February 20,2018

Aerosol Envelope Sealing for Residential New Construction

Energy Design Conference & Expo

Ben Schoenbauer, Senior Research Engineer

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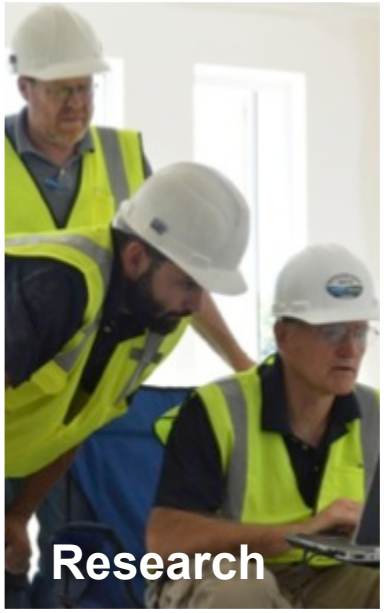
the most effective solutions for a healthy, low-carbon economy



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Presentation Overview

- Air Sealing Benefits
- Basic Concept
- Development Timeline
- Building America Project
- Other Efforts
- Path Forward

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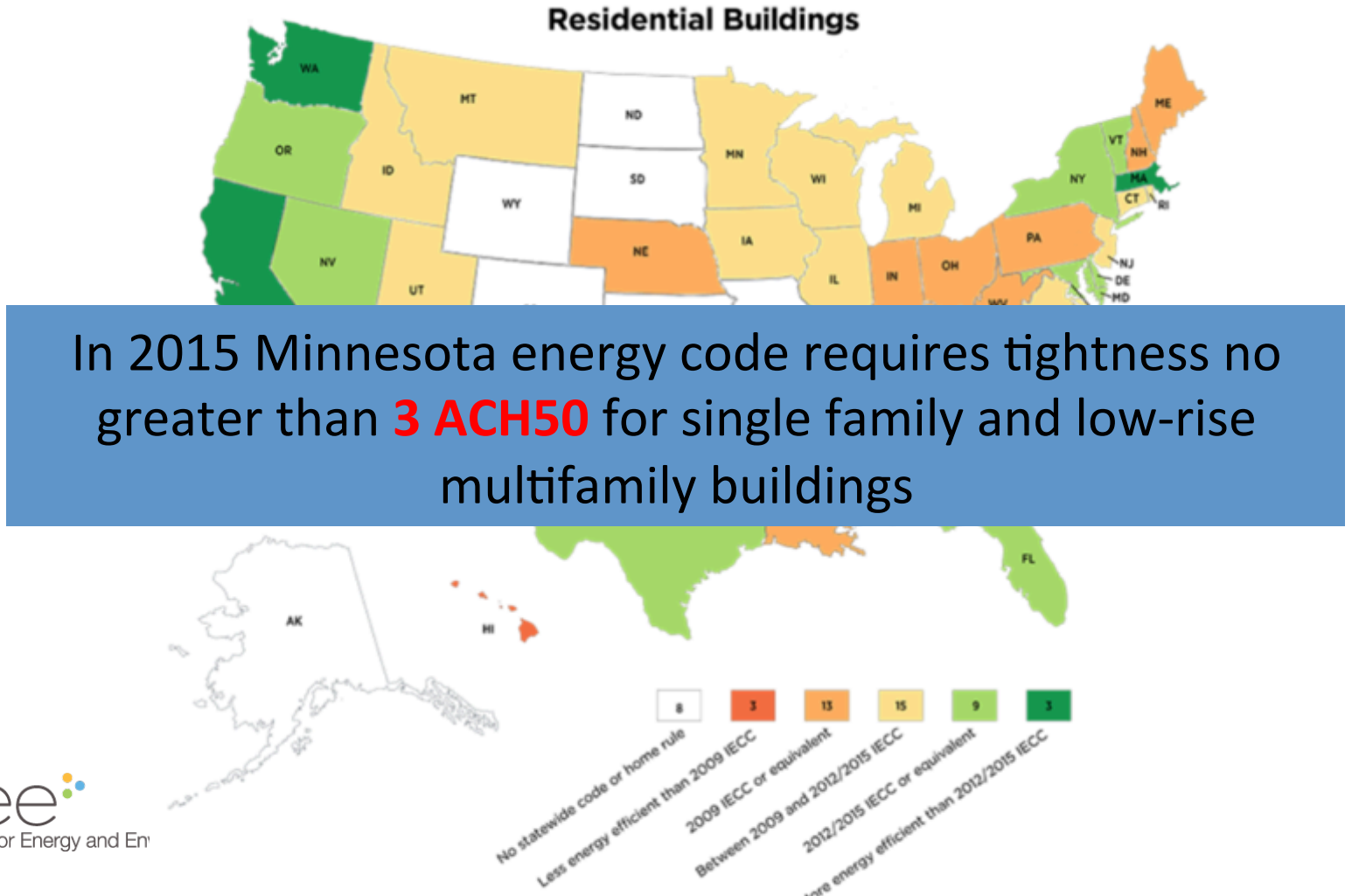
Energy Benefits

- Large fraction of energy use for heating and cooling
  - 48% in residential
  - 35% in commercial
- Reducing envelope leakage could reduce HVAC energy use by 30%
- Envelope tightness standards only recently required in codes
- Cost-effective approaches to sealing envelope leakage would improve adherence to code

IECC Codes Around U.S.

More stringent codes are forcing builders to change the way they build homes



In 2015 Minnesota energy code requires tightness no greater than **3 ACH50** for single family and low-rise multifamily buildings

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Source: DOE Energy Codes Program, updated December 15, 2017

Single Family Air Tightness

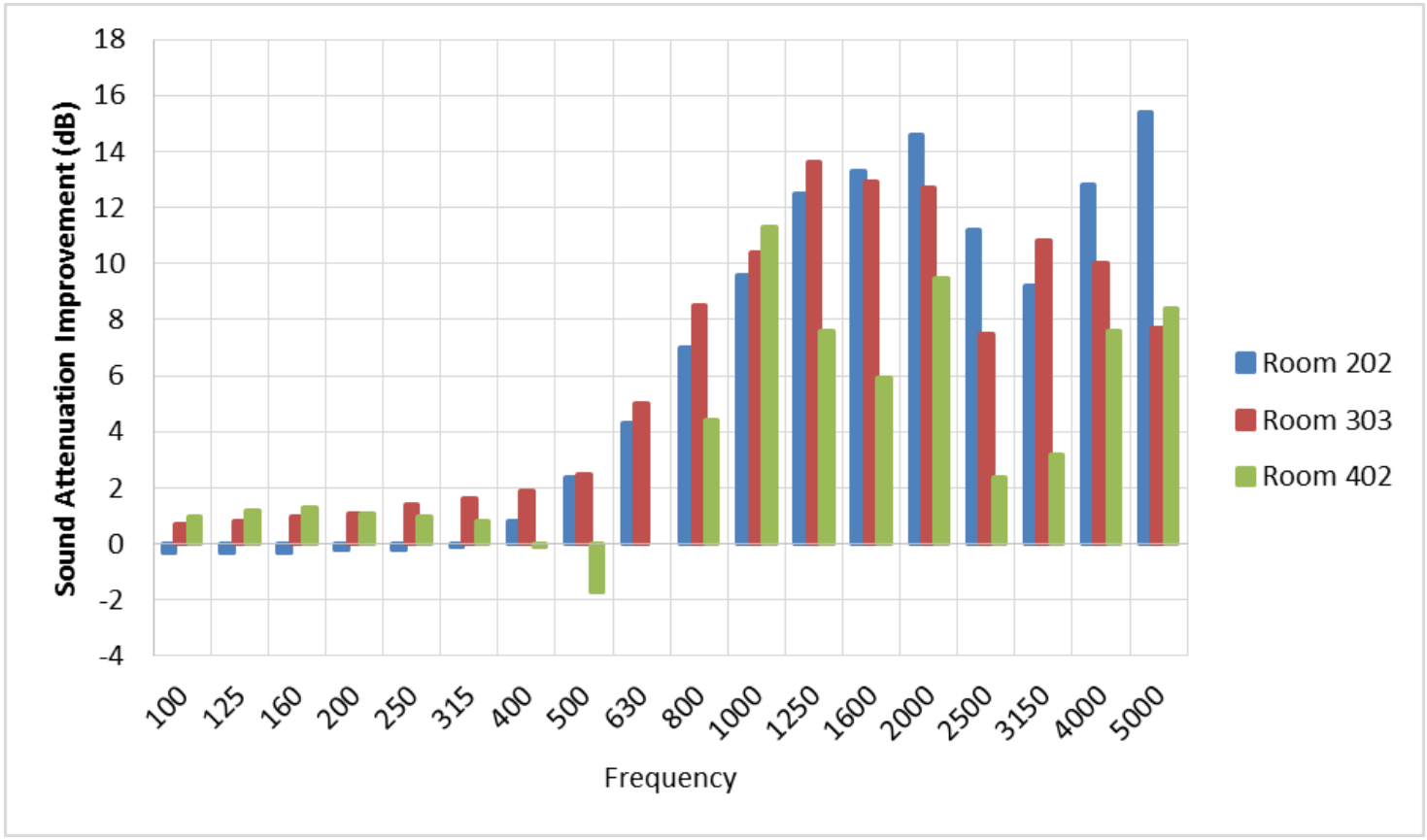
- Over the last 10 – 15 years Minnesota builders have adopted air sealing strategies to build tight single family houses.
  - Recently tightness requirements have expanded and tightened
  - For many builders townhouses and slab on grade houses have still been a challenge
  - air sealing strategies have typically not been applied to multifamily buildings

Health Benefits

- Reduced infiltration of outdoor air and outdoor pollutants: particulates ($PM_{2.5}$) and Ozone
- Improves effectiveness of mechanical ventilation
  - HRV or ERV and filters
  - Putting HRV/ERV on leaky building doesn't save energy or reduce uncontrolled infiltration
- Reduce pollutant transfer between units in multifamily buildings

Multifamily Noise Transfer

Minnesota code requirement



10 dB ~ difference between a garbage disposal and dishwasher

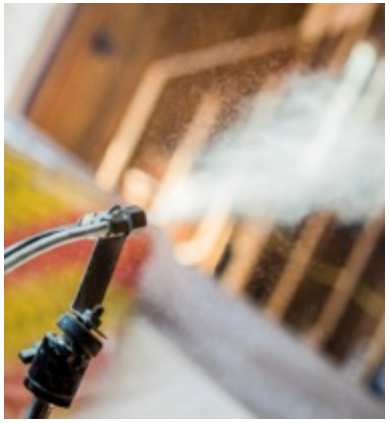
Benefits for Large Buildings

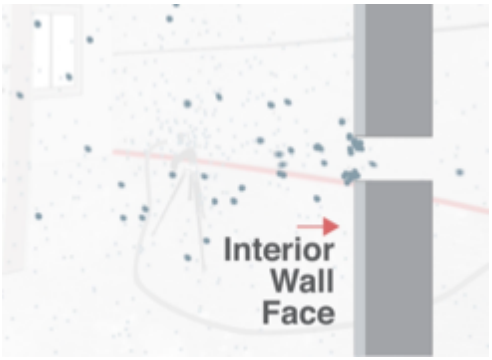
- A tighter envelope makes it possible to pressurize buildings using HVAC system – reduce infiltration

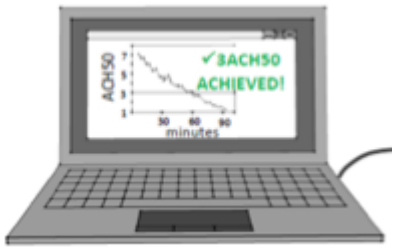
- Better and more efficient air flow control in sensitive spaces
  - Elimination of outdoor chemical infiltration
  - Contagious disease spaces
  - Clean rooms
  - Laboratories
  - **Schools in non-compliance areas (have current CEC project on HVAC and IAQ in schools)**

How Does It Work?

