Pacific Northwest
NATIONAL LABORATORY

Retrofitting Buildings with Speed and Scale

April 20, 2023

Tyler Pilet, Ph.D.
Research Engineer

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

Why Buildings?

35% of carbon emission in the US are a result of the building sector[1].

42% of energy use in buildings is a result of **thermal losses through a building's envelope**[2].

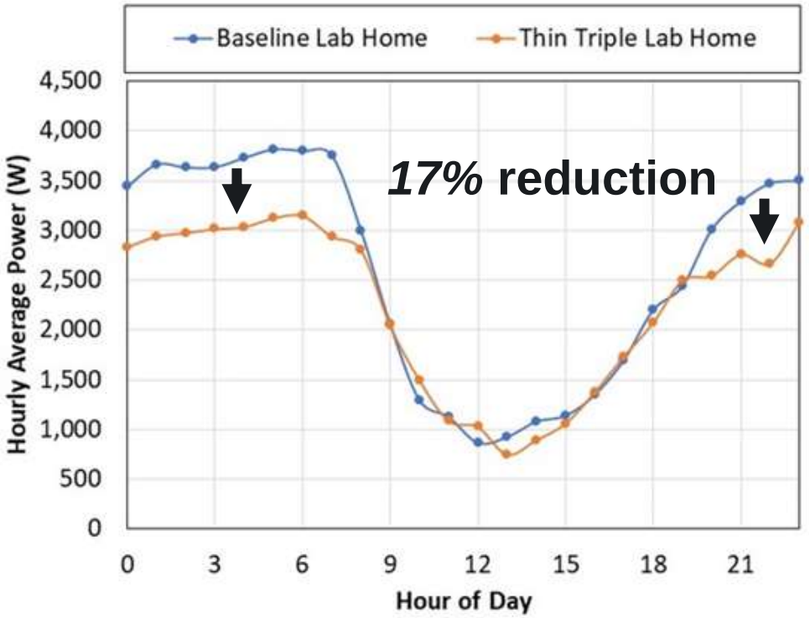
67% of the US building stock was **constructed prior to 1990**[3], and only **0.5-1%** of existing buildings are **renovated annually**[4].

[1] EIA. 2021. "What are U.S. energy-related carbon dioxide emissions by source and sector?" https://www.eia.gov/tools/faqs/faq.php?id=75&t=11
[2] DOE. 2012 "Energy Department Announces Six Projects to Develop Energy-Saving Windows, Roofs, and Heating and Cooling Equipment." https://www.energy.gov/articles/energy-department-announces-six-projects-develop-energy-saving-windows-roofs-and-heating
[2] EIA. 2012. "2012 Commercial Buildings Energy Consumption Survey (CBECS)." https://www.eia.gov/consumption/commercial
[3] NREL. 2021. "ResStock Data Viewer." https://resstock.nrel.gov/
[4] Architecture 2030. 2019. "Architecture 2030 - Existing Buildings." https://architecture2030.org/existing-buildings-operation/

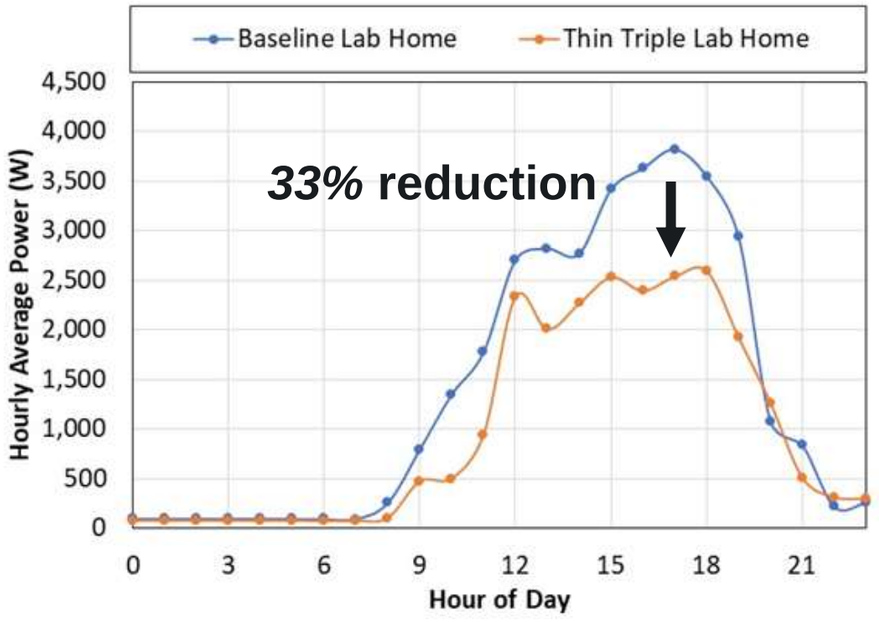
Why Buildings?

