

Building America: Aerosol Sealing of Building Envelopes in New Construction

Curtis Harrington, PE

UC Davis, Western Cooling Efficiency Center

EEBA High Performance Home Summit:

October 11, 2017



Presentation Overview

- Air Sealing Benefits
- Basic Concept
- Development Timeline
- Building America Project
- Path Forward
- AeroBarrier Update



Energy Benefits of Air Sealing

- 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%
- Better insulated envelopes increase fraction of heating & cooling associated with infiltration/ventilation
- Envelope tightness standards were fairly recently included in U.S. codes
- Cost-effective approaches to sealing envelope leakage would improve and simplify adherence to code

IECC Codes Around U.S.

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

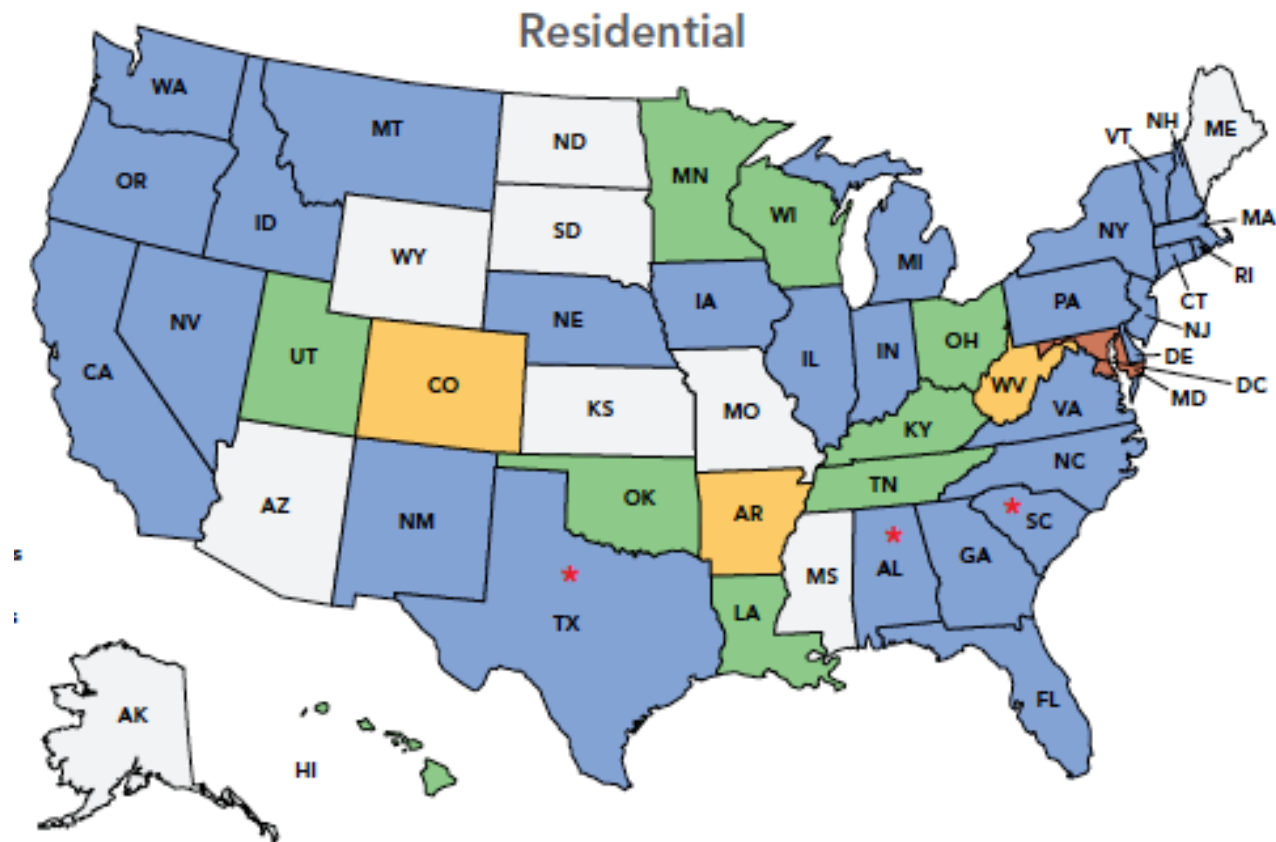


Chart courtesy of Oldcastle® Architectural

4 IECC 2003, equivalent or more energy efficient

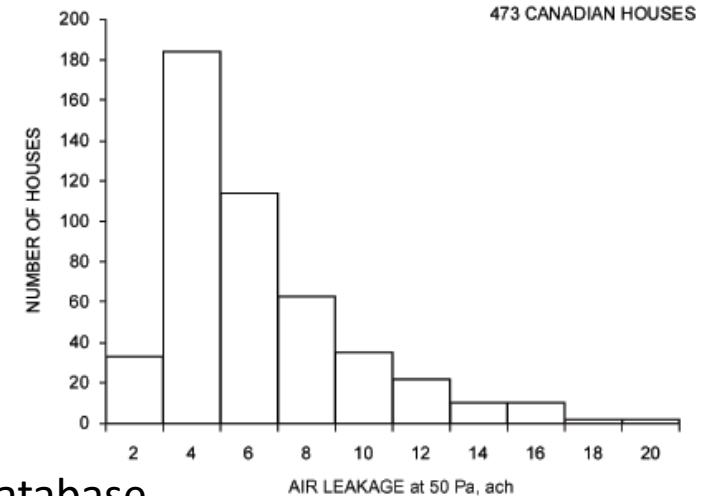
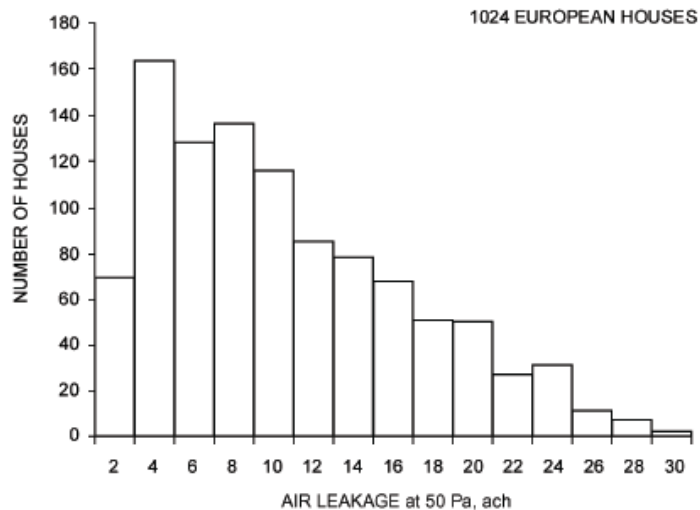
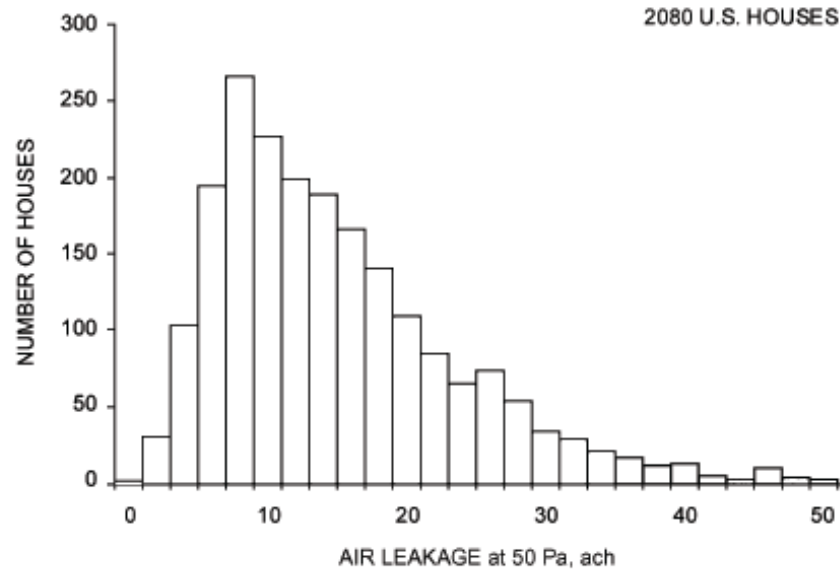
9 IECC 2006, equivalent

