PANELIZED DEEP RETROFITS OF MUNICIPAL BUILDINGS

Sir John Colborne Recreation Centre for Seniors

Case Study Report

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OAKVILLE

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ReCover

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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.

PANELIZED DEEP RETROFITS OF MUNICIPAL BUILDINGS

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

ROI

36 Years

When whole building cost of doing nothing exceeds whole building cost of deep retrofit.

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 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.

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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 Report*, https://www.recoverinitiative.ca/about-us/our-results/report-request

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 1 Sir John Colborne Centre

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.

Figure 2 Site Plan

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.

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

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.

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.

Cellulose insulation has a Class 1 fire rating, which is the best fire rating for materials with the lowest level of risk. It is treated with borate which acts as both a fire retardant and pest repellant.

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

	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)

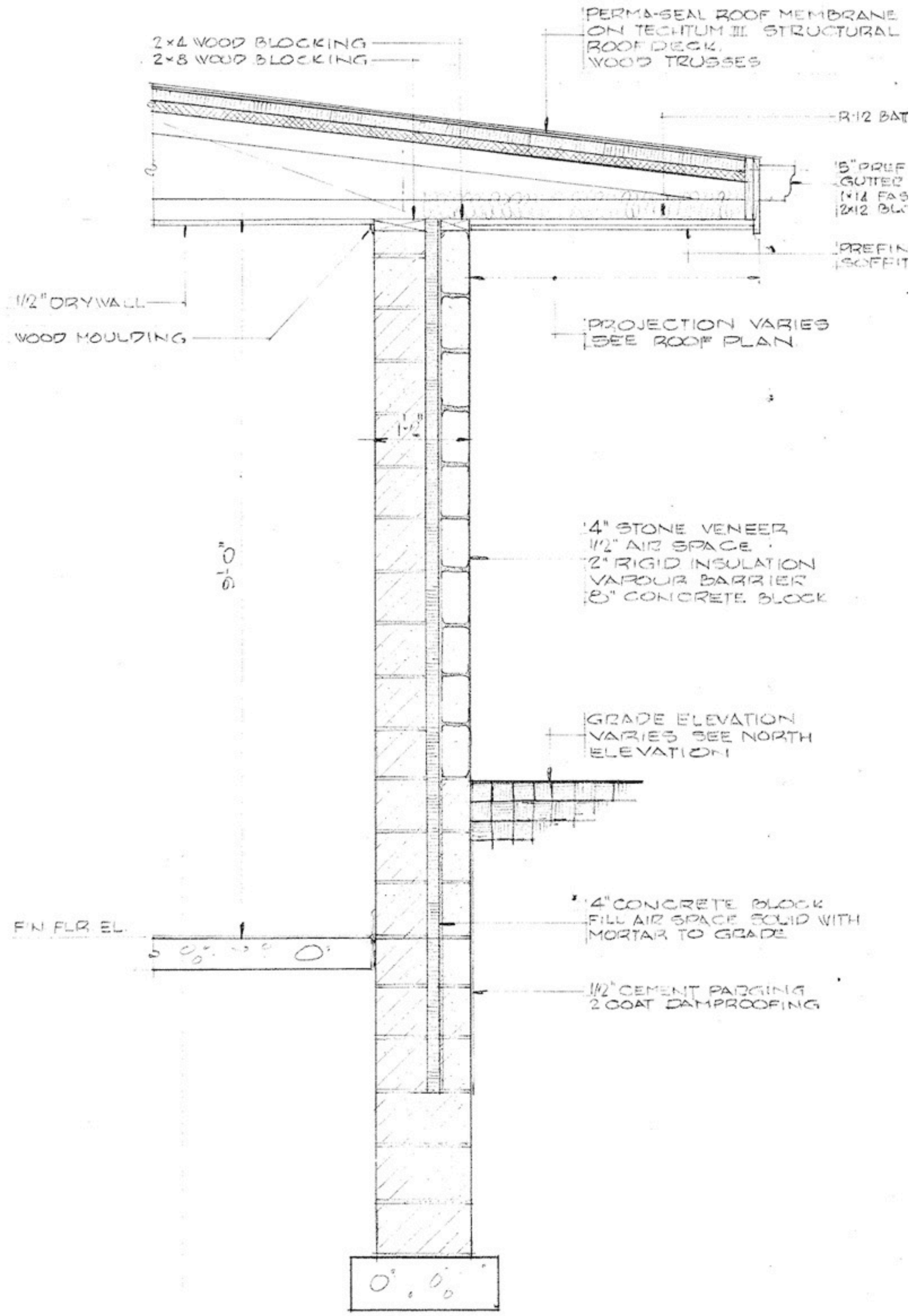

Figure 3 CMU wall and roof section

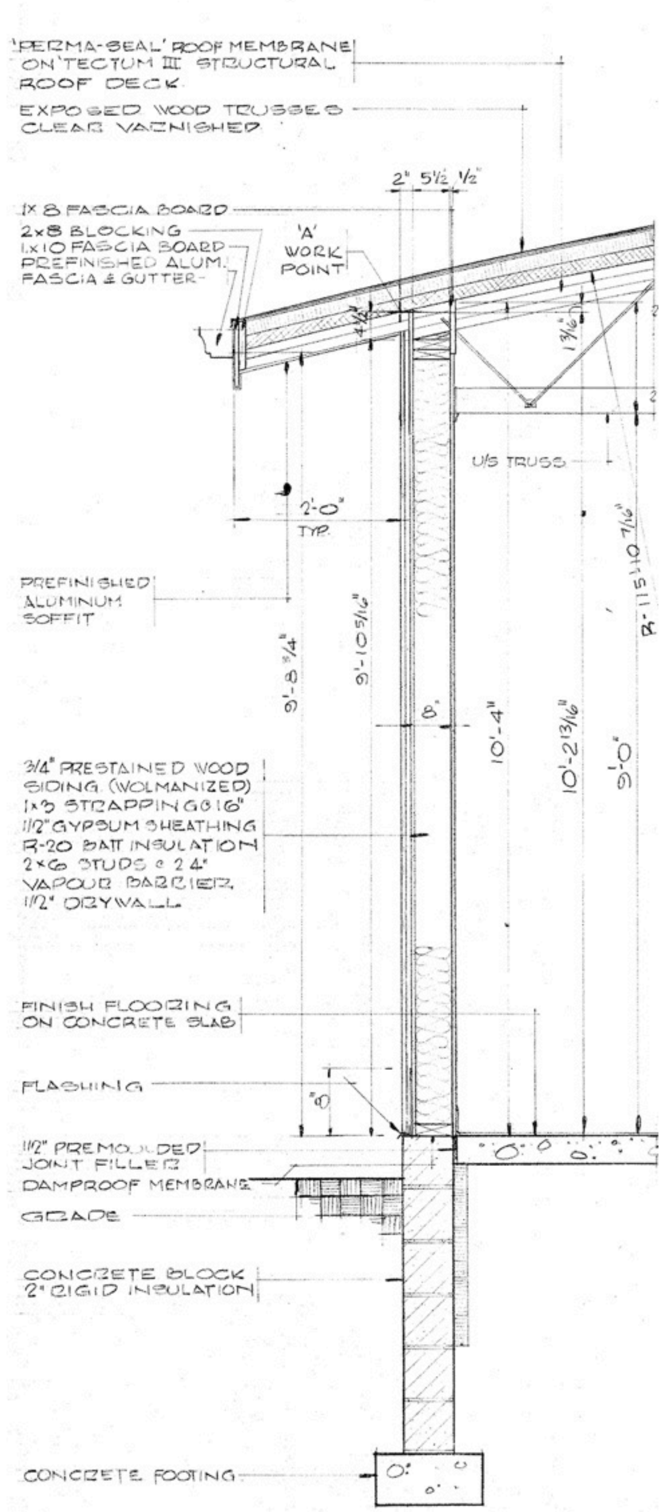

Figure 4 Sir Wood framed wall and truss roof.

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 the added loading of prefabricated panels.

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 originally variable volume and temperature (VVT) units that were retrofitted in 2018. Rooms along the south and east sides have had electric baseboards installed because of occupant comfort complaints. An electric fireplace and electric baseboards are also installed 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 corner of punched windows, is reported to be uncomfortably warm in summer.

Figure 5 Lounge Area

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.

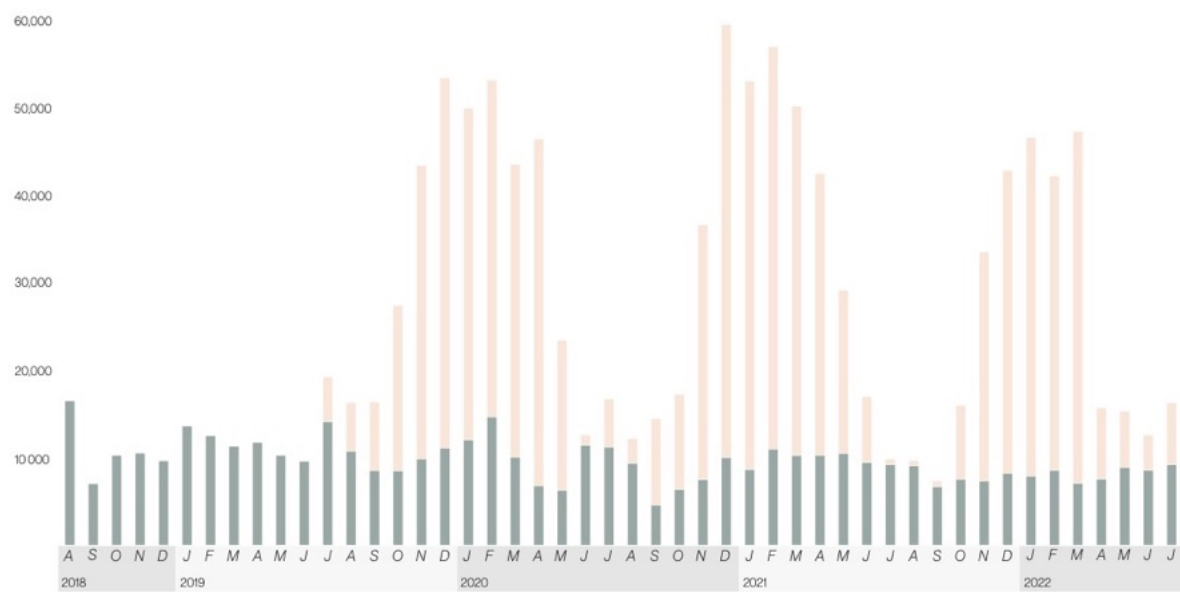

Figure 6 Historical Energy Use

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 Town 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 7). The modeled consumption deviates from existing electrical usage by 2.7% and natural gas consumption by 26%.

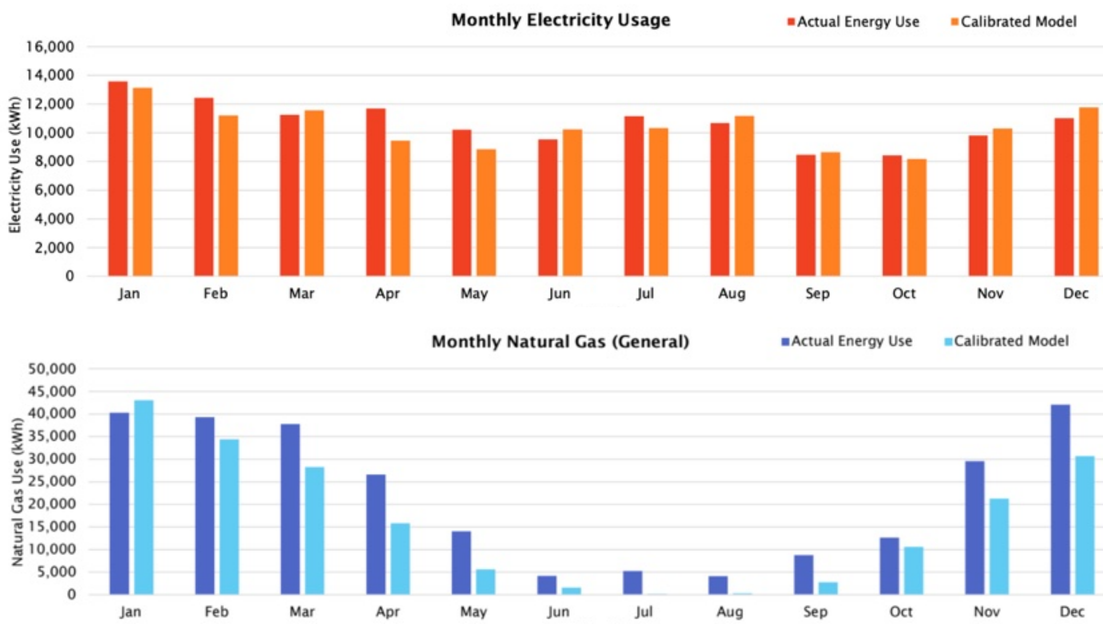

Figure 7 Calibrated Energy Use

The Thermal Energy Intensity Demand (TEDI) provides a breakdown of heat losses by building component in the existing building (Figure 8). Heat losses through the building enclosures account for 55% of heat losses and ventilation accounts for the remaining 45%.

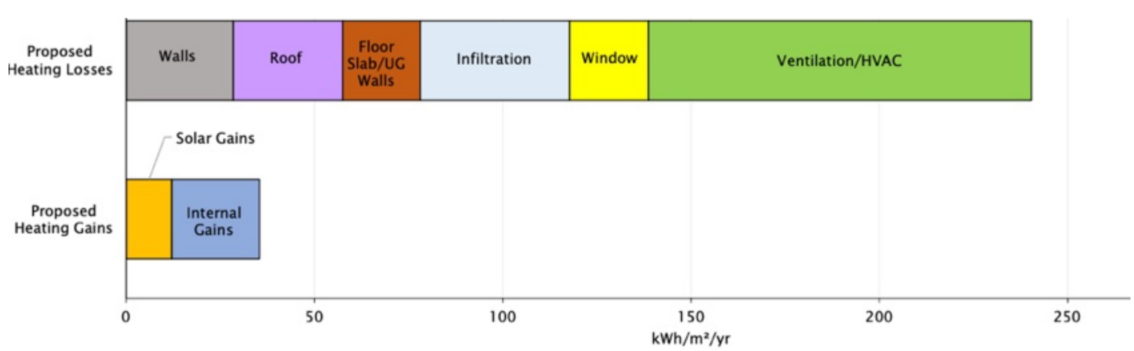

Figure 8 Thermal Energy Demand Intensity kWh/m²/yr

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.

Details of the retrofit scenarios are summarized in Table 2.

Table 2 Retrofit Scenario Summary

	Existing Building	Minimum Upgrade	NZE – ASHP[1]	NZE – GSHP[11]
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·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.

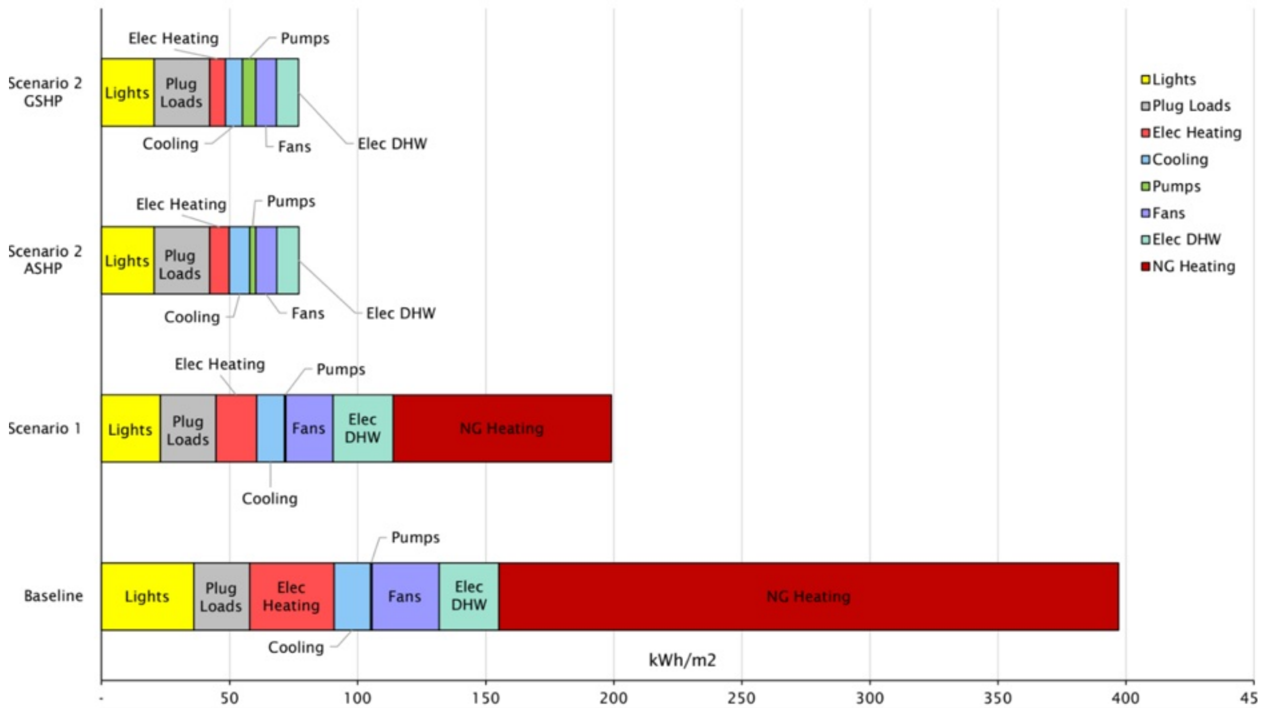

Figure 9 Total Energy Use Intensity (TEUI)

The **Total Energy Use Intensity** (TEUI) of the Sir John Colborne Centre is 397.1 ekWh/m^2/yr (figure 9). 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%

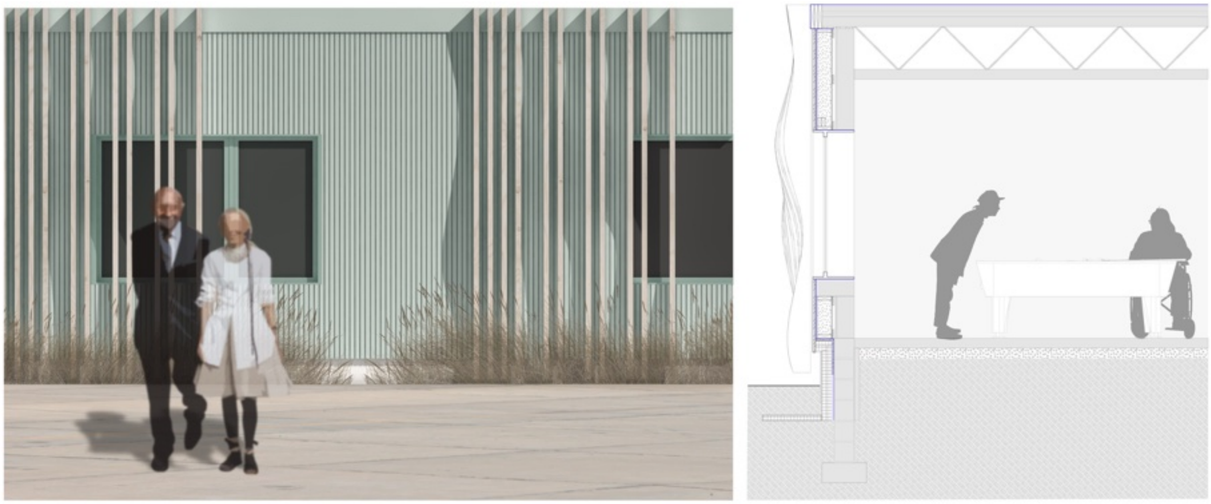

Figure 10 Design Concept partial elevation and section.

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 minimize moisture risks by shedding precipitation on the outside and by promoting drying activity to the exterior through the panel assembly. This is important as the existing assemblies include vapour retarding materials, including polyethylene vapour barrier and rigid foam insulation, which will inhibit drying to the interior of the building. These materials will also inhibit outward vapour drive, from the interior into the panels, however given the age and condition of the building it is highly unlikely that these materials comprise a continuous vapour barrier. The panels are be designed to promote any moisture movement that occurs from the interior to dry to the exterior.

Strapping on the interior side of the panel permits fitting adjustments against the existing walls and provides an internal air cavity that serves as a moisture buffer space for vapour diffusion from the inside to pass out through the panels. The frame backing layer is a “smart” vapour control membrane which varies in permeability depending on the relative humidity of its environment. If moisture is present between the panel and the existing walls the membrane fibers open to let moisture escape. Wood panel framing, plywood sheathing and cellulose insulation are all hygroscopic materials, meaning their fibers transport moisture from areas of higher humidity to those of lower humidity. A vapour-open water-resistive barrier (WRB) protects the outer plywood sheathing and provides a drainage plane behind the rainscreen cavity and metal siding.

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

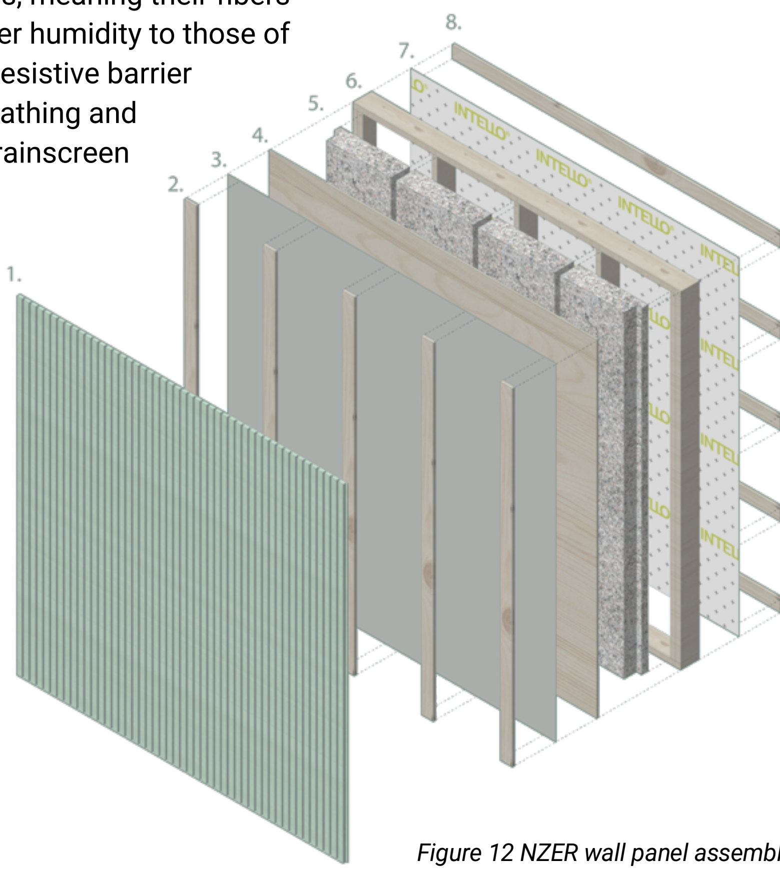

Figure 12 NZER wall panel assembly.

[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 13).

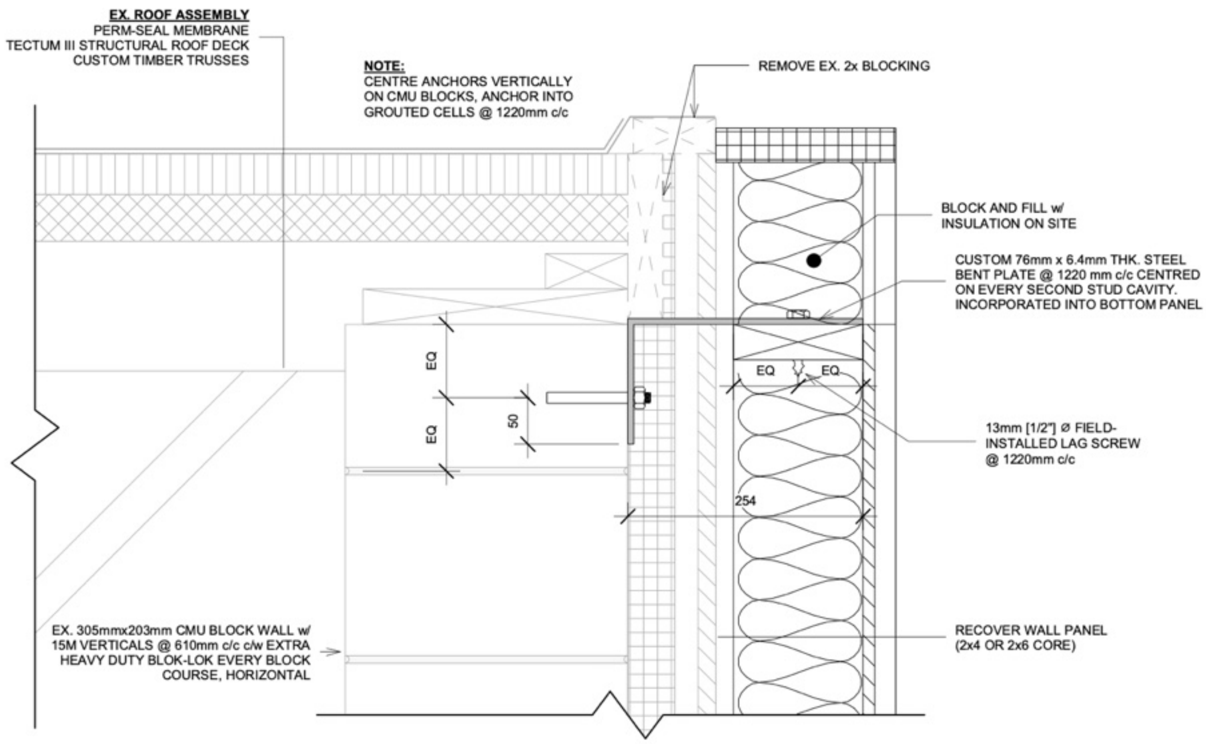

Figure 13 panel connection to CMU wall at roof

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 14).

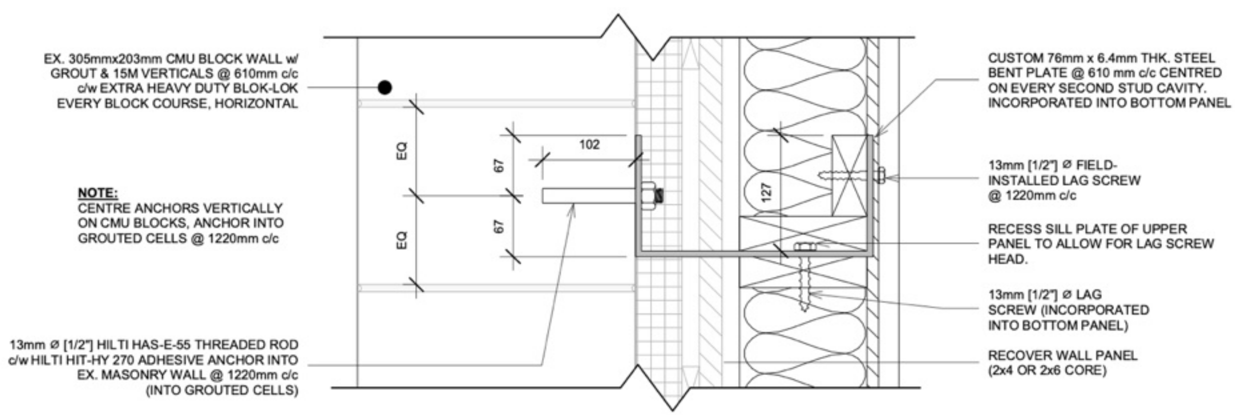

Figure 14 mid-height panel connection

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 15) The panels are supported at the base by a steel bent plate lintel fastened to the existing concrete foundation wall (Figure 16).

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

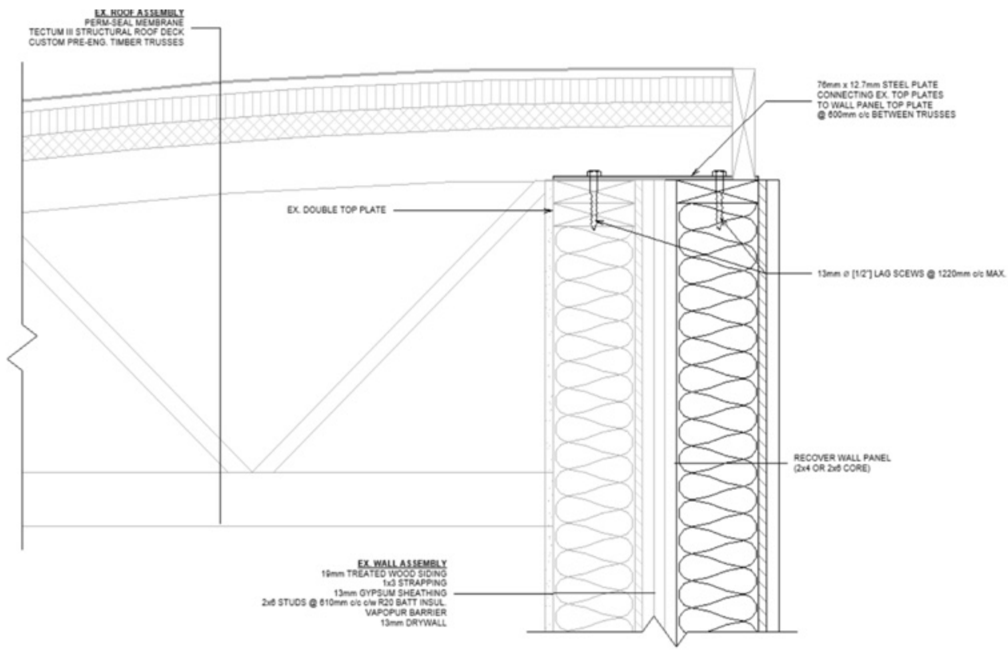

Figure 15 panel connection to wood framed walls at roof

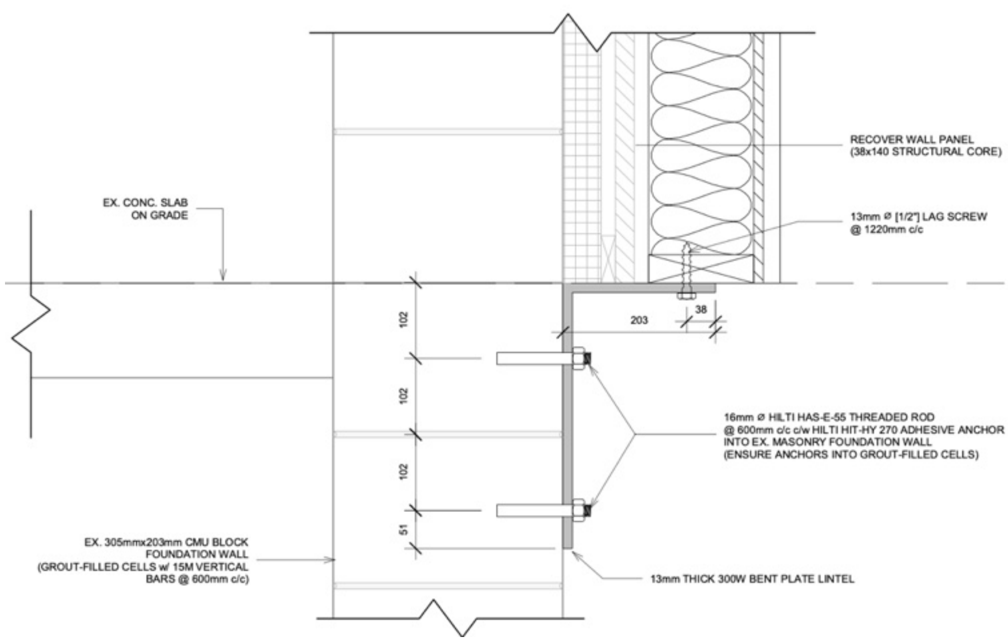

Figure 16 mid-span panel connection

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.

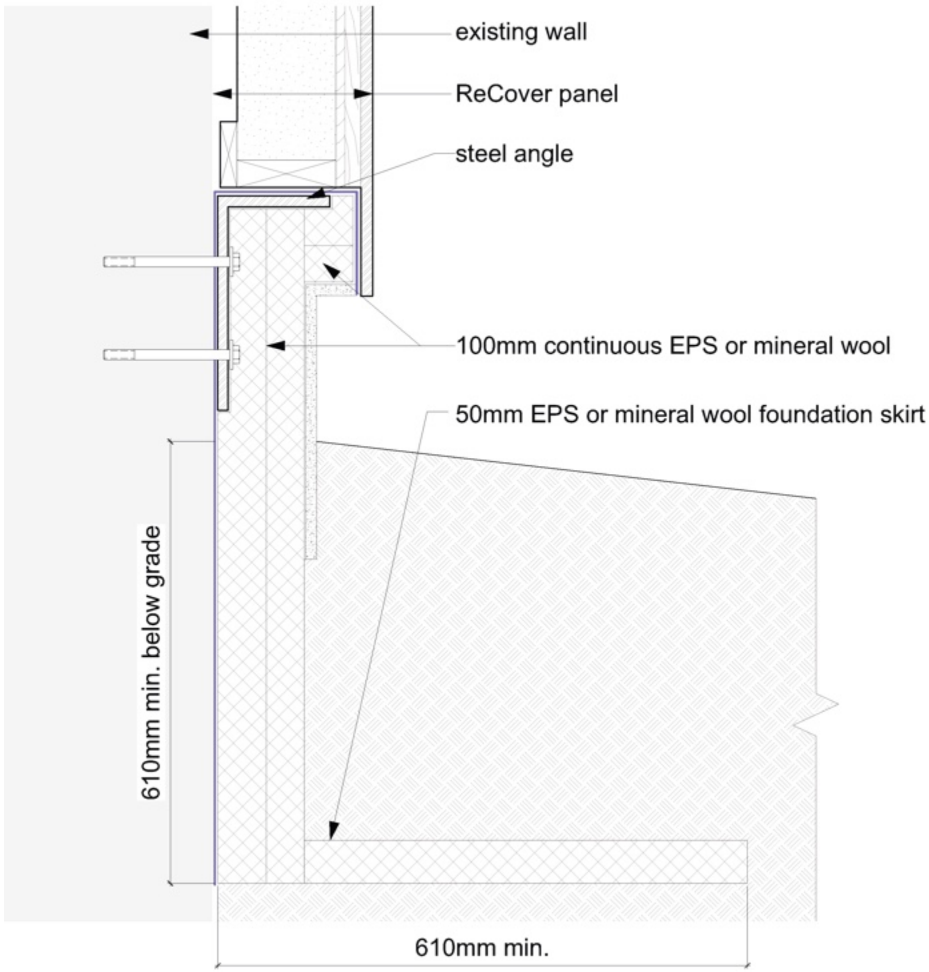

Figure 15 foundation insulation

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 if drying occurs in the summer. Spikes above 20% that persist for several years indicate a potential for mould and eventual decay.

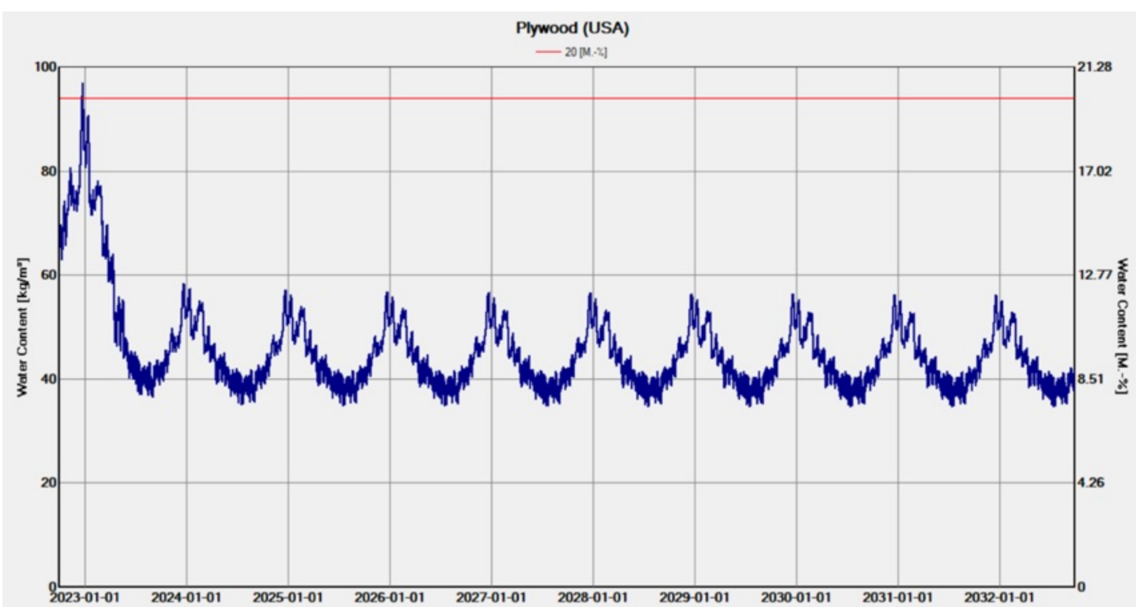

Figure 16 WUFI output – panel on west CMU wall (inner plywood layer)

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 18.

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 19.

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.

If the retrofit proceeds, is recommended that hygrothermal monitoring be implemented on selected assemblies to verify actual performance against modeling

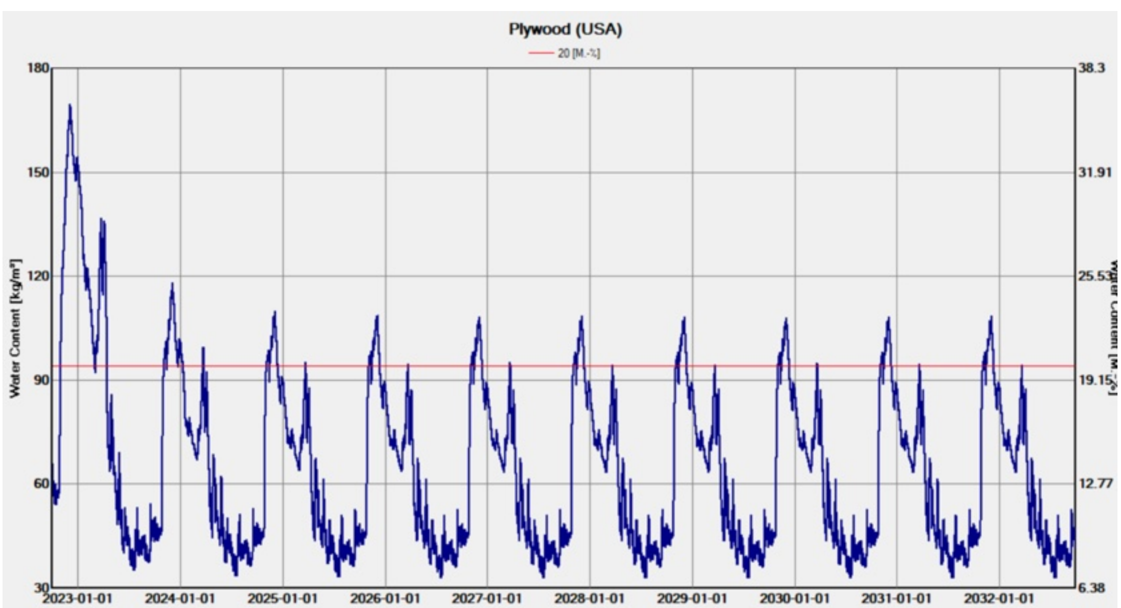

Figure 17 WUFI output - panel on northeast timber wall (outer plywood layer)

Embodied Carbon

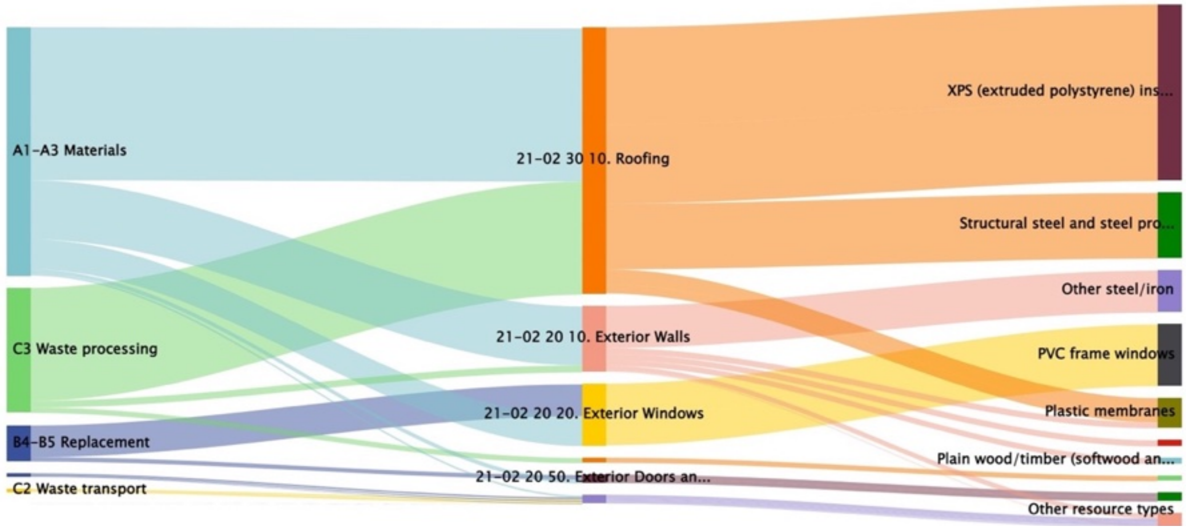

Figure 18 Global Warming by Stage and Material - NZER Retrofit

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 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 20 & 21. 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 22).

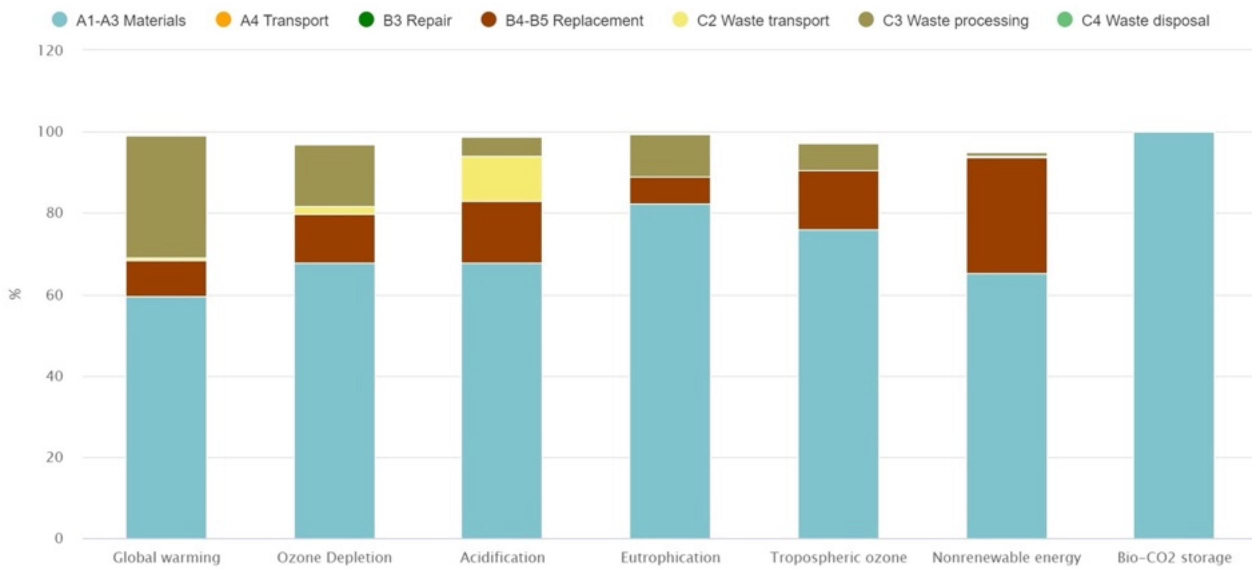

Figure 19 Life Cycle Impacts by Stage (%) – NZER Retrofit

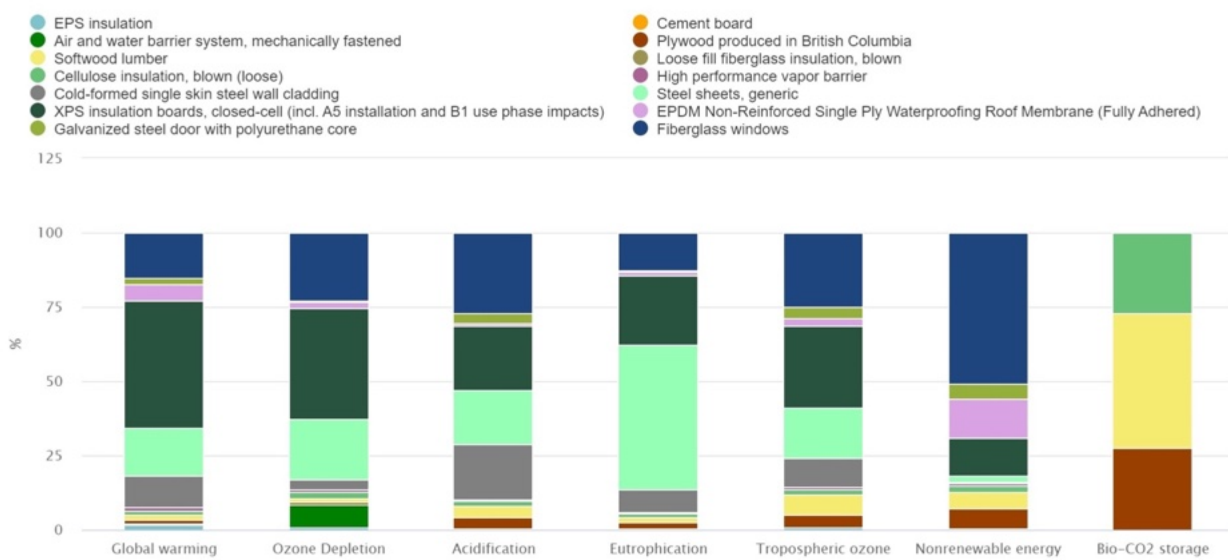

Figure 20 Life Cycle Impacts by Material (%) –NZER Retrofit

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 new CO_2 sensors for demand-controlled ventilation. An auxiliary heat relay system will be installed to control both rooftop units and electric baseboard heaters to ensure simultaneous heating does not occur.

NZER 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 dual core, 90% efficiency heat recovery ERVs will be added. 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. NZER 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
    - Changes noted in the NZER scenarios above.
    - 63 kW (DC) solar pv array (ground or wall mount[5]).

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.

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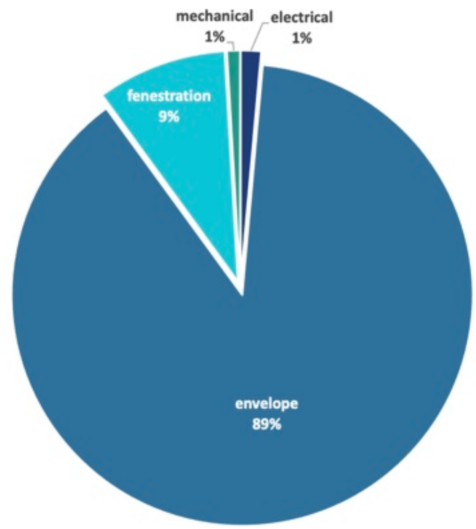
[5] The roof is unable to support roof mounted solar panels. The Town of Oakville is not in favour of installing a ground mounted solar array on this site. Subsequent phases of the project must continue the discussion with the town to decide how best to supply the 63kW needed. Options include reinforcing the roof structure, installing wall mounted building-integrated photovoltaics (BIPV) or installing a ground mount array on a different site to offset the electricity used.

Construction Costs

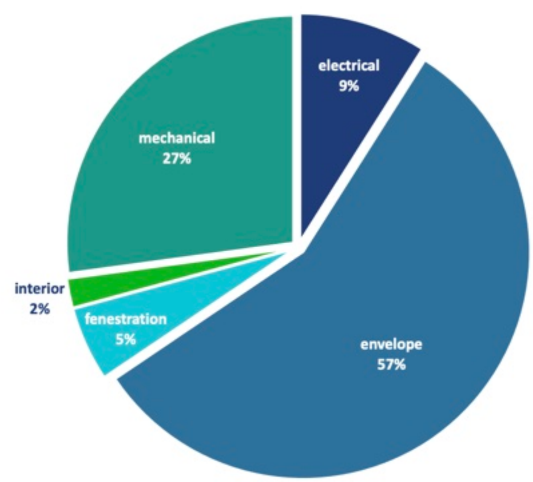
Class D – Feasibility Cost Estimates (Appendix M) were obtained for the Minimum Upgrade, the two Net Zero Energy Ready scenarios and Net Zero Energy retrofit scenarios. The costs include all materials, labour, equipment, overheads, general conditions, plus markups and contractor's profit for the retrofit options. Pricing reflects competitive bids for every element of the work for a project of this type procured under an open market stipulated lump sum bid contract in Debert, Nova Scotia.

A Class D estimate is an indicative estimate of the final project costs and is expected to be within ±25% of actual costs.

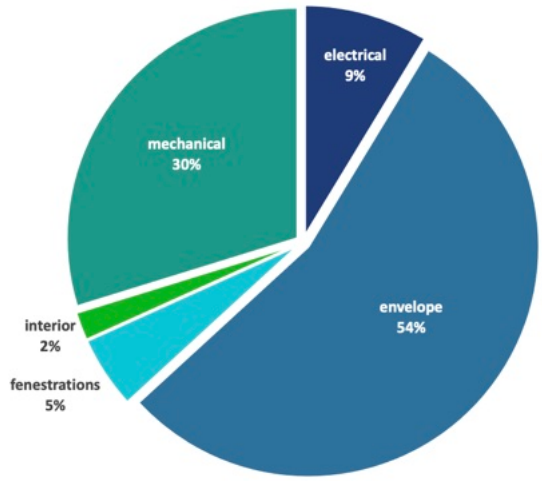
Minimum Upgrade	
Envelope	$1,916,293
Fenestration	$197,003
Mechanical	$19,906
Electrical	$30,800
total	**$2,164,002**



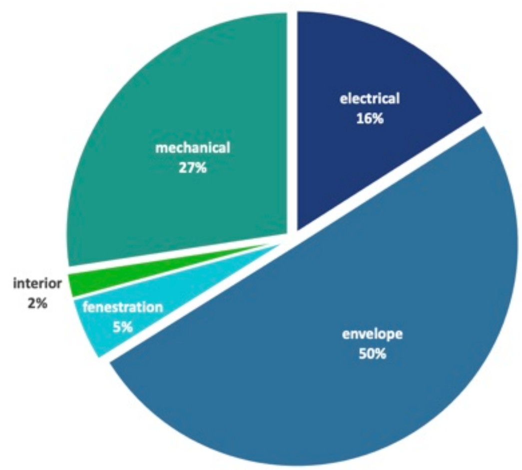
Net Zero Energy Ready ASHP	
Envelope	$2,117,130
Fenestration	$196,935
Interiors	$76,971
Mechanical	$1,016,244
Electrical	$337,718
total	**$3,744,998**



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 Sustainable Energy Efficient Facility Asset Renewal (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.

The following tables present a comparative analysis of the existing **base case** TCBO and each of the retrofit scenarios explored by the design team. The base case TCBO was evaluated based on the current condition of the building and the maintenance and renewal that would be required for the next 60 years for all components of the building, including interior elements. The TCBO for each retrofit scenario was modeled based on the design details, modeled energy performance and construction cost estimates for the retrofit scenarios outlined in this report.

Table 5 TCBO Summary

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
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
% diff. from 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 NZER options use 80% less energy but offer less than 10% savings in lifetime operating costs.
- The NZE retrofit provides 100% energy savings and saves $2.75M in lifetime operating costs.
- The best TCBO is achieved in the NZE Retrofit.

Table 6 Operating Cost Summary	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Utilities (including carbon tax)					
Cost	$ 8,018,000	$ 5,518,000	$ 3,717,000	$ 3,704,000	$ 1,725,000
Diff. from Base Case	$ -	$ (2,500,000)	$ (4,301,000)	$ (4,314,000)	$ (6,293,000)
% diff from Base Case	0%	-31%	-54%	-54%	-78%
Energy Cost ($/ft2)	$ 926.94	$ 637.92	$ 429.71	$ 428.21	$ 199.42
Maintenance					
Cost	$ 460,000	$ 587,000	$ 774,000	$ 762,000	$ 969,000
Diff. from Base Case	$ -	$ 127,000	$ 314,000	$ 302,000	$ 509,000
% diff from Base Case	0%	28%	68%	66%	111%
Cost ($/ft2)	$ 53.18	$ 67.86	$ 89.48	$ 88.09	$ 112.02
Insurance & Taxes					
Costs	$ 590,000	$ 590,000	$ 590,000	$ 590,000	$ 590,000
Diff. from Base Case	$ -	$ -	$ -	$ -	$ -
% diff from Base Case	0%	0%	0%	0%	0%
First Year Annual Maintenance					
Cost	$ 3,950	$ 5,050	$ 6,650	$ 6,550	$ 8,333
Diff. from Base Case	$ -	$ 1,100	$ 2,700	$ 2,600	$ 4,383
% diff from Base Case	0%	28%	68%	66%	111%
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 NZE 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 7 Capital Cost Summary	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Initial Retrofit / HPB CostYear 1					
Initial Cost	$ 12,000	$ 2,316,000	$ 3,991,000	$ 4,161,000	$ 4,413,000
Diff. from Base Case	$ -	$ 2,304,000	$ 3,979,000	$ 4,149,000	$ 4,401,000
% diff from Base Case	0%	19200%	33158%	34575%	36675%
Cost ($/ft2)	$ 1	$ 268	$ 461	$ 481	$ 510
Maintenance Capital Costs 60 Years					
Cost	$ 11,238,000	$ 9,013,000	$ 9,866,000	$ 9,870,000	$ 9,870,000
Diff. from Base Case	$ -	$ (2,225,000)	$ (1,372,000)	$ (1,368,000)	$ (1,368,000)
% diff from Base Case	0%	-20%	-12%	-12%	-12%
Cost ($/ft2)	$ 1,299	$ 1,042	$ 1,141	$ 1,141	$ 1,141
Retrofit / HPB + Maintenance Capital Costs 60 Years					
Total Costs	$ (11,250,000)	$ (11,329,000)	$ (13,857,000)	$ (14,031,000)	$ (14,283,000)
Diff. from Base Case	$ -	$ (79,000)	$ (2,607,000)	$ (2,781,000)	$ (3,033,000)
% diff from Base Case	0%	-1%	-23%	-25%	-27%

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 8 Annual Energy Consumption	Units	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Water	m3	1,216.00	1,216.00	1,216.00	1,216.00	1,216.00
Sewer Discharge	m3	-	-	-	-	-
Electric	kWh	124,695.00	91,482.00	63,324.00	62,922.00	62,922.00
Gas	m3	18,814.00	6,631.00	-	-	-
Heating Oil	Litres	-	-	-	-	-
GHG emissions	kg CO2 eq	38,908.28	14,901.57	1,583.10	1,573.05	-
Solar PV generated	kWh	-	-	-	-	62,922.00
Total	ekWh	319,106.33	160,002.33	63,324.00	62,922.00	-
Total	GJ	1,148.78	576.01	227.97	226.52	-
EUI	kWh/m2/yr	**396.90**	**199.01**	**78.76**	**78.26**	-

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

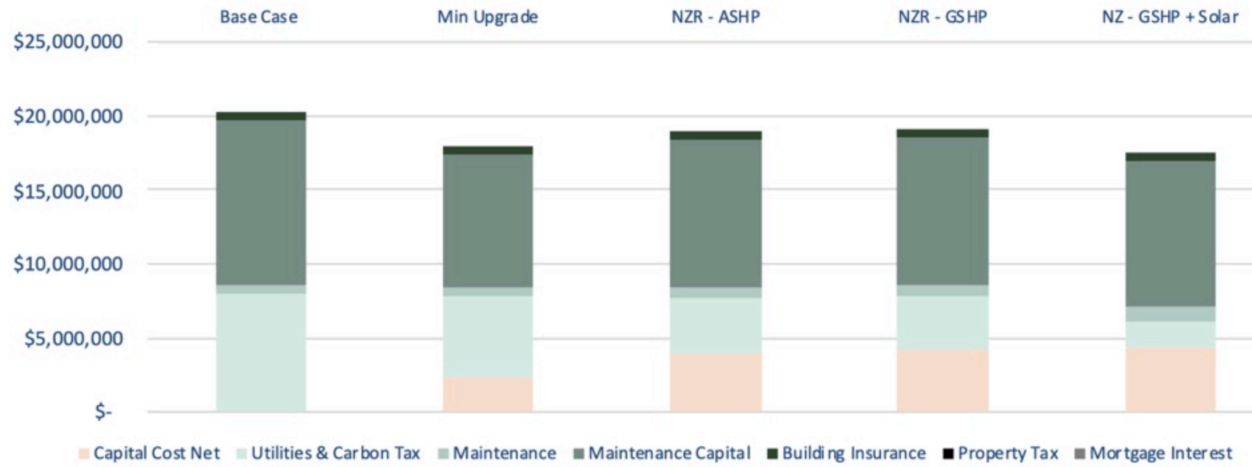


Figure 21 TCBO Comparison

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.

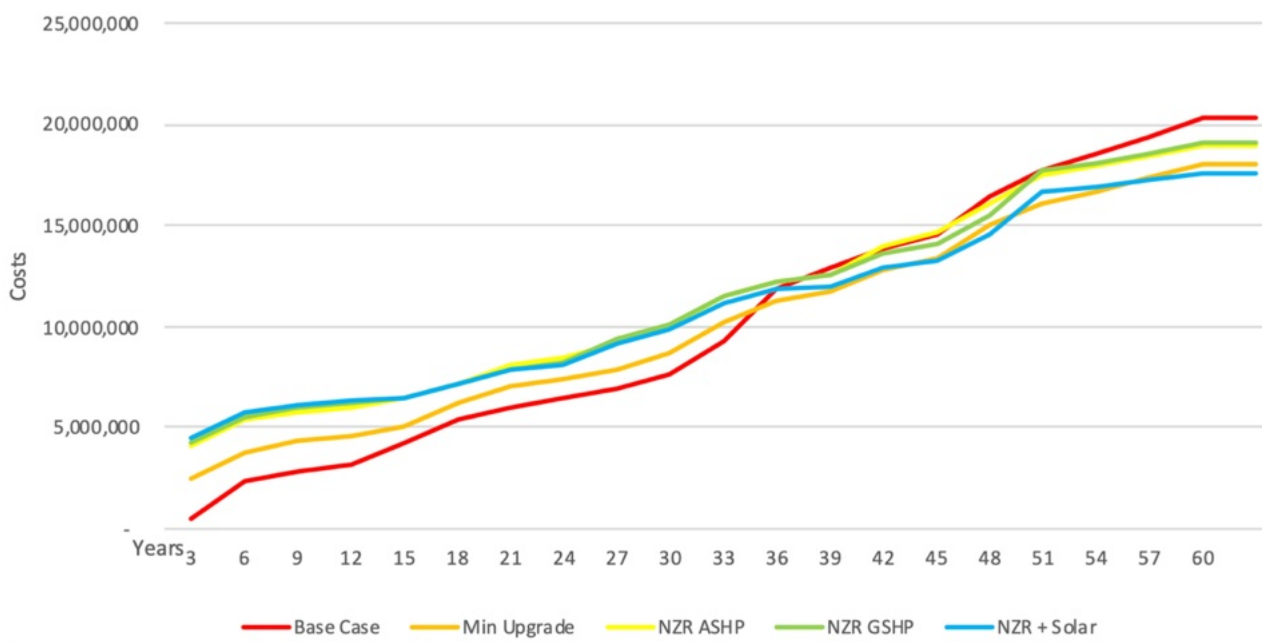


Figure 22 Cumulative TCBO

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 support the 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 Colborne 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 all retrofit scenarios explored 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 $kgCO_2e$[6]. 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[7] (excluding high EUI uses e.g., 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 significantly more robust.

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.

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

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

Conclusions

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

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

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

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

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

Over a period of four years, Energiesprong reduced the cost of their deep retrofits by 50% and decreased the amount of time retrofit buildings from months down to a matter of days. Investment in developing the skills, technologies, supply chain and financial tools to complete retrofits systematically, like Energiesprong, is our best chance to reducing the high cost of deep retrofits and to build momentum for deep retrofits in Canada.

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

Deep GHG reductions are very achievable in municipal buildings. A Net Zero Energy retrofit to Sir John Colborne Seniors Centre can prevent nearly 40,000 kg$C0_2$e 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.

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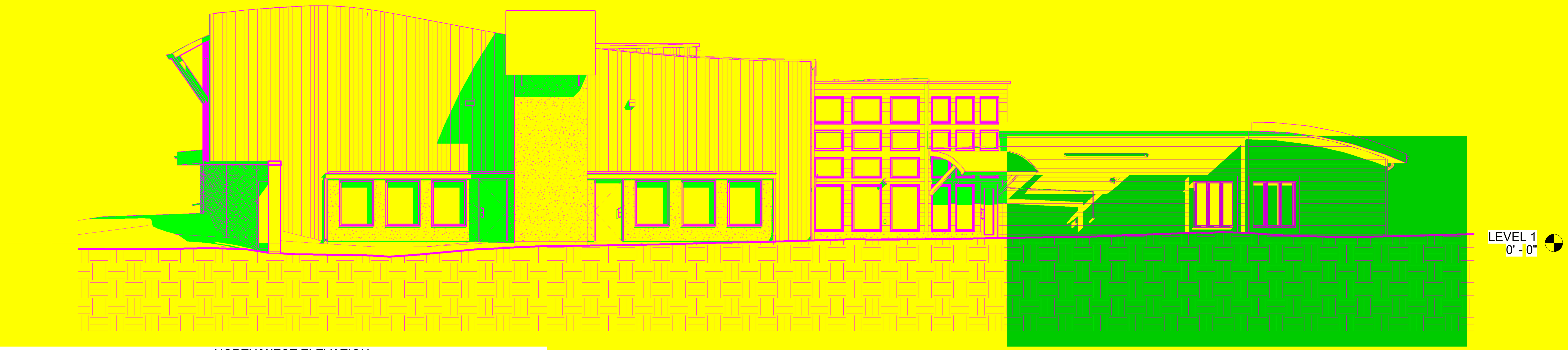
[8] ReCover Initiative (2020) *ReCover Phase One Case Study Report* and ReCover Initiative (2022) *Scarlettwood Court Deep Retrofit Case Study Report*, https://www.recoverinitiative.ca/about-us/our-results/report-request

Appendix A

Pre-retrofit Drawings

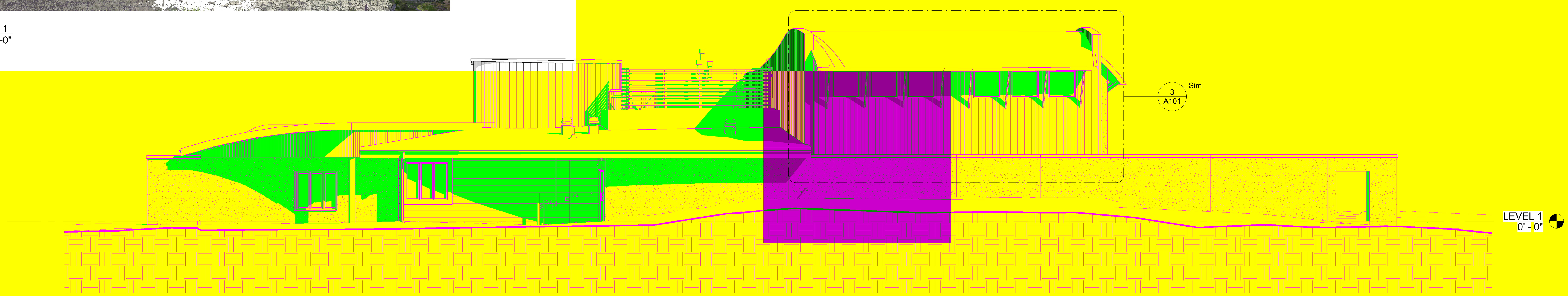
- **Existing Drawings**
- **LiDAR Drawings**



1 NORTH/WEST ELEVATION
1/8" = 1'-0"

BUILDING SIGN ON CURVED WALL

3 SECTION 1
3/16" = 1'-0"



2 NORTH/EAST ELEVATION
1/8" = 1'-0"

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1565 OLD LAKESHORE RD - EXISTING CONDITIONS

1565 OLD LAKESHORE RD,
OAKVILLE, ON

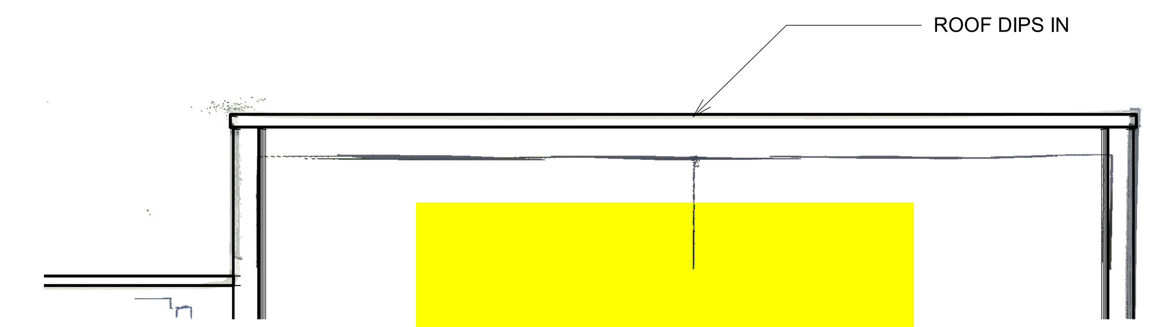
PROJECT NUMBER:	310-1627
FIELD WORK:	GH
DRAWN:	KM
AUDIT:	GH
SUBMISSION:	2022-07-26

NORTH/EAST AND NORTH/WEST ELEVATIONS

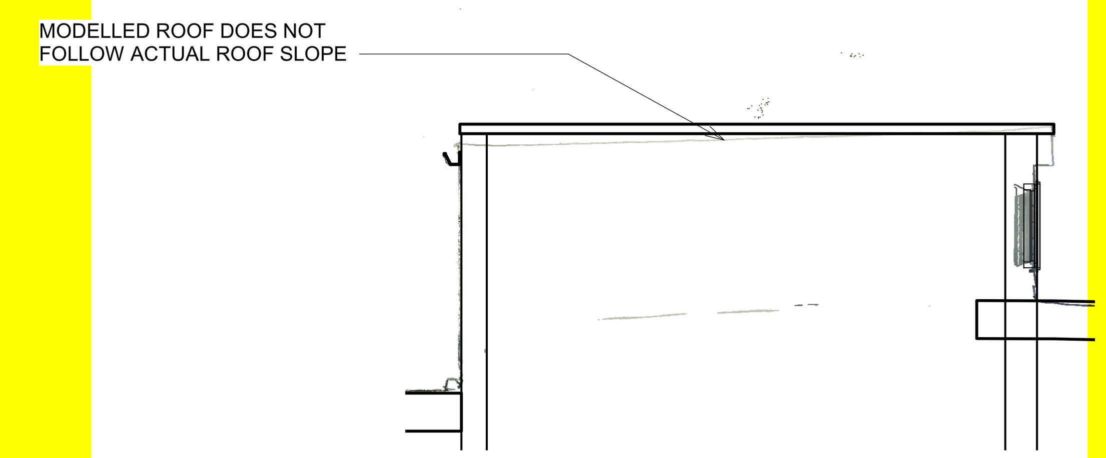
SCALE: As indicated

A101

1 SOUTH ELEVATION
1/8" = 1'-0"

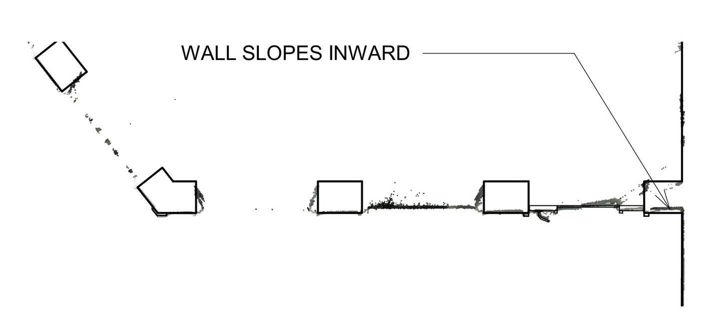


5 SECTION 2
1/4" = 1'-0"



3 SECTION 3
1/4" = 1'-0"

2 WEST ELEVATION
1/8" = 1'-0"



4 SECTION 4
1/4" = 1'-0"

SMARTER SPACES

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1565 OLD LAKESHORE RD - EXISTING CONDITIONS

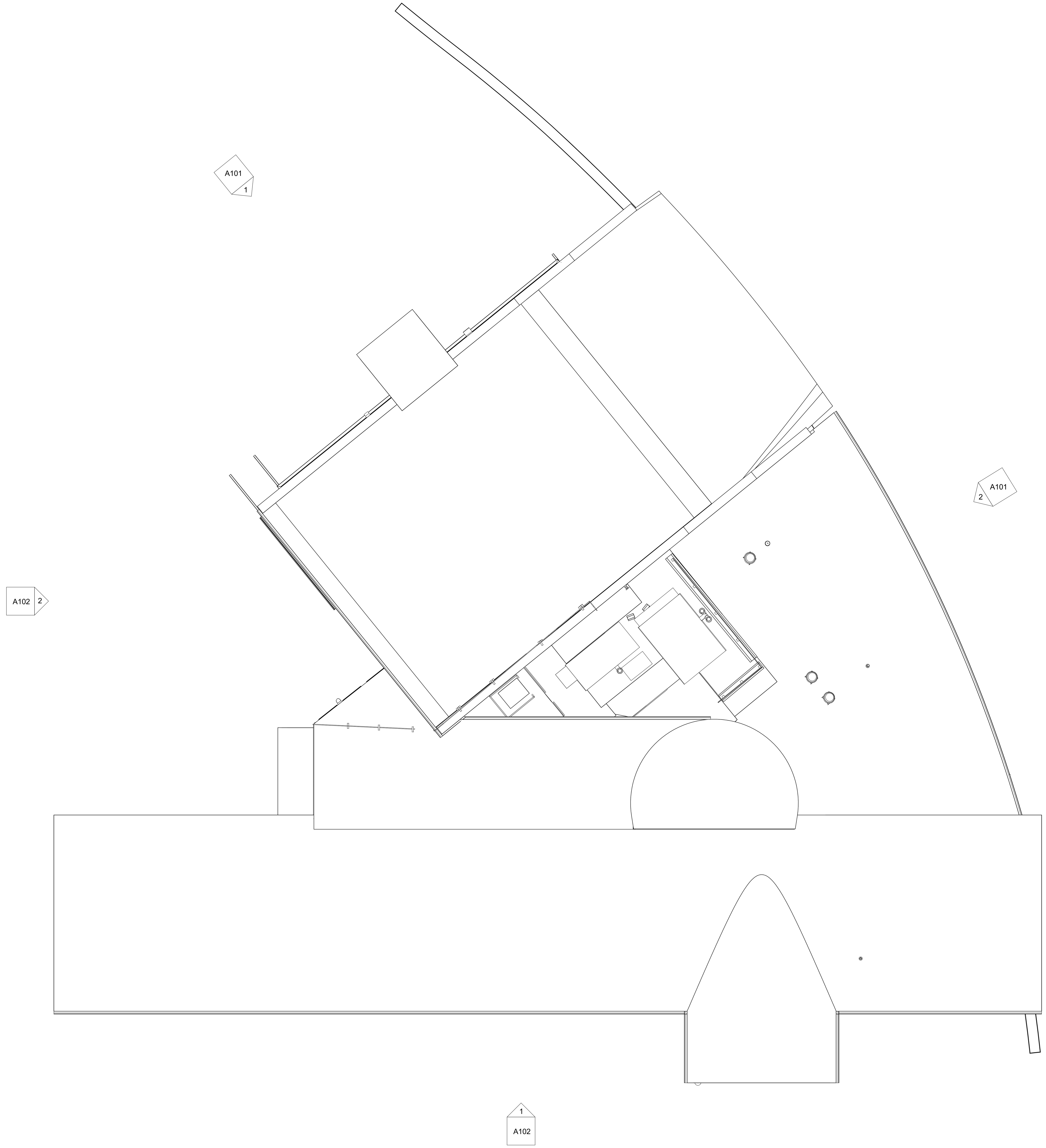
1565 OLD LAKESHORE RD,
OAKVILLE, ON

PROJECT NUMBER:	310-1627
FIELD WORK:	GH
DRAWN:	KM
AUDIT:	GH
SUBMISSION:	2022-07-26

SOUTH AND WEST ELEVATIONS

SCALE: As indicated

A102



1 ROOF PLAN
1/8" = 1'-0"

SMARTER SPACES

THESE ARE NOT CONSTRUCTION DRAWINGS.

CHECK AND VERIFY ALL DIMENSIONS ON SITE AND REPORT ALL ERRORS AND OMISSIONS TO SMARTER SPACES INC. ON A TIMELY BASIS.

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1565 OLD LAKESHORE RD - EXISTING CONDITIONS

1565 OLD LAKESHORE RD,
OAKVILLE, ON

PROJECT NUMBER:	310-1627
FIELD WORK:	GH
DRAWN:	KM
AUDIT:	GH
SUBMISSION:	2022-07-26

ROOF PLAN

SCALE: 1/8" = 1'-0"

A103

Appendix B

Facility Condition Assessment

OAKVILLE

Submission to
Town of Oakville

Facility Condition Assessment Report
Sir John Colborne Recreation Centre for Seniors

Version
Draft

Date
June 2, 2023

Prepared by:
Roth IAMS Ltd.
Project No. 23092
www.rothiams.com

Roth IAMS
Integrated Asset Management Strategies

Facility No	Oakville-001
Name	Sir John Colborne Recreation Centre for Seniors
Address	1565 Old Lakeshore Road, Oakville, Ontario
Area	842 SM
Floors	
Year Constructed	1989
Condition Assessment Date	2023-05-01

Facility Summary

General:
The Sir John Colborne Recreation Centre for Seniors is located at 1565 Old Lakeshore Road, Oakville, Ontario. The building is a single-storey structure without a basement constructed circa 1989. The total gross floor area is estimated to be approximately 842 SM (9,063 SQFT) in size.

The building includes offices, craft, and wood workshops, a games room, an auditorium, a kitchen, a lounge, mechanical rooms, and service areas. The building was assessed on May 1, 2023.

System Summaries

Structural and Architectural Summary

Foundations and Superstructure: The foundation appears to be poured concrete walls that likely bear on concrete footings. The superstructure appears to be a combination of steel and wood structure, where the roof slabs are likely metal decks supported on steel open web steel joists/wood truss and perimeter and interior columns.

Exterior Enclosure and Roofing: The exterior walls include stone veneer and metal siding with backup insulated walls. The building windows are metal framed with insulated glazing units (IGUs). A sliding double door with sensor-activated openers is provided at the east elevation main entrance. The secondary entrance/ exit/ service entrances are hollow metal single and double doors set in metal door frames. The roof covering consists of a Conventional - Modified Bitumen membrane roof assembly system for all roof sections (flat and curved roof).

Interior Construction and Finishes: The majority of the interior doors are wood panel single and double doors set in metal door frames. The interior partitions consist of painted gypsum boards and concrete masonry units (CMU). A painted finish is applied to the fixed partitions. The floor finishes include vinyl tile (auditorium and service areas), carpet (offices and lounge), laminated wood (corridor and craft rooms), ceramic tile (washrooms and vestibules), and vinyl sheet (kitchen). The ceilings are finished with adhered acoustic ceiling (auditorium, games room, and lounge), suspended acoustical ceiling tile (lobby, kitchen, and meeting room), and painted GWB ceiling. The auditorium is provided with a vinyl-faced folding retractable partition and a retractable stage of metal and wood construction. Men's and women's communal washrooms and an individual washroom for the staff are provided in the building.

Plumbing and Mechanical Systems Summary

Plumbing:

The building domestic water is provided by the local municipality water supply infrastructure and consists of a hot and cold domestic water copper pipe distribution. Domestic hot water is provided by an electric domestic hot water (DHW) heater. The sanitary waste drainage consists of cast-iron pipes directed from the building to the municipality sewer infrastructure. Plumbing fixtures include a kitchen sink, custodian sink and refrigerated drinking fountain.

HVAC: Building heating and cooling is provided by two natural gas-fired packaged rooftop units via sheet metal ductwork distribution. Supplemental heating is provided by electric unit and baseboard heaters. Exhaust fans provided ventilation for the washrooms, kiln room and electrical room. A direct digital control (DDC) system supervises the operation of the HVAC systems.

Fire Protection: Handheld dry chemical-type fire extinguishers are provided in designated areas.

Electrical Systems Summary

Electrical:
The building electrical service is fed from the site hydro utility owned transformer via underground feeders to the main service disconnect switch located in the electrical room. The switch is rated 400A at 600V. The building low voltage electrical distribution system generally consists of panelboards, disconnects, feeders, a transformer, and associated equipment. Branch wiring consists of insulated copper wire in rigid metal conduit and flexible armored cable.

Interior lighting consists of linear light fixtures in offices and pot light and track light fixtures in lobbies and entrances. The lighting is updated to LED. Exterior lighting includes wall packs and canopy-mounted fixtures along the perimeter of the building. Exit lighting includes illuminated single-sided and double-sided exit signs along egresses and at exits. Emergency lighting consists of wall mounted emergency battery pack units with local and remote quartz light heads.

A fire alarm control panel manufactured by Mircom is installed in the electrical room with pull stations, smoke detectors, audible alarms and associated equipment located throughout building. An annunciator panel is provided in the main entrance vestibule. Security and communication systems for the building include access control, video surveillance and public announcement.

Site Summary

Site Improvements:

The site improvements include two asphalt paved parking lots with cast-in-place concrete curbs located at the east and west of the property. A cast-in-place concrete paved patio at the west elevation and concrete paved/ block walkways are provided at the building entrances connecting to the parking lot, and landscaped areas. The patio is provided with metal benches, picnic tables, and two canopy structures. Two metal flag poles are located at the east elevation.

Appendix C

Structural Outline Specification

SIR JOHN COLBORNE RECREATION CENTRE

Building Use and Occupancy

The Sir John Colborne Recreation Centre for Seniors is a small, single-storey community centre building located at 1565 Old Lakeshore Road in Oakville, Ontario. The structure is owned and operated by the Town of Oakville and currently used primarily as a seniors' recreation centre with various multi-purpose activity rooms and a large auditorium space. Based on available architectural drawings, the building was determined to be constructed circa 1989. A photo of the building exterior is shown in Figure 1.

Figure 1: Sir John Colborme Recreation Centre

As the building's primary use is a community recreation 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). A High Importance building is defined as:

> "Buildings that are likely to be used as post-disaster shelters, including buildings whose primary use is:
> - As an elementary, middle, or secondary school
> - As a community centre
> - Manufacturing and storage facilities containing toxic, explosive, or other hazardous substances in sufficient quantities to be dangerous to the public if released."

High Importance structures are subject to higher environmental loading, including snow, wind, and seismic loads, than a normal importance building.

Structural Systems

Foundation System

Based on available architectural drawings, it is understood that the foundation consists of 12" [305mm] concrete block walls with cast-in-place concrete strip footings. The concrete block walls are reinforced with 15M vertical bars at 2'-0" [610mm] c/c. The building does not have a basement, and there is ½" concrete parging on the exterior face of the concrete block foundation walls.

Based on site photos provided to DesignPoint, no major cracks were observed in visible portions of the foundation wall along the exterior perimeter of the building. Although the condition of the buried foundation walls are unknown, there was no evidence identified in site visit photos to suggest structural deficiencies in the foundation.

Above-Grade Walls

The structure consists of a combination of 2x6 timber-framed walls and reinforced concrete masonry unit (CMU) walls. The timber and CMU walls act both as load-bearing elements supporting the roof trusses and as the structure's primary lateral load resisting system. The timber-framed walls consist of 2x6 studs at 24" [610mm] c/c with ½" [13mm] gypsum exterior sheathing and ½" [13mm] interior drywall. There is no mention of blocking between studs. The maximum height of stud wall appears to be approximately 13'-0".

The CMU walls consist of 8" [203mm] and 12" [305mm] blocks, with 15M rebar at 2'-0" [610mm] c/c vertically. Based on site photos provided to DesignPoint, no evidence of structural fatigue, deterioration, or failure was noted in the building's primary structural walls.

Roof Structure

The roof structure consists of various pre-engineered open web joists, consisting of timber top and bottom chords, with pinned tubular steel web members. There are no detailed structural engineering drawings, roof truss shop drawings, or original loading calculations provided. Accordingly, there is little information available on the structural members beyond what is shown in the original architectural plans and what is currently exposed. For the purposes of discussion, the roof has been separated into five distinct roof structure areas based on the geometry of the structural members in each area. A colour coded legend of the roof areas is shown below in Figure 2.

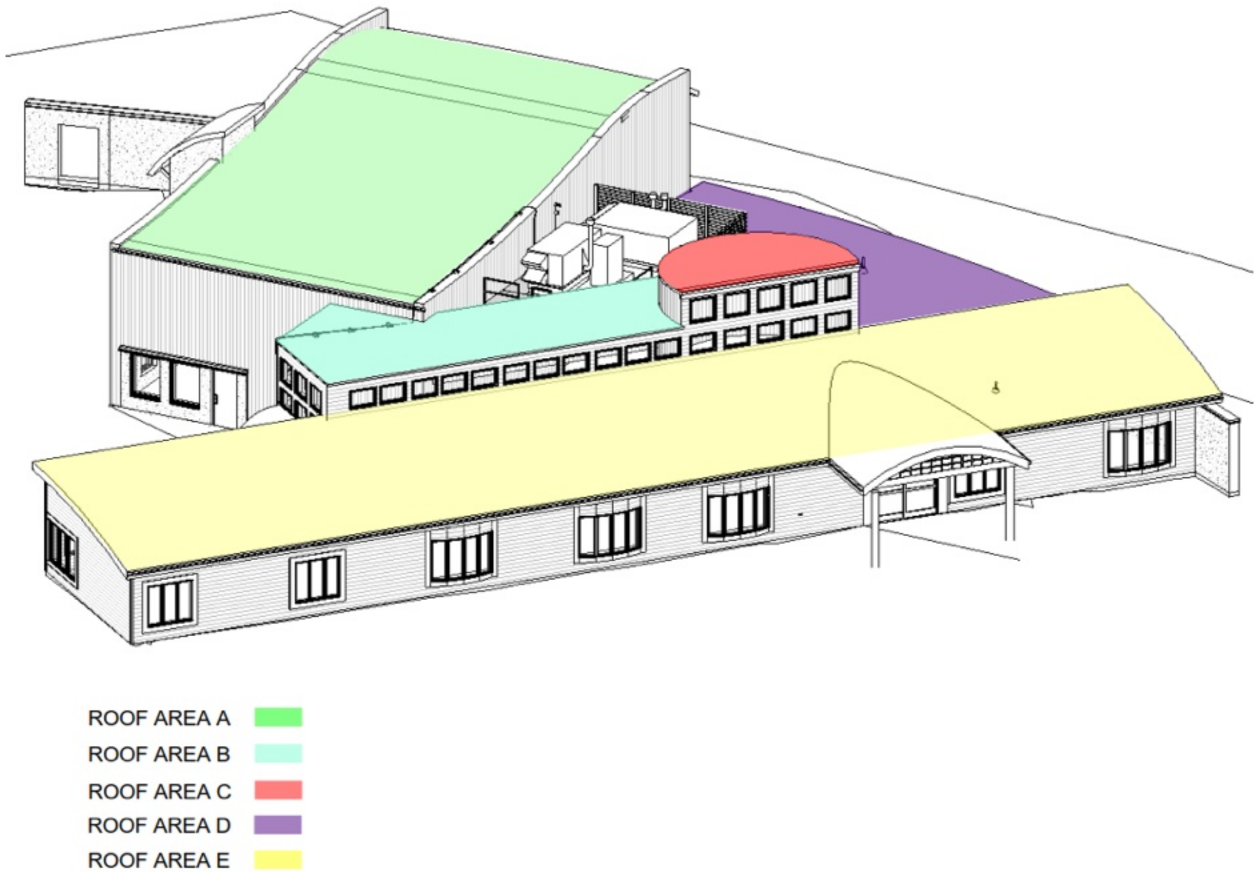


Figure 2: Sir John Colborne Recreation Centre roof area legend.

Roof Area A

Roof area A consists of pre-engineered open web trusses which span approximately 40'-3 ½" [12281mm] between load-bearing concrete masonry unit (CMU) walls on each side of the auditorium. The trusses consists of parallel timber top and bottom chords, with pinned tubular steel web members and are spaced at 3'-10½" c/c. A photo of the existing auditorium roof structure is shown in Figure 3. The roof features a wave-like profile in this area of the building, with the roof trusses spanning perpendicular to the roof slope. All trusses in this are consist of perpendicular flat top and bottom chords. The roof slope is achieved by varying the elevation of the top chord and sloping the structural deck between adjacent trusses.

Figure 3: Roof area A parallel chord trusses.

As the design of this style of open-web joist with hybrid wood and steel construction is proprietary, it is difficult to accurately quantify the capacity of the trusses without original design drawings or fabrication drawings. It is likely that the trusses were designed to nearly 100% capacity in 1989. Accordingly, it is recommended that if roof panels are added in this area, they shall be designed to span between bearing walls independent from the existing structural trusses.

Roof Area B

Roof area B consists of pre-engineered open web trusses which span approximately 13’-7½” [4153mm] between load-bearing concrete masonry unit (CMU) walls on each side of the auditorium. The trusses consists of parallel timber top and bottom chords, with pinned tubular steel web members and are spaced at 3’-10½” [1181mm] c/c. A photo of the existing auditorium roof structure is shown in Figure 3. The roof features a wave-like profile in this area of the building, with the roof trusses spanning perpendicular to the roof slope. All trusses in this are consist of perpendicular flat top and bottom chords. The roof slope is achieved by varying the elevation of the top chord and sloping the structural deck between adjacent trusses.

Figure 4: Roof Area B structure

As the design of this style of open-web joist with hybrid wood and steel construction is proprietary, it is difficult to accurately quantify the capacity of the trusses without original design drawings or fabrication drawings. It is quite likely that the trusses were designed to nearly 100% capacity in 1989. Accordingly, it is recommended that if roof panels are added in this area, they shall be designed to span between bearing walls independent from the existing structural trusses.

Roof Area C

Roof area C consists of 2x10 wood joists at 16" c/c with 3/8" plywood sheathing and 2" of rigid insulation above. This area is relatively small and consists exclusively of the structure above the circular Active Lounge on the main level of the building. Based on available design information, we have assumed a maximum span of 20'. Based on this assumption, the roof joists are at 100% capacity with a superimposed dead load of 0.65 kPa. Additionally, the joists exceed the recommended deflection criteria of L/360 for members supporting surfaces susceptible to cracking such as drywall. Accordingly, it is our recommendation that panels in this areas should also be designed to span between existing bearing walls.

Roof Area D

There is limited information available on Roof Area D based on the available architectural drawings. The roof structure generally consists of pre-engineered trusses with varying span lengths. Based on the trusses in the accessible portions of the roof, it is presumed that these trusses also consist of timber top and bottom chords with tubular steel webbing. Similar to Areas A and B, it is recommended that roof panels are designed to span independent of the existing roof structure.

Roof Area E

Roof area E consists of pre-engineered trusses that span approximately 25’-4” between load-bearing stud walls. The trusses consist of a flat timber bottom chord, arched timber top chord, and tubular steel webbing similar to other trusses in the building.

Figure 5: Roof Area E structure.

Summary and Recommendations

Overall, the main structural system of the Sir John Colborne Senior’s Recreation Centre appears to be performing at a satisfactory level with no signs of structural failure or fatigue. Based on available photos from site visits, it can be assumed that minimal modifications have been made to the original structural system of the building, as designed in 1989. Commentary L of the National Building Code of Canada provides guidance for the assessment of existing structures to analyze current performance and to support modifications to the existing structural system. It is possible to appeal to satisfactory past performance when assessing existing structures, as modern codes generally consist of stricter loading provisions than previous codes or best practices of construction.

However, these provisions are not directly applicable where the structural system of the building is being modified to a point where the loading on existing members is modified. Changes in loading may be due to:

- A change in occupancy of the building.
- Additions causing snow drifting.
- Addition of dead load to the building assemblies.
- A modification of the primary load path.

In the context of the ReCover Project, adding panels to the envelope of a structure will increase the dead load of the primary structure and, depending on connection details, may modify the load path in such a way that the loading on main structural members is changed. Accordingly, it is our opinion that the existing structure, particularly the roof structure, should be assessed as per current codes and standards, despite evidence of satisfactory past performance if it is determined that panels, insulation, or any other additional dead load will be added to the roof.

