

PANELIZED DEEP RETROFITS OF MUNICIPAL BUILDINGS

Burlington Seniors Centre

Case Study Report **DRAFT**

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CITY OF Burlington

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ReCover

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This research project was led by The ReCover Initiative, a Nova Scotia based non-profit organization working to accelerate deep retrofits in Canada.

Burlington Seniors Centre

Executive Summary

Who is ReCover

ReCover is a Nova Scotia-based non-profit focused on revolutionizing Canada's buildings to combat climate change. Through innovative research, technology, and partnerships, they lead in scalable deep retrofit solutions. Their efforts in Canada lower energy costs and enhance well-being by collaborating with communities, building owners, and financial institutions.

What is the Project

This project examines six cases of municipally owned buildings, inspired by the successful Energiesprong approach from the Netherlands, which streamlines retrofits. Despite challenges adapting to Canada's diverse buildings and climates, some projects have successfully implemented some Energiesprong-inspired retrofits. The ReCover Initiative found cost-effective benefits in panelized retrofits for multi-unit dwellings, aiming for Net Zero Energy. The study seeks to apply effective residential retrofit strategies to support municipal decarbonization.

Project Objectives

The project objectives are to make deep retrofits in Canada more feasible, showcase a panelized retrofit approach, and enhance confidence in retrofits. It aims for a 50% reduction in EUI, a NZER scenario with potential for NZE through solar PV, minimal disruption to occupants, low embodied carbon solutions, cost-effectiveness, and a payback period of 20 years or less.

Methods Used

The project progressed through several phases : building selection based on criteria and evaluation, data collection including utility info and drawings, baseline energy modeling, designing retrofit scenarios with energy conservation measures, and cost analysis involving Class D cost estimation and TCBO modeling.



Building Performance Improvements

EUI

100% improvement

Existing : 435 kWh/m^2

Recommend : 0 kWh/m^2

GHG

100% improvement

Existing : 96,836 kg/yr

Recommend : 0 kg/yr

Lifetime Maintenance Costs

13% improvement

Existing : $16.2 M

Recommend : $14.1 M

Lifetime Savings

$10.2 Million

Existing : $34.6 M

Recommend : $24.4 M

Retrofit Measures

2x8 ReCover wall panels

EPS roof insulation

High performance windows and doors

Ground source heat pump

New ventilation system

220 kW Solar PV system

Acronyms and Definitions

ACH	**A**ir **C**hanges per **H**our, measured with a blower door test
CO_2e	**C**arbon di**O**xide **E**quivalent
Deep Retrofit	A project involving multiple energy efficiency and/or renewable energy measures in an existing building, designed to achieve major reductions in energy use. A deep retrofit usually includes reducing energy demand and switching from fossil fuels to electricity for space and water heating – to achieve 70% energy savings and 80% to 100% GHG emissions reductions.
Energiesprong	A retrofit methodology developed in the Netherlands to implement Net-Zero retrofits using prefabricated envelope panels and compact exterior mechanical pods. Energiesprong retrofits are financed by the cost savings from future energy consumption and required maintenance. Translation: Energy Leap.
EUI	**E**nergy **U**se **I**ntensity
FCA	**F**acility **C**ondition **A**ssessment: a comprehensive evaluation of a building's physical condition.
GHG	**G**reen**H**ouse **G**as
GWP	**G**lobal **W**arming **P**otential: a measure of how much energy the emissions of 1 ton of gas will absorb over a given time, relative to the emissions of 1 ton of carbon dioxide.
NZE	**N**et-**Z**ero **E**nergy building: a building in which on-site renewable energy generated equals the annual energy consumption of the building
NZER	**N**et-**Z**ero **E**nergy **R**eady building: a building whose annual energy consumption is low enough that it could be Net-Zero Energy with the addition of a source of renewable energy
PV	Solar **P**hoto**V**oltaic array
TCBO	**T**otal **C**ost of **B**uilding **O**wnership: building life cycle cost analysis that includes all major operating costs over the useful life of the building.
WRB	**W**ater-**R**esistive **B**arrier: a synthetic membrane installed outside of the building's sheathing to protect it from the impacts of bulk water.
ZCB	**Z**ero **C**arbon **B**uilding:

Introduction

Over one-third of Canada's planned greenhouse gas (GHG) emissions reductions will come from energy efficiency measures.[1] Increasing the pace and scale of deep retrofits is imperative to achieving net-zero emissions, as most buildings standing today will still exist in 2050.

Municipalities across Canada are working to implement climate action plans to reduce their GHGs and to protect people and infrastructure from the impacts of climate change. Deep retrofits support both efforts.

The Panelized Deep Retrofits of Municipal Buildings project includes six deep retrofit case studies of municipally owned buildings in Canada. The buildings studied are representative of buildings in municipalities throughout the country. Their uses include community centres, administration, transit, and maintenance facilities in three Canadian climate zones.

Conventional retrofit practices are not scalable. They require large budgets, custom design, and invasive construction. The only retrofit initiative to be successfully scaled to date is the Dutch approach, Energiesprong, which involves prefabricated panelized envelope over-cladding and systematic mechanical upgrades. This approach reduces time on site and project complexity compared with common retrofit practices and permits buildings to continue to be used during the work.

Energiesprong has succeeded in part because of the Netherlands' homogenous building stock. The diversity of buildings and range of climate conditions in Canada pose challenges in adapting the approach to this country, yet several Energiesprong-inspired projects have been completed or are under way. These include Ottawa Community Housing's four-unit townhouse retrofit completed in 2021, Sundance Housing Cooperative in Edmonton, which is mid-way through retrofits on their 59 townhouses, and three single family homes in Alberta.

Measures that focus on simple payback and short-term return on investment can be counterproductive with assets as long lasting as buildings. Economic evaluation through Total Cost of Building Ownership (TCBO) analysis is more appropriate for complex retrofit projects that make changes to multiple interrelated building systems.

The ReCover Initiative has studied the potential for prefabricated panelized deep retrofits in lo-rise multi-unit dwellings in two previous case studies[2]. These studies found the lowest TCBO over the anticipated life of the building was achieved through Net Zero Energy retrofits where

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[1] IEA (2022), *Canada 2022*, IEA, Paris https://www.iea.org/reports/canada-2022 , License: CC BY 4.0

[2] ReCover Initiative (2020) *ReCover Phase One Case Study Report* and ReCover Initiative (2022) *Scarlettwood Court Deep Retrofit Case Study Repor*t, https://www.recoverinitiative.ca/about-us/our-results/report-request

the targets were met with an Energy Use Intensity (EUI) reduction of at least 75% before adding solar PV.

This study of Panelized Deep Retrofits of Municipal Buildings was undertaken to develop deep retrofit strategies to support municipal decarbonization efforts.

Project Objectives

The objectives of this study were to de-risk investment in deep retrofits in Canada, to provide evidence on the effectiveness and scalability of a panelized deep retrofit approach and to build confidence and experience in deep retrofits among Canadian municipalities and industry stakeholders.

The goals for the Deep Retrofits explored included:

1. Develop a scenario that achieves an Energy Use Intensity (EUI) reduction of 50%.
2. Develop a Net Zero Energy Ready (NZER) scenario that can achieve Net Zero Energy (NZE) with the addition of solar PV.
3. All solutions minimize occupant disruption during construction.
4. All solutions target minimal embodied carbon.
5. Identify the retrofit pathway to the lowest Total Cost of Building Ownership.
6. Demonstrate a calculated payback of 20 years or better.

Methodology

The project was completed in the following phases:

1) Building selection.
   a) Definition of selection criteria.
   b) Building evaluation and selection.
2) Data and document collection, including:
   a) Utility data
   b) Building drawings
   c) Facility Condition Assessment, ideally no more than five years old
   d) Field Review
3) Baseline energy modeling (hourly analysis).
   a) Determination of model inputs
   b) Energy Model Calibration
   c) Baseline energy model results
4) Design Energy Conservation Measures (ECMs) for retrofit scenarios, including:
   a) u-values, window, and door performance specifications
   b) mechanical and electrical systems upgrades

c) panel design, including:
    i) structural design and fastening details.
    ii) panel dimensions and layouts.
    iii) hygrothermal modeling with WUFI Pro to assess moisture risk.
    iv) embodied carbon accounting.
    v) aesthetic upgrades.
5) Cost Analysis.
    a) Class D cost estimate.
    b) TCBO modeling.

Building Selection

The Burlington Seniors Centre was selected for study by the City of Burlington with input from the ReCover team. Criteria for consideration included the following:

- high EUI
- potential to eliminate fossil fuel-based building systems.
- high maintenance deficit
- simple form
- ample space to stage a panelized construction project.
- solar potential

The Burlington Seniors Centre was selected as it has a high energy use intensity (EUI) using on average 340,000 kWh of electricity and 1,720 GJ of gas annually. The building also has a history of comfort issues at all times of year.

The one-storey structure is suitable for a panelized retrofit despite its irregular footprint because the geometry has consistent 135-degree angles. There is generous space around the structure to stage construction work. The building has good solar potential.

Data and Document Collection

The Town of New Glasgow provided the following data and supporting documents pertaining to the Municipal Operations Building:

- 1978 construction drawings (Appendix A)
- 2005 expansion drawings
- Natural gas consumption records January 2018 – March 2022 (Appendix F)
- Electrical consumption records January 2018 – March 2022 (Appendix F)
- 2017 Roof Condition Assessment.

Typically, a minimum of two years of consumption records for all utilities serving a building is required. As the time frame for this project included reduced building occupancy during the pandemic, at least one year preceding the beginning of the pandemic was included in analysis.

Smarter Spaces was engaged to complete **LiDAR** (Light Detection and Ranging) imaging to capture the external building geometry. The 3D point cloud generated from the scan was interpreted to produce CAD and BIM drawing files for use by the design team (Appendix A).

A site visit was conducted by design team members to verify structural, mechanical, and electrical details from the resources provided and to understand building conditions. The team also engaged with Town of New Glasgow staff to understand building usage patterns, baseline operational settings for mechanical systems and for information on occupant comfort and building deficiencies.

A new **Facility Condition Assessment** (FCA) was obtained. (Appendix B).

Building Description

The Burlington Seniors Centre is a one storey structure with a gross floor area of 2,000m^2 (21,526 sq.ft). Its footprint is irregularly shaped with many 135-degree angles. The original building was built in 1979 and it underwent a renovation and expansion in 2005.



Figure 2 Site Plan: Burlington Centre

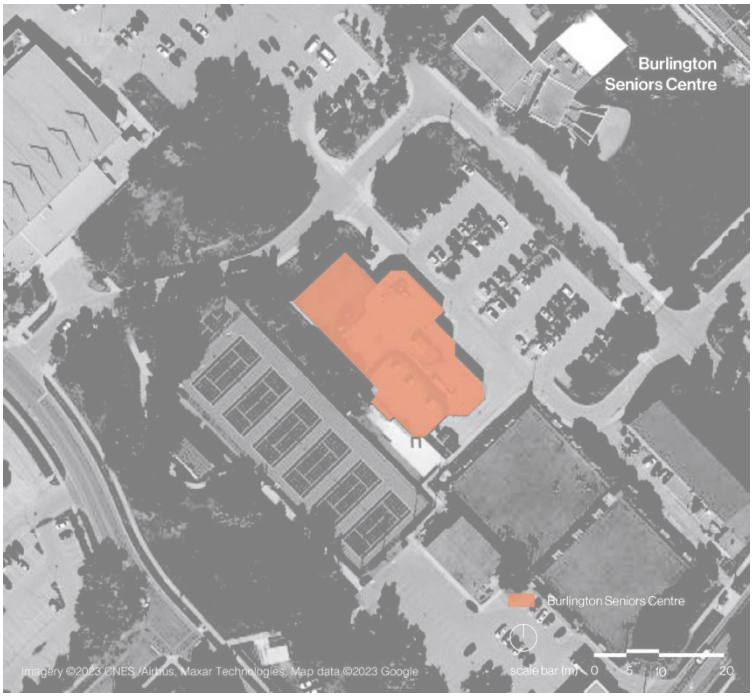


Figure 1 Site plan

The Burlington Seniors Centre offers a variety of recreation services for people aged 55 and older, including fitness and art classes, social events, church services, and workshops. It is also rented out for events such as parties, meetings, and trade shows. The facility is open year-round from 7am to 10pm on weekdays and 8:30am to 4:30pm on weekends. The space is well used with programing offered most days continuously between 8:30am to 9pm. As services are offered both on a pre-registered and a drop-in basis, the number of daily visitors to the facility fluctuates. The building also contains administration offices, a 420m^2 (4,500 sq.ft) auditorium and a commercial kitchen. Prior to the pandemic the kitchen served breakfast and lunch through the week, however currently the kitchen prepares only baked goods and drinks.

