TECHNICAL BRIEF

Existing Building Commissioning of Kortright Visitor Centre

Building commissioning is a systematic and documented process of helping to ensure that building systems perform according to the design intent and the owner's operational needs. Existing Building Commissioning (EBCx):

- Provides a better indoor environment
- Reduces health & comfort problems related to indoor air
- Reduces occupant complaints
- Reduces contractor call-backs and warranty issues
- Reduces energy consumption and operational costs

The Sustainable Technologies Evaluation Program (STEP) is a collaborative non-profit research initiative within the Toronto and Region Conservation Authority (TRCA). Among other priorities, STEP partners with government, utilities, non-profits, academic institutions, and private companies, to pilot and evaluate emerging low-carbon technologies for buildings with the aim of providing real-world data, analysis, tools, and outreach that promotes effective technological solutions for climate change mitigation.

PROJECT SUMMARY

Building Name:	Kortright Visitor Centre
Type:	Mixed-use; Office; Community/Rec Centre; Convention Centre
Location:	Vaughan, Ontario
Project:	Retro-commissioning of a mixed-use institutional building
Commissioning Scope:	Retro-commissioning of heating and cooling system, domestic hot water system, lighting, and ventilation system. Performed using internal staff.
Size of Commissioned Area:	Approximately 30,000 ft^2
Total Commissioning Investment:	Approximately $40,000 of staff time was spent for planning, investigation, and reporting (not including staff training). An additional $5,000 of staff time was used for implementation. Costs increased due to documentation gaps, overall lack of visual indicators of system parameters, and the state of repair of systems.
Estimated Energy Cost Savings:	$8,500 per year (for *all* measures identified but some not implemented yet)
Estimated Simple Payback:	6 years (including costs of EBCx and implementation of all measures identified)
Estimated Energy Savings:	50 MWh per year (for *all* measures identified but some not implemented yet)
Estimated GHG Emission Reductions:	1.5 tonnes CO_2eq per year (assuming the most recent *average* emission factor available for the Ontario electricity grid from the 2021 National Inventory Report)
Non-energy Benefits:	The EBCx identified a non-functional ventilation system. This was then rectified. Other non-functional equipment were also identified. Proposed interventions should generally increase system lifetimes and reduce service requirements. The awareness of site staff regarding the building's mechanical systems improved significantly.

INTRODUCTION

For various reasons, it is possible for the mechanical and lighting systems within a building to fall short of the current facility requirements, or otherwise operate sub-optimally. This impacts energy consumption and operating costs as well as the comfort and health of occupants. Existing building commissioning (EBCx) is an important tool that can be used to improve the performance and operation of these systems. It can also increase the lifespan of mechanical equipment and reduce the number of failures and repairs. This case study documents EBCx that was undertaken at the Visitor Centre of the Kortright Centre for Conservation in Vaughan, ON.

SITE OVERVIEW

For the past 40 years, the Kortright Centre for Conservation has been one of Canada's leading environmental education centers. With over 100,000 visitors annually, the Kortright Centre plays a key role in educating generations of youth and adults about the environment. The Visitor Centre at Kortright is a 30,000 ft^2 3-level open concept post and beam structure. It contains a 140-seat theatre, 8 classrooms, office space, a café, a commercial kitchen, an event space, and a gift shop.

It serves as the hub for all of the educational, training, and recreational programming occurring on the surrounding 325-hectare property. It was built in 1982 and underwent a significant renewal of the building envelope and mechanical systems in 2012. This involved the retrofit of a geothermal system replacing electric baseboard heating, the addition of mechanical ventilation, window upgrades, as well as opening the interior with an emphasis on increased natural daylight.

Figure 1. Interior picture of the Kortright Visitor Centre showing daylighting.

The building is regularly booked as an event space and wedding venue. In normal conditions, the occupancy of the building varies seasonally with school group tours and the various events/programming offered at Kortright. Normal staffed hours are 9 am to 5 pm. Weddings and receptions frequently occur on Thursday, Friday, and Saturday evenings.

