

PANELIZED DEEP RETROFITS OF MUNICIPAL BUILDINGS

Sir John Colborne Recreation Centre for Seniors

Case Study Report

Issue Date: August 18, 2023

OAKVILLE

Natural Resources Canada | Ressources naturelles Canada

ReCover

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Acknowledgements

The authors thank the Green Infrastructure – Energy Efficient Buildings Program from Natural Resources Canada for providing funding to this project.

We would also like to acknowledge our project partners Efficiency Canada, Efficiency ONE, Habit Studio, Passive Buildings Canada, and QUEST Canada.

Finally, thank you to the following funding partners for their contributions to the project:

The Atmospheric Fund

Nova Scotia Department of Natural Resources and Renewables

City of Burlington

Municipality of Colchester

Halifax Regional Municipality

Town of New Glasgow

City of Oakville

City of Saskatoon

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

Sir John Colborne 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 : 397 kWh/m^2

Recommend : 0 kWh/m^2

GHG

100% improvement

Existing : 38,908 kg/yr

Recommend : 0 kg/yr

Operating Costs

78% improvement

Existing : $8 M

Recommend : $1.7 M

Lifetime Savings

$2.6 Million

Existing : $20.3 M

Recommend : $17.6 M

Retrofit Measures

2x6 ReCover wall panels

EPS roof insulation

High performance windows and doors

Ground source heat pump

New ventilation system

63 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 Sir John Colborne Centre for Seniors was selected for study by the Town of Oakville 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 Sir John Colborne Centre was selected for the project due to its high EUI and comfort issues in the building that have persisted despite efforts to address them. The building is clad with wood siding, which is due for replacement, presenting an opportunity for concurrent thermal upgrades.

The building form is highly articulated and may be overly complex for a panelized retrofit.

Data and Document Collection

Oakville provided the following data and supporting documents pertaining to the Sir John Colborne Centre:

- 1989 Construction Drawings (Appendix A)
- Natural gas consumption records from August 2020 to July 2022 (Appendix F)
- Electrical consumption records from April 2020 to August 2022 (Appendix F)

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 requested.

Construction drawings of the building were available, however due to the complex building form 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 HRM 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 from Roth IAMS Ltd. as one was not available (Appendix B).

Building Description

The Sir John Colborne Centre is a one-storey building with a gross floor area of 852m^2 (9,171sq. ft) constructed in 1989.



Figure 2 Sir John Colborne Centre



Figure 1 Site Plan

The facility is well used, offering daily social, recreational, and health and wellness programming for seniors. throughout the day with little down time. The building includes an auditorium which is used recreation activities including fitness classes, drop-in social activities, music, games and for private event rentals. Smaller programming rooms offer arts and crafts, woodworking, and billiards. The central corridor of the building functions as a lounge and the kitchen operates as a café during all working hours. The building also contains administration offices for staff of the facility.

The daily hours of operation are 8:30am – 4:30pm on weekdays with extended hours until 9pm on Tuesdays. The building is also open for rentals on evenings and weekends. Prior to the pandemic the daily number of occupants ranged from 300-500 people.

Context

Sir John Colborne Centre for Seniors is located at 1565 Old Lakeshore Road West, Oakville, Ontario. The building sits in a triangular park with streets on 3 sides. It is in a residential neighbourhood within 500m of the shore of Lake Ontario. Oakville is in Canadian building code climate zone 5.

The Town of Oakville has committed to reducing corporate and community GHGs by 20% below 2014 levels by 2030, and by 80% below 2014 levels by 2050. Oakville, along with all southern Ontario, is experiencing an increase in frequency and duration of extreme weather events in both summer and winter, including tornados and extreme heat days.[3]

Building Code Considerations

A preliminary review of the National Building Code of Canada (NBCC) and the Ontario Building Code (OBC) was completed to determine building code implications of a panelized retrofit to the Sir John Colborne Centre (Appendix L). The primary focus of the review was to determine if panels made with combustible materials can 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 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 facility is currently a designated comfort centre during extreme heat events in summer and extreme cold in winter.

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[3] Town of Oakville, *Climate Change Primer* https://www.oakville.ca/home-environment/environment/climate-change-air-quality/

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

The building is an irregular shape. The closest part of the building to the property line is on the north side, with the north line 6.5m from the building and roughly parallel to the north wall. Based on the setback distances, the structure and the cladding are permitted to be of either combustible or noncombustible construction. Therefore, combustible panels are permitted to be installed on the building.

Building Enclosures

The building has two wall types and two roof types. The walls of the auditorium are concrete masonry unit (CMU) with 50mm (2") rigid insulation with stone veneer or wood cladding (Figure 3). The rest of the walls in the building are 2x6 wood stud framing with fiberglass batt insulation (Figure 4).

The roof is framed with engineered trusses. Approximately 80% of the roof is insulated with 3" panels of Tectum III acoustical roof deck. The rest of the roof is insulated with 2" rigid foam insulation.

The concrete slab-on-grade floors are not insulated although some parts of the building have perimeter insulation on the foundation wall.

TABLE 1 Existing Thermal Enclosure Performance: Sir John Colborne Centre

	Effective USI W/m^2·K (Btu/h·ft^2·°F)	Effective RSI m^2·K/W (ft^2·°F·h/BTU)
CMU walls	USI-0.77 (U-0.14)	RSI-1.29 (R-7.33)
2x6 walls	USI-0.39 (U-0.07)	RSI-2.59 (R-14.7)
Roof – rigid foam	USI-0.97 (U-0.17)	RSI-1.03 (R-5.87)
Roof – Tectum III	USI-0.39 (U-0.07)	RSI-2.58 (R-14.63)
slab	USI-4.1 (U-0.7)	RSI-0.24 (R-1.36)
windows	USI-2.27 (U-0.4)	RSI-0.44 (R-2.5)

