

Innovative Adaptations in Deep Energy Retrofits



Bess Krietemeyer, PhD
Syracuse University

Nina Wilson, PhD
Syracuse University

Caitlin Martusewicz
Cycle Architecture

Crista Shopis
Taitem Engineering

Tom King
TKFabricate

10:15 – 11:15: Presentation of DER Projects

11:15 – 11:45: Q&A and Panel Discussion

Project Teams



Bess Kriemeyer
Syracuse University



Nina Wilson
Syracuse University



Jianshun Zhang
Syracuse University



Shayan Mirzabeigi
Syracuse University



Sameera Soltanian-Zadeh
Syracuse University



Bing Dong
Syracuse University



Pratik Pandey
Syracuse University



Tamara Rosanio
SyracuseCoE



Tom King
TKFabricate



Caitlin Martusewicz
Cycle Architecture



Tony Daniels
Cycle Architecture



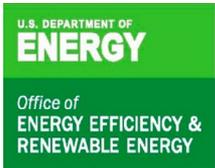
Crista Shopis
Taitem Engineering



Evan Hallas
Taitem Engineering



Avidesh Zakhor
Signetron



NYSERDA



ASHLEY MCGRAW
ARCHITECTS



**NORTHLAND
ASSOCIATES, INC.**
GENERAL CONTRACTOR



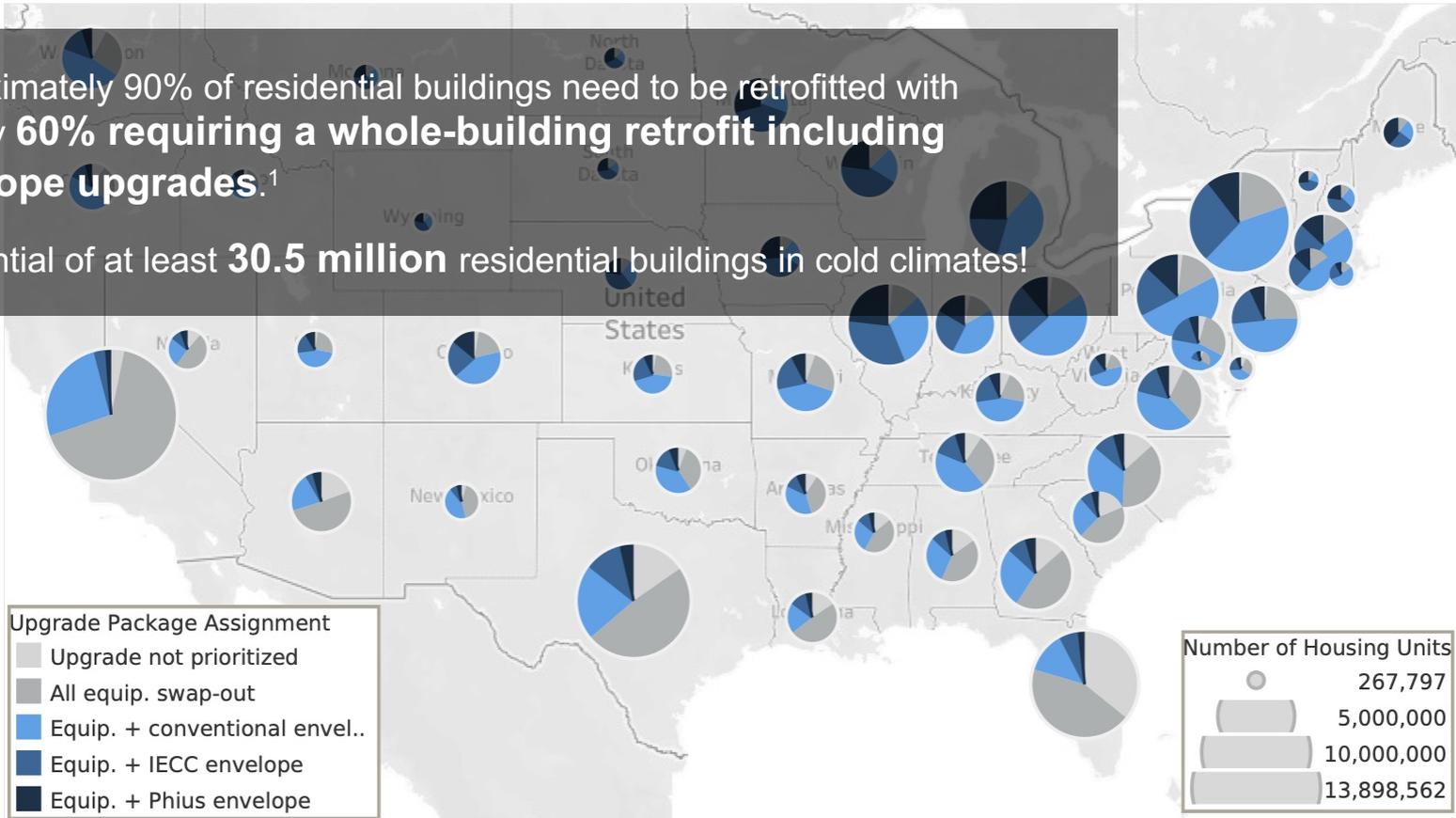
1. **Introduction:** Challenges & Goals with Deep Energy Retrofits
2. **DER Approaches:** Winding Ridge and Lambreth Lane
3. **Results:** Energy Use, IAQ, Comfort, Cost, Speed of Installation
4. **Lessons Learned:** Technical + Procedural

- 1. Introduction:** Challenges & Goals with Deep Energy Retrofits
- 2. DER Approaches:** Winding Ridge and Lambreth Lane
- 3. Results:** Energy Use, IAQ, Comfort, Cost, Speed of Installation
- 4. Lessons Learned:** Technical + Procedural

Introduction: Challenges & Goals with Deep Energy Retrofits

Approximately 90% of residential buildings need to be retrofitted with roughly **60% requiring a whole-building retrofit including envelope upgrades.**¹

A potential of at least **30.5 million** residential buildings in cold climates!



1. Accelerating Residential Building Decarbonization: Market Guidance to Scale Zero-Carbon-Aligned Buildings. ABC Collaborative (2024)

Existing retrofit approaches:

- Market fragmentation
- Project complexity and cost
- Disjointed workflows
- Disruption for residents
- Bespoke, highly labor intensive, site-installed methods, and **do not yet provide solutions to coordinate envelope and mechanical upgrades....**



How did we get there?



Retrofit Goals	Winding Ridge	Lambreth Lane
Energy Efficient	EnerPHit and > 70% energy savings	≥ 75% thermal energy savings
Improved Comfort & IAQ	>50% reductions in VOCs	30% reductions in CO ₂
Fast Installation	2.5 months of construction	2.5 months of construction
Cost-Effective	\$100K / unit	\$160K - \$184K / unit *

** Upper range for total cost includes costs of manufacturing, delivering, and installing novel mechanical pod system at prototype scale*

Key Elements of the Approaches:

Coordinated systems

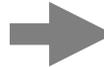
Building envelopes with compatible HVAC systems to capture energy, installation, and maintenance efficiencies

Designed from the outside in

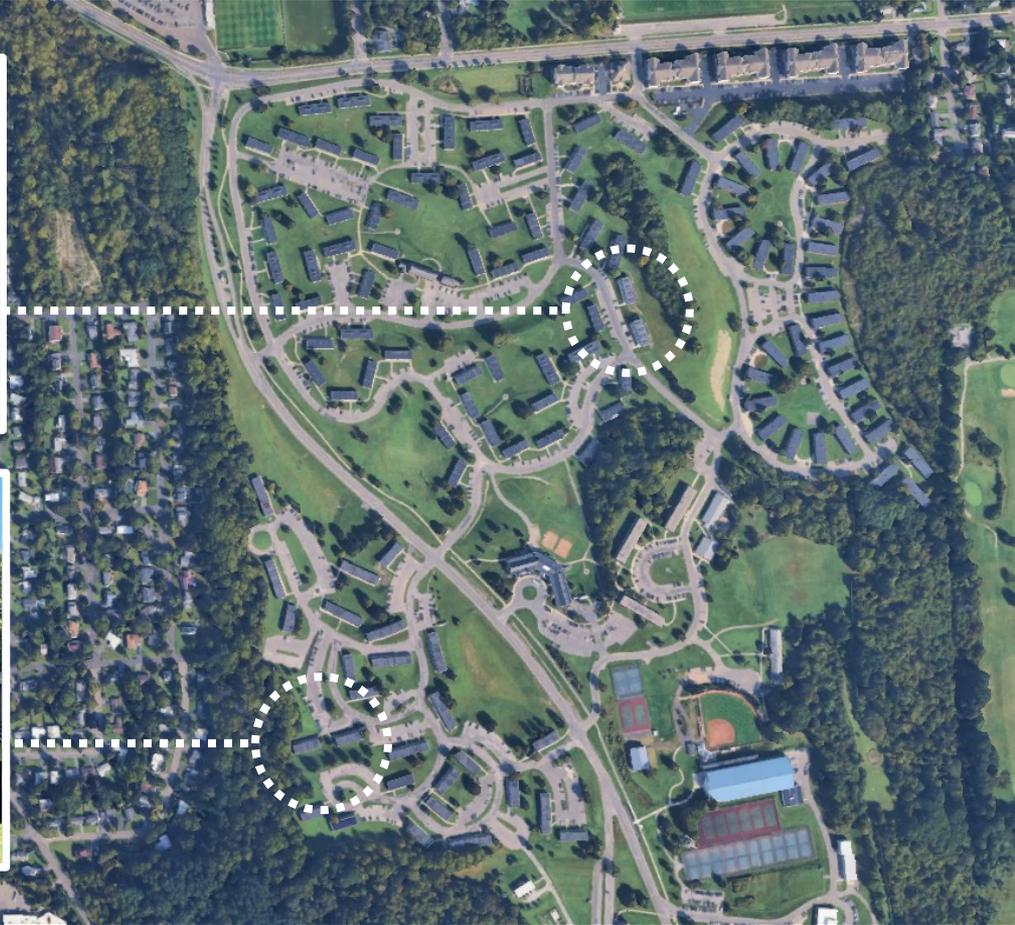
Limit interior installation work, maintenance + operations

Integrated design delivery

Coordination and collaboration across teams and trades from pre-retrofit assessment to Cx



