Humber College
Building NX

A Zero Carbon Building
Humber College – Building NX | Toronto, ON
Zero Carbon Building – Design
May 2019
humber.ca
cagbc.org/humbercollegenx
A GROUND-BREAKING DEEP ENERGY RETROFIT:
Humber College’s Zero Carbon Building NX

Humber College Institute of Technology & Advanced Learning’s Building NX in Toronto is the first retrofit project to achieve a Zero Carbon Building – Design (ZCB-Design) certification from the Canada Green Building Council (CaGBC).

The achievement is quite impressive for a retrofit project, requiring energy-saving targets unprecedented outside of new construction projects. The retrofit of the five-storey North Campus building cements Humber College’s sustainability leadership within the post-secondary sector in Canada, by highlighting their advocacy for high-performance, low-carbon buildings. Building NX’s transformation from one of the lowest performers on campus to a zero carbon building has made it a focal point for educating students on energy efficiency and sustainability more broadly, and makes a compelling case for zero carbon retrofits.

KEY INFORMATION

| Owner: | Humber College |
| Architect: | B+H Architects |
| Building Envelope and Sustainability Consultant: | Morrison Hershfield |
| Structural, Electrical and Mechanical Engineer: | Morrison Hershfield |
| Contractor: | BIRD Construction |
| Energy Engineer: | RDH Building Science |
| Total Building Area: | 4,487 m² (48,298 ft²) – GFA: 4531 m² (building footprint = 1026.8 m²) |
| Type: | Office Building |
| Climate Zone: | Zone 6 |
| EUI: | 63 kWh/m²/year |
| TEDI: | 12.5 kWh/m² |
| Peak Demand: | 88.3 kW |
| Onsite Renewable Energy: | 11.8% |
| Renewable Energy Utilization Rate: | 98.4%¹ |
| Embodied Carbon Intensity: | 377.4 kg CO₂e/m²² |

¹ Renewable energy utilization rate refers to the percentage of renewable energy generated that is consumed onsite.
² Embodied carbon calculation includes both new and existing materials.
VISION

Humber College’s commitment to sustainability leadership

Humber College’s 20-year Integrated Energy Master Plan (IEMP) reflects the institution’s sustainability focus and weaves into every aspect of the organization. Under the plan, Humber committed to ambitious goals, including halving the institution’s energy and water use and reducing its greenhouse gas (GHG) emissions by 30 per cent compared to a 2014 baseline by 2034. To achieve these goals, Humber is investing in industry-leading energy efficiency methodologies and new performance benchmarks, such as the CaGBC’s Zero Carbon Building Standard, which focuses on carbon as a key performance metric.

As part of the IEMP, the institution targeted Building NX with the ambition to transform it from one of the campus’ most inefficient to an example of zero carbon excellence. Originally built as a campus library in 1989, Building NX has 4,487 m² (48,269 ft²) of space over five-storeys and is now mainly used for administration and public safety offices.

Despite the building’s reputation for being cold in the winter and hot in the summer, the college decided to retrofit the building over building new. Due to the aggressive deep measures implemented, this retrofit has a longer payback period than more typical retrofits that the college has applied elsewhere. This better supported the college’s sustainability goals and still provided a building with optimized comfort for the staff and students spending time there.

The guiding vision for this project was to reduce GHG emissions and enhance the college’s sustainability culture. In addition to the ZCB Standard, the project team also aimed to pursue an EnerPHit Certification, designed specifically for retrofit applications. These efforts ensured that the Building NX project would be an excellent showcase of the potential of deep energy and carbon retrofits in existing building stock.
THE PROCESS

Making the most of the existing building

The Building NX retrofit project followed an integrated design approach to reduce the building’s overall energy demand and carbon emissions. The project team started with a high-performing envelope and then increased operational efficiency through a carefully designed electro-mechanical system and the installation of onsite renewable energy.

The building was constructed in 1989 and was originally used as a library. However, in 2016 the building was repurposed as a faculty office. Occupant research conducted before the retrofit revealed a high level of dissatisfaction, with complaints of the space being hot in the summer and cold in the winter. Since its construction, personal computer usage has dramatically increased, emphasizing issues with extreme glare introduced by the block wall features. The building also experienced water leaks through sections of the walls and roof. Although typical of other buildings of this vintage, these elements made Building NX an obvious choice for this first-of-its-kind upgrade.