Context

The Burlington Seniors Centre is located at 2285 New Street, Burlington, Ontario. It is one of several recreation facilities in Burlington's Central Park, an activity hub located less than a kilometer inland from Lake Ontario. The building is surrounded by sports fields, gardens, a library, theatre, an arena and more.

Southern Ontario has a humid continental climate and experiences periods of high heat and humidity in summer. The region is expected to experience continued temperature increases in both summer and winter and higher annual precipitation.[3] The site is in Canadian building code climate zone 5.

The City of Burlington is working towards a goal to become a net carbon zero community by 2050.[4]

Building Code Considerations

A preliminary review of the National Building Code of Canada (NBCC) and the Ontario Building Code (OBC) has been completed to determine building code implications of a panelized retrofit to the Burlington Seniors Centre (Appendix L). The primary focus of the review was to determine if panels made with combustible materials may be permitted to be installed on the existing structure.

As the building's primary use is a community centre, the structure is categorized as a **High Importance Building** as per Sentence 4.1.2.1.(3) in the 2015 edition of the National Building

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[3] City of Burlington, (2022) *Climate Resilient Burlington*, https://burlingtonpublishing.escribemeetings.com/filestream.ashx?DocumentId=62452

[4] City of Burlington (2020) *Climate Action Plan*, https://www.getinvolvedburlington.ca/9946/widgets/38577/documents/33658

Code of Canada (NBCC). High Importance structures are subject to higher environmental loading, including snow, wind, and seismic loads, than a normal importance building.

The construction type, cladding and fire rating requirements for each exterior wall of a building are based on the area of the wall and its proximity to the property boundaries and the building's occupancy classification. The existing building is sprinklered. Based the building's use as a recreation centre it is classified as **NBCC Group A2 - Assembly Occupancy.**

A legal survey of the property was not provided for this study. The approximate property line setbacks from the building were obtained through Burlington's online interactive mapping tool. The building has an irregular shape, with the north-west wall of the building approximately parallel to the nearest lot line and set back approximately 9.5m. This is the closest part of the building to the property line.

Based on the scaled setbacks, both the structure and the cladding are permitted to be of either combustible or noncombustible construction. This indicates that ReCover panels may be permitted to be installed on the building.

Building Enclosures

The walls are assumed to be insulated with 50mm (2") extruded polystyrene (XPS) insulation between the brick cladding and concrete block. Phenolic panel accent walls are assumed to have 75mm (3") of XPS insulation. The original drawings show 50-75mm (2"- 3") of roof insulation beneath a layer of tapered insulation. This is also assumed to be extruded polystyrene (XPS) based on the 2017 Roof Condition Assessment (Appendix B). The concrete floor slab is shown as uninsulated in the original building and the addition drawings show slab insulation at the perimeter only.

TABLE 1 Opaque Enclosure Performance: Burlington Seniors Centre

	Effective USI $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot °F$	Effective RSI $m^2 \cdot K/W$ ($ft^2 \cdot °F \cdot h/BTU$)
weighted average walls	USI-0.80 (U-0.14)	RSI-1.25 (R-7.1)
weighted average roofs	USI-0.27 (U-0.05)	RSI-3.66 (R-20.8)
slab	USI-4.1 (U-0.7)	RSI-0.24 (R-1.36)
windows	USI-3.4 (U-0.6)	RSI-0.29 (R-1.66)

Assumptions were made where references in original documents were unspecific, for example existing roof drawings reference 'roof insulation' but do not state the type (Figure 3.) and walls show insulation but do not note it in the assembly (Figure 4).

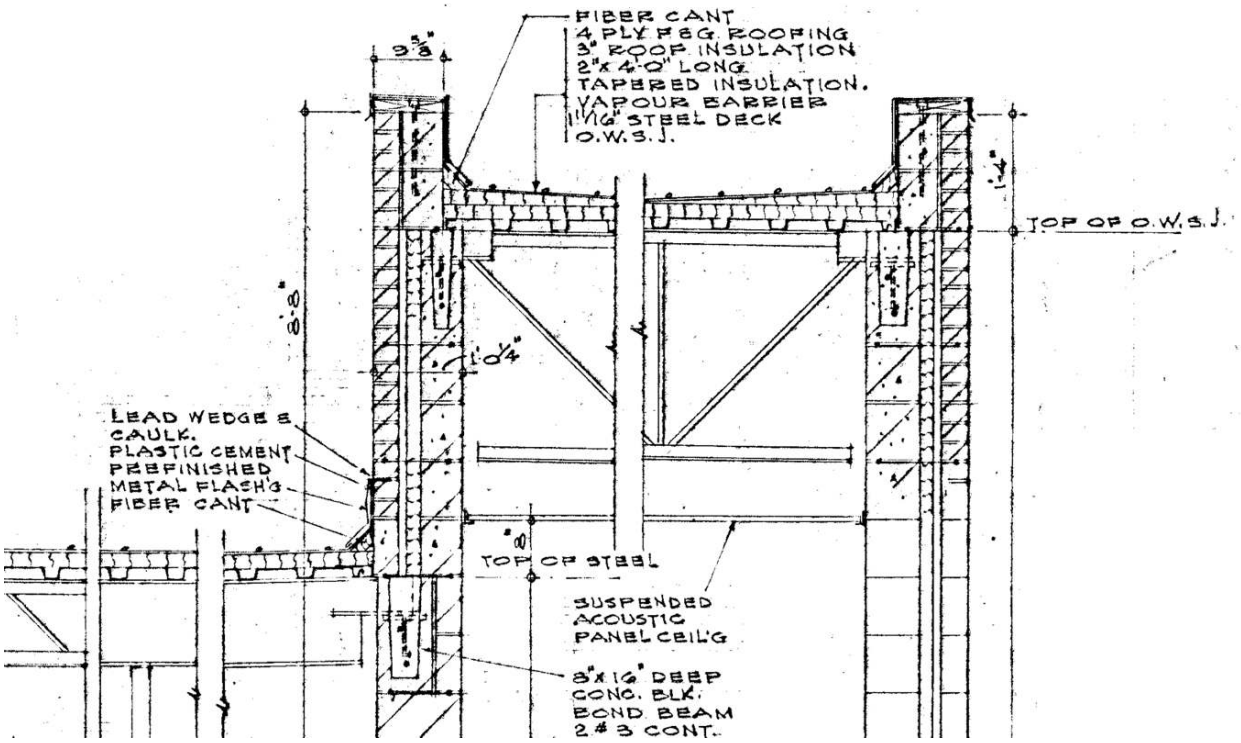


Figure 3 Partial roof to wall section detail.

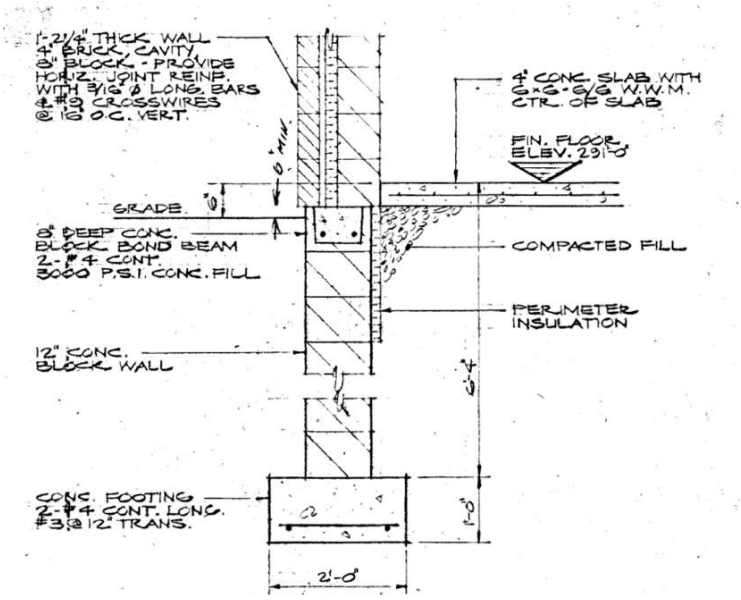


Figure 4 Partial foundation to wall section detail.

Existing Structure

The **foundation** and **above grade wall** structure are 200mm and 305mm (8" and 12") concrete masonry unit (CMU) blocks installed on **cast-in-place concrete strip footings** (Figure 4). There is capacity in the masonry walls to accommodate additional loading.

The **roof structure** is a system of pre-engineered open web steel joists (OWSJs) bearing on the CMU walls (Figure 3). Specifics of the steel strength were not available.

There is no evidence to suggest structural deficiencies in the structure of the building, however confirmation of the wall condition through selective destructive testing is recommended prior to panelized over-cladding.

The results of structural assessment are that the existing walls are suitable for a panelized retrofit but that adding prefabricated panels is not viable for the roofs.

Details of the existing structure and Structural Outline Specifications are in Appendix C.

Existing Mechanical Systems

The building has a flat roof, sloped to internal **rainwater drains** and numerous mechanical penetrations which must be carefully detailed in a panelized retrofit.

The **hot water** service includes a natural gas tankless water heater with a separate 80-gallon storage tank.

Space heating and cooling is provided by a combination of Constant Air Volume (CAV), Variable Air Volume (VAV) and Variable Volume and Temperature (VVT) rooftop air handling units complete with natural gas burners.

Due to occupant comfort complaints, electric heaters have also been added in the offices and games room. The boutique room has electric reheat for hot yoga programs.

Two small storage rooms in the kitchen area have supplemental cooling provided by mini split heat pumps. These units were recently installed due to the heat gain of commercial fridges and freezers in the storage rooms.

Ventilation is provided by the rooftop units. There are four exhaust fans that serve the kitchen, two-bathroom facilities, and kiln room. A make-up air unit is installed in the kitchen.

Apart from the multi-zone VAV system, most HVAC units are nearing the end of their 20-year lifetime and will need to be replaced.

There is no record of updates to the ductwork in the original building. As ductwork typically has a service life of 30-40 years, the efficiency of the original facility's distribution system is likely to be lower than industry norm.

Details of the existing mechanical systems and Mechanical Outline Specifications are provided in Appendix C.

Existing Electrical Systems

The incoming **power service** consists of two, 4" PVC conduits servicing a pad mount transformer. The main incoming secondary service is sized at 400A, 600V, 3P and consists of two 4" PVC conduits. The secondary service entrance enters the building in the main electrical room and terminates onto the main service entrance rated main breaker. The building's main disconnect is a 400A, 100% rated loose main breaker.

The **main distribution** is original to the building and consists of a main disconnect, a main 600V panelboard and multiple branch circuit panelboards throughout the building.

The **main building disconnect** is a 100% rated 400A fused disconnect switch. All other disconnects for panels, motors etc. are also fusible disconnects.

Several 120-208V **branch circuit panelboards** exist throughout the building servicing various areas. All panelboards appear to be original to the building and range from okay to good condition. No mini breakers are present in the existing panelboards. There is limited breaker space available for additional equipment. Depending on the scope of proposed electrical changes, additional distribution may need to be added.

No **emergency power distribution** is present on site. Emergency lighting, exit signage and the building fire alarm panel are battery operated.

Electric baseboard heaters are located throughout the building to support the main heating.

Throughout the building, most of the **interior lighting** fixtures are rectangular or linear fluorescent fixtures with T8 lamps. The office area of the building has been retrofit LED flat panel fixtures.