- Blower Door creates and maintains positive pressure
- Spray “fog” of sealant particles into the house
- Particles carried to leaks by escaping air flow
- Process is tracked and displayed in real time and documented electronically
- Finds and seals leaks missed or inaccessible by manual trial-and-error methods







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How does it do that?

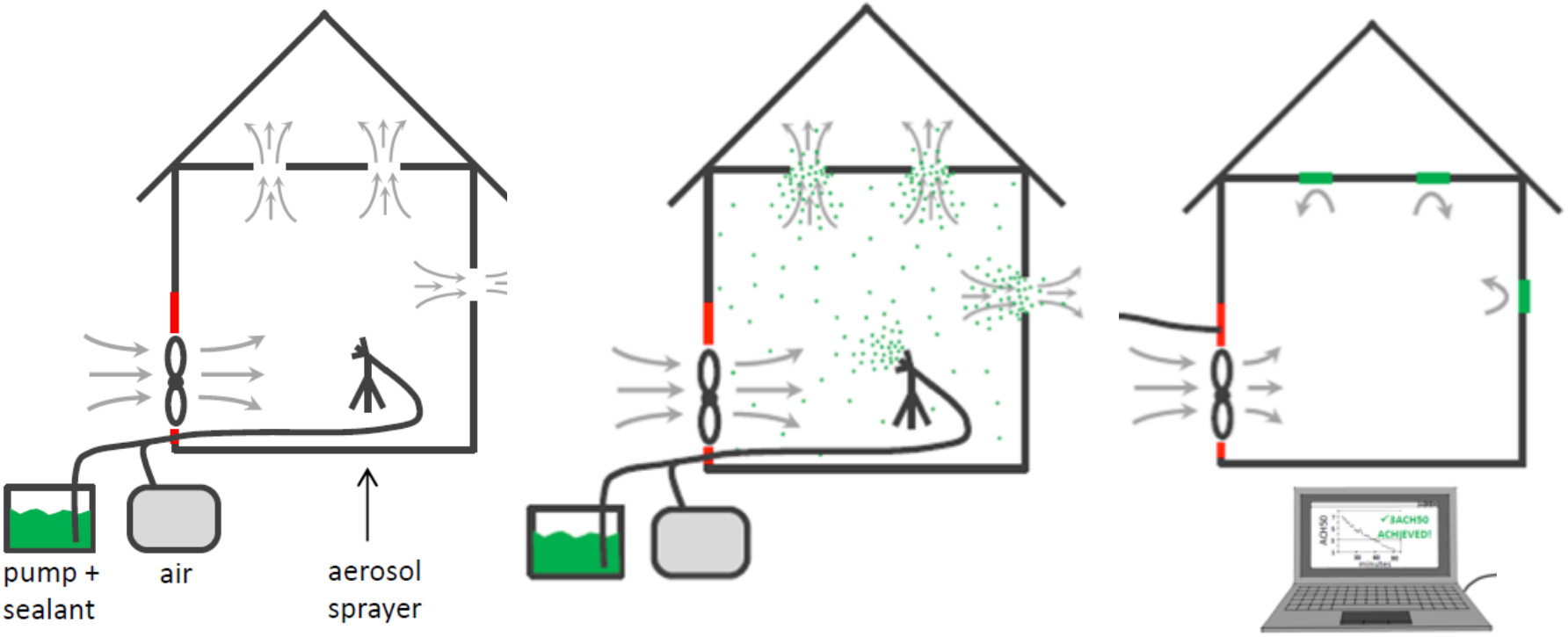
No, really?

(animation video here)

Sealant is a synthetic acrylic – typically rolled or sprayed on for monolithic exterior air barrier. Diluted for aerosol application.

Sealant is low VOC: GREEN Guard Gold Certified for use in California school and health care facilities.

Automated AeroBarrier Sealing



Bottom plate/sheathing gap

Missing foam

Penetrations

Development Timeline

Proof-of-concept in laboratory

2011

First single-family homes sealed

First single-family retrofit

2012

First multifamily sealed

2013

2014

New multipoint injection system developed

AEROSEAL

Technology licensed to Aeroseal

2015

First multifamily retrofits

First non-residential building retrofit

First commercial installation by Aeroseal

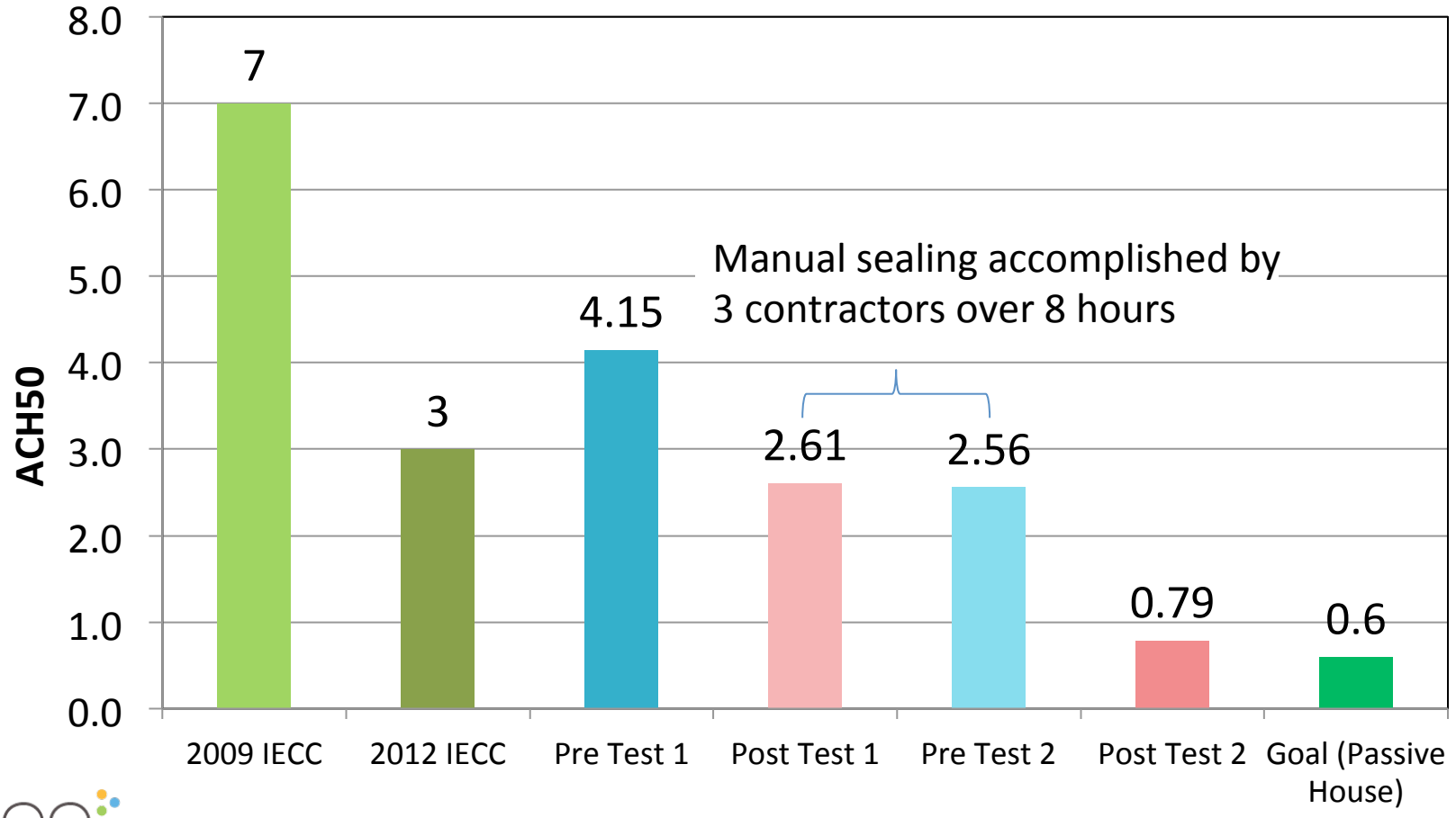
2016

Demonstrations with Habitat for Humanity

- First demonstration in real building
- Determined need for multiple injection point
- It worked!

