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Dedicated to efficiency – 2016 ASHRAE Technology Award case studies

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ABSTRACT

The Anne-Marie Edward Science Building at John Abbott College in Montreal folds itself around a century-old Ginkgo tree. The new 11 297 m^2 building has large glazing surfaces that reflect the surrounding architecture and a large atrium with an imposing staircase designed to emulate the majestic Ginkgo tree.

The contemporary six-story building, located on an historic campus, is dedicated to teaching physics, biology and chemistry. It contains classrooms, teaching laboratories with chemical hoods, faculty offices, student spaces as well as central areas including a spacious entrance foyer and a 1198 m^2 atrium.

Figure 1: The Anne-Marie Edward Science Building at John Abbott College serves as a steward of sustainable practices through education, diligent site management, reduction and recuperation of energy and water, and the use of multiple energy sources. Photo: Mark Cramer

John Abbott College named the new science building after Anne-Marie Edward, one of the victims of the 1989 shooting at École Polytechnique and a John Abbott science graduate. Edward had been pursuing an engineering degree at Polytechnique, and the John Abbott community felt that through engineering, the new building demonstrated how humans are essential to environmental sustainability using applied knowledge and technology.

Figure 2: Required laboratory conditions provide the right circumstances for DOAS and dual energy recovery. Photo: Mark Cramer

Figure 3: Interactive dashboard in the main foyer presents data in an easy to understand format.

Integration of sustainable design principles were key to the success of the project aiming for a LEED Gold certification. Early on, it was decided that geothermal wells, thermal storage, radiant heating and cooling, a primary dedicated outdoor air system and energy recovery on both general and chemical hood exhausts would set the foundations for the building's energy efficiency, indoor air quality and thermal comfort.

ENERGY EFFICIENCY

A full building energy model was simulated in Canmet ENERGY's EE4 software, which uses DOE-2.1e. The reference case for EE4 is based on the Canadian Model National Energy Code for Buildings (MNECB – 1997). The simulation predicted that the building was to consume 39% less energy than the baseline case, which, according to LEED Canada NC 2009, is equivalent to a 28% reduction when compared to ASHRAE/IESNA Standard 90.1-2007. These results include an appreciable amount of exhausted laboratory process air: 24 chemical and canopy hoods, extraction arms, solvent and acid cabinets, specialised equipment, etc. The simulation's energy consumption is much lower than the baseline case due to the extensive use of geothermal energy.

Energy metering data from February 2014 to January 2015 is provided in Figure 1. Actual energy use is 10% lower than the simulation and 45% lower than the baseline case. Site energy intensity is currently 545 MJ/m^2·yr whereas the baseline case is 990 MJ/m^2·yr.

HYDRONIC SYSTEMS

The presence of a geothermal network combined with heat pumps and stratified hot and cold thermal storage tanks enable the distribution network to operate simultaneously in cooling and heating modes. The two 3028 L thermal storage tanks are connected to five two-stage heat pumps which maintain stratification by feeding hot fluid to the upper part of the hot tank and cold fluid to the lower part of the cold tank. The 45 geothermal wells, each around 122 m deep, are used to reactivate the storage tanks. This system responds to 50% to 70% of the heating and cooling energy demands of the building. Two 528 kW air-cooled rooftop chillers and two 288 kW (983 MBH) electric boilers are used to cover the remaining loads. Variable speed pumps are used on the hot and cold sides of the distribution network to respond to real-time load conditions.

A solar heating system is used to preheat domestic hot water. The solar flat plate collectors can preheat a portion of the total daily demand for domestic hot water and yearly natural gas energy savings are evaluated at 1.7 MJ/m^2·yr.

