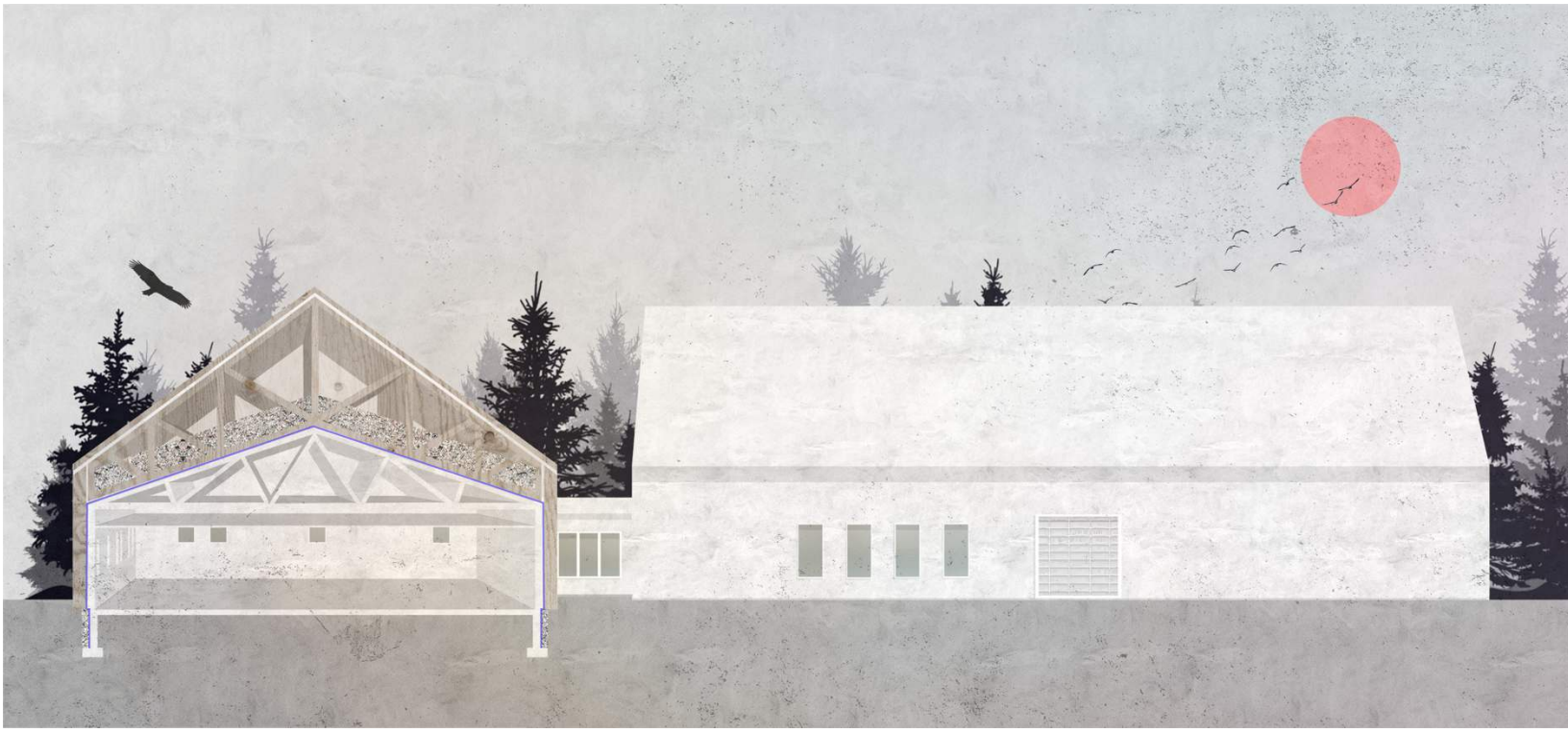


PANELIZED DEEP RETROFITS OF MUNICIPAL BUILDINGS

Debert Water Utility Building

Case Study Report DRAFT

Issue Date: August 18, 2023

Colchester

Natural Resources Canada | Ressources naturelles Canada

ReCover

Table of Contents

List of Figures **2**
Acknowledgements **3**
Acronyms and Definitions **6**
Introduction **7**
Project Objectives **8**
Methodology **8**
Building Selection 9
Data and Document Collection 9
Building Description **11**
Context 12
Building Code Considerations 13
Building Enclosures 13
Existing Structure 17
Existing Mechanical Systems 17
Existing Electrical Systems 18
Energy Consumption **19**
Baseline Energy Model and Calibration 20
Results **22**
Energy Conservation Measures 23
Table 3 Retrofit Scenario Results 26
Design 27
Panelized Wall Details 27
Roof Details 29
Building A Structural Design 30
Building B Structural Design 31
..... 31
Foundation Insulation 32
Hygrothermal Modeling 33
Embodied Carbon 35
Proposed Mechanical Systems 37
Proposed Electrical Systems 38
Nova Scotia Power Net Metering Program 38
Construction Costs 40
Total Cost of Building Ownership 42
Cumulative TCBO 46
Discussion **47**
Conclusions **48**

Appendices

Appendix A Pre-retrofit Drawings
Appendix B Facility Condition Assessment
Appendix C Structural Outline Specification
Appendix D Mechanical Outline Specification
Appendix E Electrical Outline Specification
Appendix F Pre-retrofit Utility Records
Appendix G Energy Model Reports
Appendix H Panel Schematics
Appendix I Panel Layouts
Appendix J Hygrothermal Report
Appendix K Embodied Carbon
Appendix L Architectural Elevation Drawings
Appendix M Cost Estimate
Appendix N Total Cost of Building Ownership

List of Figures

Figure 2 Site Plan 11
Figure 1 Debert Water Facility 11
Figure 3 Building A exterior wall section 15
Figure 4 Building B exterior wall section 16
Figure 5 Energy Use 19
Figure 6 Calibrated Energy Usage 20
Figure 8 Total Energy Use Intensity (TEUI) 21
Figure 7 Thermal Energy Demand Intensity (TEDI) 21
Figure 9 Building B retrofit cross section 23
Figure 10 Debert Water Utility Building Retrofit Scenarios Total Energy Use Intensity (TEUI) 26
Figure 11 Concept south view 27
Figure 12 Wall Panel Assembly 28
Figure 13 Roof Assembly 29
Figure 14 Building A panel connections at roof and foundation 30
Figure 15 Building B panel connection at roof 31
Figure 17 Foundation Insulation 32
Figure 16 panel axonometric drawing 32
Figure 18 WUFI Pro output - Building A north wall (inner plywood layer) 33
Figure 19 WUFI Pro output - Building B south roof (inner plywood) 34
Figure 20 Global Warming by Stage and Material 35
Figure 22 Life Cycle Impacts by Material (%) 36
Figure 21 Life Cycle Impacts by Stage (%) 36
Figure 24 Cumulative TCBO 46
Figure 23 TCBO Comparison 46

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

Project Team

Timon Bruulsema	Energy Consultant, RDH Building Science
Stanley Francispillai, PEng	WUFI Modeling
Mark Gardin, PQS(F), MRICS	Cost Consultant, Qsolv Incorporated,
Liam Kidson, PEng	Electrical Consultant, M&R Engineering
Hayley Knowles, PEng	Mechanical Consultant, M&R Engineering
Aidan McCracken, PEng	Structural Consultant, DesignPoint Engineering
Amanda McNeil, PEng	Project Management, ReCover
Jim Nostedt, PEng	TCBO Analysis, SEEFAR Building Analytics
Fatma Osman	Embodied Carbon Accounting
Andrea Pietila, PEng CPHD	Energy Consultant, RDH Building Science
Lorrie Rand, BEDS CPHD	Architecture, Habit Studio
Nick Rudnicki	Project Lead, RSI Projects
Aaron Smith, PEng	Mechanical Consultant, M&R Engineering
Evan Teasdale, PEng	Structural Consultant, DesignPoint Engineering

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

Debert Water Utility Building

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

69% improvement

Existing : 216 kWh/m^2

Recommend : 68 kWh/m^2

GHG

79% improvement

Existing : 57,283 kg/yr

Recommend : 12,233 kg/yr

Lifetime Utility Costs

75% improvement

Existing : $6.0 M

Recommend : $1.5 M

Lifetime Savings

$1.3 Million

Existing : $9.1 M

Recommend : $7.8 M

Retrofit Measures

Existing walls

Existing roof

High performance windows and doors

New ventilation system

42 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

---

[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

A short-list of buildings was proposed for study by the Municipality of Colchester. 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

Several factors led to the selection of the Debert Water Utility Facility for this study by the Municipality of Colchester and the ReCover team. The building incurs relatively high energy costs and has an inefficient fuel-oil heating system. It is also in need of a new siding, which is an opportune time to consider upgrading the building envelope.

The form of the building is more articulated than is ideal for a panelized retrofit, however each of its two parts are simple in isolation. Additionally, as the two parts represent different construction types, an opportunity to simultaneously explore the potential for a panelized retrofit on both a wood framed structure and a masonry structure.

Data and Document Collection

The Municipality of Colchester provided the following data and supporting documents pertaining to the Debert Water Utility Facility:

- 1979 construction drawings (Appendix A)
- Fuel oil consumption records March 2020 to March 2022 (Appendix F)
- Electrical consumption records March 2020 to March 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, however older records were not available.

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 staff of the municipality 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 Capital Management Engineering Limited as one did not exist for the property (Appendix B).

Building Description

The Debert Water Utility Building is a one-storey structure with a gross floor area of 718m^2 (7,728 sq.ft) consisting of two wings connected by an enclosed walkway.



Figure 2 Debert Water Facility



Figure 1 Site Plan

Building A is a 181m^2 (1,948 sq.ft) office space which is rented out to an engineering company. Building B is a 537m^2 (5,780 sq.ft) maintenance facility used for servicing and storage of equipment and also contains an office area.

Context

The Debert Water Utility Building is located at 251 Lancaster Crescent, Debert, Nova Scotia. Debert is a rural, predominantly agricultural community in Colchester County, NS. The Water Utility Building is in an industrial area surrounded by woodland. It was built in 1979 as a Tree Breeding Centre for the Nova Scotia Department of Lands and Forests.

Debert is in Canadian building code climate zone 6. Its weather is humid and changeable in all seasons, with year-round potential for significant precipitation. The site is approximately 10 km inland from the waters of the Minas Basin. Average temperatures in Nova Scotia are increasing and are predicted to continue to rise, with the incidence and severity of storms also accelerating.[3] High winds and driving rain are key building science concerns in Nova Scotia.

In 2021 the Municipality of Colchester implemented Carbon-Free Colchester[4], their Community Energy and Emissions Plan which targets net-zero Greenhouse Gas (GHG) emissions by 2050. Energy conservation through building upgrades, including retrofits, and building electrification are key pillars of the plan. Colchester has set a goal for deep retrofits to 80% of their existing buildings by 2040, and net-zero retrofits to all municipally owned buildings by 2035.

[3] Nova Scotia Department of Environment and Climate Change (2022) *Weathering What's Ahead: Climate Change Risk and Nova Scotia's Well-being*, https://climatechange.novascotia.ca/sites/default/files/uploads/climate-change-risk-report.pdf

[4] Municipality of Colchester. (2021) *Carbon-Free Colchester.* https://www.colchester.ca/community-1/3522-carbon-free-colchester-community-energy-emissions-plan/file

Building Code Considerations

A preliminary National Building Code of Canada (NBCC) review has been completed to determine if prefabricated envelope panels made with combustible materials can be installed on the Debert Water Utility Building (Appendix L).

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. The Debert Water Utility Building has two major occupancies. Building A is classified under the National Building Code of Canada (NBCC) as **Group D Business Occupancy** and Building B is classified as **Group F2 Medium-hazard Industrial Occupancy** due to its function as a repair garage.

Both buildings are permitted to be of combustible or non-combustible construction. The structural elements of Building B are required to have a 45-minute fire-resistance rating or to be of non-combustible construction. A fire separation is not required between the occupancies. Both parts of the building are believed to be currently in compliance with these requirements.

