2024 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

BTO Peer Review: ABC Simple Install System

Advanced Wall and Mechanical Retrofit System

Material in this presentation includes unpublished and/or preliminary data and analysis that is subject to change.

ABC Simple Install System

NREL, IBACOS, Trimble, FunForm, The University of Utah, CanmetENERGY
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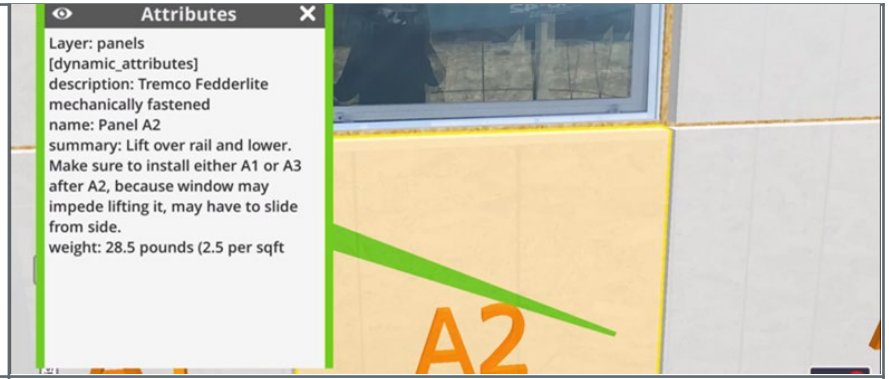
WBS: 3.2.2.132, FOA Project #NL0036669

Project Summary

OBJECTIVE, OUTCOME, & IMPACT

The process developed and demonstrated in this project will streamline tenant-in-place, deep-energy retrofits by applying advanced site capture, machine learning, and mixed reality to panelized construction. The result is a one-stop, product-agnostic solution for rapidly scalable energy efficiency retrofits with the potential for 39% emissions reductions in markets like affordable housing where the ROI does not currently exist.



TEAM & PARTNERS

IBACOS: Snap-in-place duct-chase system and companion software for specification and Commissioning
Trimble: Software and hardware infrastructure for construction applications; 17M active users
FunForm: Just-in-time envelope panel manufacturing and project delivery
NREL: Project management, M&V, ML integration
University of Utah: Process analysis, LCA

STATS

Performance Period: 10/01/2022 - 3/31/2027

DOE Budget: $4,342k, Cost Share: $1,250k

Milestone 6.2.1: Final M&V plan

Milestone 12.2.1: Final retrofit specifications with 75% load reduction, 50% cost savings

Milestone 16.3.1: Permits secured

Milestone 8.4.1: Demonstrate full machine-learning pipeline integration

Milestone 9.1.1: Demonstrate fully trained obstacle identification tool

Milestone 9.2.1: Create an integrated system that optimizes HVAC system layout

Milestone 11.1.1: Demonstrate mixed reality application on demonstration site

Milestone 17.1.1: Pre- and post-retrofit monitoring complete

Milestone 18.3.1: Final Tech-to-Market plan

Problem

The U.S. Department of Energy aims to reduce greenhouse gas emissions from the building sector by 90% by 2050 vs. 2005 levels. **80% of buildings that will exist in 2050 already exist today.**[1]

→**Deep energy retrofits** are essential to achieving Buildings Blueprint goals.

- 20 million pre-1980 attached and multifamily housing units in the U.S. could benefit from deep-energy retrofits. Commercial buildings of similar typology are also in need.
- Building typologies are varied, and custom fitting on-site is required for each project.
- The existing skilled workforce is already limited and cannot support an influx of work without improved efficiency.
- Envelope retrofits require high up-front investment and planning, and do not often offer promising ROIs without building performance standards.

→Affordable housing and low-to-mid-rise commercial building owners may not have time or capital to invest in coordinating complex retrofit projects. They need a **streamlined model with a single POC to deliver tenant-in-place retrofits**.

Varied building typologies in multifamily housing poses challenges to a one-size-fits-all retrofit approach.

[1] World Economic Forum. “For Net-zero Cities, We Need to Retrofit Our Older Buildings. Here’s What’s Needed,” November 9, 2022. https://www.weforum.org/agenda/2022/11/net-zero-cities-retrofit-older-buildings-cop27/.