Accordingly, it is recommended that if roof panels are required, they shall be designed to be independent of the existing roof trusses. Alternatively, if roof panels are omitted, a site-installed retrofit of the roof may be completed by replacing the existing roof insulation with lightweight alternatives with a higher R-value. In this case, the load path on the existing roof structure would not be modified and could be considered under satisfactory past performance as stated in Commentary L of the National Building Code of Canada.

Summary and Recommendations

Overall, based on photos provided to DesignPoint and a preliminary assessment of the existing building, the existing structural system appears to be performing to a satisfactory level with no signs of structural fatigue or failure. A thorough “arms length” structural inspection is recommended to confirm these findings and identify any signs of fatigue or failure, especially at openings in the existing masonry walls.

Based on a preliminary review of available information, the CMU walls are adequate to support the existing gravity and lateral loads, so long as the main structural walls have not been modified in the decades since construction (i.e. cutting holes in masonry for new openings). The installation of wall panels will not increase the overall magnitude of the lateral load, but the distribution of out-of-plane lateral forces (i.e. wind) to the walls will be modified based on the proposed panel connection details. It is understood that the walls will be panelized with a two-course high system consisting of 10’-0” [3048mm] tall base panels, requiring a connection to the CMU wall between the existing floor slab and roof diaphragm to avoid a hinge point where the panels are joined. Accordingly, where the exterior walls would have initially been designed for a unform area wind load, the installation of the panels will transform this area load to a linear load at the joint between the bottom and top course of panels.

The proposed panels will distribute wind load to the existing foundation and roof diaphragm, as well as to the panel connection point at 10’ above the panel base. As a result of the panel installation, half of the exterior wind loading will be distributed directly to the roof and foundation, with the other half concentrated at the panel to wall connections. This modification will reduce the overall out-of-plane wind load seen by the CMU walls. As this constitutes a change in load path, the existing CMU walls must be analyzed as per current NBCC loading requirements to confirm their adequacy. As per NBCC 2015 Appendix L, satisfactory past performance cannot be relied on when the load path in a structure is modified. A detailed investigation may be required to confirm the presence of reinforcing bars and grout in the exterior walls to facilitate this analysis. A schematic of this loading change is illustrated in Figure 6.

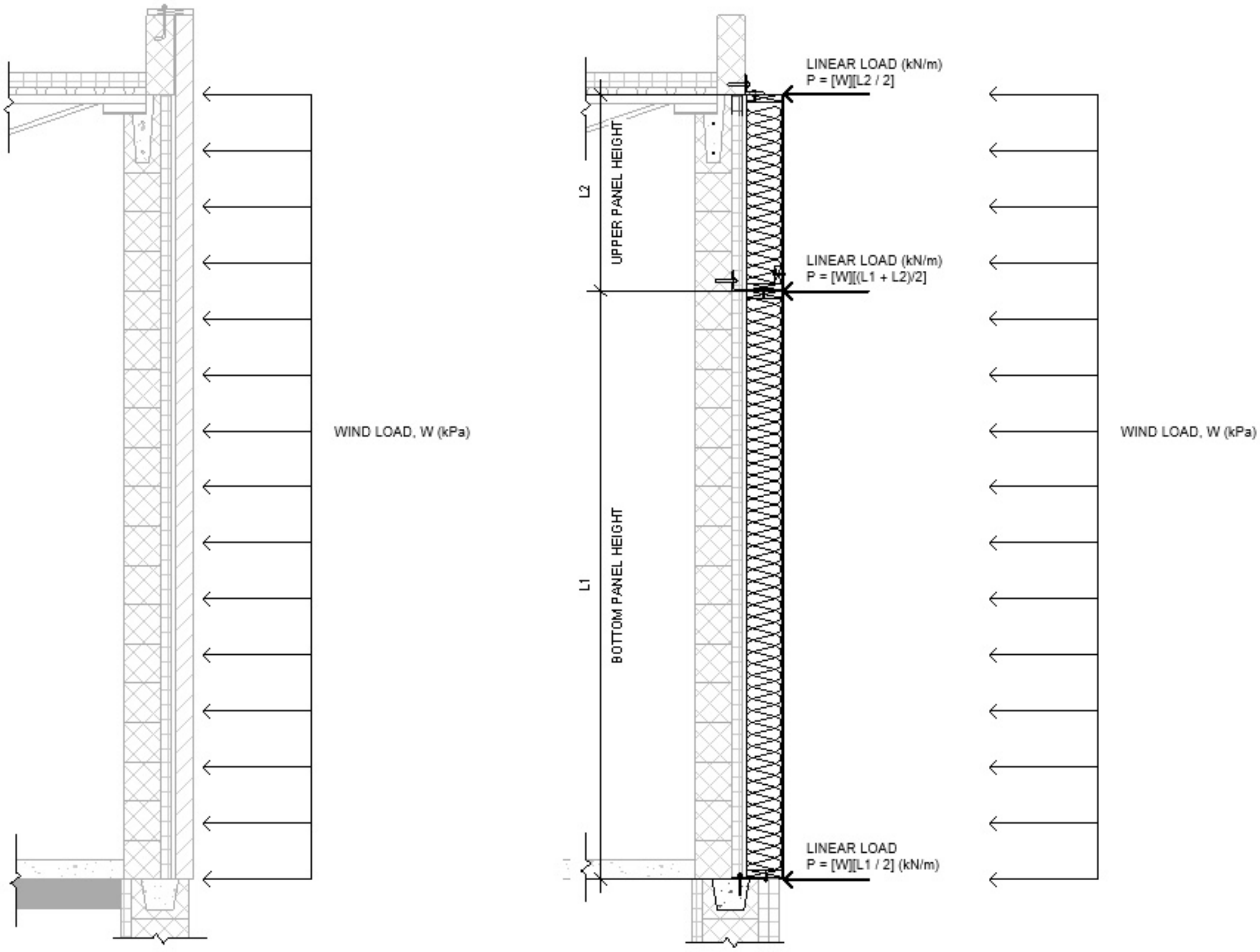


Figure 6: Wind load path with and without panels.

It is important to note that the overall panel height will be a function of the design wind load and the ReCover panel wall thickness – 2x4 or 2x6 studs. The maximum panel height shall be confirmed prior to detailed design in order to inform the location of the mid-wall panel connection locations.

It is understood that the earth adjacent to the foundation will be excavated, allowing for the installation of a structural lintel to support the proposed wall panels. A proposed panel to foundation connection is shown in Figure 7. This connection is designed to transfer out-of-plane bending forces only. In-plane wall bending (i.e. shear wall action) will be resisted by the existing CMU or sheathed timber stud walls. Gravity load from the roof will not be transferred to the panels.

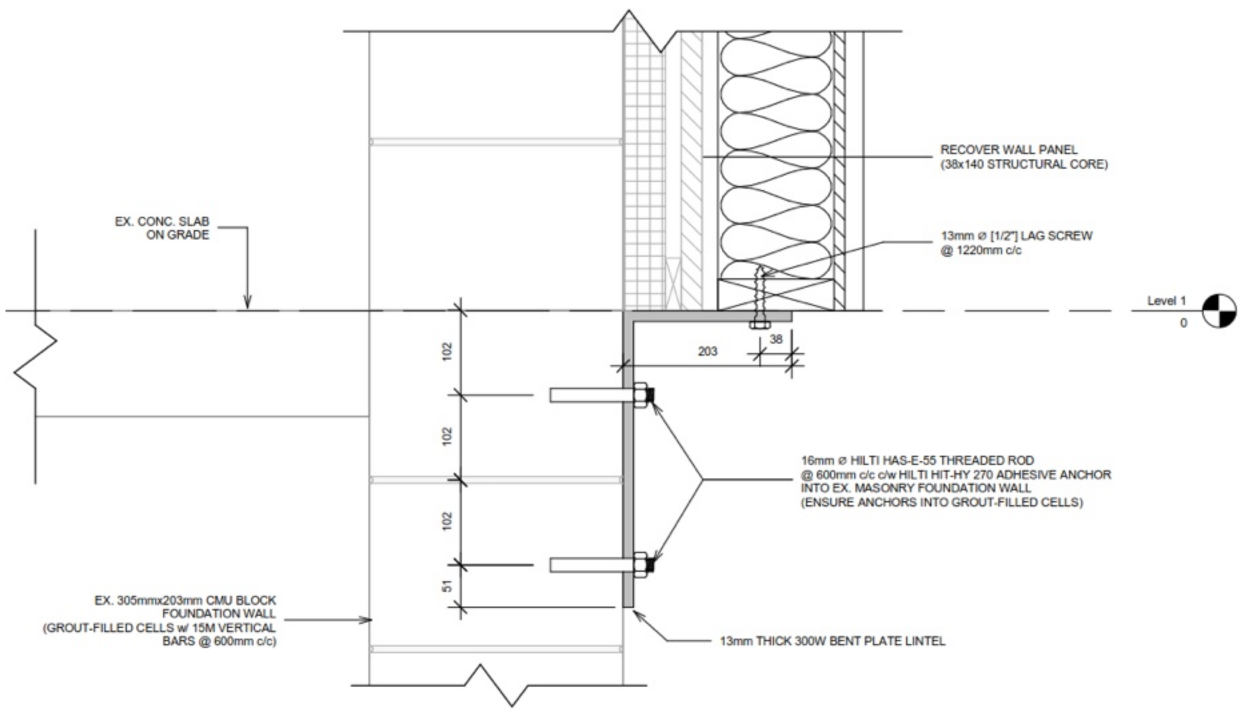


Figure 7: Proposed panel to foundation connection.

Based on original design drawings, there are two unique conditions at the wall to roof connection:

- Custom timber truss at CMU walls.
- Custom timber truss/rafters at 2x6 stud walls.

At the taller masonry walls, we have proposed 76mm lengths of custom structural steel be installed to fasten the top plate of the wall panels to the existing structure at the roof diaphragm with field-installed masonry anchors and lag screws. A proposed wall panel to roof connection detail is shown in Figure 8.

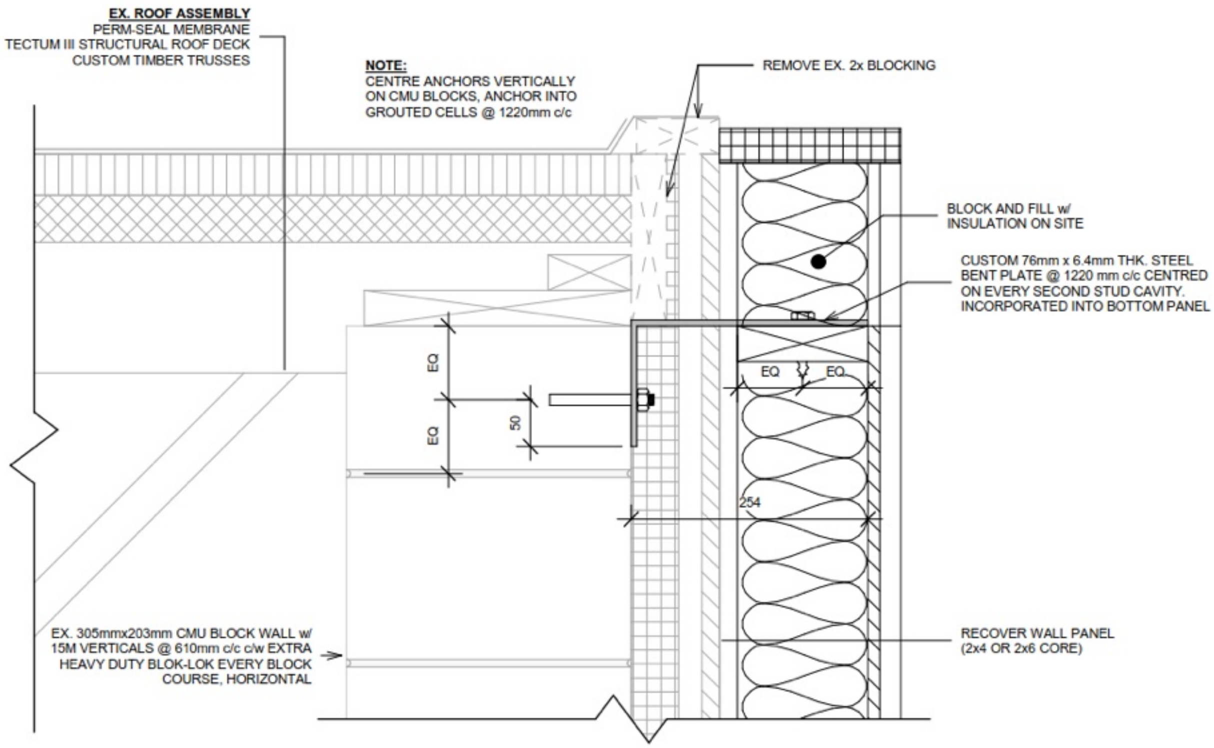
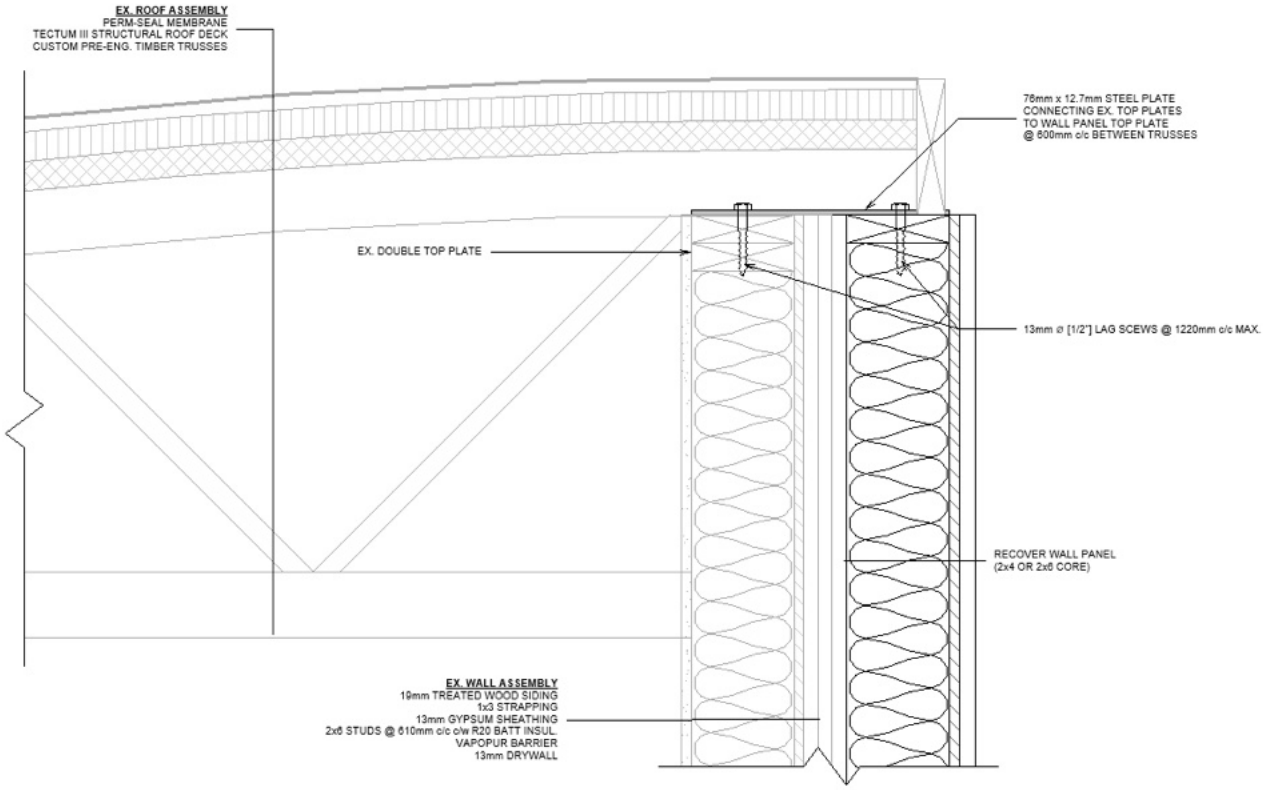


Figure 8: Panel to roof connection at CMU walls.

Alternatively, at the 2x6 stud walls, we recommend a structural steel plate installed to tie the top plate of the panels to the double top plate of the existing stud wall as shown in Figure 9.



Prior to proceeding with any installation of roof insulation, we recommend a detailed inspection and analysis of the existing roof structure to verify the existing structure's capacity. Without design information, it is very difficult to accurately quantify the strength of joists as member cross sections are often non-standard, proprietary shapes unique to each manufacturer. It is not possible to deem the roof structure satisfactory based on past performance as per NBCC Structural Commentary L if additional roof insulation is added since it cannot be argued that loading would not increase as a result of the retrofit. Increasing insulation would potentially decrease snowmelt and increase the snow load on the roof compared to the snow load that it has satisfactorily resisted in the past.

Appendix D

Mechanical Outline Specification

PURPOSE

The purpose of this Design Summary is to document the existing mechanical systems for the energy retrofit of the Sir John Colborne Recreation Centre for Seniors located at 1565 Old Lakeshore Road in Oakville, Ontario. The intent is to summarize the major features and design parameters for the Plumbing and HVAC disciplines.

The building was constructed in 1989 and is primarily used for registered and drop-in recreation services including meetings, workshops, and art classes. There are multiple offices on the east side of the building and an auditorium on the west face.

SITE SERVICES

Both water and sanitary services are connected to the municipal system.

PLUMBING SERVICES

Rainwater:
Downspouts and gutters provide drainage for the roof system.

Figure 1 Downspout

Figure 2 Roof drainage system

Domestic Water Service:
The existing hot water service is provided by an 85-gallon electric water heater. The domestic hot water loop includes an expansion tank and the building has a water meter.

Figure 3 Electric Water Heater

Figure 4 Expansion Tank

Plumbing Fixtures

The north side of the building includes a men's and women's washroom with a total of six stalls and five touchless faucets with sinks. There is also a single occupancy staff washroom in the office area. A water station has been installed in the main lounge area.

Figure 5 Touchless sinks in men's washroom

Stainless steel water fountains are installed throughout the building.

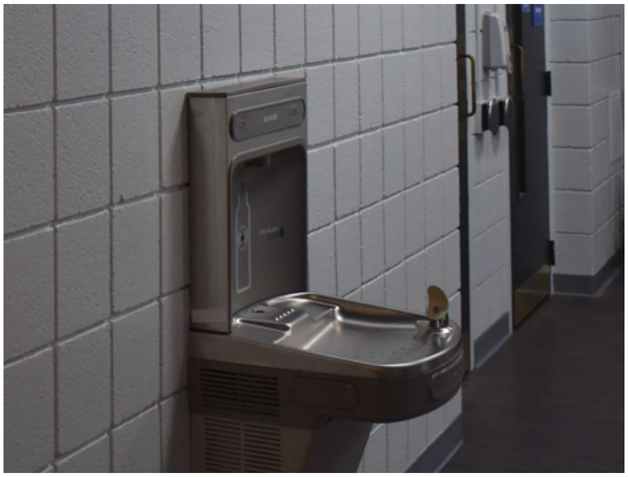


Figure 6 Typical Water Fountain in Facility

The kitchen area consists of a commercial dishwasher, two commercial fridges, two coffee machines, a freezer, two sinks, and a residential washer/dryer.


Figure 7 Dishwasher in Kitchen


Figure 8 Kitchen Fridge #1


Figure 9 Kitchen Fridge #2

Figure 10 Freezer in Kitchen

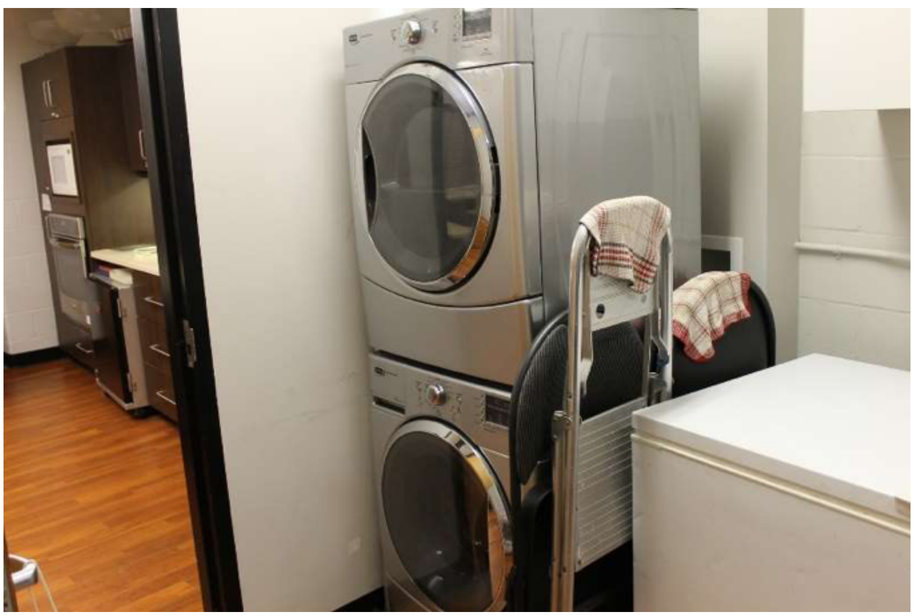


Figure 11 Washer and Dryer

HVAC SYSTEM

Heating and Cooling:

Space heating and cooling is provided through packaged VAV systems served by two natural gas fired rooftop units. The majority of the building has individual thermal zones for each room with the exception of the auditorium which has been split into four zones.

Figure 12 Rooftop unit

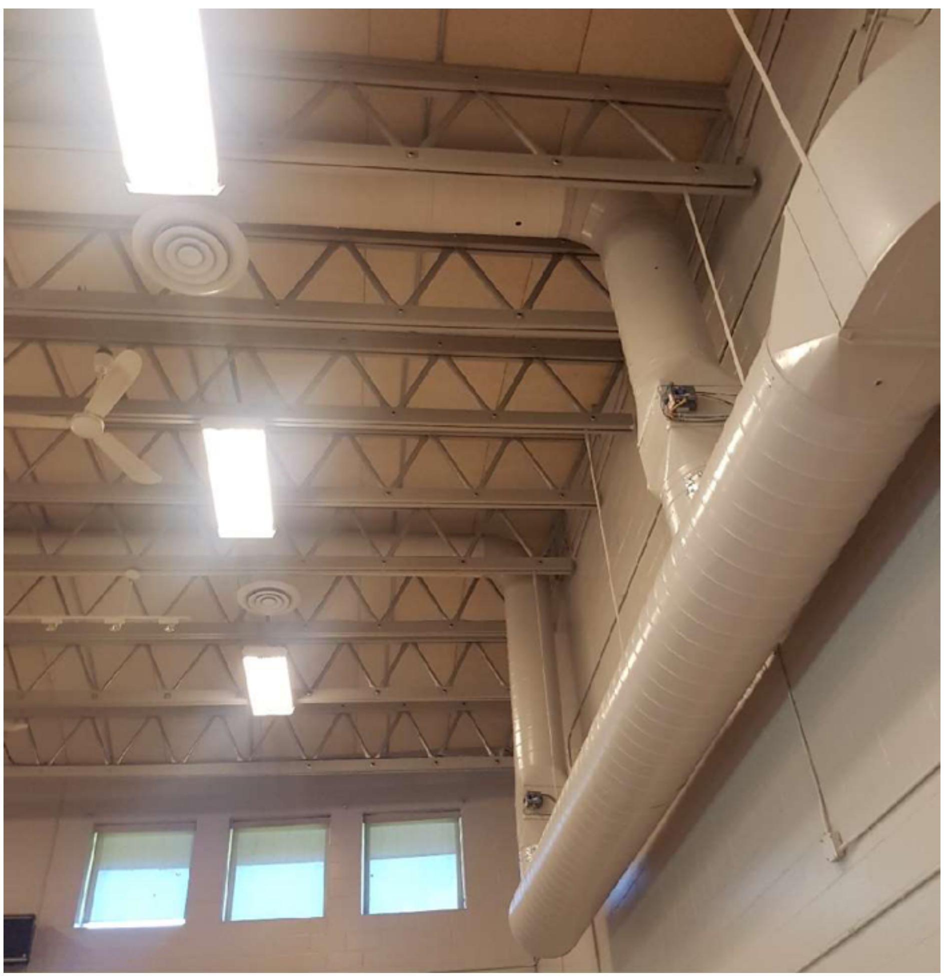


Figure 13 Auditorium VAV system

Electric baseboards have been installed in the south side rooms and southeast offices following occupant complaints of being cold. An electric fireplace has also been installed in the main lounge area.

Figure 14 Electric Baseboard

Figure 15 Electric Fireplace in Lounge Area

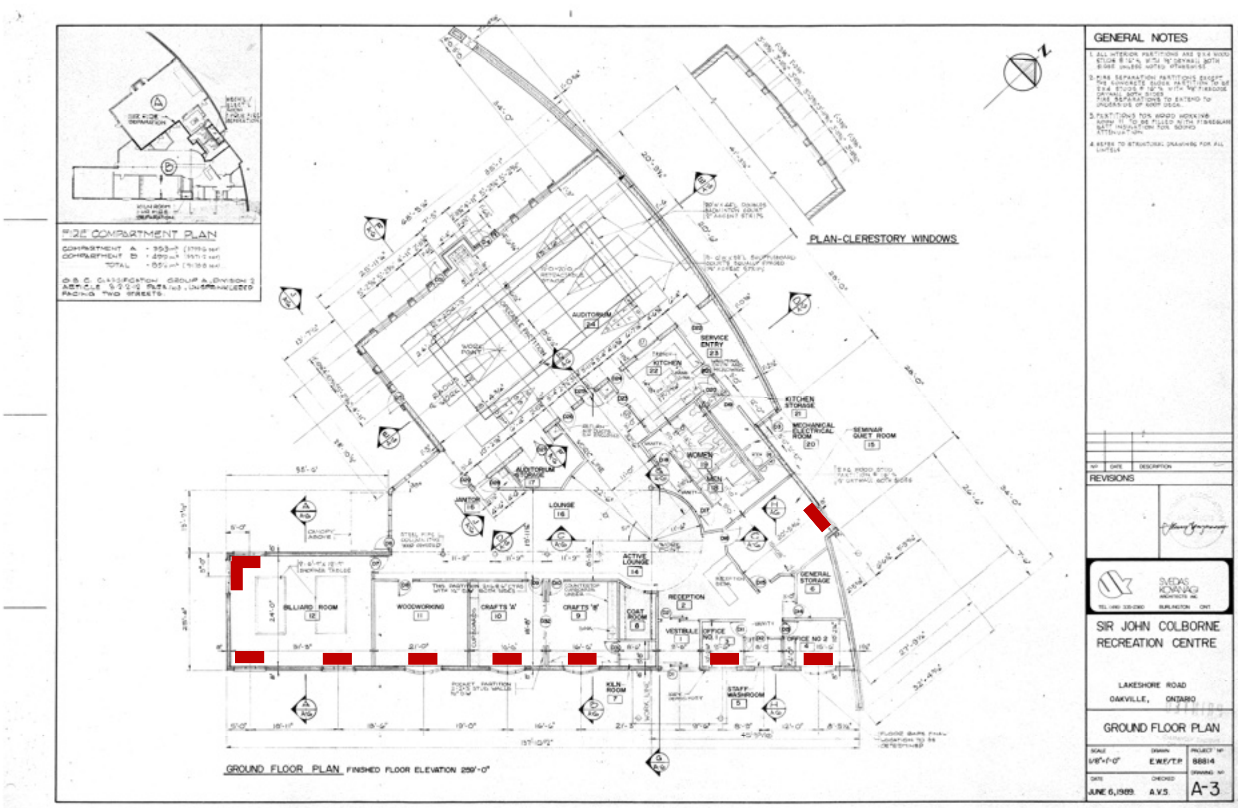


Figure 16 Locations of Electric Baseboard Heaters

Ventilation:

Outdoor air is provided by the rooftop units. Exhaust fans have also been installed in the kitchen and bathrooms. Location of exhaust fans is depicted in the figure below.

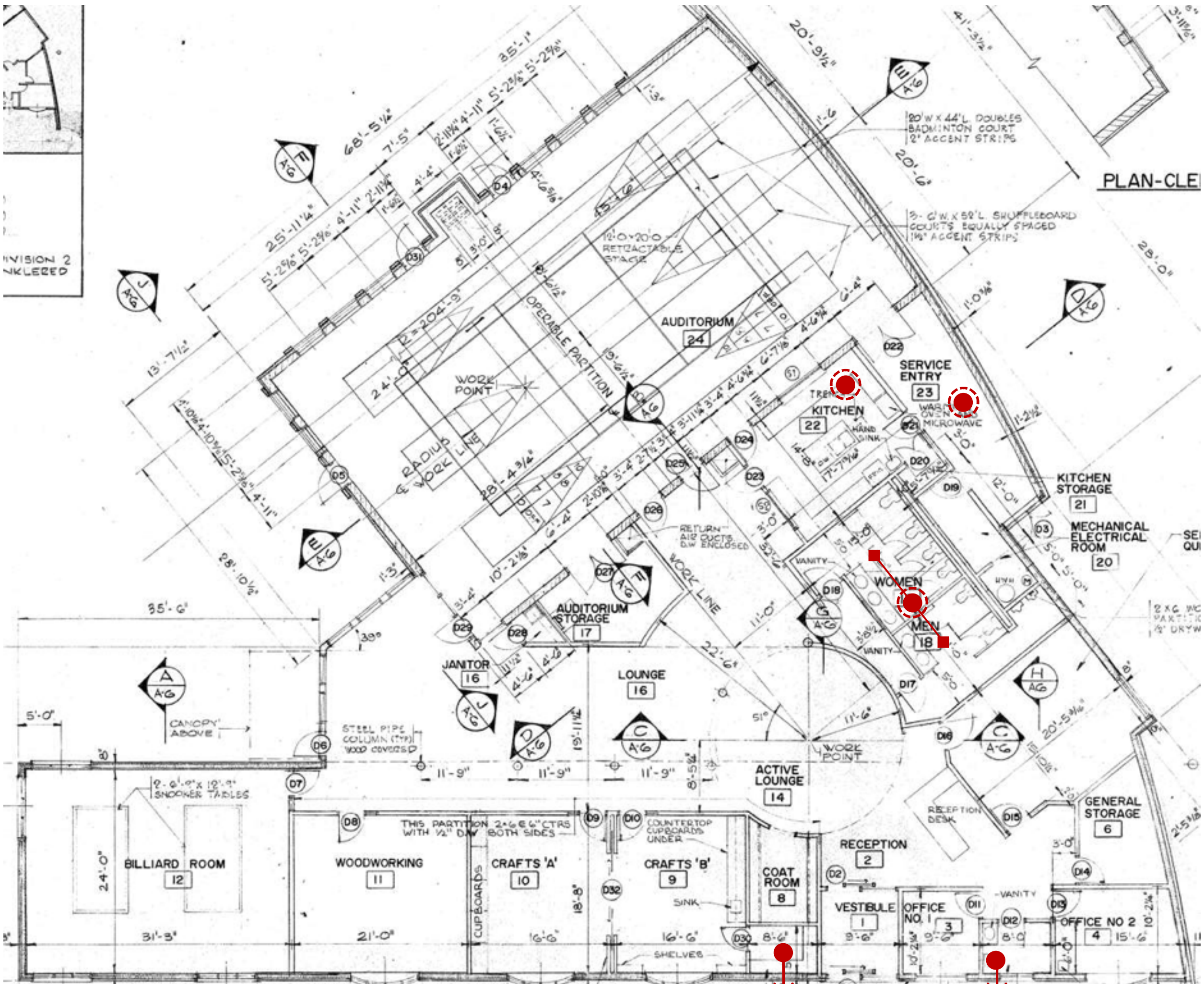


Figure 17 Exhaust Fan Locations

Controls:

A building automation system was upgraded in 2018 when the new VAV rooftop units were installed. Zone control is available in both occupied and unoccupied modes; zone diagram has been provided below. Economizer control is also available. Baseboard heaters are enabled when outside air temperature drops below 16°C.

Typical hours of operation are Monday, Wednesday, Thursday, and Fridays from 8:30am – 4:30pm, and Tuesdays from 8:30am – 8:00pm.

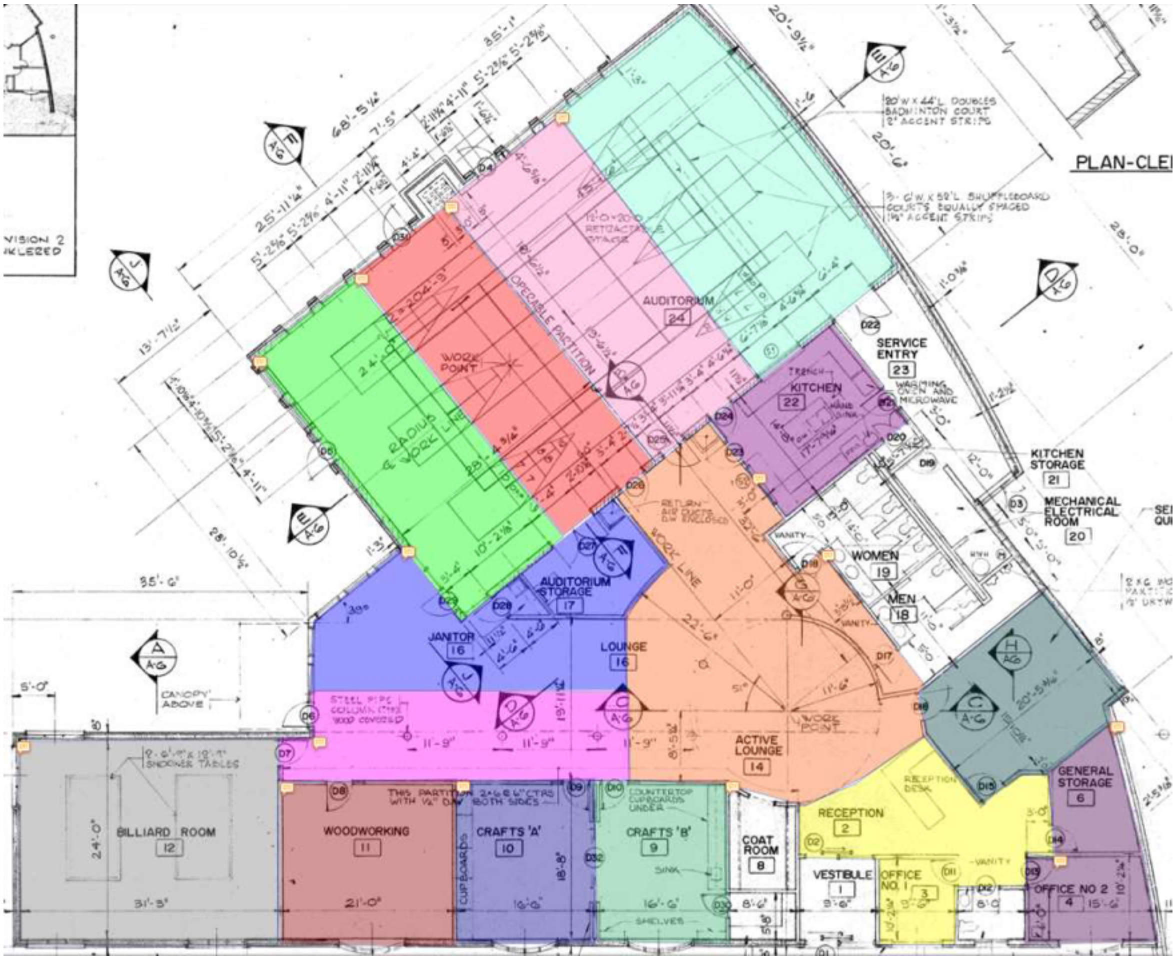


Figure 18 HVAC Zoning Diagram

Schedule of Equipment:

RTU-1	Fuel Type	Natural Gas
	Heating Capacity (Input/Output)	192/144 MBH
	Cooling Capacity	12 tons
	Cooling Efficiency (EER)	11.5
	System Power	12.8 kW
	Blower Details	VAV High Static
	Outdoor Air Details	Economizer installed
RTU-2	Fuel Type	Natural Gas
	Heating Capacity (Input/Output)	300/240 MBH
	Cooling Capacity	15 tons
	Cooling Efficiency (EER)	10.8
	System Power	15.0
	Blower Details	VAV High Static
	Outdoor Air Details	Economizer installed

Exhaust Fan ID	Location	HP	Notes
EF-1	Washroom	0.25	
EF-2	Staff Washroom	0.1	
EF-3	Kitchen	0.25	
EF-4	Inside room in Crafts B	0.25	Only operates with kiln
EF-5	Mech/Elec Storage	0.25	

VAV ID	Zone Location	CFM	RTU #
VAV-01	Auditorium	1800	RTU-1
VAV-02	Auditorium	1800	RTU-1
VAV-03	Auditorium	1400	RTU-1
VAV-04	Auditorium	1400	RTU-1
VAV-05	Kitchen	300	RTU-2
VAV-06	Seminar Room	400	RTU-2
VAV-07	Office 2 and Storage	400	RTU-2
VAV-08	Office 1 and Reception	550	RTU-2
VAV-09	Crafts B	450	RTU-2
VAV-10	Lounge	500	RTU-2
VAV-11	Active Lounge	450	RTU-2
VAV-12	Lounge	950	RTU-2
VAV-13	Crafts A	350	RTU-2
VAV-14	Wood Working	500	RTU-2
VAV-15	Billiards Room	1050	RTU-2

COMMENTS

There have been several occupant comfort complaints in the office areas where baseboard heaters have been installed. Majority of complaints included feeling too cold during the winter. Since the baseboard heaters have been installed, occupants have reported a more comfortable environment. These conditions indicate that the office heating systems are undersized.

The facility is a designated local cooling centre during times of extreme heat and a warming centre during times of extreme cold. As such, future mechanical and building enclosure designs must account for the increased dependency on building resilience during extreme climate events.

PROPOSED SYSTEMS

Systems have been proposed as per the minimally acceptable, net zero ready, and net zero scenarios. The details of each system are provided below. For the purpose of this study, it has been assumed that the occupancy schedules and space usage are consistent with existing conditions.

The minimally acceptable and net zero ready scenarios reduce the energy consumption by 50% and 80% respectively when compared to the existing building. The new HVAC and plumbing systems in the minimal acceptable scenario will meet the requirements of the 2020 National Energy Code for Buildings (NECB).

In all scenarios, it is recommended that insulation be increased or added to internal rainwater leaders and plumbing vents to prevent condensation and thermal bridging. Typically, insulation to prevent condensation on rainwater leaders is a minimum of 1/2” (~R-3) and plumbing vents are normally uninsulated; however, it is recommended that the insulation be added or increased to 3” (~R-20) to prevent thermal bridging. The insulation should be run down to the slab which may require access inside walls. To fully minimize thermal bridging, roof drain retrofits should be prioritized to be external of the enclosure.

1. Minimum Acceptable Scenario

Heating and Cooling

Heating and cooling will be provided by a combination of the existing rooftop units with new demand control ventilation. As this scenario does not reduce the heating loads sufficiently to use a lower temperature air supply system (heat pumps), the use of the existing high temperature rooftop units avoids the replacement of the existing ductwork.

Domestic hot water would continue to be served by an 85-gallon electric water heater.

Ventilation

The existing rooftop units will continue to supply ventilation for the minimum acceptable scenario.

Controls

All existing building controls will remain with the addition of the installation of CO_2 sensors for demand-controlled ventilation. An auxiliary heat relay system would also be installed to control both the rooftop units and electric baseboard heaters to ensure simultaneous heating does not occur.

Equipment List

- (15) Zone CO_2 sensors
- (10) Auxiliary heat relays for baseboard heaters
- (1) Outdoor air CO_2 sensors

2. Net Zero Carbon Energy Ready Scenario

The net zero carbon energy ready system includes full electrification of the HVAC and DHW systems. Two variable refrigerant flow (VRF) options have been proposed: air source and ground source.

a. Air Source VRF Option

Heating and Cooling

The natural gas rooftop units and baseboard heaters will be replaced with a VRF system to heat and cool the entire building.

The VRF system has been sized such that it meets 100% of the peak cooling load. Consequently, the system has been sized for heating such that it meets 85% of the heating load at 0°F. The unit's compressors will allow over speeding and flash injection for cold climate operation. Electric duct heaters would be installed in the ductwork to serve the remaining 15% of the peak load. As peak demands rarely occur throughout the year, it is much more economical for the electric heaters to provide heating during peak demand periods as reducing the heat pump capacity to 85% of peak load typically results in substantial economical savings. The VRF condensing unit would be mounted where the existing rooftop units are located.

The VRF system would include refrigerant piping from the condensing units to a branch controller which will then distribute the piping to fan coils units. The fan coils would then tie into the existing ductwork and air would be distributed to each zone. Each fan coil would be hooked up to a thermostat, thus having one fan coil per zone.

Domestic water would be provided by a packaged heat pump water heater (HPWH). The HPWH has been sized according to existing tank capacity, refer to Figure 27.

Figure 19 Air Source Cold Climate VRF Heat Pump


Figure 20 Packaged Heat Pump Water Heater

Ventilation

The existing rooftop units would be removed and two ERVs would be installed. One ERV would serve the auditorium and the other would serve the rest of the building. ERVs would be dual core type with approximately 90% heat recovery efficiency similar to Tempeff Dualcore, refer to Figure 30 below. Outdoor air and exhaust air ductwork will be insulated between the building envelope and ERV. Both ERVs would be located on the roof at the same location as the VRF unit. Variable air volume (VAV) boxes along with CO_2 sensors would be installed to enable demand-controlled ventilation.

Because the ventilation system is being decoupled from the heating and cooling system, the ventilation distribution system will need to be altered. As zones will remain unchanged, the zone (room) level ductwork will remain. However, the main duct runs will need to be removed and reinstalled to better accommodate the location of the two ERVs.

As previously mentioned, ERV ducting will consist of new main duct runs which tie into the zone distribution systems. Each zone will be equipped with a VAV box controlled by an occupancy of CO_2 sensor to optimize the required ventilation for the zone. ERV ducting will be galvanized steel.

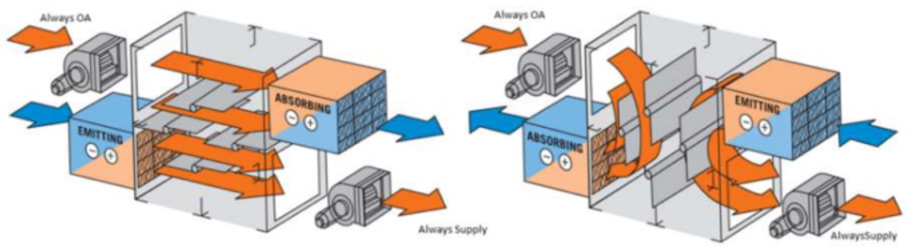


Figure 21 Tempeff Dual Core ERV

Controls
The new VRF equipment and ERVs would tie into the building's existing direct digital control system.

System Overview
A list of required equipment and system schematic have been included below.

Equipment List

- (1) Nominal 10-ton air source VRF outdoor condensing units with branch control boxes
- (15) 0.5 kW Electric duct heaters
- (15) VAV boxes (100 cfm average)
- Fan Coils
  - (2) 2-ton fan coils
  - (3) 1.5-ton fan coils
  - (1) 1-ton fan coils
  - (3) 0.5-ton fan coils
- (1) 350 L/s (750 cfm) ERV with ECM motors and dual cores
- (1) 450 L/s ERV (950 cfm) with ECM motors and dual cores
- (4) 80 gallon packaged heat pump water heater

System Schematic

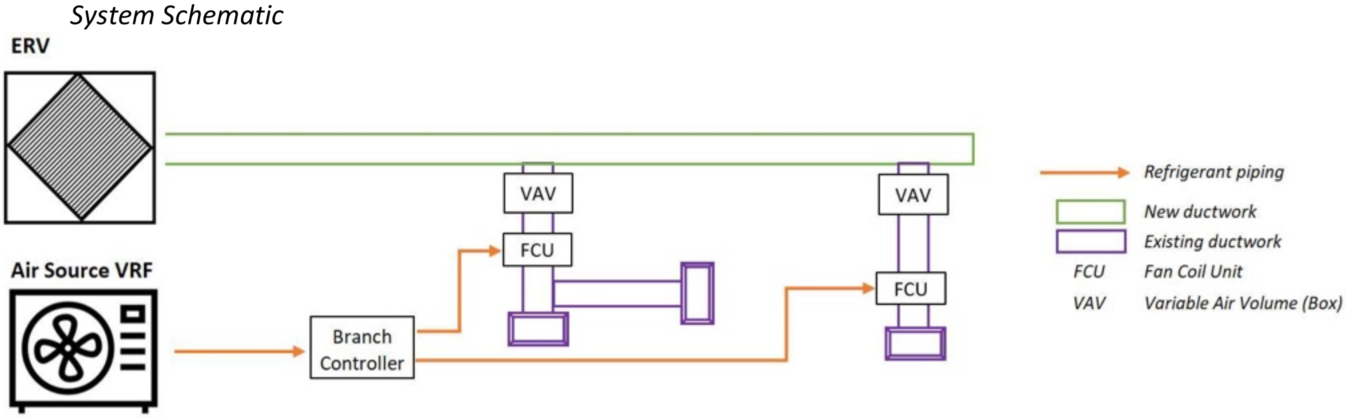


Figure 22 ASHP System Schematic

a. *Ground Source Heat Pump (GSHP) Option*

This option is the equivalent to the air source VRF scenario except heating and cooling would be generated by a water source VRF system. A series of water cooled VRF units will be connected to closed-loop vertical borehole ground heat exchangers. The vertical loop heat exchanger system will consist of long lengths of 1-1/4" diameter HDPE or PEX tubing placed in boreholes drilled to a depth of approximately 150m below the surface level and filled with thermally enhanced grout. Length of pipe, diameter of pipe, and the spacing of wells will depend on the final building heating and cooling loads during detailed design. An estimated 3 boreholes will be required for the building.[1] As the ground source VRF unit does not decrease capacity with reduced outdoor air temperatures, the unit has been sized for 100% cooling and 90% heating.

Accessories to the GSHP piping system would include glycol fill tank, expansion tank, air venting, circulation pumps and isolation valves. Each water-cooled unit will have a circulation pump on the evaporator and condenser side and be controlled when the compressor is engaged.

The boreholes would most likely be located on the north side of the property, refer to Figure 32. However, further analysis must be conducted to confirm the system design.

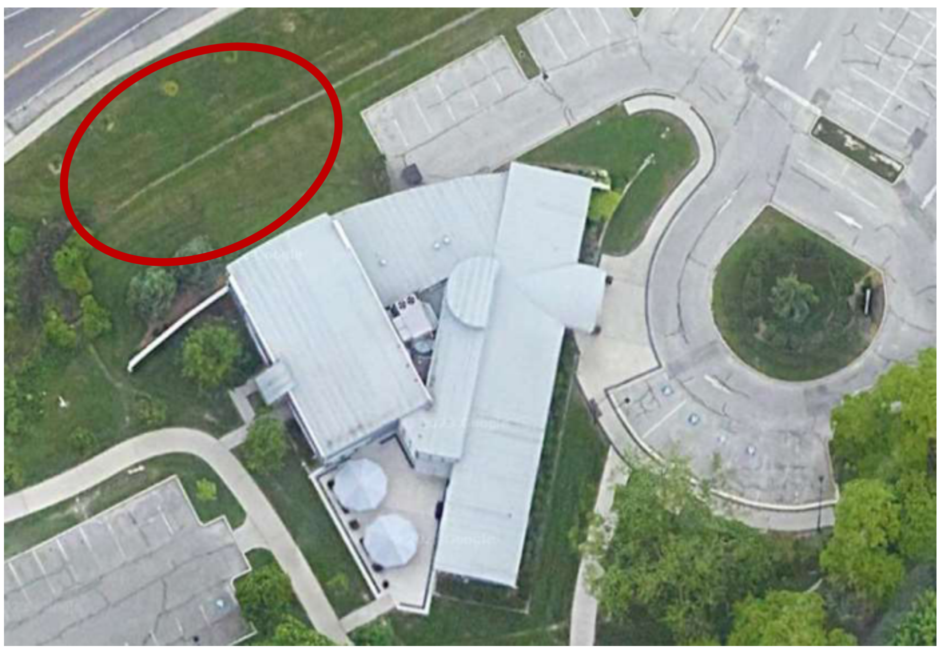


Figure 23 Proposed Borehole Location

The ground source VRF option would utilize the same distribution system outlined in the air source option.

Domestic water would be provided by a packaged heat pump water heater (HPWH). The HPWH has been sized according to existing tank capacity.

Ventilation

The ventilation system will be equivalent to the air source system. Two ERVs will be installed, one dedicated to the auditorium and one for the rest of the building. The required alterations to the distribution system are consistent with the air source option.

[1] *Assumes 150m boreholes with capacity of 160 m per kW (150 ft per ton)*

Controls
The new VRF equipment, circulation pumps and ERVs would tie into the building's existing direct digital control system.

System Overview
A list of required equipment and system schematic have been included below.

Equipment List

- (2) Nominal 10-ton ground/water source VRF condensing units with branch controllers
- (15) 0.5 kW Electric duct heaters
- (15) VAV boxes (100 cfm average)
- Ground Source Circulation Pumps (includes standby pumps)
  - (2) Ground loop circulation pumps, approximately 50 gpm, 2 hp (0.85 bHP) each with VFD
- Fan Coils
  - (2) 2-ton fan coils
  - (3) 1.5-ton fan coils
  - (1) 1-ton fan coils
  - (3) 0.5-ton fan coils
- (1) 350 L/s (750 cfm) ERV with ECM motors and dual cores
- (1) 450 L/s ERV (950 cfm) with ECM motors and dual cores
- (1) 80 gallon packaged heat pump water heater

System Schematic

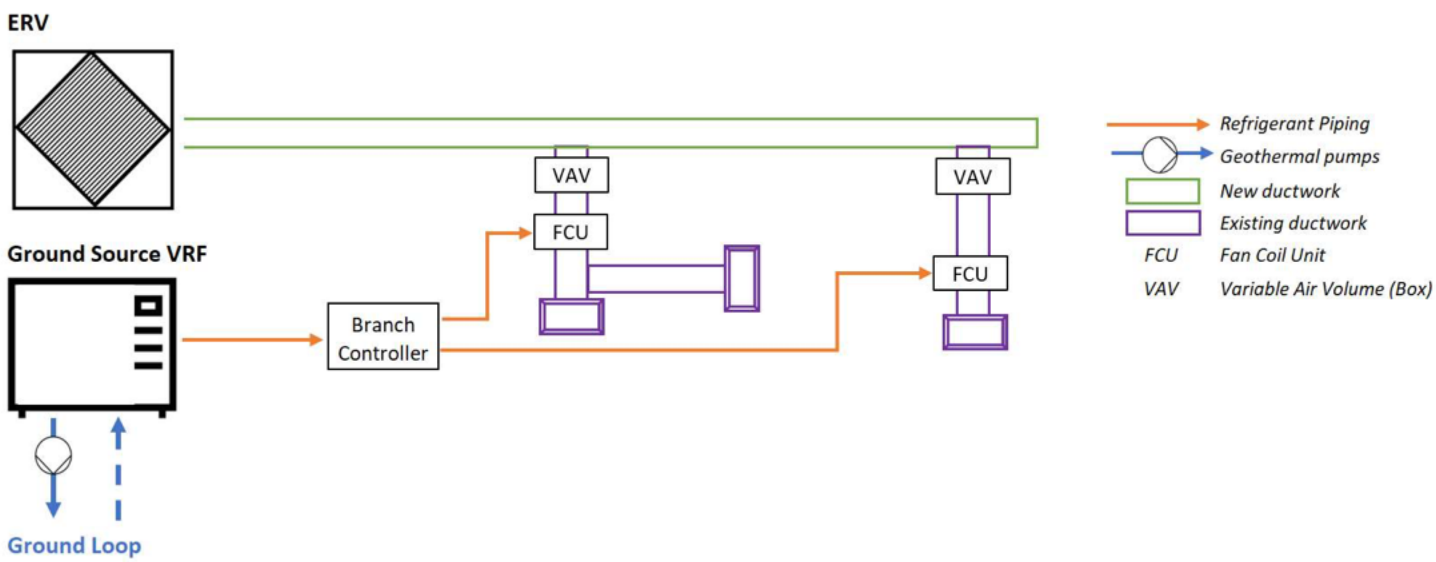


Figure 24 Ground Source VRF System Schematic

3. Net Zero Scenario
The net zero scenario is identical to the net zero ready scenario with the addition of a PV system.

Scenario System Summary

Item	Existing Building	Minimum Acceptable	ASHP Net Zero Energy[1]	GSHP Net Zero Energy [1]
Effective Wall R-value	R-10	R-15	R-25	R-25
Effective Roof R-value	R-7	R-25	R-60	R-60
Air Tightness (L/s·m^2 at 75Pa)	3.0 L/s·m2	0.5 L/s·m2	0.5 L/s·m2	0.5 L/s·m2
Central Heating Equipment	Natural gas rooftop units	Natural gas rooftop units	Air source VRF	Ground source VRF
Heating System	Ducted VAV AHUs and electric baseboards	Ducted VAV AHUs and electric baseboards	Ducted fan coil units	Ducted fan coil units
Cooling System	Ducted VAV AHUs	Ducted VAV AHUs	Ducted fan coil units	Ducted fan coil units
DHW Equipment	Electric Water Heater	Electric Water Heater	HP Water Heater	HP Water Heater
Ventilation Equipment	Ducted VAV AHUs	Ducted VAV AHUs with demand-controlled ventilation	90% SRE ERVs with VAV boxes in zones	90% SRE ERVs with VAV boxes in zones
Renewables	-	-	TBD	TBD

[1] *Net Zero Energy Ready systems are identical with exclusion of renewables*

Appendix E

Electrical Outline Specification

PURPOSE

The purpose of this Design Summary is to document the existing electrical systems for the energy retrofit of the Sir John Colborne Recreation Centre for Seniors located at 1565 Old Lakeshore Road in Oakville, Ontario. The intent is to summarize the major features and design parameters for the Electrical Power and Lighting disciplines.

The building was constructed in 1989 and is primarily used for registered and drop-in recreation services including meetings, workshops, and art classes. There are multiple offices on the east side of the building and an auditorium on the west face.

EXISTING SYSTEMS

Site Services

Existing incoming power service consists of two, 4” PVC conduits on the primary side servicing the existing pad mount transformer on site. The size of the pad mount transformer is unknown. The existing main incoming secondary service is sized at 300A, 600V, 3P and consists of two 4” PVC conduits. The secondary service feeders consist of 4#350MCM R90, which are rated for 357A when run underground in conduit. The secondary service entrance enters the building in the main electrical room and terminates onto the main service entrance rated fused disconnect switch. The building’s main disconnect is a 400A loose fusible switch fused at 300A.

Figure 1: Existing Main Disconnect

This information was obtained from the single line diagram in the drawing package provided to the team. Note the drawing package appears to be the original as-builts for the building and changes may have been made to the existing electrical systems since.

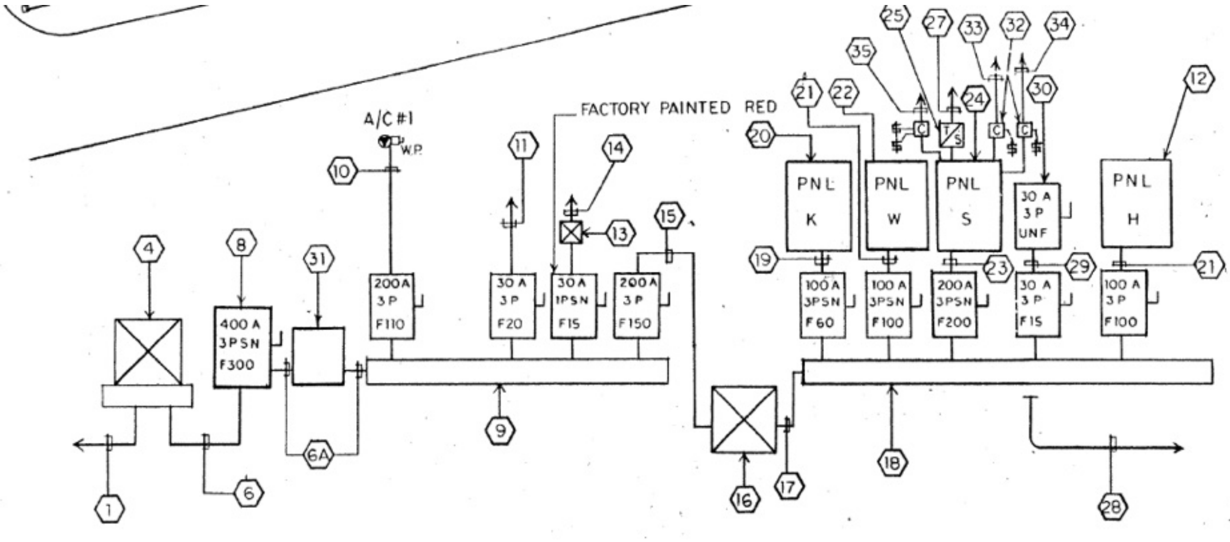


Figure 2: Existing SLD

Electrical Power Distribution Services

Main Distribution Equipment
The existing main distribution is original to the building and consists of a main disconnect, a main 600V splitter and multiple branch circuit panelboards throughout the building. There is also a 120/208V system fed from the 600V system via a step-down transformer. Based on the photos provided, the main distribution equipment appears to be in okay condition. No maintenance logs are available to determine if any work has been completed done throughout the years. It appears the main distribution equipment is near its end of life.

The main building disconnect is a 80% rated 400A fused disconnect switch fused at 300A. All other disconnects for panels, motors etc. are also fusible disconnects. Visually the disconnects appear to be in okay condition. Based on the photos provided of the main electrical room, it appears the room is nearing capacity and additional space may be required to add on additional electrical distribution in the future.

Figure 3: Main 600V Splitter and panels

Existing Branch Circuit Panelboards
Several 120-208V and 347-600V branch circuit panelboards exist throughout the building servicing all areas. All panelboards appear to be original to the building and range from okay to good condition. No mini breakers are present in the existing panelboards. Based of the photos provided, there is extremely limited breaker space available for additional equipment. Depending on the scope of electrical changes, additional distribution may need to be added. Some panels appear to have breakers installed that are no longer in use, which could be removed to allow room for new distribution and branch circuits.

No logging data on power demand of the existing panelboards is available, more information would be needed to determine if the panels have adequate capacity to allow for additional load in the future. This could either be a calculated estimation, or the panels could be logged with a power meter to determine demand load.

Although there is a single line diagram that details the electrical distribution and wiring throughout the building. The drawings appear to be original to the building and likely does not capture changes made over the years.

Figure 4: Branch Circuit Panelboard

Figure 5: Branch Circuit Panelboard

Referencing table A-8.4.3.2.2, Division B of the 2017 National Energy Code the basic plug load for each section of the building is as follows.

Occupancy Type	Demand Load	Area
Auditorium	2.5 W/m^2	2590 ft^2
Kitchen	10 W/m^2	300 ft^2
Seminar Room	2 W/m^2	340 ft^2
Offices	7.5 W/m^2	770 ft^2
Multipurpose	5 W/m^2	1480 ft^2
Lounge	1.5 W/m^2	2020 ft^2
Wood working	10 W/m^2	390 ft^2
Washrooms	1 W/m^2	410 ft^2
Service	0.5 W/m^2	320 ft^2

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

Electric Baseboard Heating
Electric baseboard heaters are located throughout the building perimeter to support the main heating system which consists of several rooftop units and a VAV system. The baseboard heaters do not appear to be original to the building. The heaters are in good condition and well within their life expectancy. There is also an electric fireplace in the lounge although this does not appear to be used often.

Figure 6: Existing Baseboard Heater

Figure 7: Existing Electric Fireplace

Lighting and Lighting Control System

Interior Lighting

The building serves many different functions and as a result has many different types of lighting throughout. The majority of the fixtures are either rectangular or linear fluorescent fixtures with T8 lamps. The fixtures appear to be well-maintained and in okay to good condition depending on the area of the building. There are also multiple areas with track lighting and or downlights throughout the building. Most of the existing fluorescent lighting appears to be within its reasonable life expectancy. The estimated LPD for the areas with fluorescent lighting is 11W/m^2.

Figure 8: Gymnasium Lighting

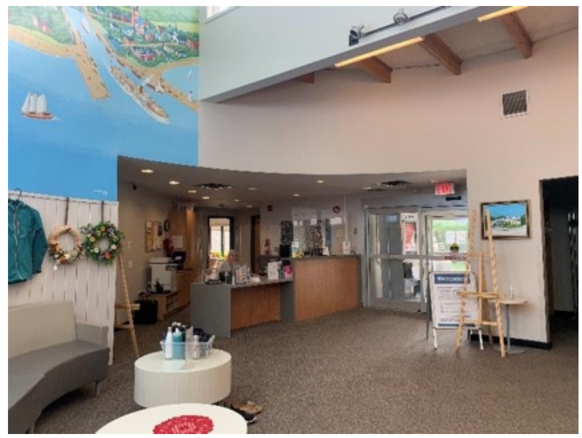


Figure 9: Lobby Lighting

Figure 10: Multipurpose Room Lighting

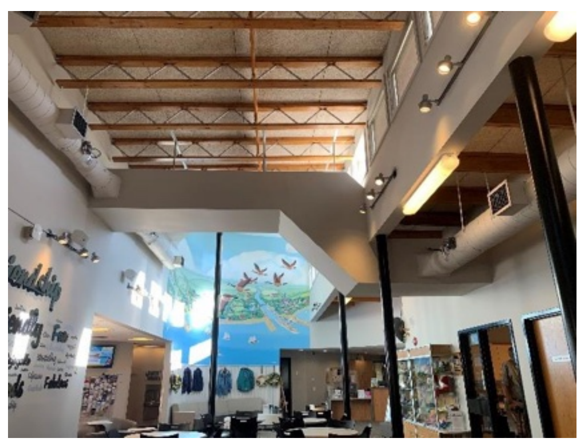


Figure 11: Lobby Track Lighting

Exterior Lighting

The existing exterior lighting is made up of a variety of different non-LED fixtures consisting mainly of high-pressure sodium. These fixtures appear to be in okay condition. The type and condition of the parking lot fixtures in unknown due to lack of photos. They do not appear to be original to the building.

PROPOSED SYSTEMS

Systems have been proposed as per the minimum acceptable, net zero ready and net zero scenarios. The details of each system are provided below. For the purpose of this study, it has been assumed that the occupancy schedules and space usage are consistent with existing conditions.

In all scenarios, it is recommended that at a minimum, existing lighting be upgraded to LED using LED lighting retrofit kits. These kits a relatively inexpensive and will help dramatically reduce energy consumption from lighting.

In some scenarios, the existing building electrical service may need to up upgraded to allow for the electrification of heating and cooling equipment and added solar capacity. The necessity of these upgrades entirely depend on how much new equipment is being added onto the existing system.

1. Minimum Acceptable Scenario

Lighting

In the minimum acceptable scenario, all existing fluorescent lighting throughout the building should be upgraded to LED using LED lighting retrofit kits. These kits come complete with LED replacement lamps and ballasts so the existing fixtures throughout the building can be internally re-wired to work with LED lamps. This will allow the existing building lighting to remain in the same areas and will reduce maintenance. In the case of downlights and track lighting, new LED bulbs will be provided. New LED retrofit kits and bulbs will be provided on an as needed basis depending on the type of fixture. These changes will help lower the existing LPD by 40% to 7W/m^2.

Figure 12: LED Retrofit Kit Tubes

Figure 13: LED retrofit Bulbs

Lighting Control
The minimum acceptable scenario does not change any of the existing lighting controls. Controls will remain manual on/off with no automatic control.

Power Distribution
The minimum acceptable scenario has no changes to the electrical distribution system due to the lack of electrification of mechanical equipment. The existing building service will remain as-is. Ten heat relays will need to be provided for the electric baseboards to ensure they can be controlled with the existing building control system.

No photovoltaics will be added or accounted for as part of the minimum acceptable scenario.

2. Net Zero Ready Scenario
The net zero scenario systems include full electrification of the HVAC and DHW systems. Two options have been proposed: air source VRFs and ground source VRFs. The net-zero ready scenario will upgrade the existing electrical distribution to accommodate a future solar array capable of producing as much energy as the building would use over the course of a year. In this scenario, the solar array will not yet be installed.

Lighting
In the net zero ready scenario, existing fluorescent fixtures will be replaced with equivalent LED fixtures on an as needed basis. Existing fixtures that are in good condition will be provided LED retrofit kits where fixtures that are nearing end of life can be replaced outright. This upgrade will also act as a lifecycle upgrade to the aging existing light fixtures. Additional light fixtures will be provided in areas where existing lighting is lacking. Light fixtures will be replaced like-for-like matching colour temperature and lumen output. In this scenario, the building lighting power density will reduce to an estimated $7W/m^2$. See replacement fixture schedule below:

Existing Fixture	Existing Wattage (total lamps)	Example Replacement Fixture Product Number	Replacement Fixture Wattage
Recessed 2x4 Highbay (GYM)	160W (4 lamps)	Lithonia: XIB-12000LM-FRGL-MVOLT	80W
Multipurpose Room Linears	80W (2 lamps)	Signify: 24-RS-L-B-C-A-H-XX-7-D-W	31W
2x2 Recessed Fixtures	80W (4 lamp)	Lithonia: BLT 40L ADP EZ1 LP835	33W

Additional light fixture alternatives and replacement bulbs will be provided as needed so all lighting is LED. Office lighting and exterior lighting to remain as-is (existing LED).

Figure 14: Lobby Lighting

Figure 15: Gymnasium Lighting

Lighting Control System

The lighting control system will be updated throughout the building to include automatic lighting control. This upgrade will help reduce unnecessary energy waste by automatically controlling the lighting to only be used while spaces are occupied. Automatic control will be provided in all areas of the building accordance with the national energy code. Daylight sensors will be provided in all areas with natural light and vacancy sensors will be provided in all areas as required by the National energy Code. All new lighting control will be low voltage 0-10V or wireless. Areas with existing occupancy sensors will have the sensors re-programed to operate in vacancy mode.

Electrical Power Distribution System

In the net zero ready scenario, a significant amount of mechanical equipment will be electrified, increasing the load on the distribution system. Since we do not have access to the facilities utility bills we cannot confirm whether or not an increase in service size will be required to accommodate the added load. The buildings demand load will need to be calculated using a demand load calculation or will need to be determined using a power meter to measure the current passing through the building's main service board. Measuring the demand load will be a year long study to determine the peak demand load every month for a year. Alternatively, if complete utility bills are made available, demand load information can be obtained from the bills. Given the size and function of the building the existing service size is larger than anticipated. A service upgrade to accommodate the proposed changes is unlikely but will need to be confirmed by the demand load study. Despite there likely being sufficient capacity on the existing electrical system, replacement of the main distribution is recommended as a lifecycle upgrade as the existing equipment is nearing its end of life. The size of the new equipment would be sized based of existing billing information or the demand study. The existing branch circuit panelboards downstream of the main distribution would remain as is and would be re-fed from the new main distribution equipment.

The net zero ready scenario should account for a PV installation when considering upgrading the buildings service size. The current energy model predicts a peak PV potential of 60kW AC. The building is currently equipped to handle the peak PV load and no service upgrades will be required to accommodate the solar upgrade. This amount of solar that can be added is based off the main disconnect size and the main bus size. The new main switchboard and main breaker would need to be sized to accommodate this load. Assuming the equipment is being replaced 1 for 1 with the existing distribution equipment, the system would be capable of handling up to 187kW (AC) of solar, far beyond what is required to achieve net-zero (this assumes a 400A bus size and a 300A breaker size). To accommodate a new solar array and the new distribution equipment, more space would be needed to allow room for a new transformer and panelboard. The existing main electrical room appears to be at capacity, so this would not be an option.

In both mechanical options, new electrical distribution will be added off the main distribution to allow for connection to mechanical equipment. A new 3P, 208Vpanelboard will be added to service all VRFs, FCUs, duct heaters, ERVs, water heaters etc. This new distribution could be added in the proposed new mechanical room.

Air Source VRF Option

Net-Zero Ready (ASHP)	Qty	kW	Total Load (kw)
Nomial 10ton air source VRF	1	15	15
0.5kW Duct Heater	15	0.5	7.5
2-Ton FCU	2	0.25	0.5
1.5-Ton FCU	3	0.25	0.75
1-Ton FCU	1	0.23	0.23
0.5-Ton FCU	3	0.23	0.69
700 L/s ERV	1	2	2
350 L/s ERV	1	1	1
80 Gallon Heat Pump Water Heater	4	5	20
Nomial 10ton air source VRF	1	15	15
Total Added Load			48

Ground Source VRF Option

Net-Zero Ready (ASHP)	Qty	kW	Total Load (kw)
Nomial 10ton ground source VRF	2	10.8	22
0.5kW Electric Duct Heater	15	0.5	8
Ground Source Circ Pumps	2	1	2
2-Ton FCU	2	0.25	1
1.5-Ton FCU	3	0.25	1
1-Ton FCU	1	0.23	0
0.5-Ton FCU	3	0.23	1
350 L/s ERV	2	1	2
450 L/s MUA w/ 30kW Electric Heater	1	2	2
80 Gallon Heat Pump Water Heater	4	5	20
Total Added Load			57

The new mechanical equipment would need to be taken into consideration when sizing the new distribution system. Assuming that the existing demand load is low, and the existing distribution equipment is being replaced 1:1, there would be sufficient room on the system for either mechanical scenario, and the proposed PV system.

A letter will be sent to the utility (Burlington Hydro) to inform them of added load onto the buildings existing electrical service. A new padmount transformer may be provided by the utility if they feel it is necessary to account for the added load. The letter will include an updated load calculation showing what the existing load is on the building (obtained from the year-long demand study) and what the new load will be. The cost of replacement of the existing pad mount transformer is covered by the utility if it is required.

3. Net Zero Scenario

The net zero scenario is identical to the net zero ready scenario with the addition of the net-zero PV system. Since the PV system is already account for in the net-zero ready scenario, there is no additional changes needed to the electrical distribution system above and beyond the net-zero ready scenario.

In Ontario, there is a 1MW on commercial net metered solar systems which is well over the amount of solar being proposed. In a net metering agreement, 100% of the excess energy generated from the solar array is put back on the utility grid and the consumers account is credited for the 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.

Air Source VRF Option

Required PV Array Size (AC)	PV Array Size (DC) DC:AC Ratio of 1.7:1	Introduced Demand Load (Mechanical)	New Estimated Panelboard Size	New Estimated Main Breaker Size	Service Entrance Replacement Recommended
37.6kW	64kW	48kW (46.4A)	400A	300A (80% rated)	Yes

Ground Source VRF Option

Required PV Array Size (AC)	PV Array Size (DC) DC:AC Ratio of 1.7:1	Introduced Demand Load (Mechanical)	New Estimated Panelboard Size	New Estimated Main Breaker Size	Service Entrance Replacement Recommended
37kW	63kW	57kW (55A)	400A	300A (80% rated)	Yes

Note a DC:AC ratio of 1.7:1 is used as recommended ratio of array size to inverter size. Final Ratio to be confirmed by system designer. Replacement of the main switchgear is recommended in all scenarios.

Appendix F

Pre-retrofit Utility Records

- **Electricity Bills**
- **Gas Bills**

Oakville
Energy Use As Reported by Client

Summarized by Monthly Consumption

As calculated by RDH

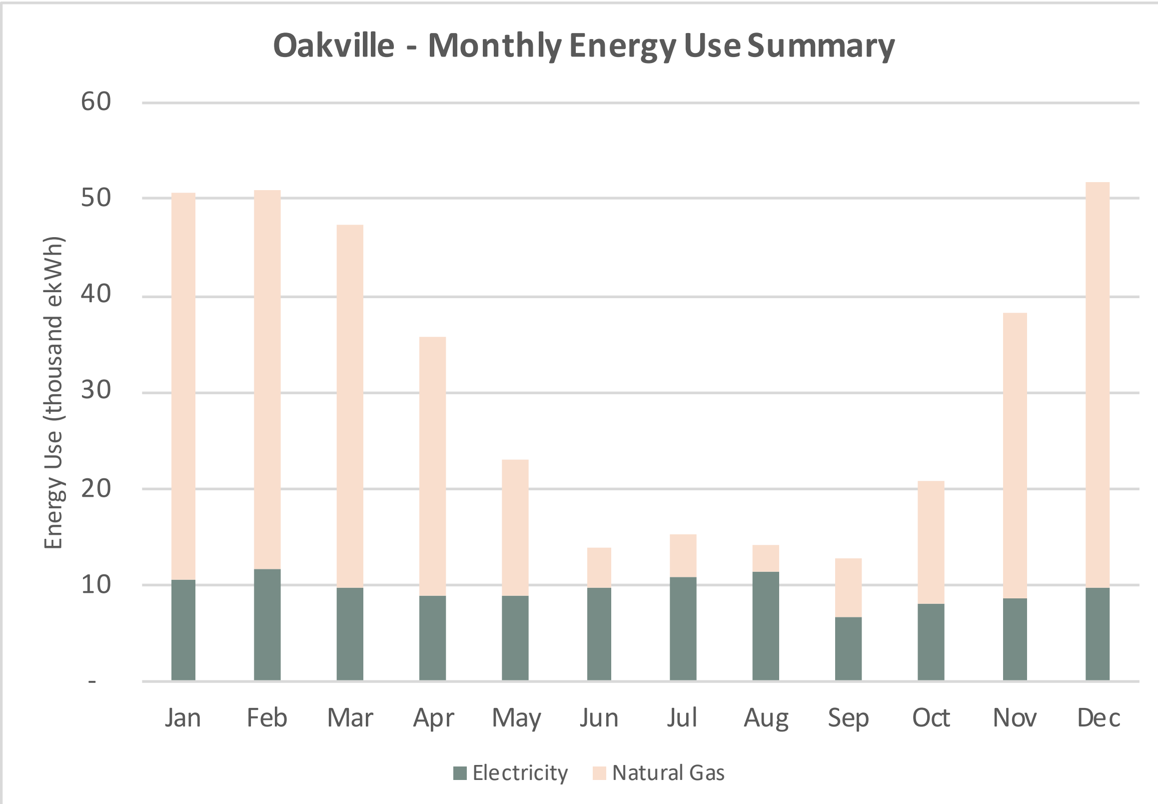
Electrical Consumption (kWh)

	2018	2019	2020	2021	2022	Average	
Jan		13,572	11,961	8,583	7,830	10,487	**Jan**
Feb		12,451	14,626	10,923	8,487	11,622	**Feb**
Mar		11,253	9,978	10,204	7,007	9,611	**Mar**
Apr		11,691	6,733	10,216	7,481	9,030	**Apr**
May		10,209	6,197	10,430	8,818	8,914	**May**
Jun		9,539	11,377	9,372	8,506	9,699	**Jun**
Jul		14,064	11,153	9,142	9,137	10,874	**Jul**
Aug	16,436	10,680	9,291	9,006		11,353	**Aug**
Sep	6,973	8,462	4,516	6,609		6,640	**Sep**
Oct	10,210	8,435	6,320	7,462		8,107	**Oct**
Nov	10,459	9,808	7,414	7,261		8,736	**Nov**
Dec	9,587	11,028	9,947	8,169		9,683	**Dec**

Natural Gas (M^3)

	2019	2020	2021	2022	Avg. (M^3)	ekWh	
Jan		3,587	4,204	3,664	3,818	40,282	**Jan**
Feb		3,638	4,354	3,186	3,726	39,311	**Feb**
Mar		3,169	3,777	3,806	3,584	37,813	**Mar**
Apr		3,752	3,047	765	2,521	26,599	**Apr**
May		1,620	1,762	603	1,328	14,014	**May**
Jun		102	708	375	395	4,168	**Jun**
Jul	480	514	54	665	428	4,520	**Jul**
Aug	520	262	51		278	2,928	**Aug**
Sep	736	929	56		574	6,054	**Sep**
Oct	1,785	1,023	793		1,200	12,664	**Oct**
Nov	3,175	2,757	2,476		2,803	29,567	**Nov**
Dec	4,008	4,690	3,275		3,991	42,102	**Dec**

ekWh converstion factor used	10.55


Oakville - Monthly Energy Use Summary
Energy Use (thousand ekWh)
60
50
40
30
20
10
-
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Electricity
Natural Gas

Appendix G

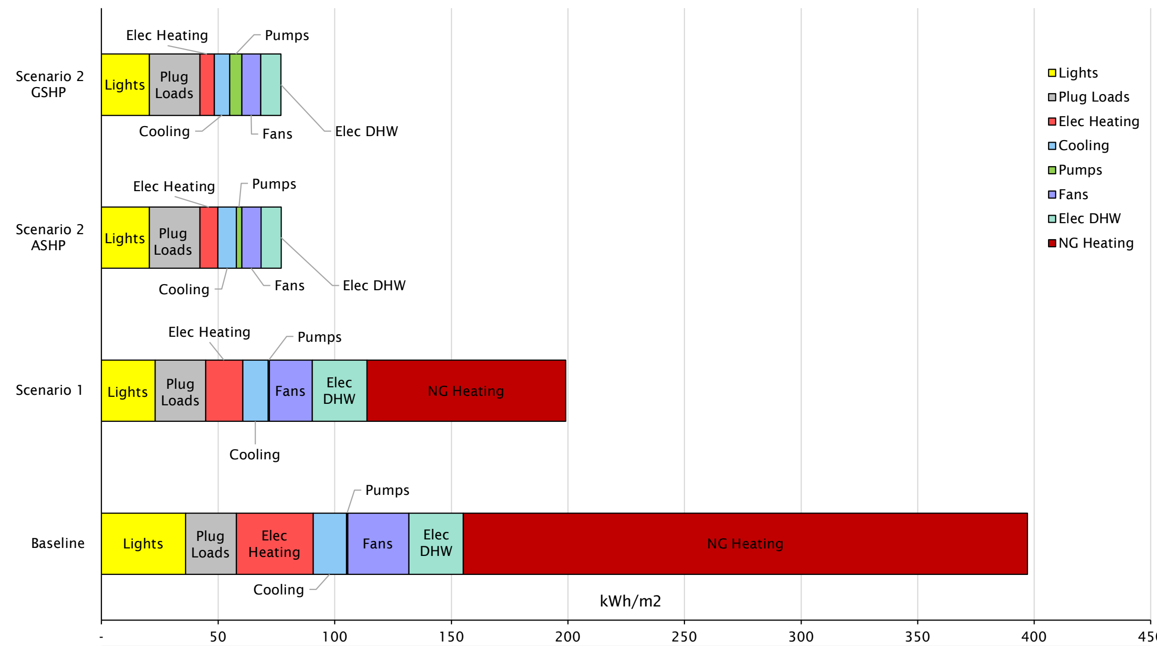
Energy Model Reports

RDH BUILDING SCIENCE

Oakville

These values are based on a model with no unmet heating hours and only represent the relative fraction of enlosure losses.

Total Energy Use Intensity TEUI (kWh/m²/yr):

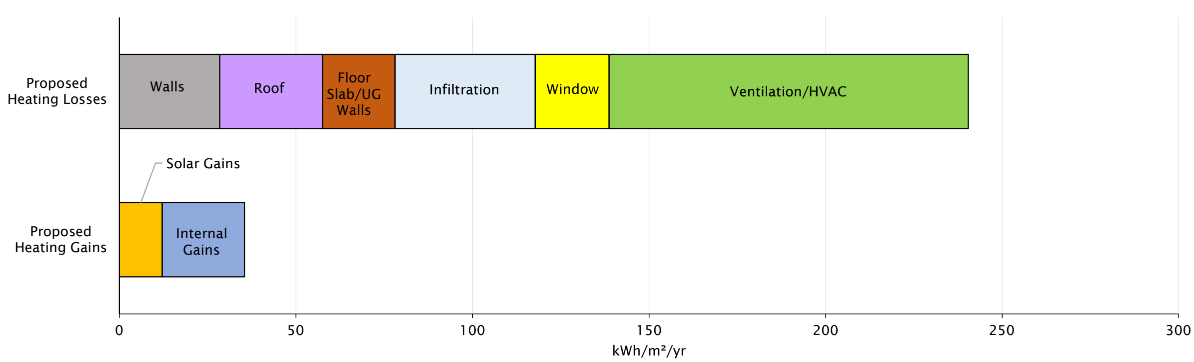


	Baseline	Scenario 1	Scenario 2 ASHP	Scenario 2 GSHP
Lights	36.06	22.93	20.44	20.44
Plug Loads	21.71	21.71	21.71	21.71
Elec Heating	32.96	15.92	7.78	6.17
Cooling	14.32	10.86	7.85	6.68
Pumps	0.57	0.57	2.40	5.11
Fans	26.12	18.39	8.19	8.18
Elec DHW	23.43	23.41	8.65	8.65
NG Heating	241.93	85.26	-	-

Note: The values presented above represent the relative proportion of each component of total energy use.

