


# PANELIZED DEEP RETROFITS OF MUNICIPAL BUILDINGS

## Access Transit Bus Storage and Dispatch Building

## Case Study Report

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City of Saskatoon

Natural Resources Canada | Ressources naturelles Canada

ReCover

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# Access Transit Bus Storage and Dispatch Building

## Executive Summary

### Who is ReCover

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

### What is the Project

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

### Project Objectives

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

### Methods Used

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



### Building Performance Improvements

#### EUI

**74% improvement**

Existing : 414 kWh/$m^2$

Recommend : 109 kWh/$m^2$

#### GHG

**100% improvement**

Existing : 567,997 kg/yr

Recommend : 0 kg/yr

#### Lifetime Utility Costs

**92% improvement**

Existing : $44.8 M

Recommend : $3.3 M

#### Lifetime Savings

**$3.7 Million**

Existing : $70.7 M

Recommend : $67.0 M

#### Retrofit Measures

2x8 ReCover wall panels

Vacuum insulated roof panels

High performance windows and doors

Geothermal heat pump system

High performance ventilation

735kW Solar PV system

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Town of New Glasgow

City of Oakville

City of Saskatoon

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

# Acronyms and Definitions

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

# Introduction

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

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

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

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

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

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

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

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

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

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

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

## Project Objectives

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

The goals for the Deep Retrofits explored included:

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

## Methodology

The project was completed in the following phases:

1) Building selection.
   a) Definition of selection criteria.
   b) Building evaluation and selection.
2) Data and document collection, including:
   a) Utility data
   b) Building drawings
   c) Facility Condition Assessment, ideally no more than five years old
   d) Field Review
3) Baseline energy modeling (hourly analysis).
   a) Determination of model inputs
   b) Energy Model Calibration
   c) Baseline energy model results

4) Design Energy Conservation Measures (ECMs) for retrofit scenarios, including:
    a) u-values, window, and door performance specifications
    b) mechanical and electrical systems upgrades
    c) panel design, including:
        i) structural design and fastening details.
        ii) panel dimensions and layouts.
        iii) hygrothermal modeling with WUFI Pro to assess moisture risk.
        iv) embodied carbon accounting.
        v) aesthetic upgrades.
5) Cost Analysis.
    a) Class D cost estimate.
    b) TCBO modeling.

## Building Selection

A short-list of facilities was proposed for study by the City of Saskatoon. 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 Access Transit Bus Storage and Dispatch Building was selected by the ReCover team and City of Saskatoon staff based on its high EUI, relatively simple form and ease of access around the structure to stage the work. The site also has good solar potential.

## Data and Document Collection

The City of Saskatoon provided the following data and supporting documents pertaining to Access Transit:

- 2009 Tender Drawing Package (Appendix A)
- Capital Plan, Building Condition and Energy Assessments, 2013 (Appendix B)
- Fuel oil consumption records January 2018 - December 2021 (Appendix F)
- Electrical consumption records April 2017 - October 2021 (Appendix F)

Typically, a minimum of two years of consumption records for all utilities serving a building is required. The City of Saskatoon provided records going back to

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 City of Vancouver staff to understand building usage patterns, baseline operational settings for mechanical systems and for information on occupant comfort and building deficiencies.

# Building Description

The City of Saskatoon's Access Transit service provides on demand transportation to people with disabilities within Saskatoon's city limits. Their operations are based out of two buildings connected via a pedestrian link, located at 422 and 510 46th Street East, Saskatoon. Both buildings are one-storey prefabricated steel structures.




*Figure 2 Access Transit Garage*




*Figure 1 Site Plan: Access Transit Facility*

The older and smaller building, on the west side of the site, contains Access Transit's dispatch offices and a maintenance shop. It is a 1,300 $m^2$ (14,000 sq.ft.) structure built in the early 1970s that was purchased by the City of Saskatoon in 1984. The dispatch office is staffed 24 hours a day, 7 days per week and the maintenance shop operates Monday to Friday from 5:30am to 4pm.

In 2010 the Access Transit bus storage garage was added next door. It was the City of Saskatoon's first LEED certified building. The 4,423$m^3$ (47,609 sq.ft) building stores the fleet of 28 lift-equipped buses and contains locker rooms and washrooms for bus drivers, service rooms and zones for refueling and washing the buses. The Access Transit bus storage facility was designed to be 25% more energy efficient than the Model National Energy Code for Buildings (MNECB) baseline and to use 70% less water than a conventional building.

Construction drawings of the bus storage garage (Appendix A) were provided to the consultant team for this study. Plans for an internal retrofit to the dispatch office and mechanic, shop completed in 2019, provide overall dimensions and information about some of the building assemblies (Appendix A).

## Context

The Access Transit facility is in Saskatoon's North Industrial neighbourhood, a 2.6 square kilometer area dominated by pre-engineered metal buildings like the Access Transit facility.

Saskatoon has a dry climate with long, cold winters and warm summers. Saskatoon is experiencing increased temperatures in all seasons and increased annual precipitation.[3] It is a sunny city with good solar potential. Building science concerns include severe storms with high wind and rain, hail, blizzards, and tornados.

The city is in Canadian building code climate zone 7a.

In 2017 Saskatoon city council committed to reducing GHG emissions in the city by 80% below 2014 levels by 2050.[4] Buildings account for over half of Saskatoon's GHG emissions[5]. Reducing

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[3] City of Saskatoon , (20. ) *Saskatoon's Adaptation Strategy,* https://www.saskatoon.ca/sites/default/files/documents/local_actions_report._.pdf

[4] City of Saskatoon City Council. (2017, June 26). '*Saskatoon Greenhouse Gas Emissions Targets*', Regular Business Meeting. https://pub-saskatoon.escribemeetings.com/Meeting.aspx?Id=4d4c82d9-da17-4b4a-8a34-cdce348f9fb9&Agenda=PostMinutes&lang=English&Item=81#80

[5] City of Saskatoon (2016) 2014 Saskatoon Greenhouse Gas Emissions Inventory Report. https://www.saskatoon.ca/sites/default/files/documents/2014_saskatoon_greenhouse_gas_emissions_inventory.pdf

GHGs through building energy efficiency is one of six activities outlined in the city's Low Emissions Community Plan.[6]

## Building Code Considerations

A preliminary National Building Code of Canada (NBCC) review was completed to determine building code implications of a panelized retrofit to the Access Transit buildings (Appendix L). The focus of the review was to determine if panels made with combustible materials may be permitted to be installed on the existing structure.

The construction type, cladding and fire rating requirements for each exterior wall of a building are based on the area of the wall and its proximity to the property boundaries and the building's occupancy classification. Based on our understanding of the building's uses as a storage and repair garage and dispatch office, the building has two occupancy classifications, NBCC Group **F2 – Medium Hazard Industrial Occupancy** and **Group D - Business**.

Building setbacks were obtained from the COS Bus Storage Tender drawing package (Appendix A). The structure is permitted to be of either combustible or noncombustible construction; however, the cladding is required to be noncombustible. This indicates that combustible prefabricated panels may be permitted to be installed on the building provided they have noncombustible cladding.

## Building Enclosures

Building assemblies for Access Transit were obtained from the existing drawings (Appendix A) provided by city of Saskatoon staff. The thermal performance of all wall and roof assemblies was reduced by 20% from the calculated values to account for the impact of thermal bridging of cladding attachments and service penetrations through the highly conductive metal structure.

The Transit garage walls and ceiling are insulated with RSI-3.5 (R-20) nominal vinyl faced fiberglass batt insulation. Its north and south walls have an RSI value of 2.1 (R-11.9) and the east and west walls are RSI-2.45 (R-13.9). The roof is RSI-1.76 (R-10). The perimeter of the bus storage garage floor slab is insulated with 50mm of rigid insulation to a width of 3,048mm. The type of rigid insulation used was assumed to be extruded polystyrene with an RSI-1.3 (R-7.5).

The dispatch building walls are also insulated with an unspecified thickness of fiberglass batt. The available drawings do not call out the roof assembly, however based on photos and field observations, the roof is also insulated with vinyl faced batt and was assumed to match the walls for this study. Based on the available drawings the walls and roof of the dispatch building

[6] City of Saskatoon (2019) The Low Emissions Community Plan, https://www.saskatoon.ca/sites/default/files/documents/low_emissions_report-aug8_web.pdf

were assumed to be RSI-1.3 (R-7.5). The slab of the dispatch building is believed to be uninsulated.

The link walls are concrete block with 50mm of rigid insulation, RSI-0.7 (R-4). The link roof is wood framed with fiberglass batt between the joists and 50mm rigid insulation, RSI-1.76 (R-10). The link slab is fully insulated with 50mm rigid insulation, assumed to be extruded polystyrene.

Overhead doors make up 21.5% of the wall area in building, representing a significant percentage of the thermal enclosure. The thermal performance of the overhead doors was not found in the available drawings. These were assumed to have a USI value of 1.13 $W/m^2K$.

**TABLE 1 Opaque Enclosures Thermal Performance: Access Transit Facility**

| | Effective USI $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot °F$) | Effective RSI $m^2 \cdot K/W$ ($ft^2 \cdot °F \cdot h/BTU$) |
|---|---|---|
| weighted average walls | USI-0.53 (U-0.09) | RSI-1.92 (R-10.6) |
| weighted average roofs | USI-0.6 (U-0.11) | RSI-1.65 (R-9.4) |
| weighted average slab | USI-2.13 (U- 0.37) | RSI-0.47 (R-2.67) |
| windows | USI-3.41 (U-0.6) | RSI-0.29 (R-1.67) |
| overhead doors | USI-1.13 (U-0.2) | RSI-0.88 (R-5) |

