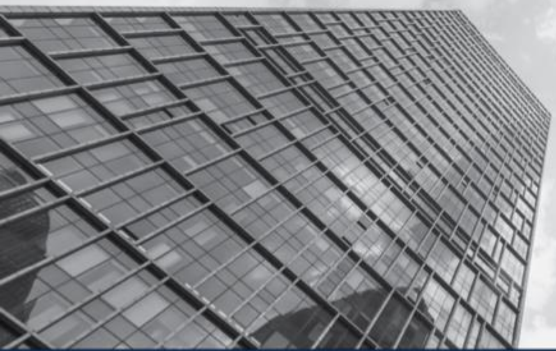

FROM THE GROUND UP
OGA CONFERENCE 2018
February 27 - 28 | The Westin Toronto Airport | Toronto, ON

Geo-Exchange w/ Solar Thermal



Evergreen Brickworks Building 16

A Brookfield Company

Overview

- Introduction
- Initial Assessment
- Evergreen Campus and Building 16
- Project Goals
- Project Obstacles
- Modelling and Evaluation
- Systems Overview
- Lessons Learned
- Final Outcome

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Evergreen Brickworks Site

- BGIS provided a campus wide Carbon Neutral assessment and roadmap

- Reviewed all existing buildings accounting for preliminary plans for the Building 16 renovation

- Determined that some combination of a geo-exchange heat pump system and renewables were required to reduce/eliminate the reliance on natural gas

- BGIS Carbon Neutral Assessment was used to obtain grants and incentives to undertake this capital intensive project

Enhanced Envelope opportunities were identified to reduce energy use by 13% at a cost of $2,600,000	Eliminates **66 tons** of carbon emissions
HVAC opportunities, including a ground source heat pump system, were identified to reduce energy use by 23% at a cost of $1,120,000	Eliminates **116 tons** of carbon emissions
Lighting opportunities were identified to reduce energy use by 5% at a cost of $125,000	Eliminates **3 tons** of carbon emissions
Operational opportunities were identified, including plug load reduction strategies, to reduce energy by 5% at a cost of $100,000	Eliminates **2 tons** of carbon emissions
Biofuel opportunities were identified to reduce energy use by 4% at a cost of $200,000	Eliminates **23 tons** of carbon emissions
Controls Upgrades and Optimization opportunities were identified to reduce energy use by 7% at a cost of $100,000	Eliminates **17 tons** of carbon emissions
Domestic Hot Water opportunities were identified at a cost of $25,000. No energy savings are realized.	Eliminates **18 tons** of carbon emissions
Solar PV and Thermal opportunities were identified to reduce energy use by 28% at a cost of $1,900,000	Eliminates **95 tons** of carbon emissions

Building 16 - Project Goals

- Near Carbon Neutral Building
- First step in Near Carbon Neutral Campus
- Promote education in sustainability and renewables via the space
    - Visible system within building
- Extensive use of renewables
- Maximize all available funding avenues

Evergreen Brickworks – Building 16

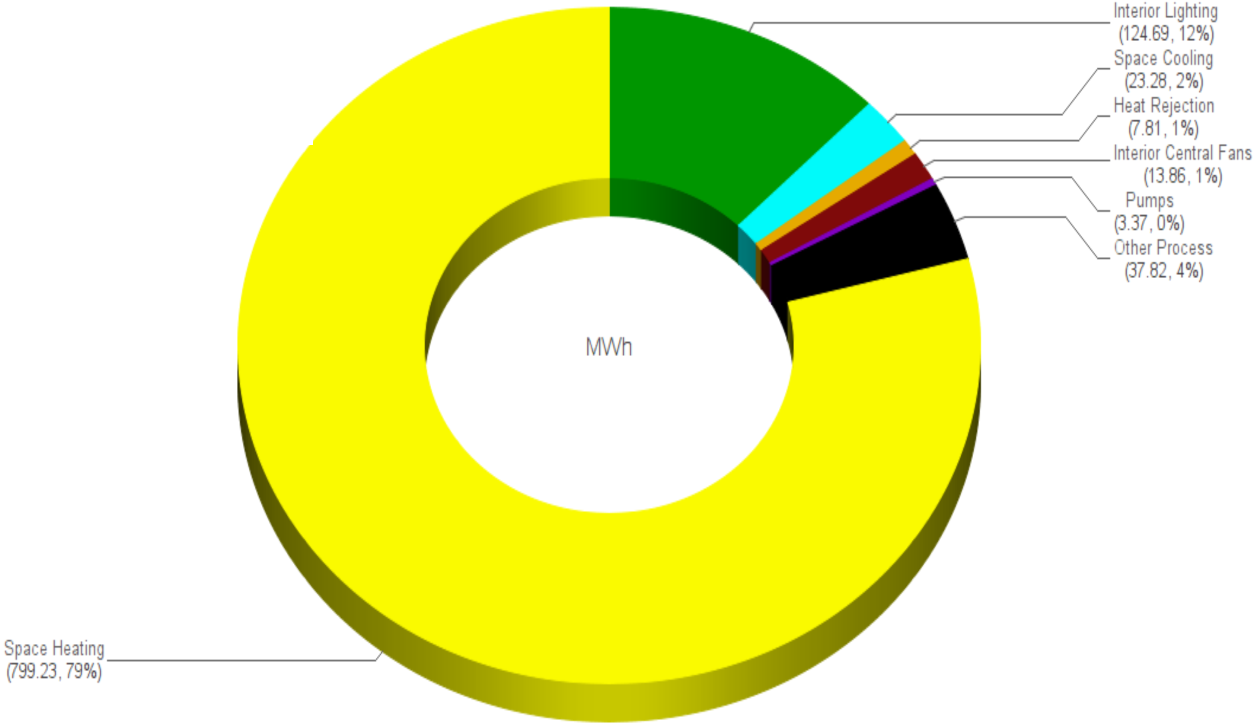
A summary of the building heating and cooling requirements is as follows:

Peak heating load – 1578 kBTU/hr

Peak cooling load – 488 kBTU/hr

Total annual heating demand – 3431 MBTU

Total annual cooling demand – 188 MBTU



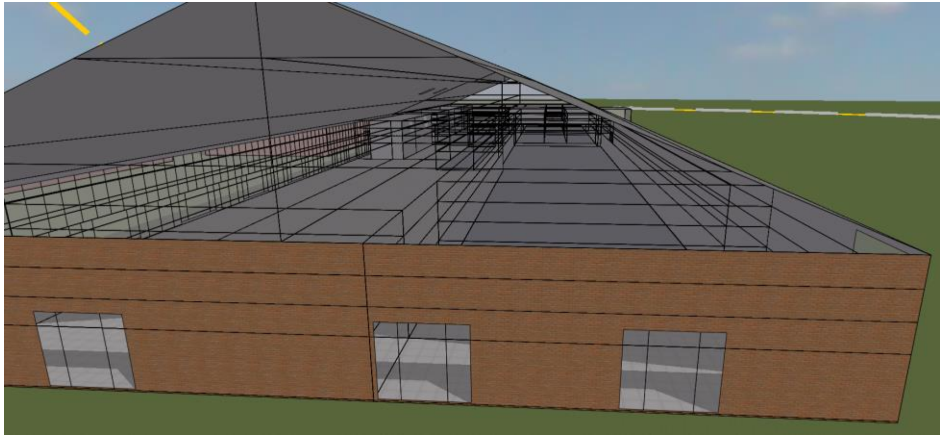
Major Project Obstacles

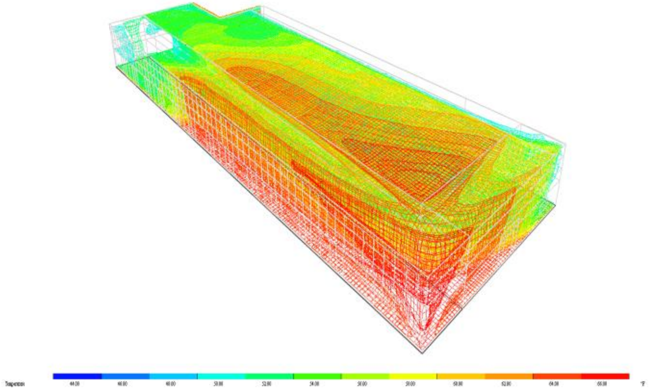
- Uninsulated old brick building
- Uninsulated Roof
- Roof structure
- Heritage building
- Building directly in flood plane
- Bore field spatial limitations

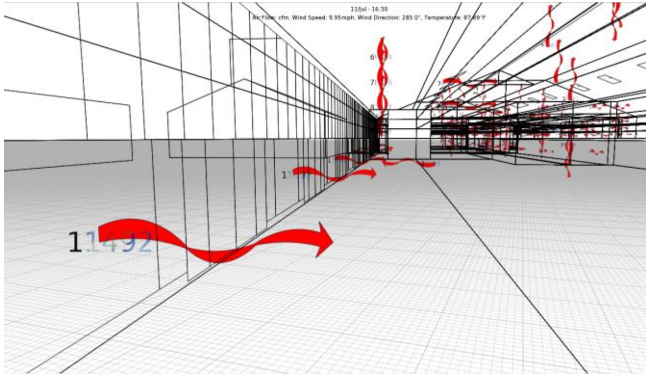
Modelling and Evaluation

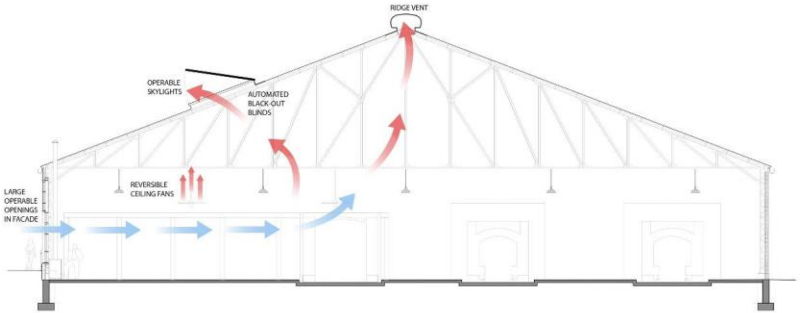
- Building modelled using IES
  - Loads calculated
  - CFD Analysis
  - Dry bulb vs. perceived temperature analysis
- Geo-source Analysis – HGS and Solar Tomorrow
  - Preliminary solar thermal investigation
  - Borefield sizing
  - Borefield temp vs. time
  - Solar Thermal array sizing
  - NPC analysis

