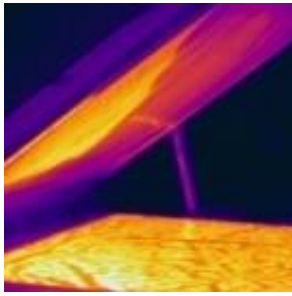
Mass Customization of Prefabricated Panel Blocks for Deep Wall Insulation Retrofits







DOE-ABC: Final Phase 1 Presentation

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December 15, 2021

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BOSTON UNIVERSITY

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Phase 1 Effort: Mass Customization of Prefabricated Panel Blocks for Deep Wall Insulation Retrofits

Fraunhofer USA

Fraunhofer USA Center for Manufacturing Innovation CMI

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Team: Expert in industrial automation, building science, and foam insulation

Fraunhofer USA CMI

- Develops and deploys energy systems and industrial automation systems
- Non-profit applied R&D organization at Boston University
- Process automation and optimization
- Established performer of applied R&D for government agencies

HC Fennell Consulting

- 45 years experience with foam insulations
- Developed on-site techniques and delivery systems for foamed-in-place injected polyurethane (PU) foams
- Applied PU foams in >3,000 buildings, from an Antarctic base to homes to Guggenheim

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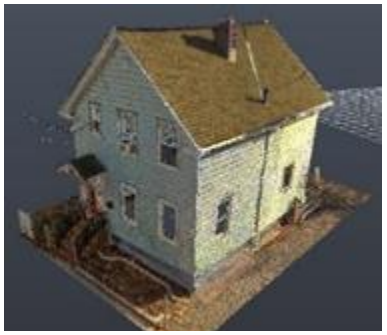
Our Solution: A complete, integrated *wall* retrofit process.

1.

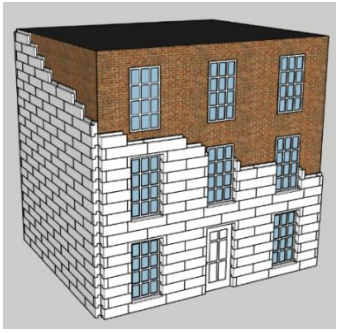
Use Standard (~4'x1') Lightweight Insulated Panel Blocks (PB)

2.



Photogrammetry Generates Façade CAD File

3.



Algorithm Determines Optimal Wall PB Set for Each Home

4.

Façade CAD File Feeds CNC PB Fabrication and Kitting Process

5.

Augmented Reality (AR) Assist for On-site Install

Image Sources: Fraunhofer UISA, HC Fennell, QYPC.

What is a panel block?

- 4” polyiso insulation
- Integral factory-applied cladding
  - Currently vinyl siding
  - Potentially: Stucco, thermally modified wood
- Tongue-and-groove feature to manage water and air leakage

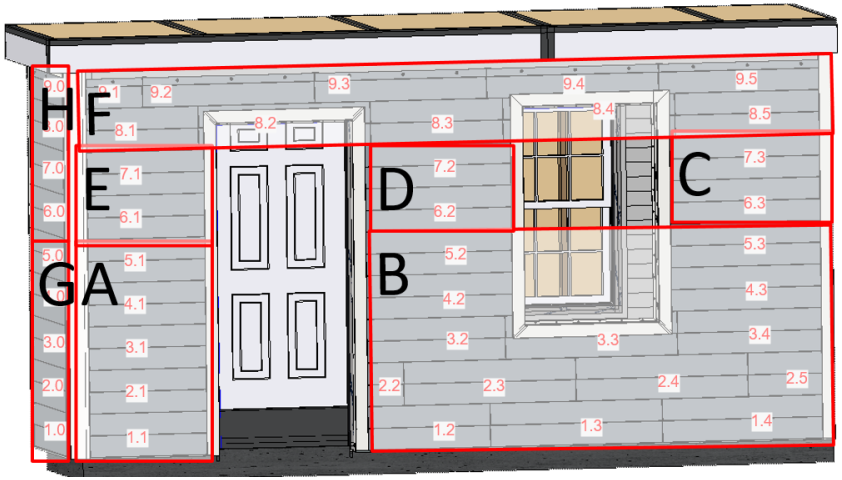
Attributes of Fraunhofer Wall Retrofit Approach

- Entire process re-engineered to deliver low-cost wall retrofits
- Greatly reduce on-site work and labor while achieving high quality
- Compatible with small contractors' existing business models – uses semi-skilled labor, no crane needed
- Viable in space-constrained applications: Cities, landscaping
- Works with Different Wall Constructions: Shingles, stucco, etc.
- Focused on single- and 1-4 family homes, can be extended to smaller multi-family, smaller commercial

Phase 1 Accomplishments

- Developed insulated panel-block (PB) design with integral vinyl siding cladding and tongue-and-groove features
- Developed trim components and finish processes to integrate PBs with windows, doors, corners, foundation, soffit, etc.
- Developed an Augmented Reality (AR) experience to empower workers installing the PBs
- Specified and produced >50 PBs based on dimensions extracted from mock-up wall point-cloud data (building scans)
- Demonstrated AR-assisted installation of the PB system on a ~10’ x 20’ mock-up wall
- Developed a conceptual automated production process and factory design.