The **exterior lighting** has been retrofit to LED. Several LED wall-packs exist around the perimeter of the building which are controlled by a timeclock. The wall-packs appear to be in good condition.

The building lacks an automatic lighting control system relying entirely on manual control. This could lead to energy waste if lights are left on in unoccupied areas of the building for extended periods of time (overnight).

Details on the existing electrical systems and Electrical Outline Specifications are provided in Appendix C.

Energy Consumption

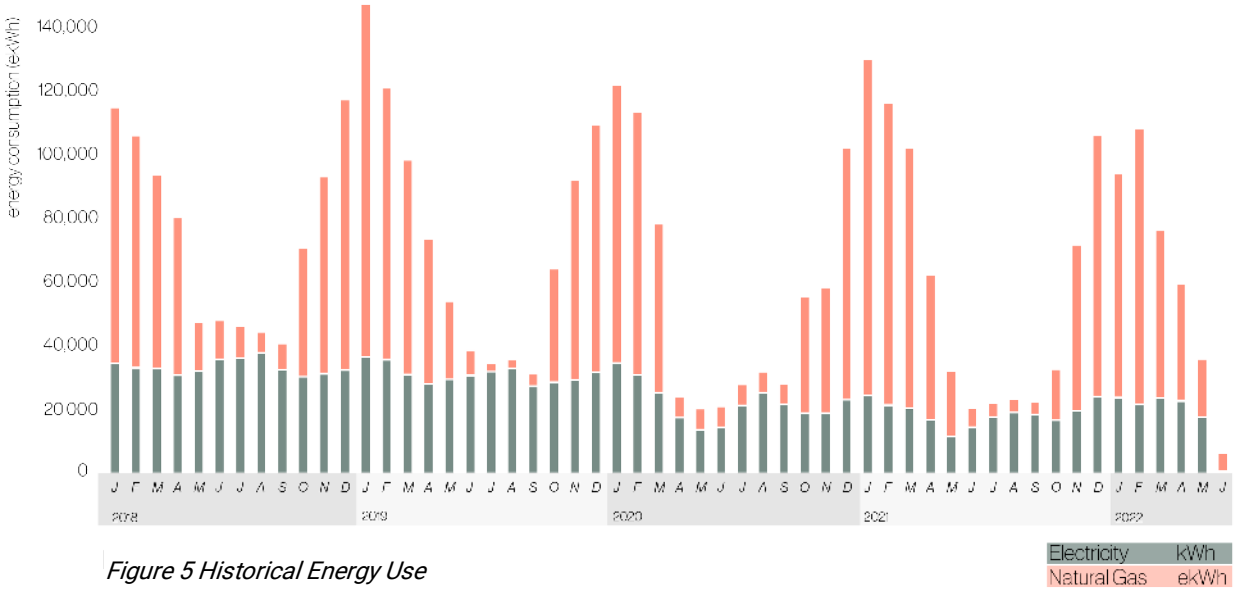


Figure 5 Historical Energy Use

Energy analysis was based on electrical and natural gas records spanning January 2018 through March 2022 (Appendix F). The earlier years are more representative of typical building operations as the Burlington Seniors Centre experienced periods of reduced building occupation due to the COVID-19 pandemic during the documented time span.

The building used an annual average of 343,746 kWh of electricity and 45,906 m3 (ekWh) of natural gas over that time span. The data shows that energy use was reduced by approximately 35% starting in 2020.

Baseline Energy Model and Calibration

Whole building energy modeling was conducted with eQUEST to understand existing performance and to inform the development of retrofit scenarios. Energy model inputs (Appendix G) were based on data and documentation described earlier in this report and in consultation with City of Oakville staff on occupancy patterns and operational set points of the mechanical and electrical equipment.

The energy model was calibrated with the historical utility data to closely reflect the current building performance. As occupancy fluctuated during the pandemic, the calibration was based on consumption prior to March 2020 to best reflect energy use during standard operations.

Summertime electrical calibration did not align as closely to actual energy use as the rest of the year. This is assumed to be due to higher levels of programming in summer months. The calibrated electrical consumption is within 1% of actual use. Natural gas calibration deviates

from actual use through the heating season. The gas heating system is supplemented with electricity in some spaces and the relative proportion of heating provided by the two systems is not consistent. The calibrated natural gas consumption varies 5% from actual use.



Figure 6 Calibrated Energy Use

Results

The design team worked collaboratively to develop retrofit scenarios targeting the project objectives. The analysis assumes a 'like for like' retrofit where space usage, occupancy schedules, internal geometry, volume of conditioned space, and window and door dimensions and locations are consistent with existing conditions.

The strategy for building enclosure upgrades is to retrofit the walls with prefabricated ReCover panels and to complete a conventional retrofit to the roof by adding outboard rigid insulation as a panelized roof retrofit is not structurally viable.

Energy Conservation Measures

Energy conservation measures for the following four scenarios were developed:

1. Minimum Upgrade Scenario targeting a 50% reduction in TEUI from the baseline.
2. NZER – ASHP targeting a 75% reduction in TEUI from the baseline.
3. NZER - GSHP targeting a 75% reduction in TEUI from the baseline.
4. Net Zero Energy.

Building enclosure upgrades were developed for each scenario with post-retrofit airtightness targeting 0.5 L/s·m^2, a 75% reduction from the estimated existing air infiltration. All scenarios propose upgrading to high performance windows.

Mechanical and electrical retrofits were developed based on ease of integration with existing systems and installation cost. As the building has a high occupant density, the heating and cooling systems were designed around the cooling loads.

For the Net Zero Energy Ready (NZER) scenarios, both air source heat pumps (ASHP) and ground source heat pumps (GSHP) were considered in the design analysis. A GSHP is more energy efficient than an ASHP, however the capital costs of installing an GSHP system are typically much higher. Depending on the specific building details it is not immediately apparent which option is the better investment. The Net Zero Energy scenario is based on the GSHP option which resulted in the lowest TCBO.

Details of the retrofit scenarios are summarized in Table 2.

Table 2 Burlington Seniors Centre Retrofit Scenarios Summary				
Item	**Existing Building**	**Minimum Upgrade**	**ASHP Net Zero Energy[1]**	**GSHP Net Zero Energy [1]**
Effective Wall R-value	RSI-1.23 (R-7)	2x4 ReCover panel RSI-2.64 (R-15)	2x8 ReCover panel RSI-4.4 (R-25)	2x8 ReCover panel RSI-4.4 (R-25)
Effective Roof R-value	RSI-3.7 (R-21)	Add 4" EPS RSI-4.4 (R-25)	Add 8" EPS RSI-10.57 (R-60)	Add 8" EPS RSI-10.57 (R-60)
windows	Aluminum double glazed RSI-0.44 (R-2.5)	triple pane RSI-1.02 (R-5.56)	triple pane RSI-1.02 (R-5.56)	triple pane RSI-1.02 (R-5.56)
Air Tightness at 75Pa	3.0 L/s·m2	0.5 L/s·m2	0.5 L/s·m2	0.5 L/s·m2
Central Heating Equipment	Natural gas rooftop units	Natural gas rooftop units	Air source VRF	Ground source VRF
Heating System	Combination ducted VAV/CAV and electric baseboards	Ducted VAV AHUs and electric baseboards	Ducted fan coil units	Ducted fan coil units
Cooling System	Combination ducted VAV/CAV and mini split units in storage rooms	Combination ducted VAV AHUs and mini split units in storage rooms	Ducted fan coil units	Ducted fan coil units
DHW Equipment	Natural gas tankless water heater and storage tank	Natural gas tankless water heater and storage tank	HP Water Heater	HP Water Heater
Ventilation Equipment	Combination ducted CAV/VAV natural gas rooftop units	Ducted VAV natural gas rooftop unit	90% SRE ERVs[2] with VAV boxes in zones	90% SRE ERVs[2] with VAV boxes in zones
Renewables	-	-	220kW (DC)	220kW (DC)

[1]Net Zero Energy Ready systems are identical with exclusion of renewables
[2] 90% heat recovery efficiency Tempeff Dualcore or similar.

Table 3 Retrofit Scenario Results				
	Target TEUI		TEUI kWh/m^2	TEUI reduction
Existing	-		435.4	-
Minimum Upgrade	50% savings	217	32%	
NZER ASHP	75% savings	113.4	74%	
NZER GSHP	75% savings	110.1	75%	
NZE	100% savings	0	100%	

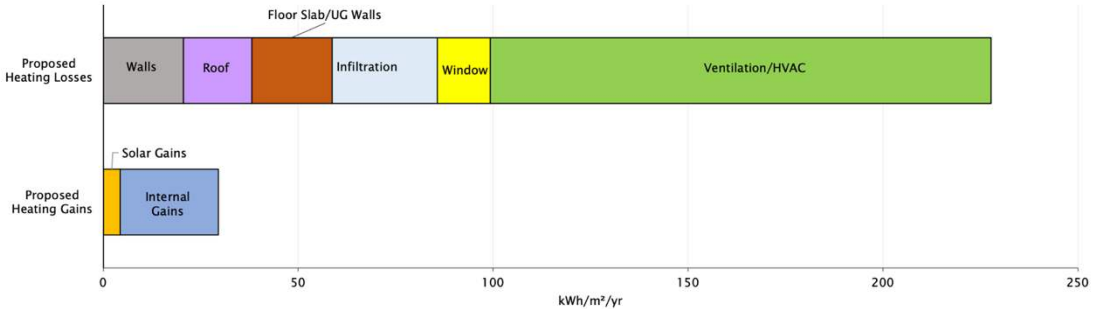


Figure 7 Thermal Energy Demand Intensity (TEDI)

The Thermal Energy Demand Intensity (TEDI) provides a breakdown of heat losses by building component in the existing building (Figure 7). Ventilation heat losses account for 55% of heat losses and the building enclosures are responsible for the remaining 45%. This indicates that upgrading the efficiency of the building's ventilation system will reduce energy use.

The **Total Energy Use Intensity** (TEUI) of the Sir John Colborne Centre is 435.4 ekWh/m^2/yr.

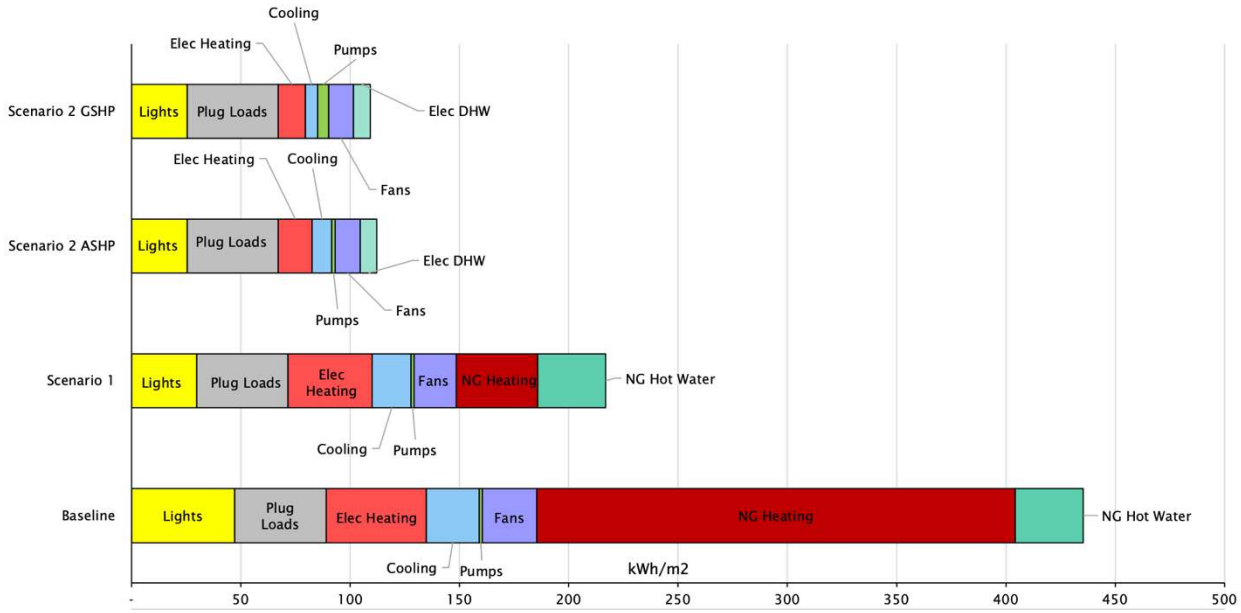


Figure 8 Total Energy Use Intensity (TEUI) kWh/m^2/yr



Figure 9 Design concept

Design

Thoughtful design decisions can reduce time and expense in ongoing maintenance and replacement of building components. In consideration for the maintenance burden facing municipalities, the design recommendations in this study prioritize durability and longevity. The proposed new cladding for the Burlington Seniors Centre is corrugated metal, which is inexpensive, low maintenance and long-lasting.