To begin the process, the project team installed temporary metering in the building to gather a couple of weeks of plug load data prior to the retrofit. This data was combined with occupancy data to provide estimates of the building’s energy use. With this baseline, they were able to model the ideal energy usage and help shape design direction early in the retrofit process.

One unique challenge of the retrofit process was that the building was occupied while the renovation was taking place. This requirement meant that the project team had to plan the extensive envelope upgrades to be accomplished mainly from the outside of the building to avoid significant occupant disruption.

The CaGBC’s Zero Carbon Building Standard and the EnerPHit’s certification process challenged the design team to satisfy stringent limits on heating and cooling demands, airtightness, and energy use intensity. Building NX surmounted these challenges through careful integration of architectural, envelope, and mechanical design.
THE DESIGN

The challenge of re-designing an existing building

Compared to a new build, retrofitting an existing building has many limitations, including the predetermined form, orientation, and openings. These existing elements can restrain the ability to apply basic principles of sustainable design, such as optimum orientation, building form, and layout. To achieve zero carbon, the project team must focus even more on efficiency and aim for advanced insulative qualities and a high degree of envelope airtightness.

Humber College’s Building NX is located in the center of the campus site. Its main orientation faces north, limiting the potential for passive solar gains and further increasing the imperative of a great envelope.

The new design proposal included a significant reduction in the amount of window area to reduce overall heat loss. The new envelope’s glazing ratio was just 14 per cent compared to 44 per cent before the renovation. The greatest reduction in glazing was seen on the west facade (-53%), followed by the north and south orientations (reductions of 36% and 32% respectively). The placement of the glazing was analyzed extensively to make sure it was put where it was needed most, with specific attention to optimized head and sill heights. The result was less glare and unwanted heat gain. Now, blinds are down less and occupants are enjoying the daylight and views.

Other significant measures to improve the building’s envelope performance included internalizing the north entrance’s glass vestibule, removing the inset chamfers on the northern side to reduce surface area, and removing the skylight to eliminate both thermal losses and water leakage.

These measures, in combination with the substantial reduction of window area, resulted in a significant reduction in energy use for heating (TEDI). Not only were design changes more efficient, but they also increased occupants’ thermal comfort and provided better natural lighting conditions.

Building NX is a great example of a retrofit project that achieved a highly-efficient, Zero Carbon Building – Design and is a candidate for Passive House EnerPHit certification despite many design limitations, setting a great example for the education sector and the building industry.
Glazing ratios before and after the retrofit.

Left to Right: Internalise vestibule, Remove chamfers and Remove and infill skylight (images courtesy of B+H Architects)

Left to Right: Building NX pre-retrofit, during the retrofit, and post-retrofit.
BUILDING ENVELOPE

Sealing the building envelope

Transforming Building NX into a zero carbon project required an upgrade of the existing building envelope and systems. The project team’s approach included a complete envelope retrofit with a highly insulated and airtight construction. The original building envelope consisted of insulated metal sandwich panel, glass block, and aluminum curtain walls and spandrel panels. It was completely replaced and shifted outward to enclose the existing concrete structure, and to achieve the thermal energy performance requirements of CaGBC’s Zero Carbon Building Standard.

“We’ve taken off the entire wall and rebuilt it completely. To stop thermal bridging at the base of the building, we dug down and insulated the foundation. The roof, which had already been replaced, is still intact. However, we did fill in a skylight and add eight inches of rigid insulation to fix more thermal bridging, and to comply with ‘passive house’ certification requirements.”

Spencer Wood, Director of Facilities Management, Humber College

New high-performance triple-pane windows including operable components were also installed, using a thermally broken, passive house-certified frame with a low-e coating.

To address water leakage issues and eliminate thermal bridging, the project team paid special attention to the envelope assembly and wall-to-window, wall-to-wall, and wall-to-roof joints. To ensure a complete thermal enclosure, the roof insulation was enhanced to achieve an effective R-50, including all thermal bridging. Air leakage testing was performed in order to ensure airtightness, and the project was able to achieve less than 0.6 air changes per hour at 50 Pa, surpassing requirements established for new construction. This demonstrates that even retrofit projects can achieve aggressive levels of airtightness.

The features of the envelope design and construction resulted in a very low thermal energy demand intensity (TEDI) of 12.5 kwh/m²/year. The project team shared that “the heating energy use is projected to be less than five per cent of the total building energy use when an average Canadian building is closer to 50 per cent.” As a result, Building NX is now among the most energy-efficient buildings in Canada.