Modelling Phase 1 - IES Model

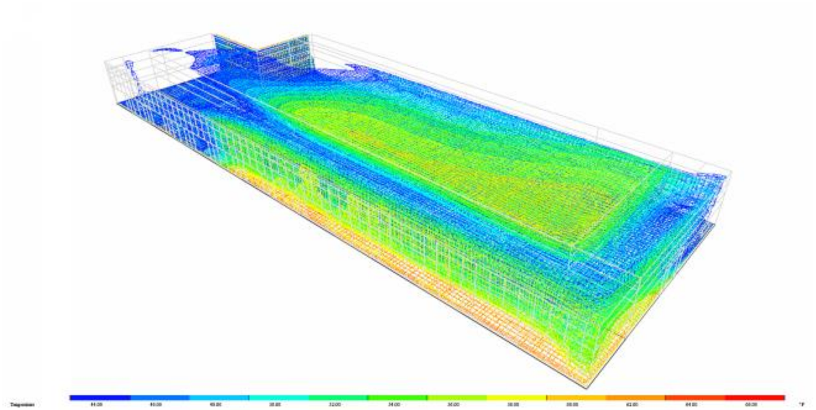




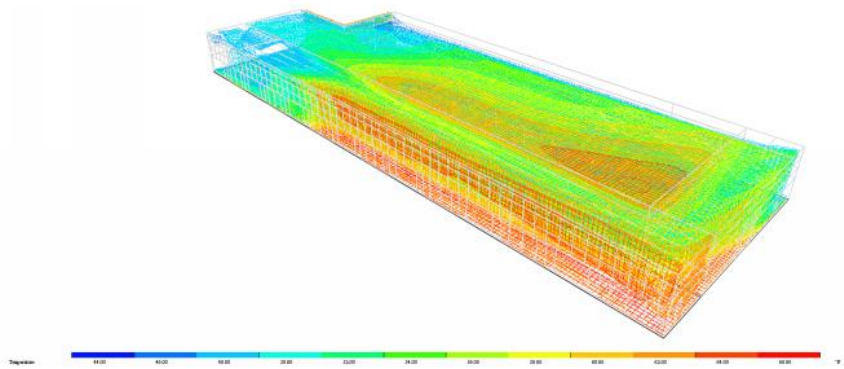




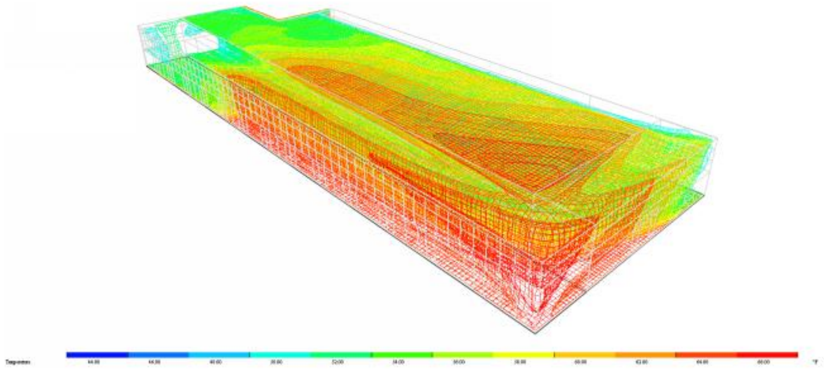
9.1 Event Space CFD Analysis for R0



9.2 Event Space CFD Analysis for R5



9.3 Event Space CFD Analysis for R20



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Modelling Internal Temperatures:

- The facility would be tempered in the colder months
- Analyzed Dry Bulb and Dry Resultant temperatures of each space within the facility
- Variables:
  - Floor temperature
  - Roof insulation R values

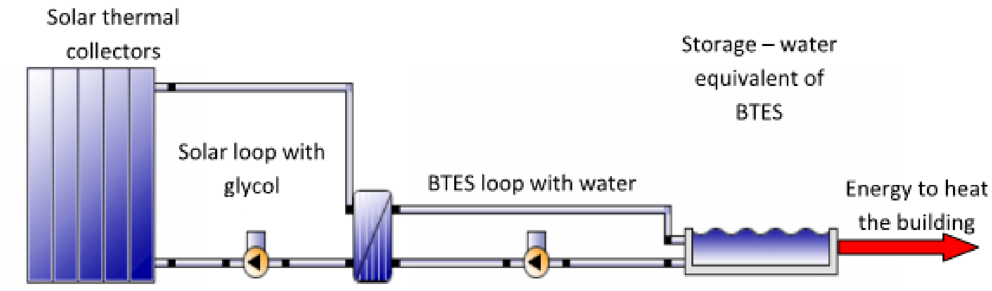
6. Zone temperature analysis with radiant floor heating/cooling and different roof insulation scenario

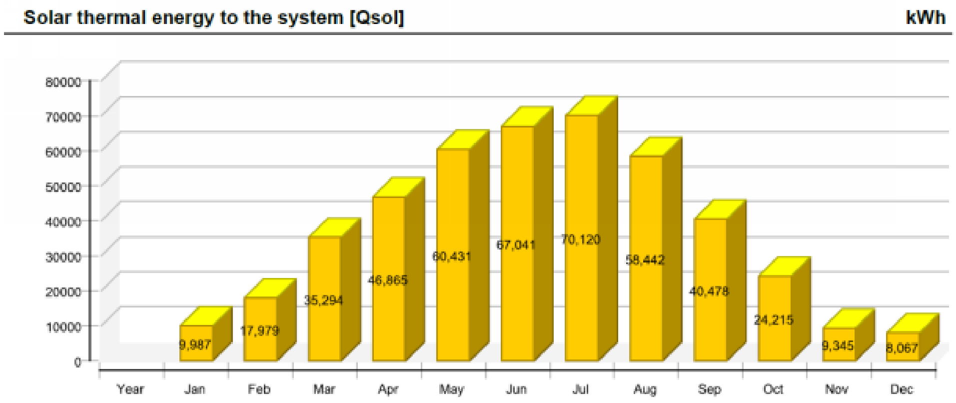
6.1 Event Space Temperature profile depending on the month and on the roof insulation.