PRELIMINARY RESULTS

Alignment and Impact

With electrification and performance upgrades, the Simple Install System could reduce carbon emissions by **63 million megatons** in the beachhead market of U.S. low-rise multifamily housing alone.†

	Vintage	Single-family detached	Single-family attached	Low-rise MF	Total
Total U.S. CO_2e savings (million Mt)	All	442	30	74	545
	<1980	279	16	47	342

Reduces project soft costs by >66%, **total costs by >50%**, and field **construction time by >50%.**

	Installation time	Installation cost	Material cost
BAU wall retrofit	20 min/ft^2	\$30/ft^2 wall area	\$30/ft^2 wall area
Proposed Simple Install System	<10 min/ft^2 (panel install ~1min /ft^2)	\$10/ft^2 wall area	\$10-20/ft^2 wall area

†*Based on current generation mix; electrification can yield further CO_2 emissions reductions as renewable energy penetration increases.*

PRELIMINARY RESULTS

Alignment and Impact

Soft cost and savings summary: CanmetENERGY pilot

Before (above) and after (below) photos from CanmetENERGY and Ottawa Community Housing

	CanmetENERGY Pilot ($/ft^2 wall area)	Proposed system projected cost reduction	Adj. cost applied to CanmetENERGY pilot
Soft Cost Component (includes foundation and roof)			
Site survey, point-to-point station	$0.88	50%	$0.44
Laser scanning	$0.82	0%	$0.82
Architectural design	$8.15	75%	$2.04
Engineering	$4.35	75%	$1.09
Permitting	$0.41	0%	$0.41
Shop drawing prep and review	$9.51	75%	$2.38
Construction administration	$6.80	50%	$3.40
Total Soft Costs	**$30.92**	**66%**	**$10.57**
Construction Cost Component (panel only)			
Material	$19.97	25%	$14.98
Labor	$10.56	50%	$5.28
Total Hard (Construction) Costs	**$30.53**	34%	**$20.26**
Combined Costs	**$61.45**	**50%**	**$30.83**
Soft Costs Share of Total Project Cost	**50%**		**34%**

Approach

The Solution

- Utilize **reality capture**, **machine learning**, **panelization configurators**, **precision prefabrication**, and **mixed reality** to facilitate streamlined retrofit delivery.
- Reduce on-site adjustment time, time spent in harsh conditions on-site → diversify workforce + reduce labor requirements.
- Improve thermal resilience and comfort via passive and active strategies.
- Reduce construction waste.

Manual measurement is error prone and can be difficult

U.S. mutlifamily building forms are highly varied

On-site modification for panel fitment is slow, labor-intensive

Automate measurement and unify data capture

Use neural networks to identify building features

Pre-dimensioned components simplify installation

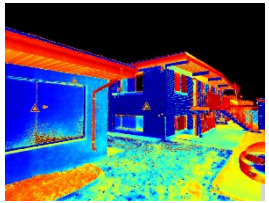
Photo credits

Row 1: Photos from Getty Images 200420345, 172279276, 182186957, 1130070411. Row 2: Photos from www.buildingpointpacific.com, Getty Images 485582678, and energiesprong.org

PRELIMINARY RESULTS

Approach

Reality Capture/Scanning

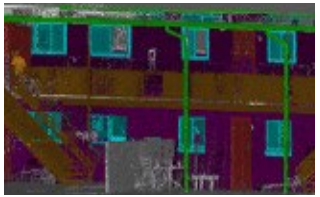


Point-cloud scan, image by NREL

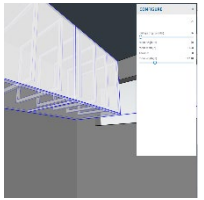
Trimble SX10 and SiteVision – courtesy trimble.com

Machine Learning Algorithms

Segmentation & Classification

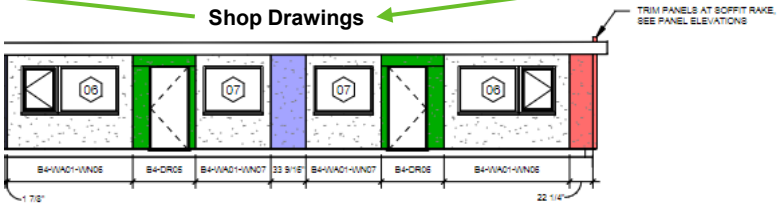


Wall & Duct-Case Panel Configurator



Materials Purchased ← **BOM**

Shop Drawings



Panel Fabrication

Simple On-Site Installation Using Mixed Reality

Mock-up of concept Mixed Reality overlay – courtesy CanmetEnergy & NREL

Trimble Connect mixed reality visualizer showing duct chase location

Approach

Pilot Demonstration

- Murray, UT (Salt Lake City)
- Typology: 2-story apartments (8 units), 1-story attached housing (8 units)
  - 4 Buildings. Each building has 4 units. Monitoring 2 units per building. Masonry
- Mechanical systems:
  - Gas furnace + window AC
  - Gas storage water heater