AIR SYSTEMS

The dedicated outdoor air system (DOAS), combined with secondary air systems, fan-coil units and radiant floor and ceiling slabs, provide the means to decouple fresh air treatment and distribution from zone temperature control and laboratory pressurisation and air changes per hour (ACH) requirements. The fresh air system incorporates two energy recovery methods. The more efficient accumulation type exchanger (using aluminium energy absorbing cassettes) is applied to the general exhaust (10,800 cfm [5,097 L/s]) and the less efficient runaround glycol loop is applied to the laboratory exhaust (25,000 cfm [11,799 L/s]) to prevent any type of cross-contamination. Based on Montreal BIN temperatures, the accumulation type exchanger has estimated yearly efficiencies of 82% for sensible energy and 70% for latent energy. The runaround glycol loop has a winter efficiency evaluated at 40%. Summer efficiency is typically lower because of smaller temperature differentials between indoors and outdoors. This temperature differential is increased in the summertime with indirect evaporative cooling (the water being collected from cooling coil pans). The increase is estimated at 20% based on comparative calculations with and without the humidification process. All air-handling unit fans are equipped with variable speed drives to respond to real-time ventilation requirements including input from CO_2 sensors.

To cut down on the amount of fresh air treated for laboratory purposes, a double duct secondary system is used to recirculate return air from common zones. Based on need, this warmer air can be recirculated to interior zones, used as compensation air for laboratory process exhaust or exhausted through the accumulation-type exchanger.

Figure 4: Atrium staircase is designed to emulate the saved Ginkgo tree. Photo: Olivier Blouin

INDOOR AIR QUALITY AND THERMAL COMFORT

Learning centers, classrooms, conference rooms and other high density spaces have CO_2 sensors within the breathing zone, which allow ventilation to be modulated according to actual need. Laboratories require 4 ach of air to be exhausted, which means that 4 ach of air needs to be supplied. To limit waste, only the minimum ventilation rate is supplied and compensation air completes the ACH requirement.

Laboratories also require 10 ach of mixing which is accomplished with the use of fan-coils, as with most other non-laboratory spaces. Although laboratories are negatively pressurized, the building in general has a positive pressurization to reduce outdoor air infiltration. During suitable weather conditions between 12°C and 20°C, natural ventilation through main circulation areas is automatically controlled (operating windows near the end of hallways open to encourage stack effect through the atrium which has operable skylight windows). Manually operable windows allow for individual control of natural ventilation in non-laboratory perimeter spaces.

Because natural lighting was an important design factor, most spaces are largely glazed. To satisfy resulting envelope loads, a heating and cooling radiant floor and ceiling system is installed in concrete slabs at the perimeter of the building. In addition to having a DOAS that dehumidifies air by supplying it saturated at 12°C special attention was brought to controlling the dew point during the cooling season to prevent condensation on the slabs. Condensation was also a concern in the entrance foyer and central atrium during the heating season. Foyer loads are mostly dealt with radiant floors whereas floor diffusers air wash windows to prevent condensation.

INNOVATION

The new building is heavily glazed and contains many laboratories yet manages to be energy efficient thanks to the particular combination of technologies in its water- and air-based systems.

The hydronic network, which supplies the cooling and heating water to all fan-coils and radiant slabs, is uniquely conceived. First, the same network simultaneously supplies cold and hot water. This is possible because of two large stratified storage tanks and five heat pumps. The heat pumps continuously extract heat from the cold storage for transfer to the hot storage and the geothermal network adds or removes energy from the system. All components work together to maintain the tanks balanced and stratified for simultaneous supply of hot and cold water.

Laboratories are large energy consumers because of their requirements for ACH, pressurisation relationships and contaminants control. These conditions actually provide the right circumstances for a DOAS and dual energy recovery. The DOAS decouples fresh air treatment from zone control by providing fresh air to secondary air treatment systems and zone fan-coils. Zone fresh air, ACH and temperature requirements are individually fulfilled and consequently provide energy savings. Also, the double duct system further reduces energy consumption by supplying warm return air to laboratories that require additional air to compensate for that which is exhausted through hoods and extraction arms. Air extracted by such equipment must be exhausted separately from the general exhaust to prevent cross-contamination in energy recovery devices. A runaround glycol loop could be applied to a combined exhaust, but provides the lowest sensible efficiency and no latent energy exchange. Therefore, this solution is retained only for the laboratory exhaust, whereas an accumulation-type exchanger is applied to the general exhaust. Since all air is returned to the double duct system, the idea is that it is either recycled as compensation air or its energy is recuperated through the general exhaust system.

