

Energy Study Report

153 Union Street East

153 Union Street East, Waterloo, ON



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EXECUTIVE SUMMARY

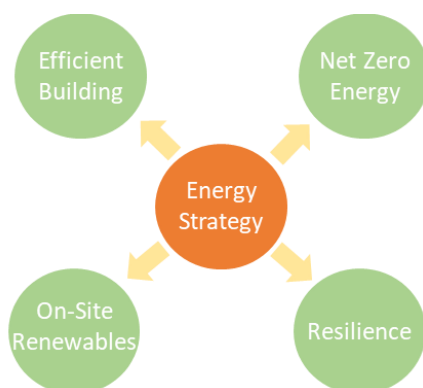
The development team has retained Internat Energy Solutions Canada (IESC) to undertake an Energy Study for a proposed new high-rise residential development located at 153 Union Street East in Waterloo, Ontario.

The redevelopment includes two 12-storey residential buildings with a shared underground parking structure, ground-floor commercial space within Building A, and associated indoor and outdoor amenities. The site is in the early stages of planning; therefore, the Energy Study is intended to inform design development and support the Zoning By-law Amendment application.

The purpose of this Energy Study is the early identification of opportunities to integrate design solutions that meet the guideline principles outlined in the Region of Waterloo's Energy Study Terms of Reference. This information will be then utilized as part of the building design process.

The following chart summarizes key metrics and performance benchmarks developed by the Region of Waterloo. The metrics include Total Energy Use Intensity (TEUI), Greenhouse Gas Emission Intensity (GHGI) and Thermal Energy Demand Intensity (TEDI). This report outlines design strategies to achieve each of the presented targets. Advanced measures such as geothermal and solar PV are recommended for highest targets. These measures were applied into the developed model and preliminary results are presented. Design options are also presented to provide enhanced resilience for the Proposed Development and should be evaluated further on a feasibility and cost basis.

As part of this study, IESC considered a variety of building level scale strategies with the potential to reduce the projects operational energy and carbon impact and to improve resilience and wellness.



Various measures were studied to develop low energy and low carbon strategy for the building. As the energy models were developed for the various Energy Study Performance tiers, there was an overall strategy for primary consideration on improved envelop performance, then advanced mechanical systems followed by onsite energy generation. Some of the energy conservation measures included: efficient low carbon HVAC systems, improved envelope performance, air tightness design, plug load reduction, improved energy recovery efficiencies and solar photovoltaic systems. Additionally, the impact of adding solar PV and other renewables was assessed with solar PV providing significant energy and GHG reductions. Advanced energy solutions including the feasibility of district energy, geothermal loops and other advanced energy reduction technologies was discussed.

A qualitative analysis on building envelop thermal bridging was provided for the design team to consider. A complimentary analysis on embodied carbon in building materials for the proposed project was completed. Concrete is the material estimated to have the highest embodied carbon content for the project. Several mitigation measures and approaches were recommended to reduce the embodied carbon content of concrete for the project.

Finally, a discussion on resiliency was provided for the building systems and energy including recommendations on design techniques to be implemented to improve the overall resiliency of the project. The recommendations and measures within the report should be studied further as the design develops.

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1 INTRODUCTION AND OVERVIEW OF PROPOSED DEVELOPMENT

The proposed development is located at 153 Union Street East in Waterloo, Ontario, within the C2-40 zone and directly adjacent to the Spur Line Trail corridor. The site is accessed via the existing easement from 139–149 Union Street East. The project is early in the development process; therefore, the contents of this report are intended to provide input into the design development of the project and support the Zoning By-law Amendment application.

The subject property has a gross site area of 8,060.9 m² (0.806 ha) and currently contains a one-storey commercial building of approximately 1,000 m² that will be demolished. The redevelopment plan proposes two 12-storey residential towers (Building A and Building B), supported by two levels of underground parking and limited surface parking. Building A includes ground-floor commercial space, while Building B is a standalone residential building. The buildings are connected functionally through shared parking and site circulation. Surrounding land uses include low-rise residential to the north and northeast, commercial uses to the west, employment lands to the east, and a rail right-of-way to the south.

The development will contain approximately:

- Total gross floor area: 2,084 m² (Building A: 1,274 m²; Building B: 810 m²)
- 289 residential units, comprising 463 bedrooms, achieving a density of 466 beds/hectare
- 376 dwelling units per hectare based on unit count
- 244 m² of ground-floor commercial space (in Building A)
- 288 parking spaces (including visitor, accessible, loading, and bicycle parking)
- Common indoor amenity areas of 183.0 m² in Building A and 146.6 m² in Building B
- Landscaped open space covering 34% of the site, exceeding the 20% requirement
- Bicycle parking consisting of 150 secured residential spaces and 9 short-term commercial spaces



Figure 1: Proposed development site layout.

This report outlines the Energy Study completed for the proposed development and is intended to address the City of Waterloo Energy Study Terms of Reference, supporting the City's TransformWR energy efficiency and emissions reduction objectives. The analysis presented in the following sections provides strategic recommendations to improve building performance and guide the design team as the project advances.

2 PURPOSE

The Region of Waterloo has developed several sustainability policies in order to address climate change, with particular focus on net-zero development and energy resilience. For buildings within a Community Energy Plan area approved by Council, the Region of Waterloo introduced the requirement for an Energy Study. The intent of the Energy Study is found in the City of Waterloo Terms of Reference.

The purpose of the Energy study is to identify strategic energy options early in the development process, with a focus on promoting communication between applicants and sustainable building designers as well as informing subsequent design decisions to reduce energy consumption and greenhouse gas (GHG) emissions with minimal project disruption and cost.

The City has committed to reducing community-based GHG emissions by 50% by 2030 and 80% by 2050 relative to 2010 levels. Performing an Energy Study at the early stages of the development including Zoning By-Law Amendments and Draft Plans of Subdivision is intended to facilitate the following¹:

- Identification of opportunities to increase energy efficiency and reduce greenhouse gas emissions in new development at the conceptual design stage.
- Consideration of opportunities to site buildings and configure blocks to take advantage of existing or proposed energy infrastructure, energy capture, and/or solar orientation.
- Consideration of opportunities to optimize the installation of future building energy systems that will allow the development to cost-effectively achieve net-zero energy performance.
- Consideration of opportunities to increase resiliency.
- Consideration of embodied carbon and material selection.
- Exploration of potential operational cost savings and capital cost incentives.

3 DESIGN OPPORTUNITIES

3.1 PASSIVE DESIGN MEASURES

At this stage of design, the building envelope is still under development. Based on typical construction practices for multi-unit residential buildings, the use of spandrel panels and a moderate-to-high window-to-wall ratio is anticipated. While it is too early in the design process to finalize envelope interface details, these elements should be carefully considered as the design progresses.

In accordance with the Terms of Reference modeling requirements, thermal bridging associated with the representative building envelope must be explicitly accounted for. This introduces an increased focus on architectural detailing, including envelope continuity, window interfaces, and structural penetrations, all of which can significantly influence overall thermal performance. This introduces new focus on architectural elements, including:

- Opaque Wall and Glazing Interfaces
- Interior and Exterior Wall Interfaces

¹ City of Waterloo. *Energy Study Terms of Reference*. Accessed February 12, 2024 from:
https://www.waterloo.ca/en/government/resources/Documents/Planning/terms-of-reference/TOR_EnergyStudy.pdf

- Slab bypasses
- Balconies
- Parapet and terrace details

Additionally, focusing on thermal insulation, air tightness and ventilation can provide significant advantages in energy reduction, thermal comfort and indoor air quality. Figure 2 below shows a summary of these passive design principles.

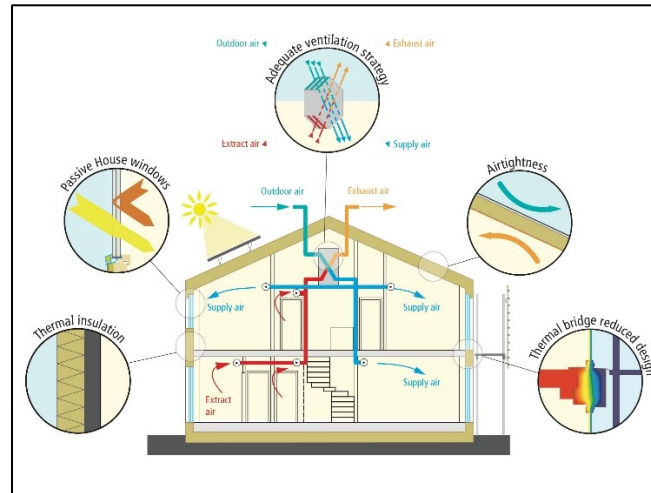


Figure 2: Passive design principles².

By explicitly accounting for all sources of thermal bridging, the energy model can more accurately represent the true thermal performance of the building envelope, resulting in more reliable energy-use estimates. When thermal bridging losses are included, a typical wall assembly will exhibit a substantially lower effective R-value than its nominal value, and this reduction must be reflected in both the modeling and design stages. Failure to do so can lead to overestimated envelope performance and underestimated energy consumption.