Introduction: Challenges & Goals with Deep Energy Retrofits



Introduction: Challenges & Goals with Deep Energy Retrofits

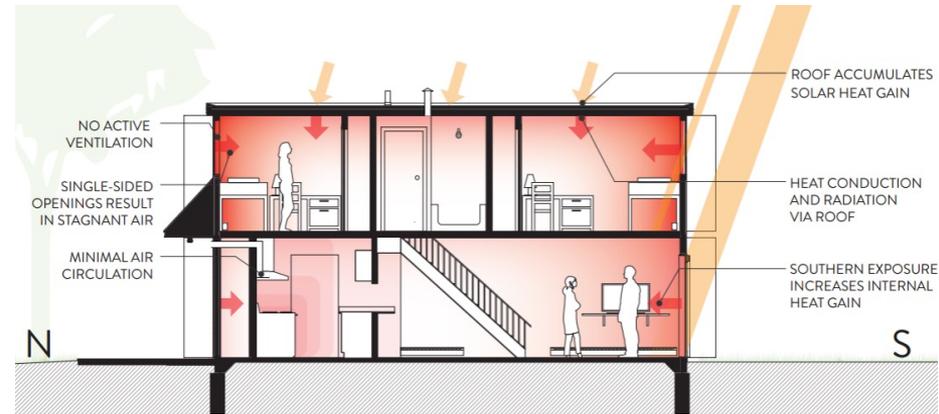


Two identical apartment buildings, constructed 1972
Single-family attached / townhouse style
Eight, 2-bedroom units each
Modular precast concrete + wood-framed walls
Electric resistance baseboard heating
No mechanical cooling or ventilation

Existing Conditions



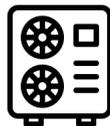
Winter



Summer

1. **Introduction:** Challenges & Goals with Deep Energy Retrofits
2. **DER Approaches:** Winding Ridge and Lambreth Lane
3. **Results:** Energy Use, IAQ, Comfort, Cost, Speed of Installation
4. **Lessons Learned:** Technical + Procedural

DER Approaches: Winding Ridge and Lambreth Lane



	Insulation	Windows	HVAC	Ventilation	Generation	Installation
Winding Ridge	Site-cut EIFS R-16 ext., R-21 infill	Double-Pane	Distributed Heat Pump, Mini-split fan coil units	HRV	Rooftop PV Array	1 Building 2.5 Months
Lambreth Lane	R-27 Prefab Panels; New R-25 Roof	Triple-Pane	Semi-centralized Air-to-Water Heat Pump, hydronic FCU	Semi-centralized ERV	N/A	2 Buildings 2.5 Months

Winding Ridge



Lambreth Lane



REV Campus Challenge

- S** Syracuse University School of Architecture
- S** Syracuse University School of Information Studies
- S** Syracuse University College of Engineering & Computer Science



Living Lab at Winding Ridge Road

Sponsor: New York State Energy Research and Development Authority (NYSERDA)

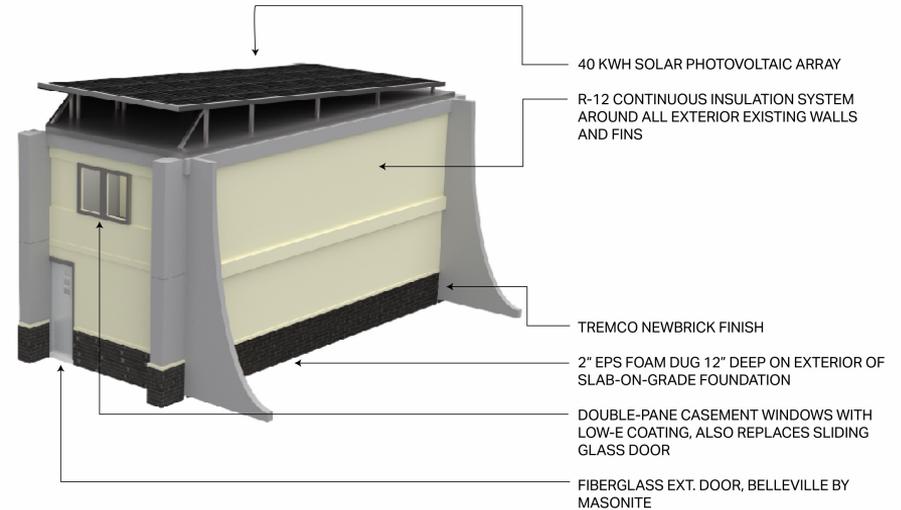
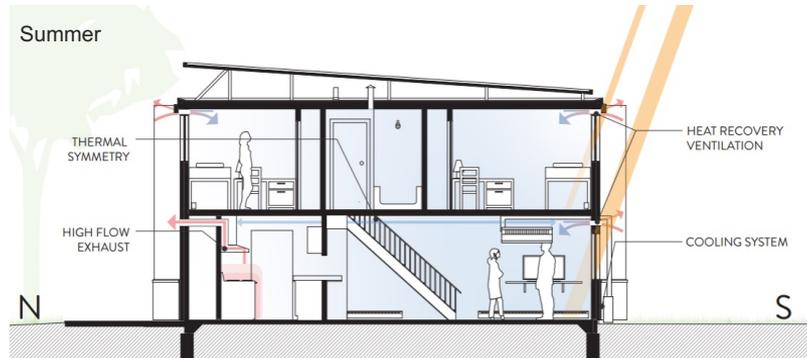
Principal Investigator: Nina Wilson, Assistant Professor, Syracuse University School of Architecture

Team: Syracuse University, Taitem Engineering, Ashley McGraw Architects, Northland Associates, C&S Companies, Klepper Hahn & Hyatt

Period of Performance: 2019 – 2025

Budget: NYSEERDA: \$1,400,000; Cost Share: \$200,000

Integrated Design at Winding Ridge



Project Delivery Approach Intent vs actual (COVID!)

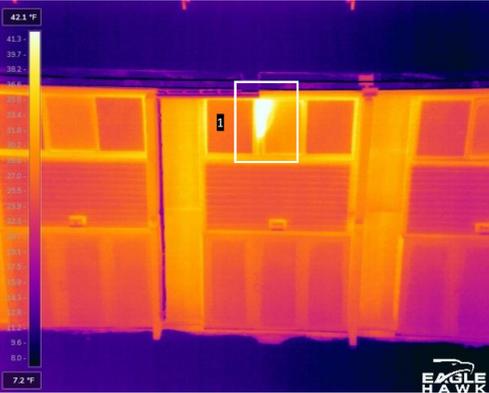
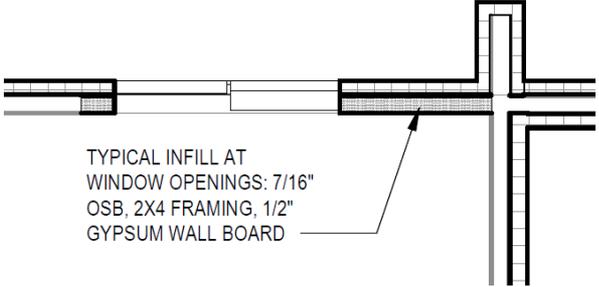
Cost estimates for the same project scope in 2020 were **1.8x** what they were in 2019 from the same bidders.

Areas of Adaptation Under COVID-19

 Insulation  Envelope  Windows  Mechanical  Certification  Monitoring

 INSULATION	Wood-fiber/mineral wool → site-cut EPS EIFS system delivered and installed on site
 INSULATION	Removed 2" outboard insulation — down to 3" total; no precut custom panel plan
 INSULATION	Eliminated added roof insulation
 ENVELOPE	Reduced envelope changes to save on lumber
 ENVELOPE	Wrapped demising wall extrusion 'fins' instead of cutting off as originally planned
 WINDOWS	Triple-pane → double-pane vinyl windows
 MECHANICAL	European packaged HP+ERV unit → Daikin HP units + mini-splits with through-wall HRV systems
 MECHANICAL	Removed upstairs bedroom mini-splits from scope
 CERTIFICATION	Stepped back from Passive House certification and Net Zero Energy target
 MONITORING	Decreased data acquisition budget and scope

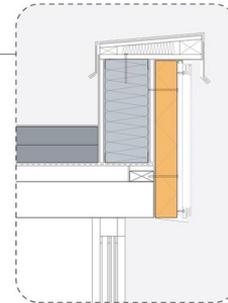
Envelope



Envelope

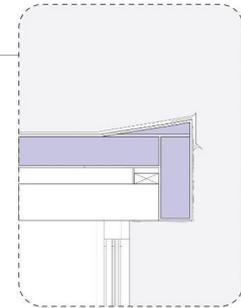


POTENTIAL ROOF SYSTEM -
MINERAL WOOL (MW)



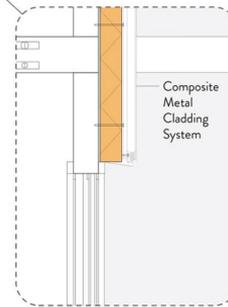
- Mineral Wool (MW)
- Rockwool COMFORTBATT Semi-Rigid Stone Wool BATT Insulation
- Rockwool TOPROCK High Density Stone Wool for Low Slope Roofing Applications

POTENTIAL ROOF SYSTEM -
EXPANDED POLYSTYRENE (EPS)



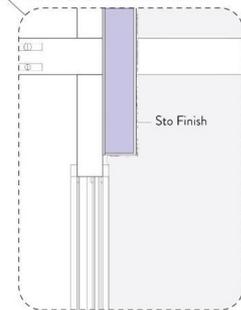
- Expanded Polystyrene (EPS)

POTENTIAL ABOVE SILL SYSTEM -
MINERAL WOOL (MW)



- Mineral Wool (MW)
- R-value: $4/in.^2$

POTENTIAL ABOVE SILL SYSTEM -
EXPANDED POLYSTYRENE (EPS)



- Expanded Polystyrene (EPS)
- R-value: $5.68/in.^2$

Envelope



Envelope – Daylight and Views Pre-Retrofit

December 21 - 12pm



The South bedroom has a high illuminance and is way too bright. The window glare is constant while this is the sun's peak angle. The room is overheating.

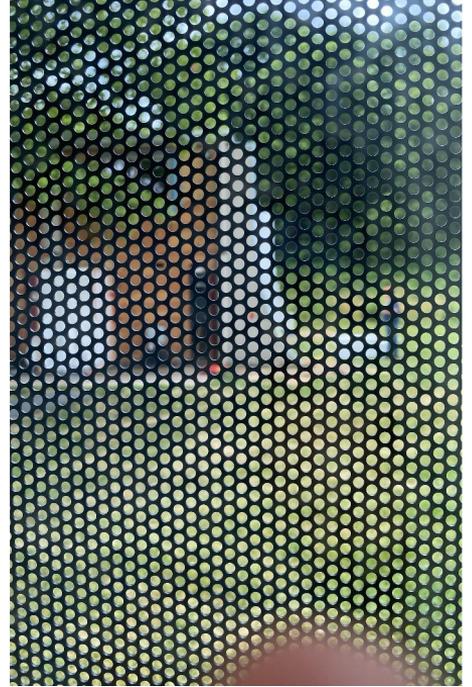
The South side of the building is heavily illuminated. The South is too bright at this time and overheating, even though it is the Winter season. The ground floor living space is also very bright and hot because the sun angle is pointing directly into the interior.