SYSTEMS OVERVIEW

Heating and Cooling

In 2012, the building heating and cooling system was upgraded from electric resistance baseboards to a geothermal system. The geothermal system consists of six water-to-air ground-source pumps (GSHPs), each having a nominal capacity between 96 and 120 kBtu/hr. The GSHPs serve different zones throughout the building but connect in parallel to a common ground loop (Figure 2). The ground loop circulator pumps are powered by variable frequency drives (VFDs) intended to operate the hydronic system at constant pressure.

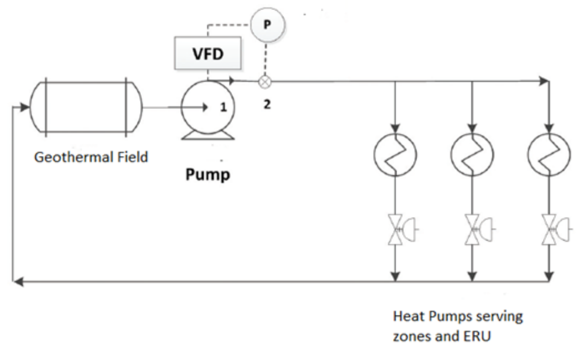

Figure 2. Simplified schematic of the geothermal system. Note that it shows only three GSHPs and a single pump. There are actually six GSHPs and two circulator pumps, as well as additional hydronic circuits and components.

Control of the heat pumps is done through local thermostats (ie. there is no central building management system). Thermostats use nighttime setbacks. When a thermostat calls for heat, the corresponding control valve opens to allow the glycol in the ground loop to pass through the corresponding GSHP and then the GSHP turns on. This reduces pressure in the hydronic system. The VFDs should then speed up to increase the flowrate. This is designed to achieve efficient use of the pump because the flowrate would adapt to the number of GSHPs operating at different points in time.

Domestic Hot Water

There is a 120-gallon electric resistance water heater that provides domestic hot water (DHW) for the facility washrooms, kitchen, and staff common areas. The system is equipped with a recirculation loop powered by a 1/6 horsepower circulator pump running constantly. The building also has a solar hot water (SHW) system consisting of four collectors and a storage tank. The SHW system was designed to pre-heat water to the electric water heater. The system was damaged during the renewal in 2012 and has since not been functional. It is likely now beyond repair.

Ventilation

In 2013, a dedicated outdoor air system (DOAS) was installed to supply fresh ventilation air to the building. The building previously relied on natural ventilation assisted by a large exhaust fan. The DOAS uses an enthalpy wheel to transfer sensible and latent heat during the heating season and remove humidity during the cooling season. The blower has a VFD and the unit is designed to supply air at constant pressure with a range of airflows between 2,000 to 6,000 cfm.

The ventilation ductwork includes dampers for each zone. Dampers are controlled by indoor air quality (IAQ) sensors.

The system was designed such that, as occupancy increases in the zones and CO_2 levels rise, the IAQ sensors begin modulating the dampers to allow more fresh air into the zone. This reduces pressure in the ventilation ductwork. A pressure sensor in the ductwork detects this change and the VFD powering the DOAS blower should then provide more fresh air and maintain a constant duct pressure setpoint. After the enthalpy wheel, ventilation air is tempered by one of the GSHPs. An electric resistance coil is used as back-up heating.

Lighting

The building has a mix of interior and exterior lighting fixtures. Interior lighting makes up an estimated 85% of the annual energy consumption for lighting and exterior accounts for 15%. More than a third of the annual energy consumption for lighting is from energy-efficient LED fixtures. Staff are transitioning to LEDs as lights are in need of replacement.

The EBCx team performed a lighting audit to inventory all fixtures, their control schedule, and other relevant information. The breakdown of annual lighting energy according to the control schedule is shown in Table 1. Overall, 70% of the annual lighting energy consumption is from fixtures that are on 24/7 or are turned on from open until close, despite a high level of natural daylight within the building.