32 IECC 2009, equivalent or more energy efficient

1 IECC 2012, equivalent or more energy efficient

10 No Statewide Code

Single Family Envelope Air Tightness



LBNL Air Leakage Database

Health Benefits of Air Sealing

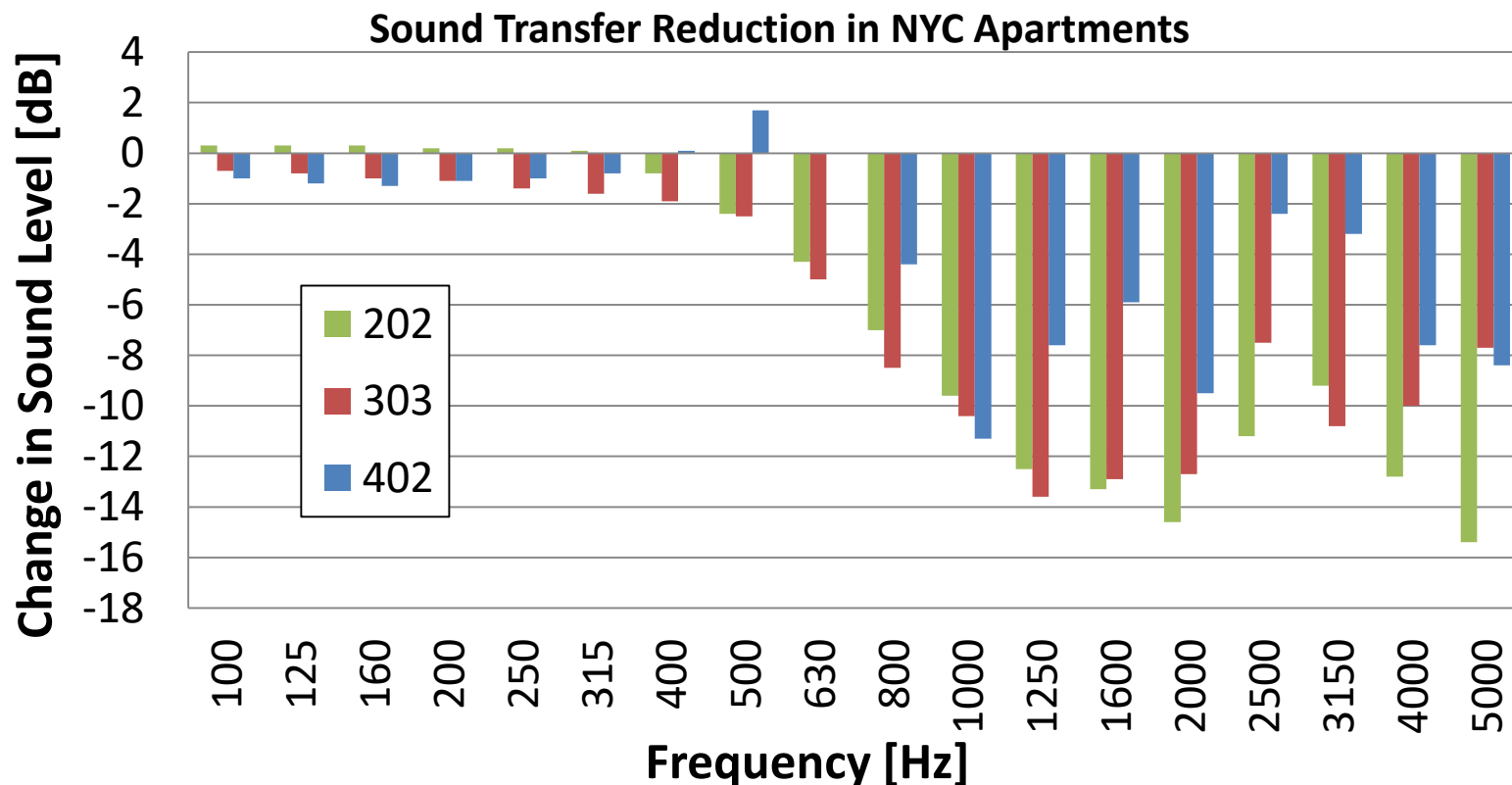
- Better control of air flow and reduced infiltration of outdoor air and outdoor pollutants (e.g. PM 2.5 or Ozone)
- Facilitates use of Mechanical Ventilation
 - HRV or ERV and filters
 - Putting HRV/ERV on leaky building doesn't save energy or reduce uncontrolled infiltration

Health Benefits of Air Sealing (Large Buildings)

- NIST measurements of large building leakage suggest that more air is needed for pressurization than for ventilation
- 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)**

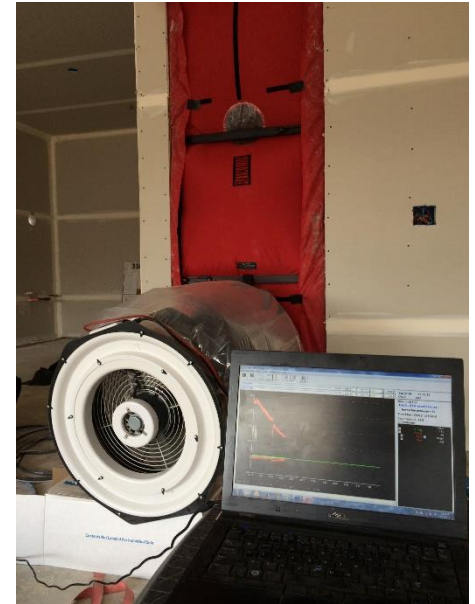
Other Benefits of Air Sealing (Multifamily and Hotels)

- Reduce noise transfer
- Reduce smell transfer

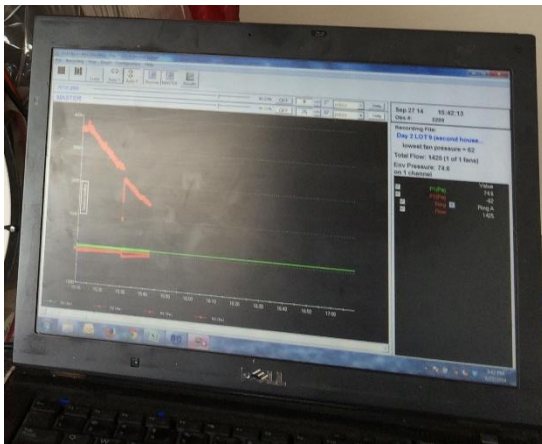


Basic Concept

- “Blower Door” creates and maintains positive pressure difference between indoors and outdoors
- Sealing performed by fogging a space with aerosolized sealant particles
- Particles carried to leaks by escaping air flow
- Entire sealing process is tracked and displayed in real time and documented electronically
- Finds and seals leaks missed or inaccessible by manual trial-and-error methods