Key parameters influencing opaque wall performance include linear thermal transmittance (Ψ -values), clear-wall effective R-values, and the cumulative impact of linear and point thermal bridges. Addressing these considerations early in the design process enables meaningful improvements to envelope performance and overall building energy efficiency through passive design strategies.

Section 3 of BC Hydro's Building Envelope Thermal Bridging Guide (BETBG) provides valuable guidance for the design of high-performance building envelopes. In cast-in-place concrete construction, floor slabs commonly connect directly to exterior concrete walls. In many cases, insulation is installed on the interior face of the wall to allow the concrete to function as the exterior finish. While this approach may be driven by architectural considerations, it can result in significant heat loss at slab edges and correspondingly high linear thermal transmittance (Ψ -values).

Non-structural precast concrete panels present an opportunity to reduce thermal bridging by introducing a thermal break at the floor-to-wall interface. A separation between floor slabs and wall panels can be incorporated and filled with non-combustible mineral wool insulation. Similarly, guidance from the Canadian Precast/Prestressed Concrete Institute (CPCI) outlines alternative detailing strategies for structural precast wall systems, such as the use of interior corbels integrated into wall panels to support floor slabs. This approach allows insulation to be placed between the slab edge and the wall, significantly reducing thermal bridging.

Projecting balconies—whether cast-in-place or precast concrete—are another major source of thermal bridging. Alternative design strategies include locating balconies within alcoves where they are supported on two opposing

² Passive House Institute. *Passive House Requirements*. Accessed February 12, 2024 from: https://passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm

sides, or introducing perimeter columns to carry moment loads. These approaches can enable continuity of insulation similar to improved floor-to-wall detailing and substantially reduce heat loss. In addition, window and door flanking losses, as well as roof parapet thermal bridges, must be included in total heat loss calculations to accurately capture envelope performance.

Comprehensive thermal bridging calculations not only improve the accuracy of building energy-use estimates but also provide a better representation of occupant thermal comfort. Enhancing envelope performance can significantly improve interior surface temperatures, increase occupant comfort, and allow for downsizing of mechanical equipment. Improved thermal stability also enables interior spaces to better maintain temperature setpoints, reducing HVAC run times and system cycling, which can extend equipment life. Passive design measures further contribute to improved building resilience by moderating indoor conditions during system interruptions.

Given the early stage of design, the window-to-wall ratio (WWR) has not yet been finalized. It is recommended that the project target a WWR of approximately 40 percent. For glazing systems, high-performance products with low solar heat gain coefficients are encouraged to balance daylight access while minimizing overheating during shoulder seasons and reducing summer cooling loads. Recommended glazing options include thermally broken aluminum frames or hybrid aluminum frame systems, along with triple-glazed, argon-filled units incorporating sputtered low-emissivity coatings for optimal performance. Electrochromic glazing may also be considered, as it can dynamically control solar gains while maintaining daylight access and exterior views in residential spaces.

Collectively, these measures are expected to have a positive impact on both heating and cooling loads. As projects move toward higher performance and net-zero-ready standards, envelope requirements become increasingly stringent, and a 40 percent WWR target will be essential to achieving improved overall envelope performance. The proposed designs should aim to balance daylighting objectives with high thermal performance. As the design progresses, the project team should continue to apply passive design principles that establish a robust envelope strategy, reduce energy losses, and enhance occupant comfort.

3.2 ACTIVE DESIGN MEASURES

At the current stage of design, the mechanical approach is conceptual; however, several active strategies can already be identified to improve energy performance and support the City of Waterloo's Energy Study objectives. For a high-rise residential building of this scale, the principal active measures relate to the efficiency of heating and cooling plant, distribution systems, ventilation approaches, and domestic hot water production. These systems form the basis of the three performance tiers assessed in the Energy Study, and the assumptions used in each tier are further detailed in Section 4.

For the Building Code Baseline, heating and cooling rely on conventional high-rise systems consisting of gas-fired boilers serving a 4-pipe fan-coil distribution network and a water-cooled chiller providing space cooling. Corridor ventilation is supplied by a gas-fired make-up-air unit, and domestic hot water is produced by gas storage heaters. These systems are representative of standard practice in the Waterloo region and provide the foundation on which higher-performance improvements are layered.

To develop the High-Performance design, several enhancements were introduced to reduce energy intensity and improve mechanical efficiency. Space heating continues to rely on gas-fired condensing boilers; however, these operate at higher efficiencies with variable-flow distribution. Cooling performance is improved through a higher-efficiency water-cooled chiller. Corridor ventilation incorporates heat recovery to reduce heating loads, replacing the simpler baseline gas-fired MUA configuration. Domestic hot water production remains gas-fired but benefits from improved system efficiency. These upgrades collectively reduce thermal demand while remaining compatible with current construction practices and available technologies.

The Net-Zero Ready design adopts a fundamentally different approach by shifting all major thermal systems to electric heat pump technologies. Space heating and cooling within suites are provided by high-efficiency air-source heat pumps, which significantly reduce greenhouse gas emissions by eliminating direct combustion. Corridor

ventilation also transitions to a heat-pump-based unit with high heat-recovery effectiveness, reducing both fan energy and thermal loads. Domestic hot water production uses an electric heat-pump water heater with substantially higher performance than combustion-based systems. This full electrification strategy is enabled by the improved building envelope performance described in Section 3.1, as lower thermal demand allows the heat pump systems to operate effectively throughout the year.

Across all tiers, ongoing design development will refine the selection and sizing of mechanical equipment, controls, and distribution strategies. As the project advances, additional opportunities for energy savings—such as demand-controlled ventilation, improved fan efficiencies, optimized plant sequencing, and integration of renewable energy—may be evaluated. These active measures, combined with the passive strategies described earlier, provide a comprehensive framework for improving energy performance and reducing greenhouse gas emissions for the proposed development.

3.3 ADVANCED ENERGY SOLUTIONS

3.3.1 District Energy Systems

District energy systems are systems that distribute thermal energy to multiple buildings in an area or neighbourhood. These systems typically consist of a heating and cooling plant or source and a thermal network of pipes connected to a group of buildings to distribute the energy. These systems not only reduce greenhouse gas emissions and improve energy resiliency but also deliver economies of scale and use of less carbon-intensive energy sources, allowing for large emission reductions at lower costs than individual building systems. District energy systems already exist in mid-size municipalities across Ontario including Windsor, London, Hamilton, Markham and Toronto.

At the time of this study, according to the Region of Waterloo, assessments have been completed on 12 district energy systems, with a pilot feasibility study centered around the King and Victoria intersection in downtown Kitchener completed. However, future plans to include the larger Kitchener-Waterloo Region are in development. It is recommended for the design team to monitor changes in the proposed district energy systems to assess any new opportunities in the future that might benefit the project as well as seek out opportunities with the city.

It is recommended the design team consider ‘Future Proofing’ the project by designing the building to be district energy-ready (DE-ready) in the event DES services become available at the project’s location. It is suggested that the following key items be incorporated into a building’s design for a future district energy connection:

- Install heating and cooling plant equipment on the lower levels for easier integration into a future district system, or provide for a future connection point into the building’s thermal piping at ground level
- Provide adequate space at or below ground level for a future energy transfer station
- Provide an easement between the mechanical room and the property line to allow for thermal piping
- Provide two-way pipes placed in the building to carry thermal energy from the district energy network to the section in the building where the future energy transfer station would be located
- Install a low temperature hydronic heating system (e.g., heat pump loop) that is compatible with a district energy system in order to reduce the pipe sized and associated valves, fitting, etc.
- Include provisions for appropriate future thermal energy metering

3.3.2 Geothermal Energy Exchange

Geothermal energy systems offer a low-carbon means of providing space heating and cooling by using the stable subsurface temperatures as a thermal reservoir. In high-rise residential developments, these systems have the potential to significantly reduce overall energy use and greenhouse gas emissions while improving long-term operating efficiencies. Their applicability on the subject site must, however, be considered within the framework of

local source water protection policies. The property at 153 Union Street East is located within Wellhead Protection Sensitivity Area (WPSA-8), as identified in the Regional Official Plan and carried forward into the City's Official Plan. Within this designation, geothermal wells may be permitted, but only subject to further hydrogeological study and approval under Regional Official Plan Policy 8.A.18. Should geothermal energy be pursued, the associated Zoning By-law Amendment would also need to be expanded to explicitly permit geothermal wells on the site.

Two principal geothermal approaches are typically considered for developments of this scale. Open-loop systems rely on groundwater extracted from bedrock aquifers, circulated through heat pump equipment, and subsequently returned to the same aquifer. Waterloo Region benefits from the presence of the Guelph and Gasport aquifers, which have supported several successful open-loop installations elsewhere in the community. These systems can offer favourable performance and lower capital costs when aquifer conditions are suitable. Their feasibility, however, is highly dependent on demonstrated aquifer yield, groundwater quality, the balance of annual heating and cooling loads, and confirmation that municipal drinking water supplies will not be affected. In WPSA-8 areas, any proposal for an open-loop installation would require a detailed hydrogeological assessment, including characterization of aquifer conditions and modelling to ensure that thermal or hydraulic impacts would not migrate toward municipal well capture zones.