- Improving the building performance has many potential impacts for utilities:
  - Reducing peak demand
  - Lessening the “duck curve”
  - Resiliency during “unprecedented” weather events
  - Reducing usage of auxiliary heat sources in winter

HVAC Load During Heating Season

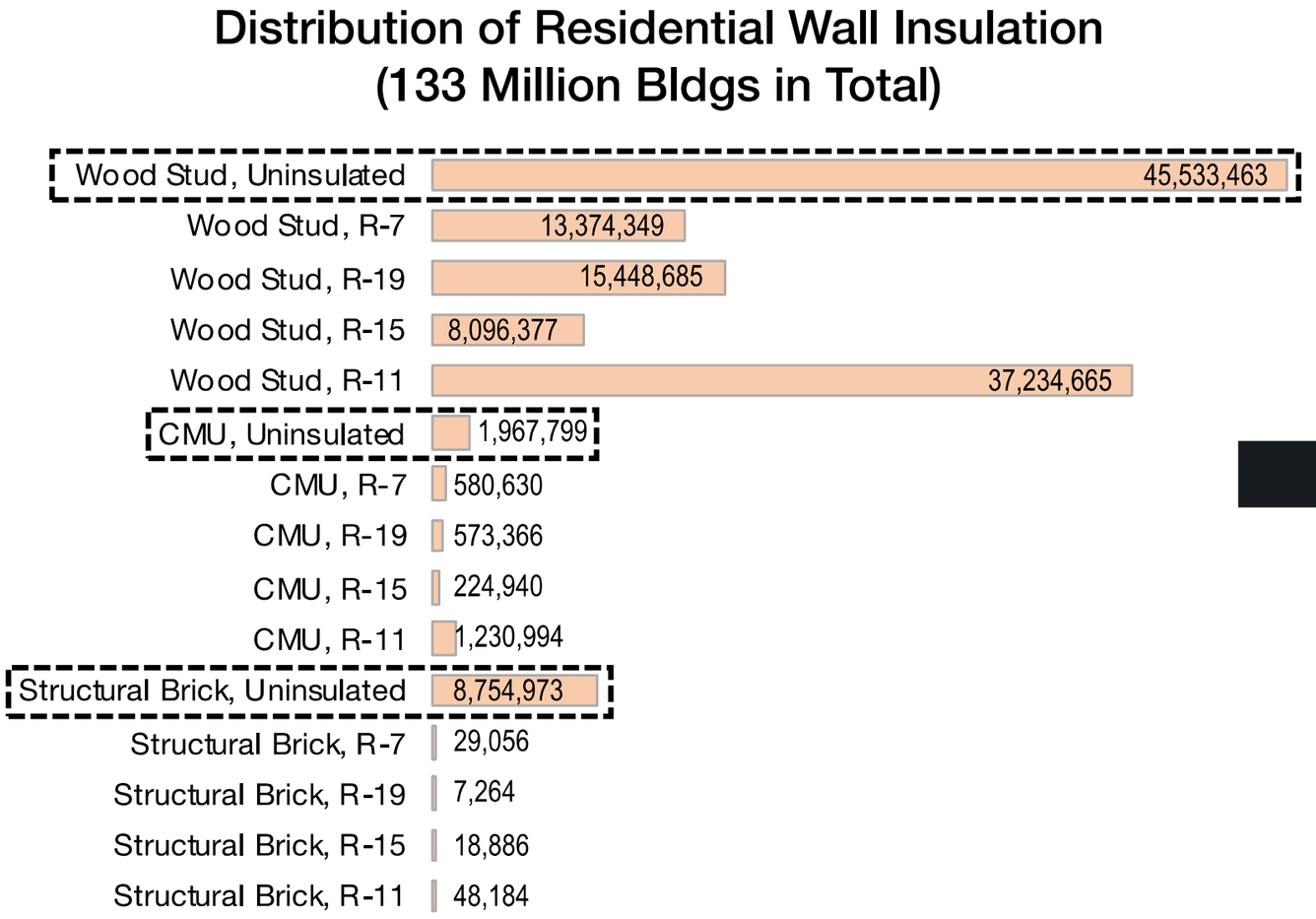


HVAC Load During Cooling Season



Source: W.E. Hunt et al. 2021. “Evaluation of Thin Triple Pane Windows in the PNNL Lab Homes” https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-31165.pdf