Photos courtesy Meghan Duff, Association for Energy Affordability

Approach

Pilot Demonstration

Staging

Stage A: 1-story envelope + ducted heat-pump retrofit

Crawl space encapsulation + insulation, roof insulation, wall panels + window cassettes, electric tank water heaters (½ of units), ducted heat pumps, panelized raceway system.

Scan→Point Cloud→Manual Panel Configuration→BOM→Subtractive Manufacturing→Install

Prototype wall & raceway panel products

Stage B: Apply ML & MR workflow on 2-story envelope

Scan→Point Cloud→*ML Segmentation*→*Panel Configurator*→BOM→*Automated Manufacturing*→*MR-Assisted Install*

Apply lessons learned from Stage A

Full cost- and time-savings evaluation

Photos courtesy Meghan Duff, Association for Energy Affordability

Approach

- **FunForm**
  - Panelized overclad system using subtractive manufacturing to custom fit to existing building shell.
  - Just-in-time fabrication: design and construction activities can run concurrently.
  - Window cassette designed to pre-install window as part of panelized system, enabling tenant-in-place retrofit.
  - Design-build project delivery.
- **IBACOS**
  - Duct chase system for high-velocity ducting (existing Rheia system) with snap-on installation method, leveraging off-the-shelf parts.
  - Auto-configure system layout using site capture, performance parameters, and machine learning algorithms.
- **Trimble (+ NREL)**
  - Machine learning and mixed reality workflow development and tool augmentation.

FunForm's foam-forming "Flying Factory" to be implemented on Stage B buildings

FunFrame window cassette

Plug-and-play chaseway system

Trimble Connect mixed reality visualizer showing duct chase location

Approach

Tech-to-Market Trajectory

- **Market Overview**
  - Building stock analysis reveals market of >50 million housing units
    →Decades of work
  - Need to simplify and de-risk retrofits by offering a single point of contact and full solution provider for building owner
- **Tech Transfer**
  - Lean on existing hardware and software to avoid scaling challenges with introducing new products to the market
- **Market Validation**
  - Document pilot project challenges & successes
  - Talk with building owners, AHJs, component manufacturers, designers, and construction trades throughout project
  - Continue momentum with scaled pilot projects
- **Risk Analysis and Mitigation**
  - Support design professionals with a new workflow vs. designing and modeling from scratch.
  - Immersive training to support construction workforce development growth.