Different sizes of a corrugated profile in a subdued green colour create a textural palette that harmonizes with the park setting and makes an understated backdrop to the myriad recreation activities that take place in the park.

To improve wayfinding and to create a sense of warmth and welcome, the recessed entrances are wrapped with cedar siding. These will be illuminated with warm lighting to mark the doors with a golden glow.

Architectural Elevation drawings are provided in Appendix L.



Figure 10 Entry Concept

Panelized Wall Design

The prototype ReCover panel is a wood framed box which holds carbon storing cellulose insulation. The depth of the frame is flexible depending on the needed performance.

Proposed NZER ReCover Panel RSI-3.7 (R-21)

1. metal cladding [5]
2. 19mm strapping/rainscreen cavity
3. WRB membrane
4. plywood sheathing
5. dense-pack cellulose
6. framing: 2x8 wood studs 24”o.c.[6]
7. variable permeability vapour control membrane
8. interior strapping

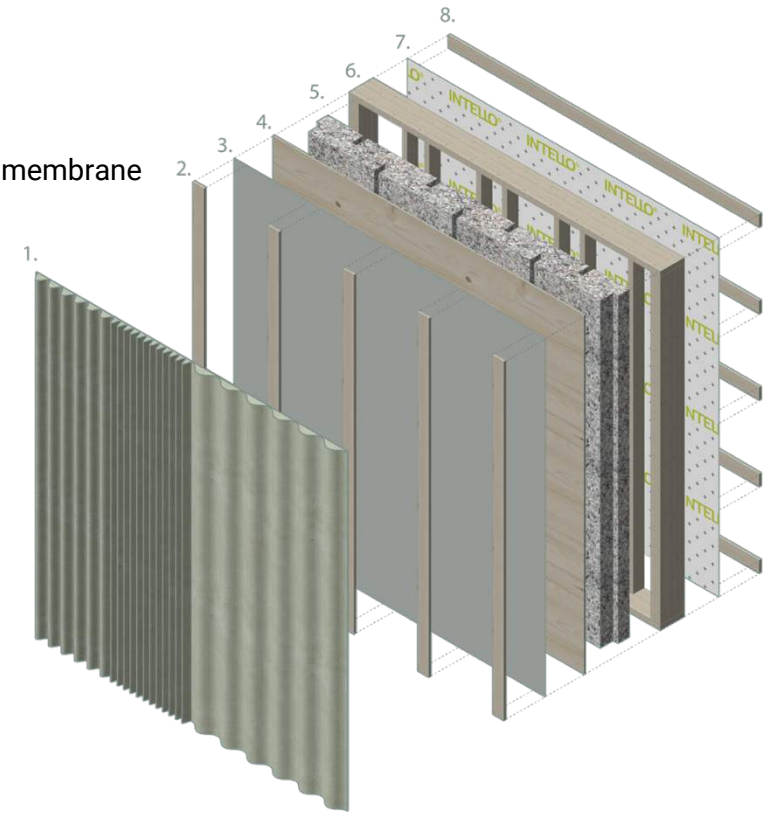


Figure 11 wall panel schematic

The existing brick will be removed, and panels will be installed in front of existing rigid insulation on the CMU wall structure. A decision can be made when this is exposed whether to install a vapour retarding membrane on its surface prior to panel installation.

[5] Panels will be assembled remotely; however, the cladding will be installed on site.
[6] Panel framing is based on 2x4s in the Minimum Upgrade scenario.

The panel components were specified to reduce moisture risks from both internal and external sources. Strapping on the back side of the panel allows for fitting adjustments and makes an internal air cavity and moisture buffer, allowing any vapour diffusion from the inside to move out through the panels. The rear panel layer is a “smart” vapour control membrane which varies in permeability, also to let vapour pass. Cellulose and wood are hygroscopic, transporting moisture to support drying activity. A vapour-open water-resistive barrier (WRB) protects the panel’s outer plywood sheathing. This acts as a drainage plane behind the rainscreen cavity and metal siding. Metal siding is recommended for longevity and durability.

Panel schematics and connection details for each scenario are in Appendix H.

Structural Design

The existing brick veneer will be removed, and the wall panels will sit on the existing brick ledge on the foundation wall (Figure 12).

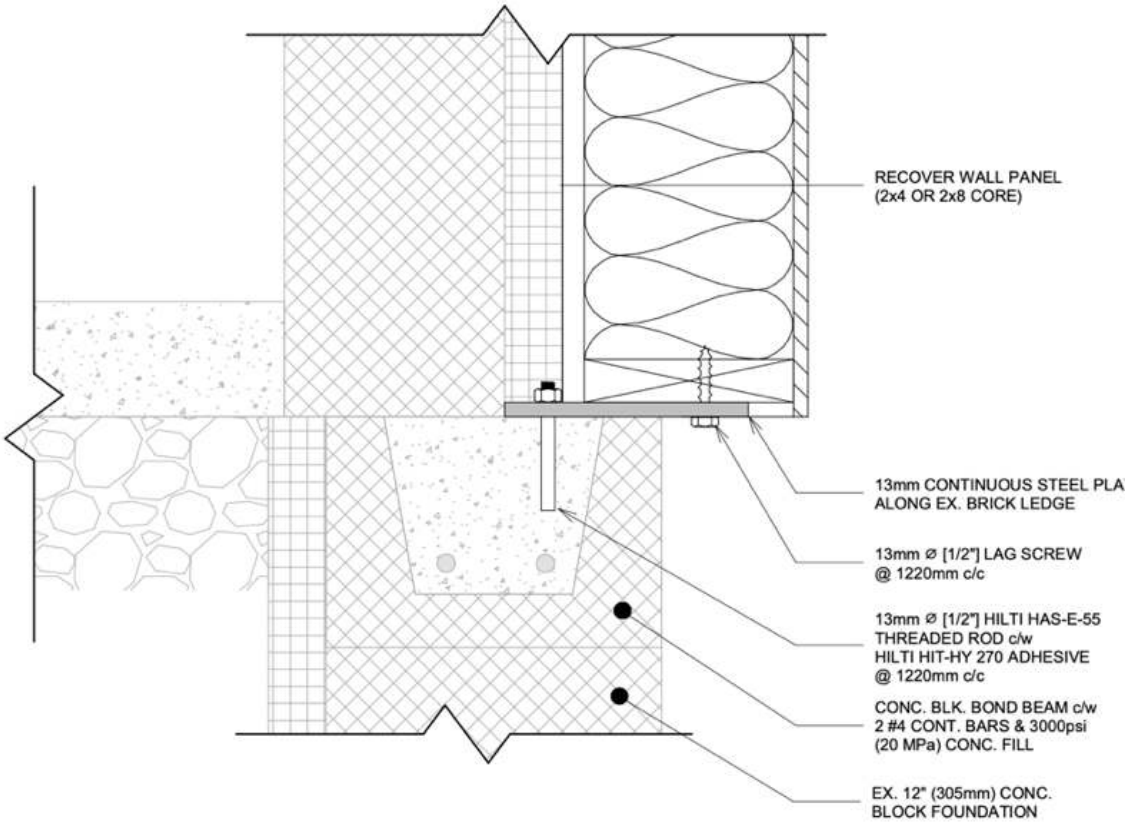


Figure 12 Panel connection at foundation.

102mm long pieces of structural steel angle will be installed to fasten the top plate of the wall panels to the existing structure at the roof diaphragm, with field- installed masonry anchors and lag screws fastened into to the parapet wall and panel top plate, respectively (Figure 13).

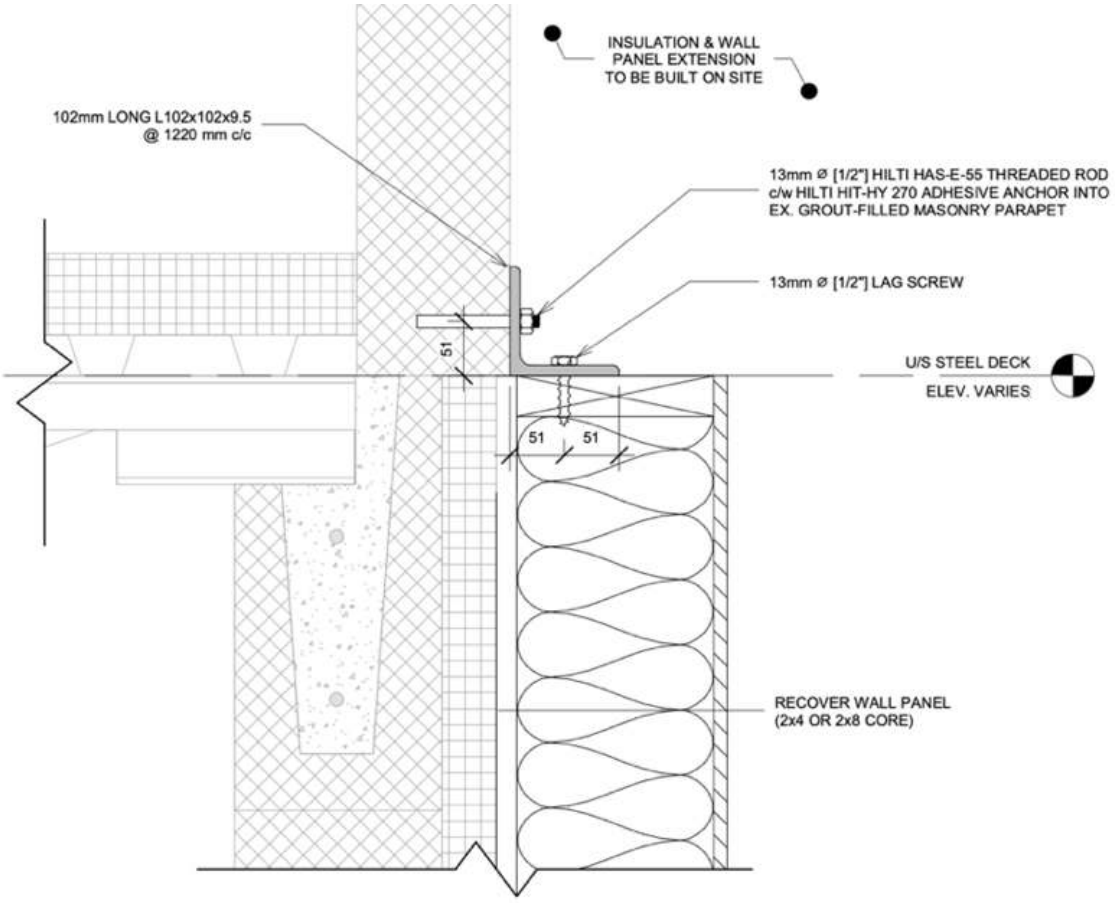


Figure 13 Panel connection at roof.

The panels will be installed in two courses with heights between 1.5m to 2m depending on their location on the building. Attachment of the panels in the middle of the wall (Figure 14) alters the wind loads impacting the structure (Figure 15 (next page)). To complete the analysis on the proposed panel connection details it is necessary to confirm the presence of reinforcing bars and grout in the CMU walls.