	TEUI		Total kWh	
Baseline	397.1	kWh/m²/yr	319089	kWh/yr
Scenario 1	199.1	kWh/m²/yr	159949	kWh/yr
Scenario 2 ASHP	78.8	kWh/m²/yr	63299	kWh/yr
Scenario 2 GSHP	78.3	kWh/m²/yr	62947	kWh/yr

Thermal Energy Demand Intensity TEDI (kWh/m²/yr) of the Baseline Model



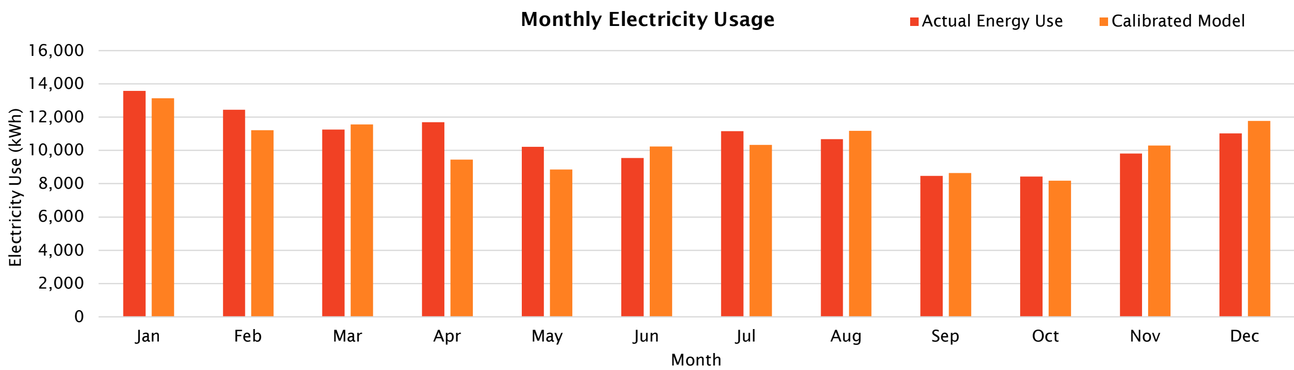
Note: The values presented above, represent the relative proportion of each component of the thermal energy demand intensity. These values include adjustments that account for internal gains from lights/plug loads/solar

Oakville

Project #, Building Name: Calibrated Model Filename: Weather File		26522, Sir John Colborne Recreation Centre for Seniors 26522_Oakville_Seniors_2022_10_21 CAN_ON_Toronto.Pearson.Intl.AP.716240_CWEC2016.bin
Total Energy, kWh	3.93E+05	**List of Model Calibrations:** - Actual electricity consumption is 2019 pre-pandemic usage - Actual natural gas with 2019-2022 average consumption as data was not available for the entire 2019 year - Natural gas consumption has not been calibrated as the source of the natural gas consumption during the summer and general increase throughout the year is not clear.
Meter EUI, kWh/m2	488	
Model EUI, kWh/m2	397	

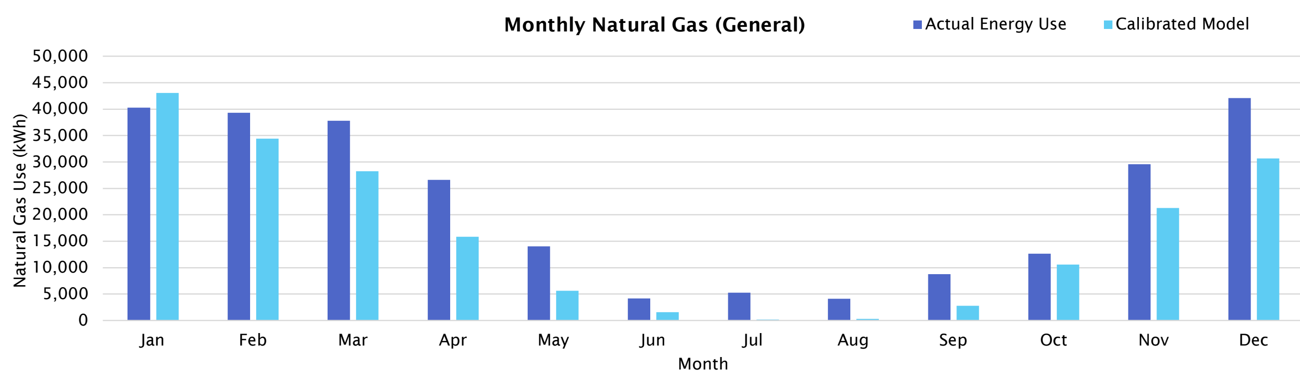
Monthly Electricity Usage (kWh)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Actual Energy Use	13,572	12,451	11,253	11,691	10,209	9,539	11,153	10,680	8,462	8,435	9,808	11,028	128,281
Calibrated Model	13,133	11,211	11,558	9,444	8,849	10,238	10,340	11,173	8,643	8,178	10,299	11,770	124,835
Difference	-439	-1,240	305	-2,247	-1,360	699	-813	493	181	-257	491	742	-3,446
% Difference	-3.2%	-10.0%	2.7%	-19.2%	-13.3%	7.3%	-7.3%	4.6%	2.1%	-3.1%	5.0%	6.7%	-2.7%



Monthly Natural Gas Usage (kWh)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Actual Energy Use	40,282	39,311	37,813	26,599	14,014	4,168	5,247	4,123	8,786	12,664	29,567	42,102	264,676
Calibrated Model	43,065	34,410	28,241	15,830	5,650	1,580	214	301	2,776	10,614	21,280	30,646	194,605
Difference	2,783	-4,901	-9,572	-10,769	-8,365	-2,589	-5,033	-3,822	-6,010	-2,050	-8,287	-11,456	-70,070
% Difference	6.9%	-12.5%	-25.3%	-40.5%	-59.7%	-62.1%	-95.9%	-92.7%	-68.4%	-16.2%	-28.0%	-27.2%	-26.5%



RDH

Oakville

Energy Model Input Summary

METHODOLOGY	
The following summary outlines the Proposed Design as presented in the drawings and narratives provided to RDH. Where these documents are not fully developed, assumptions were made based on previous experience. This information will be used to assess the energy savings of the current design to confirm the design is on track to achieve the targeted performance.	
Documents Referenced	Mechanical - Oakville Existing Outline.pdf Sir John Colborne Recreation Center drawings by Svedas Koyanagi Architects Inc. dated June 6, 1989 Site Photos

ARCHITECTURAL						
Spaces	Area	Units	System			
Total	**8650**	ft²				
Auditorium	2590	ft²	RTU-1			
Kitchen	300	ft²	RTU-2			
Seminar Room	340	ft²	RTU-2			
Office 2 and Storage	270	ft²	RTU-2			
Office 1 and Reception	500	ft²	RTU-2			
Crafts B	430	ft²	RTU-2			
Lounge	590	ft²	RTU-2			
Active Lounge	1030	ft²	RTU-2			
Lounge	400	ft²	RTU-2			
Crafts A	310	ft²	RTU-2			
Wood Working	390	ft²	RTU-2			
Billiards Room	740	ft²	RTU-2			
Service entry/mech/elec	320	ft²	N/A			
Staff washroom	50	ft²	N/A			
Washroom	360	ft²	N/A			

Building Enclosure	Oakville Seniors Center	Scenario 1: Min Acceptable 50% Reduction	Scenario 2: ASHP Net Zero Ready	Scenario 2: Net Zero Ready GSHP	Units	Notes/ Reference
Above Grade CMU Walls W1	R-7.33	Panelized walls to meet R-20 overall effective	Panelized walls to meet R-25 overall effective	Panelized walls to meet R-25 overall effective	IP	4" Stone veneer or Wood siding w/ 2" insulation (R3.5/in) over 12" conc blocks. 25% reduction of insulation effectiveness due to thermal bridging of stainless ties - drawings by Svedas Koyanagi Architects Inc. dated June 6, 1989
Above Grade Framed Wall W2	R-14.70	Panelized walls to meet R-20 overall effective	Panelized walls to meet R-25 overall effective	Panelized walls to meet R-25 overall effective	IP	2x6 Framed Wall with R-20 batt insulation - drawings by Svedas Koyanagi Architects Inc. dated June 6, 1989
Roof R1 Rigid Insulation	R-5.87	Panelized roof to meet R-25 overall effective	Panelized roof to meet R-60 overall effective	Panelized roof to meet R-60 overall effective	IP	Roof membrane w/ 2" of rigid insulation per section B-B A-6. Approximately 7% of roof area - drawings by Svedas Koyanagi Architects Inc. dated June 6, 1989
Roof R2 SIP	R-14.63	Panelized roof to meet R-25 overall effective	Panelized roof to meet R-60 overall effective	Panelized roof to meet R-60 overall effective	IP	Roof membrane over Tectum III SIP - R-value per manufacturer data
Glazing	U-0.4 SHGC-0.37 VT-0.43	U-0.18 SHGC-0.32 VT-0.43	U-0.18 SHGC-0.32 VT-0.43	U-0.18 SHGC-0.32 VT-0.43	IP	Wood windows with insulated glazing. Per Arch
Doors	Assume U-0.2	Assume U-0.2	Assume U-0.2	Assume U-0.2	IP	per Arch
Fenestration	**Oakville Seniors Center**	**Scenario 1: Min Acceptable 50% Reduction**	**Scenario 2: ASHP Net Zero Ready**	**Scenario 2: Net Zero Ready GSHP**	**Elevation**	**Notes/ Reference**
Window to Wall Ratio	5.00%				North	RDH
	9.00%				Northwest	RDH
	9.00%				South	RDH
	0.00%				East	RDH
	28.00%				South-East	RDH
	18.00%				West	RDH
	38.00%				South-West	RDH
	15%				**Overall**	Building Elevations
Infiltration	**Oakville Seniors Center**	**Scenario 1: Min Acceptable 50% Reduction**	**Scenario 2: ASHP Net Zero Ready**	**Scenario 2: Net Zero Ready GSHP**		
Infiltration Rate	3.0 L/s/m² exterior vertical enclosure and roof area @ 75Pa (Modelled as 0.52 L/s/m² @ 5Pa, assumed operating pressure)	75% Reduction to 0.75L/s/m² exterior enclosure area	75% Reduction to 0.75L/s/m² exterior enclosure area	75% Reduction to 0.75L/s/m² exterior enclosure area	L/s/m2	L/s/m² exterior vertical enclosure and roof area @ 5Pa

RDH

MECHANICAL- Airside

RTU - 1	Oakville Seniors Center	Scenario 1: Min Acceptable 50% Reduction	Scenario 2: ASHP Net Zero Ready	Scenario 2: Net Zero Ready GSHP	Units	Notes/ Reference
Zones Served	Auditorium	Auditorium	Entire Building	Entire Building		Note that building operations has observed heating and cooling running at the same time. This was not modeled and as such the model gas usage is lower than the actual use.
System Type	VAV RTU with gas fired heating and DX cooling	VAV RTU with gas fired heating and DX cooling	Air Source VRF providing refrigerant to FCUs. Outdoor unit can operate down to -22F, but at 0F it's capacity can only provide 85% of the peak building load so electric duct heaters supplement. DOAS (ERV) providing fresh air to FCUs	Ground Source VRF providing refrigerant to FCUs. Sized to meeting 100% of the peak building cooling load and 85% of the heating (electric duct heaters supplement). Ground loop circulation pumps (2) to be 2 HP (0.85 bHP) and have VFDs. DOAS (ERV) providing fresh air directly to FCUs		
Design Air Flow	Total = 5400 VAV-01 (Auditorium 1) = 1800 VAV-02 (Auditorium 2) = 1800 VAV-03 (Auditorium 3) = 1400 VAV-04 (Auditorium 3) = 1400	Total = 5400 VAV-01 (Auditorium 1) = 1800 VAV-02 (Auditorium 2) = 1800 VAV-03 (Auditorium 3) = 1400 VAV-04 (Auditorium 3) = 1400	Assume 350 cfm/ton FCUs run continuously to provide ventiation air	Assume 350 cfm/ton FCUs run continuously to provide ventiation air	cfm	Mechanical - Oakville Existing Outline.pdf
Min Airflow	60%	40%	40%	40%	ratio	BAS
Outdoor air volume	1620	max = 900 cfm min = 250 cfm	ERV provides ventilation Auditorium: Max = 750 cfm, min = 200 All other: Max = 950 cfm, min = 400	ERV provides ventilation Auditorium: Max = 750 cfm, min = 200 All other: Max = 950 cfm, min = 400	cfm	Per M&R
Outdoor air control	Dampers	CO2 sensors	VAV boxes with CO2 sensors	VAV boxes with CO2 sensors		
Heat Output	144	144	ASHP = 135,000 (@47F) Electric duct heaters = 15 x 0.5kW	HP = 135,000 Electric duct heaters = 15 x 0.5kW	MBH	Mechanical - Oakville Existing Outline.pdf
Heating Efficiency	75%	75%	ASHP: COP = 3.8 @ 47F	COP = 4.83		Mechanical - Oakville Existing Outline.pdf
Cooling	12	12	10 tons (13 FCU total)	10 tons (9 FCU total)	Tons	Mechanical - Oakville Existing Outline.pdf
Cooling Efficiency	11.5	11.5	EER = 12	EER = 14.1	EER	Mechanical - Oakville Existing Outline.pdf
Reheat	None	None	None	None		BAS
System Power	12.8	12.8	n/a	n/a	kW	Mechanical - Oakville Existing Outline.pdf
AHU Supply Fan	5.0	5.0	FCU = 0.25 W/cfm	FCU = 0.25 W/cfm	HP	per M&R
Economizer	Yes	Yes	None	None		Mechanical - Oakville Existing Outline.pdf
Energy recovery	None	None	Ventilation provided by balanced Dual Core unit: Effectiveness: Sensible = 90%, Latent = 70% Total fan power = 1 W/cfm	Ventilation provided by balanced Dual Core unit: Effectiveness: Sensible = 90%, Latent = 70% Total fan power = 1 W/cfm	Effectiveness	
RTU - 2	**Oakville Seniors Center**	**Scenario 1: Min Acceptable 50% Reduction**	**Scenario 2: ASHP Net Zero Ready**	**Scenario 2: Net Zero Ready GSHP**	**Units**	**Notes/ Reference**
Zones Served	All other	All other	see above	see above		Note that building operations has observed heating and cooling running at the same time. This was not modeled in the baseline scenario and as such the model gas usage is lower than the actual use.
System Type	VAV RTU with gas fired heating and DX cooling	VAV RTU with gas fired heating and DX cooling				
Design Air Flow	Total = 5900 VAV-05 (Kitchen) = 300 VAV-06 (Seminar Rm) = 400 VAV-07 (Office 2&Storage) = 400 VAV-08 (Office 1 & Recep.) = 550 VAV-09 (Crafts B) = 450 VAV-10 (Lounge) = 500 VAV-11(Active Lounge) = 450 VAV-12 (Lounge) = 950 VAV-13 (Crafts A) = 350 VAV-14 (Wood Working) = 500 VAV-15 (Billiards) = 1050	Total = 5900 VAV-05 (Kitchen) = 300 VAV-06 (Seminar Rm) = 400 VAV-07 (Office 2&Storage) = 400 VAV-08 (Office 1 & Recep.) = 550 VAV-09 (Crafts B) = 450 VAV-10 (Lounge) = 500 VAV-11(Active Lounge) = 450 VAV-12 (Lounge) = 950 VAV-13 (Crafts A) = 350 VAV-14 (Wood Working) = 500 VAV-15 (Billiards) = 1050			cfm	Mechanical - Oakville Existing Outline.pdf
Min Airflow	60%	40%			ratio	BAS
Outdoor air volume	1770	max = 1200 cfm min = 500 cfm			cfm	per M&R
Outdoor air control	Dampers	CO2 sensors				
Heat Input	300	300			MBH	Mechanical - Oakville Existing Outline.pdf
Heat Output	240	240			MBH	Mechanical - Oakville Existing Outline.pdf
Heating Efficiency	0.8	80%			fraction	
Cooling	15	15			tons	Mechanical - Oakville Existing Outline.pdf
Cooling Efficiency	10.8	10.8			EER	Mechanical - Oakville Existing Outline.pdf
Reheat	Electric Baseboards	Electric Baseboards				
System Power	15.0	15			kW	Mechanical - Oakville Existing Outline.pdf
AHU Supply Fan	5.0	5			HP	
Economizer	Yes	Yes				Mechanical - Oakville Existing Outline.pdf
Energy recovery	None	None				

Zone Heating	Oakville Seniors Center	Scenario 1: Min Acceptable 50% Reduction	Scenario 2: ASHP Net Zero Ready	Scenario 2: Net Zero Ready GSHP	Units	Notes/ Reference
Electric Baseboards			no baseboards	no baseboards		
Rooms	Billiard (3), Woodworking, Crafts A, Crafts B, Office 1, Office 2, Seminar Room	Billiard (3), Woodworking, Crafts A, Crafts B, Office 1, Office 2, Seminar Room				Mechanical - Oakville Existing Outline.pdf
Power	250	250			W/ft of baseboard	Assumed 4 ft per baseboard -per M&R
Electric Fireplace						
Rooms	Lounge	Lounge				Mechanical - Oakville Existing Outline.pdf
Power	1,500	1,500			W	per M&R

Miscellaneous Ventilation Systems	Oakville Seniors Center	Scenario 1: Min Acceptable 50% Reduction	Scenario 2: ASHP Net Zero Ready	Scenario 2: Net Zero Ready GSHP	Units	Notes/ Reference
EF-1 Washrooms	0.25 450	0.25 450	ducted through ERV	ducted through ERV	HP CFM	Mechanical - Oakville Existing Outline.pdf EF-4 non-operational per RFI EF1-3,5 run during occupancy plus 1 hour on either side per M&R
EF-2 Staff Washroom	0.1 50	0.1 50	ducted through ERV	ducted through ERV	HP CFM	
EF-3 Kitchen	0.25 350	0.25 350	ducted through ERV	ducted through ERV	HP CFM	
EF-4 Crafts B (Operates with Kiln only)	0.25 350	0.25 350	0.25 350	0.25 350	HP CFM - kiln no longer exists and fan is not operational	
EF-5 Mech/Elec/Storage	0.25 350	0.25 350	ducted through ERV	ducted through ERV	HP CFM	

SPACE CONDITIONS

Space types	Schedule	Scenario 1: Min Acceptable 50% Reduction	Scenario 2: ASHP Net Zero Ready	Scenario 2: Net Zero Ready GSHP	Total Occupancy	Notes/ Reference
Rec Centre (community room, fitness etc.)	Typical hours of operation are Monday, Wednesday, Thursday, and Fridays from 8:30am – 4:30pm, and Tuesdays from 8:30am – 9:00pm.	Typical hours of operation are Monday, Wednesday, Thursday, and Fridays from 8:30am – 4:30pm, and Tuesdays from 8:30am – 9:00pm.			300-500 Occupants per day	RFI 17 Mechanical - Oakville Existing Outline.pdf
Program Rooms						
Offices						
Rec Centre						
Activity Court						
Change rooms						
Space type	**Heating Setpoint/ Setback**				**Cooling Setpoint/ Setback**	**Notes/ Reference**
Community Building	72 / 64 F	72 / 64 F			75 F/ 80 F	Assumed - Mechanical to confirm
DHW	**Oakville Seniors Center**		**Scenario 2: ASHP Net Zero Ready**	**Scenario 2: Net Zero Ready GSHP**	**Units**	**Notes/ Reference**
Heating Source	Electric	Electric	Packaged HP Water Heater (ASHP)	Packaged HP Water Heater (ASHP)		per M&R
Heating Efficiency	100%	100%	COP = 3.5 (2.7 seasonal)	COP = 3.5 (2.7 seasonal)		Standard practice
DHW Tank Setpoint	140	140	140	140	F	per M&R
DHW Delivery Setpoint	120	120	120	120	F	per M&R
Toilets	1.6	1.6	1.6	1.6	gpm	per M&R
Lavatory Faucets	0.5	0.5	0.5	0.5	gpm	per M&R
Showers	2.5	2.5	2.5	2.5	gpm	per M&R
Load	0.53	0.53	0.53	0.53	gpm peak	

ELECTRICAL						
Lighting	**Oakville Seniors Center**	**Scenario 1: Min Acceptable 50% Reduction**	**Scenario 2: ASHP Net Zero Ready**	**Scenario 2: Net Zero Ready GSHP**	**Units**	**Notes/ Reference**
Lighting Power Density	1.02	0.65	0.65 Controlled with daylight sensors where applicable	0.65 Controlled with daylight sensors where applicable	W/ft2	per M&R (2022-11-10)
Process Loads	**Oakville Seniors Center**					**Notes/ Reference**
Washer	Increased from initial NECB plug load assumption to calibrate electricity					
Dryer						
Commercial Dishwasher						
Commercial Fridge/Freezer						
Auditorium fans						

Appendix H

Panel Schematics

- **Panel Schematics**
- **Panel Connection Details**

Wall Panel Schematics

Cellulose - R11 - 2x4 - 1/2" Plywood

ReCover Initiative

ReCover

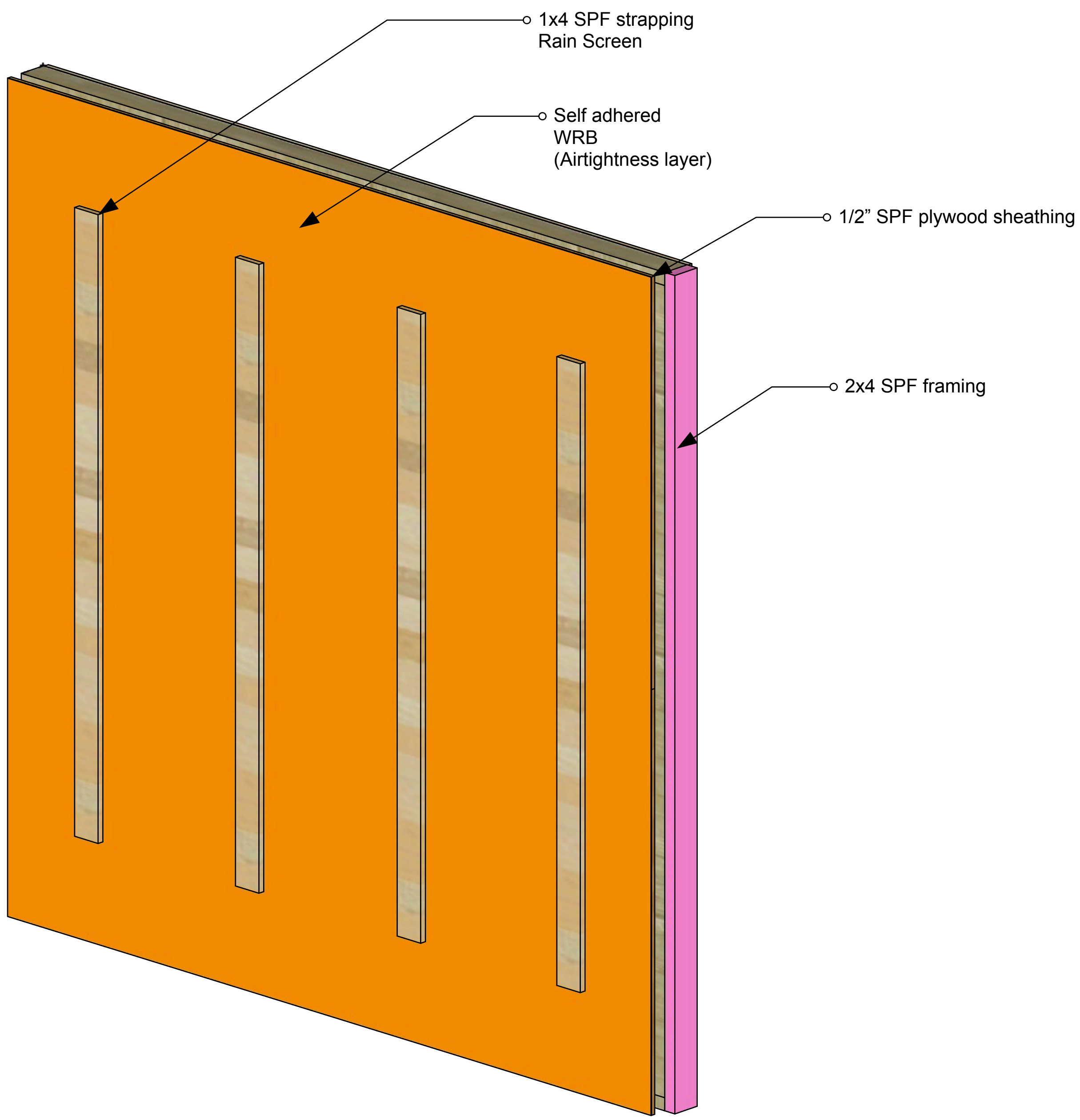
Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

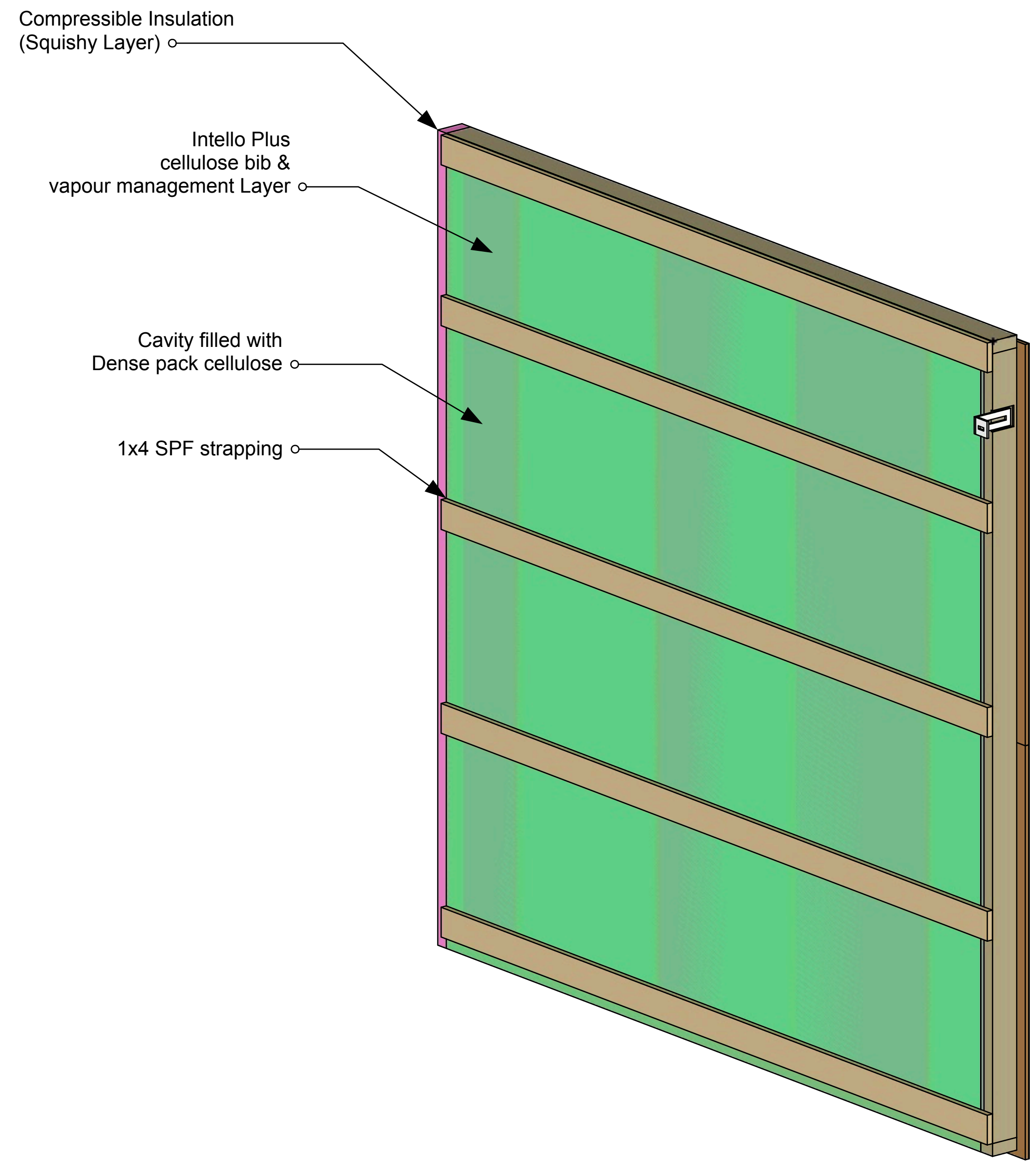
DRAWN BY
Nick Rudnicki

Panel - Overview

Panel schematic with all membranes in place



EXTERIOR VIEW



INTERIOR VIEW

ReCover

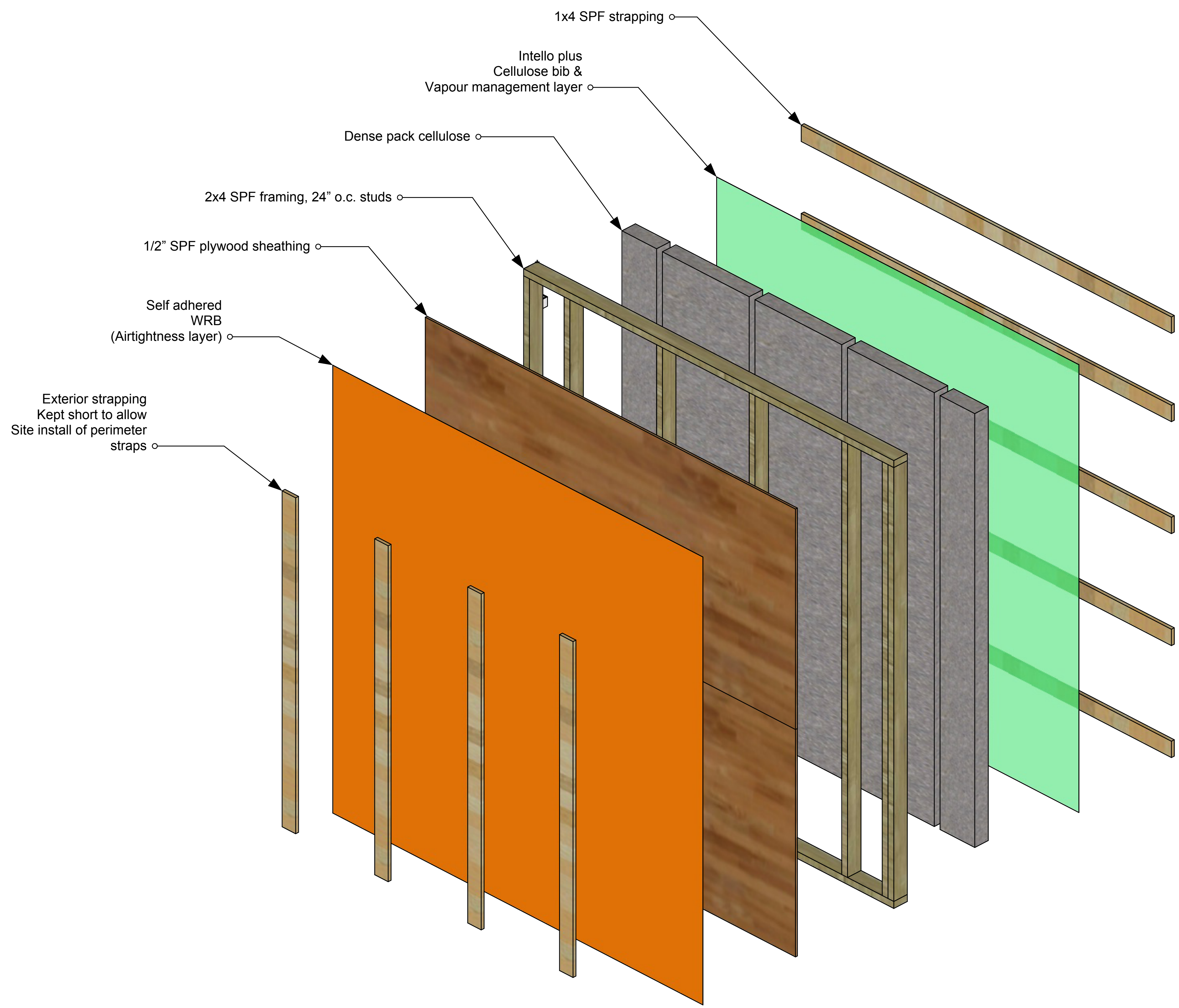
Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

Panel - Exploded View

Panel schematic with all membranes in place



ReCover

Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

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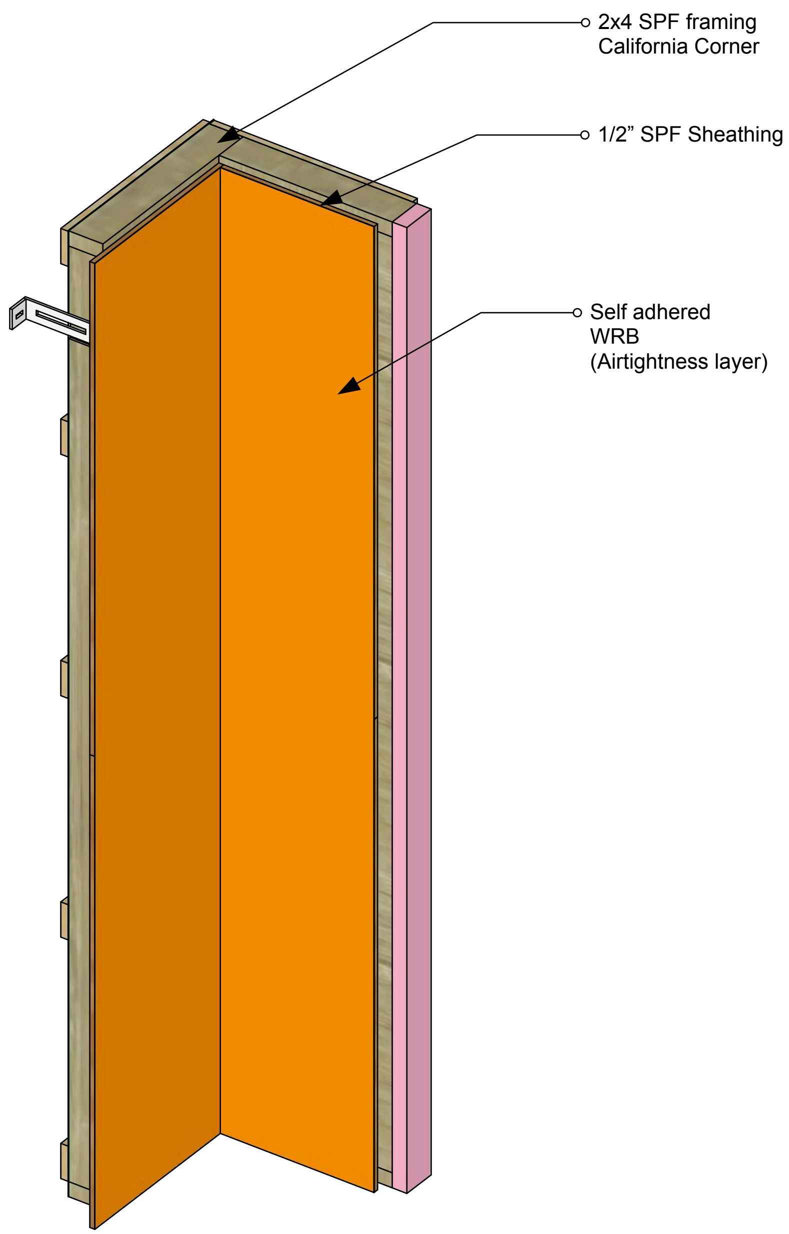
Nick Rudnicki

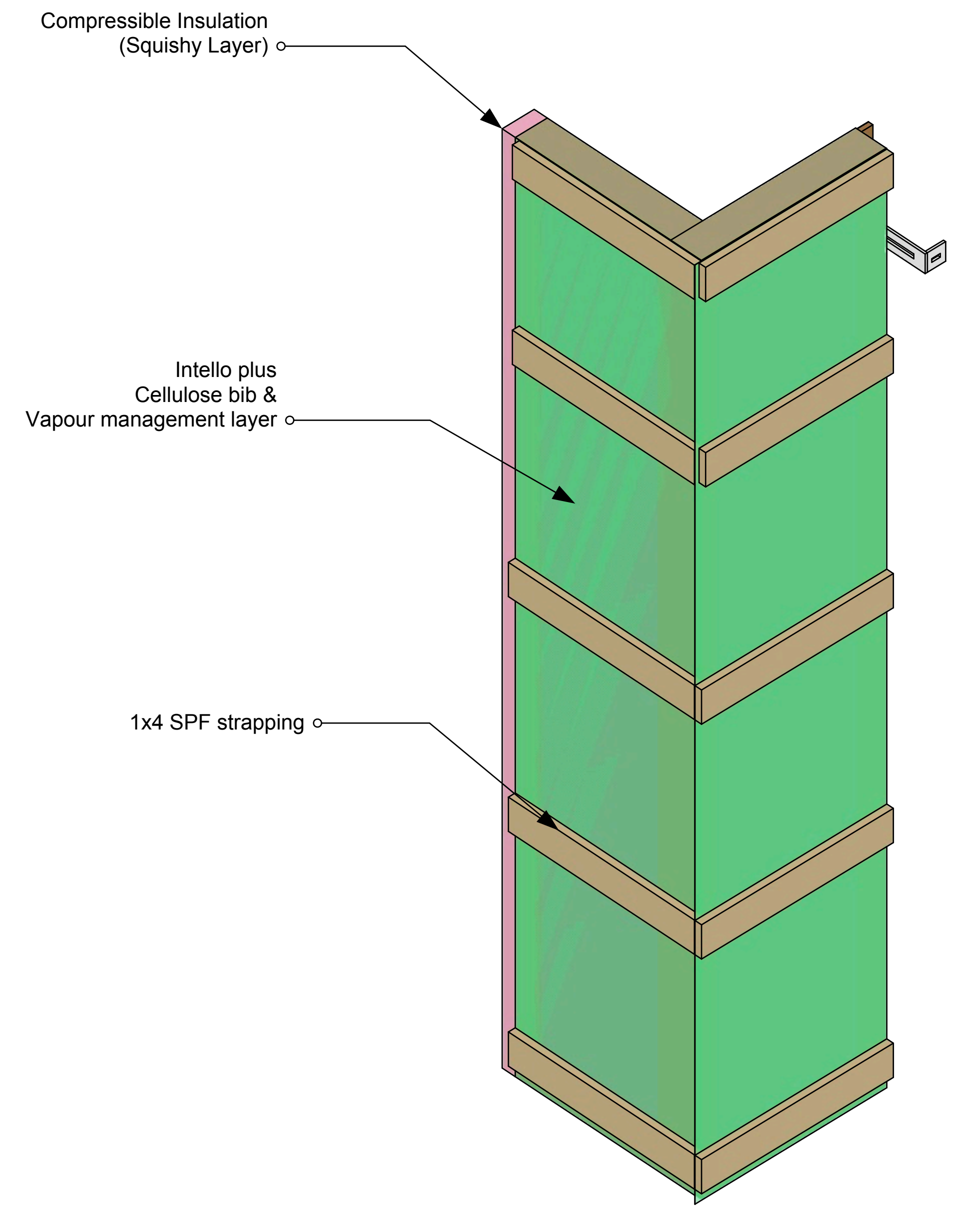
03

Panel - Inside Corner

Panel schematic with all membranes in place



EXTERIOR VIEW



INTERIOR VIEW

RSI projects

ReCo

Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

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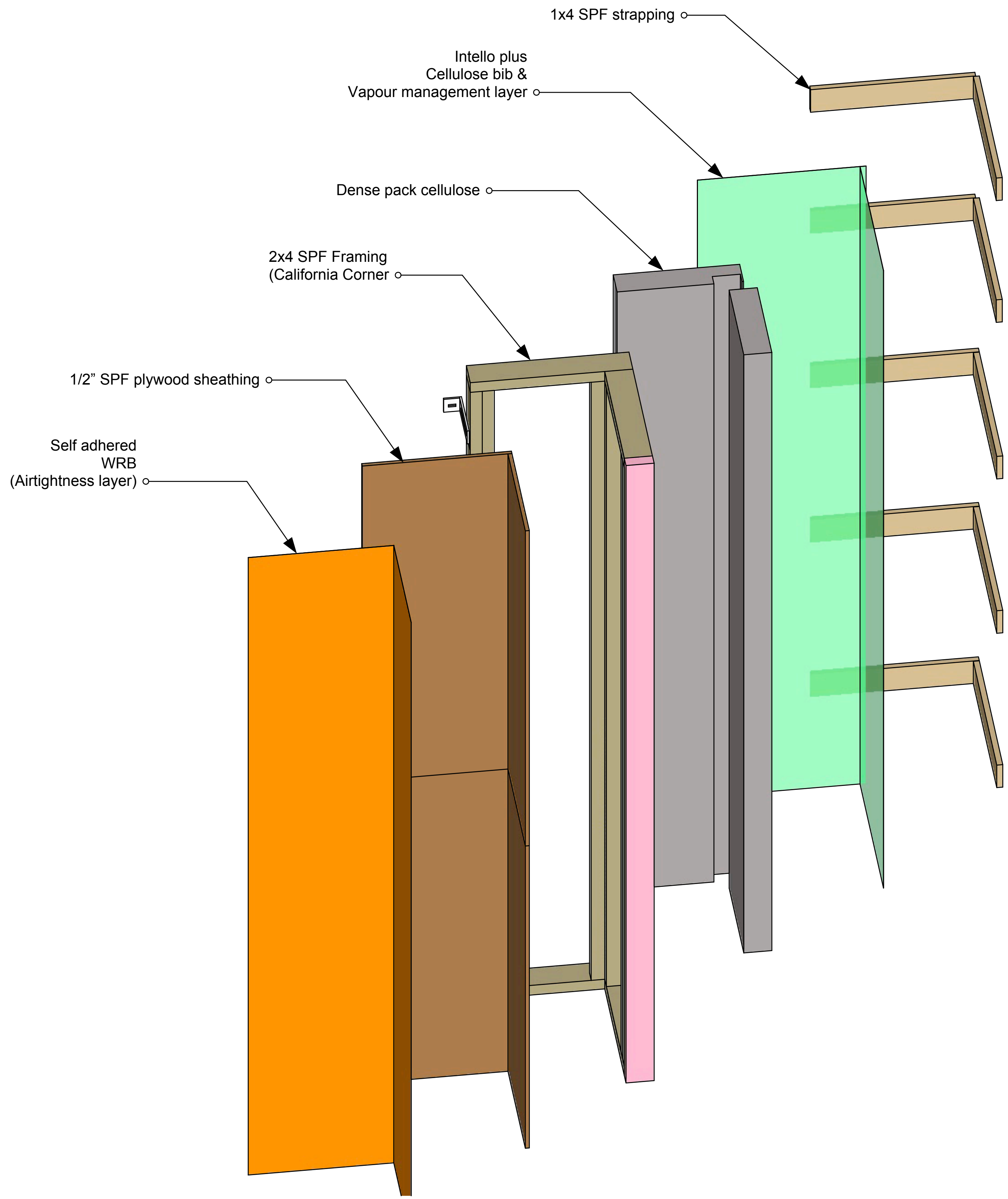
Panel - Inside Corner - Exploded

Panel schematic with all membranes in place



ReCover

Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

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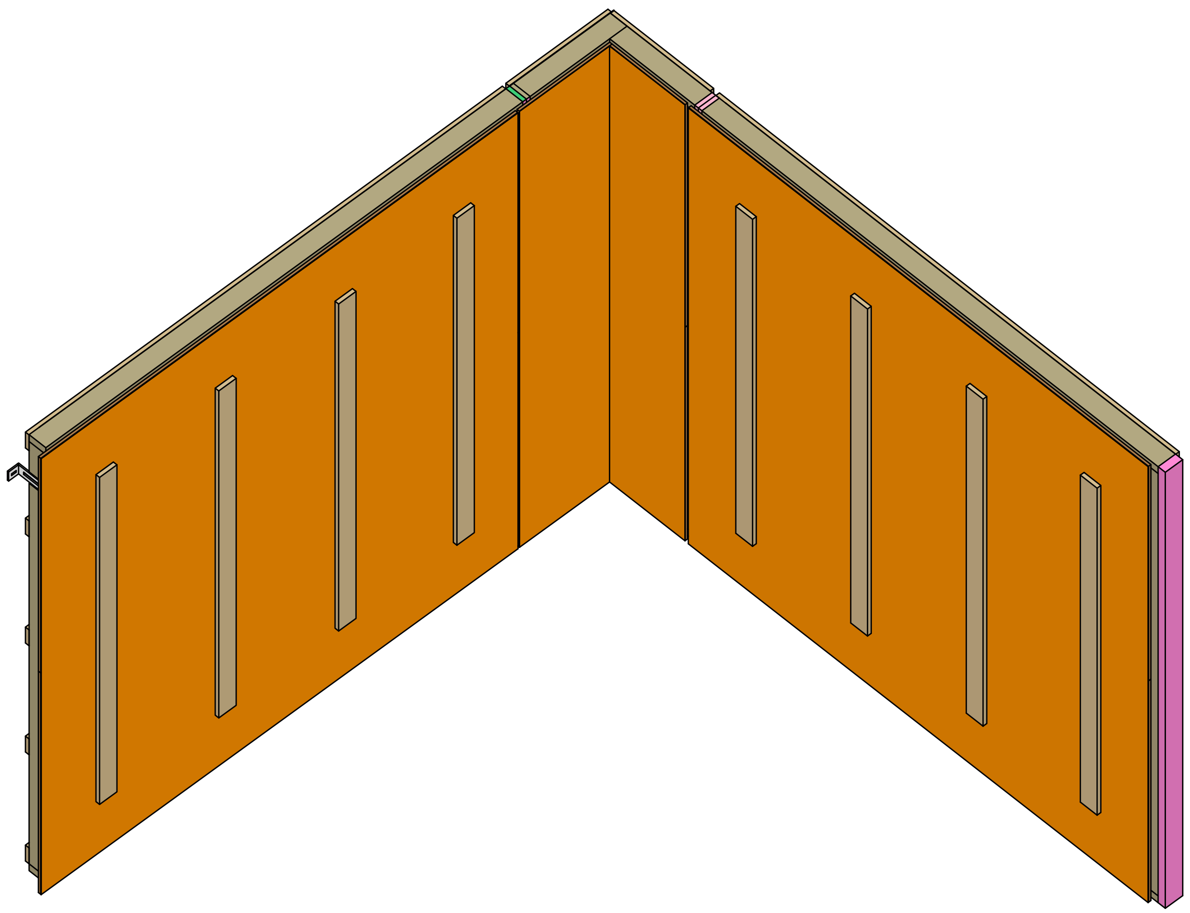
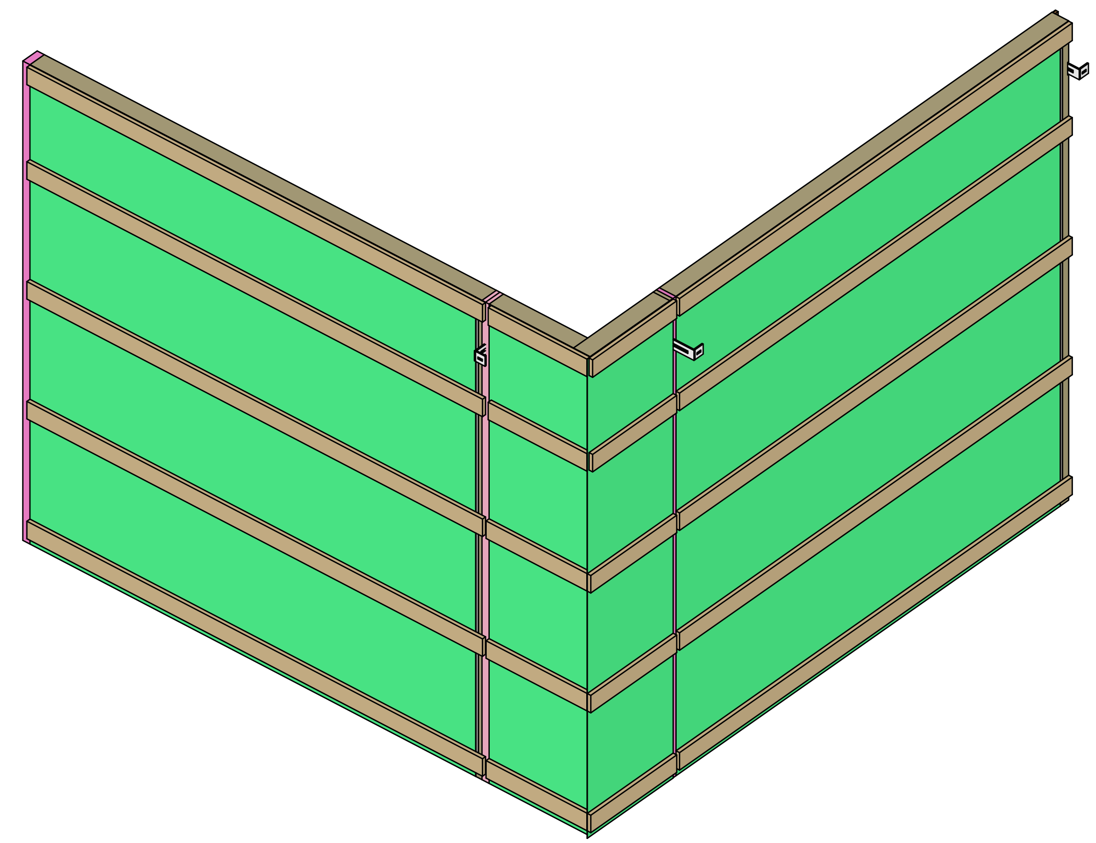
Nick Rudnicki

Inside Corner Installed



EXTERIOR VIEW



INTERIOR VIEW

ReCover

Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

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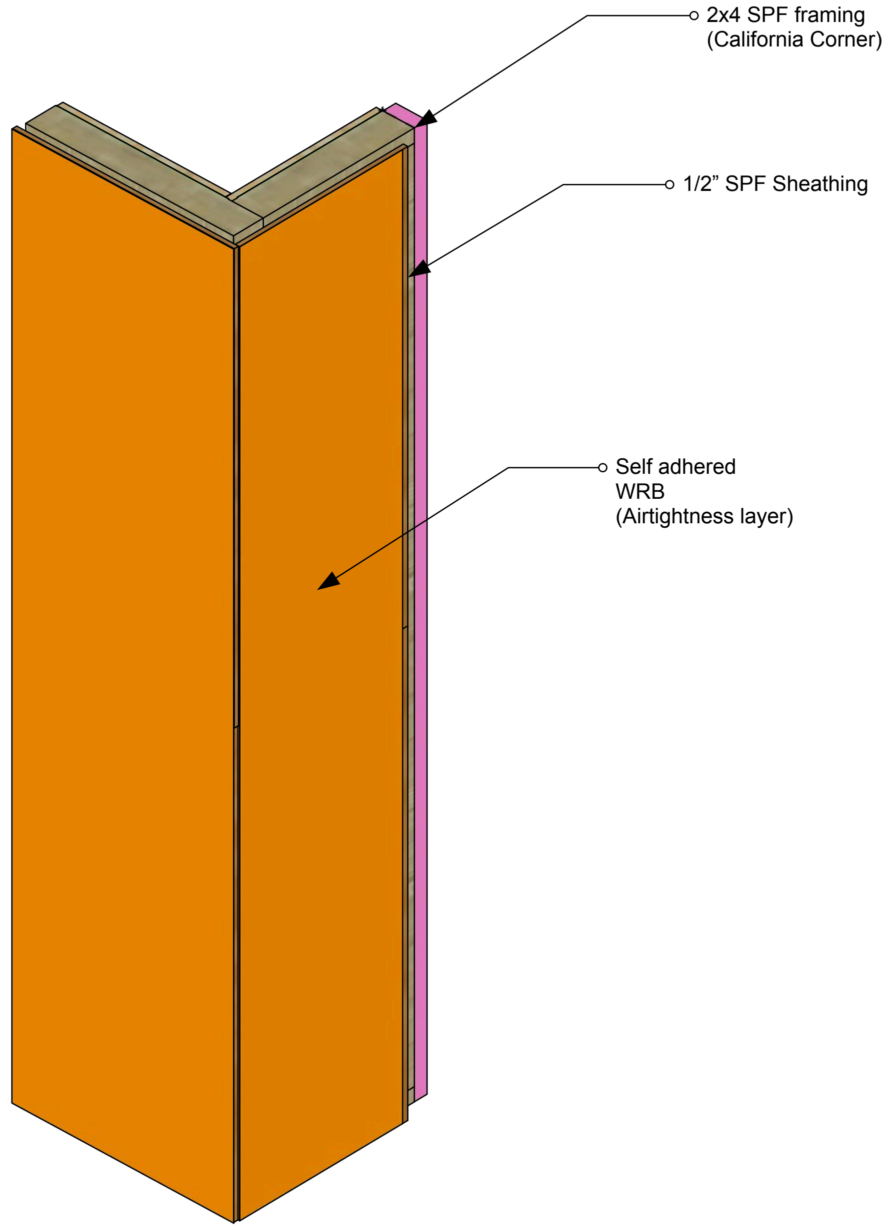
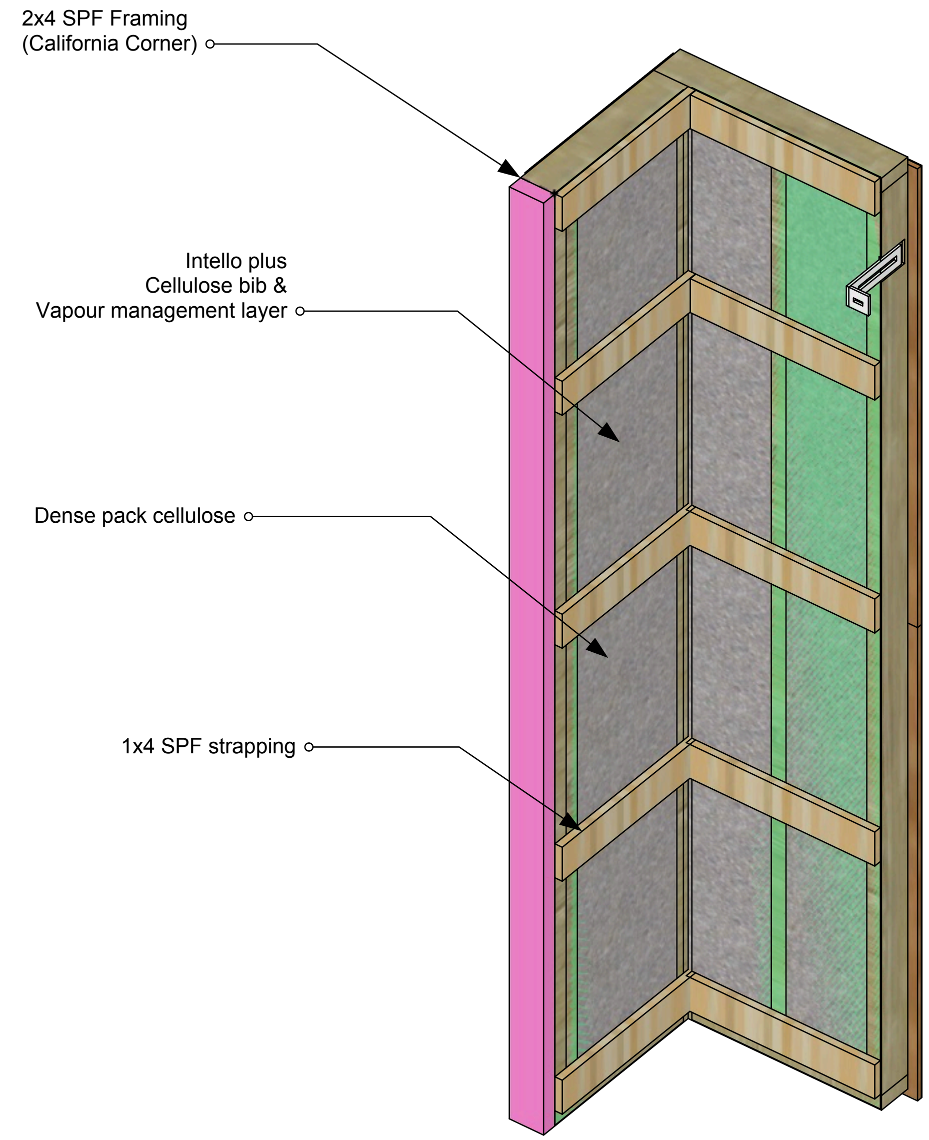
Panel - Outside Corner

Panel schematic with all membranes in place



EXTERIOR VIEW



INTERIOR VIEW

ReCover

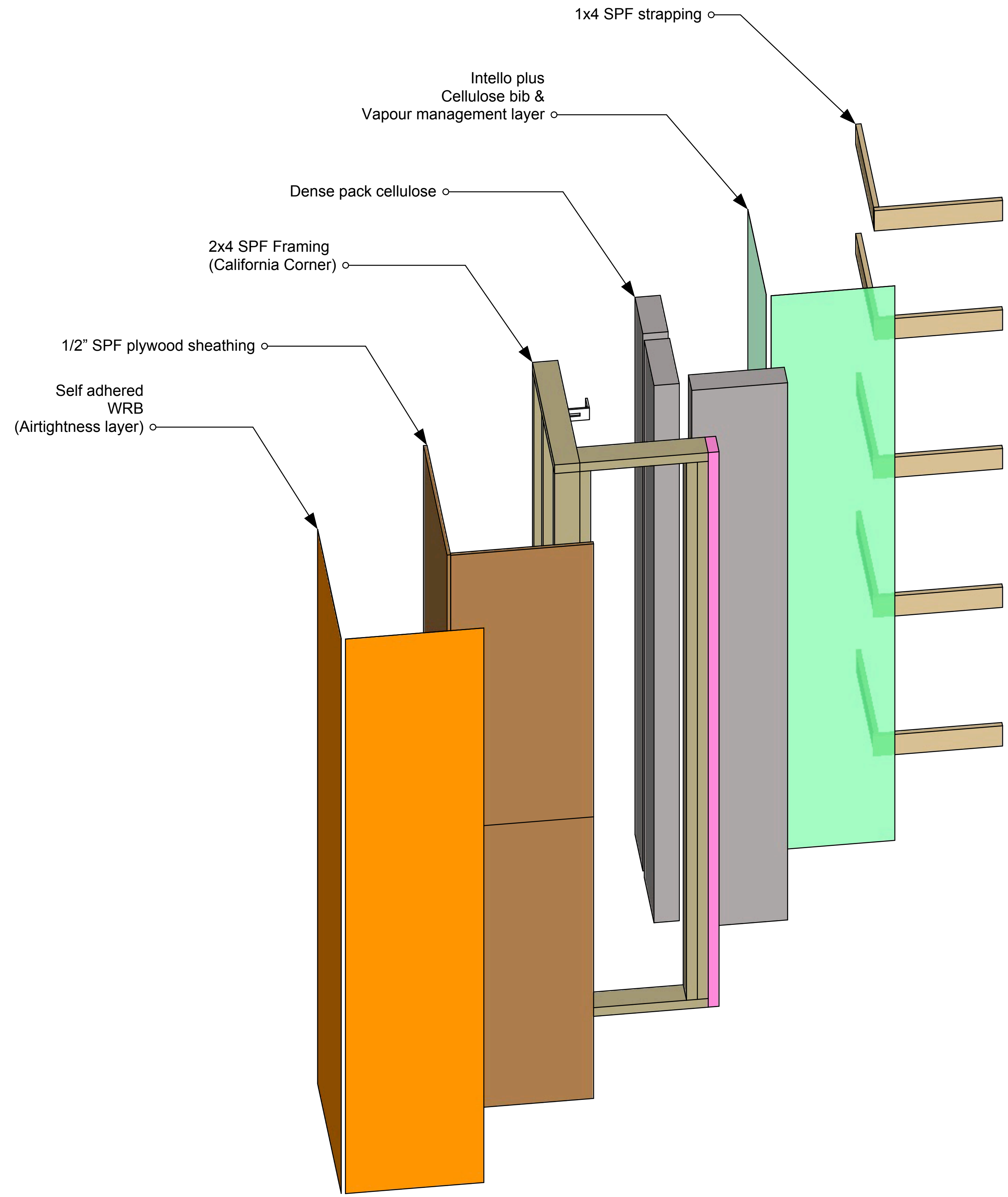
Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

Panel - Outside Corner - Exploded

Panel schematic with all membranes in place



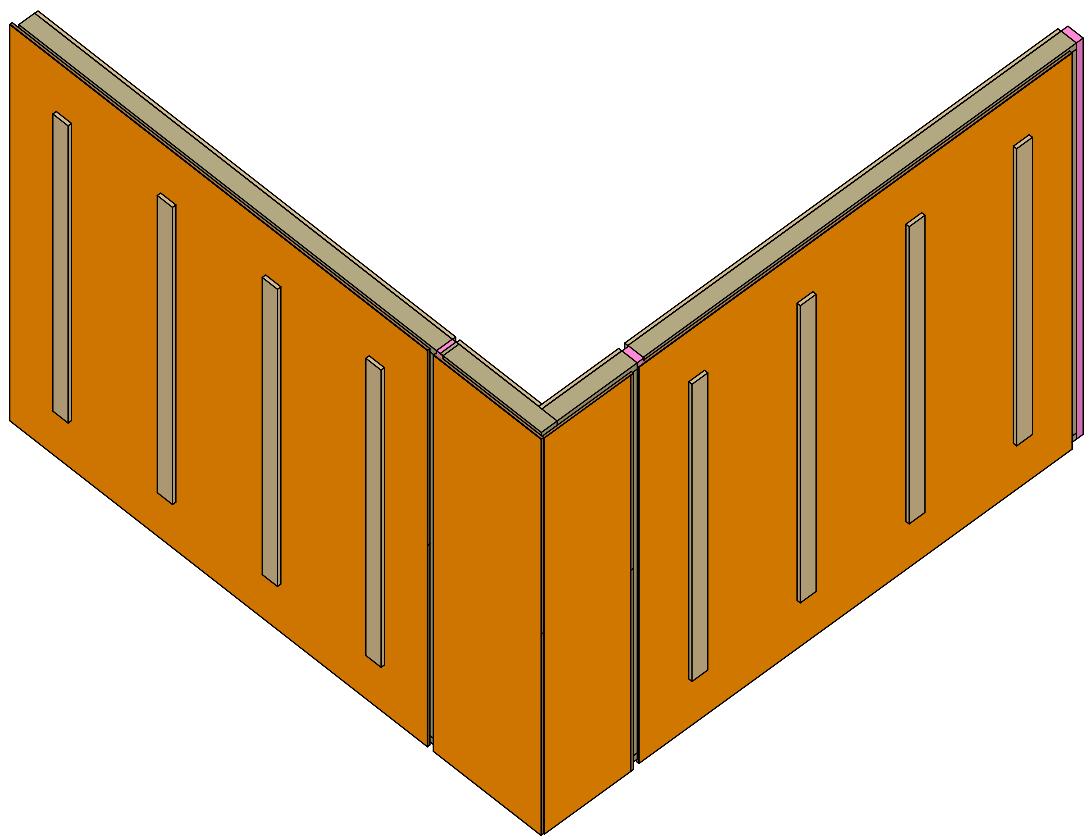
ReCover

Version Date
February 27, 2023

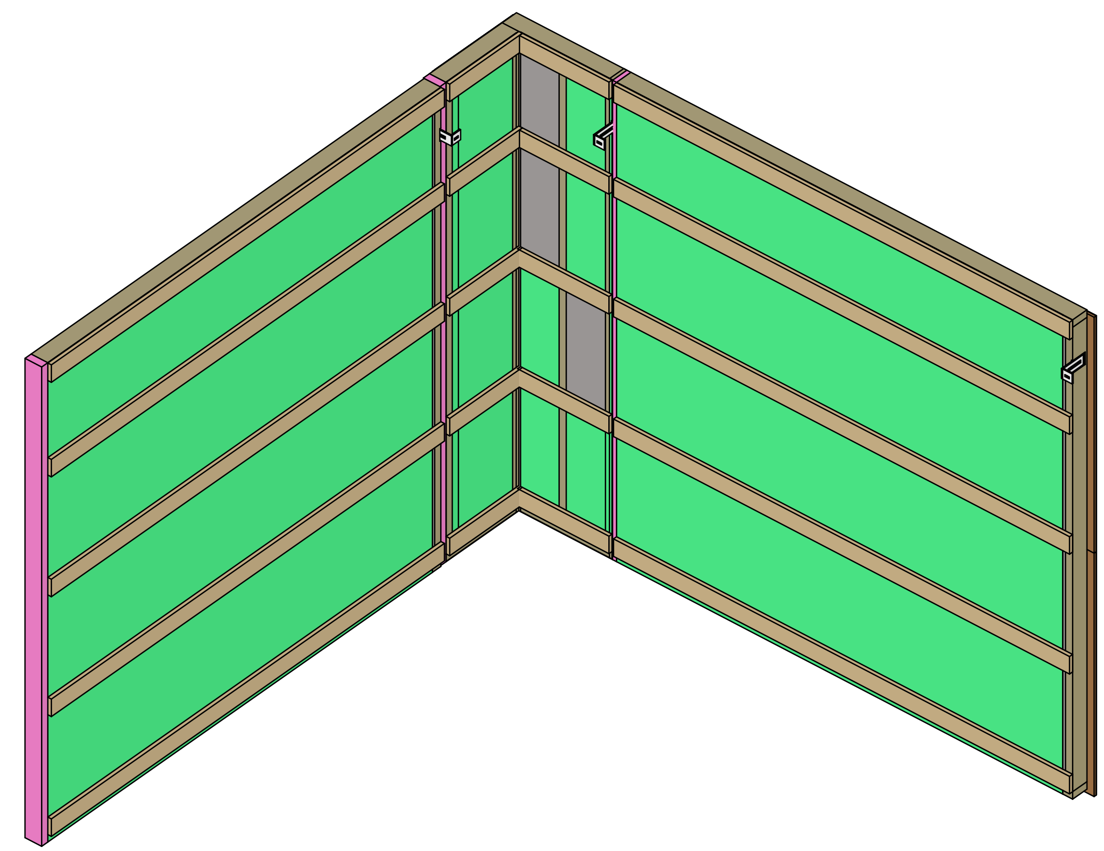
PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

Outside Corner Installed



EXTERIOR VIEW



INTERIOR VIEW

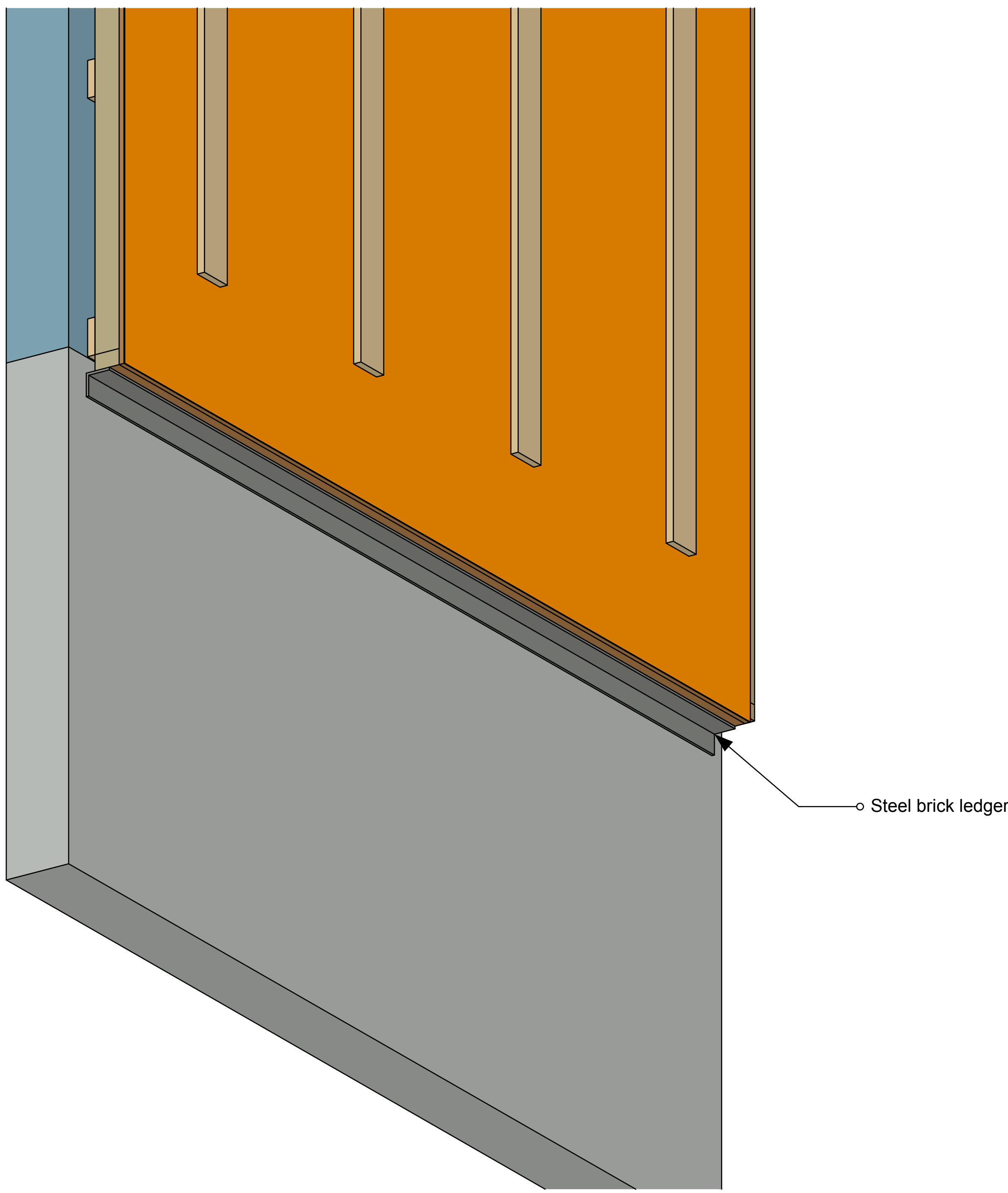
DRAWN BY
Nick Rudnicki

PROJECT
2x4 R11 Cellulose
Panel Schematics

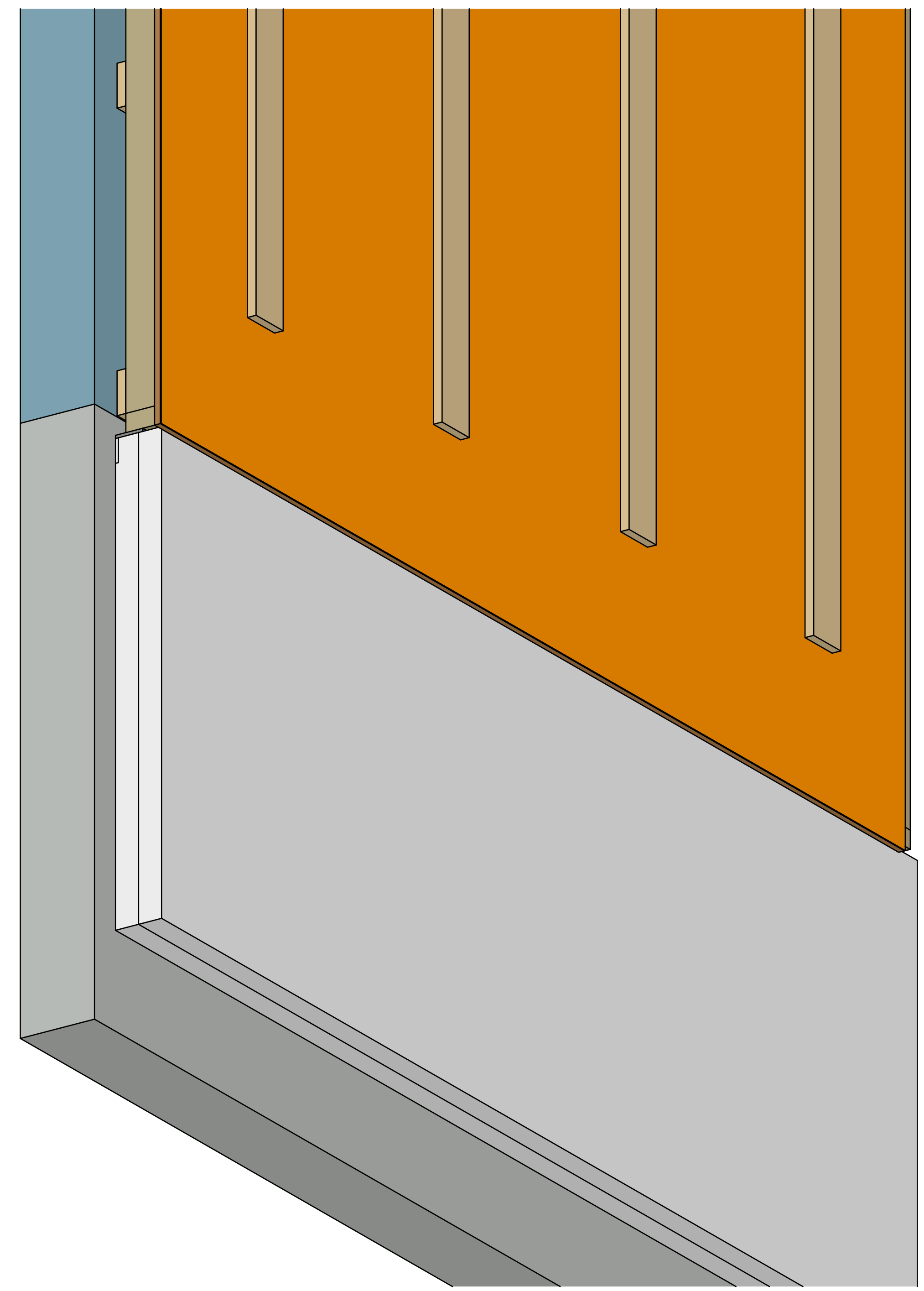
Version Date
February 27, 2023

Foundation Attachment - Ledger

"Brick Ledger" style continuous ledger for panel support



BEFORE SITE INSULATION



AFTER SITE INSULATION

ReCover

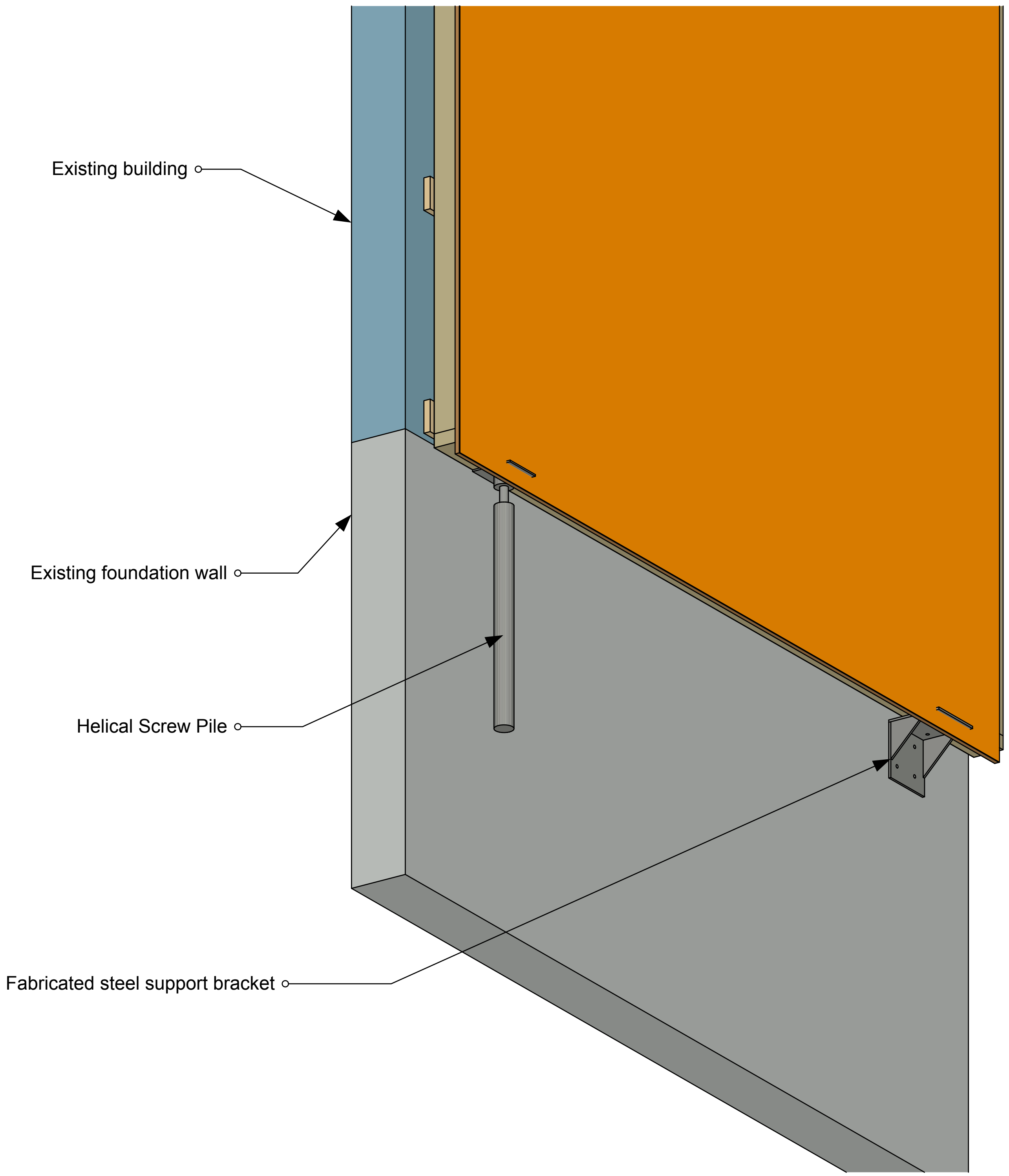
Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

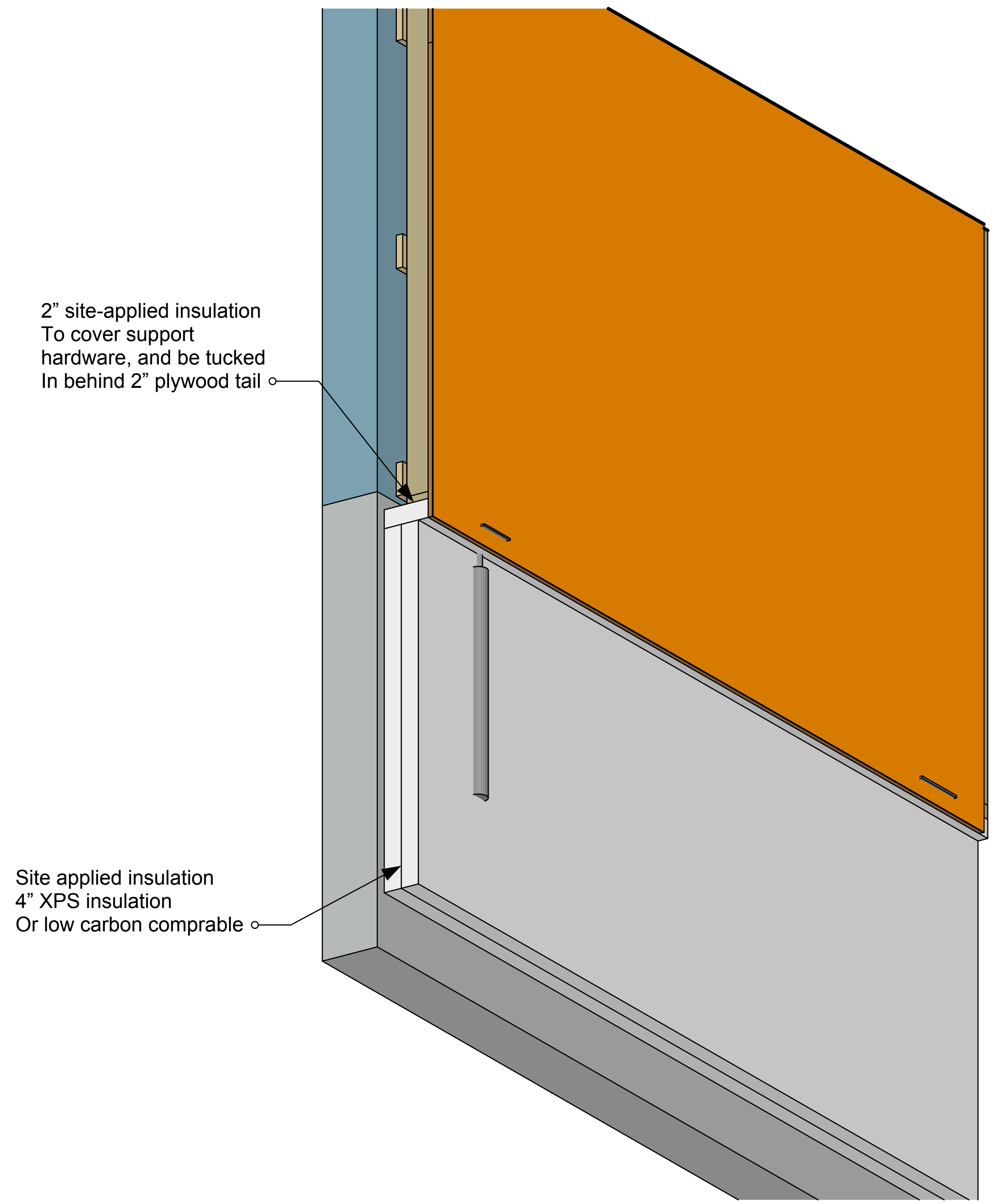
DRAWN BY
Nick Rudnicki

Foundation Attachment - Pile or Bracket

First options for attaching the panels to the foundation



BEFORE SITE INSULATION



AFTER SITE INSULATION

ReCover

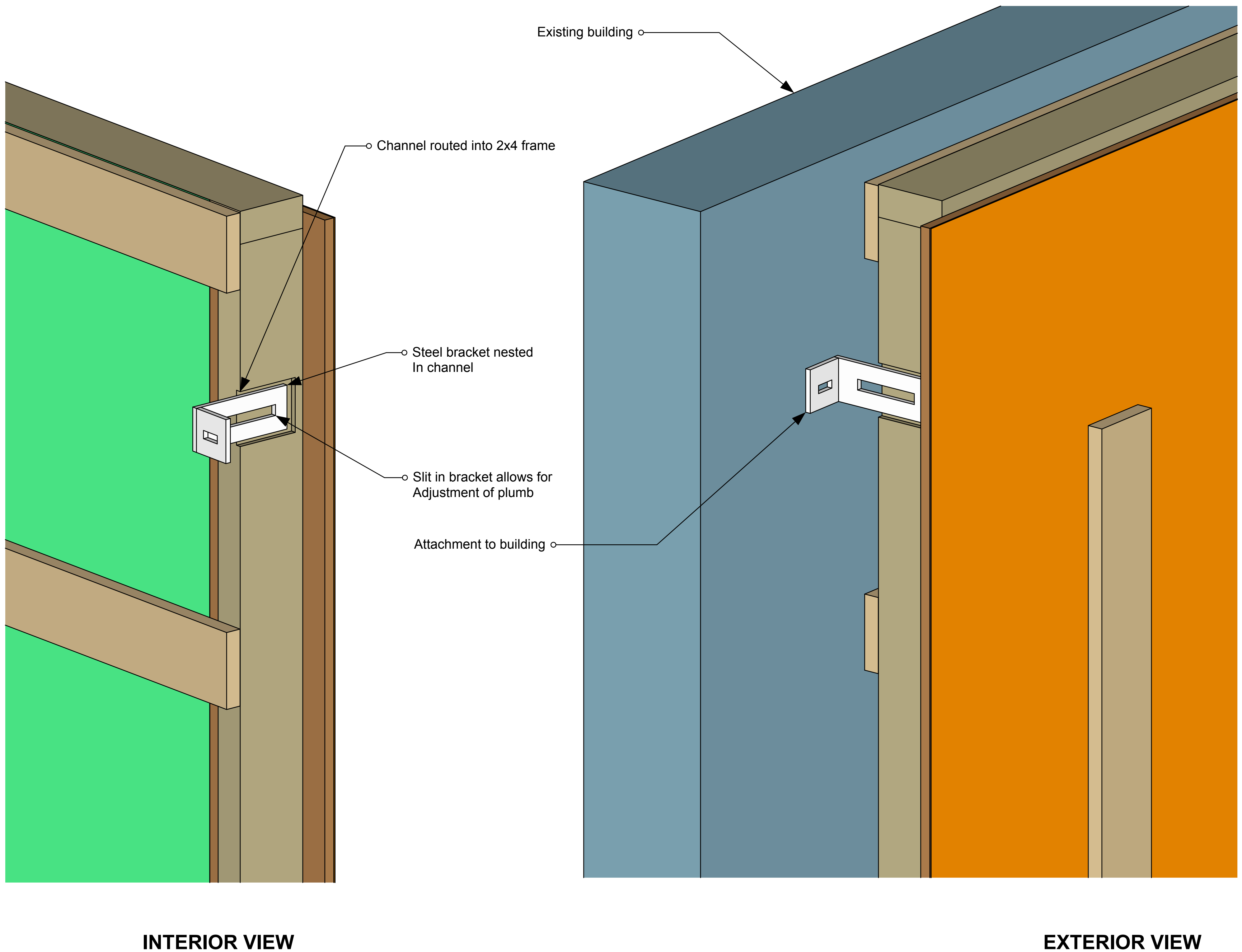
Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

Attach to Existing

Bracket to attach individual panels to existing



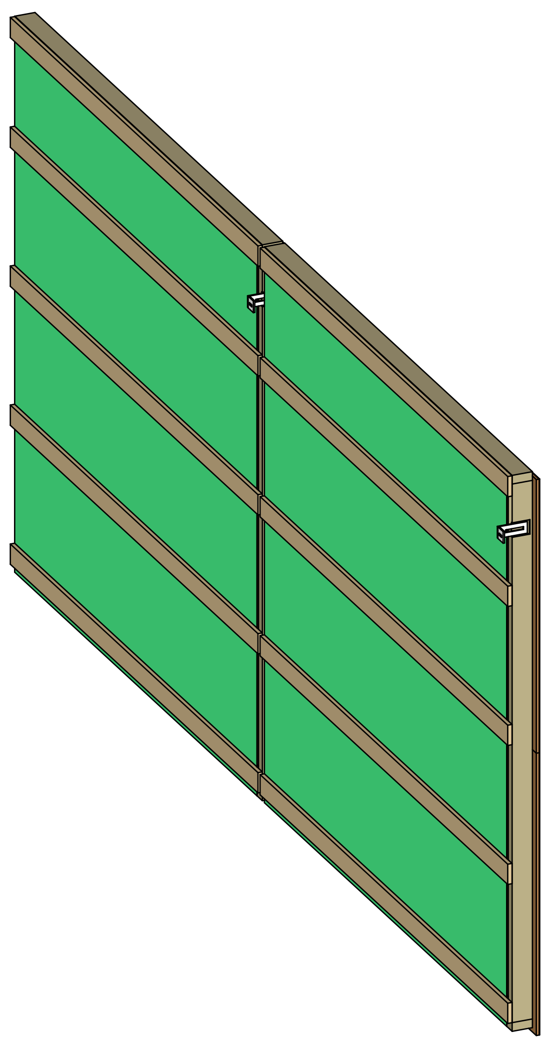
ReCover

Version Date
February 27, 2023

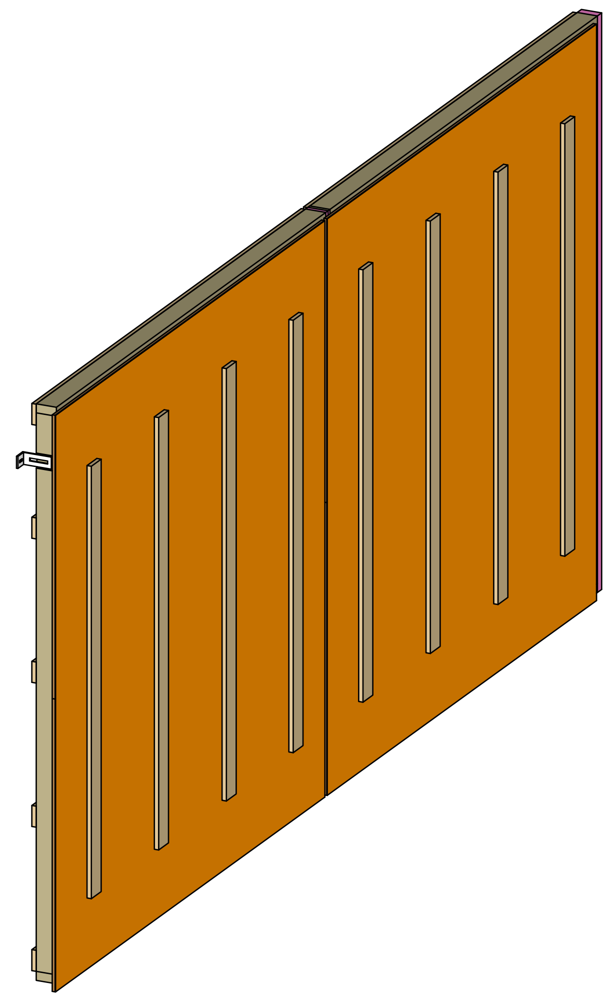
PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

