Head of the Class For No GHG-School

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Editor's Note: This article gives an overview of the innovative design of Québec's École du Tournant. *For a discussion of some specific technologies see "Ground-Source Heat Pumps: Energy Efficiency for Two Canadian Schools" on Page 28.*

The Commission *Scolaire des Grandes Seigneuries,* a school board located in Québec, Canada, wanted a building with no greenhouse gas (GHG) emissions. In November 2002, its goal was achieved with the *École du Tournant,* an alternative school for ex-dropouts. Exceeding all expectations, the school is GHG-free and is the most energy-efficient school in the province of Québec. This school is 80% more efficient than a similar school built according to the Model National Energy Code for Building (MNECB). The MNECB is the energy code used in Canada. ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* was used as the model to develop the MNECB.

The key elements distinguishing *École du Tournant* are the innovative design method, the envelope's quality, its high efficiency lighting systems, its low-energy HVAC system and its intelligent control system.

Innovative Design Methods

For the *École du Tournant*, several simulation tools were used throughout the design process, which helped the designers conceive a building that uses *80% less energy* than a typical school built according to MNECB. The simulation of several components is a requirement to evaluate their impact on the global performance of the building. The designer should know what is important so the focus is on the most affordable and best performing building features. Several incentives programs and performance base regulation motivated the use of simulations. The Commercial Building Incentives Program (CBIP) from Natural Resources Canada is an example. Similar programs exist in the U.S.

About the Authors

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High Quality Building Envelope

The materials used in the composition of the roof and the exterior walls make them more resistant to heat transfer than required in the MNECB. Although the code requires R20 (RSI 3.45) for the roof and R17 (RSI 3.03) for the walls, *École du Tournant* is composed of a R22 (RSI 3.94) roof and R21 (RSI 3.66) walls. Furthermore, the majority of the windows use double-pane, low-e glazing filled with argon. The composition of the envelope significantly contributes to minimizing heat loss and keeping the heat inside. The Standard 90.1- 2001 requires R16 for the roof and R11 for the walls.

Efficient Lighting Systems

Although for a typical school the lighting power density (LPD) is 1.63 W/ft^2 (17.6 W/m^2), *École du Tournant* school's LPD is only 0.81 W/ft^2 (8.7 W/m^2). The Standard 90.1-2001 requirement is 1.9 W/ft² (Addendum *g* requires 1.5 W/ft² [16 W/m^2]). The lighting system efficiency comes from the optimization of natural light and the use of high-efficient lamps. Most rooms have windows that let the sunshine in and are equipped with a motion sensor and a daylight sensor. The motion sensors turn off the lights when the rooms are not occupied, and the daylight sensors adjust the artificial lights level according to the amount of natural light entering the room. The artificial lighting is made of highly efficient fluorescent T8 tubes with electronic ballasts.

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Low-Energy HVAC System

The two key elements of the low energy HVAC system are using a geothermal heat pump system and a makeup air unit using solar walls and a heat exchanger on the exhaust to preheat the outside air.

Geothermal Heat Pump System

Heat pumps are known to consume at least three times less energy than conventional HVAC systems. Their efficiency is further increased by connecting them to a ground heat exchanger, collecting solar heat stored in the ground to heat the building in winter and rejecting excess heat to cool the building in the summer. A total of 24 geothermal heat pumps are distributed throughout the building for space heating and cooling. An additional heat pump is used for the fresh air (see *Figure 2*).

Solar Wall Makeup Air System

The makeup air system solves the problem of having to preheat the outdoor fresh air entering the building. The amount of fresh air is based on Standard 62-2001 (15 cfm/student [7 L/s] in the classrooms). Typically, Québec's winter temperatures vary between –13°F and 14°F (–25°C to –10°C). It takes a lot of energy to bring that air to a comfortable 72°F (22.2°C). Through proper control sequences, the use of a geothermal heat pump, heat recovery on the exhaust and two

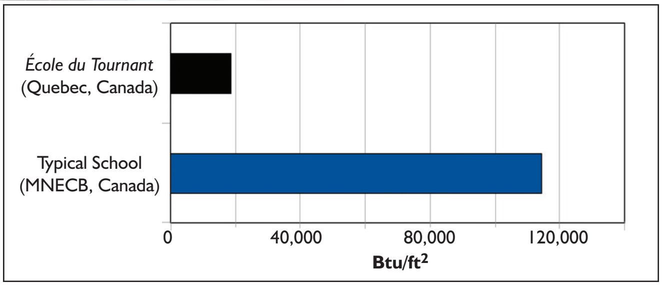

Figure 1: According to the monitoring results from Hydro-Québec's Research Institute, the metered energy consumption of École du Tournant was 22,870 Btu/ft² (0.26 GJ/m²). That's an 80% drop compared to the typical school built according to the MNECB (114 350 Btu/ft²).

