

# Building Retrofit to Achieve Sustainability Goals

Capstone Presentation  
Queen's University, Smith Engineering

March 24, 2026



*A new era for engineering.*



**Rheya  
Dutkiewicz**

Project Manager



**Lily-Anna Girard**

Environmental  
Coordinator



**Sophia Mariani**

Structural  
Coordinator



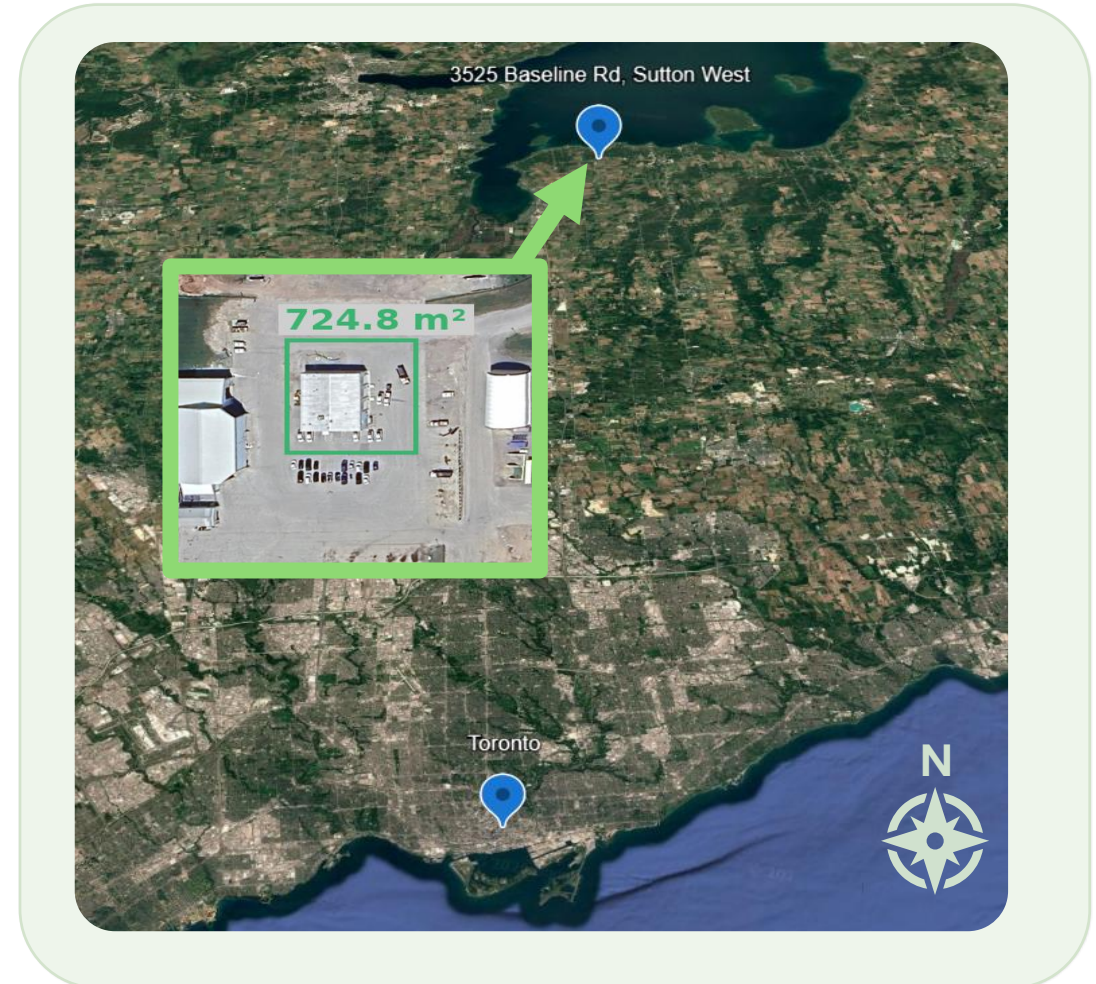
**Jordan Raftis**

Mechanical, Electrical  
& Digital Systems  
Lead

# Problem Definition

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- York Region North District Road Maintenance Facility is a municipally owned building
- Issues with significant heat loss from bay doors and aging mechanical systems
- The facility must remain operational year-round
- Energy use and carbon emissions must be reduced to meet EnerPHit Net Zero Carbon targets



# Objectives

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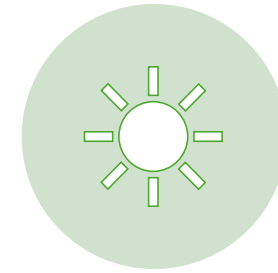
Reduce operational carbon emissions through deep energy retrofit.