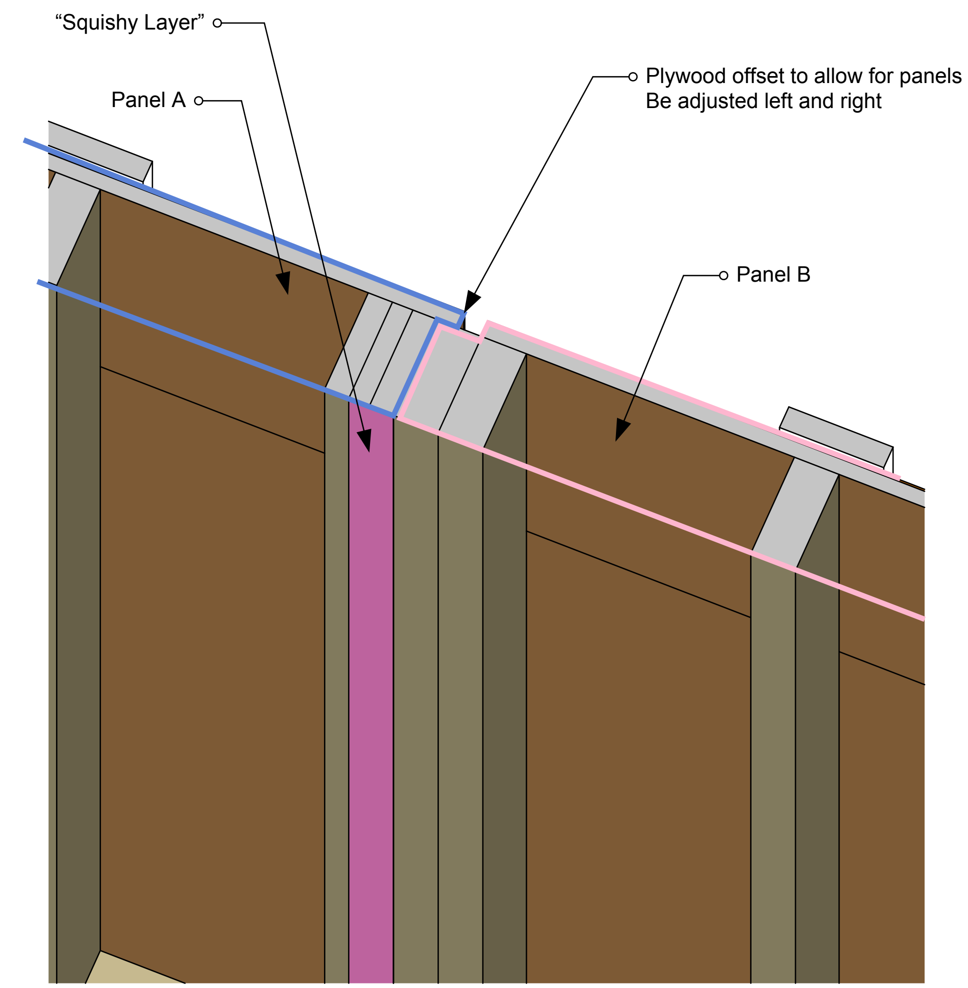
Vertical Wall Joins



INTERIOR VIEW

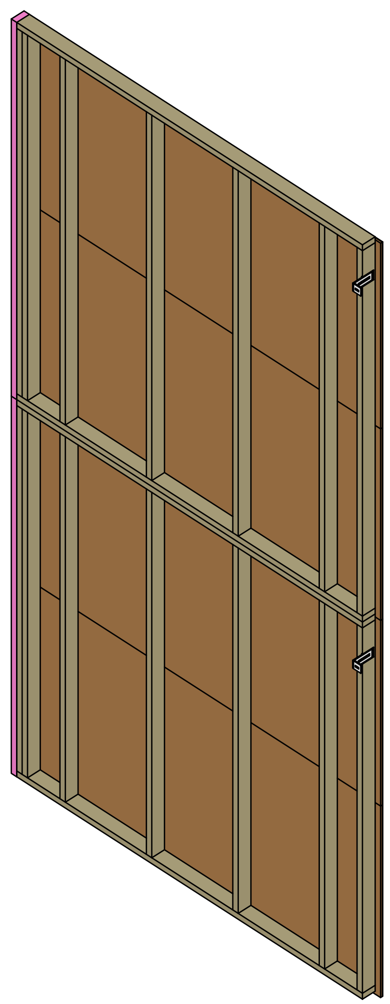


EXTERIOR VIEW

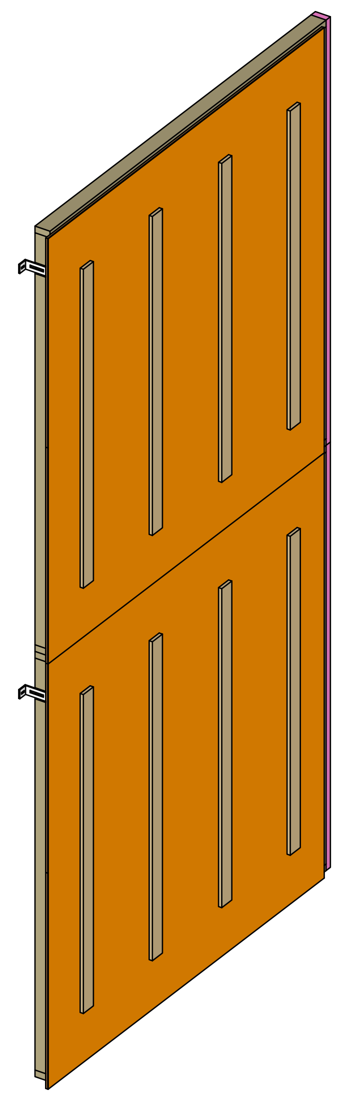


SECTION VIEW

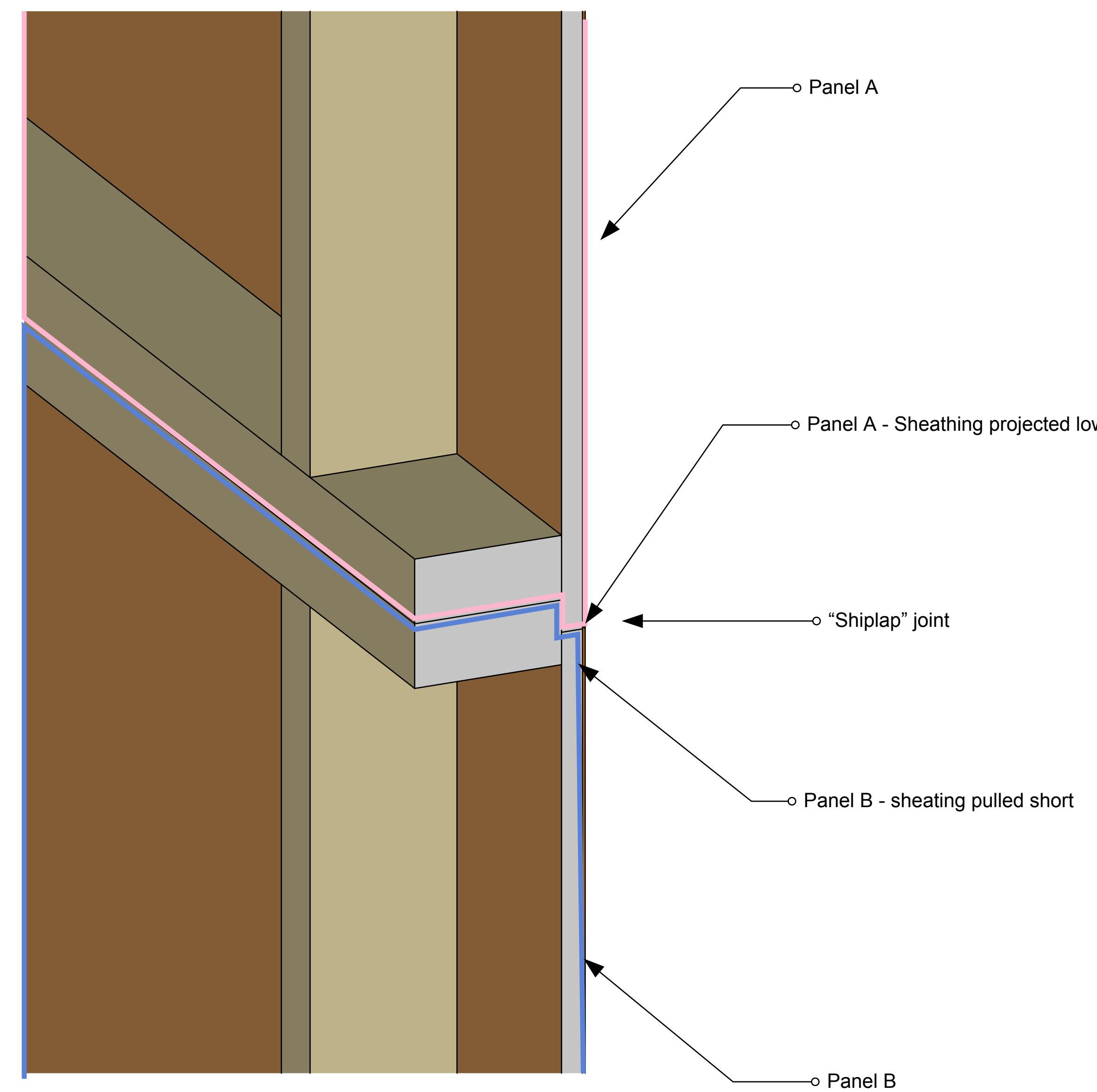
Horizontal Wall Joins



INTERIOR VIEW



EXTERIOR VIEW



SECTION VIEW

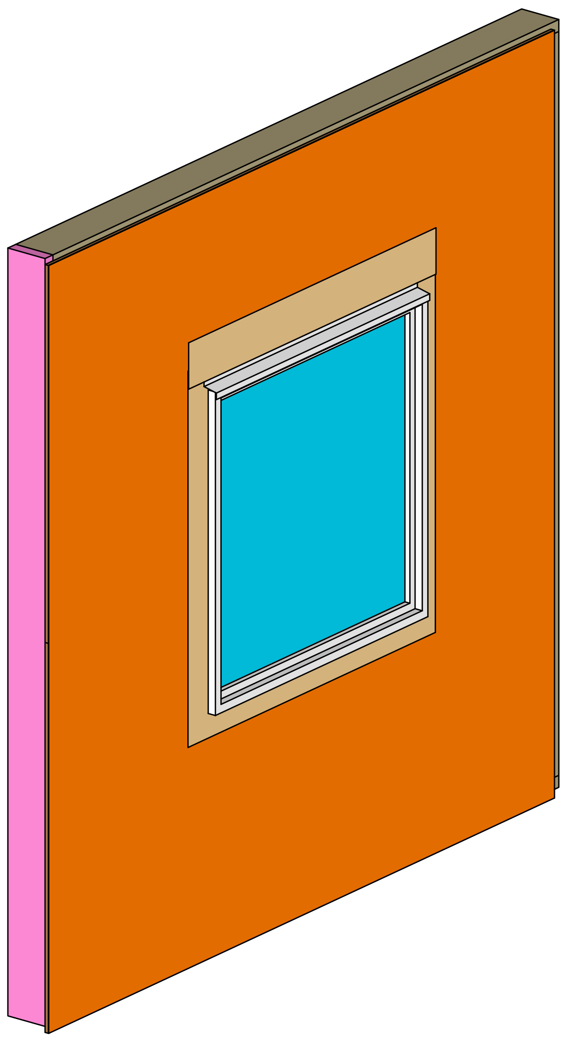
ReCover

Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

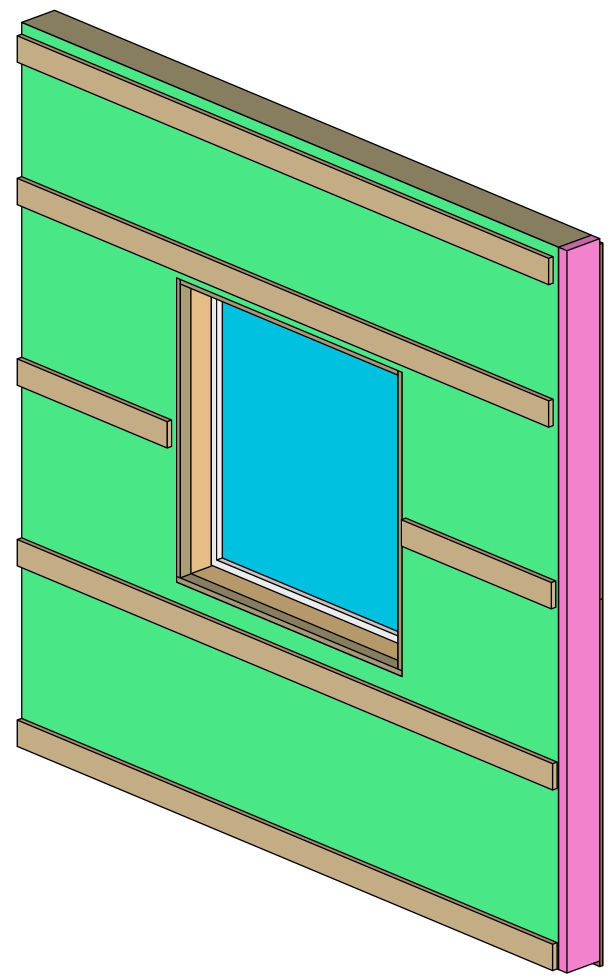
DRAWN BY
Nick Rudnicki

Window Panel

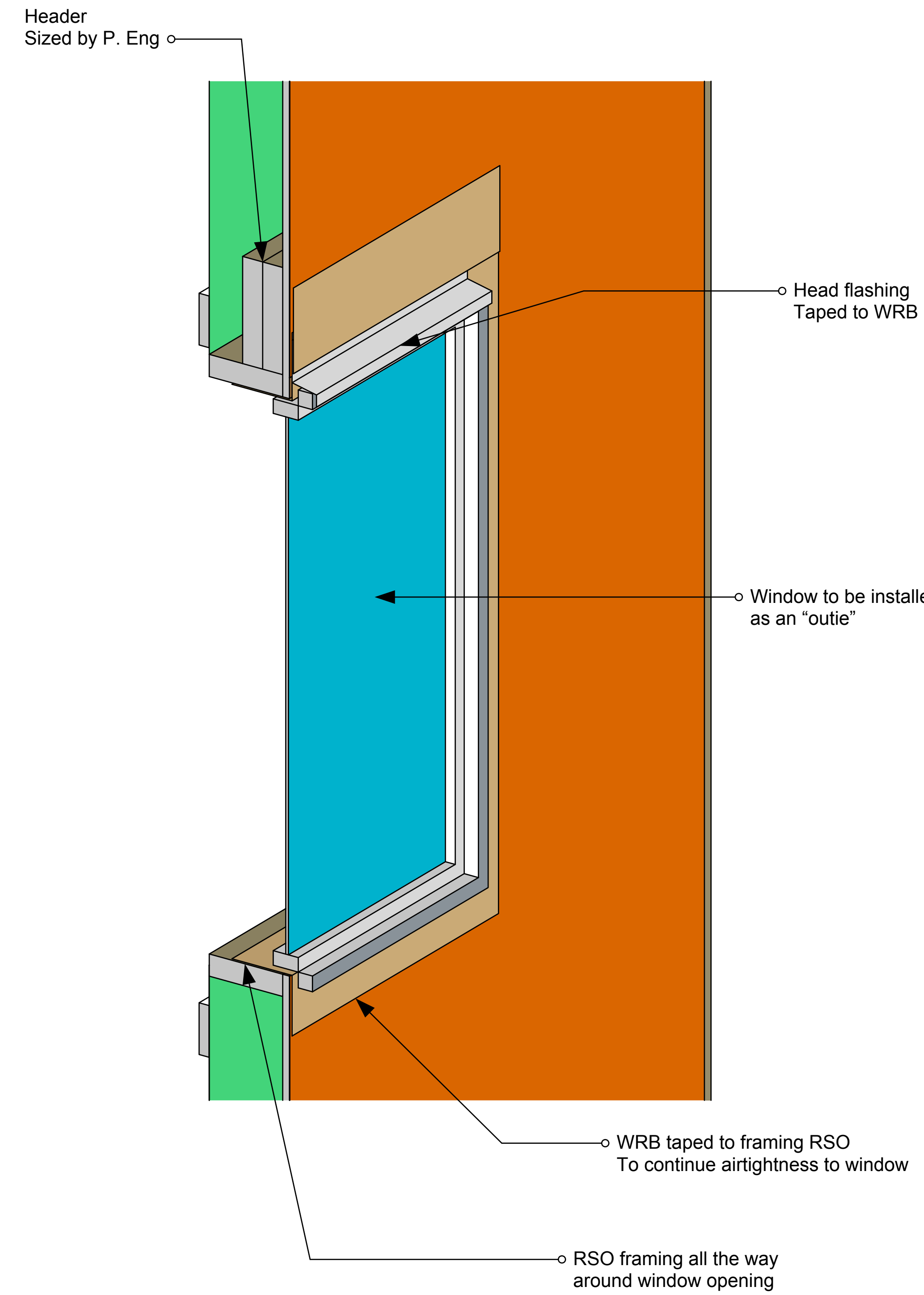


PANEL
EXTERIOR VIEW

Window installed in factory
Window installed as an "outie" to minimize how much window sill there is exposed to the rain



PANEL
EXTERIOR VIEW

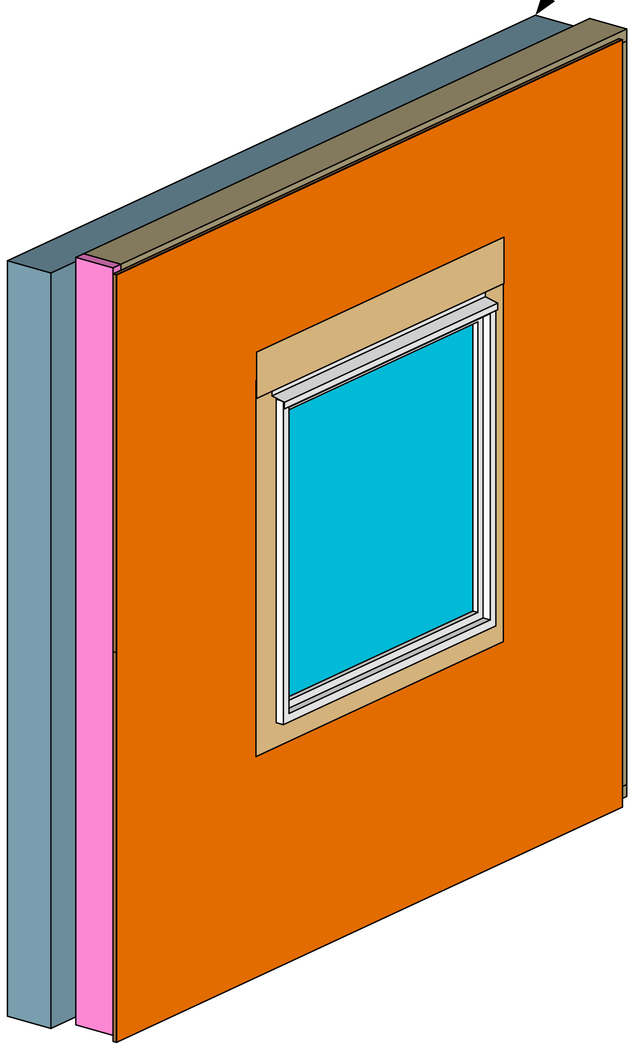


Version Date
February 27, 2023

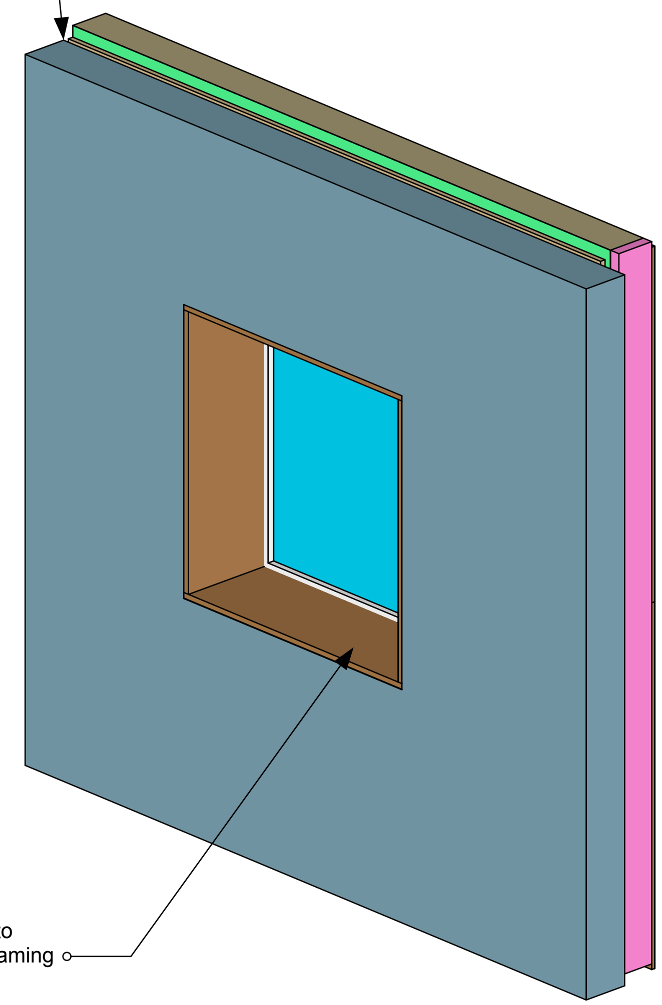
PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

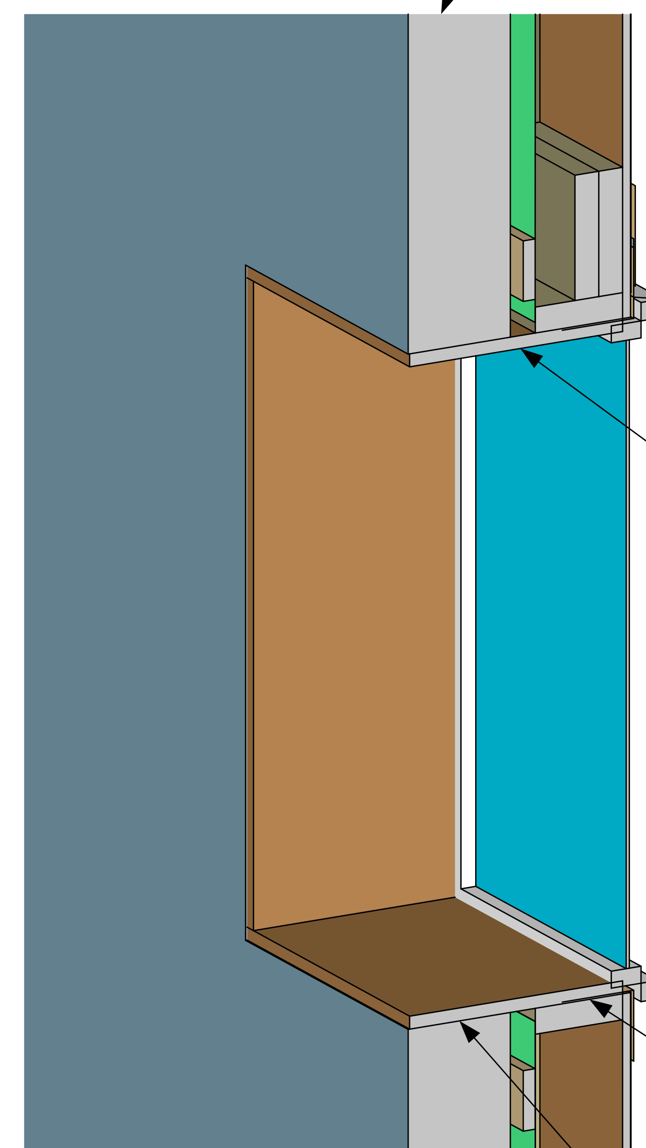
Window Penetration



EXTERIOR VIEW



INTERIOR VIEW



SECTION VIEW

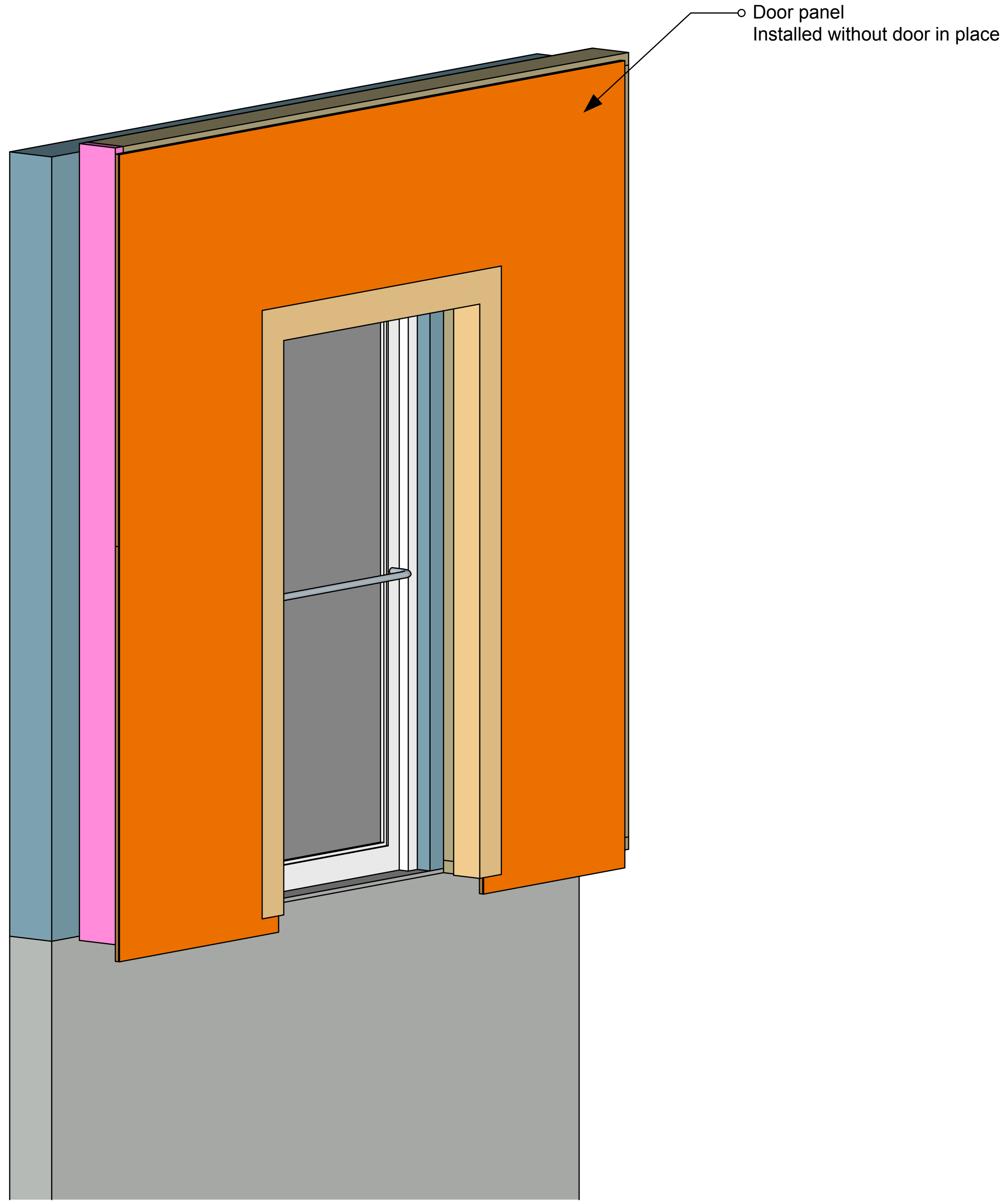
ReCover

Version Date
February 27, 2023

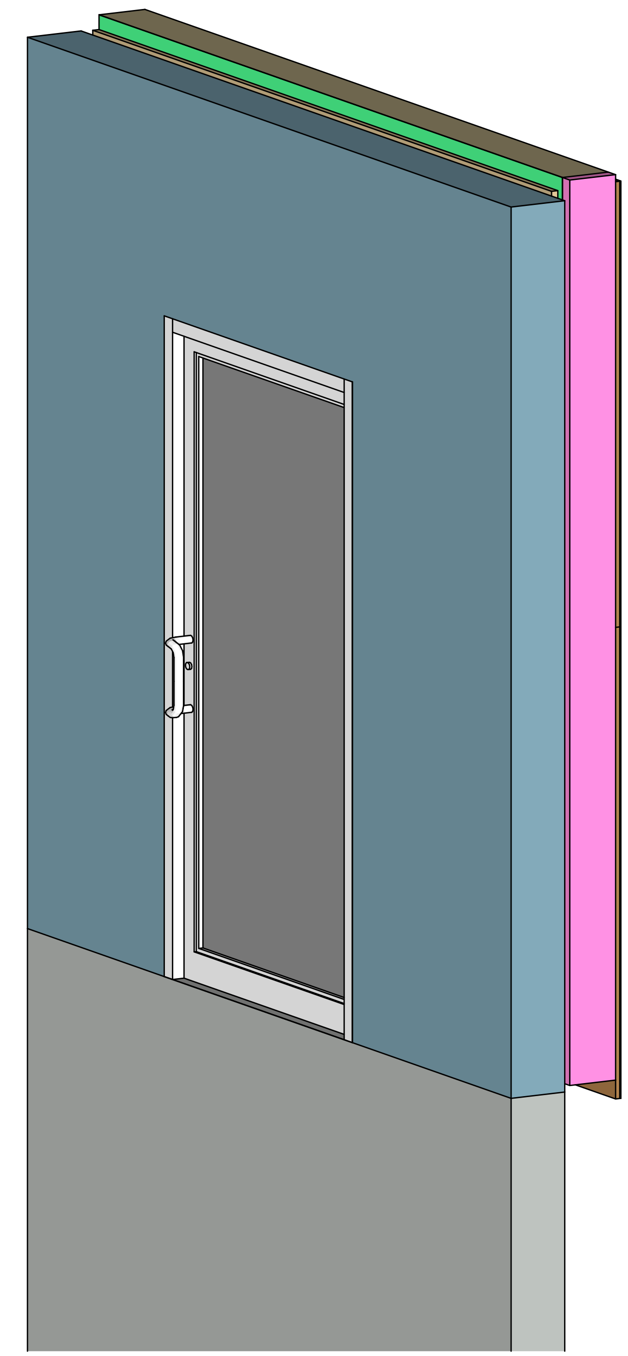
PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

Door Penetration Panel



EXTERIOR VIEW



INTERIOR VIEW

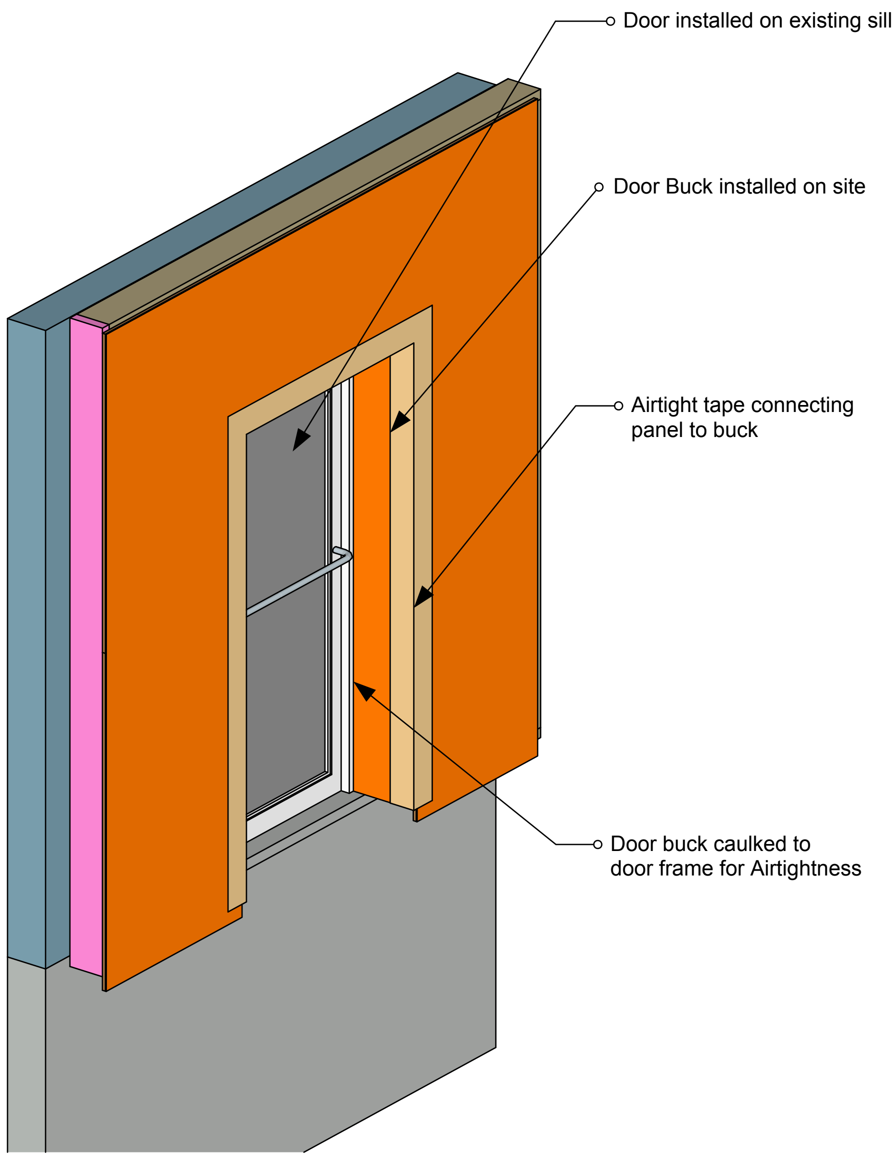
ReCover

Version Date
February 27, 2023

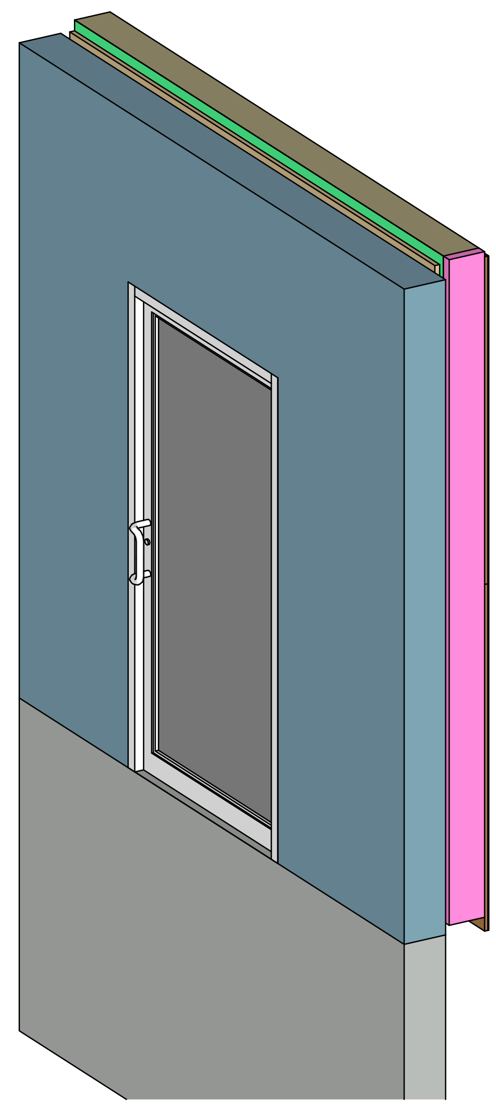
PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

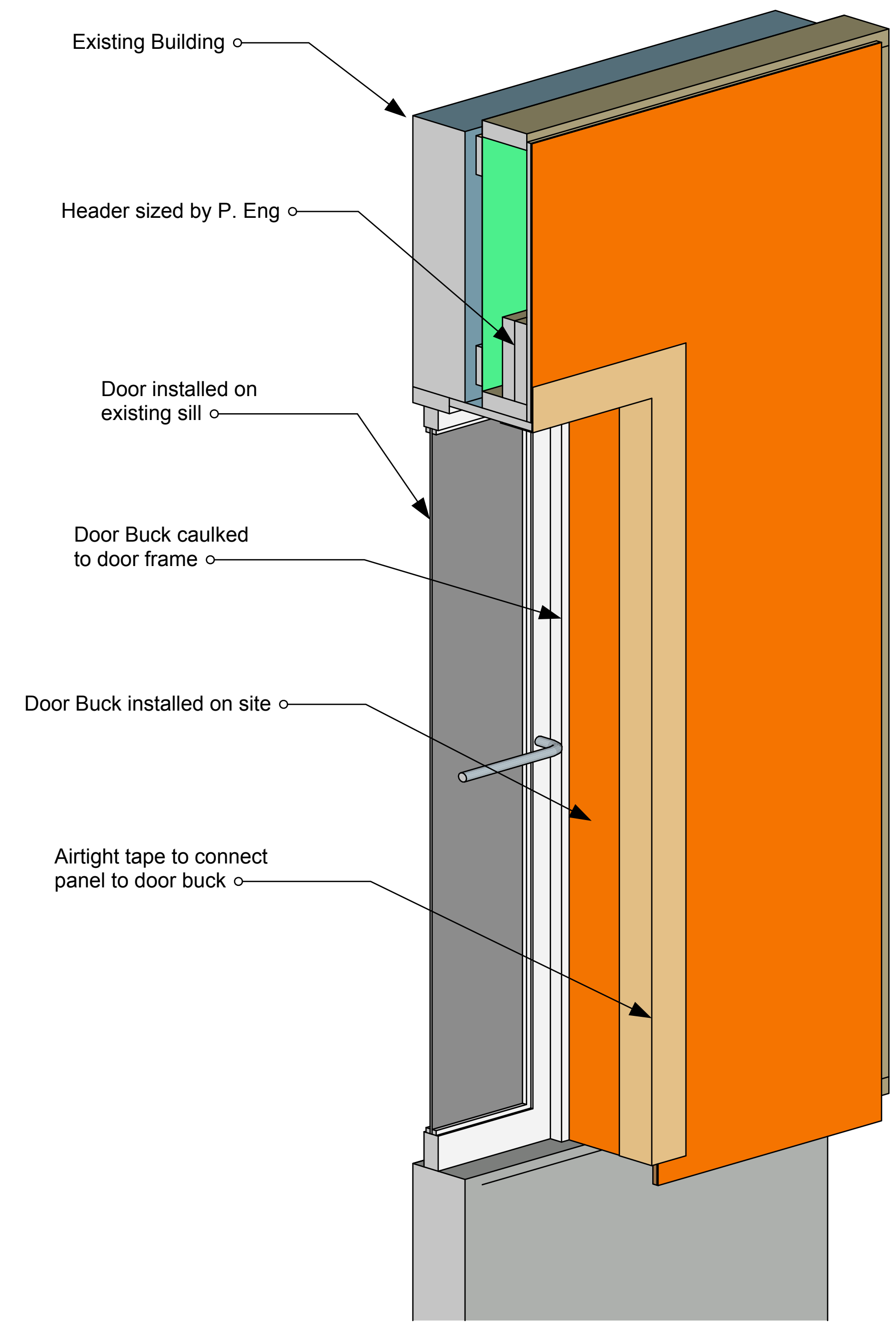
Door Penetration Panel Installed



EXTERIOR VIEW



INTERIOR VIEW



SECTION VIEW

ReCover

Version Date
February 27, 2023

PROJECT
2x4 R11 Cellulose
Panel Schematics

DRAWN BY
Nick Rudnicki

Wall Panel Schematics

Cellulose - R16 - 2x6 - 1/2" Plywood

ReCover Initiative

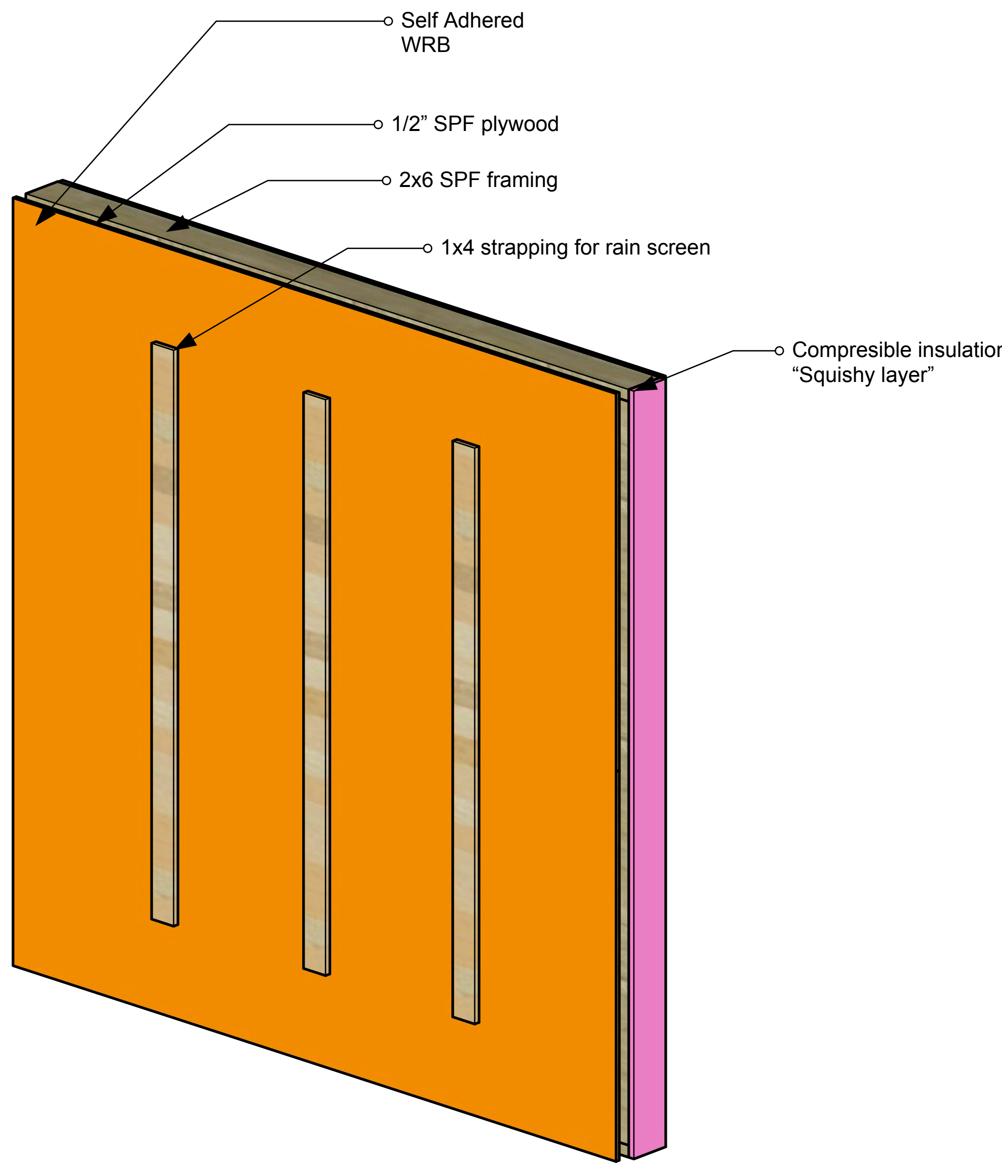
ReCover

Version Date
February 27, 2023

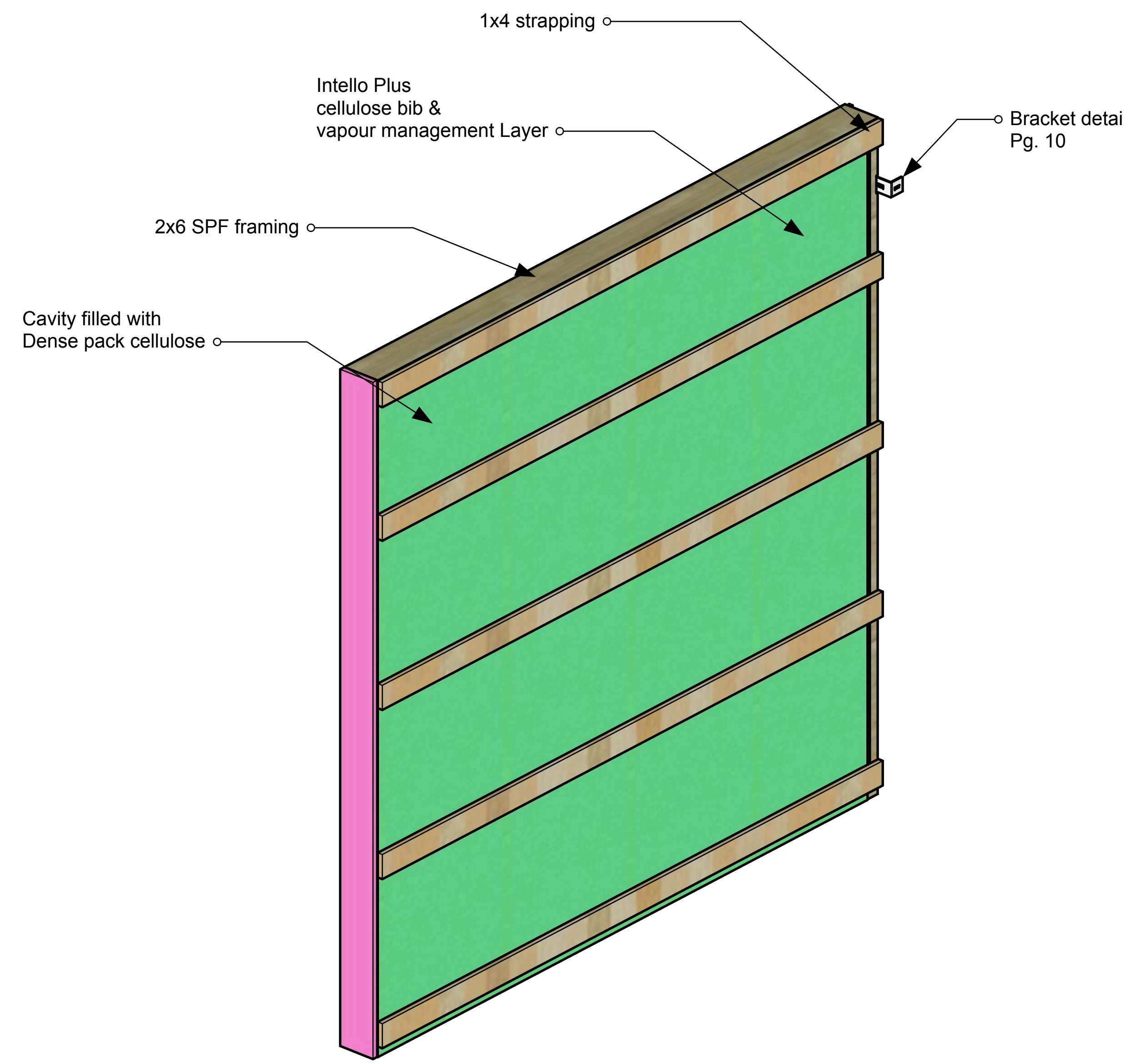
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Basic Panel - Overview



EXTERIOR VIEW



INTERIOR VIEW

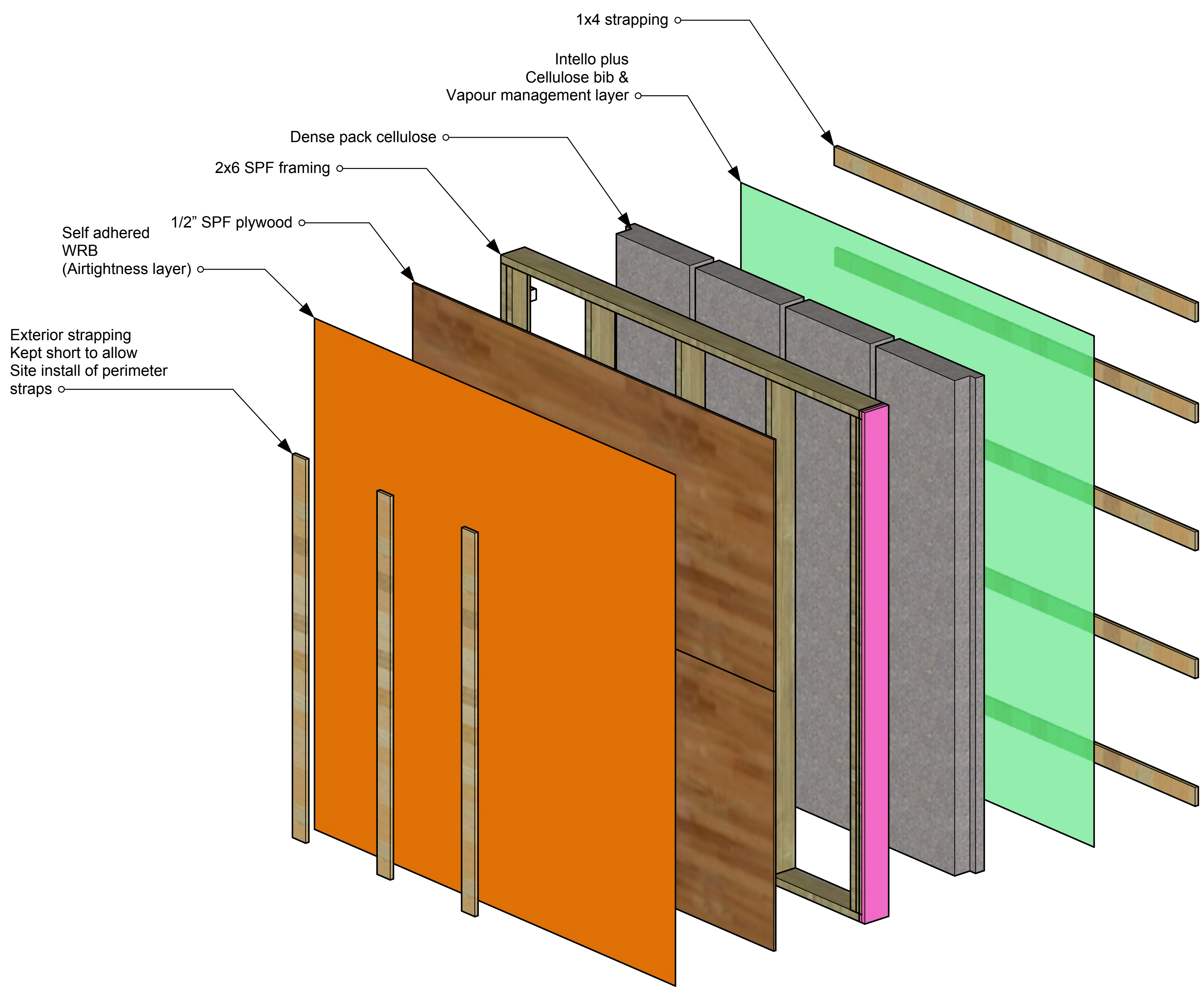
ReCover

Version Date
February 27, 2023

PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Basic Panel - Exploded View

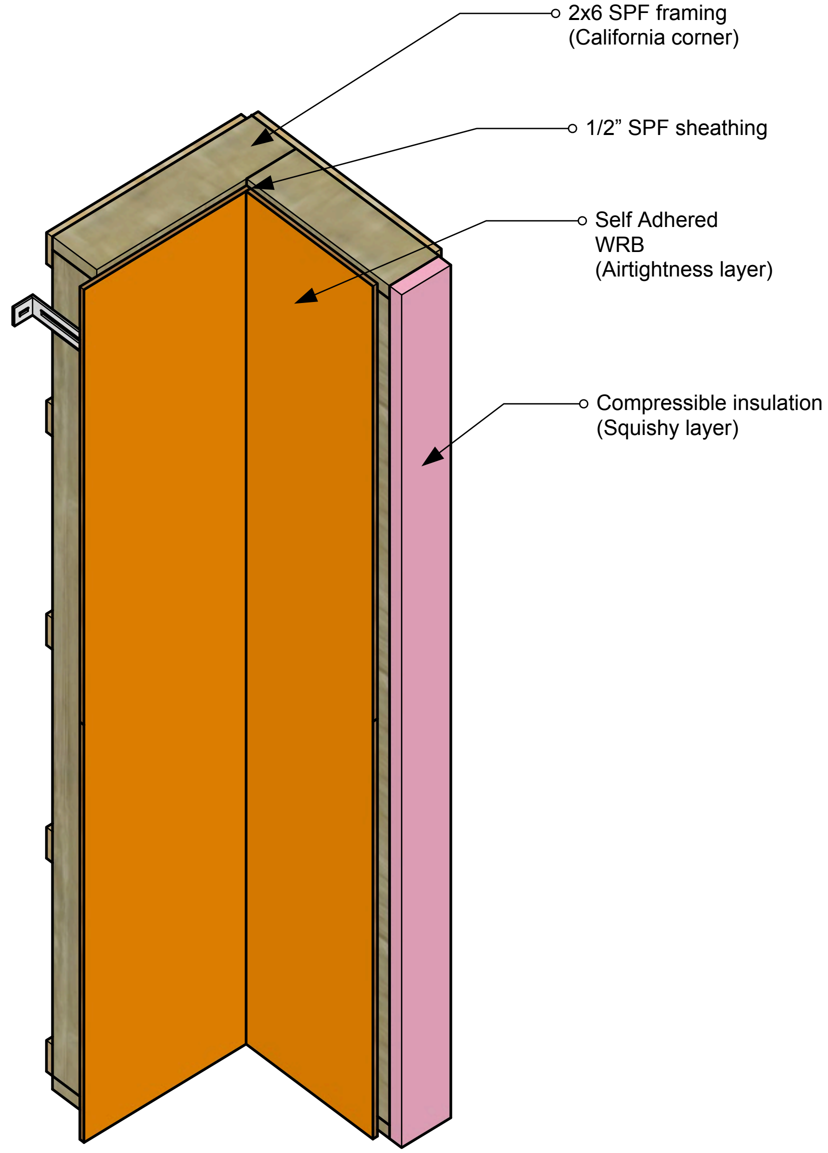


Version Date
February 27, 2023

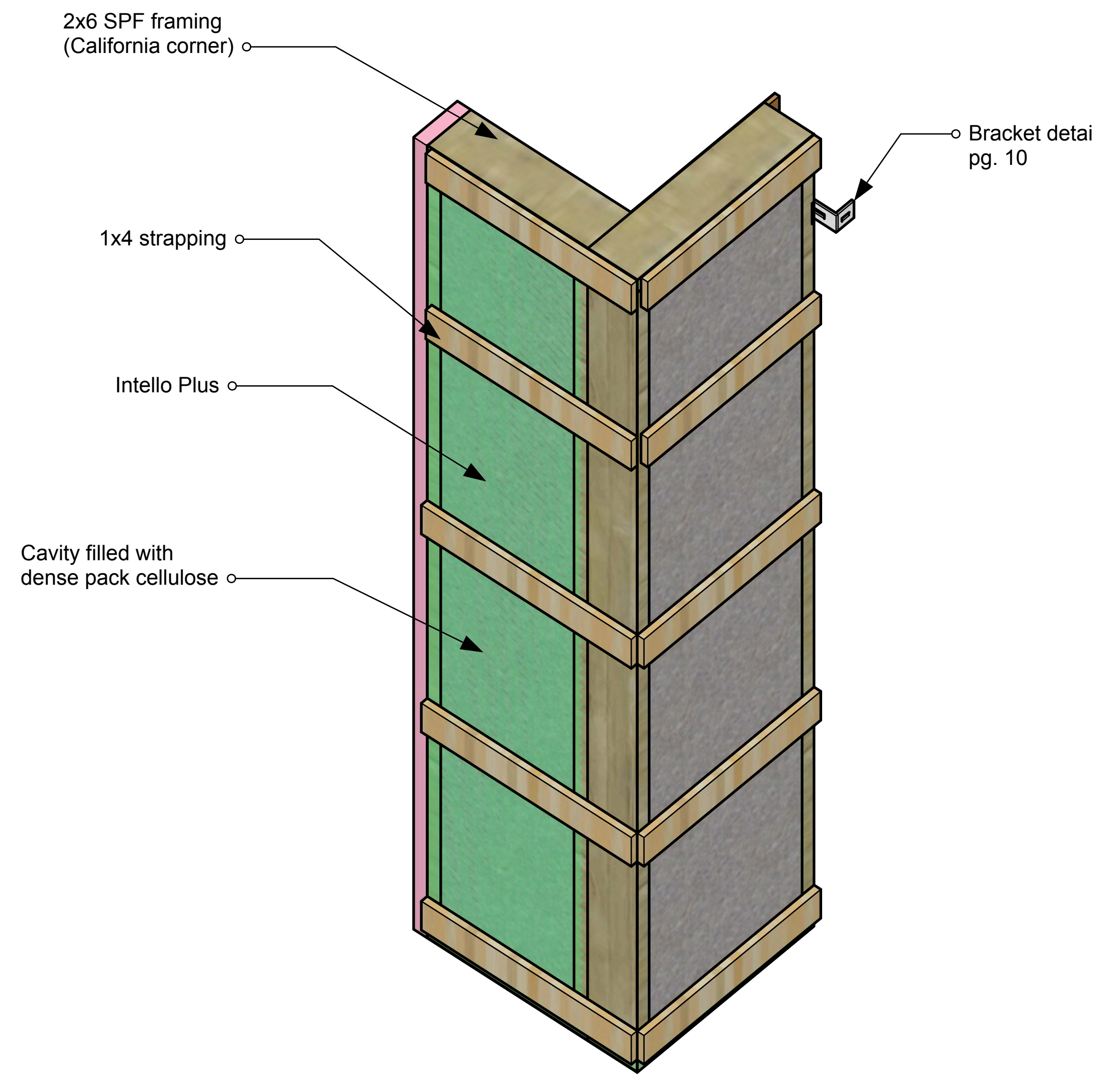
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Inside Corner Panel - Overview



EXTERIOR VIEW



INTERIOR VIEW

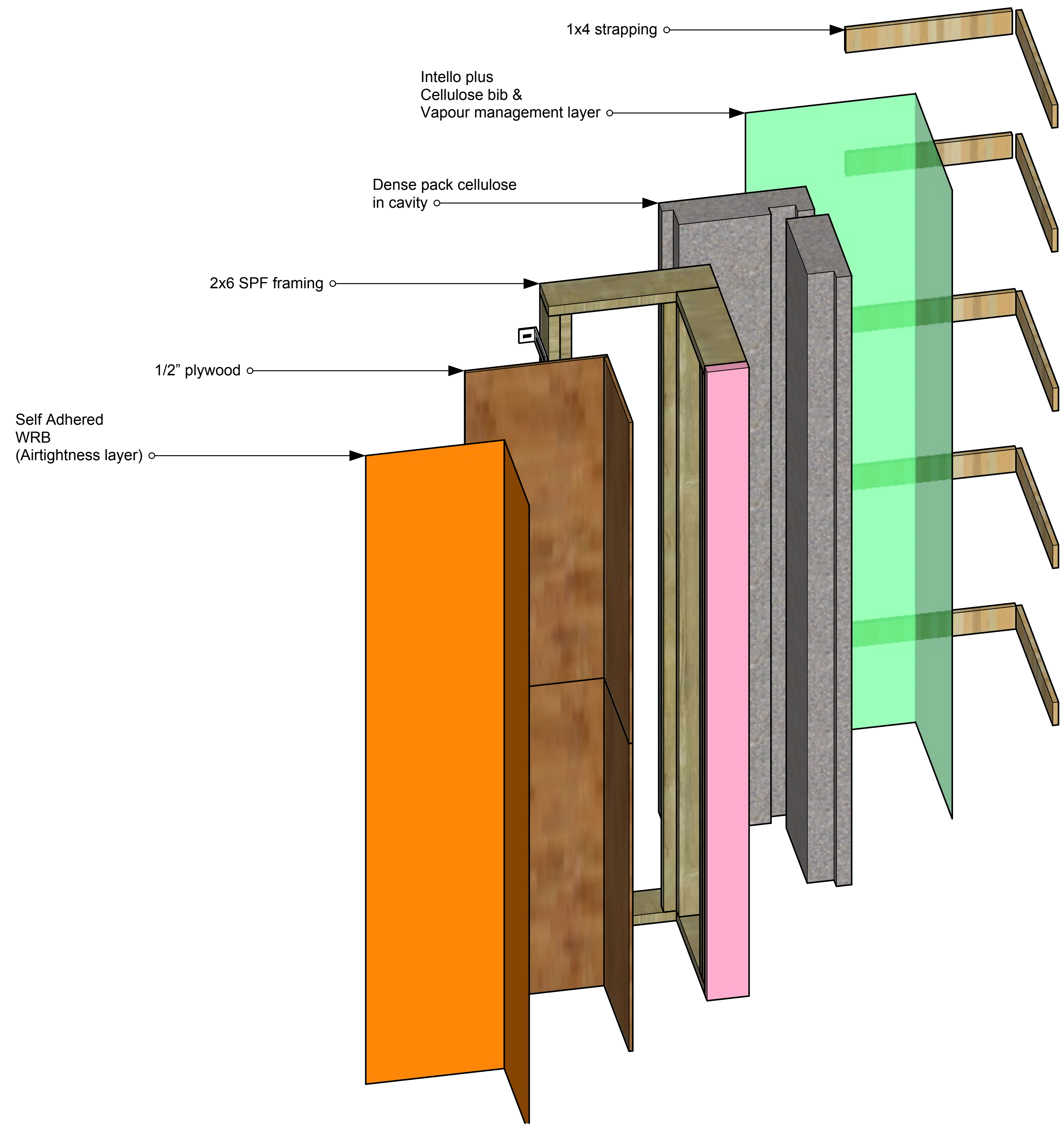
ReCover

Version Date
February 27, 2023

PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Inside Corner Panel - Exploded View



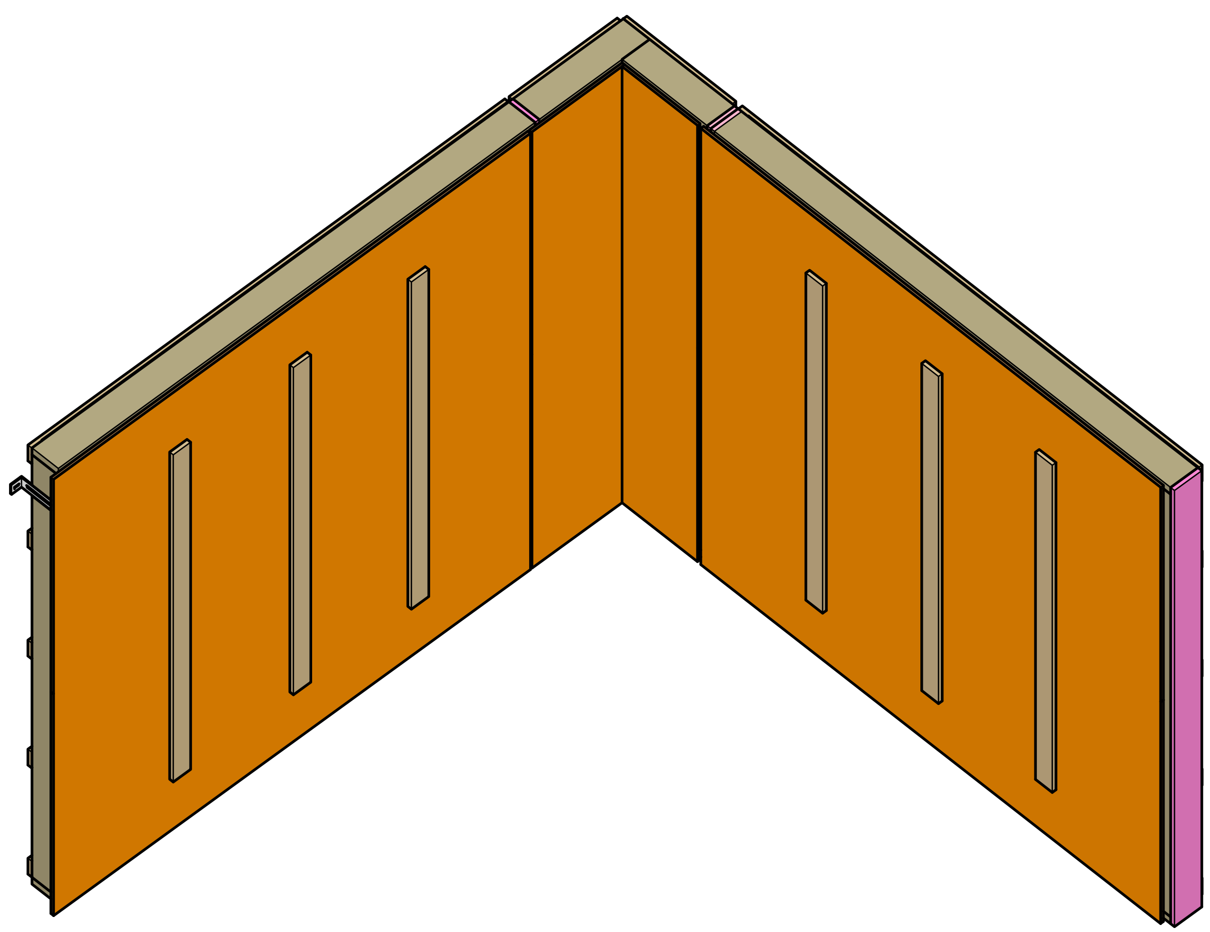
ReCover

Version Date
February 27, 2023

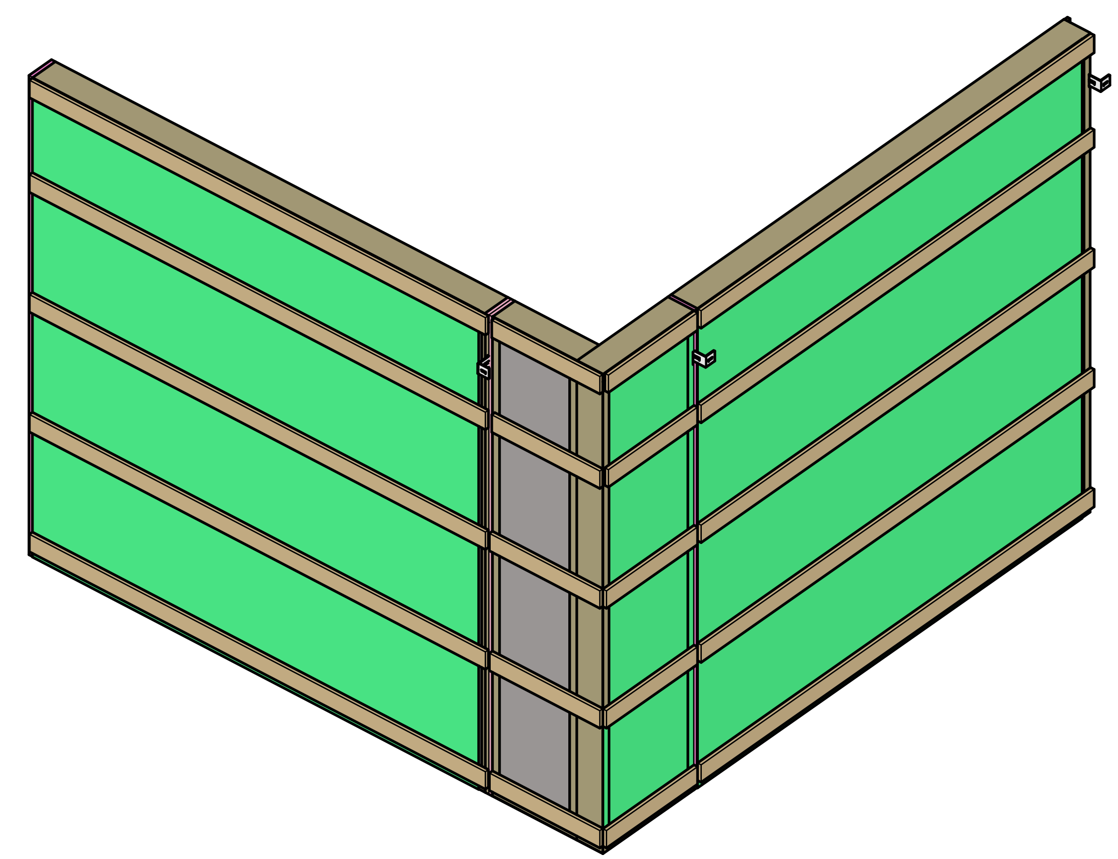
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Inside Corner Installed



EXTERIOR VIEW



INTERIOR VIEW

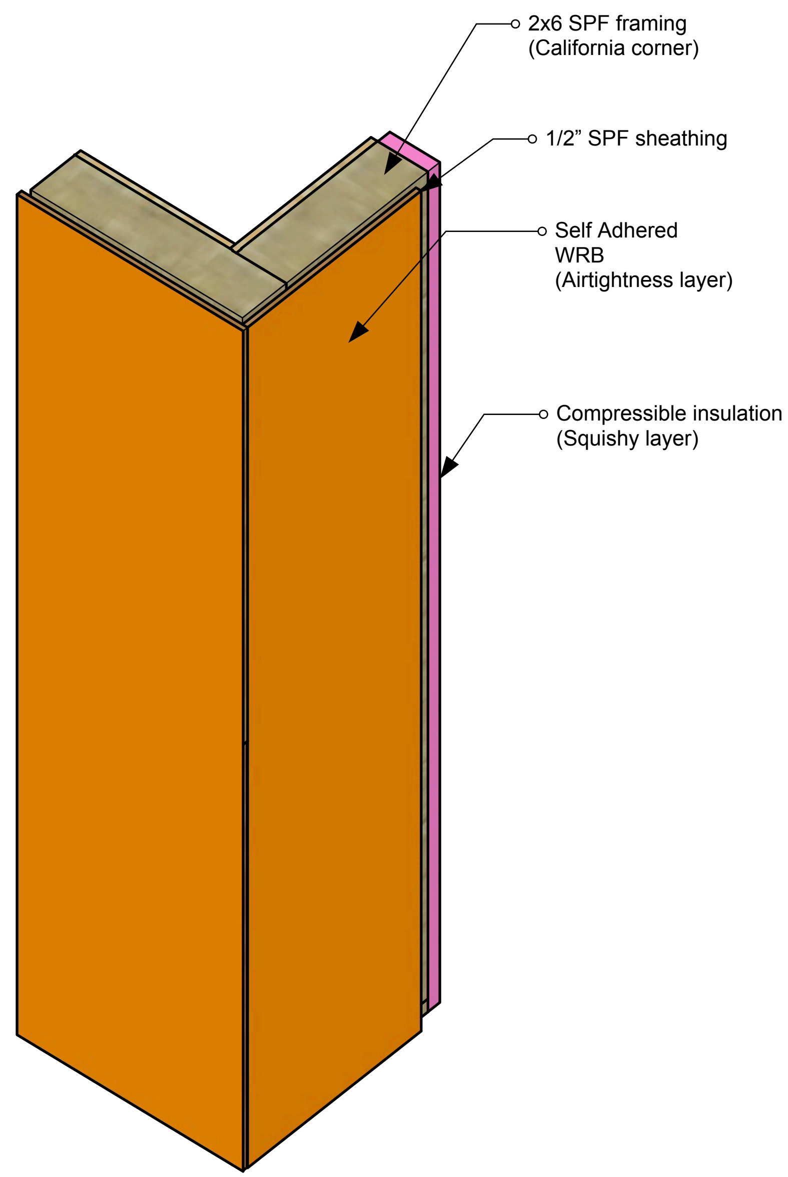
ReCover

Version Date
February 27, 2023

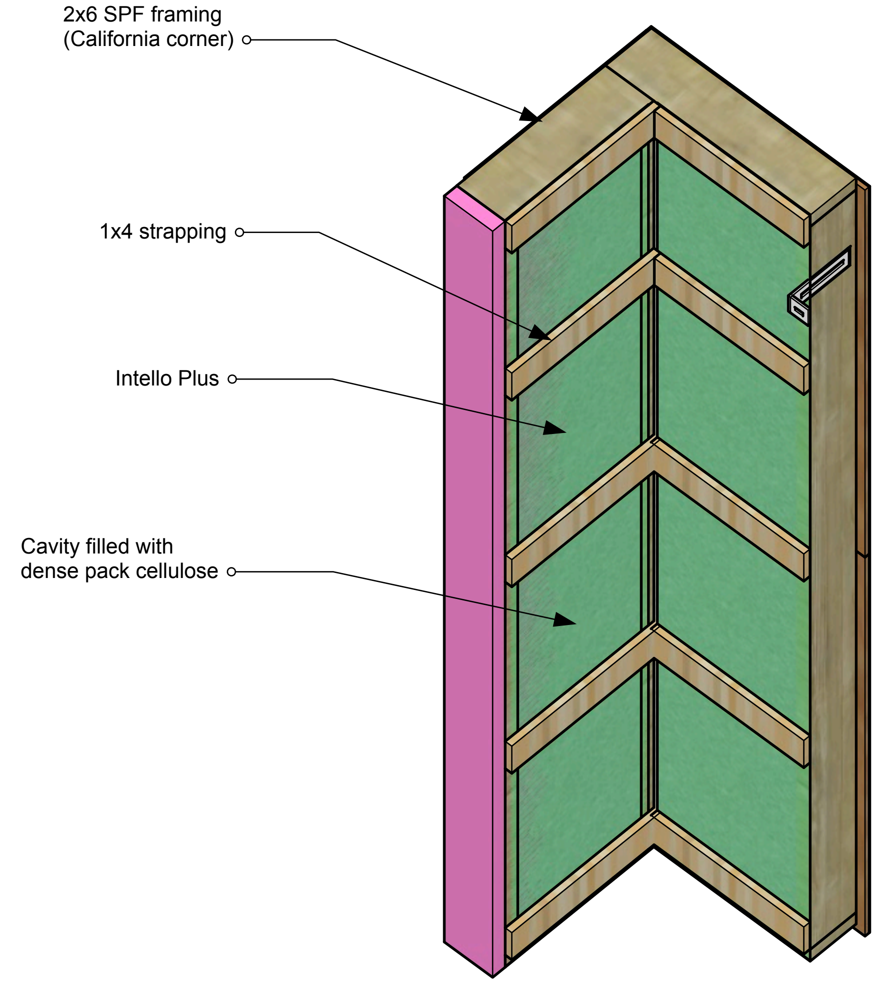
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Outside Corner Panel - Overview



EXTERIOR VIEW



INTERIOR VIEW

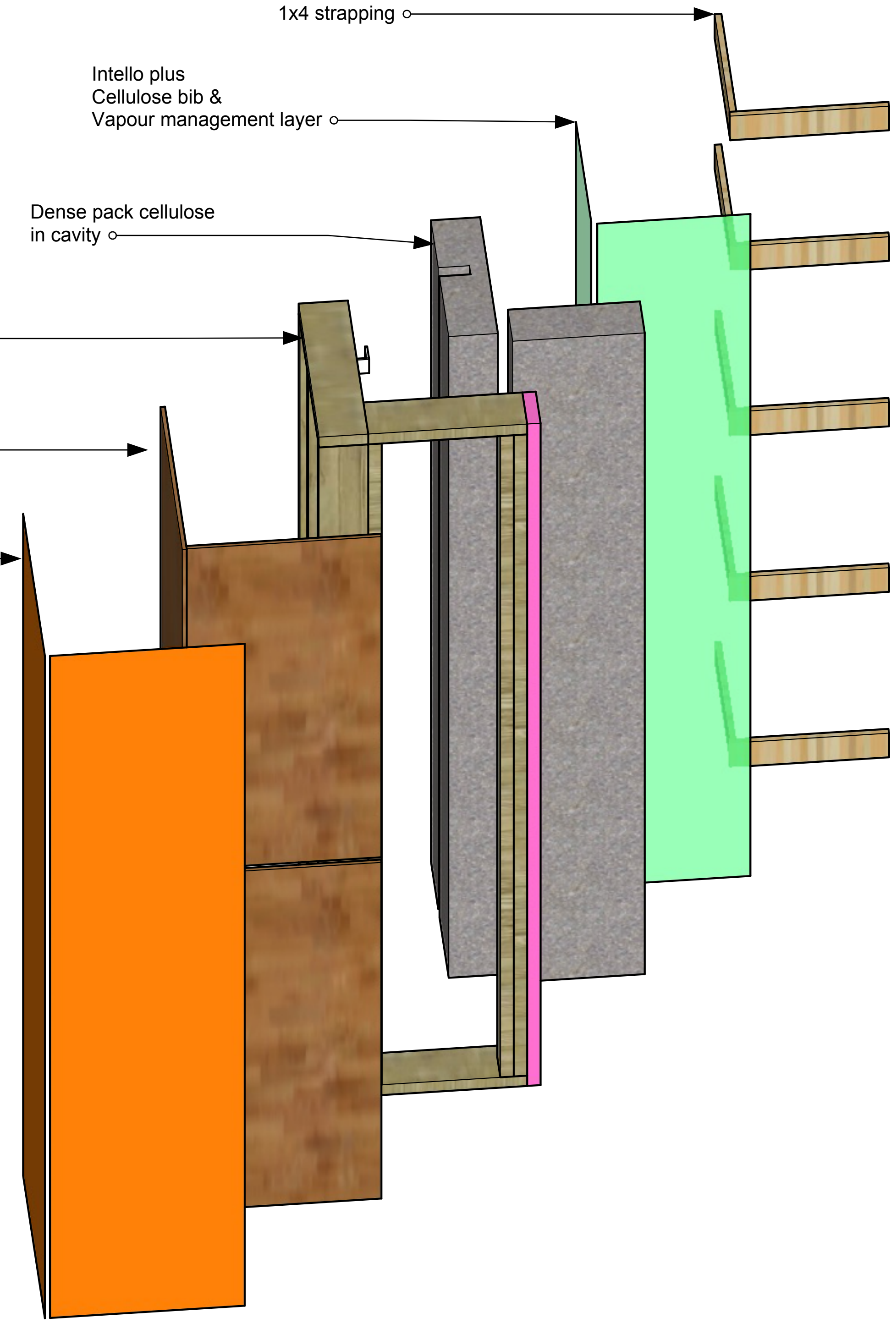
ReCover

Version Date
February 27, 2023

PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Outside Corner Panel - Exploded View



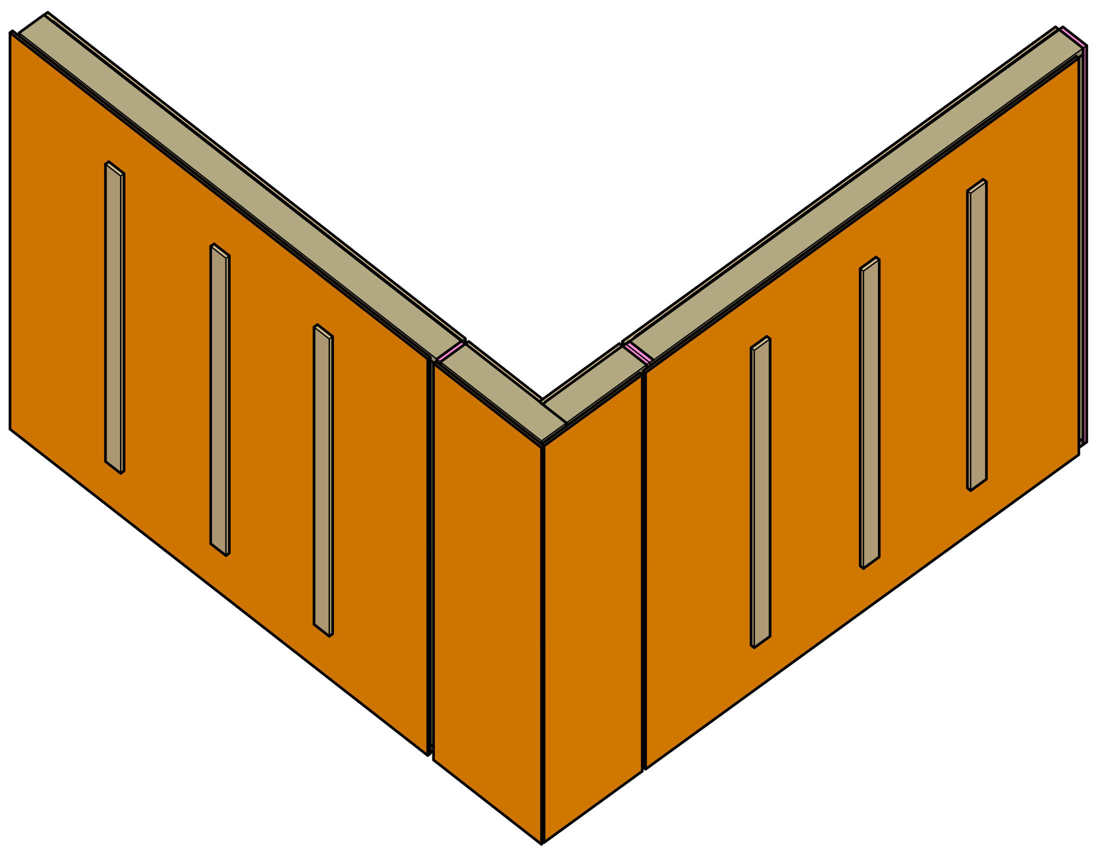
ReCover

Version Date
February 27, 2023

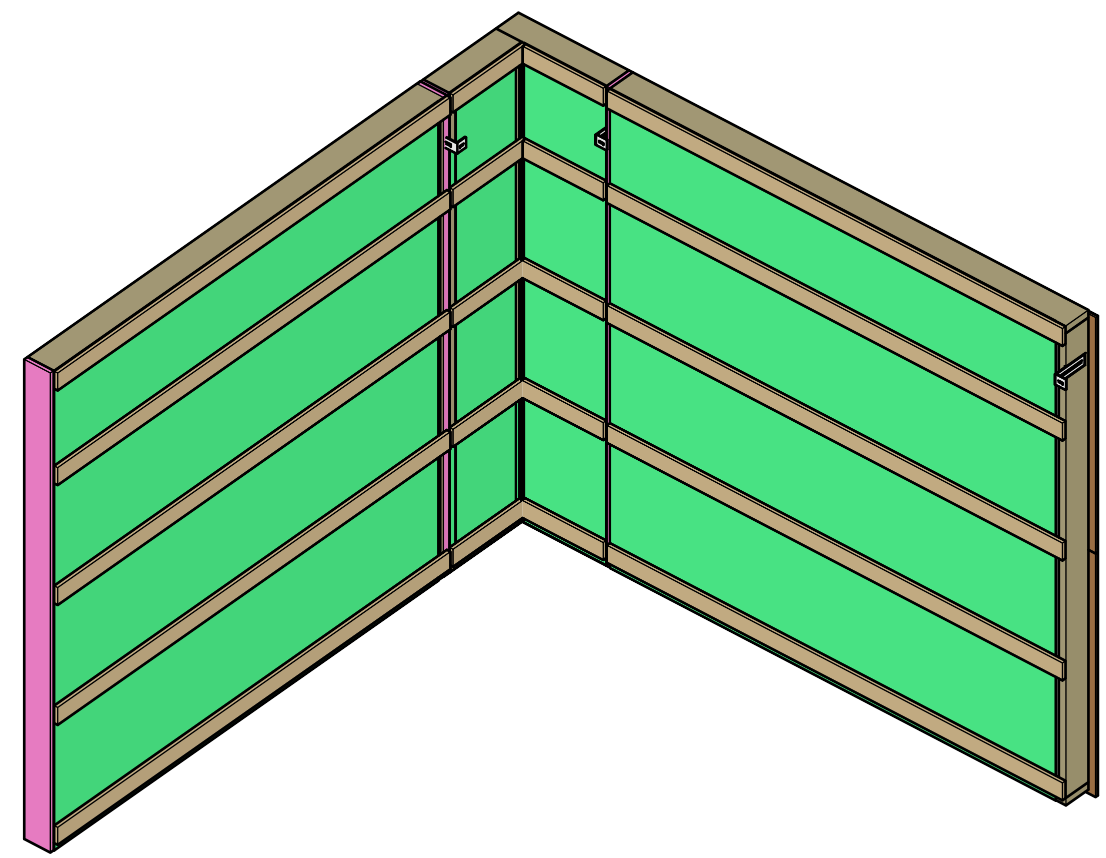
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Outside Corner Installed



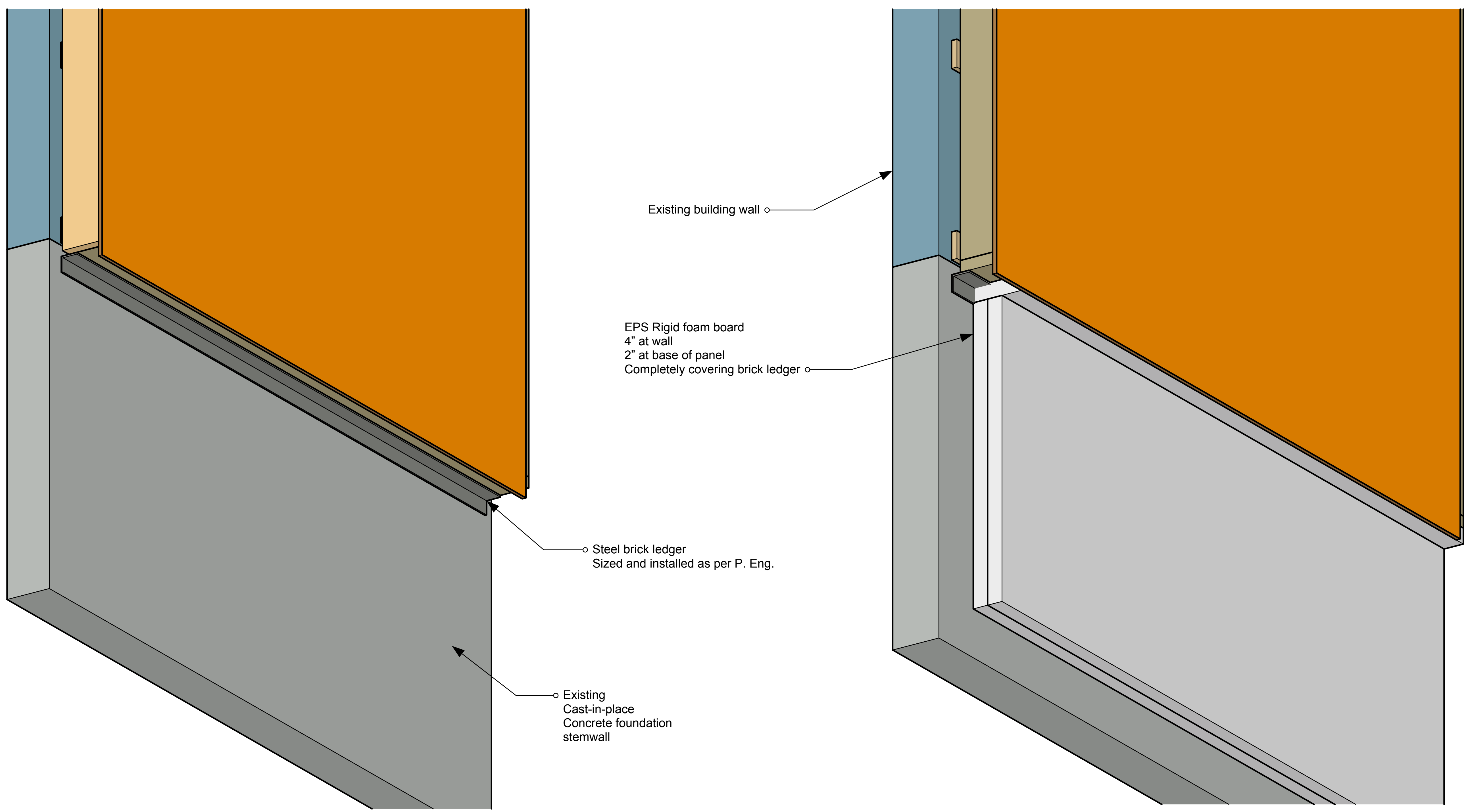
EXTERIOR VIEW



INTERIOR VIEW

Foundation Attachment - Brick Ledger

"Brick Ledger" style continuous ledger for panel support



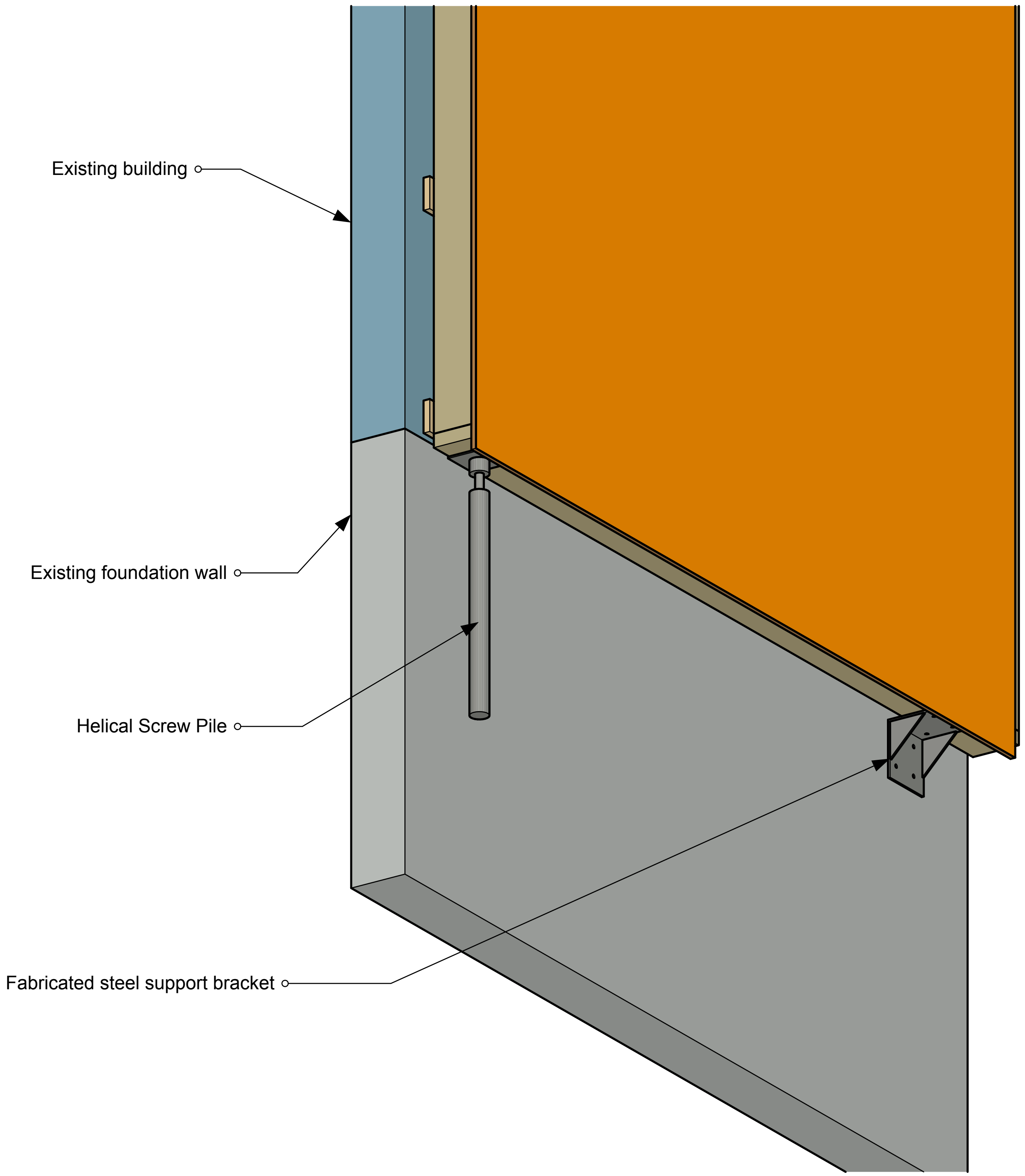
BEFORE SITE INSULATION **AFTER SITE INSULATION**

Version Date
February 27, 2023

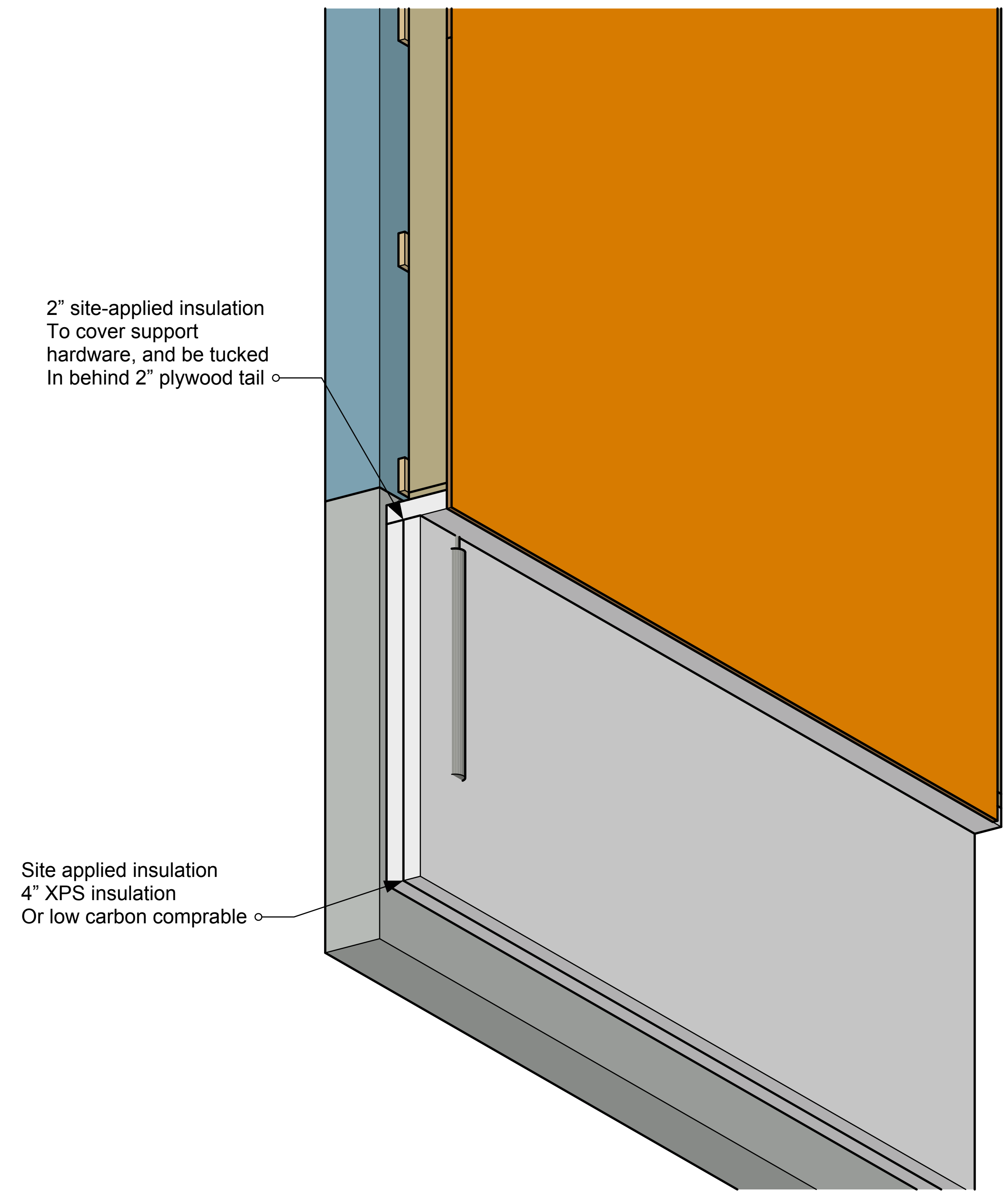
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Alternate Foundation Attachment - Pile or Bracket