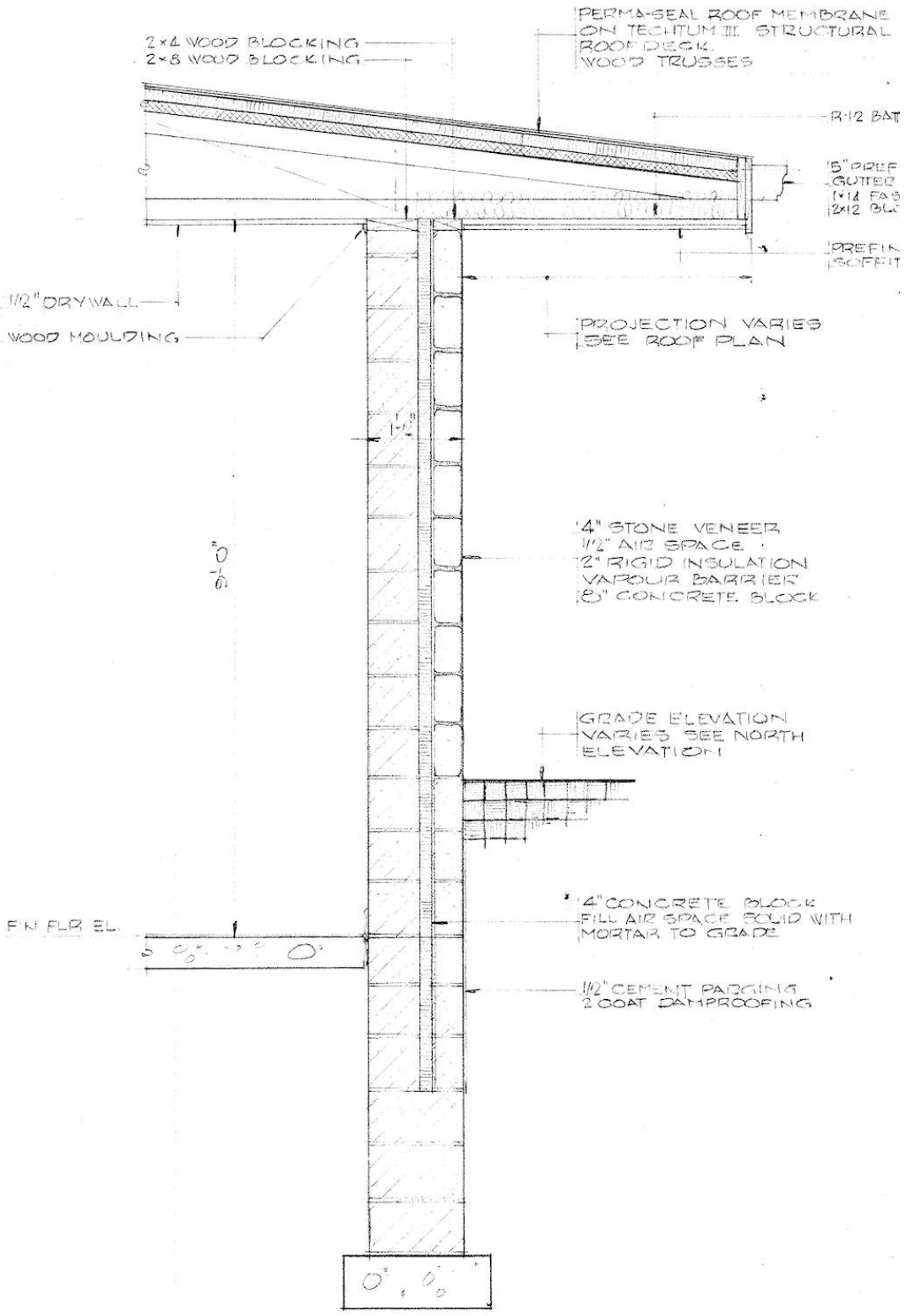


Figure 3 CMU wall and roof section

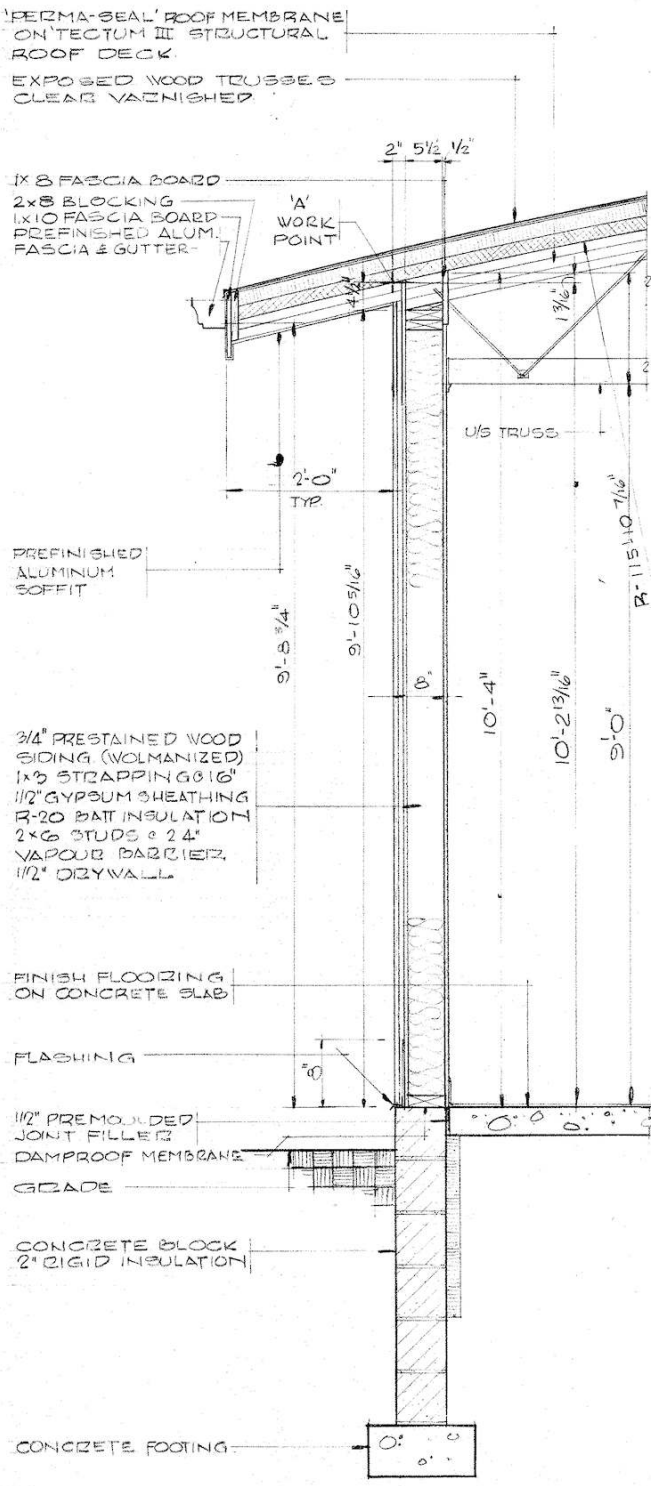


Figure 4 Sir Wood framed wall and truss roof

Existing Structure

The **foundation** consists of 305mm (12”) CMU walls with cast-in-place strip footings. There is no evidence to suggest deficiencies in the foundation.

The **above-grade walls** are a combination of 203mm (8”) and 305mm (12”) CMU walls and wood stud walls framed at 610mm (24”) o.c. These are the main load-bearing elements and the primary lateral load resisting system. There is no evidence to suggest structural deficiencies in the wall system.

The **roof structure** consists of various pre-engineered open web joists with steel webs.

Structural analysis determined the walls of the building can support added loading from a panelized retrofit, however the roof cannot support added loading.

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

Existing Mechanical Systems

Space heating and cooling is provided through variable air volume (VAV) systems served by two natural gas-fired rooftop units. These were installed in 2018. Rooms along the south and east sides have had electric baseboards installed because of occupant comfort complaints. An electric fireplace was also installd in the lounge.

Ventilation is provided by the rooftop units.The kitchen and bathrooms have exhaust fans.

Hot water is supplied by an 85-gallon electric water heater.

Controls: A building automation system (BAS) was installed in 2018 when the heating system was updated.

The Sir John Colborne Centre is a designated local cooling centre during times of extreme heat and a warming centre during times of extreme cold. Mechanical and building enclosure designs must account for the increased dependency on building resilience during extreme climate events.

Previous mechanical system upgrades have been done to address occupant discomfort. While the upgrades have resulted in fewer occupant complaints, building staff report that the comfort issues persist in both winter and summer, and that building systems are difficult to control. The lounge area, with a southwest facing



Figure 5 Lounge Area

corner of punched windows, is reported to be uncomfortably warm in summer.

Appendix D provides details of the mechanical system and Mechanical Outline Specification.

Existing Electrical Systems

The incoming **power service** from a pad mount transformer. The distribution services are in good condition although some components are nearing their end of life.

The **interior lighting** throughout the building includes fluorescent fixtures, track lighting and downlights. **Exterior lighting** is primarily high-pressure sodium fixtures. Emergency lighting, exit signage and the building fire alarm panel are battery operated.

The **main distribution** equipment is original and in reasonable condition however it is near its end of life. There are **several branch circuit panelboards** throughout the building, also original and in acceptable condition, however there is limited breaker space for new equipment.

The physical space in the electrical room is at capacity. Added space may be needed if adding equipment to the building.

Appendix E provides details of the existing electrical system and Electrical Outline Specification.

Energy Consumption

Energy analysis was based on electrical records spanning August 2018 to August 2022 and natural gas records from July 2019 to July 2022 (Appendix F). During the documented time span the building used an average of 4,810 L of fuel oil (51,722 ekWh) and 26,282 kWh of electricity annually.

Reduced occupation during COVID-19 pandemic led to lower energy use than is typical for the building starting in March of 2020 and operations had not returned to pre-pandemic levels within the time span studied.

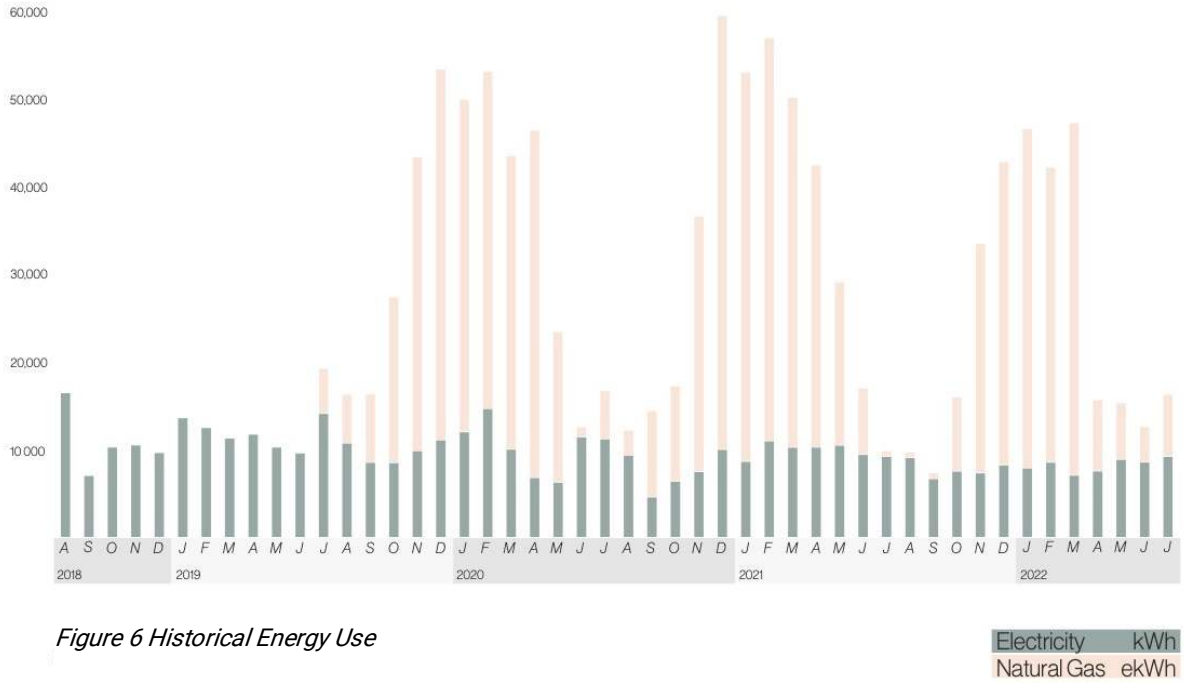


Figure 6 Historical Energy Use

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 historical utility data to closely reflect the current building performance (Figure 8). The modeled electrical consumption deviates from the existing usage by 2.7% and modeled natural gas consumption deviates by 26%.

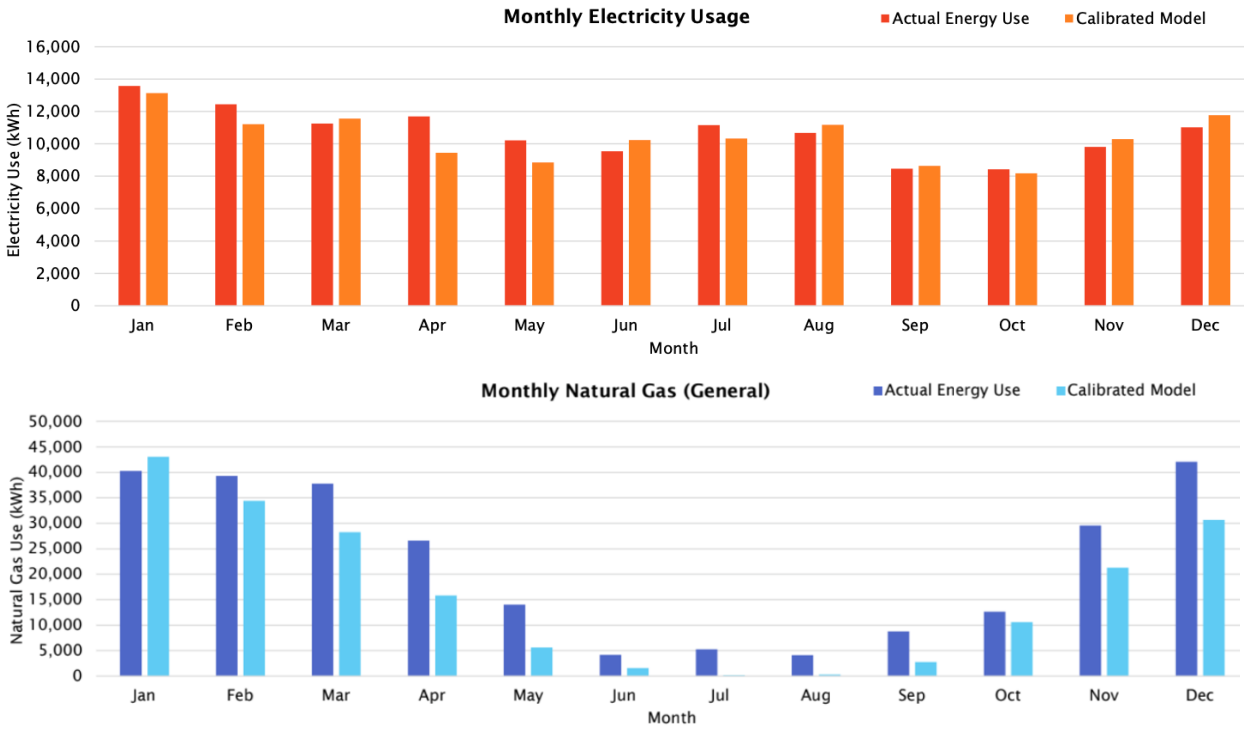


Figure 7 Calibrated Energy Use

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 0.75 L/s·m^2, a 75% reduction from the estimated air infiltration. All scenarios propose upgrading to high performance windows, including replacing the clerestory windows and south-west tall wall windows with high performance curtainwall glazing.

