U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Building America Q2 Team Project Update

U.S. Department of Energy
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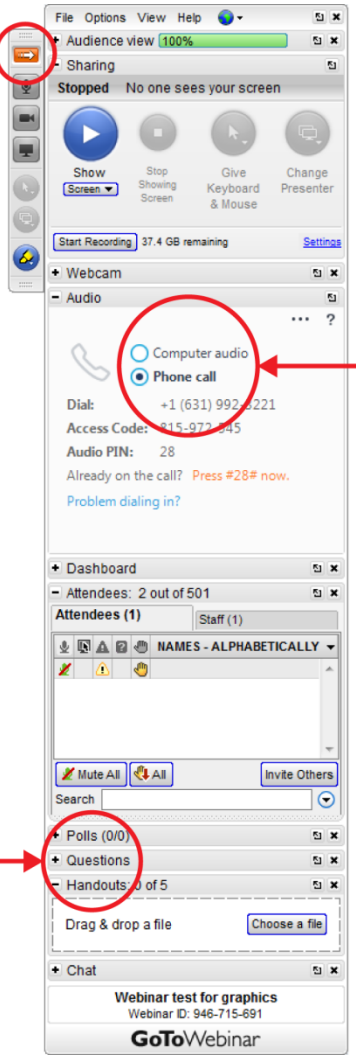
February 13, 2018

Building AMERICA
U.S. Department of Energy

Housekeeping

Open and close your control panel



Submit text questions

2 Audio Options:
Use telephone to dial into the call
OR
Use your computer's microphone & speakers ("VoIP")*

**If you are using the Mic and Speakers (VoIP) option, please make sure your computer has a microphone and it is enabled.*

Agenda

- Intro
- Project Introduction
  - Rocky Mountain Institute
- Team Project Update (2-3 minutes per project)
- IAQ Study Update (5 minutes)
- Lab Project Updates (10 minutes per lab)
- Wrap Up

Project Introduction

Up Next...

ROCKY MOUNTAIN INSTITUTE

Experimental Integrated Zero Energy Ready Retrofit Solution for Multifamily Renovations

- Develop a “building delivery system” for residential retrofits that provides a cost-effective zero energy ready solution
  - Minimally invasive
  - At least a 50% lower energy use intensity
  - Performs hygrothermaly

Building AMERICA
U.S. Department of Energy

Rocky Mountain Institute

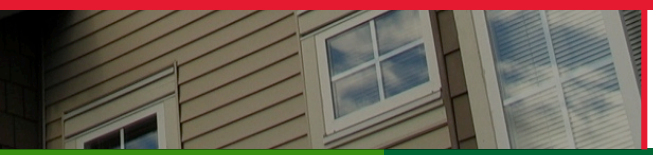
Partners

- Passive House Institute US
- Net Zero Energy Coalition

Topic Area

Moisture Managed High-R Envelopes

Success Metrics: Precipitate the market transformation needed to accelerate the wide-scale adoption of zero energy ready retrofits in the U.S. market.



Experimental Integrated Zero Energy Ready Retrofit Solution for Multifamily Renovations

Team

The project team consists of Passive House Institute US (PHIUS), Rocky Mountain Institute (RMI) and the Net Zero Energy Coalition (NZEC). This team builds on the design and performance expertise of PHIUS, combines it with RMI's business acumen, and leverages NZEC's supplier network.

This team is unique in that we are committed to the actualization of a business model that enables the market to consume net zero ready retrofits in a convenient, integrated fashion. We believe this is essential for unlocking the retrofit market.

Experimental Integrated Zero Energy Ready Retrofit Solution for Multifamily Renovations

The Problem (The Need/Challenge)

Problem Definition:

Buildings account for 70% of electricity use and 39% of emissions in the United States. Of these buildings roughly 125 million are residential units and they generate roughly 50% of buildings' emissions. This represents billions of dollars a year of wasted resources spent on energy with buildings operating sub-optimally and often delivering inferior levels of comfort, health, and wellbeing. But effective strategies that generate widespread residential consumer interest and adoption of deep energy retrofits have yet to be implemented. On the supply side this is due to several legacy issues including but not limited to:

- Industry discomfort with the perceived risk of these solutions
- Lack of industry knowledge on how to design and install deep energy retrofits
- Fragmented and complex delivery of retrofits
- One-off technical solutions for each building

Advice: If we are to increase customer desire and interest in adopting deep energy retrofits we must meet consumers where they are by offering convenience, affordability, and speaking to their desires and needs.

Experimental Integrated Zero Energy Ready Retrofit Solution for Multifamily Renovations

The Solution

Nested within a larger business model this team seeks to mitigate these issues through the development of an exterior retrofit solution and building delivery system that is replicable and relevant to a large inventory of similar homes in a mixed humidity or cold climate. Through this development process we will be able to generate standards and guidelines that demonstrate how industry can continue to innovate integrated retrofit solutions while mitigating structural, hygrothermal, and performance risk.

Experimental Integrated Zero Energy Ready Retrofit Solution for Multifamily Renovations

Advantage, Differentiation

- Integrated solution including appropriately sized mechanical systems
- Prefabricated, offering less points of asset risk and installation error
- Mass-customizable offering a plug and play solution

For Contractors: Lowers risk and relieves materials and installation decision making

For Consumers: Aesthetically pleasing update, reduces brain damage from the renovation/retrofit process

Impact

- Fabricating and testing one highly generic panelization system that is relevant to many buildings in that climate zone means many more retrofits can be conducted
- Guidelines and standards will support industry in developing many other similar solutions, catalyzing a market
- Go/No Go: Building owner's willingness to go forward with the design

Thank You

Rocky Mountain Institute
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Project Updates

Up Next...

BUILDING ENVELOPE MATERIALS

Building America
U.S. Department of Energy

Building Envelope Materials

Partner

Massachusetts Clean Energy Council

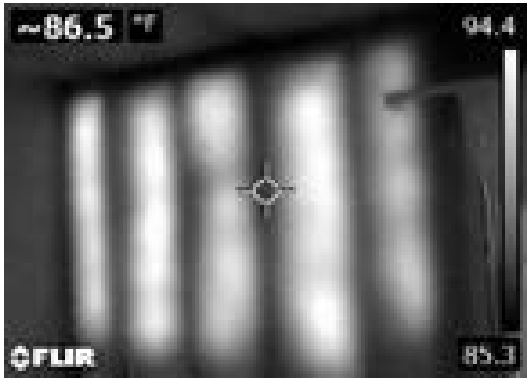
Topic Area

Moisture Managed High-R Envelopes

Success Metrics: No removal of ceiling surface, adds >R12 with few/no voids and provides perm rating <1.

Validation Study of Experimental Insulating and Air-Sealing Technology for Enclosed Roof Cavities

Modify BEM's minimally invasive Micro-Injection Foam technology for retrofit insulation of enclosed roof cavities (i.e. cathedral ceiling, dormer roofs, flat roofs)



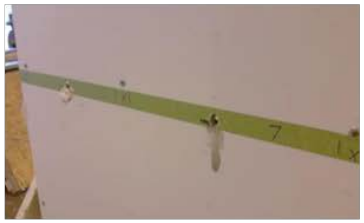
2 Big Enclosed Roof Cavity (ERC) Problems

1. ERC's Leak Heat

2. ERC's Prone To Ice Dams

Problem: In ERC's, calibration based on shot time can lead to overfilling or underfilling
Cause: Ambient temp change >> Viscosity change >> Over/underfilling of cavity