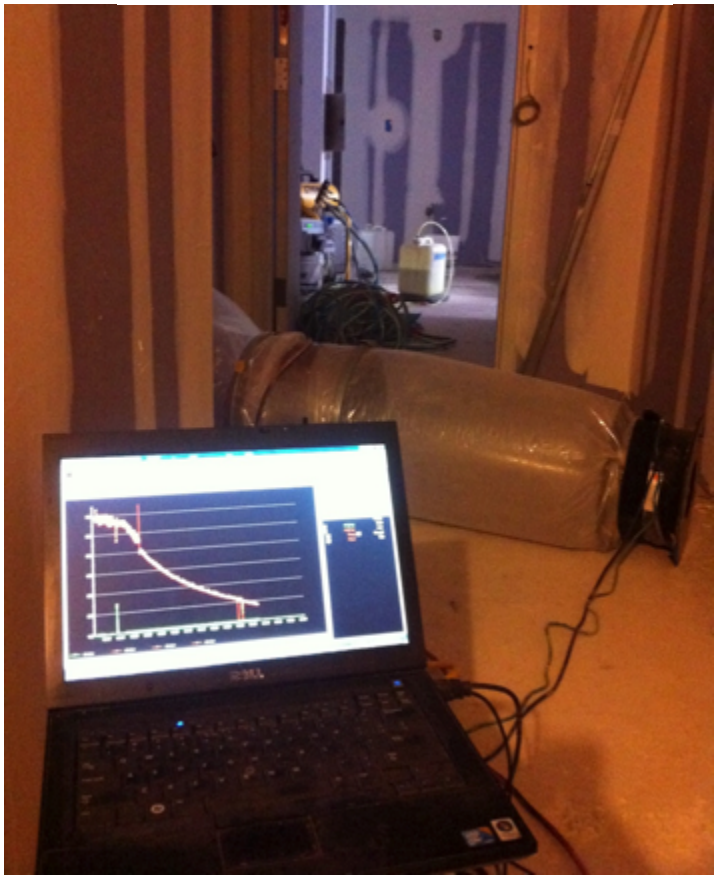
Honda Smart Home

- Implemented temp/humidity control

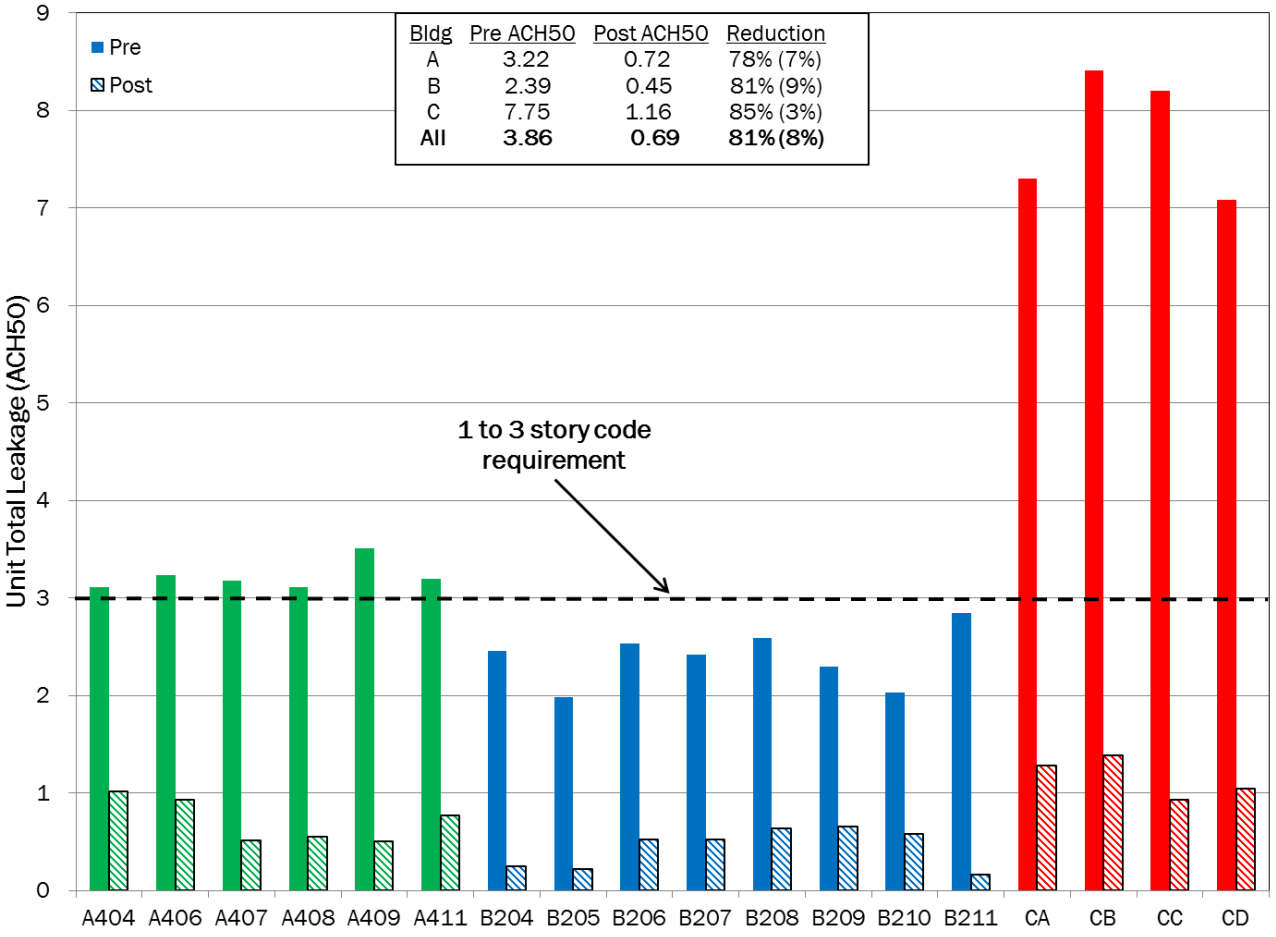


New York Apartments

- Sealed multiple apartments in a day
- Side-by-side application humidity analysis
  - Better seal quality with higher RH
- Measured sound transmission reduction
- Determined no prep required



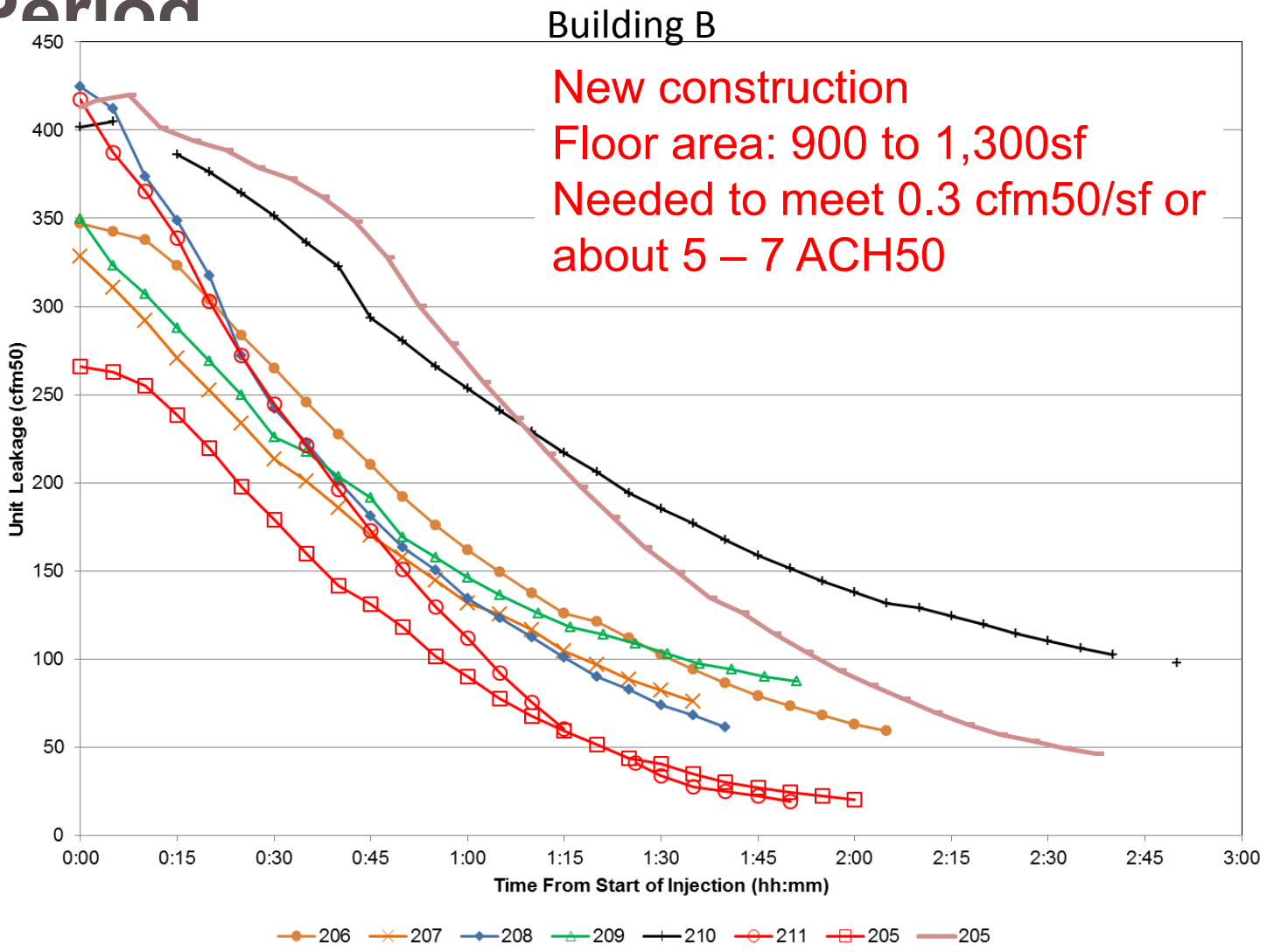
Minnesota Multifamily Sealing Results: 18 New Construction Units



Before = 3.9 ACH50, after = 0.7 ACH50
54% to 95% below code requirement

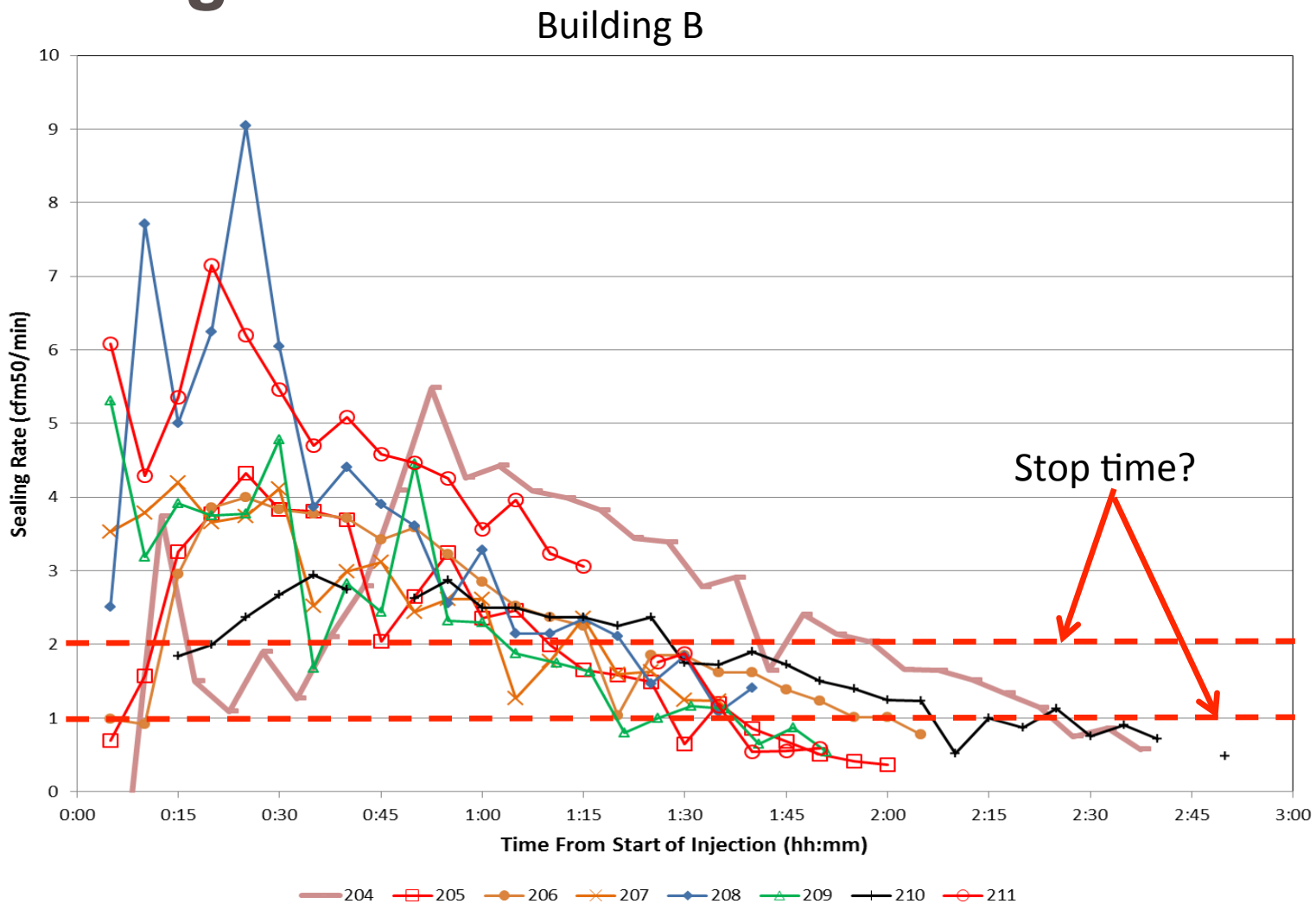
Minnesota Department of Commerce
Division of Energy Resources

