2024 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

BTO Peer Review:

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

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

Syracuse University, Cycle Architecture & Planning, Signetron, Taitem Engineering, TKFabricate, VIP Structures
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Award Number: DE-EE0009060

Project Summary

OBJECTIVE, OUTCOME, & IMPACT

This project will demonstrate a transformative solution for retrofits of single-family attached residences in cold/very cold climates that provides:

- 75% thermal energy savings
- Minimal disruption to occupants
- Improved comfort and indoor air quality
- Potential energy savings of 1,812 TBtu/year if fully adopted to multiple U.S. residential building types

TEAM & PARTNERS

Syracuse University
NYSERDA
TKFabricate
Cycle Architecture
Signetron
Taitem Engineering
VIP Structures
Cocoon Construct

STATS

Performance Period: 7/1/2020 – 6/30/2026

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

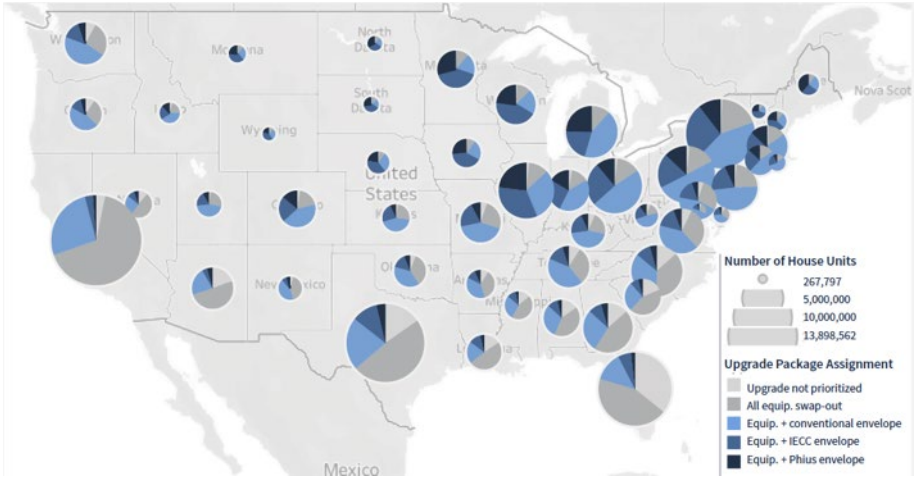
Milestone 1: Pre-retrofit monitoring, design, bid/value-eng.

Milestone 2: Installation of retrofit on two buildings

Milestone 3: Post-retrofit monitoring and verification

Problem

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



Challenges with existing retrofit approaches:

- Market fragmentation
- Project complexity and cost
- Disjointed workflows for design and implementation
- Disruption for residents during installation

For retrofits in cold climates to maximize potential thermal energy savings, they must **integrate highly insulated, tight building envelopes with compatible electrified HVAC systems** to capture energy, installation, and maintenance efficiencies, while providing thermal comfort and competitive cost benefit.

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

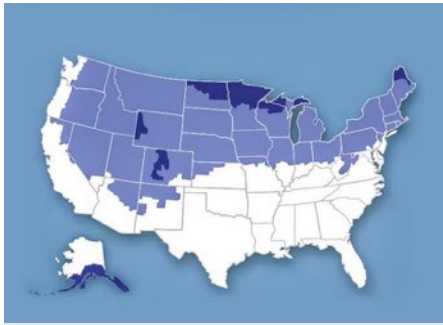
Alignment and Impact

- **Equity:** Promises significant energy savings, while emphasizing health and comfort; Applicable to single-family attached residences that can extend to single-family detached homes and low-rise multifamily buildings, especially low-to-middle income housing
- **Affordability:** Streamlined processes to reduce costs, improve quality, and minimize disruption
- **Resilience:** Improved building resiliency and grid resiliency to reduce peak demand
- A potential of **at least 30.5 million residential buildings** in cold/very cold climates**,** resulting in an overall potential energy savings of 1,812 TBtu/year.