Closed-loop vertical borehole systems represent an alternative approach that does not extract groundwater but relies on drilling boreholes into the subsurface to access stable ground temperatures. Although closed-loop systems do not interact directly with the aquifer, the Region of Waterloo imposes restrictions on their installation within areas where drilling may compromise the integrity of protected aquifer layers. As a result, a closed-loop system within WPSA-8 would similarly require a hydrogeological evaluation to confirm that drilling activities would not adversely affect groundwater protection objectives. Any approval from the Region would depend on the findings of such a study and the demonstration of appropriate safeguards.

At this stage of design, geothermal technologies have not been included in the energy modelling for 153 Union Street East. While these systems can contribute meaningfully to reductions in energy use and emissions, their implementation on this site would involve a series of additional requirements, including a comprehensive hydrogeological study, an extended review process with the Region, and modifications to the Zoning By-law Amendment. Given the early stage of planning and the anticipated project timelines, air-source heat pump technologies represent the more practical low-carbon strategy for achieving the High-Performance and Net-Zero Ready targets for this development. Nevertheless, geothermal energy remains a potential future option should the applicant wish to undertake the required investigations and seek the necessary approvals in later phases of design.

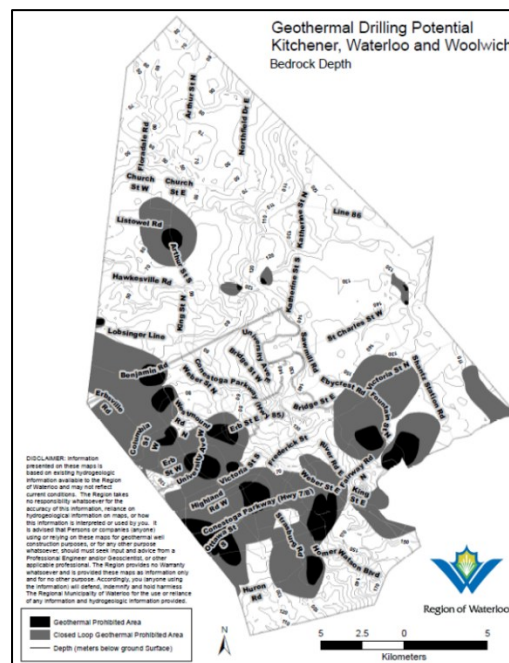


Figure 3: Bedrock depth and geothermal feasibility locations.

3.3.3 Alternative Advanced Energy Solutions

There are other advanced energy solutions that design team can consider. A summary of alternative options are as follows:

- **Combined Heat and Power (Co-generation/CHP)**
A gas fired engine that generates electricity on-site and waste heat can be recovered to pre-heat the water for domestic hot water plant. It is becoming more common to use cogeneration system as backup generators in buildings.
- **Advanced Control Technologies**
Building-level control strategies, including optimized scheduling, demand-based ventilation, heat pump staging, and coordinated operation of space conditioning and domestic hot water systems, can improve operational efficiency and reduce peak energy demand. These strategies were not modelled explicitly but can support the performance outcomes identified.
- **Solar Collectors (Air Based)**
There are various types of solar collectors such as air based or liquid-based systems. However, the air-based systems are easier and more feasible to use in multi unit residential buildings. This system can pre-heat the air for makeup air units to reduce the ventilation load and save energy and cost.
- **Drain Water Heat Recovery (DWHR)**
Drain water heat recovery system can be implemented in buildings to reduce the energy consumption in DHW plant. It is a spiral copper-based heat exchanger that replaces a vertical section of the main waste drain to transfer thermal energy from wastewater to incoming cold water into the building. DWHR system is easy to integrate to the plumbing system in MURBs and provides significant savings. DWHR option is used in Tier 4 model of this study.
- **Spectrally Selective Glazing**
Spectrally selective glazing is high-performance glazing that admits as much daylight as possible, while preventing transmission of as much solar heat as possible. This system significantly reduces building energy consumption by controlling solar heat gains in summer, preventing loss of interior heat in winter and allowing occupants to reduce electric lighting use by making maximum use of daylight.
- **Battery Storage**
Battery storage has started to receive broad interest in the building industry. With newer technologies, costs are declining significantly because of improved manufacturing efficiencies and technological development, including increased capacities and lifespan. They can be used for peak load shifting that provides cost savings as well as being integrated to the solar PV system or smart grid options. The battery storage can also be part of the backup power system to improve resilience of the building.
- **Rainwater Harvesting**
Rainwater harvesting is a sustainable practice that involves collecting and storing rainwater for later use. The system can provide several key benefits including lower water consumption and costs, minimizing storm run-off, providing a buffer against drought or water shortages and easing the demand on municipal water supply and treatment.

3.1 RENEWABLE ENERGY

Solar Photovoltaics (PV) has become an economically viable strategy for small-scale energy generation at the individual building level. Price reductions in solar panel equipment and improvements in technology efficiency drive this viability. Consequently, PV is an important design consideration for low-carbon and net-zero buildings.

PV panels, composed of PV cells, convert solar radiation into DC electricity. This electricity can directly power equipment or be stored in a battery for later use. The typical life expectancy of a PV panel exceeds 25 years and requires minimal maintenance. The expected operations and maintenance (O&M) costs for the PV system installation at this site are low. O&M activities over the system's lifetime include light cleaning (only as needed to ensure performance) and replacing the system inverter after 10 years of operation.

Rooftop PV System

High-rise buildings offer unique opportunities for solar PV energy systems, mainly due to their potential for ample sunlight exposure and available roof space. Installing solar panels on a building's rooftop is a common and effective strategy to maximize energy capture. A significant advantage of solar PV on high-rises is that peak solar energy production aligns with periods of high electricity demand, typically during daylight hours when utility rates are highest.

A conventional rooftop PV system uses a racking system secured to the roof via a ballast, such as concrete. This mounting approach avoids penetrating the existing roofing system and securing to the building structure. However, this method adds significant mass to the building structure. If the existing structure cannot accommodate the additional load, reinforcements will be necessary. Figure 4 below illustrates the potential layouts of solar PV for the proposed buildings.



Figure 4: Buildings A and B PV proposed layout.

The solar PV system could potentially offset 248,600 kWh in electricity consumption and over 9,447 kgCO₂ emissions. The details of potential solar PV systems and savings for buildings are summarized in Table 1, below.

Table 1: Building PV Summary

Scenario	System Size	System Cost	Electricity Production	Offset Utility Cost	Offset GHG Emissions
	kW	\$CAD	kWh	\$CAD*	ekgCO ₂
Building A and B	195.6	\$567,240	248,600	\$32,318	9,447

*Assumption cost of utility cost at 0.13/kWh

3.1.1 Carport PV Systems

Carport photovoltaic (PV) systems are versatile installations that can be integrated into existing parking lots while providing multiple co-benefits, including vehicle shading and compatibility with electric vehicle (EV) charging infrastructure. Despite these advantages, carport PV systems were excluded from the proposed scope for this project, as the site assessment identified excessive shading from adjacent buildings, making this option technically and economically unviable.

4 ENERGY AND EMISSIONS ANALYSIS

The City of Waterloo Terms of Reference: Energy Study (TOR) sets out the minimum requirements that must be included in the energy study. The purpose of the Energy study is to identify strategic energy options early in the development process, with a focus on promoting communication between applicants and sustainable building designers as well as informing subsequent design decisions to reduce energy consumption and greenhouse gas (GHG) emissions with minimal project disruption and cost.

The current version of the TOR defines three relative targets for buildings. The relative target intends to encourage all buildings to meet the same relative standards of performance. The targets are defined in terms of the following Key Performance Indices (KPIs):

- **Total Energy Use Intensity (EUI) [kWh/m²]:** Annual building energy use, divided by the conditioned floor area.
- **Thermal Energy Demand Intensity (TEDI) [kWh/m²]:** Annual heating load, divided by the conditioned floor area. TEDI excludes the effects of mechanical efficiencies (e.g., condensing boilers) but does include passive systems such as air heat recovery, solar gains, and internal gains.
- **Green House Gas Intensity (GHGI) [kgCO₂e/m²]:** Annual greenhouse gas emissions, divided by the conditioned floor area.

The TOR also specifies three performance levels that must be explored. These include:

- **Building Code Baseline** – used as a reference for comparison.
- **High Performance** – where TEUI and TEDI are reduced by 30% each and GHGI is reduced by 50% relative to the Building Code Baseline.
- **Net-Zero Ready Performance** – where TEUI and TEDI are reduced by 60% each and GHGI is reduced by 90% relative to the Building Code Baseline.

4.1 BUILDING CODE BASELINE

The Building Code Baseline represents the mandatory reference case required under the City of Waterloo Energy Study Terms of Reference. Since the project is at the concept design stage, the baseline model was developed using assumptions aligned with Ontario Building Code SB-10 (Division 3) and performance requirements from NECB 2015. The baseline reflects typical construction practices and conventional HVAC configurations for high-rise residential buildings in Ontario, and is used as the comparative foundation for the High-Performance and Net-Zero Ready tiers.