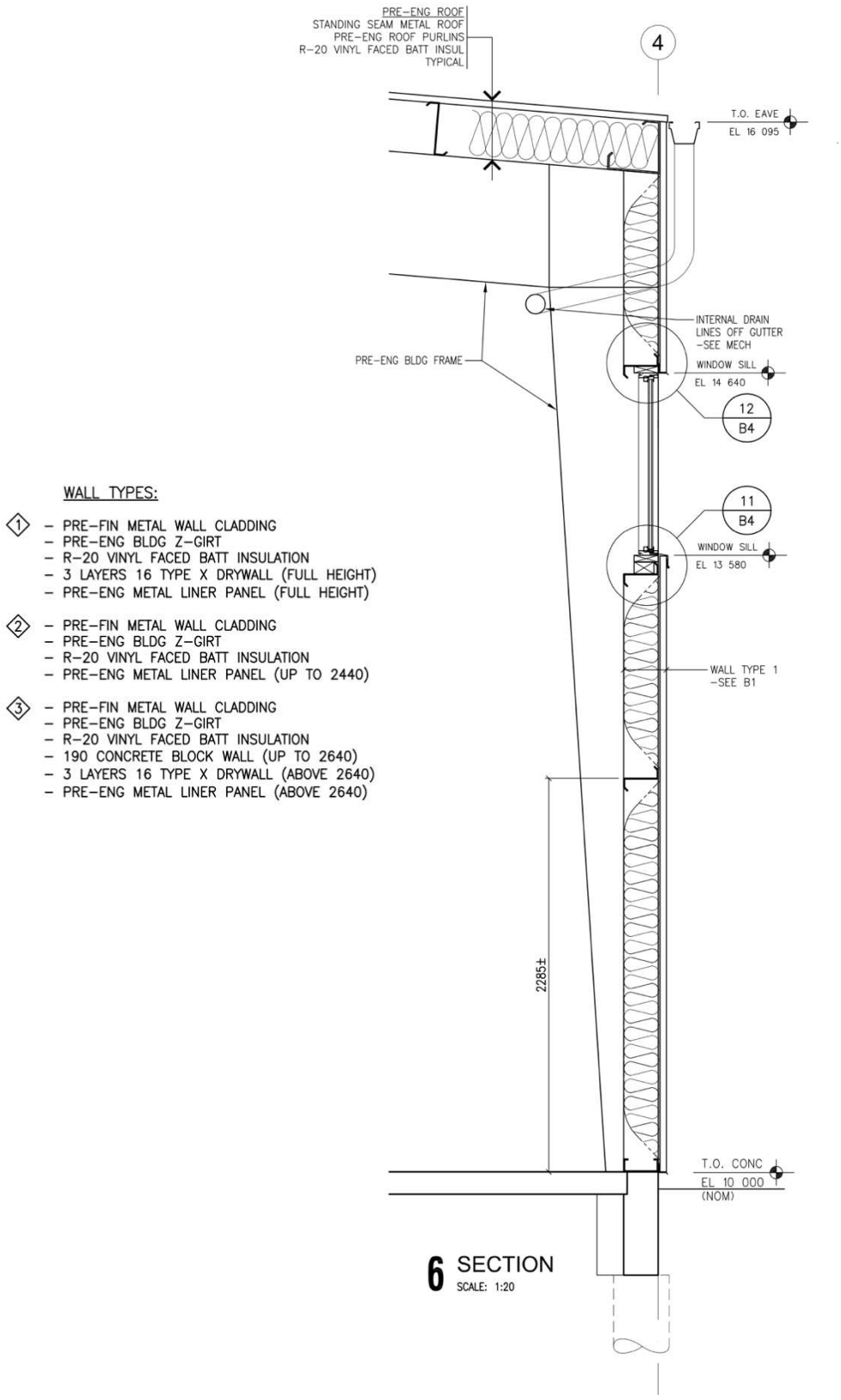



*Figure 3 Bus Storage Garage Partial Section*

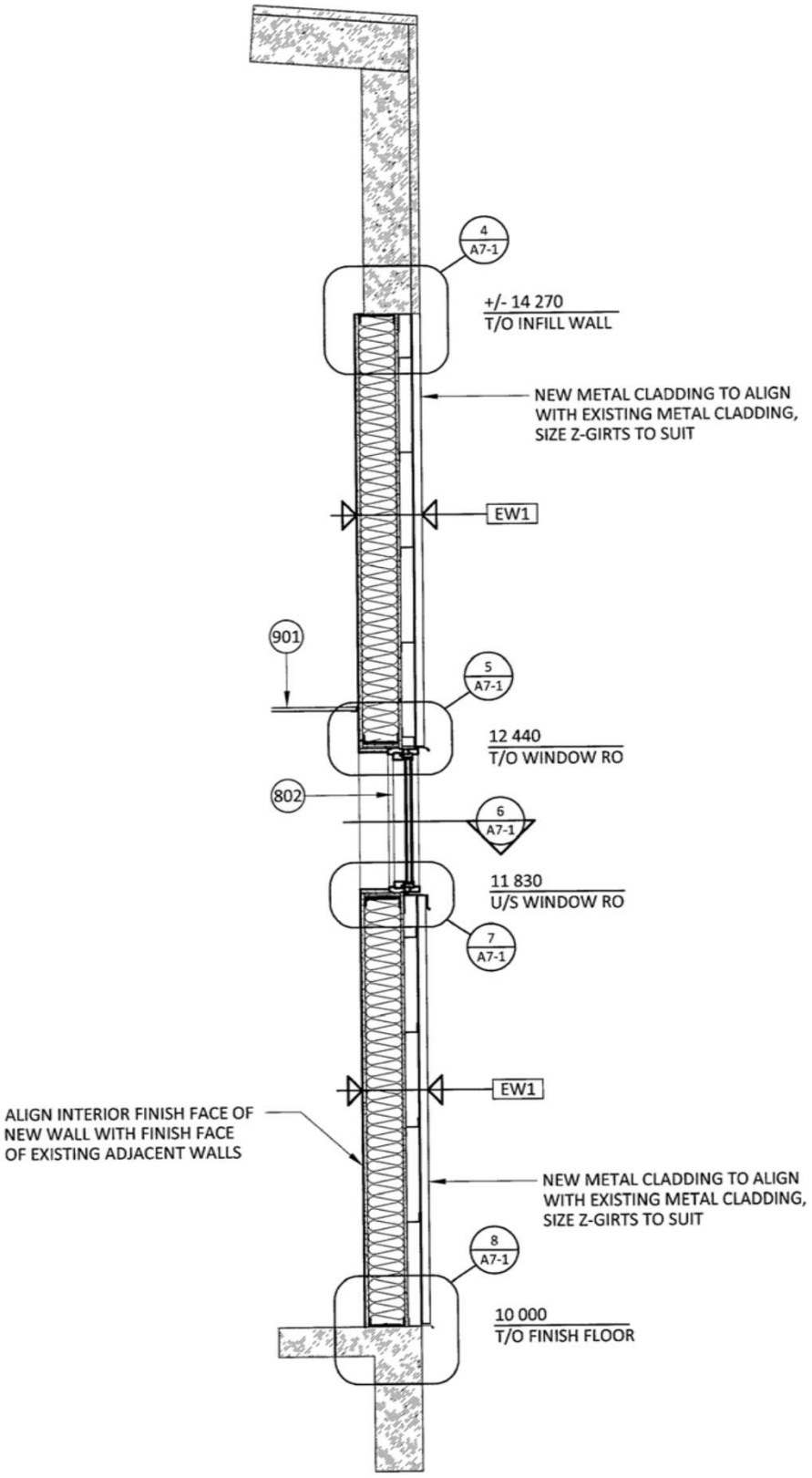



*Figure 4 Dispatch Office and Mechanic Shop Partial Section*

## Existing Structure

The primary steel structure of the bus storage garage was designed by Varco Pruden (VP) Buildings. The structure consists of a system of pre-engineered steel portal frames with lightweight steel Z-girts spanning between them. A portal frame is a grouping of columns and beams joined in a simple, structurally efficient form. A typical frame from the bus storage garage is shown in Figure 5.

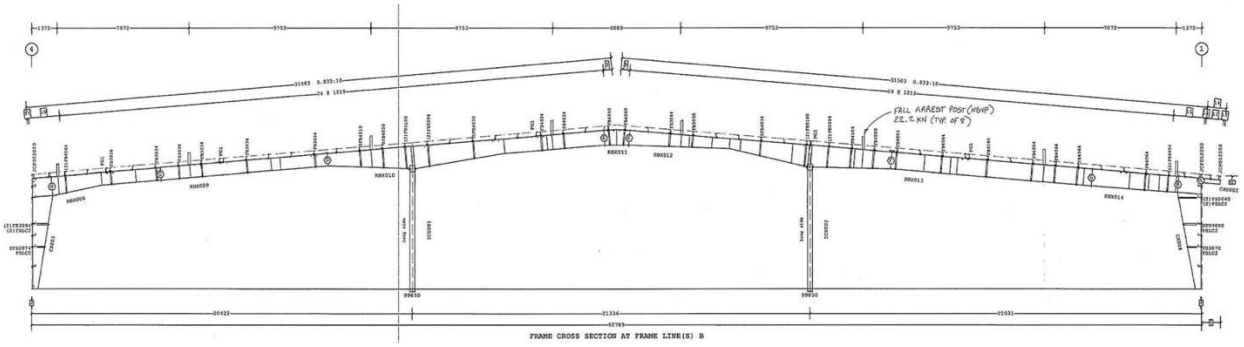


*Figure 5 Bus Storage Garage typical structural frame*

The dispatch office and maintenance building is also a pre-engineered steel structure consisting of a system of portal frames connected by lightweight steel purlins and girts. Structural review determined that added loads can be supported on the walls but neither roofs can support added weight. Alterations that increase the thermal performance of the older dispatch office building are also not possible as adding insulation may increase snow loads on that roof.

The walls may undergo a panelized retrofit but is not viable for the roofs. It is recommended that no alterations be completed to either building that would add weight, including a conventional re-roofing with additional layers of rigid foam.

The Structural Outline Specification, including details on the existing structural systems, are in Appendix C.

## Existing Mechanical Systems

Rainwater is harvested in the building to serve the bus washing and toilets.

**Domestic hot water** is provided with a domestic tank gas fired water heater serving the Dispatch building and an on-demand gas fired hot water heater in the Transit building.

**Heating** in the dispatch office is provided by two natural gas furnaces and three electric baseboard heaters for supplemental heat. The machine shop has four standalone gas fired unit heaters and one gas fired radiant tube heater. The Transit building is heated with two natural gas fired high efficiency condensing boilers and distributed through a hydronic heating system.

**Cooling** is provided to the office areas via two condensing units connected to the furnaces. There is no other cooling in the facility.

**Ventilation** is supplied in the dispatch office by a heat recovery ventilator (HRV). Six exhaust fans and three make-up air units (MUAs) provide ventilation to the machine shop. The electrical room is also served by an exhaust fan. The Transit building is ventilated by a direct fired natural gas MUA and three rooftop exhaust fans. An HRV serves the Transit building washroom and showers.

The dispatch office is controlled with standalone **controls.** A programmable thermostat controls the furnace and condenser, and a digital thermostat controls the electric heaters. In the machine shop two fans and one MUA are operated continuously during occupation and the others are controlled with CO and $NO_2$ sensors. The Transit building is equipped with a direct digital control (DDC) system. In-floor radiant heat and unit heaters have thermostatic controllers integrated in the DDC system. Ventilation is controlled with a combination of manual switches and CO sensors.

The Mechanical Outline Specification, including details on the existing mechanical systems, are in Appendix C.

## Existing Lighting Systems

The incoming **power service** is supplied through a pad mount transformer. The existing main incoming secondary service is sized at 800A, 600V, 3P.

The **main switchboard** is original to the 2010 bus storage garage. A 400A panelboard serves the bus storage garage which is fed from the new main switchboard. The main building main breaker is an 80% rated 800A main breaker. There is an 800A distribution panelboard installed inside the main switchboards second cubicle.

A 35kW emergency diesel generator is on site for **emergency backup power**.

Most of the **interior lighting** in the garage building consists of LED linear high bay fixtures. All fixtures are all in excellent condition. The fixtures for the dispatch building have  been replaced with LED lamps. Building mounted **exterior lighting** and pole top lighting have been retrofit to LED.