Single-family attached residences

Low-rise multifamily residences

Single-family detached residence

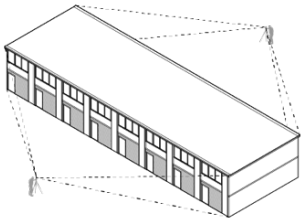


Cold / Very Cold Climate Region

Approach

- Existing whole-building retrofit approaches have used bespoke, highly labor intensive, site-installed methods, and **do not yet provide solutions to coordinate envelope and mechanical upgrades.**

- Our approach addresses the **need for innovation in integrated delivery of retrofits** through design, analysis, monitoring, fabrication, and installation.



Scanning and 3D modeling workflow

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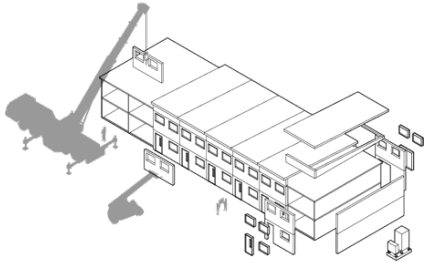

Highly-insulated prefabricated exterior building envelope

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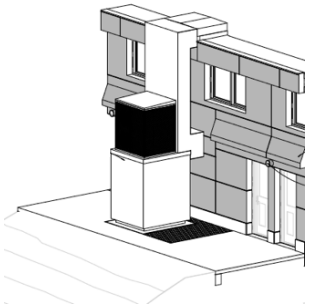


High-efficiency integrated mechanical pod solution

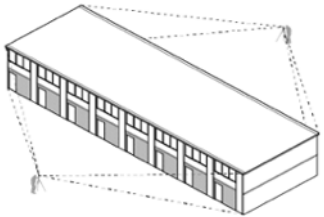
Demonstration sites: Syracuse NY

Criteria	Retrofit Targets
Energy Efficient	≥ 75% thermal energy savings
Improved Comfort	Eliminate drafts and provide consistent temperatures year-round
Improved Air Quality	Maintain less than 800ppm of CO_2
Minimal Disruption	Prefabricated with reduced time on site, cost, and disruption to occupants

Approach

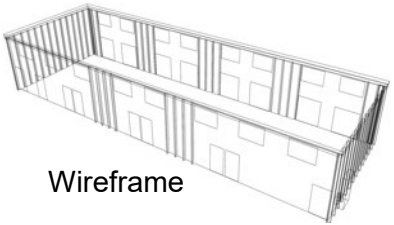
Key 3D Scanning + Design Workflow Features