The baseline envelope incorporates code-minimum levels of thermal resistance, glazing performance, and air infiltration. Above-grade opaque walls are modelled at an effective RSI 3.9 (R-22.9), while below-grade walls and roofs follow standard NECB thermal characteristics. Windows are assumed to have a U-value of 1.9 W/m²·K with an SHGC of 0.40, and an overall window-to-wall ratio of 40%. Air infiltration is represented using NECB default values for high-rise residential buildings.

Mechanical systems are consistent with typical high-rise configurations. Space heating is provided by 90% efficient gas-fired condensing boilers serving a central 4-pipe fan coil network for suites and amenity areas. Cooling is delivered by a water-cooled chiller operating at 5.75 COP. Corridor ventilation is supplied by a gas-fired make-up air unit with 80% efficiency, and minimal heat recovery is assumed for residential, amenity, and service spaces. Domestic hot water is provided by a gas-fired storage water heater with 90% AFUE.

Exhaust and supply airflows follow NECB schedules based on occupancy assumptions appropriate for a high-rise residential building. Lighting and plug loads reflect standard practice, with 7.3 W/m² for whole-building common areas and 5.0 W/m² within suites.

The baseline model was developed in DesignBuilder (EnergyPlus engine), and the parameters summarized in Table 2 were used to characterize envelope performance, mechanical efficiencies, ventilation, domestic hot water systems, and internal gains. These inputs establish the reference performance against which the High-Performance and Net-Zero Ready designs are evaluated.

Table 2: Building Code Baseline Energy Model Parameters

Component	Residential
Opaque Wall	Effective: R-22.9
Below Grade Wall	Effective: R-19.9
Roof	Effective: R-36.4
Floor (in contact with ground)	Effective: R-13.2
Fenestration	U-1.9 W/m ² ·°K + SHGC 0.40
Window-to-Wall Ratio	40.0%
Infiltration	0.25 L/(s·m ²) @ 5 Pa
Lighting Power Density (W/m ²)	Whole Building – 7.3 Suites – 5.0
Plant	Heating: Condensing Boiler 90% Efficient Constant Flow Cooling: Water Cooled Chiller 5.57-5.77 COP Constant Flow
HVAC	Residential and amenity: 4-pipe fan coil units and 55% efficient ERV Retail: RTU with Furnace 80% AFUE & DX Cooling Coil COP 3.0 Parking: Furnace 80% AFUE Misc service areas: Hydronic baseboards
Corridors Ventilation	Gas-fired MUA with 80% efficient heat recovery, 30 cfm/door
Ventilation fans	Constant Air Volume 60% Total Efficiency
Heat Recovery	Residential: Sensible 55% Latent 55% Amenity: Sensible 55% Latent 55%
Domestic Hot Water	Direct-fired Storage water heater, 90% AFUE Constant flow
Exhaust Ventilation	Residential: 2.5 l/s-person + 0.3 l/s-m ² Amenity: 2.5 l/s-person + 0.3 l/s-m ² Parking: 3.7 l/s-m ²
Supply Ventilation	Residential: 2.5 l/s-person + 0.3 l/s-m ² Amenity: 2.5 l/s-person + 0.3 l/s-m ²
Plug Load (W/m ²)	Whole Building – 5.0
Occupancy (m ² /person)	Whole Building – 25.0
Schedules (from NECB 2015 Table 8.4.3.2)	Schedule G

The following table summarizes the estimated performance values for the Building Code Baseline and absolute targets to be achieved as part of this study.

Table 3: Project KPI Performance Targets

Building Code Baseline	Total	Intensity	High Performance Target	Net-Zero Ready Performance Target
Energy Use	3,339,326 (ekWh)	102.5 (ekWh/m ²)	71.7 (ekWh/m ²)	41 (ekWh/m ²)
GHG Emissions	400,516 (kgCO ₂)	12.3 (kgCO ₂ /m ²)	6.15 (kgCO ₂ /m ²)	1.23 (kgCO ₂ /m ²)
Thermal Energy Demand	1,085,019 (kWh)	34.7 (kWh/m ²)	24.3 (kWh/m ²)	13.9 (kWh/m ²)

With the targets established the analysis can be performed for the high-performance and net-zero-ready performance for comparison.

4.2 HIGH PERFORMANCE DESIGN

The High-Performance model represents a design option that achieves meaningful reductions in energy consumption and greenhouse gas emissions relative to the Building Code Baseline. To meet the performance thresholds defined in the City of Waterloo Energy Study Terms of Reference, improvements were incorporated across the building envelope, mechanical systems, ventilation strategy, and internal load assumptions.

Envelope enhancements form a significant component of the high-performance strategy. The effective thermal resistance of above-grade walls has been increased to RSI 4.76 (R-27), while roof and floor assemblies have likewise been upgraded. Glazing performance has been improved through the use of lower U-value units (1.4 W/m²·K), with an SHGC of 0.40, and the overall air infiltration rate remains at 0.25 L/s·m² as permitted under NECB compliance modeling. These upgrades reduce conductive heat loss and peak heating demand while maintaining the 40% window-to-wall ratio characteristic of the proposed architectural massing.

Mechanical system improvements were introduced to further reduce energy intensity. Space heating is delivered by high-efficiency condensing boilers operating at 95% efficiency with variable-flow distribution, replacing the constant-flow configuration in the baseline. Cooling efficiency is increased through a higher-COP water-cooled chiller operating at 5.75–7.57 COP with variable flow. Suite and amenity areas continue to be served by a 4-pipe fan coil system, while parking ventilation is modeled using an 80% AFUE furnace. Domestic hot water is provided by a gas-fired storage water heater with 90% AFUE and variable flow control.

Ventilation energy reductions are achieved through improved heat recovery effectiveness. Corridor make-up air is supplied by a gas-fired ERV system with 80% sensible heat recovery, and washroom and amenity exhaust systems incorporate efficiency upgrades aligned with NECB recommendations. Supply and exhaust ventilation rates follow NECB Schedule G, and lighting and plug load assumptions remain consistent with high-rise residential practice.

The combination of improved envelope performance, upgraded heating and cooling plant efficiency, enhanced heat recovery, and refined distribution systems results in lower energy use intensity and reduced greenhouse gas emissions compared to the baseline case. These assumptions form the basis of the High-Performance model summarized in Table 4 and establish a viable pathway toward achieving the reduced TEUI and TEDI values required by the City of Waterloo's High-Performance tier.

Table 4: High Performance Energy Model Parameters

Component	Residential
Opaque Wall	Clear-field: R-27
Linear Thermal Bridging	Mitigated with linear transmittance 0.2 W/m-K
Below Grade Wall	Clear-field: R-19.9
Roof	Clear-field: R-50
Floor (in contact with ground)	Clear-field: R-13.2
Fenestration	U-1.4 W/m²·°K + SHGC 0.4
Window-to-Wall Ratio	40%
Infiltration	0.25 L/(s·m ²) @ 5 Pa
Lighting Power Density (W/m ²)	Whole Building – 7.3 Suites – 5.0
Plant	Heating: Condensing Boiler 90% Efficient Variable Flow Water Cooled Chiller 5.57-5.77 COP Variable Flow
HVAC	Residential and amenity: 4-pipe fan coil units and 80% efficient in-suite ERV Retail: Electric Furnace Central ERV 80% efficient with DX Cooling Coil COP 3.0 Parking: Furnace 80% AFUE Misc service areas: Hydronic baseboards
Corridors Ventilation MUA	Electric Furnace Central with 80% efficient heat recovery, 30 cfm/door
Ventilation fans	Corridors: Constant Air Volume 60% Total Efficiency Residential and Retail: Variable Air Volume 60% Total Efficiency
Heat Recovery	Residential: Sensible 80% Latent 80% Amenity: Sensible 80% Latent 80%
Domestic Hot Water	Direct-fired Storage water heater, 90% AFUE Constant flow
Exhaust Ventilation	Residential: 2.5 l/s-person + 0.3 l/s-m ² Amenity: 2.5 l/s-person + 0.3 l/s-m ² Parking: 3.7 l/s-m ²
Supply Ventilation	Residential: 2.5 l/s-person + 0.3 l/s-m ² Amenity: 2.5 l/s-person + 0.3 l/s-m ²
Plug Load (W/m ²)	Whole Building – 5.0
Occupancy (m ² /person)	Whole Building – 25.0
Schedules (from NECB 2015 Table 8.4.3.2)	Schedule G

The following table summarizes the estimated energy and carbon emissions performance values for a High Performance compliant design, based on the system design assumptions specified.

Table 5: High Performance Energy Model Results

High Performance Building	Total	Achieved Intensity	High Performance Target
Energy Consumption	2,237,862 (ekWh)	68.7 (ekWh/m ²)	71.7 (ekWh/m²)
GHG Emissions	197,883 (kgCO ₂)	6.1 (kgCO ₂ /m ²)	6.15 (kgCO₂/m²)
Thermal Energy Demand	684,061 (kWh)	21.9 (kWh/m ²)	24.3 (kWh/m²)

The energy model results demonstrate that the proposed building envelope and system configurations are capable of achieving the High-Performance energy and emissions targets established for this study.

The design strategies presented represent one viable pathway to meeting these targets at the current stage of design. Alternative configurations may also achieve equivalent performance as the design progresses.