The South side of the ground floor (living room) is highly illuminated. Because the sun is at the most direct angle, illuminance bleeds into the North side of the ground floor as well.



The North bedroom is not as bright as the South bedroom, but it is still comfortable for studying and reading. There is no window glare in this room.

The sun angle coming in from the South brings in more direct light causing the North side of the apartment to be warmer at this time of day.

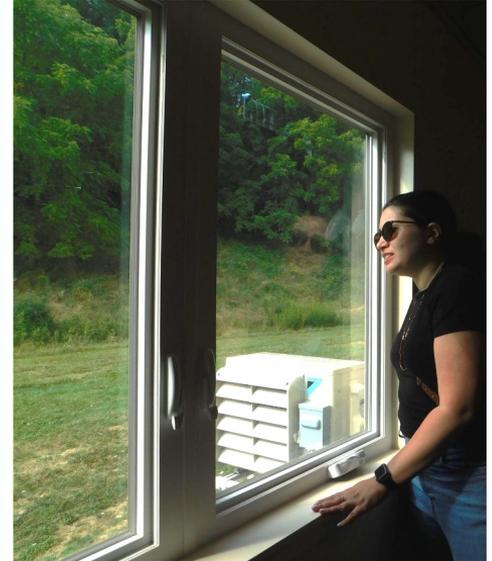
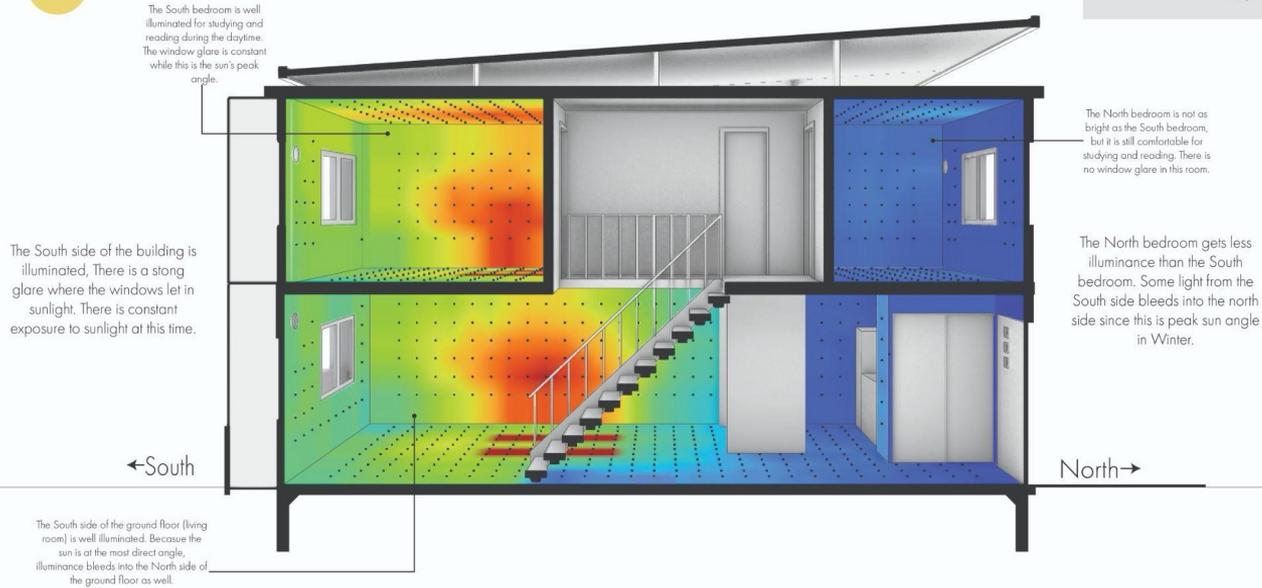


←South

North→

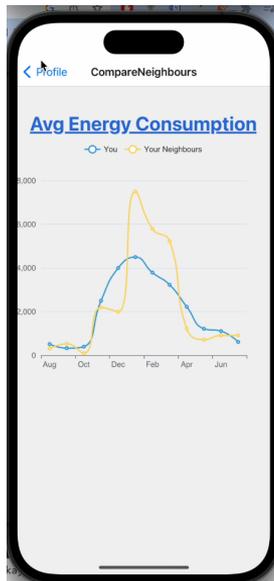
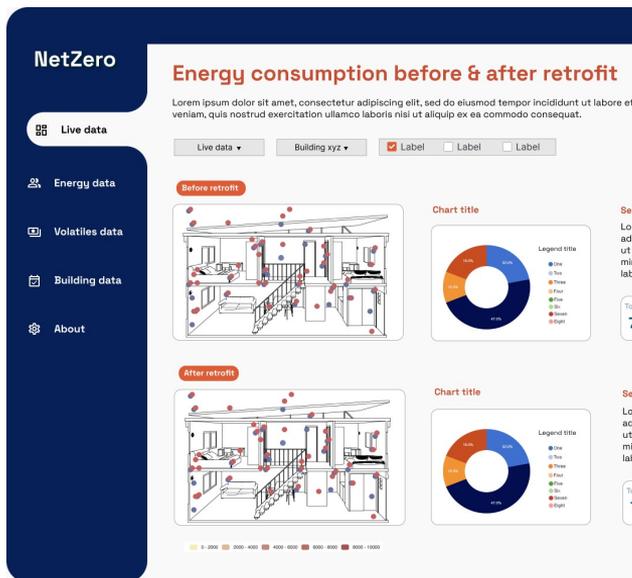
Envelope – Daylight and Views Post-Retrofit

December 21 - 12pm



U-0.28
SHGC = 0.40

HVAC + Ventilation Strategies



Energy Generation

Photovoltaic Analysis:

Projected Post-retrofit energy consumption: 25,004 kWh/yr

Site EUI: 13.8 kBtu/sf/yr

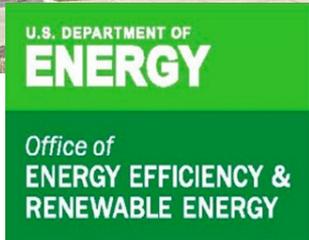
Est. kW needed for NZE: 22.8

Flat roof racking system estimate: 40,000 kWh/yr



Energy Generation





Integrated Whole-Building Energy Efficiency Retrofit Solution for Residences in Cold/Very Cold Climates

Sponsors: U.S. Department of Energy, Advanced Building Construction (ABC) Initiative and NYSERDA

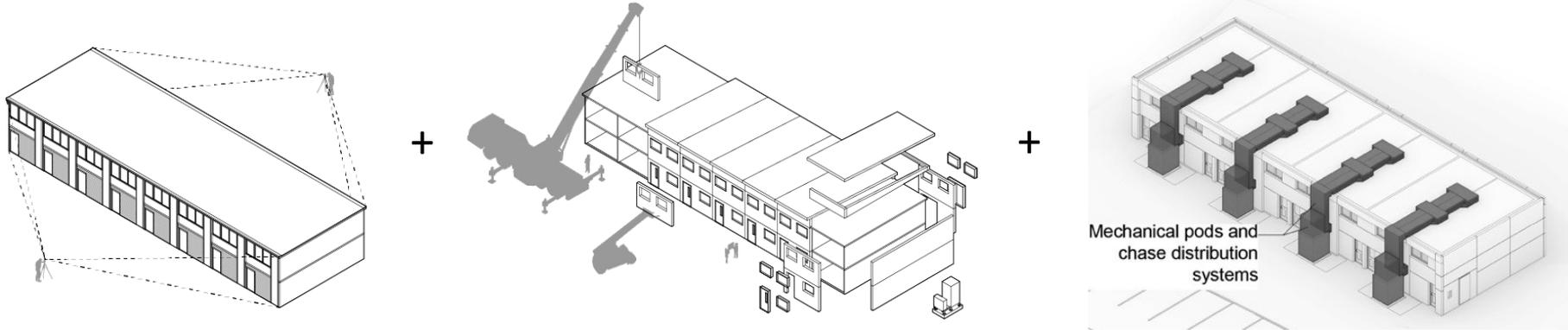
Principal Investigator: Bess Krietemeyer, Associate Professor, Syracuse University School of Architecture

Team: Syracuse University, Cycle Architecture & Planning, Signetron, Taitem Engineering, TKFabricate, VIP Structures

Period of Performance: 2020 – 2026

Budget: DOE: \$5,500,000; Cost Share: \$1,375,500

Whole-building retrofit approach is based on the principle of:



1

Capturing accurate 3D building information for retrofit design configuration, fabrication and installation

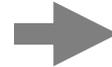
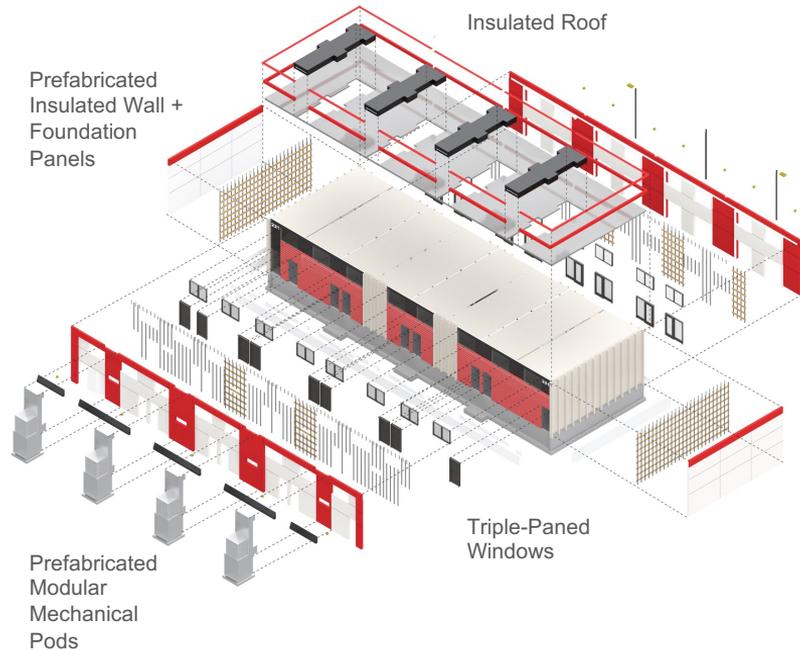
2

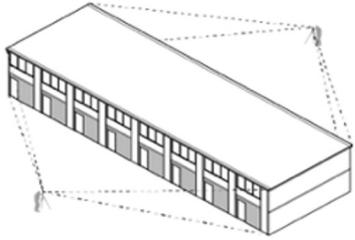
Reducing the space heating and cooling loads by insulating the building with prefabricated exterior envelope panels for improved thermal performance and airtightness