Step 1: Site-Prep



Find studs, measure, mark, drill

Insert tubes with a guide rod

Step 2: Calibration

5-10 s calibration shot

IR camera mark foam rise; **determine fill rate**

Step 3: Injection

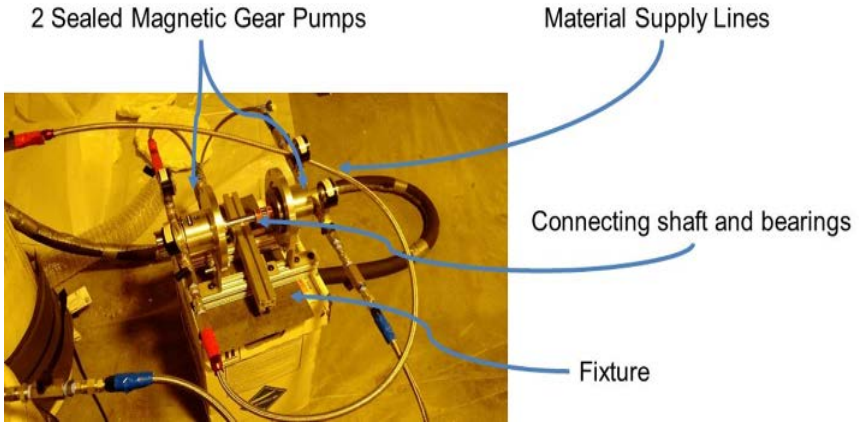
Multiple 1-foot shots to fill the lower portion;

Repeat for upper portion;

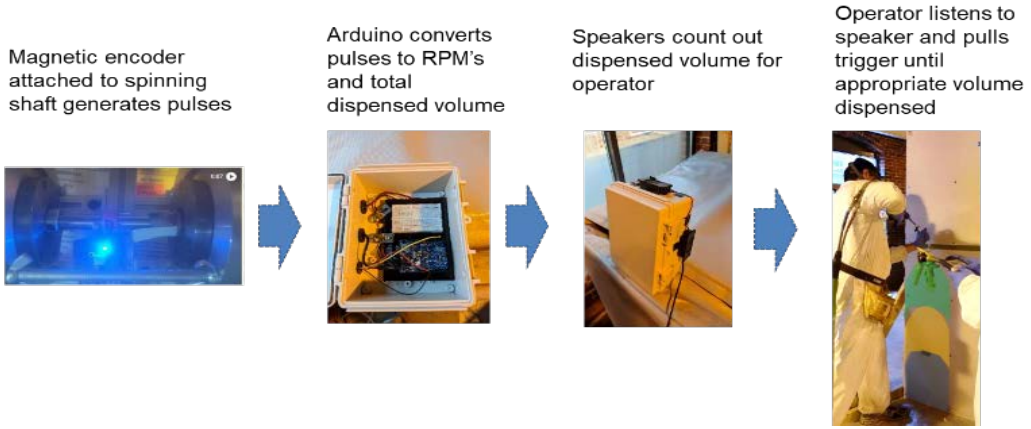
Finishing shot.

Solution: The “In-Situ Proportioner” (ISP)
Reason: Calibration with the ISP is based on shot volume not shot time

The ISP is two gear pumps linked with a common axle



Calibration is based on number of axle rotations (i.e. volume)



Project Updates

Up Next...

bsc Building Science Corporation

Monitoring of Unvented Roofs with Diffusion Vents and Interior Vapor Control in a Cold Climate

- Determine if fibrous insulation can be used to create moisture-safe roof assemblies in a cold climate
- Examine effect of insulation materials (fiberglass vs. cellulose), effect of air leakage imperfections, effects of elevated interior relative humidity levels, necessity (or lack thereof) for the diffusion vent detail, and effect of vapor control materials
- Publish research results, which will include recommendations on assemblies (if any) that provide robust moisture control, thus allowing for widespread adoption without fears of disproportionate building failures.

Team and Partners

Building Science Corporation w/North American Insulation Manufacturers Association (NAIMA), NuWool, DuPont, Owens Corning, Cosella-Dörken, K. Hovnanian Homes

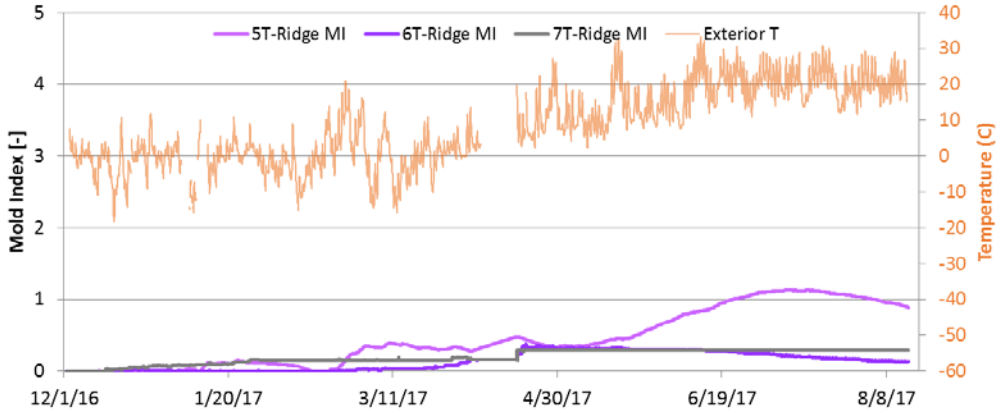
Topic Area

Moisture Managed High-R Envelopes

Success Metrics: This project's moisture-managed fibrous insulation solution can achieve code and above-code performance (R-49) while reducing material costs and energy use.

Winter 1 (Year 1) Conclusions

- **Moisture concentration at ridge-RH & MC, condensation**
  - Many roofs with extended 100% at ridge
- **Lower portions and south-facing roofs much safer**
- **Roofs with diffusion vent & variable-perm vapor consistently safest**
  - Allows for release of moisture at accumulation point
- **“Flash and blow” (spray foam + cellulose) roof safe**
- **Mold Index shows low growth, but high MCs-durability?**



Winter 2 Current Work

- **Three Year Project: planned operating conditions:**
  - Winter 1: "Normal" interior conditions
  - Winter 2: Elevated RH (50% constant): running now
  - Winter 3: Air leakage into rafter bays
- **Poor-performing roofs (no diffusion vents) modified:**
  - Retrofitted "small" diffusion vents (½ surface area)
  - Retrofitted "tight" diffusion vents (25 perms vs 300 perms)
  - Variable-perm interior vapor retarders (controlling experimental variables)

Project Updates

Up Next...

cee
Center for Energy and Environment

Building AMERICA
U.S. Department of Energy

Center for Energy and Environment

Partners

- University of California – Davis: Western Cooling Efficiency Center
- Building Knowledge, Inc.
- University of Minnesota Twin Cities: Cold Climate Housing Program
- Aeroseal, LLC

Topic Area

Moisture Managed High-R Envelopes

Success Metrics: Radically improve quality assurance of envelope sealing and significantly reduce labor costs compared to traditional air-sealing approaches.

Aerosol Technology to Satisfy Envelope-Sealing Requirement

- Simultaneously measures, locates, and seals leaks in a building remotely
- Evaluate several sealing approaches with multiple builders to establish procedures that builders can use to easily integrate the aerosol sealing technique into standard construction practices and reduce the cost of less-effective conventional sealing
- Produce more consistent sealing performance and improved air tightness in an economic manner.

Project Update

- **2 Minnesota and 2 California Builders**
- **Sealing strategies**
  - Builders are meeting tightness requirements
    - Market niche: houses tighter than requirement - more reliably
    - What current sealing can be eliminated
  - DR Horton/MN
    - Seal before drywall & wall insulation
    - Eliminate interior poly on walls and air-tight electric boxes?
    - Can you seal during a Minnesota winter?
  - Grupe Homes/CA: high performance attics
    - Seal before drywall, (1) before roof deck/rim foam and (2) after attic spray foam
    - Eliminate can foam sealing + possibly drywall gaskets