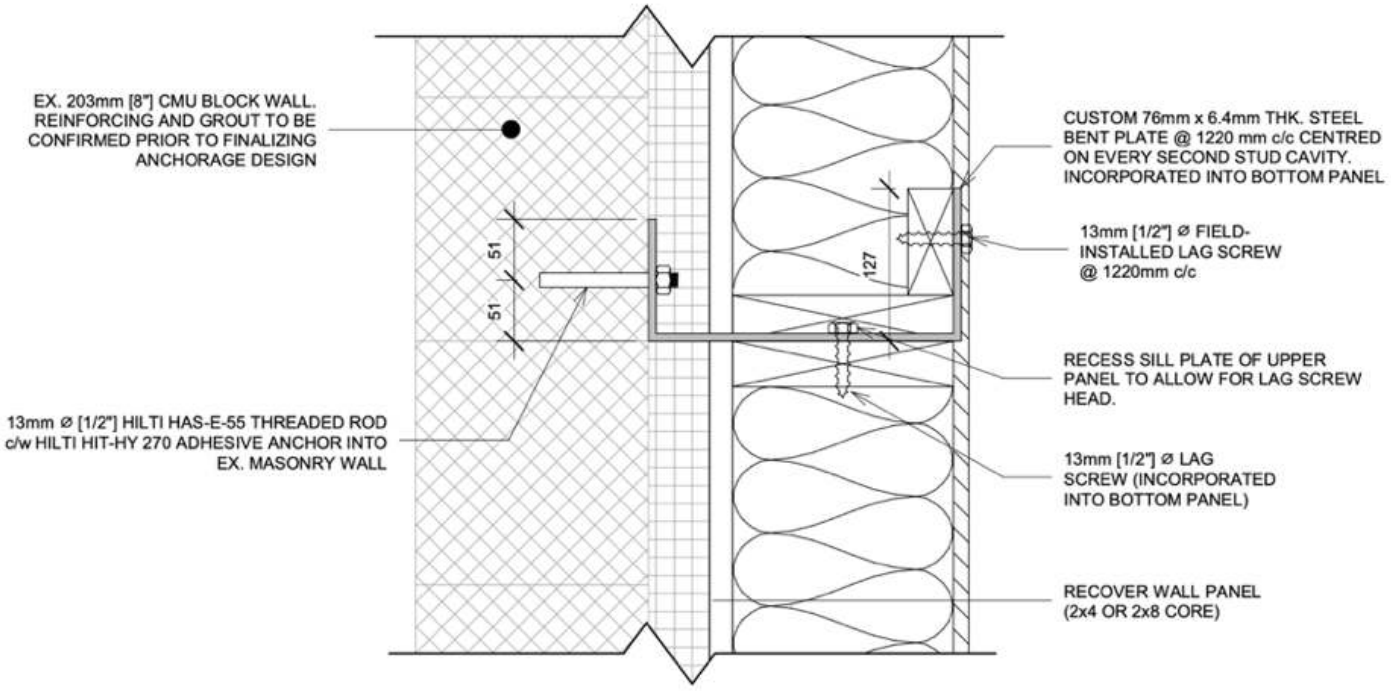


Figure 14 Mid-height panel connection

The panel widths vary based on optimized spacing around the building with a standard width of 2.4m (8') with modifications to suit the building geometry and window and door positions. The design includes prefabricated corner panels, to simplify installation in the field. These are 0.6m (2') wide in each direction.

The proposed panel layout is provided in Appendix I.

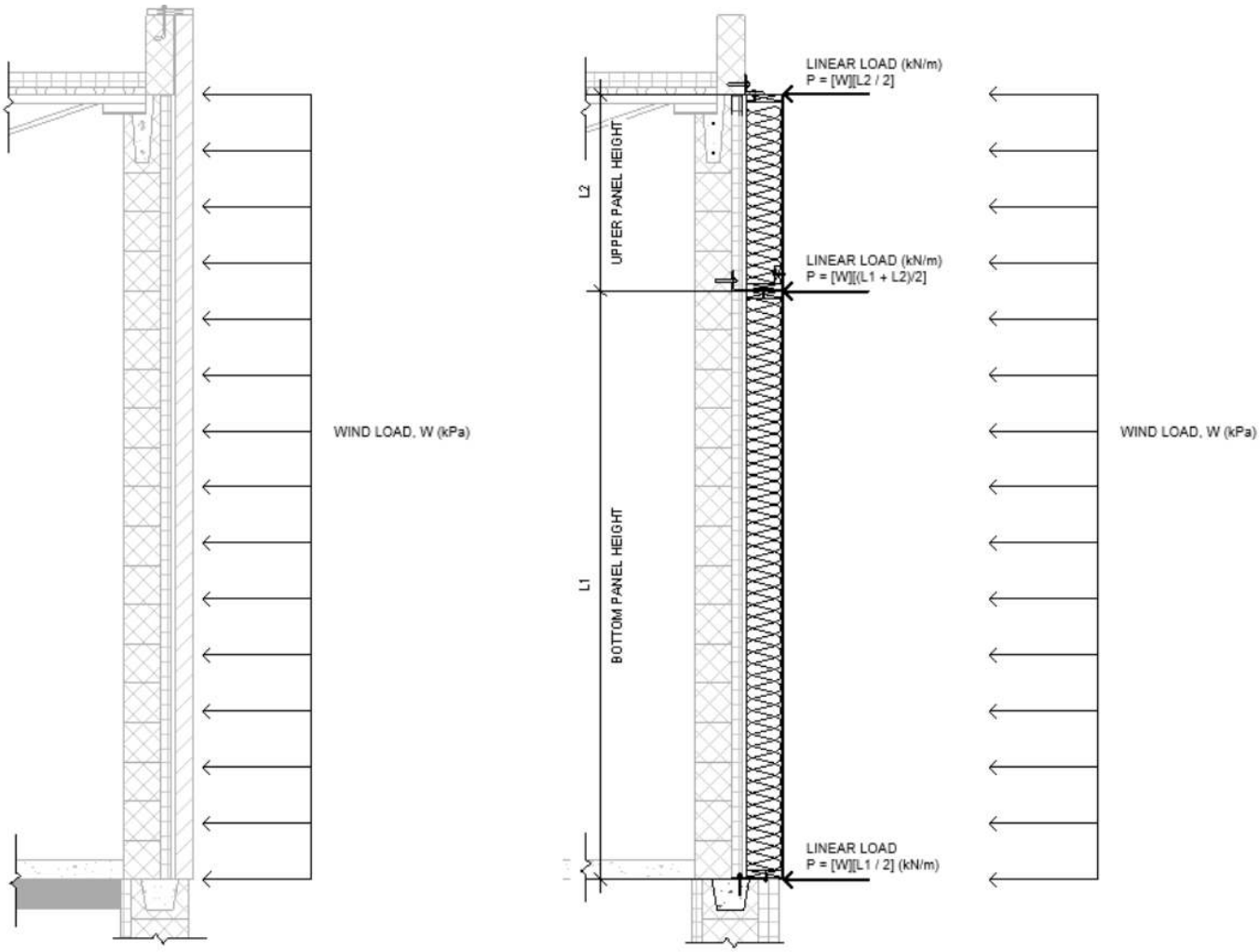


Figure 15 wind load path with and without panels

Hygrothermal Modeling

The analysis of moisture and temperature over time is called hygrothermal analysis. Adding new materials to the exterior of a building can slow or block moisture from passing through, and prolonged exposure to moisture in the building assemblies can lead to durability issues including mold growth and decay.

Hygrothermal simulations were conducted on the Burlington Seniors Centre NZER wall and roof assemblies using WUFI® Pro (Appendix J). The analysis focused on the plywood sheathing and cellulose insulation in the assemblies, as biogenic materials are most susceptible to moisture damage. When moisture content of wood exceeds 20% for prolonged periods it can decay.

Hygrothermal performance is dependent on the material characteristics of each component of a building assembly. Assumptions were made regarding the materials in the existing walls and roof and confirmation of the assumptions is required prior to finalizing the retrofit designs.

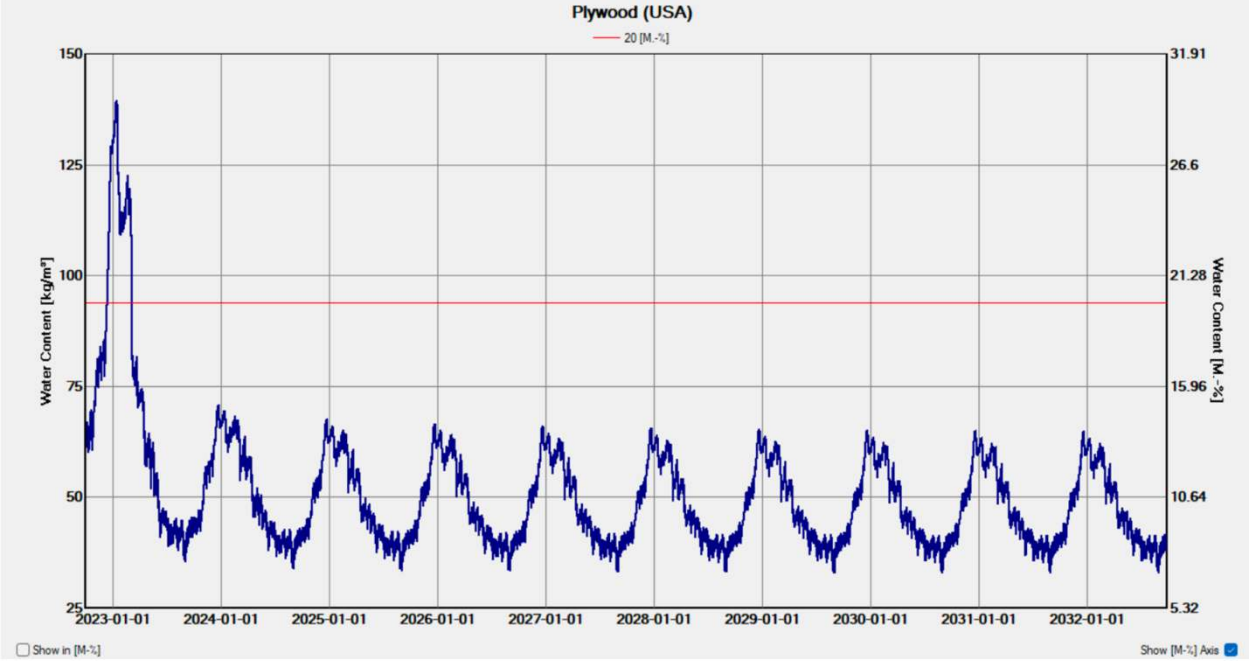


Figure 16 WUFI output south-east wall (inner plywood layer)

Simulations were run for each orientation of each assembly for a 10-year period post-retrofit. All assemblies displayed cyclical seasonal moisture fluctuations consistent with expectations for buildings in the southern Ontario climate. Specifically, moisture content peaks in winter, with the greatest peak occurring in the first year post-retrofit, and spikes decrease in subsequent years. An example of this cyclical pattern is shown in Figure 16. A moisture spike that exceeds 20% in one winter does not typically damage the building so long as drying occurs in the summer.

Spikes above 20% that persist for several years indicate a potential for mould and eventual decay.

The north-east walls demonstrate moisture content spikes above 20% in all 10 years of the analysis (Figure 17). This pattern is an indication of a risk to the wall assembly which requires further review. As assumptions were made regarding specific material properties of the components in the existing assemblies, confirmation of existing materials should inform next steps. Additionally, it is the outer surface of the plywood which displays the greatest moisture content. High moisture content may be related to precipitation rather than vapour drive, in which case a more robust WRB or gypsum based sheathing could improve the results.

