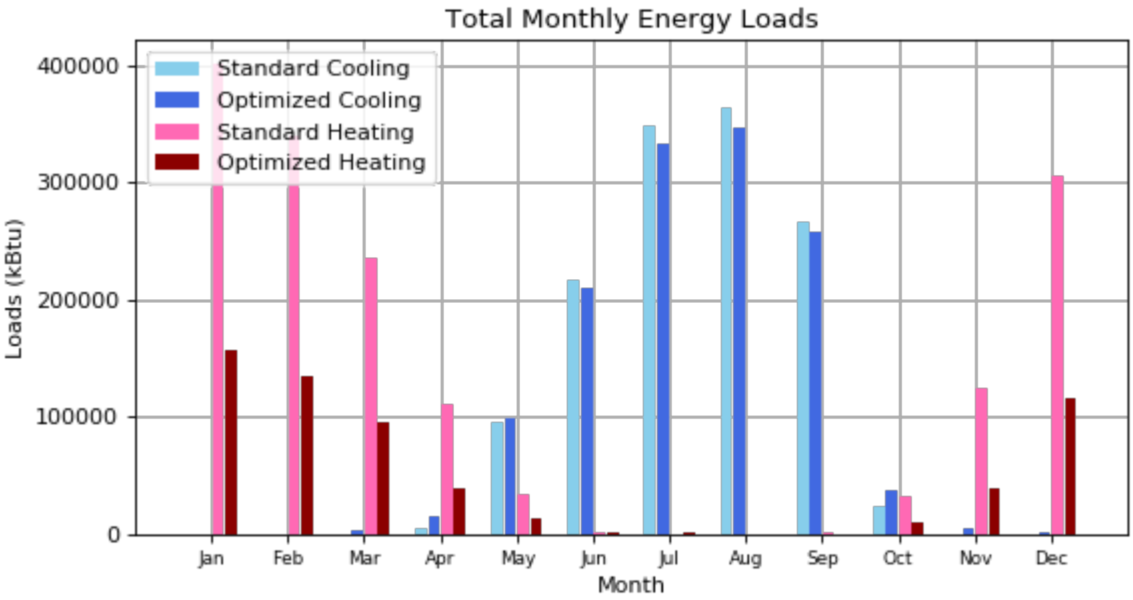

Figure 1: Comparative monthly total heating and cooling energy loads of building constructed to ASHRAE 90.1 efficiency standards and the same building with the impact of a 70% efficient energy recovery ventilation system and glass with higher U-value and lower solar heat gain factor.

Adding exhaust air energy recovery and specifying glass with a higher insulating value and lower solar heat gain reduces energy consumption for both heating and cooling.

- Cooling energy consumption is reduced approximately *0%*
- Heating energy consumption is reduced approximately *61%*