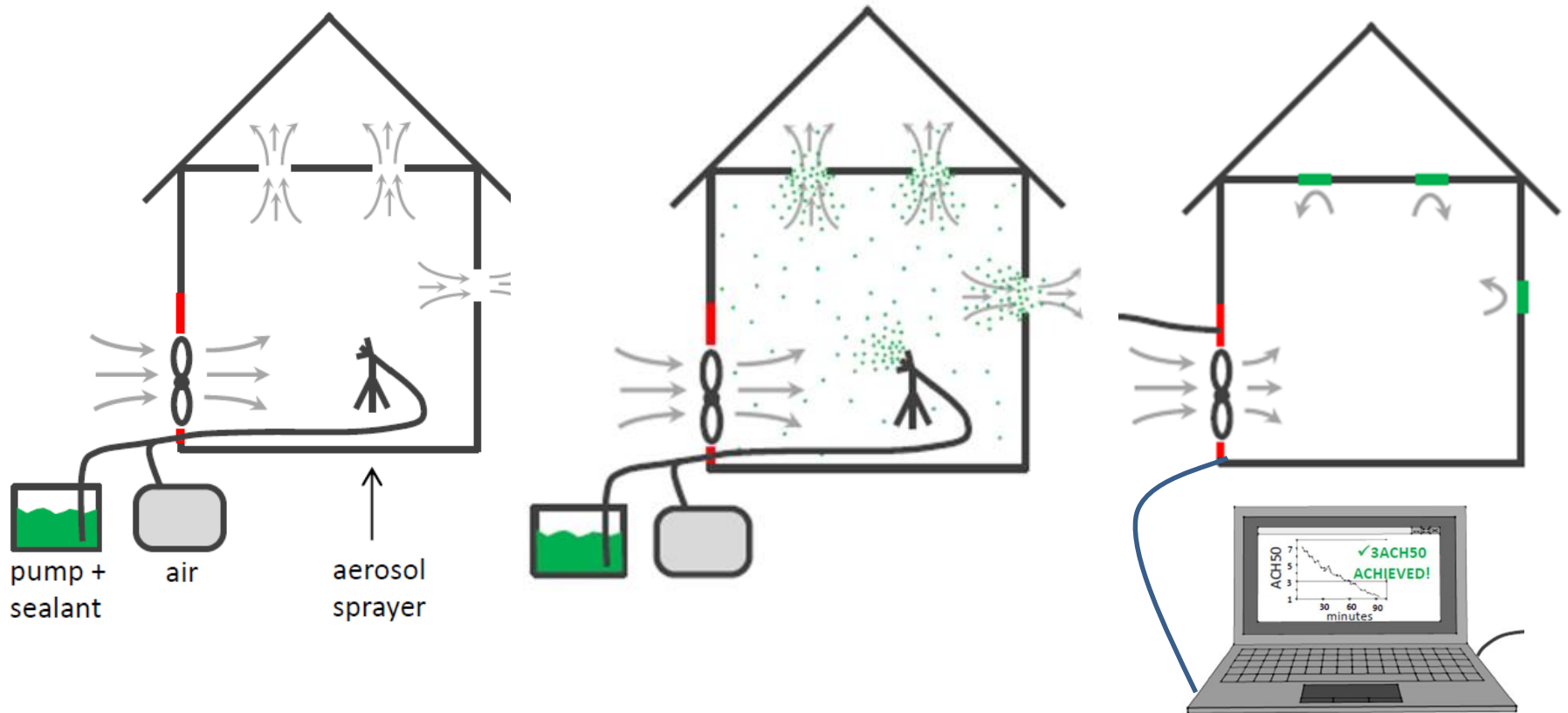


Blower door setup for pressurization

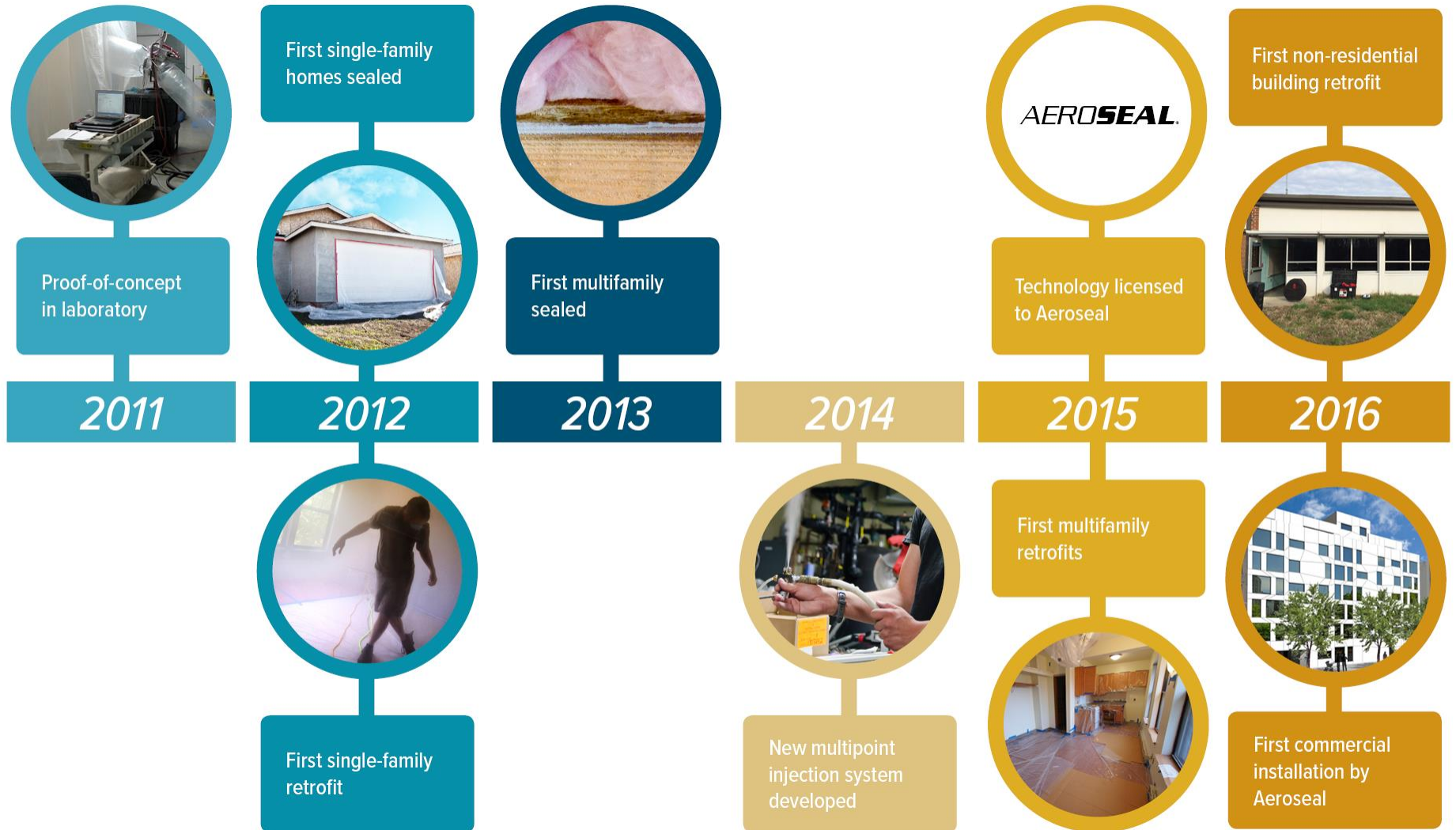


Seal formed between gap in foam

Basic Concept

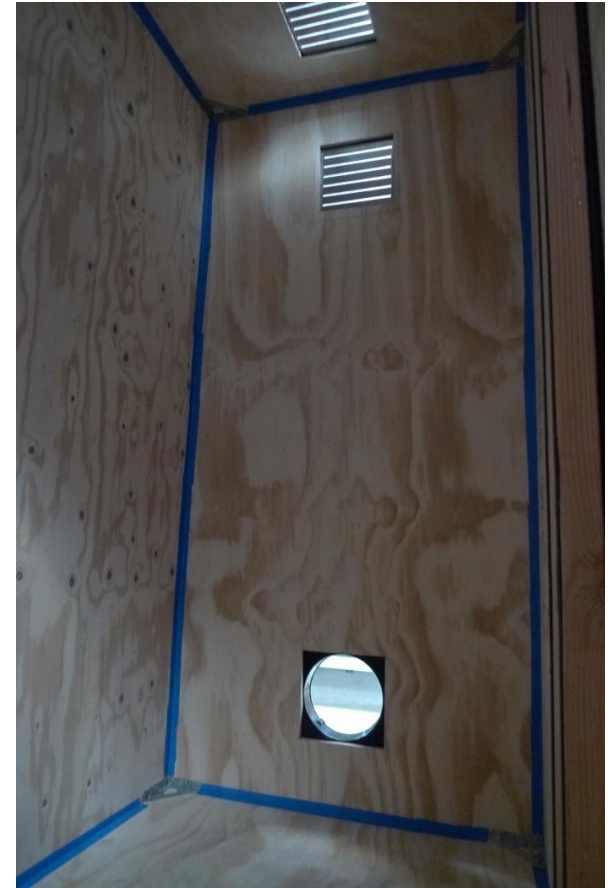
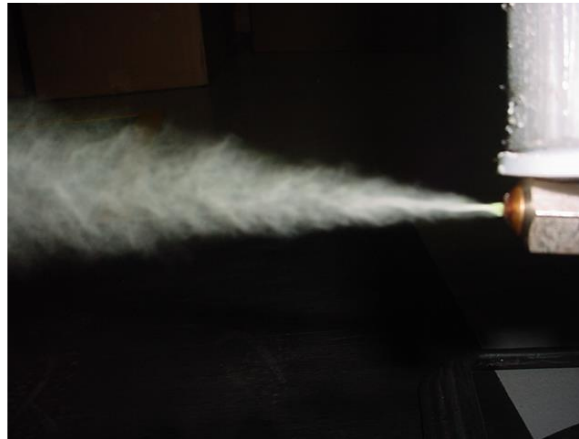


Development Timeline



Proof-of-Concept Testing

- Adapted duct sealing technology
- Started out sealing 4' by 8' by 8' box
- Independent variables tested
 - Injection rate
 - Enclosure pressure
- Dependent variables recorded
 - Sealing rate
 - Sealant use efficiency



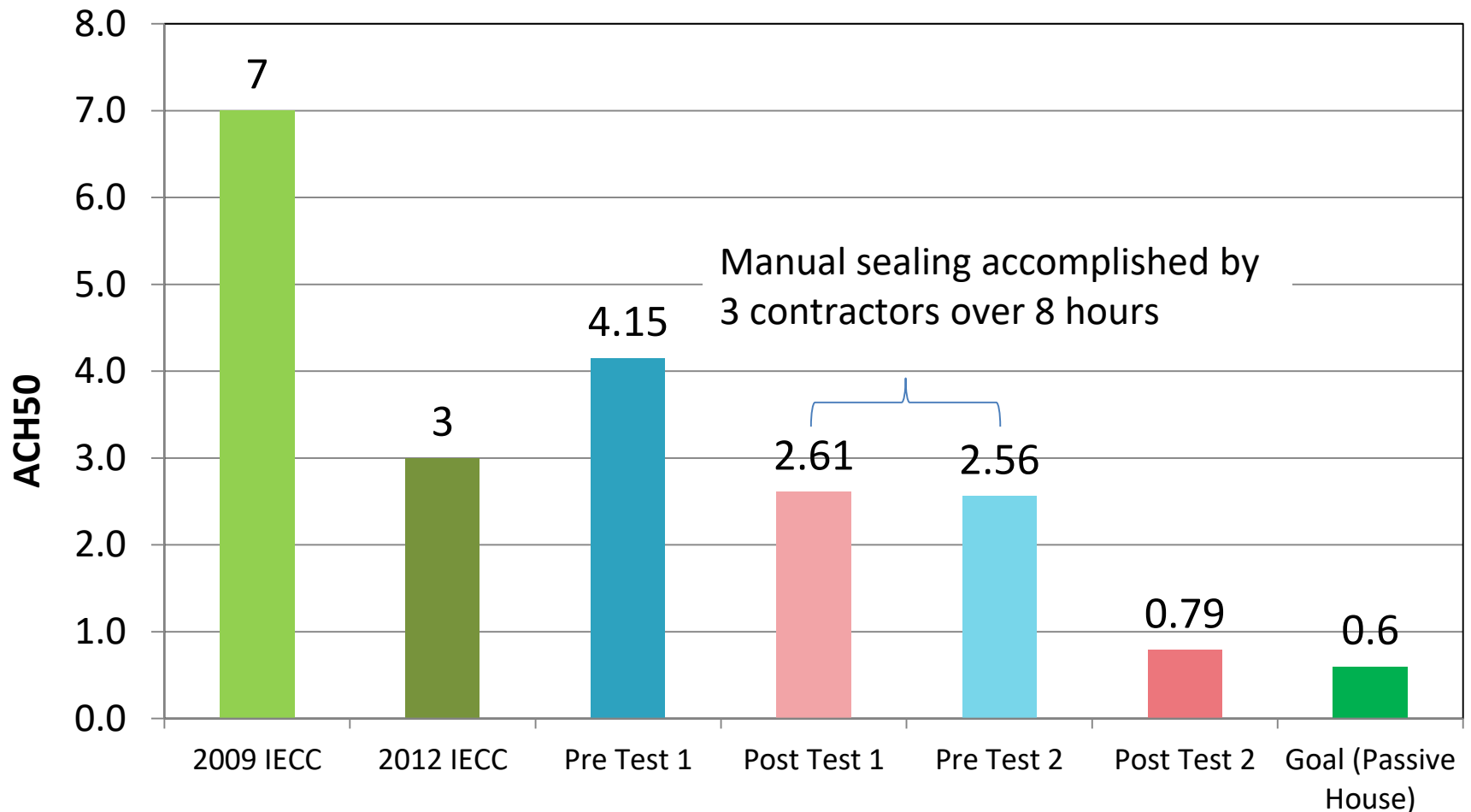
Demonstrations with Habitat for Humanity