BEFORE SITE INSULATION



AFTER SITE INSULATION

ReCover

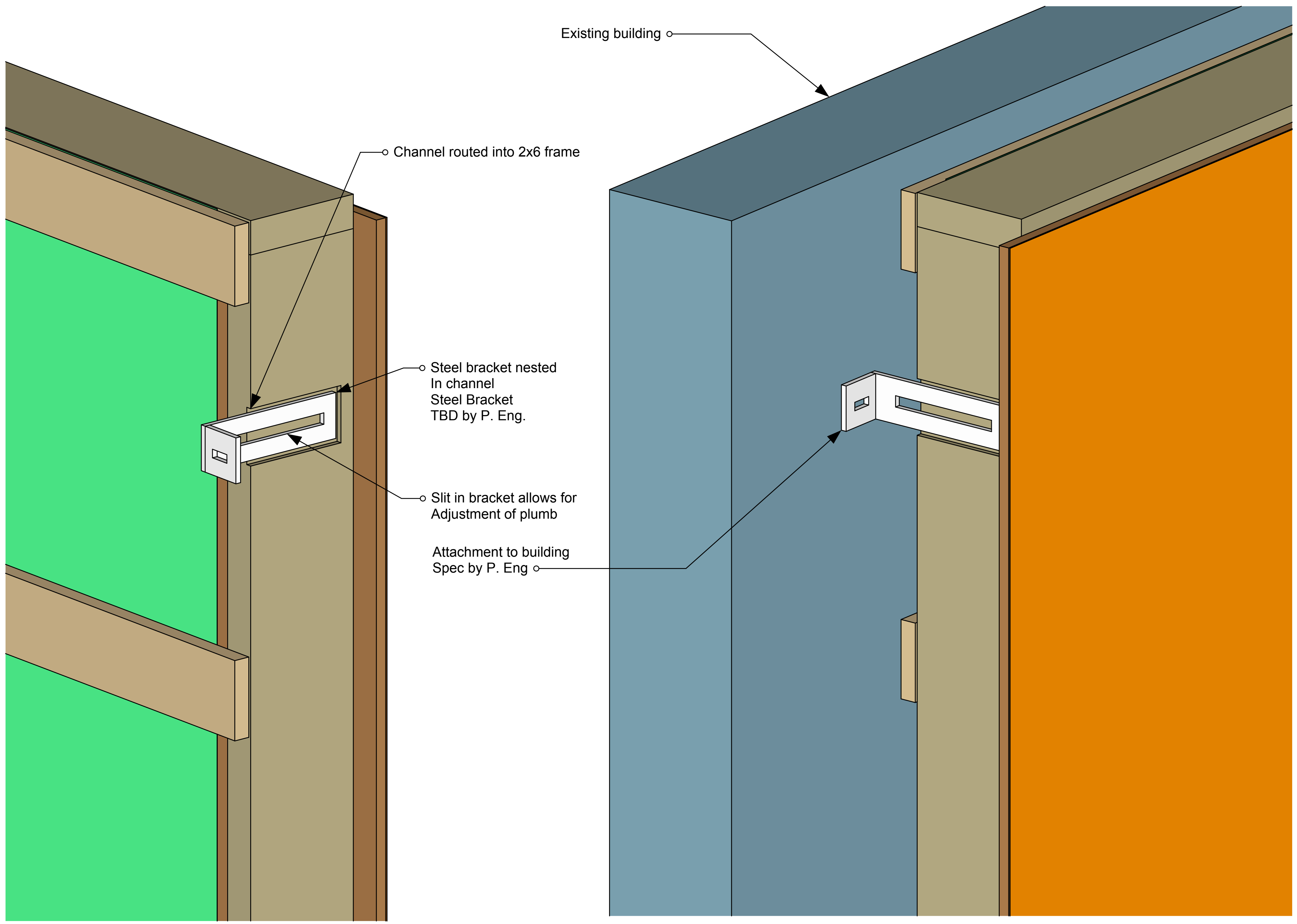
Version Date
February 27, 2023

PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Attach to Existing Building

Bracket to attach individual panels to existing



INTERIOR VIEW **EXTERIOR VIEW**

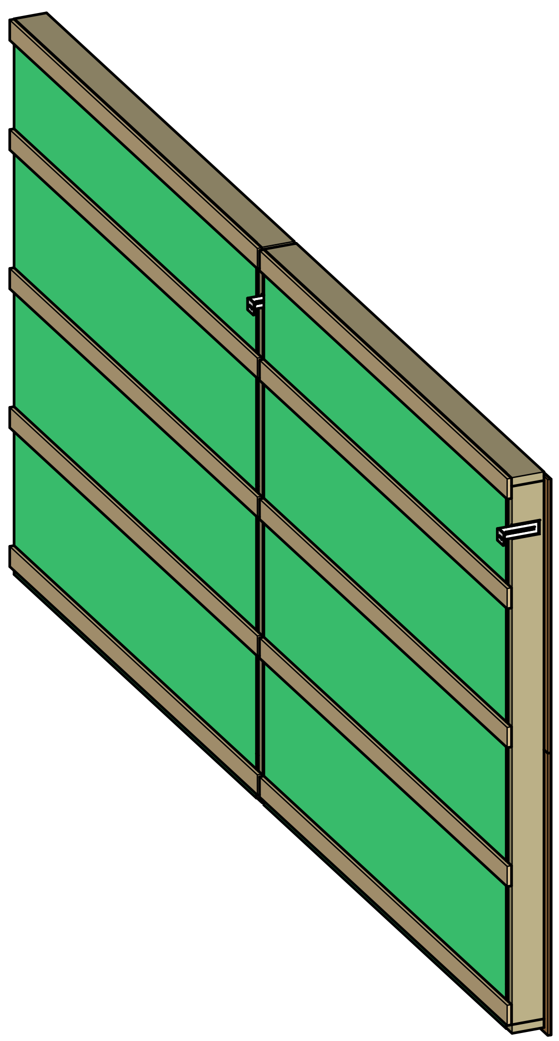
ReCover

Version Date
February 27, 2023

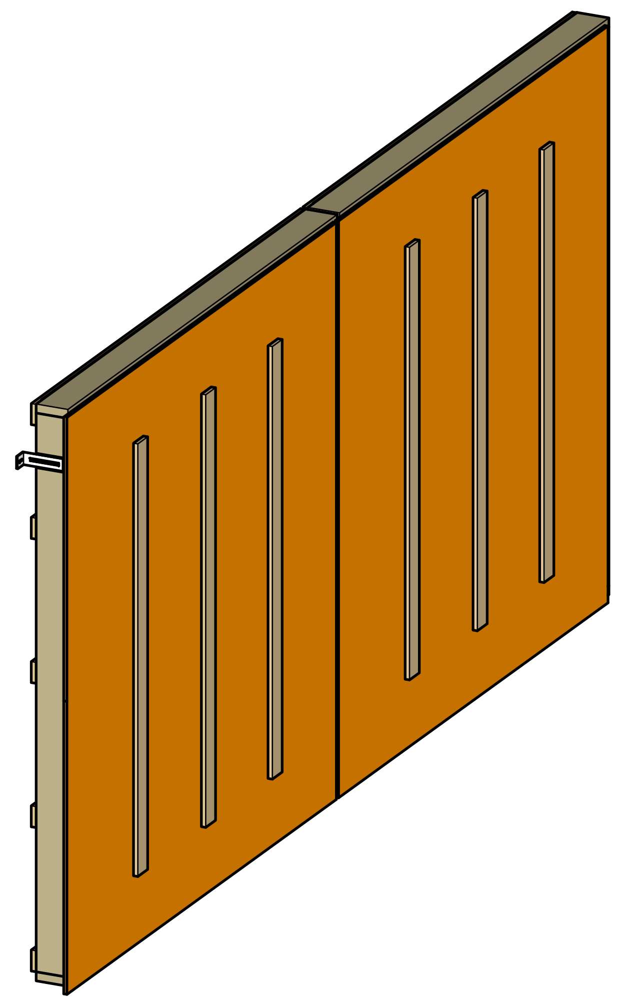
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

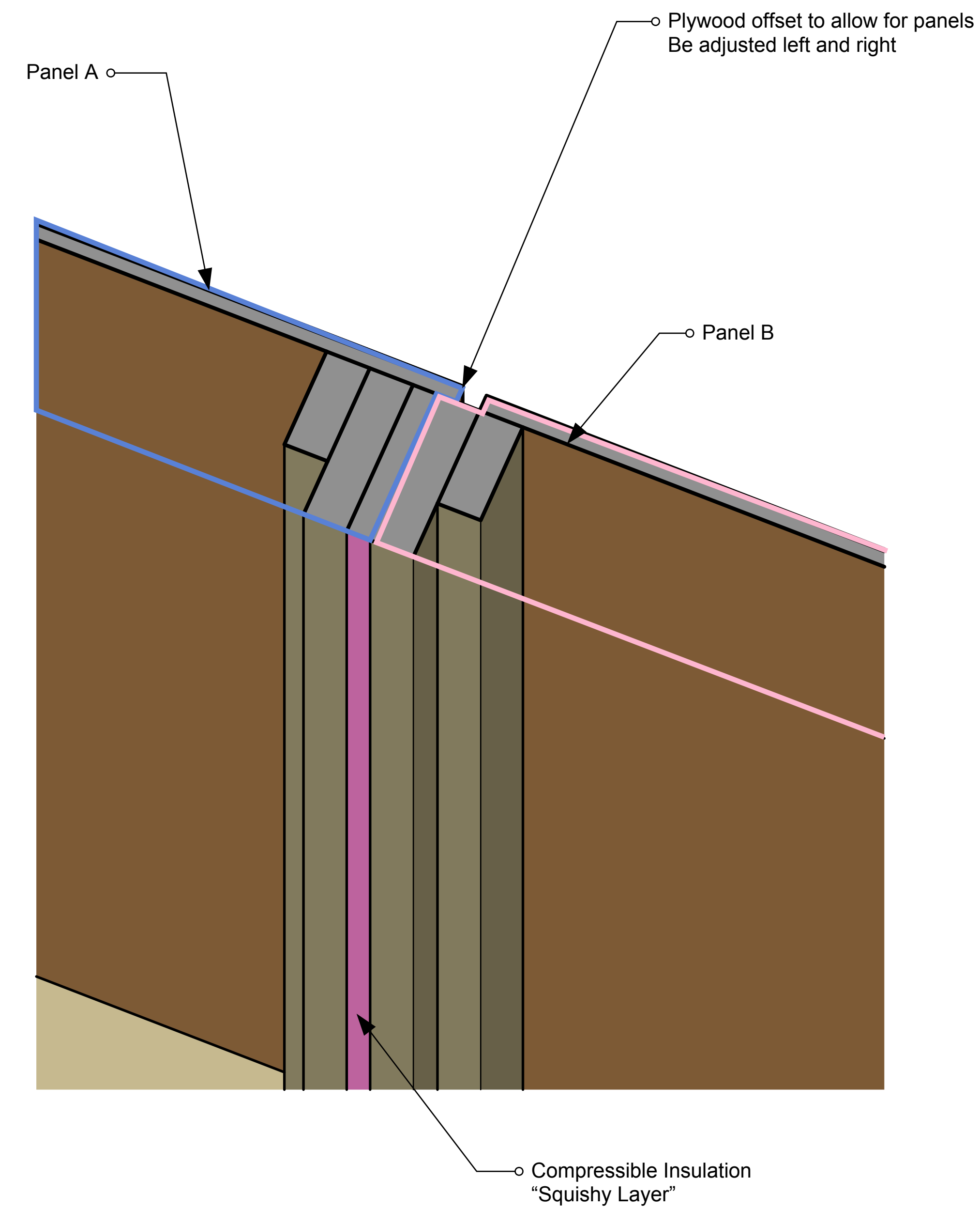
Vertical Wall Joints



INTERIOR VIEW



EXTERIOR VIEW



SECTION VIEW

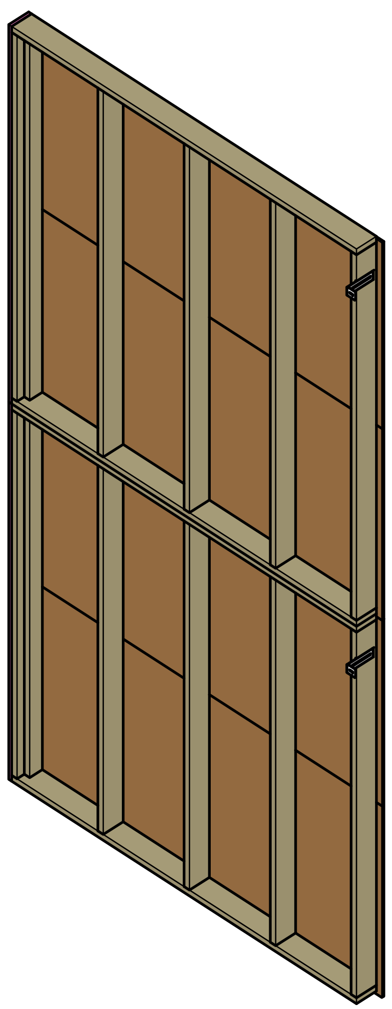
ReCover

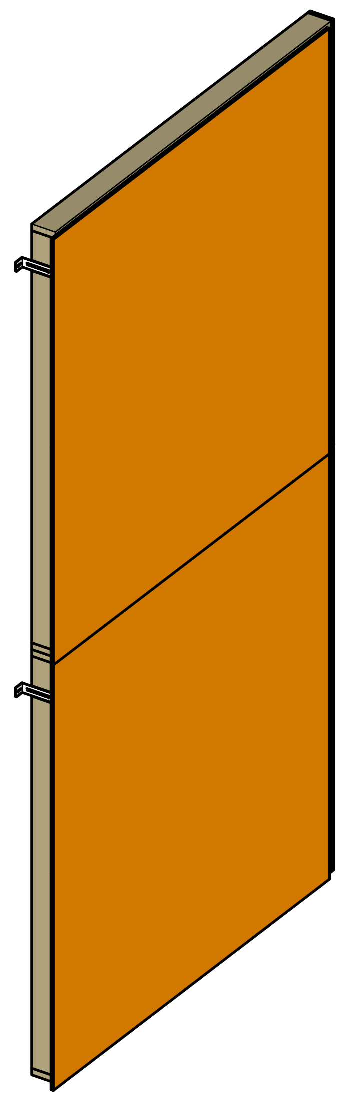
Version Date
February 27, 2023

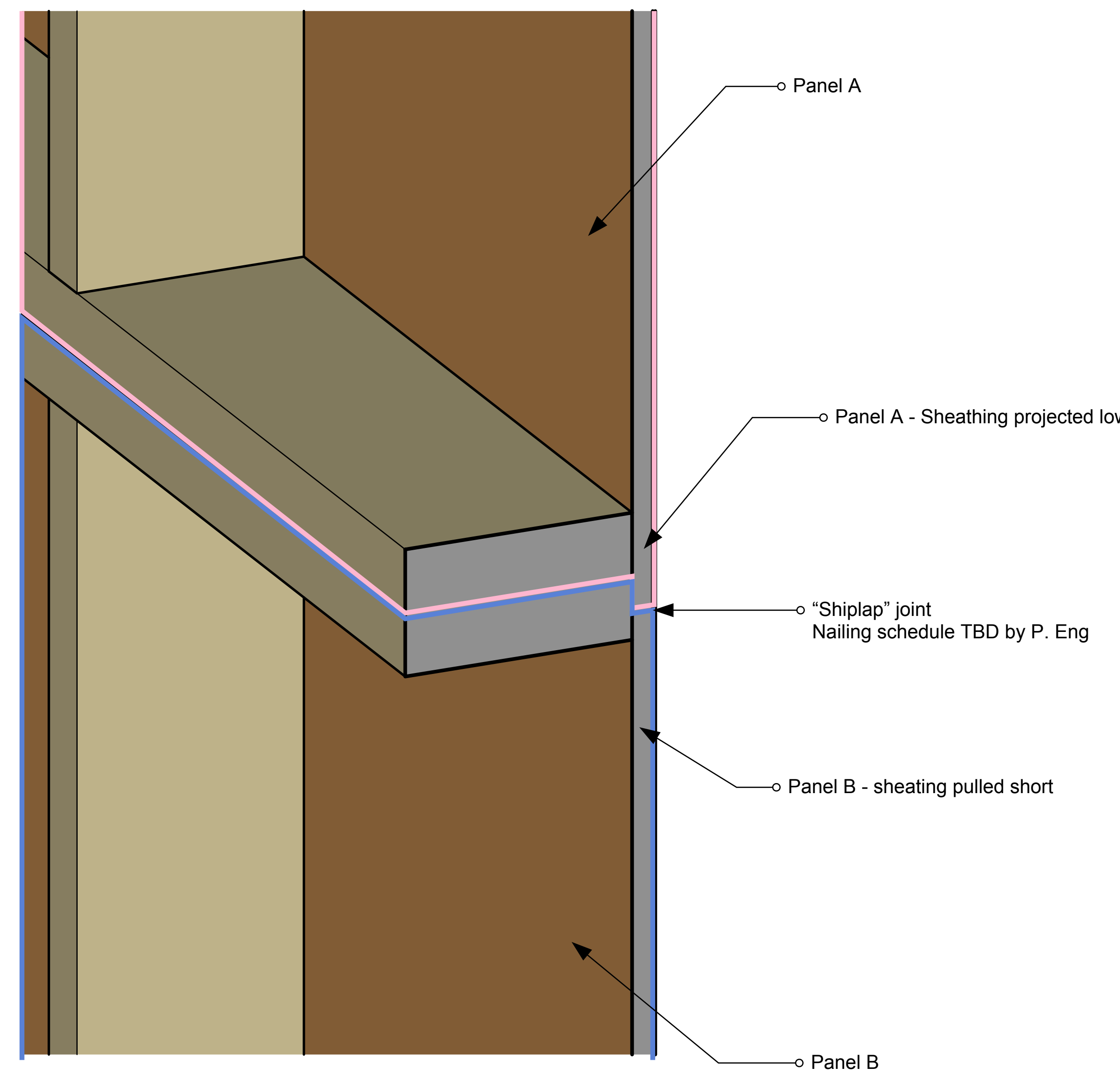
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Horizontal Wall Joins







INTERIOR VIEW

EXTERIOR VIEW

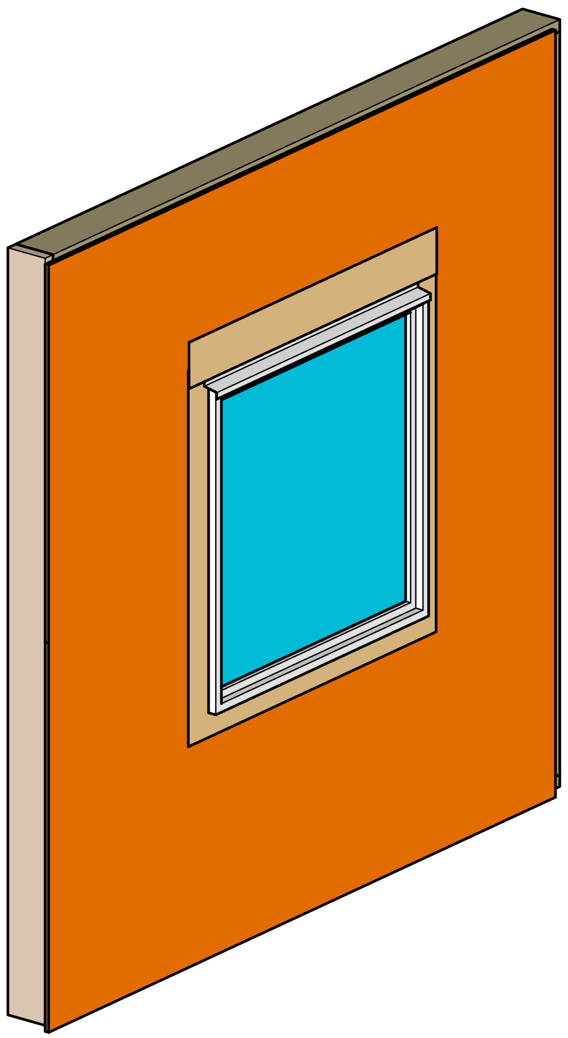
SECTION VIEW

Version Date
February 27, 2023

PROJECT
2x6 R 16 Cellulose
Panel Schematics

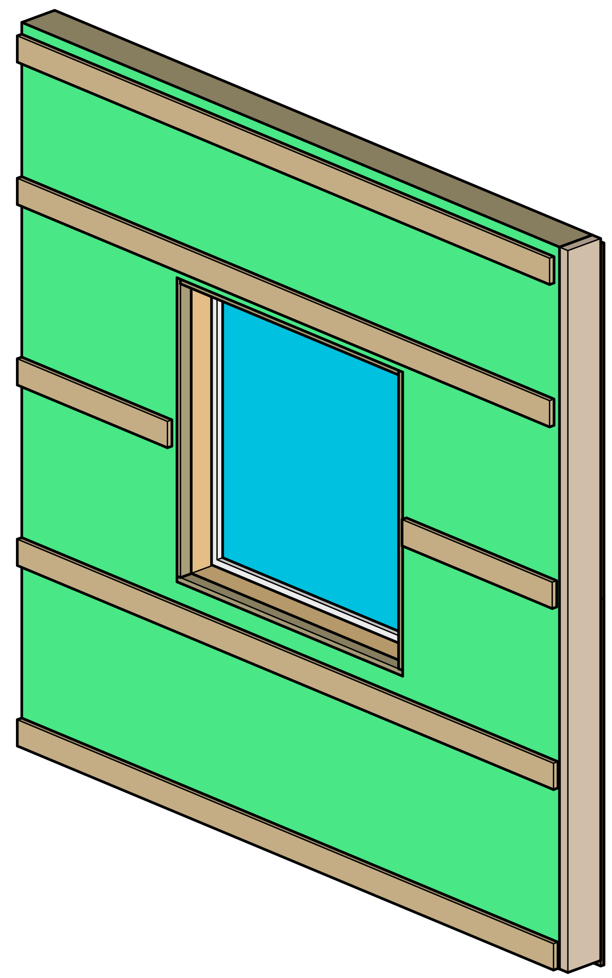
Drawn By
Nick Rudnicki

Window Panel

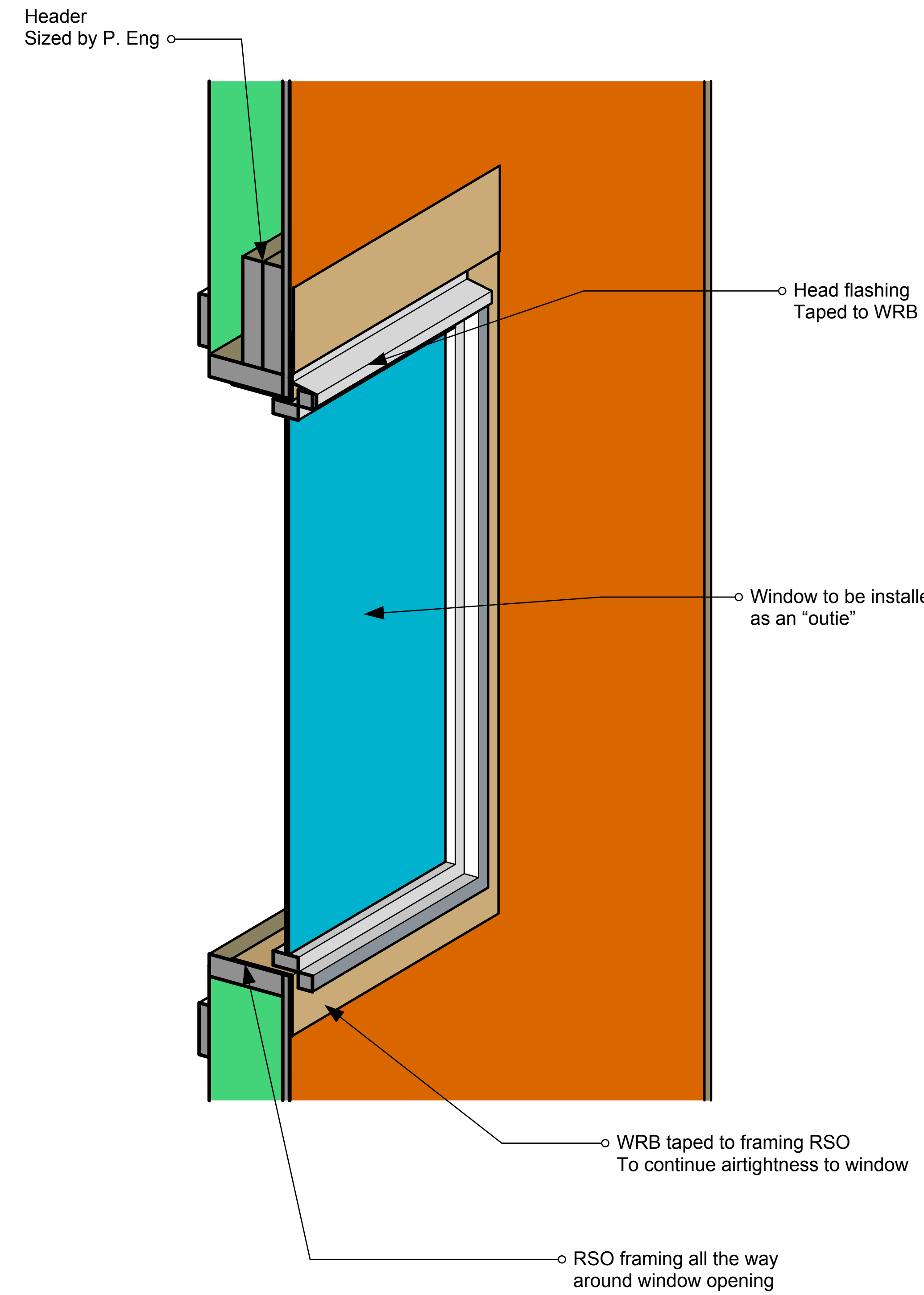


PANEL
EXTERIOR VIEW

Window installed in factory
Window installed as an "outie" to minimize how much window sill there is exposed to the rain



PANEL
EXTERIOR VIEW



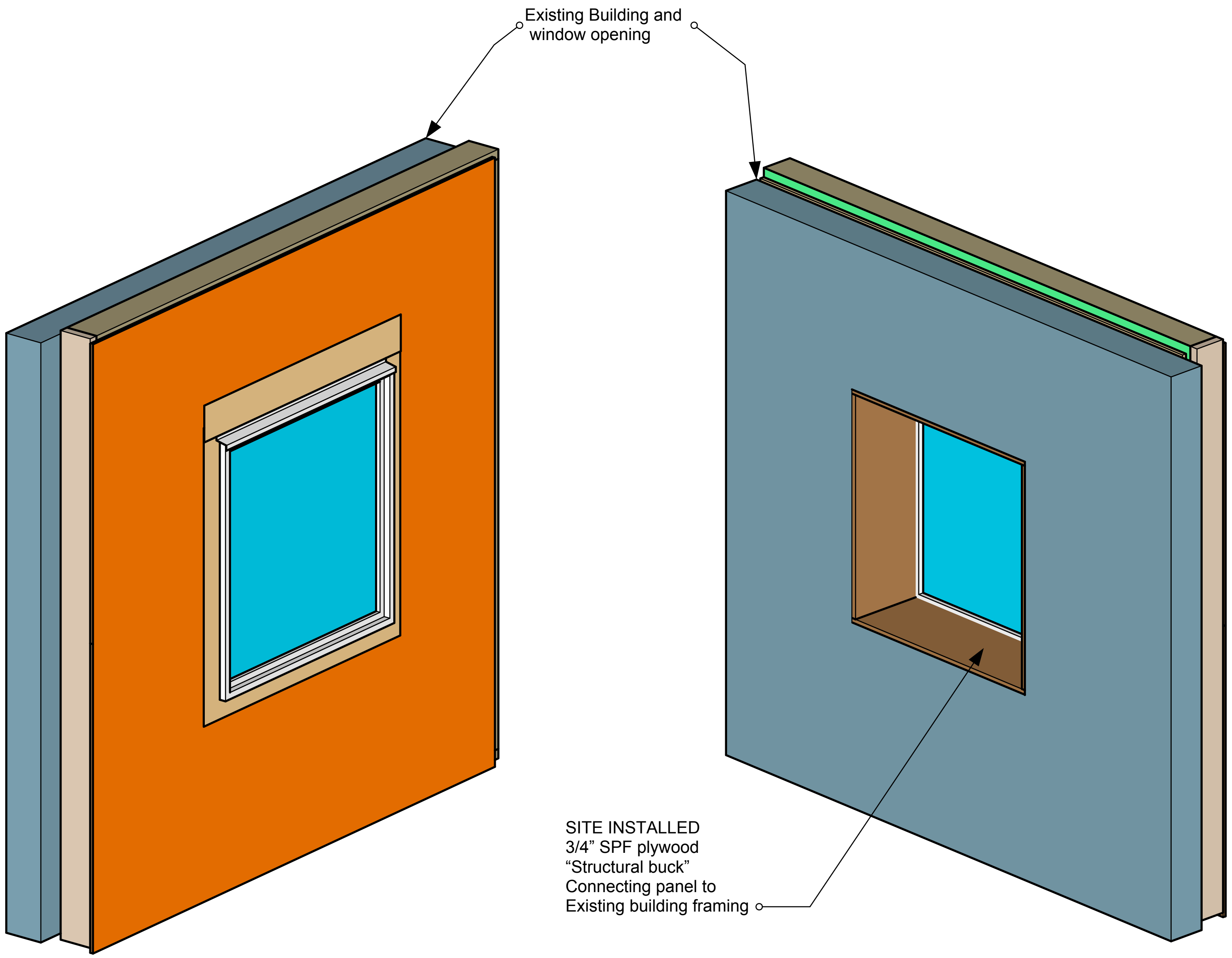
ReCover

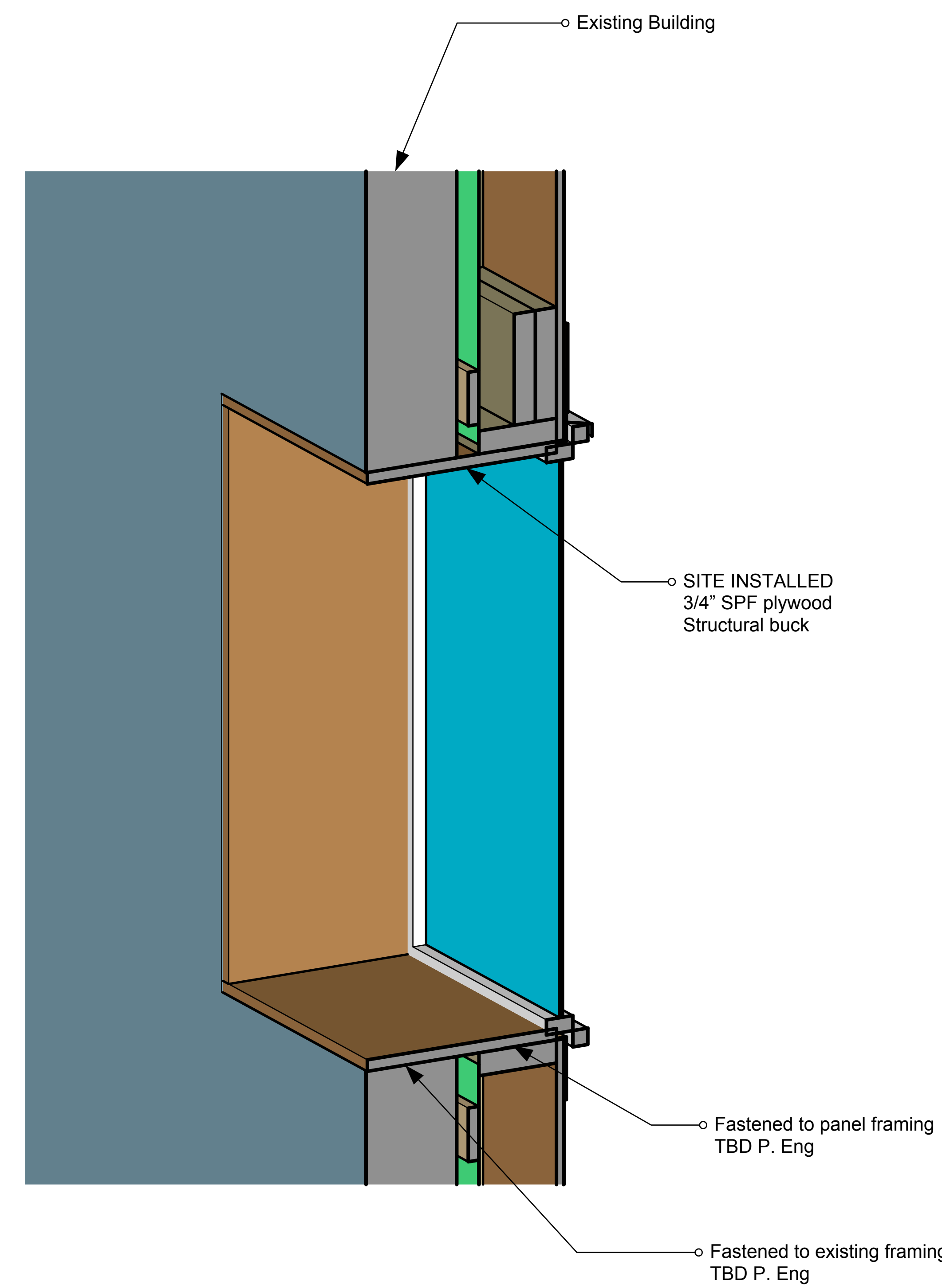
Version Date
February 27, 2023

PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Window Panel Install





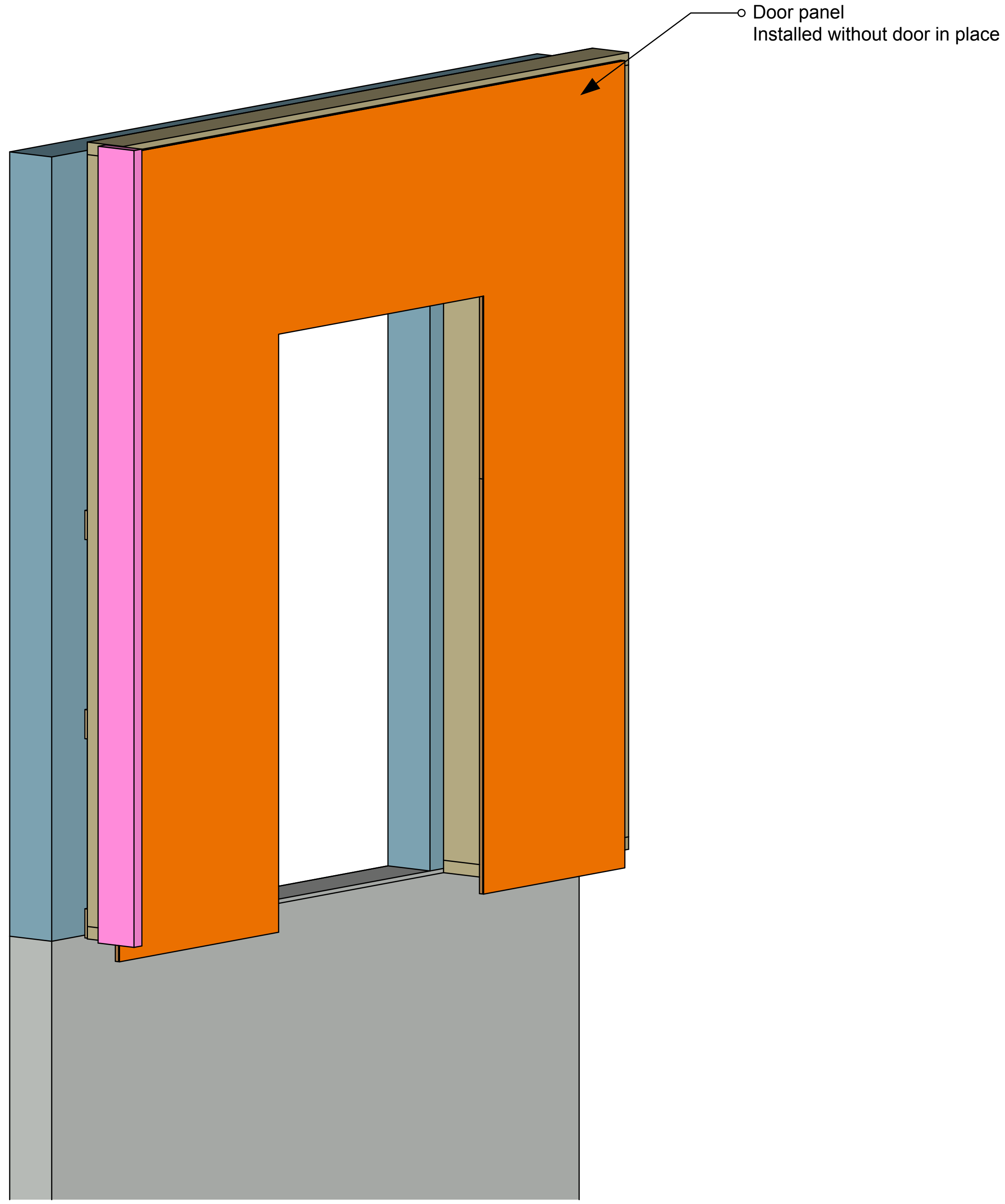
ReCover

Version Date
February 27, 2023

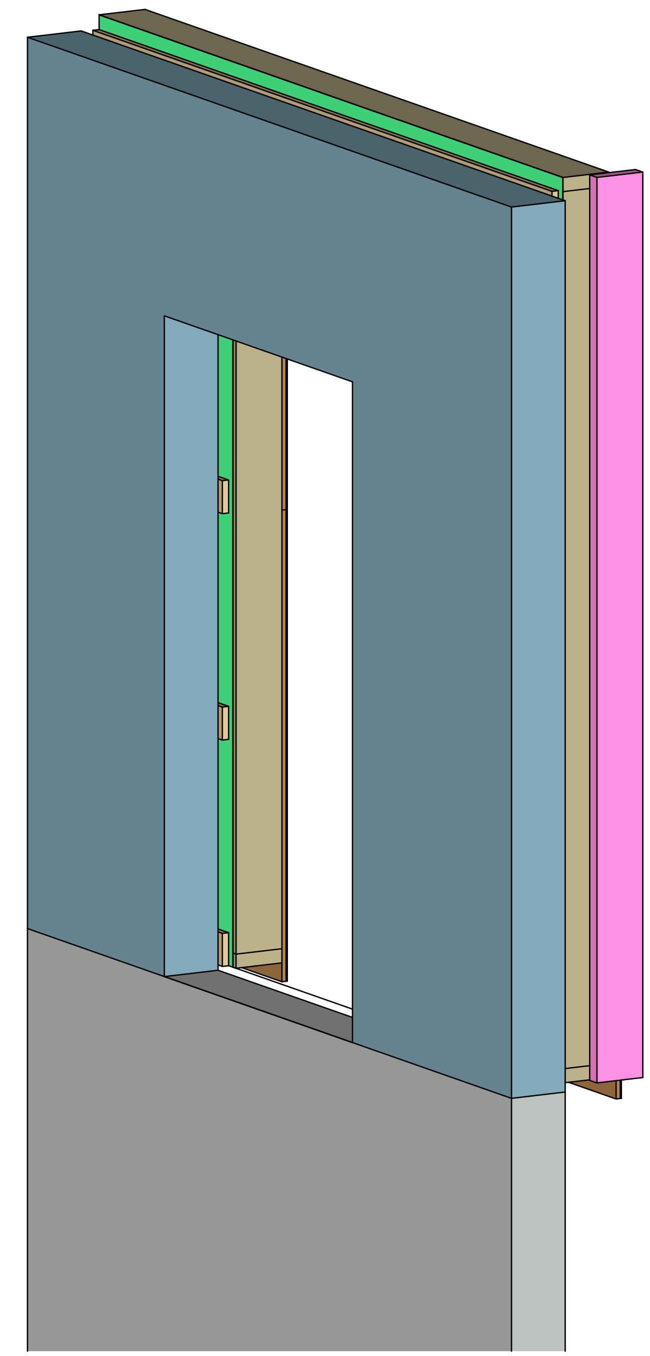
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

Door Penetration Panel



EXTERIOR VIEW



INTERIOR VIEW

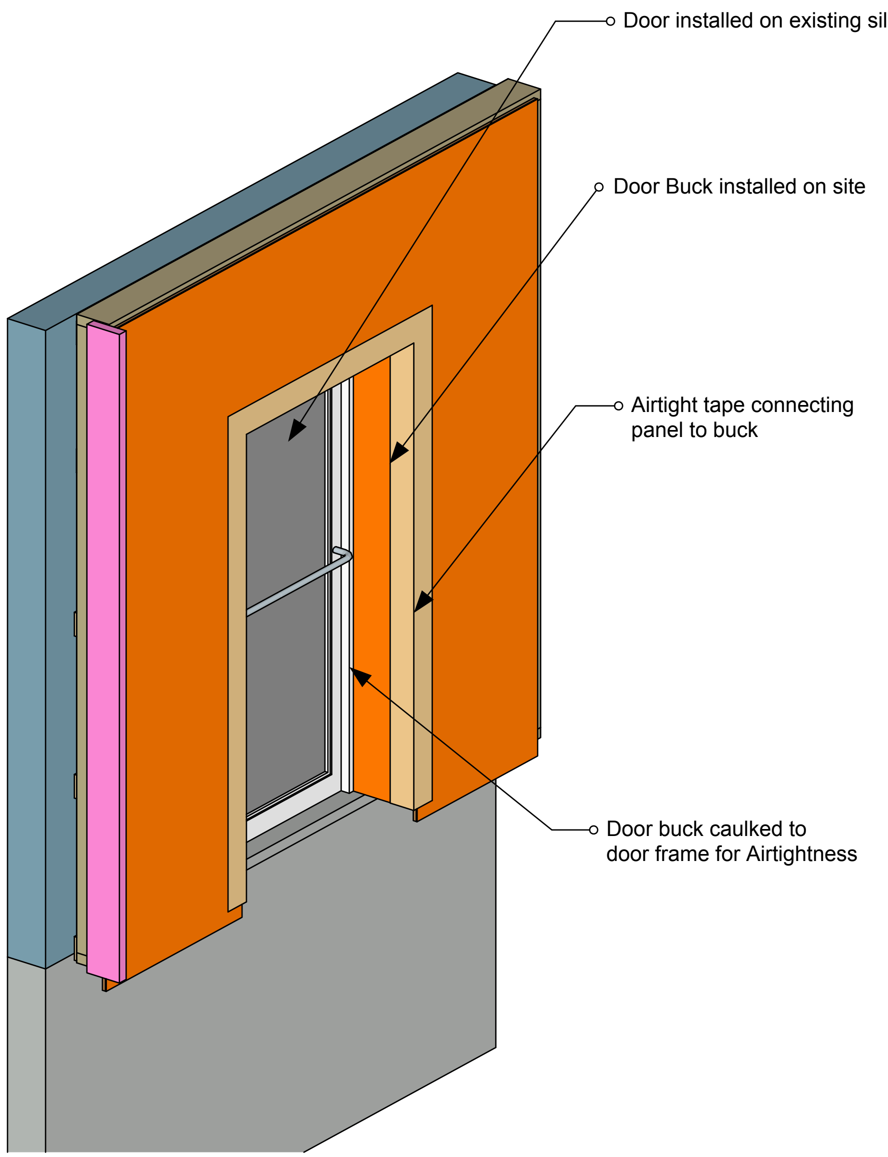
ReCover

Version Date
February 27, 2023

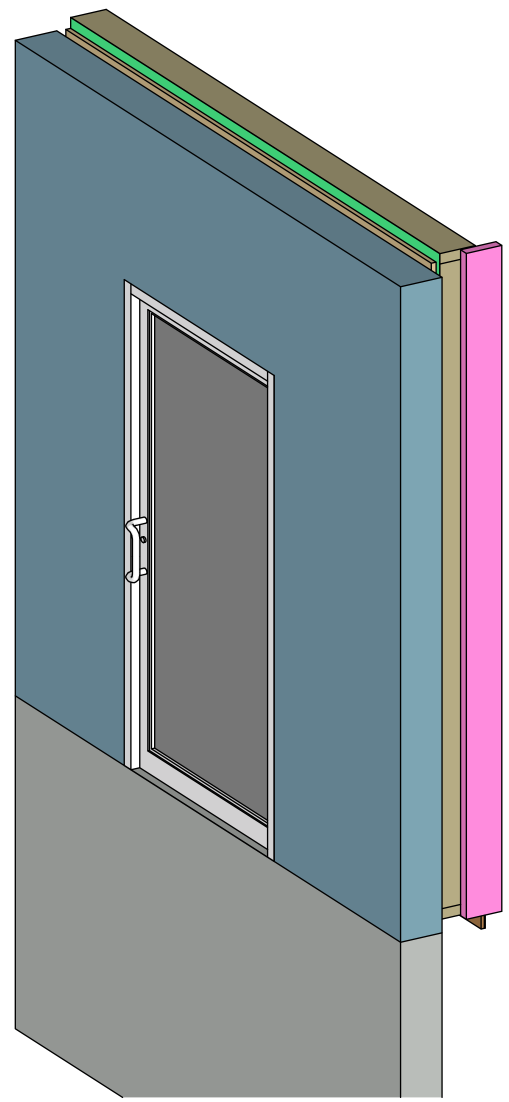
PROJECT
2x6 R 16 Cellulose
Panel Schematics

Drawn By
Nick Rudnicki

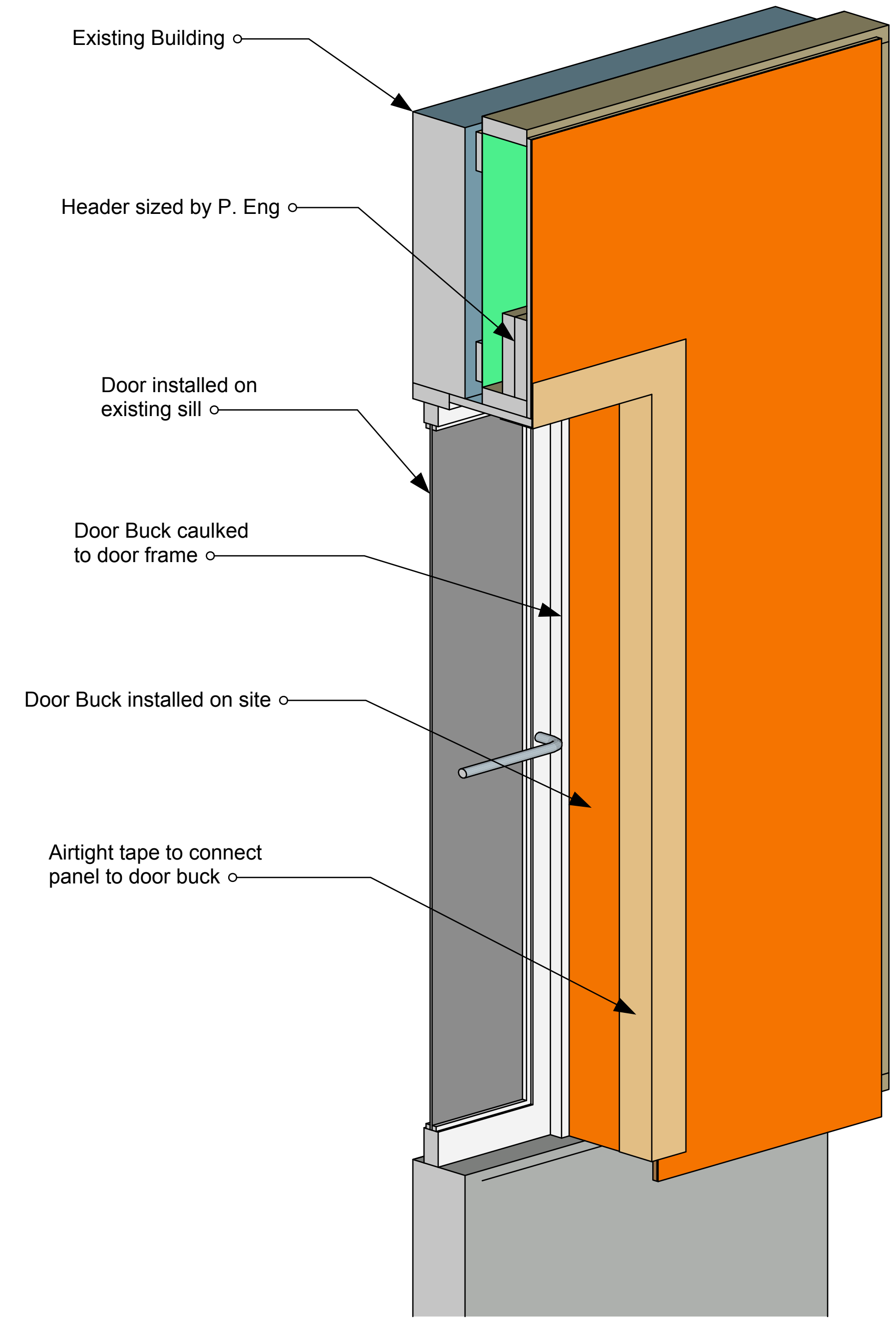
Door Penetration Panel Installed



EXTERIOR VIEW



INTERIOR VIEW



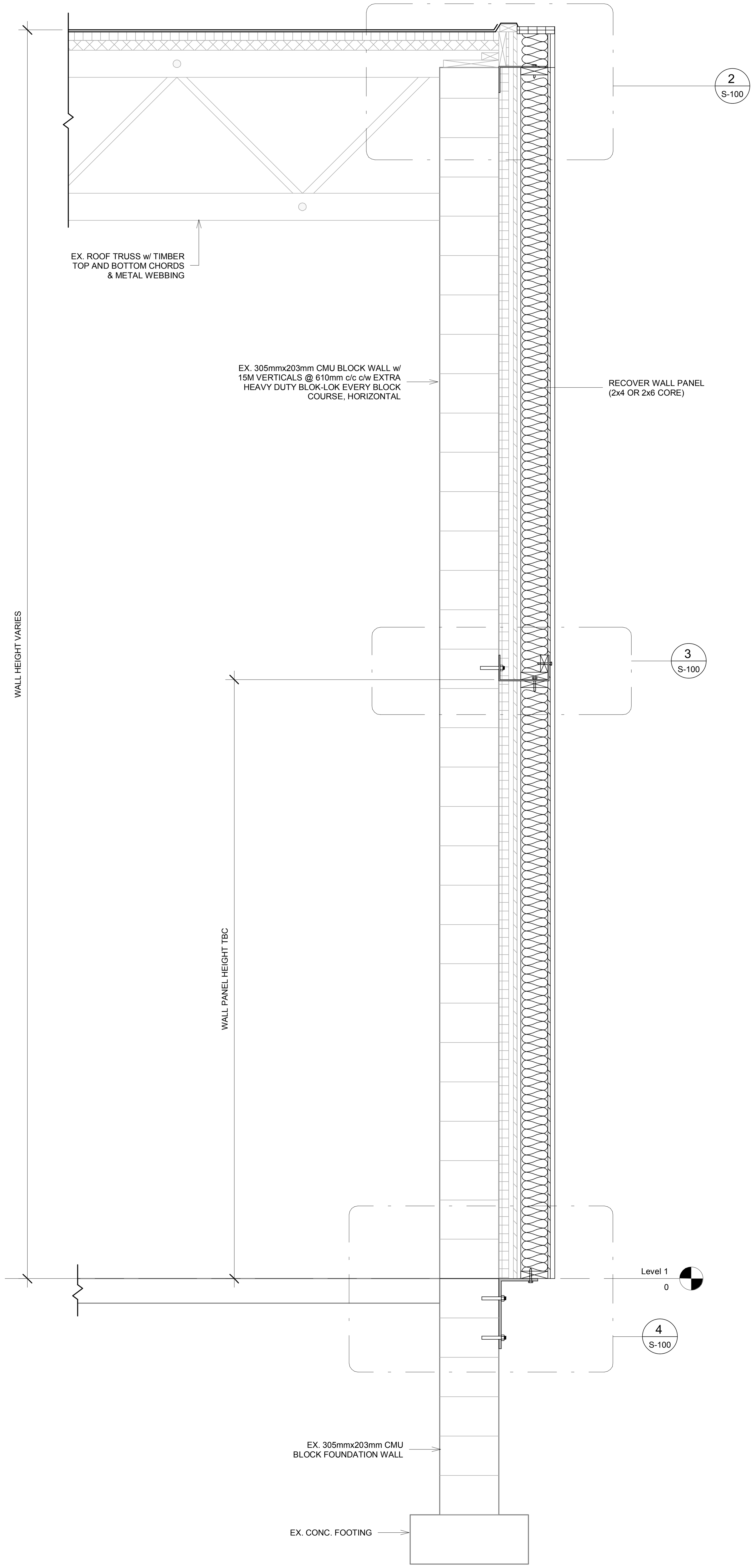
SECTION VIEW

ReCover

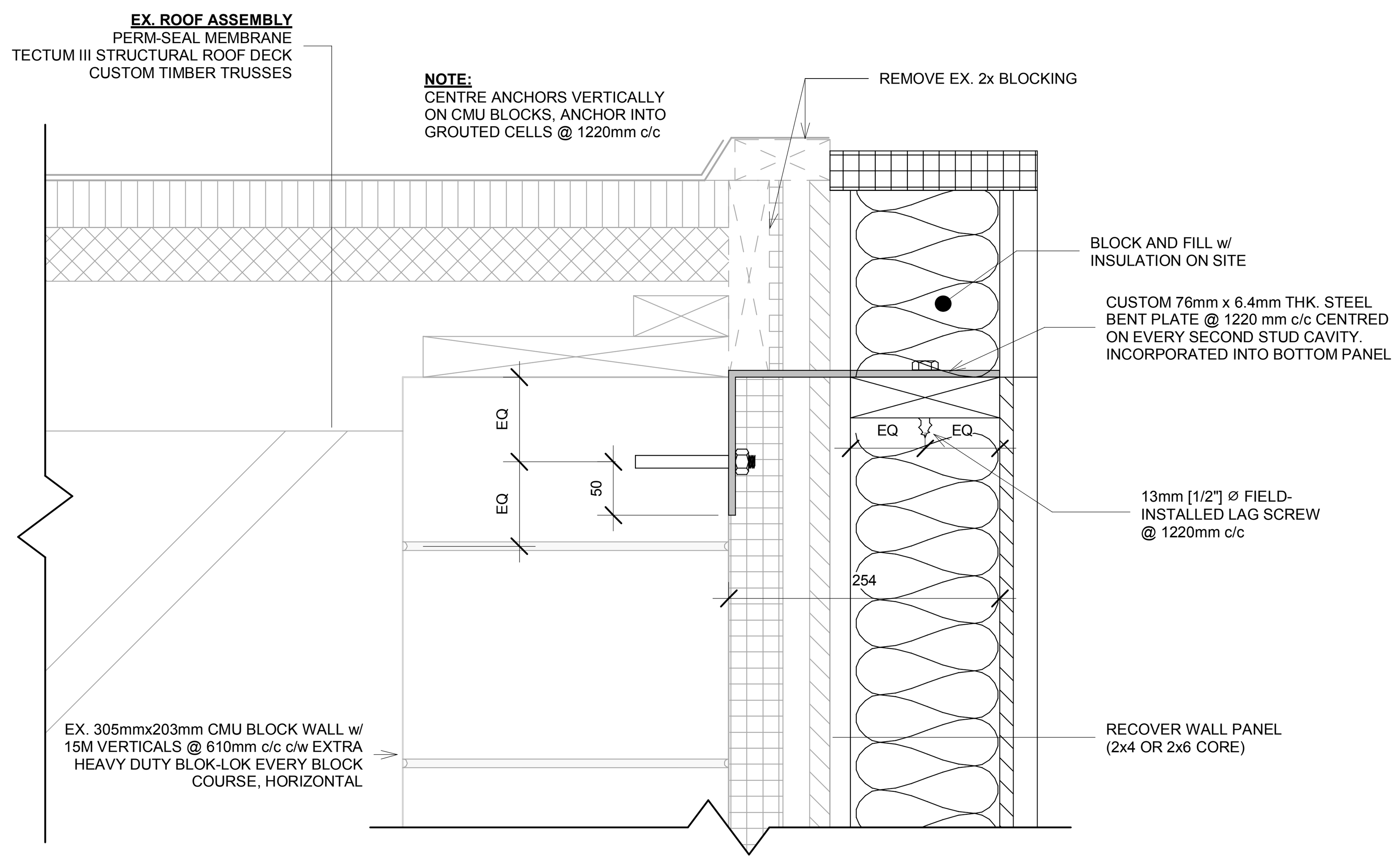
Version Date
February 27, 2023

PROJECT
2x6 R 16 Cellulose Panel Schematics

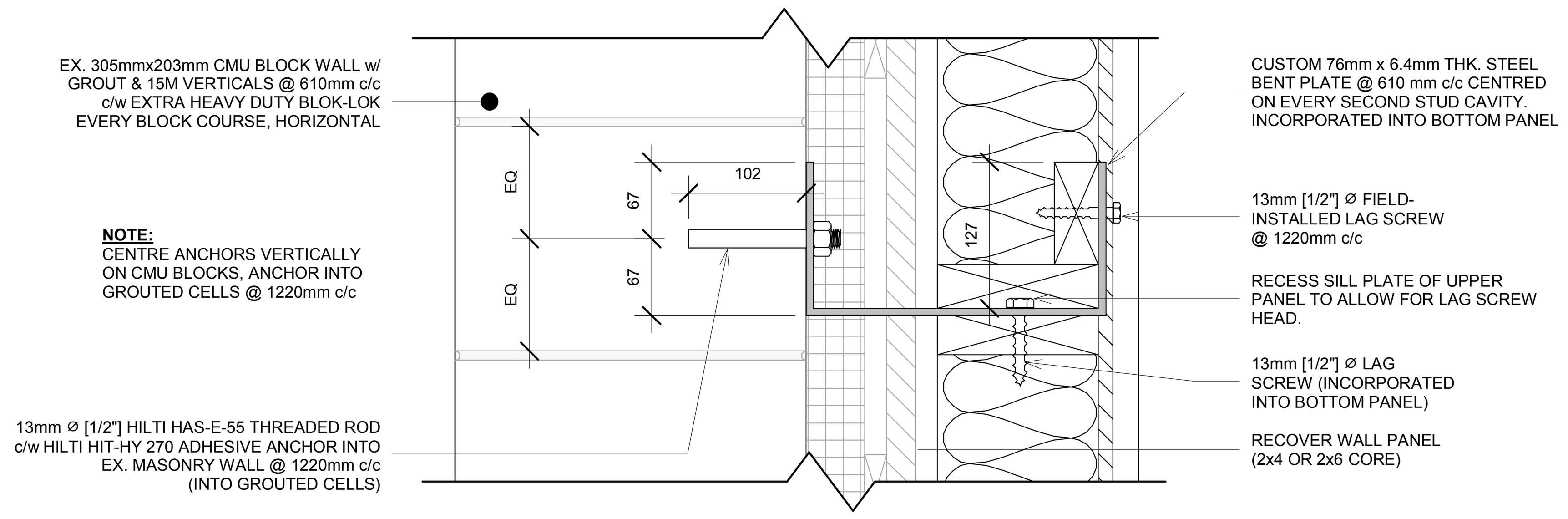
Drawn By
Nick Rudnicki



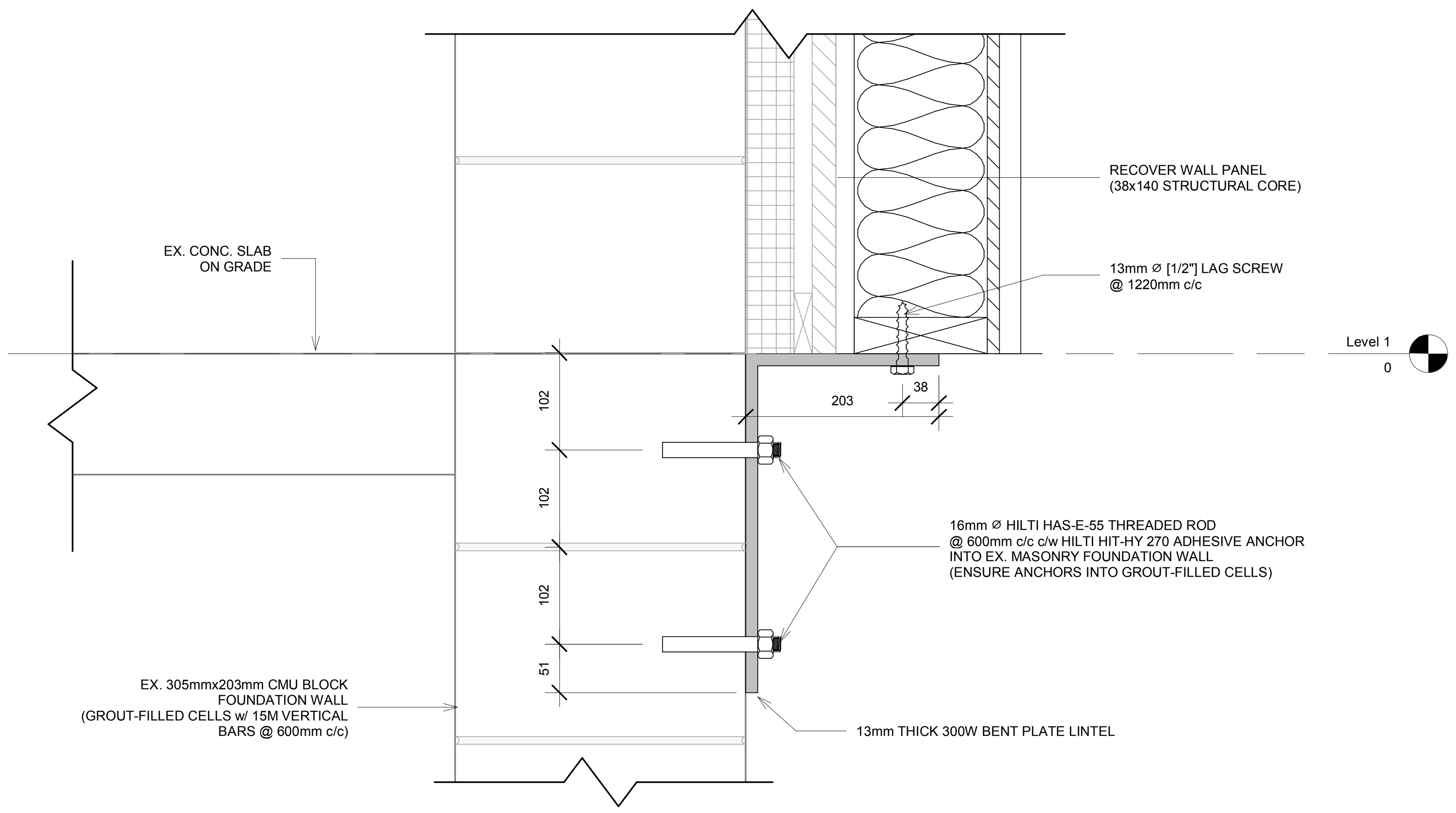
1 S-100 WALL PANEL SECTION
1 : 15



2 S-100 WALL PANEL CONNECTION AT ROOF
1 : 5



3 S-100 MID-HEIGHT WALL PANEL CONNNECTION
1 : 5



4 S-100 FOUNDATION LINTEL
1 : 5

PRELIMINARY

ISSUE	DATE	DESCRIPTION
2	12/07/2023	REVISED TO INCLUDE WOOD WALL ASSEMBLY
1	21/04/2023	ISSUED FOR REVIEW

CONSULTANT

DESIGNPOINT
engineering • surveying • solutions
902.832.5597
designpoint.ca

CLIENT

RECOVER INITIATIVE

PROJECT DESCRIPTION

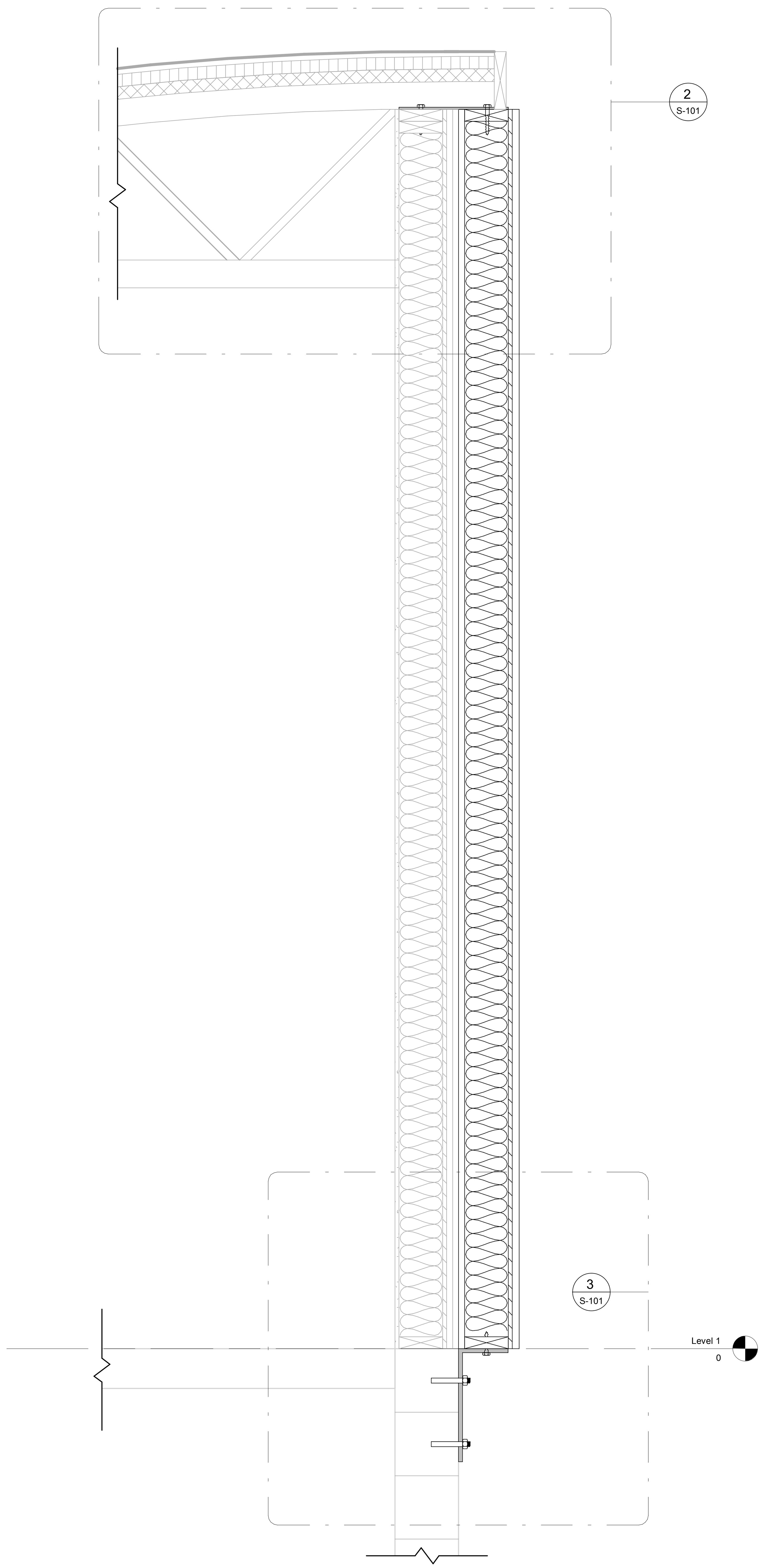
SIR JOHN COLBOURNE SENIORS CENTRE RETROFIT

OAKVILLE, ONTARIO

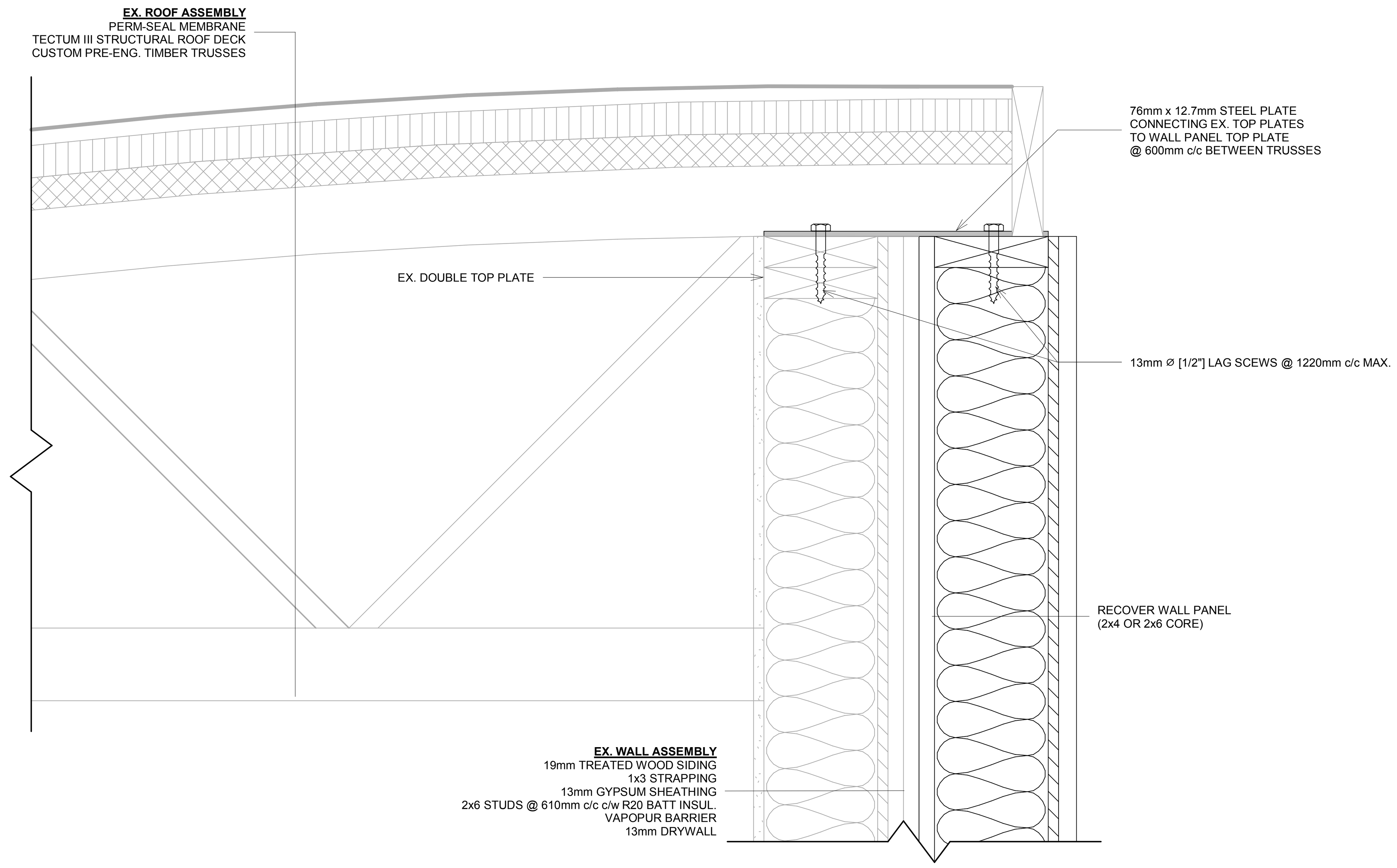
SHEET DESCRIPTION

PRELIMINARY PANEL CONNECTION DETAILS - CMU WALL

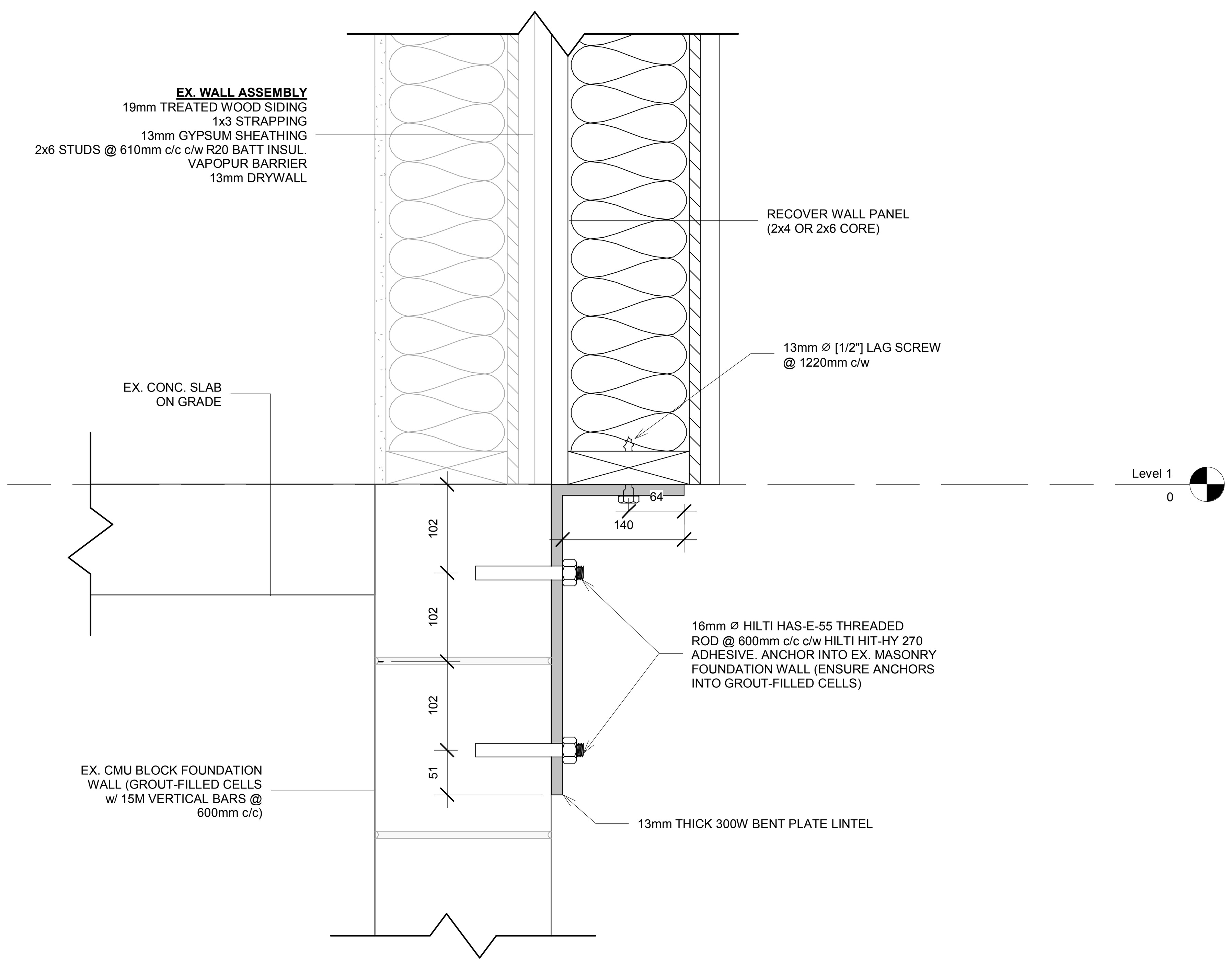
Drawn	Engineer	Project No.	Drawing No.
A. MCCRACKEN	E. TEASDALE	22-316	S-100
Scale: As indicated	Filename: 22-316_Oakville.rvt		1 of 2



1
S-101
WALL PANEL SECTION - 2x6 STUD WALL
1 : 10



2
S-101
WALL PANEL CONNECTION AT ROOF - 2X6 STUD WALL
1 : 5



3
S-101
WALL PANEL CONNECTION AT FOUNDATION - 2X6 STUD WALL
1 : 5

PRELIMINARY

ISSUE	DATE	DESCRIPTION
2	12/07/2023	REVISED TO INCLUDE WOOD WALL ASSEMBLY
1	21/04/2023	ISSUED FOR REVIEW

CONSULTANT

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RECOVER INITIATIVE

PROJECT DESCRIPTION

SIR JOHN COLBOURNE SENIORS CENTRE RETROFIT

OAKVILLE, ONTARIO

SHEET DESCRIPTION

PRELIMINARY PANEL CONNECTION DETAILS - 2x6 STUD WALL

Drawn	Engineer	Project No.	Drawing No.
A. MCCRACKEN	E. TEASDALE	22-316	S-101
Scale	Filename		2 of 2
As indicated	22-316_Oakville.rvt		

P:\2022\22-316 RSI - NRCan Retrofit\01 - Drawings\Eng Design\22-316_Oakville Panel.rvt

Appendix I

Panel Layouts

Sir John Colborne Seniors Centre

Construction Plan

City of Oakville

CLIENT
City of Oakville

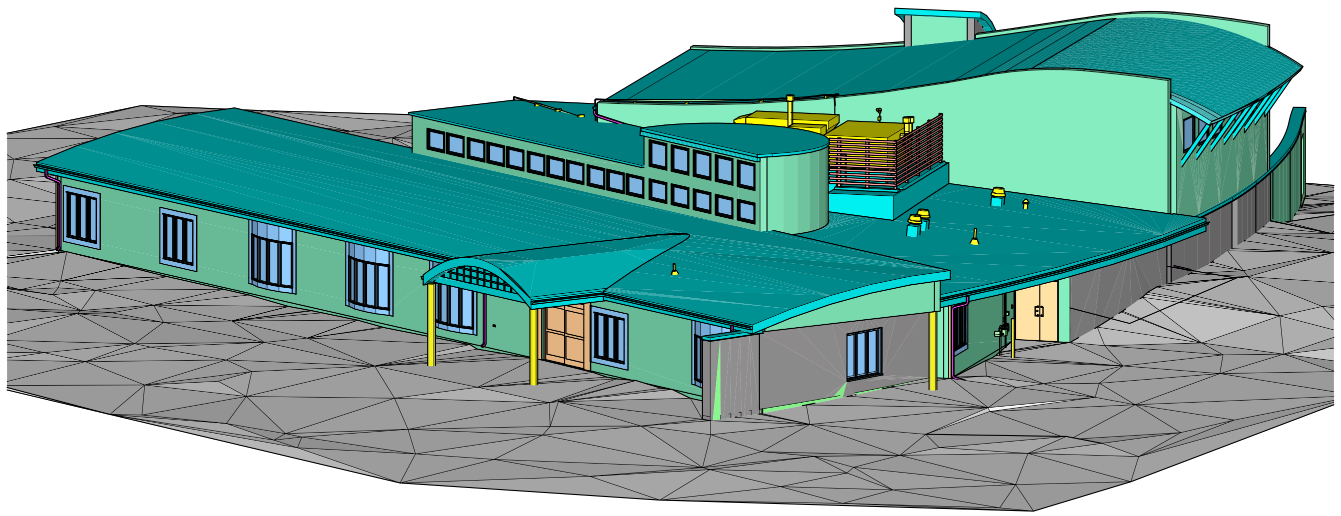
Version Date
March 27, 2023

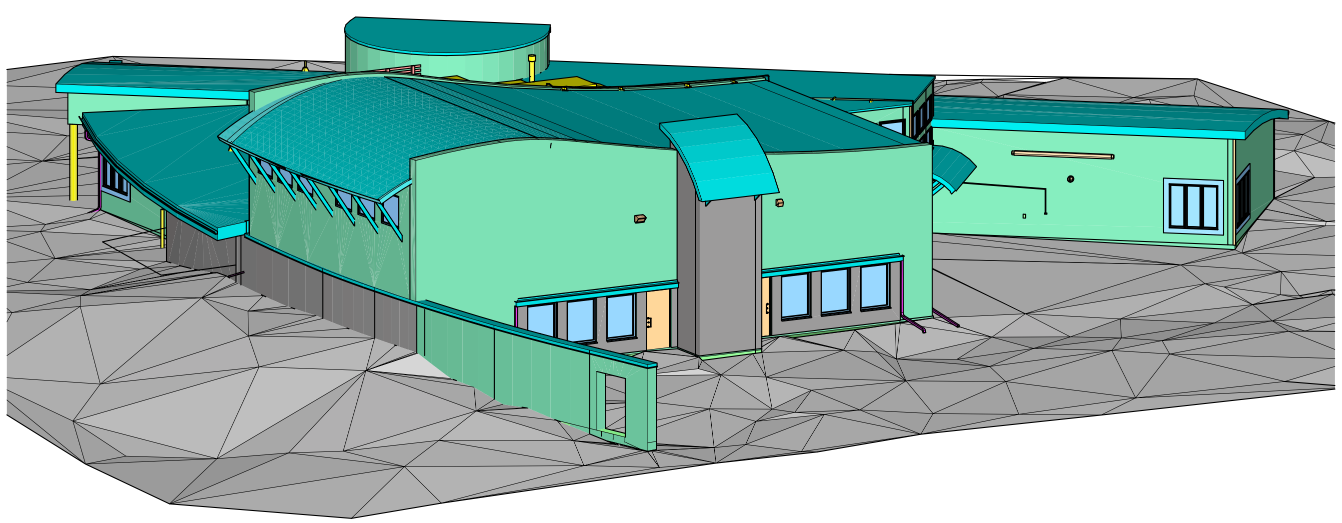
Project Address
1565 Lakeshore Road West
Oakville ON, L1L 1L1

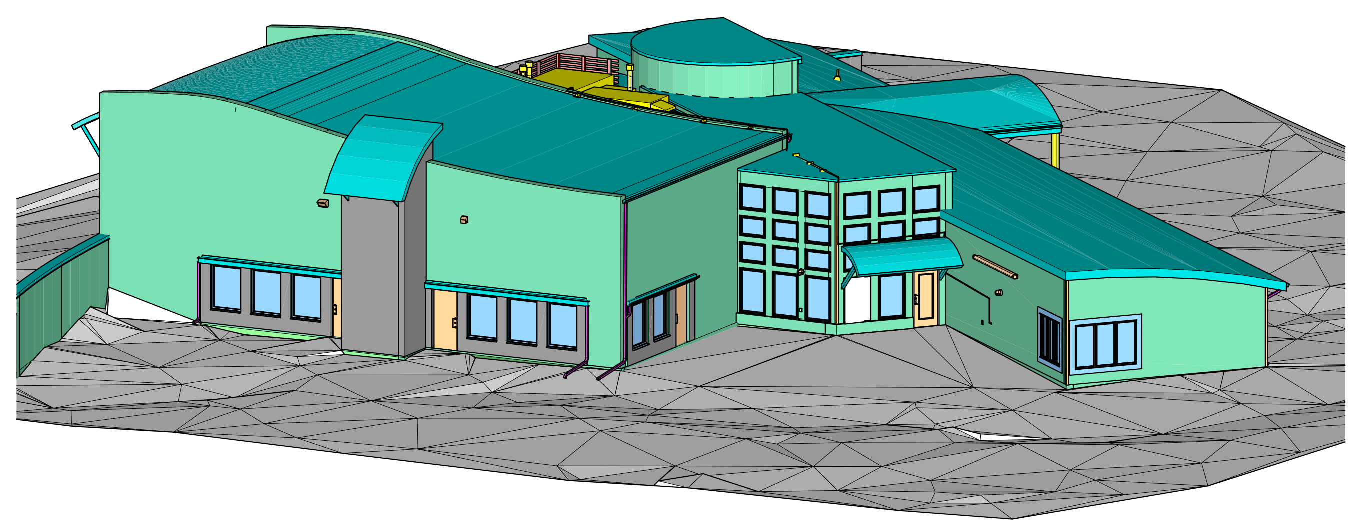
PROJECT
Sir John Colborne Seniors Centre Panelized Retrofit

DRAWN BY
Nick Rudnicki

Existing Building







ReCover

CLIENT
City of Oakville

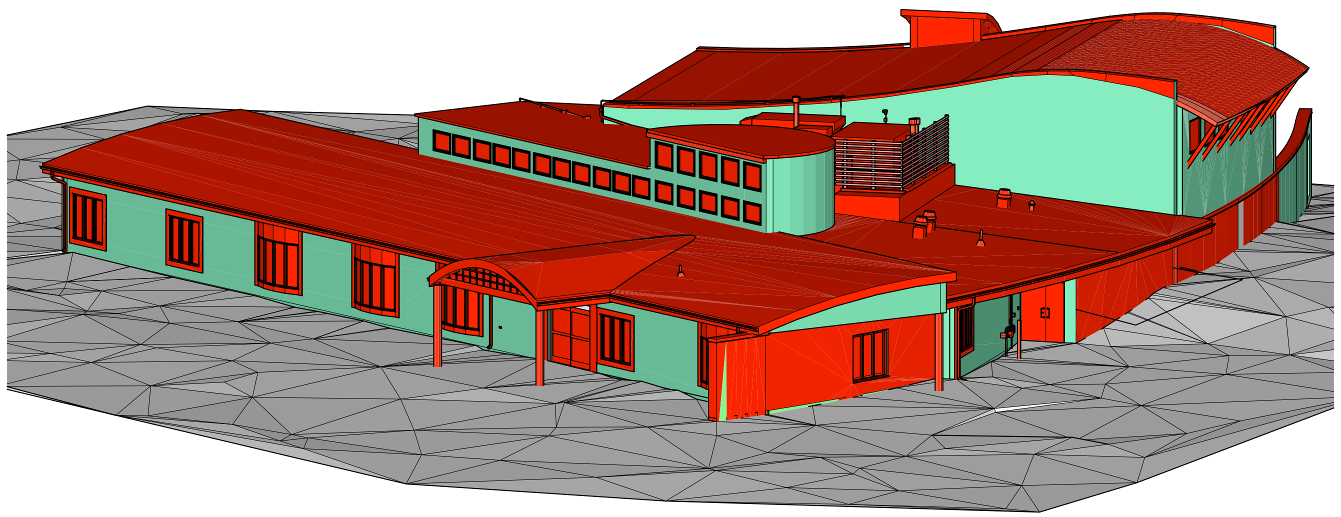
Version Date
March 27, 2023

Project Address
1565 Lakeshore Road West
Oakville ON, L1L 1L1

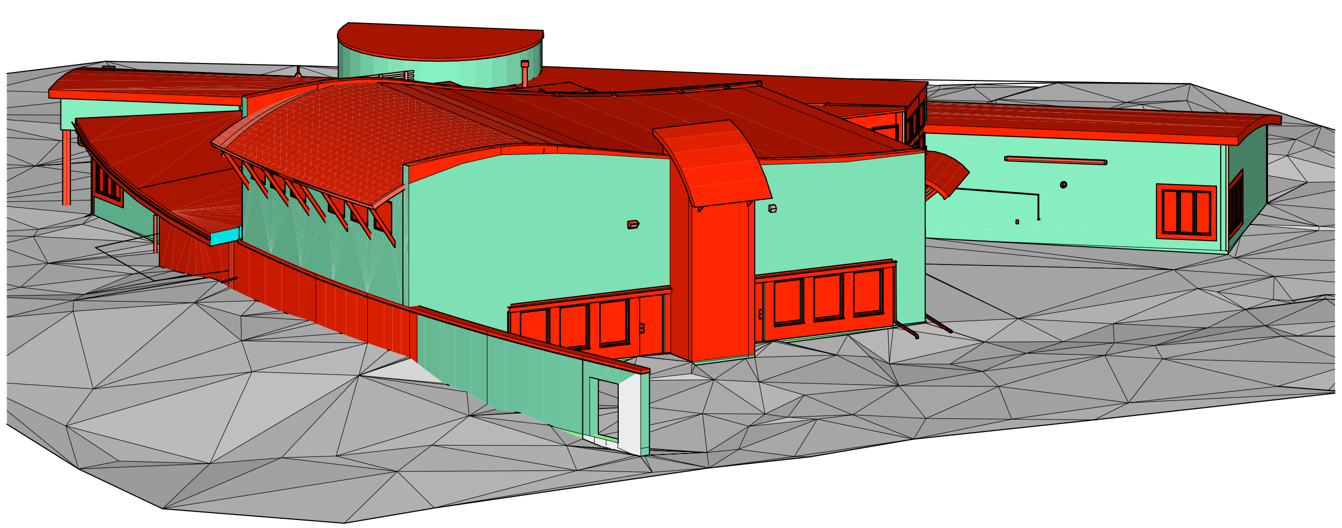
PROJECT
Sir John Colborne Seniors Centre
Panelized Retrofit

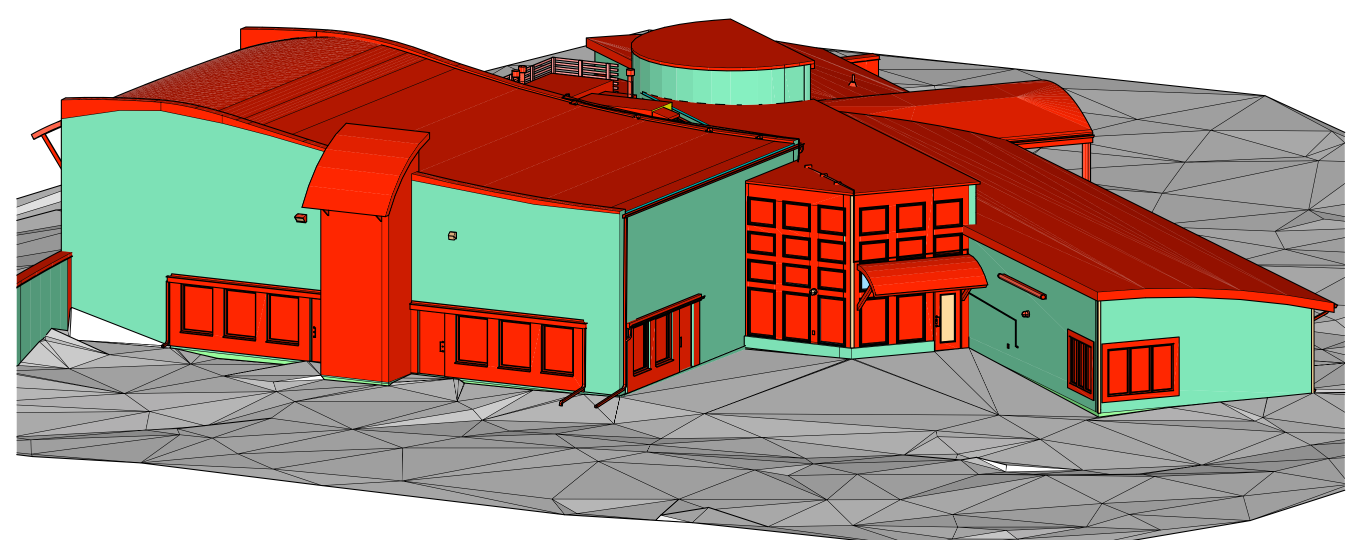
DRAWN BY
Nick Rudnicki

Demolition



1. Remove all windows and doors
2. Remove all rooftop mechanical units
3. Remove entryway overhang.
4. Remove stone cladding
5. Remove metal roofing to expose roof deck beneath
6. Remove parapet at tall roof
7. Remove roof overhangs.
8. Remove entire wall of back door.