4.3 NET-ZERO READY PERFORMANCE

The Net-Zero Ready model represents the highest performance tier evaluated for the proposed development and reflects a fully electrified design strategy with substantial improvements to the building envelope, ventilation systems, and heating and cooling plant. The objective of this tier is to reduce the Total Energy Use Intensity (TEUI) and Greenhouse Gas Emission Intensity (GHGI) by approximately 90% relative to the Building Code Baseline, in accordance with the City of Waterloo Energy Study Terms of Reference.

Envelope performance has been significantly enhanced to support deep thermal demand reductions. Above-grade walls are modeled with effective RSI 5.28 (R-30) assemblies, while roofs and ground-contact floors also incorporate high-performance insulation. Window performance has been improved through reduced U-values of 0.8 W/m²·K and an SHGC of 0.30, and the air infiltration rate has been strengthened to 0.6 ACH at 50 Pa to reflect a more airtight enclosure typical of advanced low-energy residential buildings. These upgrades collectively lower conductive heat loss and reduce peak heating demand, providing a foundation for an all-electric mechanical system.

Heating and cooling are provided through a fully electrified heat pump plant. Residential suites and amenity areas are conditioned by in-suite air-source heat pumps with a nominal heating COP of 3.3 and cooling COP of 3.5. The system eliminates reliance on natural gas and significantly reduces greenhouse gas emissions. Corridor ventilation is supplied by a package heat pump operating at COP 3.0 with 90% heat recovery effectiveness, replacing the gas-fired make-up air approach used in the baseline and high-performance tiers. Domestic hot water production is provided by a heat pump water heater with an effective COP of 4.25, further reducing energy use relative to combustion-based DHW systems.

Ventilation and distribution efficiencies have also been improved. Exhaust and supply ventilation rates remain aligned with NECB Schedule G; however, the improved heat recovery and reduced fan power associated with the heat pump-based systems contribute additional savings.

Together, the electrified mechanical systems and advanced thermal envelope significantly reduce operational energy use and nearly eliminate operational greenhouse gas emissions, establishing a clear pathway to achieving Net-Zero Ready performance. The assumptions used in the model are summarized in Table 6, and the corresponding energy and emissions results are shown in Table 6.

Table 6: Net-Zero Ready Energy Model Parameters

Component	Residential
Opaque Wall	Clear-field: R-30
Linear Thermal Bridging	Thermal bridge free – passive house design <0.01 W/m-K
Below Grade Wall	Clear-field: R-19.9
Roof	Clear-field: R-60
Floor (in contact with ground)	Clear-field: R-13.2
Fenestration	U-0.8 W/m ² ·°K + SHGC 0.3
Infiltration	0.6 ACH @ 50 Pa – passive house design
Window-to-Wall Ratio	30% (Reduced by 25%)
Lighting Power Density (W/m ²)	Whole Building – 3.0 Suites – 3.0
Plant	-
HVAC	Residential and amenity: in-suite air-air heat pump for heating (COP 3.5) and cooling (COP 4.0) Retail: Heat Pump Air Handler COP 3.5 in Heating, COP 4.0 in Cooling with 90% efficient heat recovery Parking: electric resistance Misc service areas: Electric baseboards
Corridors Ventilation MUA	Heat Pump Air Handler COP 3.5 with 90% efficient heat recovery, 20 cfm/door
Ventilation fans	Corridors: Constant Air Volume 90% Total Efficiency Residential and Retail: Variable Air Volume 90% Total Efficiency
Heat Recovery	Residential: Sensible 90% Latent 90% Amenity: Sensible 90% Latent 90%
Domestic Hot Water	Heat Pump Water Heater, 4.25 COP, Low Flow Water Fixtures (25% reduction in DHW consumption)
Exhaust Ventilation	Residential: 2.5 l/s-person + 0.3 l/s-m ² Amenity: 2.5 l/s-person + 0.3 l/s-m ² Parking: 3.7 l/s-m ²
Supply Ventilation	Residential: 2.5 l/s-person + 0.3 l/s-m ² Amenity: 2.5 l/s-person + 0.3 l/s-m ²
Plug Load (W/m ²)	Whole Building – 3.75 (Reduced by 25%)
Occupancy (m ² /person)	Whole Building – 25.0
Schedules (from NECB 2015 Table 8.4.3.2)	Schedule G

The following table summarizes the estimated energy and carbon emissions performance values for a Net-Zero Ready performance-compliant design, based on the system design assumptions specified.

Table 7: Net-Zero Ready Performance Energy Model Results

Net-Zero Ready Performance Building	Total	Intensity	Net-Zero Ready Performance Target
Energy Consumption	1,020,096 (ekWh)	31.3 (ekWh/m ²)	41.0 (ekWh/m²)
GHG Emissions	38,764 (kgCO ₂)	1.20 (kgCO ₂ /m ²)	1.23 (kgCO₂/m²)
Thermal Energy Demand	286,060 (kWh)	9.2 (kWh/m ²)	13.9 (kWh/m²)

The energy model results demonstrate that the proposed building envelope and system configurations are capable of achieving the Net-Zero Ready performance targets established for this study.

The design strategies presented represent one viable pathway to meeting these targets at the current stage of design. Alternative system configurations or envelope approaches may also be capable of achieving equivalent performance, subject to further technical and economic evaluation as the design advances.

4.4 ENERGY ANALYSIS

The comparative energy modelling results for the Building Code Baseline, High-Performance, and Net-Zero Ready design scenarios are summarized in Table 8. The results demonstrate progressive reductions in total energy use intensity (TEUI), thermal energy demand intensity (TEDI), and greenhouse gas emission intensity (GHGI) across successive performance tiers.

Table 8: Comparative Energy and Greenhouse Gas Performance of Baseline, High-Performance, and Net-Zero Ready Design Scenarios

	Baseline Design	High Performance Requirement	High Performance Design	Net-Zero Ready Requirement	Net-Zero Ready Design
Total Energy Use Intensity (ekWh/m²)	102.5	71.7	68.7	41.0	31.3
GHG Emission Intensity (kgCO₂/m²)	12.3	6.15	6.1	1.23	1.2
Thermal Energy Demand Intensity (kWh/m²)	34.7	24.3	21.9	13.9	9.2

Relative to the Building Code Baseline, the High-Performance design achieves substantial improvements, reducing TEUI from 102.5 ekWh/m² to 68.7 ekWh/m², GHGI from 12.3 kgCO₂e/m² to 6.1 kgCO₂e/m², and TEDI from 34.7 kWh/m² to 21.9 kWh/m². These reductions are driven by improved envelope performance, reduced thermal bridging, enhanced glazing specifications, increased heat recovery effectiveness, and higher-efficiency mechanical systems.

The Net-Zero Ready design represents a further step change toward deep energy reduction and operational decarbonization. As summarized in Table 8, the Net-Zero Ready scenario achieves a total energy use intensity (TEUI) of 31.3 ekWh/m², a greenhouse gas emission intensity (GHGI) of 1.2 kgCO₂e/m², and a thermal energy demand intensity (TEDI) of 9.2 kWh/m², exceeding the performance thresholds established by the Energy Study Terms of Reference.

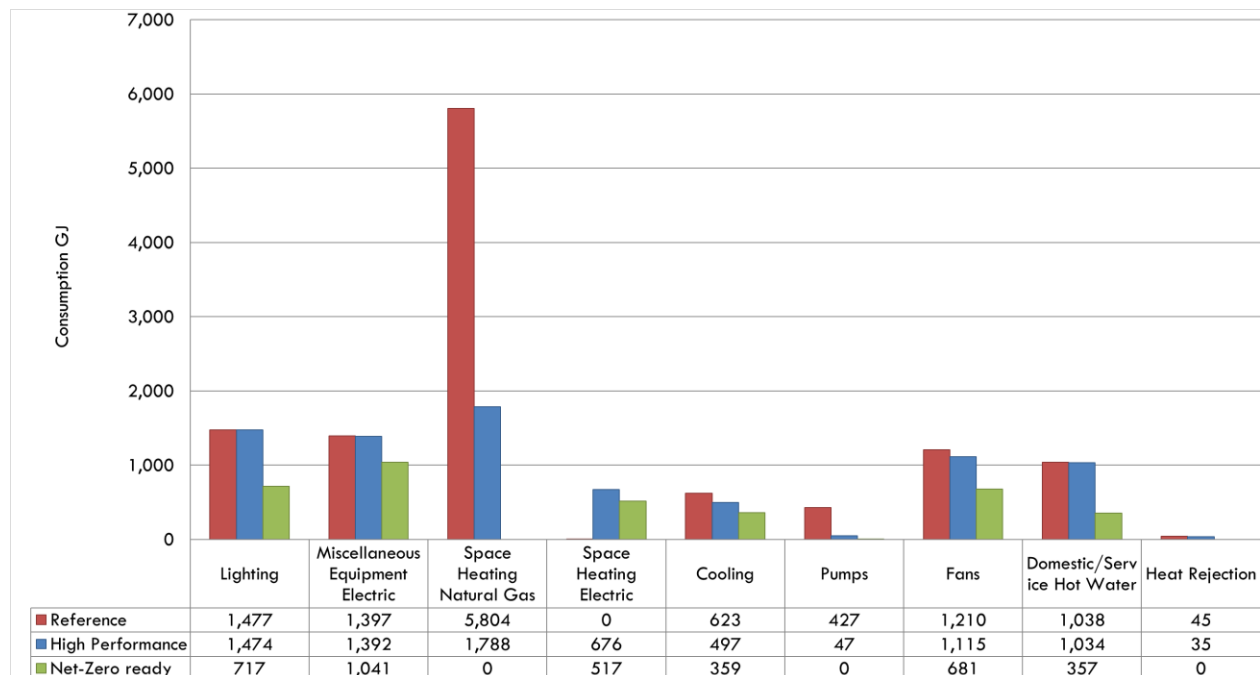


Figure 5: End-Use Energy Consumption Breakdown for Baseline, High-Performance, and Net-Zero Ready Design Scenarios