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



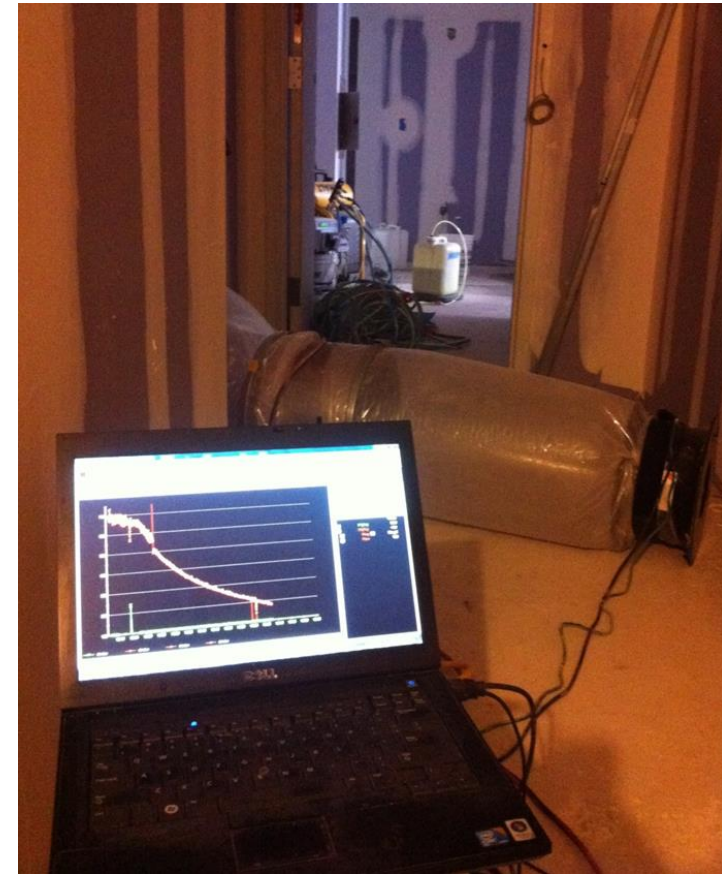
Honda Smart Home

- Implemented temp/humidity control



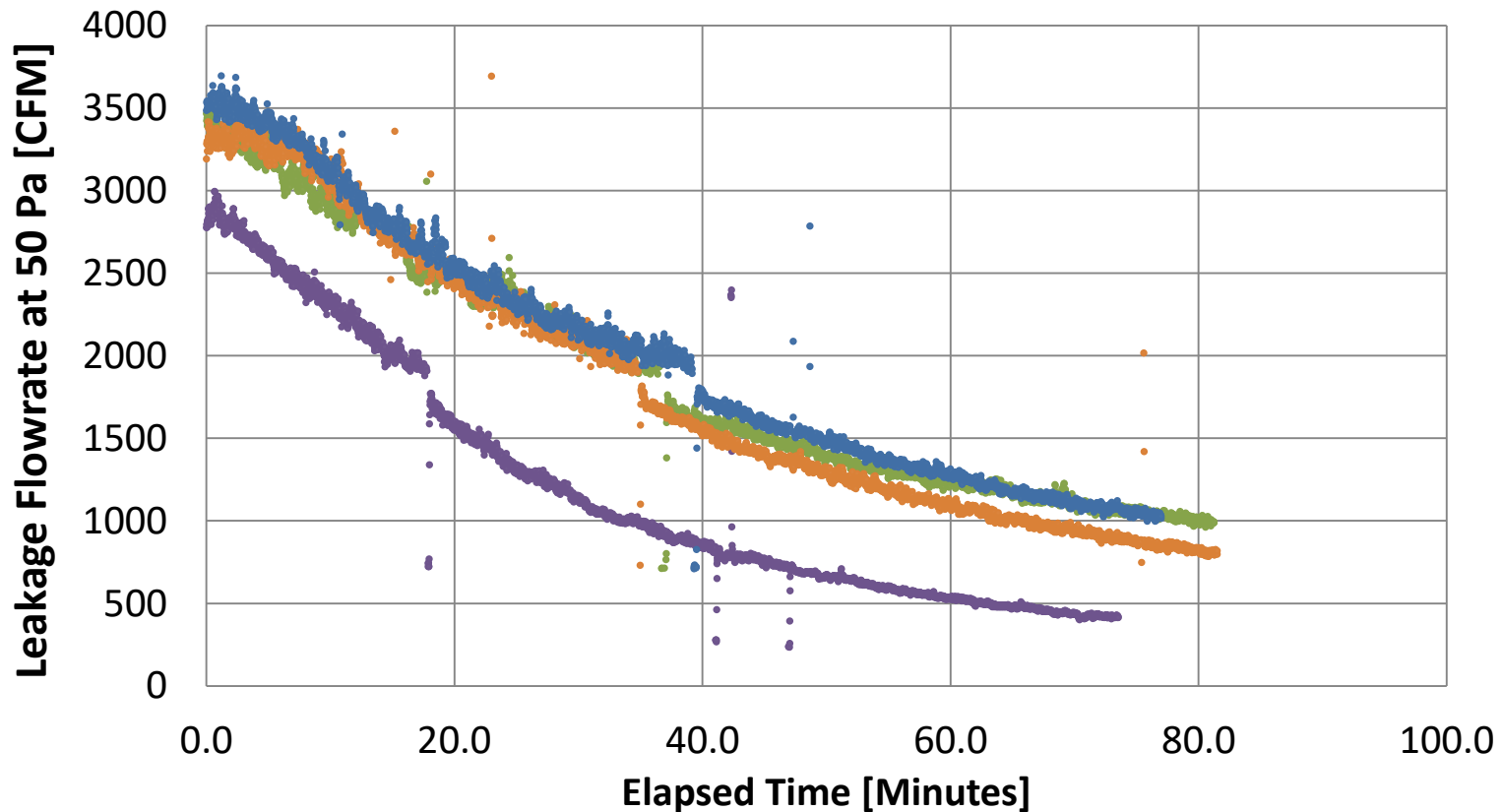
New York Apartments (Building America)

- 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



Single Family Sealing on Production Scale (Building America)

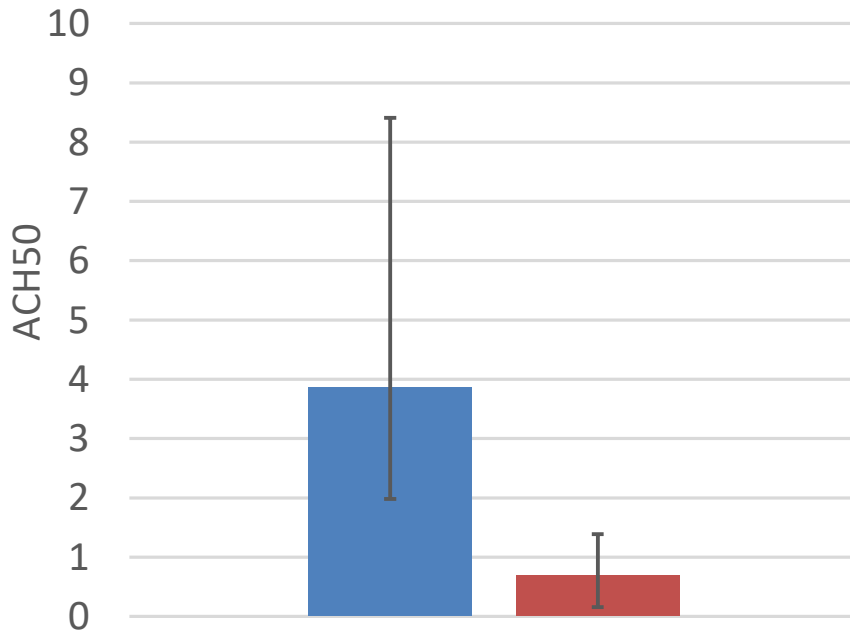
- Sealed two houses per day
- Tracked time and materials



