Earth Rangers Centre for Sustainable Technology

CASE STUDY

Earth Rangers Centre for Sustainable Technology in Vaughan, ON.

SITE PROFILE

Building owner	Earth Rangers
Building location	Vaughan, ON
Building type and use	Office building
Net floor area (ft^2)	60,000 (not including basement)
Ground loop	44 vertical boreholes (40 are 120 ft deep, 4 test wells are 160 ft deep). Loopinol is used in ground loop to mitigate harmful effects in the event of leakage.
Number of GSHPs	1
GSHP manufacturer and model[1]	Carrier 30HXC 086
Total rated heating capacity (tons)	83 (996 MBtu/hr) nominal capacity. Chiller is variable capacity.
Distribution system	Heating and cooling is via radiant slab. Building humidity is controlled and kept above the dewpoint to avoid condensation issues.
Backup system	Boiler back-up and cooling tower that can be used to reject excess heat in cooling mode
Dominant use of system	Heating
Year installed	2007

[1] This is a chiller with a water-cooled condenser rather than a ground-source heat pump, however, external plumbing gives it the same functionality. Since it is not a heat pump, it is not rated with a COP or EER.

ABOUT THE SITE

The Earth Rangers Centre for Sustainable Technology is located on the Toronto and Region Conservation Authority's Living City Campus at Kortright in Vaughan, ON. It was constructed in 2004 as the base of operations for Earth Rangers, a children-oriented conservation organization. The building is a showcase for renewable energy, energy efficiency, and water conservation technologies and practices. In 2012, the Centre achieved LEED® Platinum for Existing Buildings: Operations and Maintenance (LEED® EB) Certification and is presently the highest rated LEED® EB certified building in Canada.

RATIONALE AND PLANNING

As part of the LEED® Platinum certification process, Earth Rangers chose to install a geoexchange system in order to reduce the greenhouse gas emissions associated with operating the facility. At the time, there was also a financial case to be made for the geoexchange project. The retrofit project was initiated in 2007 when natural gas prices were at a high, and installation of a geoexchange system was chosen for security against future price increases. The expected simple payback was reported to be 22.5 years based on the cost of natural gas at the time.

GEOEXCHANGE SYSTEM DESIGN

The geoexchange retrofit was performed simultaneously with an expansion of the facility's parking lot in order to increase the cost effectiveness of the project. A horizontal directional drill was required for the boreholes due to a large existing network of gas and communication lines on site. The building had existing radiant slab heating and cooling as well as a high thermal mass, and attributes such as these meant that fewer upgrades were necessary to accommodate the geoexchange system. When the geoexchange system was installed, the building's plumbing was altered to connect the heat pump to the existing cooling tower which was available as a secondary option to dissipate waste heat from the heat pump when operating in cooling mode. The cooling tower has since been decommissioned because the ground loop was found to be considerably more efficient under a wide range of operating conditions.

Figure 1. The geothermal heat exchanger in the basement mechanical room of the Earth Rangers Centre for Sustainable Technology.

PROJECT IMPLEMENTATION

The installation of the geoexchange system was preceded by a feasibility assessment which incorporated the drilling of test wells, groundwater analysis, a building energy analysis and ultimately, an economic analysis. Commissioning was a joint venture between the system designer, the mechanical contractor, the building automation contractor and the building operator. The building operator was well integrated into the work done by external consultants and contractors and it was felt that this saved both time and money when rectifying any issues in the installation and commissioning process. The commissioning of the system was reported to be straightforward aside from a few minor issues. One such issue was faulty ground loop temperature sensors which then required adjustments to the ground loop control algorithm. The building operator was very satisfied with the work done by all parties involved with the system.

MONITORING

The building is monitored and controlled by a Building Automation System (BAS) from Schneider. The BAS monitors relevant temperatures and flows using Onicon System 10 Btu meters. This data alongside electrical power consumption monitoring, is sufficient for geoexchange system performance analysis.