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.

The Thermal Energy Intensity Demand (TEDI) provides a breakdown of heat losses by building component in the existing building (Figure 10). Heat losses through the building enclosures account for 55% of heat losses and ventilation accounts for the remaining 45%

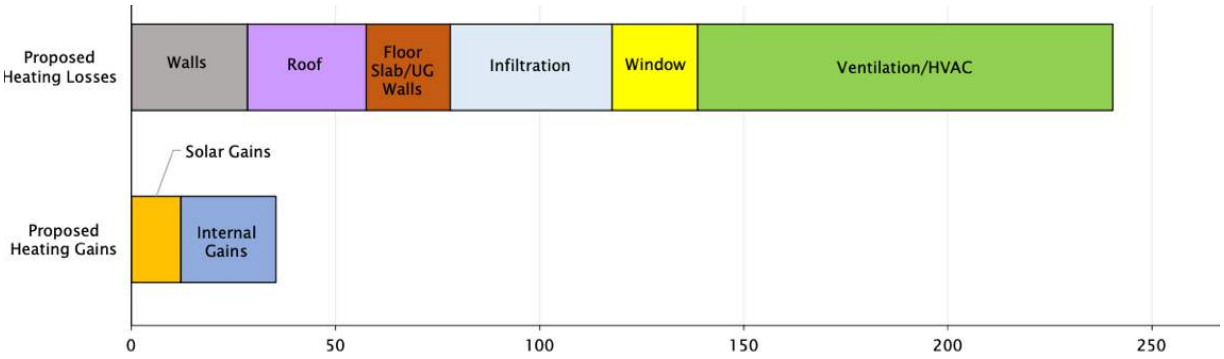


Figure 8 Thermal Energy Demand Intensity kWh/m^2/yr

Details of the retrofit scenarios are summarized in Table 3.

Table 2 Sir John Colborne Centre Retrofit Scenarios Summary				
	Existing Building	**Minimum Upgrade**	**ASHP Net Zero Energy[1]**	**GSHP Net Zero Energy [1]**
Effective Wall R-value	RSI-1.29 (R-7.33) and RSI-2.59 (R-14.7)	2x4 ReCover panel RSI-3.52 (R-20)	2x6 ReCover panel. RSI-4.4 (R-25)	2x10 ReCover panel. RSI-4.4 (R-25)
Effective Roof R-value	RSI-1.03 (R-5.87) and RSI-2.58 (R-14.63)	Existing + 4" XPS RSI-4.4 (R-25)	Existing + 12" XPS RSI-10.5 (R-60)	Existing + 12" XPS RSI -10.5 (R-60)
windows	wood, double glazed RSI-0.44 (R-2.5)	High perf. Curtainwall + triple pane RSI-1.02 (R-5.56)	High perf. Curtainwall + triple pane RSI-1.02 (R-5.56)	High perf. Curtainwall + triple pane RSI-1.02 (R-5.56)
Air Tightness ($L/s{\cdot}m^2$ at 75Pa)	2.3 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	Ducted VAV AHUs and electric baseboards	Ducted VAV AHUs and electric baseboards	Air Source VRF	Ground Source VRF VRF
Air Conditioning	Ducted VAV AHUs	Ducted VAV AHUs	Ducted fan coil units	Ducted fan coil units
DHW Equipment	Electric water heater	Electric Water Heater	Heat pump Water Heater	Heat pump Water Heater
Ventilation Equipment	Ducted VAV AHUs	Ducted VAV AHUs with Demand controlled ventilation	90% SRE ERVs [2] with VAV boxes in zones	90% SRE ERVs [2] with VAV boxes in zones
Solar PV	none	none	63kW (DC)	63kW (DC)

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

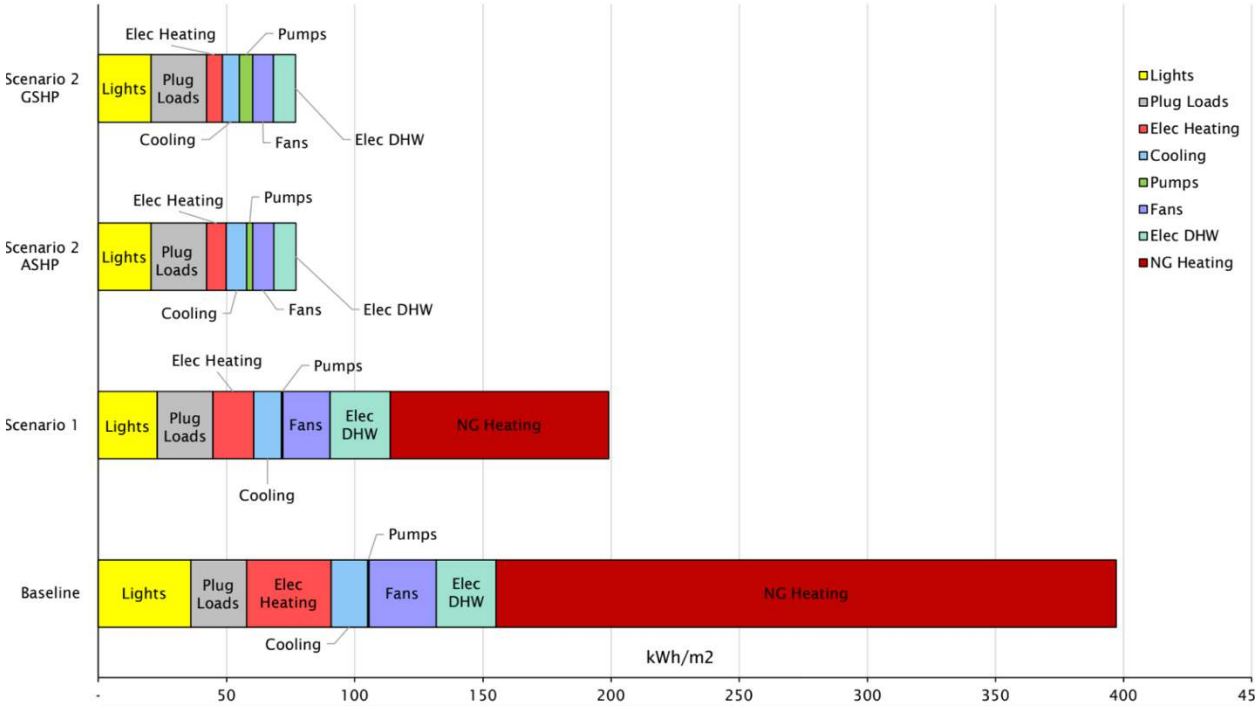


Figure 9 Total Energy Use Intensity (TEUI)

The **Total Energy Use Intensity** (TEUI) of the Sir John Colborne Centre is 397.1 ekWh/m^2/yr (figure 11). The ECMs for all retrofit scenarios meet the targeted savings.

Table 3 Retrofit Scenario Results			
	Target TEUI	**TEUI kWh/m^2**	**TEUI reduction**
Existing	-	397.1	-
Minimum Upgrade	50% savings	199.1	50%
NZER ASHP	75% savings	78.8	80%
NZER GSHP	75% savings	78.3	80%
NZE	100% savings	0	100%

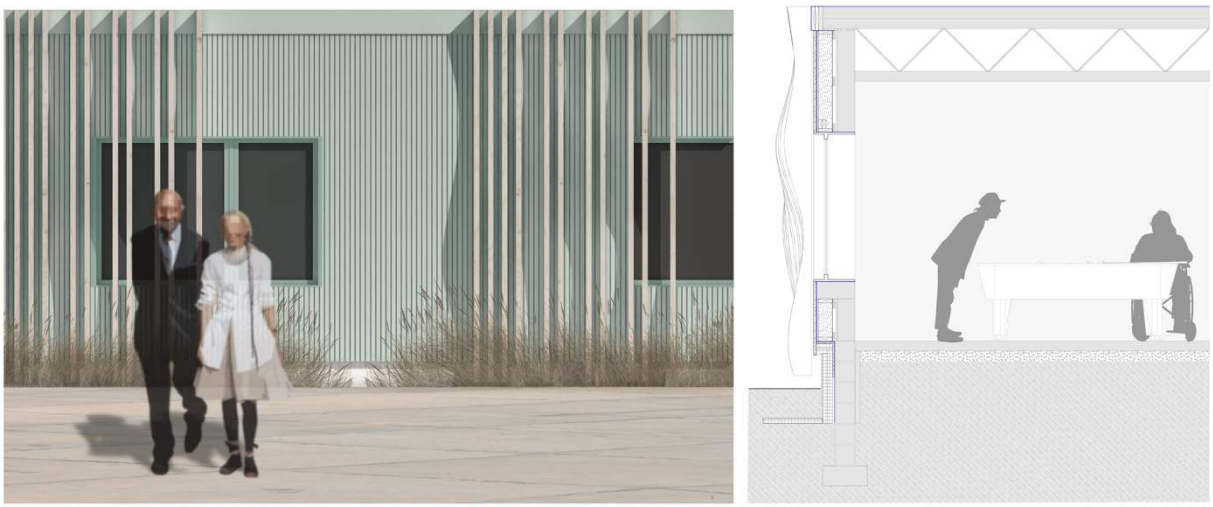


Figure 10 Design Cncept

Design

The concept design Sir John Colborne Centre is a highly articulated building and despite having some curves, its geometry is somewhat awkward. The concept design involves introducing sections of organic undulating screens along the façade. These add a sense of warmth to the corrugated metal siding and can provide shading to mitigate overheating in key areas like the southwest facing lounge area.