Electrify mechanical systems while maintaining winter maintenance functionality.



Improve energy efficiency of building systems and controls.



Integrate on-site renewable energy and future-ready infrastructure.

# Retrofit Design Components

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Building Envelope



Mechanical & Electrical



Renewable Energy



Water Efficiency

## Kingspan Prefabricated Insulated Metal Panels

- Increased air tightness and lowered the number of materials installed
- R-values of up to 46 for roofing panels and up to 72 for wall panels
- Exceeds EnerPHit standards with air leakage rate of 0.8 ACH50

## Overhead Rolling Steel Bay Door Systems

- Insulated slats provide thermal resistance, air leakage, and resist heat flow
- Compliant with EnerPHit standards with a secondary barrier

# Mechanical & Electrical Systems

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## Heating

Two 45 kW cold-climate air-to-water heat pumps provide the base load, backed by a high-efficiency condensing boiler for extreme winter events.

## Ventilation

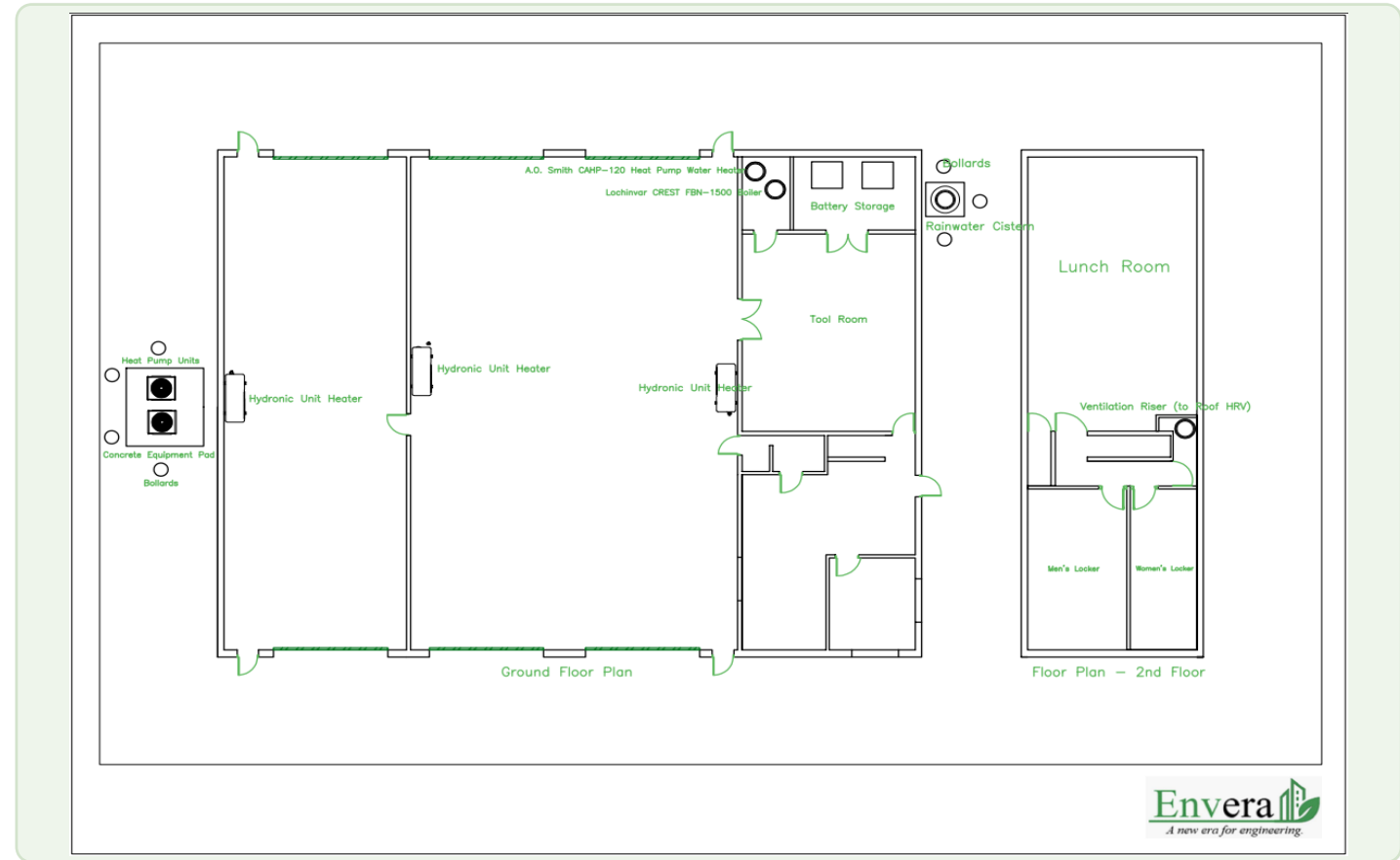
A centralized 2,000 CFM HRV/DOAS tempers outdoor air and reduces ventilation loads while CO / NOx sensing controls exhaust in the bays.