Leakage Reduced Over Injection Period

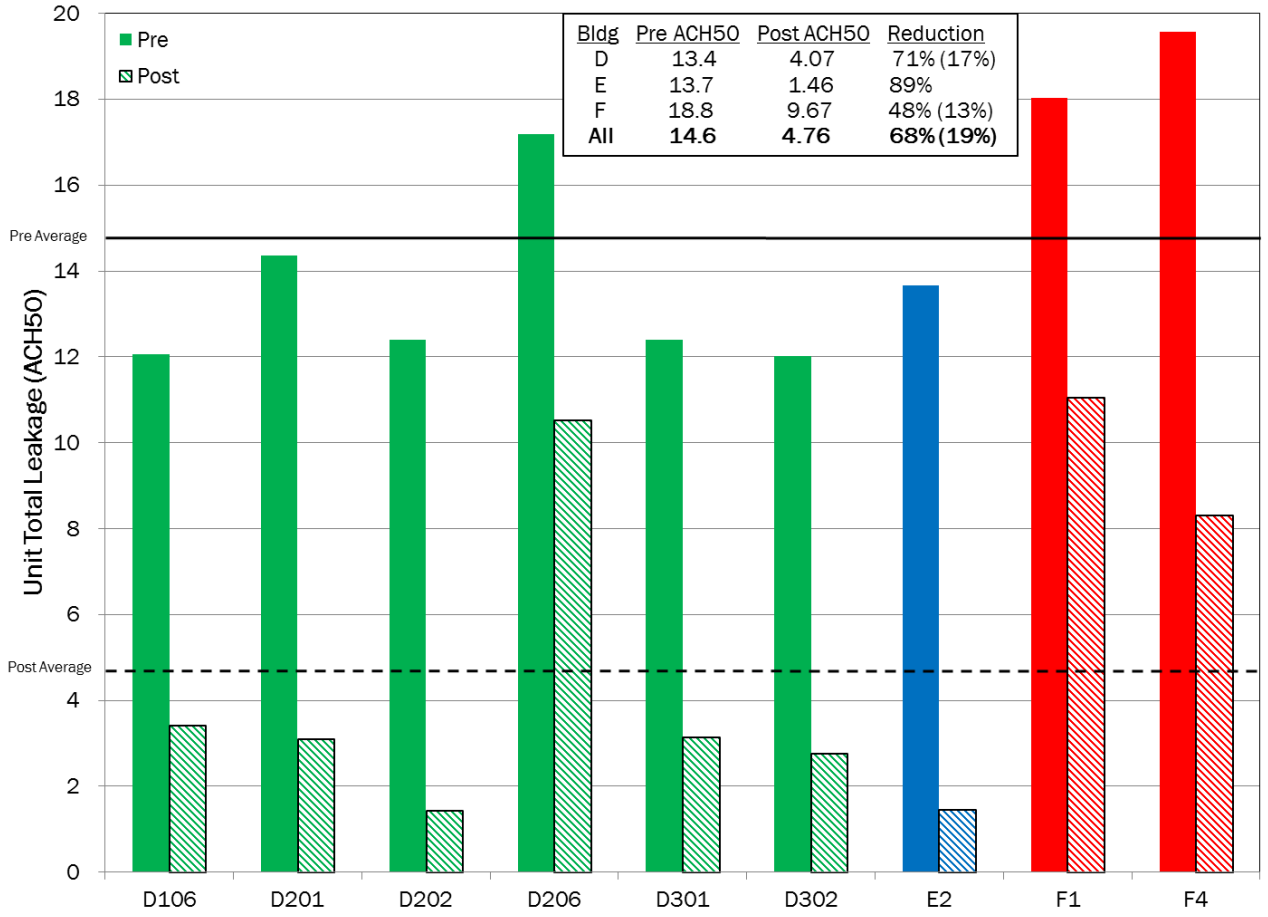


ACH50 pre: 2.0 – 2.9, post: 0.2 – 0.7; 71% to 94% reduction

Sealing Rate



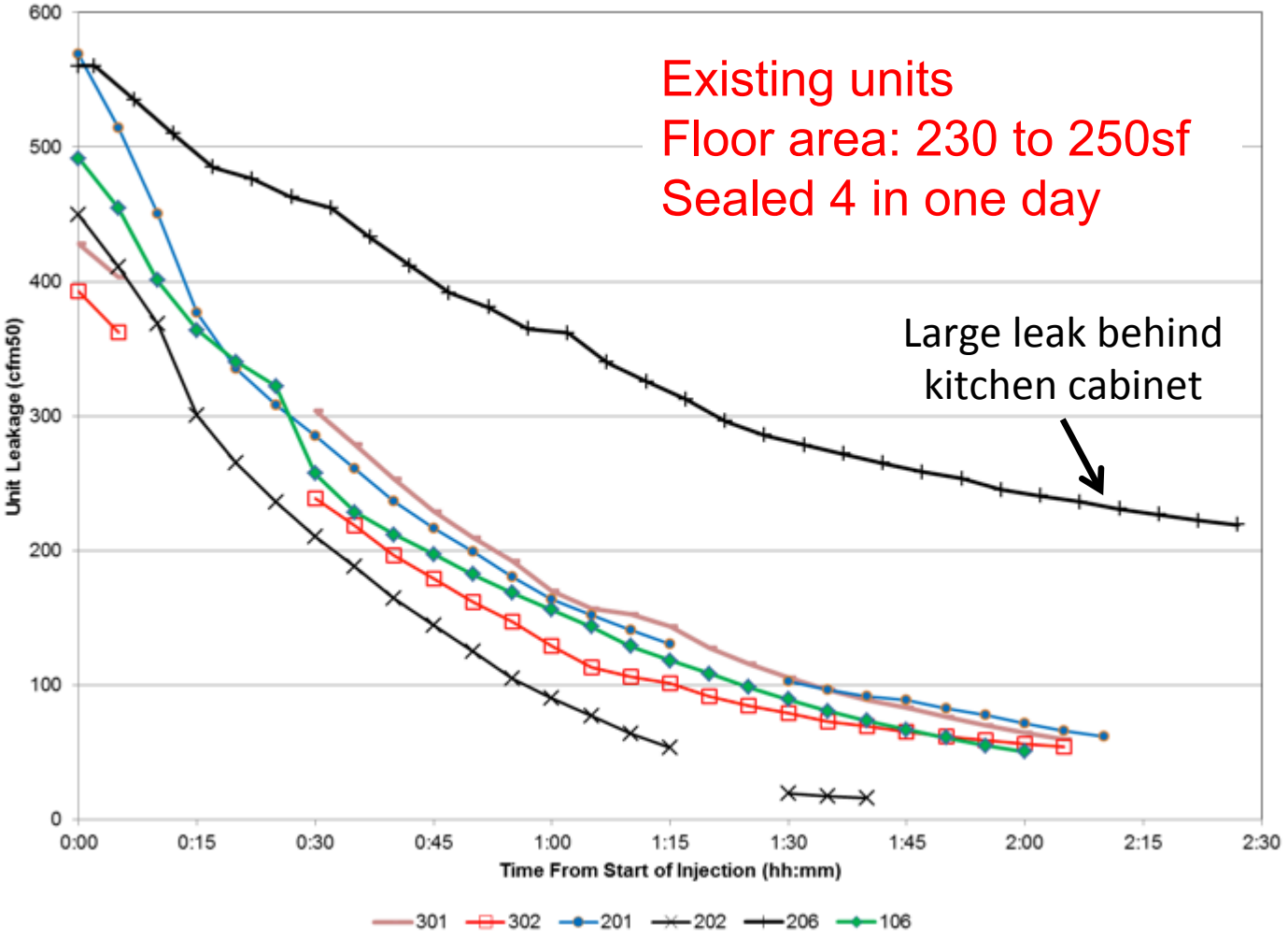
Minnesota Multifamily Sealing Results: 9 Existing Units



Average leakage: pre= 14.6 ACH50, post= 4.8 ACH50
6 of 9 within 15% of new construction code requirement

Leakage Reduced Over Injection Period

Building D – Affordable Housing

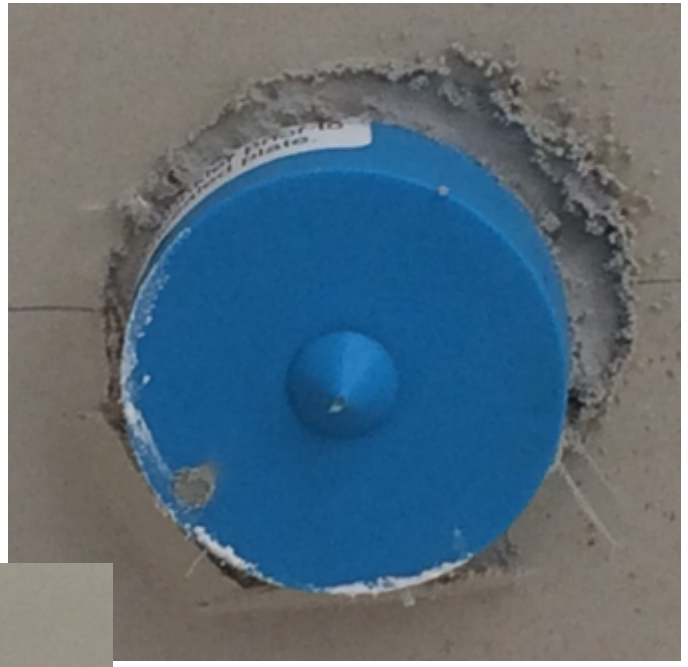


ACH50 pre: 12.0 – 17.2, post: 1.4 – 10.5; 39% to 88% reduction

Pre-Sheetrock Sealed leaks

Seal formed between gap in foam

Post-Sheetrock Sealed Leaks



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Seal formed between gap in foam

Aerosol Envelope Air Sealing Technology for New Homes

How to integrate AeroBarrier envelope sealing into home building process:

- Determine appropriate time during construction for application
- Measure performance relative to conventional methods
- Determine existing sealing efforts that could be avoided
- Determine cost-effectiveness

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Building AMERICA U.S. Department of Energy

Partners: Building Knowledge, UC Davis, U of M Cold Climate Housing, Aeroseal

Project Team

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WCEC
Western Cooling Efficiency Center

AEROSEAL
Duct Sealing From The Inside

BUILDING KNOWLEDGE

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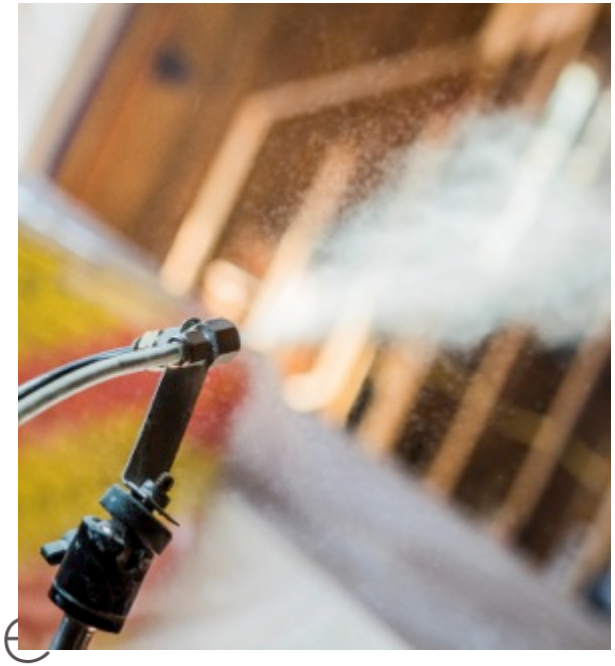

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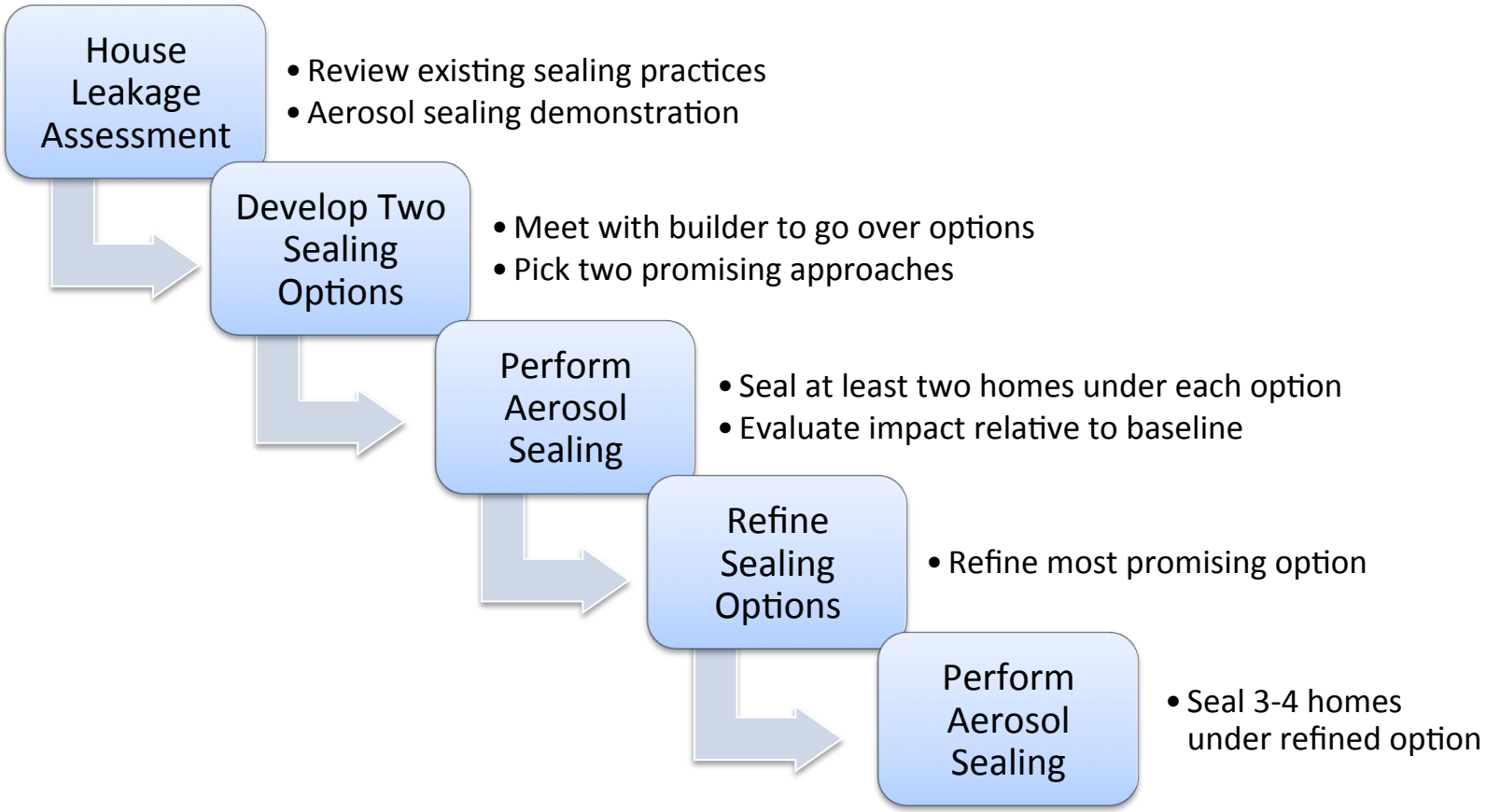
Building America Project Approach