Table 1. Control approaches for lighting systems within the building.

Control Schedule	Estimated Fraction of Annual Energy Consumption for Lighting
Lights on when space is occupied based on an occupancy sensor	10%
Lights on as needed (controlled by a wall switch)	20%
Lights on from open until close (controlled by a circuit breaker)	60%
Lights on 24/7	10%

Commercial Kitchen

The building has a commercial kitchen designed to serve large groups and wedding receptions. There is a walk-in freezer, multiple refrigerators, large and small kitchen appliances, a dishwasher, and an exhaust hood in the cooking area. These loads together likely represent a large fraction of base energy use. The kitchen is rented by a tenant.

Plug Loads

The primary plug loads in the facility consist of typical equipment found in educational facilities and office spaces. This includes a small number of computers, monitors, and various electronics. There are some displays and flatscreen televisions in the learning spaces. These plug loads are estimated to be a relatively low fraction of the base energy use.

EBCx PROCESS

The EBCx process consists of four phases: planning, investigation, implementation, and hand-off & persistence.

Phase 1: Planning

A previous consultant report identified the Kortright Visitor Centre as a facility with energy conservation potential. The building also had suspected operational issues. Issues were not fully diagnosed due to the lack of a central building management system and the lack of gauges for basic system parameters like temperatures, pressures, or flowrates. The lack of a central building management system is not uncommon for this type of building. However, the lack of gauges is highly uncommon and it made EBCx much more challenging.

The Kortright Visitor Centre was selected for EBCx, in part, to diagnose suspected issues. Objectives of the EBCx were:

1. develop the current facility requirements (CFR);
2. determine the current state of the building systems and develop a strategy to bring them back into functionality;
3. optimize the performance of systems where possible;
4. update the system documents and assist the building staff in maintaining functional performance.

The EBCx team was composed entirely of internal staff that received formal training on EBCx but had no prior experience implementing it in a building. It included a facility supervisor, energy management staff, a technician, and a mechanical engineer. The scope of the EBCx was defined to encompass the heating and cooling system, DHW, ventilation, and lighting.

The commercial kitchen was outside of scope. Plug loads in the building were estimated to be a small fraction of electricity consumption and also considered outside of scope. The building envelope was also largely excluded. It underwent a recent renewal and is a static component. That being said, there are small known air leaks (Figure 3) in certain areas of the building that will be addressed in the future.

The planning process began with a kickoff meeting, building walkthrough, discussion with facility staff to determine the CFR, documentation review, and energy analysis of the facility. The team was able to understand the high-level design intent of the systems from the available documentation.

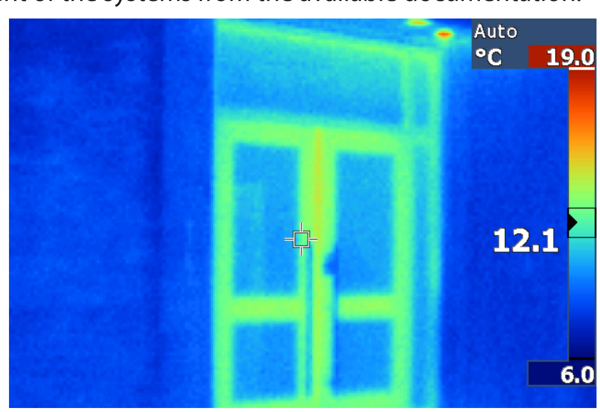

Figure 3. Infrared thermograph showing heat loss through the east entrance. It is difficult to see but there is a faint red line between the doors indicating air leakage. The weather stripping should be inspected and replaced if necessary. Also, shown in the top right, is an exterior soffit light. There are 50 of these lights operating 24/7 with a cumulative power draw of 475 W.

However, there were significant information gaps in terms of undocumented service calls as well as missing details on control set-points and programming. The walkthrough also identified key control sensors and controllers that were not installed.