The building **lighting control system** is a mix of manual and automatic control. Manual switches are located throughout for manual controls, while occupancy sensors are for automatic control.

The Electrical Outline Specification, including details on the existing electrical systems, are in Appendix E.

## Energy Consumption

Electrical records and natural gas records dating from 2002 through August 2022 were shared with the team. The energy analysis for this study was based on data from 2015 through 2021 (Appendix F). A portion of the data from this time is shown in Figure 6.

The pre-2010 utility data (Appendix F) was analyzed to quantify the relative EUI of the two buildings as the two Access Transit buildings share common electricity and natural gas services. Prior to 2010 the original building used an average of 129,000kWh of electricity and 65,900 m3 of natural gas per year for an EUI of 634 ekWh/$m^2$/yr. Currently the annual electrical use is 339,400kWh and natural gas use averages 169,500$m^3$ per year. The current combined EUI is 413.6 ekWh/$m^2$/yr. The bus storage garage, if isolated from the older building, would have an EUI of 295 ekWh/$m^2$/yr.

The dispatch office and maintenance shop building is 23% of the total building area and is responsible for nearly 40% of its energy use.

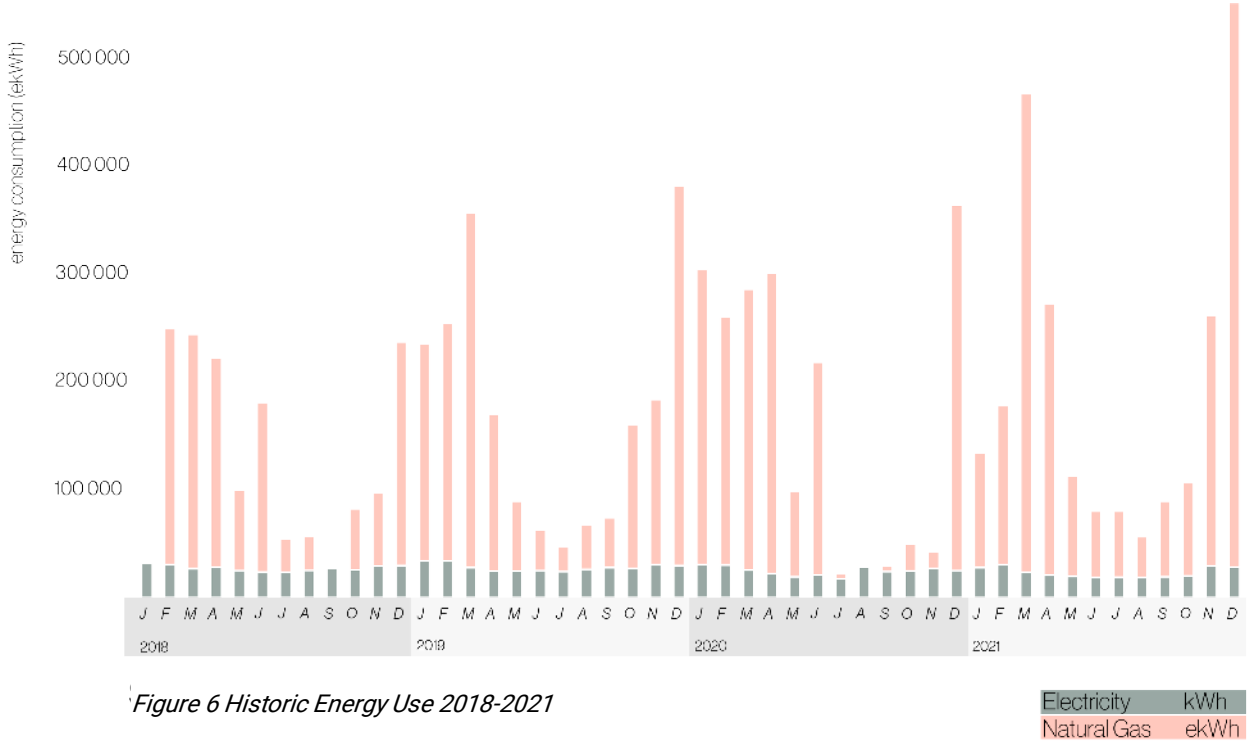



*Figure 6 Historic Energy Use 2018-2021*

## Baseline Energy Modeling and Calibration

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

The energy model was calibrated with historical utility data (Appendix G) to closely reflect the current building performance (Figure 7). The modeled annual electrical consumption deviates from actual electrical usage by an average of 3.5% over the year. The largest difference occurs from March to May, where the calibrated electrical use ranges between 8.5 and 9% higher than reported use.

The modeled annual natural gas consumption deviates from actual use by an average of 10.5% over the year. The largest difference occurs in October, where the calibrated model shows gas use 135% higher than actual.

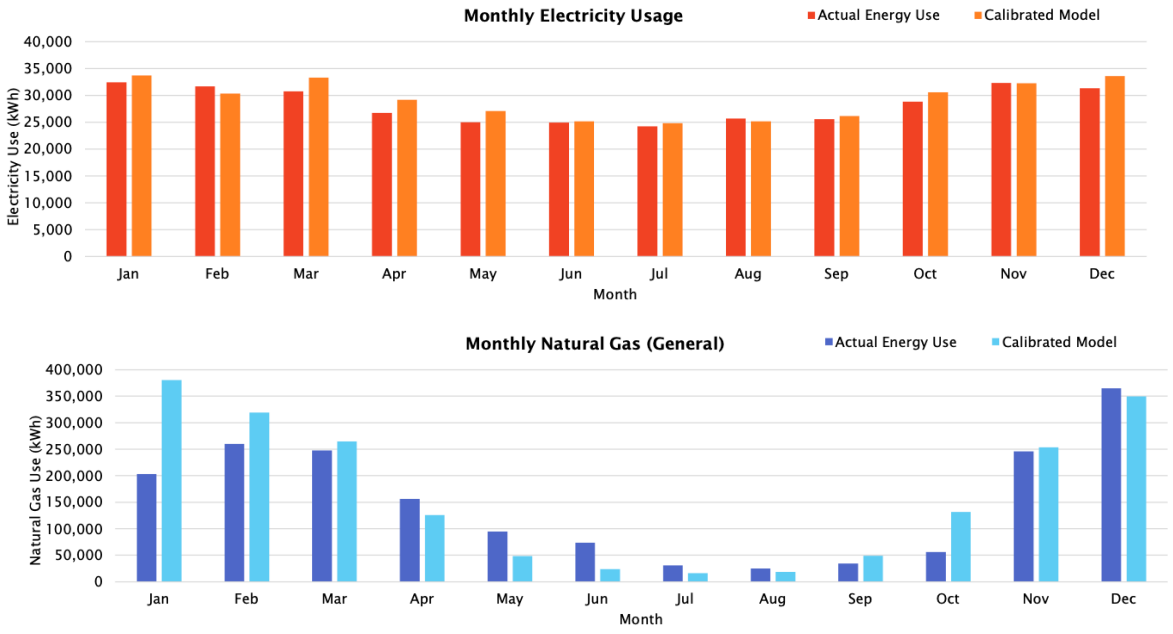



*Figure 7 Facility Calibrated Energy Use*

The Thermal Energy Demand Intensity (TEDI) graph (Figure 8) shows the amount of heat needed to offset heat losses that occur through the building envelope and ventilation equipment. It also accounts for internal heat gains from lights, plug loads, solar etc.

Heat losses from air infiltration and the building's ventilation system account for more than half of the annual heating energy demand. The large number of overhead doors in the building and the age of the original structure both contribute to a high infiltration rate. Heat losses through the roof are responsible for 25% of the heat losses.

The Total Energy Use Intensity (TEUI) of the Access Transit Facility is 413.6 ekWh/m$^2$/yr.

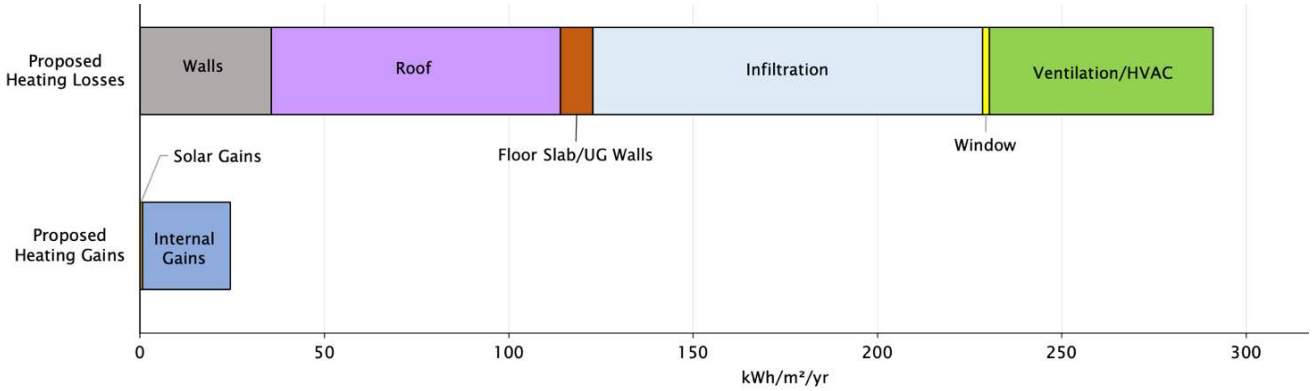



*Figure 8 Thermal Energy Demand Intensity (TEDI)*

# 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. The proposed roof retrofit involves removing existing metal roofing and insulation and replacing it with lightweight vacuum insulated panels (VIPs) and replacing the metal roof.

## 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 existing air infiltration.

Mechanical and electrical retrofits were developed based on ease of integration with existing systems and installation cost.

Details of the retrofit scenarios are summarized in Table 3.

## Energy Conservation Measures

As infiltration and ventilation are responsible for more than half of the building's heat losses, Scenario 1 was created to determine if the 50% energy savings target could be met through airtightness and ventilation efficiency upgrades alone. This option reduces energy use by only 32%. With the addition of a ground source heat pump, Minimum Upgrade Scenario 1b, does meet the target, with a 55% reduction in EUI from the baseline.

The Net Zero Energy Ready scenario also falls short of the targeted 75% EUI reduction. As a quarter of the total heat losses in the building are through the roof, it is necessary to improve the roof's thermal performance to reduce energy use by 75%. As the structural loading on the roof can't increase, options are limited to solutions that improve the roof that weigh the same as the existing roof components. Optimizing the thermal performance of the roof is critical to achieving net-zero energy ready performance in this building.

The Net Zero Energy Ready scenario is a 65% energy savings over the baseline.