Trimble

Phase 1 proof of concept

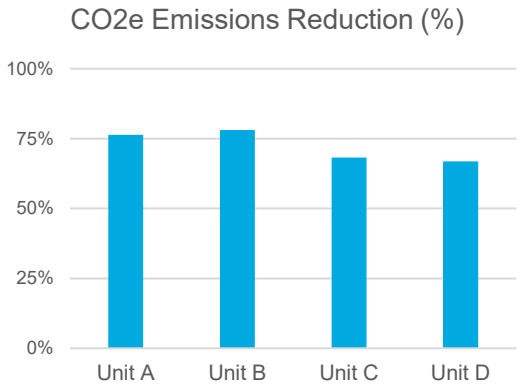
PRELIMINARY RESULTS

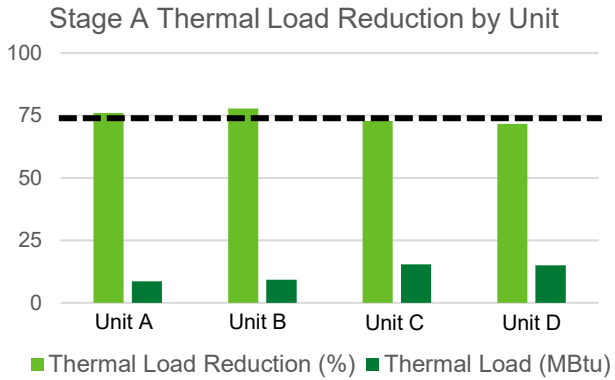
Progress and Future Work

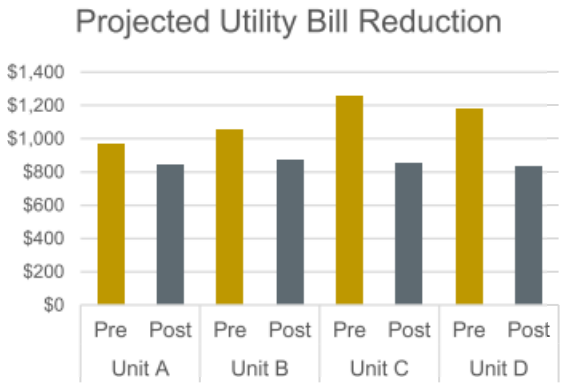
Pilot Demonstration Progress

Energy modeling

- Average of **74.5% thermal load reduction** per dwelling unit
- Average of **72% carbon emissions reduction** per unit
  - Calculated per ANSI/RESNET/ICC 301-2022
- Average of **23% projected utility bill reduction** per unit
  - Assumes relatively inexpensive gas prices (2022 tariff) and 2025 electricity tariff
  - Note: tariffs are not future projected