Monthly electricity data from the past 5 years is plotted in Figure 4. Interval data was not available. This made it challenging to estimate the relative share of each electricity end-use within the facility. However, regression analysis of monthly utility bills showed a relatively weak dependence on heating degree days and cooling degree days.

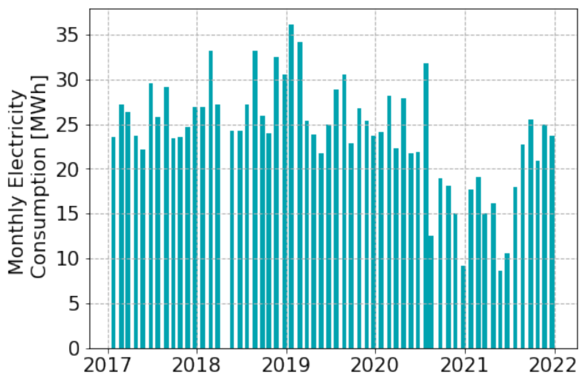

Figure 4. The facility has a baseload electricity consumption on the scale of 23 MWh per month and a relatively weak dependence on heating and cooling degree days. Note that the baseload decreased by nearly 15 MWh per month throughout 2020 and 2021 related to COVID-19.

Based on 3-years of consumption from 2016 to 2019 (normal operation before COVID-19) the average annual electricity load was 313 MWh. Utility analysis, the lighting audit, and other engineering calculations were used to estimate that the geothermal system accounts for approximately 20% of the annual load, lighting accounts for another 20%, and the remainder is plug loads, the commercial kitchen, and DHW. Ventilation was not included in this breakdown because it was believed to be non-functional during this time period.

This process informed the development of an EBCx plan. The plan is central to the EBCx process. It includes objectives, scope, a building description, utility bill analysis, a description of energy systems, observations from the walkthrough, a list of systems and equipment targetted by the EBCx, investigation methods, team members, roles, deliverables, timeline, and the CFR. Costs would normally be included as well if hiring an external agent. The planning phase occurred over a three-month period (approximately).

Phase 2: Investigation

The investigation phase of the EBCx took place over approximately one year. It began with visual *on-site inspections* and interviews with site staff both to confirm known issues and identify unknown issues. The key observations from the on-site inspections are listed below.

- **Some office staff in the mezzanine used portable electric space heaters.** One of the GSHPs heat pumps serving this zone was non-functional.
- **The make-up glycol reservoir was empty.** This could cause future system issues if it was not caught.
- **The thermostats use an appropriate setback schedule and there are no improvements to be gained from further adjustment of setpoints.** Historically, thermostats were set at a constant value of 70 °F with no setback. This was changed in July 2019 when a setback schedule was introduced. The schedule changes based on the day since events are common on Thursday, Friday, and Saturday evenings during normal operation. In cooling mode, the set-point changes from 70 °F to 78 °F when the building is unoccupied. In heating mode, the set-point changes from 70 °F to 62 °F when the building is unoccupied. Thermostats are turned off entirely from mid-May to late June. Figure 4 shows a decrease in energy consumption before and after this change.
- **The ground loop circulators are not operating according to the design intent**, but rather at a constant high-speed year-round regardless of the heating or cooling load. This has been the case since 2012 and is due to the control point pressure transducer having not been installed. Previous monitoring studies have found that running the ground loop circulator pump at a constant high speed can increase the overall power consumption of the full geothermal system by on the scale of 50%.[1]
- **The ground loop hydronic system is no longer balanced.** The TAB report for the system suggests it had been balanced when initially installed. At some point after that, all balancing valves were set to fully open and have remained in that state. This change was not recorded in any documentation available to the EBCx team. Balancing ensures each load is getting the correct amount of flow. When a system is unbalanced, some loads may get more flow than is required, and other loads may not get enough. This is inefficient in terms of pump energy and may be problematic for the operation of equipment.
- **Two of four heat pumps serving the Mezzanine level were non-functional.** Of the remaining functional heat pumps, one serves the kitchen and appears to be on relatively infrequently and the other appears to be managing the additional load for the two that are offline. If the latter heat pump were to go offline then the building would not be able to maintain set-point temperatures. Compressor issues are suspected.
- **The recirculation pump for DHW is on 24/7.** This expends unnecessary pump energy when the building is unoccupied. It also increases the electricity consumption for the water heater since heat is lost from the DHW when it travels through the piping of the building.
- **Exterior soffit lights are on 24/7.** There are 50 LED bulbs with a cumulative power draw of 475 W.