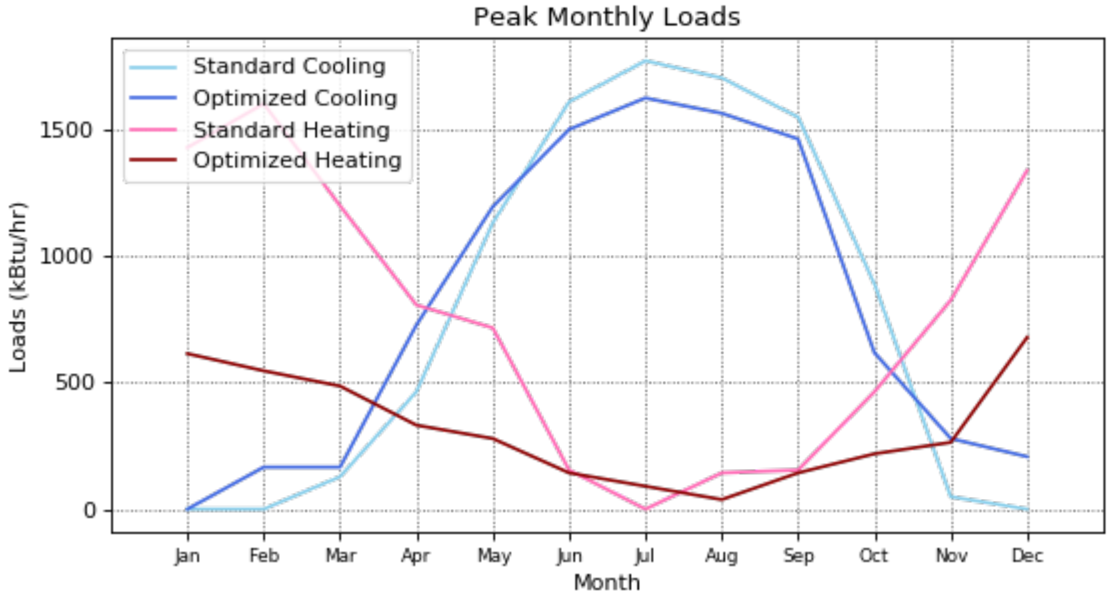

Figure 2: Comparative monthly peak heating and cooling loads of building constructed to ASHRAE 90.1 efficiency standards and the same building with the impact of a 70% efficient energy recovery ventilation system and glass with higher U-value and lower solar heat gain factor.

- Peak cooling load is reduced from 1,773 kBtu/hr to 1,626 kBtu/hr, a reduction of approximately *8%*

- Peak heating load is reduced from 1,603 kBtu/hr to 679 kBtu/hr, a reduction of approximately *57%*

Ground Heat Exchanger (GHX)

Modifying the building and mechanical system design changes the amount of energy rejected to the ground heat exchanger (GHX) when the building is being cooled and the amount of energy extracted from the GHX when the building is being heated. This directly impacts the size and cost of the GHX needed to meet the building energy loads.

The design of the GHX also directly impacts the size and cost of the GHX. The geology, borehole layout and spacing, the grout installed in the borehole and the efficiency of the heat pump equipment connected to the GHX are some of the major factors that affect the size and cost of the system.

Taking some time to review the geology at the site, the land area available for constructing the GHX, and the numerous optimization options for GHX designs can result in significant capital cost savings.

We created an initial GHX design based on the energy loads of the “Standard Building”:

- A 7 x 7 grid borehole layout at a depth of 600 ft
- 15 foot spacing between boreholes
- Medium soil thermal conductivity
- Standard (low) grout thermal conductivity
- Standard-efficiency heat pump equipment

We generated a second GHX design based on the same building that incorporates the “Optimized Building” energy efficiency measures previously described. The new GHX design, based on customized inputs, includes:

- A 2 x 18 grid borehole layout at a depth of 600 ft
- 25 foot spacing between boreholes
- Medium soil thermal conductivity
- High grout thermal conductivity
- High-efficiency heat pump equipment

By implementing the selected energy efficiency measures and optimizing the design of the GHX *the total required amount of borehole decreases from 29,400 ft to 21,600 ft*. At an estimated cost of $20.00 per foot of borehole, this has resulted in a *capital cost saving of $156,000*. The land area required for the optimized GHX design would be approximately *22,500 square feet*, compared to 11,025 square feet for the standard loopfield. Figure 3 compares the size, cost and GHX land area for a building built to ASHRAE 90.1 standards to that of the energy model-optimized building and optimized GHX design.

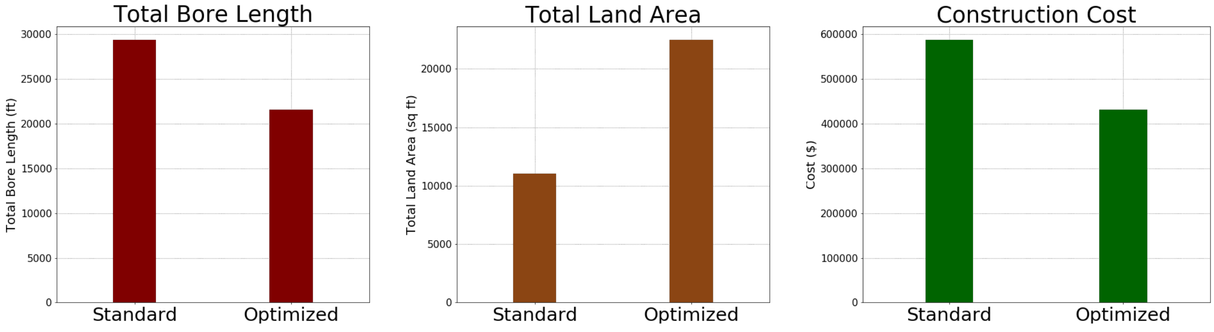

Figure 3: Compares the total amount of drilling, land area required and estimated capital cost of constructing the GHX for the proposed GSHP system at the Playtime Community Centre in Toronto.