## Domestic hot water

A heat-pump water heater supplies the base demand, with electric storage backup covering peaks for staff spaces and wash-bay needs.

## Electrical & Controls

A 600 A, 600 V service upgrade enables electrification, LED lighting, EV charging, and BAS coordination across the full retrofit.



**2 × 45 kW**  
Air-to-water heat pumps  
(base-load heating)

**Heating**

**2,000 CFM**  
Heat recovery ventilator  
(Cubic Feet per Minute)

**Ventilation**

**COP 4.2**  
Heat pump efficiency  
(coefficient of performance)

**Heat Pump**

**600 A / 600 V**  
New electrical service

**Electrical**

**10-20%**  
BAS energy reduction

**Controls**

## 1. Solar PV System

- Rooftop solar PV array
- Generates roughly 191,625 kWh annually

## 2. EV Charging Stations

- To support future fleet electrification, the retrofit supports four level 3 DC fast chargers
- Reduce carbon emissions and dependency on fossil fuels



## 1. Greywater Recycling

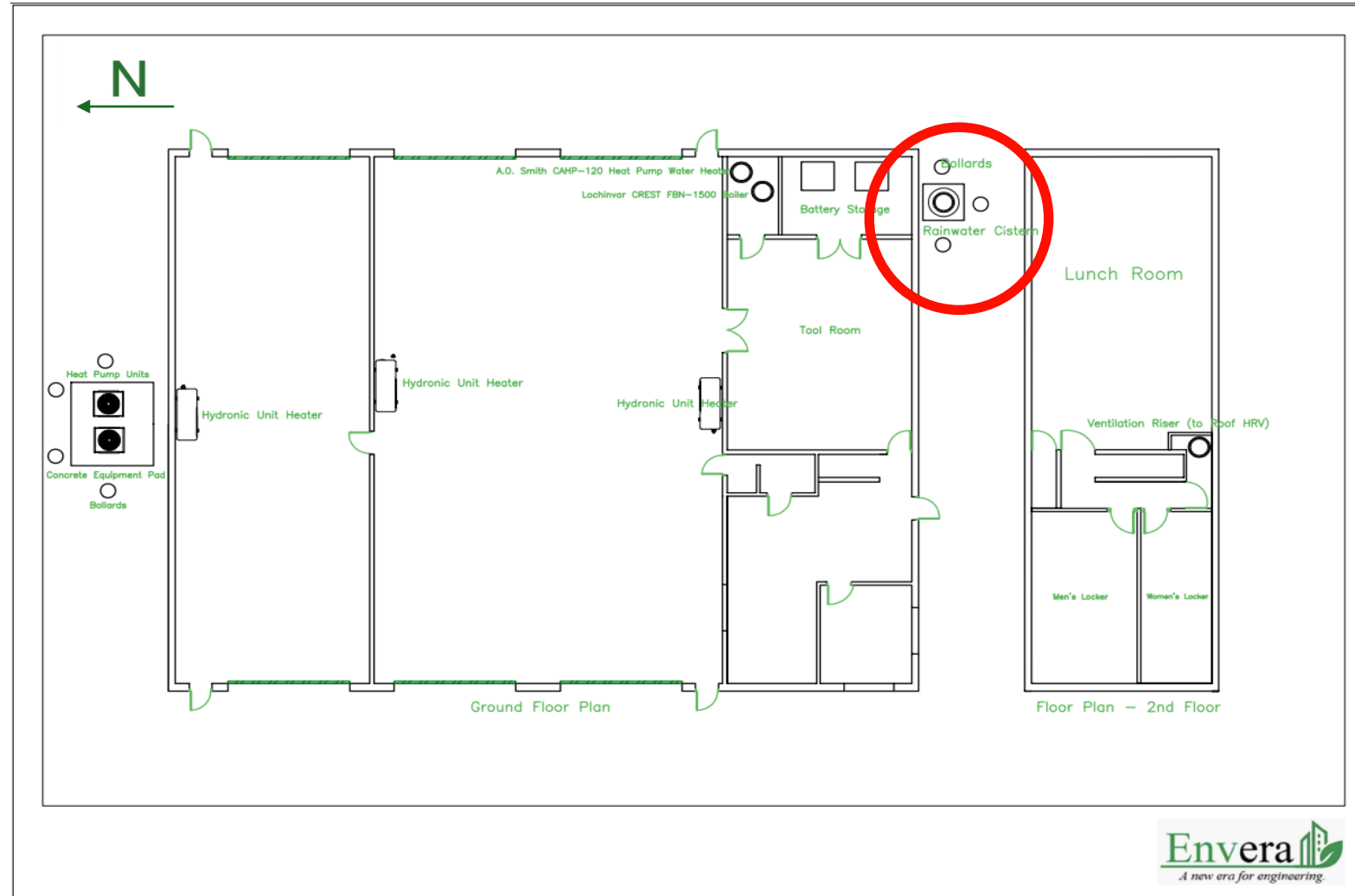
- Hydraloop Cascade greywater recycling system to treat on-site water use
- Reduces potable water consumption with minimal disruption