Side setbacks have been reviewed based on a scaled site plan and it was determined that walls of the building may be constructed of either combustible or non-combustible elements. Based on this a panelized retrofit made with combustible elements and metal cladding complies with NBCC requirements.

Building Enclosures

Building A is a timber structure insulated with fiberglass batt in both the exterior walls and roof. It has 2" of continuous sub-slab rigid insulation and 2" of rigid insulation installed on the interior perimeter of the frost walls to a depth of 48". Figure 3 shows the Building A existing wall section taken from the original 1979 drawings.

Building B has concrete block walls insulated with 2 ½" of rigid insulation on the exterior. The drawings specify a protected membrane roof assembly with 4" of rigid insulation, however the current roof is a conventional modified bitumen roof system. It is believed that the current roof has 4" of rigid insulation. The perimeter frost walls are insulated with 3" of rigid insulation. In all instances of rigid insulation in this building the material is assumed to be extruded polystyrene.

TABLE 1 EXISTING THERMAL PERFORMANCE		
	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-0.44 (U-0.077)	RSI-2.27 (R-12.9)
weighted average roofs	USI-0.37 (U-0.065)	RSI-2.71 (R-15.4)
weighted average slab	USI-4.1 (U-0.7)	RSI-0.24 (R-1.36)
overhead door	USI-1.13 (U-0.2)	RSI-0.88 (R-5)
windows	USI-1.98 (U-0.35)	RSI-0.5 (R-2.86)

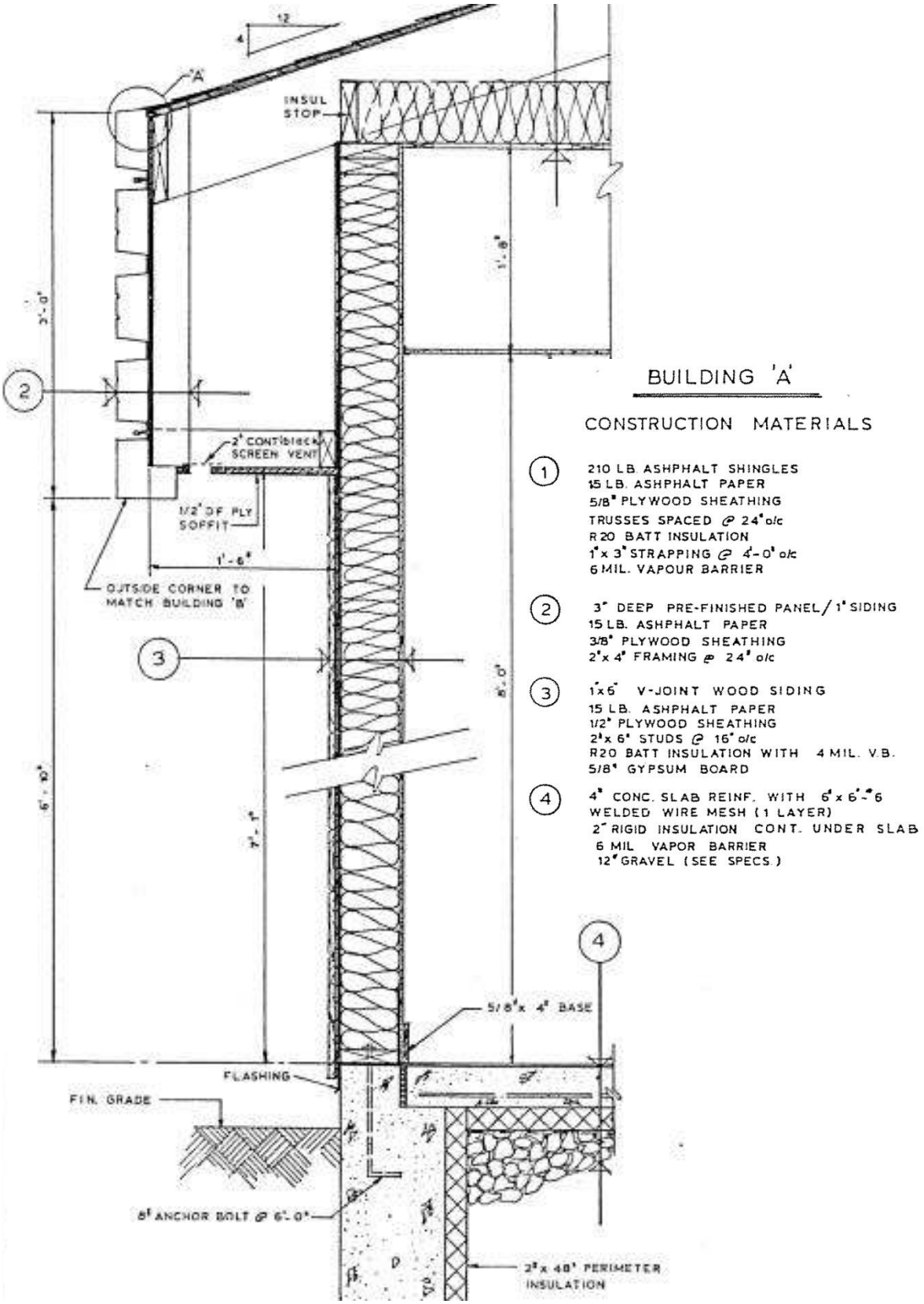


Figure 3 Building A exterior wall section

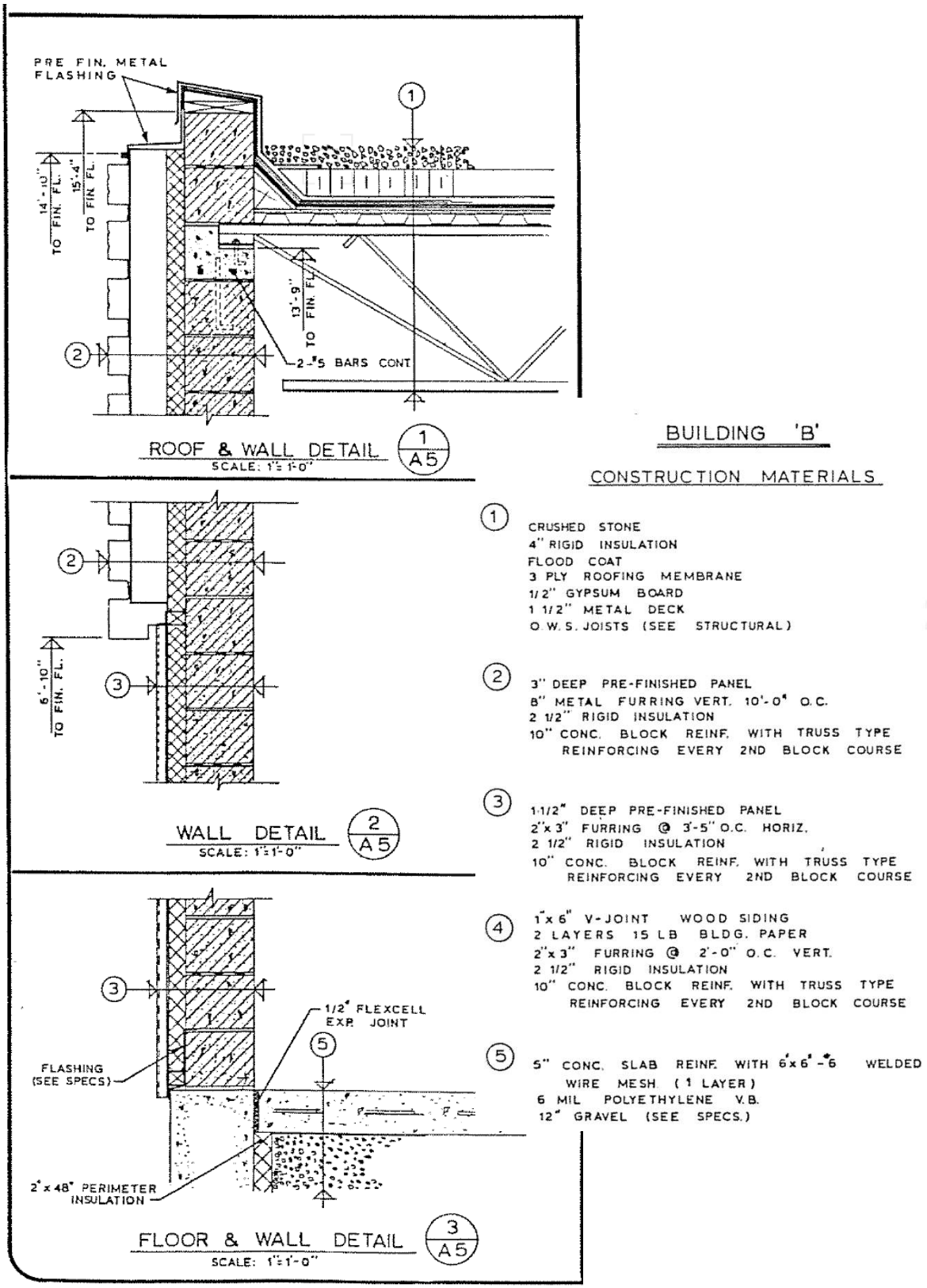


Figure 4 Building B exterior wall section

Existing Structure

Building A & B are connected via a ±7' wide timber framed walkway. Both buildings, and the walkway, are founded on **concrete slab-on-grades**, with perimeter **frost walls and interior strip footings** to support load bearing walls.

Building A is **wood framed** with 2x6 studs at 16" on centre and pre-engineered timber roof trusses. The wall and roof assemblies are shown in Figure 3. The walkway between Building A and B is also wood framed with a 2" x 8" central ridge board and 2" x 6" rafters and ceiling joists at 24". The rafters are structurally deficient based on current loading.

Building B is constructed with 10" **reinforced concrete block** walls and an **open web steel joist** (OWSJ) and corrugated metal deck roof. The existing masonry walls in Building B extend beyond the existing roof to form a parapet wall. Details are shown in Figure 4.

The walls of both buildings can support additional loading. A panelized roof solution is not structurally viable for Building A. Adding roof panels to Building B is possible, however reinforcing of the existing roof structure would be required. The recommended retrofit for both sides of the building is for new structure to bear on the existing load-bearing walls.

Existing Mechanical Systems

Hot water is supplied by an electric water heater located in the mechanical room.

Space heating in all parts of the building is by hot water baseboard heaters or unit heaters. Hot water is provided by one oil-fired boiler which is in good condition and still has some remaining useful life. Baseboard heaters are installed in all parts of the building except for the office area of the maintenance facility which has an electric baseboard heater. Supplemental hot water unit heaters have also been installed in the work area on the south side of the building and outside the mechanical room.

A 2.5-ton heat pump was installed in the Building A in June 2022 to provide heating and cooling. The office area was previously cooled with a ducted air conditioner. The maintenance garage has two window unit air conditioning units installed in the offices but does not have cooling anywhere else.

The facility is inadequately ventilated for occupation. The only **ventilation** provided is bathroom exhaust fans.

The building does not have a building automation system. Standalone pneumatic thermostats control baseboard heater control valves and electronic thermostats control force flow heater fans.

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

Existing Electrical Systems

In general, the electrical system is in acceptable condition, however many of the components have reached end of life or no longer comply with current codes. The incoming **power service** is supplied via a pad mount transformer. The main incoming secondary service is sized at 800A which is not compliant with current electrical codes.

The **main switchboard** is original to the building. It appears to be well maintained but has reached its end of life. Several **branch circuit panelboards** exist throughout the building servicing various areas. Their overall condition is good, and while some are original to the building, circuit capacity has been expanded through the years.

The **interior lighting** in Building A was upgraded in the past 20 years to 2x2 and 2x4 fixtures complete with T8 lamps. Building B is lit with original fluorescent lighting with high output fixtures in the warehouse areas. Approximately 40% of the Building B fixtures are not functional. The mechanical room lacks lighting entirely.

The building lacks an automatic **lighting control** system and relies on manual control which could lead to energy waste if lights are left on in unoccupied areas of the building for extended periods of time.