3

Meeting the reduced space heating and cooling loads with a high-efficiency integrated mechanical pod solution for heating, cooling, ventilation, and DHW

Integrated Design at Lambreth Lane



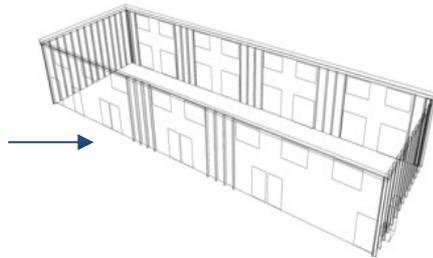


Signetron 3D Scanning + Design Workflow Features

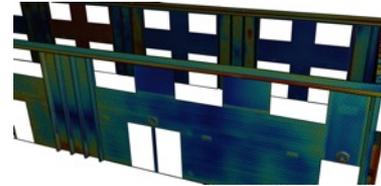
- Fast 3D building information capture, taking into account building imperfections
- Verified accuracy on BEST lab to be 0.01 foot or relative error of 0.14%
- Output 3D mesh used in design, fabrication, and installation.
- Panel layout configuration & conflict resolution software supports design & fabrication
- Provides more automated, cost-effective approach and reduces onsite retrofit time



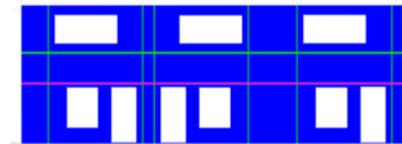
3D pointcloud



Wireframe



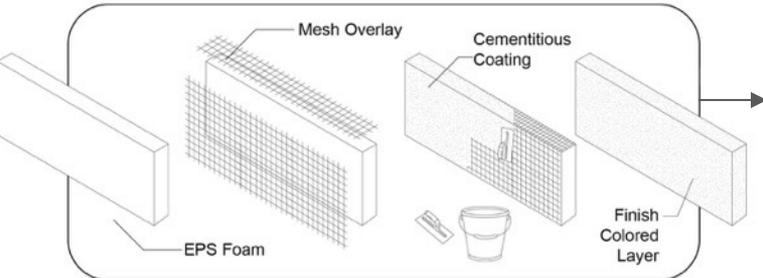
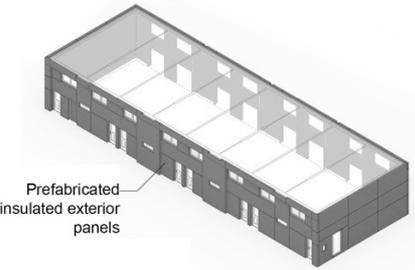
3D mesh with Deviation map



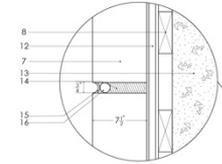
Automated panel layout

Exterior Insulated Panel System

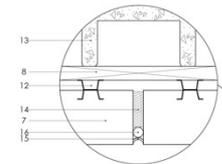
- Prefabricated, insulated (R-27) EPS foam panel system
- Provides varying thicknesses (4" to 7-1/2") for integration with existing wall construction
- Acts as barrier system; sealant and backer rod for continuous seal
- Air-sealing at seams and penetrations for mechanicals, windows, doors, foundation



Typical Horizontal Connection (Section)

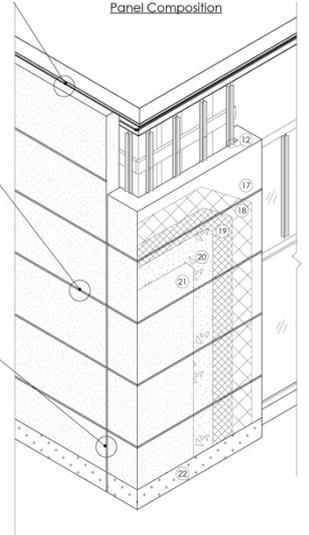


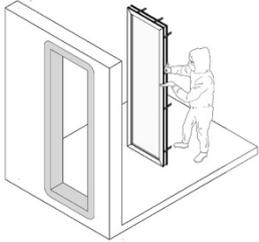
Vertical Connection (Plan)



- Key:
- | | |
|---------------------------------|------------------------------|
| 1. EPDM Membrane | 12. Vertical Hat Channels |
| 2. Coping | 13. Concrete Fins |
| 3. 3/4" Plywood | 14. 3/4" Rigid Foam |
| 4. 3" Fastening Screw | 15. 1/8" Sealant |
| 5. Embedded 2"x6" Wood Blocking | 16. 3/4" Diameter Backer Rod |
| 6. Trem Grip Adhesive | 17. EPS Foam |
| 7. Exterior Panels | 18. Primary Mesh Overlay |
| 8. 2"x4" Wood Blocking | 19. Secondary Mesh Overlay |
| 9. 1/2" Cover Board | 20. Cementitious Coat |
| 10. 6" Insulation Board | 21. Finish Coat + Color |
| 11. EXO 2.5" Concrete Deck | 22. Tile |

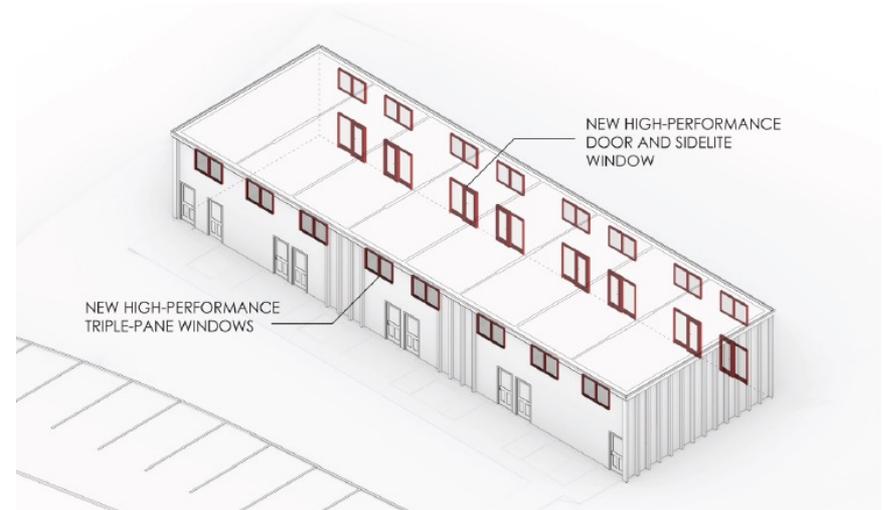
Panel Composition





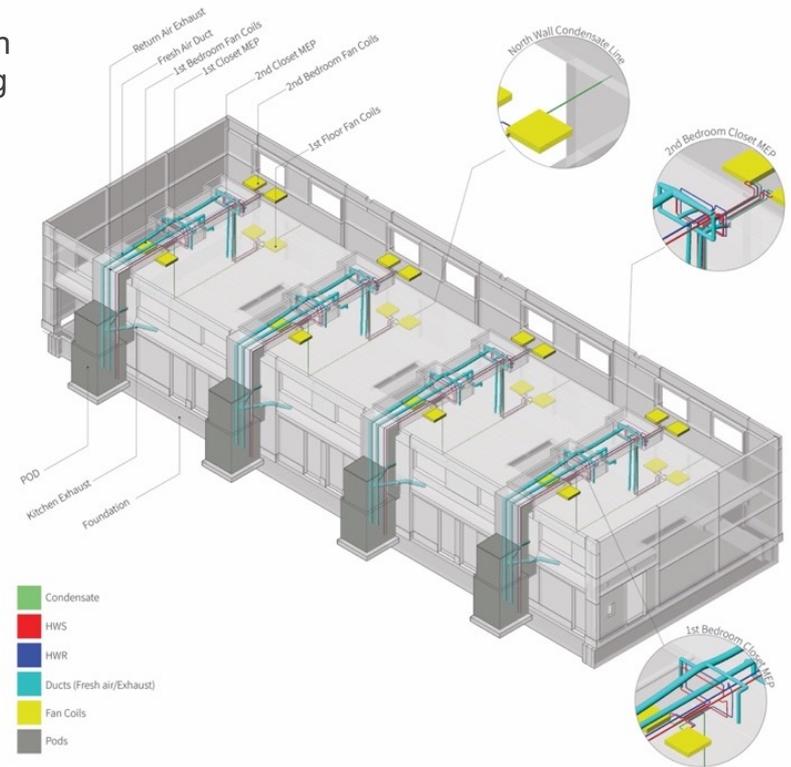
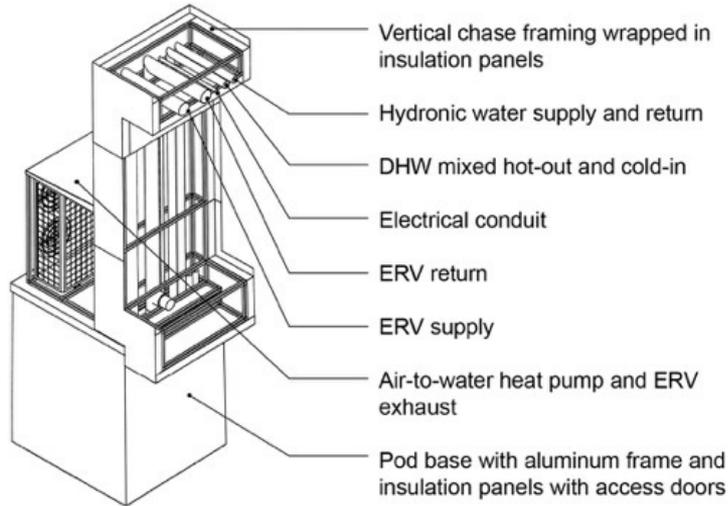
High-Performance Windows and Rear Doors

- New triple-paned casement windows, rear doors and sidelites by Intus
- Operable windows with uPVC frames
- Inswing rear glass doors w/ security screens



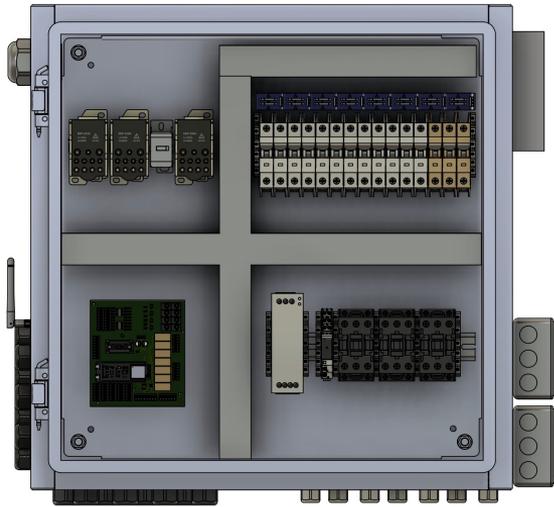
TKFabricate Hydropod Systems Integration