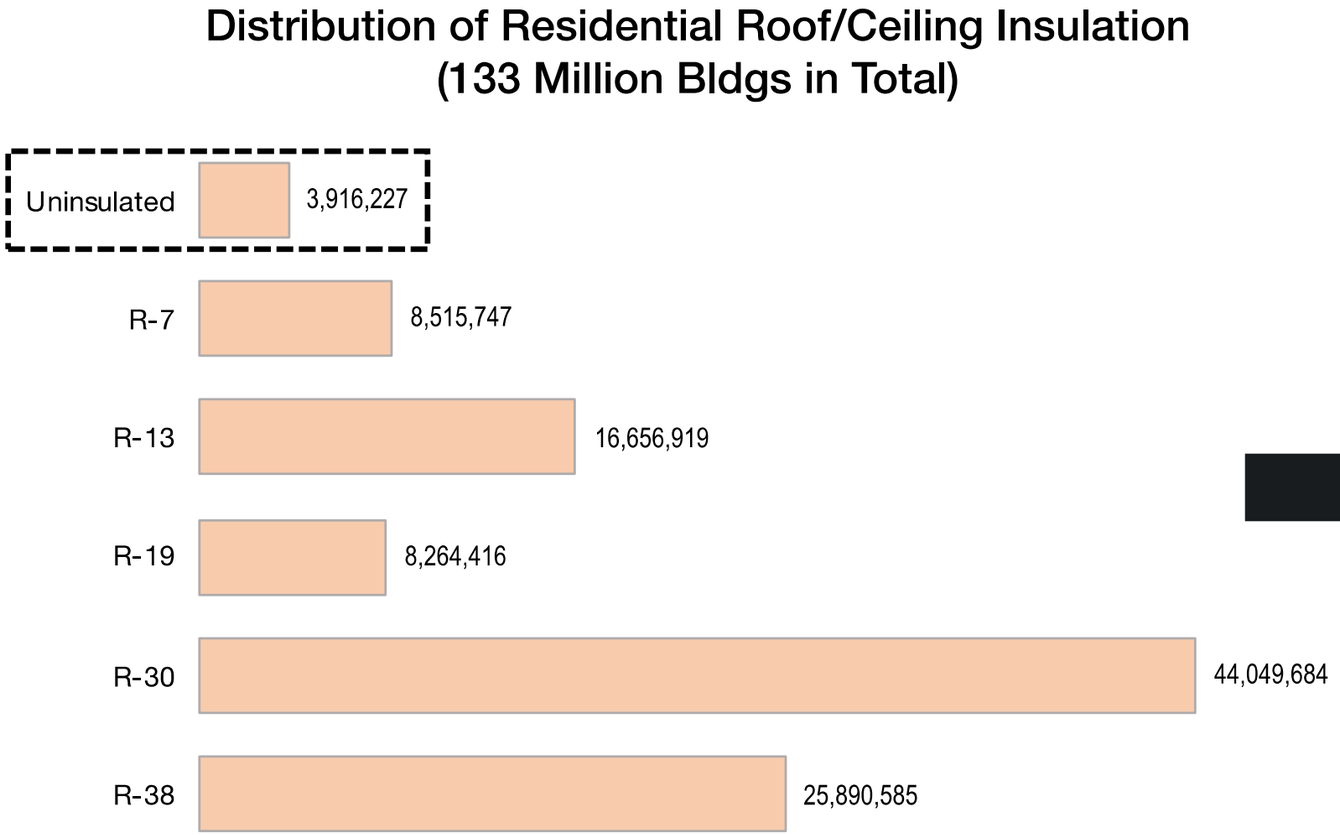
Taking a closer look at US Buildings…



42% of homes have **no wall insulation**