- **Despite strong natural daylighting, a large fraction of the indoor lighting is on from open until close.** Staff agreed that much of the indoor lighting was not actually necessary much of the time given the level of daylighting. The building would benefit from a lighting awareness program for occupants/staff. This would need to begin with proper labeling of circuit breakers. In particular, the low-efficiency decorative ambient string lights should be used judiciously. They total 1.5 kW on the interior of the building and 4.1 kW on the exterior.

Visual inspection of the DOAS showed that it was nonfunctional. Based on an evaluation of historical electricity data looking back to 2012, the EBCx team speculates that the heat pump air temperating and electric resistance back-up system likely went offline in 2015. More detailed *pre-functional checks* were required to diagnose the DOAS issues. Findings are listed below.

- **There was a failed signal conditioner on the enthalpy wheel that was preventing it from operating.** This was replaced based on interventions from the EBCx team.
- **The VFD for the enthalpy wheel had failed and this prevented it from operating.** This was replaced based on interventions from the EBCx team.
- **The heat pump used for tempering ventilation air in the DOAS had failed** due to the wrong low refrigerant pressure switch having been installed from the factory. The low-pressure switch was replaced based on interventions from the EBCx team.
- **The hydronic flowrate through the DOAS water-to-air heat pump was below the design flowrate causing a low-flow switch to prevent the heat pump from operating in some conditions.** This is related to the system balancing issues. The flow switch was adjusted to accommodate the lower flow. The engineering staff of the manufacturer confirmed that the system would still function adequately at the lower condenser flow rate.
- **The control of the DOAS system prevented the electric resistance to engage as back-up heating in some conditions.** The system was configured such that the electric resistance back-up can only turn on if the heat pump is on. However, the heat pump was unable to turn on because of the refrigerant pressure switch and the hydronic low-flow switch. It follows that the DOAS system has had no tempering for some period of time.
- **The inlet and exhaust dampers of the DOAS, as well as the blower VFD, do not modulate with the duct pressure as per the design intent.** The system is either fully on at full speed or fully off.
- **A small number of the indoor dampers connected to the IAQ sensors are stuck in a closed position.** This prevents ventilation air from reaching some zones.

Diagnostic monitoring and *functional tests* were performed on the GSHPs. For each GSHP, the EBCx team measured the total airflow, entering and leaving glycol temperatures, supply and return air temperatures, and hydronic flowrate as well as a visual inspection of the filter conditions.

- **The temperature rise on the glycol side of the heat pumps was very low for most heat pumps** except for the heat pump within the DOAS. This is a consequence of the unbalanced system and the pump operating at a constant high speed. This wastes pump energy.
- **The airflow for some heat pumps was notably lower than that in the TAB report, and higher for others.** The blower settings should be adjusted to achieve the right airflow.

Figure 5. As part of the diagnostic monitoring, a custom airflow monitoring set-up was used by the EBCx team to check the operating parameters of the GSHPs.

Phase 3: Implementation

Table 2 provides a log of the EBCx findings and the current implementation status of different measures. Savings, costs, and paybacks have not been provided for some measures. It is important in the context of COVID-19 that the ventilation system is in functional condition and the decision to proceed with measures related to the DOAS was not based on financial metrics. These measures were immediately implemented to bring the ventilation system into a functional state.