ReCover

CLIENT
City of Oakville

Version Date
March 27, 2023

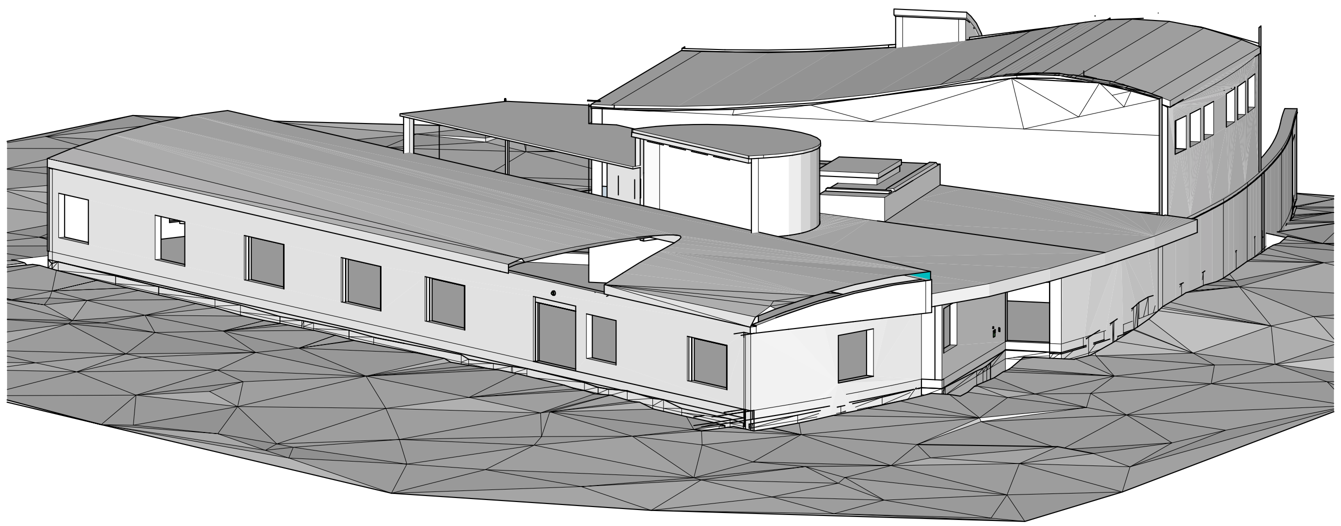
Project Address
1565 Lakeshore Road West
Oakville ON, L1L 1L1

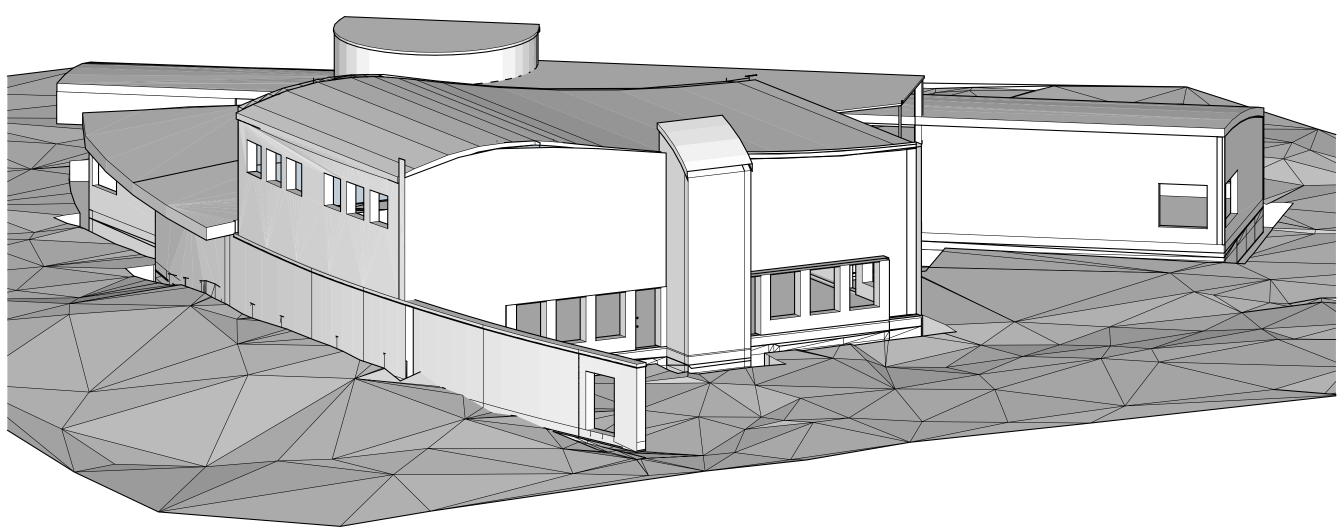
PROJECT
Sir John Colborne Seniors Centre
Panelized Retrofit

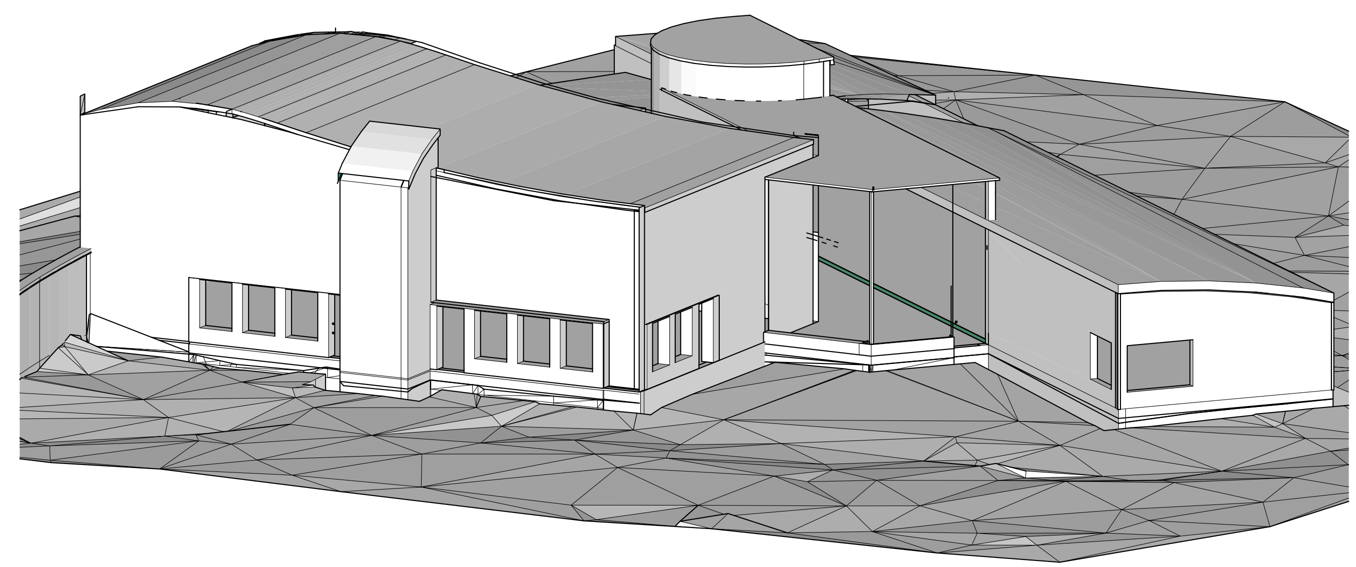
DRAWN BY
Nick Rudnicki

Excavation and Foundation Support

Excavate a trench all the way around the perimeter to facilitate the install of a foundation insulation as well as foundation support ledger. (See foundation detail page)







ReCover

CLIENT
City of Oakville

Version Date
March 27, 2023

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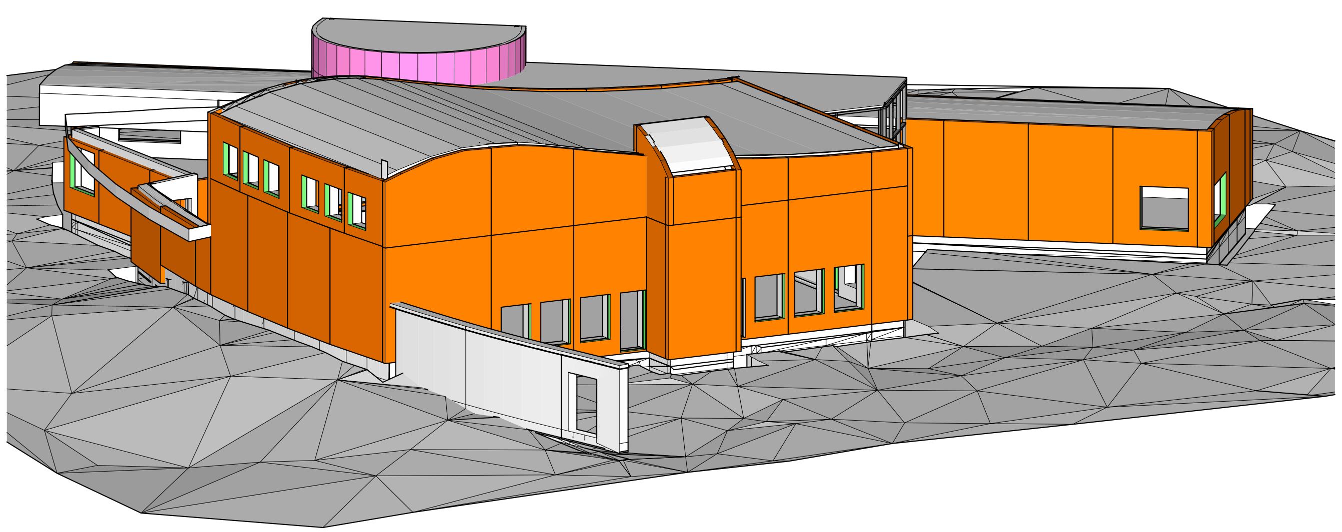
1565 Lakeshore Road West
Oakville ON, L1L 1L1

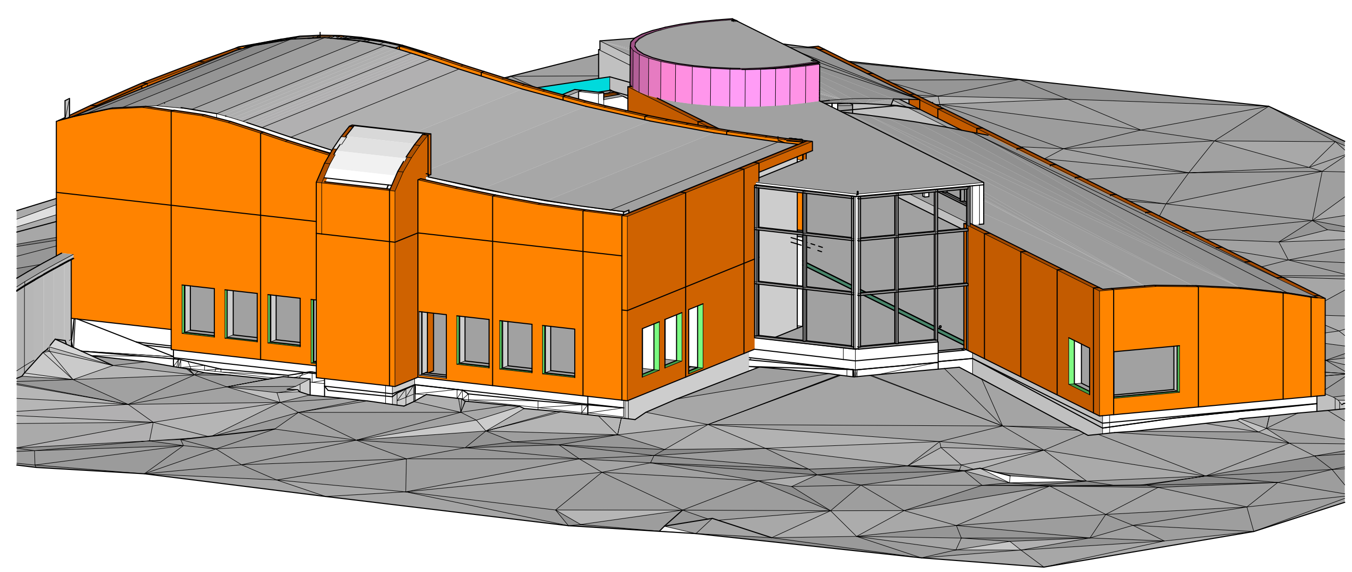
PROJECT
Sir John Colborne Seniors Centre
Panelized Retrofit

DRAWN BY
Nick Rudnicki

Wall Panel Install

1. Install wall panels as per P. Eng. direction.
2. Tape all panels to one another for air tightness.
3. Install curtain wall at clear-storey as well as at back entry.
4. Install foam board insulation at walls of turret.





CLIENT
City of Oakville

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PROJECT
Sir John Colborne Seniors Centre
Panelized Retrofit

DRAWN BY
Nick Rudnicki

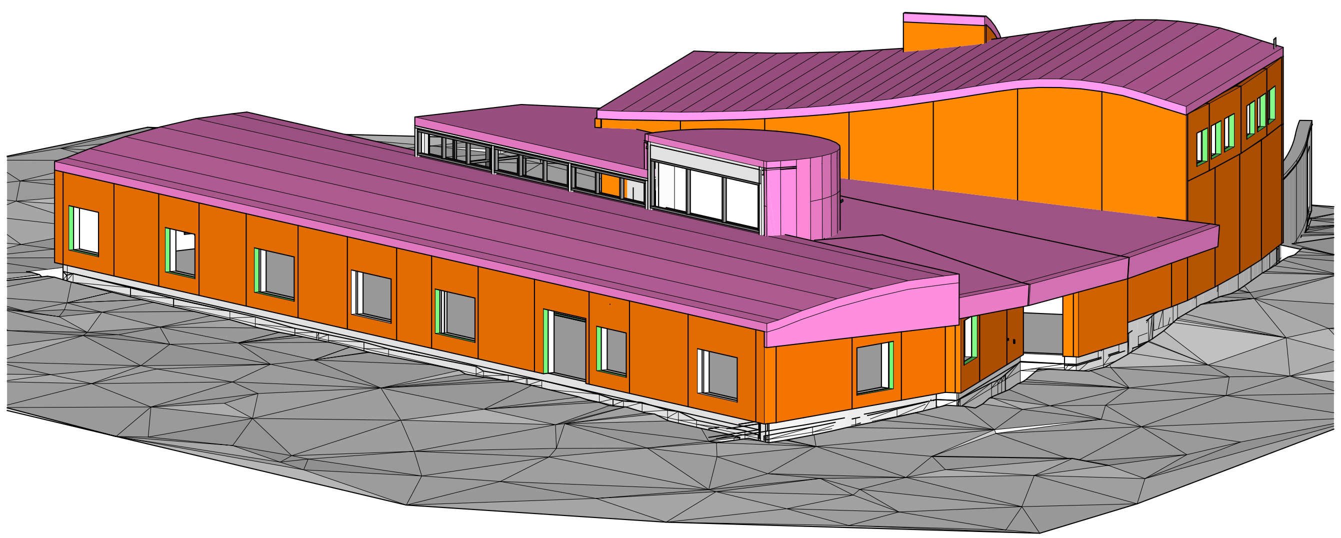
Roof Insulation

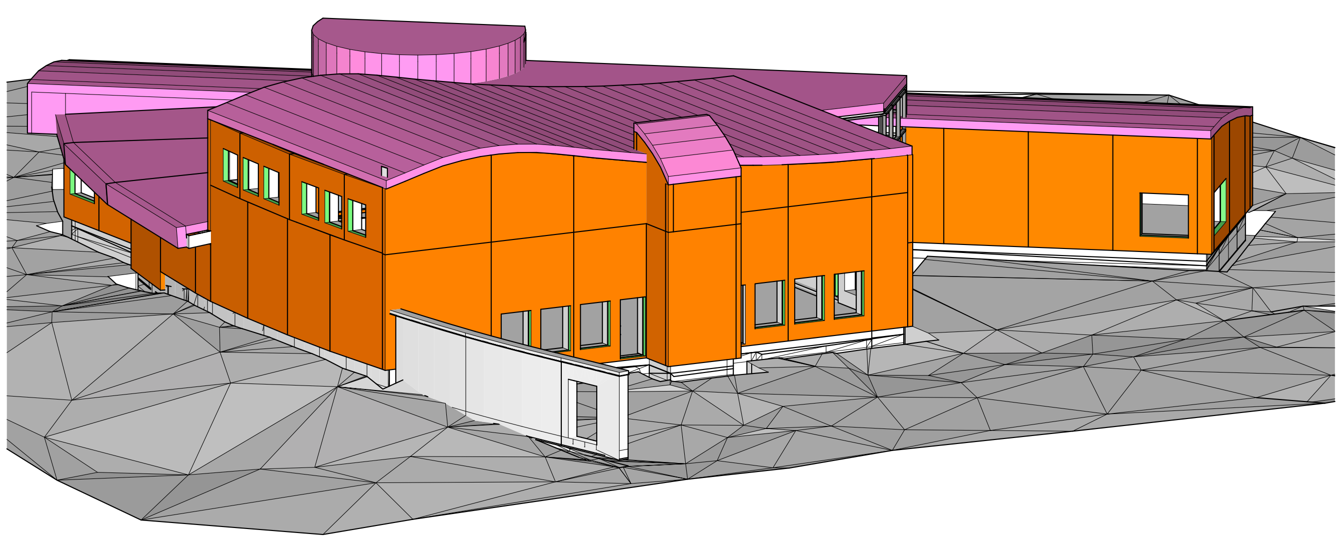
1. Air seal roof deck with membrane laid over top of exposed roof deck.

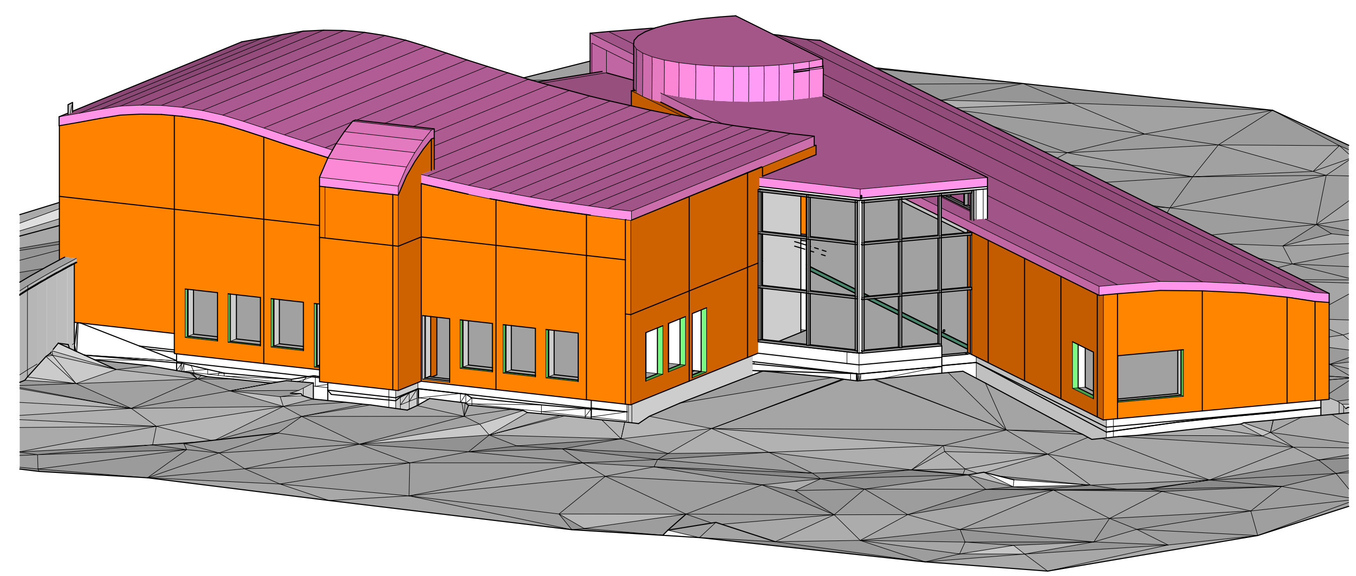
2. Connect panel air barrier to roof-deck membrane

3. Install 30 cm (12”) of low carbon XPS to all roof decks.

4. Reclad in curved metal roofing and membrane.







ReCover

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City of Oakville

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March 27, 2023

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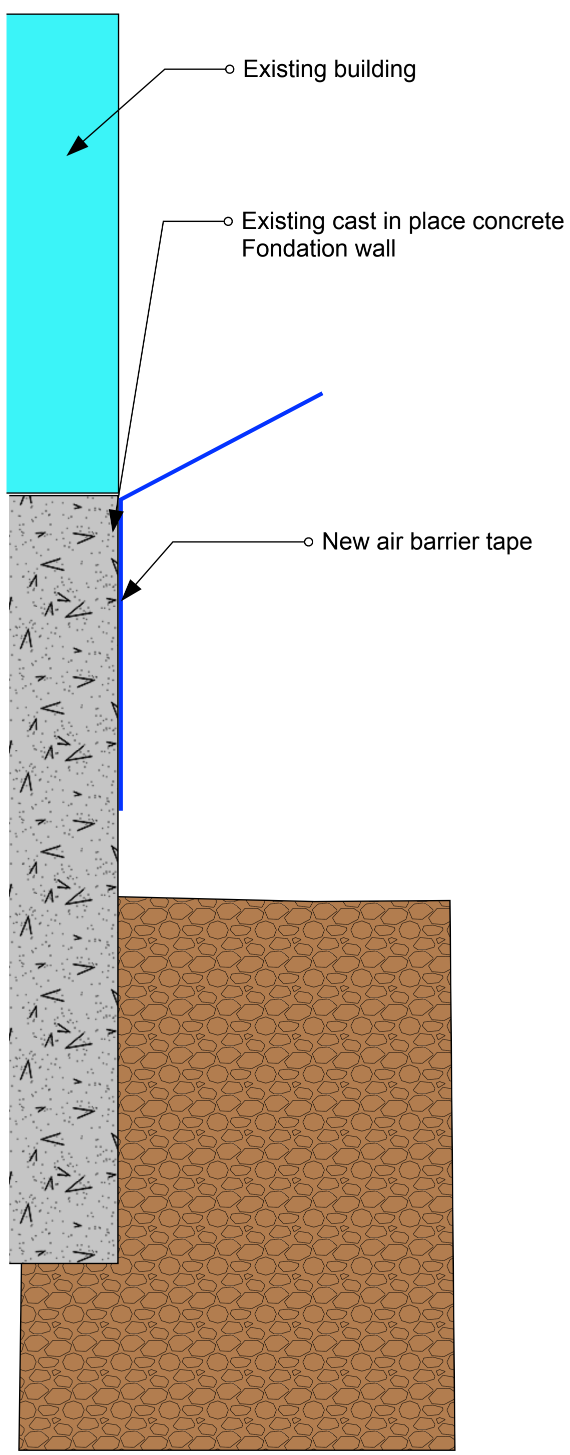
1565 Lakeshore Road West
Oakville ON, L1L 1L1

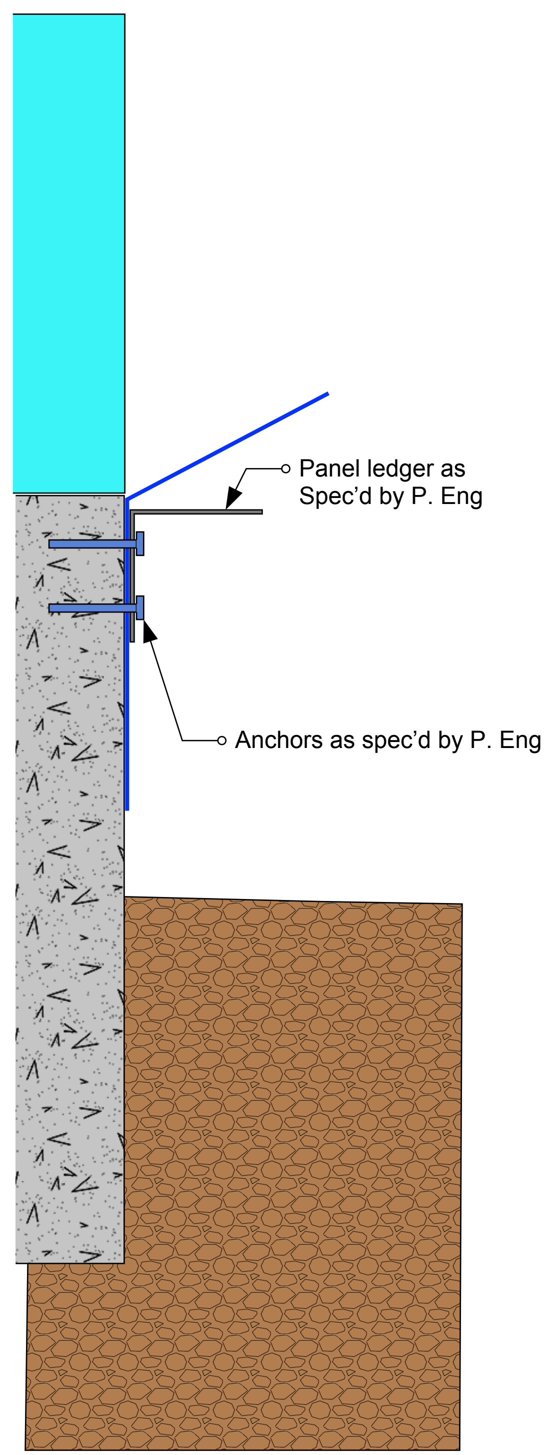
PROJECT
Sir John Colborne Seniors Centre
Panelized Retrofit

DRAWN BY
Nick Rudnicki

Foundation Insulation and Panel Base

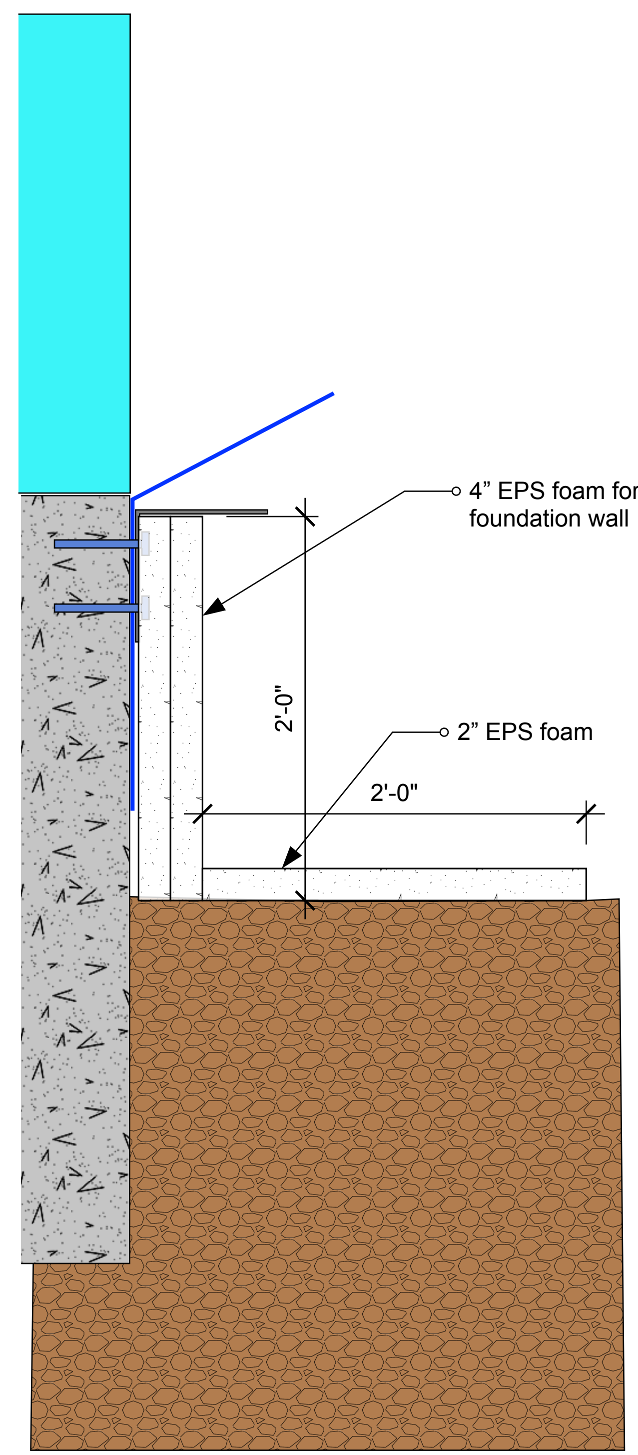


STEP 1
Install the Air barrier



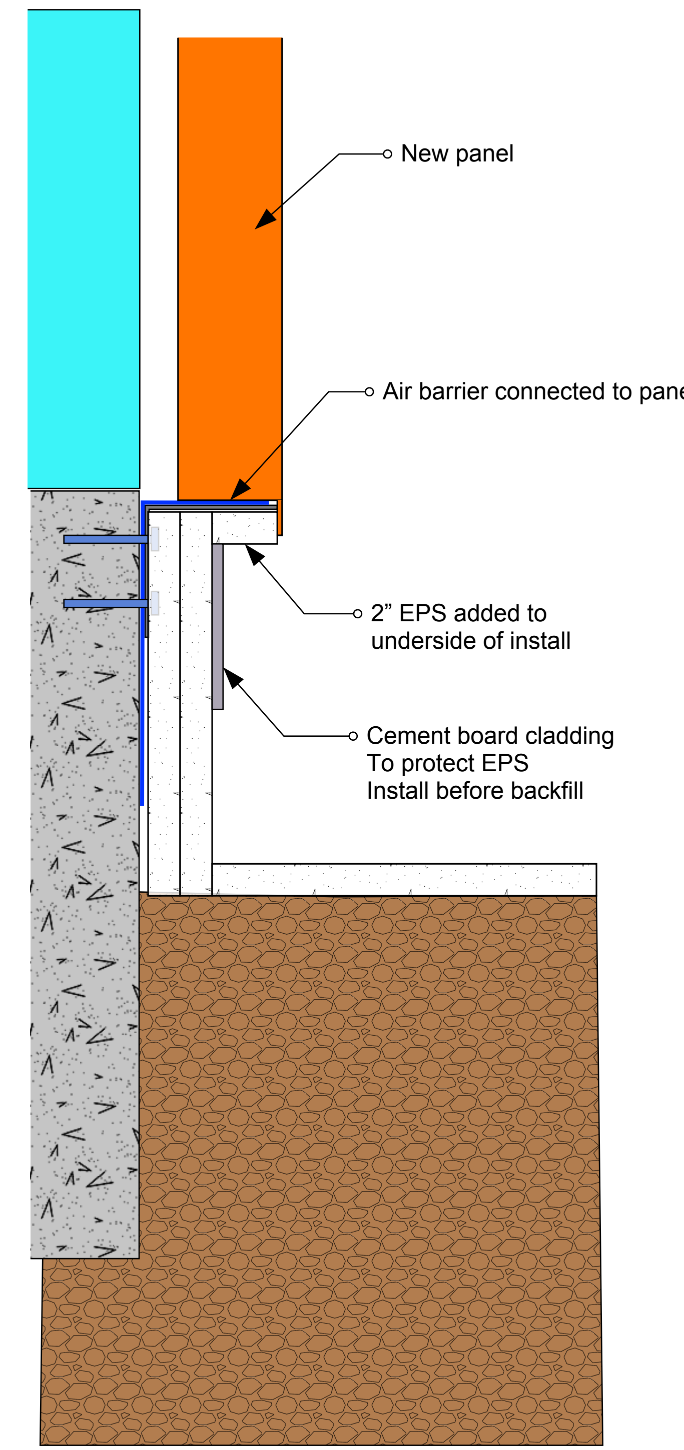
STEP 2
Install panel ledger overtop of air barrier.

Allow flap of air barrier to come out over the top of the ledger.



STEP 3
Install 4" of EPS to foundation wall to a depth of 24"

Install a 2" thick and 24" wide fin of EPS at a depth of 24" below grade



STEP 4
Install Panel on top of ledge

Tie air barrier to panel

Attach cement board to portion of foundation wall EPS that will be exposed after backfill.

Backfill (not shown)

ReCover

CLIENT
City of Oakville

Version Date
March 27, 2023

Project Address
1565 Lakeshore Road West
Oakville ON, L1L 1L1

PROJECT
Sir John Colborne Seniors Centre
Panelized Retrofit

DRAWN BY
Nick Rudnicki

07

Appendix J

Hygrothermal Report

- **Report**

RE: Preliminary WUFI® Pro Results – PRELIMINARY DRAFT, FOR FINAL REVIEW

Location: 1565 Old Lakeshore Road, Oakville, Ontario

Date: 2023-03-25

The services of Stanley Francispillai, P. Eng. (Quebec, Nova Scotia), were retained by Habit Studio Incorporated for the ReCover Initiative: Panelized Deep Energy Retrofits of Municipal Buildings project. These services were limited to the presentation of results for the hygrothermal modelling of the post-retrofit above-grade wall and roof assemblies of six municipal buildings using the ReCover Initiative team's panel design. The present report serves as a summary of the WUFI® Pro results obtained for the Sir John Colborne Recreation Centre for Seniors located at 1565 Old Lakeshore Rd in Oakville, Ontario.

INTRODUCTION

It is understood that the Sir John Colborne Recreation Centre for Seniors (henceforth named the Recreation Centre for the purposes of this report) was built in 1989 and resides in the suburbs of Oakville. The building is positioned south of Lakeshore Road W, and approximately 300-m north-west of Lake Ontario. The Recreation Centre consists of many notable architectural features, such as a mix of masonry and wood siding and a complex geometry including numerous curved roofs. The north-eastern side of the building faces the Centre's parking lot, while the southern sides face large deciduous trees (see **Figure 1**).

Figure 1 – Plan view location and orientation of the Sir John Colborne Recreation Centre for Seniors (shaded red), Oakville (Google, 2023)

SCOPE OF WORK

The scope of work for this project includes the presentation of results associated with the hygrothermal modelling of the post-retrofit exterior wall assemblies of the Recreation Centre over a 10-year period using the software WUFI® Pro. The simulations use preliminary assumptions based on discussions made with the ReCover team, as well as the PHIUS+ protocol *Moisture Risk Analysis & Assessment using WUFI v1.1* (G. Wright, P. Ferreira, R. Richman, 2021).

The hygrothermal modelling includes all above-grade exterior wall of the Recreation Centre. The retrofit designs used in the hygrothermal models were provided by the ReCover team.

It is of note that no design was conducted by Stanley Francispillai, P. Eng. Existing and retrofit assemblies were defined by the ReCover team for simulation through WUFI® Pro. This report consists of the output of these simulations.

INPUTS & ASSUMPTIONS

Prior to completing the preliminary simulations in WUFI®, the inputs and assumptions guiding the simulations were chosen with the ReCover team. These inputs and assumptions were made based on information received from the City of Oakville, including photos and drawings (such as the ReCover-annotated drawing *Oakville A3 wall assemblies.pdf*). The inputs and assumptions of the hygrothermal simulations are based on this received information. Reference documents are included in **APPENDIX D.**

OUTDOOR CLIMATE: The outdoor climate was modelled using the closest location to the City of Oakville with data available to the author of this report – this was Toronto, Ontario. A specific Oakville climate file is not available in the WUFI database.

INDOOR CLIMATE: The non-residential indoor climate was modelled using sinusoidal functions. The average indoor temperature and relative humidity setpoints of 22.5°C and 50% were used in these simulations. The average temperature simulated was based on RDH Building Science's energy model inputs for the heating and cooling setbacks of approximately 18°C and 27°C respectively (*2023 01 10 Oakville Energy Model Inputs.pdf*). The relative humidity setpoint of 50% was assumed for regular occupancy. As it is unclear as to what future tenancy patterns and moisture loads will be present, the following assumptions were made regarding the indoor climate:

Table 1 – Setpoints and assumptions used in WUFI for interior climate of building

Interior Setpoints	Average	Amplitude	Range	Date of Maximum Value
Temperature	22.5°C	4.5°C	18°C – 27°C	July 20th (assumed)
Relative Humidity	50%	10%	40% – 60%	July 20th (assumed)

Note: it is assumed that the temperature and relative humidity setpoints are applied to the entire building

ASSEMBLY MATERIALS: Based on the information obtained, the primary existing wall assemblies shown in **Table 2** were modelled for the Recreation Centre (detailed material properties are included in **APPENDIX A** and **APPENDIX B**). The retrofit panel assembly proposed by ReCover for the building was originally sourced from the ReCover drawing *Basic Panel – Overview* used for the Burlington project as it was indicated that a similar panel assembly was under investigation – however, a 2x6 panel was later specified to be used for Oakville (see *2023 02 27 - wall - cellulose - R21 - 2x8 - 0.5 Plywood.pdf*). Other clarifications were discussed and conveyed by the ReCover team via emails and phone calls.

It should also be noted that assumptions were made regarding certain assemblies. For instance, the "rigid insulation" specified in the *Oakville A3 wall assemblies.pdf* document was assumed to be extruded polystyrene (XPS). Other modelling assumptions are included in notes below the following table as well as in the Appendices. **Assembly material choices and assumptions should be reviewed for agreement with existing and proposed conditions, including thermal resistance and permeance.**

Table 2 – Recreation Centre's assemblies and material components used in WUFI simulations

Assembly	Materials (Interior to Exterior)	Thickness, m (inch)
Wall W1	Drywall	0.0125 (0.5)
	Vapour Retarder*	0.001 (0.04)
	R20 Batt Insulation**	0.14 (5.51)
	Gypsum Sheathing	0.013 (0.51)
	Air Space (Strapping)	0.025 (1.0)
	Wood Siding	0.0105 (0.41)
	Panel Assembly	-
Wall W2	Concrete Brick	0.305 (12.0)
	Vapour Retarder*	0.001 (0.04)
	Extruded Polystyrene Insulation	0.051 (2.0)
	Air Space (Strapping)	0.025 (1.0)
	Wood Siding	0.0105 (0.41)
	Panel Assembly	-
Wall W3	Concrete Brick	0.203 (8.0)
	Vapour Retarder*	0.001 (0.04)
	Extruded Polystyrene Insulation	0.051 (2.0)
	Panel Assembly	-
Wall W4	Concrete Brick	0.305 (12.0)
	Vapour Retarder*	0.001 (0.04)
	Extruded Polystyrene Insulation	0.051 (2.0)
	Panel Assembly	-
Panel Assembly	**Air Space**	0.020 (0.79)
	Cellulose Bib	0.001 (0.04)
	Dense-Pack Cellulose	0.127 (5.0)
	Plywood	0.013 (0.51)
	Weather Resistive Barrier (WRB)	0.001 (0.04)
	Air Space	0.010 (0.39)
	Metal Cladding* **	0.001 (0.04)

* Vapour Retarder modelled using **PE-Membrane (Poly; 0.07 perm)** from WUFI

** R20 Batt Insulation modelled using 0.152-m (6-in) of **Low Density Glass Fiber Batt Insulation** from WUFI

***Metal Cladding modelled using **Roof Membrane V13** from WUFI as per protocol

MOISTURE & AIR SOURCES: To determine how the retrofit walls perform under certain environmental stresses, a 1% driving rain moisture source was placed on the exterior face of the WRB in the form of a fictitious 1-mm layer of brick, as per the PHIUS+ protocol. Moreover, the new vented cladding was given a default ventilation rate of 25 air changes per hour (ACH) and was placed within the 10 mm "*Air layer 10mm; metallic*" material which is pre-defined by WUFI® for use adjacent to metal surfaces.

ORIENTATIONS: Given that the wall assemblies differ in materials and orientations around the building, the four assembly types (W1, W2, W3, W4) were studied independently. In WUFI® Pro, the Recreation Centre's W1 assembly was simulated in all cardinal orientations as well as the North-East and South-East orientations (high driving rain), the W2 assembly was simulated in the South and West orientations, the W3 assembly was simulated in the North orientation, and the W4 assembly was simulated in the North, South, and West orientations. All walls were set to 90° inclinations from the horizontal.

RAIN LOAD: In terms of rain loading, the ASHRAE Standard 160 rain load calculation method was utilized. For the wall assemblies, the rain exposure factor was based on the building's height of less than 10-m, while the rain exposure category was assumed to be medium as the building is located approximately 300-m from the western side of Lake Ontario. The rain deposition factor was automatically defined based on the slope of the roof structures involved. Given that the roofs are generally curved at varying slopes, the "*low-slope*" option was conservatively assumed in WUFI®.

BOUNDARY CONDITIONS: For the post-retrofit condition studied, it was assumed that the proposed exterior metal cladding would be painted, while the interior side of the various walls were also simulated with painted finishes based on site-visit photographs. The presence of these paints would affect the surface transfer (sd) coefficients of the hygrothermal models – other sd-coefficients considered in the models are included in **APPENDIX B**.

INITIAL CONDITIONS: Finally, as per ASHRAE 160, initial material conditions were set to EMC80 (equilibrium moisture content at 80% relative humidity), while concrete-based materials were set to EMC90; for all materials, the starting temperature was set to 20°C. The simulations were defined to begin on October 1st, 2022, which is the default starting day for WUFI®, and continue for a period of 10-years.

Other inputs of the WUFI simulations can be found in the software's auto-generated results report, included in **APPENDIX B**.

RESULTS

The PHIUS+ protocol's post-processing and evaluation procedure was sourced for describing the results of the hygrothermal simulations conducted.

POST-RETROFIT WALL ASSEMBLY: W1

The post-retrofit W1 wall assembly simulated in all cardinal orientations as well as the North-East and South-East orientations with a 22.5°C interior temperature setpoint did not demonstrate any numerical errors for all orientations and conditions tested – no convergence failures occurred, and the differences between balances of change in total water content and the sum of the moisture fluxes were very small.

As recommended by the protocol, the plywood layers were subdivided into three adjacent layers for near-surface condition assessment, with the outermost and innermost layers being 1/8-inch thick, respectively. The plywood layers and other biogenic materials were focused upon for this feasibility report given their susceptibility to decay and mold. To estimate decay risk, the time periods during which the mass percentage of water content (MC) remains above 20% were studied.

In all orientations except South and West, at least one of the three plywood layers experiences a significant spike in MC above 20% (West innermost plywood layer only experiences short-duration spikes slightly above 20% in the first year of simulation). In general, the primary spike occurs in the first year, after which the MC decreases annually. The North and South-East orientations experience their most significant spike in the innermost plywood layer, lasting from approximately mid-December 2022 to late March 2023 (including a five-day dip below 20% in mid-March) in the North and mid-December 2022 to mid-January 2023 in the South-East (**Figure 2**). However, the East and North-East orientations experience more important MC spikes.

In the East orientation, the outermost plywood layer experiences a large MC spike above 20% from the beginning of November 2022 until late February 2023, another between mid to late March 2023, and another from beginning to mid-April 2023. Subsequent years indicate a significant decrease in MC spikes, with an annual sinusoidal pattern beginning in the third year of simulation, with two, small, annual spikes above 20% (**Figure 3**). The center and innermost plywood layers experience MC spikes above 20% in only the first year of simulation, lasting from early January to mid-April 2023 and mid-December 2022 to late March 2023 in each respective layer.

In the North-East orientation, very similar results to the East orientation were outputted by WUFI®. The outermost plywood layer experiences a large MC spike above 20% from the beginning of November 2022 until mid-April 2023 with a dip below 20% in early March. An annual sinusoidal pattern is demonstrated beginning in the third year of simulation, with an annual spike between the beginning of November and lasting until mid-December (**Figure 4**). The center and inne rmost plywood layers experience MC spikes above 20% in only the first year of simulation, lasting from approximately mid-December 2022 to mid-April 2023 in each layer. (Note: all orientations' MC graphs are available in **APPENDIX C**)

For mold-related durability, a VTT simulation was conducted using the WUFI® Pro plug-in which examines the mold growth index at the specified locations. The plywood layers were defined with a sensitivity class of "Sensitive" (second-highest risk category) and a material class experiencing "Almost no decline". The cellulose and fiberglass layers were simulated in VTT as proxies for the structural wood members (not modelled) located within their respective cavities. Based on discussions with ReCover, it was assumed that the chemical properties of the cellulose insulation may impart greater mold resistance to the cavity wood members – for this reason, a sensitivity class of "Medium resistant" was used to simulate the wood members within the cellulose cavity, while "Sensitive" was used for the wood members within the fiberglass cavity. (Note: the existing wood siding was assumed to have adequate mold resistance)

The mold growth index ranges from 0 to 6 and is coupled with a traffic light scheme in the WUFI® plug-in, ranging from green (uncritical) to yellow to red (inacceptable) – within the yellow range, there is potential risk for mold growth, however more information would be required (such as the specific material used) to decide whether the risk is deemed acceptable or inacceptable. The plywood layers and outermost and innermost cellulose and fiberglass elements in all orientations simulated demonstrated a green VTT traffic light, indicating low mold growth indices (see **Figure 5**).

It should be noted that a sheathing substitution (e.g., WUFI®'s pre-defined DensElement™ Barrier System) may eliminate certain durability issues related to the biogenic nature of plywood – this wall assembly was also simulated per ReCover's request (North-East orientation). However, this substitution causes an increase in the cellulose layer's MC (see plywood and DensElement sheathing scenarios' cellulose MC graphs in **Figure 6** and **Figure 7**). The mold growth indices remain in the green VTT region within the cellulose and fiberglass layers (which serve as proxies for wood studs that are assumed to be part of the new and existing wall assemblies). Alternative sheathing options in the various orientations of the wall assemblies should be further explored.

For these reasons, and per the PHIUS+ protocol, it is understood that the proposed post-retrofit wall assembly may manage moisture adequately based on the information available and the assumptions presented in this report. However, this is dependent on whether the plywood can be subject to certain periods of high moisture content, as well as all wood layers' mold resistance properties.

It should be noted that a sheathing substitution from the originally defined plywood material may create a more suitable panelized retrofit strategy for this building in terms of mold and decay resistance based on the information available and the assumptions presented in this report – this should be explored further.

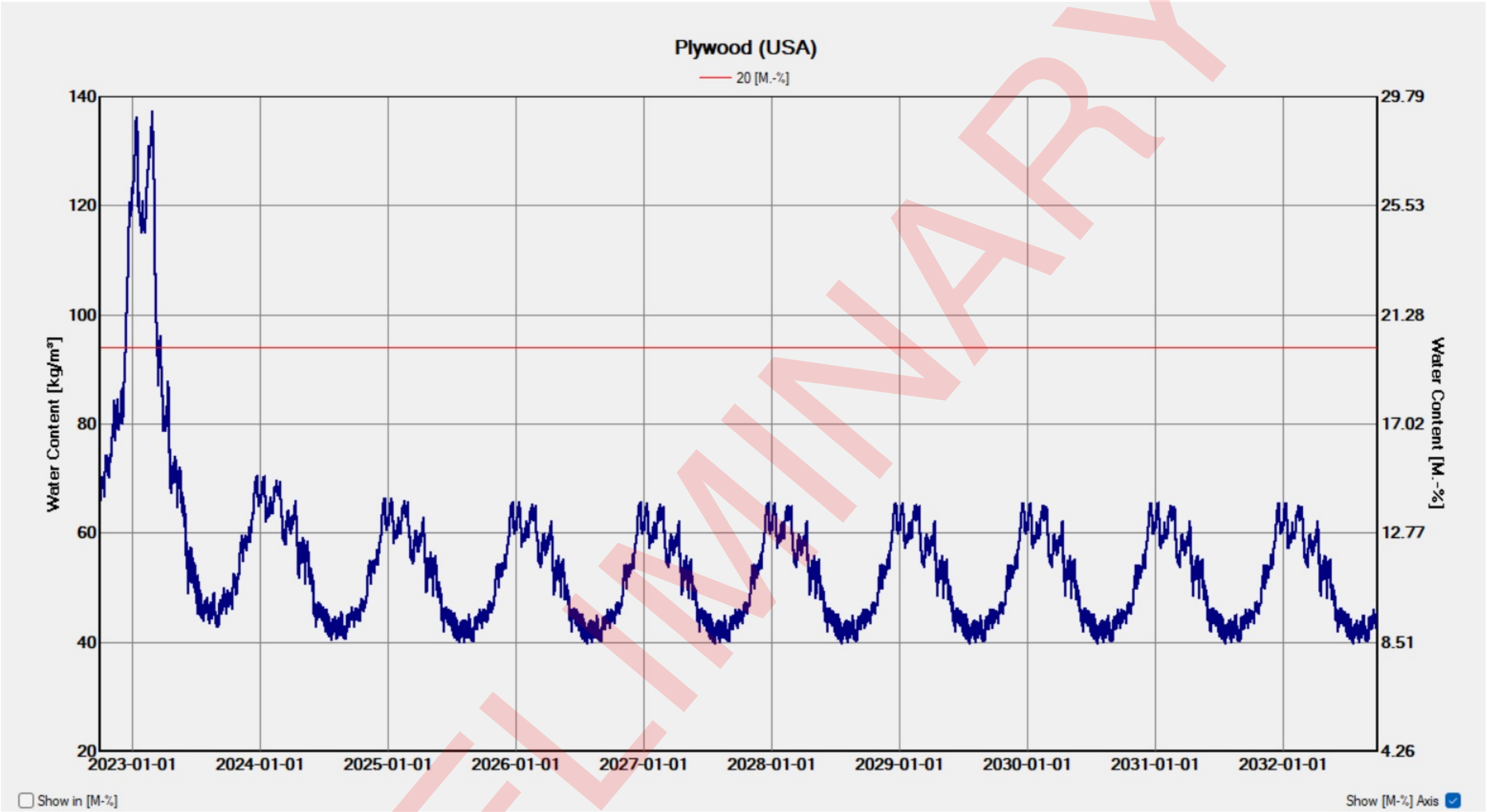


Figure 2 – WUFI® output for W1 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre North wall assembly's inner 1/8-inch plywood layer

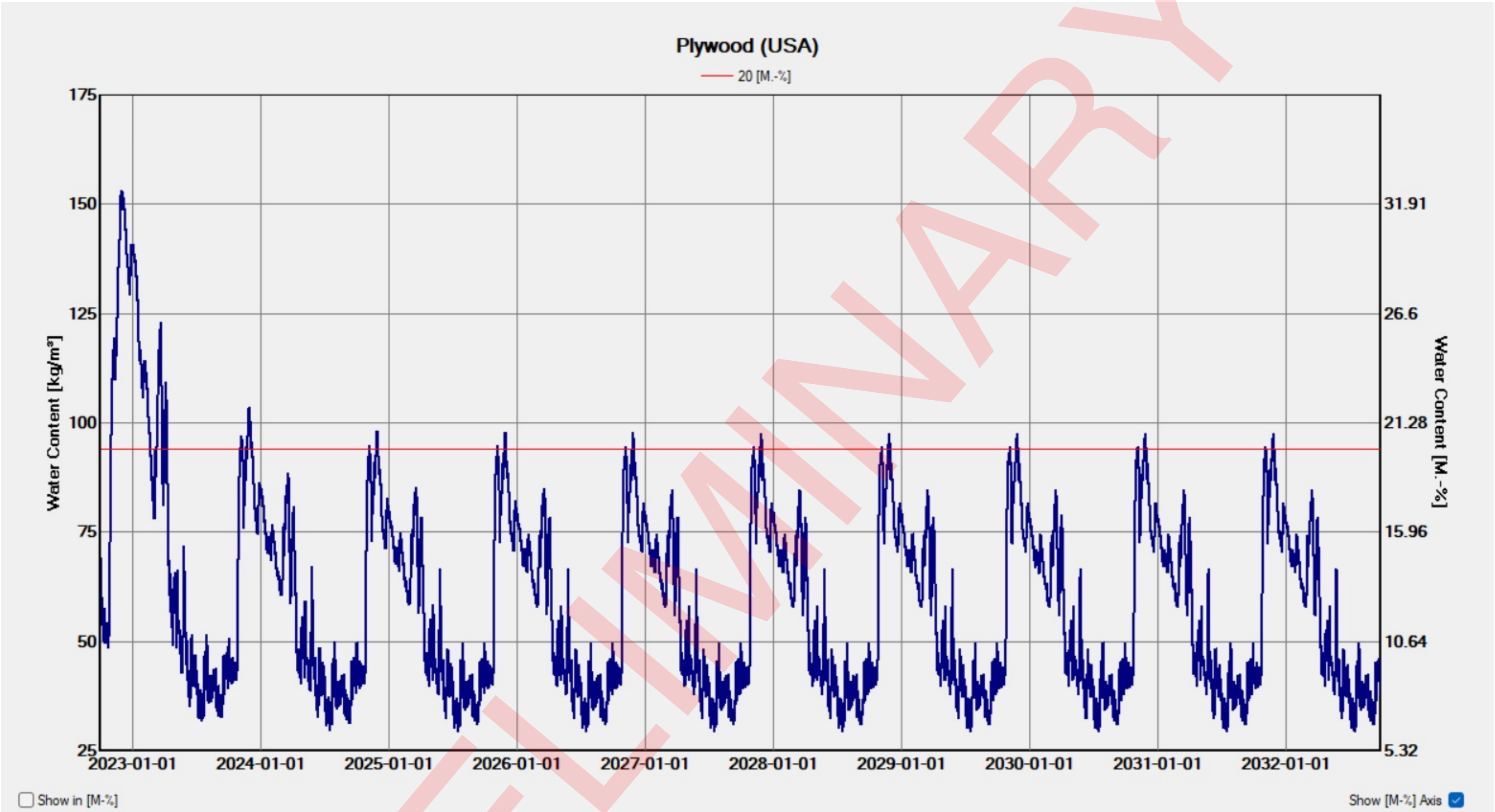


Figure 3 – WUFI® output for W1 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre East wall assembly's outer 1/8-inch plywood layer

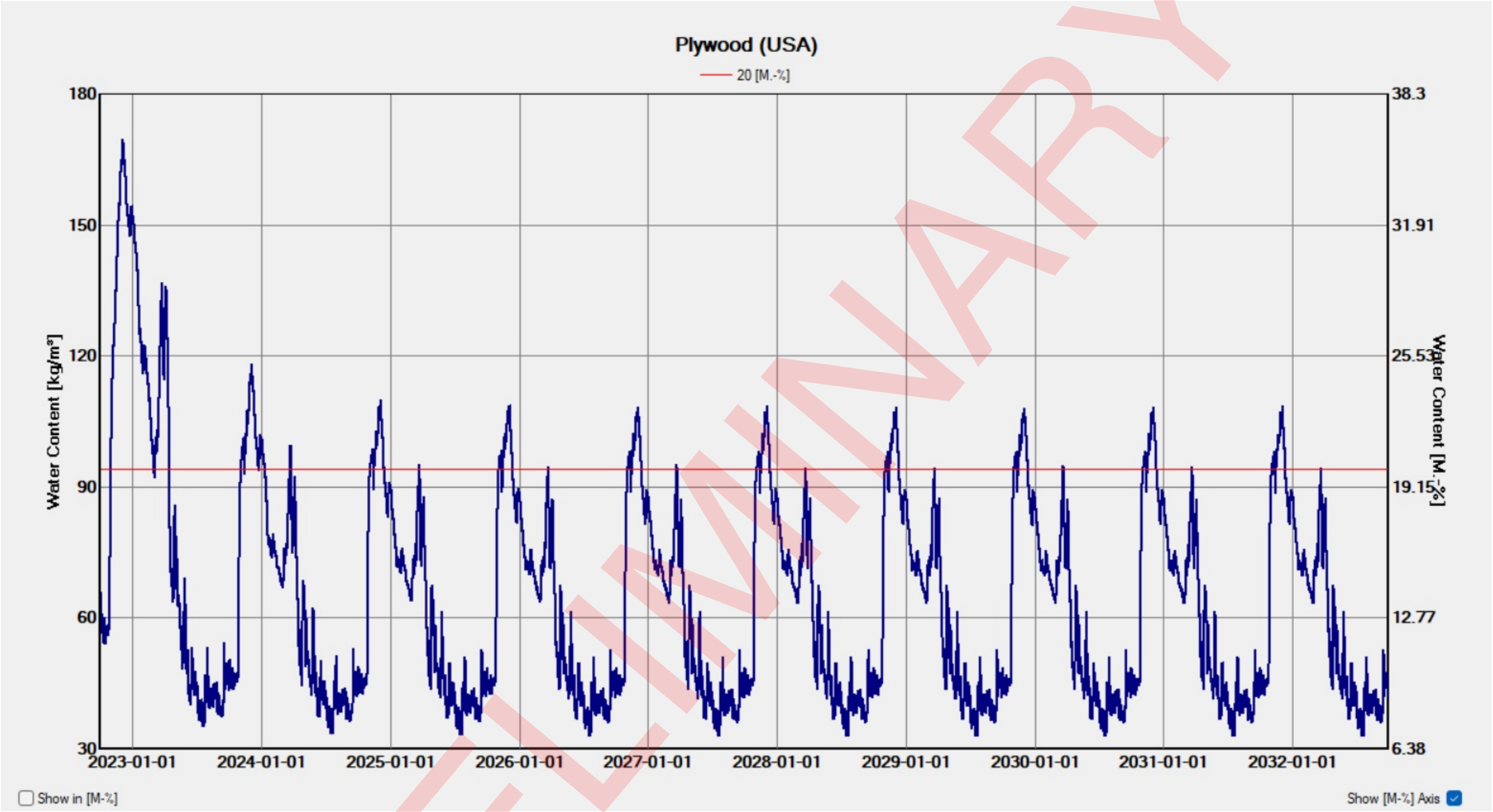


Figure 4 – WUFI® output for W1 wall assembly: water content (kg/m3, %) over 10-year period studied for post-retrofit Recreation Centre North-East wall assembly's outer 1/8-inch plywood layer

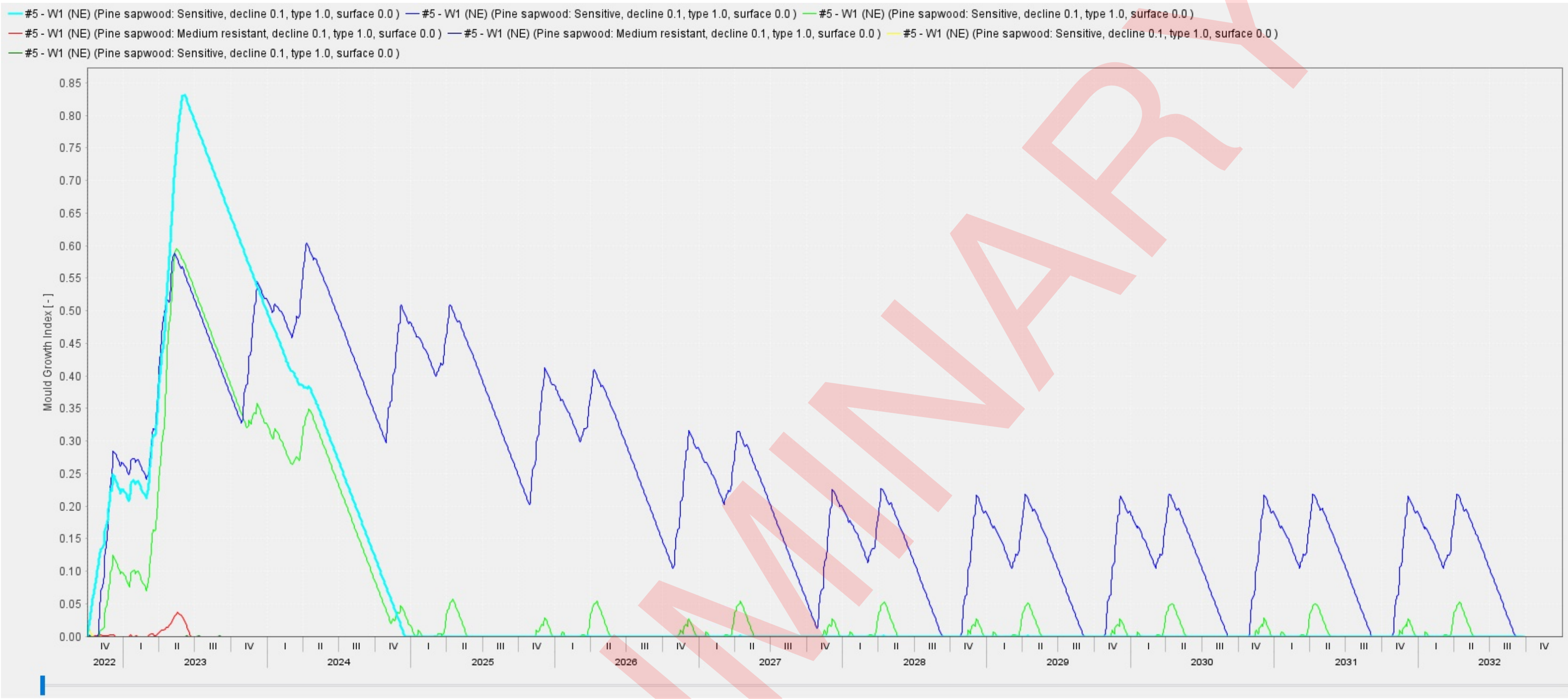


Figure 5 – WUFI® output for W1 wall assembly: VTT mold growth index simulation over 10-year period studied for post-retrofit Recreation Centre North-East wall assembly's plywood, cellulose, and fiberglass layers
(blue: outer plywood; light green: center plywood; light blue: inner plywood; red: outermost cellulose element; black: innermost cellulose element; yellow: outermost cellulose element; green: innermost cellulose element)

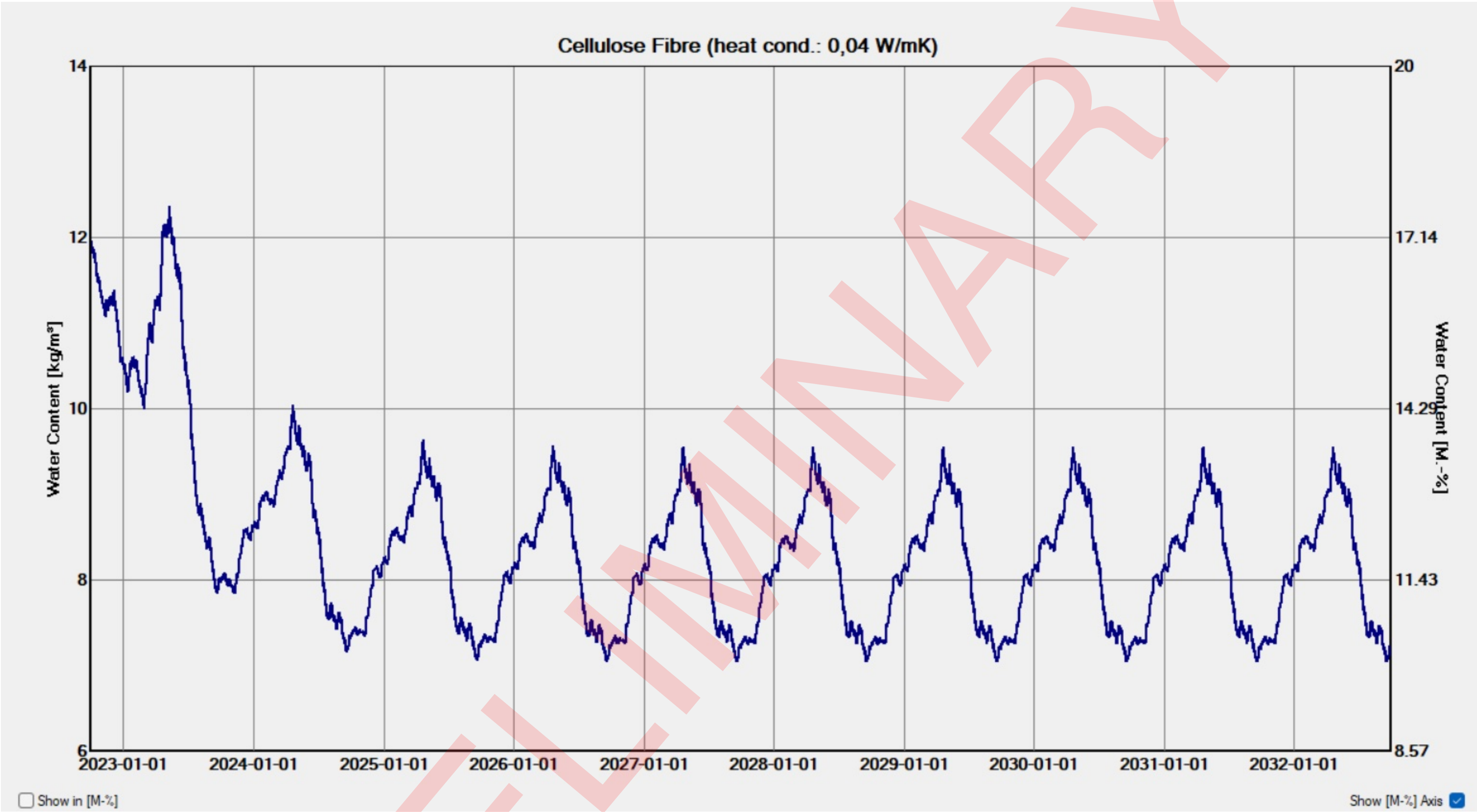


Figure 6 – WUFI® output for W1 wall assembly: water content (kg/m3, %) over 10-year period studied for post-retrofit Recreation Centre North-East wall assembly's cellulose layer (scenario with plywood sheathing)

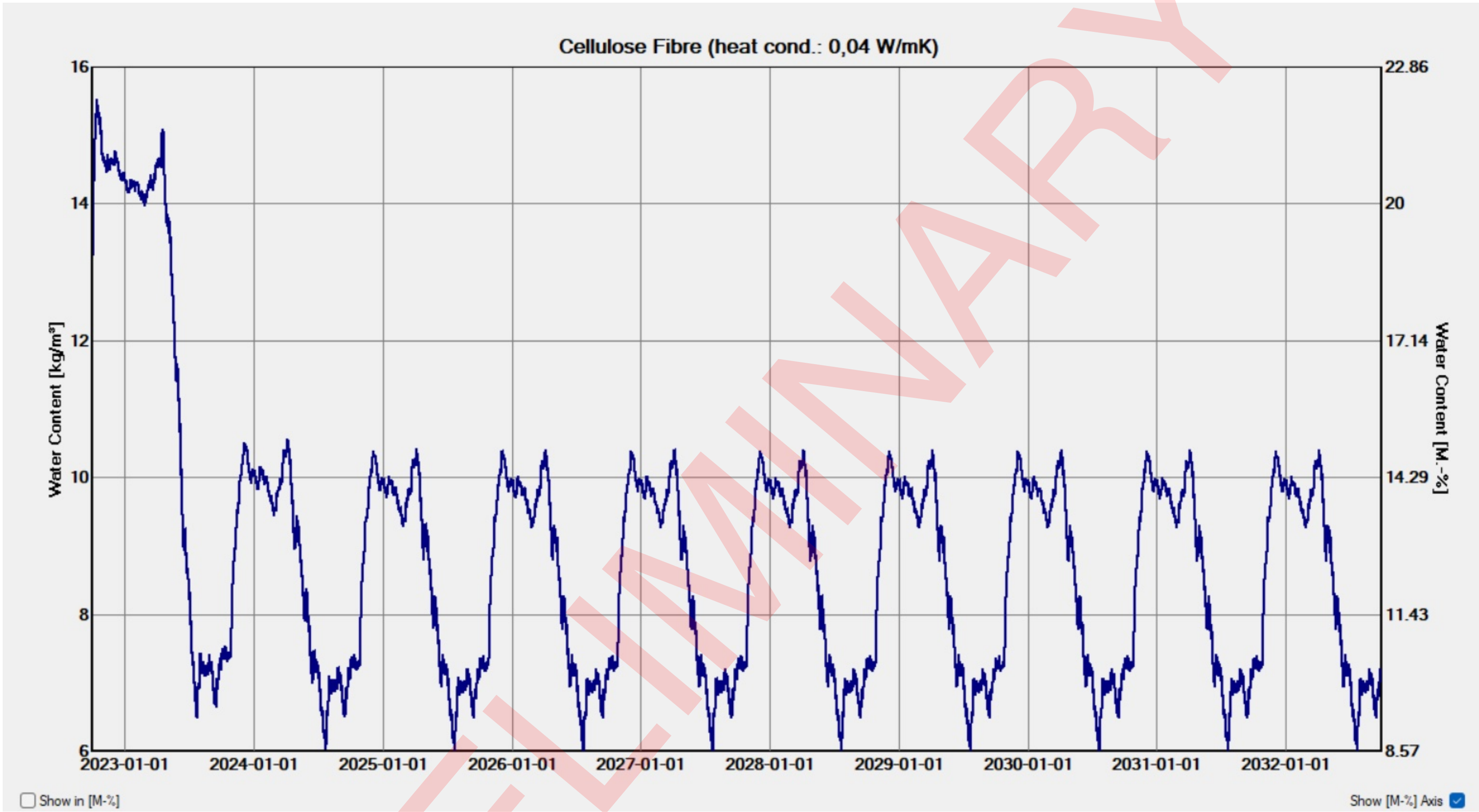


Figure 7 – WUFI® output for W1 wall assembly: water content (kg/m3, %) over 10-year period studied for post-retrofit Recreation Centre North-East wall assembly's cellulose layer (scenario with DensElement sheathing)

POST-RETROFIT WALL ASSEMBLY: W2

The post-retrofit W2 wall assembly simulated in the South and West orientations with a 22.5°C interior temperature setpoint did not demonstrate any numerical errors for all orientations and conditions tested – no convergence failures occurred, and the differences between balances of change in total water content and the sum of the moisture fluxes were very small.

Again, as recommended by the protocol, the plywood layer was subdivided into three adjacent layers, with the outermost and innermost layers being 1/8-inch thick, respectively. However, only one layer, namely the West W2 assembly's innermost plywood layer, experienced a significant spike above 20% MC. This occurred in the first year of simulation for approximately one month between mid-December 2022 and late January 2023 (a smaller spike above 20% MC occurs from late February to beginning of March 2023) (Figure 8). The South orientation plywood layers experienced no spikes above 20% MC (**Figure 9**). (Note: all orientations' MC graphs are available in **APPENDIX C**)

For mold-related durability, a VTT simulation was again conducted to simulate the mold growth index at the specified locations within the plywood layers as well as the outermost and innermost elements of the cellulose layer. Using the same assumptions as per the W1 wall assembly's simulations, the results of the W2 wall assembly VTT simulation indicate a green VTT traffic light in all locations simulated (**Figure 10**).

For these reasons, and per the PHIUS+ protocol, it is understood that the proposed post-retrofit wall assembly may manage moisture adequately based on the information available and the assumptions presented in this report. However, this is dependent on whether the plywood can be subject to certain periods of high moisture content, as well as all wood layers' mold resistance properties.

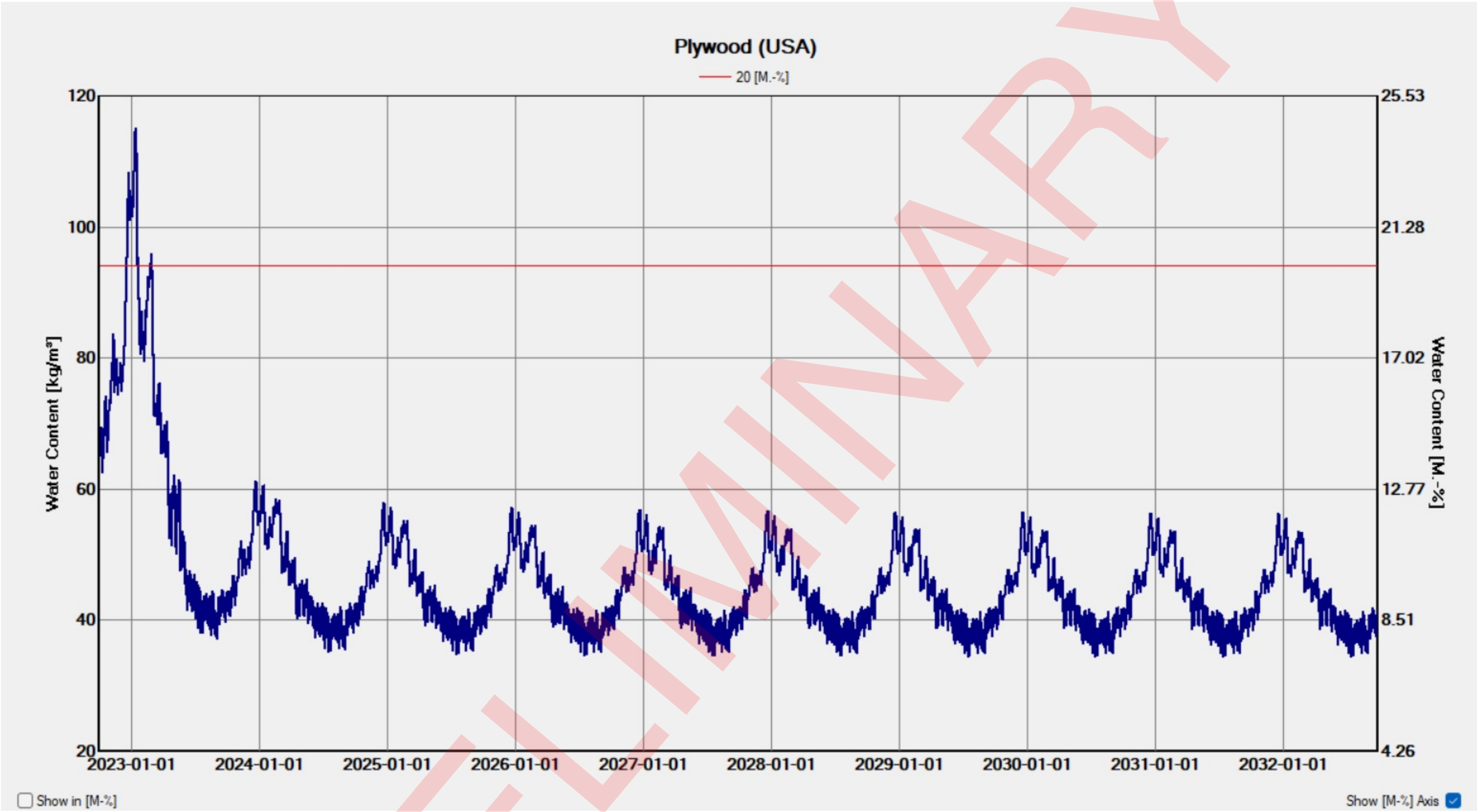


Figure 8 – WUFI® output for W2 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre West wall assembly's inner 1/8-inch plywood layer

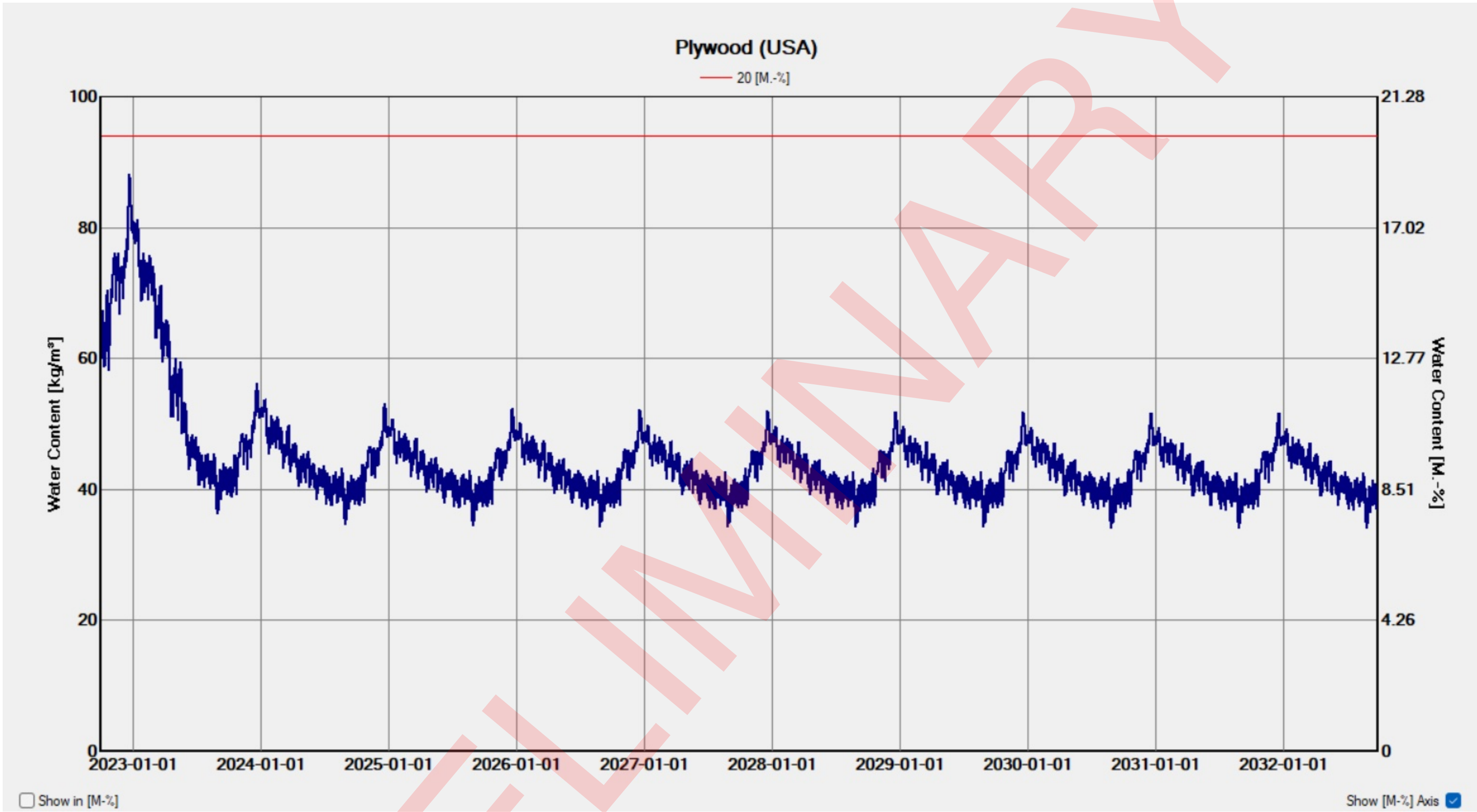


Figure 9 – WUFI® output for W2 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre South wall assembly's inner 1/8-inch plywood layer

Figure 10 – WUFI® output for W2 wall assembly: VTT mold growth index simulation over 10-year period studied for post-retrofit Recreation Centre West wall assembly's plywood and cellulose layers
(blue: outer plywood; green: center plywood; light blue: inner plywood; red: outermost cellulose element; black: innermost cellulose element)

POST-RETROFIT WALL ASSEMBLY: W3

The post-retrofit W3 wall assembly simulated in the North orientation with a 22.5°C interior temperature setpoint did not demonstrate any numerical errors for all orientations and conditions tested – no convergence failures occurred, and the differences between balances of change in total water content and the sum of the moisture fluxes were very small.

Again, as recommended by the protocol, the plywood layer was subdivided into three adjacent layers, with the outermost and innermost layers being 1/8-inch thick, respectively. Of these three layers, only the innermost plywood layer experiences a significant spike in MC above 20%. This spike lasts from approximately mid-December 2022 to early March 2023 (with short dips below 20% at the end of January 2023 and again in early February 2023) – after this point, a sinusoidal pattern below 20% MC is observed (**Figure 11**). The outermost plywood layer experiences three spikes, each approximately one day in duration, which minimally exceed 20% MC (Figure 12). (Note: all orientations' MC graphs are available in **APPENDIX C**)

For mold-related durability, a VTT simulation was again conducted to simulate the mold growth index at the specified locations within the plywood layers as well as the outermost and innermost elements of the cellulose layer. Using the same assumptions as per the W1 wall assembly's simulations, the results of the W3 wall assembly VTT simulation indicate a green VTT traffic light in all locations simulated (Figure 13Figure 10).

For these reasons, and per the PHIUS+ protocol, it is understood that the proposed post-retrofit wall assembly may manage moisture adequately based on the information available and the assumptions presented in this report. However, this is dependent on whether the plywood can be subject to certain periods of high moisture content, as well as all wood layers' mold resistance properties.

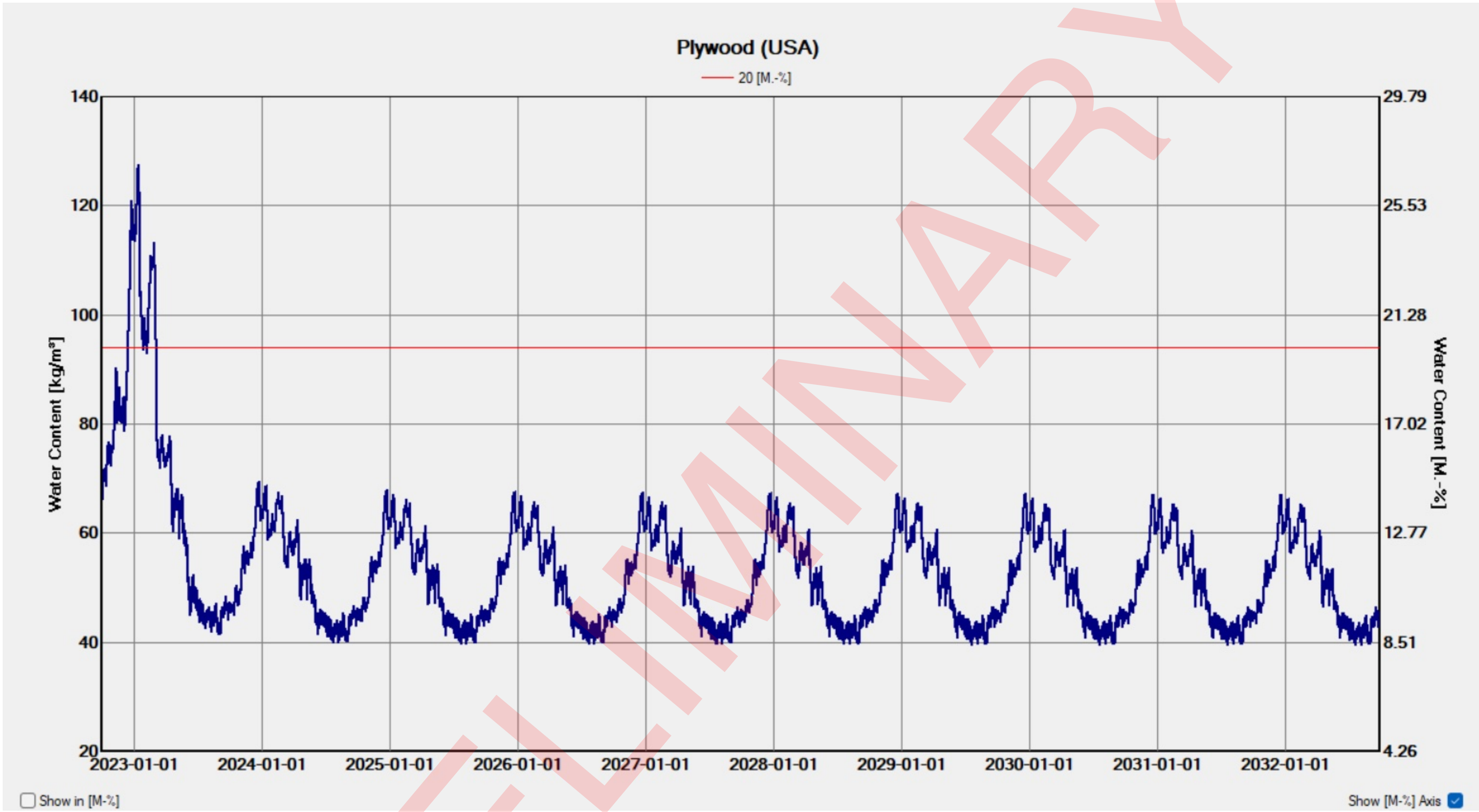


Figure 11 – WUFI® output for W3 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre North wall assembly's inner 1/8-inch plywood layer

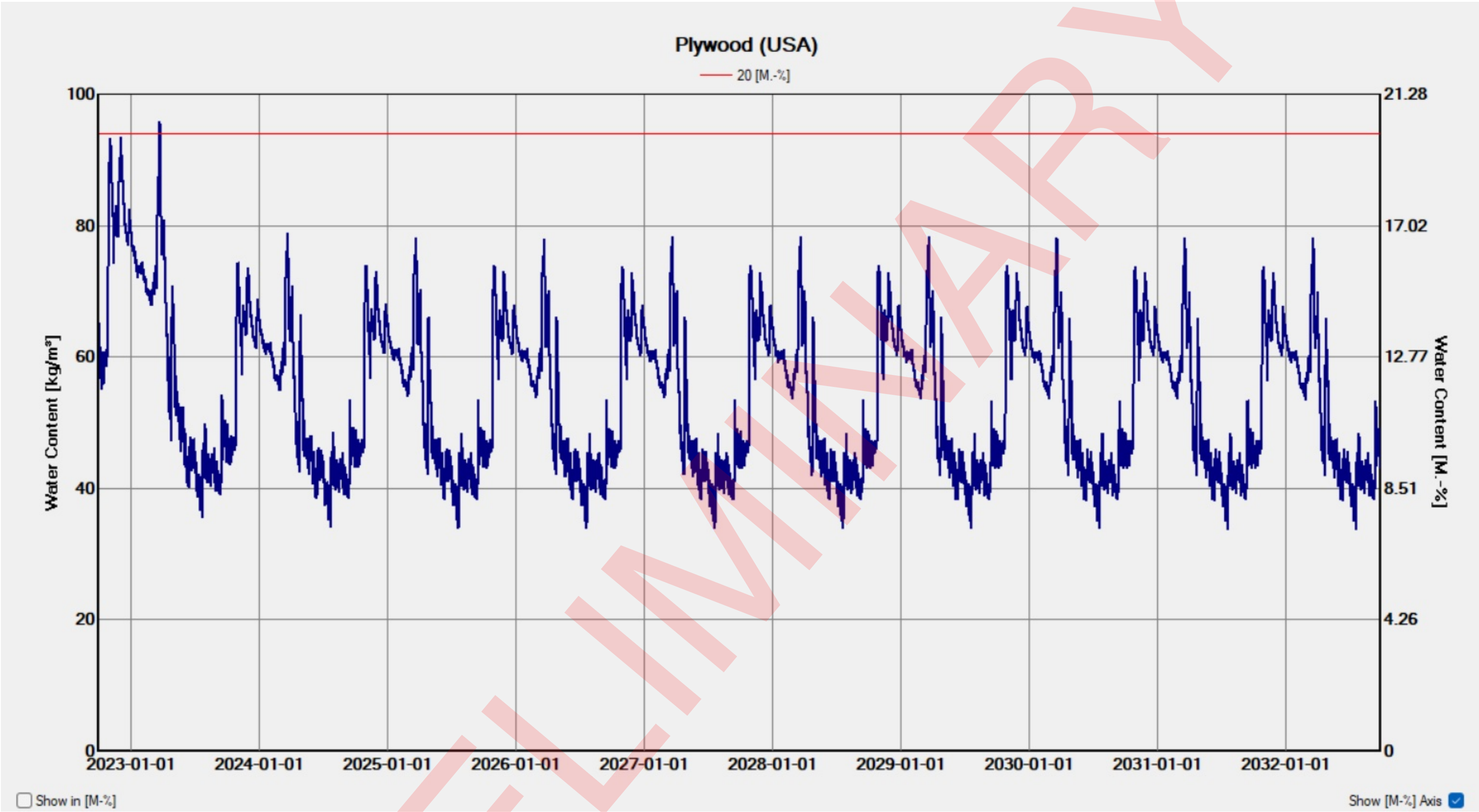


Figure 12 – WUFI® output for W3 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre North wall assembly's outer 1/8-inch plywood layer

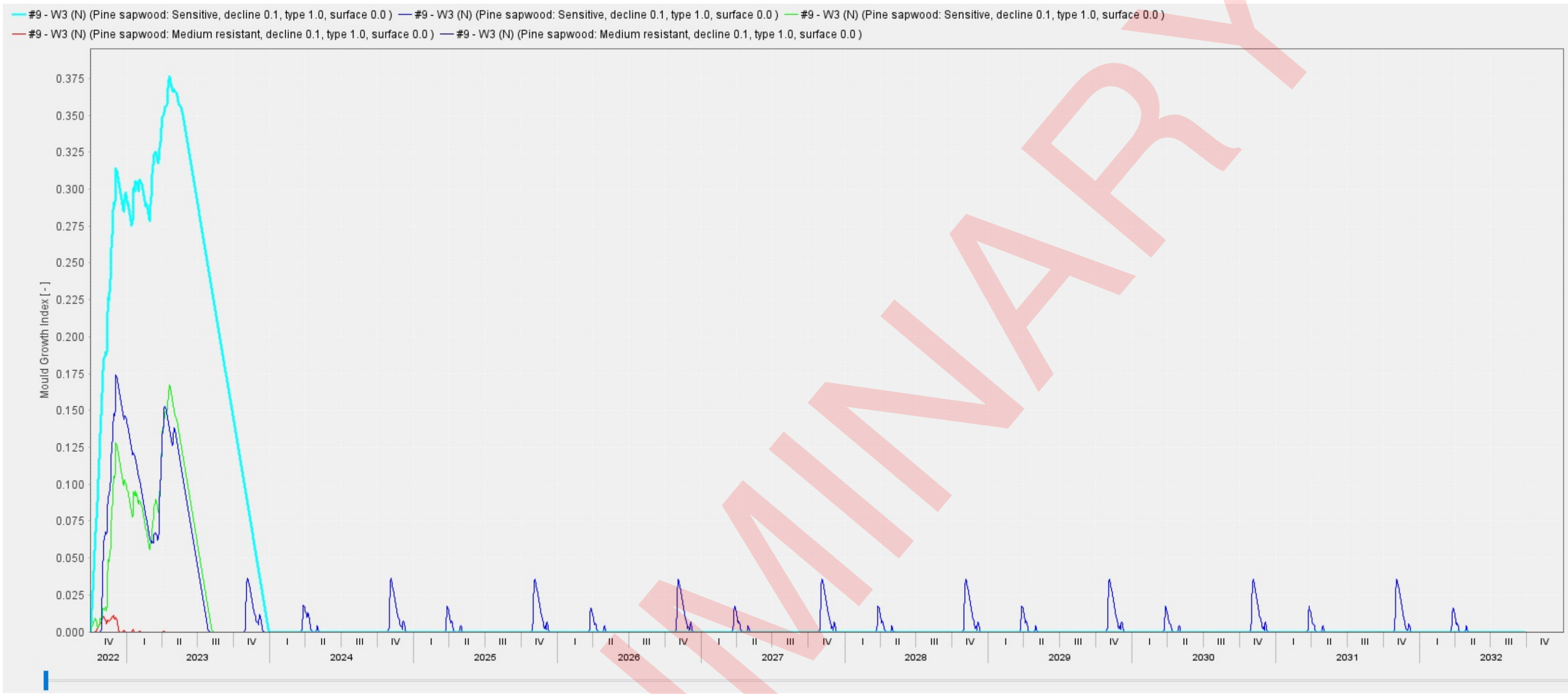


Figure 13 – WUFI® output for W3 wall assembly: VTT mold growth index simulation over 10-year period studied for post-retrofit Recreation Centre North wall assembly's plywood and cellulose layers
(blue: outer plywood; green: center plywood; light blue: inner plywood; red: outermost cellulose element; black: innermost cellulose element)

POST-RETROFIT WALL ASSEMBLY: W4

The post-retrofit W4 wall assembly simulated in the North, South, and West orientations with a 22.5°C interior temperature setpoint did not demonstrate any numerical errors for all orientations and conditions tested – no convergence failures occurred, and the differences between balances of change in total water content and the sum of the moisture fluxes were very small.