Source: https://resstock.nrel.gov/

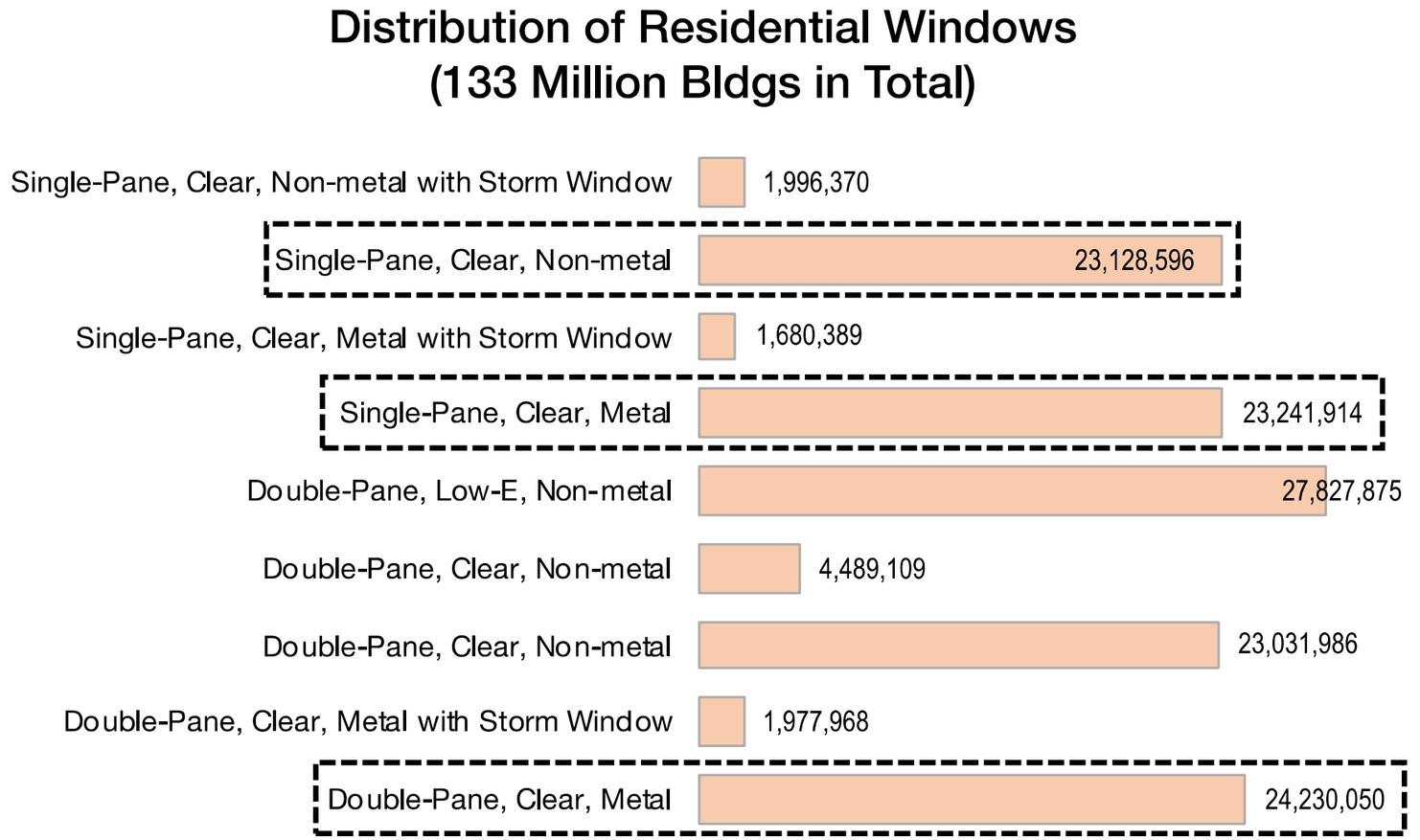
Taking a closer look at US Buildings…(Cont.)