- 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

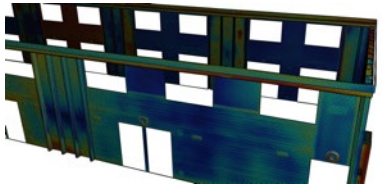


3D scan

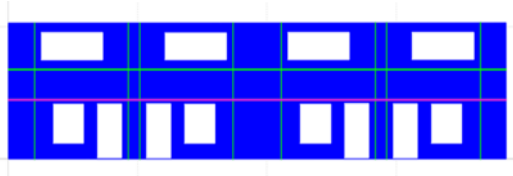
3D pointcloud



Wireframe



3D mesh with Deviation map

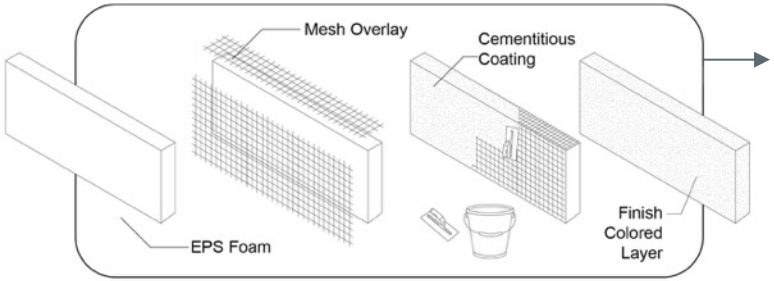


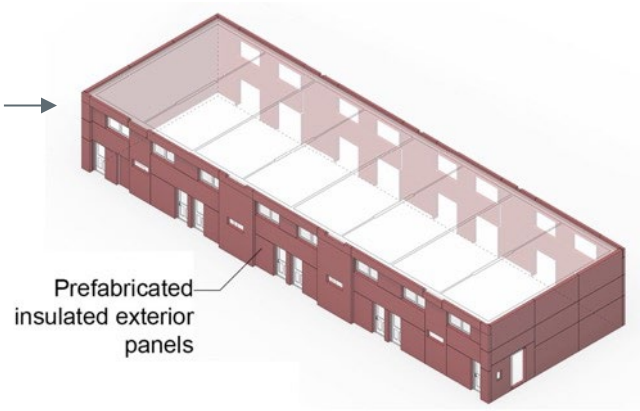
Automated panel layout

Approach

Key Envelope Features

- Prefabricated, reinforced, insulated (R-27) EPS foam exterior panel system
- Air-sealing at seams and penetrations for mechanicals, windows, doors, foundation
- Sealant and backer rod; continuous seal for air and moisture barrier
- Provides varying thicknesses (6”-7-1/2”) for integration with existing wall construction

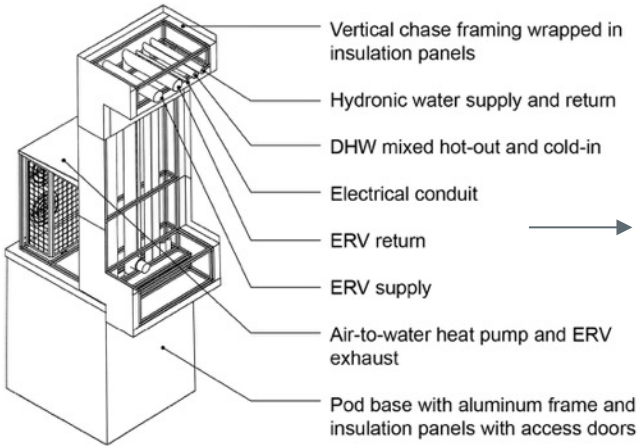


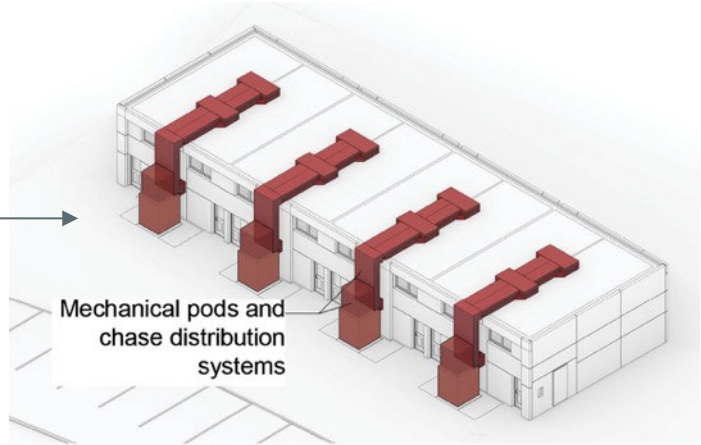


Approach

Key Mechanical Features

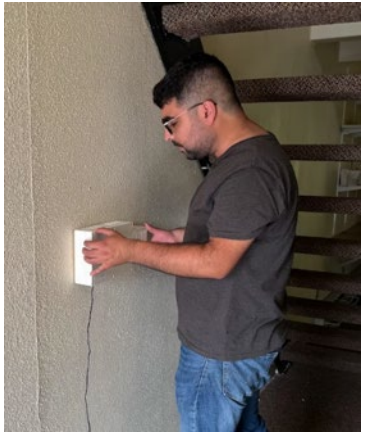
- Utilizes TKFabricate's Hydropod
- High-efficiency heating, cooling, hot water, energy recovery ventilation
- Low Global Warming Potential (GWP) refrigerants
- Access doors and real-time performance monitoring with off-site fault detection and diagnosis
- Operating temperatures of -17°F to 122°F