To accurately evaluate the retrofit options, the pre- and post-retrofit scenarios were modeled in a “like for like” manner. For this reason, the impact of structural shading devices was not explored in the study, however passive design elements can be very effective energy conservation strategies and should be explored in future project phases.

Architectural Elevation drawings are provided in Appendix L.



Figure 11 Design Concept : southwest view

Panelized Wall Details

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.

The panel components were specified to reduce risks from moisture from the existing assemblies or from external sources. Cellulose and wood are hygroscopic, transporting moisture through their fibers to support drying activity. The plywood sheathing is protected by a vapour-open water-resistive barrier (WRB) and a rain screen cavity. The rear membrane of the panel has variable permeability (a smart vapour barrier), which allows moisture to leave the wall. The panel backing is 1x4 strapping, which makes an interior void cavity that acts as a moisture buffer, allowing any moisture that moves through from the existing wall to slowly move through the panel and out.

Panel schematics and connection details are found in Appendix H.

Proposed NZER Scenario ReCover Panel RSI-2.8 (R-16)

1. metal cladding
2. 19mm strapping/rainscreen cavity
3. WRB membrane
4. plywood sheathing
5. dense-pack cellulose
6. framing: 2x6 wood studs 24”o.c.[4]
7. variable permeability vapour control membrane
8. interior strapping

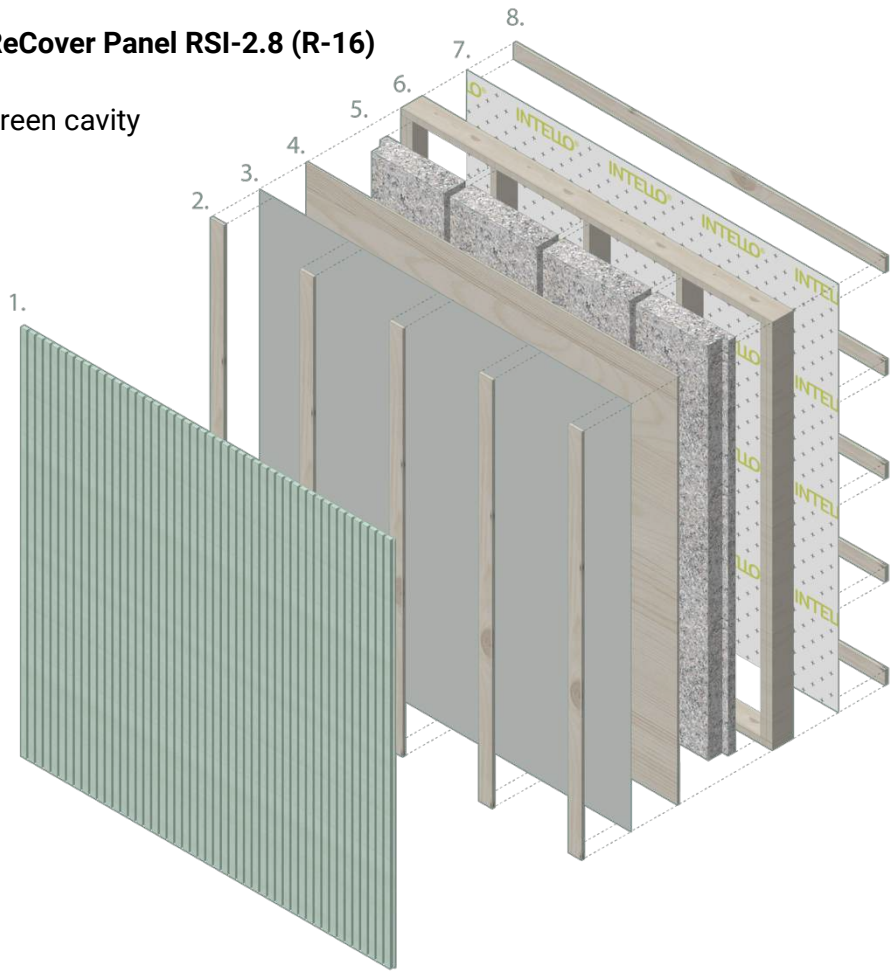


Figure 12 ReCover NZER wall panel assembly.

[4] Panel framing is based on 2x4s in the Minimum Upgrade scenario.

The wall panels will be two panels high on the auditorium side of the building, which is approximately 8m tall. Panels will be one panel high on the lower part of the building, approximately 4m high. Panel layouts are found in Appendix I.

Panels will connect to the roof at the top of the CMU walls with bent steel plates fastened with masonry anchors and lag screws (Figure 15).

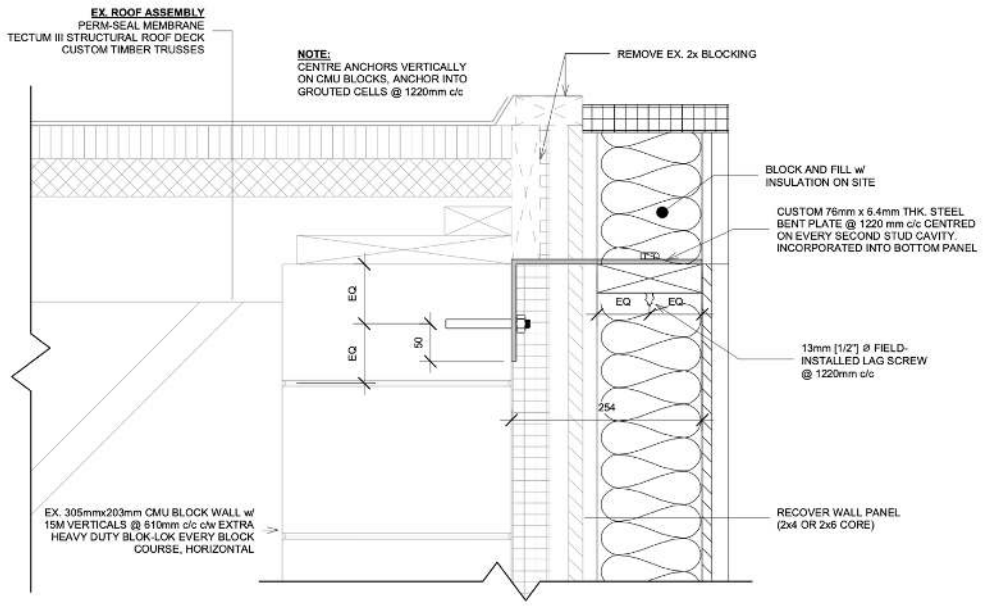


Figure 13 panel connection to CMU wall at roof

The mid-height panel connection is similar, with steel plates fastened to panels with lag screws, and to masonry anchored to the CMU wall (Figure 16).

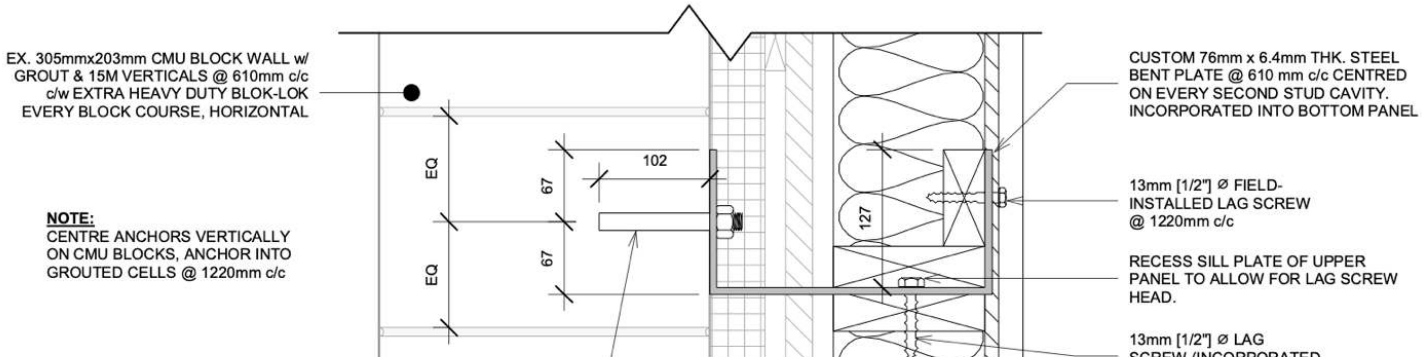


Figure 14 mid-height panel connection

The panels will be tied to the wood framed walls with a steel plate fastened into the top plate of the panel and the double top plate of the stud wall (Figure 17) The panels are supported at the base by a steel bent plate lintel fastened to the existing concrete foundation wall (Figure 18).