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

Energy Consumption

Energy analysis was based on electrical and fuel oil consumption spanning March 2020 to March 2022 (Appendix F). During the documented time span the building used an average of 10,167 L of fuel oil (105,232 ekWh) and 44,400 kWh of electricity annually.

The time span of the consumption records includes times of reduced building occupation due to the COVID-19 pandemic, and typical energy use is believed to be higher than modeling suggests.

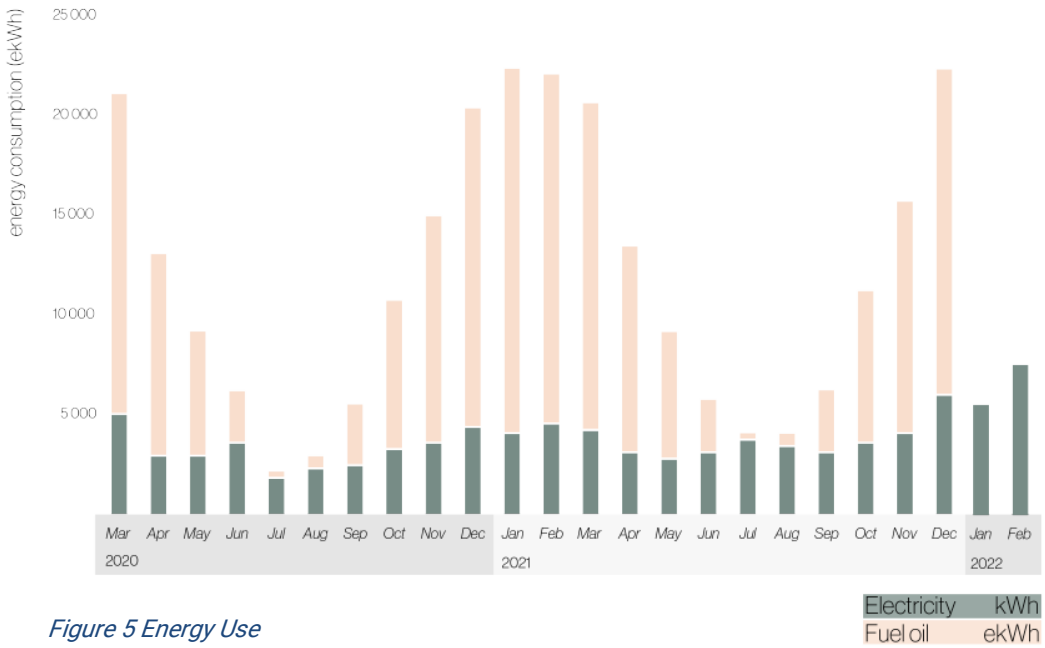


Figure 5 Energy Use

Baseline Energy Model and Calibration

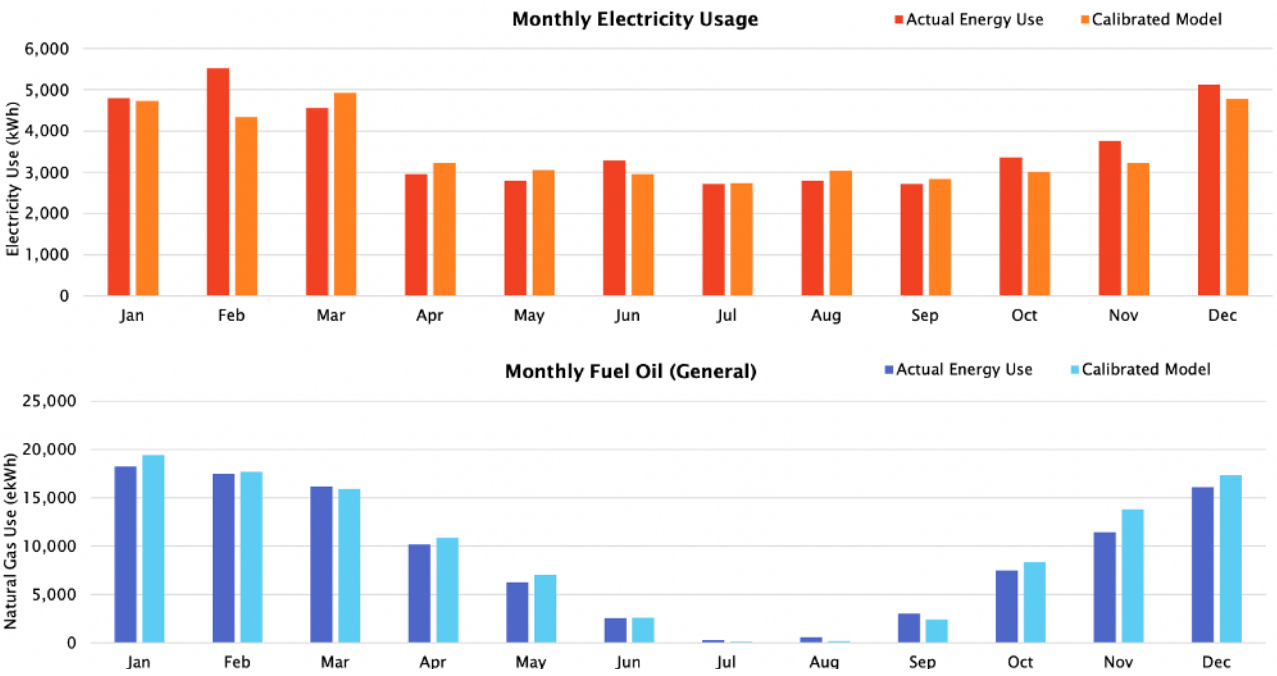


Figure 6 Calibrated Energy Usage

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 staff from the Municipality of Colchester 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. Fuel oil deliveries to the building are irregular and occurred only once in 2020 and four times in 2021. As such, consumption rates could not be tied to a regular billing cycle and monthly usage was estimated based on climate data.

The building is heated primarily with fuel oil and supplemented with electric heat. Accurately apportioning the ratio of fuel oil to electricity presented challenges in model calibration. To facilitate calibration, the heating impacts from the air source heat pump serving Building A were excluded from the baseline model. The modeled electrical consumption deviates from the existing usage by 3.5% and modeled fuel oil deviates by 5.5%.

The Total Energy Use Intensity (TEUI) for the building is 220.6 kWh/m^2/yr. More than 75% of its energy use is for space heating (Figure 8) The building is currently unventilated and ventilation, ventilation heat losses are less than 1% of the total. Adding a mechanical ventilation system will be an essential part of any retrofit to this building, however even a highly efficient heat recovery ventilator will increase heat loss through ventilation and the EUI.

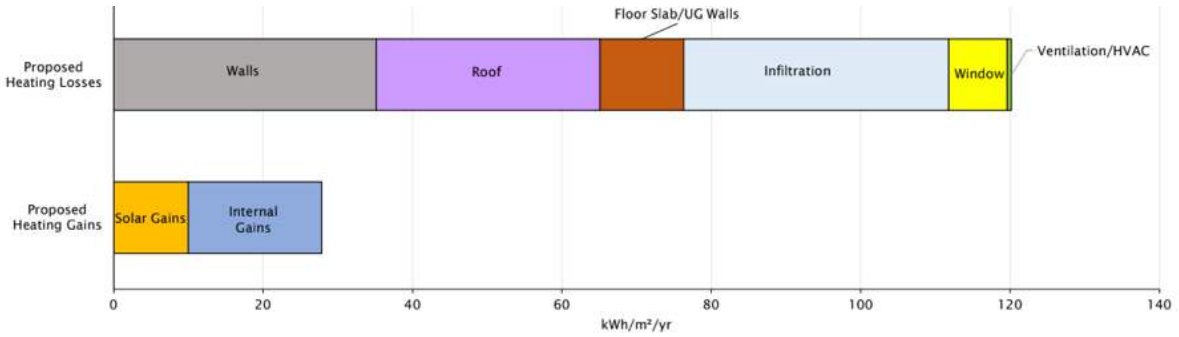


Figure 8 Thermal Energy Demand Intensity (TEDI)

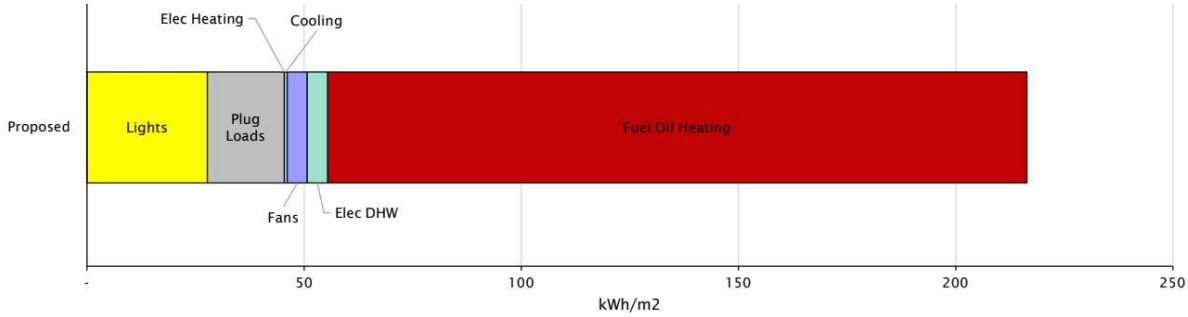


Figure 7 Total Energy Use Intensity (TEUI)

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 install new pre-engineered timber roof systems over the existing roofs, supported on the existing exterior bearing walls.

A panelized roof retrofit is technically possible for Building B; however, it would cost more in up front and lifetime costs. A new flat roof would require expensive reinforcing of the existing steel OWSJ system to support the weight of the new panels and higher snow loads than the current roof, since improved thermal performance will increase snow accumulation. Flat roofs typically require more ongoing maintenance than sloped roofs, representing higher costs over the life of the building. For these reasons a truss roof is a better investment for this retrofit.

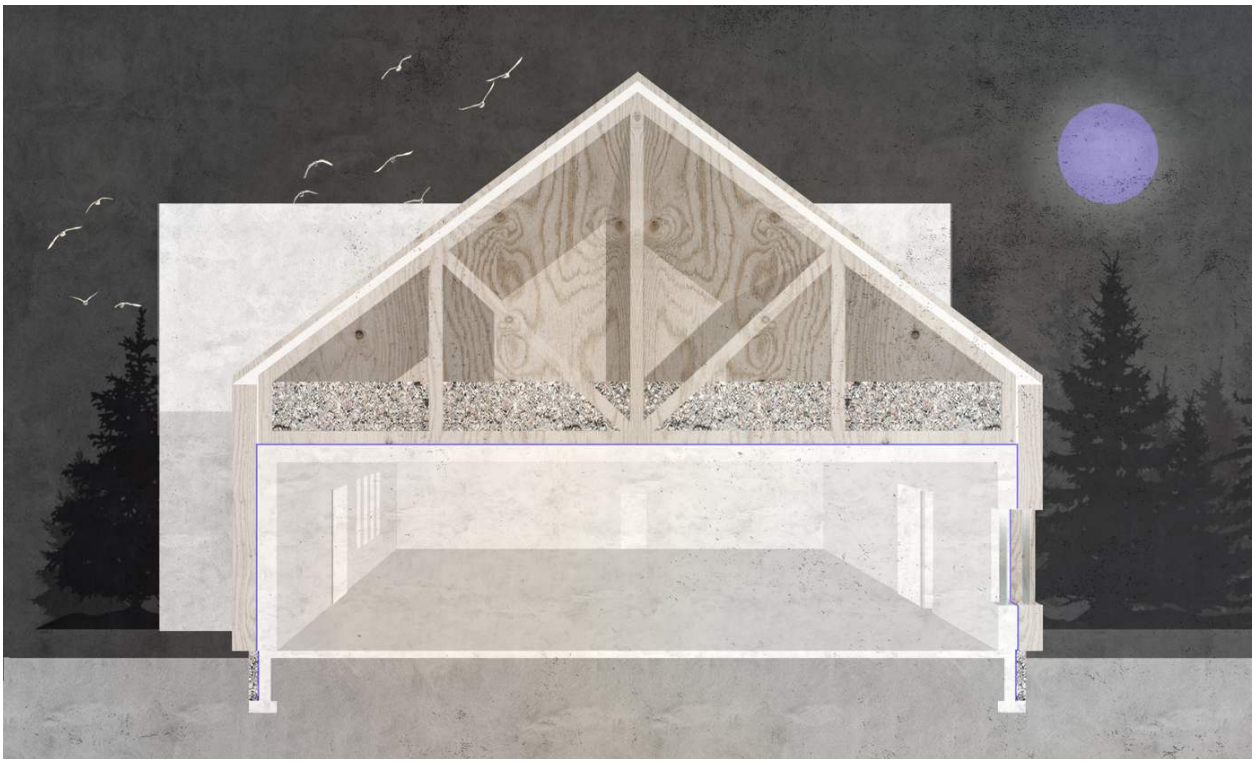


Figure 9 Building B retrofit cross section

Energy Conservation Measures

Energy conservation measures (ECMs) 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, an estimated 67% reduction from the 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. Both air source heat pumps (ASHP) and ground source heat pumps (GSHP) were considered in the analysis to learn which option has the lowest TCBO. A GSHP is more energy efficient than an ASHP, however the capital costs of installing a GSHP are typically significantly higher, so the best investment depends on specific building conditions. The Net Zero Energy scenario is based on the ASHP option which resulted in the lowest TCBO.