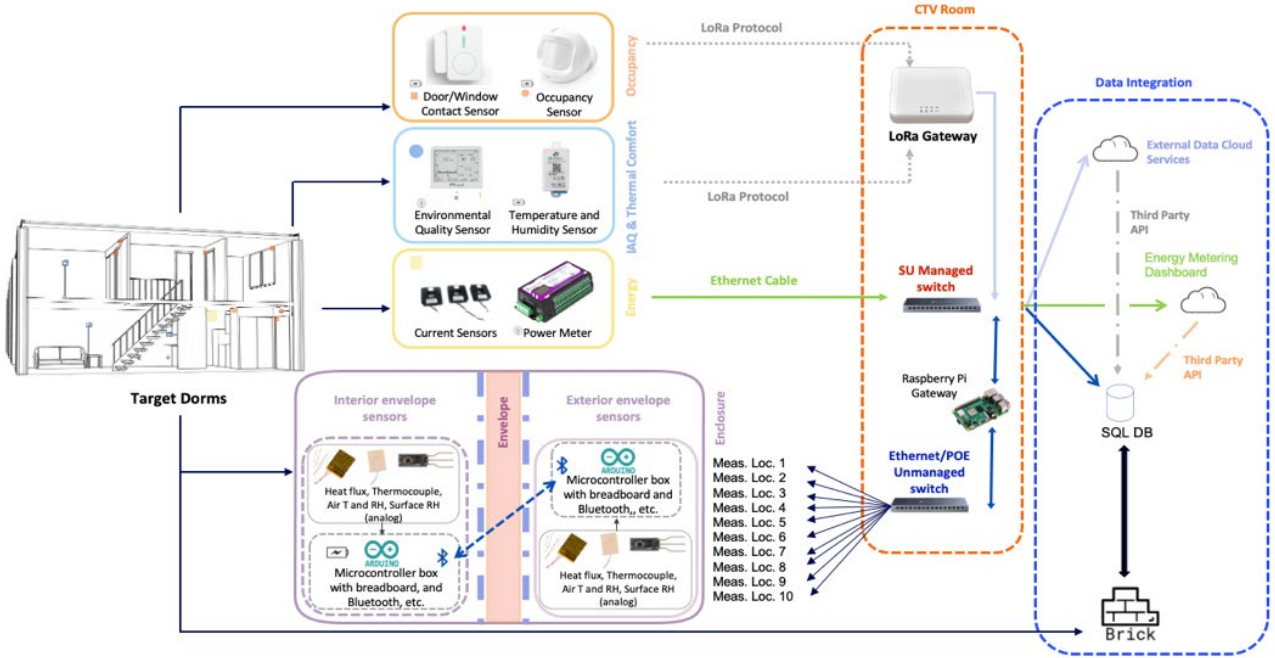
Approach

Demonstration / Validation



Planning Spring 2023 – Spring 2024	**Pre-Installation** Spring 2023 – Fall 2024	**Installation** Summer 2024 – Fall 2024	**Validation** Fall 2024 – Spring 2026
• Assessment • Scanning • Pre-Retrofit Monitoring • Resident Surveys	• Design and Engineering • Energy Modeling • Bidding • Value-Engineering • Permitting	• Installation of Retrofits on Two Apartment Buildings • Start-up and Commissioning • Maintenance Planning • Resident Engagement	• Post-Retrofit Monitoring and Modeling • Analyze Installation Process, Time and Cost • Resident Surveys

