THOMPSON CITY HALL - FEASIBILITY OF INSTALLING A GEOTHERMAL HEAT PUMP SYSTEM

Prepared For:

City of Thompson

Thompson, MB

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EXECUTIVE SUMMARY

The Thompson City Hall is approximately 26,500 square feet in size. The building was completed in 1970. It is currently heated with electric resistance heat. Total energy costs have averaged approximately $48,000 annually for the last two years.

The building was built with large areas of glass. The City also wishes to determine the effect of retrofitting the glass in the building with a variety of more efficient window types.

Fresh air is currently provided directly to the building without heat recovery from the exhaust air. The building simulations were completed on the building as it currently is, with additional simulations taking into account the effect of room heat recovery from the exhaust air.

The addition of heat recovery from the exhaust air reduces the overall building heating costs by approximately 8%, or $1,800 annually.

The estimated energy cost of the building was simulated with five different types of glass. Dual and triple pane glass was simulated, as was tinted and clear glass with low-E coatings. Because of the colder climate the building is located in, it is advantageous to use clear glass rather than tinted or reflective glass. Clear glass allows greater solar gains that help contribute to the heating of the building. The comfort of the occupants, however, should be considered when the type of glass is selected. Clear, dual pane glass reduces the building loads by approximately $7,240 annually, or by approximately 29%.

The main effect of reducing the building heating and cooling loads is the reduction of the size and cost of the ground heat exchanger required for this building. The equipment capacity is reduced by approximately 12 tons, or about 22%. The size of the ground heat exchanger is reduced by approximately 26% compared to leaving the existing glass in place and continuing to operate the building without room heat recovery from the exhaust air.

The cost of heating and cooling the building is reduced by approximately 65% compared to heating the building with electric resistance heating. If only the geothermal system is installed and the existing glass and ventilation system is maintained, energy cost savings are estimated at slightly less than $16,000 annually. If heat recovery is added to the exhaust air and the glass is replaced, energy cost savings are estimated at $11,100 annually.

This building will qualify for incentives from the Manitoba Hydro Power Smart program of approximately $26,000 to $32,000.

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1. INTRODUCTION

The City of Thompson wishes to determine the feasibility of installing a geothermal heating and cooling system in the existing City Hall, and has asked Geo-Xergy Systems Inc. to calculate the heating and cooling loads of the building.

The City Hall was built in 1970. The facility includes office space and meeting rooms on three levels and is linked to a fire hall. The total area of the building is approximately 26,500 square feet in area, with office space and meeting rooms encompassing approximately 22,300 square feet and the fire hall approximately 4,200 square feet.

The glass walls of the office building are to be replaced. The City wishes to determine the impact of installing glass with a higher insulating value on the heating and cooling costs of the facility.

The City Hall currently utilizes air handlers with electric resistance heating and with external chillers for cooling, and perimeter electric resistance heat in selected zones. The Fire Hall is heated using 3 duct heaters.

2. ENERGY ANALYSIS

The size of a ground heat exchanger (GHX) is directly affected by the peak heating and cooling loads of the building as well as the annual amount of energy that must be extracted from the GHX when the building is being heated and how much energy must be rejected to the GHX when the building is being cooled.

Electricity bills for the last two years are shown on the following table. The actual energy consumption has been used to compare the projected energy consumption of the building based on the calculated heating and cooling loads to ensure a reasonable degree of accuracy.

	Cost	kWh	kVA
2007	$45,960	838,580	258
2008	$48,481	911,400	242
Average	**$47,221**	**874,990**	**250**

Building plans provided by the City were used to calculate the heating and cooling loads for the building. Additional information provided by the City included:

- A series of photos of the inside of the building as well as photos of the building from outside the structure
- Information about the lighting and electrical plug load in the building
- Information about the occupancy of the building, including an estimated number of people and hours of use.

This information was used to develop a building simulation model to calculate the peak heating and cooling loads and the monthly energy. The heating and cooling loads of the building were simulated in several different scenarios. Heat recovery is for room exhaust air only.

- The building, assuming the current glass is maintained and the fresh air is supplied directly to the building without heat recovery from the ventilation air.

- The building assuming the current glass is maintained but the fresh air is supplied to the building with ventilation air heat recovery at 60% efficiency.
- The building retrofitted with dual-pane, air filled, Low-E tinted glass and fresh air is supplied to the building with ventilation air heat recovery at 60% efficiency.
- The building retrofitted with triple-pane, air filled, Low-E tinted glass and fresh air is supplied to the building with ventilation air heat recovery at 60% efficiency.
- The building retrofitted with dual-pane, argon filled, Low-E clear glass and fresh air is supplied to the building with ventilation air heat recovery at 60% efficiency.
- The building retrofitted with triple-pane, air filled, Low-E clear glass and fresh air is supplied to the building with ventilation air heat recovery at 60% efficiency.