Air Sealing Assessment

Category	Component	Who does sealing?	Material used for sealing?	Can AeroBarrier Replace?	Quality of seal work
Ceiling/Attic	Attic access panels		Gasketed Door	No	Excellent
	Drop down stairs	N/A			N/A
	Whole-house fans	N/A			N/A
	Recessed lighting fixtures	N/A	Gasketed fixture	Yes	Excellent
	Drop ceiling/soffit	Insulation Contractor	Closed Cell Spray Foam	Yes	Excellent
Walls	Exterior Walls	Insulation Contractor	Gasket/OSB	N/A	Excellent
	Sill Plate	Carpentry Contractor	Gasket/OSB	Yes	Acceptable
	Top Plate	Insulation Contracor	Gasket	Yes	Acceptable
	Drywall to top plate	Insulation Contracor	Gasket	Yes	Excellent
	Interior partition wall to exterior wall	Carpentry Contractor/Insulation Contractor	Solid Blocking/Can Foam	Yes	Excellent
	Knee walls	Carpentry Contractor	OSB		Excellent
Windows, skylights and doors	Rough openings	Window Installation Contractor	Can Foam	Yes	Excellent
Rim joists		Insulation Contractor	Open Cell Spray Foam	Yes	Excellent
Shafts, penetrations to unconditioned spaces	Ducts	Insulation Contractor	Can Foam/Open Cell Spray Foam	No	Excellent
	Flues	Insulation Contractor	Can Foam/Open Cell Spray Foam	No	Excellent
	Shafts	Insulation Contractor	Can Foam/Open Cell Spray Foam	No	Excellent
	Plumbing	Insulation Contractor	Can Foam/Open Cell Spray Foam	Yes	Excellent
	Piping	Insulation Contractor	Can Foam/Open Cell Spray Foam	Yes	Excellent
	Wiring	Insulation Contractor	Can Foam/Open Cell Spray Foam	Yes	Excellent
	Exhaust fans	Insulation Contractor	Can Foam/Open Cell Spray Foam	Yes	Excellent
	Other				N/A
Garage separation walls	Floor cavities aligned with garage separation walls	Carpentry Contractor/Insulation Contractor	Blocking/Open Cell Spray Foam	No	Excellent
Other	Shower/tub on exterior wall	Carpentry Contractor/Insulation Contractor	OSB/Open Cell Spray Foam	Yes	Excellent
	Stair stringer on exterior wall		None	Yes	N/A
	Fireplace on exterior wall	N/A	N/A	N/A	N/A
	Electrial/low voltage boxes on exterior walls		None	Yes	N/A
	HVAC register boots that penetrate building thermal envelope	N/A		Yes	N/A

Building America Interim Results

- California Builder #1
- Homes designed with sealed attics
- Using open-cell spray foam
  - Under roof deck
  - At rim joist and other mechanical penetrations
- Fiberglass in wall cavity
- HRV integrated into central air handler
- Target leakage of 800 CFM50 (2.1-2.4 ACH50)

Conventional Sealing

Can foam at seams where wood is joined

Can foam and gasket at sill plate

Foam gasket to seal drywall to top plate

Sealing Options

- Sealing options
  - Option 1: Seal home after open-cell spray foam insulation
  - Option 2: Seal home before spray foam insulation
- Advantage of sealing before drywall
  - Addresses outer wall surface
  - Seals less prone to damage in wall cavity
  - Better aerosol distribution

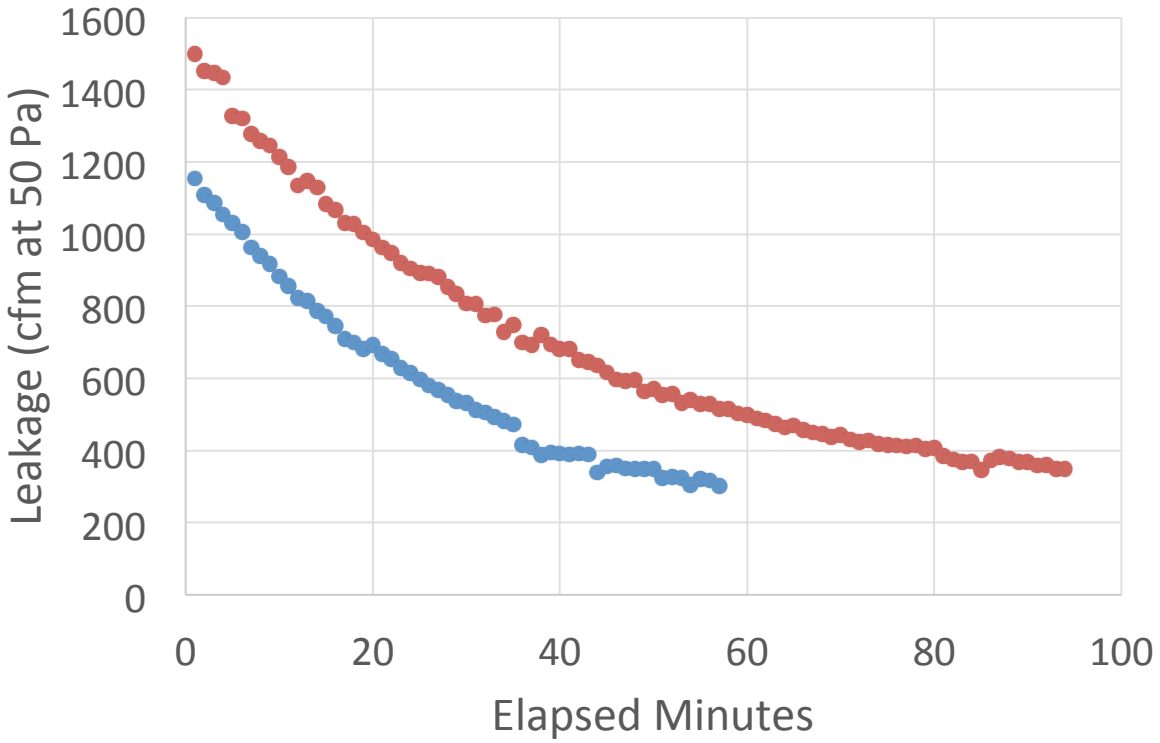
Option 1

Foam at roof deck

Foam at rim joist

Option 1 Results

Stage/Option	Lot	Plan	Floor Area (ft^2)	Volume (ft^3)	Pre-Seal		Post-Seal		
					CFM50	ACH50	CFM50	ACH50	% Reduction
After Foam	7	3	2569	23121	1690	4.39	429	1.11	75%
After Foam	8	1	2032	22215	1286	3.47	351	0.95	73%



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Option 1 Example Seals

Seals formed under trusses

Seal formed at corner of wall assembly

Option 2

Exposed roof deck

Rim joist penetrations

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Option 2 Pre sealing work

- Large penetrations needed to be sealed prior to aerosol sealing
- Time/materials for pre-sealing was tracked

Prepare for unexpected!

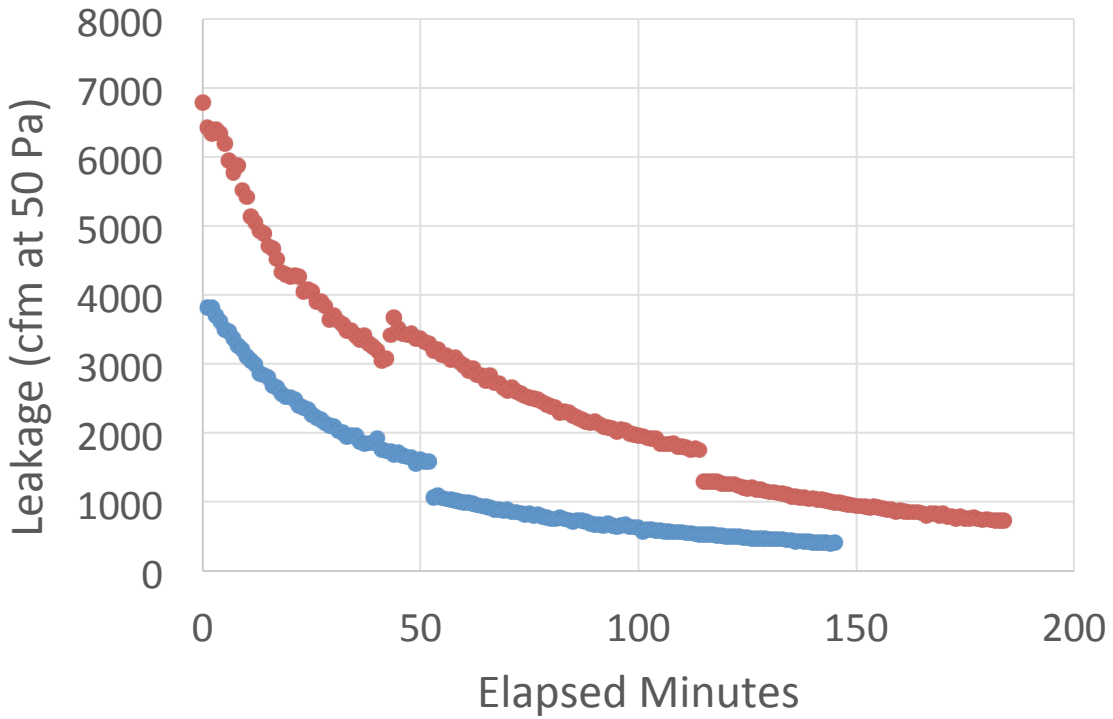
Pre-Sealing Time/Materials

		Sealing Penetrations		Sealing Gap at Eaves	
Stage/Option	Lot	Time for Manual Sealing (person-hours)	Cans of Foam Used	Time for Manual Sealing (person-hours)	Cans of Foam Used
Before Foam	23	1.5	3	1.5	4
Before Foam	24	4.5	6	1	4

*Note: Pre-sealing work performed by inexperienced staff

Option 2 Results

Stage/Option	Lot	Plan	Floor Area (ft^2)	Volume (ft^3)	Pre-Seal		Post-Seal			After Foam		
					CFM50	ACH50	CFM50	ACH50	% Reduction	CFM50	ACH50	% Reduction
Before Foam	23	3	2569	23121	5836	15.14	828	2.15	86%	483	1.25	42%
Before Foam	24	2	2223	20007	3005	9.01	477	1.43	84%	352	1.06	26%