Progress



Conceptual diagram for real-time performance monitoring

Monitoring & Verification

Monitoring Scopes:

- Whole-building energy use
- Interior environmental quality
- Building envelope performance
- Building occupancy and activity

Lessons Learned

- Type and placement of sensors are important for capturing the interactions between building performance, occupant behavior, IAQ, and weather
- Minimize disruption to residents and eliminate wiring requirements by using wireless and battery-operated sensors
- Clearly communicate with owner's / residents' plan for sensor maintenance and calibration

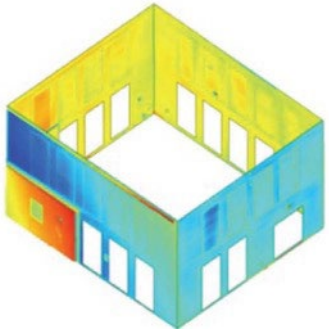
Progress

Energy Modeling of the Whole-Building Retrofit Solution

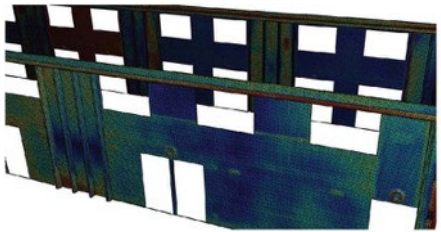
#	Thermal Load on the building	Baseline Annual Energy Usage (kWh/Yr)	Proposed Annual Energy Usage (kWh/Yr)	Annual Energy Savings (kWh/Yr)	Total Thermal Load Reduction (%)
1	Space Heating	65,711	7,613	58,098	**76.7%**
2	Space Cooling	0	3,086	-3,086	
3	Pumps & Auxiliary	12	1,703	-1,691	
4	Ventilation	289	3,444	-3,155	
5	Domestic Hot Water	13,981	2,776	11,205	
Total		79,993	18,623	61,370	

Progress

Development of Scanning to Modeling Workflow



Syracuse Univ. BEST Lab 3D deviation map



Signetron Software PaTER 3D pointcloud output for demonstration buildings

Improvements in 3D scanning accuracy and wireframe modeling

- Signetron developed a systematic way of modeling the warp, buckle, and imperfections of building facades
- Demonstrated 0.15% relative accuracy
- Compatible with industry standard software
- PaTER improves building measurements throughout the retrofit process, QA/QC during modeling, and during installation

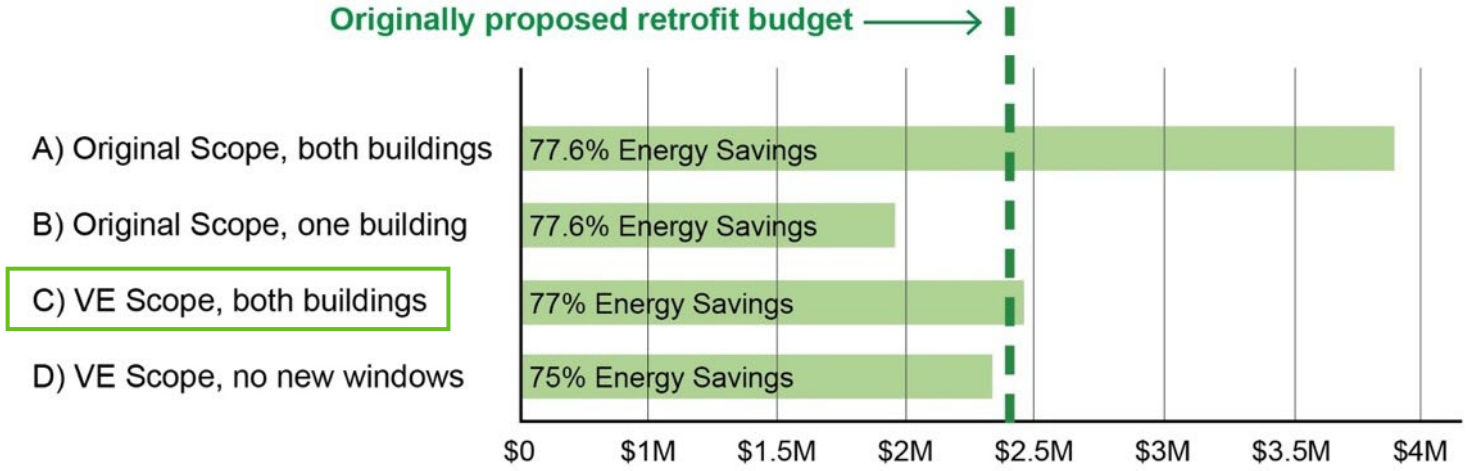
Best Practices for Laser Scanning and Data Capture