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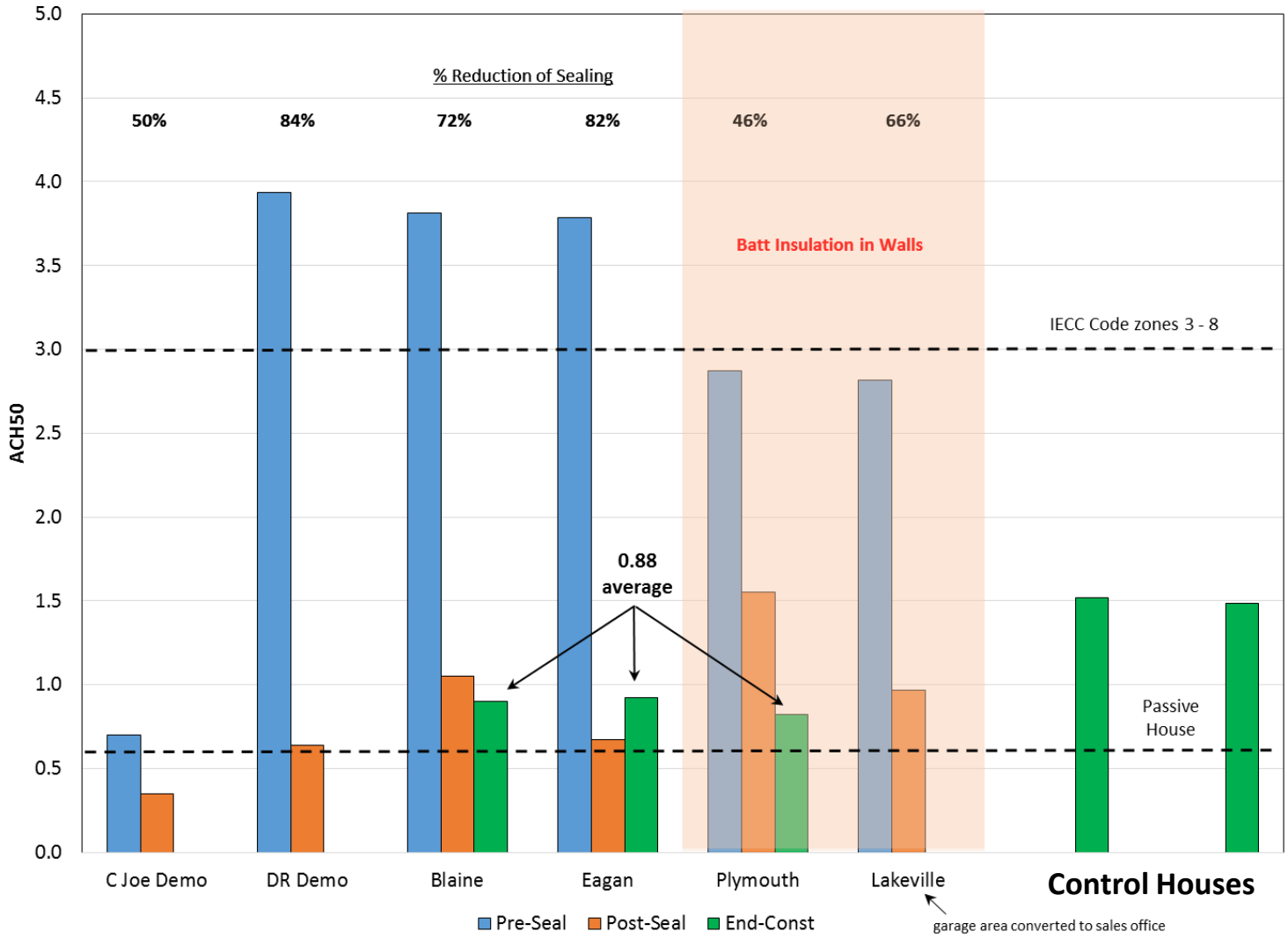
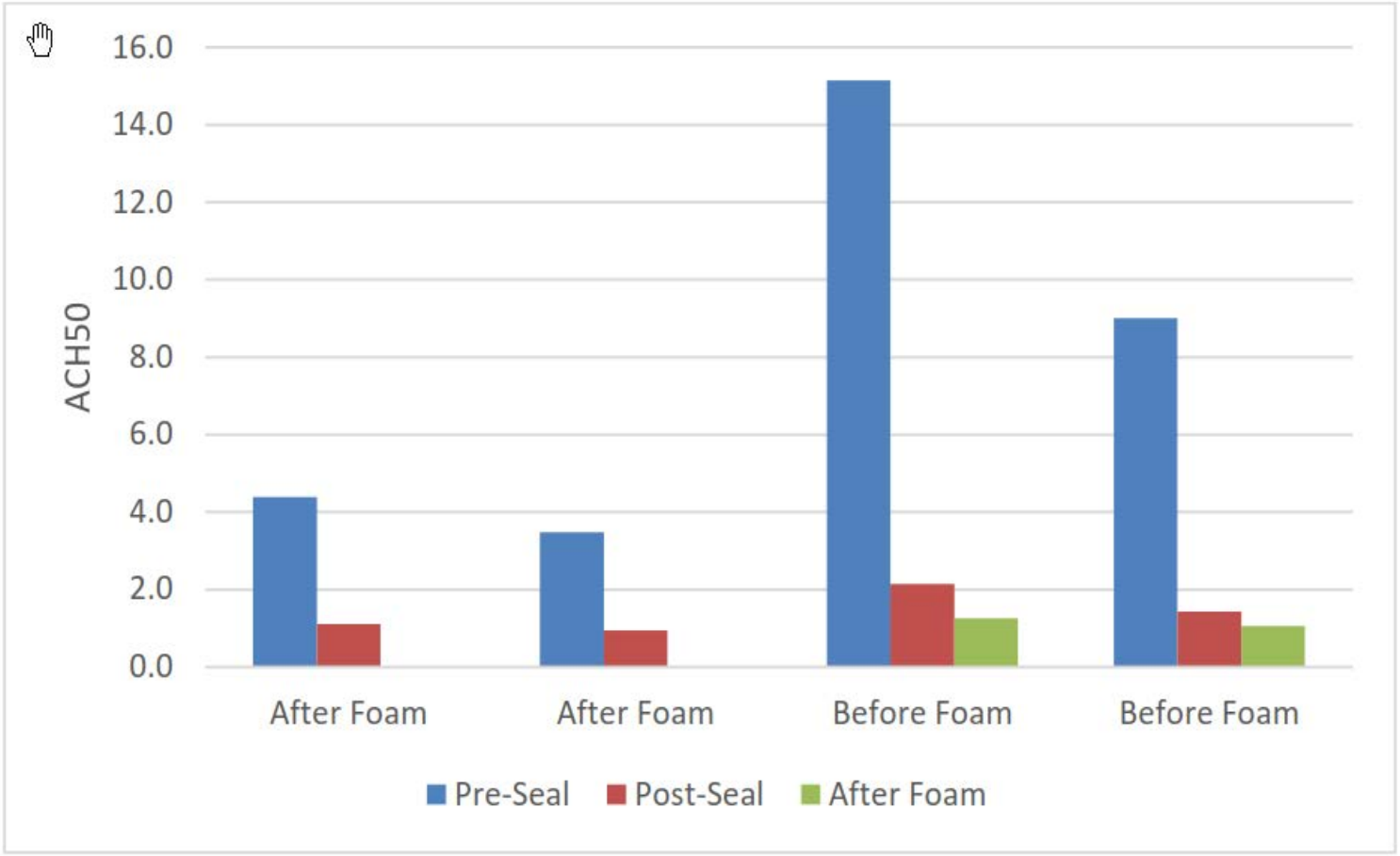
Initial Results: First Minnesota Builder



Seal before drywall & wall insulation

Initial Results: First California Builder

AeroBarrier more effective than spray foam



Seal before and after spray foam under roof deck

Project Updates

Up Next...

Fraunhofer

Physics-Based Interval Data Models to Automate and Scale Home Energy Performance Evaluations

Fraunhofer Center for Sustainable Energy Systems CSE

Partners

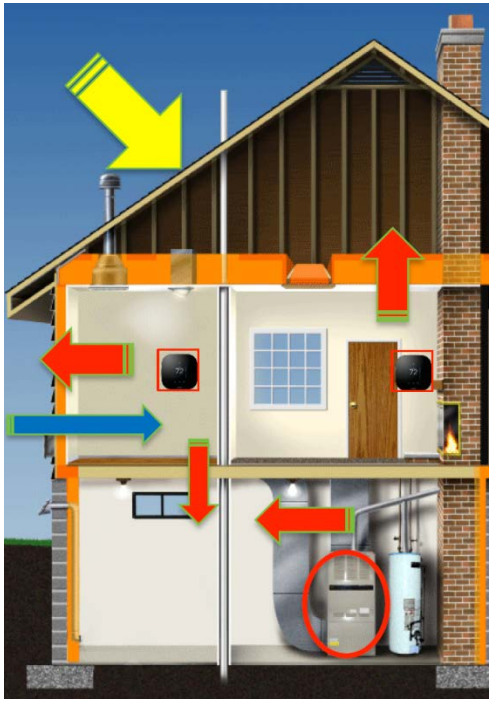
- Eversource Energy
- Holyoke Gas and Electric
- National Grid

Topic Area

Moisture Managed High-R Envelopes

Success Metrics: Increase the uptake of enclosure and heating system retrofits and reduce the number of energy assessments conducted in homes unlikely to benefit from retrofits, thereby increasing energy savings and lowering program costs.