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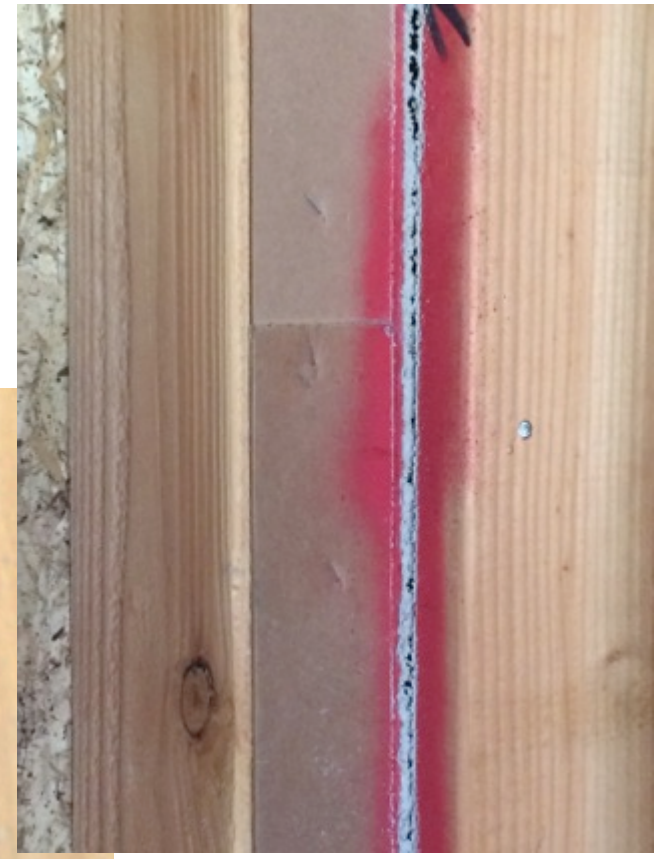
Option 2 Example Seals

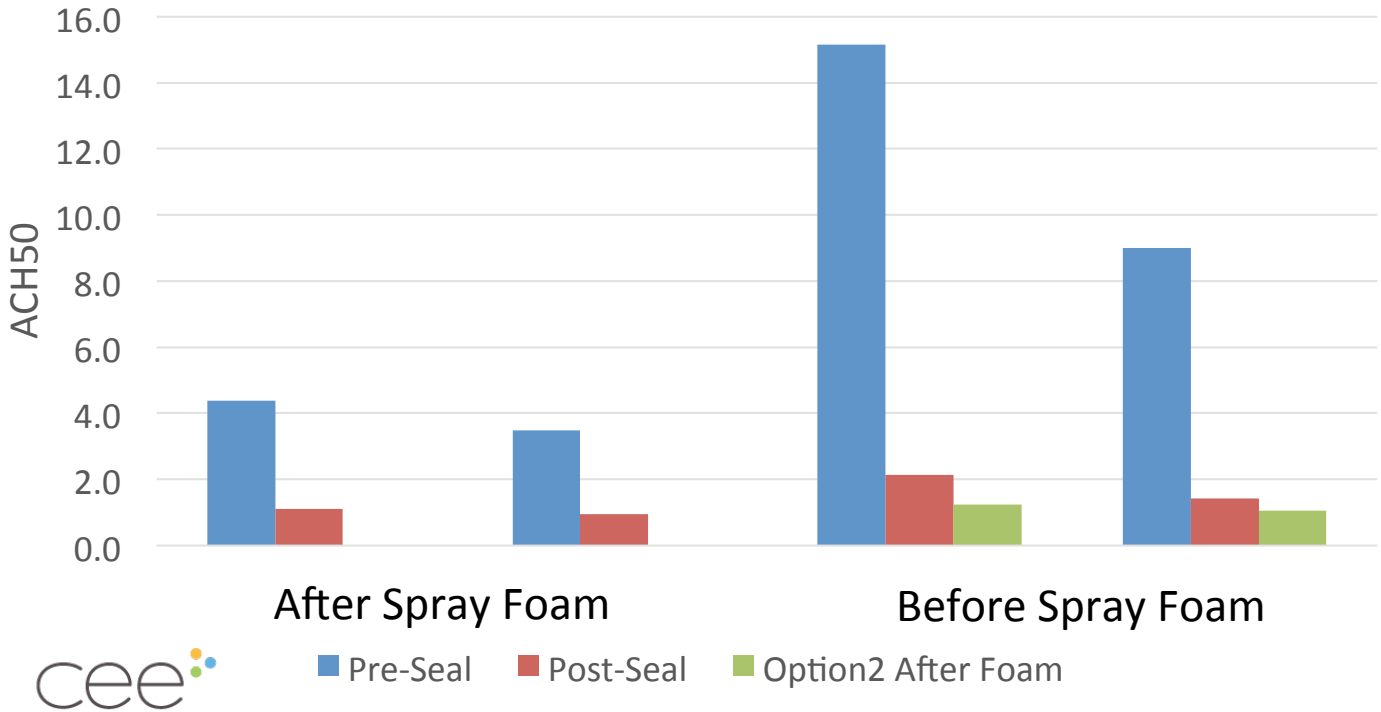


Summary Results

79%
Average leakage reduction

73%
Tighter than baseline homes

56%
Greater building tightness using Aerosols versus open-cell spray foam



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Tightness goals achieved w/o spray foam

California Builders - Path Forward

- Final leakage tests when homes are complete
- Work with Builder #2 high performance (sealed) attics
  - Owens Corning box netting attic insulation
  - AeroBarrier produce tighter houses than current sealing?
- Work with Builder #1 vented attic houses
  - Before drywall in place
- Develop guidelines for future installations

Minnesota Builders

- Minnesota Builder #1
- Homes designed with ventilated attics
- Closed-cell spray foam at rim joist
- Interior poly wrap
- Fiberglass/mineral wool in wall cavity
- ERV integrated into central air handler

Conventional Sealing

Caulk at seams where wood is joined

Can foam at wire penetrations

Caulk at sill plate

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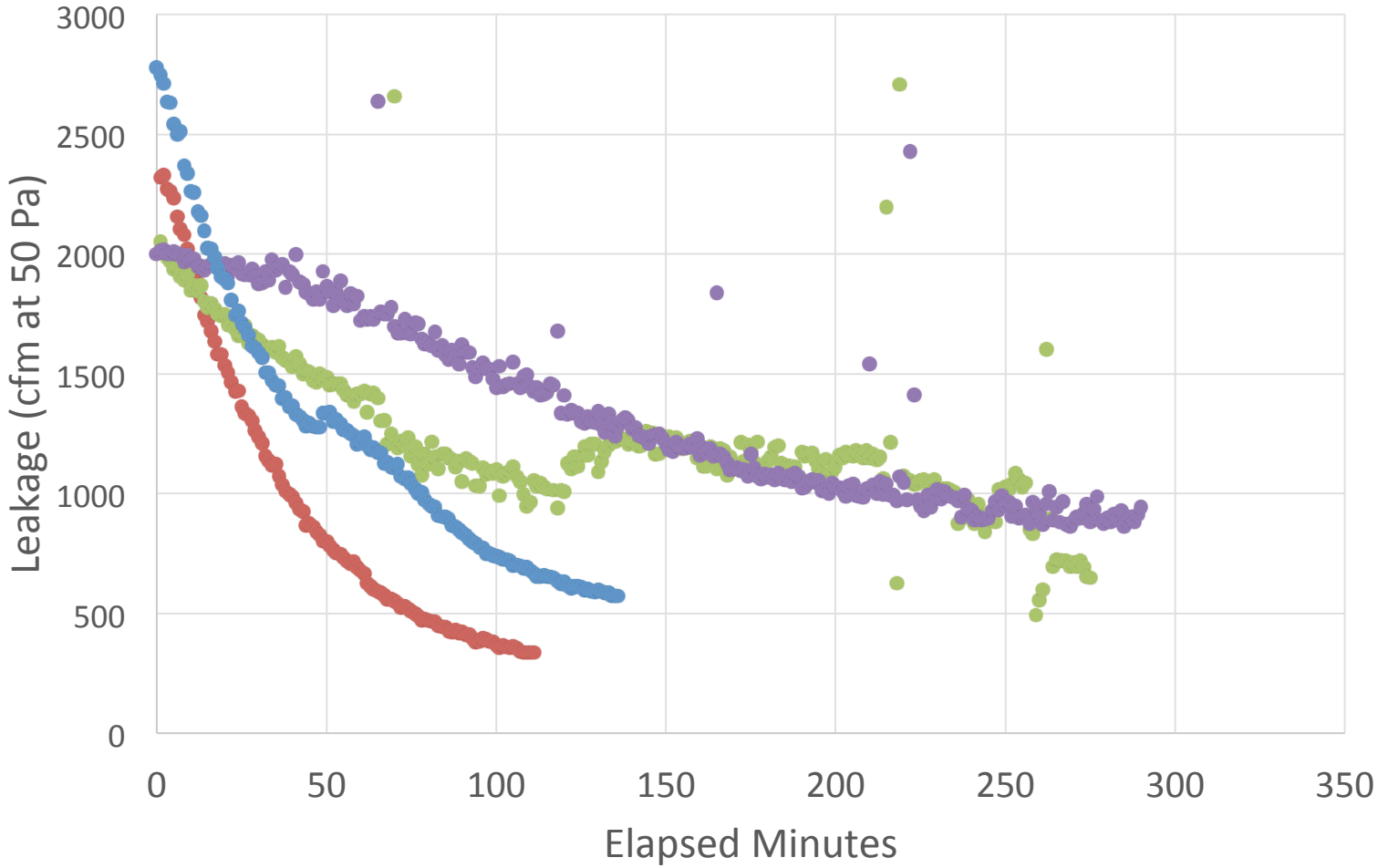
Proposed Sealing Options

- Option 1:
  - Seal home after spray foam at rim joist
  - Reinforced poly at ceiling-attic interface
  - Maintain conventional sealing
- Option 2 (Ultimately not implemented):
  - Seal home after spray foam at rim joist
  - Reinforced poly at ceiling-attic interface
  - Do not install:
    - Airtight electrical boxes
    - Interior poly