Scanning: A 10-foot high by 20-foot wide wall.



Full system installation on mock-up wall (1 of 2)

Base System

WRB Installation

Full system installation on mock-up wall (2 of 2).

Tape Joints

Install Finish Trim

Augmented reality (A/R) – Installer point of View

Mock-up Wall Demonstration Video at ~40x speed.

Phase 1 Objectives

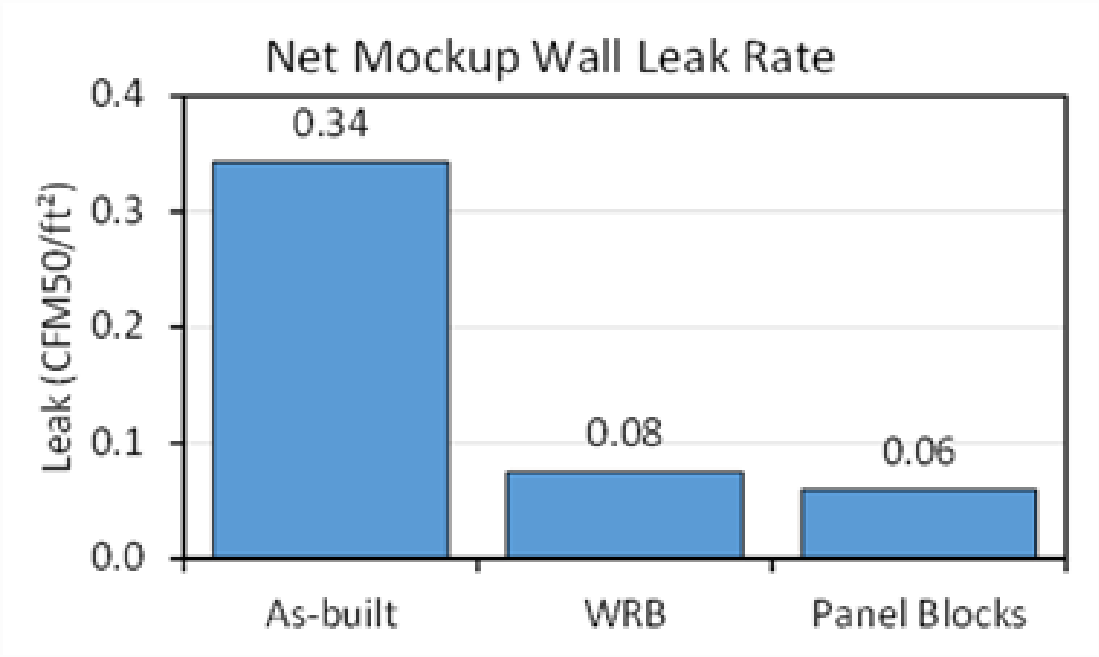
1. Post-retrofit R-30 to 40 and ≤0.28 cfm/ft^2 (@50Pa) wall
2. Installation on a single-family home in ≤5 days by two semi-skilled workers
3. Installed Cost of <$6.00/ft^2 of wall area (at volume production)

A PNNL-led team estimated the post-retrofit wall R-value based on U. Minnesota field testing and THERM simulations.

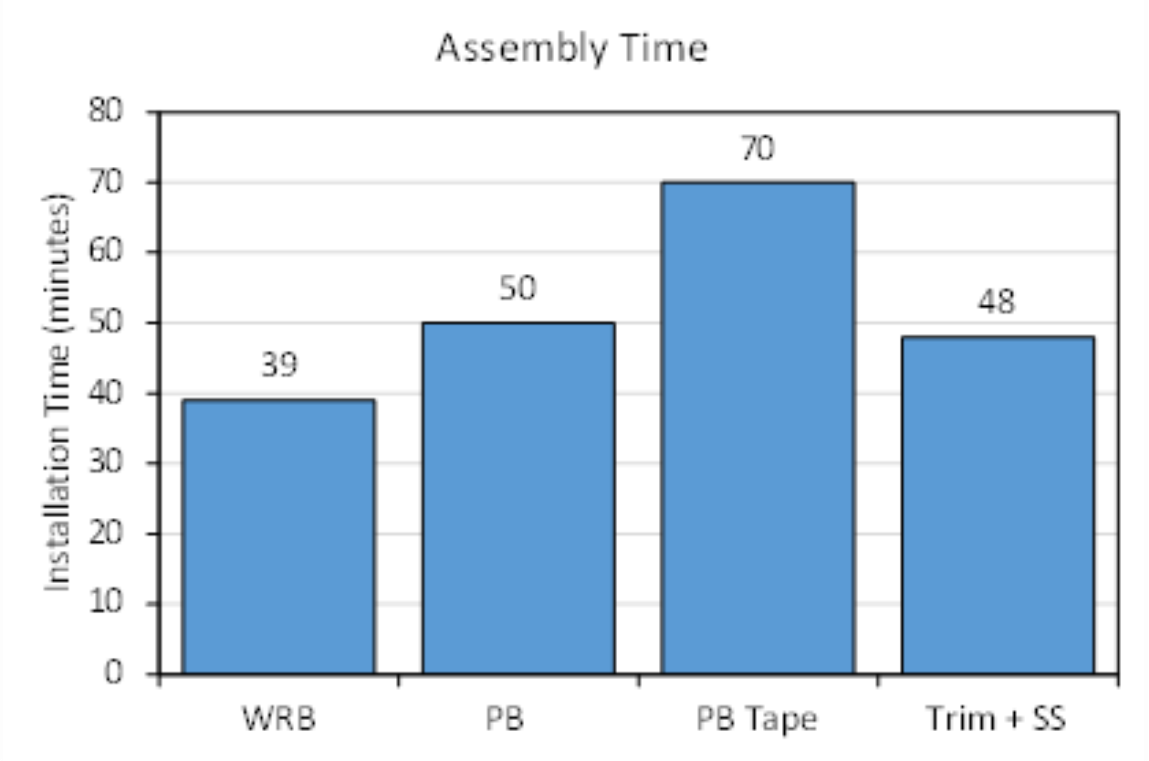
- No wall cavity insulation: R-27.6
- With filled cavity: R-34 to R-38