The EBCx team estimated that the sub-optimal operation of the ground loop circulators could cost on the scale of $2,750 per year (totaling on the scale of $27,500 to date). Fixing this issue will have a short payback. However, some level of capital is required because it involves more than simply installing a sensor. Information on the control set-points and overall engineering calculations for the hydronic system was not available. Furthermore, the VFD uses a dated proprietary controller that will be costly to re-program. The control strategy needs to be re-engineered, the controller needs to be programmed, and the sensor needs to be installed.

Given the level of effort required to rectify the issue, it is worthwhile to re-evaluate the control approach entirely and

Table 2. Summary of the findings log from the EBCx for the Kortright Visitors Centre.

	Observation	Measure	Savings	Estimated Cost	Simple Payback (years)	Imple-mentation Status
1	Failed signal conditioner on the enthalpy wheel	Replace signal conditioner	N/A	N/A	N/A	Implemented
2	Failed VFD on enthalpy wheel preventing it from operating	Replace VFD	N/A	N/A	N/A	Implemented
3	Items 1 and 2 prevent enthalpy wheel from functioning	Implement Measures 1 & 2	$3,500/yr	See 6	<3	Implemented
4	Incorrect DOAS heat pump refrigerant low-pressure switch	Replace low-pressure switch	N/A	N/A	N/A	Implemented
5	Low-flow switch preventing DOAS heat pump from operating	Adjust flow switch after manufacturer confirmation	N/A	N/A	N/A	Implemented
6	DOAS non-functional overall	Measures 1, 2, 4 & 5	N/A	$8,900	N/A	Implemented
7	Electric back-up heating in DOAS only turns on if heat pump is on	Adjust controls such that electric back-up can turn on	N/A	N/A	N/A	Not Yet
8	Some indoor dampers connected to IAQ sensors non-functional	Replace damper or IAQ sensor as required	N/A	N/A	N/A	Not Yet
9	DOAS blower VFD and damper do not modulate	TBD	N/A	N/A	N/A	Not Yet
10	The DHW recirculation pump functions continuously	Place pump on a timer	$500/yr	$500	1	Not Yet
11	All hydronic balancing valves are set to fully open	Balance the hydronic system	N/A	N/A	N/A	Not Yet
12	Ground loop circulators are operating at constant high speed	Need a mechanical engineer to advise on and implement a strategy for variable speed pump control	$2,750/yr	$5,000 - $10,000	<3.5	Not Yet
13	Exterior soffit lights run 24/7	Add photocell control of soffit lights	$250/yr	$1,000	<4	Not Yet
14	High level of natural daylight but 60% of lighting energy consumption is on open until close	Implement lighting awareness program for occupants	$1,500/yr	0	0	Not Yet
15	Lack of visual indicators and control systems*	Implement building management system	$10,500/yr	$64,500	<6.5	Not Yet
16	GSHP heat pump airflow greater or lower than required	Adjust blower settings as required	TBD	0	TBD	Not Yet
17	Two GSHPs were nonfunctional because of compressor issues	Have GSHPs serviced	N/A	N/A	N/A	Not Yet

*This quote and estimate of savings were provided for a building management system from a vendor. The quote did not provide detail on the estimated savings and may have simply been estimated based on similar buildings. The total savings from Line items 3, 10, 12, 13, and 14 ($8,500) is likely a more realistic estimate of savings.

this will require input from a mechanical engineer. As an example, the EBCx team is currently considering sensorless pump technologies. Given the overall need for different control points and visualization of system operating parameters, the team is also considering a building management system and has received a quote (Table 2; Line 15). This could help resolve many of the issues as well as promote operations and maintenance (O&M) moving forward.

Some measures were immediately rectified and others required a deeper level of consideration. As a result, the EBCx team has not yet created an implementation plan or report. An implementation plan would normally be the next step if using an external commissioning agent. The implementation plan would normally include a detailed description of measures, scope of work, implementation method, expected results, verification method, implementation sequence, and O&M requirements (if applicable), amongst other information. The implementation report would then add additional information, including implementation status, verification of results, and future recommendations.