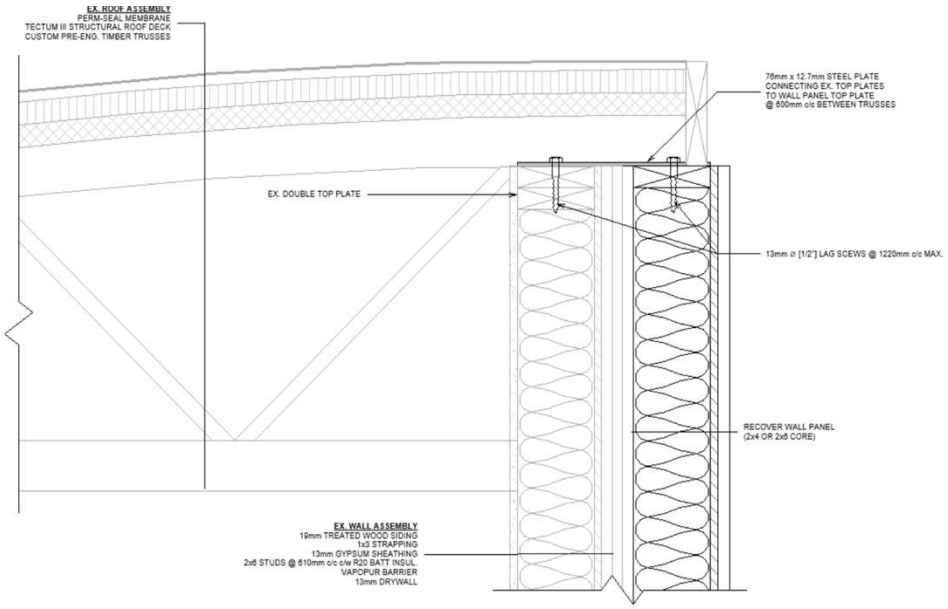


Figure 16 panel connection to wood framed walls at roof

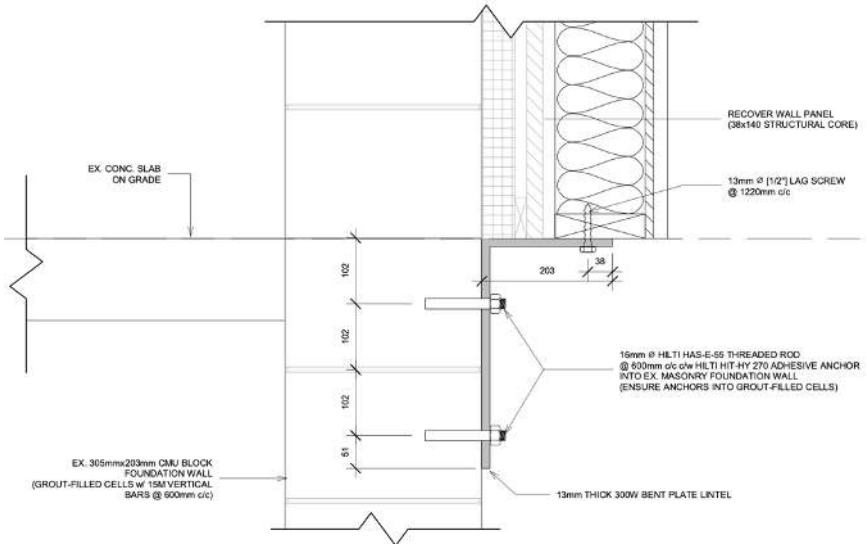


Figure 15 mid-span panel connection

Refer to Appendix C for the Structural Outline Specification and Appendix H for Panel connection details.

Foundation Insulation

The angled steel panel support at the foundation is a linear thermal bridge and should be fully covered by 100mm (4”) of expanded polystyrene or mineral wool insulation to reduce heat losses and prevent localized condensation on the steel.

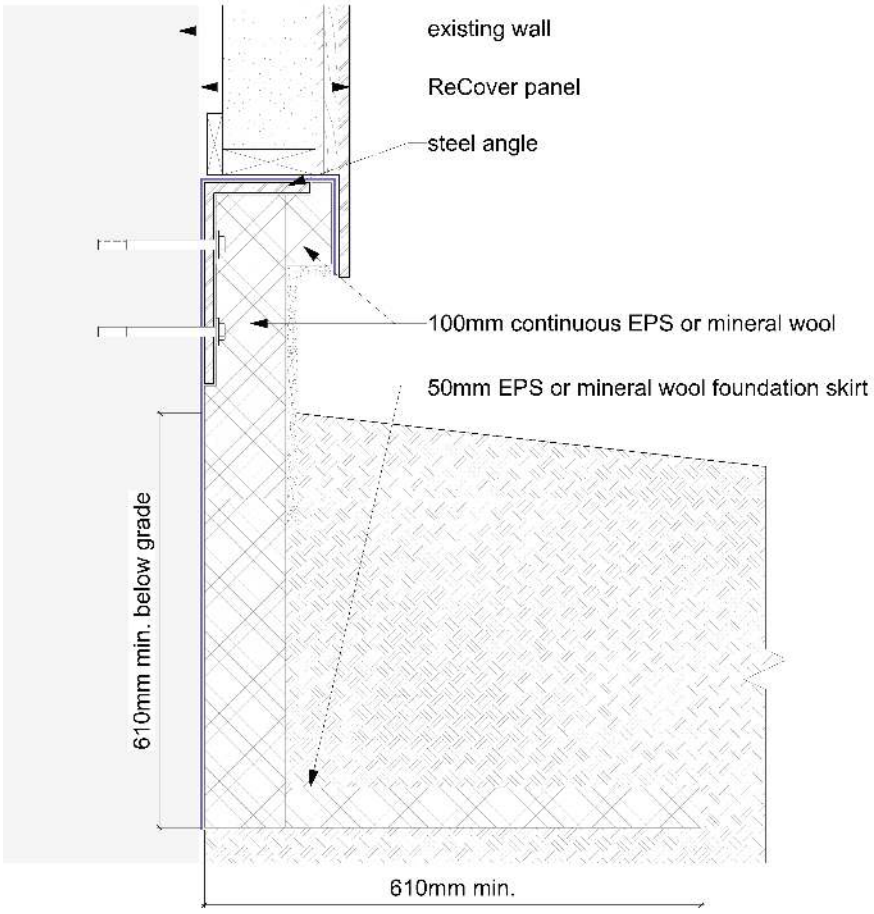


Figure 17 foundation insulation

Roof Retrofit

A conventional roof retrofit with 4” of extruded polystyrene (XPS) or expanded polystyrene (EPS) added to the roof in the Minimum Upgrade scenario and 12” XPS or EPS added in the NZER scenarios. The performance of these materials is similar, and the specific product should be the one with the lowest embodied carbon. We have modeled this using Sopra XPS in our embodied carbon model as it has a high percentage of recycled content which gives it a relatively low global warming potential (GWP).

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 proposed Sir John Colborne Centre NZER wall 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 wood 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. Destructive testing and confirmation of the assumptions is required prior to finalizing the retrofit designs.

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 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. A moisture spike that exceeds 20% in one winter does not typically damage the building as long as drying occurs in the summer. Spikes above 20% that persist for several years indicate a potential for mould and eventual decay.

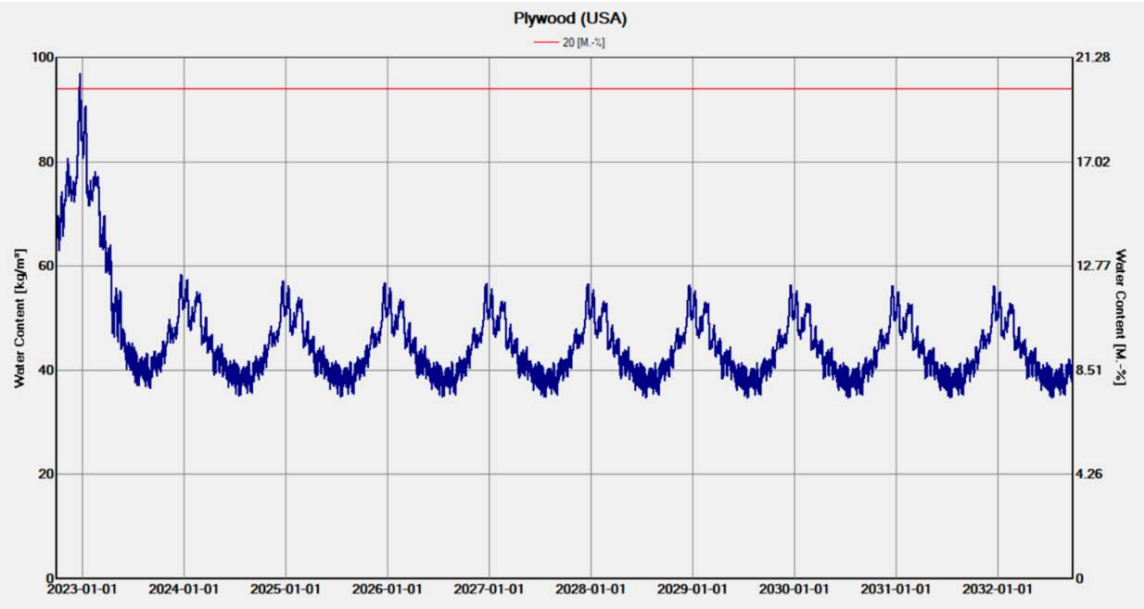


Figure 18 WUFI output – panel on west CMU wall (inner plywood layer)

All assemblies simulated were found to undergo seasonal moisture fluctuations consistent with expectations for buildings in the southern Ontario climate. Specifically, for each material analyzed, the moisture content peaks in winter, with the greatest peak occurring in the first year post-retrofit. In subsequent years the peak moisture content and duration of the spikes decrease. A moisture spike that exceeds 20% in one winter is does not typically indicate damage to the building, however spikes above 20% that persist for several years indicate a potential risk to the assembly.

The analysis indicates that assemblies where panels are installed on CMU can walls manage moisture well. The moisture content in these follows a pattern like the one in Figure 20.

The assemblies where panels are installed on wood-framed structure demonstrate less drying capacity. Panels installed on the north and east facing wood framed walls demonstrate the highest risk. These follow the typical pattern of a high spike in year one post-retrofit; however, the annual peaks exceed 20% moisture in all ten years of the analysis. An example of this pattern is shown in Figure 21.

Substituting the plywood sheathing in the panel with gypsum-based sheathing was considered for improved mould and moisture resistance. When this option was tested, it was shown to cause an unacceptable increase in moisture content in the cellulose layer.

As assumptions were made regarding specific material properties of the existing assemblies, further investigation into the behavior of the panels on wood framed walls is necessary prior to a retrofit. This must include confirmation of the specific materials in the existing assemblies.