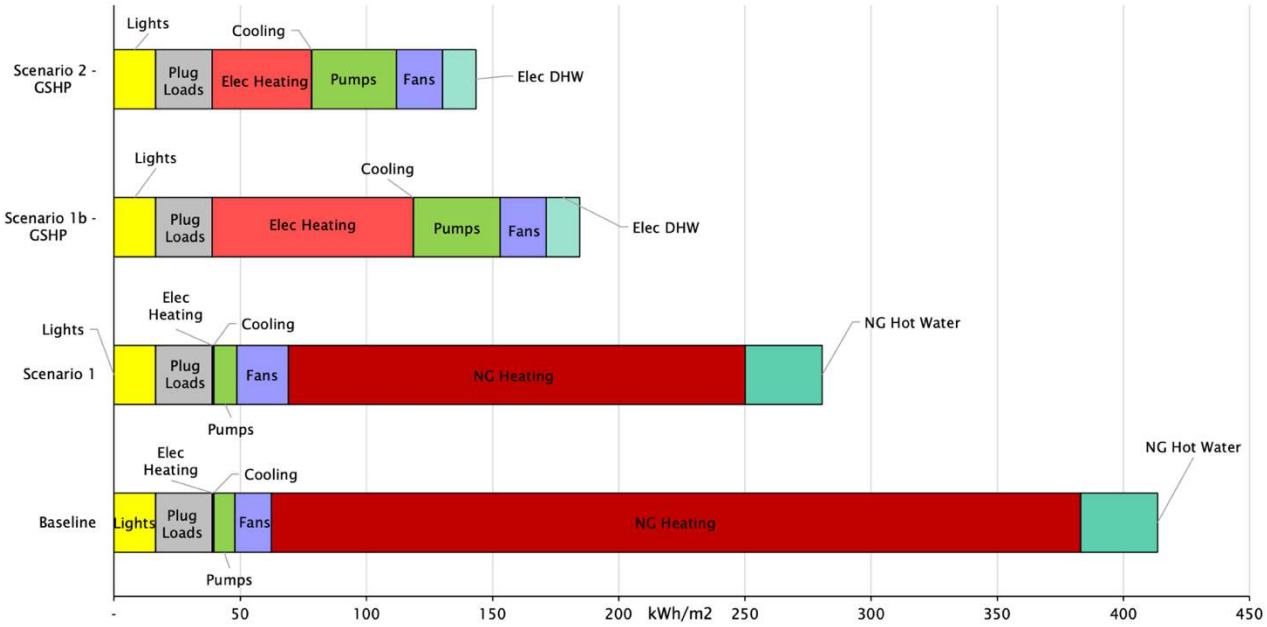



*Figure 9 ECM Scenarios TEUI comparison*

| Table 2 Retrofit Scenario Results | | | |
|---|---|---|---|
| | **Target TEUI** | **TEUI kWh/m$^2$** | **TEUI reduction** |
| **Existing** | - | 435.4 | - |
| **Minimum Upgrade** | 50% savings | 217 | 32% |
| **Min. Upgrade 1b** | 50% savings | 113.4 | 55% |
| **NZER GSHP** | 75% savings | 110.1 | 75% |
| **NZE** | 100% savings | 0 | 100% |

| Table 3 Access Transit Facility: Scenario System Summary | | | | |
|---|---|---|---|---|
| **Item** | **Existing Building** | **Minimum Upgrade 1** | **Minimum Upgrade 1b** | **GSHP Net Zero Energy [1]** |
| Effective Wall R-value Dispatch Bldg | Existing RSI-1.3 (R-7.5) | | | 2x8 ReCover Panel RSI-4.93 (R-28.5) |
| Effective Roof R-value Dispatch Bldg | Existing RSI-1.3 (R-7.5) | | | VIP insulation RSI-8 (R-45.5) |
| Effective Wall R-value Bus Garage | Existing RSI-2.27 (R-12.9) | | | Existing RSI-2.27 (R-12.9) |
| Effective roof R-value Bus Garage | Existing RSI-1.76 (R-10) | | | Existing RSI-1.76 (R-10) |
| Air Tightness @ 75Pa | 3.0 L/s·m2 | 0.75 L/s·m2 | | |
| Central Heating Equip. Disp Maintenance | - | | Water-to-Water Ground Source Heat Pumps Booster Heat Pumps Supplemental electric boiler | |
| Heating System Disp Maintenance | Natural gas burners in Make-up air units | Natural gas burner in ERV | Two pipe fan coils | |
| Central Heating Equip. Disp Office | Natural gas-fired furnaces | | Water-to-Water Ground Source Heat Pumps Booster Heat Pumps Supplemental electric boiler | |
| Heating System Disp | Ducted air system w/ furnace blower and condenser coil | | Ducted AHU w/ hydronic coil | |

| | | | |
|---|---|---|---|
| Office | | | |
| Central Heating Equip. Bus Garage | Natural gas-fired condensing boilers | | Water-to-Water Ground Source Heat Pumps<br>Booster Heat Pumps<br>Supplemental electric boiler |
| Heating System Bus Garage | In-floor radiant heating system, hot water unit | | |
| Air Cond. Disp. Maint. & Bus Garage | none | | |
| Air Cond. Disp. Office | Rooftop Condensing Units | | Ducted AHU w/ hydronic coil |
| DHW Equip. Dispatch Bldg | Natural Gas Water Heater | | HP Water Heater |
| DHW Equip. Bus Storage | Natural Gas Tankless Water Heater | | HP Water Heater |
| Ventilation Equip. Disp.Maintenance and Bus Garage | Make-up air units and exhaust fans | 90% SRE ERVs | |
| Ventilation Equip. Disp. Office | 60% Efficiency HRV | | |
| Solar PV | - | | 735 kW DC |
| [1]Net Zero Energy Ready systems are identical with exclusion of renewables | | | |




*Figure 10 Design concept front view*

## Design

The motivations for deep retrofits typically relate to high operating costs and poor occupant comfort, yet cosmetic upgrades are a significant driver of building retrofits. It is important to demonstrate that deep retrofits can play a role in building beautification and in making welcoming places in our communities.

Noncombustible cladding is required for this building, and continuing to clad the building with metal is recommended. Metal is highly durable and long-lasting, reducing time and expense in lifetime maintenance and replacement costs, and at its end of life, it can be recycled or repurposed.

The proposed palette for the Access Transit Facility injects colour into this neighbourhood of drab metal buildings. The walls will be a galvanized silver finish, with each overhead door painted in a unique colour and labeled with large, person-sized numbers. This will offer variety to the streetscape and serve as a wayfinding tool for bus drivers.

The Net Zero Energy retrofit includes wall mounted solar panels. These are shown in drawings as standard black panels however there is also an opportunity to explore building integrated photovoltaic panels with a custom finish.




*Figure 11 Concept back view*

Proposed Architectural Elevation drawings are provided in Appendix L

## Panelized Wall Details

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

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

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

**NZER Scenario Wall Panel effective RSI-2.46 (R-14)**

1. metal cladding [7]
2. strapping/rain screen cavity
3. WRB membrane
4. plywood sheathing
5. dense-pack cellulose
6. framing – 2x8 with staggered 2x4 studs @ 24”oc
7. variable permeability vapour control membrane
8. interior strapping

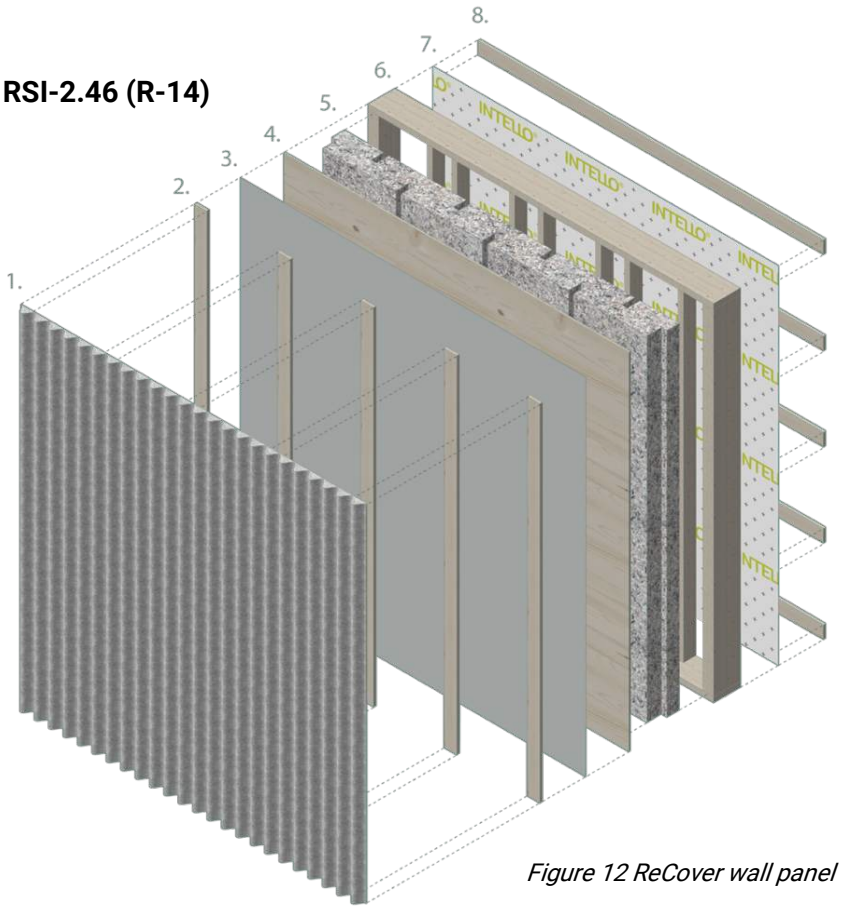



*Figure 12 ReCover wall panel*

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

The walls will consist of two courses of panels, each approximately 3m in height. New steel girts will span between existing steel frames, allowing the panels to be fastened to the structure at the top and bottom of the panels only.

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

A steel lintel will support the proposed steel wall structure and wall panels at the base. The proposed lintel would be fastened to the existing concrete grade beams using post-installed epoxy anchors. The existing concrete piles protrude beyond the extend of the grade beams. Therefore, it is recommended that the steel lintel is non-continuous at existing pile locations.