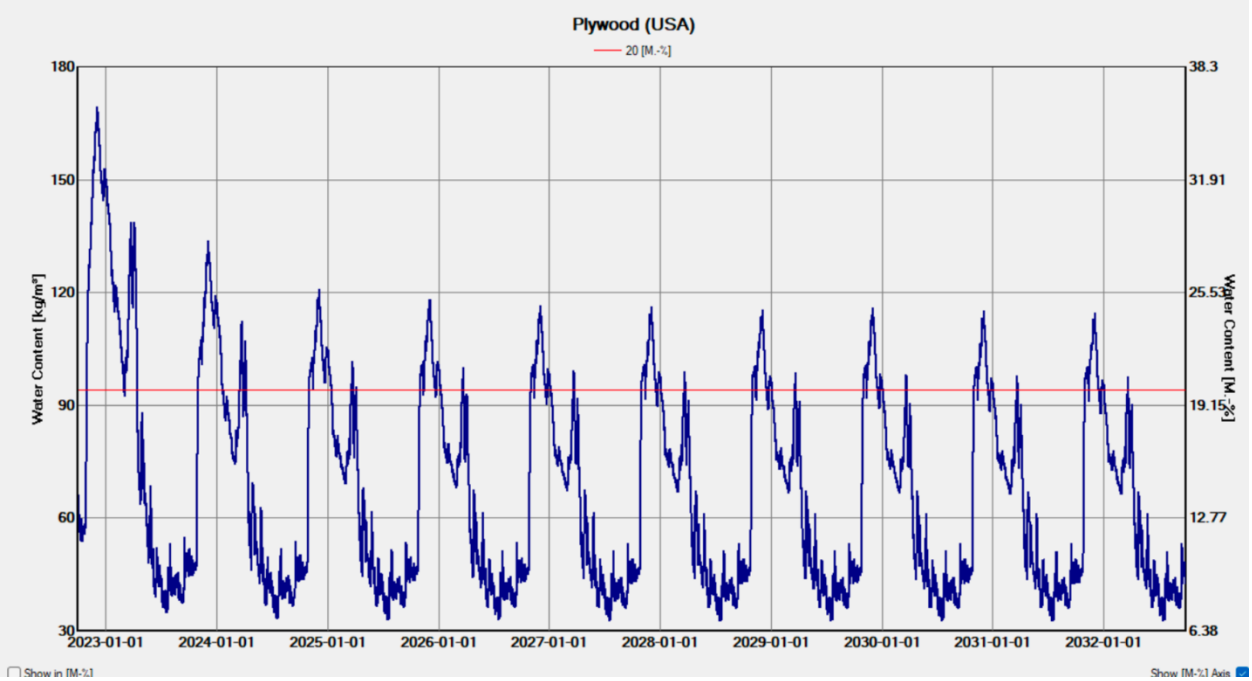


Figure 17 WUFI output north-east wall (outer plywood layer)

The plywood layers and outermost cellulose in all orientations simulated present acceptable durability with respect to potential mold growth. Simulations indicate a higher risk of mold in the outermost layer of plywood in the North-East orientation, however the risk is still within acceptable limits.

Embodied Carbon

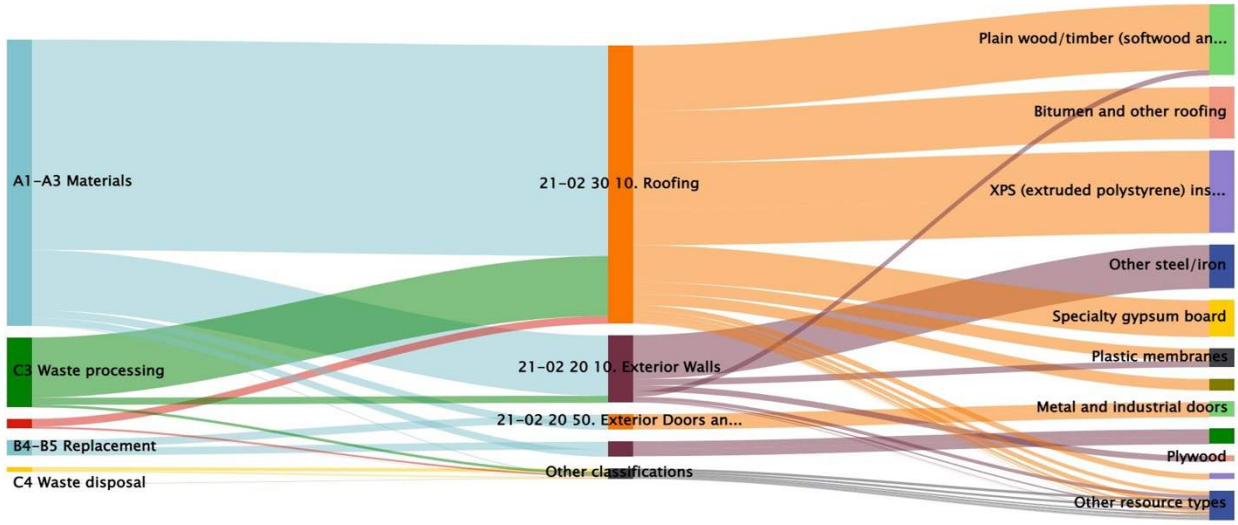


Figure 18 Life Cycle Impacts by Stage (%)

With the short time remaining to limit the impacts of climate change, it is not responsible to complete retrofits that reduce long-term operational emissions while emitting high up-front embodied carbon. Materials used in retrofits must emit the lowest possible carbon or the construction emissions may offset the intended GHGs saved through the retrofit.

Carbon accounting is complex and imperfect. This is frequently used as justification for not factoring embodied carbon into decision making. The objective of including it in this study is not to deliver a definitive value for embodied carbon in the building, rather it is to contribute to the necessary discourse in the building industry, so that the impacts of embodied carbon on GHG emissions are more widely understood.

Table 4 Burlington Seniors Centre – Total Global Warming Potential

gross floor area m^2	A1-A3 $KgCO2e/m^2$	A1-C4 KgCO2e/m2	Biogenic carbon KgCO2e/m2
1941	**18.06**	**46.07**	**20.5**

Embodied Carbon was modeled for the Burlington Seniors Centre NZER scenario in One Click LCA (Appendix K). Materials modeled were based on the most representative materials available to the Canadian market with Environmental Product Declarations (EPDs) available in the One Click LCA database. The analysis was limited to embodied carbon of assembly materials being added to the building including panel additions to above-grade walls, roofs,

below-grade components, and windows and doors. HVAC and electrical components were excluded from the analysis.

The results include a whole life cycle assessment of the building in six impact categories: Global Warming, Ozone Depletion, Acidification, Eutrophication, Formation of tropospheric ozone, Depletion of nonrenewable energy, and Biogenic carbon storage.

The major contributors to the GWP in this design are the metal roofing, EPS insulation, roofing membranes and windows. The A1-A3 Materials stage contributed 39% of the total carbon emissions associated with this building followed by C3 Waste processing at 34% as illustrated in Figure 18 & 19. The biogenic carbon of this building offsets 44.5% of the total A1-C4 carbon emissions. This storage is attributed to the wood products (68%) and cellulose insulation (32%) used in the assembly as shown in Figure 20. The results graphs below show the breakdowns of life cycle stages and impact categories associated with the building materials.

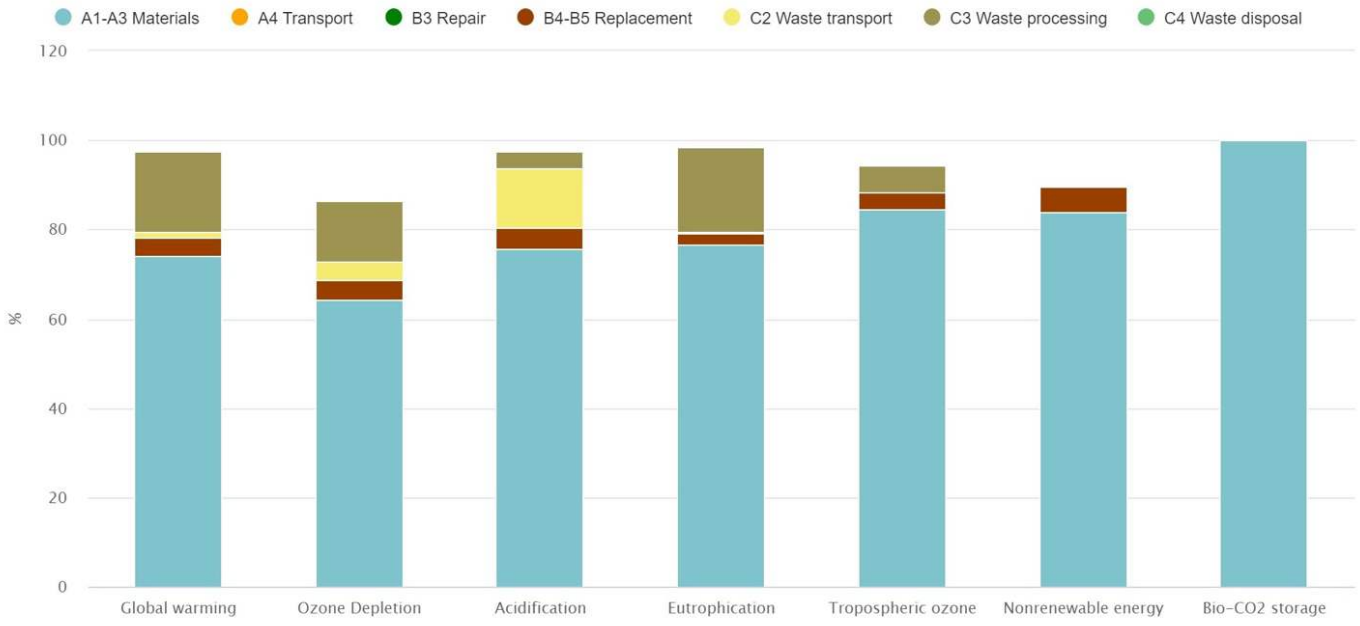


Figure 19 Global Warming by Stage and Material

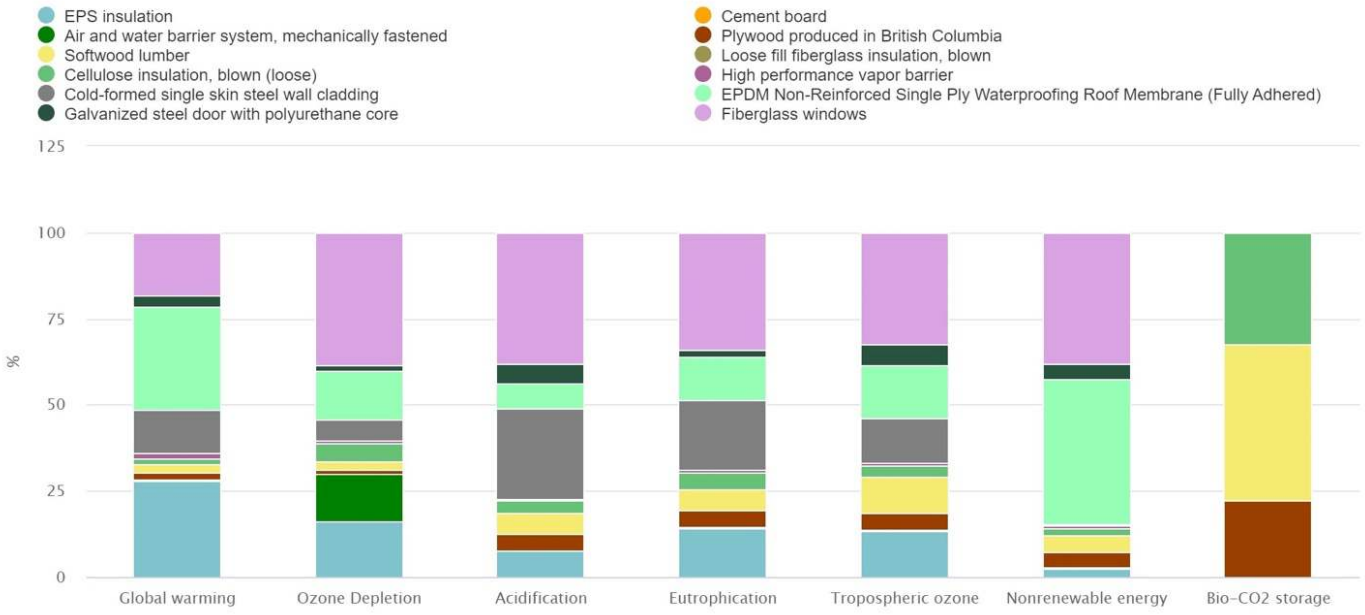


Figure 20 Life Cycle Cost by Material

Proposed Mechanical Systems

All scenarios:

- Rainwater drains and plumbing vents that penetrate the roof are to be insulated from ceiling to floor with 3” pipe insulation to prevent thermal bridging.