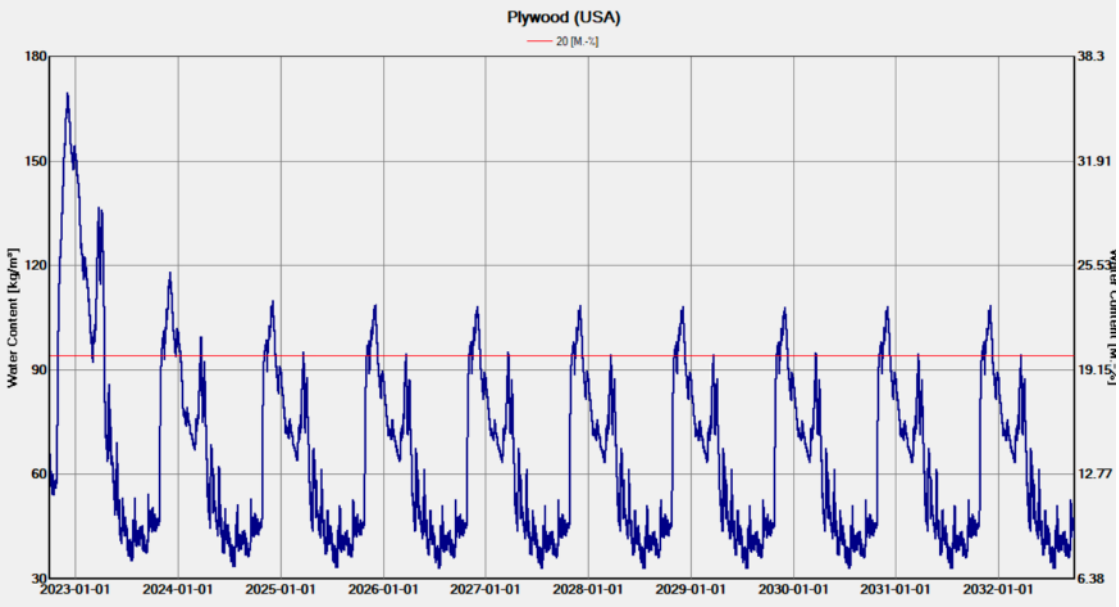


Figure 19 WUFI output - panel on northeast timber wall (outer plywood layer)

Embodied Carbon

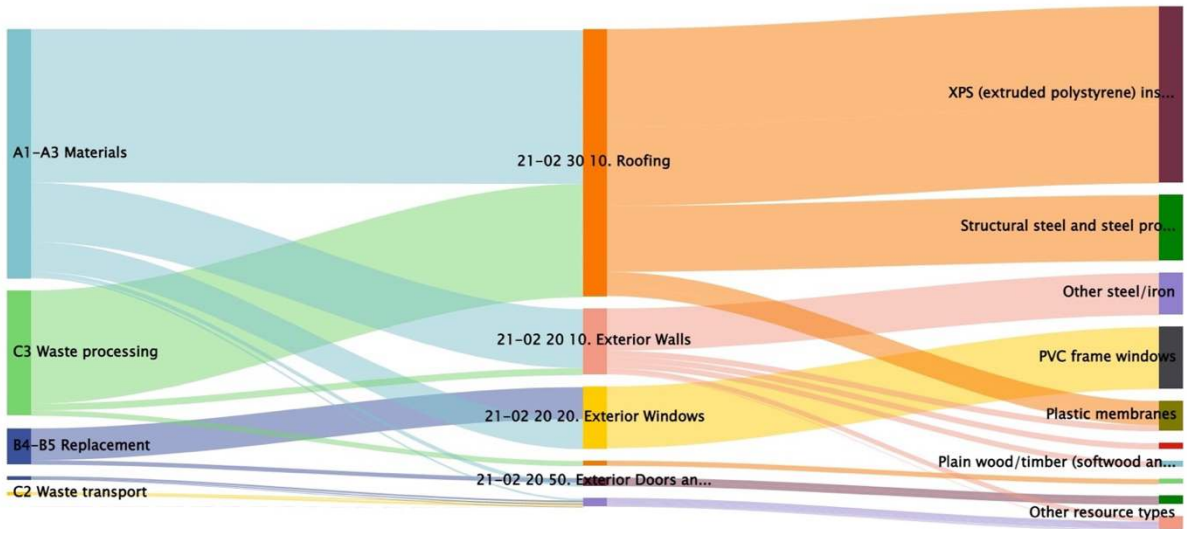


Figure 20 Global Warming by Stage and Material - NZER Retrofit

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.

Embodied Carbon was modeled for this project 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 existing 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.

Table 4 Sir John Colborne Centre – Total Global Warming Potential			
gross floor area m^2	A1-A3 $KgCO2e/m^2$	A1-C4 KgCO2e/m2	Biogenic carbon KgCO2e/m2
818	**71.71**	**120.25**	**38.2**

The major contributors to the GWP in this design are the metal roofing and cladding as well as the XPS foam roof insulation. The A1-A3 Materials stage contributed 60% of the total carbon emissions associated with this building as illustrated in Figure 24 & 23. The biogenic carbon of this building offsets 32% of the total A1-C4 carbon emissions. This storage is attributed to the wood products (73%) and cellulose insulation (27%) used in the panel assembly.

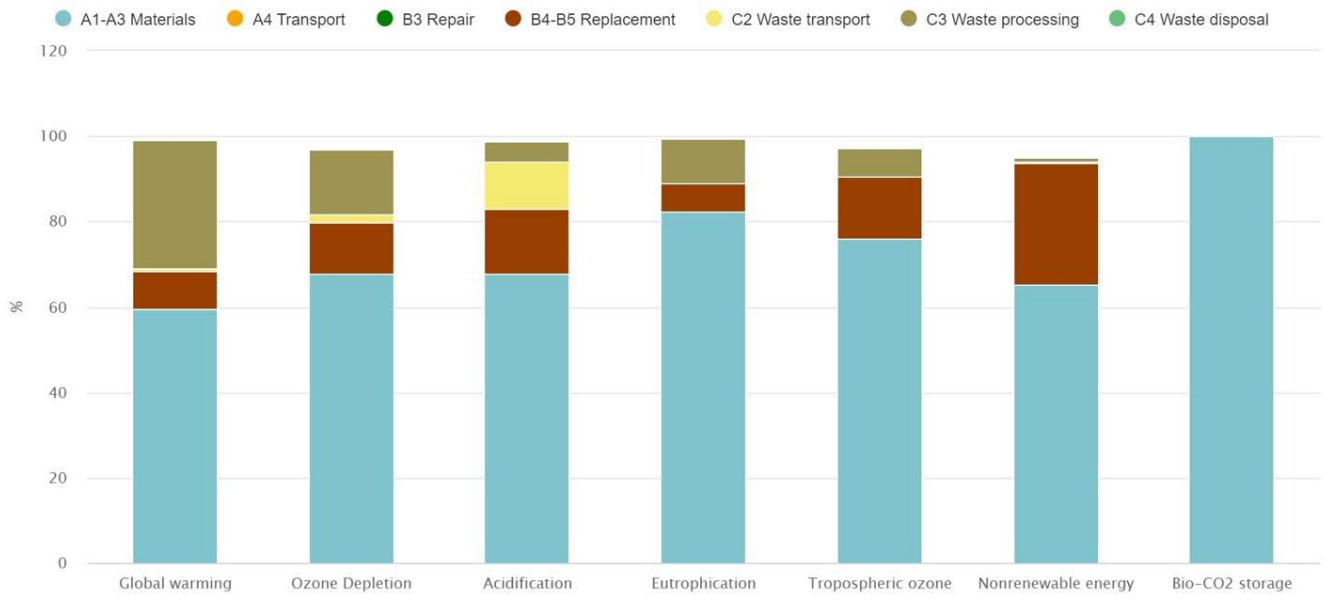


Figure 21 Life Cycle Impacts by Stage (%) – NZER Retrofit

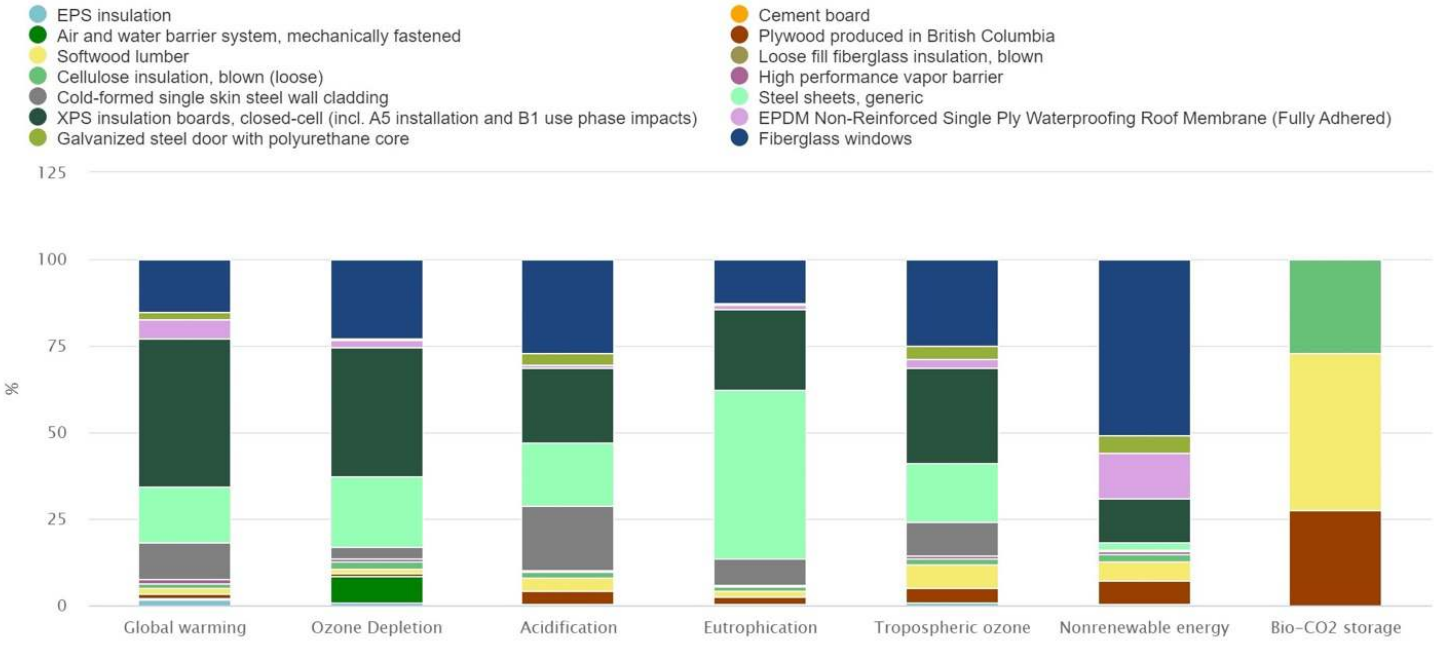


Figure 22 Life Cycle Impacts by Material (%) –NZER Retrofit

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.