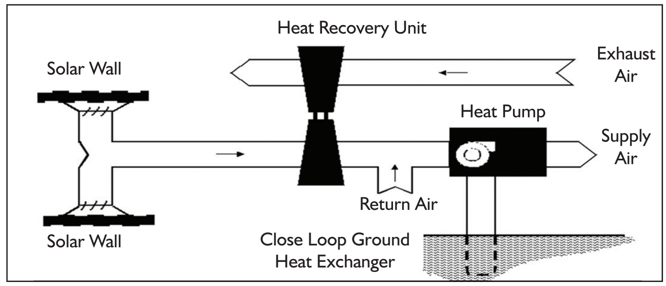

Figure 2: During the heating season, the fresh air enters the building through the solar walls and benefits from solar radiation heat. The air is then heated through the heat recovery unit and finally though a geothermal heat pump. Electrical resistance heat is used only in extreme weather conditions.

solar walls (solar collectors), the designers were able to considerably reduce the amount of energy required.

Fresh air is admitted only according to the needs of the zones. A geothermal heat pump heats or cools the air as required with little effort, a heat exchanger recovers heat from the exhaust for air preheating, and the two solar walls considerably increase the outdoor air temperature, reducing the effort required of the heating system. The solar walls have proven to be very effective. According to the owner, when the sun is shining, the air temperature rises from –7°F to 39.2°F (–22°C to 4°C) just by going through the solar wall. That's a 46.2°F (25°C) temperature increase for free!

Intelligent Control System

One of the easiest ways to reduce energy consumption is to turn off the equipment when not in use. The HVAC systems are programmed to be turned off for any unoccupied hour and when the motion sensors detect no one inside. The amount of required fresh air is adjusted with the amount of CO_2 detected by the sensors. The control system also includes the possibility of choosing between two solar walls (solar collectors) located on different parts of the building to optimize the temperature of the outdoor air admitted to the building based on sunlight conditions.

Indoor Air Quality

The ventilation rate in every room was based on the ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality's* Ventilation Rate Procedure. A centralized supply air system with 100% outside air is dedicated to provide ventilation. The goal is to provide enough outside air to limit the CO_2 content at a level that does not exceed 500 ppm over the outside air level. With this control strategy, other contaminants are expected to be removed from the building.

Special attention was given to the selection of building components (inspired by the U.S. Green Building Council's Leadership in Energy and Environmental Design® requirements). No carpet is used. All floors are made of hard surfaces for ease of maintenance and cleaning. All material, including any paint, adhesives and sealants, have low VOC emissions.

CO_2 is monitored by the energy management and control system. A control strategy provides adequate ventilation without any excessive use of outside air. The ventilation effectiveness is achieved by supplying outside air to the return duct of each heat pump unit. Ventilation air is supplied with the full airflow of each air-conditioning unit. Full airflow ensures an adequate distribution of ventilation air.

Innovation

What sets *École du Tournant* apart from other buildings isn't only its high performance but also the innovative means by which the building was made energy efficient and GHG-free. Instead of trying "new-and-yet-to-be-proven" building technologies, the designers gathered together and decided on a feasible way to significantly reduce the school's energy consumption and eliminate GHG emissions. The concept of the HVAC system is the key element to the