The GHX for the 80,000 square foot community center building located in or near Toronto is based on a 20-year temperature prediction. The maximum and minimum temperatures the GHX can be expected to operate at are 85.6°F in summer and 40.9°F in winter. Table II presents the GHX-related results summarized in a more organized format.

Table II: GHX Summary

Description	Standard ASHRAE 90.1 Building	Optimized Building
Soil Thermal Conductivity [Btu/(h·ft·°F)]	Medium	
Total Borehole Length	**29,400 ft**	**21,600 ft**
Borehole Length	600 ft	600 ft
Number of Boreholes	49	36
Grid Pattern	7 x 7	2 x 18
Spacing between Boreholes	15 ft	25 ft
Approximate Land Area Required	11,025 ft^2	22,500 ft^2
Grout Thermal Conductivity [Btu/(h·ft·°F)]	Standard	High
Maximum Expected Temperature	**84.3 °F**	**85.6 °F**
Minimum Expected Temperature	**33.7 °F**	**40.9 °F**

NOTE: The preliminary GHX design considers changes to the GHX resulting in a significant reduction in the size of the GHX. A review of the geology and unique features of your specific project may reveal additional opportunities that may result in further capital cost and energy consumption reductions.

GSHP Project Environmental Impact

A GSHP system eliminates or reduces the amount of fossil fuel used for heating and generating hot water. GSHP systems reject heat more efficiently than air-cooled condenser or evaporative cooling tower systems, thereby reducing onsite greenhouse gas emissions. Figure 4 compares the predicted CO_2 emissions from the proposed building built to ASHRAE 90.1 standards with gas heating and conventional cooling, versus the same gas-heated building utilizing the user-selected energy efficiency measures, versus the same efficient building heated and cooled with a GSHP system.

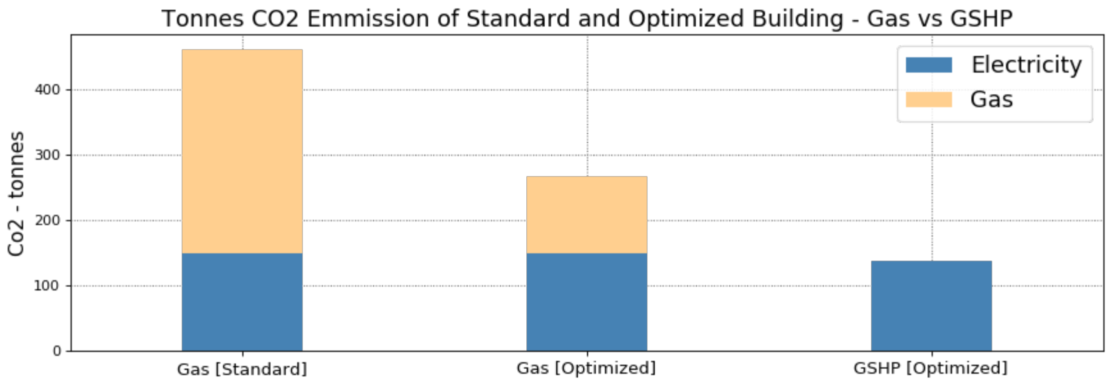

Figure 4: Compares CO_2 emissions from the proposed community center building with gas heating and conventional cooling built to ASHRAE 90.1 standards, versus the same gas-heated building including energy efficiency measures, versus the same community center building with the same energy efficiency measures but heated and cooled using a GSHP system.

Conclusion

The installation of energy recovery ventilation system and glass with higher U-value and lower solar heat gain coefficient reduces energy consumption and cost and reduces the size and cost of the GHX required to service the heating and cooling loads of the facility. Eliminating the use of fossil fuels on the site for space conditioning, pool heating and domestic hot water production shows a reduction in CO2 emissions of approximately 70%, compared to a reduction of 42% with high-efficiency gas boilers and chillers.