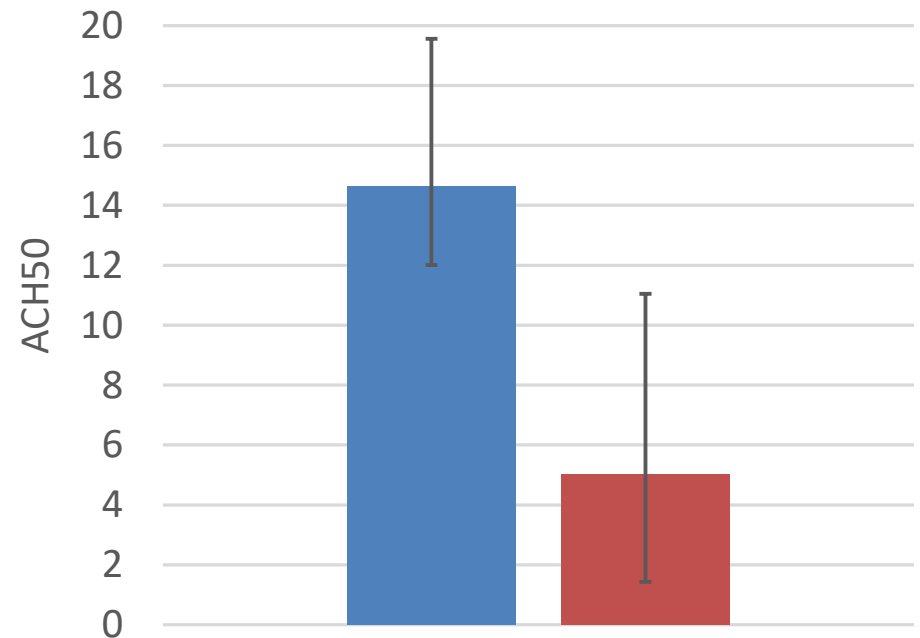
Minnesota Apartments

- New and existing apartments
- Applied in cold weather

Results from 18 New Apartments



Results from 9 Existing Apartments



■ Pre-Sealing ■ Post-Sealing

Pre-Sheetrock Sealed leaks



Post-Sheetrock Sealed Leaks



Building America Project Goals

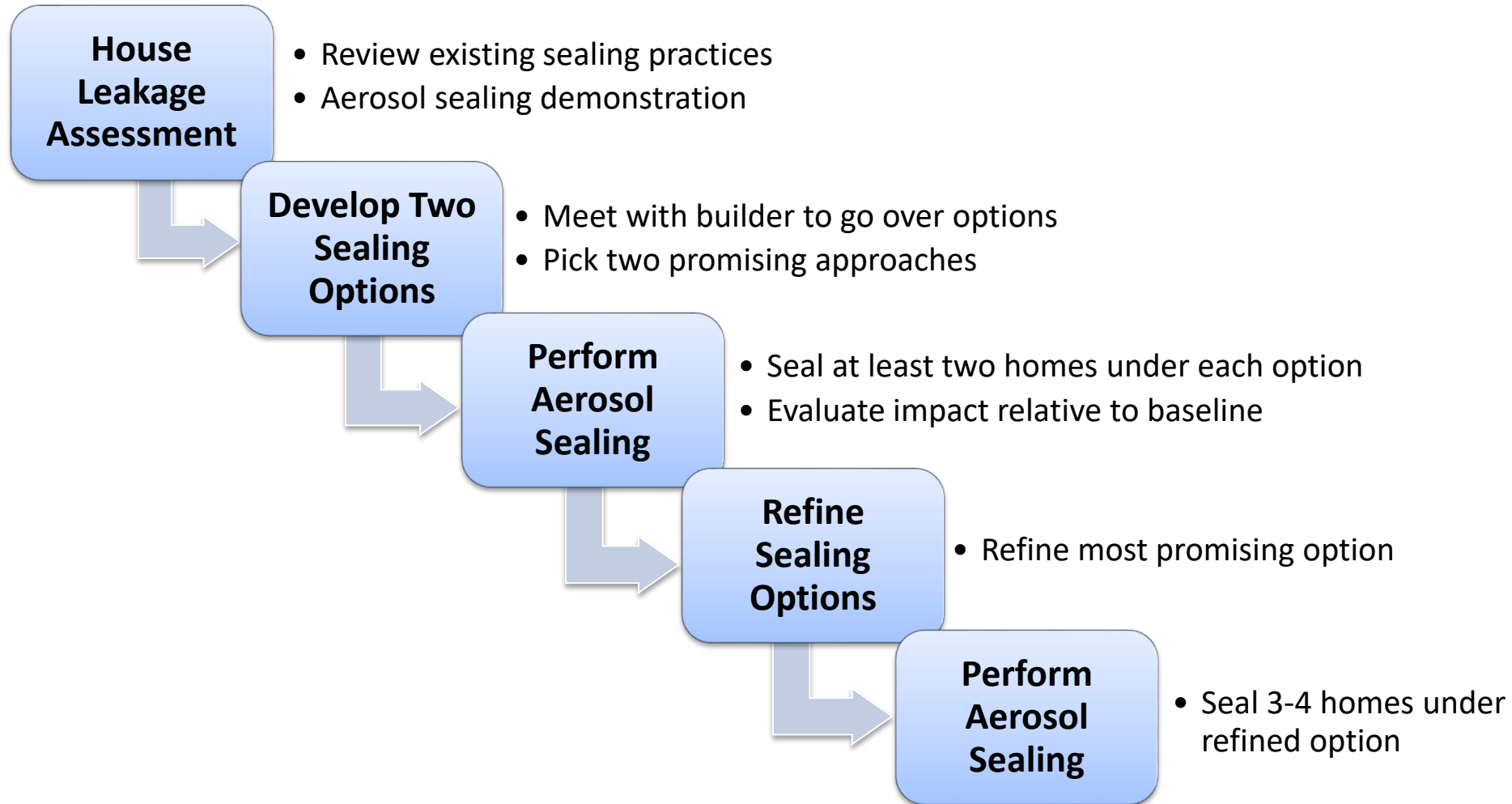
Integrate aerosol envelope sealing into home building process

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

Building America Project Team

- Project Partners:
 - Center for Energy and Environment
 - Building Knowledge Inc.
 - University of Minnesota's Cold Climate Housing Program
 - Aeroseal LLC
- Builders:
 - Two in California
 - Two in Minnesota

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 Contractor	Gasket	Yes	Acceptable
	Drywall to top plate	Insulation Contractor	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
	Electrical/low voltage boxes on exterior walls		None	Yes	N/A
	HVAC register boots that penetrate building thermal envelope	N/A		Yes	N/A

ENERGY STAR Rater Field Checklist

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/mineral wool 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
 - Easier aerosol distribution