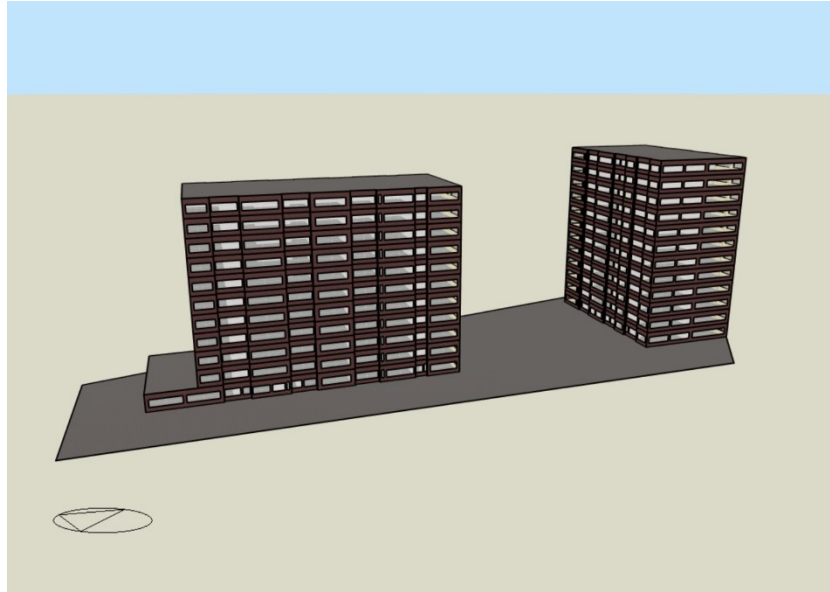


Figure 6: 3D Energy Model visualization with floor levels in multiplication factor mode to represent identical floors.

These results are achieved through a combination of high-performance envelope measures, minimized thermal bridging, enhanced heat recovery, and widespread electrification of space heating, ventilation, and domestic hot water systems. The elimination of combustion-based heating systems results in near-complete operational decarbonization under typical electricity grid emission factors. The significant reduction in TEDI relative to the Building Code Baseline highlights the critical role of envelope performance and passive design strategies in achieving Net-Zero Ready performance.

Energy use by end-use category is illustrated in Figure 5 above. These charts show that heating loads dominate energy consumption in the Baseline model, reflecting the thermal characteristics of conventional high-rise residential construction. The High-Performance design reduces these loads substantially, while the Net-Zero Ready design achieves further reductions through both envelope-based demand reduction and the higher efficiency of

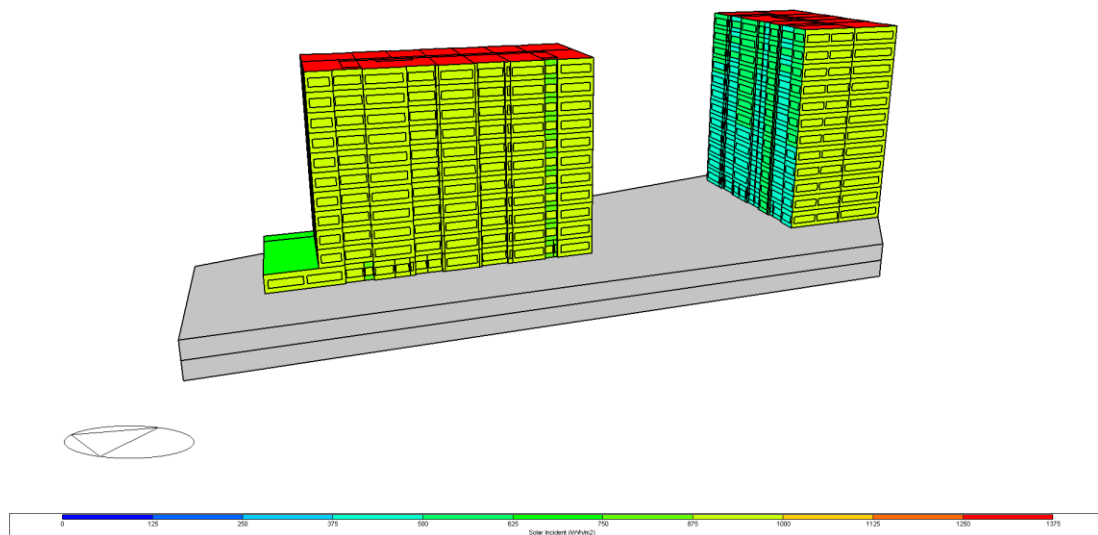


Figure 7: Normalized annual solar incidence on the residential buildings.

electric heat pump systems. Cooling and domestic hot water consumption are also reduced across tiers, though to a lesser extent than heating. The reduction in heating-related consumption drives the majority of the TEUI and GHGI improvements observed between tiers.

Figure 7 provides a visualization of normalized annual solar access across the residential building masses. This analysis supports future decisions regarding rooftop solar photovoltaic placement and helps identify opportunities for on-site renewable energy generation that may complement the efficiency measures already integrated into the design. The modelling results confirm that the proposed high-performance and electrified design scenarios meet the City of Waterloo Energy Study performance requirements.

5 ENVELOPE ANALYSIS

Envelope thermal performance, air leakage control, and moisture management are key determinants of energy efficiency, durability, and occupant comfort in residential buildings. Energy modelling results presented in Section 4 demonstrate that enclosure performance has a significant influence on heating demand and overall energy use.

To preserve the original 40% window-wall ratio (WWR) while achieving higher performance targets set by the city of Waterloo it is necessary to implement integrated design principles at the concept design phase of the project while minimizing thermal bridging. The proportion of total heat loss through the different sections of the building envelope has the following breakdown for the Baseline Building:

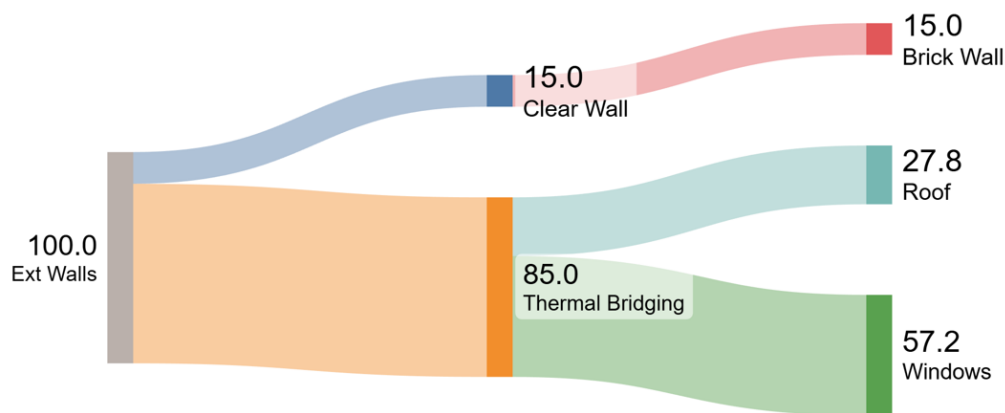


Figure 8: Relative heat loss through the components of enclosure in the Baseline building.

In high-rise residential buildings with relatively high window-to-wall ratios (WWR), a significant proportion of heat loss occurs at the interfaces between glazing and opaque wall assemblies, followed by penetrations associated with projecting balcony slabs. These locations introduce both linear and point thermal bridges and therefore require careful detailing to limit conductive heat transfer. As the proportion of glazing increases, the thermal performance of window perimeter detailing and frame assemblies becomes increasingly influential on overall enclosure performance.

Typical high-rise residential construction in Ontario commonly relies on window-wall or spandrel panel systems with interior spray foam and backpan insulation. While spandrel assemblies are classified as opaque elements for compliance modelling purposes, their effective thermal resistance is limited by conductive framing components and repetitive steel bracing, which introduce significant point thermal bridging. As a result, increasing spandrel performance beyond approximately R-12 (RSI 2.1), even with the addition of roughly 25 mm of interior continuous insulation, is generally not feasible within the constraints of conventional spandrel systems.

Given these limitations, the design team should evaluate opportunities to reduce reliance on spandrel panels and introduce higher-performing opaque “real wall” assemblies where feasible. The wall assembly assumed in the energy

model for this study, illustrated in Figure 9, reflects a more thermally robust approach that reduces thermal bridging and supports improved overall enclosure performance.