## 2. Rainwater Harvesting

- Rainwater is routed to a concrete cistern
- Support non-potable functions

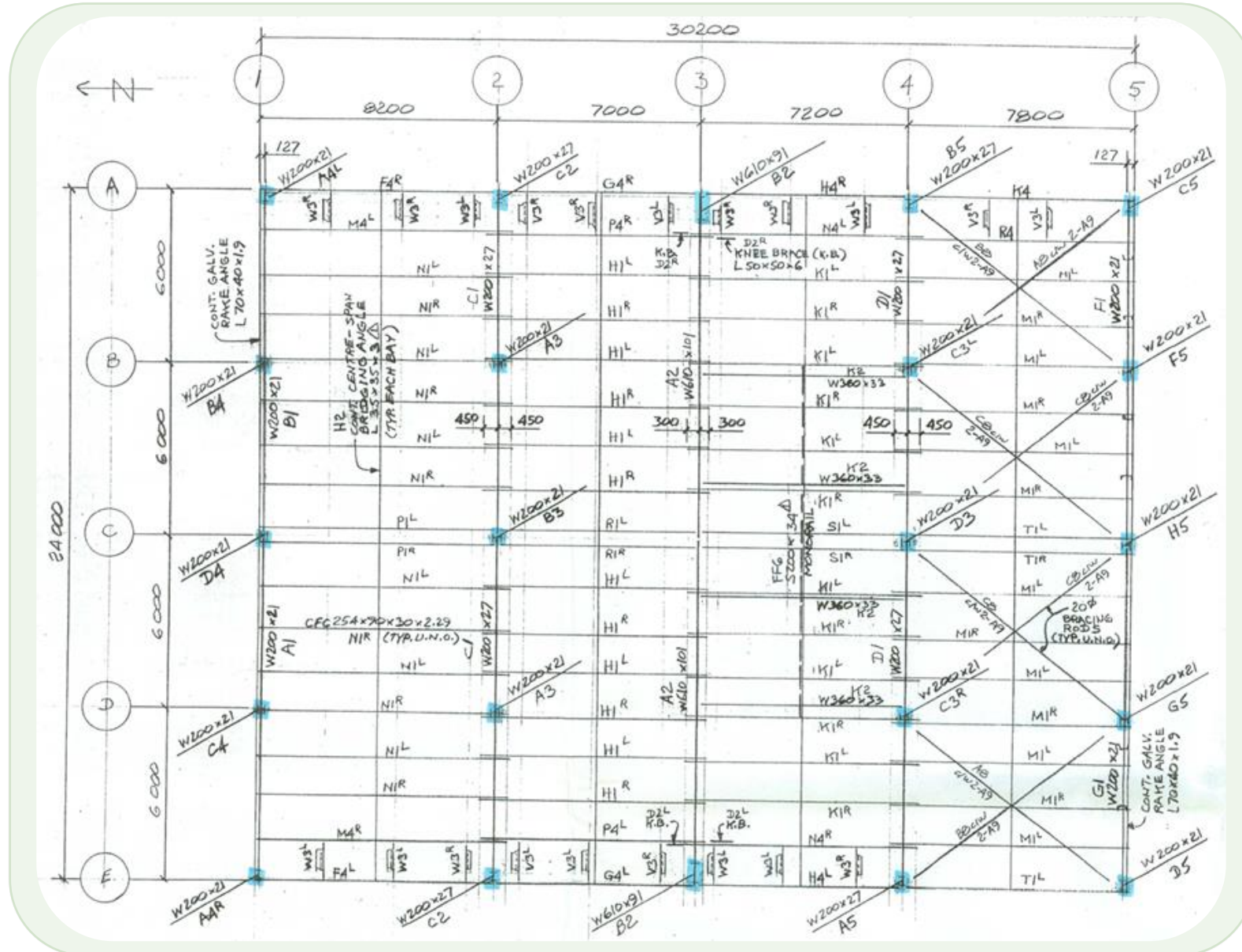
## 3. Fixture Upgrades

- Conserve potable water by installing high-efficiency models



# Structural Upgrades

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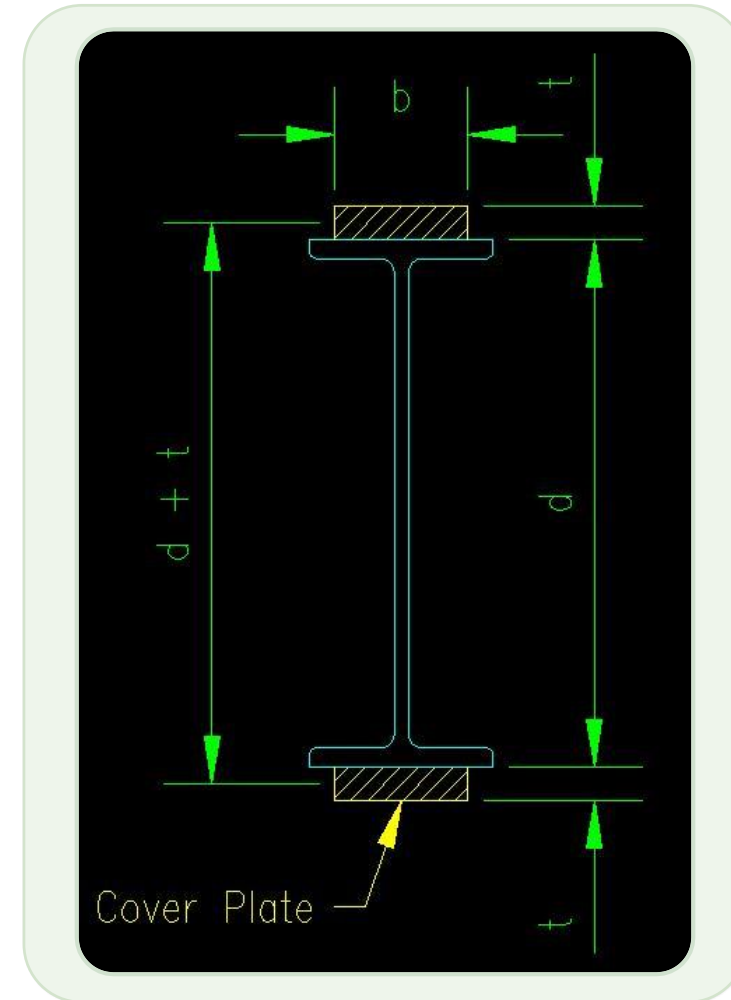


## Welded Steel Cover Plate:

- An additional steel plate welded to the top and bottom of a steel beam to increase flexural capacity.

## Installation:

- Steel shoring will be installed throughout the building to relieve the current loading and weld plates onto beams.