Minimum Upgrade Scenario

- Heating and cooling will be with a combination of existing rooftop units, mini split units and electric baseboard heaters. The existing CAV rooftop units will be retrofitted to become single zone VAV units with demand-controlled ventilation through the addition of a packaged solution that includes a variable frequency drive, CO_2 sensor and controller.
- Domestic hot water will continue to be provided by a natural gas tankless water heater and a separate 80-gallon storage tank.
- The existing rooftop units will continue to supply ventilation and existing kitchen MUA will remain.
- All existing controls will remain, with the addition of the controls for the VFD units on the rooftop units and CO_2 sensors for demand-controlled ventilation.

Net Zero Energy Ready Scenarios:

- Domestic hot water will be provided by an 80-gallon heat pump hot water heater.
- Two ERVs will replace the existing rooftop units, one serving the auditorium and one for the rest of the building. They will be dual core type with approximately 90% heat recovery efficiency. Variable air volume (VAV) boxes along with CO_2 sensors would be installed to enable demand-controlled ventilation.
- Main ventilation distribution duct runs will be replaced to accommodate new location of the ERVs on the roof.
- The kitchen MUA and exhaust fan will be converted to VAV with a new high performance kitchen hood.
- New VRF and ERVs will use the existing direct digital control system.

ASHP Scenario

- New air source variable refrigerant flow (VRF) system with two 8-ton units, installed on the roof to replace all existing heating and cooling equipment. The VRF system is sized to meet 100% of the peak cooling load, which meets 85% of the heating load.
- An 12kW electric duct heater will serve the remaining 15% of the peak heating load.

GSHP Scenario

- New water source VRF system with two 8-ton ground/water condensing units to replace all existing heating and cooling equipment.
- 7 kW electric duct heater.

Proposed Electrical Systems

1. Minimum Upgrade Scenario
    - All existing fluorescent lighting upgraded to LED using LED lighting retrofit kits.
    - Existing manual lighting controls remain.
    - No changes to the electrical distribution system or the building service.

2. Net Zero Energy Ready Scenarios
    - All existing fluorescent fixtures will be replaced with equivalent LED fixtures.
    - The lighting control system will be updated to include automatic lighting control.
    - New Power Distribution System
    - New Electrical Service

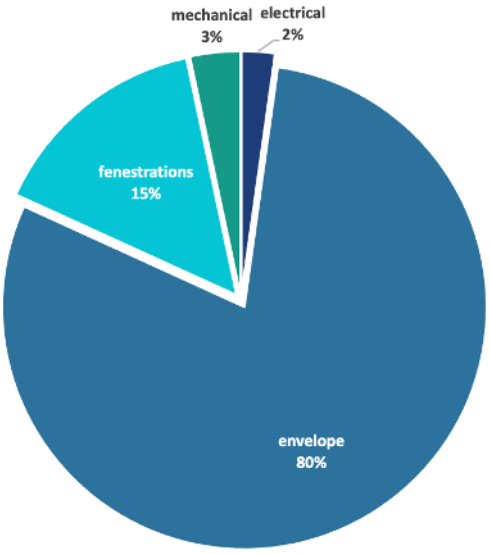
3. Net Zero Energy Scenario
    - 220 kW (DC) solar pv array

In Ontario, there is a 1MW limit on commercial net metered solar systems which is well over the amount of solar being proposed. In a net metering agreement, 100% of the excess energy generated from the solar array is put back on the utility grid and the consumers account is credited for the amount generated. This credit is applied against the amount of energy consumed to reduce the consumers power bill. With a net zero solar installation, the consumers bill would average zero dollars over the course of a year. Since 100% of the excess energy generated is configured to go back onto the grid, the solar array will be shut off in the event of a grid outage.

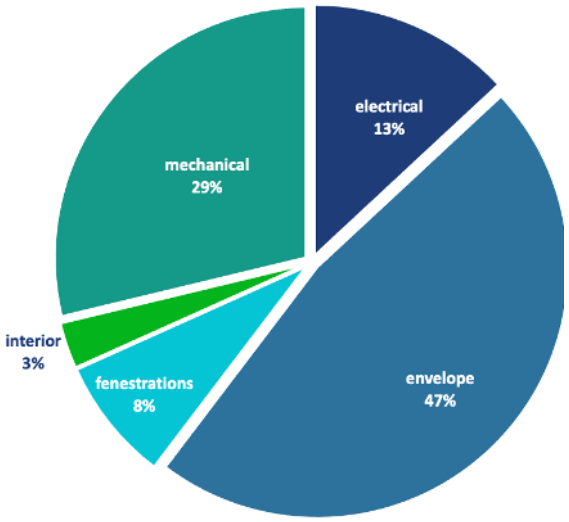
Construction Costs

Class D – Feasibility Cost Estimates (Appendix M) were obtained for the Minimum Upgrade, the two Net Zero Energy Ready scenarios and Net Zero Energy retrofit scenarios (Appendix M).

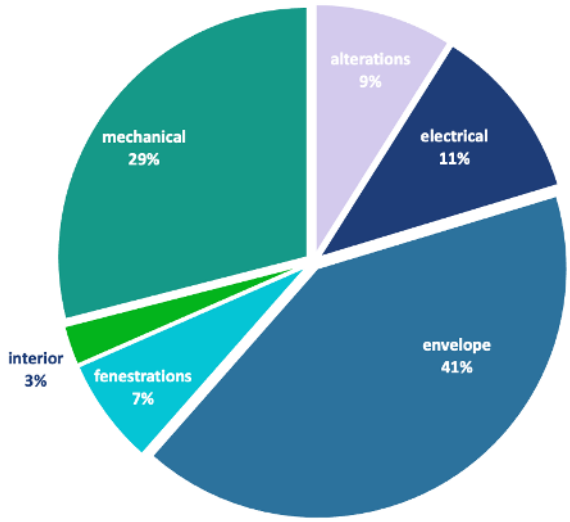
Minimum Upgrade	
Envelope	2,380,755
Fenestration	$444,565
Mechanical	$99,504
Electrical	$66,176
total	**$2,991,000**



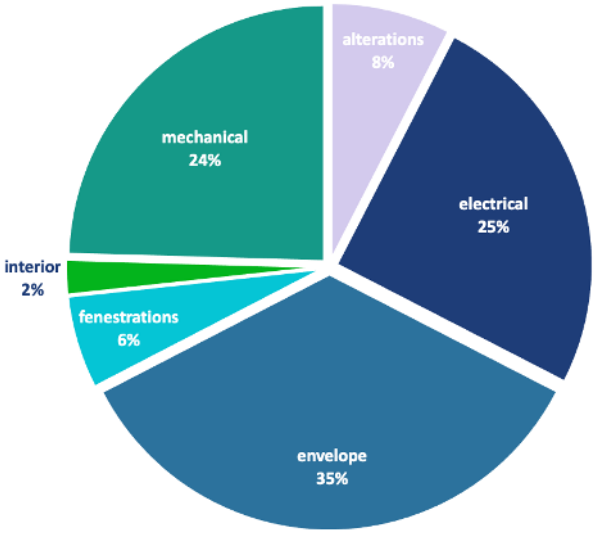
Net Zero Energy Ready ASHP	
Envelope	$2,643,505
Fenestration	$444,565
Interiors	$165,443
Mechanical	$1,608,597
Electrical	$730,892
total	**$5,593,002**



Net Zero Energy Ready GSHP	
Envelope	$2,643,239
Fenestration	$444,520
Interiors	$165,426
Mechanical	$1,860,996
Electrical	$730,819
Alterations	$574,003
total	**$6,593,002**



Net Zero Energy - GSHP	
Envelope	$2,643,479
Fenestration	$444,560
Interiors	$165,441
Mechanical	$1,861,165
Electrical	$1,894,302
Alterations	$574,055
total	**$7,583,002**



Total Cost of Building Ownership

Total Cost of Building Ownership (TCBO) analysis was conducted using the SEEFAR-Valuation© program. Calculations include costs for utilities, insurance, carbon tax, maintenance, maintenance capital (replacing major components as they age out), interest, and escalation of these costs over time. TCBO analysis typically includes property taxes, however the building is not subject to property tax. The input parameters for the SEEFAR-Valuation© are given in Appendix N.

A base case TCBO was evaluated based on the current condition of the building and the maintenance and renewal that would be required for the next 60 years for all components of the building, including interior elements. The TCBO for each retrofit scenario was modeled based on the design details, modeled energy performance and construction cost estimates for the retrofit scenarios outlined in this report.

Table 5 TCBO Summary

	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZR - GSHP + Solar
GHG emissions (kg) (60 Years)	5,810,144	1,869,799	325,130	315,764	0
EUI (kWh/m2/year)	435.4	217.0	113.4	110.1	0.0
TCBO at 60 years	**$34,646,000**	**$30,430,000**	**$30,182,000**	**$28,977,000**	**$24,430,000**
TCBO Savings at 60 years	$0	$4,216,000	$4,464,000	$5,669,000	$10,216,000
60 Year TCBO savings compared to Base Case		12%	13%	16%	29%

Key TCBO Results:

- The Burlington Seniors Centre is 43 years old and could last an additional 60 years if well-maintained. The TCBO model shows that it will cost over $30M to continue operations of the existing building for the next 60 years if the building does not undergo upgrades that improve thermal performance and reduce energy consumption.
- The base case TCBO is about five times the building's estimated Cost Replacement Value (CRV) of $7.2M.
- The Minimum Upgrade uses 50% less energy than the base case and saves 12% in TCBO.
- The Net Zero Energy Ready options use 75% less energy but save only 13-16% in TCBO.
- The lowest TCBO for the Burlington Seniors Centre is the Net Zero Energy retrofit with a 29% reduction in lifetime operating costs and a savings of $10.2 M.

Table 6 Operating Cost Summary

Utilities (including carbon tax)	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Cost	$ 16,927,000	$ 10,416,000	$ 6,735,000	$ 6,547,000	$ 198,000
Difference in Cost from A		$ (6,511,000)	$ (10,192,000)	$ (10,380,000)	$ (16,729,000)
Percentage Change Over Base Cost		-38%	-60%	-61%	-99%
Energy Cost ($/ft2)	$ 822.96	$ 506.41	$ 327.44	$ 318.30	$ 9.63

Maintenance	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Cost	$ 285,000	$ 378,000	$ 390,000	$ 372,000	$ 1,097,000
Difference in Cost from A		$ 93,000	$ 105,000	$ 87,000	$ 812,000
Percentage Change Over Base Cost		33%	37%	31%	285%
Maintenance Cost ($/ft2)	$ 13.86	$ 18.38	$ 18.96	$ 18.09	$ 53.33

Insurance & Taxes	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Costs	$ 518,000	$ 518,000	$ 518,000	$ 518,000	$ 518,000
Difference in Cost from A		$ -	$ -	$ -	$ -
Percentage Increase over Base Cost		0%	0%	0%	0%

First Year Annual Maintenance	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Cost	$ 2,450	$ 3,250	$ 3,350	$ 3,200	$ 9,428
Difference in Cost from A		$ 800	$ 900	$ 750	$ 6,978
Percentage Change Over Base Cost		33%	37%	31%	285%
First Year Maintenance Cost ($/ft2)	$ 0.12	$ 0.16	$ 0.16	$ 0.16	$ 0.46

- The 60-year utility costs for the Base Case are two times the CRV of the building.
- The NZR options reduce the 60-year utility costs by over 60%.
- A Net Zero Energy retrofit reduces the energy costs by 99%. The NZE option is still $198K because it contains water charges.
- The maintenance costs for the Minimum Upgrade and NZER options are all around $100K more than the Base Case. The NZE option is $1M because of the added maintenance costs of the solar panels ($5400 per year). This cost is more than offset by the $16M in energy savings over the life of the building.
- Insurance costs are the same for all options.
- Burlington does not pay property tax on the building.