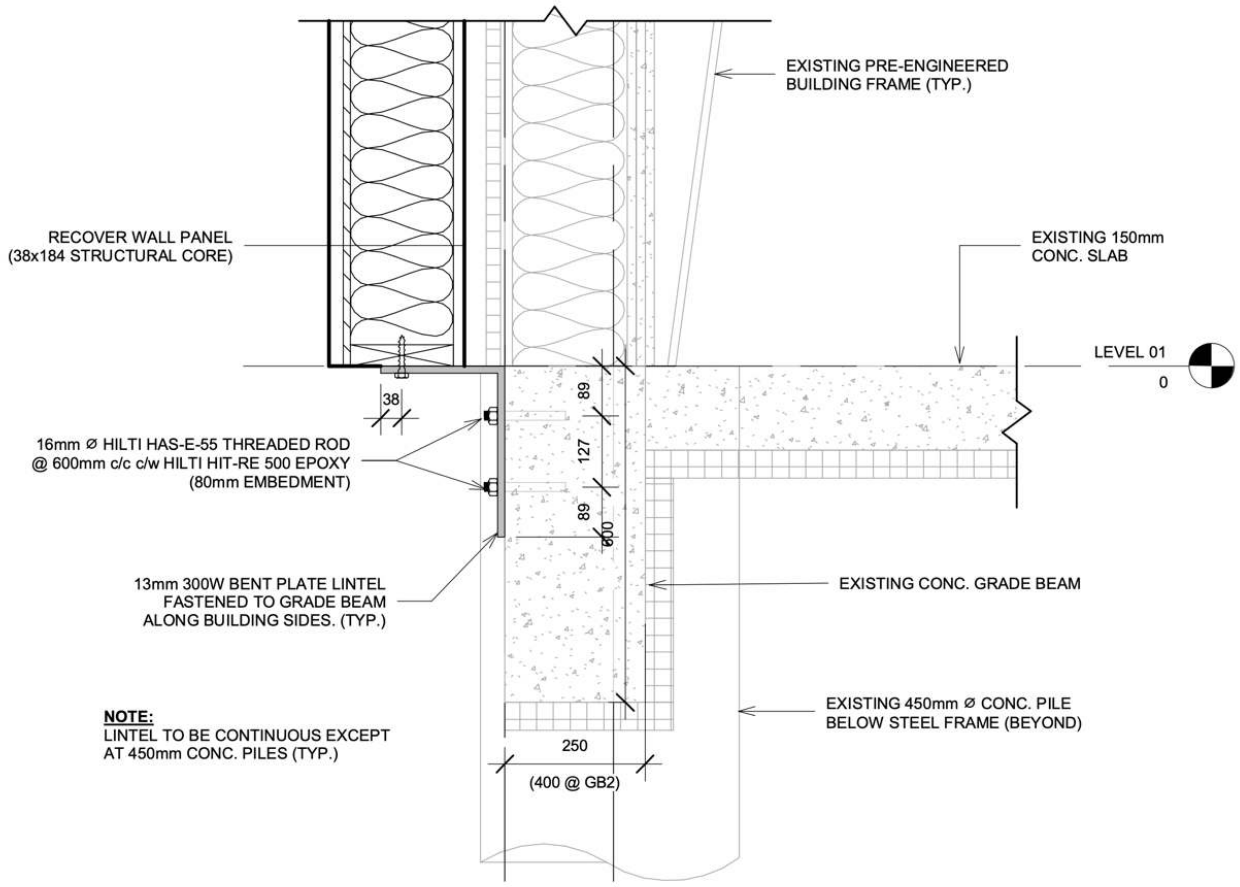



*Figure 13 Proposed ReCover panel connection at existing grade beam.*

To connect the bottom and top courses of panels, a custom steel tab will be welded to the proposed steel girts, connecting the top plate of the bottom panel and the bottom plate of the top panel to the mid-height girt. A front-mounted lag screw connection allows the top panel to be connected after installation of the girt and bottom panel.

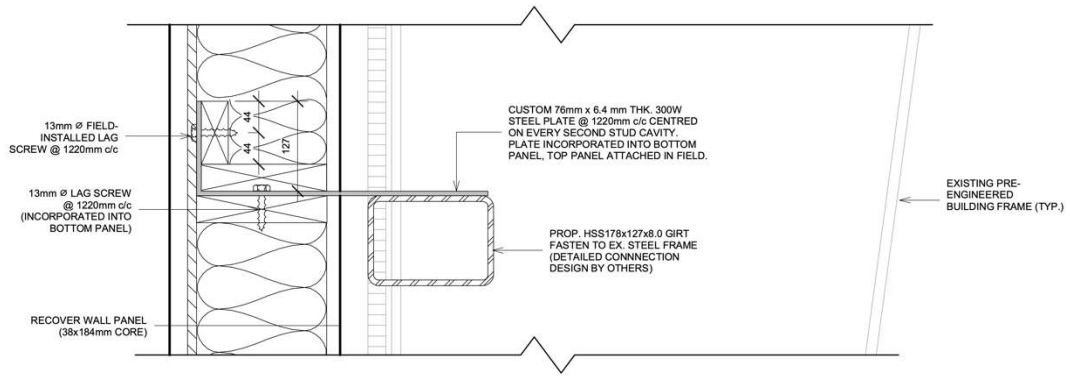



*Figure 14 Proposed mid-height wall panel connection detail.*

At the roof of the structure, a hollow section steel (HSS) girt will be fastened to the primary steel frame to transfer load from the wall panels to the primary structure.

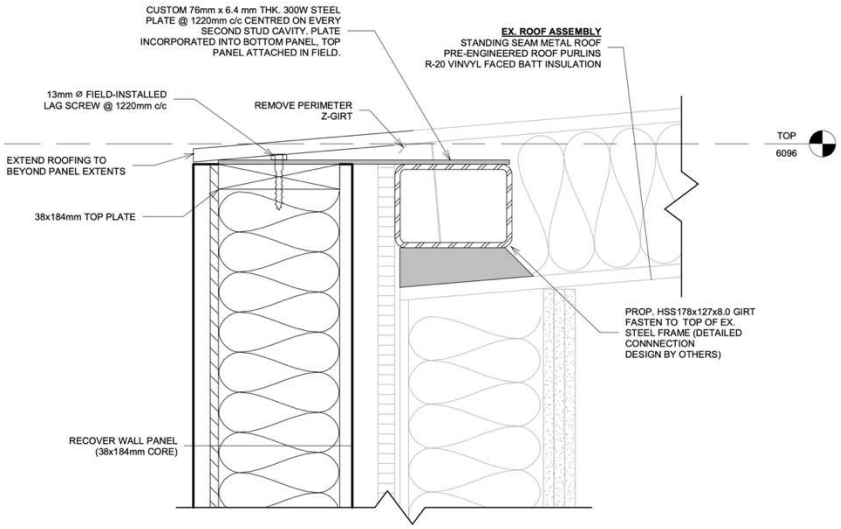



*Figure 15 Proposed wall panel connection at roof.*

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

### Roof Design

Thermal upgrades to the roof enclosure of the Access Transit bus storage garage are only possible if the proposed retrofit does not add weight. The proposed solution for the roof is to remove the existing steel roof cladding and the vinyl faced batt insulation and to install a new metal roof and insulation that has a much higher thermal performance than the batt.

The proposed insulation is a light-weight assembly made of a 25mm vacuum insulated panel laminated between two layers of rigid polyisocyanurate. These laminated panels would have a nominal performance of RSI-13.38 (R76). The impacts of thermal bridging in steel buildings mean that the nominal RSI value of this assembly is significantly degraded due to fastening attachments and service penetrations. A conservative estimate of RSI-7.9 (R-45) as the effective roof R-value was assumed for this assembly in the energy model to account for thermal bridging.

## 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.

Hygrothermal simulations were conducted on the Access Transit NZER wall and roof assemblies using WUFI® Pro (Appendix J). The 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 Saskatoon climate. Specifically, moisture content peaks in winter, with the greatest peak occurring in the first year

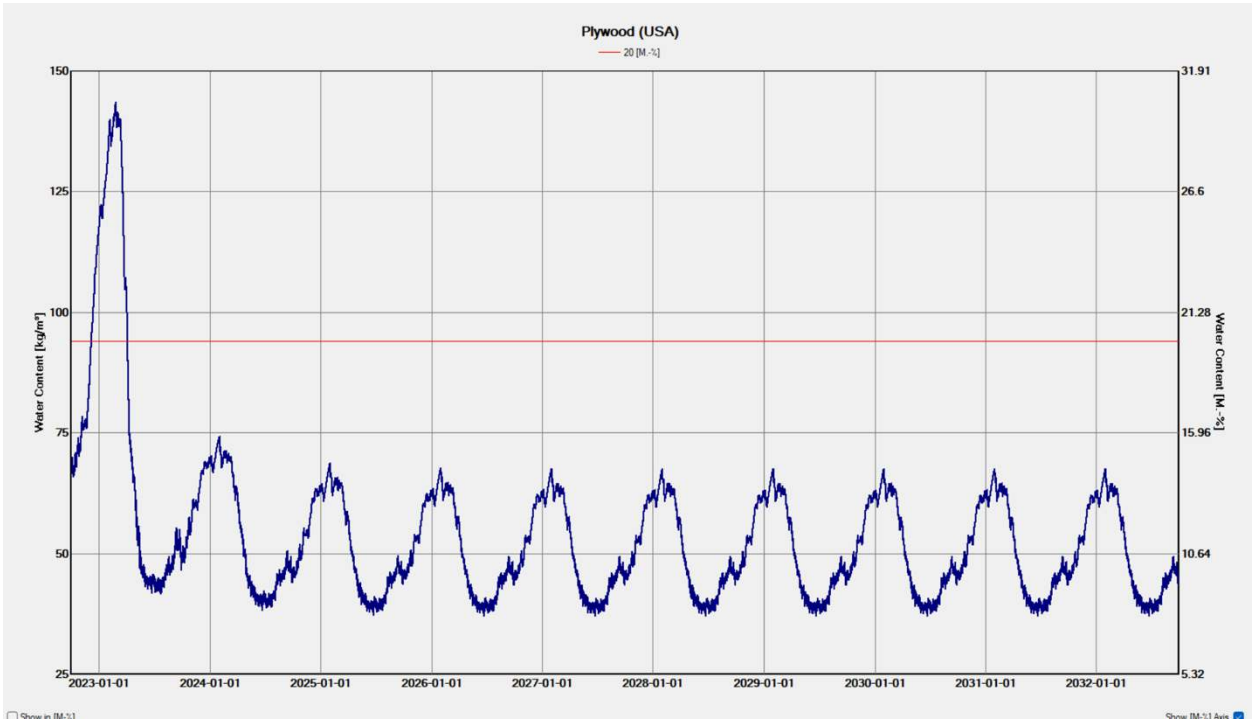



*Figure 16 WUFI output north wall (inner plywood layer)*

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

For all wall types and orientations, simulations indicated good drying potential in the layers of the panel. None of the panel materials were shown to experience moisture spikes above 20% moisture content after the first year. They followed a pattern similar to the example shown in Figure 16. The analysis also indicated low risk of mold growth within the plywood and cellulose in the assemblies.

Unexpectedly, a risk was identified in the existing fiberglass batt insulation. The outermost portion of the batt, adjacent to the existing metal cladding, was shown to experience moisture content of approximately 100% in the east and west walls for an extended time between approximately October and June, and 80% in the north and south walls between approximately October and March. This is presumably related to outward vapour drive. In the post-retrofit scenario, the existing metal siding is protected by the wall panel and should not be a cold surface, however this does represent a risk if detailing is not airtight and thermal bridge free as vapour may condense on the metal and damage the fiberglass.

Additionally, shading of building surfaces can affect the ability of assemblies to dry. The walls in the area where the two parts of the building are approximately 1.3m apart, a situation that alters solar radiation and rain exposure to the assemblies. Should the project proceed, this area should be studied further.