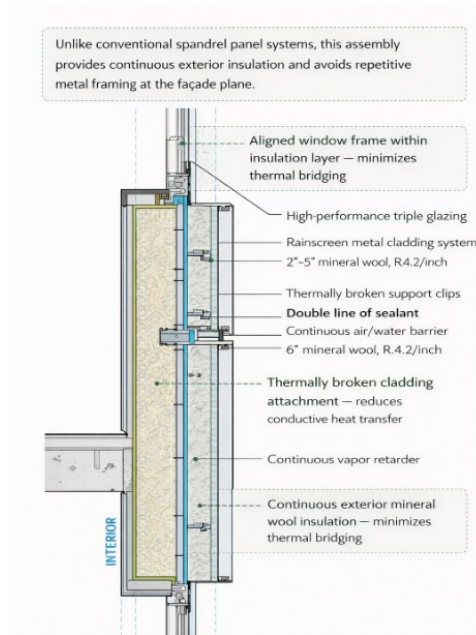


Figure 9: Typical high-performance wall assembly for a high-rise residential building. Note: 2" mineral wool is assumed for the High-Performance Design and 5" for the Net-Zero ready.

Another feasible approach for achieving clear-field R-values above R-20 while retaining a curtain wall aesthetic is the use of large-format prefabricated façade panels. These systems incorporate continuous exterior insulation, minimized thermal bridging through engineered attachment hardware, and high-performance glazing units integrated into a unified panelized assembly. A precedent for this strategy is the CURV building in Vancouver—currently the tallest Passive House-certified building in the world—where prefabricated façade panels were successfully employed to meet stringent thermal performance and airtightness requirements without compromising architectural expression.

Unlike the opaque enclosure, windows are tested as complete assemblies. The U-value of the window assembly measures the insulating characteristics of the entire system and accounts for heat transfer through the glazing, frame, spacers, and perimeter interfaces. Center-of-glass (COG) performance reflects the glazing alone, whereas whole-window U-values incorporate the thermal bridging associated with framing elements. These U-values are more representative of the true enclosure performance.

The proposed building includes a window-to-wall ratio (WWR) of approximately 40–50%, whereas 40% is the maximum for the Reference Building under the Building Code. With such a high WWR, even high-performance glazing systems have a significant influence on the overall façade performance. Figure 10 shows how increasing

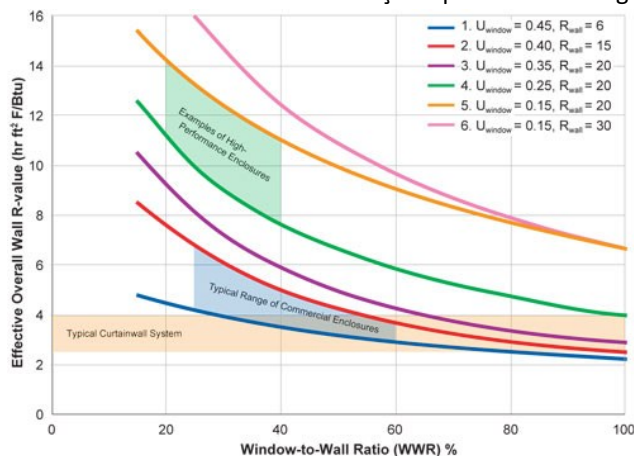


Figure 10: Relationship between nominal and effective insulation against the WWR in a high-rise building.

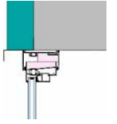
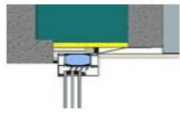
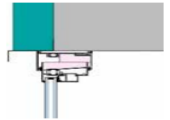
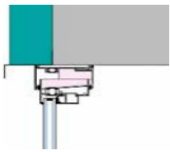
WWR reduces the effective thermal resistance of the wall, and why higher-performing glazing systems and careful detailing are required to meet high-performance and Net-Zero Ready enclosure targets.

While frames represent only 5–8% of the glazed area, they can contribute disproportionately to heat loss because framing materials are typically much more conductive than the glazing itself. Aluminum framing, although non-combustible, durable, and dimensionally stable, is highly conductive and therefore requires thermal breaks to reduce heat transfer. High-performance frames increasingly use hybridized materials such as polyamide breaks, fiberglass reinforcement, or non-metal alternatives that significantly improve performance in cold climates. For this project, punched-window systems are preferred over window-wall or curtainwall systems for residential floors, as punched windows allow for more insulation continuity and reduce the extent of thermally exposed framing. Glazing systems with assembly U-values in the range of 0.8–1.0 W/m²·K and SHGC values between 0.30 and 0.40 are recommended for the project and align with the High-Performance and Net-Zero Ready design assumptions. Frame and perimeter detailing should ensure continuous insulation and robust air and water barrier integration.

For the roof system, high levels of thermal performance are required for both High-Performance and Net-Zero Ready tiers. A clear-field R-50 roof assembly is recommended to reduce heating loads and support overall enclosure performance. In cold climates, conventional warm-roof assemblies—with insulation placed above the structural deck—offer more stable and reliable thermal behaviour than assemblies that place insulation below the membrane. Multiple staggered layers of mineral wool insulation help avoid thermal discontinuities at joints and minimize the impact of fasteners. Mineral wool also maintains more stable R-values at lower temperatures compared to polyisocyanurate, which can experience a reduction in thermal resistance in cold weather. Detailing at parapets, roof-to-wall interfaces, mechanical curbs, and penetrations must ensure continuity of insulation and air barrier systems, as these areas often represent significant thermal bridging points if not carefully addressed.

There are similar challenges with balcony slabs, which act as linear thermal bridges at the enclosure. Slab-edge heat loss can significantly reduce effective wall R-values and create cold interior surfaces. For this project, consideration should be given to thermally broken balcony connectors, enclosed balcony strategies, or reducing the extent of exposed slab edges. Structural thermal breaks such as insulated balcony connectors can meaningfully reduce heat transfer while preserving structural capacity. Where possible, balcony geometry and frequency should be evaluated to minimize thermal bridging impacts on overall enclosure performance.

Based on the Building Envelope Thermal Bridging Guide analysis method, the following linear thermal bridging coefficients are assumed for the transitional components in the building enclosure:

Building Type	Performance Target	Thermal bridge category	Transmittance ϕ	Description and Examples	
Residential	High Performance	Mitigated	0.2 W/m K	Thermally broken connections with good alignment of adjacent thermal insulation Examples: large structural thermal breaks where the thickness of the thermal break is similar in size as the thermal insulation.	
				Well aligned glazing with minimal conductive bypasses Examples: the glazing thermal break is within the wall insulation, but there is thermal bridging related to conductive window frames, flashing partially bypasses the exterior insulation, and un-insulated window perimeters.	
	Net-Zero Ready	Thermal-bridge free	<0.01 W/m K	Fully exterior insulated and fully aligned thermal insulation between components Examples: exterior insulated walls at intermediate floors.	
				Well aligned glazing without conductive bypasses and minimal thermal bridging in clear wall Examples: wall insulation is aligned with the glazing thermal break and insulation is provided around the perimeter of the window framing. Flashing does not bypass the thermal break. Low conductive window frames and/or insulation outboard of the window frame.	
Non-residential	High Performance	Mitigated	0.2 W/m K	Thermally broken connections with good alignment of adjacent thermal insulation Examples: large structural thermal breaks where the thickness of the thermal break is similar in size as the thermal insulation.	
				Well aligned glazing with minimal conductive bypasses Examples: the glazing thermal break is within the wall insulation, but there is thermal bridging related to conductive window frames, flashing partially bypasses the exterior insulation and uninsulated window perimeters.	
	Net-Zero Ready	Mitigated	0.2 W/m K	Thermally broken connections with good alignment of adjacent thermal insulation Examples: large structural thermal breaks where the thickness of the thermal break is similar in size as the thermal insulation.	
				Well-aligned glazing with minimal conductive bypasses Examples: the glazing thermal break is within the wall insulation, but there is thermal bridging related to conductive window frames, flashing partially bypasses the exterior insulation, and uninsulated window perimeters.	

6 EMBODIED CARBON ANALYSIS

In addition to operational energy performance, there is growing recognition of the importance of embodied carbon in building materials. Embodied carbon refers to the greenhouse gas emissions associated with material extraction, processing, manufacturing, transportation, and construction. As the industry moves toward lower-carbon construction practices, early design decisions regarding structure and major envelope systems have a significant influence on the overall carbon footprint of a project.

For high-rise residential buildings such as the proposed development at 153 Union Street East, concrete typically represents the largest contributor to embodied carbon due to the substantial volumes required for foundations, shear walls, floor slabs, and transfer structures. Although concrete has a relatively low carbon intensity per kilogram, the large quantities used in mid- and high-rise buildings result in concrete being the dominant material in the overall embodied carbon profile. Steel reinforcement and structural steel elements also contribute meaningfully, while aluminum—used primarily in window frames and façade components—has a high carbon intensity per unit mass but is used in much smaller quantities.

Figure 11 provides a high-level comparison of the embodied carbon intensities of common building materials. These values are intended as a general guide only, as actual carbon intensities vary by supplier, manufacturing process, transportation distance, and mix design.