A series of building energy simulation models was developed with the different types of glass to determine the effect on the building loads and annual energy consumption. This information is tabulated in the following tables.

Cooling	Existing Glass (no HRV)	Existing Glass (with HRV)	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Jan	853	1,090	913	825	1,989	1,593
Feb	2,434	2,649	1,739	1,216	4,752	3,674
Mar	8,180	8,431	5,145	3,110	13,291	10,458
Apr	14,674	14,991	9,481	5,674	22,623	18,274
May	39,717	39,929	29,636	21,838	48,525	42,147
Jun	53,669	53,796	41,637	32,522	61,608	54,725
Jul	73,396	73,380	59,080	48,400	79,647	72,269
Aug	72,652	72,531	58,409	48,344	77,633	70,636
Sep	23,121	23,389	17,917	14,026	28,776	25,152
Oct	6,685	7,158	5,516	4,413	9,818	8,371
Nov	2,800	3,178	2,507	2,098	4,214	3,601
Dec	760	985	912	879	1,553	1,289
Total kBtu	**298,942**	**301,508**	**232,893**	**183,346**	**354,430**	**312,190**

Heating	Existing Glass (no HRV)	Existing Glass (with HRV)	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Jan	275,486	255,262	214,939	198,434	192,881	191,399
Feb	207,829	190,010	161,769	151,141	142,826	142,263
Mar	158,873	142,278	122,974	116,610	105,974	106,308
Apr	86,891	78,921	68,821	66,192	58,140	58,450
May	28,045	25,516	22,464	21,818	19,414	19,560
Jun	10,123	8,897	7,987	7,798	7,366	7,383
Jul	3,393	2,979	2,939	2,936	2,953	2,953
Aug	3,005	2,424	2,153	2,120	2,075	2,070
Sep	28,611	26,267	21,065	19,626	15,879	16,066
Oct	79,298	74,060	60,606	55,733	49,961	50,033
Nov	149,883	136,546	113,501	104,350	99,898	99,130
Dec	259,502	240,337	200,596	184,418	180,493	178,551
Total kBtu	**1,290,939**	**1,183,497**	**999,813**	**931,176**	**877,858**	**874,167**
kWh	**378,353**	**346,863**	**293,029**	**272,912**	**257,286**	**256,204**
Est. Heating Cost	**$22,701**	**$20,812**	**$17,582**	**$16,375**	**$15,437**	**$15,372**

Using this information, the cost of heating and cooling the building can be estimated by multiplying the kWh times the cost per kWh.

The building modeling software also calculates the peak heating and cooling loads on a monthly basis, as well as the estimated number of hours the heating and cooling systems will need to operate annually. This information is tabulated in the following tables.

Cooling	Existing Glass (no HRV)	Existing Glass (with HRV)	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Jan	38	38	20	12	60	47
Feb	90	90	57	39	106	90
Mar	111	111	76	50	140	120
Apr	140	140	101	70	160	140
May	337	331	278	239	322	303
Jun	311	308	248	208	295	274
Jul	389	382	322	280	366	346
Aug	361	353	297	261	342	322
Sep	317	312	254	218	299	281
Oct	107	107	79	58	128	112
Nov	77	78	52	36	97	83
Dec	21	21	12	12	43	33
Annual Hours	768	789	723	655	968	902
Cooling kWh*	**32,385**	**32,663**	**25,230**	**19,862**	**38,397**	**33,821**
Est. Cooling Cost	**$1,943**	**$1,960**	**$1,514**	**$1,192**	**$2,304**	**$2,029**

Heating	Existing Glass (no HRV)	Existing Glass (with HRV)	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Jan	696	662	565	527	542	533
Feb	564	547	467	435	447	438
Mar	509	492	433	406	414	405
Apr	463	429	383	361	332	337
May	275	265	244	230	187	197
Jun	178	172	146	142	102	103
Jul	72	72	71	71	71	71
Aug	89	88	86	89	77	77
Sep	274	259	234	223	218	218
Oct	359	340	305	287	278	285
Nov	444	434	383	360	359	356
Dec	574	556	474	441	452	443
Annual Hours	**1,855**	**1,789**	**1,769**	**1,767**	**1,620**	**1,640**

Heating & Cooling Costs	Existing Glass (no HRV)	Existing Glass (with HRV)	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Cooling	$1,943	$1,960	$1,514	$1,192	$2,304	$2,029
Heating	$22,701	$20,812	$17,582	$16,375	$15,437	$15,372
Total Estimated Cost	**$24,644**	**$22,772**	**$19,096**	**$17,566**	**$17,741**	**$17,401**

From experience we have found that when a building is heated with electric resistance heat, as the City Hall is, approximately 50% of the total electrical consumption is used to provide space heating and cooling.

