2021 ASHRAE Technology Awards | First Place

Dalhousie IDEA building with Design Building in the background. (Credit: Lindsay Construction)

Innovation for Engineering and Architecture Buildings

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One reason thermally active building systems aren't commonly used in North America is due to the risk of condensation. But, the design team behind a Canadian university engineering campus' building was able to mitigate this risk and deliver a high performance building. The adjoining IDEA Building uses in-floor radiant heating with chilled water fan coils.

The Innovation and Design in Engineering and Architecture (IDEA) Building houses welding, wood, paint and machine shops along with labs, an incubator space, meeting rooms, a classroom and an atrium. The Design Building includes a 450-seat auditorium, study areas, design studios and meeting spaces. Total square footage of the buildings at Dalhousie University's Sexton Engineering campus in Halifax, Nova Scotia, Canada is 8511 m^2 (96,228 ft^2).

Energy Efficiency

The mechanical systems of the IDEA and Design Building included the installation of a new campus geoexchange system, consisting of sixty 152 m (500 ft) deep vertical bore holes. Three modular

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175 kW (50 ton) water-to-water heat pumps are set up in a heat recovery arrangement, allowing heat recovered from areas requiring cooling to be used directly for heating. Hot water and chilled water buffer tanks are used to prevent short-cycling. The heat pumps feed in-floor radiant heating and cooling, using a thermally active building systems (TABS) in the Design Building and in-floor radiant heating with chilled water fan coils in the IDEA Building.

The university's district energy system, which is fed by natural gas fired boilers, provides supplemental and auxiliary heat to the heating system, allowing the heat pumps to be sized for the (smaller) cooling load. Ventilation in all areas except the auditorium is provided through dedicated outdoor air systems (DOAS) with energy recovery wheels, heating and cooling coils, high-efficiency filters and direct-drive plenum fans. Circulation pumps and air-handling unit (AHU) fans are equipped with variable frequency drives.

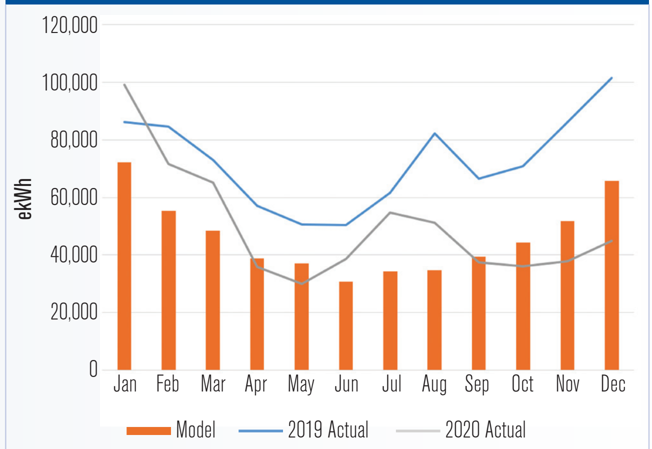
Demand-controlled ventilation (DCV) is used throughout the buildings, as occupancy is variable throughout the day and year. DCV is achieved through the use of carbon dioxide sensors or occupancy sensors and pressure independent variable air volume (VAV) boxes on supply and exhaust systems.

The auditorium has a dedicated single zone VAV AHU, which supplies conditioned air through an underfloor air distribution system. Fan arrays were selected for the supply and return fans to reduce noise levels, which is critical in a teaching auditorium. The AHU has a reheat coil to enable dehumidification while maintaining a comfortable supply air temperature of 18°C (65°F) for underfloor ventilation. Reheat is achieved without an energy penalty due to the "free" heat recovery from the central plant.

Dust collectors serving the wood shops are equipped with motorized blast gates, and their fans have variable frequency drives allowing collectors to be downsized (sized for a percentage of the total equipment in operation), reducing the first cost of the system, noise levels and energy use, as all equipment is not simultaneously used.

To enable the use of TABS, low loads were enabled through the use of a low energy lighting design and a high-performance building envelope system. The envelope system included R-30 walls, an R-40 roof and triple glazing in the Design Building and a modest 20% window-to-wall ratio, resulting in a thermal energy demand intensity (TEDI) of 21 kWh/m^2·yr (72 kBtu/ft^2·yr) and a net sensible cooling load of under 30 W/m^2 (2.8 W/ft^2), which is within the recommendations for buildings using TABS.

FIGURE 1 Monthly energy use comparison.



The buildings' electrical systems include LED lighting throughout, coupled to a lighting control system using occupancy and daylight sensors. A 150 kW solar photovoltaics (PV) system is installed on the buildings' roofs over two arrays. A 184 kWh/100 kW battery energy storage system reduces peak demand on the electricity grid, lowering energy costs, while also being available as a teaching tool for engineering classes.

Prior to calibration, the energy model indicated a 55% energy savings against the 1997 Model National Energy Code for Buildings (MNECB) (approximately equal to a 45% savings against ANSI/ASHRAE/IES Standard 90.1-2007) with almost 15% of energy use being produced by the solar PV arrays.

Actual energy use for the year 2019 was 48% higher than forecasted (*Figure 1*). The energy use discrepancy is largely because of higher-than-expected lighting and heat pump energy use due to controls issues that caused lights and AHUs to operate for longer periods of time than planned. Even with the higher energy use, the project still met the goal set out in Architecture 2030 of using 70% less energy than average educational buildings.