Parameters:

- The analysis start year is 2024. Utility, construction, and maintenance costs have been escalated to 2024. Construction costs have been escalated by 20% for 2022-23, and by 10% from 2023-24, or 32% over the two years.
- Carbon tax has been applied to electricity.

Table 7 Capital Cost Summary

Initial Retrofit / HPB CostYear 1	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Initial Cost	$ 718,000	$ 3,630,000	$ 6,538,000	$ 7,418,000	$ 8,496,000
Difference in Cost from A		$ 2,912,000	$ 5,820,000	$ 6,700,000	$ 7,778,000
Percentage Change Over Base Cost		406%	811%	933%	1083%
Cost ($/ft2)	$ 34.91	$ 176.48	$ 317.87	$ 360.65	$ 413.06

Maintenance Capital Costs 60 Years	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Cost	$ 16,197,000	$ 15,488,000	$ 16,002,000	$ 14,121,000	$ 14,121,000
Difference in Cost from A		$ (709,000)	$ (195,000)	$ (2,076,000)	$ (2,076,000)
Percentage Change Over Base Cost		-4.38%	-1.20%	-12.82%	-12.82%
Cost ($/ft2)	$ 787.47	$ 753.00	$ 777.99	$ 686.54	$ 686.54

Retrofit / HPB + Maintenance Capital Costs 60 Years	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Total Costs	$ 16,915,000	$ 19,118,000	$ 22,540,000	$ 21,539,000	$ 22,617,000
Difference in Cost from A		$ 2,203,000	$ 5,625,000	$ 4,624,000	$ 5,702,000
Percentage Change over Base Cost		13.02%	33.25%	27.34%	33.71%

The Capital Cost Summary compares the first-year capital investment in maintaining the existing building with the construction costs for the retrofit scenarios. The capital costs for the retrofits have been escalated to 2024 values from the construction cost estimate. The retrofit costs are high because of the extensive building enclosure upgrades and new mechanical systems and solar PV.

Maintenance capital is the cost of replacing major building components as they wear or age out. For example, a boiler needs to be replaced every 25 years. The retrofits have reduced the maintenance capital costs because more durable and long-lasting materials were specified.

Table 7 Annual Energy Consumption and GHG Emissions

	Units	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Annual Water Consumption	m3	300.0	300.0	300.0	300.0	300.0
Annual Sewer Discharge	m3	0.0	0.0	0.0	0.0	0.0
Annual Electric Consumption	kWh	354452.9	284017.0	216753.0	210509.0	210509.0
Annual Gas Consumption	m3	46245.0	12649.0	0.0	0.0	0.0
Annual Heating Oil Consumption	Litres	0.0	0.0	0.0	0.0	0.0
GHG emissions	kg CO2 eq	96835.7	31163.3	5418.8	5262.7	0.0
Annual Solar PV generated	kWh	0.0	0.0	0.0	0.0	210509.0
Total Annual Energy Consumption	ekWh	832317.9	414723.3	216753.0	210509.0	0.0
Total Annual Energy Consumption	GJ	2996.3	1493.0	780.3	757.8	0.0
EUI	kWh/m2/yr	435.4	217.0	113.4	110.1	0.0

Key Results:

- Electricity consumption decreases in all retrofit scenarios.
- Total annual energy consumption decreases in the retrofit scenarios, and the Net Zero Energy scenarios have zero consumption.
- GHG emissions and EUI are reduced across all retrofit scenarios.
- The Minimum Upgrade reduces GHGs by 67% and EUI by 50%. This scenario maintains existing fossil fuel-based mechanicals which must be removed by 2050.
- The NZR options reduce GHGs by 95% and EUI by 75%.
- Net Zero Energy retrofit reduces GHGs and EUI by 100%.
- 96,836 kgCO_2e are prevented annually in the NZE retrofit.

Notes

- Natural gas mechanicals are included in the base case and minimum upgrade scenarios. Gas use must be eliminated by 2050.
- The solar photovoltaic array is sized to match the energy consumption for the GSHP option. The roof has more capacity for solar and could be a Net Positive building.
- Water consumption is based on pre-pandemic usage. This study did not consider plumbing upgrades related to water conservation efforts.

Cumulative TCBO

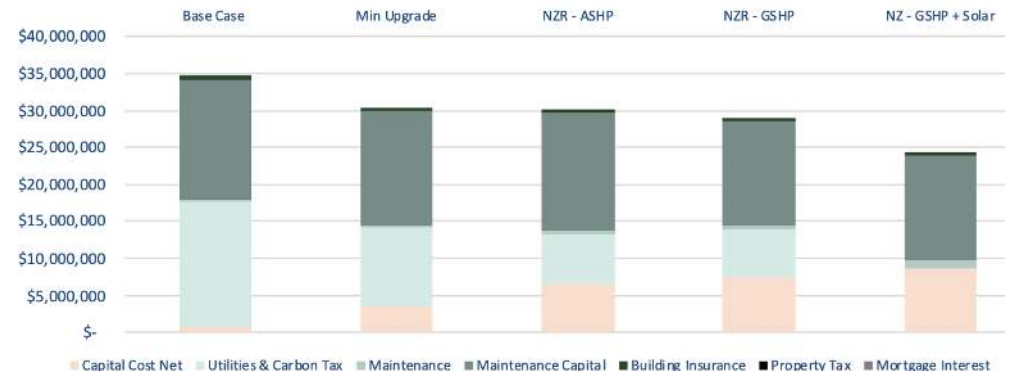


Figure 22 TCBO Comparison

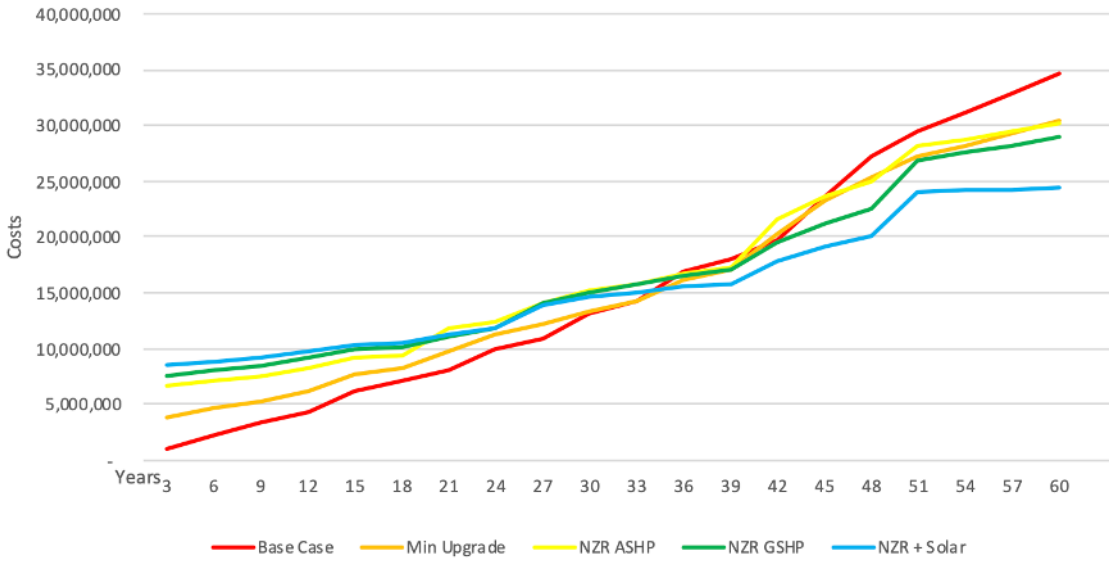


Figure 21 Cumulative TCBO

Figures 21 and 22 compare the 60-year TCBO of the various retrofit scenarios.

The existing building has the lowest TCBO for the first 30 years, however the Net Zero Energy scenario has the lowest costs for the life of the building, a 29% reduction over the existing base case. Operational savings in the Net Zero Energy Scenario exceed the retrofit costs by 34 years post-retrofit.

A Net Zero Energy retrofit achieves 100% GHG reductions and costs 29% less to operate than the existing building. With a 60-year savings of $10.2 M, the Net Zero Energy retrofit is the best investment for this building.

Discussion

The results of this project did not support the hypothesis, that substantial TCBO savings for municipal buildings could be achieved through Net Zero Energy retrofits by prioritizing high performance building enclosures, electrification of all systems and adding solar PV.

Burlington Seniors Centre uses 40% more energy than the average community centre in Canada[7] (excluding high EUI uses such as pools, ice rinks). It can achieve 100% GHG and EUI reductions and prevent nearly 100,000 $kgCO^2e$ from being emitted annually. It can't achieve that level of performance and expect a twenty-year return on investment; it will take 30 years before the savings from the retrofit cost less than the business-as-usual scenario.

Yet municipalities can't simply carry on with business as usual because our communities must be decarbonized. Return on investment can't be the driver of decisions if we are going to meet our net-zero goals. Making a financial case for electrification of buildings with natural gas-based HVAC is not easy, but this project will save the City of Burlington 29% in lifetime operating costs.

During this project the ReCover team met with several prefabricated panel manufacturers working in southern Ontario. These companies are keen to apply their skills to the retrofit problem. The first panelized retrofits are going to be challenging and costs will be high. We still need to start and to accept that the costs will be high until we get faster and more experienced. The industry is ready to start.

Burlington Seniors Centre is a promising demonstration project. Its geometry lends itself to panelization and by removing the existing brick and making use of the existing brick ledge the structural system is more straightforward than some of the other buildings in the study.

The Burlington Seniors Centre has undergone several incremental retrofits which were not completely effective at addressing concerns with comfort. A Net-Zero Energy retrofit will mean no more incremental retrofits between now and 2050. We need to plan to touch every building just once on the road to net-zero.

[7] Energy Star (2021) Technical Reference. Canadian Energy Use Intensity by Property Type, https://portfoliomanager.energystar.gov/pdf/reference/Canadian%20National%20Median%20Table.pdf

Conclusions

This study of Panelized Deep Retrofits of Municipal Buildings was undertaken to develop deep retrofit strategies to support municipal decarbonization efforts by adapting the Energiesprong approach to the Canadian context.

The project goals were to develop deep retrofit scenarios that achieve 50% or more EUI savings and a scenario that can achieve Net Zero Energy (NZE) with the addition of solar PV. The solutions needed to minimize occupant disruption and embodied carbon. The recommended retrofit pathway would be the option with the lowest Total Cost of Building Ownership. Finally, the recommended solution should demonstrate a calculated payback of 20 years or better.

The technical details of the retrofit scenarios were straightforward. The economic targets were challenging and in the case of the 20-year payback, not one of the six proposed retrofits can achieve it.

The ReCover Initiative has studied the potential for prefabricated panelized deep retrofits in lo-rise multi-unit dwellings in two previous case studies[8]. These studies found the lowest TCBO over the anticipated life of the building was achieved through Net Zero Energy retrofits where the targets were met with an Energy Use Intensity (EUI) reduction of at least 75% before adding solar PV. This was not the result in the Panelized Retrofits to Municipal Buildings study.

While the results of this project were not expected, they do serve the objectives to de-risk investment in deep retrofits in Canada, to provide evidence on the effectiveness and scalability of a panelized deep retrofit approach and to build confidence and experience in deep retrofits among Canadian municipalities and industry stakeholders.

This study shows that the technical challenges are secondary to the overwhelming barrier of cost. It also showed that if investment in deep retrofits doesn't start now robust building upgrades now, municipalities will pay exponentially more down the road.

Deep GHG reductions are very achievable in municipal buildings. A Net Zero Energy retrofit to the Burlington Seniors Centre can prevent nearly 100,000 kg$C0_2$e per year and save more than $10M for the City of Burlington. It will also halt decades of comfort issues for the building users and make the building more resilient, both physically and economically, in the decades to come.

[8] ReCover Initiative (2020) *ReCover Phase One Case Study Report* and ReCover Initiative (2022) *Scarlettwood Court Deep Retrofit Case Study Repor*t, https://www.recoverinitiative.ca/about-us/our-results/report-request