Again, as recommended by the protocol, the plywood layer was subdivided into three adjacent layers, with the outermost and innermost layers being 1/8-inch thick, respectively. Only the North orientation's innermost plywood layer demonstrates significant MC spikes above 20% – this lasts from approximately mid-December 2022 to early March 2023 (**Figure 14**). In subsequent years, an annual sinusoidal pattern is observed in the mass percentage of water content. Other plywood layers and orientations experience negligible spikes above 20% MC (for instance, see Figure 15 and Figure 16). (Note: all orientations' MC graphs are available in **APPENDIX C**)

For mold-related durability, a VTT simulation was again conducted to simulate the mold growth index at the specified locations within the plywood layers as well as the outermost and innermost elements of the cellulose layer. Using the same assumptions as per the W1 wall assembly's simulations, the results of the W4 wall assembly VTT simulation indicate a green VTT traffic light in all locations simulated (**Figure 17**Figure 13Figure 10).

For these reasons, and per the PHIUS+ protocol, it is understood that the proposed post-retrofit wall assembly may manage moisture adequately based on the information available and the assumptions presented in this report. However, this is dependent on whether the plywood can be subject to certain periods of high moisture content, as well as all wood layers' mold resistance properties.

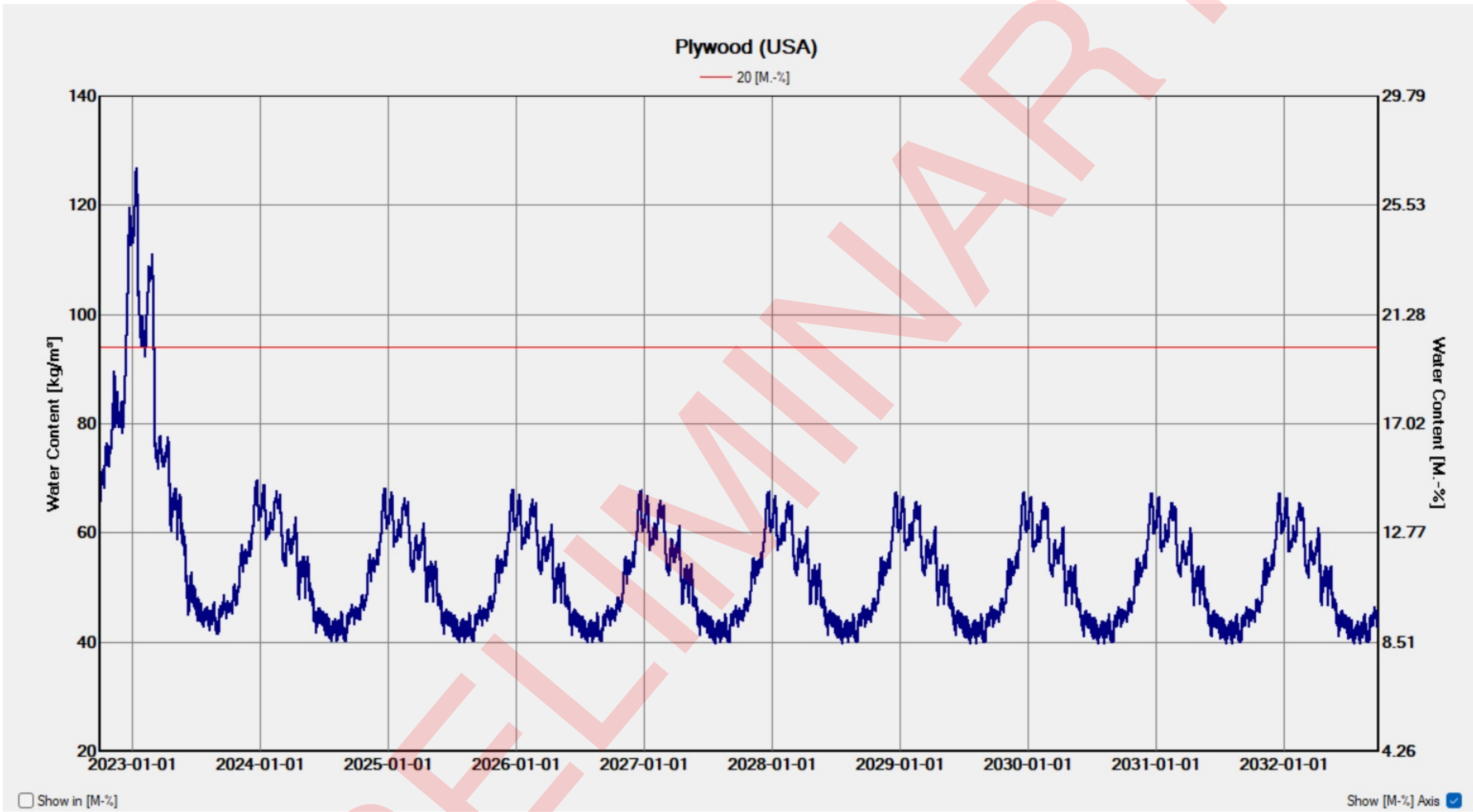


Figure 14 – WUFI® output for W4 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre North wall assembly's inner 1/8-inch plywood layer

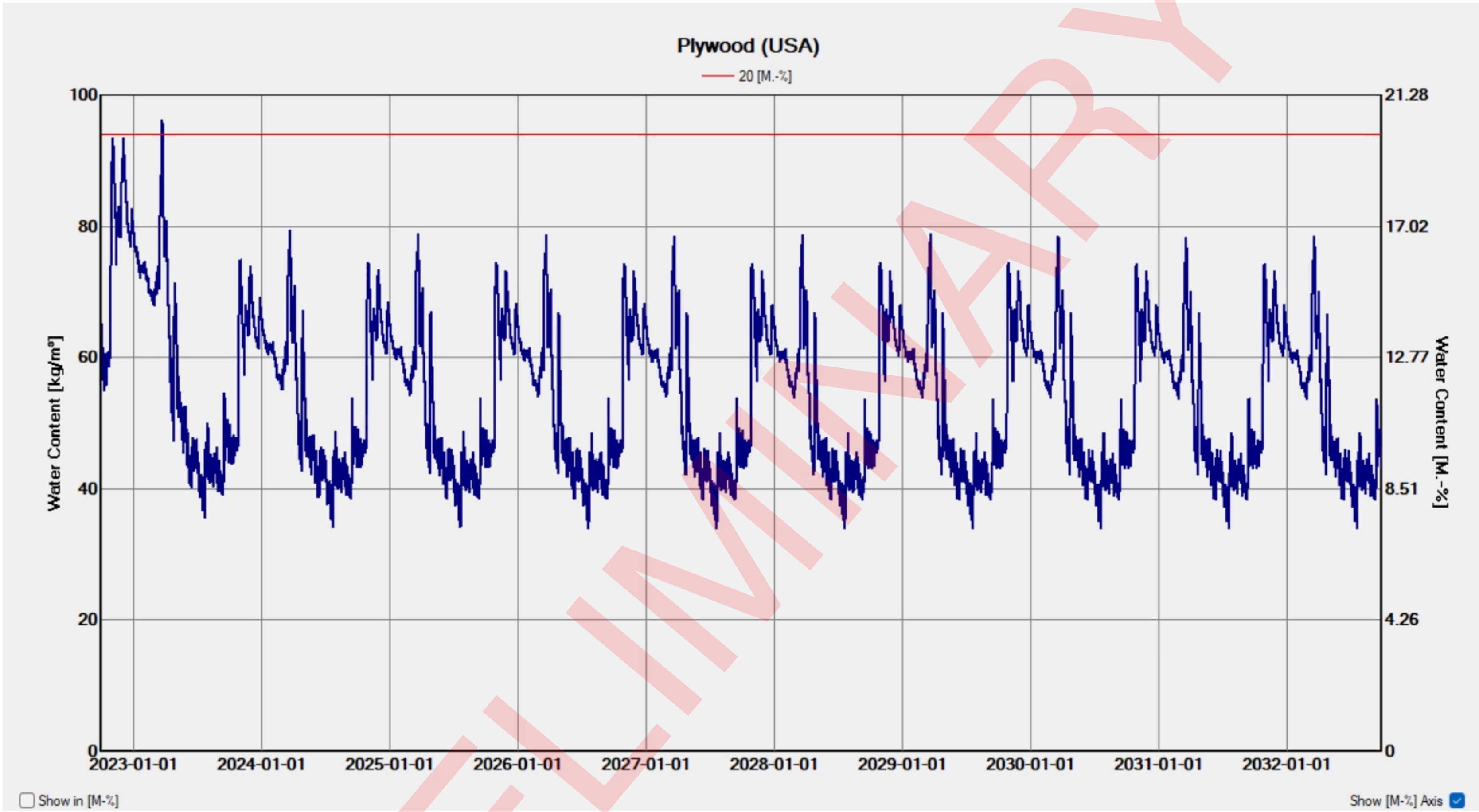


Figure 15 – WUFI® output for W4 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre North wall assembly's outer 1/8-inch plywood layer

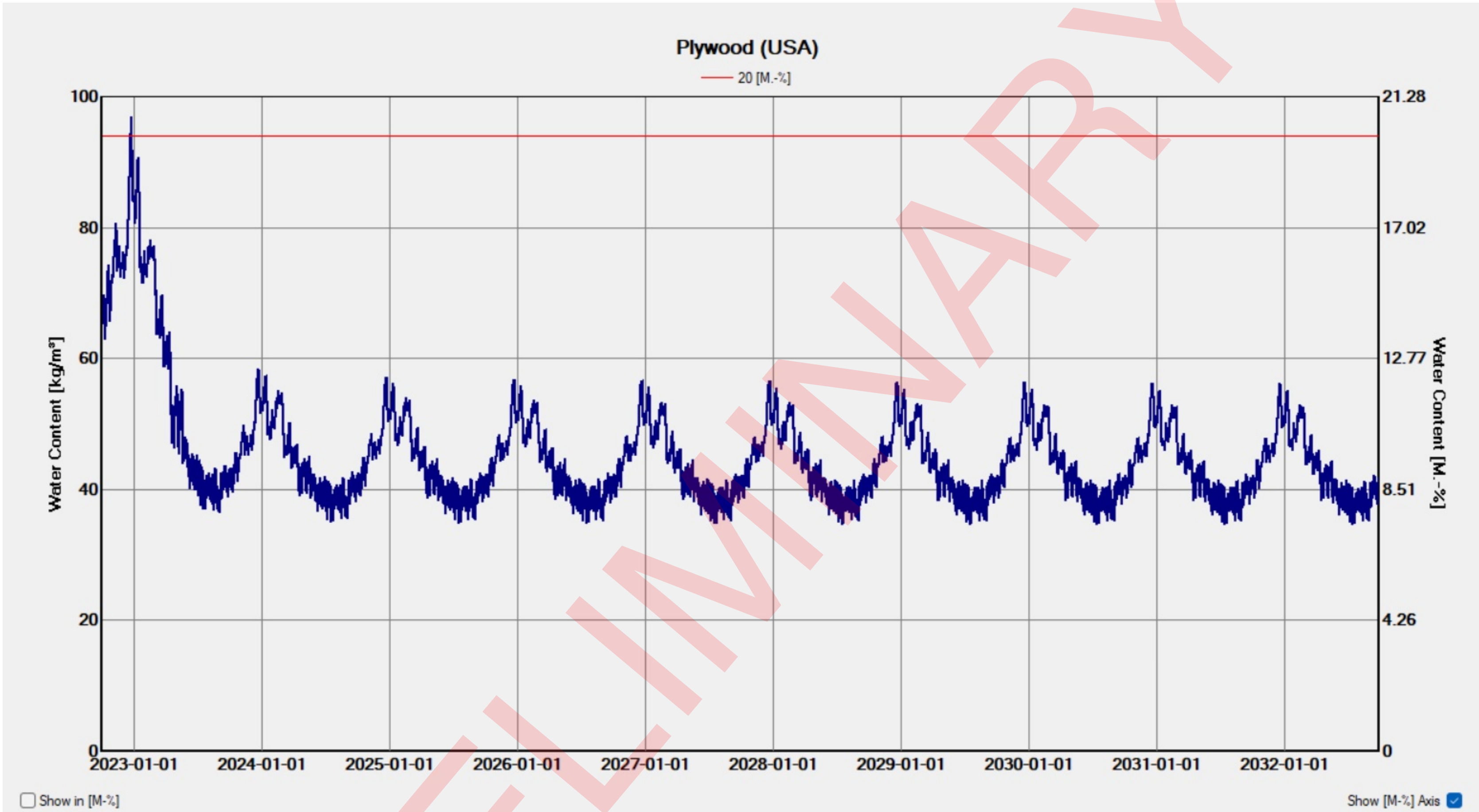


Figure 16 – WUFI® output for W4 wall assembly: water content (kg/m³, %) over 10-year period studied for post-retrofit Recreation Centre West wall assembly's inner 1/8-inch plywood layer

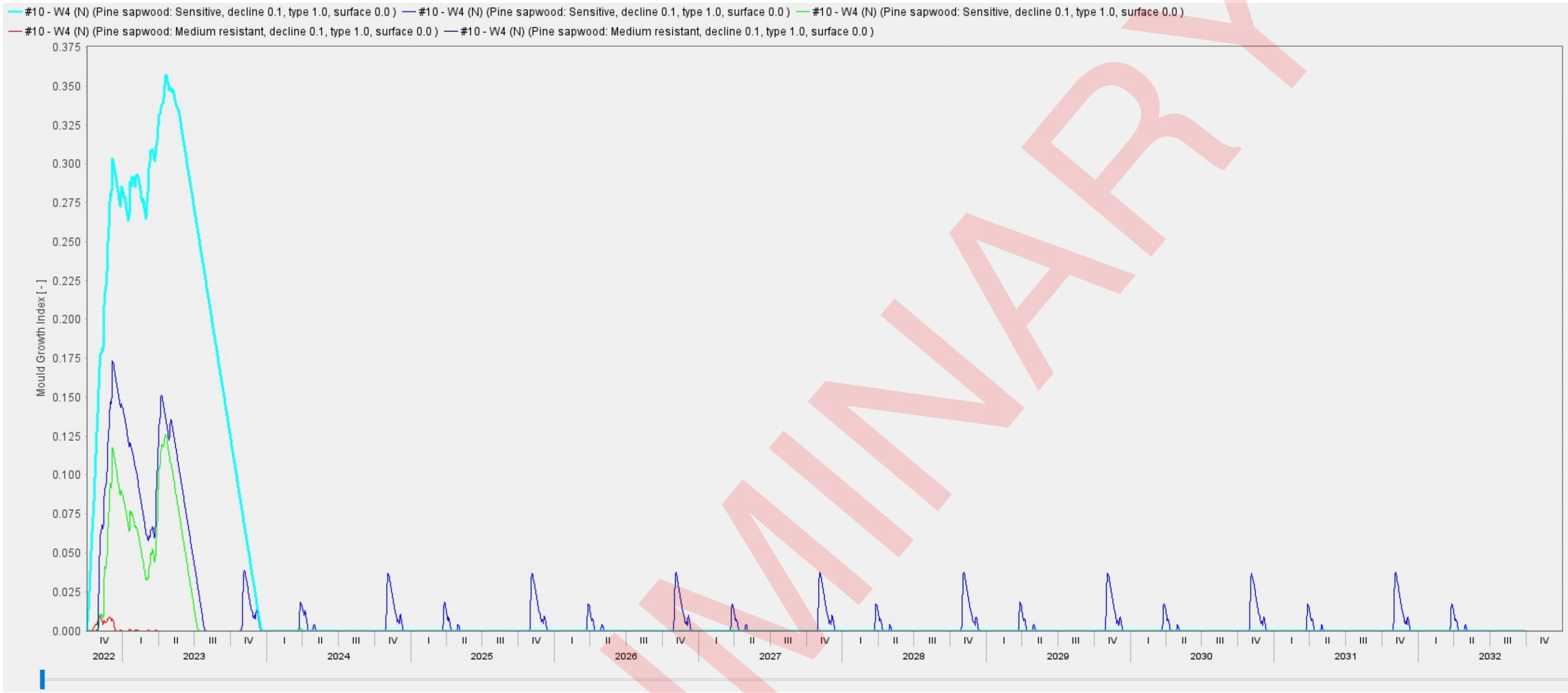


Figure 17 – WUFI® output for W4 wall assembly: VTT mold growth index simulation over 10-year period studied for post-retrofit Recreation Centre North wall assembly's plywood and cellulose layers
(blue: outer plywood; green: center plywood; light blue: inner plywood; red: outermost cellulose element; black: innermost cellulose element)

LIMITATIONS OF STUDY

The results presented in this report are subject to certain limitations, including the following:

- Wall assembly materials and thicknesses were assumed based on information obtained from the City of Oakville and the ReCover team, as well as available predefined WUFI® materials. The existing assemblies were obtained from the document *Oakville A3 wall assemblies.pdf* and should be validated by others prior to conducting future simulations;
- The venting behind the wall (25-ACH) metal cladding system was estimated for this preliminary draft report based on the PHIUS+ protocol;
- All material properties, including but not limited to thermal conductivity and permeability, were assumed based on WUFI® Pro default values as well as the ReCover team's approximations. The specific vulnerability of the existing and proposed materials to moisture and mold growth is approximated, and should be validated with specialists;
- Damage functions indicated in the report were the only ones studied – rot/decay of the wood elements (excluding sheathing), corrosion of any metal elements, bulk water leaks, and any other damage functions were not simulated due to limitations of the one-dimensional WUFI® Pro software, information available, and scope of work;
- Mold growth index simulation using VTT requires estimation of the properties of each material layer studied. The assumptions used in this preliminary feasibility report should be validated with specialists in this field. The mold growth risks involved could be higher if the materials specified for the project are more vulnerable to mold growth than the approximated materials modelled in WUFI®;
- VTT results can vary from one element to another within a given material layer – the results presented in this report are dependent on the elements chosen for simulation;
- Performance at interfaces and details (e.g., interface between wall and roof assemblies) of the building were not modelled in WUFI® Pro and should be validated by others;
- The Toronto climate file used for the simulations approximates the weather experienced by the Oakville building under simulation. This climate file also cannot adequately model the micro-climate experienced by the building in its specific location;
- All interfaces, connections, and details (e.g., interface between wall and roof assemblies) were not modelled in WUFI® Pro and should be validated by others;
- This report assumes that any issues with the existing envelope will be addressed prior to conducting the retrofit, including but not limited to cracking of the masonry, unsealed penetrations, etc.;
- WUFI® Pro is a one-dimensional software that cannot quantify all real-world hygrothermal phenomena. For instance, WUFI® 2-D could better approximate a complex two-dimensional phenomenon that WUFI® Pro could not – certain software is therefore better served in certain situations;
- WUFI® Pro is a software and is limited by the quality of data inputted into each case simulated – given the nature of the preliminary study in question, the information

available for the assemblies' components, the unknown properties of each material, and the approximated indoor/outdoor conditions, great care must be taken when using the WUFI® Pro results presented in this preliminary feasibility report.

If the ReCover team's retrofit design should move forward to construction, it is imperative that a more thorough investigation of the wall assemblies in question be conducted so that more accurate predictions of the assemblies' hygrothermal performance can be made. Further information of the building is necessary, including but not limited to validation of the wall assemblies (e.g., comparison with drawing assemblies), determination of material thicknesses and properties, etc. Therefore, the results of the WUFI® Pro models presented in this report can only be used as a first step towards understanding the post-retrofit hygrothermal performance of the wall assemblies in question. **This preliminary feasibility report cannot be used for construction purposes.** Once further investigation of the actual conditions is completed (e.g., wall openings) and the design of the panels are reviewed and approved by the appropriate parties, hygrothermal models will need to be simulated with the validated inputs, a specific location-based climate file, etc. This will create a more accurate WUFI® model of the building envelope in question and allow for a better understanding of the assemblies' hygrothermal performance post-retrofit.

It is hoped that this report is to your satisfaction. If you have any questions, please do not hesitate to contact Stanley Francispillai.

Stanley Francispillai, P. Eng. (QC, NS)
WUFI® Pro Software Modeller
(438) 872-5524

APPENDIX A

Assembly Notes

Assembly Notes			
Project:	Oakville NRCan Pilot Project		
Case:	W1 (North, South, East, West, North-East, South-East)		
Reference Files:	*Oakville A3 wall assemblies.pdf*		
	2023 02 27 - wall - cellulose - R21 - 2x8 - 0.5 Plywood.pdf		
Assembly (Exterior to Interior)	**Modeled Material (DB/Mat'l)**	**Alterations (If Applicable)**	**Supporting Docs. (If Applicable)**
7/8" corrugated metal siding (vented)	Roof Membrane V13 (Generic Materials)	-	PHIUS+ protocol
3/4" air gap	Air Layer 10 mm; metallic (Generic Materials)	Specific air layer behind metallic surfaces	PHIUS+ protocol
High Perm WRB (Assume PERM 50, Tech specs available)	Spun Bonded Polyolefin Membrane (SBP) (North America Database)	-	-
1/2" SPF Plywood sheathing	Plywood (USA) (N.A. Database)	Split into three layers, 1/8" inner and outer	PHIUS+ protocol
5" of dense pack cellulose	Cellulose Fibre (heat cond.: 0,04 W/mK) (Fraunhofer Database)	-	Past ReCover project assumption
Cellulose Bib Super high PERM	INTELLO PLUS (ETA) (N.A. Database)	-	ReCover Team
1/2" air gap (from 1x4 SPF strapping)	Air Layer 20 mm; without additional moisture capacity (Generic Materials)	-	For strapping + existing wall abnormalities
Wood Siding	Composite Wood Siding	Permeability at each RH level increased by 15% to achieve approximately 10 perms permeance under WET conditions	Building Science Corp. Info-312
1x3 Strapping (air space)	Air Layer 25 mm; without additional moisture capacity (Generic Materials)	-	For existing strapping
1/2" Gypsum Sheathing	Gypsumboard, exterior (LTH Lund University, Sweden)	-	-
R20 Batt Insulation	Low Density Glass Fiber Batt Insulation (N.A. Database)	R20 indicated in drawings approximated at 6"	-

Vapour Retarder	PE-Membrane (Poly; 0.07 perm) (Fraunhofer-IBP)	-	Assumption
1/2" Drywall	Gypsum Board (USA) (N.A. Database)	-	-

Assembly Notes			
Project:	Oakville NRCan Pilot Project		
Case:	W2 (South, West)		
Reference Files:	*Oakville A3 wall assemblies.pdf*		
	2023 02 27 - wall - cellulose - R21 - 2x8 - 0.5 Plywood.pdf		
Assembly (Exterior to Interior)	**Modeled Material (DB/Mat'l)**	**Alterations (If Applicable)**	**Supporting Docs. (If Applicable)**
7/8" corrugated metal siding (vented)	Roof Membrane V13 (Generic Materials)	-	PHIUS+ protocol
3/4" air gap	Air Layer 10 mm; metallic (Generic Materials)	Specific air layer behind metallic surfaces	PHIUS+ protocol
High Perm WRB (Assume PERM 50, Tech specs available)	Spun Bonded Polyolefin Membrane (SBP) (North America Database)	-	-
1/2" SPF Plywood sheathing	Plywood (USA) (N.A. Database)	Split into three layers, 1/8" inner and outer	PHIUS+ protocol
5" of dense pack cellulose	Cellulose Fibre (heat cond.: 0,04 W/mK) (Fraunhofer Database)	-	Past ReCover project assumption
Cellulose Bib Super high PERM	INTELLO PLUS (ETA) (N.A. Database)	-	ReCover Team
1/2" air gap (from 1x4 SPF strapping)	Air Layer 20 mm; without additional moisture capacity (Generic Materials)	-	For strapping + existing wall abnormalities
Wood Siding	Composite Wood Siding	Permeability at each RH level increased by 15% to achieve approximately 10 perms permeance under WET conditions	Building Science Corp. Info-312
1x3 Strapping (air space)	Air Layer 25 mm; without additional moisture capacity (Generic Materials)	-	For existing strapping
2" Rigid Insulation	Extruded Polystyrene Insulation (N.A. Database)	-	Assumed XPS
Vapour Retarder	PE-Membrane (Poly; 0.07 perm) (Fraunhofer-IBP)	-	Assumption

12" Concrete Block	Concrete Brick (N.A. Database)	-	-

Assembly Notes

Project: Oakville NRCan Pilot Project
Case: W3 (North)
Reference Files: *Oakville A3 wall assemblies.pdf*
2023 02 27 - wall - cellulose - R21 - 2x8 - 0.5 Plywood.pdf

Assembly (Exterior to Interior)	**Modeled Material (DB/Mat'l)**	**Alterations (If Applicable)**	**Supporting Docs. (If Applicable)**
7/8" corrugated metal siding (vented)	Roof Membrane V13 (Generic Materials)	-	PHIUS+ protocol
3/4" air gap	Air Layer 10 mm; metallic (Generic Materials)	Specific air layer behind metallic surfaces	PHIUS+ protocol
High Perm WRB (Assume PERM 50, Tech specs available)	Spun Bonded Polyolefin Membrane (SBP) (North America Database)	-	-
1/2" SPF Plywood sheathing	Plywood (USA) (N.A. Database)	Split into three layers, 1/8" inner and outer	PHIUS+ protocol
5" of dense pack cellulose	Cellulose Fibre (heat cond.: 0,04 W/mK) (Fraunhofer Database)	-	Past ReCover project assumption
Cellulose Bib Super high PERM	INTELLO PLUS (ETA) (N.A. Database)	-	ReCover Team
1/2" air gap (from 1x4 SPF strapping)	Air Layer 20 mm; without additional moisture capacity (Generic Materials)	-	For strapping + existing wall abnormalities
2" Rigid Insulation	Extruded Polystyrene Insulation (N.A. Database)	-	Assumed XPS
Vapour Retarder	PE-Membrane (Poly; 0.07 perm) (Fraunhofer-IBP)	-	Assumption
8" Concrete Block	Concrete Brick (N.A. Database)	-	-

Assembly Notes			
Project:	Oakville NRCan Pilot Project		
Case:	W4 (North, South, West)		
Reference Files:	*Oakville A3 wall assemblies.pdf*		
	2023 02 27 - wall - cellulose - R21 - 2x8 - 0.5 Plywood.pdf		
Assembly (Exterior to Interior)	**Modeled Material (DB/Mat'l)**	**Alterations (If Applicable)**	**Supporting Docs. (If Applicable)**
7/8" corrugated metal siding (vented)	Roof Membrane V13 (Generic Materials)	-	PHIUS+ protocol
3/4" air gap	Air Layer 10 mm; metallic (Generic Materials)	Specific air layer behind metallic surfaces	PHIUS+ protocol
High Perm WRB (Assume PERM 50, Tech specs available)	Spun Bonded Polyolefin Membrane (SBP) (North America Database)	-	-
1/2" SPF Plywood sheathing	Plywood (USA) (N.A. Database)	Split into three layers, 1/8" inner and outer	PHIUS+ protocol
5" of dense pack cellulose	Cellulose Fibre (heat cond.: 0,04 W/mK) (Fraunhofer Database)	-	Past ReCover project assumption
Cellulose Bib Super high PERM	INTELLO PLUS (ETA) (N.A. Database)	-	ReCover Team
1/2" air gap (from 1x4 SPF strapping)	Air Layer 20 mm; without additional moisture capacity (Generic Materials)	-	For strapping + existing wall abnormalities
2" Rigid Insulation	Extruded Polystyrene Insulation (N.A. Database)	-	Assumed XPS
Vapour Retarder	PE-Membrane (Poly; 0.07 perm) (Fraunhofer-IBP)	-	Assumption
12" Concrete Block	Concrete Brick (N.A. Database)	-	-

Appendix K

Embodied Carbon

NRCan | Recover FEED Studies

Oakville Retrofit Building Embodied Carbon Assessment

Fatma Osman, BA, Toronto Metropolitan University

INTRODUCTION

This report presents an embodied carbon analysis of the Oakville retrofit project proposed by the Recover Initiative as part of the NRCan FEED studies. Understanding the embodied carbon in the construction industry can help reduce the overall carbon footprint of buildings, which is one of the main goals the Recover initiative works to achieve. This report emphasizes the importance of embodied carbon analysis and the environmental impacts attributed to material selection.

SCOPE OF WORK

The scope of work includes conducting an embodied carbon analysis of the retrofit project; all materials that are proposed to be added to the existing building. This analysis is limited to embodied carbon of assembly materials and does not include other systems, such as the HVAC systems. Specifically, the analysis looks at additions to above-grade walls, roofs, below-grade components, and windows and doors. 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.

INPUTS AND ASSUMPTIONS

- The materials used in the analysis were chosen based on the most representative materials available to the Canadian market that has Environmental Product Declarations (EPDs) available in the One Click LCA software database.
- Materials were chosen based on their environmental performance; averages were prioritized (unless low-carbon materials were specified by the Recover design team).
- The service life used in the analysis is 60 years as per LEED v4 minimum requirement for whole building LCAs.
- Materials within assembly panels were assumed to have a 60 years service life as the building; all other materials were left to default service lives as per the One Click software.

THIS REPORT CONTAINS

- Summary of Results.
- Summary of Global Warming Potential (GWP) per building floor area.
- Graphs that summarize the detailed tables.
- Detailed data on assembly materials and specific products used in the assessment (in Appendix).
- Detailed data on embodied carbon of the different life stages of the buildings in the form of tables (in Appendix).

Oakville Retrofit Project LCA results summary

Table 1: Total Global Warming Potential

Oakville building gross floor area m2	A1-A3 KgCO2e/m2	A1-C4 KgCO2e/m2	Biogenic carbon KgCO2e/m2
818	71.72	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 1 & 2. 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 assembly as shown in Figure 3. The results graphs below show the breakdowns of life cycle stages and impact categories associated with the building materials.

Results Graphs

Oakville Retrofit Global Warming by Stage and Material

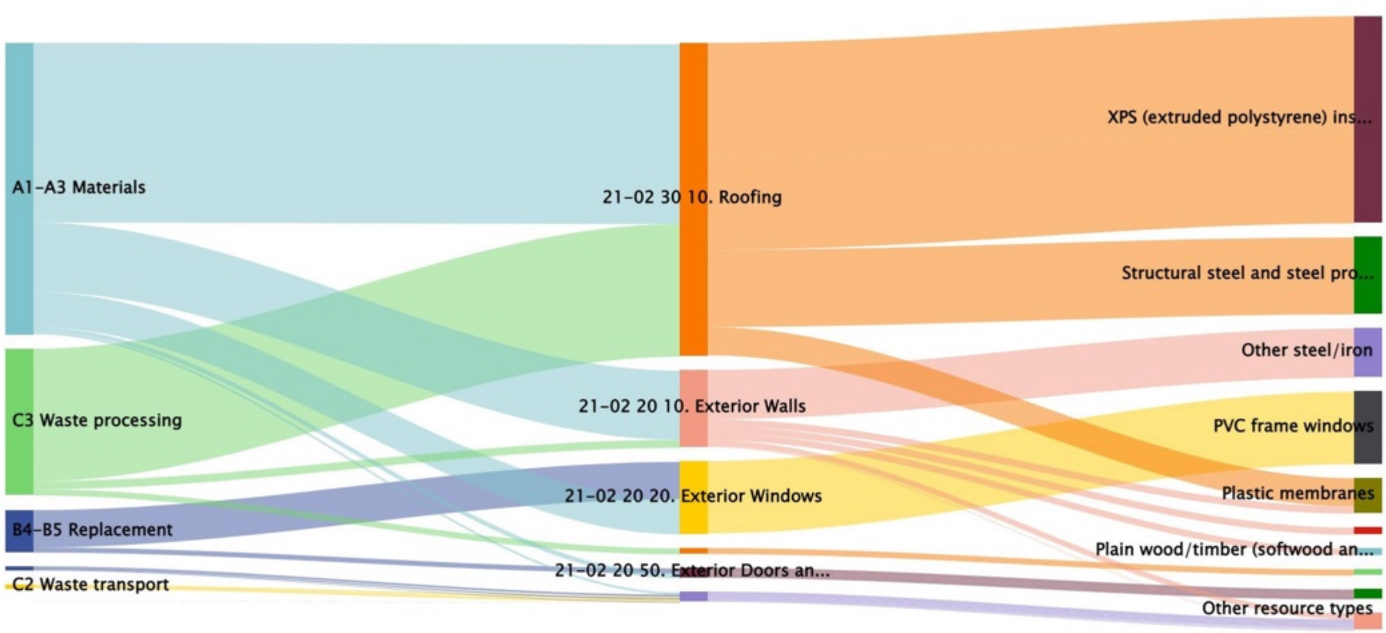


Figure 1: Oakville retrofit design breakdown of the life cycle stages and the associated materials

Oakville Retrofit Life-Cycle Impacts by Stage (%)

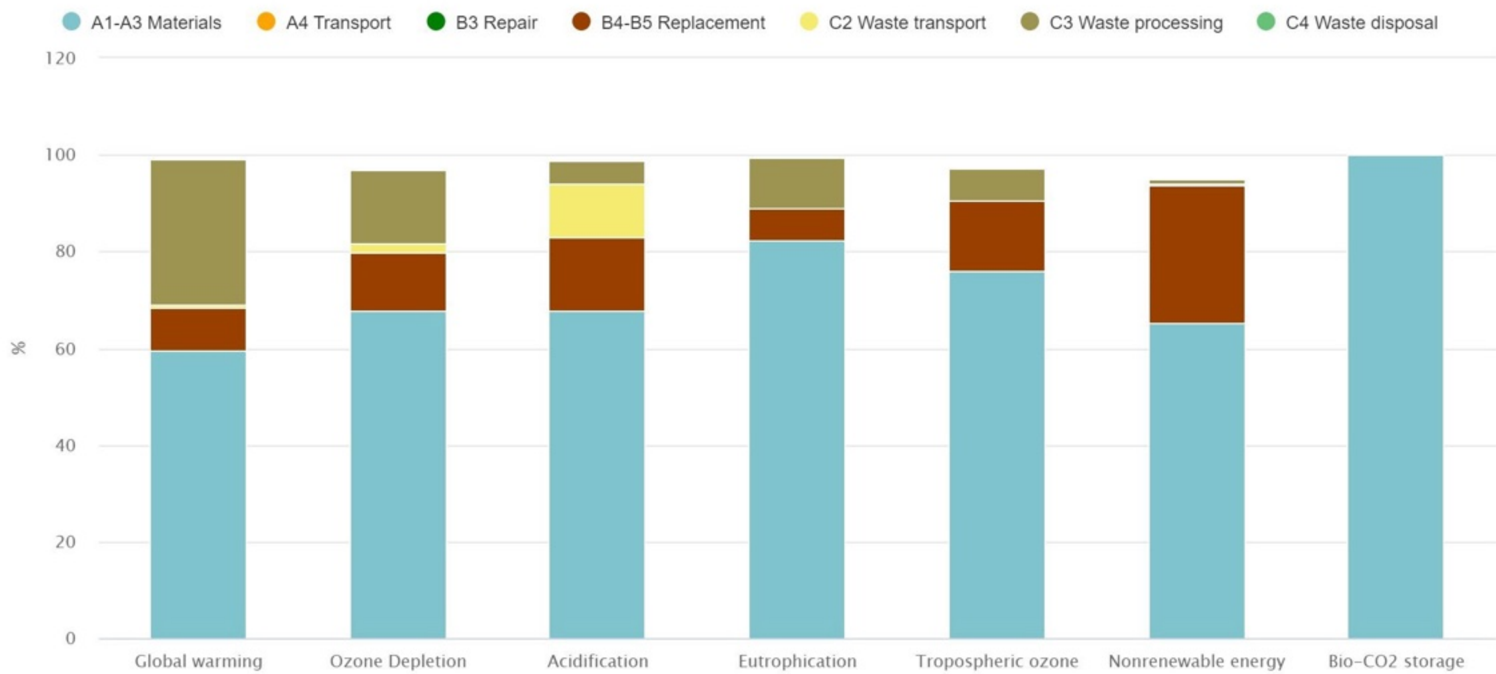


Figure 2: Oakville retrofit design breakdown of the life cycle impact categories and the associated life cycle stag

Oakville Retrofit Life-Cycle Impacts by Material (%)

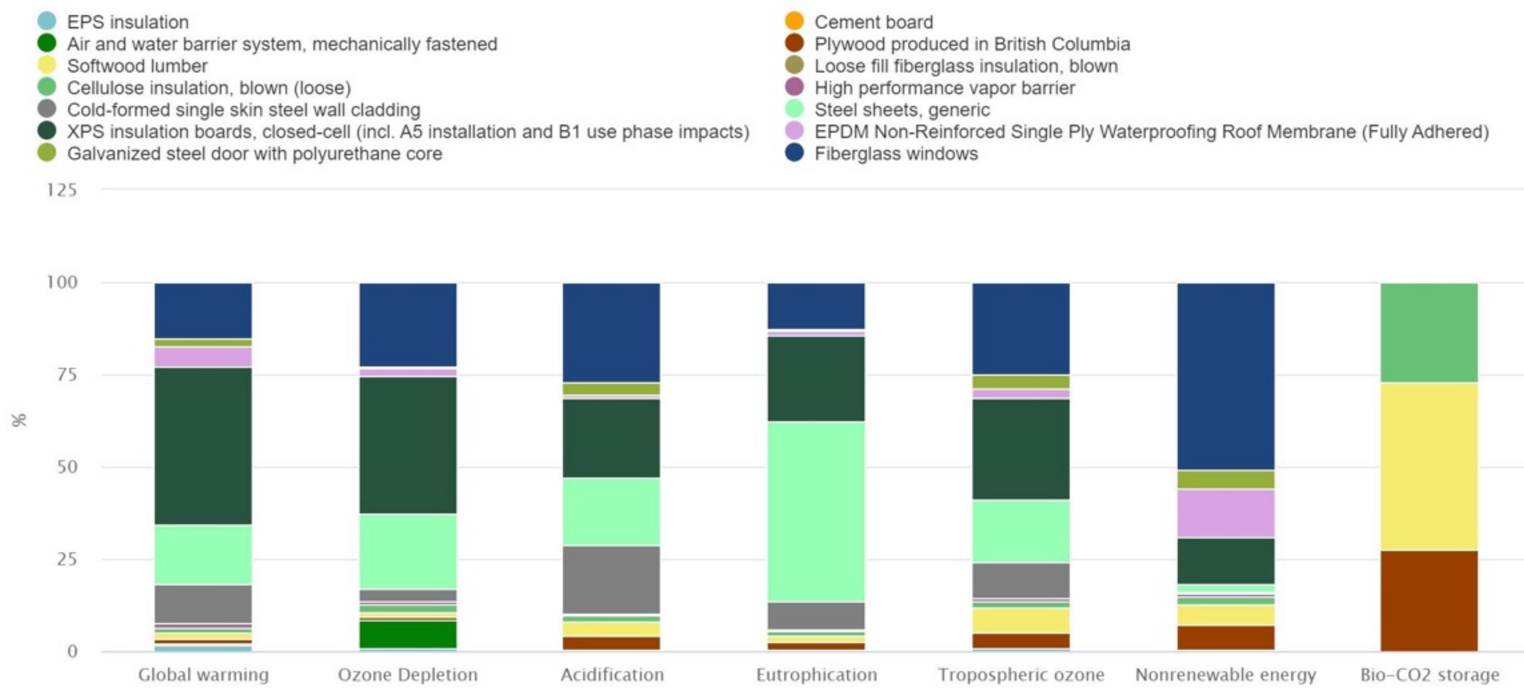


Figure 3: Oakville retrofit design breakdown of the life cycle impact categories and the associated materials

Appendix

Proposed Retrofit Assemblies and Environmental Impact calculations

Oakville

Wall Panel Assembly (R16)

Material (ReCover specification)	Description (from EPD)	Thickness (mm)	Volume of material (m3)	Carbon emissions (A1-A3) (KgCO2E)	% of total
Self Adhered WRB	Air and water barrier system, mechanically fastened, 0.0225 lbs/ft2, 0.11 kg/m2, Tyvek (DuPont)		*	70.7	0.5%
1/2" SPF plywood sheathing	Plywood produced in British Columbia, 477.33 kg/m3 (Forestry Innovation Investment)	13	10.926	1438.7	10.0%
2x6 SPF framing	Softwood lumber, 405 kg/m3 (Canadian Wood Council)		15.167	1122.7	7.8%
Compressible insulation	Loose fill fiberglass insulation, blown, Rsi=1 m2K/W, 19.84 mm, 0.46 kg/m2, 23.2 kg/m3, (Johns Manville)	21	1.017	28.2	0.2%
Exterior strapping (#3)	Softwood lumber, 405 kg/m3 (Canadian Wood Council)		0.896	66.3	0.5%
Dense pack cellulose (5.5")	Cellulose insulation, blown (loose), L = 0.039 W/mK, R = 2.56 m2K/W (15 ft2°Fh/BTU), 50 kg/m3 (3.12lbs/ft3), (applicable for densities: 40-90 kg/m3 (2.5-5.62 lbs/ft3)),	140	97.618	857.2	6.0%
Intello plus	High performance vapor barrier, 0.021 in (0.5 mm), 0.76 kg/m2, Florprufe® 120 (GCP Applied Technologies)		*	247.2	1.7%
1x4 strapping	Softwood lumber, 405 kg/m3 (Canadian Wood Council)		1.992	147.5	1.0%
Metal siding (cladding)	**Cold-formed single skin steel wall cladding, 0.36-1.27 mm, 4.17 kg/m2 (Metal Building Manufacturers Association)**		*****	**9954.5**	**69.3%**
4" EPS wall insulation	EPS insulation (generic)	101.6	27	312.6	2.2%
2" thick below grade fin		50.8			
Cement board	Cement board, 1/2 in (12.7 mm), 11.8 kg/m2, PLUS (PermaBASE Building Products)	6.35	0.2794	121.3	0.8%
Total				**14366.9**	100.0%
* Software calculates the impact based on the area provided			**Per m2**	**17.6**	**kg CO2/m2**

Roof Assembly

Material (ReCover specification)	Description (from EPD)	Thickness (mm)	Volume of material (m3)	Carbon emissions (A1-A3) (KgCO2E)	% of total
12" low carbon XPS	**XPS insulation boards, closed-cell, (SOPREMA)**	**0.3**	**293.6**	**18,643.90**	**51.5%**
Roofing (metal)	**Steel sheets, generic, 60% recycled content, S235, S275 and S355**		*	**15,487.55**	**42.7%**
Roofing membrane	EPDM Non-Reinforced Single Ply Waterproofing Roof Membrane (Fully Adhered), 60 mils: 2.07 kg/m2 (Single Ply Roofing Industry)		*	2,098.73	5.8%
Total				**36,230.18**	100.0%
* Software calculates the impact based on the area provided			**Per m2**	**44.3**	**kg CO2/m2**

Windows and Doors

Material (ReCover specification)	Description (from EPD)	Thickness (mm)	Volume of material (m3)	Carbon emissions (A1-A3) (KgCO2E)	% of total
Insulated core steel doors	Galvanized steel door with polyurethane core, 44.5 mm (1.75 inch), 42.5 kg/unit, 490 kg/m3 (DE LA FONTAINE)	*	*	1,000.00	12.3%
High performance triple pane windows	Fiberglass windows, 1.5m x 1.3 m, 40 mm frame thickness, 1.42 m2 glazing area, 60.50 kg/m2, 300 Series Tilt and Turn, 300 Series Fixed, 325 Series Awning/Casement, 325 Series Fixed, 400 Series (Inline)	*	*	7,100.00	87.7%
Total				**8,100.00**	100.0%
* Quantity is calculated in software based on area and/or number of units			**Per m2**	**8.7**	**kg CO2/m2**

Environmental Emissions

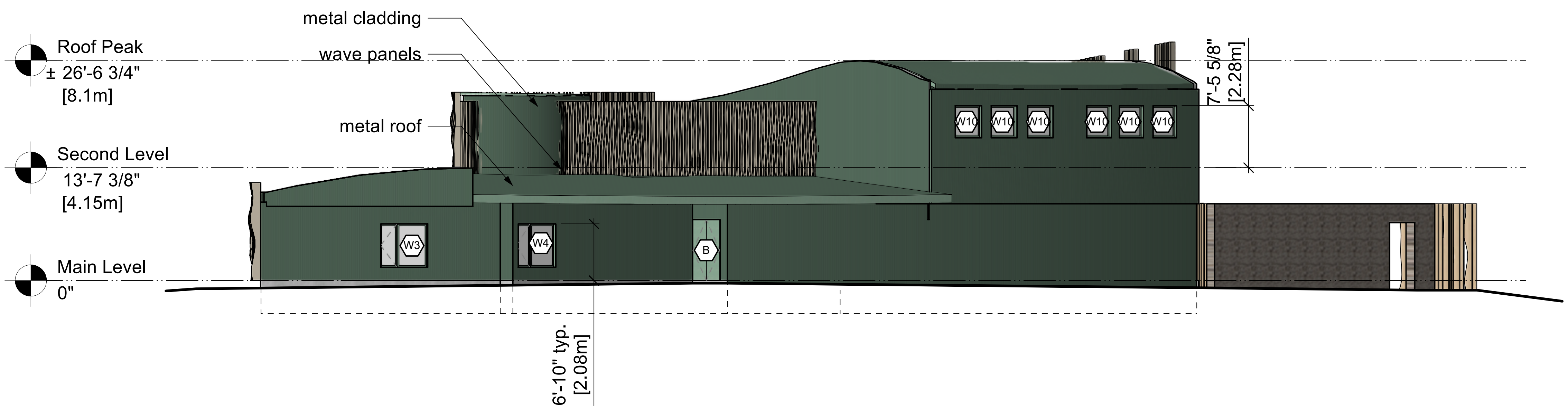
Oakville Project		**A1 to C4**	**A1-A3**	**A4-A5**	**B1-B5**	**C1-C4**	**A1-A3**
Result category	**Units**	**Total**	**Construction Materials**	**Transportation to site & construction**	**Material replacement & refurbishment**	**Deconstruction**	**A1-A3 % of total**
Global warming	kg CO2e	98,364.29	58670.23	847.73	8538.46	30307.87	59.6%

Ozone Depletion	kg CFC11e	0.01	0.0047	0.00022	0.00082	0.0012	67.7%
Acidification	kg SO_2e	469.21	318.27	4.83	71.48	74.63	67.8%
Eutrophication	kg Ne	157.15	129.33	0.68	10.37	16.77	82.3%
Formation of tropospheric ozone	kg O3e	5,028.73	3822.82	136.94	726.88	342.09	76.0%
Depletion of nonrenewable energy	MJ	489,927.93	320112.7	24104.73	138610.6	7099.9	65.3%
Biogenic carbon storage	kg CO2e	31,208.24	31208.24	0	0	0	100.0%

Appendix L
Architectural Elevation Drawings

1 North Elevation

1/16" = 1'-0"



2 East Elevation

1/16" = 1'-0"

0 6 12 18 24 30FT

graphic scale:

north arrow:

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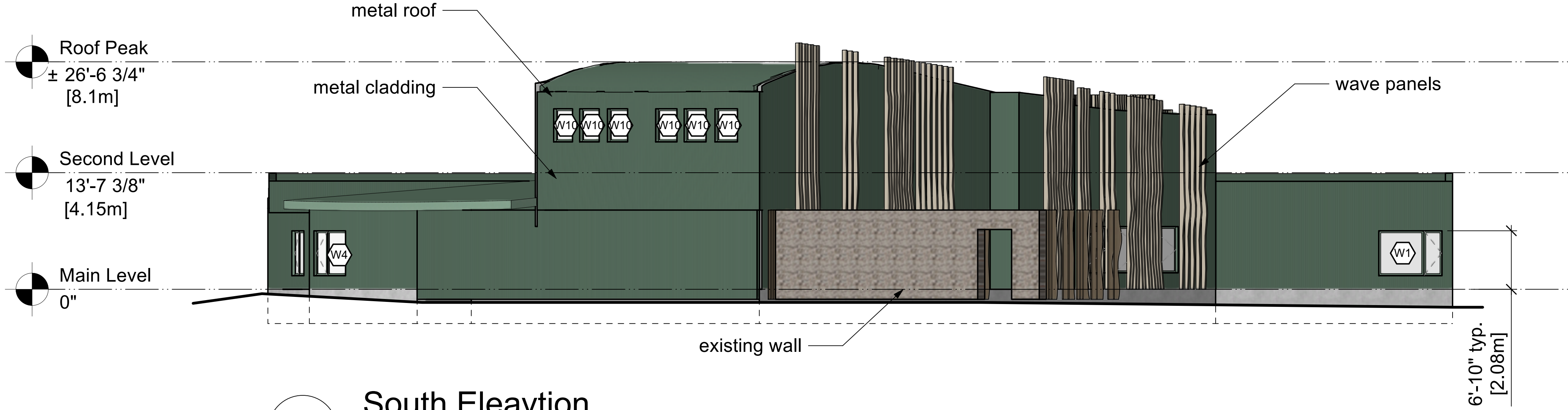
Sir John Colburne Recreation centre

Oakville, ON

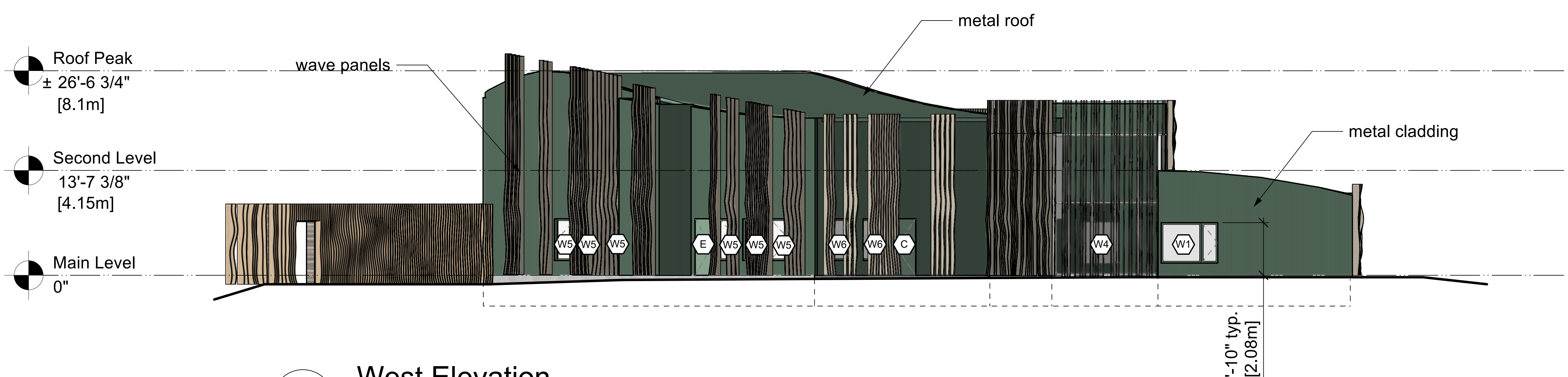
ReCover Initiative Panelized Deep Retrofit Study

drawing title: Proposed North & East Elevations		
phase: concept		sheet size: 17x11
drawn by: IG	checked by: LR	drawing number: A1
date: 2023-08-15	scale: as noted	

oakville_CURRENT.vwx



3 South Eleavtion
1/16" = 1'-0"



4 West Elevation
1/16" = 1'-0"

0 6 12 18 24 30FT

graphic scale:

north arrow:

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Sir John Colburne Recreation centre

Oakville, ON

ReCover Initiative Panelized Deep Retrofit Study

oakville_CURRENT.vwx

drawing title: Proposed South & West Elevations

phase: concept		sheet size: 17x11
drawn by: IG	checked by: LR	drawing number: A2
date: 2023-08-15	scale: as noted	

APPLICABLE CODES AND STANDARDS

Building Code:	Ontario Building Code (OBC) 2015 National Building Code of Canada (NBCC)
Fire Code:	Ontario Fire Code 2015 National Fire Code of Canada
Accessibility:	Oakville Universal Design Standards (OUDS) 2015 National Building Code of Canada (NBCC)

BUILDING DESCRIPTION

Oakville Municipal Operations Building

		NSBC Reference
Building Area (Footprint):	852 m²	
Gross Floor Area:	852 m²	
Building Height:	1 Storey	1.4.1.2
Major Occupancy, Proposed:	Group A2 - assembly occupancy based on activities of community centre	3.1.2.1.

CONSTRUCTION REQUIREMENTS

		NSBC Reference
Construction Governed by:	NBC Part 3	1.3.3.2.
Building Area:	< 2400 m²	3.2.2.25.(1)
Building Height:	1 Storey	3.2.2.25.(1)(a)
Streets to Face:		3
Construction Type:	Combustible or Noncombustible	3.2.2.25.(1)
Fire Resistance Ratings:		
Upper Floors (n/a):	45min FRR	3.2.2.25.(2)(a)
Loadbearing Elements supporting an assembly required to have a fire-resistance rating	45 min FRR or noncombustible construction	3.2.2.25.(2)(d)
Roof, Occupied (n/a):	not required	3.2.2.25.(2)(c)
Loadbearing Elements supporting a fire separation	N/A	3.2.2.25.(2)
Sprinkler:	not required	3.2.2.27.(1)a)
Standpipe:	not required	3.2.5.8.(1)(c)
Fire Alarm:	Required	3.2.4.1.(4)(d)
Portable Fire Extinguisher:	Required within 22.9 m of travel from all points within	NFC 2.1.5.1. / NFPA 10
Fire Hydrant:	N/A	3.2.5.15.

SPATIAL SEPARATIONS

The type of construction, cladding and fire-resistance rating of the exposed building faces is summarized below.
NSBC References: Article 3.2.3.1. and NSBC Table 3.2.3.1.-E

Facing	Limiting Distance (m)	Wall Area (m²)	H:L Ratio	Unprotected Openings		Exposing Building Face		
				Permitted	Proposed	FRR	Construction	Cladding
North	22.5	195.0	1:9.2	100.0%	7.0%	-	Comb. or Noncomb.	Comb. or Noncomb.*
West	70.0	242.5	1:2.6	100.0%	11.0%	-	Comb. or Noncomb.	Comb. or Noncomb.
South	35.0	52.7	1:1.8	100.0%	31.5%	-	Comb. or Noncomb.	Comb. or Noncomb.
East	35.0	276.0	1:10	100.0%	17.0%	-	Comb. or Noncomb.	Comb. or Noncomb.

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Sir John Colburne Recreation centre
Oakville, ON
ReCover Initiative Panelized Deep Retrofit Study

drawing title: Code review
phase: concept
sheet size: 17x11
drawn by: IG
checked by: LR
drawing number: A3
date: 2023-08-15
scale: as noted
graphic scale:
north arrow:
oakville_CURRENT.vwx

Appendix M

Cost Estimate

Retrofit 1565 Old Lakeshore Road

Oakville, Ontario

ELEMENTAL COST PLAN
CLASS D - FEASIBILITY ESTIMATE
JULY 20, 2023

163 Village Road, Herring Cove, Nova Scotia, Canada, B3V 1H2
www.qsolv.ca

Preamble

INTRODUCTION

The Class D - Feasibility Estimate enclosed represents the construction costs for the proposed energy retrofit options to the existing multi-purpose facility located at 1565 Old Lakeshore Road in Oakville, Ontario as design by RSI Projects Inc.

Four scenario cost options are presented in this report as follows:

Scenario One Code Minimum generally includes the replacement of the stone and siding facade with new metal siding on prefab insulated panels, roof replacement with upgraded insulation, replacement of windows with new triple pane windows, new sensors and relays, and upgrade lighting with LED retrofit kits.

Scenario Two Net Zero Ready - ASHP generally includes the replacement of the stone and siding facade with metal siding on prefab insulated panels, insulation on foundation walls, replacement of windows, replacement of roof with additional insulation, change HVAC to a VRF air source heat pump system, replacement of lighting with LED fixtures and new lighting controls, upgrade the service entrances, and add heat pump hot water heaters.

Scenario Two Net Zero Ready - ASHP generally includes the replacement of the stone and siding facade with metal siding on prefab insulated panels, insulation on foundation walls, replacement of windows, replacement of roof with additional insulation, change HVAC to a VRF ground source heat pump system, replacement of lighting with LED fixtures and new lighting controls, upgrade the service entrances, and add heat pump hot water heaters.

Scenario Four Net Zero generally includes all scope items from Scenario Three plus adds photovoltaics.

APPROACH

The construction costs for this report include all materials, labour, equipment, overheads, general conditions, plus markups and contractor's profit, for the retrofit options as presented in the project documents.

Preamble

APPROACH

The estimated **Construction Value** per Scenario is as follows:

Scenario One Minimum Code	$2,164,000.00
Scenario Two Net Zero Ready - ASHP	$3,745,000.00
Scenario Three Net Zero Ready - GSHP	$3,886,000.00
Scenario Four Net Zero	$4,223,000.00

Quantities were measured based on the Canadian Institute of Quantity Surveyors (CIQS) standards for Method of Measurement and presented in elemental format.

Pricing reflects competitive bids for every element of the work for a project of this type procured under an open market stipulated lump sum bid contract in Oakville, Ontario. Unit costs are developed and expressed as typical sub-contractor pricing and are inclusive of subcontractor's overheads and profits.

This estimate is an indication of the probable construction costs and is intended to represent fair market value of the construction costs. This estimate should not be considered a prediction of the lowest bid.

SPACE MEASUREMENT

The Gross Floor Area (GFA) was measured at 10,057 square feet (sf) based on the Canadian Institute of Quantity Surveyors (CIQS) Method of Measurement and the International Construction Measurement Standards (ICMS).

COST BASE

All costs are expressed in third quarter 2023 Canadian dollars (3Q2023).

All costs are shown exclusive of the 13% Harmonized Sales Tax (HST).

Preamble

ESCALATION

An Escalation Allowance is excluded from this report as no project schedule was provided.

Ontario is experiencing significant construction escalation currently with no signs of easing moving forward. It is recommended the Owner carry a Construction Escalation allowance of 10% per annum to the mid point of construction and should be monitored and reviewed continuously during the remaining design phase.

CONTINGENCIES

A Design Development Contingency Allowance of 10% is included in this report to allow for scope and budget adjustments during the remaining design phase.

A Construction Contingency Allowance of 10% is included in this report to allow for scope changes and possible change orders during the construction phase.

EXCLUSIONS

The following have been excluded from this cost report:

Premium for single source materials or equipment unless noted otherwise
Third party commissioning
Professional and design fees
Project management fees
Interim financing
Legal fees and surveys
Owners risk allowance
Moving costs or swing space
Furniture and equipment unless noted otherwise
Hazardous materials abatement
Rock excavation
Accelerated schedule premiums
Shift premiums or after-hours work

Preamble

EXCLUSIONS

Cash allowances
Testing and inspections
Cost premiums due to new tariffs placed on material and equipment
Cost premiums due to changes in COVID-19 protocols
Allowances for rebates

DOCUMENTATION

This Class D estimate is based on the following documentation:

Drawings/Specifications/Reports	**Dated:**
A101	July 26, 2022
A102	July 26, 2022
A103	July 26, 2022
Mechanical Outline Specification	January 4, 2023
Electrical Outline Specification	January 13, 2023
Structural Assessment	No Date
Retrofit Scenarios Details	No Date
Wall Panel Schematics	February 27, 2023

PROJECT COST SUMMARY

PROJECT:	RETROFIT 1565 OLD LAKESHORE ROAD	DATE:	JULY 20, 2023
LOCATION:	OAKVILLE, ONTARIO	CLASS:	D - FEASIBILITY
CLIENT:		FILE	13456
DESIGNER:	RSI PROJECTS		

Class D Estimate

DESCRIPTION		ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE		ELEMENTAL AMOUNT		NOTES
1	SCENARIO 1 CODE MINIMUM	10057	sf	$	215.00	$	2,164,000	
2	SCENARIO 2 NET ZERO READY, ASHP	10057	sf	$	372.00	$	3,745,000	
3	SCENARIO 3 NET ZERO READY, GSHP	10057	sf	$	386.00	$	3,886,000	
4	SCENARIO 4 NET ZERO	10057	sf	$	420.00	$	4,223,000	

ELEMENTAL COST SUMMARY

Scenario 1 Code Minimum

PROJECT:	RETROFIT 1565 OLD LAKESHORE ROAD	DATE:	JULY 20, 2023
LOCATION:	OAKVILLE, ONTARIO	CLASS:	D - FEASIBILITY
CLIENT:		FILE	13456
DESIGNER:	RSI PROJECTS	GFA:sf	10057

GROSS FLOOR AREA 10057 sf

ELEMENT	RATIO TO GFA	ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GFA	TOTAL AMOUNT	%
A SHELL						$ 137	$ 1,380,111	63.78
A1 SUBSTRUCTURE						$ -	$ -	0.00
A11 Foundations	1.000	10057	sf	$ -	$ -	$ -		0.00
A12 Basement Excavation	1.000	10057	sf	$ -	$ -	$ -		0.00
A2 STRUCTURE						$ -	$ -	0.00
A21 Lowest Floor Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A22 Upper Floor Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A23 Roof Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A3 EXTERIOR ENCLOSURE						$ 137	$ 1,380,111	63.78
A31 Walls Below Grade	1.000	10057	sf	$ -	$ -	$ -		0.00
A32 Walls Above Grade	0.248	2495	sf	$ 314.26	$ 784,178	$ 78		36.24
A33 Windows and Entrances	1.000	10057	sf	$ 12.79	$ 128,655	$ 13		5.95
A34 Roof Coverings	1.000	10057	sf	$ 41.98	$ 422,166	$ 42		19.51
A35 Projections	0.056	564	sf	$ -	$ 45,113	$ 4		2.08
B INTERIORS						$ -	$ -	0.00
B1 PARTITIONS AND DOORS						$ -	$ -	0.00
B11 Partitions	1.000	10057	sf	$ -	$ -	$ -		0.00
B12 Doors	1.000	10057	sf	$ -	$ -	$ -		0.00
B2 INTERIOR FINISHES						$ -	$ -	0.00
B21 Floor Finishes	1.000	10057	sf	$ -	$ -	$ -		0.00
B22 Ceiling Finishes	1.000	10057	sf	$ -	$ -	$ -		0.00
B23 Wall Finishes	1.000	10057	sf	$ -	$ -	$ -		0.00
B3 FITTINGS AND EQUIPMENT						$ -	$ -	0.00
B31 Fittings and Fixtures	1.000	10057	sf	$ -	$ -	$ -		0.00
B32 Equipment	1.000	10057	sf	$ -	$ -	$ -		0.00
B33 Conveying Systems	1.000	10057	sf	$ -	$ -	$ -		0.00
SERVICES						$ 3	$ 33,114	1.53
C1 MECHANICAL						$ 1	$ 13,000	0.60
C11 Plumbing and Drainage	1.000	10057	sf	$ -	$ -	$ -		0.00
C12 Fire Protection	1.000	10057	sf	$ -	$ -	$ -		0.00
C13 HVAC	1.000	10057	sf	$ -	$ -	$ -		0.00
C14 Controls	1.000	10057	sf	$ 1.29	$ 13,000	$ 1		0.60
C2 ELECTRICAL						$ 2	$ 20,114	0.93
C21 Services and Distribution	1.000	10057	sf	$ -	$ -	$ -		0.00
C22 Lighting, Devices and Heating	1.000	10057	sf	$ 2.00	$ 20,114	$ 2		0.93
C23 Systems and Ancillaries	1.000	10057	sf	$ -	$ -	$ -		0.00
NET BUILDING SUBTOTAL - LESS SITE						$ 141	$ 1,413,225	65.31
D SITE & ANCILLARY WORK						$ -	$ -	0.00
D1 SITEWORK						$ -	$ -	0.00
D11 Site Development	1.000	10057	sf	$ -	$ -	$ -		0.00
D12 Mechanical Site Services	1.000	10057	sf	$ -	$ -	$ -		0.00
D13 Electrical Site Services	1.000	10057	sf	$ -	$ -	$ -		0.00
D2 ANCILLARY WORK						$ -	$ -	0.00
D21 Demolition	1.000	10057	sf	$ -	$ -	$ -		0.00
D22 Alterations	1.000	10057	sf	$ -	$ -	$ -		0.00
NET BUILDING SUBTOTAL - INCLUDING SITE						$ 141	$ 1,413,225	65.31
Z GENERAL REQUIREMENTS AND ALLOWANCES						$ 75	$ 749,928	34.65
Z1 GENERAL REQUIREMENTS AND FEES						$ 37	$ 374,505	17.31
Z11 General Requirements and Overheads		15%			$ 211,984	$ 21		9.80
Z12 Contractors Profit		10%			$ 162,521	$ 16		7.51
Z2 ALLOWANCES						$ 37	$ 375,423	17.35
Z21 Design Allowance		10%			$ 178,773	$ 18		8.26
Z22 Escalation Allowance TBD		0%			$ -	$ -		0.00
Z23 Construction Allowance		10%			$ 196,650	$ 20		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)				$215 per sf			$ 2,164,000	100.00

Element	Quantities		Unit Rates	Sub-totals
EXTERIOR ENCLOSURE				
A32 Walls Above Grade				
▪ remove stone facade	2495	sf	$ 10.00	$ 24,953
▪ remove siding facade	7121	sf	$ 3.00	$ 21,364
▪ structural upgrades including base angle and mid girts	33000	lbs	$ 4.00	$ 132,000
▪ supply and install prefab r11 insulated wall panels	9617	sf	$ 25.00	$ 240,421
▪ supply and install prefinished metal siding	9617	sf	$ 38.00	$ 365,439
A32 Walls Above Grade Total	**2495**	**sf**	**$ 314.26**	**$ 784,178**
A33 Windows and Entrances				
▪ replace windows with triple pane	1029	sf	$ 125.00	$ 128,655
A33 Windows and Entrances Total	**10057**	**sf**	**$ 12.79**	**$ 128,655**
A34 Roof Coverings				
▪ remove existing roof finish	10057	sf	$ 3.00	$ 30,171
▪ new metal or mod bit roof finish with 4" XPS insulation	10057	sf	$ 35.00	$ 351,995
▪ allowance for removing, reinstalling mechanical	1	sum	$ 40,000.00	$ 40,000
A34 Roof Coverings Total	**10057**	**sf**	**$ 41.98**	**$ 422,166**
A35 Projections				
▪ soffit replacement	564	sf	$ 80.00	$ 45,113
▪ canopies - no change	1	sum	$ -	$ -
A35 Projections Total	**564**	**sf**	**$ 80.00**	**$ 45,113**
MECHANICAL				
C14 Controls				
▪ new CO2 sensors, air CO2 sensors and heat relays	26	no	$ 500.00	$ 13,000
C14 Controls Total	**10057**	**sf**	**$ 1.29**	**$ 13,000**
ELECTRICAL				
C22 Lighting, Devices and Heating				
▪ install LED retrofit kits to all existing lights	10057	sf	$ 2.00	$ 20,114
C22 Lighting and Heating Total	**10057**	**sf**	**$ 2.00**	**$ 20,114**
GENERAL REQUIREMENTS AND FEES				
Z11 General Requirements and Overheads				
▪ contractor's overheads			15.00%	$ 211,984
Z11 General Requirements and Overheads Total	**10057**	**sf**	**$ 21.08**	**$ 211,984**
Z12 Contractor's Profit				
▪ contractor's profit			10.00%	$ 162,521
Z12 Contractor's Profit Total	**10057**	**sf**	**$ 16.16**	**$ 162,521**

Element	Quantities		Unit Rates		Sub-totals	
ALLOWANCES						
Z21 Design Allowance						
▪ design development contingency				10.00%	$	178,773
Z21 Design Allowance Total	10057	sf	$	17.78	$	178,773
Z23 Construction Contingency						
▪ construction contingency				10.00%	$	196,650
Z23 Construction Contingency	10057	sf	$	19.55	$	196,650

ELEMENTAL COST SUMMARY

PROJECT: RETROFIT 1565 OLD LAKESHORE ROAD
LOCATION: OAKVILLE, ONTARIO
CLIENT:
DESIGNER: RSI PROJECTS

Scenario 2 NZR - ASHP

DATE: JULY 20, 2023
CLASS: D - FEASIBILITY
FILE 13456
GFA:sf 10057

GROSS FLOOR AREA 10057 sf

ELEMENT			RATIO TO GFA	ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GFA	TOTAL AMOUNT	%
A	SHELL							$ 150	$ 1,511,748	40.37
	A1	SUBSTRUCTURE						$ -	$ -	0.00
	A11	Foundations	1.000	10057	sf	$ -	$ -	$ -		0.00
	A12	Basement Excavation	1.000	10057	sf	$ -	$ -	$ -		0.00
	A2	STRUCTURE						$ -	$ -	0.00
	A21	Lowest Floor Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
	A22	Upper Floor Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
	A23	Roof Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
	A3	EXTERIOR ENCLOSURE						$ 150	$ 1,511,748	40.37
	A31	Walls Below Grade	1.000	10057	sf	$ 4.13	$ 41,564	$ 4		1.11
	A32	Walls Above Grade	0.248	2495	sf	$ 318.11	$ 793,795	$ 79		21.20
	A33	Windows and Entrances	1.000	10057	sf	$ 12.79	$ 128,655	$ 13		3.44
	A34	Roof Coverings	1.000	10057	sf	$ 49.98	$ 502,621	$ 50		13.42
	A35	Projections	0.056	564	sf	$ -	$ 45,113	$ 4		1.20
B	INTERIORS							$ 5	$ 50,285	1.34
	B1	PARTITIONS AND DOORS						$ -	$ -	0.00
	B11	Partitions	1.000	10057	sf	$ -	$ -	$ -		0.00
	B12	Doors	1.000	10057	sf	$ -	$ -	$ -		0.00
	B2	INTERIOR FINISHES						$ 5	$ 50,285	1.34
	B21	Floor Finishes	1.000	10057	sf	$ -	$ -	$ -		0.00
	B22	Ceiling Finishes	1.000	10057	sf	$ 2.50	$ 25,142	$ 3		0.67
	B23	Wall Finishes	1.000	10057	sf	$ 2.50	$ 25,142	$ 3		0.67
	B3	FITTINGS AND EQUIPMENT						$ -	$ -	0.00
	B31	Fittings and Fixtures	1.000	10057	sf	$ -	$ -	$ -		0.00
	B32	Equipment	1.000	10057	sf	$ -	$ -	$ -		0.00
	B33	Conveying Systems	1.000	10057	sf	$ -	$ -	$ -		0.00
	SERVICES							$ 88	$ 884,526	23.62
	C1	MECHANICAL						$ 66	$ 663,899	17.73
	C11	Plumbing and Drainage	1.000	10057	sf	$ 1.59	$ 16,000	$ 2		0.43
	C12	Fire Protection	1.000	10057	sf	$ -	$ -	$ -		0.00
	C13	HVAC	1.000	10057	sf	$ 57.42	$ 577,500	$ 57		15.42
	C14	Controls	1.000	10057	sf	$ 7.00	$ 70,399	$ 7		1.88
	C2	ELECTRICAL						$ 22	$ 220,627	5.89
	C21	Services and Distribution	1.000	10057	sf	$ 10.94	$ 110,000	$ 11		2.94
	C22	Lighting, Devices and Heating	1.000	10057	sf	$ 11.00	$ 110,627	$ 11		2.95
	C23	Systems and Ancillaries	1.000	10057	sf	$ -	$ -	$ -		0.00
NET BUILDING SUBTOTAL - LESS SITE								$ 243	$ 2,446,559	65.33
D	SITE & ANCILLARY WORK							$ -	$ -	0.00
	D1	SITEWORK						$ -	$ -	0.00
	D11	Site Development	1.000	10057	sf	$ -	$ -	$ -		0.00
	D12	Mechanical Site Services	1.000	10057	sf	$ -	$ -	$ -		0.00
	D13	Electrical Site Services	1.000	10057	sf	$ -	$ -	$ -		0.00
	D2	ANCILLARY WORK						$ -	$ -	0.00
	D21	Demolition	1.000	10057	sf	$ -	$ -	$ -		0.00
	D22	Alterations	1.000	10057	sf	$ -	$ -	$ -		0.00
NET BUILDING SUBTOTAL - INCLUDING SITE								$ 243	$ 2,446,559	65.33
Z	GENERAL REQUIREMENTS AND ALLOWANCES							$ 129	$ 1,298,266	34.67
	Z1	GENERAL REQUIREMENTS AND FEES						$ 64	$ 648,338	17.31
	Z11	General Requirements and Overheads		15%			$ 366,984	$ 36		9.80
	Z12	Contractors Profit		10%			$ 281,354	$ 28		7.51
	Z2	ALLOWANCES						$ 65	$ 649,928	17.35
	Z21	Design Allowance		10%			$ 309,490	$ 31		8.26
	Z22	Escalation Allowance TBD		0%			$ -	$ -		0.00
	Z23	Construction Allowance		10%			$ 340,439	$ 34		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)						$372 per sf			$ 3,745,000	100.00

Element	Quantities		Unit Rates		Sub-totals	
EXTERIOR ENCLOSURE						
A31 Walls Below Grade						
▪ remove concrete sidewalk and dispose	606	sf	$	3.00	$	1,819
▪ remove asphalt paving and dispose	86	sf	$	5.00	$	430
▪ remove landscaped areas and dispose	1274	sf	$	2.00	$	2,549
▪ excavate to 2 feet below grade	109	cyd	$	40.00	$	4,367
▪ new 2" EPS fin insulation	984	sf	$	3.50	$	3,442
▪ cement board	984	sf	$	5.00	$	4,918
▪ backfill to subgrade	109	cyd	$	50.00	$	5,458
▪ reinstate concrete sidewalks	606	sf	$	18.00	$	10,917
▪ reinstate asphalt paving	86	sf	$	15.00	$	1,291
▪ reinstate landscaping	1274	sf	$	5.00	$	6,372
A31 Walls Below Grade Total	10057	sf	$	4.13	$	41,564
A32 Walls Above Grade						
▪ remove stone facade	2495	sf	$	10.00	$	24,953
▪ remove siding facade	7121	sf	$	3.00	$	21,364
▪ structural upgrades including base angle and mid girts	33000	lbs	$	4.00	$	132,000
▪ supply and install prefab r16 insulated wall panels	9617	sf	$	26.00	$	250,037
▪ supply and install prefinished metal siding	9617	sf	$	38.00	$	365,439
A32 Walls Above Grade Total	2495	sf	$	318.11	$	793,795
A33 Windows and Entrances						
▪ replace windows with triple pane	1029	sf	$	125.00	$	128,655
A33 Windows and Entrances Total	10057	sf	$	12.79	$	128,655
A34 Roof Coverings						
▪ remove existing roof finish	10057	sf	$	3.00	$	30,171
▪ new metal or mod bit roof finish with 12" XPS insulation	10057	sf	$	43.00	$	432,450
▪ allowance for removing, reinstalling mechanical	1	sum	$	40,000.00	$	40,000
A34 Roof Coverings Total	10057	sf	$	49.98	$	502,621
A35 Projections						
▪ soffit replacement	564	sf	$	80.00	$	45,113
▪ canopies - no change	1	sum	$	-	$	-
A35 Projections Total	564	sf	$	80.00	$	45,113
FINISHES						
B22 Ceiling Finishes						
▪ cut and patch ceilings for new mechanical/electrical	10057	sf	$	2.50	$	25,142
B22 Ceiling Finishes Total	10057	sf	$	2.50	$	25,142
B23 Wall Finishes						
▪ cut and patch walls for new mechanical/electrical	10057	sf	$	2.50	$	25,142

Element	Quantities		Unit Rates		Sub-totals	
B23 Wall Finishes Total	10057	sf	$	2.50	$	25,142
MECHANICAL						
C11 Plumbing and Drainage						
▪ new 80gal HP hot water tanks	4	no	$	4,000.00	$	16,000
C11 Plumbing and Drainage Total	10057	sf	$	1.59	$	16,000
C13 Heating, Ventilation, Air Conditioning						
▪ VRF ASHP condensing units - 10 tons	2	no	$	60,000.00	$	120,000
▪ VRF fancoils	9	no	$	8,500.00	$	76,500
▪ refrigerant piping, branch controllers	1000	lf	$	100.00	$	100,000
▪ VAVs	15	no	$	3,000.00	$	45,000
▪ ERV 950cfm	1	no	$	28,000.00	$	28,000
▪ ERV 750cfm	1	no	$	28,000.00	$	28,000
▪ new ERV ductwork	10000	lbs	$	18.00	$	180,000
C13 Heating, Ventilation, Air Conditioning Total	10057	sf	$	57.42	$	577,500
C14 Controls						
▪ building automated controls - connect to existing system	10057	sf	$	7.00	$	70,399
C14 Controls Total	10057	sf	$	7.00	$	70,399
ELECTRICAL						
C21 Services and Distribution						
▪ replace main entrance, 400A switchgear	1	sum	$	25,000.00	$	25,000
▪ new feeders	1	sum	$	50,000.00	$	50,000
▪ new panel, transformer for HVAC	1	sum	$	20,000.00	$	20,000
▪ new disconnects, mechanical connections	1	sum	$	15,000.00	$	15,000
C21 Services and Distribution Total	10057	sf	$	10.94	$	110,000
C22 Lighting, Devices and Heating						
▪ new LED light fixtures, or retrofit kits	10057	sf	$	8.00	$	80,456
▪ lighting controls	10057	sf	$	3.00	$	30,171
C22 Lighting and Heating Total	10057	sf	$	11.00	$	110,627
GENERAL REQUIREMENTS AND FEES						
Z11 General Requirements and Overheads						
▪ contractor's overheads				15.00%	$	366,984
Z11 General Requirements and Overheads Total	10057	sf	$	36.49	$	366,984
Z12 Contractor's Profit						
▪ contractor's profit				10.00%	$	281,354
Z12 Contractor's Profit Total	10057	sf	$	27.98	$	281,354
ALLOWANCES						

Element	Quantities		Unit Rates		Sub-totals
Z21 Design Allowance					
▪ design development contingency				10.00%	$ 309,490
Z21 Design Allowance Total	10057	sf	$	30.77	$ 309,490
Z23 Construction Contingency					
▪ construction contingency				10.00%	$ 340,439
Z23 Construction Contingency	10057	sf	$	33.85	$ 340,439

ELEMENTAL COST SUMMARY

Scenario 3 NZR - GSHP

PROJECT:	RETROFIT 1565 OLD LAKESHORE ROAD	DATE:	JULY 20, 2023
LOCATION:	OAKVILLE, ONTARIO	CLASS:	D - FEASIBILITY
CLIENT:		FILE	13456
DESIGNER:	RSI PROJECTS	GFA:sf	10057

GROSS FLOOR AREA 10057 sf

ELEMENT		RATIO TO GFA	ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GFA	TOTAL AMOUNT	%
A	SHELL						$ 150	$ 1,511,748	38.90
A1	SUBSTRUCTURE						$ -	$ -	0.00
A11	Foundations	1.000	10057	sf	$ -	$ -	$ -		0.00
A12	Basement Excavation	1.000	10057	sf	$ -	$ -	$ -		0.00
A2	STRUCTURE						$ -	$ -	0.00
A21	Lowest Floor Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A22	Upper Floor Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A23	Roof Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A3	EXTERIOR ENCLOSURE						$ 150	$ 1,511,748	38.90
A31	Walls Below Grade	1.000	10057	sf	$ 4.13	$ 41,564	$ 4		1.07
A32	Walls Above Grade	0.248	2495	sf	$ 318.11	$ 793,795	$ 79		20.43
A33	Windows and Entrances	1.000	10057	sf	$ 12.79	$ 128,655	$ 13		3.31
A34	Roof Coverings	1.000	10057	sf	$ 49.98	$ 502,621	$ 50		12.93
A35	Projections	0.056	564	sf	$ -	$ 45,113	$ 4		1.16
B	INTERIORS						$ 5	$ 50,285	1.29
B1	PARTITIONS AND DOORS						$ -	$ -	0.00
B11	Partitions	1.000	10057	sf	$ -	$ -	$ -		0.00
B12	Doors	1.000	10057	sf	$ -	$ -	$ -		0.00
B2	INTERIOR FINISHES						$ 5	$ 50,285	1.29
B21	Floor Finishes	1.000	10057	sf	$ -	$ -	$ -		0.00
B22	Ceiling Finishes	1.000	10057	sf	$ 2.50	$ 25,142	$ 3		0.65
B23	Wall Finishes	1.000	10057	sf	$ 2.50	$ 25,142	$ 3		0.65
B3	FITTINGS AND EQUIPMENT						$ -	$ -	0.00
B31	Fittings and Fixtures	1.000	10057	sf	$ -	$ -	$ -		0.00
B32	Equipment	1.000	10057	sf	$ -	$ -	$ -		0.00
B33	Conveying Systems	1.000	10057	sf	$ -	$ -	$ -		0.00
	SERVICES						$ 97	$ 976,526	25.13
C1	MECHANICAL						$ 75	$ 755,899	19.45
C11	Plumbing and Drainage	1.000	10057	sf	$ 0.40	$ 4,000	$ 0		0.10
C12	Fire Protection	1.000	10057	sf	$ -	$ -	$ -		0.00
C13	HVAC	1.000	10057	sf	$ 67.76	$ 681,500	$ 68		17.54
C14	Controls	1.000	10057	sf	$ 7.00	$ 70,399	$ 7		1.81
C2	ELECTRICAL						$ 22	$ 220,627	5.68
C21	Services and Distribution	1.000	10057	sf	$ 10.94	$ 110,000	$ 11		2.83
C22	Lighting, Devices and Heating	1.000	10057	sf	$ 11.00	$ 110,627	$ 11		2.85
C23	Systems and Ancillaries	1.000	10057	sf	$ -	$ -	$ -		0.00
NET BUILDING SUBTOTAL - LESS SITE							$ 252	$ 2,538,559	65.33
D	SITE & ANCILLARY WORK						$ -	$ -	0.00
D1	SITEWORK						$ -	$ -	0.00
D11	Site Development	1.000	10057	sf	$ -	$ -	$ -		0.00
D12	Mechanical Site Services	1.000	10057	sf	$ -	$ -	$ -		0.00
D13	Electrical Site Services	1.000	10057	sf	$ -	$ -	$ -		0.00
D2	ANCILLARY WORK						$ -	$ -	0.00
D21	Demolition	1.000	10057	sf	$ -	$ -	$ -		0.00
D22	Alterations	1.000	10057	sf	$ -	$ -	$ -		0.00
NET BUILDING SUBTOTAL - INCLUDING SITE							$ 252	$ 2,538,559	65.33
Z	GENERAL REQUIREMENTS AND ALLOWANCES						$ 134	$ 1,347,086	34.67
Z1	GENERAL REQUIREMENTS AND FEES						$ 67	$ 672,718	17.31
Z11	General Requirements and Overheads		15%			$ 380,784	$ 38		9.80
Z12	Contractors Profit		10%			$ 291,934	$ 29		7.51
Z2	ALLOWANCES						$ 67	$ 674,368	17.35
Z21	Design Allowance		10%			$ 321,128	$ 32		8.26
Z22	Escalation Allowance TBD		0%			$ -	$ -		0.00
Z23	Construction Allowance		10%			$ 353,240	$ 35		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)					$386 per sf			$ 3,886,000	100.00

Element	Quantities		Unit Rates		Sub-totals	
EXTERIOR ENCLOSURE						
A31 Walls Below Grade						
▪ remove concrete sidewalk and dispose	606	sf	$	3.00	$	1,819
▪ remove asphalt paving and dispose	86	sf	$	5.00	$	430
▪ remove landscaped areas and dispose	1274	sf	$	2.00	$	2,549
▪ excavate to 2 feet below grade	109	cyd	$	40.00	$	4,367
▪ new 2" EPS fin insulation	984	sf	$	3.50	$	3,442
▪ cement board	984	sf	$	5.00	$	4,918
▪ backfill to subgrade	109	cyd	$	50.00	$	5,458
▪ reinstate concrete sidewalks	606	sf	$	18.00	$	10,917
▪ reinstate asphalt paving	86	sf	$	15.00	$	1,291
▪ reinstate landscaping	1274	sf	$	5.00	$	6,372
A31 Walls Below Grade Total	10057	sf	$	4.13	$	41,564
A32 Walls Above Grade						
▪ remove stone facade	2495	sf	$	10.00	$	24,953
▪ remove siding facade	7121	sf	$	3.00	$	21,364
▪ structural upgrades including base angle and mid girts	33000	lbs	$	4.00	$	132,000
▪ supply and install prefab r16 insulated wall panels	9617	sf	$	26.00	$	250,037
▪ supply and install prefinished metal siding	9617	sf	$	38.00	$	365,439
A32 Walls Above Grade Total	2495	sf	$	318.11	$	793,795
A33 Windows and Entrances						
▪ replace windows with triple pane	1029	sf	$	125.00	$	128,655
A33 Windows and Entrances Total	10057	sf	$	12.79	$	128,655
A34 Roof Coverings						
▪ remove existing roof finish	10057	sf	$	3.00	$	30,171
▪ new metal or mod bit roof finish with 12" XPS insulation	10057	sf	$	43.00	$	432,450
▪ allowance for removing, reinstalling mechanical	1	sum	$	40,000.00	$	40,000
A34 Roof Coverings Total	10057	sf	$	49.98	$	502,621
A35 Projections						
▪ soffit replacement	564	sf	$	80.00	$	45,113
▪ canopies - no change	1	sum	$	-	$	-
A35 Projections Total	564	sf	$	80.00	$	45,113
FINISHES						
B22 Ceiling Finishes						
▪ cut and patch ceilings for new mechanical/electrical	10057	sf	$	2.50	$	25,142
B22 Ceiling Finishes Total	10057	sf	$	2.50	$	25,142
B23 Wall Finishes						
▪ cut and patch walls for new mechanical/electrical	10057	sf	$	2.50	$	25,142