Sealing Results



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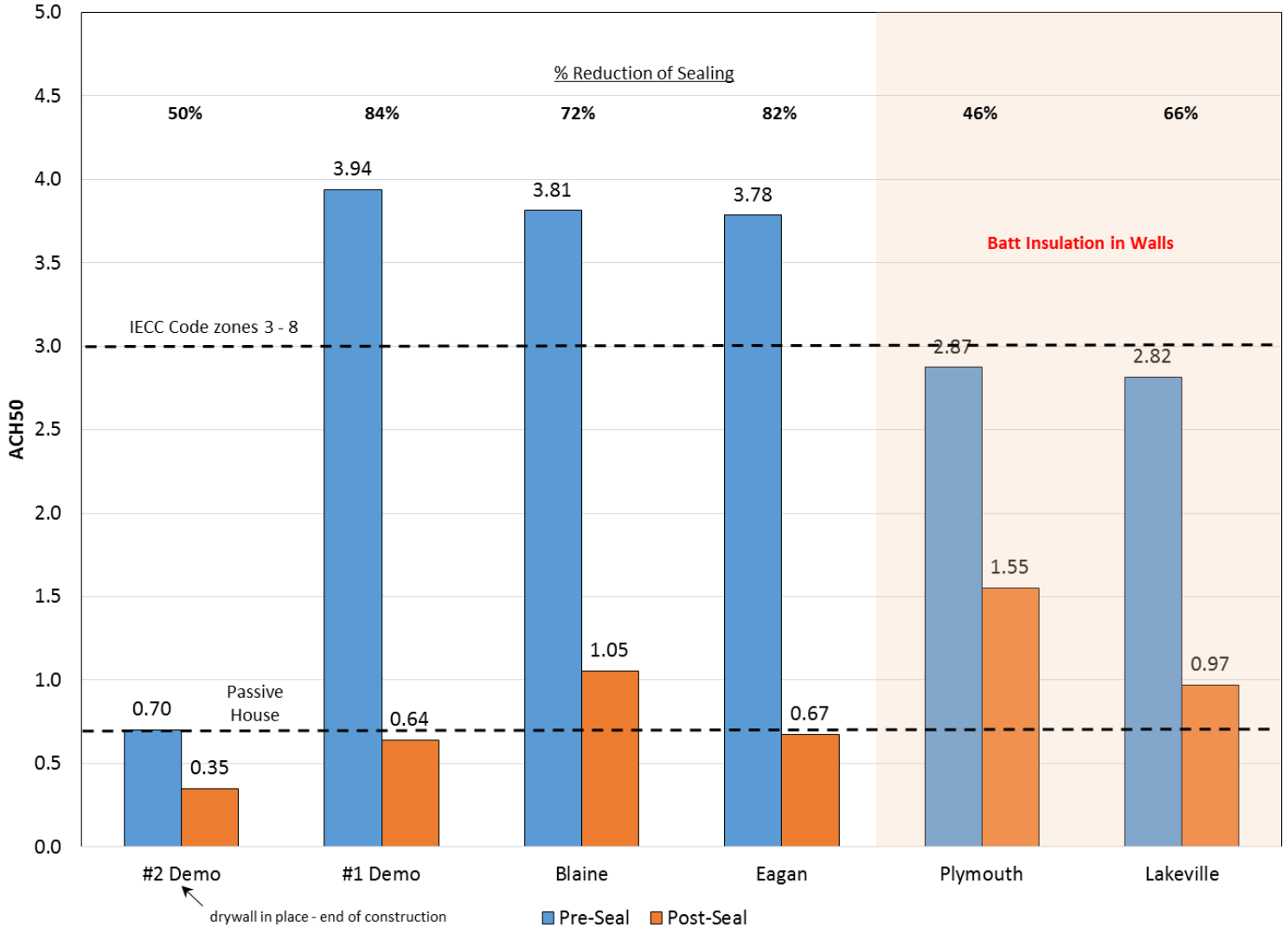
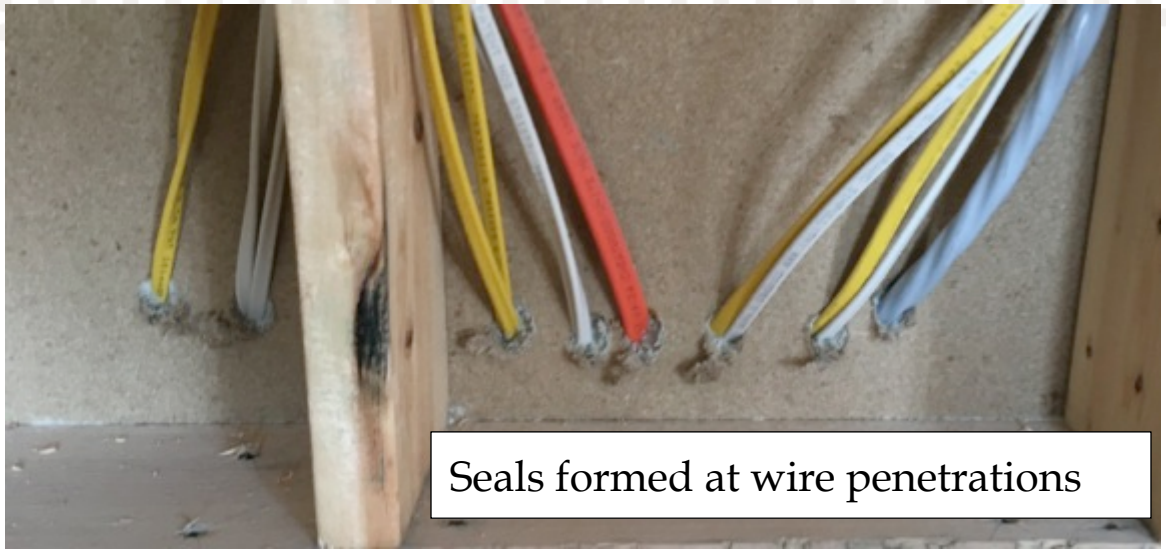
Reinforced Poly Failure

MN Builder #1 Results Summary



Seals

Seal formed between studs



Seals formed at wire penetrations

Seal formed at electrical box

Seals formed at plumbing penetrations

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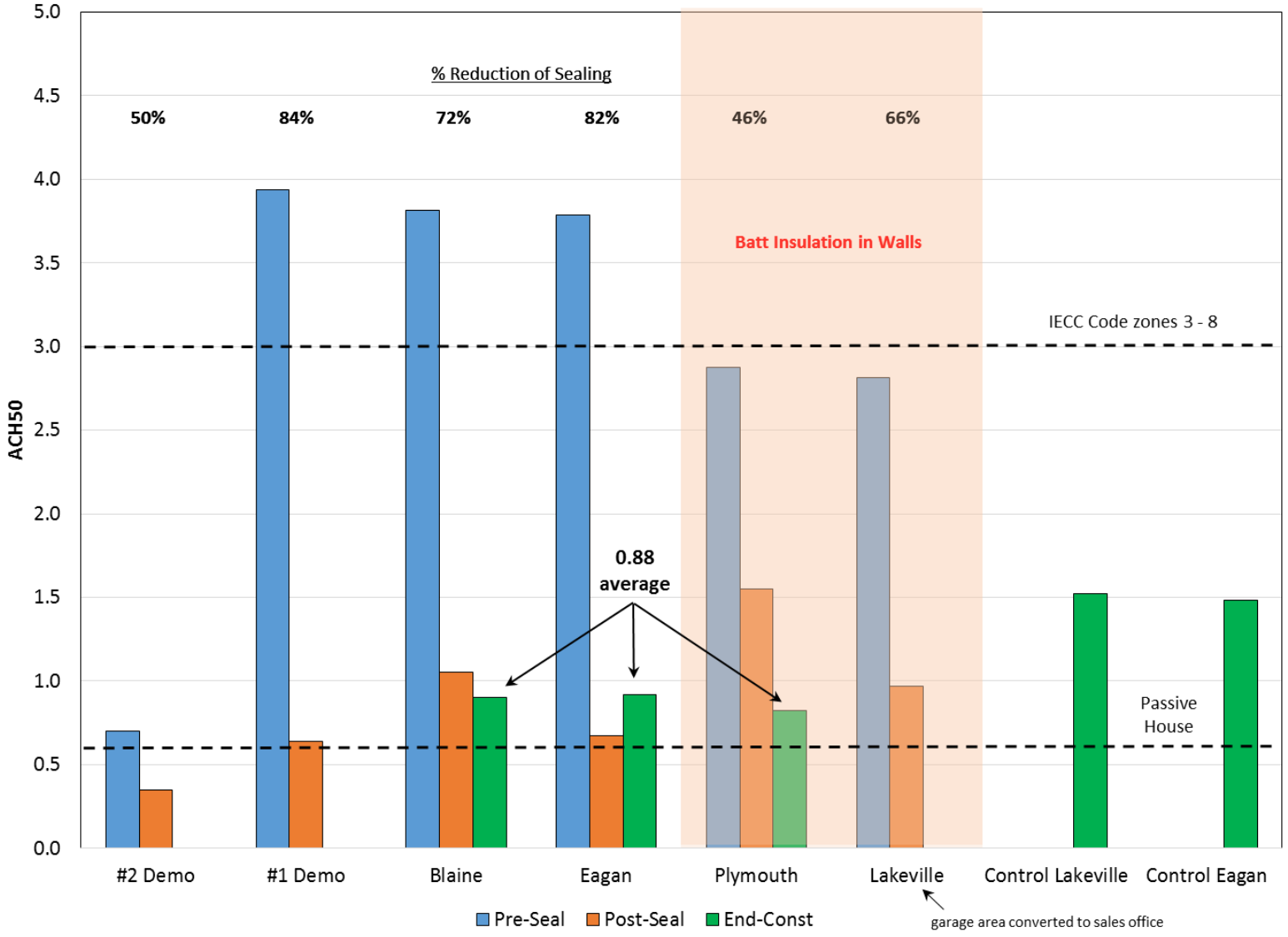
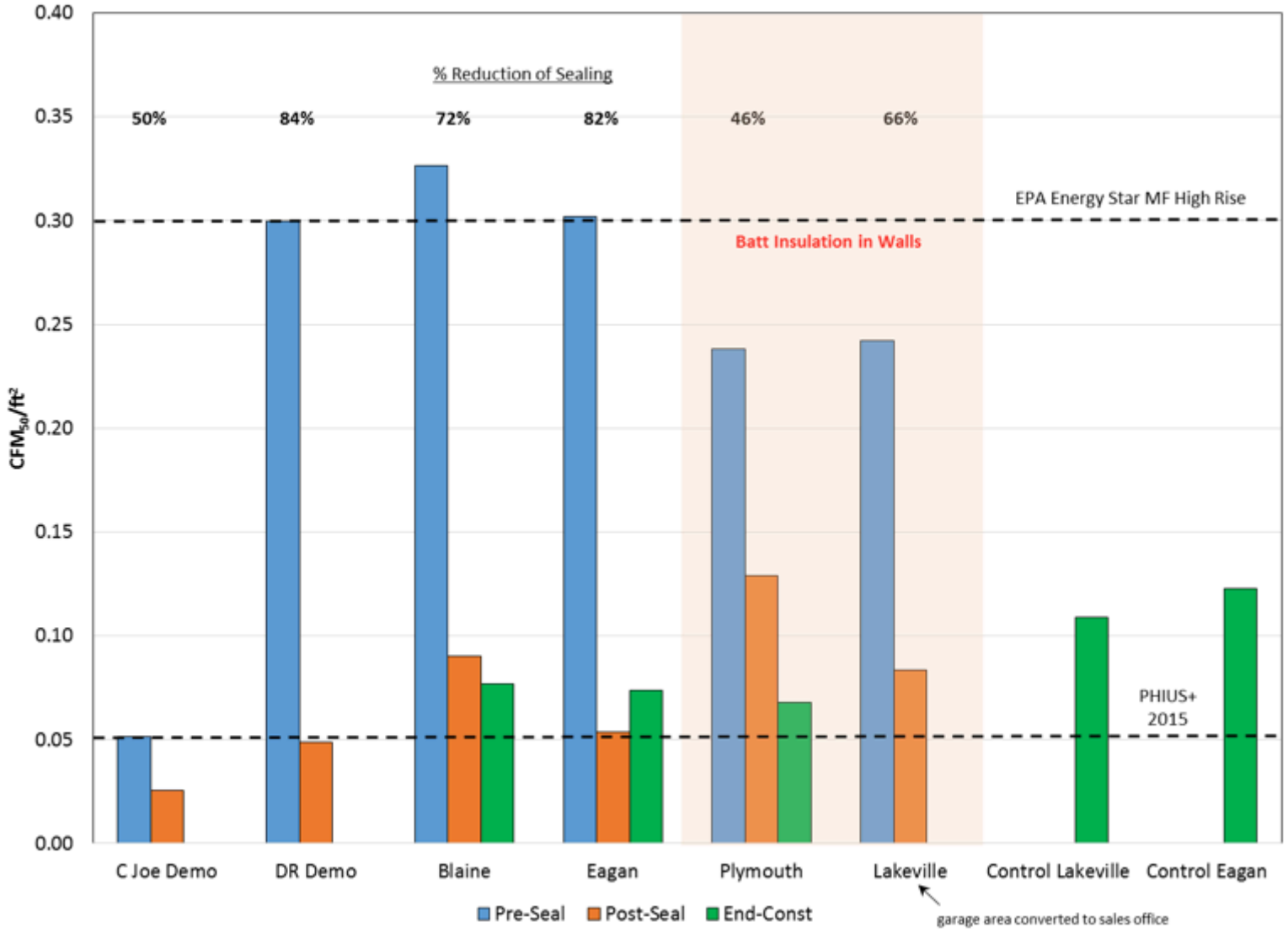
Initial Results: First Minnesota Builder