The electrical consumption predicted in the building modeling software corresponds well with the actual electrical consumption. The predicted consumption shows the heating cost to be slightly lower than 50% of the actual electricity costs.

3. GEOTHERMAL SYSTEM COMPARISONS

There are several benefits for the owners of a building when a geothermal system is installed. The primary benefit is the reduction in heating and cooling costs. A second benefit is the elimination of outdoor condensing units or cooling towers to provide air conditioning.

Both heating and cooling costs are reduced with the installation of a geothermal system. Electric resistance heating operates at a coefficient of performance (COP) of 1.0. For every unit of electricity that is purchased, one unit of energy is converted to heat for the building. A geothermal system transfers heat from the ground to the building in the heating mode. A well designed geothermal system operates at a COP of 3.2 to 3.5. That means that every unit of electricity purchased by the building owner provides 3.2 to 3.5 units of heat to the building. One unit is used to operate the compressors and pumps while 2.2 to 2.5 units of energy are extracted from the ground.

Air conditioning provides energy cost savings of approximately 40% to 50% compared to conventional air cooled condensers. The following table shows the estimated energy cost savings that can be realized by installing a geothermal system in this facility.

Heating & Cooling Costs	Existing Glass (no HRV)	Existing Glass (with HRV)	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Electric Heating & Cooling	$24,644	$22,772	$19,096	$17,566	$17,741	$17,401
Geothermal Heating & Cooling	$8,688	$8,068	$6,734	$6,146	$6,475	$6,295
Total Estimated Cost Savings	**$15,956**	**$14,704**	**$12,362**	**$11,421**	**$11,266**	**$11,107**

The capacity of the heat pump equipment required for the building is dependent on the type of glass selected for the building, the size and cost of the ground heat exchanger (GHX) and the heating and cooling loads that will be expected. Ground Loop Design software was used to model the size of both a horizontal and vertical GHX required.

4. GHX CONSTRUCTION

The results from the building energy analysis software were used to determine the energy requirements from the ground. In addition to the energy loads that were calculated, the software requires additional input for:

- The type of soil/rock available to construct the GHX
- The land area available for the construction of the GHX
- The estimated natural ground temperature
- The moisture content of the soil

This information is not available without drilling a test borehole for a vertical GHX or a test excavation for a horizontal GHX.

The size of various GHX configurations required with the different building energy analyses were modeled using GLD Ground Loop Design software. Three different GHX configurations were modeled because the ground conditions vary significantly in the Thompson area. The land area available on site may allow the installation of a shallow vertical GHX (less than 100' depth) or the installation of a horizontally bored GHX. The configurations include:

- Deep vertical GHX: Drilling through the overburden into the underlying bedrock (granite)
- Shallow vertical GHX: Some areas in Thompson have up to 80-100' of clay overburden, and may allow the installation of a shallow vertical borehole field.
- Horizontal bore GHX: The ground conditions may allow the installation of a horizontally bored GHX or trenched GHX.

The following table summarizes the capacity of the heat pump equipment required and the size of the GHX required. *(Please note these are preliminary estimates of the equipment and GHX required for the system. A review of the ground conditions and of the building heating and cooling distribution system must be conducted before an accurate assessment can be made.)*

	Existing Glass (no HRV)	Existing Glass (with HRV)	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Equipment Capacity Required	54-60 tons	52-58 tons	45-51 tons	42-46 tons	42-46 tons	42-46 tons
Vertical GHX in Granite	15,100’	14,200’	12,200’	11,500’	11,100’	11,100’
Vertical GHX in Clay	24,100’	22,700’	19,500’	18,300’	17,600’	17,600’
Horizontal GHX in Clay	42,900’	40,500’	34,700’	32,700’	31,800’	31,600’

The following assumptions were made to develop the configurations of the various GHX types modeled for this building:

	Vertical GHX in Granite	Vertical GHX in Clay	Horizontal Bore GHX
Thermal Conductivity	1.50	0.80	0.80
Thermal Diffusivity	1.20	0.60	0.60
Ground Temperature	44ºF	44ºF	44ºF
Number of Boreholes	48	240	60
Borehole Spacing	30’	15’	10’
Borehole spacing (vertical)	n/a	n/a	4’
Pipe size	1” SDR11	0.75” SDR11	0.75” SDR11
Grout Conductivity	0.85	0.45	0.45
Prediction time	15 years	1 year	1 year

The cost of a GHX varies depending on the drilling conditions encountered. The following table provides an estimate of the cost of the various GHX configurations for this building.