- High-efficiency heating, cooling, hot water, energy recovery ventilation
- Low Global Warming Potential (GWP) refrigerants, no onsite charging
- Operating range of -17° F to 122° F



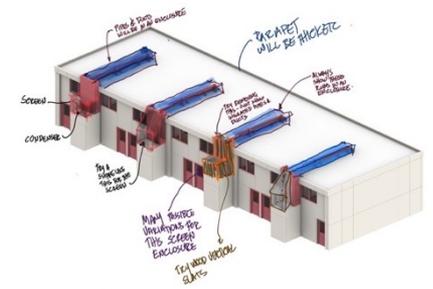
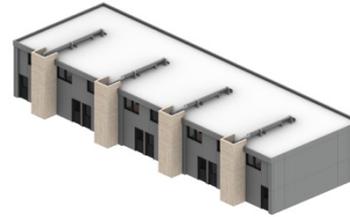
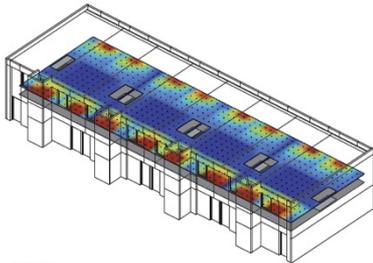
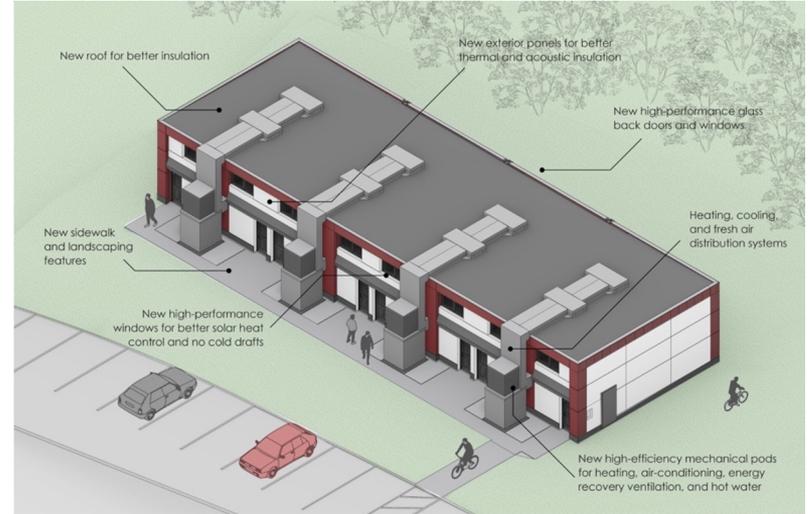
TKFabricate Hydropod Systems Integration

- Real-time Performance Monitoring
- Automated Fault Detection
- Maintenance Reminders
- Remote Control Functions



Constraints and Iterative Design Approach

- ✓ Meets the project **budget**
- ✓ Fixed construction window **< 3 months**
- ✓ **Minimize penetrations** of existing building
- ✓ **Easy access** for maintenance
- ✓ Design for **sloped site**
- ✓ **Match color scheme** of surrounding buildings



Planning

Winter 2022 – Spring 2023

- Assessment
- Scanning
- Pre-Retrofit Monitoring
- Resident Surveys

Pre-Installation

Spring 2023 – Fall 2023

- Design and Engineering
- Energy Modeling
- Bidding
- Value-Engineering
- Permitting

Mobilization, Installation & Commissioning

Spring 2024 – Fall 2024

- Construction mobilization & long lead items
- Installation of Retrofits on Two Apartment Buildings
- Start-up and Commissioning
- Maintenance Planning
- Resident Engagement

Validation

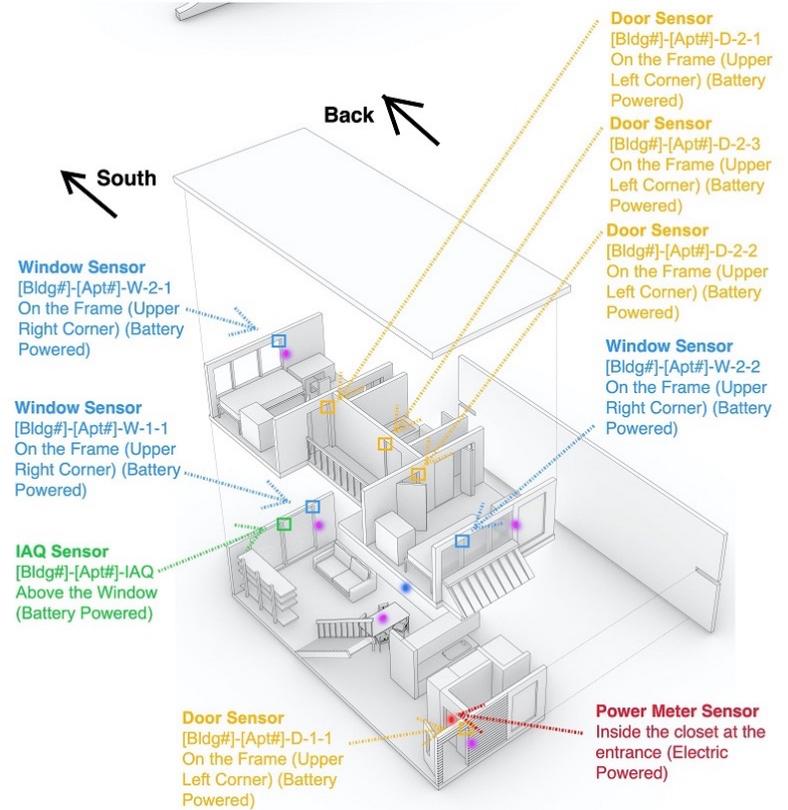
Fall 2024 – Summer 2026

- Post-Retrofit Monitoring and Modeling
- Analyze Installation Process, Time and Cost
- Resident Surveys



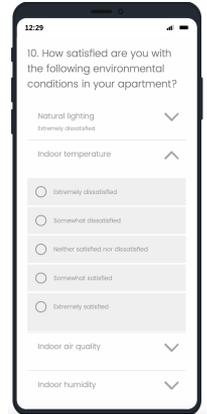
Monitoring Scopes

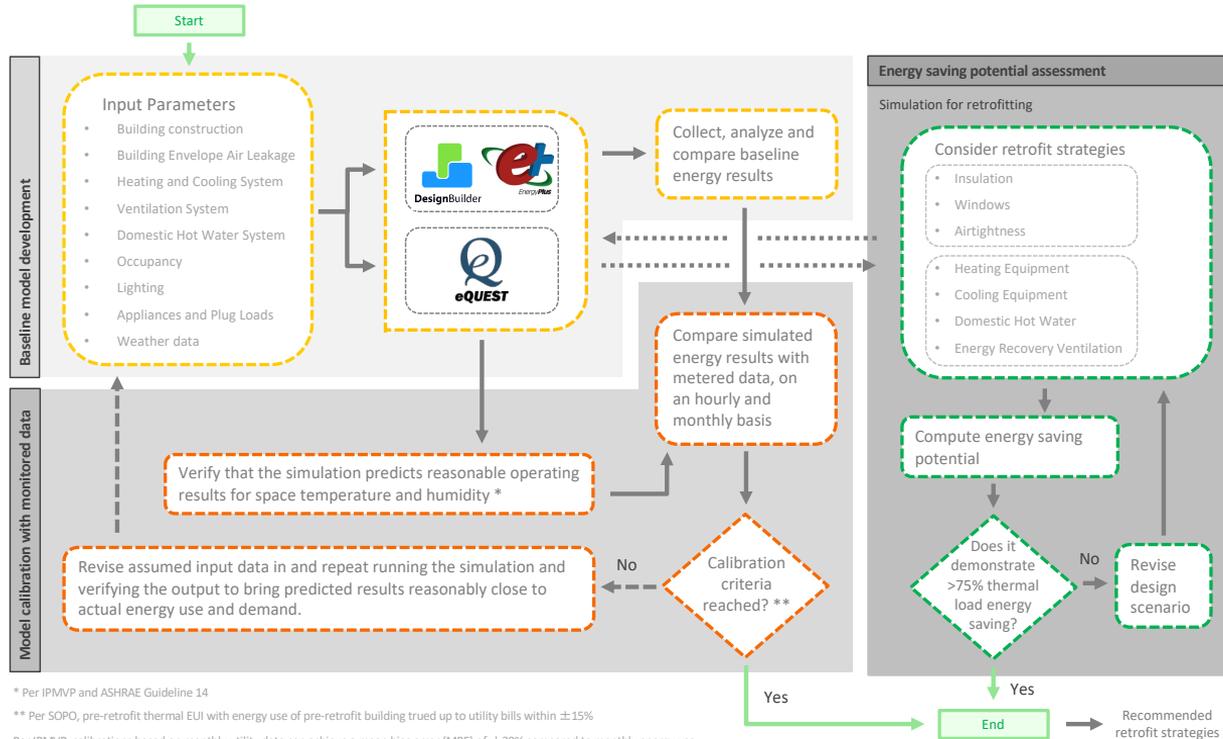
	Winding Ridge	Lambreth Lane
Whole-Building Energy Use Total energy consumption at the building level	✓	✓
Unit-Level Energy Use Per-apartment energy consumption and end-use metering	✓	✓
Indoor Environmental Quality Temperature, humidity, CO ₂ , and VOCs per unit	✓	✓
Occupancy & Activity Door and window contact sensors capturing occupant behavior	✓	✓
Resident Surveys Pre- and post-retrofit comfort, satisfaction, and behavioral data	✓	✓
Energy Generation Winding Ridge only — no solar at Lambreth Lane	✓	—
Building Envelope Performance Lambreth Lane only — added based on Winding Ridge lessons	—	✓



Monitoring Scopes

	Winding Ridge	Lambreth Lane
Whole-Building Energy Use Total energy consumption at the building level	✓	✓
Unit-Level Energy Use Per-apartment energy consumption and end-use metering	✓	✓
Indoor Environmental Quality Temperature, humidity, CO ₂ , and VOCs per unit	✓	✓
Occupancy & Activity Door and window contact sensors capturing occupant behavior	✓	✓
Resident Surveys Pre- and post-retrofit comfort, satisfaction, and behavioral data	✓	✓
Energy Generation Winding Ridge only — no solar at Lambreth Lane	✓	—
Building Envelope Performance Lambreth Lane only — added based on Winding Ridge lessons	—	✓





* Per IPMVP and ASHRAE Guideline 14

** Per SOPO, pre-retrofit thermal EUI with energy use of pre-retrofit building trued up to utility bills within $\pm 15\%$

Per IPMVP, calibrations based on monthly utility data can achieve a mean bias error (MBE) of $\pm 20\%$ compared to monthly energy use