Event Space		Room Dry Bulb Temperature (°F)			Room Dry Resultant Temperature (°F)		
Month	Occupied desired Air Temperature SP (Heating, Cooling)	DB Max, Mean, Min, R0	DB Max, Mean, Min, R5	DB Max, Mean, Min, R20	DR Max, Mean, Min, R0	DR Max, Mean, Min, R5	DR Max, Mean, Min, R20
January	66°F(18.9°C), 80.6°F(27°C)	42°F(5.6°C), 36°F(2.2°C), 30°F(-1.1°C)	52°F(11.1°C), 49°F(9.4°C), 46°F(7.8°C)	55°F(12.8°C), 53°F(11.7°C), 51°F(10.6°C)	53°F(11.7°C), 47°F(8.3°C), 41°F(5°C)	62°F(16.7°C), 57°F(13.9°C), 53°F(11.7°C)	65°F(18.3°C), 62°F(16.7°C), 54°F(12.2°C)
February	66°F(18.9°C), 80.6°F(27°C)	52°F(11.1°C), 46°F(7.8°C), 41°F(5°C)	59°F(15°C), 56°F(13.3°C), 54°F(12.2°C)	61°F(16.1°C), 60°F(15.6°C), 58°F(14.4°C)	62°F(16.7°C), 55°F(12.8°C), 50°F(10°C)	68°F(20°C), 63°F(17.2°C), 60°F(15.6°C)	70°F(21.1°C), 67°F(19.4°C), 64°F(17.8°C)
March	66°F(18.9°C), 80.6°F(27°C)	57°F(13.9°C), 53°F(11.7°C), 49°F(9.4°C)	60°F(15.6°C), 59°F(15°C), 58°F(14.4°C)	63°F(17.2°C), 62°F(16.7°C), 61°F(16.1°C)	63°F(17.2°C), 60°F(15.6°C), 57°F(13.9°C)	67°F(19.4°C), 66°F(18.9°C), 64°F(17.8°C)	69°F(20.6°C), 67°F(19.4°C), 66°F(18.9°C)
April	66°F(18.9°C), 80.6°F(27°C)	68°F(20°C), 62°F(16.7°C), 58°F(14.4°C)	70°F(21.1°C), 69°F(20.6°C), 67°F(19.4°C)	70°F(21.1°C), 69°F(20.6°C), 68°F(20°C)	73°F(22.8°C), 68°F(20°C), 65°F(18.3°C)	75°F(23.9°C), 73°F(22.8°C), 71°F(21.7°C)	75°F(23.9°C), 73°F(22.8°C), 71°F(21.7°C)
May	66°F(18.9°C), 80.6°F(27°C)	74°F(23.3°C), 71°F(21.7°C), 68°F(20°C)	74°F(23.3°C), 73°F(22.8°C), 68°F(20°C)	74°F(23.3°C), 73°F(22.8°C), 68°F(20°C)	78°F(25.6°C), 74°F(23.3°C), 71°F(21.7°C)	78°F(25.6°C), 75°F(23.9°C), 73°F(22.8°C)	78°F(25.6°C), 75°F(23.9°C), 73°F(22.8°C)
June	66°F(18.9°C), 80.6°F(27°C)	81°F(27.2°C), 78°F(25.6°C), 75°F(23.9°C)	81°F(27.2°C), 78°F(25.6°C), 75°F(23.9°C)	81°F(27.2°C), 78°F(25.6°C), 75°F(23.9°C)	82°F(27.8°C), 79°F(26.1°C), 76°F(24.4°C)	82°F(27.8°C), 79°F(26.1°C), 76°F(24.4°C)	82°F(27.8°C), 79°F(26.1°C), 76°F(24.4°C)
July	66°F(18.9°C), 80.6°F(27°C)	81°F(27.2°C), 78°F(25.6°C), 75°F(23.9°C)	81°F(27.2°C), 78°F(25.6°C), 75°F(23.9°C)	81°F(27.2°C), 78°F(25.6°C), 75°F(23.9°C)	82°F(27.8°C), 79°F(26.1°C), 76°F(24.4°C)	82°F(27.8°C), 79°F(26.1°C), 76°F(24.4°C)	82°F(27.8°C), 79°F(26.1°C), 76°F(24.4°C)
August	66°F(18.9°C), 80.6°F(27°C)	83°F(28.3°C), 80°F(26.7°C), 74°F(23.3°C)	83°F(28.3°C), 80°F(26.7°C), 74°F(23.3°C)	83°F(28.3°C), 80°F(26.7°C), 74°F(23.3°C)	83°F(28.3°C), 80°F(26.7°C), 76°F(24.4°C)	83°F(28.3°C), 80°F(26.7°C), 76°F(24.4°C)	83°F(28.3°C), 80°F(26.7°C), 76°F(24.4°C)
September	66°F(18.9°C), 80.6°F(27°C)	74°F(23.3°C), 69°F(20.6°C), 63°F(17.2°C)	74°F(23.3°C), 72°F(22.2°C), 69°F(20.6°C)	74°F(23.3°C), 73°F(22.8°C), 70°F(21.1°C)	78°F(25.6°C), 72°F(22.2°C), 69°F(20.6°C)	78°F(25.6°C), 75°F(23.9°C), 71°F(21.7°C)	78°F(25.6°C), 75°F(23.9°C), 71°F(21.7°C)
October	66°F(18.9°C), 80.6°F(27°C)	65°F(18.3°C), 64°F(17.8°C), 62°F(16.7°C)	68°F(20°C), 67°F(19.4°C), 66°F(18.9°C)	68°F(20°C), 67°F(19.4°C), 66°F(18.9°C)	70°F(21.1°C), 68°F(20°C), 67°F(19.4°C)	73°F(22.8°C), 71°F(21.7°C), 70°F(21.1°C)	73°F(22.8°C), 71°F(21.7°C), 70°F(21.1°C)
November	66°F(18.9°C), 80.6°F(27°C)	56°F(13.3°C), 52°F(11.1°C), 49°F(9.4°C)	62°F(16.7°C), 61°F(16.1°C), 60°F(15.6°C)	65°F(18.3°C), 63°F(17.2°C), 63°F(17.2°C)	63°F(17.2°C), 59°F(15°C), 56°F(13.3°C)	68°F(20°C), 67°F(19.4°C), 65°F(18.3°C)	70°F(21.1°C), 69°F(20.6°C), 68°F(20°C)
December	66°F(18.9°C), 80.6°F(27°C)	45°F(7.2°C), 44°F(6.7°C), 43°F(6.1°C)	51°F(10.6°C), 51°F(10.6°C), 51°F(10.6°C)	53°F(11.7°C), 53°F(11.7°C), 53°F(11.7°C)	53°F(11.7°C), 52°F(11.1°C), 51°F(10.6°C)	58°F(14.4°C), 58°F(14.4°C), 57°F(13.9°C)	60°F(15.6°C), 60°F(15.6°C), 60°F(15.6°C)
Worst day of the year in heating	66°F(18.9°C), 80.6°F(27°C)	34°F(1.1°C), 33°F(0.6°C), 32°F(0°C)	42°F(5.6°C), 41°F(5°C), 41°F(5°C)	46°F(7.8°C), 45°F(7.2°C), 45°F(7.2°C)	47°F(8.3°C), 46°F(7.8°C), 45°F(7.2°C)	53°F(11.7°C), 53°F(11.7°C), 53°F(11.7°C)	56°F(13.3°C), 56°F(13.3°C), 56°F(13.3°C)
Worst day of the year in cooling	66°F(18.9°C), 80.6°F(27°C)	87°F(30.6°C), 83°F(28.3°C), 77°F(25°C)	87°F(30.6°C), 83°F(28.3°C), 77°F(25°C)	87°F(30.6°C), 83°F(28.3°C), 77°F(25°C)	86°F(30°C), 83°F(28.3°C), 78°F(25.6°C)	86°F(30°C), 83°F(28.3°C), 78°F(25.6°C)	86°F(30°C), 83°F(28.3°C), 78°F(25.6°C)