Only 3.7% of homes have **no roof insulation**

Source: https://resstock.nrel.gov/

Taking a closer look at US Buildings…(Cont.)



53% of windows are **in need of an upgrade**

Source: https://resstock.nrel.gov/

Approaches to Retrofits

“Light-Touch” Energy Retrofits

Deep Energy Retrofits

“Industrialized” Energy Retrofits

Image Source: Building America Solution Center, Green Building Advisor, EnergieSprong

Light-Touch Retrofits

- Weatherization
  - **Non-Intrusive** interventions
  - **Light** Air Sealing
  - Installation of **Storm Windows**
  - Health and Safety Upgrades

  - **Pros**: Often Affordable; Non-Invasive
  - **Cons**: Can compound existing problems
- Insulating Upon Residing
  - **At the time of residing, add a layer of continuous insulation**.
  - Installation of **Storm Windows**

  - **Pros**: Leveraging existing work; Cost Reduction
  - **Cons**: Minor Learning Curve

Image Source: Building America Solution Center, Patrick Huelman (UMN)

Deep Energy Retrofits

- **New** Windows
- **New** Insulation
- **New**… Everything
- **Deep Air Sealing**
- Major Health and Safety Upgrades

- **Pros**: Reduced Utility Bills, Enhanced Comfort
- **Cons**: Extremely Disruptive, Often Require Large Capital Investment

Image Source: Green Building Advisor, Author

Industrialized Energy Retrofits

- **Integrated Systems, including:**
  - **Cladding**
  - **Insulation**
  - **WRBs/Vapor Barriers**
  - **Windows**

- For Less “Deep Retrofits”, there is a need for products which can **combine steps while leveraging existing knowledge**.

- **Pros**: Time Savings, Labor Savings, Possibly Cost Savings,
- **Cons**: Market Availability; Integration Details

Image Source: RMI REALIZE-MA

DOE's Advanced Building Construction Initiative

The **Advanced Building Construction (ABC) Initiative** accelerates the **speed and scale of U.S. building decarbonization** through industrialized* innovations that deliver low carbon, affordable, and appealing **new buildings and retrofits**.