- WUFI simulations found low moisture risk in all climates studied

We conducted blower-door testing while installing the PBs on the mock-up wall, achieving values well below 0.25 CFM_{50}/ft^2.

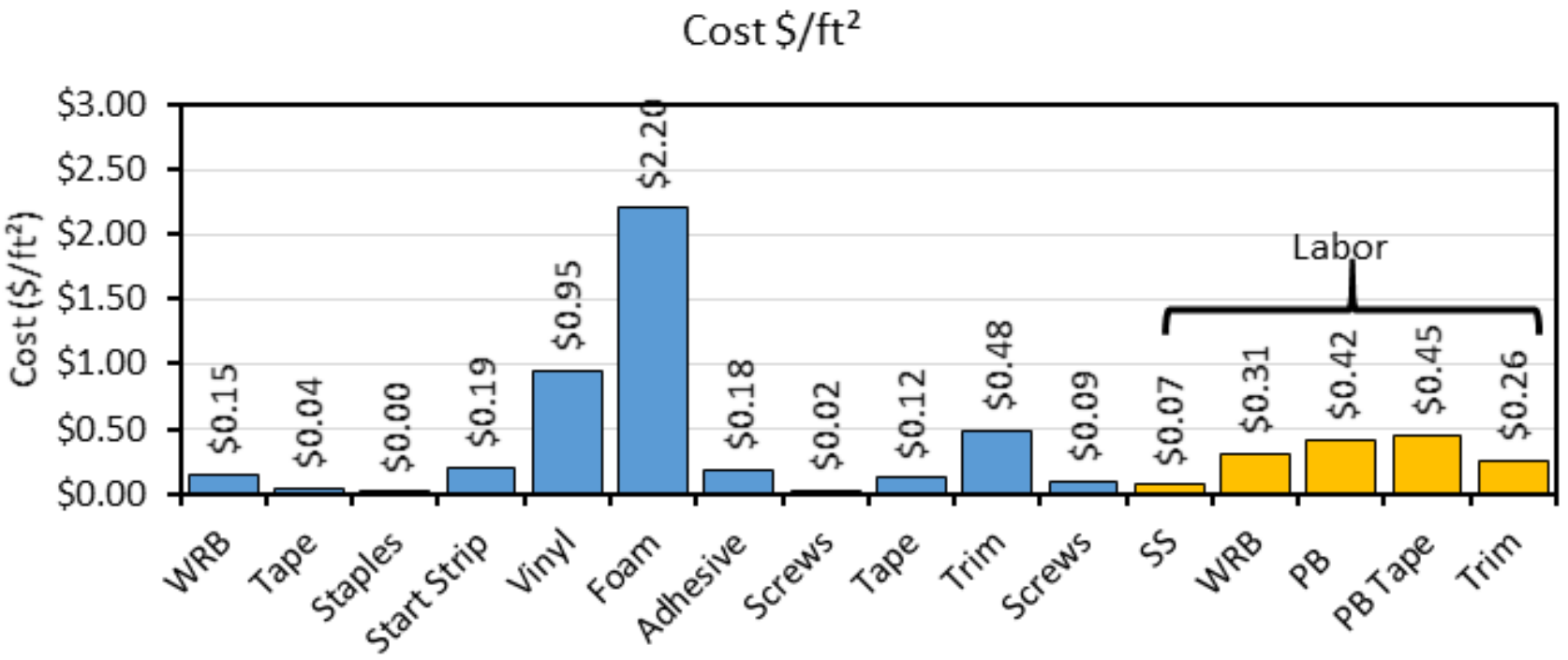


The mock-up wall installation time of ~3.5 hours for two semi-skilled workers (target: 4 hours). We see ways to reduce this appreciably.



This translates into ~31 hours for a full-size home.

Our cost model estimates that the PB would, at scale, cost ~$5.94/ft² (opaque wall area).



Foam, install labor, trim and vinyl siding ~ 85% of cost.

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