The new envelope is a combination of aluminum composite panels and pre-finished corrugated steel with an effective insulation value between R-38 and R-42 (including all thermal bridging). The composite system is thicker than the older panels and features a six-inch metal stud as well as four-inches of spray foam insulation in an interior cavity. On the outside, there is an additional eight-inches of mineral wool insulation, and thermal clips are used to attach to the new siding.
HEATING, COOLING AND VENTILATION SYSTEM

Designed to meet new energy demand

Improvements to Building NX’s envelope resulted in significantly lower heating and cooling loads. The heating energy represents less than 5 per cent of the total building energy. Subsequently, the mechanical systems needed to be redesigned and resized. For this reason, the original mechanical system was removed and replaced with a new air-source variable refrigerant flow (VRF) heat recovery system. The system includes two new air source heat pumps installed on the roof (complete with a thermally separated support system) and new fan-coil units installed in each thermal zone. To provide a vestibule buffer zone, an electric radiant flooring system and a ceiling radiant panel were installed at the main entrance, located at the north side of the building.

This VRF system also recovers and transfers heat between zones using refrigerant lines. This system improves efficiency and eliminates the need for simultaneous heating and cooling of different zones in the building. The improved building envelope meant that building’s cooling load was dominant, and the VRF was able to use the removed heat to heat the perimeter zones of the building. The use of refrigerant instead of air enabled the duct size to be reduced from fourteen inches to six inches.

A dedicated outdoor air system equipped with heat recovery is used to provide fresh air as efficiently as possible. CO₂ sensors are installed in densely occupied spaces as well as spaces with variable occupancy, such as meeting rooms. All motors are controlled using variable frequency drives (VFDs).
ELECTRICAL SYSTEM

The renovated NX Building features a new Osram’s Encelium® sensor-based lighting control system. Occupancy sensors trigger lighting as needed, aiming to reduce the electrical load even further for the offices’ already-efficient LEDs. The advanced lighting control system also features peak shaving, daylight harvesting and dimming.

The lighting occupancy sensors are integrated with the building automation system. This allows the heating, ventilation, and air conditioning systems to turn off or set back when spaces are unoccupied. This type of smart building integration helps further drive energy savings.

A building-level meter isolates the electricity use from that of the campus, and all the circuits from the main switchboard are also sub-metered to provide an additional layer of granularity when making decisions.

RENEWABLE ENERGY

To reduce the building’s carbon footprint and to minimize the environmental impact from power generation facilities, a new 24kW solar photovoltaic (PV) system was mounted on the roof. It is estimated that the new PV system will generate approximately 31,500kWh per year and cover approximately 11 per cent of the building’s total energy consumption. Over 98 per cent of the solar energy generated will be used in the building, with any excess energy fed into the campus’ upstream electrical distribution, to be used by other buildings.
SUMMARY

With Building NX, Humber College has succeeded in developing a showcase example of how to perform deep retrofits of existing buildings. The building has been redesigned to operate without producing carbon emissions. It will use 70 per cent less energy than before, making a strong case for this project to also take its place as one of the most energy-efficient buildings in North America. In Ontario, the electrical grid peaks are often met using natural gas-fired power generation plants. The passive design strategies used by Building NX will reduce the strain on the electrical grid for heating and cooling and help minimize the use of natural gas by the grid.

Building NX also holds the distinct honour of being the first Zero Carbon Building – Design certification for a retrofit. By choosing to retrofit an existing, low-performing building instead of building new, Humber took the less embodied carbon intensive route, reflecting the institution's sustainability focus and advocacy for high-performance, low-carbon buildings. They also reduced the costs associated with tearing down the building and replacing it.

Today, Building NX operates on electricity, decreasing its carbon emissions. The project team continues to monitor the effectiveness of the measures applied and follow a consistent post-occupancy monitoring process to verify the building's energy consumption and occupants’ satisfaction. Already, occupants have provided complimentary feedback to the maintenance and operations team regarding the comfortable temperatures and ample daylight. This demonstrates that zero carbon buildings can be comfortable and enjoyable while also delivering on deep reductions in energy use and carbon emissions.

---

KEY PERFORMANCE METRICS

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEDI</td>
<td>12.5 kWh/m²/year</td>
</tr>
<tr>
<td>EUI</td>
<td>63 63 kWh/m²/year</td>
</tr>
<tr>
<td>Peak Demand</td>
<td>88 kW</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>31,500 kWh/year</td>
</tr>
<tr>
<td>Embodied Carbon</td>
<td>377.4 kg CO₂ eq/m²</td>
</tr>
</tbody>
</table>