Definition of Dry resultant: The Dry Resultant is the temperature in °F felt by the occupant if we take into consideration both the air dry bulb temperature and the radiant surfaces heating or cooling effect.

Solar Thermal Modelling: Can we do this without a borefield?.....No, we NEED storage.





Number of 2.65 m^2 thermal collectors	300
Collector gross area	792 m^2
Total annual field yield to the system	448,300 kWh
Weight of collector	49 kg
Total weight	14,700 kg
Price (300 collectors, roof mounting hardware, inter-collector fittings)	$229,000
Estimated number of 70 m (~225 ft) deep boreholes	52
Value of natural gas saved annually (@ $0.25/$m^3$)	$13,300
CO_2 annual savings	91 ton

1.1. Description of tasks

HGS has performed the following tasks:

- Analysis of the building energy simulation results provided by Brookfield engineers
- Calculations confirming ground thermal imbalance, and the need for auxiliary heating
- Finite-element simulation to determine the thermal response of the ground
- Development of a system optimization algorithm to compute COP and financial projections
- Computation of solar energy flow into the ground for varying number of solar thermal panels
- Determination of system COP and financial projections for varying number of solar panels

Solar Thermal Modelling: Can we do this without Solar Thermal?.....NO! We NEED heat.

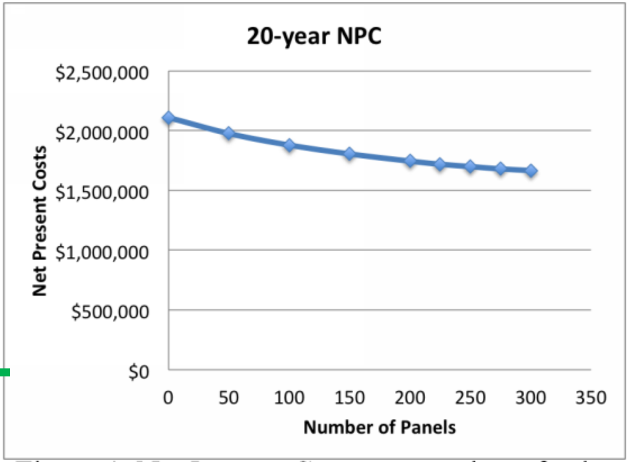
Table 1. Summary of projected costs and system failure time for varying number of solar panels

# of Panels	20-year NPC	40-year NPC	Projected System Failure Time
0	$2,111,000	$6,889,000	In year 1
50	$1,976,000	$6,052,000	In year 2
100	$1,879,000	$5,291,000	In year 4
150	$1,805,000	$4,641,000	In year 7
200	$1,745,000	$4,113,000	In year 32
225	$1,719,000	$3,882,000	N/A
250	$1,699,000	$3,682,000	N/A
275	$1,680,000	$3,509,000	N/A
300	$1,666,000	$3,362,000	N/A

