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ENERGY RETROFITS

Comparing Active and Passive Strategies

BY AMAN HEHAR AND MATTHEW TOKARIK

Building for energy efficiency in new construction has become routine when the right technical expertise is enlisted, proper building technology is selected, and few constraints limit the design. Retrofitting for energy efficiency poses a greater challenge when existing buildings employ dated systems, materials, and design practices. Priority must be given to those upgrades that will enable the building to achieve the greatest performance within the given constraints. This article describes how a post-secondary institution selected retrofit packages when presented with many possible options, including both building envelope and HVAC system upgrades.

ABOUT HUMBER COLLEGE AND THE 'N' BUILDING

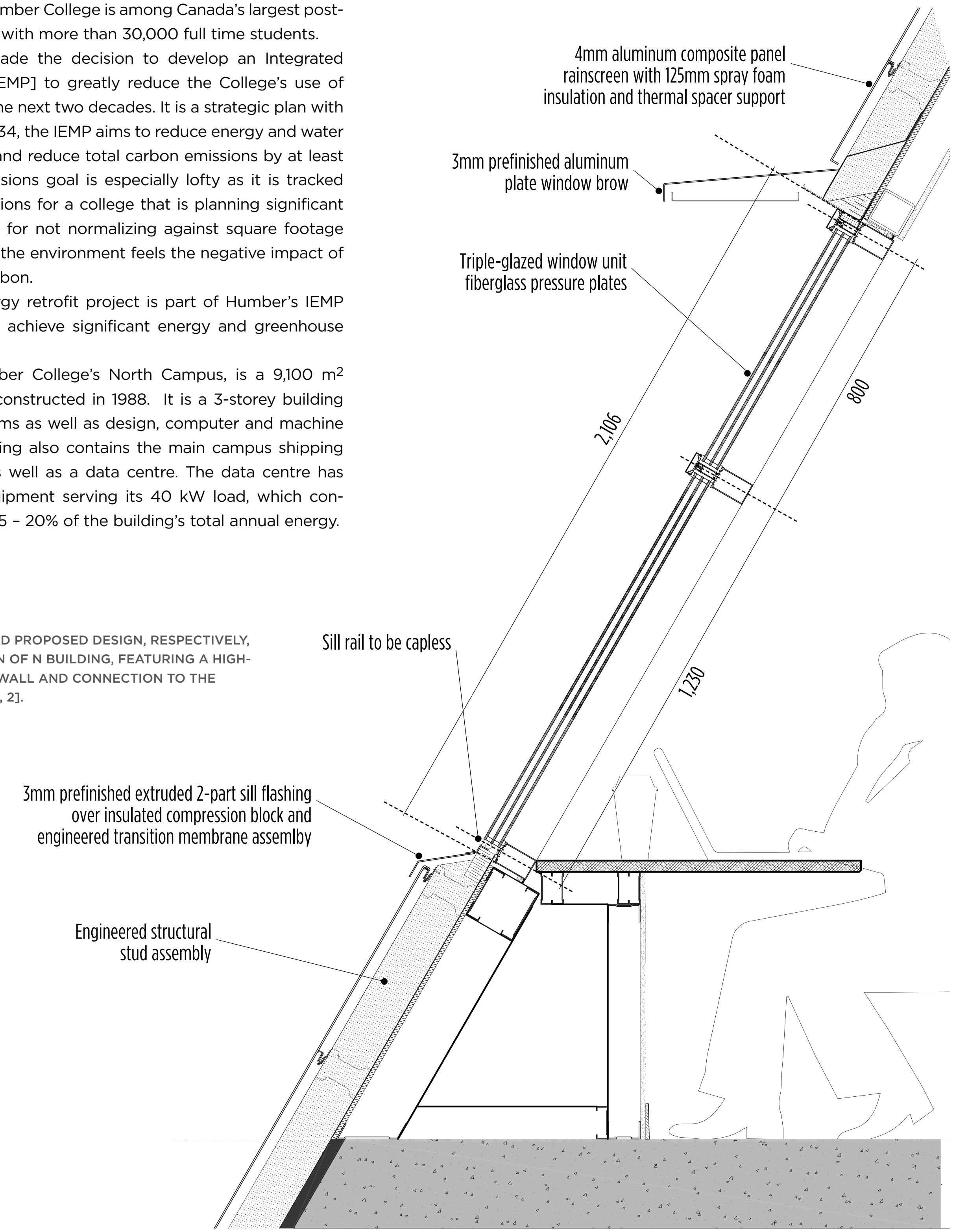
Based in Toronto, Humber College is among Canada's largest post-secondary institutions, with more than 30,000 full time students.