- Remotely identify the homes (~20%) that would benefit most from at least one target retrofit measure to reduce space heating energy consumption: insulation, air sealing, heating system upgrade
- Accurately predict the energy savings of the target retrofit measures and evaluate the realized energy savings (remote EM&V) for individual homes
- Increase the rate of onsite home energy assessments for homes with one or more target retrofit measures by offering custom recommendations
- Increase the fraction of onsite audits resulting in implementation of the target retrofit measures



Project Approach and Progress

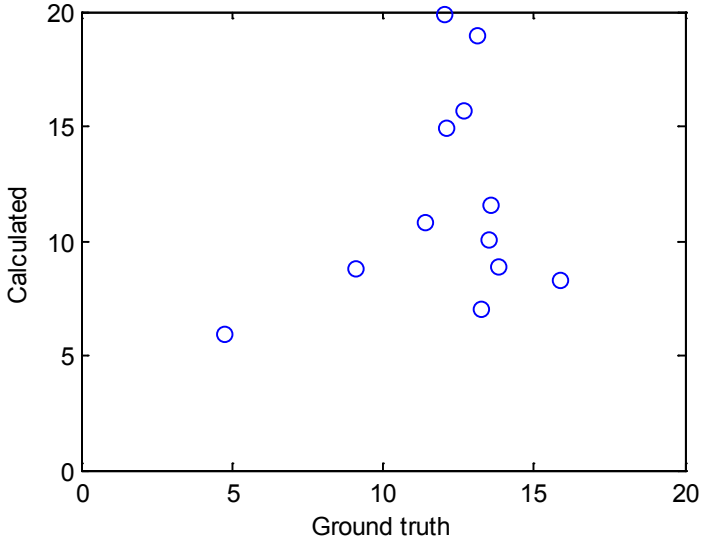
- Develop coarse-grained gray-box models
  - Connect CT data & home thermal parameters
- Leverage existing and new utility data
  - ~80 homes: CT data, home assessments, interval gas and electric meter data
  - Several hundred homes: CT data + home energy evaluations
- Apply to homes/systems of increasing application complexity over project life
  - Regular gas furnaces to condensing boilers
  - Single-zone to multi-zone homes
- Apply Machine Learning to increase accuracy
- Use models to:
  - Estimate home thermal parameters
  - Characterize home-specific classes of retrofit opportunities (e.g., insulation upgrade)
  - Predict home-specific retrofit energy savings

Data Acquisition Progress Update:

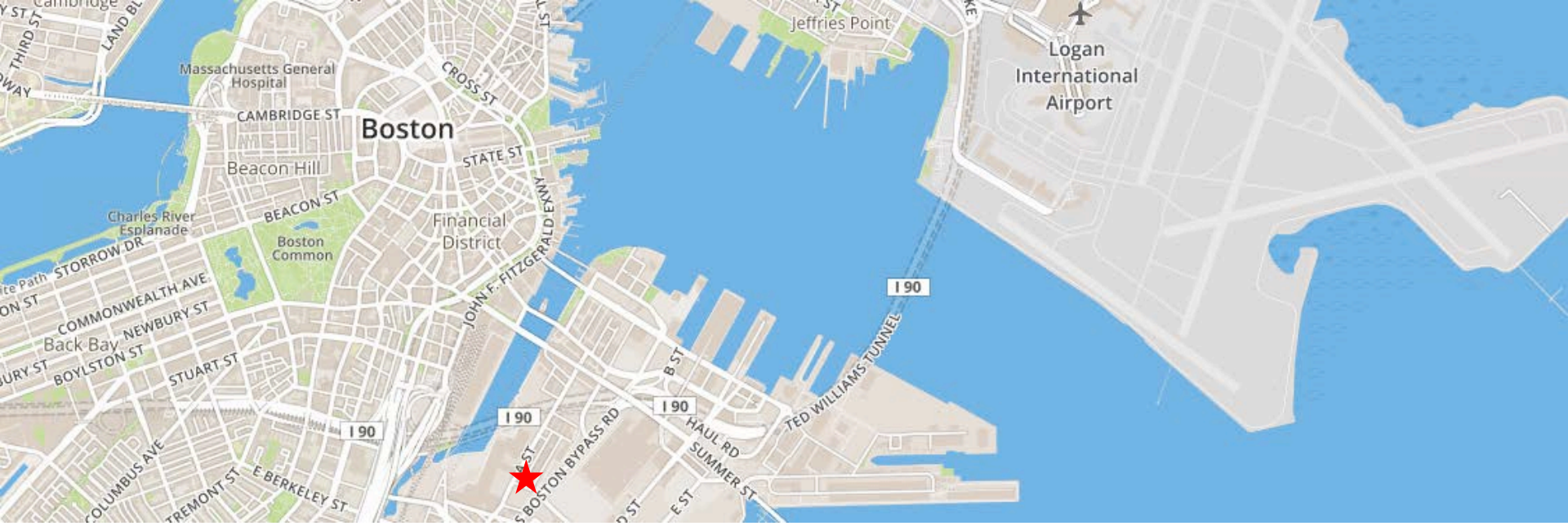
- Just obtained CT-, billing- and home-assessment data for 200+ homes
- Additional data for another 200+ homes coming soon
- Blower-door test results for select homes coming soon

Technical Progress update:

- Algorithms for whole homes developed
- Tested on previously obtained data for 12 homes
- Issues with ground truth (only R-values and efficiencies seem to be OK)



Estimated vs. ground truth overall R-values (external walls + attic) for twelve homes



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Project Updates

Up Next...

gti®

GAS TECHNOLOGY INSTITUTE

Energy Savings with Acceptable IAQ through Improved Air Flow Control

Gas Technology Institute

Partners

- University of Illinois
- Midwest Energy Efficiency Alliance
- Chitwood Energy Management
- National Center for Healthy Housing

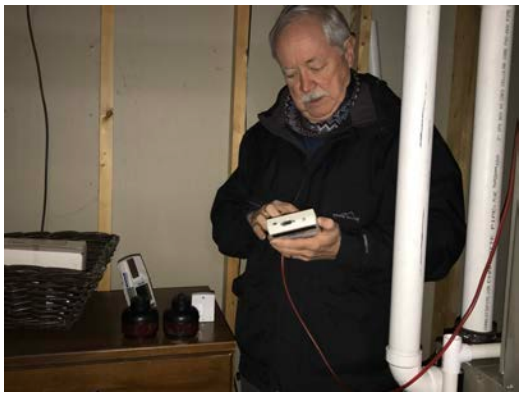
Topic Area

Smarter Indoor Air Quality Solutions

- Developing integrated assessment to measure the impact of controlled HVAC duct losses and system flow, infiltration, and ventilation options on IAQ and energy savings
- Conducting field tests of 20 control homes and 20 treatment homes in cooperation with field practitioners
- Energy measurements and multiple IAQ measurements including CO_2, radon, formaldehyde, humidity

Status:

- Expanded Field Test Plan eligibility criteria in Q3'17 to broaden pool of available homes; focus on unfinished basements and crawlspaces.
- Recruited and trained five home performance contractor teams
- Implemented homeowner and contractor incentives
- Conducted direct outreach to identify leads
- Instrumented six homes, with three more enrolled



Success Metrics: Through systematic management of airflows, provide guidance for improved energy savings with the same IAQ or improved IAQ with the same energy savings.

Project Updates

Up Next...