The primary difference between the Minimum Upgrade and the NZER scenarios is that in the Minimum Upgrade the existing oil-fired boiler is retained. If fossil fuels are not removed now another retrofit will be necessary before 2035 (Colchester's target for corporate buildings to be

net-zero). This option was considered as it is a lower cost strategy that can still achieve approximately 50% EUI savings when combined with other efficiency upgrades.

Details of the retrofit scenarios are summarized in Table 2.

Table 2 Debert Water Utility Building Retrofit Scenarios Summary				
	Existing Building	**Minimum Upgrade**	**ASHP Net Zero Energy[1]**	**GSHP Net Zero Energy [1]**
Effective Wall R-value	RSI-2.11 (R-12)	RSI-4.4 (R-25) existing +ReCover panels)	RSI-4.4 (R-25) existing +ReCover panels)	RSI-4.4 (R-25) existing +ReCover panels)
Effective Roof R-value	RSI 2.71 (R-15.4)	RSI-7.04 (R-40) existing + new cellulose)	RSI-7.04 (R-40) existing + new cellulose)	RSI-7.04 (R-40) existing + new cellulose)
Air Tightness (at 75Pa)	2.3 L/s·m2	0.75 L/s·m2	0.75 L/s·m2	0.75 L/s·m2
Central Heating Equipment	Oil-fired boiler with single stage burner	Oil-fired boiler with single stage burner	ASHP	GSHP
Heating System	Bldg A: Hydronic baseboards Bldg B: Hydronic baseboards & unit heaters	Bldg A: Hydronic baseboards Bldg B: Hydronic baseboards & unit heaters	Bldg A: Hydronic baseboard Bldg B: Hydronic baseboards & unit heaters	Bldg A: Hydronic baseboard Bldg B: Hydronic baseboards &unit heaters
Air Conditioning[2]	Bldg A: Existing ASHP Bldg B: Packaged air conditioning units	Bldg A: Existing ASHP Bldg B: Mini split units	Bldg A: Existing ASHP Bldg B: Mini split units	Bldg A: Existing ASHP Bldg B: Water to Air consoles
DHW Equip	Electric Water Heater	Electric Water Heater	HP Water Heater	HP Water Heater
Ventilation Equipment	Extract (bathrooms only)	Bldg A: 90% SRE ERV Bldg B: 90% SRE ERV	Bldg A: 90% SRE ERV Bldg B: 90% SRE ERV	Bldg A: 90% SRE ERV Bldg B: 90% SRE ERV
Solar PV	none	none	45 kW (DC)	45 kW (DC)

[1] Net Zero Energy Ready systems are identical with exclusion of renewables.
[2] Building B only provides cooling in north and south offices.

Table 3 Retrofit Scenario Results			
	Target TEUI	**TEUI kWh/m^2**	**TEUI reduction**
Existing	-	220.6	-
Minimum Upgrade	50% savings	125.7	43%
NZER ASHP	75% savings	55.3	75%
NZER GSHP	75% savings	55.3	75%
NZE	100% savings	0	100%

The modeled performance of the Minimum Upgrade and NZER scenarios does not meet the EUI reduction targets. This is primarily due to the impact of adding code compliant mechanical ventilation in the retrofits, which offsets some of the savings from the energy conservation measures. The design team explored options to further reduce the EUI, however achieving greater savings in this scenario were not cost effective.

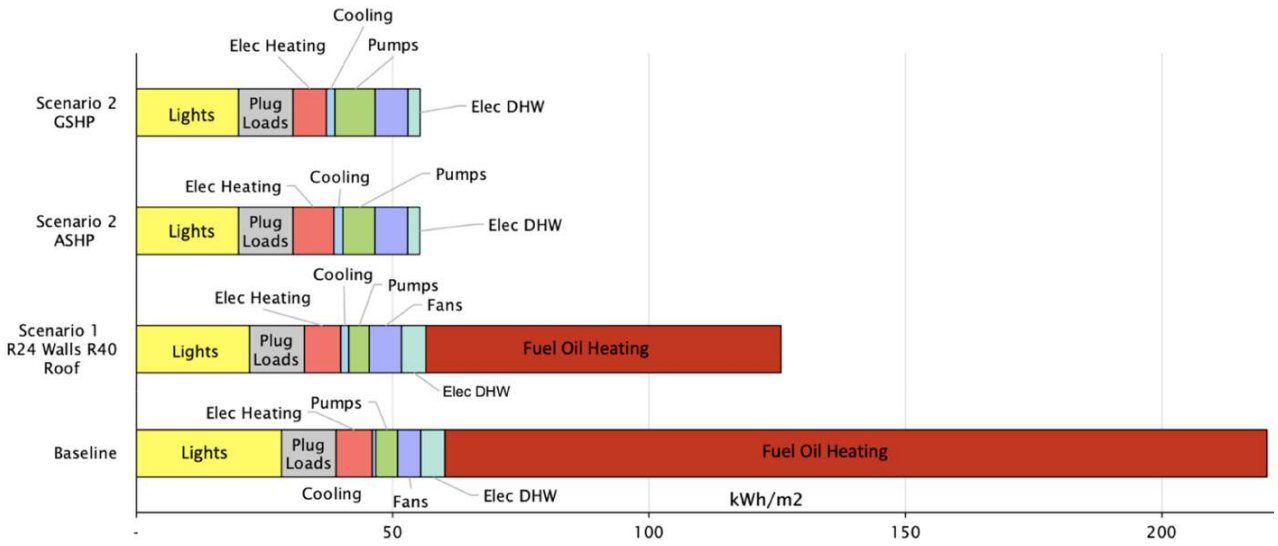


Figure 10 Debert Water Utility Building Retrofit Scenarios Total Energy Use Intensity (TEUI)



Figure 11 Concept south view

Design

Cosmetic upgrades are a significant driver of building retrofits, and it is important to demonstrate that deep retrofits can play a role in building beautification.

The new roof trusses will have an 8:12 pitch. A higher roofline will shed snow more effectively and gives the building more presence. The overall proportions of the two buildings in the proposed design are more in keeping with the vernacular agricultural buildings in the community.

Metal cladding is recommended on the walls and roof for resilience and durability, low maintenance, and for the lowest TCBO. A muted shade of green is suggested to be harmonious in the wooded setting. Wood accents add warmth at the entrance and a complementary wood-look finish highlights the overhead doors.

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. All retrofit scenarios for the Debert Water Utility Building use panels with 2x6 stud framing.

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 are found in Appendix H.

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

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

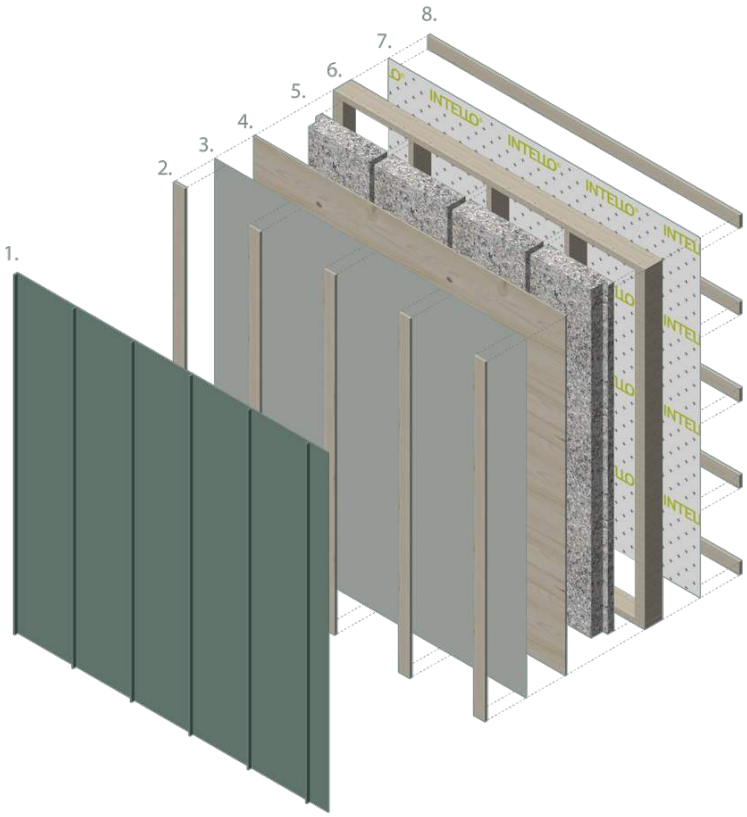


Figure 12 Wall Panel Assembly

The wall panels span from foundation to roof, a height of approximately 4.25m (14') when they are extended to the underside of the new roof overhangs. 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 for the Debert Water Utility Building is provided in Appendix I.

[5] Panels will be assembled remotely; however, the cladding will be installed on site.

Roof Details

The proposed roof assemblies are conventional truss roofs. The new Building A roof will have scissor trusses with a 4:12 bottom chord that fits above the existing roof slope and an 8:12 top chord. The pitch of Building B will have a flat bottom and an 8:12 to match Building A. Hygrothermal modeling shows that the roofs should be well ventilated for optimal longevity.

Building B Roof Assembly effective RSI-7.04 (R-40)[6]

1. metal roofing
2. strapping
3. WRB membrane
4. plywood sheathing
5. pre-engineered roof trusses
6. new cellulose insulation
7. WRB membrane

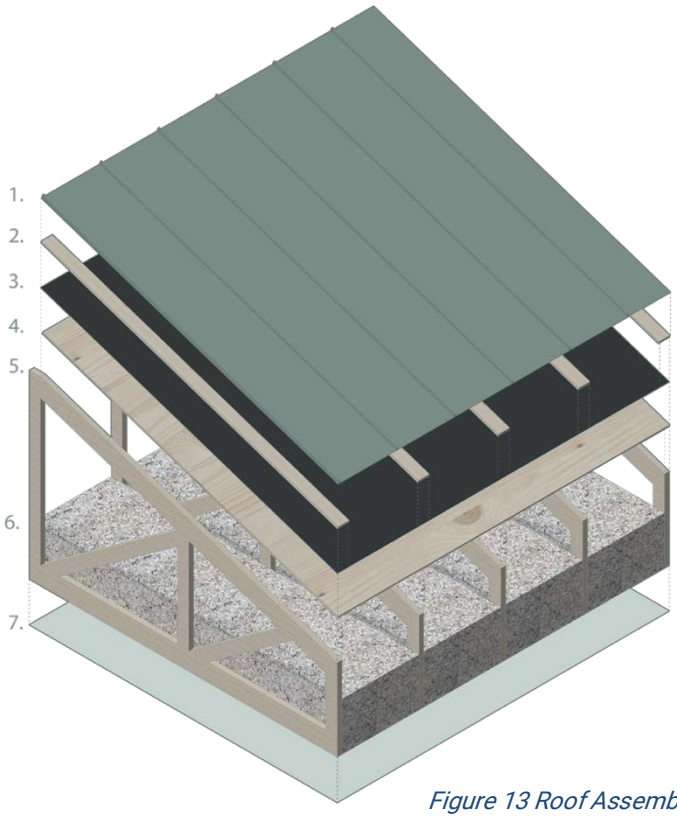


Figure 13 Roof Assembly

[6] Building A roof assembly is like Building B, except with a scissor truss.