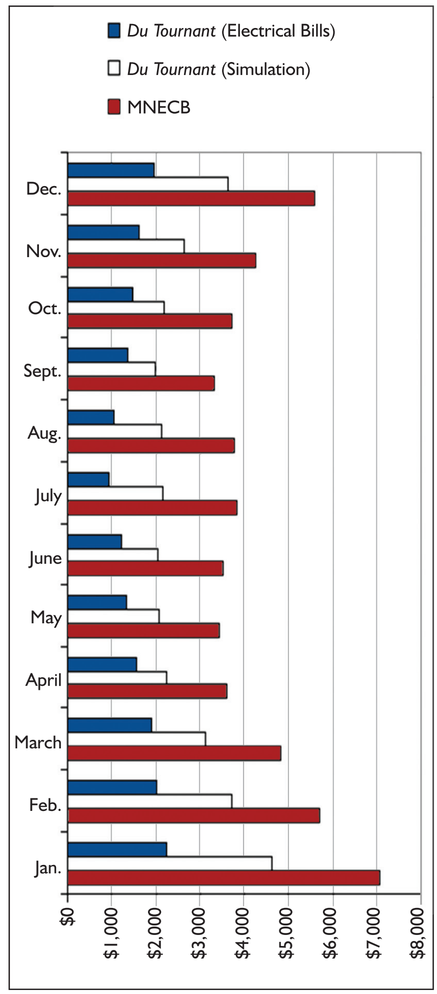

Figure 3: Based on the results from the energy simulations, the school was supposed to save more than Can$20,000 per year in energy cost. Exceeding everyone's expectations, the electrical bills showed that the annual energy savings are closer to Can$34,400.

overall building performance. The HVAC system maximizes use of renewable energy and operates intelligently with an efficient control system.

Maximizing Renewable Energy Sources

For this project, no need existed for a polluting boiler, a noisy chiller or an unsightly cooling tower. *École du Tournant* runs on clean, quiet, visually pleasing and renewable solar energy. With the help of a geothermal heat pump system, most of the required heat during the heating season comes from the ground, previously heated by the sun. During the cooling season, excess heat is extracted from the building and sent back to the ground.

Exterior solar wall.

The designers took their design further and maximized the efficiency of the system by allowing an electrical coil, located in the heat pumps, to contribute during extremely cold days where the efficiency of the heat pump system would have dropped due to the low outside temperature. A glycol preheating coil is not required. Two perfectly integrated solar walls and a heat recovery unit meet the requirement for heating the cold outdoor air supply in winter. This design was improved further by integrating a control system that can decide which solar wall offers the best temperature increase. Also, once the air enters the building, it is further heated through a heat exchanger, recovering heat from the building's exhaust air.

Intelligent Ventilation System

The simplest way to save energy is to turn off equipment when not in use. This concept was applied to the school's ventilation and the lighting system by introducing sensors throughout the building. The HVAC system uses occupancy sensors and CO_2 sensors to determine when and how much air is required in a room. When no air is required, the system is closed. Similarly, the already efficient lighting system is enhanced through using occupancy sensors and light sensors to determine if enough light is in a room. If the amount of natural light is adequate, the artificial lights are off and as the amount of natural light decreases, the system calibrates the lighting intensity according to the need of the rooms.

Operation and Maintenance

Compared to schools with a conventional HVAC system, maintaining and operating *École du Tournant* is much easier. Because it has few moving parts, uses a closed loop geothermal system and centralized control, its design is more durable, and its operation is more reliable. Also, most of the components are buried underground and, therefore, protected from the elements. In addition, each of the pipes going into the ground and back into the building have a shut-off and control valve on the supply and return lines. Not only does this give more control to the user on the amount of heat that goes into or out of the school, if by any chance one of the pipe is flawed, it won't jeopardize the entire system. This detail contributes to increasing the ease of maintenance and operation of the system. The ASHRAE guidelines on commissioning was a useful reference for the startup of this building.

Cost Effectiveness

To incorporate all the previously mentioned energy-efficient components into the school, Can$220,500 was invested. The efforts put into the design were rewarded with a Can$44,600 incentive from Commercial Building Incentive Program (Natural Resources Canada) and another Can$40,000 from the Renewable Energy Development Initiative (Natural Resources Canada). The net investment for the energy-efficient component of the school is Can$135,000. The energy bills from the past two years as well as the results from the simulations show that *École du Tournant* school saves Can$34,400 in energy per year, resulting in a payback period of 3.9 years.

Environmental Impact

École du Tournant is one of the few buildings in Québec proven to encourage sustainable development and have a positive impact on the environment. Reports during the past two years show that the majority of the heating energy comes from a renewable energy source. The secondary heat source comes from a hydroelectric source and doesn't emit GHG. As an alternative, given the small amount of artificial energy, the GHG emitted by natural gas heating would be close to none.

Conclusion

At the end, the school district received a GHG-free building. Most of the required solar heat is harvested from the ground through using geothermal heat pumps. Much of the otherwise rejected or unused heat is recovered with a heat exchanger unit. Two intelligent solar walls provide free heat to preheat the incoming fresh air. This school is 80% more efficient than a similar school built, according to the MNECB.