Home Innovation RESEARCH LABS™

Performance of Windows in Walls with Continuous Insulation

Home Innovation Research Labs

Partners/Advisory Group:

- McIntyre Builders
- Dow Building Solutions
- Milgard
- NAHB
- Lennar
- Pella
- Brinc Building Products
- Rmax
- Owens Corning
- JELD-WEN
- American Chemistry Council
- AAMA
- WDMA

- Develop objective performance data based on full-scale laboratory testing and establish applicability boundaries for conventional installation method (window installed directly over foam sheathing).
- The focus is on capturing performance of a broad range of window and foam sheathing installation configurations. Variables include window type, window weight, foam material, foam sheathing thickness, etc.

Topic Areas: High Performance Moisture Managed Building Envelope Systems; High Performance Envelope Systems

Success Metrics: The results of this project will be used to develop window installation solutions that can be broadly accepted by industry stakeholders.

Test / Observation Program

Program developed with Advisory Group input over nine-month period, and will be performed on full-size wall specimens.

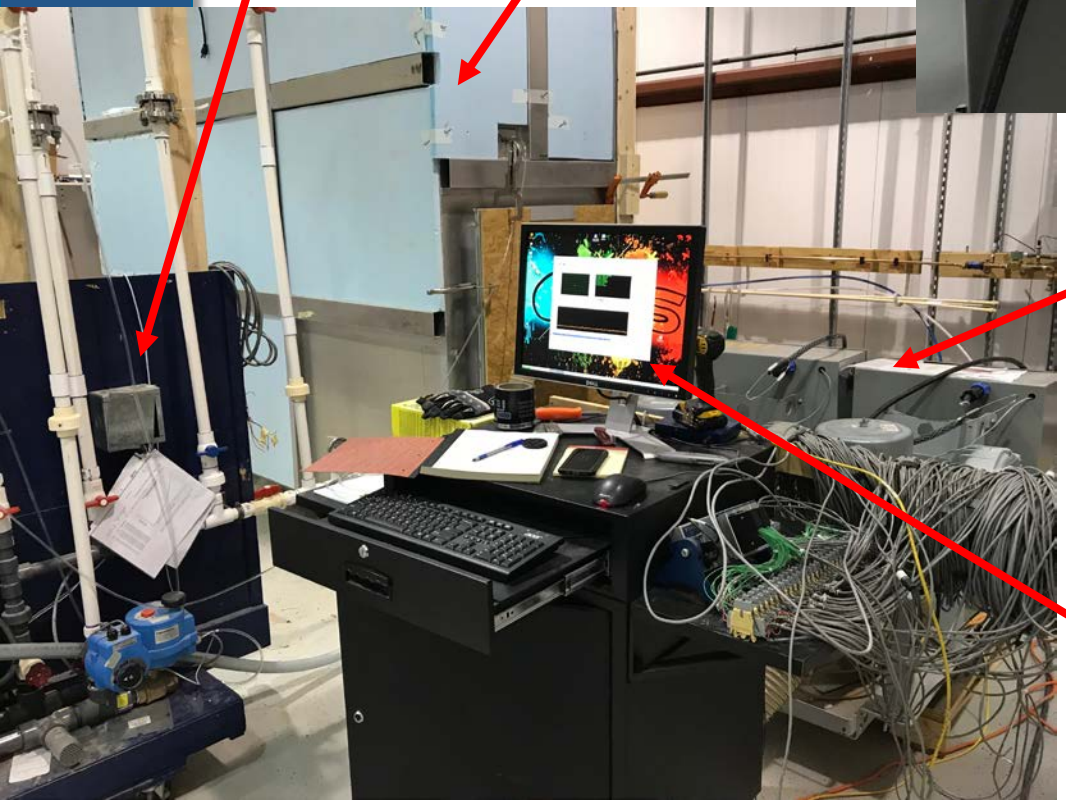
Step	Test / Observation	Ref. Std.
1	Initial water penetration resistance test (two part: step and cyclic, 5.43 psf max)	ASTM E331 and ASTM E547
2	Temperature cycling (14 durability cycles, 12 hours each, range from 0°F to 120°F)	ASTM E2264 Method B Level 1
3	Service-condition wind loading (10 cycles at 20 psf, positive then negative direction)	Adapted from ASTM E330
4	Service-conditioned water penetration resistance test	ASTM E331 and ASTM E547
5	Vertical displacement (gravity load) monitoring (6 months)	Lab measurement
6	Final water penetration resistance test	ASTM E331 and ASTM E547
7	Structural performance testing (wind loading, 1.5 x DP, max 37.5 psf, positive and negative)	ASTM E330

Proposed Matrix of Wall Specimens

#	Detail	#	Detail
1	Housewrap and OSB	10	2” of 15 psi XPS
2	#15 felt and OSB	11	1.5” or 3” of 15 psi XPS
3	ROESE	12	Mulled casement window
4	1” of 15 psi XPS	13	Mulled 2H window
5	1” of 25 psi XPS	14	Mulled 2H window, heavy
6	1” of 15 psi XPS no OSB	15	Large slider window
7	1” of 15 psi EPS	16	Slider over two layers (total 3.5”) of 15 psi XPS
8	1” of 16 psi foil-faced PIR		
9	1” of 15 psi XPS, flimsy flange	17	Full interior trim