Building A Structural Design

- new roof trusses connect to solid blocking fastened to existing two-ply top plates.
- top of the ReCover panel fastens to the roof with Simpson Strong-Tie tie plates.
- panels span from foundation to roof.
- supported at the concrete foundation with a steel bent plate lintel.

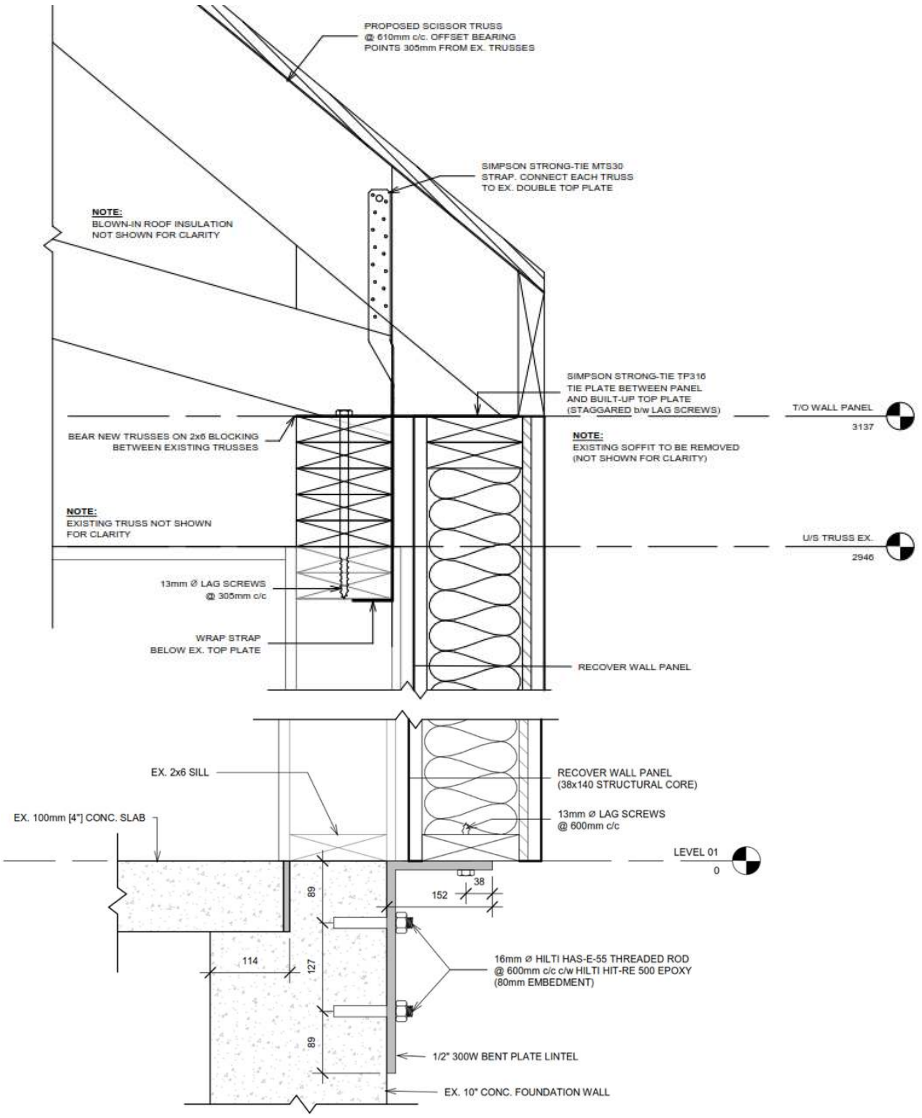


Figure 14 Building A panel connections at roof and foundation

Building B Structural Design

- roof trusses are supported on the existing masonry parapet wall.
- top of the ReCover panel fastens to the roof with Simpson Strong-Tie tie plates.
- panels span from foundation to roof.
- supported at the foundation with a steel bent plate lintel like Figure 14.

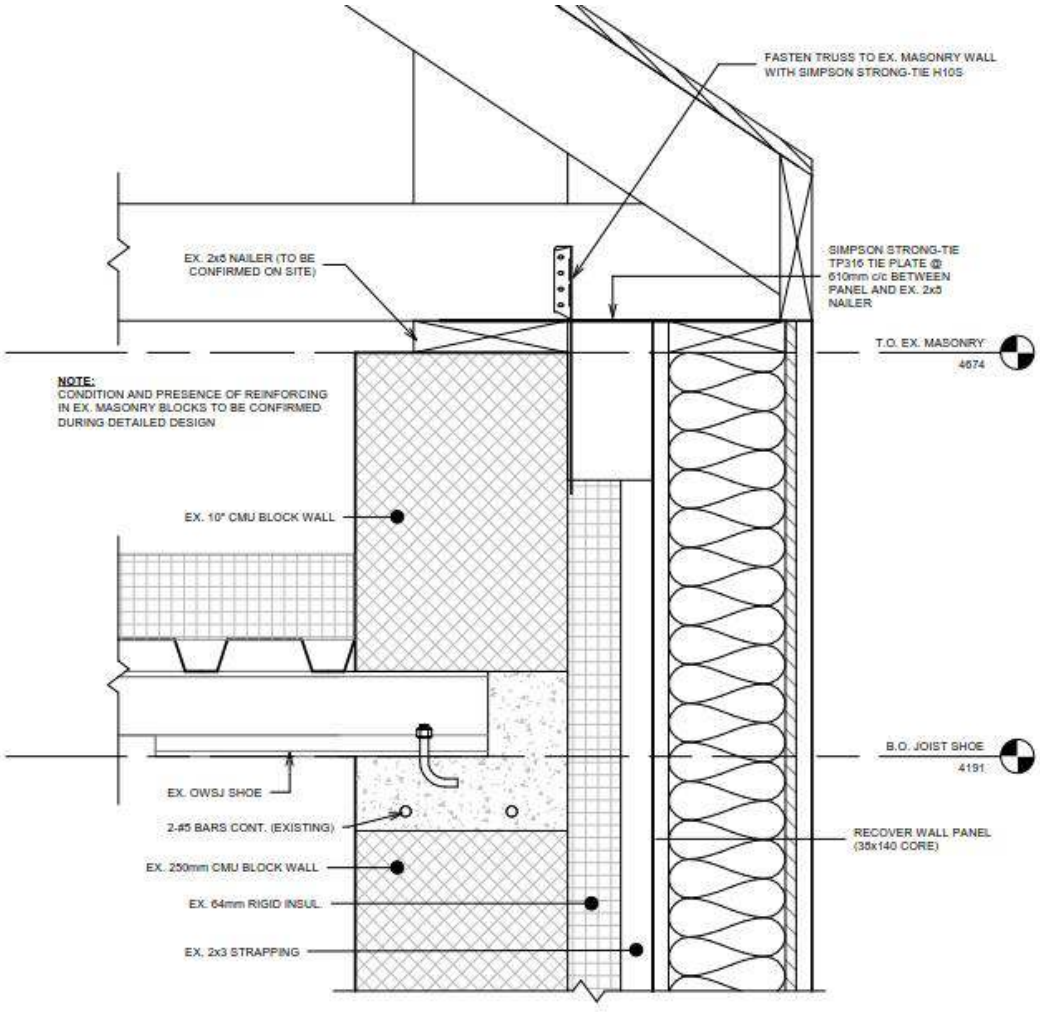


Figure 15 Building B panel connection at roof

Foundation Insulation

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

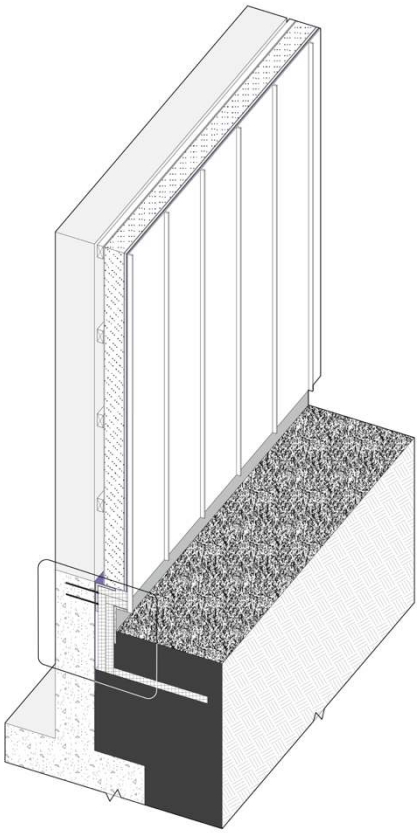


Figure 17 panel axonometric drawing

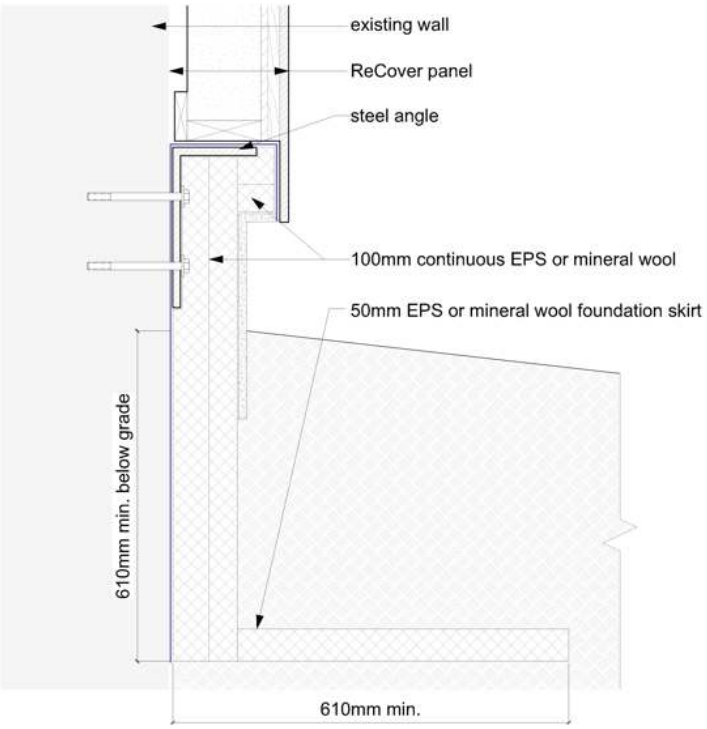


Figure 16 Foundation Insulation

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 Debert Water Utility Building NZER wall and roof assemblies with WUFI® Pro (Appendix J). The analysis focused on 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. 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 were found to undergo cyclical seasonal moisture fluctuations consistent with expectations for buildings in the Nova Scotia climate. Specifically, the moisture content peaks in winter, with the greatest peak occurring in the first year post-retrofit, and with spikes that decrease over the subsequent years. A moisture spike that exceeds 20% in one winter does not typically damage the building so long as drying occurs in the warm season. Spikes above 20% that persist for several years indicate a potential for mould and eventual decay.