Option 1



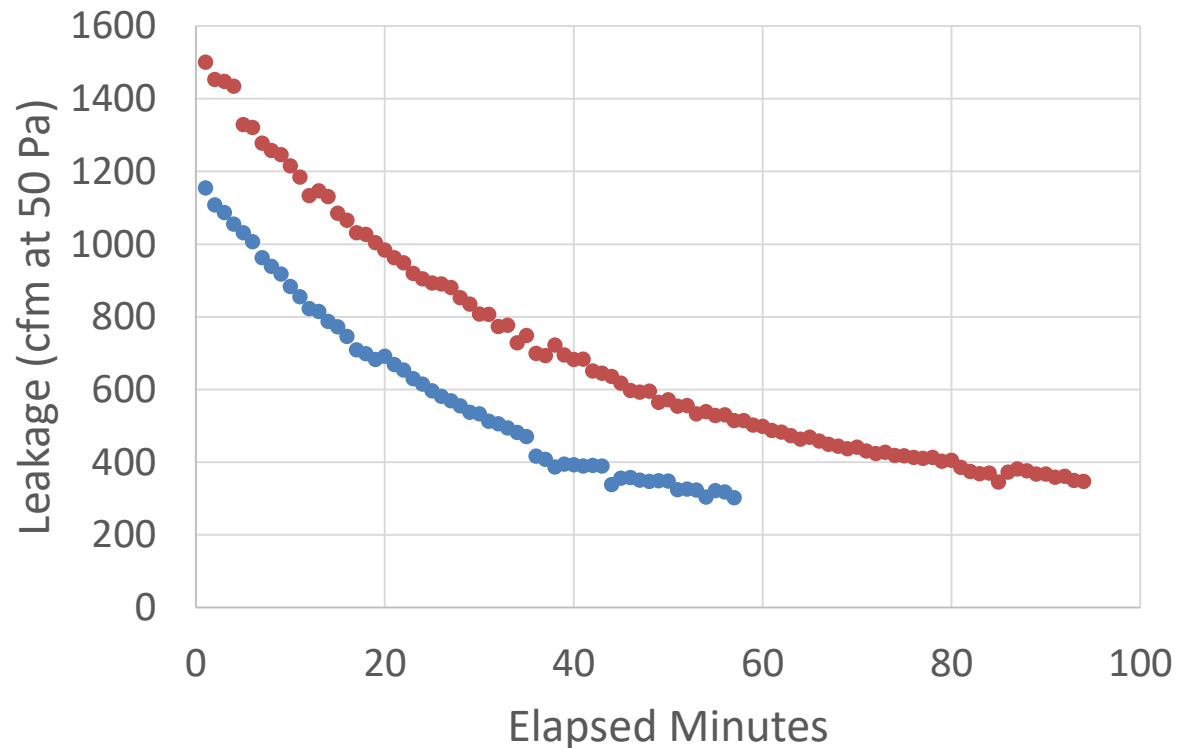
Foam at roof deck



Foam at rim joist

Option 1 Results

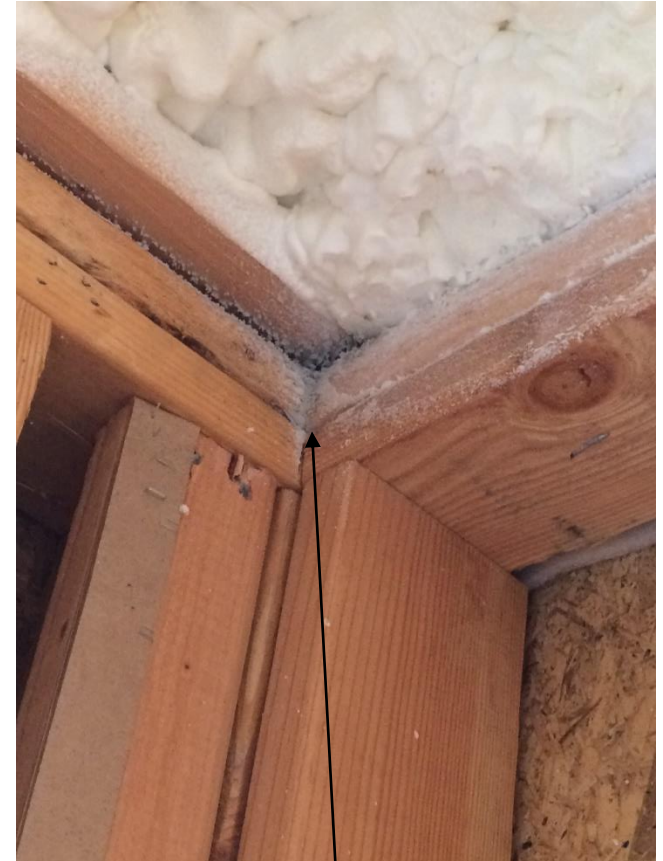
Stage/Option	Lot	Plan	Floor Area (ft ²)	Volume (ft ³)	Pre-Seal		Post-Seal		
					CFM50	ACH50	CFM50	ACH50	% Reduction
After Foam	7	3	2569	23121	1690	4.39	429	1.11	75%
After Foam	8	1	2032	22215	1286	3.47	351	0.95	73%



Option 1 Example Seals



Seals formed under trusses



Seal formed at corner of wall assembly

Option 2



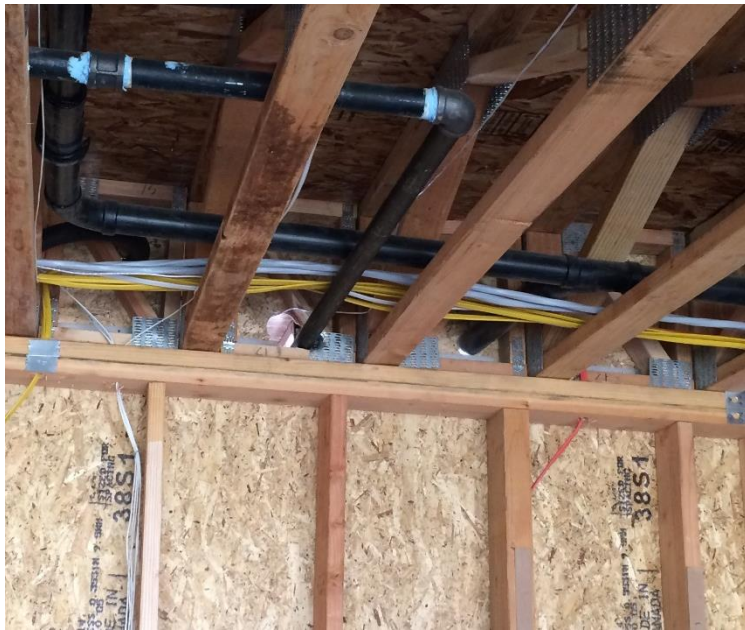
Exposed roof deck



Rim joist penetrations

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

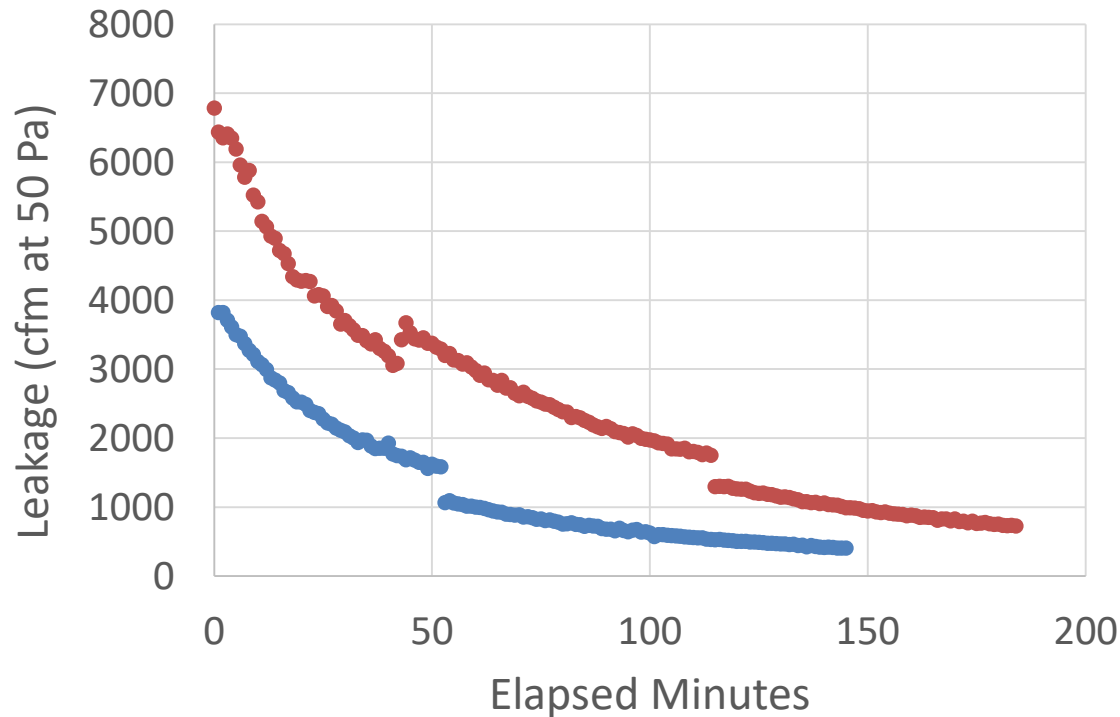
		Sealing Penetrations		Sealing Gap at Eaves	
Stage/Option		Time for Manual Sealing (person-hours)	Cans of Foam Used	Time for Manual Sealing (person-hours)	Cans of Foam Used
Before Foam		1.5	3	1.5	4
Before Foam		4.5	6	1	4