Element	Quantities		Unit Rates		Sub-totals	
B23 Wall Finishes Total	10057	sf	$	2.50	$	25,142
MECHANICAL						
C11 Plumbing and Drainage						
▪ new 80gal HP hot water tanks	1	no	$	4,000.00	$	4,000
C11 Plumbing and Drainage Total	10057	sf	$	0.40	$	4,000
C13 Heating, Ventilation, Air Conditioning						
▪ geothermal wells, testing	3	no	$	18,000.00	$	54,000
▪ gshp piping, trenching, backfill, reinstatement	1	sum	$	40,000.00	$	40,000
▪ gshp circulation pumps, interior piping, HX	1	sum	$	40,000.00	$	40,000
▪ VRF condensing units - 10 tons	2	no	$	45,000.00	$	90,000
▪ VRF fancoils	9	no	$	8,500.00	$	76,500
▪ refrigerant piping, branch controllers	1000	lf	$	100.00	$	100,000
▪ VAVs	15	no	$	3,000.00	$	45,000
▪ ERV 950cfm	1	no	$	28,000.00	$	28,000
▪ ERV 750cfm	1	no	$	28,000.00	$	28,000
▪ new ERV ductwork	10000	lbs	$	18.00	$	180,000
C13 Heating, Ventilation, Air Conditioning Total	10057	sf	$	67.76	$	681,500
C14 Controls						
▪ building automated controls - connect to existing system	10057	sf	$	7.00	$	70,399
C14 Controls Total	10057	sf	$	7.00	$	70,399
ELECTRICAL						
C21 Services and Distribution						
▪ replace main entrance, 400A switchgear	1	sum	$	25,000.00	$	25,000
▪ new feeders	1	sum	$	50,000.00	$	50,000
▪ new panel, transformer for HVAC	1	sum	$	20,000.00	$	20,000
▪ new disconnects, mechanical connections	1	sum	$	15,000.00	$	15,000
C21 Services and Distribution Total	10057	sf	$	10.94	$	110,000
C22 Lighting, Devices and Heating						
▪ new LED light fixtures, or retrofit kits	10057	sf	$	8.00	$	80,456
▪ lighting controls	10057	sf	$	3.00	$	30,171
C22 Lighting and Heating Total	10057	sf	$	11.00	$	110,627
GENERAL REQUIREMENTS AND FEES						
Z11 General Requirements and Overheads						
▪ contractor's overheads				15.00%	$	380,784
Z11 General Requirements and Overheads Total	10057	sf	$	37.86	$	380,784
Z12 Contractor's Profit						
▪ contractor's profit				10.00%	$	291,934

Element	Quantities		Unit Rates		Sub-totals	
Z12 Contractor's Profit Total	10057	sf	$	29.03	$	291,934
ALLOWANCES						
Z21 Design Allowance						
▪ design development contingency				10.00%	$	321,128
Z21 Design Allowance Total	10057	sf	$	31.93	$	321,128
Z23 Construction Contingency						
▪ construction contingency				10.00%	$	353,240
Z23 Construction Contingency	10057	sf	$	35.12	$	353,240

ELEMENTAL COST SUMMARY

PROJECT:	RETROFIT 1565 OLD LAKESHORE ROAD	DATE:	JULY 20, 2023
LOCATION:	OAKVILLE, ONTARIO	CLASS:	D - FEASIBILITY
CLIENT:		FILE	13456
DESIGNER:	RSI PROJECTS	GFA:sf	10057

Scenario 4 Net Zero

GROSS FLOOR AREA 10057 sf

ELEMENT	RATIO TO GFA	ELEMENTAL QUANTITY		ELEMENTAL UNIT RATE	ELEMENTAL AMOUNT	RATE PER GFA	TOTAL AMOUNT	%
A SHELL						$ 150	$ 1,511,748	35.80
A1 SUBSTRUCTURE						$ -	$ -	0.00
A11 Foundations	1.000	10057	sf	$ -	$ -	$ -		0.00
A12 Basement Excavation	1.000	10057	sf	$ -	$ -	$ -		0.00
A2 STRUCTURE						$ -	$ -	0.00
A21 Lowest Floor Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A22 Upper Floor Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A23 Roof Construction	1.000	10057	sf	$ -	$ -	$ -		0.00
A3 EXTERIOR ENCLOSURE						$ 150	$ 1,511,748	35.80
A31 Walls Below Grade	1.000	10057	sf	$ 4.13	$ 41,564	$ 4		0.98
A32 Walls Above Grade	0.248	2495	sf	$ 318.11	$ 793,795	$ 79		18.80
A33 Windows and Entrances	1.000	10057	sf	$ 12.79	$ 128,655	$ 13		3.05
A34 Roof Coverings	1.000	10057	sf	$ 49.98	$ 502,621	$ 50		11.90
A35 Projections	0.056	564	sf	$ -	$ 45,113	$ 4		1.07
B INTERIORS						$ 5	$ 50,285	1.19
B1 PARTITIONS AND DOORS						$ -	$ -	0.00
B11 Partitions	1.000	10057	sf	$ -	$ -	$ -		0.00
B12 Doors	1.000	10057	sf	$ -	$ -	$ -		0.00
B2 INTERIOR FINISHES						$ 5	$ 50,285	1.19
B21 Floor Finishes	1.000	10057	sf	$ -	$ -	$ -		0.00
B22 Ceiling Finishes	1.000	10057	sf	$ 2.50	$ 25,142	$ 3		0.60
B23 Wall Finishes	1.000	10057	sf	$ 2.50	$ 25,142	$ 3		0.60
B3 FITTINGS AND EQUIPMENT						$ -	$ -	0.00
B31 Fittings and Fixtures	1.000	10057	sf	$ -	$ -	$ -		0.00
B32 Equipment	1.000	10057	sf	$ -	$ -	$ -		0.00
B33 Conveying Systems	1.000	10057	sf	$ -	$ -	$ -		0.00
SERVICES						$ 119	$ 1,196,526	28.33
C1 MECHANICAL						$ 75	$ 755,899	17.90
C11 Plumbing and Drainage	1.000	10057	sf	$ 0.40	$ 4,000	$ 0		0.09
C12 Fire Protection	1.000	10057	sf	$ -	$ -	$ -		0.00
C13 HVAC	1.000	10057	sf	$ 67.76	$ 681,500	$ 68		16.14
C14 Controls	1.000	10057	sf	$ 7.00	$ 70,399	$ 7		1.67
C2 ELECTRICAL						$ 44	$ 440,627	10.43
C21 Services and Distribution	1.000	10057	sf	$ 32.81	$ 330,000	$ 33		7.81
C22 Lighting, Devices and Heating	1.000	10057	sf	$ 11.00	$ 110,627	$ 11		2.62
C23 Systems and Ancillaries	1.000	10057	sf	$ -	$ -	$ -		0.00
NET BUILDING SUBTOTAL - LESS SITE						$ 274	$ 2,758,559	65.32
D SITE & ANCILLARY WORK						$ -	$ -	0.00
D1 SITEWORK						$ -	$ -	0.00
D11 Site Development	1.000	10057	sf	$ -	$ -	$ -		0.00
D12 Mechanical Site Services	1.000	10057	sf	$ -	$ -	$ -		0.00
D13 Electrical Site Services	1.000	10057	sf	$ -	$ -	$ -		0.00
D2 ANCILLARY WORK						$ -	$ -	0.00
D21 Demolition	1.000	10057	sf	$ -	$ -	$ -		0.00
D22 Alterations	1.000	10057	sf	$ -	$ -	$ -		0.00
NET BUILDING SUBTOTAL - INCLUDING SITE						$ 274	$ 2,758,559	65.32
Z GENERAL REQUIREMENTS AND ALLOWANCES						$ 146	$ 1,463,829	34.66
Z1 GENERAL REQUIREMENTS AND FEES						$ 73	$ 731,018	17.31
Z11 General Requirements and Overheads		15%			$ 413,784	$ 41		9.80
Z12 Contractors Profit		10%			$ 317,234	$ 32		7.51
Z2 ALLOWANCES						$ 73	$ 732,811	17.35
Z21 Design Allowance		10%			$ 348,958	$ 35		8.26
Z22 Escalation Allowance TBD		0%			$ -	$ -		0.00
Z23 Construction Allowance		10%			$ 383,853	$ 38		9.09
TOTAL CONSTRUCTION COST (HST EXTRA)				$420 per sf			$ 4,223,000	100.00

Element	Quantities			Unit Rates		Sub-totals
EXTERIOR ENCLOSURE						
A31 Walls Below Grade						
▪ remove concrete sidewalk and dispose	606	sf	$	3.00	$	1,819
▪ remove asphalt paving and dispose	86	sf	$	5.00	$	430
▪ remove landscaped areas and dispose	1274	sf	$	2.00	$	2,549
▪ excavate to 2 feet below grade	109	cyd	$	40.00	$	4,367
▪ new 2" EPS fin insulation	984	sf	$	3.50	$	3,442
▪ cement board	984	sf	$	5.00	$	4,918
▪ backfill to subgrade	109	cyd	$	50.00	$	5,458
▪ reinstate concrete sidewalks	606	sf	$	18.00	$	10,917
▪ reinstate asphalt paving	86	sf	$	15.00	$	1,291
▪ reinstate landscaping	1274	sf	$	5.00	$	6,372
A31 Walls Below Grade Total	10057	sf	$	4.13	$	41,564
A32 Walls Above Grade						
▪ remove stone facade	2495	sf	$	10.00	$	24,953
▪ remove siding facade	7121	sf	$	3.00	$	21,364
▪ structural upgrades including base angle and mid girts	33000	lbs	$	4.00	$	132,000
▪ supply and install prefab r16 insulated wall panels	9617	sf	$	26.00	$	250,037
▪ supply and install prefinished metal siding	9617	sf	$	38.00	$	365,439
A32 Walls Above Grade Total	2495	sf	$	318.11	$	793,795
A33 Windows and Entrances						
▪ replace windows with triple pane	1029	sf	$	125.00	$	128,655
A33 Windows and Entrances Total	10057	sf	$	12.79	$	128,655
A34 Roof Coverings						
▪ remove existing roof finish	10057	sf	$	3.00	$	30,171
▪ new metal or mod bit roof finish with 12" XPS insulation	10057	sf	$	43.00	$	432,450
▪ allowance for removing, reinstalling mechanical	1	sum	$	40,000.00	$	40,000
A34 Roof Coverings Total	10057	sf	$	49.98	$	502,621
A35 Projections						
▪ soffit replacement	564	sf	$	80.00	$	45,113
▪ canopies - no change	1	sum	$	-	$	-
A35 Projections Total	564	sf	$	80.00	$	45,113
FINISHES						
B22 Ceiling Finishes						
▪ cut and patch ceilings for new mechanical/electrical	10057	sf	$	2.50	$	25,142
B22 Ceiling Finishes Total	10057	sf	$	2.50	$	25,142
B23 Wall Finishes						
▪ cut and patch walls for new mechanical/electrical	10057	sf	$	2.50	$	25,142

Element	Quantities			Unit Rates		Sub-totals
B23 Wall Finishes Total	**10057**	**sf**	**$**	**2.50**	**$**	**25,142**
MECHANICAL						
C11 Plumbing and Drainage						
▪ new 80gal HP hot water tanks	1	no	$	4,000.00	$	4,000
C11 Plumbing and Drainage Total	**10057**	**sf**	**$**	**0.40**	**$**	**4,000**
C13 Heating, Ventilation, Air Conditioning						
▪ geothermal wells, testing	3	no	$	18,000.00	$	54,000
▪ gshp piping, trenching, backfill, reinstatement	1	sum	$	40,000.00	$	40,000
▪ gshp circulation pumps, interior piping, HX	1	sum	$	40,000.00	$	40,000
▪ VRF condensing units - 10 tons	2	no	$	45,000.00	$	90,000
▪ VRF fancoils	9	no	$	8,500.00	$	76,500
▪ refrigerant piping, branch controllers	1000	lf	$	100.00	$	100,000
▪ VAVs	15	no	$	3,000.00	$	45,000
▪ ERV 950cfm	1	no	$	28,000.00	$	28,000
▪ ERV 750cfm	1	no	$	28,000.00	$	28,000
▪ new ERV ductwork	10000	lbs	$	18.00	$	180,000
C13 Heating, Ventilation, Air Conditioning Total	**10057**	**sf**	**$**	**67.76**	**$**	**681,500**
C14 Controls						
▪ building automated controls - connect to existing system	10057	sf	$	7.00	$	70,399
C14 Controls Total	**10057**	**sf**	**$**	**7.00**	**$**	**70,399**
ELECTRICAL						
C21 Services and Distribution						
▪ replace main entrance, 400A switchgear	1	sum	$	25,000.00	$	25,000
▪ new feeders	1	sum	$	50,000.00	$	50,000
▪ new panel, transformer for HVAC	1	sum	$	20,000.00	$	20,000
▪ new disconnects, mechanical connections	1	sum	$	15,000.00	$	15,000
▪ photovoltaic system complete with racking, inverters	55	kW	$	4,000.00	$	220,000
C21 Services and Distribution Total	**10057**	**sf**	**$**	**32.81**	**$**	**330,000**
C22 Lighting, Devices and Heating						
▪ new LED light fixtures, or retrofit kits	10057	sf	$	8.00	$	80,456
▪ lighting controls	10057	sf	$	3.00	$	30,171
C22 Lighting and Heating Total	**10057**	**sf**	**$**	**11.00**	**$**	**110,627**
GENERAL REQUIREMENTS AND FEES						
Z11 General Requirements and Overheads						
▪ contractor's overheads				15.00%	$	413,784
Z11 General Requirements and Overheads Total	**10057**	**sf**	**$**	**41.14**	**$**	**413,784**
Z12 Contractor's Profit						
▪ contractor's profit				10.00%	$	317,234

Element	Quantities		Unit Rates		Sub-totals
Z12 Contractor's Profit Total	10057	sf	$ 31.54	$	317,234
ALLOWANCES					
Z21 Design Allowance					
▪ design development contingency			10.00%	$	348,958
Z21 Design Allowance Total	10057	sf	$ 34.70	$	348,958
Z23 Construction Contingency					
▪ construction contingency			10.00%	$	383,853
Z23 Construction Contingency	10057	sf	$ 38.17	$	383,853

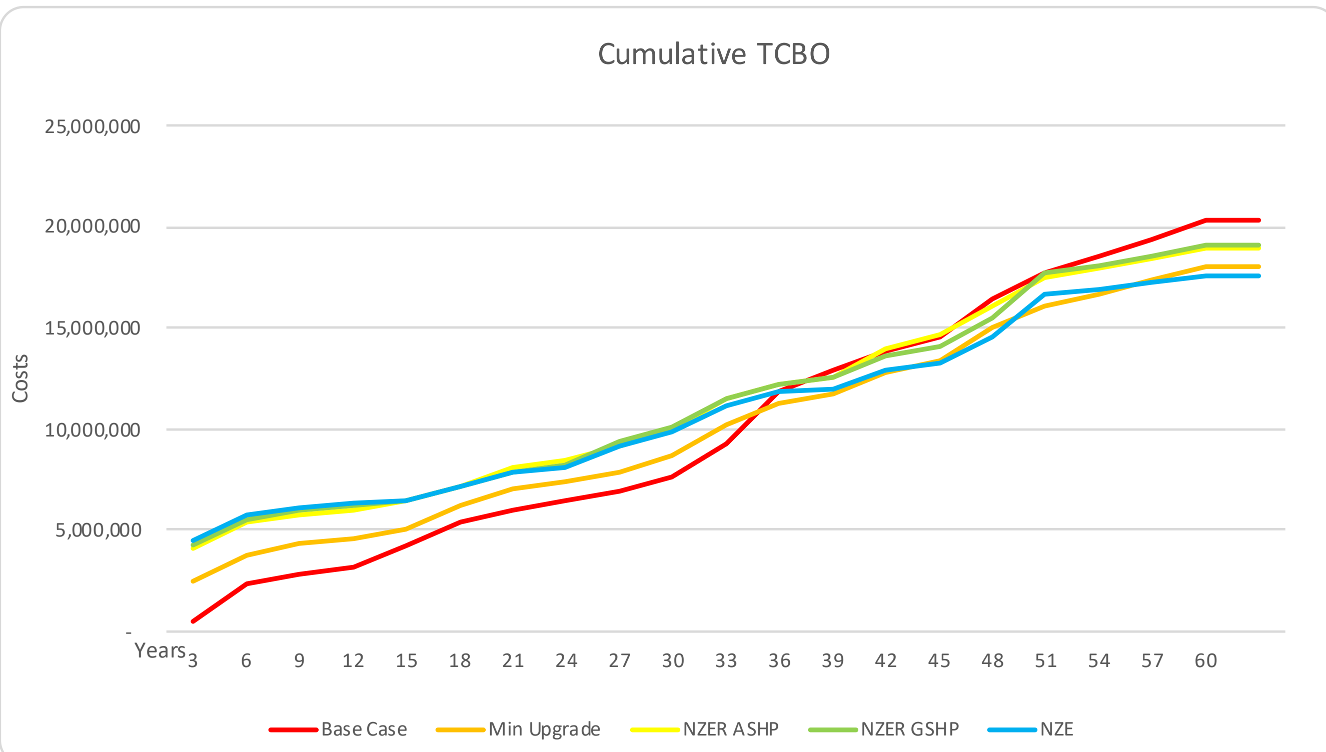
Appendix N

Total Cost of Building Ownership

SEEFAR BUILDING ANALYTICS INC.

ON Community Centre - Deep Retrofit

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
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%**



Total Cost of Building Ownership (TCBO)

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
GHG emissions (kg) (60 Years)	2,334,497	894,094	94,986	94,383	-
EUI (kWh/m2/year)	397	199	79	78	-
TCBO at 12 Years	$ 3,212,000	$ 4,581,000	$ 6,030,000	$ 6,197,000	$ 6,303,000
TCBO at 25 Years	$ 6,564,000	$ 7,522,000	$ 8,884,000	$ 9,125,000	$ 8,995,000
TCBO at 60 years	$ 20,317,000	$ 18,024,000	$ 18,937,000	$ 19,087,000	$ 17,567,000
TCBO Savings at 60 years		$ 2,293,000	$ 1,380,000	$ 1,230,000	$ 2,750,000
60 Year TCBO savings compared to Base Case		11%	7%	6%	14%
TCBO/Year/m2	$ 421	$ 374	$ 393	$ 396	$ 364
TCBO/Year/ft2	$ 39	$ 35	$ 36	$ 37	$ 34
60-Year TCBO/m2	$ 25,270	$ 22,418	$ 23,553	$ 23,740	$ 21,850
60-YearTCBO/ft2	$ 2,349	$ 2,083	$ 2,189	$ 2,206	$ 2,031
60 Year Energy Cost / m2	$ 6,288	$ 4,128	$ 2,415	$ 2,400	$ -

Total Cost of Building Ownership (TCBO)

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
GHG emissions (kg) (60 Years)	2,334,497	894,094	94,986	94,383	0
EUI (kWh/m2/year)	397	199	79	78	0
TCBO at 12 Years	3212000	4581000	6030000	6197000	6303000
TCBO at 25 Years	6564000	7522000	8884000	9125000	8995000
TCBO at 60 years	$ 20,317,000	$ 18,024,000	$ 18,937,000	$ 19,087,000	$ 17,567,000
TCBO Savings at 60 years		$ 2,293,000	$ 1,380,000	$ 1,230,000	$ 2,750,000
60 Year TCBO savings compared to Base Case		0	0	0	0
TCBO/Year/m2	$ 421	$ 374	$ 393	$ 396	$ 364
TCBO/Year/ft2	$ 39	$ 35	$ 36	$ 37	$ 34
60-Year TCBO/m2	$ 25,270	$ 22,418	$ 23,553	$ 23,740	$ 21,850
60-YearTCBO/ft2	$ 2,349	$ 2,083	$ 2,189	$ 2,206	$ 2,031
60 Year Energy Cost / m2	$ 6,288	$ 4,128	$ 2,415	$ 2,400	$ -

CAPITAL COST SUMMARY

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Initial Retrofit / HPB CostYear 1					
Initial Cost	$ 12,000	$ 2,316,000	$ 3,991,000	$ 4,161,000	$ 4,413,000
Difference From Base Case		$ 2,304,000	$ 3,979,000	$ 4,149,000	$ 4,401,000
% Difference from Base Case		19200%	33158%	34575%	36675%
Cost ($/ft2)	$ 1.39	$ 267.75	$ 461.39	$ 481.04	$ 510.17

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Maintenance Capital Costs 60 Years					
Cost	$11,238,000	$ 9,013,000	$ 9,866,000	$ 9,870,000	$ 9,870,000
Difference From Base Case		$ (2,225,000)	$ (1,372,000)	$ (1,368,000)	$ (1,368,000)
% Difference from Base Case		-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

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Retrofit / HPB + Maintenance Capital Costs 60 Years					
Total Costs	$11,250,000	$11,329,000	$13,857,000	$14,031,000	$14,283,000
Difference From Base Case		$ 79,000	$ 2,607,000	$ 2,781,000	$ 3,033,000
% Difference from Base Case		0.70%	23.17%	24.72%	26.96%

OPERATING COST SUMMARY

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Utilities (including carbon tax)					
Cost	$ 8,018,000	$ 5,518,000	$ 3,717,000	$ 3,704,000	$ 1,725,000
Difference From Base Case		$ (2,500,000)	$ (4,301,000)	$ (4,314,000)	$ (6,293,000)
% Difference from Base Case		-31%	-54%	-54%	-78%
Energy Cost ($/ft2)	$ 926.94	$ 637.92	$ 429.71	$ 428.21	$ 199.42
Maintenance					
Cost	$ 460,000	$ 587,000	$ 774,000	$ 762,000	$ 969,000
Difference From Base Case		$ 127,000	$ 314,000	$ 302,000	$ 509,000
% Difference from Base Case		28%	68%	66%	111%
Maintenance Cost ($/ft2)	$ 53.18	$ 67.86	$ 89.48	$ 88.09	$ 112.02
Insurance & Taxes					
Costs	$ 590,000	$ 590,000	$ 590,000	$ 590,000	$ 590,000
Difference From Base Case		$ -	$ -	$ -	$ -
% Difference from Base Case		0%	0%	0%	0%
First Year Annual Maintenance					
Cost	$ 3,950	$ 5,050	$ 6,650	$ 6,550	$ 8,333
Difference From Base Case		$ 1,100	$ 2,700	$ 2,600	$ 4,383
% Difference from Base Case		28%	68%	66%	111%
First Year Maintenance Cost ($/ft2)	$ 0.46	$ 0.58	$ 0.77	$ 0.76	$ 0.96

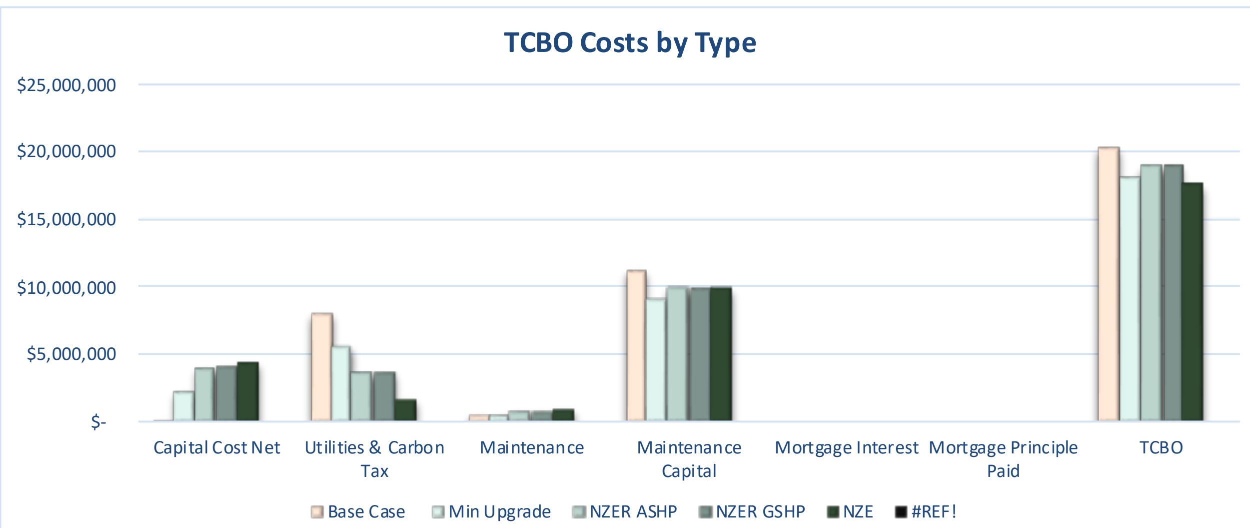
Annual Energy Consumption and GHG Emissions

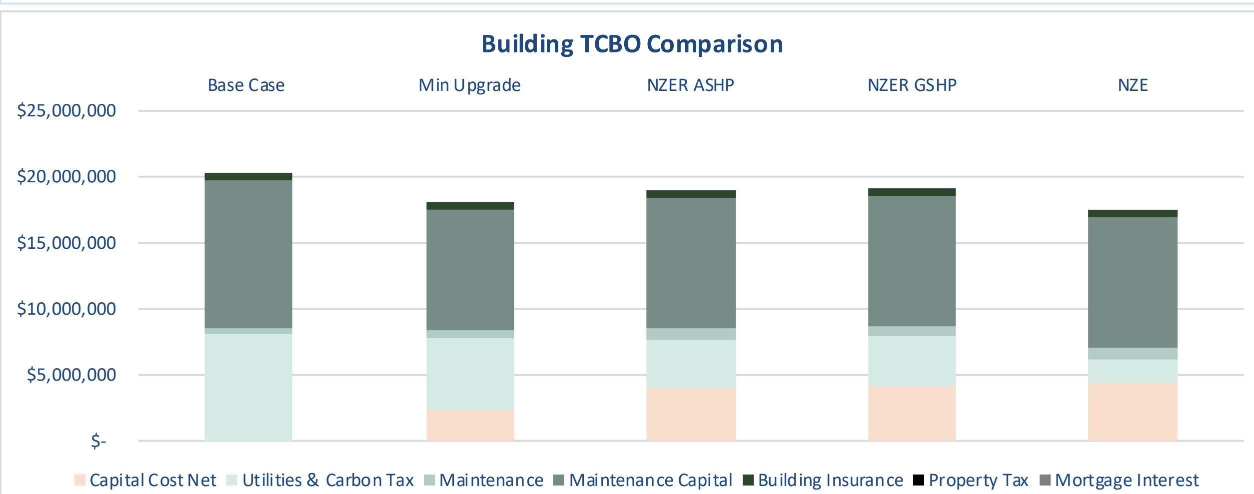
	Units	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Annual Water Consumption	m3	1,216.0	1,216.0	1,216.0	1,216.0	1,216.0
Annual Sewer Discharge	m3	0.0	0.0	0.0	0.0	0.0
Annual Electric Consumption	kWh	124,695.0	91,482.0	63,324.0	62,922.0	62,922.0
Annual Gas Consumption	m3	18,814.0	6,631.0	0.0	0.0	0.0
Annual 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

60 Year Cost of Ownership Comparison

	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Capital Cost	$ 11,749	$ 2,316,224	$ 3,991,084	$ 4,160,672	$ 4,412,672
Utility Subsidy	$ -	$ -	$ -	$ -	$ -
Capital Cost Net	$ 11,749	$ 2,316,224	$ 3,991,084	$ 4,160,672	$ 4,412,672
Utilities & Carbon Tax	$ 8,017,501	$ 5,517,702	$ 3,716,888	$ 3,704,241	$ 1,724,717
Maintenance	$ 459,514	$ 587,479	$ 773,612	$ 761,978	$ 969,454
Maintenance Capital	$ 11,237,889	$ 9,012,618	$ 9,865,683	$ 9,870,015	$ 9,870,015
Building Insurance	$ 589,875	$ 589,875	$ 589,875	$ 589,875	$ 589,875
Property Tax	$ -	$ -	$ -	$ -	$ -
Mortgage Interest	$ -	$ -	$ -	$ -	$ -
Mortgage Principle Paid	$ -	$ -	$ -	$ -	$ -
Mortgage Principal Received	$ -	$ -	$ -	$ -	$ -
TCBO	$ 20,316,527	$ 18,023,898	$ 18,937,141	$ 19,086,781	$ 17,566,733

	Cost as a Percentage of TCBO				
Capital Cost Net	0.1%	12.9%	21.1%	21.8%	25.1%
Utilities & Carbon Tax	39.5%	30.6%	19.6%	19.4%	9.8%
Maintenance	2.3%	3.3%	4.1%	4.0%	5.5%
Maintenance Capital	55.3%	50.0%	52.1%	51.7%	56.2%
Building Insurance	2.9%	3.3%	3.1%	3.1%	3.4%
Property Tax	0.0%	0.0%	0.0%	0.0%	0.0%
Mortgage Interest	0.0%	0.0%	0.0%	0.0%	0.0%
TCBO	100.0%	100.0%	100.0%	100.0%	100.0%





INPUTS : General

	Units	Base Case	Min Upgrade	NZER ASHP	NZER GSHP	NZE
Utility Costs						
Water						
unit water cost	$/m3	2.864	2.864	2.864	2.864	2.864
annual water escalation rate	%	3%	3%	3%	3%	3%
include annual "Basic Charge Water" for active service, else 0	$/year	$ 4,860.96	$ 4,860.96	$ 4,860.96	$ 4,860.96	$ 4,860.96
"Basic Charge Water" escalation rate	%	4%	4%	4%	4%	4%
annual consumption	m3	1216	1216	1216	1216	1216
refrofit reduction	%	0%	0%	0%	0%	0%
Sewer						
unit sewer cost	$/m3					
annual sewer escalation rate	%	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03
include annual "Basic Charge Sewer" for active service, else 0	$/year					
"Basic Charge Sewer" escalation rate	%	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03
annual consumption	m3					
refrofit reduction	%	0%				
Electricity						
unit cost	$/kWh	$ 0.19	$ 0.19	$ 0.19	$ 0.19	$ 0.19
annual escalation rate	%	3%	3%	3%	3%	3%
include annual "Basic Charge" for active service, else 0	$/year					
"Basic Charge" escalation rate	%	3%	3%	3%	3%	3%
GHG emission factor	kg/kWh	0.025	0.025	0.025	0.025	0.025
Is Carbon Tax ADDED TO energy cost?	No = 0 or Yes = 1	1	1	1	1	1
annual consumption	kWh	124,695	91,482	63,324	62,922	62,922
refrofit reduction (only use this when TCPO calculation)	%	0%	0%	0%	0%	0%

Natural Gas						
unit cost	$/m3	$ 0.36	$ 0.36			
annual escalation rate	%	3%	3%	3%	3%	3%
include annual "Basic Charge" for active service, else 0	$/year	$ 754.83	$ 754.83			
"Basic Charge" escalation rate	%	3%	3%			
GHG emission factor	kg/m3	1.90	1.90	1.90	1.90	1.90
Is Carbon Tax ADDED TO energy cost?	No = 0 or Yes = 1	0	0	1	1	1
annual consumption	m3	18814	6631			
refrofit reduction	%	0%	0%	0%	0%	0%
No 2 Heating Oil						
unit cost	$/Litre					
annual escalation rate	%	3%	3%	3%	3%	3%
include annual "Basic Charge" for active service, else 0	$/year					
"Basic Charge" escalation rate	%	3%	3%	3%	3%	3%
GHG emission factor	kg/L	2.66	2.66	2.66	2.66	2.66
Is Carbon Tax ADDED TO energy cost?	No = 0 or Yes = 1					
annual consumption	Litres					
refrofit reduction	%	0%				

GHG Emissions

Carbon Tax escalation rate - after carbon tax finishes	%	4%	4%	4%	4%	4%
Carbon Tax Year	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
GHG unit cost ($/tonne)	$ 30.00	$ 170.00	$ 251.64	$ 372.49	$ 551.38	$ 816.17
Carbon Tax for Project Year	$ 80.00	$ 198.88	$ 294.38	$ 435.76	$ 645.03	$ 954.81

Mortgage Financing of New Investment

1st Year New Investment Capital Amount	$			No input here - See Value Tab Calculation		
Percent of 1st Year Capital Investment Financed with Mortgage	%					
Mortgage Financing of New Investment				No input here - See Value Tab Calculation		
Interest Rate	%					
Amortization in Years	#	25	25	25	25	25
Start Date (yyyy-mm-dd)		2023-12-31	2023-12-31	2023-12-31	2023-12-31	2023-12-31

Property Tax

property tax lump sum OR	$					
property tax rate (% of building value) (e.g. .43%)	%					
property tax escalation rate	%	1.50%	1.50%	1.50%	1.50%	1.50%

Insurance

property insurance annual cost lump sum OR	$	$ 5,172.00	$ 5,172.00	$ 5,172.00	$ 5,172.00	$ 5,172.00
property insurance rate (% of building value) (e.g. .27%)	%					
property insurance escalation rate	%	2.00%	2.00%	2.00%	2.00%	2.00%

Property Market Value Forecast by Decade:

0-10 years	%	4.00%	4.00%	4.00%	4.00%	4.00%
11-20 years	%	4.00%	4.00%	4.00%	4.00%	4.00%
21-30 years	%	4.00%	4.00%	4.00%	4.00%	4.00%
31-40 years	%	4.00%	4.00%	4.00%	4.00%	4.00%
41-50 years	%	4.00%	4.00%	4.00%	4.00%	4.00%
51-60 years	%	4.00%	4.00%	4.00%	4.00%	4.00%

Market Value Inputs

Project Type - Either Retrofit or New Build only	Input	**Retrofit**	**Retrofit**	**Retrofit**	**Retrofit**	**Retrofit**
Current Building Value (normally existing building at current status (before new capital investment) or New Code Built Building). Include Comments on the source of Market Value Information.					Current Replacement Value: $ 351/ft2	
Market Value Base Case For Retrofits only (else Zero)	Input $	$ 3,460,000				
New Investment Project Cost - A thru F				No input here - See Value Tab Calculation		
New Investment over Current Market Value				No input here - See Value Tab Calculation		
Rate of Inclusion of New Investment for Mkt Val Calc.	Input %	75.00%	75.00%	75.00%	75.00%	75.00%
Market Value Estimate Upon Completion of the Project				No input here - See Value Tab Calculation		
Net Present Value Rate (NPV) for Discounting Results		0.0242				
Annual Service Cost Escalation Rate		2.00%	2.00%	2.00%	2.00%	2.00%
Annual Capital Cost Escalation Rate		2.00%	2.00%	2.00%	2.00%	2.00%

Total Cost of Portfolio Ownership

Is this a TCPO calculation	No = 0 or Yes = 1	0	0	0	0	0
Year 1 Retrofit Capital Unit Cost	$/ft2	Base Case				
Year 1 Retrofit Capital Total Cost	$	See Value Tab				
Maintenance Capital Cost Reduction for Retrofit	%	0%				

Solar PV Array

Array Unit Cost	$/kWdc					$ 4,000.00
Array Size	kWdc	0	0	0	0	63.0

Total System Cost	$					$252,000.00
System Annual Maintenance Cost (1)	$/kWdc/year					$ 28.31
Total System Annual Maintenance Cost	$/year					$ 1,783.47
Annual Solar Energy Output Degradation	%					0
Unit cost of solar energy displacing utility energy	$/kWac	$ 0.19	$ 0.19	$ 0.19	$ 0.19	$ 0.19
Annual Solar Energy Produced, Displacing Utility Energy	kWh/year					62922
Unit cost of solar energy generated back to the grid	$/kWhac					
Annual Solar Energy Generated Back to the Grid	kWh/year					

Input : Base Case

Line No.	Building Components Subject to M&R / Units	Include in Option 0=no or 1=yes	Cost $	Useful Life (years) Years	Current Age Years	Annual Service Cost $	Annual Service Cost Escalation Rate 2.00%	Annual Capital Cost Escalation Rate 2.00%
1	Standard Foundations	0	$ 290,394	75	34		2.00%	2.00%
2	Slab on Grade	0	$ 116,028	75	34		2.00%	2.00%
3	Roof Construction	0	$ 110,468	75	34		2.00%	2.00%
4	Structure	0	$ 435,651	75	34		2.00%	2.00%
5	Other Structural Systems	0	$ 16,900	50	33		2.00%	2.00%
6	Wood Siding	1	$ 163,800	30	24	$ 1,000	2.00%	2.00%
7	Stone Veneer	0	$ 361,075	75	34		2.00%	2.00%
8	Windows	1	$ 221,520	35	33		2.00%	2.00%
9	Automatic Door Openers	1	$ 26,156	15	9		2.00%	2.00%
10	Single Door - Hollow Metal	1	$ 20,904	30	24		2.00%	2.00%
11	Sliding Glass Doors	1	$ 32,604	25	19	$ 500	2.00%	2.00%
12	Gutters and Downspouts	1	$ 22,675	30	24		2.00%	2.00%
13	Conventional - Modified Bitumen	1	$ 350,740	22	8	$ 1,000	2.00%	2.00%
14	Hatches	1	$ 4,758	40	33		2.00%	2.00%
15	Fixed Partitions	0	$ 154,339	75	34		2.00%	2.00%
16	Retractable Partitions - Folding Panel	1	$ 216,996	25	19		2.00%	2.00%
17	Retractable Partitions - Overhead Counter Shutter	1	$ 9,802	30	24		2.00%	2.00%
18	Single Door - Wood	1	$ 65,520	40	33		2.00%	2.00%
19	Double Door - Hollow Metal	1	$ 7,358	40	33		2.00%	2.00%
20	Double Door - Wood	1	$ 5,720	40	34		2.00%	2.00%
21	Fixed Casework	1	$ 51,597	35	11		2.00%	2.00%
22	Fixed Casework	1	$ 73,710	35	23		2.00%	2.00%
23	Retractable Stage	1	$ 29,406	25	19		2.00%	2.00%
24	Communal Washroom Refurbishment	1	$ 230,685	25	19		2.00%	2.00%
25	Individual Washroom Upgrade / Refurbishment	1	$ 18,460	25	19		2.00%	2.00%
26	Interior Access Ladders	1	$ 3,120	40	33		2.00%	2.00%
27	Paint Wall Covering	1	$ 58,014	10	4		2.00%	2.00%
28	Ceramic Tile Floor	1	$ 5,312	40	34		2.00%	2.00%
29	Carpet Floor	1	$ 43,423	10	6		2.00%	2.00%
30	Vinyl Tile / Plank Floor	1	$ 51,652	15	9		2.00%	2.00%
31	Vinyl Sheet Floor	1	$ 10,681	15	14		2.00%	2.00%
32	Wood Laminate Floor	1	$ 54,527	25	19		2.00%	2.00%
33	Acoustic Tile Ceiling	1	$ 52,967	30	24		2.00%	2.00%
34	Painted Ceiling Structures	1	$ 10,423	15	9		2.00%	2.00%
35	Suspended Acoustic Ceiling Panels	1	$ 24,898	25	10		2.00%	2.00%
36	Sinks	1	$ 1,560	35	11	$ 100	2.00%	2.00%
37	Drinking Water Fountains - Refrigerated	1	$ 6,825	15	5		2.00%	2.00%
38	Custodial Sinks	1	$ 3,120	30	27		2.00%	2.00%
39	Domestic Water Piping and Fittings	1	$ 65,676	40	34		2.00%	2.00%
40	Domestic Water Heaters - Commercial Electric	1	$ 23,860	15	12		2.00%	2.00%
41	Sanitary Waste and Vent Piping and Fittings	1	$ 65,676	50	34		2.00%	2.00%
42	Natural Gas Supply Piping and Fittings	1	$ 8,190	75	34		2.00%	2.00%
43	Air Distribution Systems	1	$ 194,839	50	34		2.00%	2.00%
44	Exhaust Fans - Centrifugal	1	$ 24,505	25	23	$ 100	2.00%	2.00%
45	Unit Heaters (Electric)	1	$ 11,193	18	1		2.00%	2.00%
46	Electric Baseboard Heaters	1	$ 1,872	18	15		2.00%	2.00%
47	Packaged Rooftop Units - Less than 20 Tons	1	$ 51,181	20	5	$ 200	2.00%	2.00%
48	Packaged Rooftop Units - Less than 20 Tons	1	$ 51,181	20	5	$ 200	2.00%	2.00%
49	Direct Digital Control Systems	1	$ 49,257	20	11	$ 500	2.00%	2.00%
50	Fire Extinguishers	1	$ 2,189	10	4		2.00%	2.00%
51	Main Service Disconnects	1	$ 16,328	40	34		2.00%	2.00%
52	Electrical Distribution	1	$ 86,473	40	34		2.00%	2.00%
53	Branch Wiring and Devices	1	$ 154,339	50	34		2.00%	2.00%
54	Interior Lighting	1	$ 122,595	35	29		2.00%	2.00%
55	Exterior Lighting	1	$ 7,462	20	17		2.00%	2.00%

BASE CASE

Line No.	Building Components Subject to M&R Units	Include in Option 0=no or 1=yes	Cost $	Useful Life (years) Years	Current Age Years	Annual Service Cost $	Annual Service Cost Escalation Rate 2.00%	Annual Capital Cost Escalation Rate 2.00%
56	Exit Lighting	1	$ 4,378	35	32		2.00%	2.00%
57	Fire Alarm Systems	1	$ 82,095	20	11	$ 200	2.00%	2.00%
58	Public Address and Music Systems	1	$ 32,838	15	11		2.00%	2.00%
59	Video Surveillance Systems	1	$ 24,081	20	11	$ 100	2.00%	2.00%
60	Access Control Systems	1	$ 24,081	20	11		2.00%	2.00%
61	Emergency Lighting	1	$ 6,568	20	17		2.00%	2.00%
62	Asphalt Paved Surfaces - Parking Area	0	$ 413,355	25	23		2.00%	2.00%
63	Concrete Paved Surfaces	0	$ 211,723	30	24		2.00%	2.00%
64	Flagpoles	0	$ 13,723	40	33		2.00%	2.00%
65	Benches - Metal	0	$ 14,321	25	10		2.00%	2.00%
66	Message Sign - Post-Mounted	0	$ 12,675	20	10		2.00%	2.00%
67	Covers, Shelters, Dugouts	0	$ 12,285	30	10		2.00%	2.00%
68	Water Supply Service - Medium	1	$ 40,508	50	34	$ 50	2.00%	2.00%
69	Sanitary Sewer Service - Medium	1	$ 25,331	50	34		2.00%	2.00%
70	Electrical Service	1	$ 84,630	50	34		2.00%	2.00%
71	Site Branch Wiring and Devices	0	$ 61,152	40	34		2.00%	2.00%
72	Site Lighting	0	$ 153,530	25	19		2.00%	2.00%

Input : Min Upgrade

BASE CASE

Line No.	Building Components Subject to M&R	Include in Option	Cost	Useful Life (years)	Current Age	Annual Service Cost	Annual Service Cost Escalation Rate	Annual Capital Cost Escalation Rate
	Units	0=no or 1=yes	$	Years	Years	$	2.00%	2.00%
1	Standard Foundations	0	$ 290,394	75	34		2.00%	2.00%
2	Slab on Grade	0	$ 116,028	75	34		2.00%	2.00%
3	Roof Construction	0	$ 110,468	75	34		2.00%	2.00%
4	Structure	0	$ 435,651	75	34		2.00%	2.00%
5	Other Structural Systems	0	$ 16,900	50	33		2.00%	2.00%
6	Wood Siding	0	$ 163,800	30	24	$ 1,000	2.00%	2.00%
7	Stone Veneer	0	$ 361,075	75	34		2.00%	2.00%
8	Windows	0	$ 221,520	35	33		2.00%	2.00%
9	Automatic Door Openers	1	$ 26,156	15	9		2.00%	2.00%
10	Single Door - Hollow Metal	0	$ 20,904	30	24		2.00%	2.00%
11	Sliding Glass Doors	1	$ 32,604	25	19	$ 500	2.00%	2.00%
12	Gutters and Downspouts	0	$ 22,675	30	24		2.00%	2.00%
13	Conventional - Modified Bitumen	0	$ 350,740	22	8	$ 1,000	2.00%	2.00%
14	Hatches	1	$ 4,758	40	33		2.00%	2.00%
15	Fixed Partitions	0	$ 154,339	75	34		2.00%	2.00%
16	Retractable Partitions - Folding Panel	1	$ 216,996	25	19		2.00%	2.00%
17	Retractable Partitions - Overhead Counter Shutter	1	$ 9,802	30	24		2.00%	2.00%
18	Single Door - Wood	1	$ 65,520	40	33		2.00%	2.00%
19	Double Door - Hollow Metal	1	$ 7,358	40	33		2.00%	2.00%
20	Double Door - Wood	1	$ 5,720	40	34		2.00%	2.00%
21	Fixed Casework	1	$ 51,597	35	11		2.00%	2.00%
22	Fixed Casework	1	$ 73,710	35	23		2.00%	2.00%
23	Retractable Stage	1	$ 29,406	25	19		2.00%	2.00%
24	Communal Washroom Refurbishment	1	$ 230,685	25	19		2.00%	2.00%
25	Individual Washroom Upgrade / Refurbishment	1	$ 18,460	25	19		2.00%	2.00%
26	Interior Access Ladders	1	$ 3,120	40	33		2.00%	2.00%
27	Paint Wall Covering	1	$ 58,014	10	4		2.00%	2.00%
28	Ceramic Tile Floor	0	$ 5,312	40	34		2.00%	2.00%
29	Carpet Floor	1	$ 43,423	10	6		2.00%	2.00%
30	Vinyl Tile / Plank Floor	1	$ 51,652	15	9		2.00%	2.00%
31	Vinyl Sheet Floor	1	$ 10,681	15	14		2.00%	2.00%
32	Wood Laminate Floor	1	$ 54,527	25	19		2.00%	2.00%
33	Acoustic Tile Ceiling	0	$ 52,967	30	24		2.00%	2.00%
34	Painted Ceiling Structures	1	$ 10,423	15	9		2.00%	2.00%
35	Suspended Acoustic Ceiling Panels	1	$ 24,898	25	10		2.00%	2.00%
36	Sinks	1	$ 1,560	35	11	$ 100	2.00%	2.00%
37	Drinking Water Fountains - Refrigerated	1	$ 6,825	15	5		2.00%	2.00%
38	Custodial Sinks	1	$ 3,120	30	27		2.00%	2.00%
39	Domestic Water Piping and Fittings	1	$ 65,676	40	34		2.00%	2.00%
40	Domestic Water Heaters - Commercial Electric	0	$ 23,860	15	12		2.00%	2.00%
41	Sanitary Waste and Vent Piping and Fittings	1	$ 65,676	50	34		2.00%	2.00%
42	Natural Gas Supply Piping and Fittings	1	$ 8,190	75	34		2.00%	2.00%
43	Air Distribution Systems	1	$ 194,839	50	34		2.00%	2.00%
44	Exhaust Fans - Centrifugal	1	$ 24,505	25	23	$ 100	2.00%	2.00%
45	Unit Heaters (Electric)	1	$ 11,193	18	1		2.00%	2.00%
46	Electric Baseboard Heaters	1	$ 1,872	18	15		2.00%	2.00%
47	Packaged Rooftop Units - Less than 20 Tons	1	$ 51,181	20	5	$ 200	2.00%	2.00%
48	Packaged Rooftop Units - Less than 20 Tons	1	$ 51,181	20	5	$ 200	2.00%	2.00%
49	Direct Digital Control Systems	1	$ 49,257	20	11	$ 500	2.00%	2.00%
50	Fire Extinguishers	1	$ 2,189	10	4		2.00%	2.00%
51	Main Service Disconnects	1	$ 16,328	40	34		2.00%	2.00%
52	Electrical Distribution	1	$ 86,473	40	34		2.00%	2.00%
53	Branch Wiring and Devices	1	$ 154,339	50	34		2.00%	2.00%
54	Interior Lighting	0	$ 122,595	35	29		2.00%	2.00%
55	Exterior Lighting	0	$ 7,462	20	17		2.00%	2.00%

	Line No.	Building Components Subject to M&R	Include in Option	Cost	Useful Life (years)	Current Age	Annual Service Cost	Annual Service Cost Escalation Rate	Annual Capital Cost Escalation Rate
		Units	0=no or 1=yes	$	Years	Years	$	2.00%	2.00%
	56	Exit Lighting	1	$ 4,378	35	32		2.00%	2.00%
	57	Fire Alarm Systems	1	$ 82,095	20	11	$ 200	2.00%	2.00%
	58	Public Address and Music Systems	1	$ 32,838	15	11		2.00%	2.00%
	59	Video Surveillance Systems	1	$ 24,081	20	11	$ 100	2.00%	2.00%
	60	Access Control Systems	1	$ 24,081	20	11		2.00%	2.00%
	61	Emergency Lighting	1	$ 6,568	20	17		2.00%	2.00%
	62	Asphalt Paved Surfaces - Parking Area	0	$ 413,355	25	23		2.00%	2.00%
	63	Concrete Paved Surfaces	0	$ 211,723	30	24		2.00%	2.00%
	64	Flagpoles	0	$ 13,723	40	33		2.00%	2.00%
	65	Benches - Metal	0	$ 14,321	25	10		2.00%	2.00%
	66	Message Sign - Post-Mounted	0	$ 12,675	20	10		2.00%	2.00%
	67	Covers, Shelters, Dugouts	0	$ 12,285	30	10		2.00%	2.00%
	68	Water Supply Service - Medium	1	$ 40,508	50	34	$ 50	2.00%	2.00%
	69	Sanitary Sewer Service - Medium	1	$ 25,331	50	34		2.00%	2.00%
	70	Electrical Service	1	$ 84,630	50	34		2.00%	2.00%
	71	Site Branch Wiring and Devices	0	$ 61,152	40	34		2.00%	2.00%
	72	Site Lighting	0	$ 153,530	25	19		2.00%	2.00%
	98		1					2.00%	2.00%
RETROFIT	111	A32 Walls Above Grade	1					2.00%	2.00%
	112	remove stone facade	1	$ 24,953	61	0		2.00%	2.00%
	113	remove siding facade	1	$ 21,364	61	0		2.00%	2.00%
	114	structural upgrade including base angle	1	$ 132,000				2.00%	2.00%
	115	supply and install prefab r11 insulated wall panels	1	$ 240,421	61	0		2.00%	2.00%
	116	supply and install prefinished metal siding	1	$ 365,439	61	0		2.00%	2.00%
	117	A33 Windows and Entrances	1					2.00%	2.00%
	118	replace windows with triple pane	1	$ 128,655	30	0		2.00%	2.00%
	119	A34 Roof Coverings	1					2.00%	2.00%
	120	remove existing roof finish	1	$ 30,171	61	0		2.00%	2.00%
	121	mod bit roof finish with 4" XPS insulation	1	$ 351,995	20	0	$ 1,000	2.00%	2.00%
	122	allowance for removing, reinstalling mechanical	1	$ 40,000	61	0		2.00%	2.00%
	123	A35 Projections	1					2.00%	2.00%
	124	soffit replacement	1	$ 45,113	61	0		2.00%	2.00%
	125	canopies - no change	1					2.00%	2.00%
	143	C14 Controls	1					2.00%	2.00%
	144	new CO2 sensors, air CO2 sensors and heat relays	1	$ 13,000	20	0	$ 100	2.00%	2.00%
	151	C22 Lighting, Devices and Heating	1					2.00%	2.00%
	152	install LED retrofit kits to all existing lights	1	$ 20,114	15	0		2.00%	2.00%
	153		1					2.00%	2.00%
	154	Z11 General Requirements and Overheads	1					2.00%	2.00%
	155	contractor's overheads	1	$ 211,984	61	0		2.00%	2.00%
	156	Z12 Contractors Profit	1					2.00%	2.00%
	157	contractor's profit	1	$ 162,521	61	0		2.00%	2.00%
	158	Z21 Design Allowance	1					2.00%	2.00%
	159	design development contingency	1	$ 178,773	61	0		2.00%	2.00%
	160	Z23 Construction Allowance	1					2.00%	2.00%
	161	construction contingency	1	$ 196,650	61	0		2.00%	2.00%
	164		1					2.00%	2.00%
	165	construction escalation for 2024	1	$ 141,323	61	0		2.00%	2.00%

Input : NZER ASHP

BASE CASE

	Building Components Subject to M&R	Include in Option	Cost	Useful Life (years)	Current Age	Annual Service Cost	Annual Service Cost Escalation Rate	Annual Capital Cost Escalation Rate
Line No.	Units	0=no or 1=yes	$	Years	Years	$	2.00%	2.00%
1	Standard Foundations	0	$ 290,394	75	34		2.00%	2.00%
2	Slab on Grade	0	$ 116,028	75	34		2.00%	2.00%
3	Roof Construction	0	$ 110,468	75	34		2.00%	2.00%
4	Structure	0	$ 435,651	75	34		2.00%	2.00%
5	Other Structural Systems	0	$ 16,900	50	33		2.00%	2.00%
6	Wood Siding	0	$ 163,800	30	24	$ 1,000	2.00%	2.00%
7	Stone Veneer	0	$ 361,075	75	34		2.00%	2.00%
8	Windows	0	$ 221,520	35	33		2.00%	2.00%
9	Automatic Door Openers	1	$ 26,156	15	9		2.00%	2.00%
10	Single Door - Hollow Metal	0	$ 20,904	30	24		2.00%	2.00%
11	Sliding Glass Doors	1	$ 32,604	25	19	$ 500	2.00%	2.00%
12	Gutters and Downspouts	0	$ 22,675	30	24		2.00%	2.00%
13	Conventional - Modified Bitumen	0	$ 350,740	22	8	$ 1,000	2.00%	2.00%
14	Hatches	1	$ 4,758	40	33		2.00%	2.00%
15	Fixed Partitions	0	$ 154,339	75	34		2.00%	2.00%
16	Retractable Partitions - Folding Panel	1	$ 216,996	25	19		2.00%	2.00%
17	Retractable Partitions - Overhead Counter Shutter	1	$ 9,802	30	24		2.00%	2.00%
18	Single Door - Wood	1	$ 65,520	40	33		2.00%	2.00%
19	Double Door - Hollow Metal	1	$ 7,358	40	33		2.00%	2.00%
20	Double Door - Wood	1	$ 5,720	40	34		2.00%	2.00%
21	Fixed Casework	1	$ 51,597	35	11		2.00%	2.00%
22	Fixed Casework	1	$ 73,710	35	23		2.00%	2.00%
23	Retractable Stage	1	$ 29,406	25	19		2.00%	2.00%
24	Communal Washroom Refurbishment	1	$ 230,685	25	19		2.00%	2.00%
25	Individual Washroom Upgrade / Refurbishment	1	$ 18,460	25	19		2.00%	2.00%
26	Interior Access Ladders	1	$ 3,120	40	33		2.00%	2.00%
27	Paint Wall Covering	1	$ 58,014	10	4		2.00%	2.00%
28	Ceramic Tile Floor	0	$ 5,312	40	34		2.00%	2.00%
29	Carpet Floor	1	$ 43,423	10	6		2.00%	2.00%
30	Vinyl Tile / Plank Floor	1	$ 51,652	15	9		2.00%	2.00%
31	Vinyl Sheet Floor	1	$ 10,681	15	14		2.00%	2.00%
32	Wood Laminate Floor	1	$ 54,527	25	19		2.00%	2.00%
33	Acoustic Tile Ceiling	0	$ 52,967	30	24		2.00%	2.00%
34	Painted Ceiling Structures	1	$ 10,423	15	9		2.00%	2.00%
35	Suspended Acoustic Ceiling Panels	1	$ 24,898	25	10		2.00%	2.00%
36	Sinks	1	$ 1,560	35	11	$ 100	2.00%	2.00%
37	Drinking Water Fountains - Refrigerated	1	$ 6,825	15	5		2.00%	2.00%
38	Custodial Sinks	1	$ 3,120	30	27		2.00%	2.00%
39	Domestic Water Piping and Fittings	1	$ 65,676	40	34		2.00%	2.00%
40	Domestic Water Heaters - Commercial Electric	0	$ 23,860	15	12		2.00%	2.00%
41	Sanitary Waste and Vent Piping and Fittings	1	$ 65,676	50	34		2.00%	2.00%
42	Natural Gas Supply Piping and Fittings	1	$ 8,190	40	34		2.00%	2.00%
43	Air Distribution Systems	0	$ 194,839	50	34		2.00%	2.00%
44	Exhaust Fans - Centrifugal	0	$ 24,505	25	23	$ 100	2.00%	2.00%
45	Unit Heaters (Electric)	0	$ 11,193	18	1		2.00%	2.00%
46	Electric Baseboard Heaters	0	$ 1,872	18	15		2.00%	2.00%
47	Packaged Rooftop Units - Less than 20 Tons	0	$ 51,181	20	5	$ 200	2.00%	2.00%
48	Packaged Rooftop Units - Less than 20 Tons	0	$ 51,181	20	5	$ 200	2.00%	2.00%
49	Direct Digital Control Systems	0	$ 49,257	20	11	$ 500	2.00%	2.00%
50	Fire Extinguishers	1	$ 2,189	10	4		2.00%	2.00%
51	Main Service Disconnects	0	$ 16,328	40	34		2.00%	2.00%
52	Electrical Distribution	1	$ 86,473	40	34		2.00%	2.00%
53	Branch Wiring and Devices	1	$ 154,339	50	34		2.00%	2.00%
54	Interior Lighting	0	$ 122,595	35	29		2.00%	2.00%
55	Exterior Lighting	0	$ 7,462	20	17		2.00%	2.00%

Line No.	Building Components Subject to M&R / Units	Include in Option (0=no or 1=yes)	Cost ($)	Useful Life (years) (Years)	Current Age (Years)	Annual Service Cost ($)	Annual Service Cost Escalation Rate (2.00%)	Annual Capital Cost Escalation Rate (2.00%)
56	Exit Lighting	1	$ 4,378	35	32		2.00%	2.00%
57	Fire Alarm Systems	1	$ 82,095	20	11	$ 200	2.00%	2.00%
58	Public Address and Music Systems	1	$ 32,838	15	11		2.00%	2.00%
59	Video Surveillance Systems	1	$ 24,081	20	11	$ 100	2.00%	2.00%
60	Access Control Systems	1	$ 24,081	20	11		2.00%	2.00%
61	Emergency Lighting	1	$ 6,568	20	17		2.00%	2.00%
62	Asphalt Paved Surfaces - Parking Area	0	$ 413,355	25	23		2.00%	2.00%
63	Concrete Paved Surfaces	0	$ 211,723	30	24		2.00%	2.00%
64	Flagpoles	0	$ 13,723	40	33		2.00%	2.00%
65	Benches - Metal	0	$ 14,321	25	10		2.00%	2.00%
66	Message Sign - Post-Mounted	0	$ 12,675	20	10		2.00%	2.00%
67	Covers, Shelters, Dugouts	0	$ 12,285	30	10		2.00%	2.00%
68	Water Supply Service - Medium	1	$ 40,508	50	34	$ 50	2.00%	2.00%
69	Sanitary Sewer Service - Medium	1	$ 25,331	50	34		2.00%	2.00%
70	Electrical Service	0	$ 84,630	50	34		2.00%	2.00%
71	Site Branch Wiring and Devices	0	$ 61,152	40	34		2.00%	2.00%
72	Site Lighting	0	$ 153,530	25	19		2.00%	2.00%
99		1					2.00%	2.00%
	RETROFIT							
100	A31 Walls Below Grade	1					2.00%	2.00%
101	remove concrete sidewalk and dispose	1	$ 1,819	61	0		2.00%	2.00%
102	remove asphalt paving and dispose	1	$ 430	61	0		2.00%	2.00%
103	remove landscaped areas and dispose	1	$ 2,549	61	0		2.00%	2.00%
104	excavate to 2 feet below grade	1	$ 4,367	61	0		2.00%	2.00%
105	new 2" EPS fin insulation	1	$ 5,823	61	0		2.00%	2.00%
106	cement board	1	$ 8,319	61	0		2.00%	2.00%
107	backfill to subgrade	1	$ 5,458	61	0		2.00%	2.00%
108	reinstate concrete sidewalks	1	$ 10,917	61	0		2.00%	2.00%
109	reinstate asphalt paving	1	$ 1,291	61	0		2.00%	2.00%
110	reinstate landscaping	1	$ 6,372	61	0		2.00%	2.00%
111	A32 Walls Above Grade	1					2.00%	2.00%
112	remove stone facade	1	$ 24,953	61	0		2.00%	2.00%
113	remove siding facade	1	$ 21,364	61	0		2.00%	2.00%
114	structural upgrade including base angle	1	$ 132,000	61	0		2.00%	2.00%
115	supply and install prefab r16 insulated wall panels	1	$ 250,037	61	0		2.00%	2.00%
116	supply and install prefinished metal siding	1	$ 365,439	61	0		2.00%	2.00%
117	A33 Windows and Entrances	1					2.00%	2.00%
118	replace windows with triple pane	1	$ 128,655	30	0		2.00%	2.00%
119	A34 Roof Coverings	1					2.00%	2.00%
120	remove existing roof finish	1	$ 30,171	61	0		2.00%	2.00%
121	mod bit roof finish with 12" XPS insulation	1	$ 432,450	20	0	$ 1,000	2.00%	2.00%
122	allowance for removing, reinstalling mechanical	1	$ 40,000	61	0		2.00%	2.00%
123	A35 Projections	1					2.00%	2.00%
124	soffit replacement	1	$ 45,113	61	0		2.00%	2.00%
125	canopies - no change	1					2.00%	2.00%
126	B22 Ceiling Finishes	1					2.00%	2.00%
127	cut and patch ceilings for new mechanical/electrical	1	$ 25,142	61	0		2.00%	2.00%
128	B23 Wall Finishes	1					2.00%	2.00%
129	cut and patch walls for new mechanical/electrical	1	$ 25,142	61	0		2.00%	2.00%
130	C11 Plumbing and Drainage	1					2.00%	2.00%
131	new 80gal HP hot water tanks	1	$ 4,000	14	0		2.00%	2.00%
132	C13 HVAC	1					2.00%	2.00%
133	VRF ASHP condensing units - 10 tons	1	$ 120,000	15	0	$ 500	2.00%	2.00%
134	VRF fancoils	1	$ 76,500	20	0		2.00%	2.00%
137		1					2.00%	2.00%
138	refrigerant piping, branch controllers	1	$ 100,000	20	0	$ 500	2.00%	2.00%
139	VAVs	1	$ 45,000	25	0		2.00%	2.00%

Line No.	Building Components Subject to M&R Units	Include in Option 0=no or 1=yes	Cost $	Useful Life (years) Years	Current Age Years	Annual Service Cost $	Annual Service Cost Escalation Rate 2.00%	Annual Capital Cost Escalation Rate 2.00%
140	ERV 950cfm	1	$ 28,000	25	0	$ 100	2.00%	2.00%
141	ERV 750cfm	1	$ 28,000	25	0	$ 100	2.00%	2.00%
142	new ERV ductwork	1	$ 180,000	61	0		2.00%	2.00%
143	C14 Controls	1					2.00%	2.00%
144	building automated controls - connect to existing system	1	$ 70,399	20	0	$ 500	2.00%	2.00%
145	C21 Services and Distribution	1					2.00%	2.00%
146	replace main entrance, 400A switchgear	1	$ 25,000	40	0		2.00%	2.00%
147	new feeders	1	$ 50,000	61	0		2.00%	2.00%
148	new panel, transformer for HVAC	1	$ 20,000	61	0		2.00%	2.00%
149	new disconnects, mechanical connections	1	$ 15,000	40	0		2.00%	2.00%
150		1					2.00%	2.00%
151	C22 Lighting, Devices and Heating	1					2.00%	2.00%
152	new LED light fixtures, or retrofit kits	1	$ 80,456	25	0		2.00%	2.00%
153	lighting controls	1	$ 30,171	25	0		2.00%	2.00%
154	Z11 General Requirements and Overheads	1					2.00%	2.00%
155	contractor's overheads	1	$ 366,051	61	0		2.00%	2.00%
156	Z12 Contractors Profit	1					2.00%	2.00%
157	contractor's profit	1	$ 280,639	61	0		2.00%	2.00%
158	Z21 Design Allowance	1					2.00%	2.00%
159	design development contingency	1	$ 308,703	61	0		2.00%	2.00%
160	Z23 Construction Allowance	1					2.00%	2.00%
161	construction contingency	1	$ 339,573	61	0		2.00%	2.00%
164		1					2.00%	2.00%
165	construction escalation for 2024	1	$ 244,034	61	0		2.00%	2.00%

Input : NZER GSHP

Line No.	Building Components Subject to M&R	Include in Option	Cost	Useful Life (years)	Current Age	Annual Service Cost	Annual Service Cost Escalation Rate	Annual Capital Cost Escalation Rate
	Units	0=no or 1=yes	$	Years	Years	$	2.00%	2.00%
1	Standard Foundations	0	$ 290,394	75	34		2.00%	2.00%
2	Slab on Grade	0	$ 116,028	75	34		2.00%	2.00%
3	Roof Construction	0	$ 110,468	75	34		2.00%	2.00%
4	Structure	0	$ 435,651	75	34		2.00%	2.00%
5	Other Structural Systems	0	$ 16,900	50	33		2.00%	2.00%
6	Wood Siding	0	$ 163,800	30	24	$ 1,000	2.00%	2.00%
7	Stone Veneer	0	$ 361,075	75	34		2.00%	2.00%
8	Windows	0	$ 221,520	35	33		2.00%	2.00%
9	Automatic Door Openers	1	$ 26,156	15	9		2.00%	2.00%
10	Single Door - Hollow Metal	0	$ 20,904	30	24		2.00%	2.00%
11	Sliding Glass Doors	1	$ 32,604	25	19	$ 500	2.00%	2.00%
12	Gutters and Downspouts	0	$ 22,675	30	24		2.00%	2.00%
13	Conventional - Modified Bitumen	0	$ 350,740	22	8	$ 1,000	2.00%	2.00%
14	Hatches	1	$ 4,758	40	33		2.00%	2.00%
15	Fixed Partitions	0	$ 154,339	75	34		2.00%	2.00%
16	Retractable Partitions - Folding Panel	1	$ 216,996	25	19		2.00%	2.00%
17	Retractable Partitions - Overhead Counter Shutter	1	$ 9,802	30	24		2.00%	2.00%
18	Single Door - Wood	1	$ 65,520	40	33		2.00%	2.00%
19	Double Door - Hollow Metal	1	$ 7,358	40	33		2.00%	2.00%
20	Double Door - Wood	1	$ 5,720	40	34		2.00%	2.00%
21	Fixed Casework	1	$ 51,597	35	11		2.00%	2.00%
22	Fixed Casework	1	$ 73,710	35	23		2.00%	2.00%
23	Retractable Stage	1	$ 29,406	25	19		2.00%	2.00%
24	Communal Washroom Refurbishment	1	$ 230,685	25	19		2.00%	2.00%
25	Individual Washroom Upgrade / Refurbishment	1	$ 18,460	25	19		2.00%	2.00%
26	Interior Access Ladders	1	$ 3,120	40	33		2.00%	2.00%
27	Paint Wall Covering	1	$ 58,014	10	4		2.00%	2.00%
28	Ceramic Tile Floor	0	$ 5,312	40	34		2.00%	2.00%
29	Carpet Floor	1	$ 43,423	10	6		2.00%	2.00%
30	Vinyl Tile / Plank Floor	1	$ 51,652	15	9		2.00%	2.00%
31	Vinyl Sheet Floor	1	$ 10,681	15	14		2.00%	2.00%
32	Wood Laminate Floor	1	$ 54,527	25	19		2.00%	2.00%
33	Acoustic Tile Ceiling	0	$ 52,967	30	24		2.00%	2.00%
34	Painted Ceiling Structures	1	$ 10,423	15	9		2.00%	2.00%
35	Suspended Acoustic Ceiling Panels	1	$ 24,898	25	10		2.00%	2.00%
36	Sinks	1	$ 1,560	35	11	$ 100	2.00%	2.00%
37	Drinking Water Fountains - Refrigerated	1	$ 6,825	15	5		2.00%	2.00%
38	Custodial Sinks	1	$ 3,120	30	27		2.00%	2.00%
39	Domestic Water Piping and Fittings	1	$ 65,676	40	34		2.00%	2.00%
40	Domestic Water Heaters - Commercial Electric	0	$ 23,860	15	12		2.00%	2.00%
41	Sanitary Waste and Vent Piping and Fittings	1	$ 65,676	50	34		2.00%	2.00%
42	Natural Gas Supply Piping and Fittings	1	$ 8,190	40	34		2.00%	2.00%
43	Air Distribution Systems	0	$ 194,839	50	34		2.00%	2.00%
44	Exhaust Fans - Centrifugal	0	$ 24,505	25	23	$ 100	2.00%	2.00%
45	Unit Heaters (Electric)	0	$ 11,193	18	1		2.00%	2.00%
46	Electric Baseboard Heaters	0	$ 1,872	18	15		2.00%	2.00%
47	Packaged Rooftop Units - Less than 20 Tons	0	$ 51,181	20	5	$ 200	2.00%	2.00%
48	Packaged Rooftop Units - Less than 20 Tons	0	$ 51,181	20	5	$ 200	2.00%	2.00%
49	Direct Digital Control Systems	0	$ 49,257	20	11	$ 500	2.00%	2.00%
50	Fire Extinguishers	1	$ 2,189	10	4		2.00%	2.00%
51	Main Service Disconnects	0	$ 16,328	40	34		2.00%	2.00%
52	Electrical Distribution	1	$ 86,473	40	34		2.00%	2.00%
53	Branch Wiring and Devices	1	$ 154,339	50	34		2.00%	2.00%
54	Interior Lighting	0	$ 122,595	35	29		2.00%	2.00%
55	Exterior Lighting	0	$ 7,462	20	17		2.00%	2.00%

BASE CASE

Line No.	Building Components Subject to M&R	Include in Option	Cost	Useful Life (years)	Current Age	Annual Service Cost	Annual Service Cost Escalation Rate	Annual Capital Cost Escalation Rate
	Units	0=no or 1=yes	$	Years	Years	$	2.00%	2.00%
56	Exit Lighting	1	$ 4,378	35	32		2.00%	2.00%
57	Fire Alarm Systems	1	$ 82,095	20	11	$ 200	2.00%	2.00%
58	Public Address and Music Systems	1	$ 32,838	15	11		2.00%	2.00%
59	Video Surveillance Systems	1	$ 24,081	20	11	$ 100	2.00%	2.00%
60	Access Control Systems	1	$ 24,081	20	11		2.00%	2.00%
61	Emergency Lighting	1	$ 6,568	20	17		2.00%	2.00%
62	Asphalt Paved Surfaces - Parking Area	0	$ 413,355	25	23		2.00%	2.00%
63	Concrete Paved Surfaces	0	$ 211,723	30	24		2.00%	2.00%
64	Flagpoles	0	$ 13,723	40	33		2.00%	2.00%
65	Benches - Metal	0	$ 14,321	25	10		2.00%	2.00%
66	Message Sign - Post-Mounted	0	$ 12,675	20	10		2.00%	2.00%
67	Covers, Shelters, Dugouts	0	$ 12,285	30	10		2.00%	2.00%
68	Water Supply Service - Medium	1	$ 40,508	50	34	$ 50	2.00%	2.00%
69	Sanitary Sewer Service - Medium	1	$ 25,331	50	34		2.00%	2.00%
70	Electrical Service	0	$ 84,630	50	34		2.00%	2.00%
71	Site Branch Wiring and Devices	0	$ 61,152	40	34		2.00%	2.00%
72	Site Lighting	0	$ 153,530	25	19		2.00%	2.00%
99		1					2.00%	2.00%
100	A31 Walls Below Grade	1					2.00%	2.00%
101	remove concrete sidewalk and dispose	1	$ 1,819	61	0		2.00%	2.00%
102	remove asphalt paving and dispose	1	$ 430	61	0		2.00%	2.00%
103	remove landscaped areas and dispose	1	$ 2,549	61	0		2.00%	2.00%
104	excavate to 2 feet below grade	1	$ 4,367	61	0		2.00%	2.00%
105	new 2" EPS fin insulation	1	$ 5,823	61	0		2.00%	2.00%
106	cement board	1	$ 8,319	61	0		2.00%	2.00%
107	backfill to subgrade	1	$ 5,458	61	0		2.00%	2.00%
108	reinstate concrete sidewalks	1	$ 10,917	61	0		2.00%	2.00%
109	reinstate asphalt paving	1	$ 1,291	61	0		2.00%	2.00%
110	reinstate landscaping	1	$ 6,372	61	0		2.00%	2.00%
111	A32 Walls Above Grade	1					2.00%	2.00%
112	remove stone facade	1	$ 24,953	61	0		2.00%	2.00%
113	remove siding facade	1	$ 21,364	61	0		2.00%	2.00%
114	structural upgrade including base angle	1	$ 132,000	61	0		2.00%	2.00%
115	supply and install prefab r16 insulated wall panels	1	$ 250,037	61	0		2.00%	2.00%
116	supply and install prefinished metal siding	1	$ 365,439	61	0		2.00%	2.00%
117	A33 Windows and Entrances	1					2.00%	2.00%
118	replace windows with triple pane	1	$ 128,655	30	0		2.00%	2.00%
119	A34 Roof Coverings	1					2.00%	2.00%
120	remove existing roof finish	1	$ 30,171	61	0		2.00%	2.00%
121	mod bit roof finish with 12" XPS insulation	1	$ 432,450	20	0	$ 1,000	2.00%	2.00%
122	allowance for removing, reinstalling mechanical	1	$ 40,000	61	0		2.00%	2.00%
123	A35 Projections	1					2.00%	2.00%
124	soffit replacement	1	$ 45,113	61	0		2.00%	2.00%
125	canopies - no change	1					2.00%	2.00%
126	B22 Ceiling Finishes	1					2.00%	2.00%
127	cut and patch ceilings for new mechanical/electrical	1	$ 25,142	61	0		2.00%	2.00%
128	B23 Wall Finishes	1					2.00%	2.00%
129	cut and patch walls for new mechanical/electrical	1	$ 25,142	61	0		2.00%	2.00%
130	C11 Plumbing and Drainage	1					2.00%	2.00%
131	new 80gal HP hot water tanks	1	$ 4,000	14	0		2.00%	2.00%
132	C13 HVAC	1					2.00%	2.00%
133	geothermal wells, testing	1	$ 54,000	61	0		2.00%	2.00%
134	gshp piping, trenching, backfill, reinstatement	1	$ 40,000	61	0		2.00%	2.00%
135	gshp circulation pumps, interior piping, HX	1	$ 40,000	25	0		2.00%	2.00%

RETROFIT

Line No.	Building Components Subject to M&R Units	Include in Option 0=no or 1=yes	Cost $	Useful Life (years) Years	Current Age Years	Annual Service Cost $	Annual Service Cost Escalation Rate 2.00%	Annual Capital Cost Escalation Rate 2.00%
136	VRF condensing units - 10 tons	1	$ 90,000	25	0	$ 400	2.00%	2.00%
137	VRF fancoils	1	$ 76,500	25	0		2.00%	2.00%
138	refrigerant piping, branch controllers	1	$ 100,000	25	0	$ 500	2.00%	2.00%
139	VAVs	1	$ 45,000	25	0		2.00%	2.00%
140	ERV 950cfm	1	$ 28,000	25	0	$ 100	2.00%	2.00%
141	ERV 750cfm	1	$ 28,000	25	0	$ 100	2.00%	2.00%
142	new ERV ductwork	1	$ 180,000	61	0		2.00%	2.00%
143	C14 Controls	1					2.00%	2.00%
144	building automated controls - connect to existing system	1	$ 70,399	20	0	$ 500	2.00%	2.00%
145	C21 Services and Distribution	1					2.00%	2.00%
146	replace main entrance, 400A switchgear	1	$ 25,000	40	0		2.00%	2.00%
147	new feeders	1	$ 50,000	61	0		2.00%	2.00%
148	new panel, transformer for HVAC	1	$ 20,000	61	0		2.00%	2.00%
149	new disconnects, mechanical connections	1	$ 15,000	40	0		2.00%	2.00%
150		1					2.00%	2.00%
151	C22 Lighting, Devices and Heating	1					2.00%	2.00%
152	new LED light fixtures, or retrofit kits	1	$ 80,456	25	0		2.00%	2.00%
153	lighting controls	1	$ 30,171	25	0		2.00%	2.00%
154	Z11 General Requirements and Overheads	1					2.00%	2.00%
155	contractor's overheads	1	$ 381,651	61	0		2.00%	2.00%
156	Z12 Contractors Profit	1					2.00%	2.00%
157	contractor's profit	1	$ 292,599	61	0		2.00%	2.00%
158	Z21 Design Allowance	1					2.00%	2.00%
159	design development contingency	1	$ 321,859	61	0		2.00%	2.00%
160	Z23 Construction Allowance	1					2.00%	2.00%
161	construction contingency	1	$ 354,044	61	0		2.00%	2.00%
164		1					2.00%	2.00%
165	construction escalation for 2024	1	$ 254,434	61	0		2.00%	2.00%

Input : NZE

BASE CASE

Line No.	Building Components Subject to M&R	Include in Option	Cost	Useful Life (years)	Current Age	Annual Service Cost	Annual Service Cost Escalation Rate	Annual Capital Cost Escalation Rate
	Units	0=no or 1=yes	$	Years	Years	$	2.00%	2.00%
1	Standard Foundations	0	$ 290,394	75	34		2.00%	2.00%
2	Slab on Grade	0	$ 116,028	75	34		2.00%	2.00%
3	Roof Construction	0	$ 110,468	75	34		2.00%	2.00%
4	Structure	0	$ 435,651	75	34		2.00%	2.00%
5	Other Structural Systems	0	$ 16,900	50	33		2.00%	2.00%
6	Wood Siding	0	$ 163,800	30	24	$ 1,000	2.00%	2.00%
7	Stone Veneer	0	$ 361,075	75	34		2.00%	2.00%
8	Windows	0	$ 221,520	35	33		2.00%	2.00%
9	Automatic Door Openers	1	$ 26,156	15	9		2.00%	2.00%
10	Single Door - Hollow Metal	0	$ 20,904	30	24		2.00%	2.00%
11	Sliding Glass Doors	1	$ 32,604	25	19	$ 500	2.00%	2.00%
12	Gutters and Downspouts	0	$ 22,675	30	24		2.00%	2.00%
13	Conventional - Modified Bitumen	0	$ 350,740	22	8	$ 1,000	2.00%	2.00%
14	Hatches	1	$ 4,758	40	33		2.00%	2.00%
15	Fixed Partitions	0	$ 154,339	75	34		2.00%	2.00%
16	Retractable Partitions - Folding Panel	1	$ 216,996	25	19		2.00%	2.00%
17	Retractable Partitions - Overhead Counter Shutter	1	$ 9,802	30	24		2.00%	2.00%
18	Single Door - Wood	1	$ 65,520	40	33		2.00%	2.00%
19	Double Door - Hollow Metal	1	$ 7,358	40	33		2.00%	2.00%
20	Double Door - Wood	1	$ 5,720	40	34		2.00%	2.00%
21	Fixed Casework	1	$ 51,597	35	11		2.00%	2.00%
22	Fixed Casework	1	$ 73,710	35	23		2.00%	2.00%
23	Retractable Stage	1	$ 29,406	25	19		2.00%	2.00%
24	Communal Washroom Refurbishment	1	$ 230,685	25	19		2.00%	2.00%
25	Individual Washroom Upgrade / Refurbishment	1	$ 18,460	25	19		2.00%	2.00%
26	Interior Access Ladders	1	$ 3,120	40	33		2.00%	2.00%
27	Paint Wall Covering	1	$ 58,014	10	4		2.00%	2.00%
28	Ceramic Tile Floor	0	$ 5,312	40	34		2.00%	2.00%
29	Carpet Floor	1	$ 43,423	10	6		2.00%	2.00%
30	Vinyl Tile / Plank Floor	1	$ 51,652	15	9		2.00%	2.00%
31	Vinyl Sheet Floor	1	$ 10,681	15	14		2.00%	2.00%
32	Wood Laminate Floor	1	$ 54,527	25	19		2.00%	2.00%
33	Acoustic Tile Ceiling	0	$ 52,967	30	24		2.00%	2.00%
34	Painted Ceiling Structures	1	$ 10,423	15	9		2.00%	2.00%
35	Suspended Acoustic Ceiling Panels	1	$ 24,898	25	10		2.00%	2.00%
36	Sinks	1	$ 1,560	35	11	$ 100	2.00%	2.00%
37	Drinking Water Fountains - Refrigerated	1	$ 6,825	15	5		2.00%	2.00%
38	Custodial Sinks	1	$ 3,120	30	27		2.00%	2.00%
39	Domestic Water Piping and Fittings	1	$ 65,676	40	34		2.00%	2.00%
40	Domestic Water Heaters - Commercial Electric	0	$ 23,860	15	12		2.00%	2.00%
41	Sanitary Waste and Vent Piping and Fittings	1	$ 65,676	50	34		2.00%	2.00%
42	Natural Gas Supply Piping and Fittings	1	$ 8,190	40	34		2.00%	2.00%
43	Air Distribution Systems	0	$ 194,839	50	34		2.00%	2.00%
44	Exhaust Fans - Centrifugal	0	$ 24,505	25	23	$ 100	2.00%	2.00%
45	Unit Heaters (Electric)	0	$ 11,193	18	1		2.00%	2.00%
46	Electric Baseboard Heaters	0	$ 1,872	18	15		2.00%	2.00%
47	Packaged Rooftop Units - Less than 20 Tons	0	$ 51,181	20	5	$ 200	2.00%	2.00%
48	Packaged Rooftop Units - Less than 20 Tons	0	$ 51,181	20	5	$ 200	2.00%	2.00%
49	Direct Digital Control Systems	0	$ 49,257	20	11	$ 500	2.00%	2.00%
50	Fire Extinguishers	1	$ 2,189	10	4		2.00%	2.00%
51	Main Service Disconnects	0	$ 16,328	40	34		2.00%	2.00%
52	Electrical Distribution	1	$ 86,473	40	34		2.00%	2.00%
53	Branch Wiring and Devices	1	$ 154,339	50	34		2.00%	2.00%
54	Interior Lighting	0	$ 122,595	35	29		2.00%	2.00%
55	Exterior Lighting	0	$ 7,462	20	17		2.00%	2.00%
56	Exit Lighting	1	$ 4,378	35	32		2.00%	2.00%

	Line No.	Building Components Subject to M&R / Units	Include in Option (0=no or 1=yes)	Cost ($)	Useful Life (years)	Current Age (Years)	Annual Service Cost ($)	Annual Service Cost Escalation Rate	Annual Capital Cost Escalation Rate
				$	Years	Years	$	2.00%	2.00%
	57	Fire Alarm Systems	1	$ 82,095	20	11	$ 200	2.00%	2.00%
	58	Public Address and Music Systems	1	$ 32,838	15	11		2.00%	2.00%
	59	Video Surveillance Systems	1	$ 24,081	20	11	$ 100	2.00%	2.00%
	60	Access Control Systems	1	$ 24,081	20	11		2.00%	2.00%
	61	Emergency Lighting	1	$ 6,568	20	17		2.00%	2.00%
	62	Asphalt Paved Surfaces - Parking Area	0	$ 413,355	25	23		2.00%	2.00%
	63	Concrete Paved Surfaces	0	$ 211,723	30	24		2.00%	2.00%
	64	Flagpoles	0	$ 13,723	40	33		2.00%	2.00%
	65	Benches - Metal	0	$ 14,321	25	10		2.00%	2.00%
	66	Message Sign - Post-Mounted	0	$ 12,675	20	10		2.00%	2.00%
	67	Covers, Shelters, Dugouts	0	$ 12,285	30	10		2.00%	2.00%
	68	Water Supply Service - Medium	1	$ 40,508	50	34	$ 50	2.00%	2.00%
	69	Sanitary Sewer Service - Medium	1	$ 25,331	50	34		2.00%	2.00%
	70	Electrical Service	0	$ 84,630	50	34		2.00%	2.00%
	71	Site Branch Wiring and Devices	0	$ 61,152	40	34		2.00%	2.00%
	72	Site Lighting	0	$ 153,530	25	19		2.00%	2.00%
	99		1					2.00%	2.00%
RETROFIT	100	A31 Walls Below Grade	1					2.00%	2.00%
	101	remove concrete sidewalk and dispose	1	$ 1,819	61	0		2.00%	2.00%
	102	remove asphalt paving and dispose	1	$ 430	61	0		2.00%	2.00%
	103	remove landscaped areas and dispose	1	$ 2,549	61	0		2.00%	2.00%
	104	excavate to 2 feet below grade	1	$ 4,367	61	0		2.00%	2.00%
	105	new 2" EPS fin insulation	1	$ 5,823	61	0		2.00%	2.00%
	106	cement board	1	$ 8,319	61	0		2.00%	2.00%
	107	backfill to subgrade	1	$ 5,458	61	0		2.00%	2.00%
	108	reinstate concrete sidewalks	1	$ 10,917	61	0		2.00%	2.00%
	109	reinstate asphalt paving	1	$ 1,291	61	0		2.00%	2.00%
	110	reinstate landscaping	1	$ 6,372	61	0		2.00%	2.00%
	111	A32 Walls Above Grade	1					2.00%	2.00%
	112	remove stone facade	1	$ 24,953	61	0		2.00%	2.00%
	113	remove siding facade	1	$ 21,364	61	0		2.00%	2.00%
	114	structural upgrade including base angle	1	$ 132,000	61	0		2.00%	2.00%
	115	supply and install prefab r16 insulated wall panels	1	$ 250,037	61	0		2.00%	2.00%
	116	supply and install prefinished metal siding	1	$ 365,439	61	0		2.00%	2.00%
	117	A33 Windows and Entrances	1					2.00%	2.00%
	118	replace windows with triple pane	1	$ 128,655	30	0		2.00%	2.00%
	119	A34 Roof Coverings	1					2.00%	2.00%
	120	remove existing roof finish	1	$ 30,171	61	0		2.00%	2.00%
	121	mod bit roof finish with 12" XPS insulation	1	$ 432,450	20	0	$ 1,000	2.00%	2.00%
	122	allowance for removing, reinstalling mechanical	1	$ 40,000	61	0		2.00%	2.00%
	123	A35 Projections	1					2.00%	2.00%
	124	soffit replacement	1	$ 45,113	61	0		2.00%	2.00%
	125	canopies - no change	1					2.00%	2.00%
	126	B22 Ceiling Finishes	1					2.00%	2.00%
	127	cut and patch ceilings for new mechanical/electrical	1	$ 25,142	61	0		2.00%	2.00%
	128	B23 Wall Finishes	1					2.00%	2.00%
	129	cut and patch walls for new mechanical/electrical	1	$ 25,142	61	0		2.00%	2.00%
	130	C11 Plumbing and Drainage	1					2.00%	2.00%
	131	new 80gal HP hot water tanks	1	$ 4,000	14	0		2.00%	2.00%
	132	C13 HVAC	1					2.00%	2.00%
	133	geothermal wells, testing	1	$ 54,000	61	0		2.00%	2.00%
	134	gshp piping, trenching, backfill, reinstatement	1	$ 40,000	61	0		2.00%	2.00%
	135	gshp circulation pumps, interior piping, HX	1	$ 40,000	25	0		2.00%	2.00%
	136	VRF condensing units - 10 tons	1	$ 90,000	25	0	$ 400	2.00%	2.00%

Line No.	Building Components Subject to M&R Units	Include in Option 0=no or 1=yes	Cost $	Useful Life (years) Years	Current Age Years	Annual Service Cost $	Annual Service Cost Escalation Rate 2.00%	Annual Capital Cost Escalation Rate 2.00%
137	VRF fancoils	1	$ 76,500	25	0		2.00%	2.00%
138	refrigerant piping, branch controllers	1	$ 100,000	25	0	$ 500	2.00%	2.00%
139	VAVs	1	$ 45,000	25	0		2.00%	2.00%
140	ERV 950cfm	1	$ 28,000	25	0	$ 100	2.00%	2.00%
141	ERV 750cfm	1	$ 28,000	25	0	$ 100	2.00%	2.00%
142	new ERV ductwork	1	$ 180,000	61	0		2.00%	2.00%
143	C14 Controls	1					2.00%	2.00%
144	building automated controls - connect to existing system	1	$ 70,399	20	0	$ 500	2.00%	2.00%
145	C21 Services and Distribution	1					2.00%	2.00%
146	replace main entrance, 400A switchgear	1	$ 25,000	40	0		2.00%	2.00%
147	new feeders	1	$ 50,000	61	0		2.00%	2.00%
148	new panel, transformer for HVAC	1	$ 20,000	61	0		2.00%	2.00%
149	new disconnects, mechanical connections	1	$ 15,000	40	0		2.00%	2.00%
150	photovoltaic system complete with racking, inverters	1					2.00%	2.00%
151	C22 Lighting, Devices and Heating	1					2.00%	2.00%
152	new LED light fixtures, or retrofit kits	1	$ 80,456	25	0		2.00%	2.00%
153	lighting controls	1	$ 30,171	25	0		2.00%	2.00%
154	Z11 General Requirements and Overheads	1					2.00%	2.00%
155	contractor's overheads	1	$ 381,651	61	0		2.00%	2.00%
156	Z12 Contractors Profit	1					2.00%	2.00%
157	contractor's profit	1	$ 292,599	61	0		2.00%	2.00%
158	Z21 Design Allowance	1					2.00%	2.00%
159	design development contingency	1	$ 321,859	61	0		2.00%	2.00%
160	Z23 Construction Allowance	1					2.00%	2.00%
161	construction contingency	1	$ 354,044	61	0		2.00%	2.00%
164		1					2.00%	2.00%
165	construction escalation for 2024	1	$ 254,434	61	0		2.00%	2.00%
199		1					2.00%	2.00%
200	Array Size 63 kWdc	1	$ 252,000	61	0	$ 1,783	2.00%	2.00%