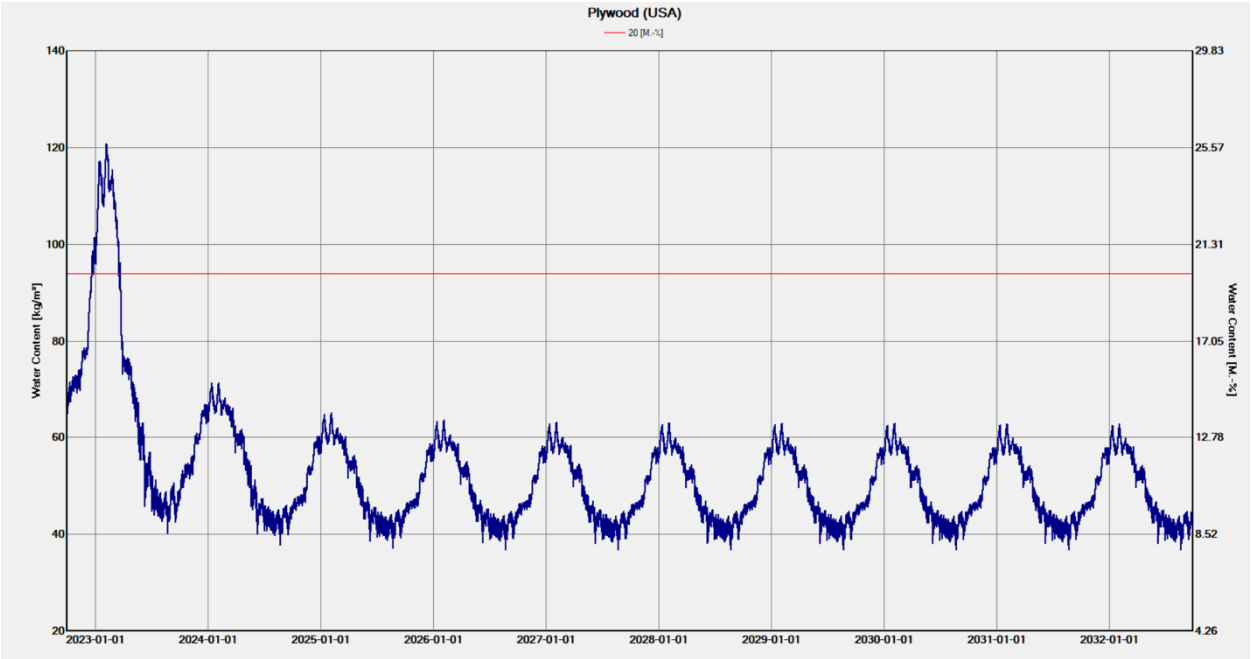


Figure 18 WUFI Pro output - Building A north wall (inner plywood layer)

The materials tested in all walls of the building follow a pattern like that shown in the graph in Figure 18, with a moisture content spike above 20% in the first winter and smaller spikes in subsequent years. This is an indication of good drying potential. The wall materials tested also demonstrate a low risk of mould.

The materials tested in the post-retrofit roof materials of both buildings follow a pattern like the one shown in Figure 19. The first year moisture spike in the plywood layer tested does not reach 20% moisture content, however the annual peak moisture is consistent from year to year. This is an indication that the material is undergoing seasonal moisture fluctuations but that it is not drying over time. Analysis in both roofs showed that relative humidity inside the ventilated attics reach nearly 100% in the plywood and at the surface of the cellulose layers in summer. The findings indicate that while the assembly may be a low risk for mould or decay, the design should prioritize generous air flow in the ventilated attics.

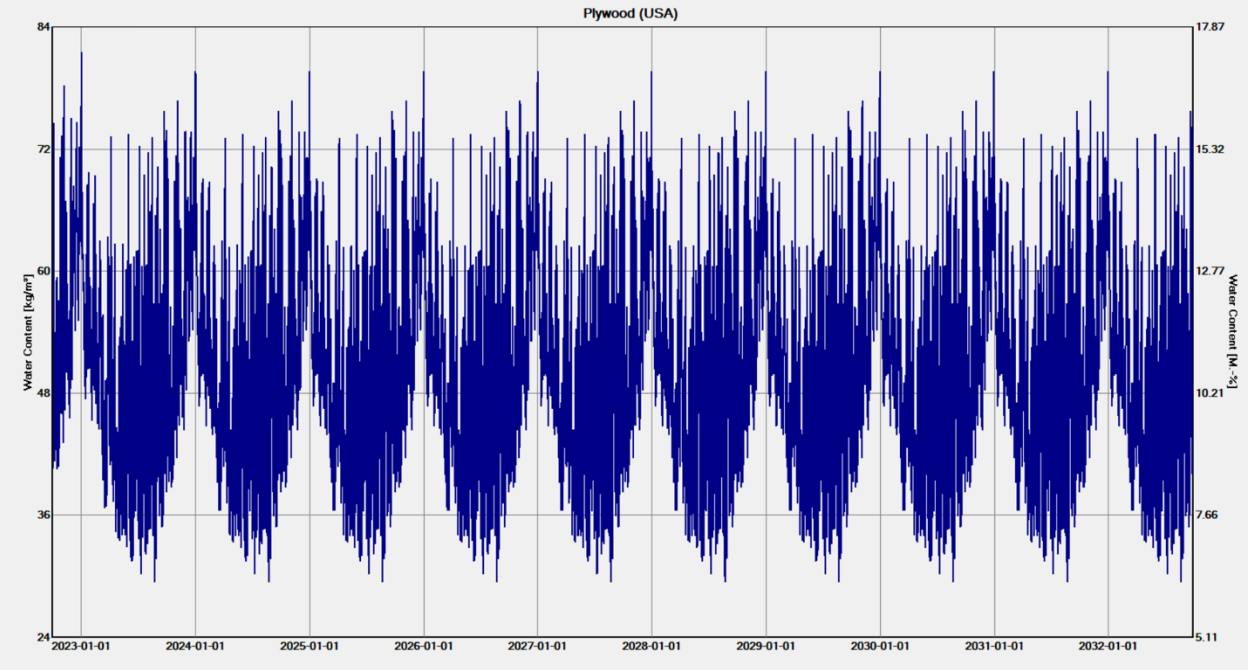


Figure 19 WUFI Pro output - Building B south roof (inner plywood)

Embodied Carbon

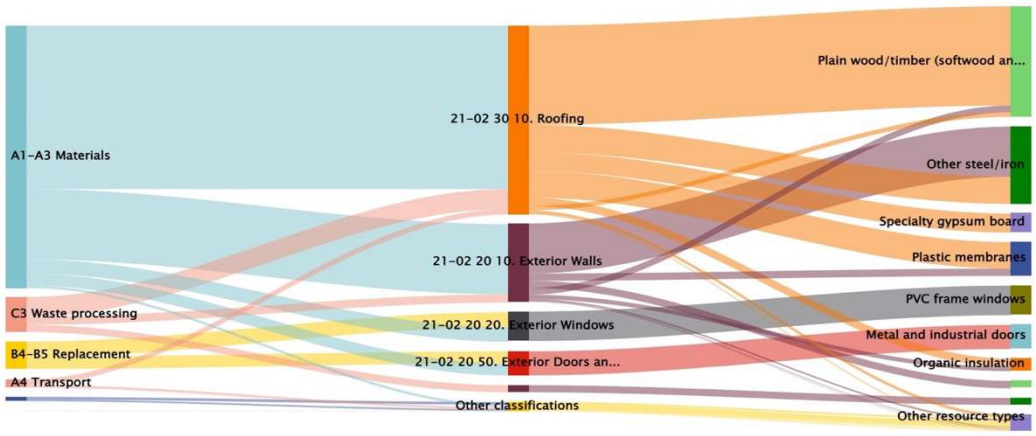


Figure 20 Global Warming by Stage and Material

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 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.

Table 4 Debert Water Utility Building Retrofit – Total Global Warming Potential

gross floor area m^2	A1-A3 $KgCO_2e/m^2$	A1-C4 $KgCO_2e/m2$	Biogenic carbon $KgCO_2e/m2$
720	**69.47**	**89.28**	**156.5**

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 global warming potential (GWP) in this design are the wood trusses and the steel cladding. The A1-A3 Materials stage contributed 78% of the total carbon emissions associated with this building as illustrated in Figure 21 & 22.

The biogenic carbon storage surpasses that of the A1-C4 emissions by 43%, making a surplus in carbon storage capacity as shown in Table 4. This storage is attributed to the wood products (92.7%) and cellulose insulation (7.3%) used in the assemblies (Figures 21 & 22).

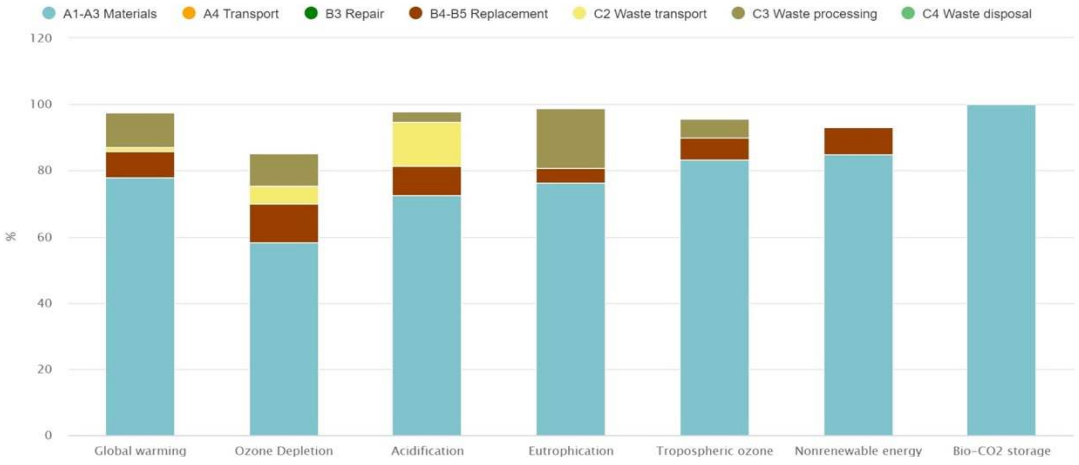


Figure 22 Life Cycle Impacts by Stage (%)

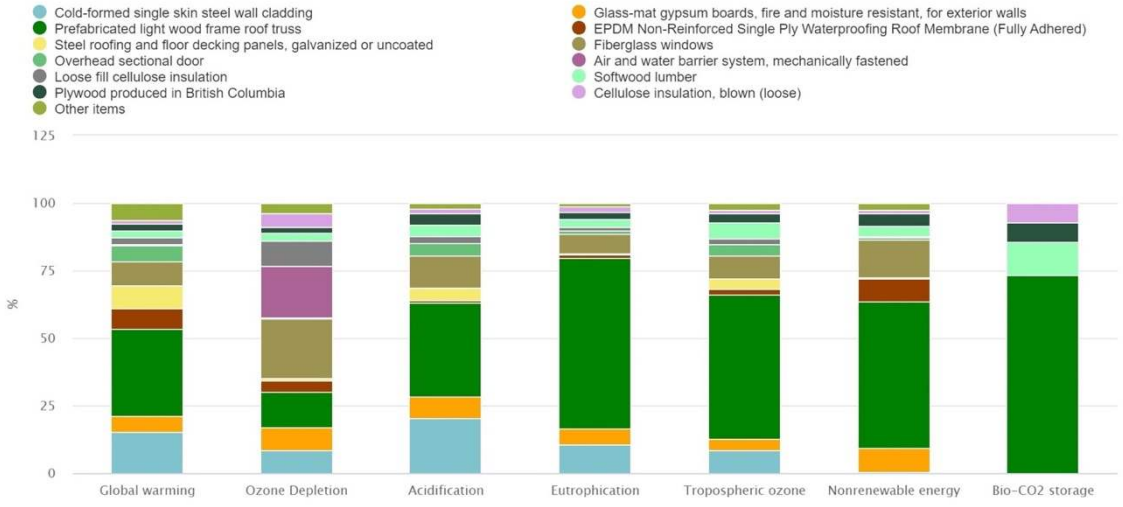


Figure 21 Life Cycle Impacts by Material (%)

Proposed Mechanical Systems

All scenarios:

- Two energy recovery ventilators (ERVs) will be added in Building A and Building B. They will be dual core type with approximately 90% heat recovery efficiency. Programmable time of day controls would run the ERVs.
- Cooling will be provided only to spaces that already have existing cooling.
- Cooling in Building A will continue to be provided by existing ASHPs.
- 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 continue to be provided by the existing combination of the oil-fired boiler and electric baseboard heaters. As the existing boiler still has some remaining useful life this avoids the replacement of the distribution system. The system still needs to be replaced by 2035 in this scenario.
    - Building B: office spaces upgrade to new two 0.75-ton mini split units
    - Domestic hot water will be supplied by the existing electric water heaters.
    - Existing building controls will remain with new time clocks to control the ERVs.
    - In the south office, an auxiliary heat relay system will control both the mini split unit and hydronic baseboards to ensure simultaneous heating and cooling does not occur.