1. Minimum Upgrade Scenario:
    - Heating will be provided by existing rooftop units with new demand control ventilation.
    - Domestic hot water will be with the existing 85-gallon electric water heater.
    - The existing rooftop units will continue to provide ventilation.
    - All existing building controls will remain with the new CO_2 sensors for demand-controlled ventilation. An auxiliary heat relay system will be installed to control both the rooftop units and electric baseboard heaters to ensure simultaneous heating does not occur.

Net Zero Energy Ready Scenarios:

- Electric duct heaters to provide the remaining 15% of the peak heating load (15 0.5 kW heaters).
- Domestic hot water will be provided by a new 80-gallon heat pump hot water heater.
- Two energy recovery ventilators (ERVs) will be added. They will be dual core type with approximately 90% heat recovery efficiency. Variable air volume (VAV) boxes and CO_2 sensors will be installed to enable demand-controlled ventilation.
- The new VRF system and ERVs will tie into the existing direct digital control system.

2. NZER - ASHP:
    - Heating and cooling provided by a new 10-ton air source cold climate Variable Refrigerant Flow (VRF) heat pump, sized for 100% of the peak cooling load. This meets 85% of the heating load.

3. NZER - GSHP:
    - Heating and cooling provided by a 10-ton ground/water source VRF heat pump, sized for 100% of the peak cooling load. This meets 85% of the heating load.

Proposed Electrical Systems

1. Minimum Upgrade Scenario:
    - Lighting upgrade with LED kits and LED bulbs.
    - Existing lighting controls will remain.

2. Net Zero Energy Ready Scenarios
    - Fluorescent fixtures replaced with LED fixtures. New lighting in underlit areas. LED retrofit kits and LED bulbs provided in all other fixtures so that all lighting is LED.
    - The lighting control system will be updated to include automatic lighting control throughout the building, complete with daylight sensor and vacancy sensors.
    - Replacement of main distribution equipment.

- New 3P, 280V panelboard to service all new mechanical equipment added.

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

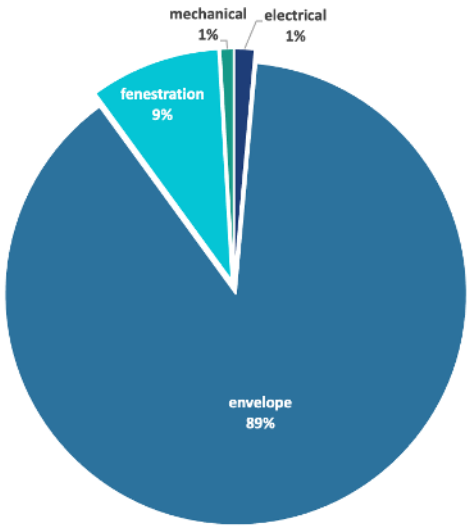
Net Metering

In Ontario, there is a 1MW limit on commercial net metered solar systems which is well over the amount of solar being proposed for this building. 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 excess 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.

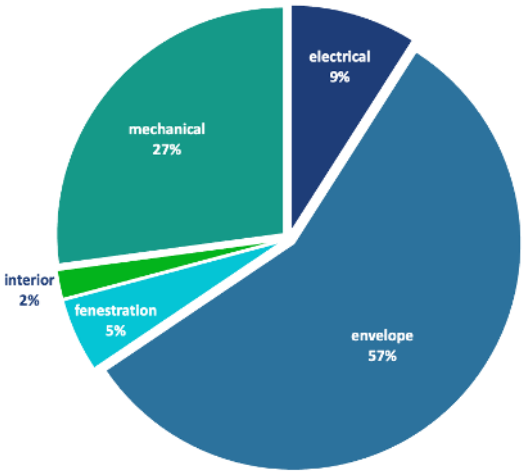
Construction Costs

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.

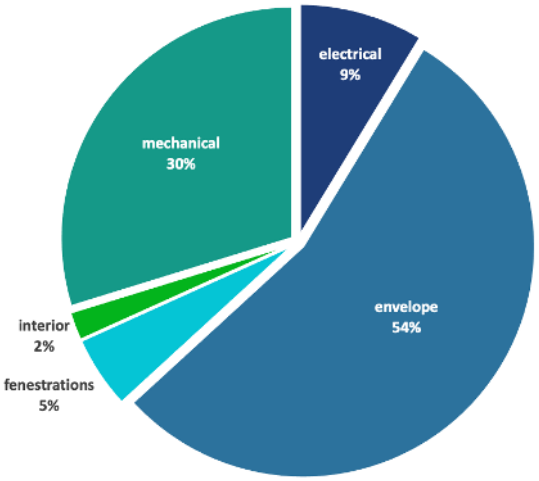
Minimum Upgrade	
Envelope	$1,916,293
Fenestration	$197,003
Mechanical	$19,906
Electrical	$30,800
total	**$3,744,998**



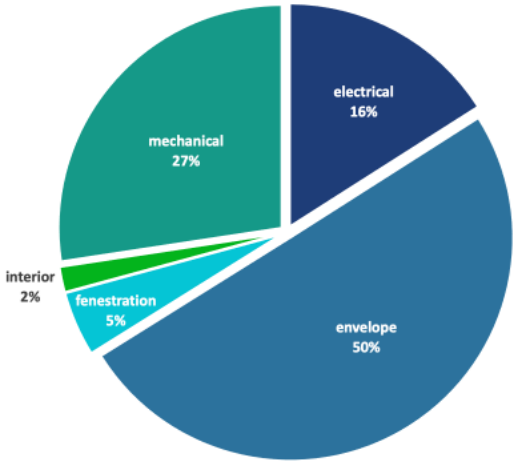
Net Zero Energy Ready ASHP	
Envelope	$2,117,130
Fenestration	$196,935
Interiors	$76,971
Mechanical	$1,016,244
Electrical	$337,718
total	**$3,744,998**



Net Zero Energy Ready GSHP	
Envelope	$2,117,225
Fenestration	$196,944
Interiors	$76,974
Mechanical	$1,157,122
Electrical	$337,734
total	**$3,885,998**



Net Zero Energy - GSHP + PV	
Envelope	$2,117,338
Fenestration	$196,954
Interiors	$76,978
Mechanical	$1,157,184
Electrical	$674,543
total	**$4,222,998**



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 tax, 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 1 Total Cost of Building Ownership (TCBO)

	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZR - GSHP + Solar
GHG emissions (kg) (60 Years)	2,334,497	894,094	94,986	94,383	0
EUI (kWh/m2/year)	396.9	199.0	78.8	78.3	0.0
TCBO at 60 years	**$20,317,000**	**$18,024,000**	**$18,937,000**	**$19,087,000**	**$17,567,000**
TCBO Savings at 60 years	$0	$2,293,000	$1,380,000	$1,230,000	$2,750,000
60 Year TCBO savings compared to Base Case		**11%**	**7%**	**6%**	**14%**

Key TCBO Results:

- The base case TCBO is $20.3M, almost 6 times the estimated Cost Replacement Value (CRV) of $3.46M.
- The TCBO is lower than the base case in the retrofit scenarios, however the results are similar across all scenarios.
- The Minimum Upgrade scenario uses 50% less energy than the base case and saves 11% in lifetime operating costs.
- The Net Zero Energy Ready options use 80% less energy but offer less than 10% savings in lifetime operating costs.
- The Net Zero Energy retrofit provides 100% energy savings and saves $2.75M in lifetime operating costs.
- The best TCBO is achieved in the Net Zero Energy Retrofit.

Table 2 Operating Cost Summary

Utilities (including carbon tax)	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Cost	$ 8,018,000	$ 5,518,000	$ 3,717,000	$ 3,704,000	$ 1,725,000
Difference in Cost from A		$ (2,500,000)	$ (4,301,000)	$ (4,314,000)	$ (6,293,000)
Percentage Change Over Base Cost		-31%	-54%	-54%	-78%
Energy Cost ($/ft2)	$ 926.94	$ 637.92	$ 429.71	$ 428.21	$ 199.42

Maintenance	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Cost	$ 460,000	$ 587,000	$ 774,000	$ 762,000	$ 969,000
Difference in Cost from A		$ 127,000	$ 314,000	$ 302,000	$ 509,000
Percentage Change Over Base Cost		28%	68%	66%	111%
Maintenance Cost ($/ft2)	$ 53.18	$ 67.86	$ 89.48	$ 88.09	$ 112.02

Insurance & Taxes	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Costs	$ 590,000	$ 590,000	$ 590,000	$ 590,000	$ 590,000
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	$ 3,950	$ 5,050	$ 6,650	$ 6,550	$ 8,333
Difference in Cost from A		$ 1,100	$ 2,700	$ 2,600	$ 4,383
Percentage Change Over Base Cost		28%	68%	66%	111%
First Year Maintenance Cost ($/ft2)	$ 0.46	$ 0.58	$ 0.77	$ 0.76	$ 0.96

- The 60-year utility costs for the base case are more than twice the estimated replacement cost of the building.
- The NZER options reduce the 60-year utility costs by 54%.
- A Net Zero Energy retrofit reduces the utility costs by 78%. The utility cost would be reduced by 99% if water costs were excluded.
- The maintenance costs for the NZER and NZE options increased due to the added mechanical equipment and solar pv.
- The Insurance and Taxes costs are for insurance only.

Model 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 and is captured in the carbon costs.
- The utility applies carbon tax for natural gas, this is captured in the fuel cost.
- Solar panel maintenance is based on $28/kWdc/year.