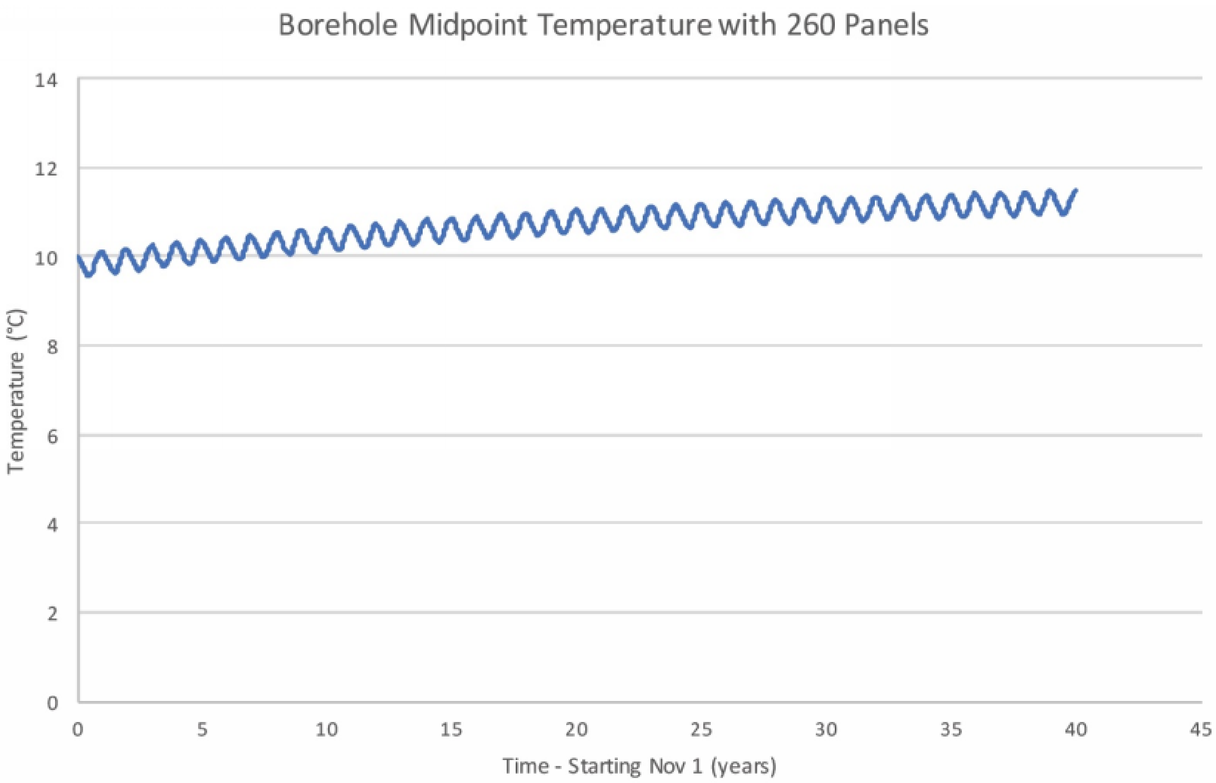
- NPC Analysis

Table 3. Comparative analysis for costs associated with varying numbers of solar panels

1. # of panels	2. Panel Cost Installed	3. Avg. Heating COP	4. Avg. Annual Elec. Cost ($.12)	5. Avg. Annual Elec. Cost ($.17)	6. 20-year NPC ($.12)	7. 20-year NPC ($.17)	8. 40-year NPC ($.12)	9. System Failure Time
0	$0.00	2.69	$105,569	$149,556	$2,111,000	$2,991,000	$6,889,000	year 1
50	$120,450	2.94	$92,753	$131,400	$1,976,000	$2,748,000	$6,052,000	year 2
100	$240,900	3.16	$81,907	$116,035	$1,879,000	$2,562,000	$5,291,000	year 4
150	$341,962	3.36	$73,148	$103,626	$1,805,000	$2,414,000	$4,641,000	year 7
200	$430,100	3.54	$65,746	$93,140	$1,745,000	$2,293,000	$4,113,000	year 32
225	$469,322	3.62	$62,473	$88,503	$1,719,000	$2,239,000	$3,882,000	N/A
250	$505,313	3.69	$59,693	$84,565	$1,699,000	$2,197,000	$3,682,000	N/A
275	$538,072	3.75	$57,092	$80,880	$1,680,000	$2,156,000	$3,509,000	N/A
300	$567,600	3.81	$54,906	$77,783	$1,666,000	$2,123,000	$3,362,000	N/A