*Note: Pre-sealing work performed by inexperienced staff

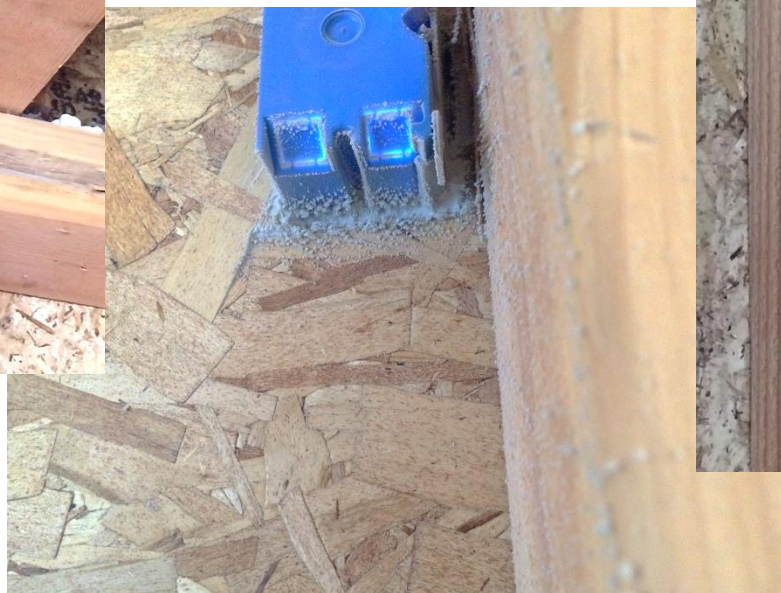


Option 2 Results

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%



Option 2 Example Seals



CA Builder #1 Results Summary



79%

Average leakage reduction



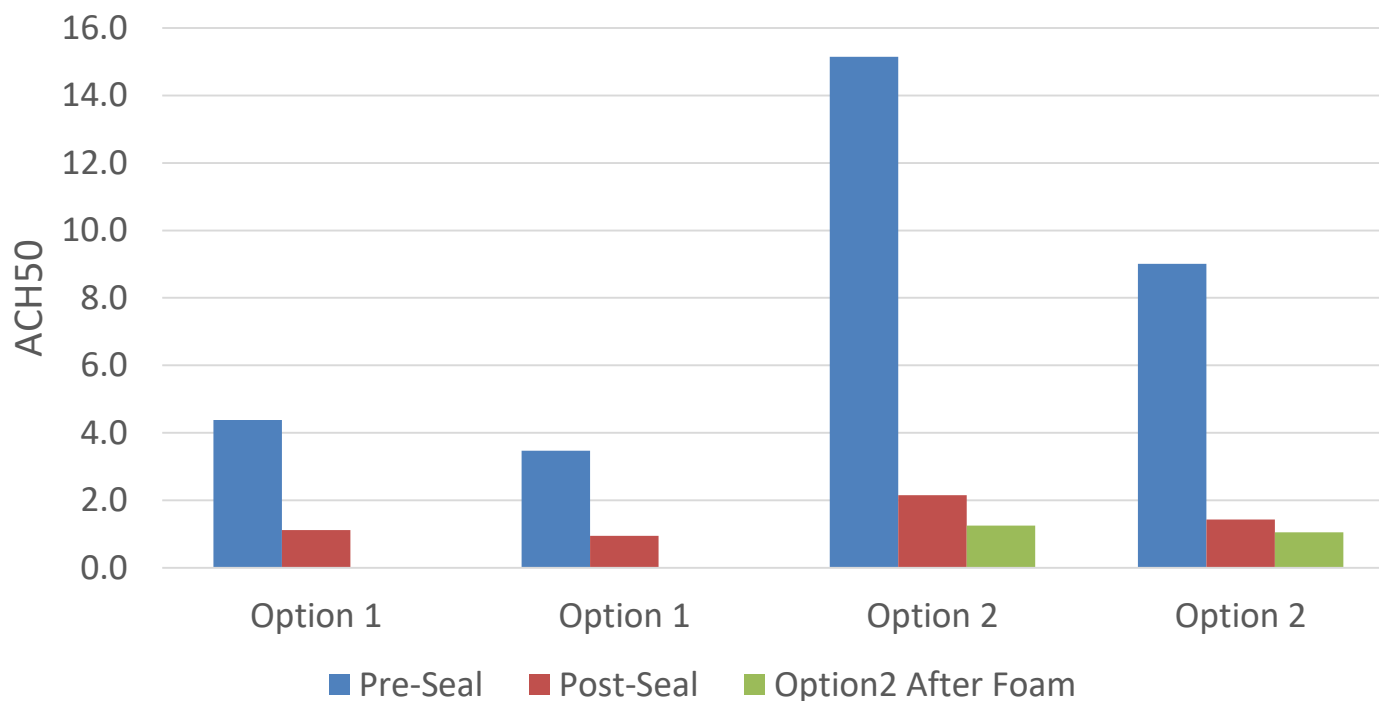
73%

Tighter than baseline homes



56%

Greater building tightness using Aerosols versus open-cell spray foam



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

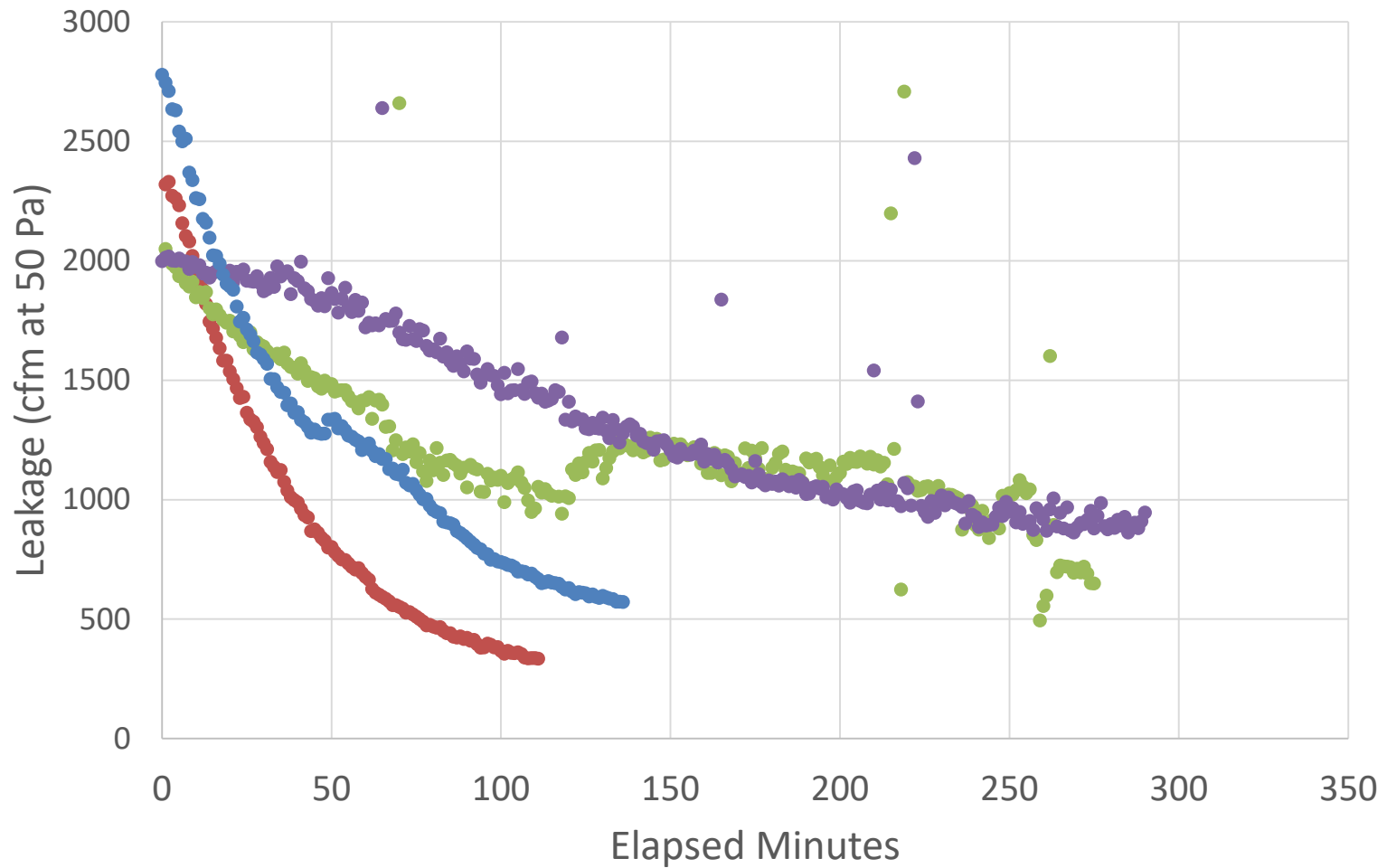


Caulk at sill plate

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

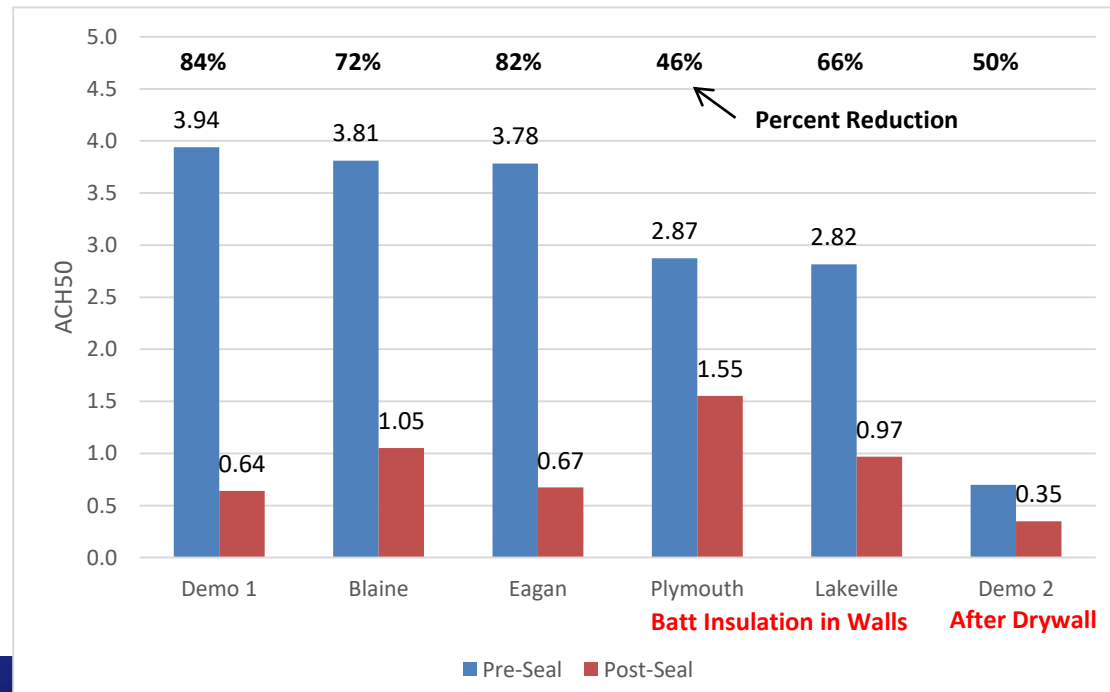


Reinforced Poly Failure



MN Builder #1 Results Summary

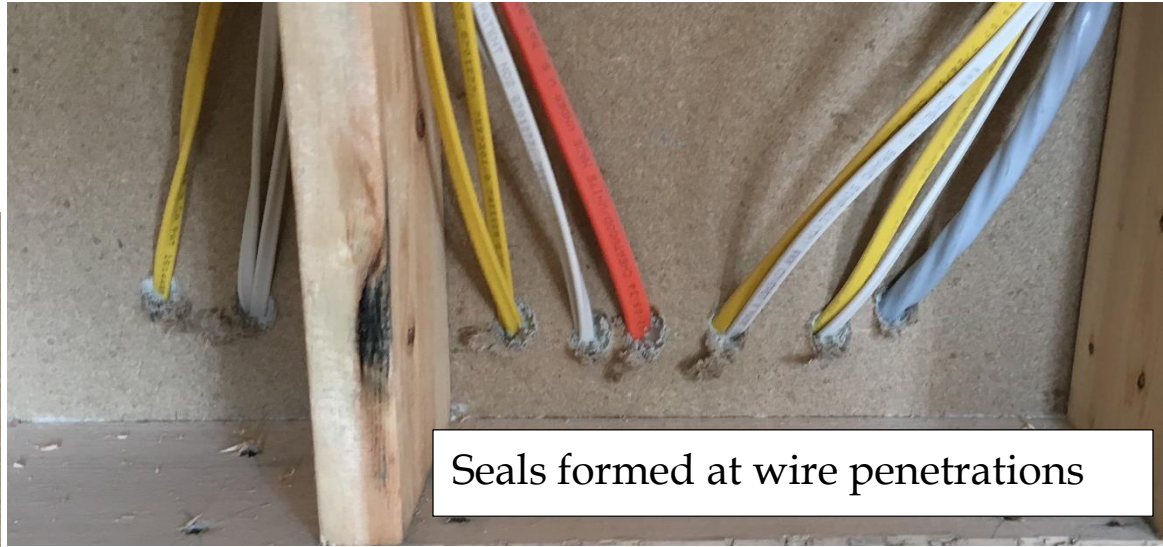
Stage/Option	Floor Area (ft2)	Pre-Seal		Post-Seal		% Reduction
		CFM50	ACH50	CFM50	ACH50	
Demo 1	3,636	2,200	3.94	358	0.64	84%
Blaine	4,470	2,637	3.81	728	1.05	72%
Eagan	3,955	2,300	3.78	409	0.67	82%
Plymouth	4,248	1,893	2.87	1,023	1.55	46%
Lakeville	4,478	1,959	2.82	674	0.97	66%
Demo 2	4,135	419	0.70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



Example Seals



Seal formed between studs



Seals formed at wire penetrations



Seal formed at electrical box



Seals formed at plumbing penetrations

Building America Project Path Forward

- Final leakage tests when homes are complete
- Refine sealing option
 - Demonstrate refined option on 3-4 homes
- Start work with Builder #2 in both CA and MN
 - Currently looking for builders in Sacramento area
- Develop guidelines for future installations

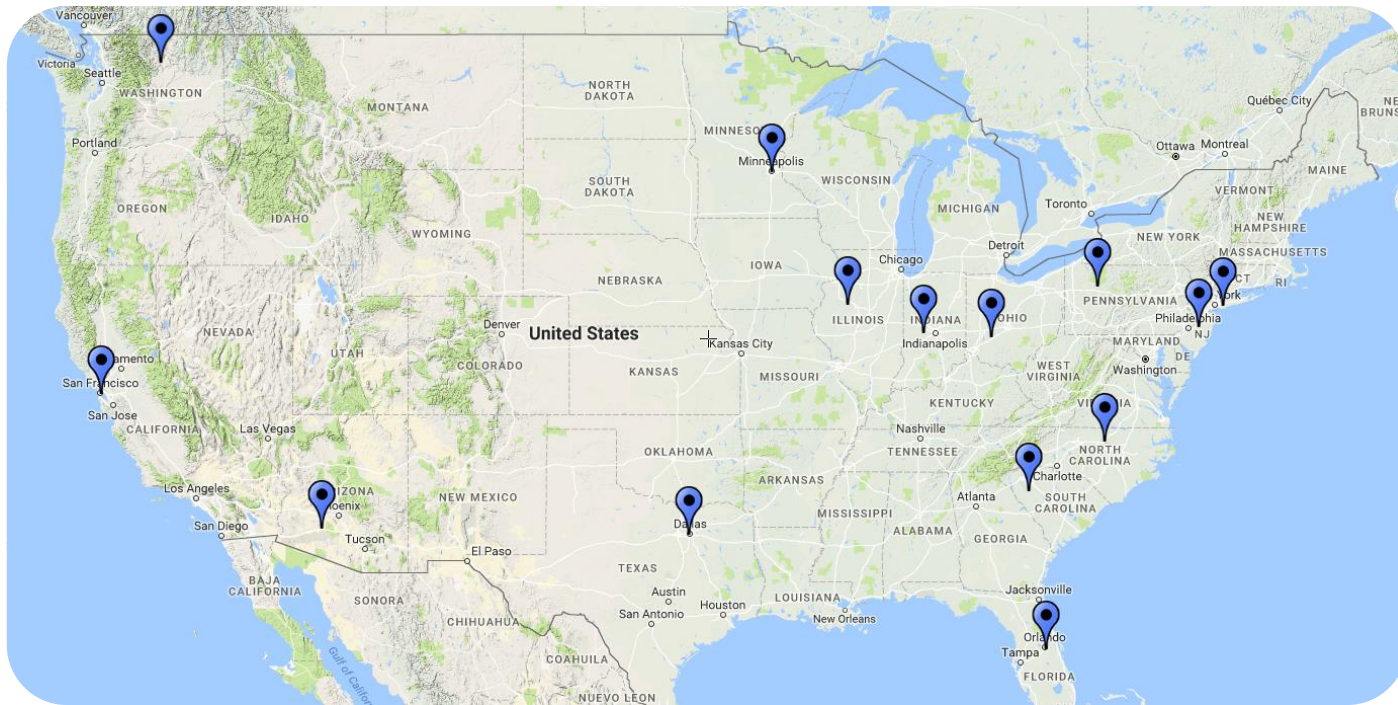
Research Path Forward

- 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 CFM₅₀ 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:



Project: DOE Challenge Home

Builder: Mandalay Homes

Location: Prescott, Arizona

Results:

Pre-leakage: 3.1 ACH₅₀

Post-Leakage: 0.4 ACH₅₀

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



AeroBarrier Allows Engineers to Easily Attain Desired Tightness for Energy Efficiency, Comfort, and Livability.