$$M_r = \phi_s Z_x F_y \quad (1)$$

$$M_r = \phi_s M_p \quad (2)$$

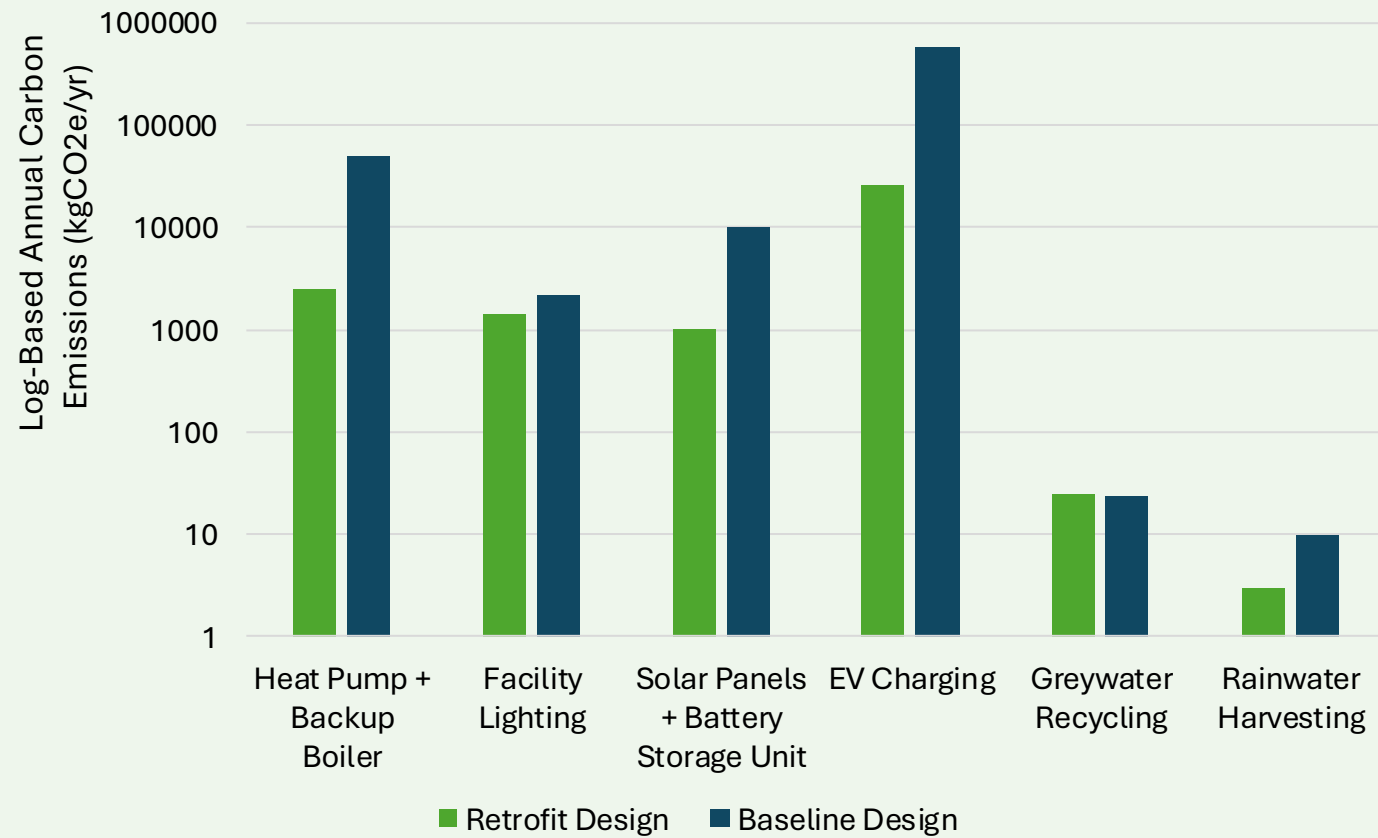
Beam	W200x21	W200x27
Applied Moment	103.45 kNm	121.59 kNm
Moment Resistance	64.56 kNm	83.00 kNm
Top Cover Plate	6.35 mm	6.35 mm
Bottom Cover Plate	6.35 mm	6.35 mm
Plastic Moment Resistance	115.84 kNm	135.22 kNm

# Carbon Emissions & Environmental Impact

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Subassembly	Component	Emissions (kg CO <sub>2</sub> )	Emission Timeline
Building Envelope	Kingspan Panels	23,952	Embodied
	Steel Doors	79,161	Embodied
	Steel Cover Plates	2,228	Embodied
Mechanical and Electrical	Heat Pump	8,130	Annual
	Backup Boiler	2,476	Annual
	VRF Refrigerant	1,924	Lifecycle
	DHW System	643	Annual
	Lighting System	1,078	Annual
Renewable Energy	Solar PV	1,016	Annual
	– Battery Storage Unit		
	DC Fast Charger	5,148	Embodied
	DC Fast Charger	26,124	Annual
Water Efficiency	Greywater Recycling System	23	Annual
	Rainwater Harvesting – Concrete Cistern	28,698	Embodied
	Rainwater Harvesting	3	Annual