In 2015, Humber made the decision to develop an Integrated Energy Master Plan [IEMP] to greatly reduce the College's use of energy and water for the next two decades. It is a strategic plan with ambitious goals. By 2034, the IEMP aims to reduce energy and water consumption by 50% and reduce total carbon emissions by at least 30%. The carbon emissions goal is especially lofty as it is tracked against absolute emissions for a college that is planning significant growth – the rationale for not normalizing against square footage or students being that the environment feels the negative impact of every ton of added carbon.

The N building energy retrofit project is part of Humber's IEMP and was mandated to achieve significant energy and greenhouse gas reductions.

N building, at Humber College's North Campus, is a 9,100 m^2 [98,000 ft^2] building constructed in 1988. It is a 3-storey building which houses classrooms as well as design, computer and machine laboratories. The building also contains the main campus shipping and receiving areas as well as a data centre. The data centre has dedicated cooling equipment serving its 40 kW load, which consumes approximately 15 – 20% of the building's total annual energy.

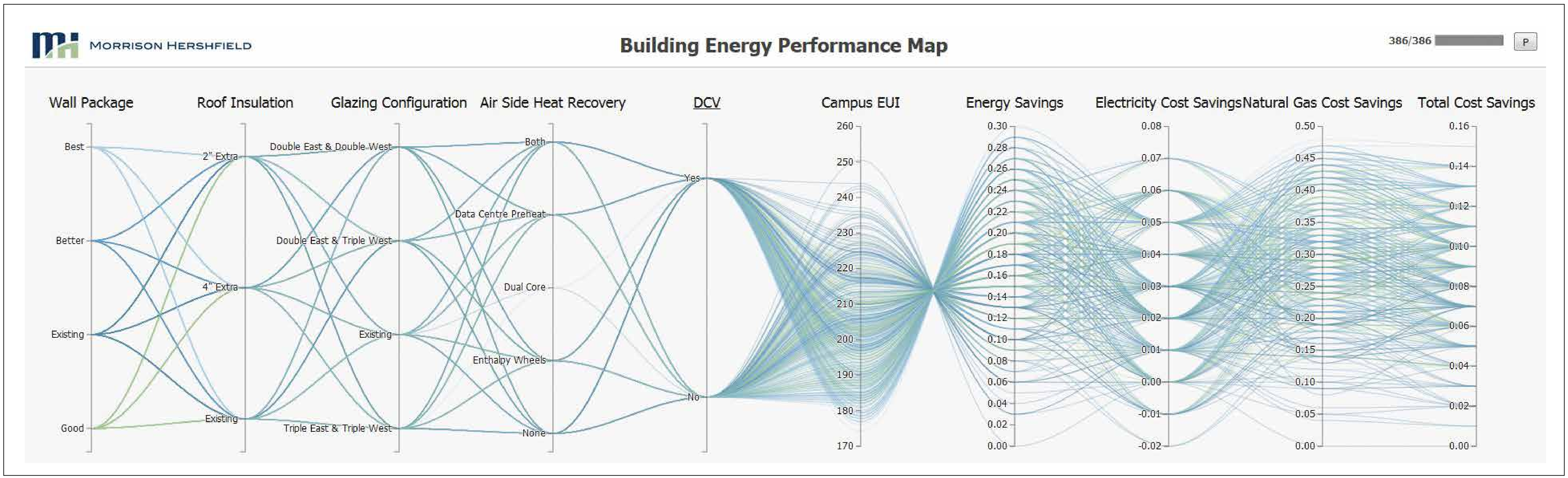
THE EXISTING FAÇADE AND PROPOSED DESIGN, RESPECTIVELY, FOR THE WEST ELEVATION OF N BUILDING, FEATURING A HIGH-PERFORMANCE CURTAIN WALL AND CONNECTION TO THE ADJACENT COURTYARD [1, 2].