	Existing Glass (no HRV)	Existing Glass (with HRV)	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Estimated Equipment Cost	$132-152,000	$130-150,000	$115-135,000	$105-125,000	$115-135,000	$115-135,000
Vertical GHX in Granite	$300-360,000	$284-340,000	$244-293,000	$230-276,000	$222-266,000	$222-266,000
Vertical GHX in Clay	$169-217,000	$159-204,000	$136-175,000	$128-165,000	$123-158,000	$123-158,000
Horizontal GHX in Clay	$150-193,000	$142-182,000	$121-156,000	$115-147,000	$112-143,000	$111-142,000

5. ENERGY REDUCTION MEASURES

The building energy loads have been modeled in several ways. These include:

- The building as it currently exists. The building currently has dual pane glass and is ventilated without heat recovery from the ventilation air
- Alternative 1: Room heat recovery has been added to the ventilation air (60% efficiency) and the existing glass is left in place.
- Alternative 2: Glass has been replaced with dual pane, low-E, tinted glass with air in the space between the glass. Room heat recovery has been added to the ventilation air.

- Alternative 3: Glass has been replaced with triple pane, low-E, tinted glass with air in the space between the glass. Room heat recovery has been added to the ventilation air.
- Alternative 4: Glass has been replaced with dual pane, low-E, clear glass with argon in the space between the glass. Room heat recovery has been added to the ventilation air.
- Alternative 5: Glass has been replaced with triple pane, low-E, clear glass with air in the space between the glass. Room heat recovery has been added to the ventilation air.

Clear glass was modeled in two of the alternatives. Clear glass allows more solar gains into the building. These alternatives increase the solar gains in the building during the summer, increasing the cooling loads, but the winter time solar gains reduce the heat loss and energy consumption during the winter. This slightly reduces the overall energy consumption for the building.

An estimated cost of supplying the glass (delivered to the site) in this building has been estimated as follows:

	2-Pane Low E Air Tinted	3-Pane Low-E Air Tinted	2-Pane Low-E Argon Clear	3-Pane Low-E Air Clear
Estimated Glass Cost	$27.50 / sq. ft.	$33.75 / sq. Ft.	$27.50 / sq. ft.	$33.75 / sq. ft.

The information was supplied by Duxton Windows and Doors of Winnipeg.

6. CONCLUSIONS

Significant energy consumption and cost reductions are available in this building by adding heat recovery to the ventilation air for the building. Adding ventilation air room heat recovery reduces energy cost by approximately $2,000 per year.

Additional energy cost savings can be realized by replacing the existing glass in the building with glass with better insulating qualities. In this building with the cold climate, there is an advantage in replacing the glass with clear glass to increase the winter solar gains. This helps reduce the building loads and in turn reduces the size and cost of the GHX.

7. RECOMMENDATIONS

To confirm the results of this analysis and provide accurate costing for the installation of the GHX for this building, the ground conditions of the land area available for the construction of a GHX must be confirmed.

A horizontal GHX is typically the most cost-effective configuration of GHX. Several test pits excavated with a backhoe to a depth of 15-16’ are recommended in different locations of the proposed horizontal GHX field (if the City has excavation equipment available to excavate approximately 4 test pits, this can be very cost-effective). A site visit will be required to determine the thermal conductivity of the ground in the area.

If the space is not available to install a horizontal GHX, it is recommended that a test borehole be drilled. This will determine if it is possible to install a vertical GHX drilled only into the clay overburden, or if deeper holes drilled into the underlying bedrock will be required. A minimum depth of approximately 50' of overburden will be required for the installation of a shallow vertical GHX into the overburden.

If bedrock is encountered at a shallower depth on site, and enough space is unavailable to install a horizontal GHX, a vertical borehole GHX drilled into bedrock will be required. A test borehole will be required and it is recommended that a thermal conductivity test be completed. The cost of conducting a thermal conductivity test will be approximately $12,000 plus the cost of a test borehole to a depth of approximately 250-300' (approximately $5,000 to $6,000). This borehole can be used as part of the GHX if it is located appropriately.

8. CLOSURE

Please do not hesitate to contact the undersigned if you have questions or if the information provided herein requires clarification.

Yours truly,

Geo-Xergy Systems Inc.

Ed Lohrenz, BES. C.G.D.
Partner