2. Net Zero Energy Ready Scenario - ASHP:
    - Two 9-ton, cold climate air source heat pumps sized for 60% of the peak heating load.
    - 15 kW electric boiler sized for the remaining 40% of the load. Reducing the heat pump capacity to 60% of peak load typically results in the boiler providing 5 – 15% of heating.
    - Building B: office spaces upgrade to new mini split units.
    - Domestic water provided by a new 80-gallon heat pump water heater (HPWH)
    - The ASHP control system to operate circulation pumps and heat pumps.
    - In the south office, an auxiliary heat relay system will control the mini split unit and hydronic baseboards to ensure simultaneous heating and cooling does not occur.

3. Net Zero Energy Ready Scenario - GSHP:
    - 24-ton GSHP system, which has also been sized for 60% capacity. The GSHP option will use the existing hydronic baseboard heaters as the distribution method. Hydronic baseboard heaters will be installed in the north office.
    - 20 kW electric boiler, sized for the remaining 40% of the load.
    - Two water-to-air console heat pumps will be installed in the Building B offices to provide cooling.
    - Domestic hot water provided by a new 80-gallon heat pump water heater (HPWH).

Proposed Electrical Systems

1. Minimum Upgrade Scenario:
    - Existing electrical service to remain.
    - LED lighting upgrade with LED retrofit kits in all parts of the building.

2. Net Zero Energy Ready Scenarios
    - Service upgrade to power the existing loads plus added loads from newly electrified mechanical equipment and for solar photovoltaics.
    - New switchboard and distribution system upgrade.
    - Lighting replacement with LED fixtures throughout the building, with additional fixtures provided to under-illuminated areas.
    - Lighting control system upgrade to automatic lighting controls, complete with daylight sensors and vacancy sensors.

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

Nova Scotia Power Net Metering Program

The current NS Power net metering agreement has expired. An update to the program is currently being reviewed by the Nova Scotia Utility Review Board and Nova Scotia Power. Under the old agreement only 100kW of solar could be installed on any building. Under the new net metering agreement, it is proposed to allow up to 1MW of solar to be installed on any building that incurs a demand charge. There will be two new classifications of net metered systems in the new program, a class 1 system which is under 100kW and a class 2 system which is under 1MW.

In the net metering program, 100% of the excess energy generated from the solar array goes back onto the NSPI grid, and the customer gets a credit for the energy generated. Under the new proposal, the credit will be a percentage of the customers electricity rate for class 2 systems and will be equal to the customers electricity rate for class 1 systems. The credits automatically come off the power bill, further reducing the cost, the more solar that is installed. Being involved in a net-metering program is an essential part of achieving net-zero as it allows any excess energy generated to flow back onto the grid. This building would be considered a class 1 building due to the size of the PV array being proposed.

It is possible to install photovoltaics and not enroll in the net metering program. In this scenario, the building would draw power from the solar array as it is needed (up to the arrays maximum capacity). Any excess energy that is generated by the array is clipped (wasted) and no credit is given by the utility for that power. This scenario is only feasible if the customer routinely uses the approximate amount of power the array would generate. To optimize this, a short load study

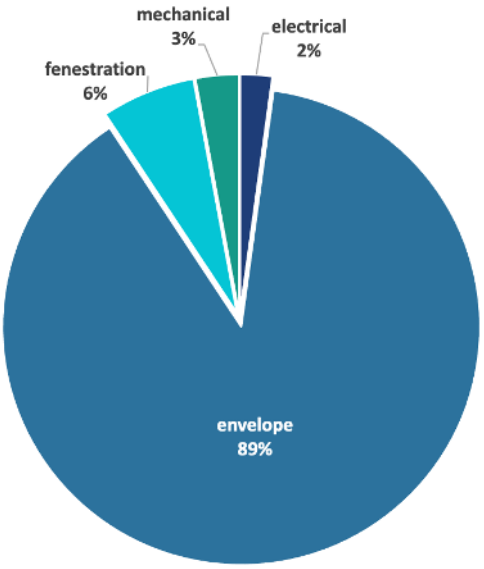
would be performed on the building to determine approximately how much energy is used at any given time of the day/ year, and an array of the average size could be constructed to offset that consumption. This scenario isn't truly considered net-zero since to use 100% of the energy generated, the solar array must overproduce.

The net-metered option is recommended to ensure that a net-zero system can be achieved. As the current conditions for the net-metering program are changing day to day, further consultation with Nova Scotia Power will be needed to ensure all requirements are met prior to construction.

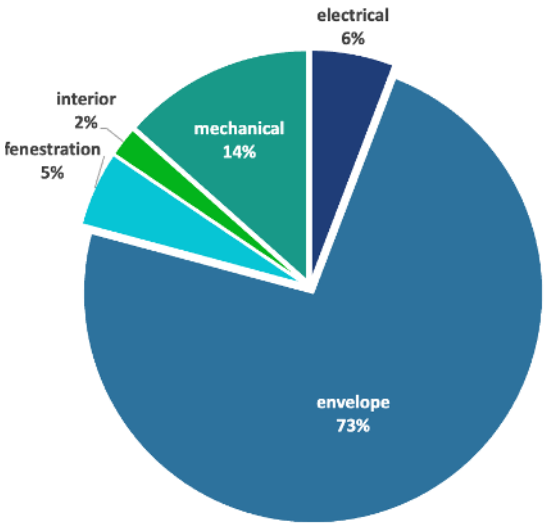
Construction Costs

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. A cost estimate for a fifth scenario, the Minimum Upgrade + Solar PV was extrapolated from data in the Class D estimates.

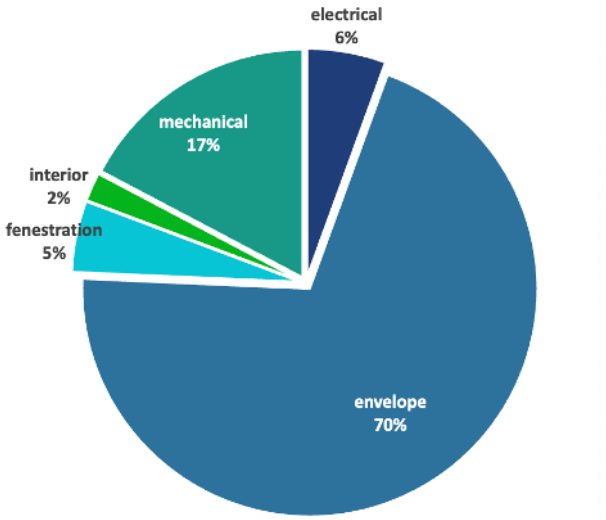
Minimum Upgrade	
Envelope	$1,737,399
Fenestration	$124,708
Mechanical	$57,427
Electrical	$42,466
total	**$1,962,000**



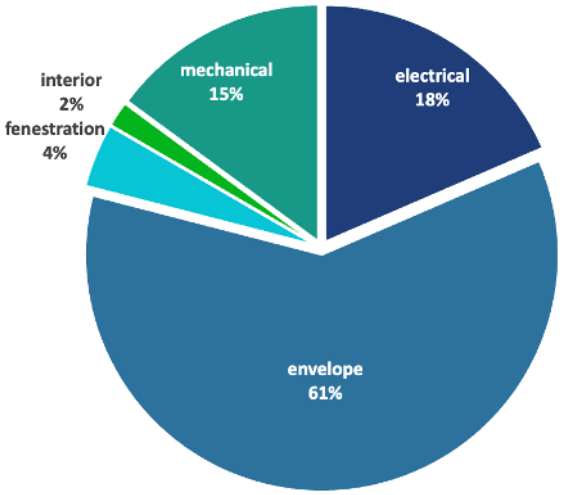
NZER ASHP	
Envelope	$1,737,200
Fenestration	$124,694
Interiors	$49,563
Mechanical	$318,433
Electrical	$137,810
total	**$2,367,700**



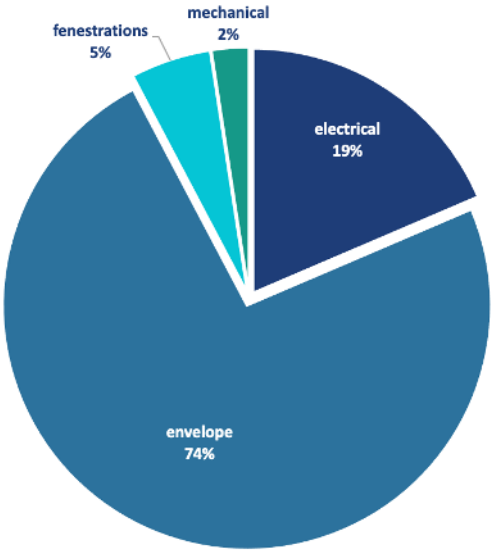
NZER GSHP	
Envelope	$1,736,879
Fenestration	$124,671
Interiors	$49,554
Mechanical	$427,837
Electrical	$137,785
total	**$2,476,725**



Net Zero Energy - GSHP	
Envelope	$1,736,759
Fenestration	$124,662
Interiors	$49,550
Mechanical	$427,807
Electrical	$531,220
total	**$2,869,998**



Net Zero Energy – Min. + PV	
Envelope	$1,737,399
Fenestration	$124,708
Mechanical	$57,427
Electrical	$437,567
total	**$2,357,101**



Total Cost of Building Ownership

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

A final scenario was modeled as part of the TCBO that was not considered in the earlier analysis, the Minimum Upgrade scenario plus solar. This was in part modeled because the construction costs for the NZER and NZE scenarios are higher than the building's estimated Cost Replacement Value (CRV) of $2.37M. This scenario resulted in the best TCBO for the building as it is the only scenario considered that saves money over the life of the building.

Table 5 Total Cost of Building Ownership (TCBO)

	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
GHG emissions (kg) (60 Years)	3,437,029	2,299,297	1,659,416	1,660,662	0	734029.32
EUI (kWh/m2/year)	220.6	123.5	57.5	57.5	0.0	69.3
TCBO at 60 years	**$9,076,000**	**$9,814,000**	**$10,363,000**	**$10,351,000**	**$10,408,000**	**$7,820,000**
TCBO Savings at 60 years	$0	-$738,000	-$1,287,000	-$1,275,000	-$1,332,000	$1,256,000
60 Year TCBO savings compared to Base Case		**-8%**	**-14%**	**-14%**	**-15%**	**14%**

Key Results:

- The base case TCBO is $9M, three times the CRV of $2.37M.
- The minimum upgrade scenario uses 44% less energy than the base case but adds 8% to the TCBO.
- The Net Zero Energy Ready options use 74% less energy but cost 14% more in lifetime operating costs.
- The Net Zero Energy retrofit provides 100% energy savings yet increases the TCBO by 15%.
- The lowest TCBO is the Minimum Upgrade plus PV which delivers a 68% reduction in EUI for a 14% TCBO savings of $1.25M.