- Ensure every visible surface is scanned;
- Important to have survey points done by a total station at the same time as laser scanning so that the “virtual” BIM can be connected to physical conditions during installation

Progress

Design, Engineering, Modeling, Bidding & Value-Engineering

- Team designed and modeled proposed retrofit scope to meet project goals
- Bids for the initial retrofit design scope came in significantly higher than original budget
- Rigorous value-engineering process - designing, modeling, and pricing multiple options

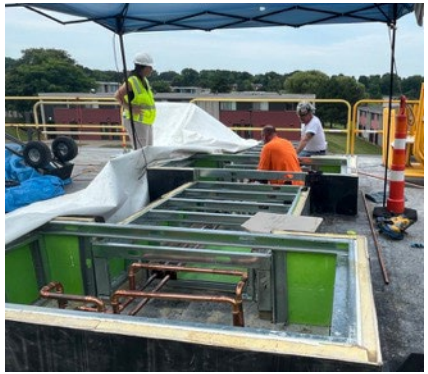


Progress and Future Work

Retrofit Installation & Commissioning

Prefabricated exterior panel installation

TKFabricate mechanical pod installation



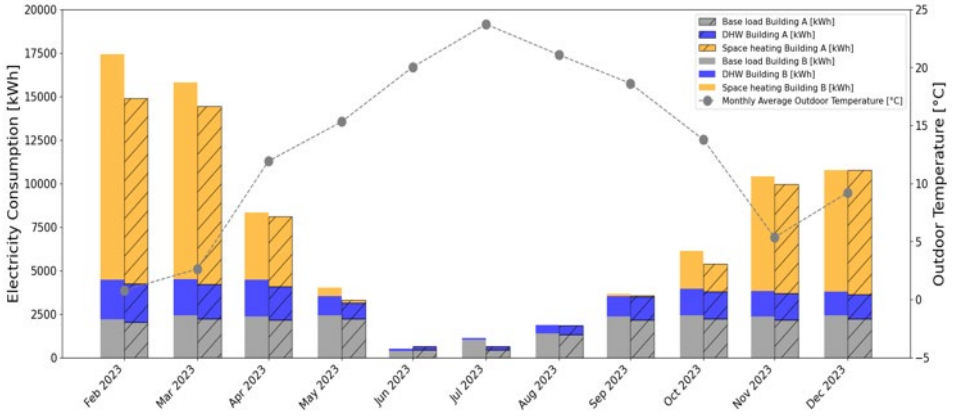
Installation of mechanical roof chases and rear doors