Per IPMVP, hourly calibrations can achieve $\pm 10\%$ to $\pm 20\%$ CV (RMSE) of hourly energy use, or $\pm 1\%$ to $\pm 5\%$ of the monthly utility bill

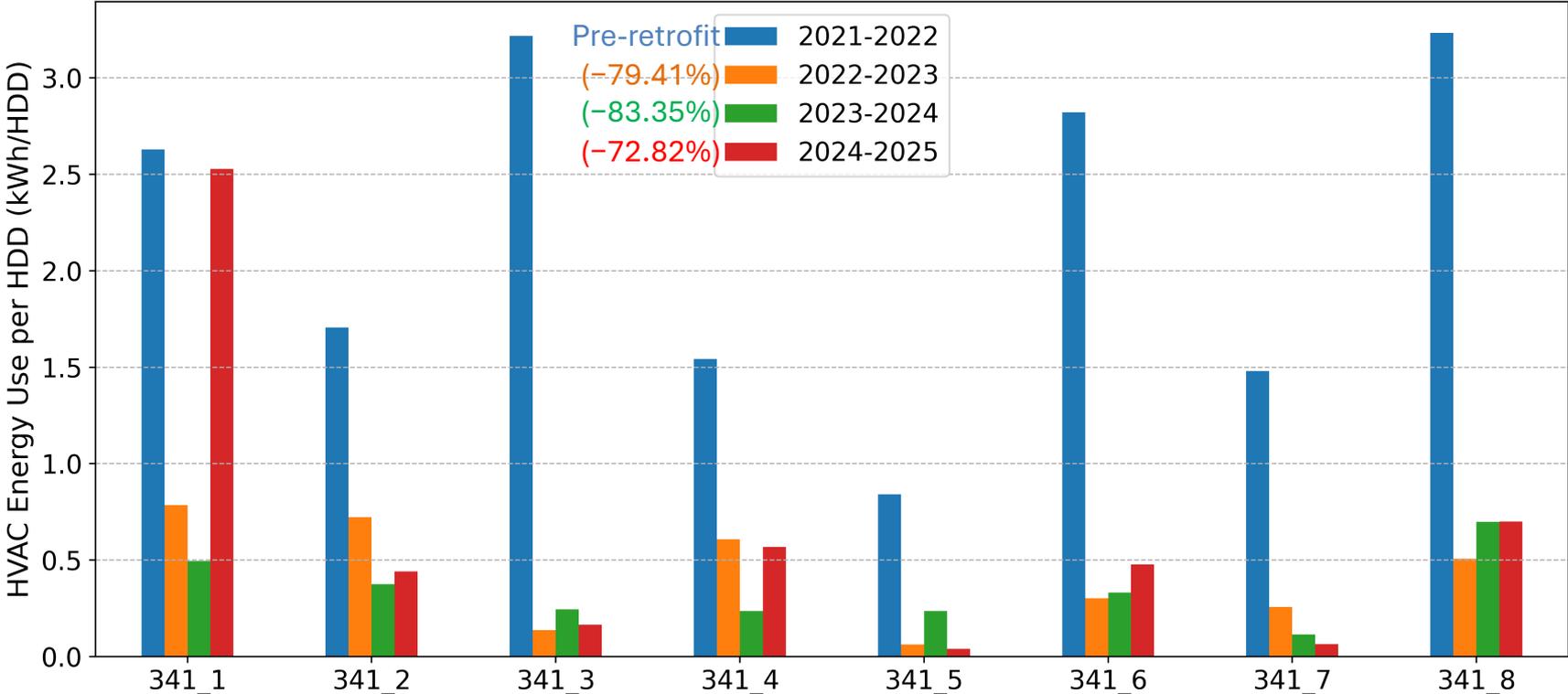


Photos by Angela Ryan

1. **Introduction:** Challenges & Goals with Deep Energy Retrofits
2. **DER Approaches:** Winding Ridge and Lambreth Lane
3. **Results:** Energy Use, IAQ, Comfort, Cost, Speed of Installation
4. **Lessons Learned:** Technical + Procedural

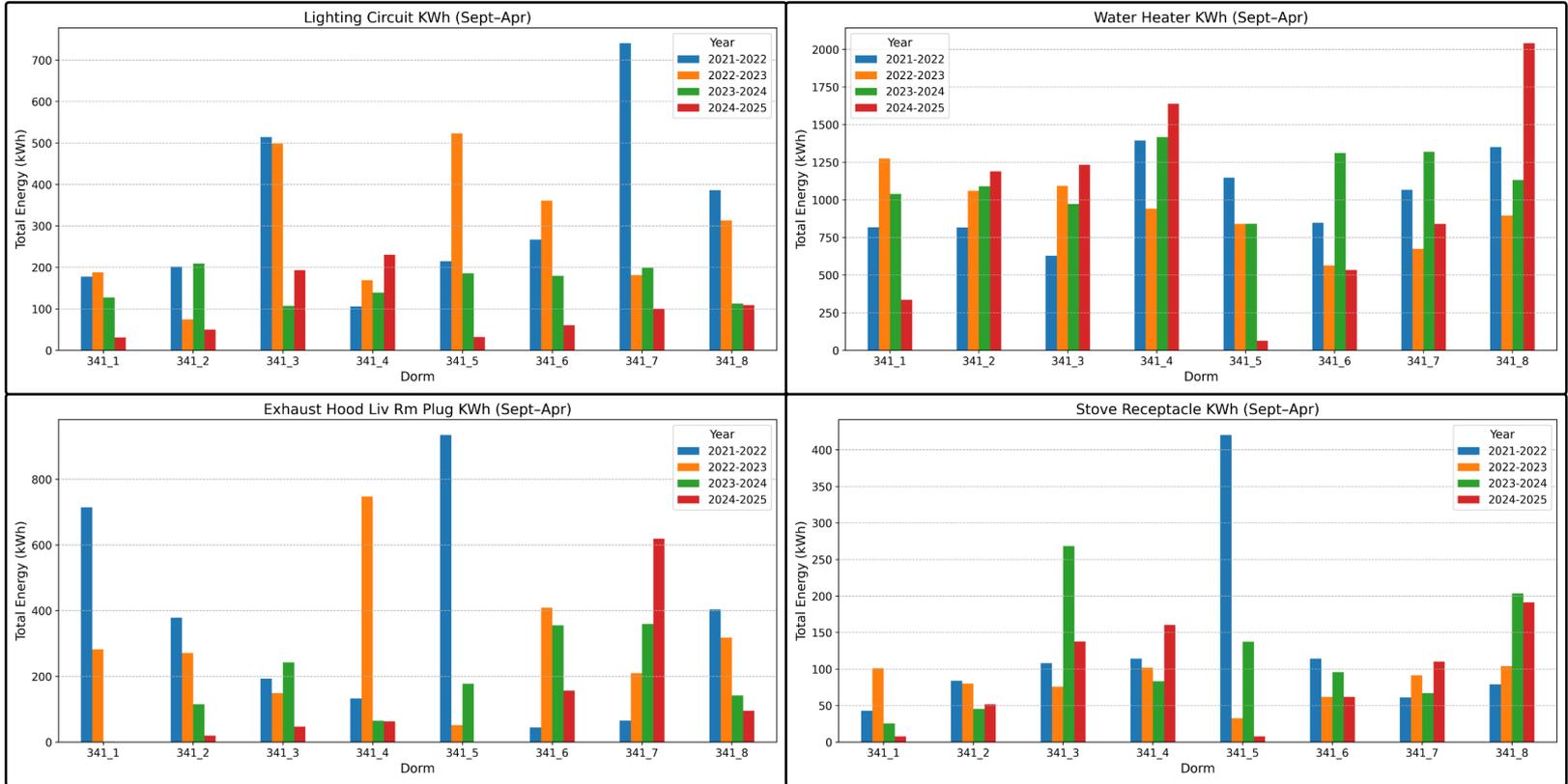
Pre- and Post-Retrofit Energy Trends: Winding Ridge

HDD-Normalized HVAC Energy use (kWh) (Oct-Apr)