## Annual Carbon Emissions Retrofit Design vs Baseline Design



# Project Budget Overview

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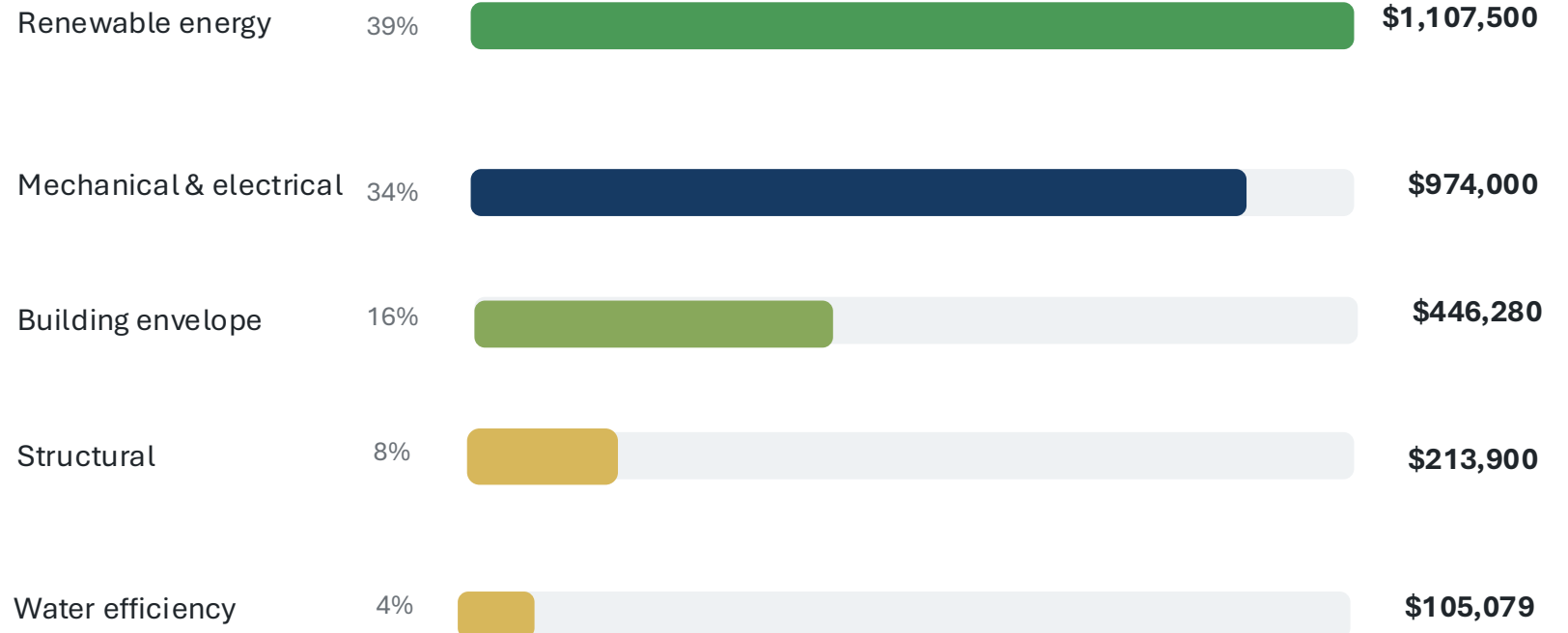
## Total retrofit cost

# \$3,482,119M

Subtotal	<b>\$2.9M</b>
20% contingency	<b>\$580k</b>
Cost intensity	<b>\$4,803/m<sup>2</sup></b>
Demolition	<b>\$55K</b>

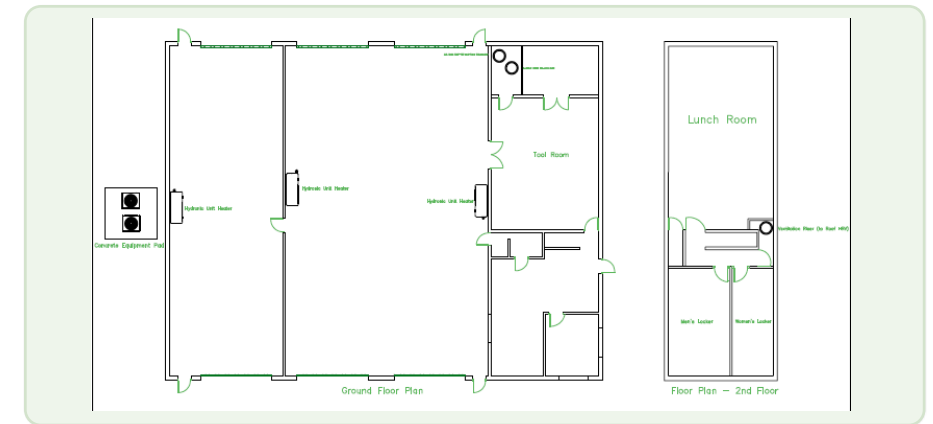
## Cost by system (CAD)

High-range door pricing used in the preliminary total.



# Digital Model: Revit, Enscape Visuals & AutoCAD

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**Design Communication**

**System Coordination**

**Presentation Value**

# Risk Assessment

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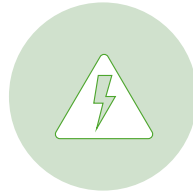
1 = Lower Risk    2 = Moderate Risk    3 = Higher Risk					
Component	Probability of Underperformance	Impact on Facility Operations	Cost Sensitivity	Maintenance Demand	Installation Complexity
Exterior Walls & Roof	1	2	2	1	2
Bay Doors	2	2	2	2	2
Solar PV System	2	2	3	1	3
EV Charging Stations	2	3	2	2	2
Battery Energy Storage	1	2	3	1	2
Building & Truck Bay Heating	2	3	2	2	2
Office & Support Space Conditioning	1	2	2	1	2
Mechanical Ventilation	2	2	2	2	2
Domestic Hot Water System	1	2	2	1	2
Electrical Service Expansion	2	3	3	2	3
Lighting & Controls	1	2	2	1	1
Automation System	2	3	2	1	2
Greywater Recycling	2	2	2	2	2
Rainwater Harvesting	2	1	2	2	2
Fixture Upgrades	1	1	1	1	1