## Embodied Carbon

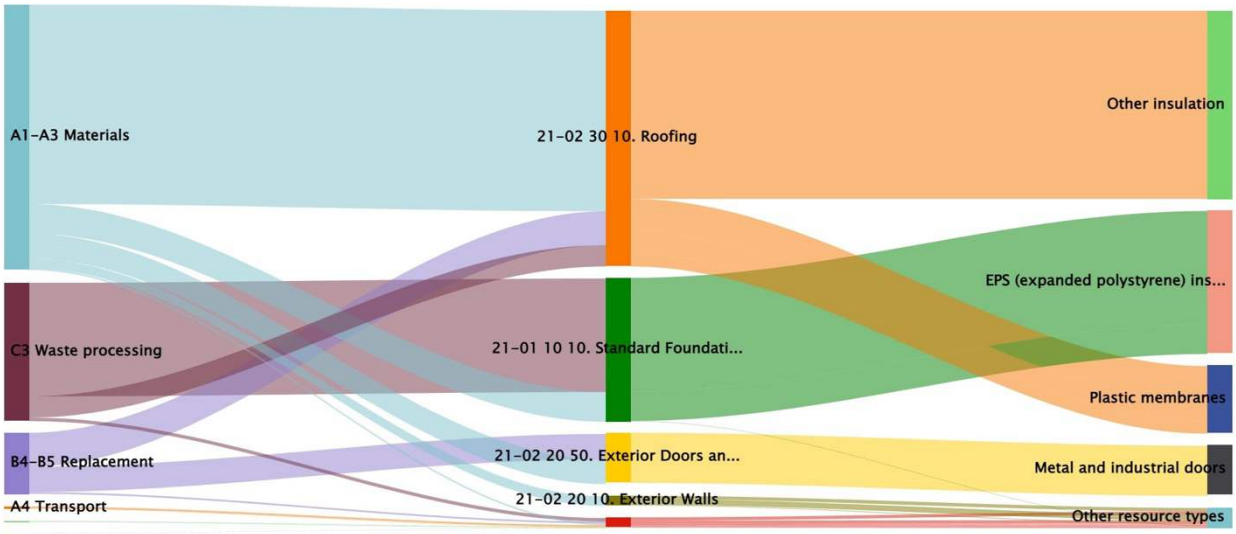



*Figure 17 Global Warming by Stage and Material - NZER retrofit*

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 Access Transit Facility – Total Global Warming Potential | | | |
|---|---|---|---|
| gross floor area $m^2$ | A1-A3 $KgCO2e/m^2$ | A1-C4 KgCO2e/m2 | Biogenic carbon KgCO2e/m2 |
| **5,629** | **54.12** | **95,28** | **16.2** |

The GWP in this design is dominated by the roof vacuum insulated panel (VIP) and EPS wall insulation. Figure 17 above which is generated by One Click LCA shows the VIP as "other insulation", which is made of non-combustible fumed silica, mixed with fibers and opacifier. The A1-A3 Materials stage contributed 57% of the total carbon emissions associated with this building followed by C3 Waste processing at 30% as illustrated in Figure 18 & 19. The biogenic carbon of this building offsets 17% of the total A1-C4 carbon emissions. This storage is attributed to the wood products (67.6%) and cellulose insulation (32.4%) used in the assembly as shown in Figure 19. The results graphs below show the breakdowns of life cycle stages and impact categories associated with the building materials.

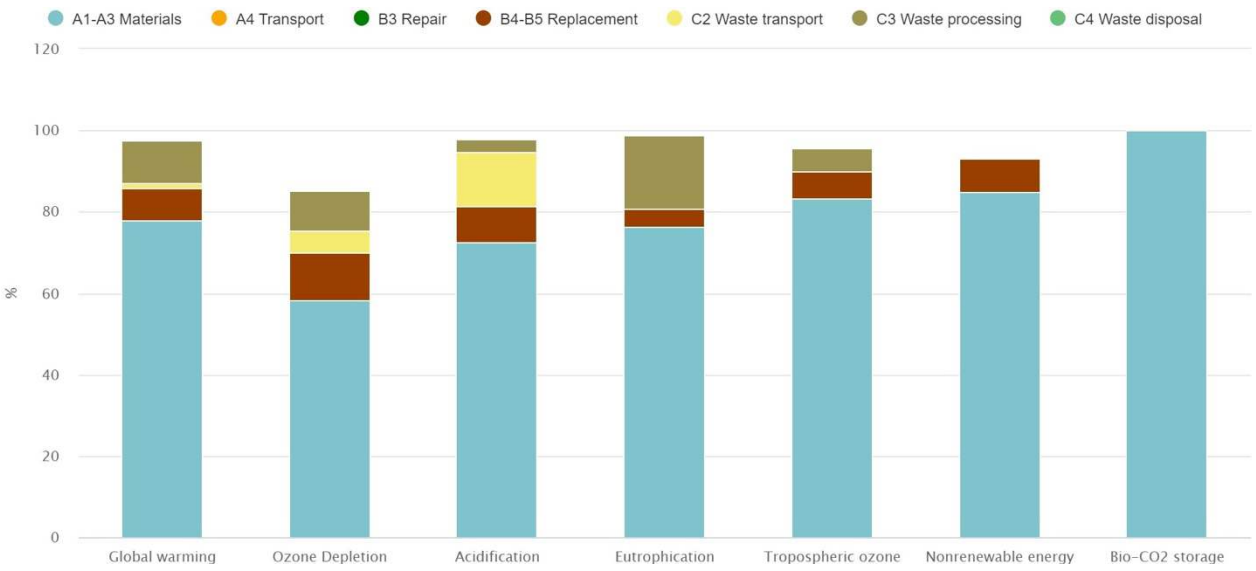



*Figure 18 Life Cycle Impacts by Stage - NZER retrofit*

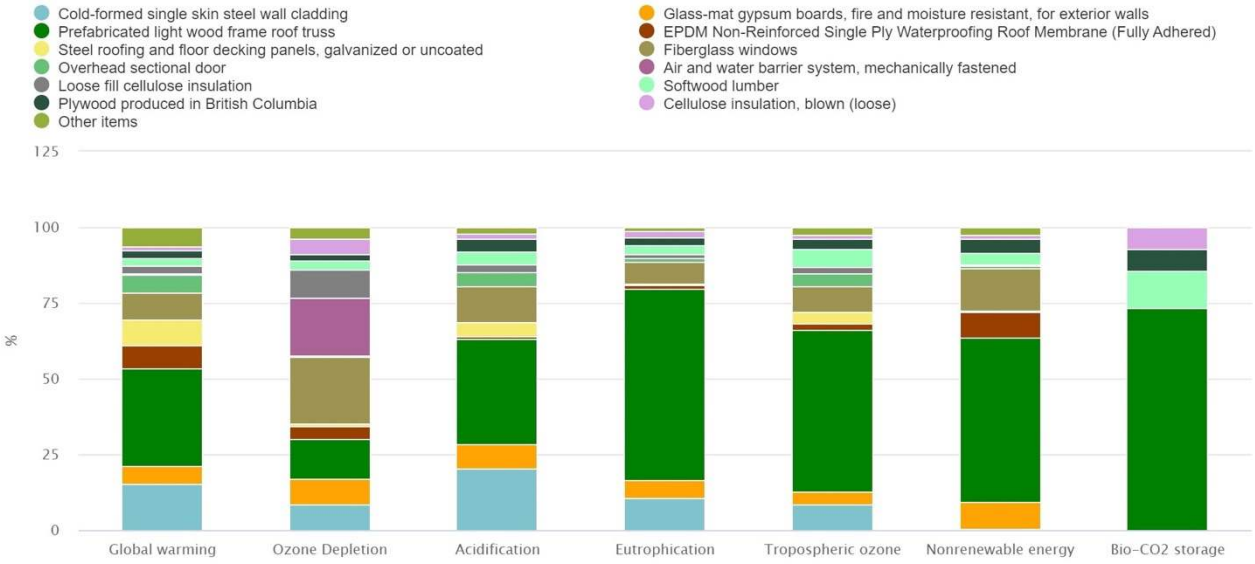



*Figure 19 Life Cycle Impacts by Material - NZER retrofit.*

## Proposed Mechanical Systems

All scenarios:

- Plumbing vents and rainwater leaders that penetrate the roof are to be insulated from ceiling to floor with 3” pipe insulation to prevent thermal bridging.

1. Minimum Upgrade Scenario 1

- Heating will continue to be provided by a combination of the existing natural gas boilers, natural gas furnaces, unit heaters, electric baseboards, and force flow heaters.
- Cooling in the office area only, through existing rooftop condenser units.
- Domestic hot water supplied by existing natural gas water heaters.
- New destratification fans for the transit and dispatch buildings to reduce heating use and provide cooling in the summer.
- Two energy recovery ventilators (ERVs) will be added, one for the Transit building and one for the Dispatch building machine shop area. They will be dual core type with approximately 90% heat recovery.
- The dispatch building office area and transit building washrooms will maintain the existing HRVs for ventilation.
- The existing direct digital control (DDC) system serving the Transit building will remain and be expanded to serve the dispatch building for control and monitoring of all new and existing systems.

2. Minimum Upgrade Scenario 1b

- Both heating and cooling for the whole building provided by a 35-ton ground source heat pump system (GSHP) sized for 60% heating capacity. A 72-ton booster heat pump is needed to bring the water to temperature for the in-floor radiant heating system.
- A 90kW electric boiler will provide supplemental heating.
- Destratification fans will be installed for both transit and dispatch buildings to reduce heating use and provide cooling in the summer.
- The domestic hot water for both the Dispatch and Transit buildings will be provided by packaged heat pump water heaters (HPWH).
- Two energy recovery ventilators (ERVs) will be added, one for the Transit building and one for the Dispatch building machine shop area. They will be dual core type with approximately 90% heat recovery.
- The existing direct digital control (DDC) system serving the Transit building will remain and be expanded to serve the dispatch building for control and monitoring of all new and existing systems.

3. Net Zero Energy Ready Scenario
The Net Zero Energy Ready scenario is the same as the Minimum Upgrade Scenario 1b, however the Net Zero Energy Ready system uses lower capacity pumps and boiler due to the improved building envelope.

- The supplemental electric boiler is reduced to 70kW.

Complete mechanical details of the proposed scenarios including system specifications and schematics are found in Appendix D.

## Proposed Electrical Systems

1. Minimum Upgrade Scenario 1
- All exterior lighting that is not LED to be updated to new LED fixtures.
- No changes to the lighting control system are required.
- The existing building service will remain as-is.

2. Minimum Upgrade Scenario 1b
Scenario 1b includes the retrofit solutions from the Scenario 1 with the following changes:

- The existing service entrance will be upgraded to 1200A service with an 80% rated main breaker. This includes replacing the main switchboard, the secondary service conductors, and the main breaker. An additional 600A panel board will be added.

3.Net Zero Energy Ready
The NZER scenario includes the solutions from Scenario 1 and 1b, and the following changes:

- The switchboard size will increase to 1600A.