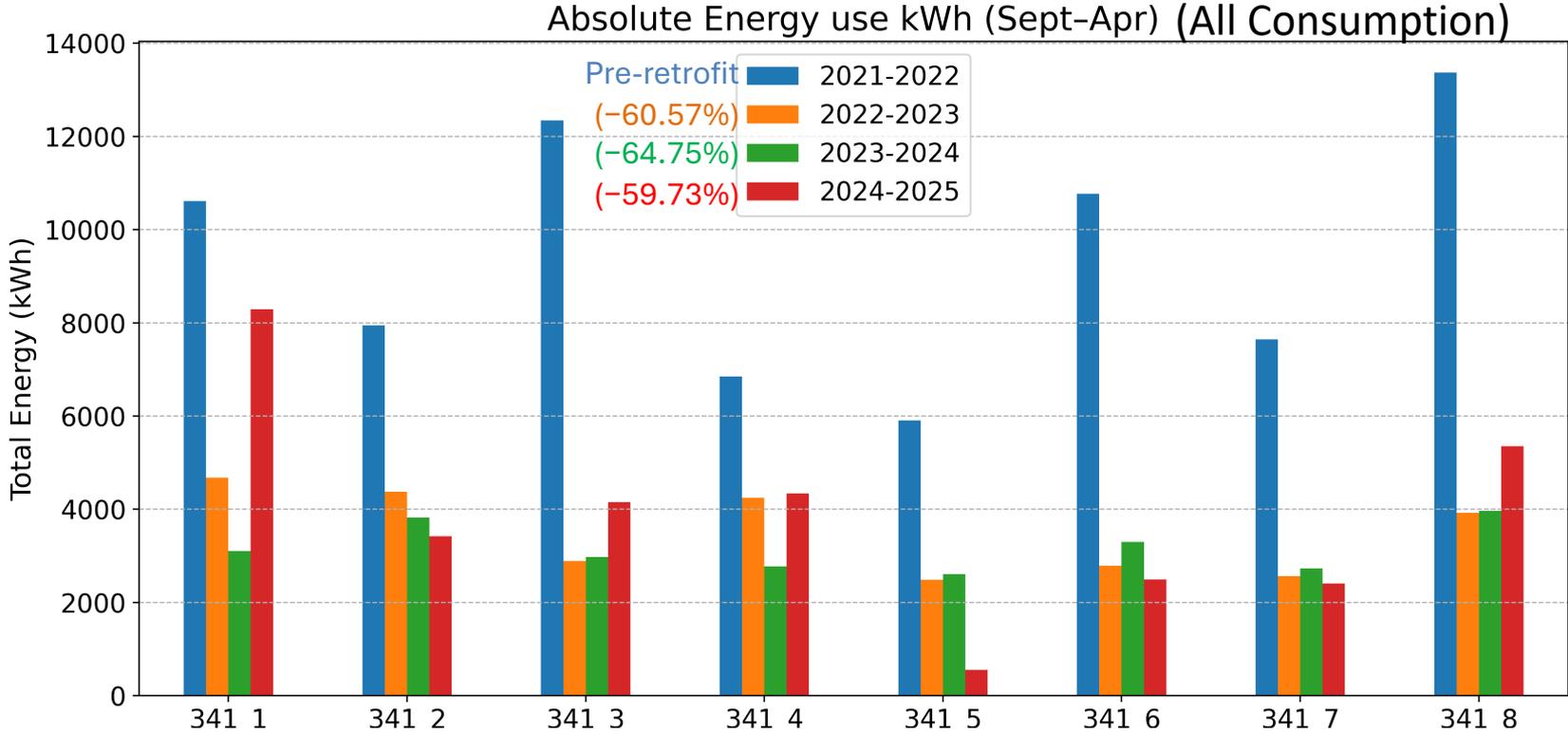


Pre- and Post-Retrofit Energy Trends: Winding Ridge

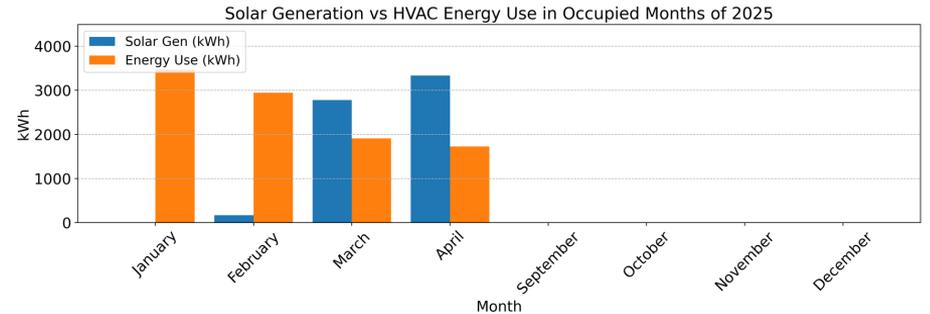
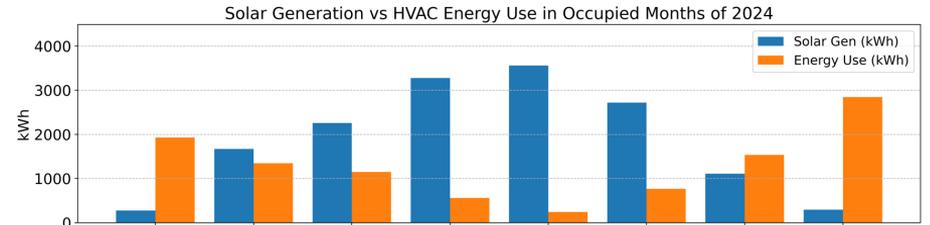
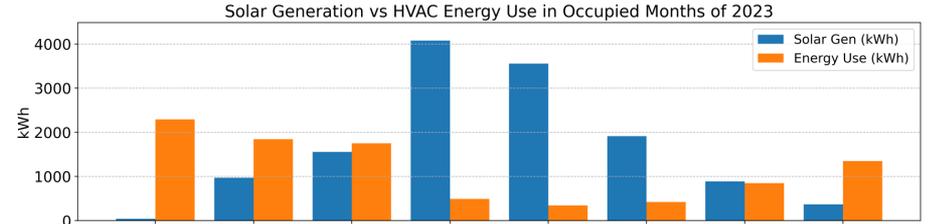
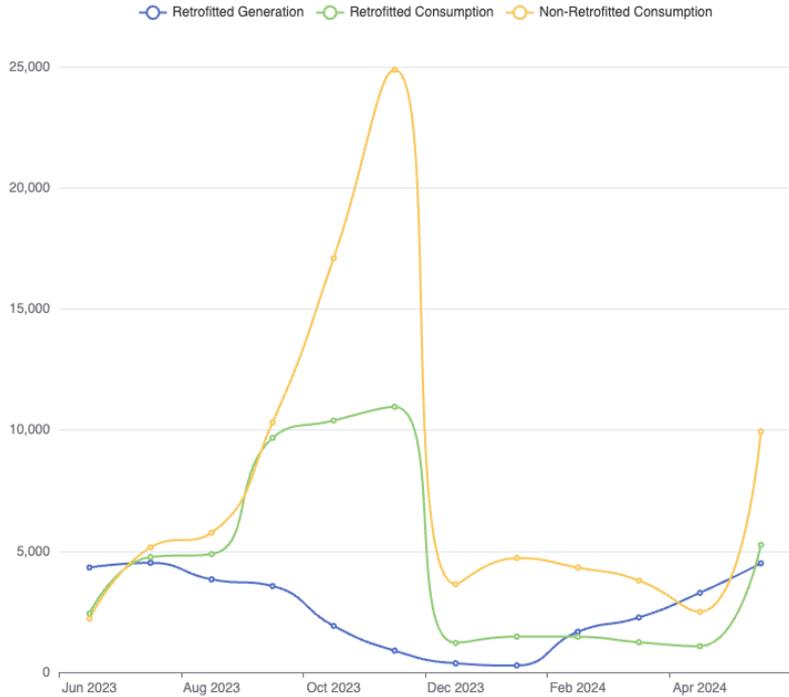
(Non-HVAC Consumption)



Pre- and Post-Retrofit Energy Trends: Winding Ridge

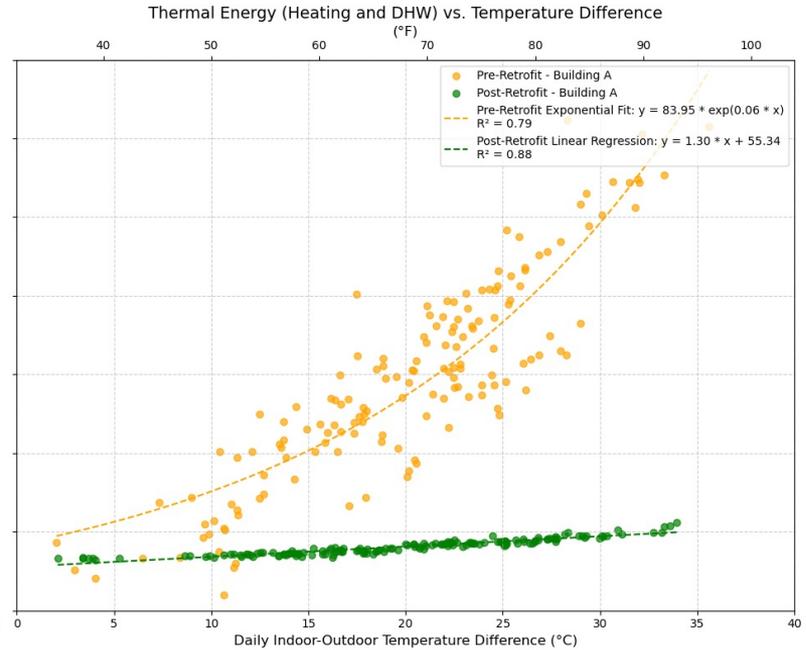
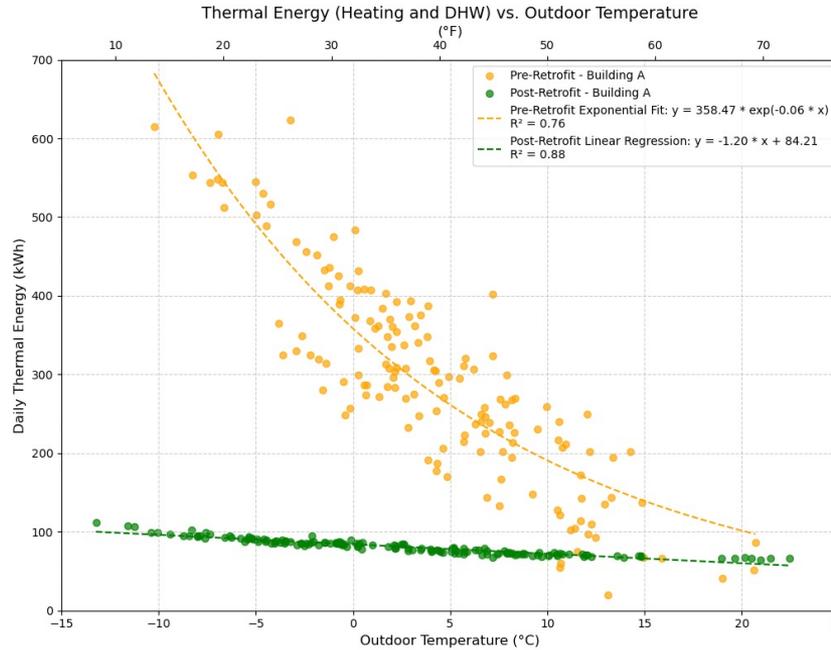