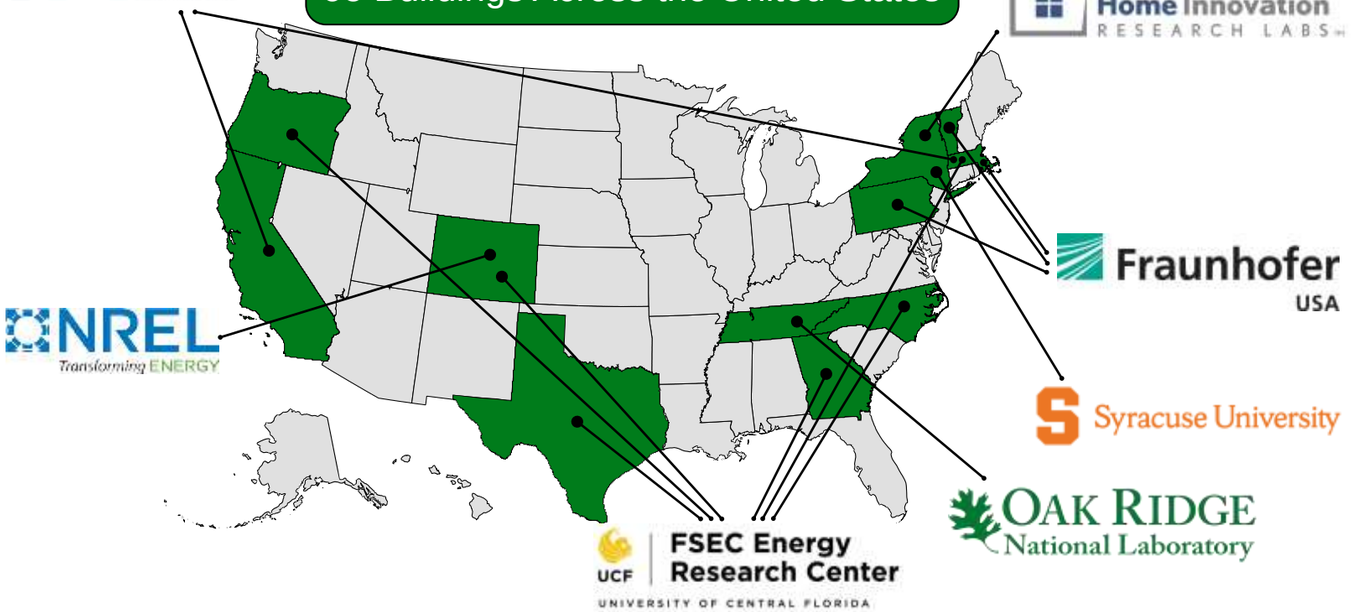
ABC Innovations are:

- High performance **— Reducing energy use** and the carbon footprint of buildings.
- **Affordable** to developers and consumers.
- **Improvements over traditional construction and less invasive**—easier to implement in building retrofits.
- **Providers of added value**, such as better indoor air quality, improved comfort, resilience, reduced maintenance.

*Industrialization refers to streamlining manufacturing, business models, and installation of technologies to become reproducible at scale.

DOE's Advanced Building Construction Initiative (Cont.)

Demonstrating Retrofit Solutions on **38** Buildings Across the United States



RMI · Home Innovation Research Labs · NREL Transforming Energy · Fraunhofer USA · Syracuse University · Oak Ridge National Laboratory · UCF FSEC Energy Research Center, University of Central Florida

Example ABC Retrofit Technologies:

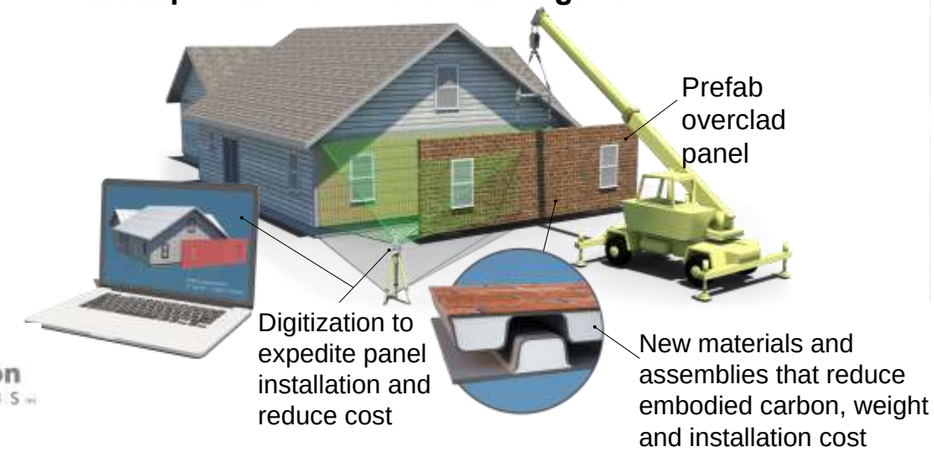


Image Courtesy of Oak Ridge National Laboratory

Combining scanning, computer aided manufacturing (CAM), and augmented reality (AR) to retrofit buildings at scale.