# Proposed Mitigation Strategies

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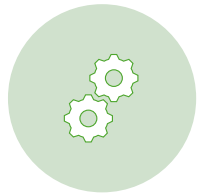
Envelope & Building  
Fabric



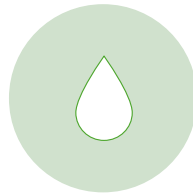
Electrical & Energy  
Systems



Mechanical &  
Thermal Systems



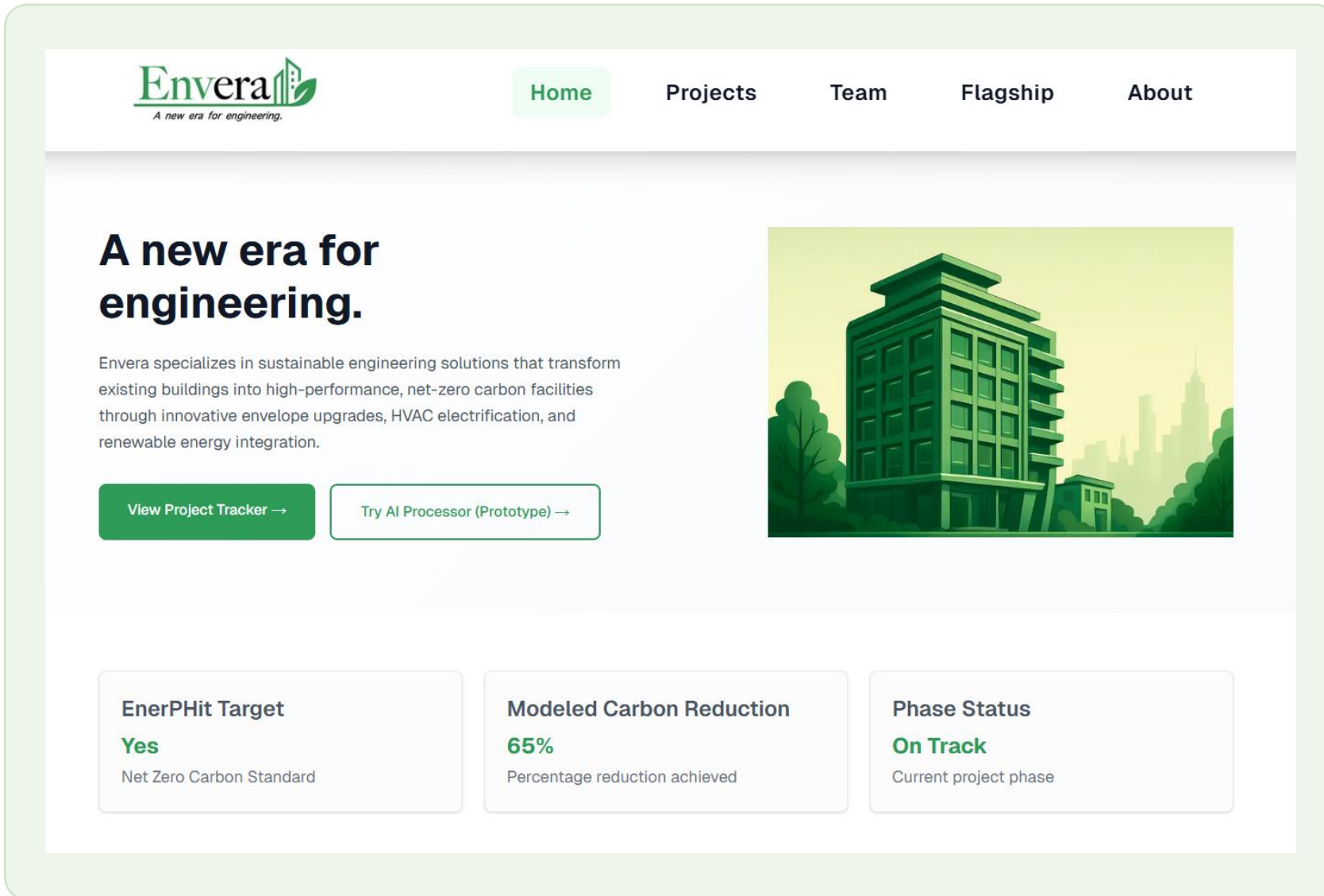
Controls &  
Automation



Water Efficiency  
Systems



Low-Risk Interior  
Upgrades



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**Thank you!**

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