### Net Metering

The current City of Saskatoon net metering agreement allows for up to 100kW AC (170kW DC, assuming a 1.7:1 DC:AC ratio) of solar to be installed on any building. In the net metering program, 100% of the excess energy generated from the solar array goes back onto the grid, and the customer gets a credit for the energy generated. The credit is equal to what the customer would pay the City of Saskatoon for energy at that time. The credits automatically come off future power bills, reducing the cost the more solar that is exported. Being enrolled in a net-metering program is an essential part of maintaining a net-zero building, as the utility grid essentially acts as a financial battery, allowing overproduced energy to be used later at no-cost.

The Net Zero Energy Scenario requires a 735kW DC array. This greatly exceeds the net-metering limit currently in place.

Staying within the capacity of the net-zero program, up to 100kW AC of solar could be installed on site. To accommodate this, the switchboard size should be increased to 1600A, up from the

1200A recommended in the Minimum Upgrade GSHP scenario. Although only a 1200A switchboard would be required to support a 100kW AC array, a 1600A switchboard would allow for the full 735kW (DC) required to achieve a net-zero building. If the 100kW limit to the net-metering program was ever lifted, this would allow for the array to be expanded without impacting the electrical distribution system.

The site has capacity for 525kW DC of solar including wall mounted pv on the south elevation of the building. Additional land will be required to install a full 735kW array.

It is possible to install photovoltaics and not enroll in the net metering program. In this scenario, the building would draw power from the solar array as it is needed (up to the arrays maximum capacity). Any excess energy that is generated by the array is clipped (wasted) and no credit is given by the utility for that power.

This scenario is only feasible if the customer routinely uses more power than what the array would generate, or if the energy usage is consistent over the course of the year. This isn't feasible for a net-zero installation, as to break even on energy the array would need to overproduce.

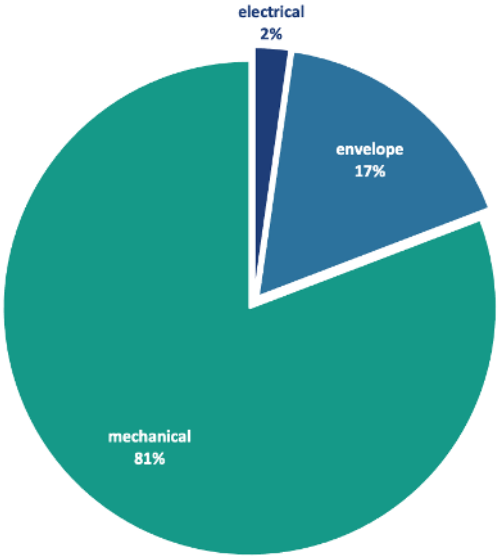
If the entire 735kW DC array is installed, the only limitation in place preventing the system from being net-metered is the 100kW AC limit imposed by the utility. If this limit is removed or increased in the future, minimal work would be required to convert the system to a net-metered system. Only the utility meter would need to be changed to a bi-directional meter.

With the 100kW AC limit currently in place for net-metered system, the full system will not be eligible for the net-metering program. If it is decided to install the full non net-metered system, it is recommended to first install the mechanical upgrades associated with the GSHP scenario and then install the solar at a later date. This allows the building to be monitored for some time before sizing the array, which will help determine a more optimized array size. It is essential to have an optimized array size in a non net-metered system, as any excess energy will be wasted if not used. Installing a non net-metered system does not prevent changing to a net-metered system at a later date if regulation changes and the capacity is increase past 100kW.

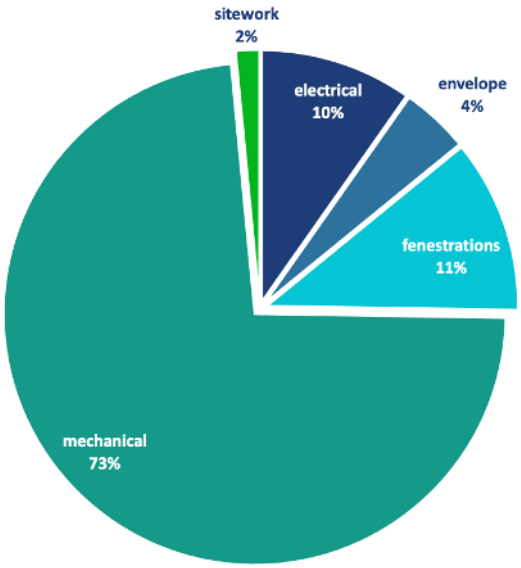
## Construction Costs

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

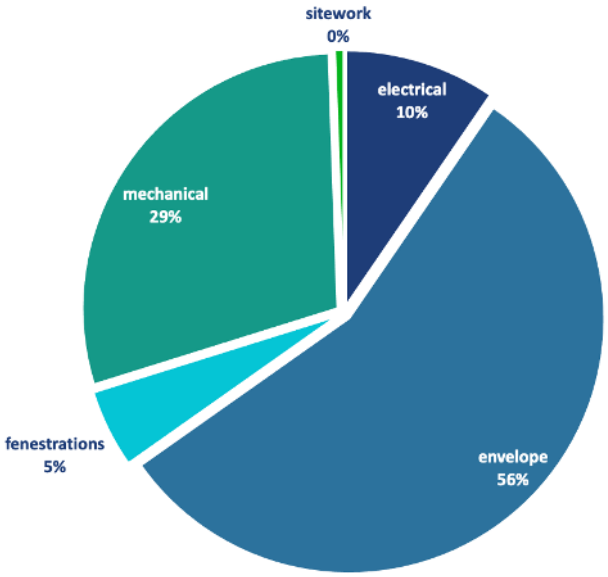
| Minimum Upgrade | |
|---|---|
| Envelope | $289,838 |
| Mechanical | $1,382,543 |
| Electrical | $38,619 |
| total | **$1,711,000** |



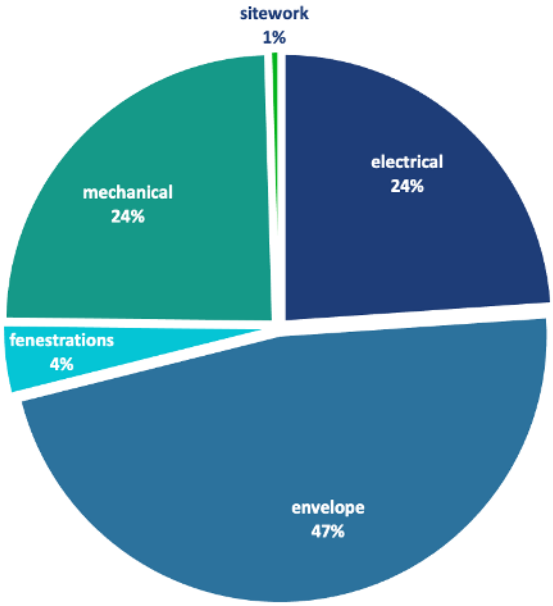

| Minimum Upgrade + GSHP | |
|---|---|
| Envelope | $287,199 |
| Fenestration | $734,724 |
| Mechanical | $4,829,6983 |
| Electrical | $642,884 |
| Sitework | $99,494 |
| total | **$6,593,998** |



| NZER GSHP | |
|---|---|
| Envelope | $10,028,320 |
| Fenestration | $892,624 |
| Mechanical | $5,273,564 |
| Electrical | $1,722,000 |
| Sitework | $99,493 |
| total | **$18,016,002** |




| NZE GSHP + 735 kW DC pv | |
|---|---|
| Envelope | $10,216,975 |
| Fenestration | $892,627 |
| Mechanical | $5,273,581 |
| Electrical | $5,181,324 |
| Sitework | $99,494 |
| total | **$21,664,000** |



## Total Cost of Building Ownership

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

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

A final scenario was modeled as part of the TCBO that was not considered in the earlier analysis, the Minimum Upgrade scenario plus solar. This was in part modeled because the construction costs for the NZER and NZE scenarios are higher than the building's estimated Cost Replacement Value (CRV) of $9.5M. This scenario resulted in the best TCBO for the building as it is the only scenario considered that saves money over the life of the building.

**Table 5 TCBO Summary**

| | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|
| GHG emissions (kg) (60 Years) | 34,079,828 | 26,714,472 | 36,189,390 | 28,134,060 | 21,382,860 | 0 |
| EUI (kWh/m2/year) | 414 | 281 | 185 | 143 | 109 | 0 |
| TCBO at 60 years | $ 70,728,000 | $ 69,115,000 | $ 97,656,000 | $ 101,644,000 | $ 93,799,000 | $ 66,991,000 |
| TCBO Savings at 60 years | | $ 1,613,000 | $ (26,928,000) | $ (30,916,000) | $ (23,071,000) | $ 3,737,000 |
| 60 Year TCBO savings compared to Base Case | | 2% | -38% | -44% | -33% | 5% |

**Key Results:**

- The base case TCBO is $70.7M, about seven times the CRV of $9.5M.
- The Minimum Upgrade scenario uses 32% less energy than the base case and is a 2% savings in the TCBO.
- The Minimum Upgrade + GSHP uses 55% less energy but costs 38% more in lifetime operating costs.
- The NZER retrofit provides 65% energy savings yet increases the TCBO by 44%.
- NZE with 170 kW PV delivers 100% reduction in EUI and a 33% TCBO increase.
- NZE with 735 kW PV delivers 100% reduction in EUI and a 5% TCBO savings.

**The Net Zero Energy retrofit with 735 kW pv has the lowest TCBO, with a 5% TCBO savings of $3.7M.**

**Table 6 Operating Cost Summary**

| Utilities (including carbon tax) | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|
| Cost | $ 44,802,000 | $ 37,310,000 | $ 55,706,000 | $ 44,055,000 | $ 34,290,000 | $ 3,362,000 |
| Difference in Cost from A | | $ (7,492,000) | $ 10,904,000 | $ (747,000) | $ (10,512,000) | $ (41,440,000) |
| Percentage Change Over Base Cost | | -17% | 24% | -2% | -23% | -92% |
| Energy Cost ($/ft2) | $ 739.04 | $ 615.45 | $ 918.91 | $ 726.72 | $ 565.64 | $ 55.46 |

| Maintenance | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|
| Cost | $ 279,000 | $ 396,000 | $ 454,000 | $ 454,000 | $ 1,014,000 | $ 2,874,000 |
| Difference in Cost from A | | $ 117,000 | $ 175,000 | $ 175,000 | $ 735,000 | $ 2,595,000 |
| Percentage Change Over Base Cost | | 42% | 63% | 63% | 263% | 930% |
| Maintenance Cost ($/ft2) | $ 4.60 | $ 6.53 | $ 7.49 | $ 7.49 | $ 16.73 | $ 47.41 |

| Insurance & Taxes | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|
| Costs | $ - | $ - | $ - | $ - | $ - | $ - |
| Difference in Cost from A | | $ - | $ - | $ - | $ - | $ - |
| Percentage Increase over Base Cost | | 0% | 0% | 0% | 0% | 0% |

| First Year Annual Maintenance | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|
| Cost | $ 2,400 | $ 3,400 | $ 3,900 | $ 3,900 | $ 8,713 | $ 24,707 |
| Difference in Cost from A | | $ 1,000 | $ 1,500 | $ 1,500 | $ 6,313 | $ 22,307 |
| Percentage Change Over Base Cost | | 42% | 63% | 63% | 263% | 929% |
| First Year Maintenance Cost ($/ft2) | $ 0.04 | $ 0.06 | $ 0.06 | $ 0.06 | $ 0.14 | $ 0.41 |

- The 60-year cost of utilities for the Base Case is nearly five times the CRV.
- The Net Zero Energy Ready (NZR) options reduce the 60-year energy consumption by 55-65% (see Table 5), but the utility costs:
    - NZR – GSHP increased by 11%,
    - NZR- GSHP + 170 kW Solar decreased by 14%.
    - NZR – GSHP + 315 kW Solar decreased by 95%

  The utility cost savings would be higher, but the unit cost of natural gas (.0375 $/ekWh) compared to electricity (.1956 $/ekWh) is 5 times cheaper.
- The study did not include water reduction, but it is a significant cost even with the rainwater harvesting system reducing consumption.
- The maintenance costs for the NZE options are dramatically higher due to the added maintenance of added mechanical equipment and solar panel maintenance
- Saskatoon does not pay property taxes and does not have insurance.