PERFORMANCE

The monthly geoexchange heating and cooling coefficients of performance (COPs) plotted in Figure 2 include the energy required to run the chiller and the ground loop circulator pumps. Higher COPs/EERs indicate lower operating costs. Reasons for the low heating COPs have not been identified and requires further study. The cooling EERs however, are extremely high owing to the innovative cooling mode control strategy termed "free-exchange". During free-exchange, the fluid circulating through the ground loop

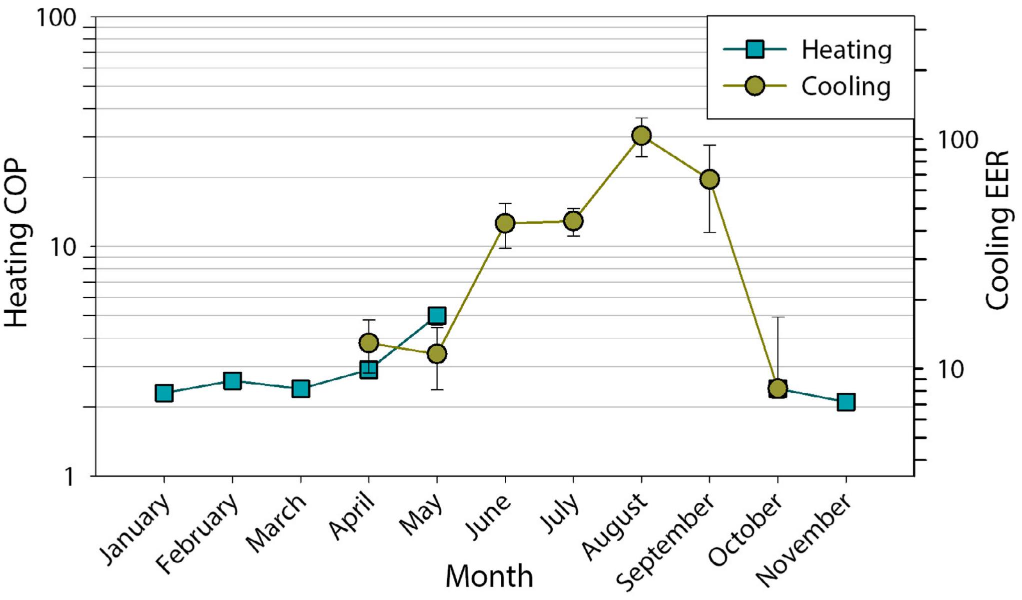

Figure 2. The monthly heating and cooling mode COPs for Earth Rangers. Cooling mode COPs are extremely good due to the primarily free-exchange mode of operation.

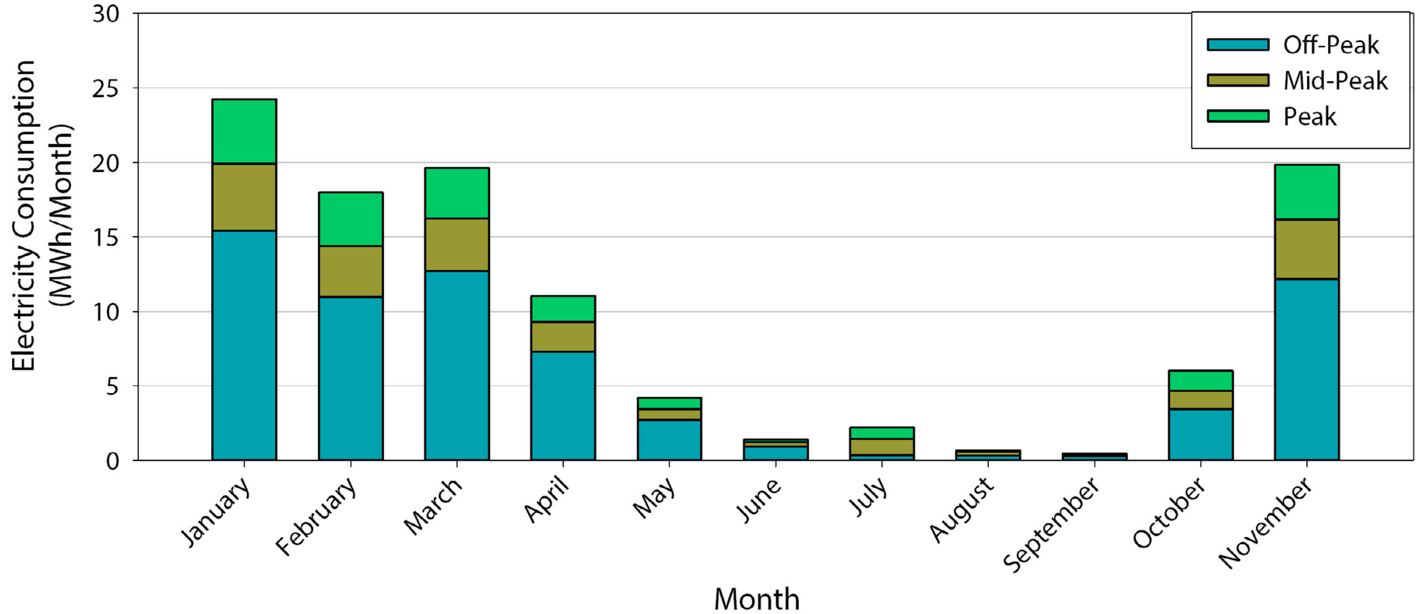

Figure 3. The monthly electrical consumption of the geoexchange system shows that the free-exchange mode of operation is able to cool the building with only minimal electrical energy. Included in this plot is the electricity required for the chiller and the ground-loop circulator pumps.

is directly circulated through the building (or interfaced with the building via a heat exchanger) and the heat pump is not used.