Home Innovation RESEARCH LABS™

Water penetration testing



Thermal cycling and service condition wind loading box

Chiller fans

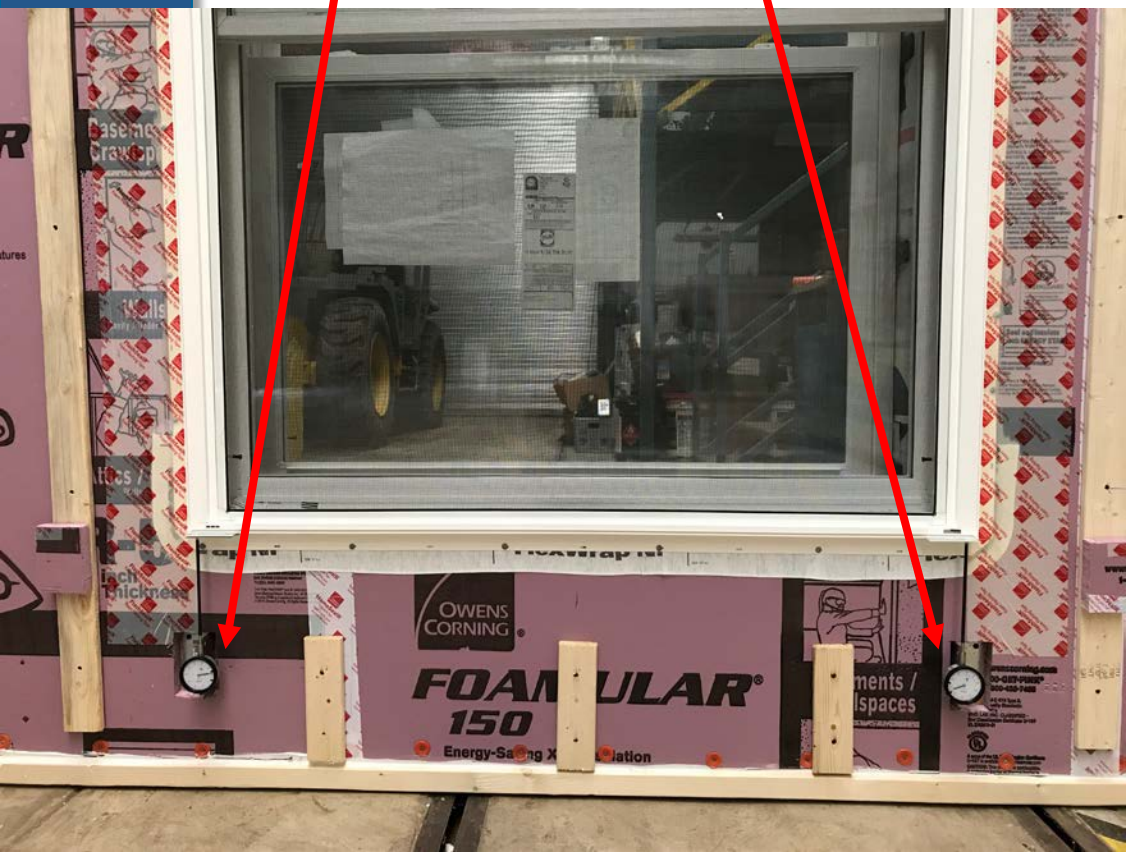
Heaters

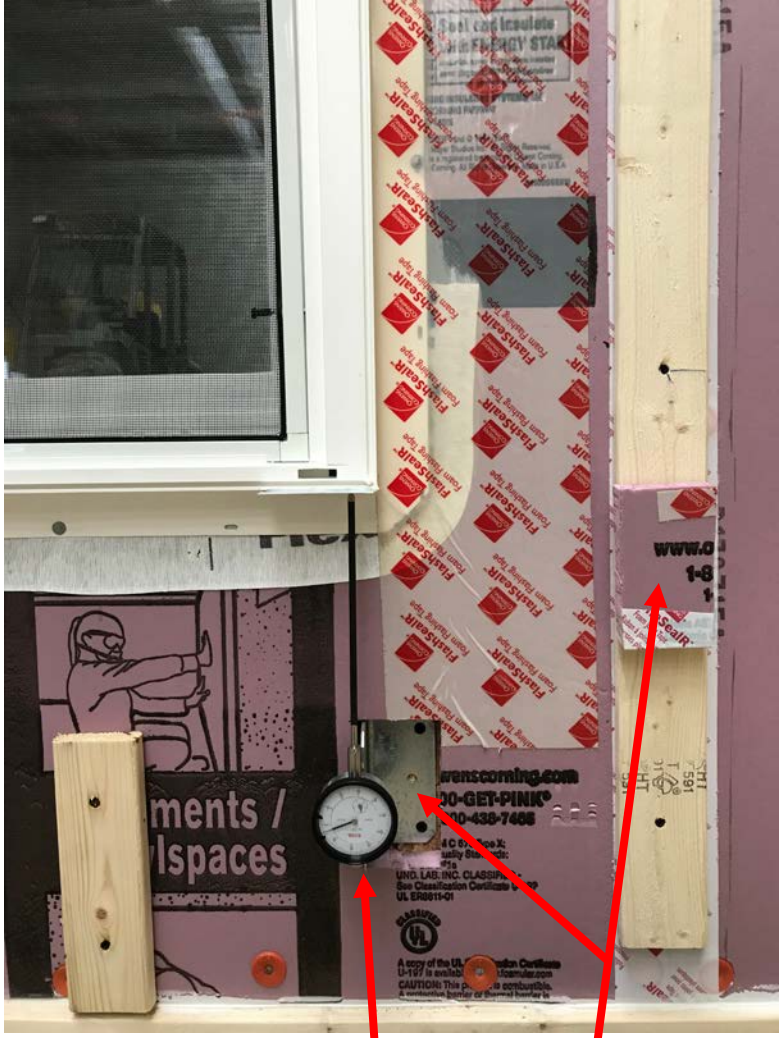
Plastic sucked in during service loading

Furring strips to hold foam in place when wall exterior faces into box and specimen undergoes suction

Vertical displacement monitoring

Dial gauges at window corners





Mounted to stud

Foam cut-out to be re-installed for final water/wind testing

Advanced HVAC Humidity Control for Hot-Humid Climates

Home Innovation Research Labs

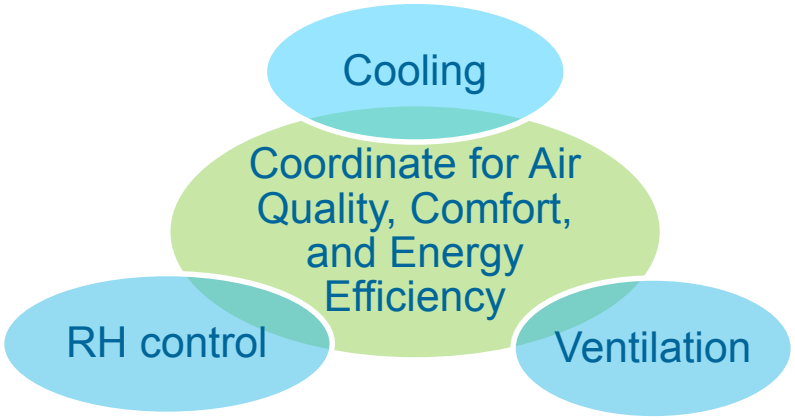
Partners

- Goodman Manufacturing
- Aprilaire® Research Products
- Wrightsoft®
- Air Conditioning Contractors of America (ACCA)
- National Association of Home Builders (NAHB)
- K. Hovnanian Companies
- David Weekley Homes
- AB Systems, LLC
- National Renewable Energy Laboratory (NREL)

Topic Areas

Optimized Comfort Systems; High Performance Ventilation Systems & IAQ Strategies

- **Purpose**: Develop and validate an integrated humidity and ventilation control solution that improves IAQ, comfort, and energy performance for low-load homes in hot-humid climates.
- **Solution Strategy**: Coordinate the cooling, dehumidification, and ventilation functions of central HVAC systems to capture energy savings and improve comfort.
  - Re-evaluate the AC system to optimize dehumidification during part-load conditions (enhanced dehumidification).
  - Develop a control strategy to integrate supply-type ventilation prioritized to operate during on-cycles (prioritized ventilation).
  - Develop metrics to quantify system performance including energy savings and cost-effectiveness.



Success Metrics: Provide a turnkey solution to simplify the transition to high-performance ventilation and humidity control systems.

Project Update

- Milestones
  - Submitted the Project Management Plan – accepted.
  - Established the Project Team – conducted meetings and calls with manufacturers and builders to kick-off the project and develop the prototype HVAC system.
  - Submitted the draft research plan
- Developed a draft specification for the prototype system
  - Established design parameters, test house criteria, HVAC equipment type, and testing and monitoring criteria
  - Identified equipment variables and initial settings for enhanced dehumidification.
  - Identified strategy and control integration variables for prioritized ventilation.
- Selected a prototype system test house (two are planned)
  - Description: 2,536 SF, 2-story, SOG, vented attic, heat pump.
  - Location: Savannah, GA, IECC CZ-2A (planned test house 2: Houston, TX).
  - Reviewed the Manual J load calculation and equipment selection.
- Next Steps
  - Conduct modeling to predict loads/op-costs and fine-tune the design.
  - Meeting with manufacturers to fine-tune controls integration.
  - Team meeting to finalize the prototype HVAC system design.

Project Updates

Up Next...

The Levy Partnership

Integrated Design: A High-Performance Solution for Affordable Housing

The Levy Partnership, Inc.

Partners

- Habitat for Humanity International
- Systems Building Research Alliance
- Manufacturers