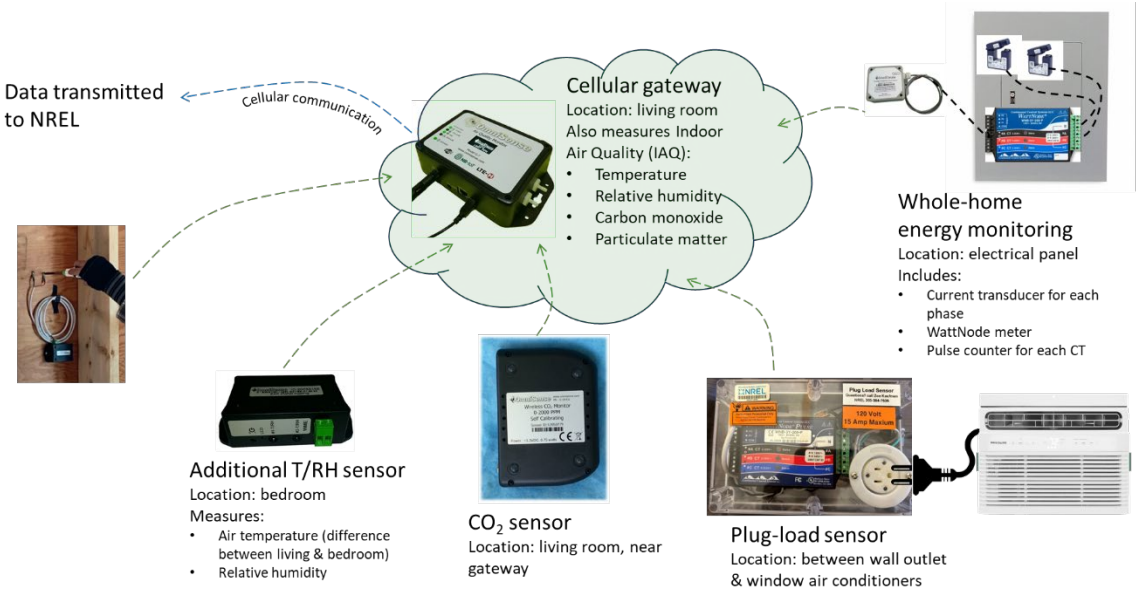




Progress and Future Work

Pilot Demonstration

Monitoring & verification schematic



Instrumentation installed in apartment units

PRELIMINARY RESULTS

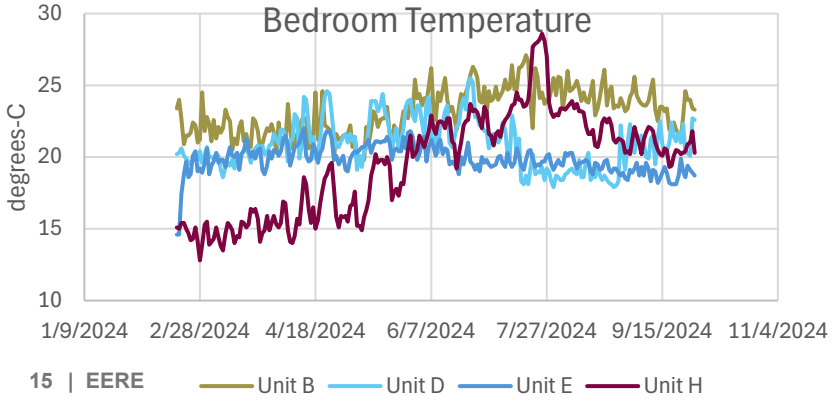
Progress and Future Work

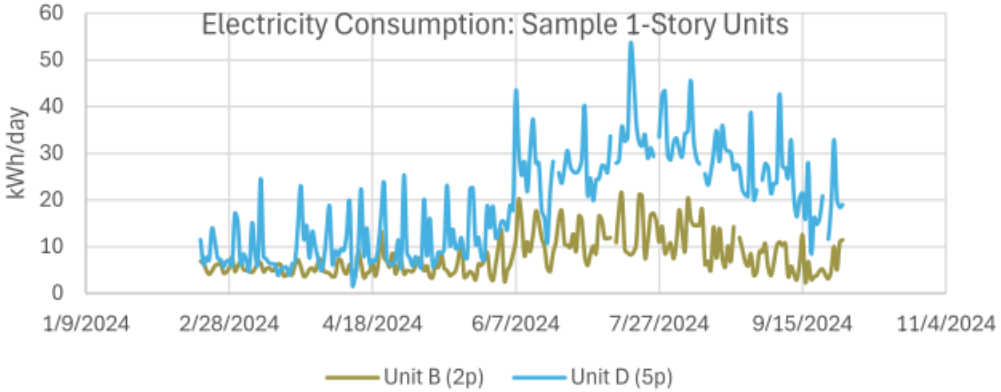
Pilot Demonstration – Electrical Consumption (pre-retrofit)

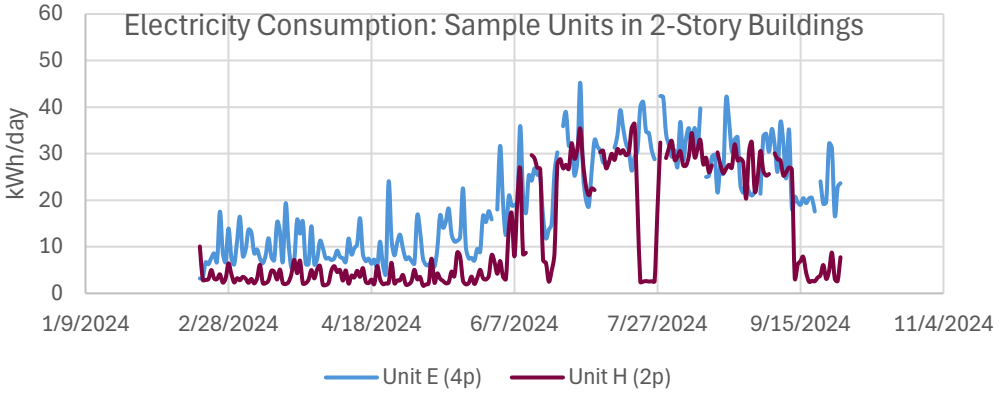
Units with higher occupancy show higher electricity use.

Some tenants maintain the same temperature year-round, while others use seasonal set-backs.

Calculation of post-retrofit changes should account for this varying occupant behavior.