Phase 4: Hand-off and Persistence

The EBCx team is not yet at Phase 4. The ventilation system was brought into a functional state but some energy efficiency measures have not yet been implemented. Energy efficiency measures may require notable capital and there are different approaches to implement them, either at a local level or via a new centralized building management system. Regardless, Phase 4 will be an ongoing process with the EBCx team continuing to be involved with the system moving forward since they are internal staff. The team will harmonize and complete a documentation package for the system, help create an O&M checklist, assist staff training, perform future site visits, assist in energy tracking as well as measurement and verification (M&V) for the facility. The team also plans on EBCx of other buildings in the TRCA portfolio.

LESSONS LEARNED

The Kortright Visitor Centre is equipped with energy-efficient mechanical equipment and the design intent included high-performance control strategies. However, the EBCx process revealed that different systems were nonfunctional and others were not functioning optimally. Some of the issues that were uncovered have existed since the system was installed. In the future, third-party commissioning is recommended to ensure that the systems are installed and operating as designed prior to hand-off. For example, this would have identified the incomplete installation of the ground circulator pump control system.

"I now have a better understanding of how the different components were intended to function, like the ERV system and the IAQ sensors for example, and that in turn helps with troubleshooting and diagnosing issues that arise. The experience in general has been rewarding and valuable. We have identified some ways of increasing energy efficiency. Will be using what I've learned to build an O&M checklist for the other Operations staff here to follow. I think all too often my role as a building operator gets overwhelmed by other issues, like the delivery of events and programs at this site. Without this project, I may never have had the opportunity for a deep dive into the Visitor Centre's mechanical systems, not to the extent to which it deserves anyway. So I am very grateful for this. " - Operations Supervisor

Issues have then persisted in part because the building does not have an O&M contract. Building operations are left to site staff but staff turnover, documentation gaps, competing responsibilities at the site, and an overall absence of any visual indications of system operating parameters (whether through a dashboard or even just sensors or gauges), has left notable room for improvement in regards to O&M and the overall state-of-repair of the equipment.

As a result, for this building, much of the resources for EBCx were consumed by outstanding state-of-repair issues. In general, building owners should be aware that the building's state of repair, data availability, level of existing documentation, and the ability to visually evaluate system operational parameters will all impact the resources required to conduct EBCx and subsequently implement recommendations. It should also be understood that EBCx is an investment and it is in these kinds of buildings that benefits may be greatest.

Moving forward for this building, there needs to be an effective strategy for O&M. If it continues to be the responsibility of site staff rather than an external maintenance contractor, then staff need to be given the tools to be successful and an operating budget sufficient to address the issues that arise. That means proper training on the systems, a preventative maintenance plan, O&M checklists, complete documentation packages, and the installation of gauges, indicators, or sensors that can aid in regular O&M activities. Training and documentation are being developed through this project, but some level of additional capital will be required to ensure effective O&M. Some level of building management system is also highly recommended.

PROJECT BENEFITS

The largest benefit of this project is that the building ventilation was brought into a functional state. Repairs to the enthalpy wheel are already generating savings. Prior to the EBCx, it was not known that the ventilation system was non-functional. In the context of COVID-19, adequate ventilation helps ensures both occupant comfort and occupant health.

An additional benefit is the engagement and capacity building of site staff. They have a much better understanding of the systems through being involved in this process. Information gaps have been filled and new procedures are being formulated to ensure more effective O&M moving forward. Site staff have learned what to look for and how they can tell if systems are running or out of service. This exercise will lead to developing an O&M checklist that staff can use in their weekly inspections.

A final benefit is that the EBCx team has documented and quantified a number of opportunities within the building, including no-/low-cost measures, to help promote energy performance.

REFERENCES

[1]Toronto and Region Conservation Authority. Performance Assessment of Urban Geoexchange Projects in the GTHA. 2015. Accessed online Mar 2022: sustainabletechnologies.ca/app/uploads/2015/03/GeoExchangeMonitoring_Final_Feb2015.pdf. See the Restoration Services Building geothermal system starting on p. 43.

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