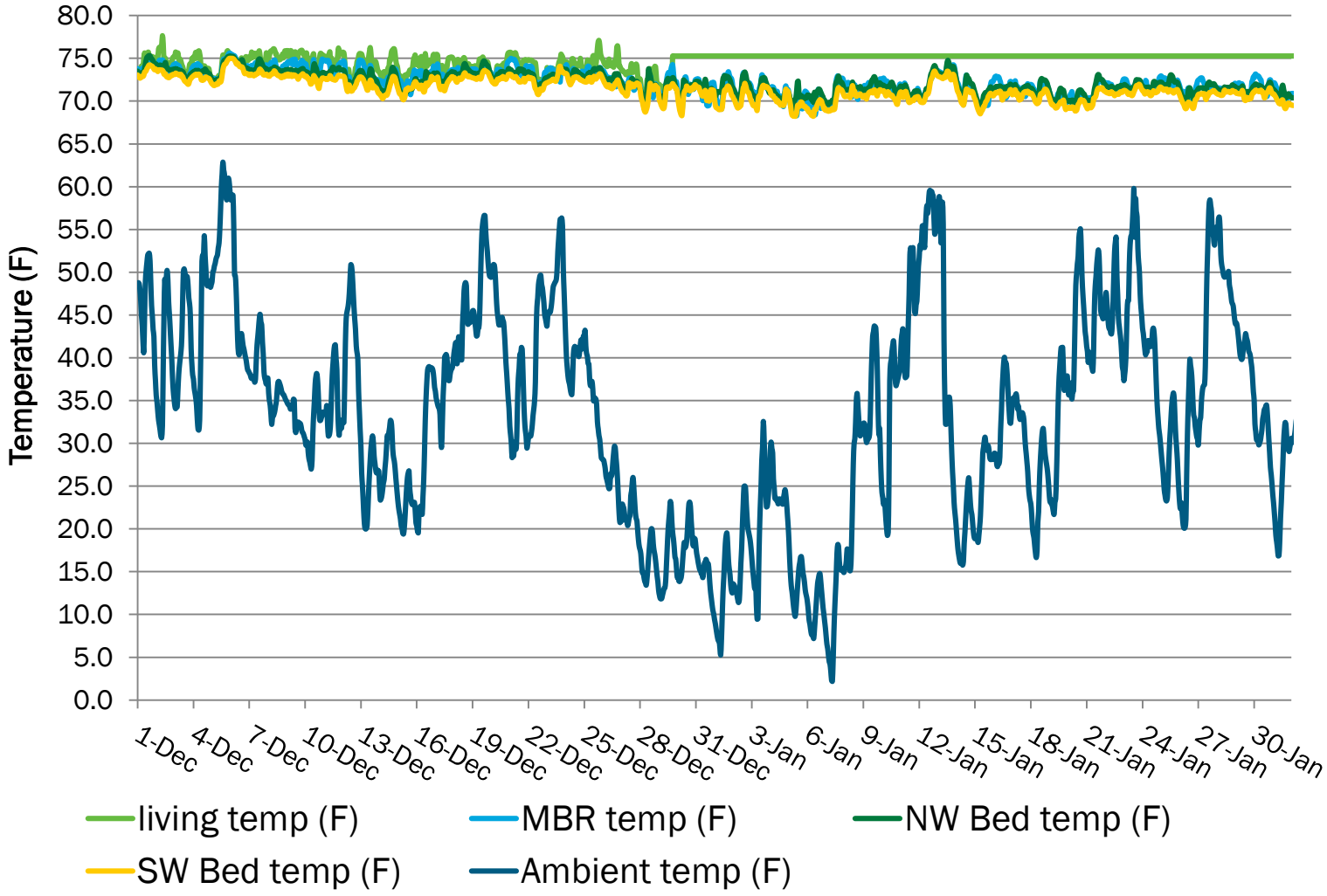
Topic Area

Optimized Low-Load Comfort Solutions

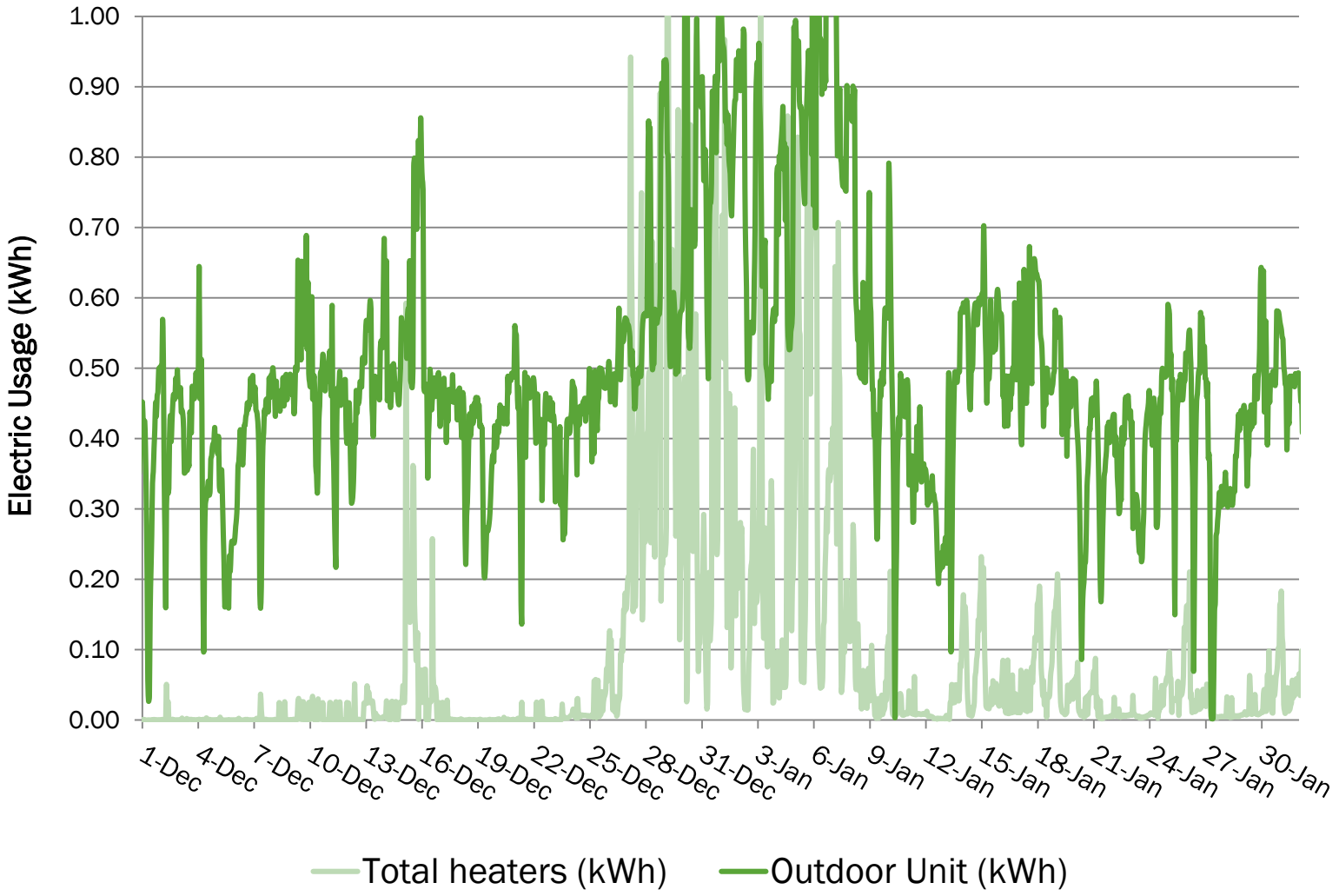
Success Metrics: Reduce space conditioning energy use by 50% relative to IECC 2009 in Habitat- and factory-built homes in mixed-humid and cold climates while minimizing costs.

- Combine a high-performance enclosure, ductless mini-split heat pump, transfer fans, and ventilation
- Monitor three test homes, occupied and unoccupied, for 1 year+; TRNSYS and BEopt models calibrated to field data
- Develop a high-performance integrated design for affordable housing (Habitat for Humanity- and factory-built)