Seal before drywall & wall insulation

Initial Results: First Minnesota Builder



Seal before drywall & wall insulation

Control Houses

Minnesota Builders - Path Forward

- Refine sealing option
  - Demonstrate refined option on 2-3 homes
- Start work with Builder #2
  - Will seal before drywall
- Possibly recruit another builder that is struggling to achieve 3 ACH50 tightness requirement
- Develop guidelines for future installations

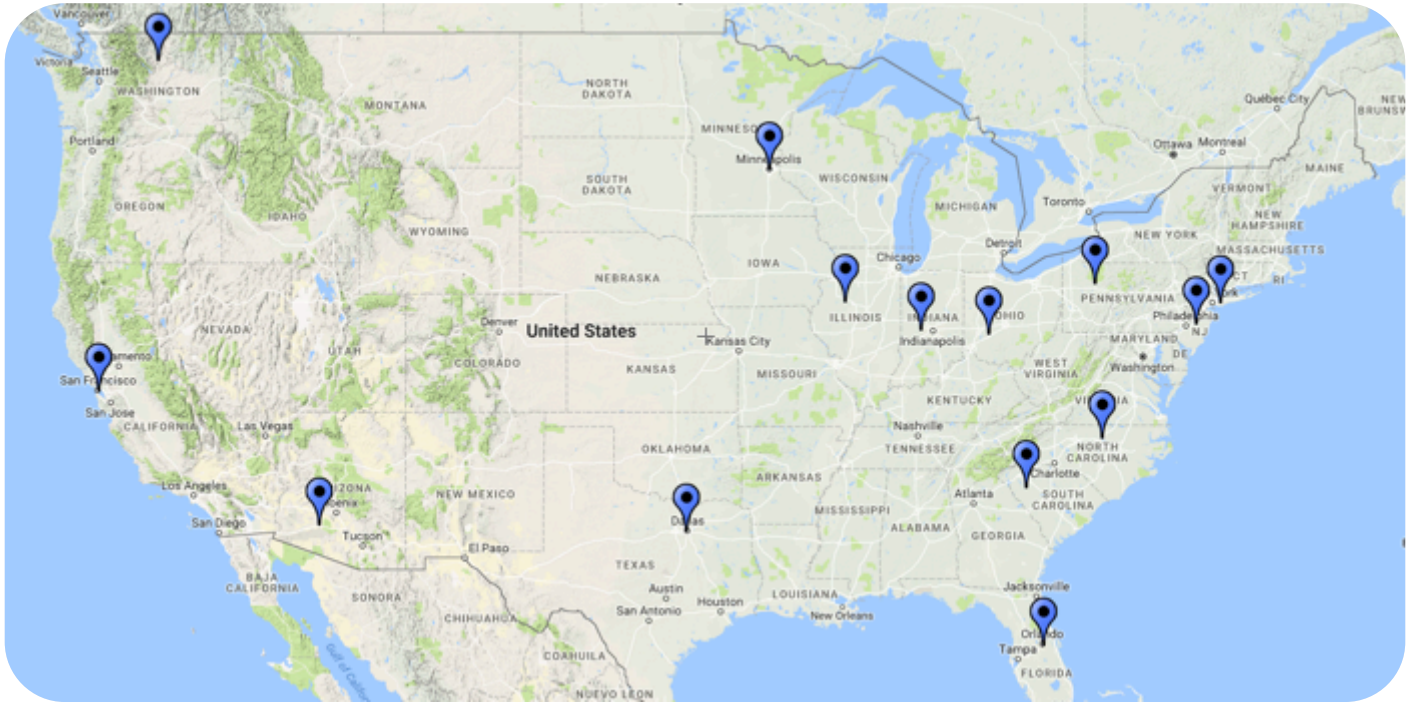
Research Path Forward

- Application in commercial buildings
  - Wrapping up project for DoD on non-res retrofits
  - Commercial buildings present challenges
    - Roof-to-wall connection
    - Supplemental manual sealing sometimes required
- Application in existing homes
  - Existing homes are leakier
  - Apply at time of tenant change

AeroBarrier Update

Recent Successes and Upcoming Projects

- Passive House: Mandalay Homes (Prescott, AZ) and 9thAve. (Brooklyn, NY)
- Multi-Family (New Build): 101 Apartments (Queens, NY)
- Renovation Application: 7 renovated apartments sealed to 1 ACH50(Rockford, IL)
- Apartment Compartmentalization: 36 semi-finished apartments (Brooklyn, NY)
- Apartment Comparison: 3 units sealed pre drywall, 3 units to be sealed after drywall to 3 ACH50(Dayton, OH)
- Center for Energy and Environment and DOE project: 34 single family houses (17 in California, 17 in Minnesota)
- Duke Energy: 45 rooms to 74 CFM_{50} or tighter to create “safe spaces” (North and South Carolina, and Indiana)
- Smoke Control Compartmentalization: 202 rooms in a micro-hotel (San Francisco, CA)



Mandalay Homes became the first production builder to incorporate AeroBarrier into all of their homes

Project Overview:

MANDALAY HOMES

Project: DOE Challenge Home
Builder: Mandalay Homes
Location: Prescott, Arizona

Results:

Pre-leakage: 3.1 ACH_{50}
Post-Leakage: 0.4 ACH_{50}
Reduction: 86.4%
Sealing Time: 2.5 hours

"AeroBarrier may be the most important innovation to hit the building community in years…The ability to consistently seal all the small leaks that would otherwise take countless man hours to seek and hand seal, assuming you even find them all, in just 1 automated application is simply amazing. The cost effectiveness is beyond immeasurable when you consider the total sealing solution AeroBarrier provides and all the labor saved by automating the application process. We couldn't be happier with AeroBarrier and the fine folks behind the product."

- Geoff Ferrel
Chief Technology Officer, Mandalay Homes

7X WINNER
HOUSING INNOVATION AWARD
ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

AeroBarrier Works in Renovation Applications Too.

Project Overview:

Project: Low Income Housing of the Future
Builder: Evolutionary Home Builders
Location: Rockford, IL

Results:
AeroBarrier was able to seal each of the 7 apartments to 1 ACH50 or less in two days. Without AeroBarrier this project wouldn't have met the certification criteria and wouldn't have received the funding it needed.

Low air leakage numbers can be hard to achieve in renovation applications because the exterior and framing typically stays in place. When the builder is looking to achieve 1 ACH_{50} or less, this becomes significantly more difficult.

"Without AeroBarrier we would have spent countless hours seeking out and manually sealing all the leaks we could find. The problem was, we couldn't see most of the leaks because they were in the walls or framing that was staying in place. So to achieve our goal of 1 ACH_{50} with manual sealing was a very daunting, most likely unachievable task.

AeroBarrier was able to seal all 7 apartments within two days, without a problem. We even had some apartments starting as high as 17 ACH_{50} that AeroBarrier got down to 1 ACH_{50}. The time that was saved and the results that were achieved were amazing. We wouldn't have been able to achieve the results we did without AeroBarrier…"

- Jason LeFleur.
President, Eco Achievers

AeroBarrier used to seal “safe havens” in industrial buildings

AeroBarrier’s versatility has been on display sealing “safe haven” rooms in a coal power plant

If there were ever to be an airborne leak at the power plant employees can close themselves in one of these rooms and fresh air will be pumped into the space. Because of the effectiveness of AeroBarrier and the results we can achieve, the “safe havens” will keep the fresh air in the room and the chemical leak out. Allowing the employees to stay in the room up to 2 hours.

Results:

Pre-Leakage:	10.4 ACH_{50} (1,323.2 CFM)
Post-Leakage:	0.5 ACH_{50} (60.4 CFM)
Sealing Time:	2 hours 20 min

AeroBarrier is **Available Now**
Anywhere in the Country.

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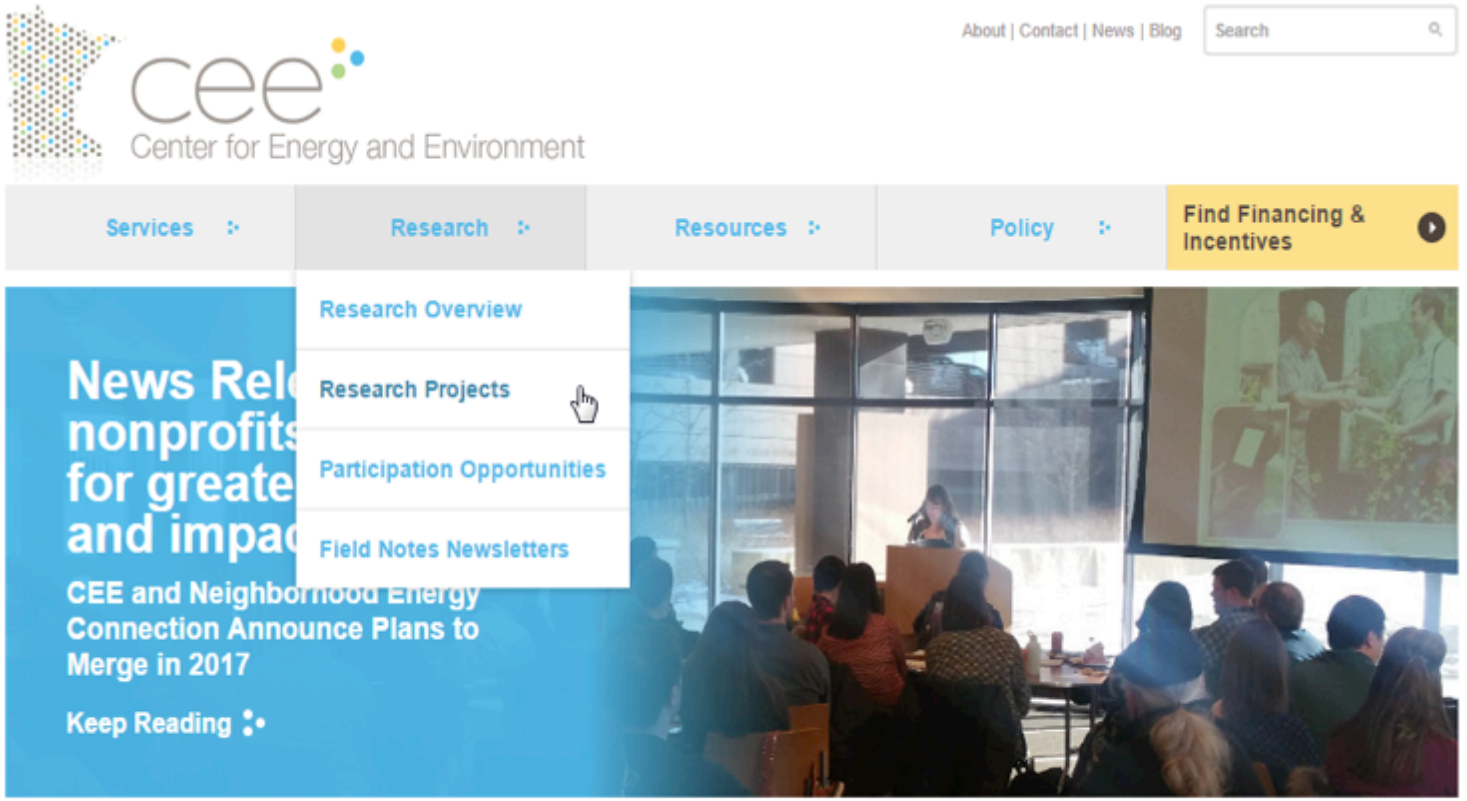
Breakthrough Envelope Sealing Technology

www.mncee.org/AeroResidential



Practical energy solutions for homes, businesses, and communities

THANK *you!*

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MN Builder #1 Results Summary

		Pre-Seal		Post-Seal		
Stage/Option	Floor Area (ft2)	CFM50	ACH50	CFM50	ACH50	% Reduction
Demo 1	3,636	2,200	3.94	358	0.64	84%
Blaine	4,470	2,637	3.81	728	1.05	72%
Eagan	3,955	2,300	3.78	409	0.67	82%
Plymouth	4,248	1,893	2.87	1,023	1.55	46%
Lakeville	4,478	1,959	2.82	674	0.97	66%
Demo 2	4,135	419	0.70	209	0.35	50%