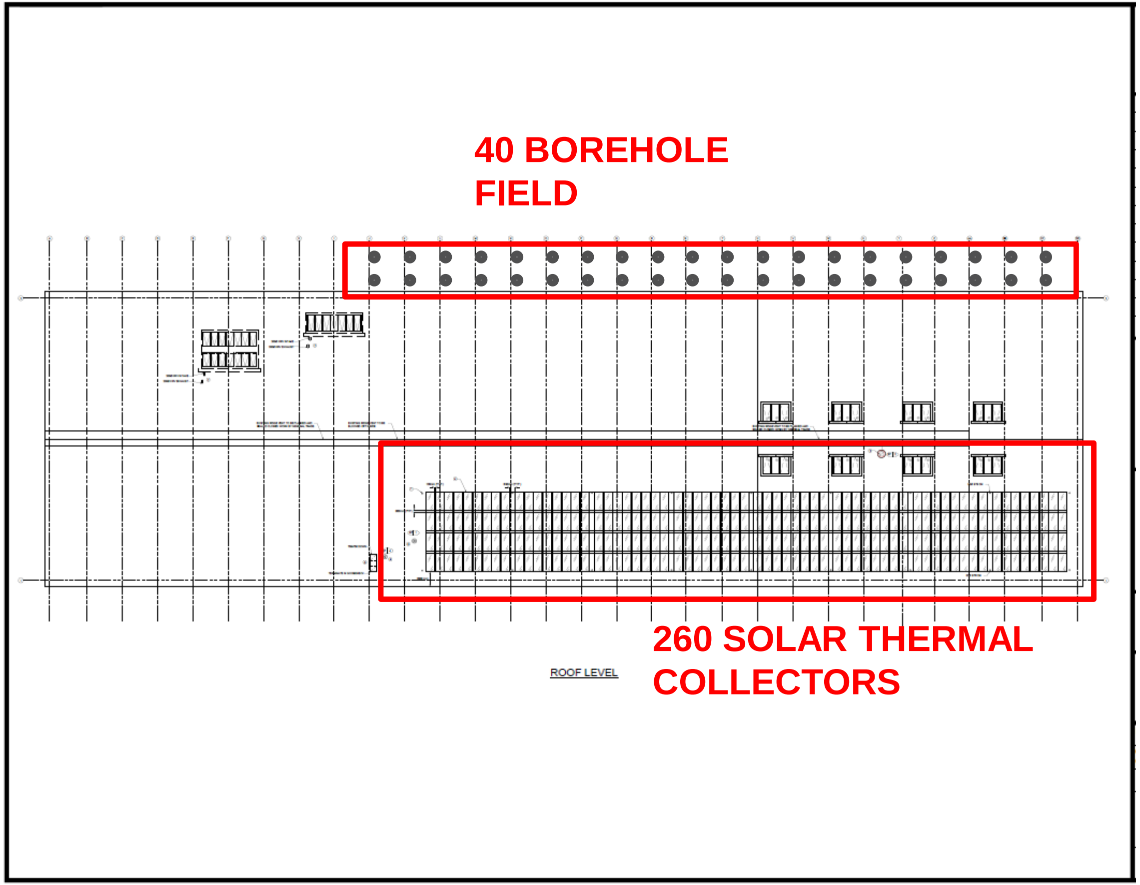


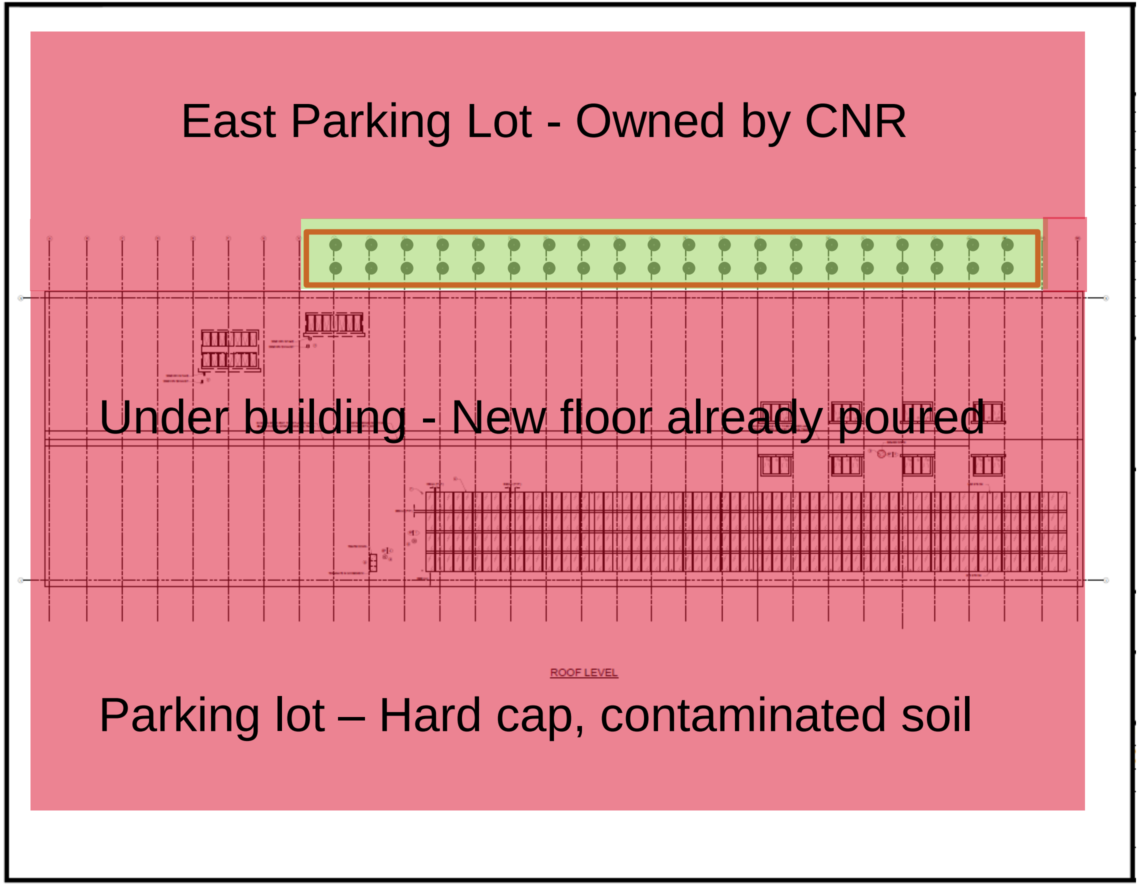
- Bore Field Temperature vs. Time

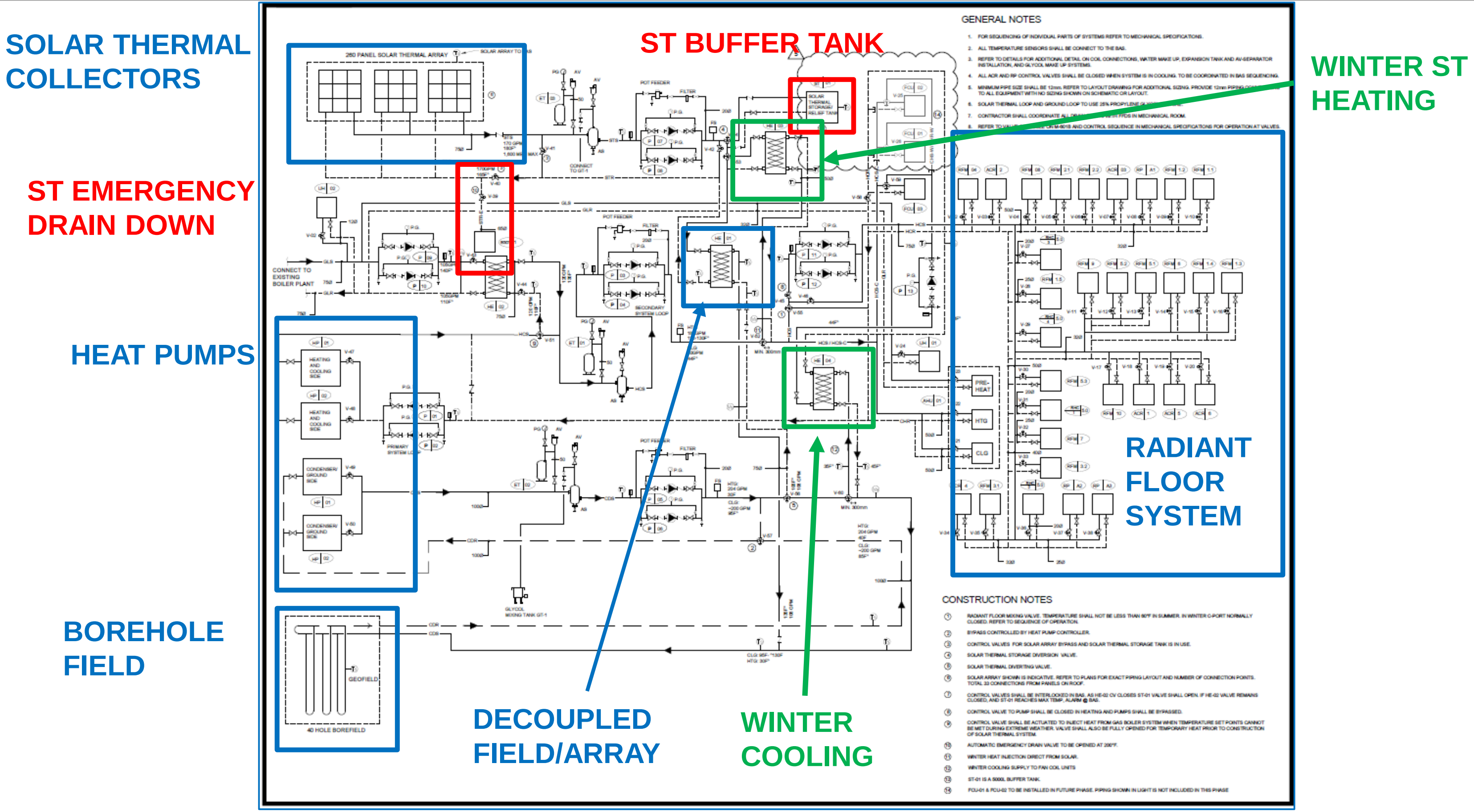


BGIS

- Low temperature radiant floor heating and cooling
- Fan-assist natural ventilation
- Two 60 ton heat pumps
- 40 hole borefield
- 260 panel solar thermal array, 8000 sqft
- 100% OA ventilation unit w/ enthalpy wheel
- Natural gas boiler back up


40 BOREHOLE FIELD
260 SOLAR THERMAL COLLECTORS
ROOF LEVEL


East Parking Lot - Owned by CNR
Under building - New floor already poured
ROOF LEVEL
Parking lot – Hard cap, contaminated soil


SOLAR THERMAL COLLECTORS
ST EMERGENCY DRAIN DOWN
HEAT PUMPS
BOREHOLE FIELD
ST BUFFER TANK
WINTER ST HEATING
RADIANT FLOOR SYSTEM
DECOUPLED FIELD/ARRAY
WINTER COOLING
GENERAL NOTES
CONSTRUCTION NOTES
280 PANEL SOLAR THERMAL ARRAY
CONNECT TO EXISTING BOILER PLANT
40 HOLE BOREFIELD
GEOFIELD

Proposed → (Option A)

Avoided → (Option B)

Option	Yearly Electricity (kWh)	Yearly Natural Gas m3 (ekWh)	Yearly Total Energy usage (ekWh)	Yearly Total Energy Cost ($)	Yearly Carbon Generated (eCO2tons)
A	1,010,000 kWh	0 m3 (0 ekWh)	1 010 000 ekWh	$121 000	41 eCO2tons
B	200 000 kWh	380 000 m3 (4 000 000 ekWh)	4 200 000 ekWh	$184 000	688 eCO2tons
C	338 000 kWh	59 500 m3 (625 000 ekWh)	963 000 ekWh	$114 000	120 eCO2tons

Our modelling shows that Option A, the proposed building design using our solar thermal ground source solution has the lowest carbon output.

- **Projected Annual Carbon Emittance Avoided = 647 tons**
- **Projected Annual Cost Avoidance = $63,000**

Lessons Learned

- Know what you don’t know…Bring in reinforcements!
- You can’t turn off Solar Thermal
- Large scale Solar Thermal is unchartered territory…Plan accordingly
- Work with a build team you can trust:
    - Geosource Energy
    - Ellis Don
    - Engie Multitech