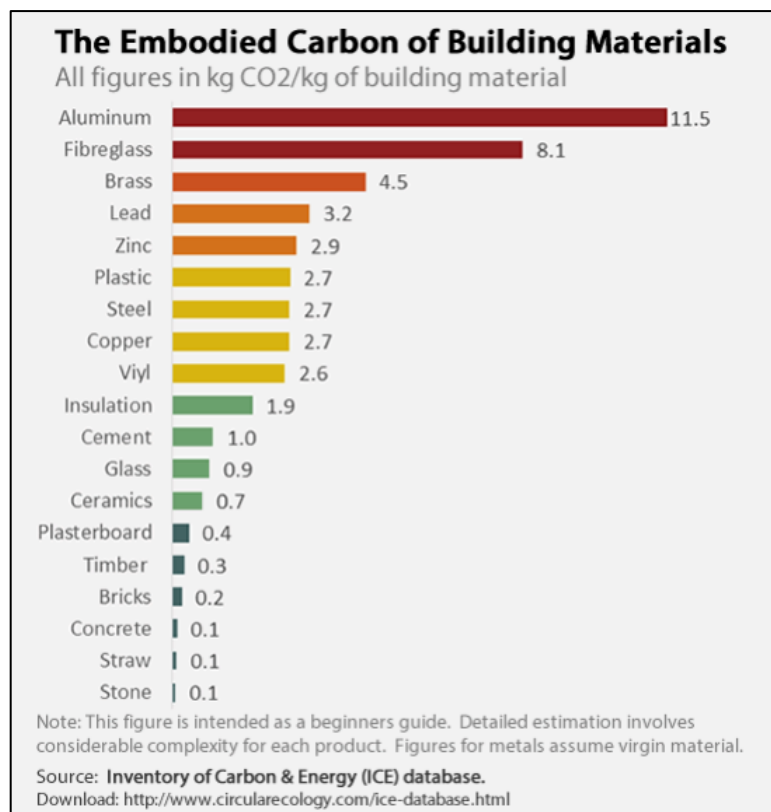


Figure 11: Embodied carbon per unit mass of typical building materials.

To reduce the embodied carbon of concrete, the use of supplementary cementing materials (SCMs) such as ground granulated blast-furnace slag or fly ash should be considered where structurally appropriate. SCMs can replace a portion of Portland cement—the highest-carbon component of concrete—and can reduce embodied carbon significantly while also improving long-term durability and shrinkage performance. Mix designs with reduced cement content, extended curing times, and optimized aggregate proportions should also be explored in collaboration with the structural engineer and concrete supplier.

Opportunities to reduce embodied carbon also exist within the envelope. Prefabricated façade systems with continuous insulation, reduced thermal bridging, and integrated high-performance glazing can minimize the amount of aluminum framing required compared to conventional window-wall systems. Where feasible, punched-window systems and thermally optimized framing materials such as fiberglass or composite frames can further reduce carbon impacts. Mass timber may be considered in select non-loadbearing applications; however, for a twelve-storey concrete building such as this project, mass timber is generally not appropriate for major structural elements but may be integrated into interior finishes or amenity spaces.

Additional embodied carbon reductions can be achieved by specifying materials with environmental product declarations (EPDs), selecting local or regionally sourced materials to minimize transportation impacts, and working with suppliers who offer low-carbon manufacturing processes. Salvaging or reusing materials where practical, and designing building systems to remain adaptable for future uses, can also reduce lifecycle carbon impacts.

As the project progresses into later design stages, the design team is encouraged to evaluate material options through a more detailed embodied-carbon assessment and to engage with suppliers early to identify low-carbon products that align with the performance and durability requirements of the development.

7 RESILIENCY

In addition to meeting efficiency and low-carbon performance objectives, the Region of Waterloo emphasizes the need for new buildings to remain functional, safe, and habitable under future climate conditions. Climate projections for the Waterloo region indicate higher frequency and severity of extreme heat events, increased precipitation, and more intense storm systems over the next several decades. Temperatures above 39°C are expected to occur more regularly, and the number of extreme heat days (defined as days exceeding 32°C) may double by 2050 and continue increasing toward 2100. Annual precipitation is projected to rise by 12–18% by mid-century, accompanied by more frequent short-duration, high-intensity rainfall events that can contribute to surface flooding in urban areas.

New high-rise residential buildings must therefore be designed with strategies that reduce the impact of extreme heat, improve thermal resilience, and ensure continuity of essential services during power outages. A building's ability to maintain safe indoor temperatures during prolonged loss of power—known as passive survivability—is increasingly important as climate conditions worsen. Lower Thermal Energy Demand Intensity (TEDI), achieved through improved envelope performance, has a direct correlation with better indoor comfort during heat waves and unconditioned periods. Buildings with high-performance façades, reduced infiltration, and minimized thermal bridging will retain acceptable temperatures longer during power interruptions.

To support occupant safety and building functionality during emergencies, the design team should consider incorporating backup power solutions beyond the minimum life-safety requirements. Life-safety backup power must support systems such as fire pumps, emergency egress lighting, fire alarms, and smoke control, but does not provide for ongoing heating, cooling, or water supply. Supplemental backup power, however, can support essential services such as domestic water pumping, minimum space heating, corridor ventilation, and the operation of amenity spaces that can serve as refuge areas during extreme heat events or extended outages. Federal emergency preparedness guidelines recommend the ability for occupants to shelter-in-place for at least 72 hours.

Table 9: Emergency and Back-up Power Requirements

	Emergency Power	Back-up Power
Purpose	Minimum life safety requirements	Non-life-safety requirements for occupant wellbeing
Duration	2 hours (Building Code requirement)	72 hours (Federal emergency preparedness guideline)
Loads	Fire pumps, fire elevator, stair pressurization fans, alarm system	Water supply, minimum space heating, domestic booster pumps, additional elevators, power to common refuge area

Additional resiliency considerations for the project include maintaining serviceability of building systems during weather-related disruptions, locating critical equipment above potential flood levels, using flood-resistant materials in susceptible areas, and providing space to accommodate future onsite renewable energy or battery storage should these become feasible as the design progresses. Where possible, mechanical rooms and electrical distribution areas should be arranged to facilitate future connection to district energy systems or alternative energy sources. Ensuring thermal continuity at key enclosure interfaces and improving airtightness also contribute to maintaining habitable indoor conditions during extreme weather events.

By integrating these resiliency measures into the building's design, the development will be better prepared to maintain safe indoor environments, reduce operational disruptions, and support long-term adaptability under evolving climate conditions.

8 CONCLUSIONS

The energy study was completed for the proposed high-rise residential development at 153 Union Street East in Waterloo, Ontario. Energy models were developed using DesignBuilder (EnergyPlus) to evaluate Total Energy Use Intensity (TEUI), Thermal Energy Demand Intensity (TEDI), and Greenhouse Gas Emissions Intensity (GHGI) for three performance tiers defined in the City of Waterloo Energy Study Terms of Reference: the Building Code Baseline, the High-Performance tier, and the Net-Zero Ready tier. These scenarios evaluate progressively more advanced envelope and mechanical strategies to demonstrate feasible pathways toward low-carbon building operation.

The modeling results indicate that the proposed development can achieve all three performance tiers with appropriate design measures. For the High-Performance tier, improvements include enhanced envelope assemblies, reduced air leakage, upgraded glazing performance, improved heat recovery effectiveness, and higher-efficiency heating and cooling plant. These measures collectively reduce TEUI and TEDI by approximately 30% relative to the baseline and lower GHGI significantly through reduced gas consumption.

Achieving the Net-Zero Ready tier requires a shift to a fully electrified mechanical system and further envelope enhancements. The Net-Zero Ready design incorporates high-performance opaque wall assemblies, reduced thermal bridging, improved airtightness, lower-U-value glazing, and high-efficiency electric heat pump systems for space heating, cooling, corridor ventilation, and domestic hot water production. These upgrades substantially reduce operational greenhouse gas emissions and demonstrate a viable pathway toward a future net-zero operational carbon building.

Renewable energy opportunities—including the use of rooftop solar photovoltaic systems—were also reviewed. Solar PV can provide meaningful reductions in electricity consumption and GHGI, and can complement the electrified Net-Zero Ready mechanical configuration. Additional advanced energy options such as district energy interconnection and geothermal feasibility were discussed and may be evaluated further as design progresses and as supporting studies become available.

An embodied carbon analysis identified concrete as the dominant source of embodied carbon for a high-rise residential project of this type. Strategies to mitigate embodied carbon—such as increasing the use of supplementary cementing materials, optimizing mix designs, and evaluating opportunities for prefabricated façade systems with reduced aluminum content—were outlined for consideration during later design stages.

A resiliency review was also completed to support the project's long-term performance under future climate conditions. Improved envelope performance, reduced thermal bridging, and electrified mechanical systems contribute to passive survivability during extended power outages, while backup power planning, thermal resilience measures, and equipment siting strategies support occupant safety during extreme weather events.

The study demonstrates that the proposed development can meet the City of Waterloo's energy and emissions performance expectations with appropriate design enhancements. The strategies and recommendations presented in this report should be refined and evaluated in greater detail as the project advances through schematic and detailed design.