OPERATION AND MAINTENANCE

A building's optimal performance goes hand in hand with optimal operations, which directly depends on existing and experienced staff. During the design phase, the design team advocated for the involvement of the operation and maintenance personnel on campus to discuss the proposed principles and obtain feedback.

Mechanical rooms and air-handling units are set up to provide the required access and space for maintenance. Laboratories don't have ceilings and most fan-coils are installed either in hallway cabinets or local mechanical rooms to facilitate access to equipment.

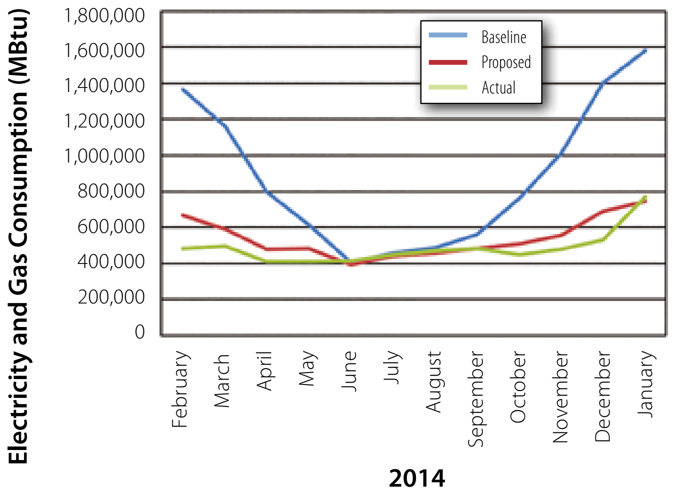

Figure 5: Total energy consumption.

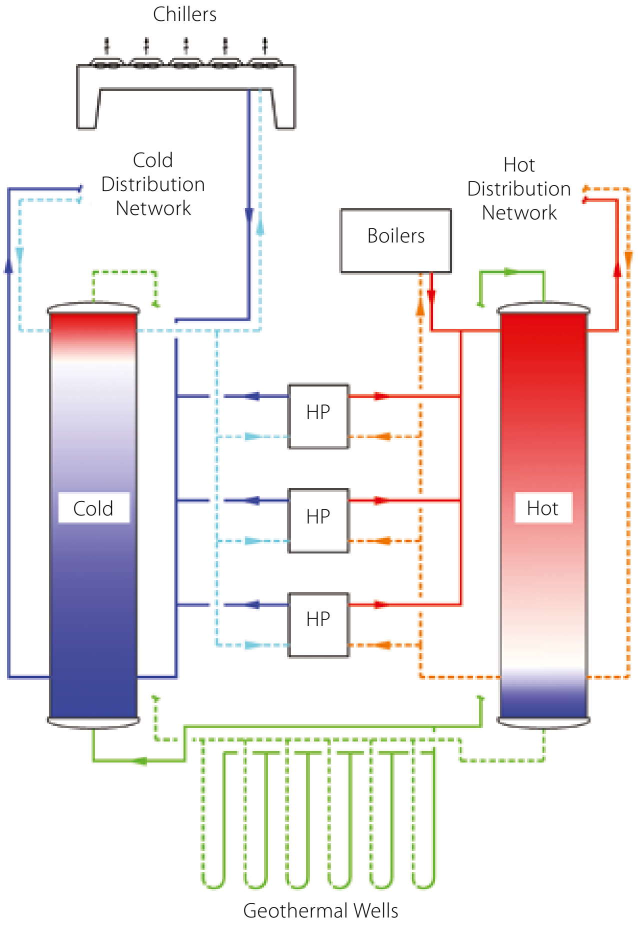

Figure 6: Hydronic network.

A building automation system (BAS) is implemented to automatically control the various building systems and provide operation and maintenance alarms. The building went through a commissioning process that began long before start-up (December 2012) to improve systems even before construction. After start-up, seasonal reports were provided over a one-year span with comments and corrective actions that have all been resolved.

One of the objectives recommended by the designers and supported by John Abbott College was to ensure the building would be used as a sustainability awareness tool. Information about geothermal and solar energy use as well as grey water recuperation is presented in an easy to understand format on an interactive dashboard in the main foyer for consultation by students, teachers and visitors. Additionally, mechanical rooms are designed to showcase the various equipment as their use is explained through a training program overseen by operations personnel in collaboration with teachers from the engineering technology department. Scale mock-up air and hydronic systems are also being prepared for use as teaching setups.