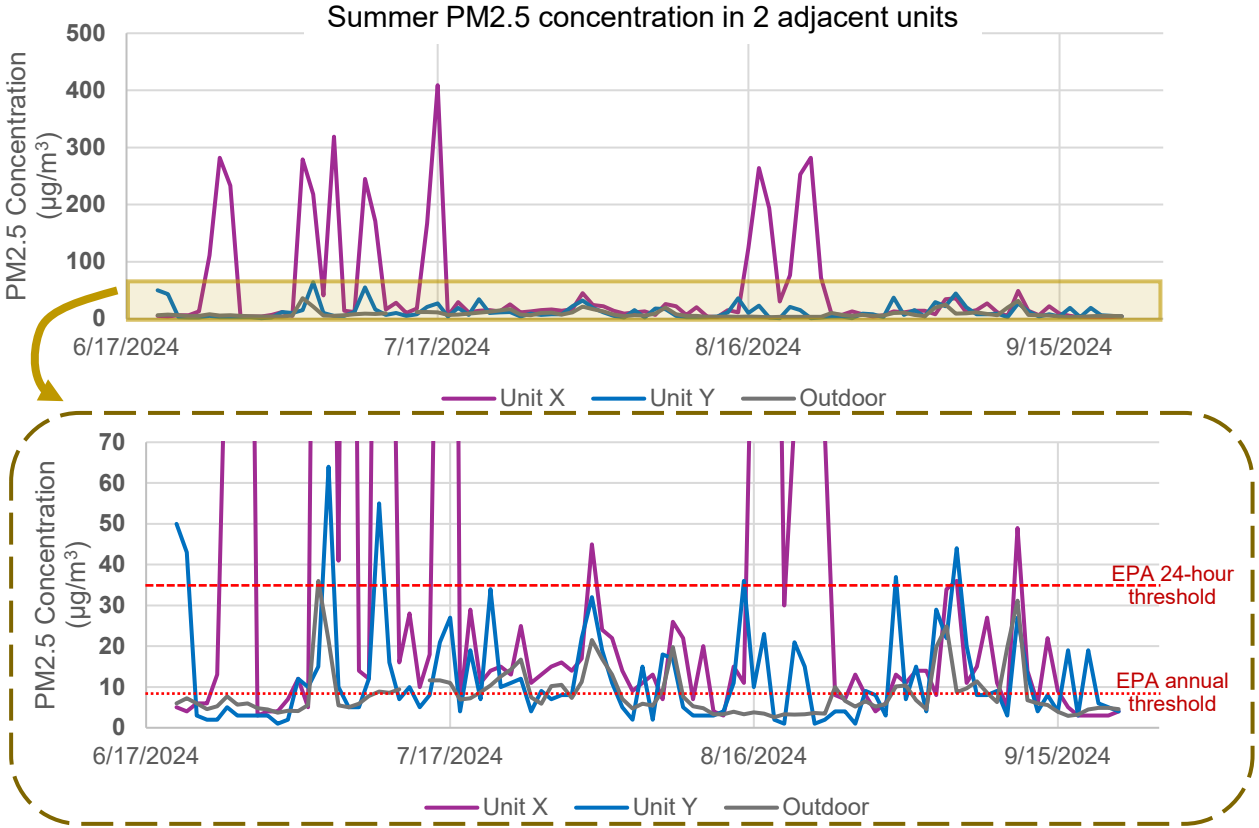


Progress and Future Work

Pilot Demonstration – IAQ: PM2.5 (pre-retrofit)

PM2.5 levels can differ greatly among units—even those sharing walls.

PM2.5 concentrations correlate with outdoor PM2.5 levels but can be significantly increased by household activities like cooking and cleaning.



Progress and Future Work

Pilot Demonstration – Construction Progress

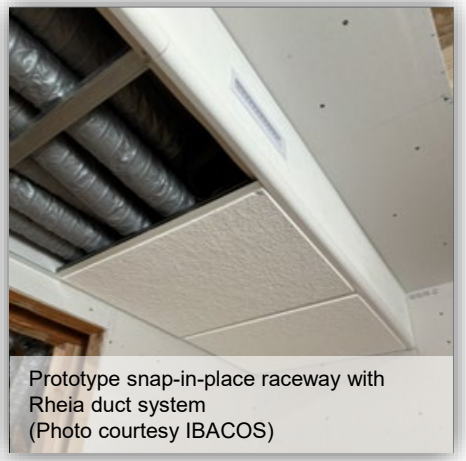
- Site prep work and building scans complete
- Panels fabricated offsite in parallel with site work
- Electric and gas meters relocated
- Liquid-applied air barrier applied to masonry and sheathing
- Wall + window panels installed
- Anticipated wall retrofit timeline: Sept.–Oct. 2024
- Labor:
  - Reducing from 6-person crew to 4-person crew (removing 2 masons)
  - Framers instead of masons except where window resizing required (reduced need for skilled labor)
  - No shaving/cutting of foam
- Stage A completion: November 2024
- Pre-retrofit monitoring complete for Stage A; ongoing for Stage B
- Stage B pilot with automated workflow planned for summer 2025

First panels with window cassettes installed on first building.
(Photo courtesy Michele Knapp, FunForm)

Progress and Future Work

Pilot Demonstration – Heat-Pump Retrofit Snap-In-Place Duct Raceway

- IBACOS soffit specifications and BOM drafted
  - Achieve a plug-and-play, snap-on installation method, similar to Rheia duct system
- Prototype frames and panels fabricated and assembled
- Prototype “raceway configurator” developed using Trimble tools
  - Future configurator to include additional features
    - Clearances
    - Auto-sizing based on duct layout
    - Integration with duct configurator



Prototype snap-in-place raceway with Rheia duct system
(Photo courtesy IBACOS)