Typical wall section

The exterior façade has sections of exposed structural concrete and masonry, sloped aluminum sandwich panels, and curtain wall glazing. Space conditioning is provided by a central chiller and steam boiler plant, which also serves much of the campus, as well as three roof top units [RTU's] with gas fired heating and direct expansion [DX] cooling. A dedicated cooling system provides chilled water for the data centre. Supply air is delivered to the spaces with variable air volume [VAV] systems.

As part of a value engineering exercise during the original design of the building, the proposed rainscreen for exterior cladding was omitted. As a result, the building has experienced significant water penetration issues for over a decade. Temporary solutions to improve the face-seal, which have far exceeded the initial value engineering cost savings, have failed to resolve the underlying issues.



A review of the envelope was recently undertaken by a building science consultant and several issues including failing sealants, displaced gaskets, lack of air/weather barrier tie-ins, missing flashings and corroding fasteners were identified. Due to the advanced state of disrepair, a complete replacement of the existing panels was recommended.

WHY RETROFIT?

For an institutional owner, or those with similarly large portfolios, it is important to factor existing assets into broad sustainability or energy efficiency strategies. Although it is exciting to plan a new state-of-the-art facility, aging building stock must not be overlooked as such structures may comprise the majority of a typical building portfolio. Apart from the operational energy savings an energy retrofit will provide, there are many other reasons to upgrade an existing facility.

For common building materials, such as steel, concrete, aluminum, glass, and rock wool, a vast amount of energy is needed to melt and process raw material, transport product, and construct on site. All of this embodied energy is stored in the building as it is in service. By retrofitting existing buildings, unnecessary carbon emissions associated with demolition, material production, and new construction can be avoided.

Thermal comfort and indoor air quality problems are often sited in buildings with poor thermal envelopes and dated mechanical systems. Especially for occupants sitting next to windows, a cold draft, extreme solar exposure, or a cycling HVAC system trying to keep up to the demand can lead to discomfort. Combined with underperforming ventilation systems and control strategies, indoor air can seem stale and stagnant. By improving envelope thermal performance and air system controls, thermal comfort and indoor air quality can be maintained with less reliance on conditioned air delivery.

As is the case for many campuses or other dense urban settings, space for expansion at Humber College is limited. Further, for all asset owners, capital investment, cash flow, and returns are always top of mind. Improving existing buildings, rather than constructing new ones, provides desirable space on already-owned land for less capital.

From Humber's perspective, the decision to invest in the envelope replacement was a relatively easy one. The building is built like a tank – having originally been designed for heavy machinery programs, the concrete structure is in good condition and was built to last. The college has also invested in significant interior renovations over the years to cater to changing functions and user demands. Once the envelope has been replaced, the service life of the building should be significantly increased.

And because the envelope had to be changed anyway for deferred maintenance reasons, the opportunity was taken to upgrade the building for superior energy efficiency at the same time.

DEFERRED MAINTENANCE

Deferred maintenance refers to the financial value of building maintenance and repairs that are past due, typically due to lack of funds. In a 2010 report, the Auditor General of Ontario estimated that the deferred maintenance backlog at colleges was in the range of $568 to $745 million. Without a significant investment, the problem with deferred maintenance is that the backlog continues to get larger as more and more infrastructure comes due for repair. Indications are that the backlog for the college sector has since increased and may now be as high as $1 billion.

The sector as a whole is operating in an era of changing demographics and funding models that mean that operating and maintenance budgets continue to feel squeezed. The bottom line is that colleges have to be extremely selective when making investments in existing infrastructure.

HOLISTIC ENERGY ANALYSIS

Humber had to select a combination of building envelope and HVAC system retrofit options that best aligned with the IEMP, addressed the building's durability and condition issues, and made financial sense.