COST EFFECTIVENESS

Total construction costs are of $35 million of which $10.8 million are for electromechanical services. A total of $1.1 million (98 m^2) is associated specifically to energy efficient measures with a payback period estimated at 7.6 years. The payback is reduced to 6.1 years when Hydro-Quebec ($216,647) and Gaz Metro ($8,250) grants are included. Continuous measurement has substantiated annual energy savings, which are currently evaluated at $144,783. Natural gas savings account for $1,970 (domestic and laboratory hot water), $730 of which are estimated as savings from the solar thermal system.

Electrical savings are calculated based on both energy and power usage: energy is charged $0.0441/kWh up to 210,000 kWh and then $0.0391 per additional kWh, whereas power is charged a monthly base rate of $7,541, plus $13.44 per kW over the first 561 kW.

ENVIRONMENTAL IMPACT

The design team adapted the building to the site and not the other way around. Indeed, a century-old Ginkgo tree inspired the design team and explains the unusual shape of the building. The inflection point in the middle of the structure is uniquely due to the safeguarding of the tree. During construction, 75% of waste was diverted from landfill sites and construction materials contain 15% recycled content.

The 45 geothermal wells located within the grassy central courtyard and the solar domestic hot water preheat system offer sustainable forms of energy sources. The dedicated outdoor air system's two energy recovery systems as well as natural ventilation during balmy weather offer significant energy savings. According to the simulation, the building is 39% more efficient than the baseline case which is estimated to be equivalent to 359 tonnes of CO_2 per year (as per Environment Canada). This value is actually larger considering that the building surpassed the simulation results by 10%. Additionally, the geothermal heat pumps and chillers, the only equipment with refrigerant, do not use any CFCs.

In terms of water use, the building limits potable water consumption and recuperates rainwater and coil condensation. Potable water consumption is reduced by 60% relative to the baseline case with the use of low flow plumbing fixtures such as infrared-controlled faucets and low flow toilets and urinals. Also, rainwater and cooling coil condensate is recuperated and redistributed to the building's sanitary fixtures. The grey water installation consists of a large underground tank to store the

Figure 7: The building uses a combination of water and air based systems for energy efficiency. Photo: Mark Cramer

collected water and of a smaller indoor tank to treat the water before its distribution. The condensation from the cooling coil in the fresh air system is also recovered. It is then pumped to the humidifiers in the chemical exhaust system to improve the summertime efficiency of the runaround glycol loop.

CONCLUSION

The new Anne-Marie Edward Science Building at John Abbott College accomplishes energy diversification with the use of geothermal wells, electrical heating and cooling, natural gas hot water heating and solar preheating. Potable water consumption is reduced with the use of low flow plumbing fixtures and resources are maximized through reuse and recuperation:

- Reuse of return air as compensation air in laboratories;
- Reuse of coil condensation water to humidify exhaust air;
- Recuperation on both general and laboratory exhausts;
- Recuperation through heat pump extraction and storage in stratified tanks; and
- Recovery of rainwater and fan-coil condensation water.

Laboratory ventilation requirements and large glazing surfaces can have devastating effects on energy efficiency. Nonetheless, the building's actual energy use is 45% lower than the baseline case and 10% lower than the proposed simulation. ▮

Anne-Marie Edward Science Building

Location: Montreal, Canada

Owner: John Abbott College

Principal Use: Teaching facility

Includes: Laboratories, classrooms, learning center, offices, public spaces

Gross Square Meterage: 11,297

Conditioned Space Square Meterage: 11,297

Substantial Completion/Occupancy: Summer 2012

Occupancy: 100%

National Distinctions/Awards: 2014 Énergia Award (AQME) – New Building, All sectors (First Place); 2014 Contech Trophy – Innovative Practices (First Place)

Architects: Saucier + Perrotte Architectes

Structural Engineers: SDK et associés inc.

ABOUT THE AUTHORS

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ABOUT THIS PAPER

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