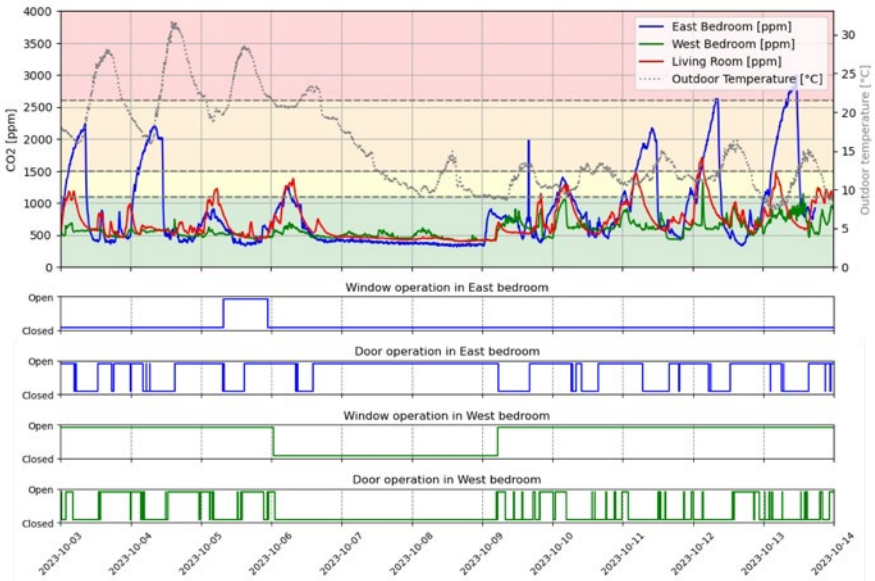
Progress and Future Work

Post-Retrofit Monitoring, Analysis & Verification

Examples of pre-retrofit monitoring of energy use, indoor air quality, and occupant behaviors that will be compared to post-retrofit conditions

- Whole-building energy consumption (below)
- Occupant behavior influence on CO_2 levels (right)
- Building envelope insulation and air-tightness





Lessons Learned

- Retrofit demonstration projects require **time and budget for research, design, and iteration**
- Strive for **continuous process and workflows** that promote integrated project delivery
- **Begin design early** and ensure the budget is monitored through design stages
- **Identify schedule constraints** and downstream effects of a potential value-engineering process
- **Socialize the project early** with the town/county for permitting
- **Engage contractors** and subs early and often to clarify scopes and responsibilities.
- **Plan for assumed risk** with unfamiliar products; engage building owners, contractors, and residents to communicate plans for retrofit operation and maintenance.

Challenges / Areas for Feedback

- **Integrated Delivery Process**
  - Strategies for engaging contractors early and often
  - Workflows for continuous integration through installation
  - Management and training for installation

- **Resident Engagement & Monitoring**
  - Incentivizing resident feedback
  - Sensor calibration and commissioning
  - Data acquisition and coordination with ITS

- **Tech to Market**
  - Financing team growth, manufacturing, sales for new tech
  - Pathway for scaling integrated delivery process

Thank you

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

Elizabeth (“Bess”) Krietemeyer, Associate Professor, Syracuse University School of Architecture

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Award Number: DE-EE0009060

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Reference Slides

Project Execution

	FY2023				FY2024				FY2025				FY2026			
Planned budget	$943K				$2.25M				$2.68M				$345K			
Spent budget	$943K				$2.25M				$2.65M							
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work																
Milestone: IPMP, IRB	◆															
Milestone: Design and Planning			◆													
Milestone: Modeling				◆												
Milestone: Pre-Retrofit Assessment							◆									
Milestone: Arch/Eng Design and Coord.								◆								
Milestone: Fabrication and Installation									◆							
Current/Future Work																
Milestone: Monitoring and Field Verification															◆	

BP 1 Go/No-Go (Phase 1): Results from prototype testing and modeling that promise to achieve FOA goals of 75% EUI reduction
BP 2 Go/No-Go (Phase 2): Delivery of modeling report demonstrating a minimum 75% thermal energy savings
BP 3 Go/No-Go (Phase 2): Permit application materials submitted
BP 4 Go/No-Go (Phase 2): Retrofit package installed according to retrofit documentation and systems commissioned
End of Project Goals: Results from the modeling and monitoring of the demonstration sites that promise to achieve FOA goals of 75% EUI reduction in attached single-family residences in cold/very cold climates.

Team

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