Prototype raceway configurator in Trimble Creator

Progress and Future Work

Lessons Learned To Date

- Pilot project tenants are agreeable, especially when given ample information and opt-out options. Tenants especially like being provided central AC (upgrade from window units).
  - → Use Stage A as template for tenant information package for Stage B
  - → Encourage owners to consider ducted heat-pump retrofits for Stage B as well
- Multifaceted barriers to electrification
  - Messaging from utility: if gas service removed, costly to reinstall (despite monthly cost advantage and cost to put gas meters back after moving them)
  - Recent local gas tariff decrease (though fluctuations unpredictable)
  - General lack of understanding that gas appliance operation still requires electricity
  - Owners reluctant to commit fully to the concept of electrification
  - Space constraints for heat-pump water heaters in small apartment units
  - → Use Bldg 4 as case study and comparison for electrification benefits and drawbacks

Progress and Future Work

Lessons Learned To Date (Cont'd)

- Permitting and inspection challenges
  - Local permitting requirements: fragmented system, slow review process
  - AHJ not set up for review of standardized, repeated system
  - Unfamiliar construction practices (e.g., EIFS) trigger additional inspections
  - → Provide feedback to AHJs with support from commercial partners & DOE
  - → Apply permitting and inspections lessons learned from Stage A to Stage B planning and contracts
  - → Opportunities for workforce development
- Tenant-in-place retrofits
  - Feasible based on project's envelope innovations; however…
  - If moving power service/panel location, need to immediately upgrade meter banks if out of date, so not feasible to do within 1 day for multiple units
  - Inspection delays can halt work, preventing completion by end of day
  - → Contact utility companies well in advance of site work so that all prep and panel installs can benefit from a well-defined timeline
  - → For realistic construction timeline planning, determine early in project whether meter banks require upgrades
  - → Emphasize need for offsite-construction-friendly inspection options

Progress and Future Work

Upcoming Work

- Machine learning
  - Model training
  - Validation
- Panel configurator development
  - Duct chase
  - Envelope
- Demonstration – Stage B
  - Use of ML-based tools and configurator tools
  - Mixed reality integration
  - Just-in-time wall/window panel manufacturing
- Ongoing data analysis
- Tech to market
  - Workforce pilots and workshops
  - Integration with additional wall panel manufacturers

Panel layout


Building scan
(Photo courtesy FunForm)


Mixed reality view of panel placement on Building 4

Thank you

NREL
IBACOS
FunForm
Trimble
University of Utah
CanmetENERGY

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Reference Slides

Project Execution

	FY2024				FY2025				FY2026				FY2027			
Planned budget	$1,227,249				$2,703,843				$1,000,000				$638,400			
Spent budget	$1,085,287															
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work																
Q1 Milestone: Final Draft M&V Plan																
Q2 Milestone: Industry Best-Practice Site Audit																
Q3 Milestone: Draft T2M Plan																
Q4 Milestone: Retrofit Specifications Meet Criteria																
Q4 Milestone: Permits Secured; Begin Construction																
Current/Future Work																
Q1 Milestone: Pre-Retrofit Data submitted																
Q2 Milestone: Preliminary Data Reporting																
Q3 Milestone: Software Tool Readiness																
Q4 Milestone: Model Training Data Curated																
G/NG: Retrofit Stage A Commissioning																

Challenges arose securing permits due to lack of transparency in AHJ submission requirements and disjointed processes and reviewing roles. This is anticipated to be the case for many locations and should be considered moving forward in terms of standardizing drawing sets and specifications.

Team

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Founder, FunForm

Andrew Poerschke

Building Performance Specialist, IBACOS

Ian Warner

Director of Industry Workforce Development & Innovations, Trimble

Tom Kluyskens

Product Manager, Trimble

Vendors & Partners

Working partners:

Supporting partners:

- CanmetENERGY
- Sto
- Alpen
- BASF
- ClarkDietrich
- Leviton
- Fischer

Reference Slide: Window Cassettes

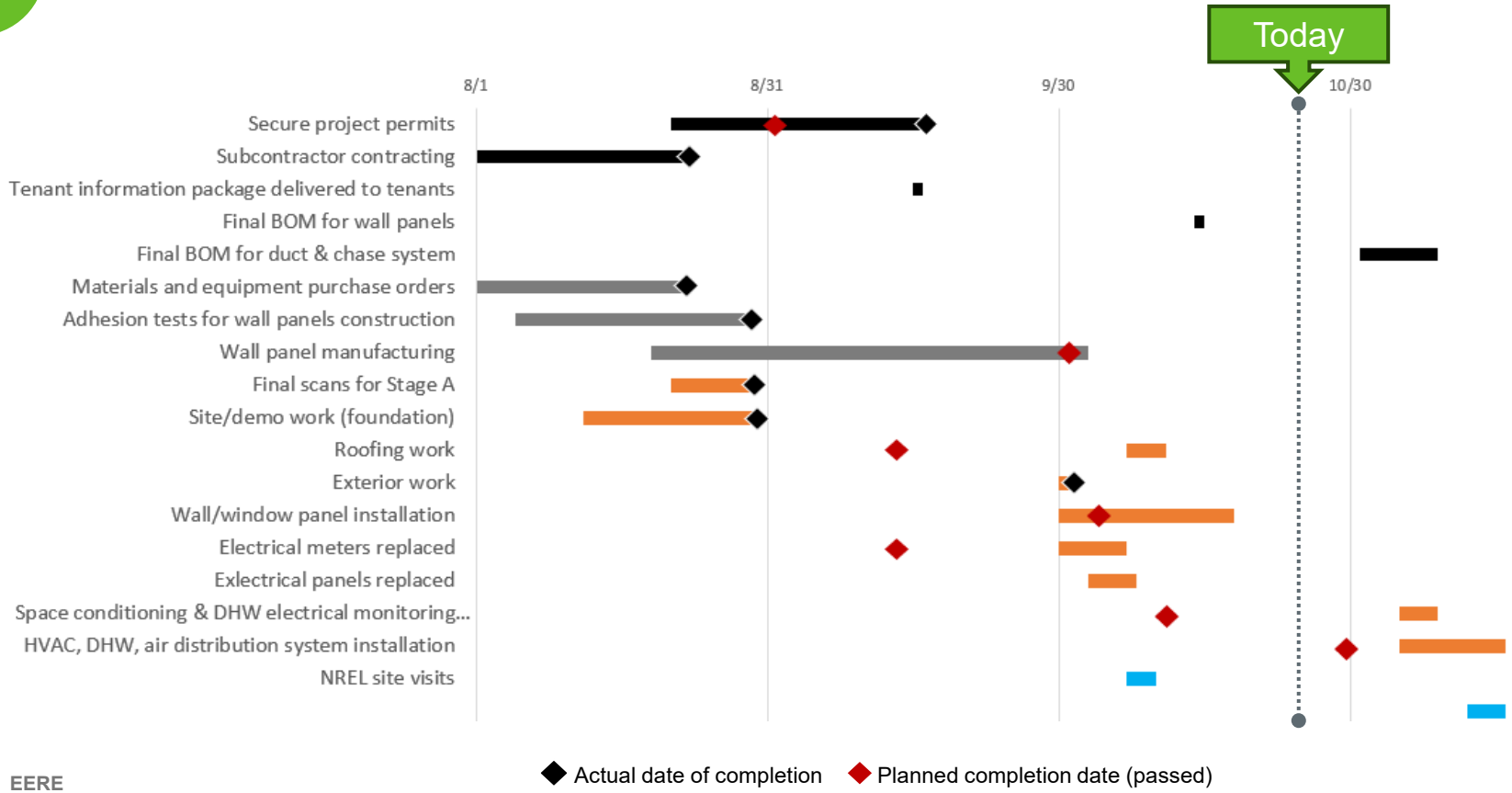
Facilitate retrofit-in-place.

Window cassettes prototyped in factory:

- Window units received with window frame and sash separated.
- Window frame molded into cassette, and cassette is hot-wire cut to fit rough opening.
- Cassette built out of wall-panel insulating material (GPS) and spray coated with polyuria for watertightness.
- Sash inserted into frame from inside dwelling unit.

Wall panel fabrication in factory during Stage A retrofit; window frame and door cutouts prepared for window frame attachment.

Pilot Demonstration Construction Schedule



Two 1-story 4-plexes

Two 2-story 4-plexes

CANARY MEDIA

In the press

"…the team's improved process for external insulation retrofits could be adopted by industry partners before the final results are in."

Foam panels can turn old abodes into energy-efficient homes of the future

A research team at the National Renewable Energy Laboratory is using machine learning and AR headsets to speed up energy retrofits for residences.

10 February 2023

A shipping container clad in insulating polystyrene panels at the U.S. National Renewable Energy Laboratory (Alison F. Takemura)