When using free exchange during the cooling season, the heat pump is only turned on to dehumidify the building or to boost cooling performance during very hot days. This means that the only electrical load involved in cooling the building is generated by the circulator pumps, which consume marginal electricity relative to the chiller (or heat-pump). This is illustrated in the monthly geoexchange system electrical consumption plotted in Figure 3. Since dehumidification requires that the heat pump be turned on, the humidity level in the building is kept at approximately 70%, higher than what it is in most office buildings. To compensate for the elevated humidity and achieve the desired level of thermal comfort, the building is maintained at a lower temperature which consumes less energy overall.

Circulator pumps generally require much less electricity when compared to heat pumps. In some buildings, it is feasible to meet the cooling load by using only the circulator pumps and the ground loop without even requiring the heat pump. This is termed "free-exchange" and it is at least 2 to 3 times more efficient than conventional geoexchange cooling mode operation.

OPERATION AND MAINTENANCE

The Earth Rangers Centre and BAS is managed by internal staff making it cost effective and streamlined for optimizing the system based on facility needs. Approximately 2 to 3 hours of preventative maintenance is performed on the system on a quarterly basis, much less than what is required by a conventional system. Furthermore, maintenance and operational decisions are made simpler by the BAS. It is effective in terms of creating alarms and showing daily, weekly, or monthly trends to make informed decisions and ensuring the system operates within the expected ranges.

COSTS

Earth Rangers has a unique business model in that the organization acquires nearly all of the technologies installed in the Centre by donation. The geoexchange project was financed by Earth Rangers founder Robert Shad as well as donations from several partners. This arrangement has been proven mutually beneficial as Earth Rangers gains access to innovative green technologies and donor organizations take the opportunity to exhibit their products and receive tax benefits for charitable donations.

GREENHOUSE GAS EMISSIONS ANALYSIS

GHG emissions reduction was calculated for the case of a geoexchange system versus that of a baseline natural gas heating appliance, each delivering the amount of heat determined from the experimental building load data. To simplify analysis, the heating distribution system was considered to be the same in both cases and only the heating mode was considered. It is estimated that by opting to heat the building with geoexchange rather than a conventional fossil fuel based heating technology (such as a high-efficiency boiler with assumed 84% efficiency) the system is saving greater than 39,000 kg eCO_2 of GHG emissions every year; a highly conservative estimate since it only considers the heating mode operation.

SUCCESSES

Post-retrofit, the facility manager at Earth Rangers has received positive feedback from building occupants regarding the thermal comfort of the building. Management reports that operation and maintenance of the geoexchange system is very simple and that operating costs are lower than what they had been pre-retrofit. Going forward, the organization would consider installing geoexchange in other buildings. This project helped the Earth Rangers Centre to achieve LEED® EB certification and it is a step toward the organization's next goal of becoming energy neutral. The project also serves as a real word demonstration of geoexchange for the thousands of visitors that frequent the Earth Rangers Centre every year, helping to build public awareness and confidence in the technology.

LESSONS LEARNED

Free-exchange offered an extremely efficient cooling mode of operation. Free-exchange was effective for at least three reasons: (i) the building used radiant slab cooling with a high heat exchange area that allowed warmer fluid temperatures in cooling mode, (ii) the building had a high thermal mass that reduced peak cooling loads that may have otherwise required the heat pump to turn on and (iii) the ground-loop appeared to be oversized and provided cooler than average fluid temperatures to the building.

The strategy of keeping a higher humidity but lower temperature was effective at reducing overall energy consumption. Alternatively, the building operator suggests that a smaller dedicated chiller for dehumidification would be more efficient than operating the main unit for this purpose.

The building uses zoned demand-controlled ventilation (i.e., ventilation only occurs if CO_2 drops below a certain level), reportedly increasing energy efficiency. However, the building operator cautioned that the system is most effective if the ventilation zones have similar usage profiles.

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