Table 6 Operating Cost Summary

Utilities (including carbon tax)	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
Cost	$ 5,978,000	$ 3,782,000	$ 2,436,000	$ 2,438,000	$ 42,000	$ 1,523,000
Difference in Cost from A		$ (2,196,000)	$ (3,542,000)	$ (3,540,000)	$ (5,936,000)	$ (4,455,000)
Percentage Change Over Base Cost		-37%	-59%	-59%	-99%	-75%
Energy Cost ($/ft2)	$ 773.78	$ 489.54	$ 315.31	$ 315.57	$ 5.44	$ 197.13

Maintenance	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
Cost	$ 279,000	$ 174,000	$ 122,000	$ 122,000	$ 270,000	$ 313,000
Difference in Cost from A		$ (105,000)	$ (157,000)	$ (157,000)	$ (9,000)	$ 34,000
Percentage Change Over Base Cost		-38%	-56%	-56%	-3%	12%
Maintenance Cost ($/ft2)	$ 36.11	$ 22.52	$ 15.79	$ 15.79	$ 34.95	$ 40.51

Insurance & Taxes	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
Costs	$ 465,000	$ 465,000	$ 465,000	$ 465,000	$ 465,000	$ 465,000
Difference in Cost from A		$ -	$ -	$ -	$ -	$ -
Percentage Increase over Base Cost		0%	0%	0%	0%	0%

First Year Annual Maintenance	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
Cost	$ 2,400	$ 1,500	$ 1,150	$ 1,050	$ 2,324	$ 2,689
Difference in Cost from A		$ (900)	$ (1,250)	$ (1,350)	$ (76)	$ 289
Percentage Change Over Base Cost		-38%	-52%	-56%	-3%	12%
First Year Maintenance Cost ($/ft2)	$ 0.31	$ 0.19	$ 0.15	$ 0.14	$ 0.30	$ 0.35

- The 60-year utility costs for the Base Case are 2.5 times the CRV of the building.
- The NZR options reduce the 60-year utility costs by 59%.
- A Net Zero Energy retrofit reduces the energy costs by 99% to $42,000, which is the meter charge or minimum charge for the electrical service.
- The maintenance costs for all scenarios cost less than the base case because of the reduced maintenance costs for metal roof and siding compared with asphalt shingles and wood siding. Eliminating the boiler also represents significant maintenance savings.
- Insurance costs are the same for all options.

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.
- NS Power rates will increase by 7.1% in 2023 and 7.0% in 2024.
- Carbon tax for fuel oil came into effect in NS in 2023, it is calculated separately in the SEEFAR model and is not included in the fuel oil price.
- Carbon tax has been applied to electricity as it is expected to be passed on to the customer by NS Power.
- Solar panel maintenance is based on $28/kWdc/year.

Table 7 Capital Cost Summary

Initial Retrofit / HPB CostYear 1	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
Initial Cost	$ 95,000	$ 2,110,000	$ 2,687,000	$ 2,804,000	$ 3,720,000	$ 2,278,000
Difference in Cost from A		$ 2,015,000	$ 2,592,000	$ 2,709,000	$ 3,625,000	$ 2,183,000
Percentage Change Over Base Cost		2121%	2728%	2852%	3816%	2298%
Cost ($/ft2)	$ 12.30	$ 273.12	$ 347.80	$ 362.95	$ 481.51	$ 294.86

Maintenance Capital Costs 60 Years	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
Cost	$ 2,181,000	$ 1,530,000	$ 2,419,000	$ 2,192,000	$ 2,819,000	$ 1,349,000
Difference in Cost from A		$ (651,000)	$ 238,000	$ 11,000	$ 638,000	$ (832,000)
Percentage Change Over Base Cost		-29.85%	10.91%	0.50%	29.25%	-38.15%
Cost ($/ft2)	$ 282.31	$ 198.04	$ 313.11	$ 283.73	$ 364.89	$ 174.61

Retrofit / HPB + Maintenance Capital Costs 60 Years	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
Total Costs	$ 2,276,000	$ 3,640,000	$ 5,106,000	$ 4,996,000	$ 6,539,000	$ 3,627,000
Difference in Cost from A		$ 1,364,000	$ 2,830,000	$ 2,720,000	$ 4,263,000	$ 1,351,000
Percentage Change over Base Cost		59.93%	124.34%	119.51%	187.30%	59.36%

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 retrofits costs are high because of the extensive work on the building enclosure and new mechanical systems and solar panels. The NZE scenario costing $1M more than the CRV of the building.

Maintenance Capital is the cost of replacing major building components as they wear or age out. For example, the boiler needs to be replaced every 25 years. The costs to maintain the building in all scenarios is similar, at around $1M.

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 8 Annual Energy Consumption and GHGs

	Units	Base Case	Min Upgrade	NZR ASHP	NRZ GSHP	NZR ASH Solar	Min Solar
Annual Water Consumption	m3	0.0	0.0	0.0	0.0	0.0	0.0
Annual Sewer Discharge	m3	0.0	0.0	0.0	0.0	0.0	0.0
Annual Electric Consumption	kWh	43,240.00	38,937.00	41,279.00	41,310.00	41,279.00	38,973.00
Annual Gas Consumption	m3	-	-	-	-	-	-
Annual Heating Oil Consumption	Litres	10,632.00	4,594.00	-	-	-	4,594.00
GHG emissions	kg CO2 eq	57,283.82	38,321.61	27,656.93	27,677.70	-	12,233.82
Annual Solar PV generated	kWh	-	-	-	-	41,279.00	38,973.00
Total Annual Energy Consumption	ekWh	158,420.00	88,705.33	41,279.00	41,310.00	-	49,768.33
Total Annual Energy Consumption	GJ	570.31	319.34	148.60	148.72	-	179.17
EUI	kWh/m2/yr	220.64	123.55	57.49	57.53	-	69.32

Key Results:

- Electricity consumption, GHGs and EUI are decreased in all retrofit scenarios.
- Water consumption and sewer discharge were not measured. There may be an opportunity for savings by replacing plumbing fixtures, but that was not undertaken in this study.
- The Minimum Upgrade plus solar reduces GHG emissions by 78% and EUI by 68%
- Fuel oil is used in the Base Case, Minimum Upgrade and Minimum Upgrade + solar scenarios. Fossil fuel must be eliminated by 2035 to meet the Municipality of Colchester's emissions targets, and by 2050 to meet Canada's.

Cumulative TCBO

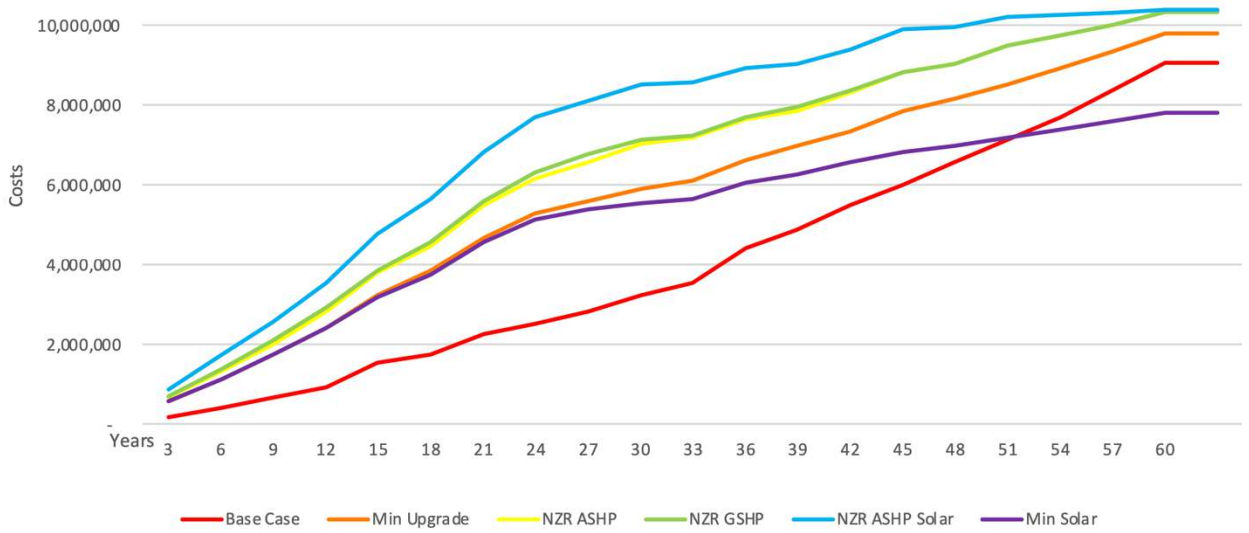


Figure 23 Cumulative TCBO

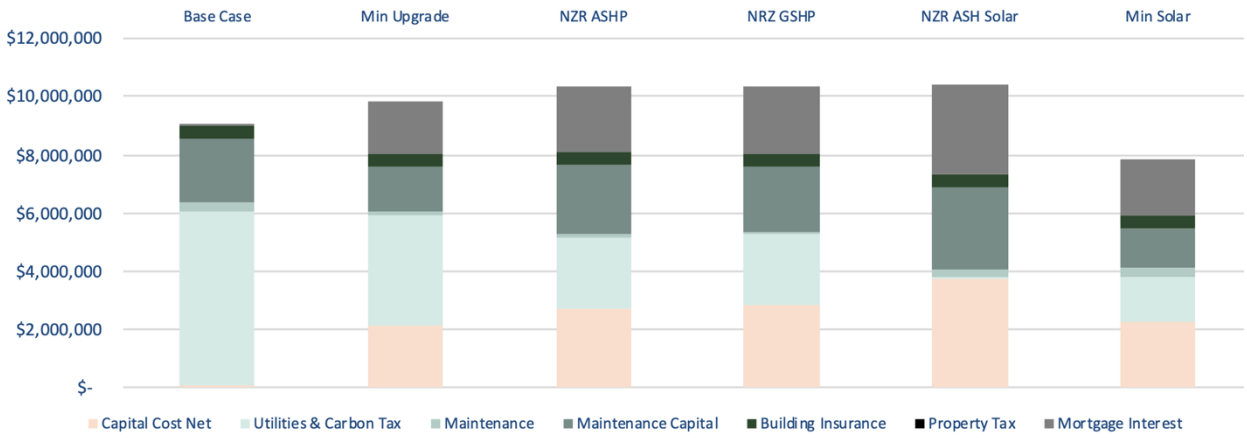


Figure 24 TCBO Comparison

The existing building has the lowest TCBO for the first 51 years, and the Minimum Upgrade with Solar scenario has lower costs for the remaining life of the building.

Discussion

There are two key issues we are trying to address in this study, reducing GHG emissions and minimizing the lifetime Total Cost of Building Ownership.

This results for this project are perhaps the most surprising out of the six buildings studied. All the retrofit scenarios initially developed represent a higher TCBO than the existing building. Adding solar panels to the Minimum Upgrade was the only way to achieve a positive TCBO. This indicates that the proposed retrofits and their capital costs need to be examined to find more savings.

The cost of the retrofits designed in this study are much higher than anticipated. It doesn't feel practical to invest over $\$400/ft^2$ to upgrade a building when a new facility could be built for similar money, however stopping emissions is about more than energy used for heating and cooling.

The embodied carbon emissions from the retrofit are 89 $kgCO_2e$. Embodied carbon data is not readily available for commercial buildings of this type, but this building is small enough that it can be evaluated at the scale of a large house. If the Debert Water Utility Facility were to be replaced by a new build with moderate carbon materials, its embodied carbon would be 108,000 $kgCO_2e$ based on a value of 150 $kgCO_2e$ per m^2.[7] This number doesn't include the embodied carbon content of the existing structure which would be sent to landfill, which contains significant amounts of concrete and steel. If our goal is to stop emissions today, evaluating every retrofit through the lens of embodied carbon is valuable.

The recommended retrofit is the Minimum Upgrade + solar with its 14% TCBO savings over the next 60 years. This retrofit maintains fuel-oil based heating equipment in the building, which must be removed by 2050 to meet Canada's net-zero goals. The costs to retrofit the heating system at that future date are not captured in the TCBO and may well offset the 14% savings achieved. For this reason this scenario is no more viable than the options with negative TCBOs.

This retrofit is not viable with the current numbers and further work should be done to identify a satisfactory retrofit pathway for the Debert Water Utility Facility.

[7] Passive Buildings Canada and Builders for Climate Action (2022) Emissions of Materials Benchmark Assessment for Residential Cosntruction Report. https://www.buildersforclimateaction.org/report---embarc-report.html

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.

The Minimum Upgrade scenario with the addition of solar, is the only option considered that resulted in a positive TCBO. The retrofit will cost 2.36M, which is $10,000 less than the cost replacement value of the building. It results in a 69% reduction in EUI and 79% reduction in GHGs and saves $1.3M over the life of the building.

The retrofit is not recommended until a more cost effective approach can be identified.

[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