The first step was to identify all possible retrofit options based on the condition of the building, system design, age of equipment, and building energy use pattern. From an initial assessment, the following items were put forward as possible retrofit options: additional wall and roof insulation, high-performance glazing, thermal bridge mitigation, RTU heat recovery ventilation, data-centre heat recovery, demand control ventilation [DCV], VAV box upgrades, a steam-to-hot water heat exchanger upgrade, and domestic hot water [DHW] production improvement.

Some of these items were removed quickly from the list without any detailed analysis. Humber plans to replace the central steam boiler plant with a hot water boiler plant in the near future, so all steam-to-hot water heat exchangers will be removed making any heat exchanger upgrade a temporary solution. Humber concluded that the DHW upgrade was out of the scope of this capital project because the DHW boiler for N Building was located in a separate neighboring building. They also decided to forego the VAV box upgrade because ultimately it would do little to improve the operational efficiency of the building relative to the other measures.

A detailed energy analysis was performed to compare the efficacy of the remaining retrofit options. An energy model was created using drawings, site visit findings, energy use data, and discussions with the building operator to imitate the energy performance of the existing building. This analysis method was selected because it is otherwise difficult to compare the interactions of concurrently changing envelope and HVAC parameters.

For the remaining energy efficiency measures – thermal envelope improvements, air-side heat recovery, and DCV – improvement values were assigned along a range of realistic intervention. For example, 50 mm [2 in.], 100 mm [4 in.], or 150 mm [6 in.] of wall insulation thickness, or 70% versus 85% sensible energy recovery effectiveness could be tested in the energy model.

To capture the holistic effects of the upgrades, each possible parametric combination was tested. This resulted in 386 unique simulations. Engineering consultant Morrison Hershfield's Performance Mapping Tool, for the N Building simulation batches, was used to visualize and compare the data produced by the simulations. Vertical axes on the left, labelled wall package, roof insulation, glazing configuration, air side heat recovery, and DCV, represent tested energy conservation measures. Vertical axes on the right, labelled campus EUI, energy savings, electricity cost savings, natural gas savings, and total cost savings, report the results produced. Each curve represents a unique simulation. This type of visualization can be customized to include any input parameters or results of interest, and can be produced for thousands of comparative simulations if desired.

By manipulating the Performance Mapping Tool to filter simulations with unwanted results [i.e., high campus EUI, low cost savings], input trends can be observed to aid in decision making. This workflow and visualization streamlined Humber's decision making process and made for efficient use of stakeholder meetings. By assessing all possible combinations at the start of the study, any 'what if' scenario was available for immediate consideration.

SELECTED MEASURES

The results from the energy analysis were compared to the cost estimates provided by the cost consultant. By comparing these two datasets, Humber was able to see which retrofit packages would provide the best energy savings for a given investment, and where diminishing returns made additional investment unattractive.

For example, investment in heat recovery ventilation provided significant energy savings, but the more efficient heat recovery unit did not add equally significant energy savings and therefore did not make sense to pursue financially. Similarly, the cost and effort required to recover the data centre waste heat did not lead to proportional energy savings and was therefore not selected.

The final package chosen by Humber included the most efficient wall package with improved thermal-bridging details, additional exterior roof insulation, triple-glazed curtain wall with thermally broken frames, RTU enthalpy wheels, and DCV. Building N is expected to save approximately 29% annual energy by implementing the energy retrofit.

LOOKING FORWARD

It is critical for today's students, the leaders of tomorrow, to understand how sustainability relates to their lives and future careers. They will need new knowledge and skills to be able to address the challenges they will face in the 21st century and beyond. Humber College truly believes that incorporating the concepts of sustainability into learning can help shape the future – so much so that the IEMP specifically attempts to find linkages with Humber's academic curriculum.

On the N building project specifically, a multi-disciplinary student team covering various programs – architectural technology, sustainable energy & building technology, civil engineering technology, project management and supply chain management – was created and tasked with designing the project in parallel. Working towards creating various deliverables, the student team meets regularly with the architecture and engineering professionals involved on the project to get feedback and garner insights.