Images Courtesy of Fraunhofer-USA Center for Manufacturing Innovation

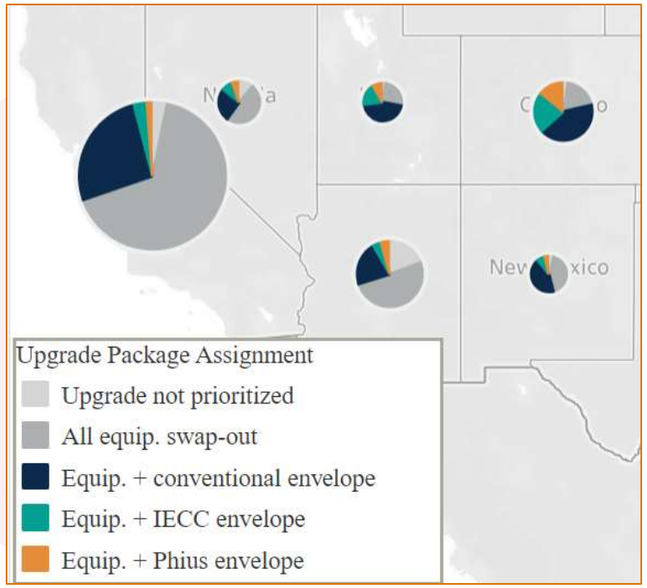
The Challenge Ahead…

- To reach the Biden Administration's 2050 climate goals, **most American buildings will require retrofits** with **varying levels of performance:**
  - Some buildings **need light intervention**,
  - Some buildings need to be brought up to **modern code**,
  - Some buildings need **deep retrofits**,
  - And some buildings may need **no envelope upgrade at all** (but still need to electrify)

How do we identify what upgrade should be prioritized, and for what buildings?

Tools for Prioritizing Building Retrofits

1) Utilizing the (Forthcoming) ABC Market Guidance Report



PARTNERS

Link: https://public.tableau.com/app/profile/nrel.buildingstock/viz/ABCMarketGuidanceforZero-carbonAlignedResidentialBuildings_16759824008870/Introduction

Tools for Prioritizing Building Retrofits (Cont.)

2) Utilizing the PNNL Retrofit Decision Tool

SCAN FOR RETROFIT DECISION TOOL

12 Easy Questions
1 Recommended Package

PARTNERS

Link: https://basc.pnnl.gov/retrofit_decision_tool

Conclusion

- The US Building stocks is aging, and **often does not meet performance levels required for decarbonization goals** so **tens of millions** of buildings will require **retrofits**.
- There are many **different options** for retrofitting existing buildings, but there are pros and cons to each approach.
- DOE's Advanced Building Construction Initiative works to **support RD&D and adoption of techniques** to improve the **speed, scale, and quality** of innovative retrofit technologies.
- Not every building needs the deepest level of retrofits, some buildings need more intervention than others.
- Both the **ABC Market Guidance Report** and the **PNNL Retrofit Decision Tool** can assist in prioritizing both the **retrofit packages** and the **building segments** to focus on when decarbonizing the US building stock.

Pacific Northwest
NATIONAL LABORATORY

Questions?

Tyler Pilet
tyler.pilet@pnnl.gov

Sample Questions from the Retrofit Decision Tool

4. What is the **square footage** of your building? *

- Less than 1500 sq ft
- 1500 to 2800 sq ft
- Greater than 2800 sq ft

5. What is the **primary fuel** for the existing **heating** system? *

- Natural Gas
- Electricity
- Fuel Oil
- Propane
- Other Fuel
- None

6. What is the existing **cooling method**? *

- Central AC
- Room AC
- Heat Pump
- None

7. Does your building have **ducts**? *

If you have Central AC, your building has ducts. See images below for examples (click to zoom in and see more info).

9. What **type of windows** does the building have? *

- Single-pane
- Double-pane
- Triple-pane

10. What **type of walls** does the building have? *

- Wood frame
- Brick
- Concrete
- Steel frame

11. Does your building have **wall insulation**? *

See images below for some examples (click to zoom in and see more info).

Fiberglass Insulation | Blown-in Insulation | Rigid Foam Insulation

- Yes
- No
- Not Sure