Energy use fell substantially in 2020 due to operational improvements and reduced AHU operating schedules in areas unoccupied during the pandemic. Further commissioning, measurement and verification are ongoing to help maintain the building energy use in line with the energy model's results.

IAQ and Thermal Comfort

A superior level of thermal comfort was a goal of the design, which resulted in a system selection that not only controls air but also radiant temperature. Lower airflows also reduce the chance of drafts, and diffusers were selected with an ADPI of greater than 80. The building was designed with the thermal comfort assumptions found in *Table 1* to comply with ANSI/ASHRAE Standard 55-2010.

Ventilation airflow rates were calculated following the ANSI/ASHRAE 62.1-2007 ventilation rate procedure. As most systems are DOAS with air supply below space temperature, the zone air distribution effectiveness is 1.0. The auditorium has a stratified underfloor air distribution design with low-velocity displacement supply, achieving a zone air distribution effectiveness of 1.2; an airflow measuring station was installed on its outdoor air intake to ensure proper airflow is maintained during all operating conditions, as well as to enable DCV. Floor diffuser selection and location were carefully analyzed to ensure thermal comfort was achieved for occupants. All AHUs are provided with MERV-13 final filters. Carbon dioxide sensors are installed in densely occupied spaces (including the top row of the auditorium due to stratification) and they produce an alarm in the BAS when CO_2 levels exceed setpoints. Laboratories and shops are negatively pressurized to contain pollutants.

TABLE 1 Design thermal comfort assumptions.

Assumed Activity Levels	1.1 met (All Areas Except Workshops)
Clothing Thermal Resistance	0.5 clo (Summer), 1.0 clo (Winter)
Dry-Bulb Temperature	Summer: 77°F in Radiant Cooled Areas, 75.2°F in Areas Without Radiant Cooling Winter: 69.8°F
Radiant Thermal Control	Designed for 84°F Maximum, 70°F Minimum Floor Temperature
Humidity	60% Maximum
Air Velocity	< 40 fpm

Innovation

The use of TABS for radiant heating and cooling is not common in North America. Design manuals were used from North America and Europe to help make the project design go smoothly and give the team confidence. As the Design Building used the TABS for both heating and cooling, a finite element analysis (FEA) study took place to determine the minimum slab surface temperature required to meet the space loads. The minimum slab temperature was determined to be 21°C (70°F), using 18°C (64°F) chilled water. The slab surface temperature was compared to typical annual weather data for the city, and it was determined that, on average, the dew point exceeded 21°C (70°F) only four hours a year. Nonetheless, mitigation strategies were put in place, and dew point is monitored throughout the building. These strategies include increasing airflow rate to high dew-point zones, followed by shutting off water flow to zones, if required. During unoccupied hours, the AHU is enabled in recirculation mode as required to meet dew-point requirements that may result from infiltration.

Operation and Maintenance

Operation and maintenance personnel were involved in design presentations throughout the design process, providing feedback on design improvements to ease maintenance. The auditorium supply plenum was made accessible to ease cleaning, and baskets were included with diffusers to catch items that may fall through the diffusers. Radiant cooling was discussed to ensure the appropriate measures were incorporated into the design. The radiant tubing was placed in the middle of the 250 mm (10 in.) structural slabs to reduce the chance of anchors piercing the tubing.

All major mechanical equipment (AHUs, heat pumps and rainwater cistern) are located indoors to ease maintenance during harsh weather conditions and increase equipment life at this coastal location.

The mechanical and electrical systems are also designed to be used as a teaching aid for engineering students. Piping systems in mechanical rooms are color coded according to service, matching the building automation system (BAS) graphics, allowing students to more easily understand system operation. Large screen TVs are located in mechanical rooms, allowing tour guides to display BAS graphics to students.

Cost-Effectiveness

An economic analysis took place, comparing three options for the heating system. The baseline was using the university's district heating plant. A second option considered was an air-to-water heat pump backed up by district heating, while the third option was a ground source heat pump (GSHP) system backed up by district heating. The GSHP system was found to have the lowest life-cycle cost over a 25-year period, when considering initial cost, maintenance cost and energy cost.

The use of radiant heating and cooling systems allowed for smaller ductwork due to airflow rates being reduced by over 50%, which minimized the ceiling height requirements and building cost compared to a typical HVAC system design. After the GSHP system was chosen, funding from a federal incentive program was secured. This allowed the geoexchange system to double in size to fill the whole area of the soccer field on campus, providing spare capacity for other buildings and process uses in laboratories. This grant also funded the solar PV installation, among many other green initiatives.

Environmental Impact

Greenhouse gas emissions have so far been reduced by 354 tons of CO_2e per year, equal to a 39% savings. Almost 15% of energy use is generated by an on-site solar PV array. The refrigerant used in the heat pumps was a hydrofluorocarbon (HFC), resulting in zero ozone depletion potential. HFCs still have a significant global warming potential (GWP), but the use of water-cooled equipment significantly reduces the refrigerant charge and, thus, the potential impact on climate change. A rainwater cistern provides recovered water to low-flow toilets and urinals, reducing potable water use by 50% compared to a conventional building. The campus geoexchange system is also used for process cooling needs within laboratories, reducing water use where once-through cooling was used in the past. The project is a LEED Platinum candidate.

Acknowledgments

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