Table 3 Capital Cost Summary

Initial Retrofit / HPB CostYear 1	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Initial Cost	$ 12,000	$ 2,316,000	$ 3,991,000	$ 4,161,000	$ 4,413,000
Difference in Cost from A		$ 2,304,000	$ 3,979,000	$ 4,149,000	$ 4,401,000
Percentage Change Over Base Cost		19200%	33158%	34575%	36675%
Cost ($/ft2)	$ 1.39	$ 267.75	$ 461.39	$ 481.04	$ 510.17

Maintenance Capital Costs 60 Years	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Cost	$ 11,238,000	$ 9,013,000	$ 9,866,000	$ 9,870,000	$ 9,870,000
Difference in Cost from A		$ (2,225,000)	$ (1,372,000)	$ (1,368,000)	$ (1,368,000)
Percentage Change Over Base Cost		-19.80%	-12.21%	-12.17%	-12.17%
Cost ($/ft2)	$ 1,299.19	$ 1,041.97	$ 1,140.58	$ 1,141.04	$ 1,141.04

Retrofit / HPB + Maintenance Capital Costs 60 Years	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Total Costs	$ 11,250,000	$ 11,329,000	$ 13,857,000	$ 14,031,000	$ 14,283,000
Difference in Cost from A		$ 79,000	$ 2,607,000	$ 2,781,000	$ 3,033,000
Percentage Change over Base Cost		0.70%	23.17%	24.72%	26.96%

The Capital Cost Summary compares the first-year capital investment in maintaining the existing building with the construction costs for the retrofit scenarios. The NZER and NZE costs are high because of the extensive work on the building enclosures and new mechanical systems and solar panels.

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.

This analysis assumes that solar panels will not be replaced in the 60-year time frame of the analysis, but that they will undergo regular renewal through annual maintenance.

Table 4 Annual Energy Consumption and GHGs

	Units	Base Case	Min Upgrade	NZR - ASHP	NZR - GSHP	NZ - GSHP + Solar
Annual Water Consumption	m3	1,216.0	1,216.0	1,216.0	1,216.0	1,216.0
Annual Sewer Discharge	m3	0.0	0.0	0.0	0.0	0.0
Annual Electric Consumption	kWh	124,695.0	91,482.0	63,324.0	62,922.0	62,922.0
Annual Gas Consumption	m3	18,814.0	6,631.0	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	38,908.3	14,901.6	1,583.1	1,573.1	0.0
Annual Solar PV generated	kWh	0.0	0.0	0.0	0.0	62,922.0
Total Annual Energy Consumption	ekWh	319,106.3	160,002.3	63,324.0	62,922.0	0.0
Total Annual Energy Consumption	GJ	1,148.8	576.0	228.0	226.5	0.0
EUI	kWh/m2/yr	396.9	199.0	78.8	78.3	0.0

Key Results:

- Electricity consumption decreases in the 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 62% and EUI by 45%. This scenario maintains existing fossil fuel-based mechanicals which must be removed by 2050.
- The NZR options reduce GHGs and EUI by 60% and the Net Zero Energy retrofits reduce GHGs by 100%.
- 38,908 kgCO_2e are prevented annually in the NZE retrofit.

Notes:

- The solar array was sized to match the energy consumption for the GSHP option.

Cumulative TCBO

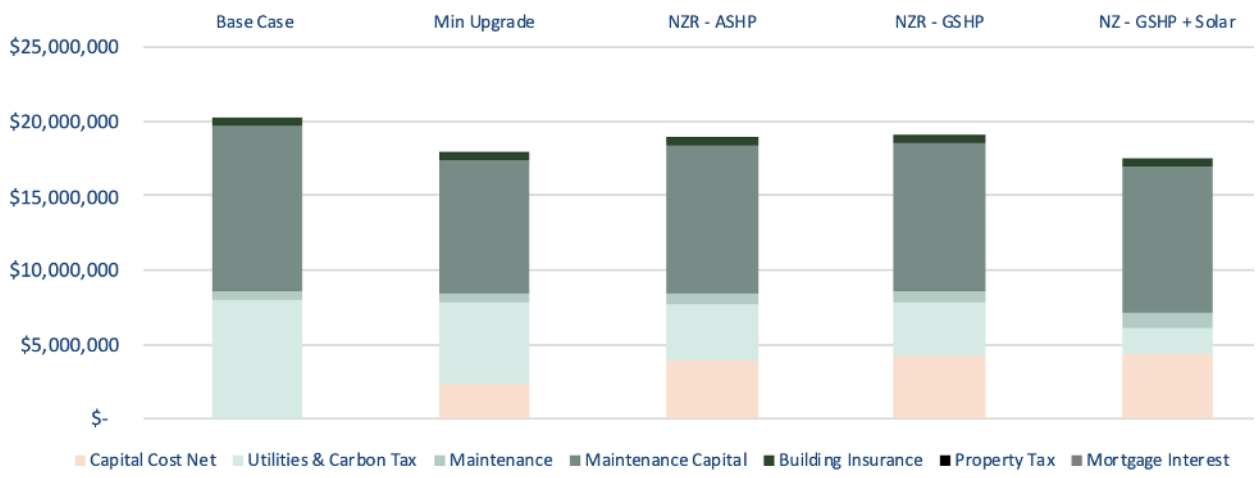


Figure 24 TCBO Comparison

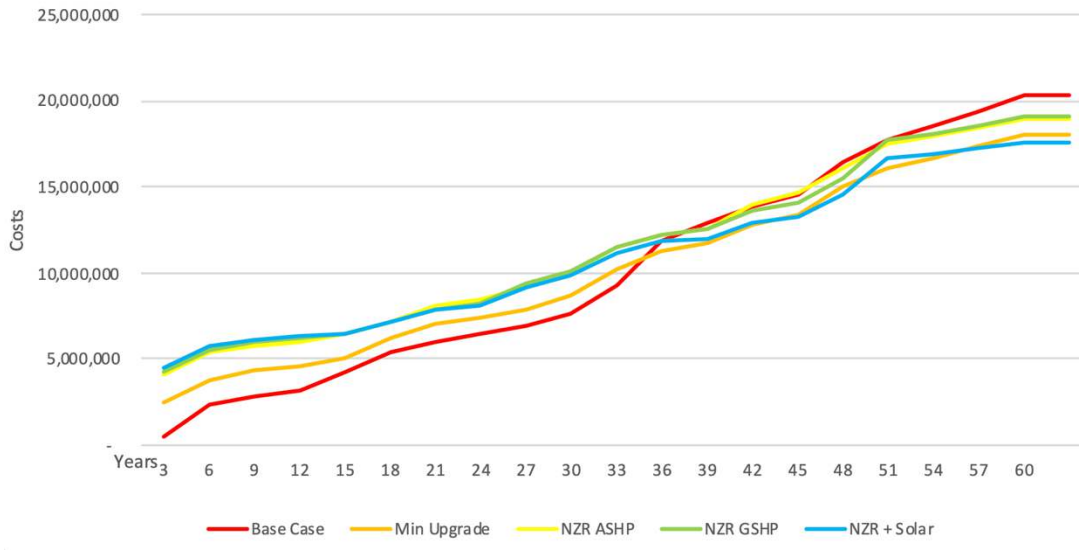


Figure 23 Cumulative TCBO

The existing building has the lowest TCBO for the first 36 years, but the Net Zero Energy scenario has lower costs for the remaining life of the building. Operational savings exceed the retrofit costs by 36 years.

The Net Zero Energy retrofit scenario is the best investment for this building, with 100% GHG reductions and 14% operational savings compared with the base case.

Discussion

The results of this project did not hold up our hypothesis, that substantial TCBO savings for municipal buildings can be achieved through Net Zero Energy retrofits which prioritize high performance building enclosures, electrification and adding solar PV.

Sir John Colbourne Senior's Centre can achieve 100% GHG and EUI reductions and prevent 38,908 $kgCO^2e$ from being emitted annually, but it will not have a twenty-year ROI. It will be 36 years post retrofit before the cost of doing nothing is more expensive than the cost of a retrofit.

The cost of the retrofits designed in this study are much higher than anticipated. The recommended option costs $510 per square foot, which may be higher than the cost to build new. It may be tempting to demolish and start fresh.

There is not a lot of data available on embodied carbon, however a small survey of Ontario buildings showed that embodied carbon in non-residential buildings can range between 220 to 695 $kgCO_2e$[5]. The retrofit to Sir John Colborne Centre has an embodied carbon of 120 $kgCO_2e$ and prevents emissions from materials sent to landfill should it be demolished. The culture of demolishing buildings for convenience must stop.

Sir John Colborne Centre has a highly articulated envelope and the cost to retrofit it will be high regardless of if it is through a panelized approach or a conventional retrofit because its surface area to volume ratio is high. This high amount of exterior envelop makes it more vulnerable in extreme storms, so it's important to plan for its retrofit.

Sir John Colborne Senior's Centre uses 30% more energy than the average community centre in Canada[6](excluding high EUI uses eg pools, arenas). It is also a designated comfort centre for people in the Town of Oakville in times of extreme heat and cold. This highlights the importance of implementing energy-efficient measures to reduce its energy consumption and to invest in envelope upgrades that will enhance its resilience during extreme weather events.

We can't underestimate the need for resilience. Climate change is here now. Every building we touch needs to be not only energy efficient but more robust than we've built before.

[5] Mantle Developments (2022) Part 3 Building Self-Reported Embodied Carbon. https://drive.google.com/file/d/15EDzjF2-Oe3Zv7Jy1jjVEp25dUUbf32u/view

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

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.

We don’t have the time or the labour force to scale retrofits without learning to implement them systematically. The solutions will be inspired by the example set by Energiesprong but adapted to work for Canada.

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[7]. 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.

A Net Zero Energy retrofit to Sir John Colborne Seniors Centre can prevent nearly 40,000 kgCO_2e of GHGs per year. A deep retrofit to the building will also help it to better serve in its function as a dedicated cooling and warming centre for the community of Oakville in extreme weather events. It will be more comfortable to the seniors who visit, and it will save $2.75M for the Town of Oakville.

[7] 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