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 cost.
- The utility applies the carbon tax for natural gas, and this is capture in the fuel cost.

**Table 7 Capital Cost Summary**

| Initial Retrofit / HPB CostYear 1 | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|
| Initial Cost | $ 525,000 | $ 2,357,000 | $ 6,722,000 | $ 19,116,000 | $ 20,476,000 | $ 22,736,000 |
| Difference in Cost from A | | $ 1,832,000 | $ 6,197,000 | $ 18,591,000 | $ 19,951,000 | $ 22,211,000 |
| Percentage Change Over Base Cost | | 349% | 1180% | 3541% | 3800% | 4231% |
| Cost ($/ft2) | $ 8.66 | $ 38.88 | $ 110.88 | $ 315.33 | $ 337.77 | $ 375.05 |

| Maintenance Capital Costs 60 Years | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|
| Cost | $ 25,122,000 | $ 29,053,000 | $ 34,773,000 | $ 38,019,000 | $ 38,019,000 | $ 38,019,000 |
| Difference in Cost from A | | $ 3,931,000 | $ 9,651,000 | $ 12,897,000 | $ 12,897,000 | $ 12,897,000 |
| Percentage Change Over Base Cost | | 15.65% | 38.42% | 51.34% | 51.34% | 51.34% |
| Cost ($/ft2) | $ 414.41 | $ 479.25 | $ 573.61 | $ 627.15 | $ 627.15 | $ 627.15 |

| Retrofit / HPB + Maintenance Capital Costs 60 Years | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|
| Total Costs | $ 25,647,000 | $ 31,410,000 | $ 41,495,000 | $ 57,135,000 | $ 58,495,000 | $ 60,755,000 |
| Difference in Cost from A | | $ 5,763,000 | $ 15,848,000 | $ 31,488,000 | $ 32,848,000 | $ 35,108,000 |
| Percentage Change over Base Cost | | 22.47% | 61.79% | 122.77% | 128.08% | 136.89% |

The Capital Cost Summary compares the first-year capital investment in maintaining the existing building with the construction costs for the retrofit scenarios. The capital costs for the retrofits have been escalated to 2024 values from the construction cost estimate.

The NZER and NZE retrofit costs range from $313-$373/ft$^2$ due to 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 increased the maintenance capital costs because of the increase in mechanical, electrical, and solar equipment.

**Table 8 Annual Energy Consumption and GHGs**

| | Units | Base Case | Min Upgrade | Min - GSHP | NZR - GSHP | NZR GSHP 170 KW PV | NZR GSHP 735 KW PV |
|---|---|---|---|---|---|---|---|
| Annual Water Consumption | m3 | 40,697 | 40,697 | 40,697 | 40,697 | 40,697 | 40,697 |
| Annual Sewer Discharge | m3 | - | - | - | - | - | - |
| Annual Electric Consumption | kWh | 351,026 | 389,408 | 1,039,925 | 808,450 | 808,450 | 808,450 |
| Annual Gas Consumption | m3 | 191,553 | 115,322 | - | - | - | - |
| Annual Heating Oil Consumption | Litres | - | - | - | - | - | - |
| GHG emissions | kg CO2 eq | 567,997 | 445,241 | 603,157 | 468,901 | 356,381 | - |
| Annual Solar PV generated | kWh | - | - | - | - | 194,000 | 808,450 |
| Total Annual Energy Consumption | ekWh | 2,330,408 | 1,581,074 | 1,039,925 | 808,450 | 614,450 | - |
| Total Annual Energy Consumption | GJ | 8,389 | 5,692 | 3,744 | 2,910 | 2,212 | - |
| EUI | kWh/m2/yr | 414 | 281 | 185 | 143 | 109 | - |

**Key Results:**

- Water consumption is the same across all options.
- Electricity consumption increased from the Base Case to the Net Zero Energy options because of the switch from natural gas to electricity.
- Natural gas consumption was reduced in all options except the Minimum Upgrade, however electricity is generated with fossil fuels in Saskatchewan, so the GHG reductions are not at large as it would be in a location with a cleaner grid.
- The building can only use 170kW of solar within Saskatoon's net-metering program. This is not enough to offset all its electric consumption.

## Cumulative TCBO

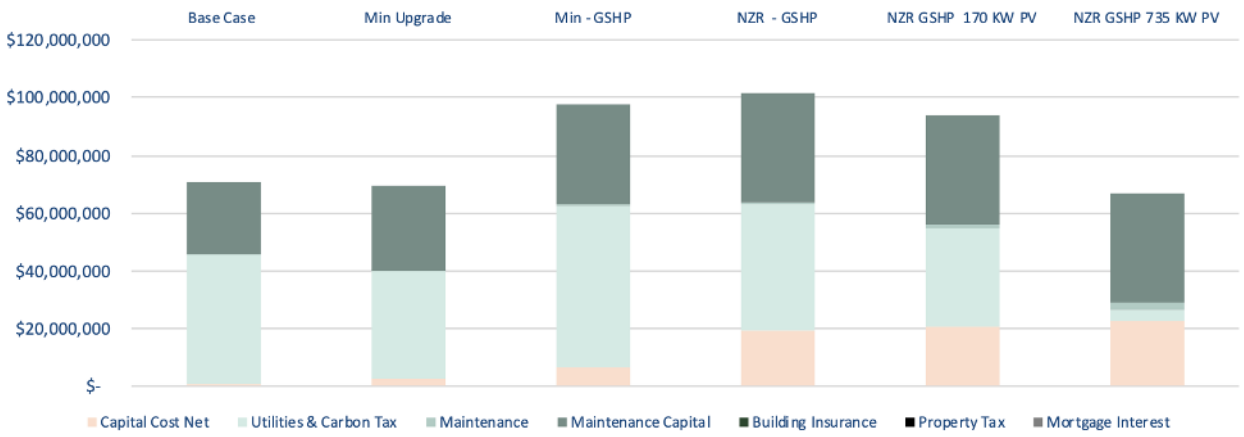



*Figure 21 TCBO Comparison*

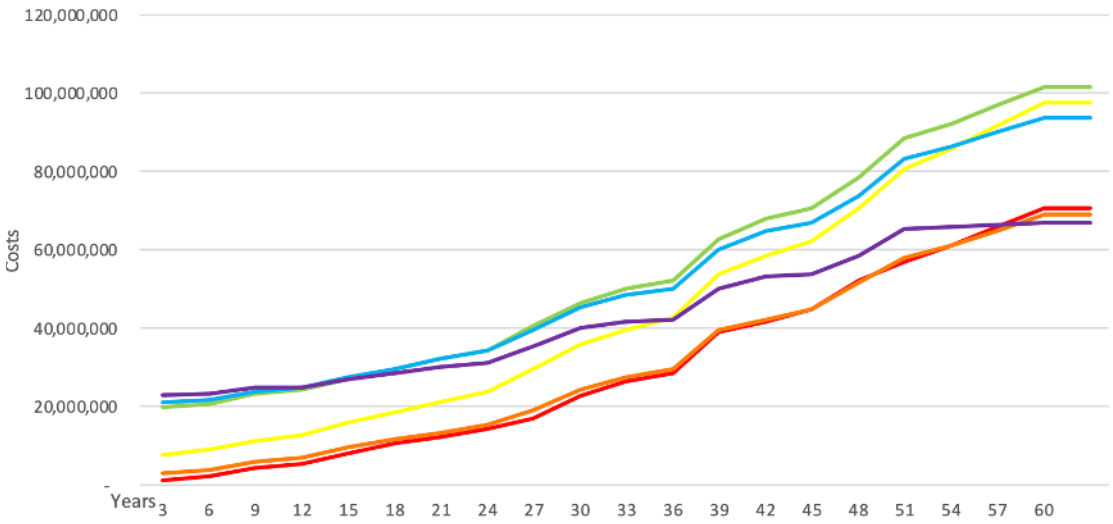



*Figure 20 Cumulative TCBO*

The existing Base Case has the Lowest TCBO for the first 39 years, with the Minimum Upgrade costing less for the remaining 21 years.

# Discussion

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

The original hypothesis of the ReCover team, based previous work, was that electrification plus optimization of building enclosures plus renewables would equal the lowest TCBO. The hypothesis was not supported by the results of the study.

Two options had only marginal improvements in TCBO, the Minimum Upgrade + solar option with a 2% savings, and the Net-Zero Energy with 735kW DC of pv. Neither is actually a viable option. The Minimum Upgrade maintains existing natural gas equipment which will need to be removed by 2050. The retrofits involved in electrifying the building later will offset the 2% savings in the TCBO. The NZE with 735kW DC pv is not viable because only 170kW DC can be installed under the current net-metering program. If it becomes an option in future for higher amounts of solar to be net-metered then this scenario would be viable.

The capital costs for the retrofit need to be significantly reduced to make the project more attractive financially. A compromise that the City of Saskatoon may consider is to complete a deep retrofit to the original part of the building only. It is significantly less energy efficient and responsible for 40% of the total energy used by the building, despite being only a quarter of the total area. This will result in a significantly lower cost project with proportionally more impact.

There are thousands of pre-engineered steel buildings across Canada that are responsible for an incredible amount of GHGs due to thermal bridging, lack of airtightness and inefficient fossil fuel-based systems. Developing a retrofit recipe that can impactfully reduce emissions from this building type will have far reaching benefits.




*Figure 22 Roof View*

# Conclusions

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

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

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

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

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

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

The recommendation for the Access Transit Facility is to return to the drawing board. The only option that has a TCBO savings and eliminates the fossil fuel-based mechanical equipment is not viable because it requires too much solar pv to participate in net-metering. There is a viable retrofit pathway to decarbonize Access Transit, but it hasn't been found yet.

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