Pre- and Post-Retrofit Energy Trends: Winding Ridge

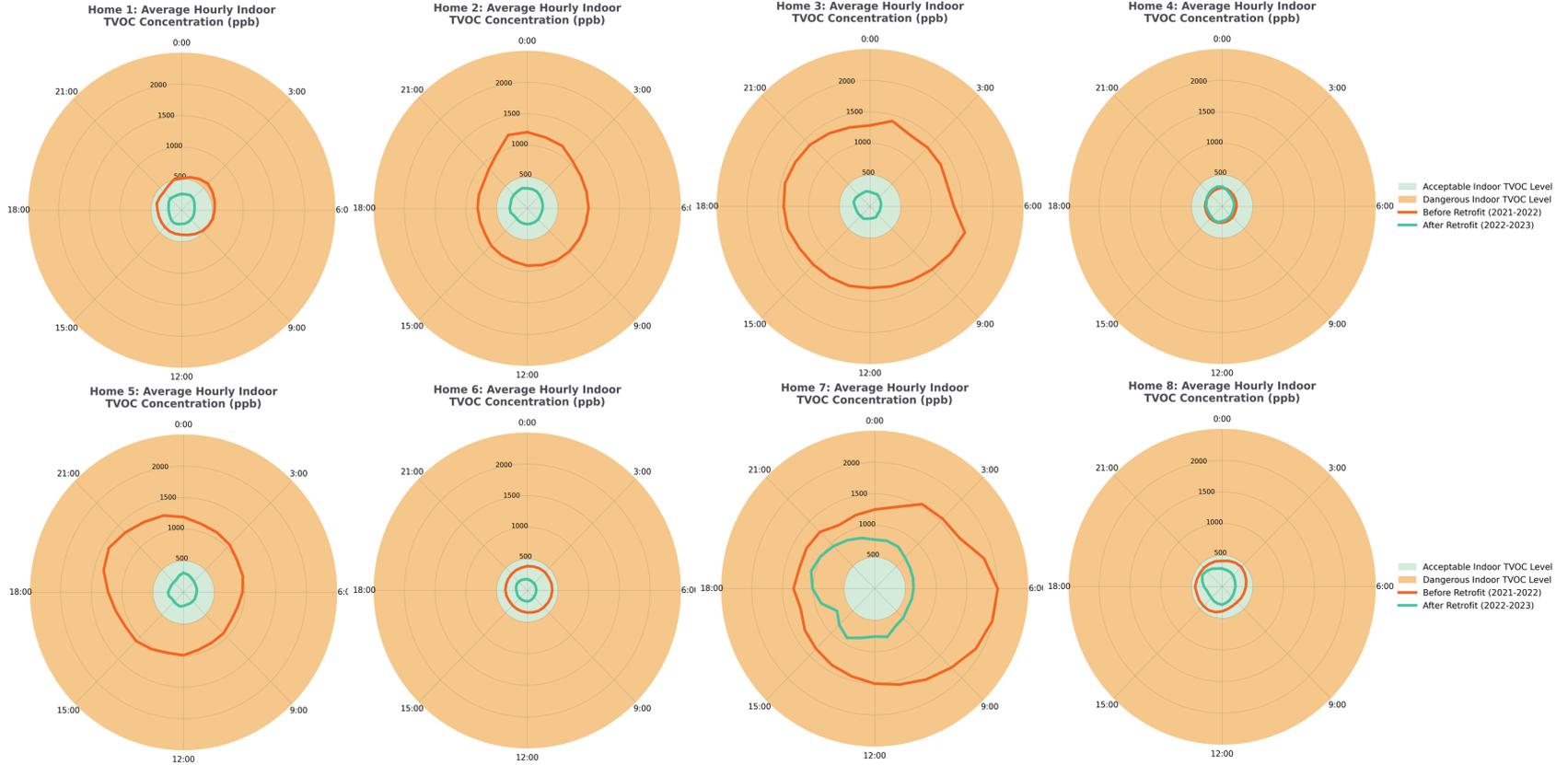


Pre- and Post-Retrofit Energy Trends with Temperature: Lambreth Lane

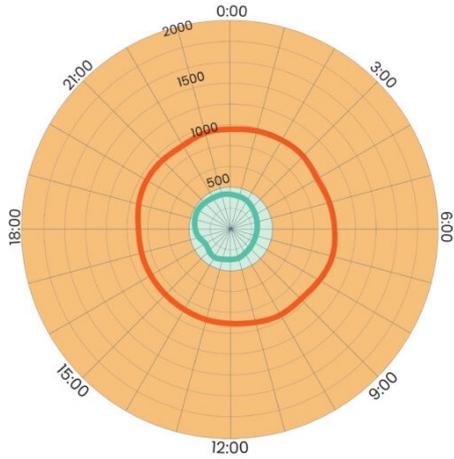
Pre-Retrofit Normalized Thermal Energy: 20.7 kWh/HDD
Post-Retrofit Normalized Thermal Energy: 5.1 kWh/HDD  75% improvement



Improvements in Indoor Air Quality – Winding Ridge

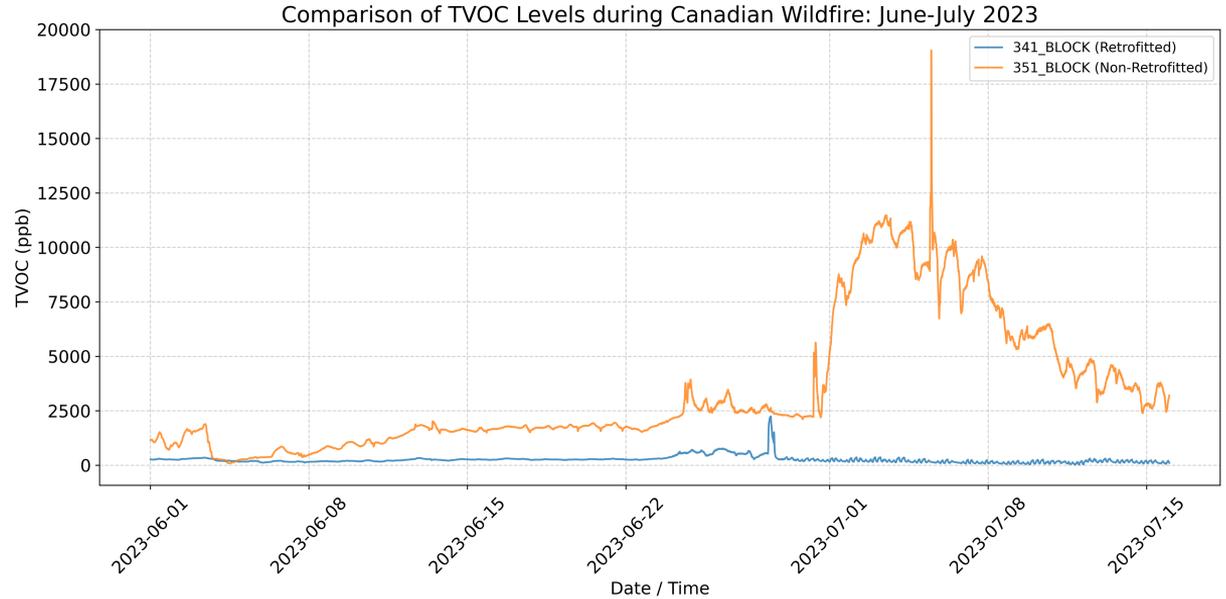


Improvements in Indoor Air Quality – Winding Ridge



Average annual hourly indoor volatile organic compounds (VOC) Concentration (ppb)

- Before Retrofit
- After Retrofit
- Acceptable Indoor VOC Level
- Dangerous Indoor VOC Level



Comparison of TVOC Levels during Canadian Wildfire: June-July 2023

- 341_BLOCK (Retrofitted)
- 351_BLOCK (Non-Retrofitted)







Installation / Mechanical Pods and Distribution Chases with Envelope



Results / Installation Complete!



Results / Cooling in Action During Late Summer/Early Fall



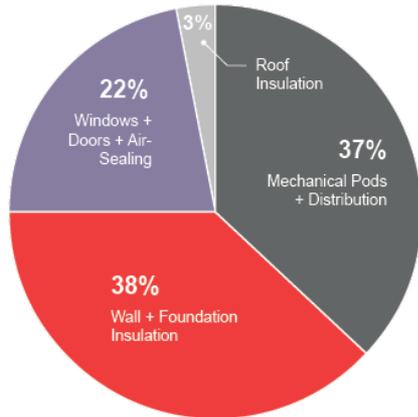
Results / Heating in Action during Winter Months



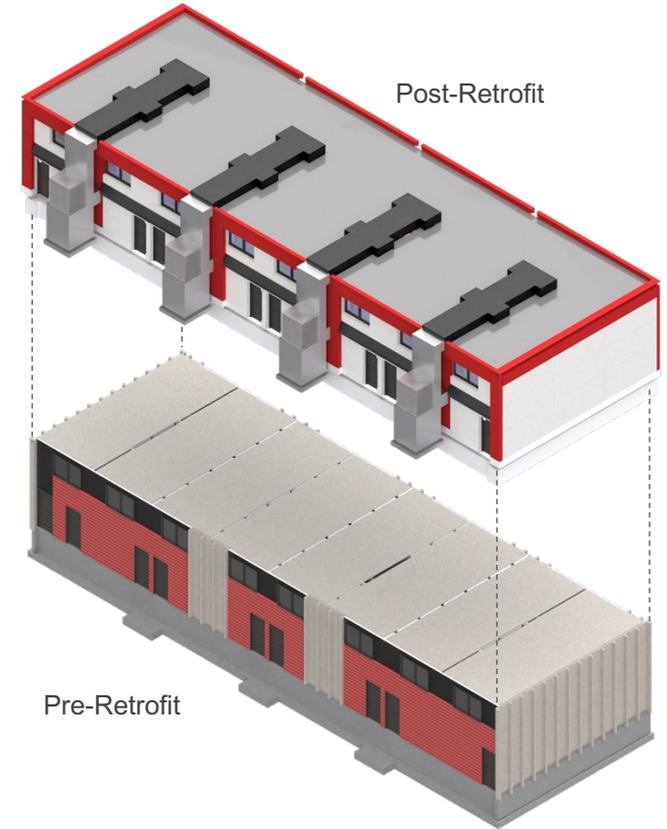
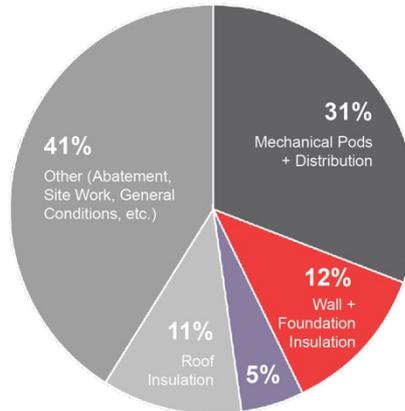
Impact of envelope on energy savings and cost

- Wall + foundation panels contribute over 1/3 to the 75% thermal energy savings goal at ~1/8 (12%) of total cost
- Sized based on loads reduced by the envelope, mechanical pods contribute over 1/3 to the energy savings while adding cooling + ventilation

% of Total Energy Savings



% of Total Installed Cost



* Preliminary results of energy savings and cost; Total cost include costs of manufacturing, delivering, and installing novel mechanical pod system at prototype scale

1. **Introduction:** Challenges & Goals with Deep Energy Retrofits
2. **DER Approaches:** Winding Ridge and Lambreth Lane
3. **Results:** Energy Use, IAQ, Comfort, Cost, Speed of Installation
4. **Lessons Learned:** Technical + Procedural

Lessons Learned

- **Envelopes matter!** Reduced loads from the envelope led to optimally-sized mechanical pod systems—making the 75% energy savings possible while improving comfort.
- **Deep Energy Retrofits can ‘punch above their weight’** even with cost-cutting. More research is needed on the magnitude of ECMs.
- **Strive for continuous process and workflows** that promote integrated project delivery. Engage CMs, contractors and subs early and often to clarify scopes, and responsibilities.
- **Identify schedule constraints and downstream effects** of a potential value-engineering process and monitor the budget through all stages.
- **Plan for assumed risk** with unfamiliar products and communicate plans for retrofit operation and maintenance.
- **Socialize the project early** with the town/county for permitting.
- **Whole-building retrofits require time and budget** for research, design, and iteration, especially for meeting fast installation schedules.



Thank you!



Bess Krietemeyer, PhD
Syracuse University

Nina Wilson, PhD
Syracuse University

Caitlin Martusewicz
Cycle Architecture

Crista Shopis
Taitem Engineering

Tom King
TKFabricate