Project Overview:

Project: 153rd St Apartments

Builder: Synapse Development Group

Architect: Chris Benedict, R.A.

Location: Upper West Side, Manhattan

Results:

Post-manual sealing, AeroBarrier reduced unit leakage by an additional 47%, providing overall compartmentalization levels well within calculated passive house parameters.

"It was blowing people's minds – mostly because monitoring compartmentalization in a multi-family building under construction is typically a very difficult, time consuming task. The level of coordination and commitment you need to get from all contractors on the job is as critical as it is nearly impossible to achieve. With AeroBarrier, it's simply not a problem."

*- Chris Benedict, R.A.
Architect - CBRA*

"I don't know of any other way to get the level of tightness we were looking for. No amount of caulking could get this type of result. Most importantly, with AeroBarrier, you know you're going to get the results you want in the end. It's cost-effective and highly efficient at reducing energy costs and improving livability for our tenants. There's nothing that can compete with that."

*- Justin Palmer, CEO
Synapse Development*

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 ACH₅₀ 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 ACH₅₀ 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 ACH₅₀ that AeroBarrier got down to 1 ACH₅₀. 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.

AEROBARRIER™

Breakthrough Envelope Sealing Technology

CASE STUDIES | PRESS
ARTICLES | NEWS |
HVAC PRESENTATIONS |
NEWSLETTER | REPORTS
PUBLICATIONS |
INTERVIEWS | RESEARCH
EDUCATION |
DEMONSTRATION BRIEFS |
OVERVIEW | OUTREACH |
MISSION | CONTACT |
TECHNICAL SERVICE
AGREEMENTS |

wcec.ucdavis.edu

| TECHNOLOGY TOPICS |
SECTOR RESEARCH |
BEHAVIORAL RESEARCH |
SYSTEMS INTEGRATION |
CONTROLS | DEMAND
SIDE MANAGEMENT |
E V A P O R A T I V E
TECHNOLOGIES |
RADIANT COOLING |
MULTI-TENANT LIGHT
COMMERCIAL |