Putting the students in a multi-disciplinary team environment that will mimic their future careers and give them an opportunity to interact with industry professionals is not only invaluable, but also not that difficult to do for a project already happening on campus. Humber hopes to continue this model on future projects.

CONCLUSION

Humber College used a holistic energy approach to select a retrofit package for the N Building. The strategy meets their IEMP carbon target while remaining within the capital budget, and will provide ongoing operational energy savings over the remaining lifecycle of the building. These benefits are additional to moisture and durability improvements that originally spurred the retrofit action, and show the advantage of addressing energy issues in parallel with condition upgrades or end-of-life equipment upgrades. ◀

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Energy Retrofits – Comparing Active and Passive Strategies
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Purpose of the article:
The article describes how a post-secondary institution selected retrofit packages when presented with many possible options, including both envelope and HVAC strategies. It provides an overview of the N Building Energy Retrofit Project at Humber College in Toronto, and the process it underwent in order to help achieve the University's Integrated Energy Master Plan's energy and greenhouse gas targets. It clarifies the important aspects of a holistic approach to energy savings as it relates to Humber College selecting an energy retrofit package for the N building. The article introduces the reader to the relationship between the energy savings of a retrofit strategy and the cost implications of that strate-gy, and discusses how particular potential strategies for the N Building were evaluated based on cost and energy sav-ings. The article also uses the N Building as a case study to introduce the reader to various building envelope design and maintenance issues, such as exposed structure and lack of a rainscreen system, which have adversely affected the overall energy performance of the building and the occupant thermal comfort and indoor air quality.

Learning Objectives:
1. Understand the value of retrofitting existing buildings over demolishing and constructing new buildings, and why this can help reduce costs, increase occupant health and thermal comfort, and reduce energy consumption and greenhouse gas emissions.

2. Understand deferred maintenance and why the growing amount of unaddressed deferred maintenance items are negatively impacting the overall energy performance of buildings.

3. Understand the aspects of a holistic energy analysis, and the factors and outcomes owners must consider when making decisions on a retrofit package under a holistic energy analysis framework.

4. Understand the relationship between passive or active retrofit strategies, and the building's life cycle and long-term durability.

Questions:
1. Most Canadian Universities normalize emissions against total building square footage or student population when tracking the total carbon emissions of their buildings or building portfolios.
a. True
b. False

2. An important factor contributing to the thermal discomfort of occupants in the N building is/are:
a. The aluminum sandwich panel siding
b. The large square footage (98,000 ft2)
c. The sections of exposed structural concrete and masonry
d. All of the above

3. What item, as a result of value-engineering, was omitted from the original design of the N building, and has since caused significant maintenance and repair issues?
a. High performance HVAC system
b. Curtain wall glazing
c. Rainscreen cladding system
d. Operable exterior windows

4. The energy required to extract and process raw materials, then fabricate, transport and install building products is known as:
a. Source Energy
b. Embedded Energy
c. Expended Energy
d. Embodied Energy

5. Poor occupant thermal comfort and indoor air quality are common problems in buildings:
a. That are built during or before the 1970's
b. With poor thermal envelopes and dated mechanical systems
c. That have a concrete structure
d. That house data centres

6. Constructing new buildings, rather than retrofitting existing buildings, is typically desirable because it delivers more space for less capital.
a. True
b. False

7. 'Deferred maintenance' refers to the total financial value of the building, minus the cost of building mainte-nance and repairs that are past due.
a. True
b. False

8. All possible retrofit options of the N building were included in the energy model and were subject to a detailed analysis.
a. False
b. True

9. Morrison Hershfield's simulation tool, which compared retrofit options against a variety of measures such as EUI, Energy and Cost Savings, is known as:
a. Building Performance Simulator
b. Building Simulation and Mapping Tool
c. Building Retrofit Simulation Tool
d. Performance Mapping Tool

10. What does IEMP stand for as it refers to Humber College's campus goals outlined in 2015?
a. International Energy Management Program
b. Integrated Energy Modelling Platform
c. Integrated Energy Management Plan
d. Integrated Energy Master Plan