Eatontown House Occupied Temperatures



Eatontown Heating System Usage

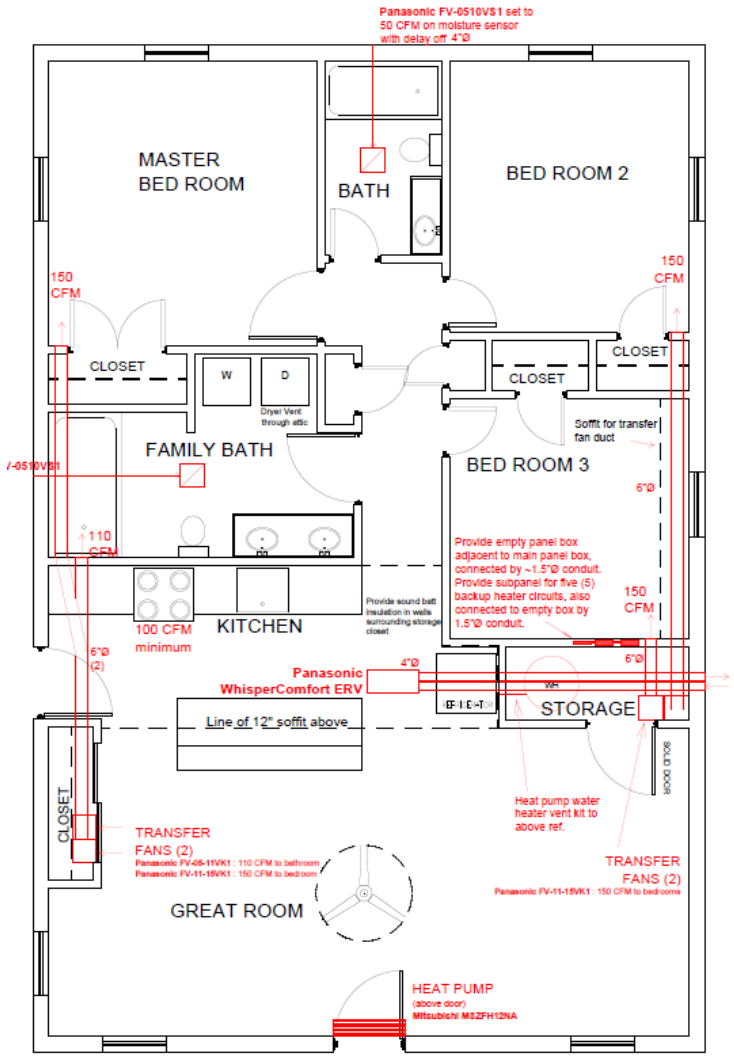


Share of space heating energy consumption

Heat pump: 86%

Backup resistance: 14%

Worcester House Update



Project Updates

Up Next...

Newport Partners L.L.C.

Development of Laboratory Test Methods for Low-Cost Indoor Air Quality Sensors

Newport Partners, LLC

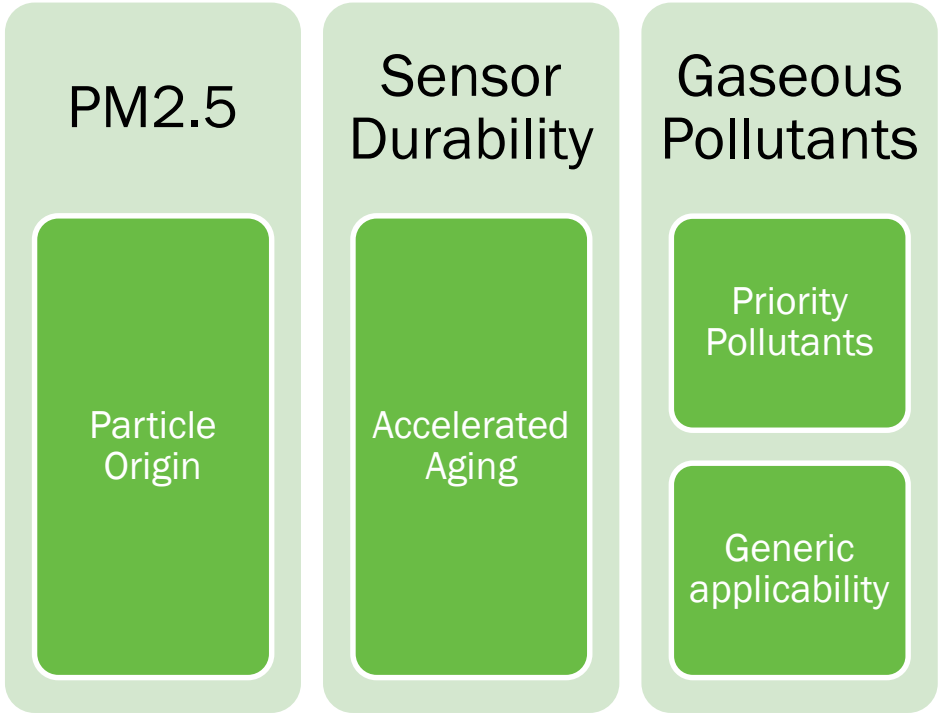
Partners

- South Coast Air Quality Management District
- Home Ventilating Institute

Topic Area

Smarter Indoor Air Quality Solutions

- Develop laboratory test methods for performance verification of low-cost IAQ sensors that establishes a consensus standard
- Provide technical support to industry stakeholders during the development of an ASTM standard based on the new laboratory test methods



Success Metrics: Establishing a consensus test method for verifying the performance of low-cost IAQ sensors will open the door to confident and optimized specification of smart ventilation systems.

Advisory Work Group

Lab/Research

- South Coast Air Quality Management District
- LBNL
- Texas A&M

Ventilation

- Home Ventilating Instute
- Healthy Air Research and Certification Authority
- Air King
- Broan-Nutone

Sensor/Device Manufacturers

- Alphasense
- Kaiterra
- Foobot
- Airthinx
- Spec Sensors
- Purple Air

Government

- EPA
- NIST

ASTM D22.05 Subcommittee members

- EPA
- Zefon
- American Petroleum Institute
- Battelle
- Collaborative for High Performance Schools
- US Gypsum
- Consultants

Building AMERICA
U.S. Department of Energy

Newport Partners, LLC

Partner: Broan

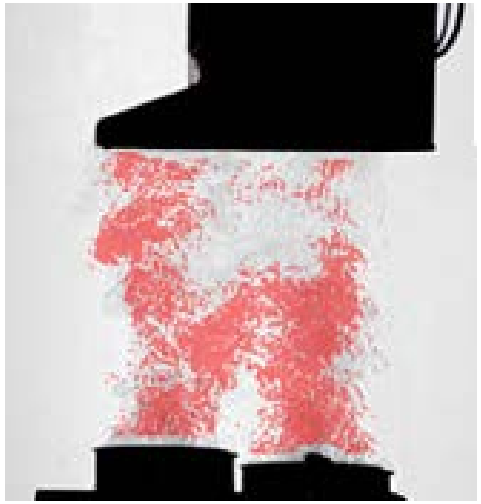
Topic Area

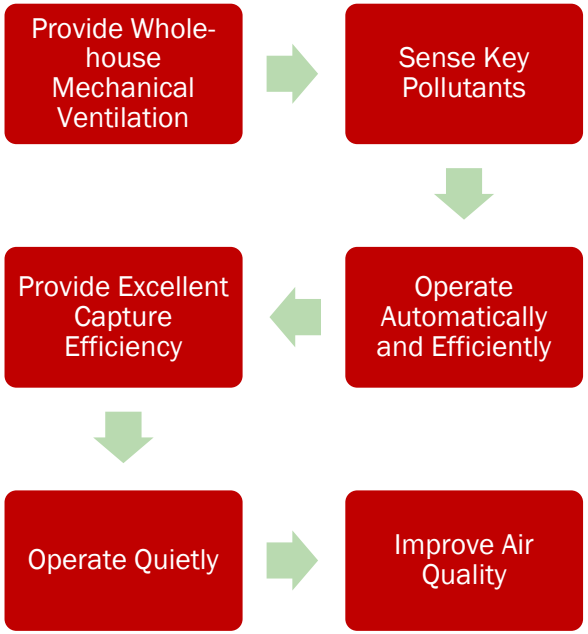
Smarter IAQ Solutions

Success Metrics: Enable tighter homes, ZERH specs, and better IAQ, extend lives, and save billions of dollars in health-related costs annually by addressing this major indoor pollutant source.

Development of a Smart Range Hood

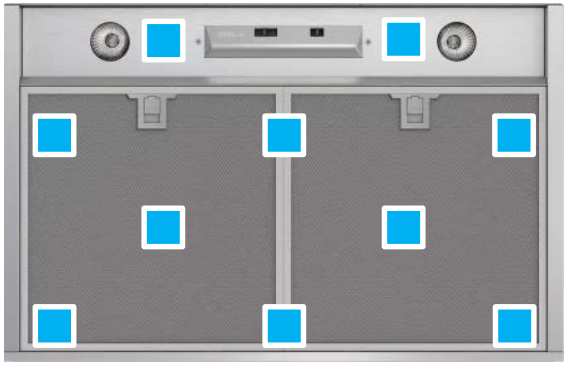
- Develop, test, and demonstrate a Smart Range Hood
  - Quiet: ≤ 1 sone at 150 cfm
  - Sensing: Primary pollutants
  - Automated: Hands-Free
  - Effective: ~100% CE
  - Efficient: 1.5x more efficient than ENERGY STAR
  - Affordable: mid-market
- Integrate smart features in future, commercially available range hoods



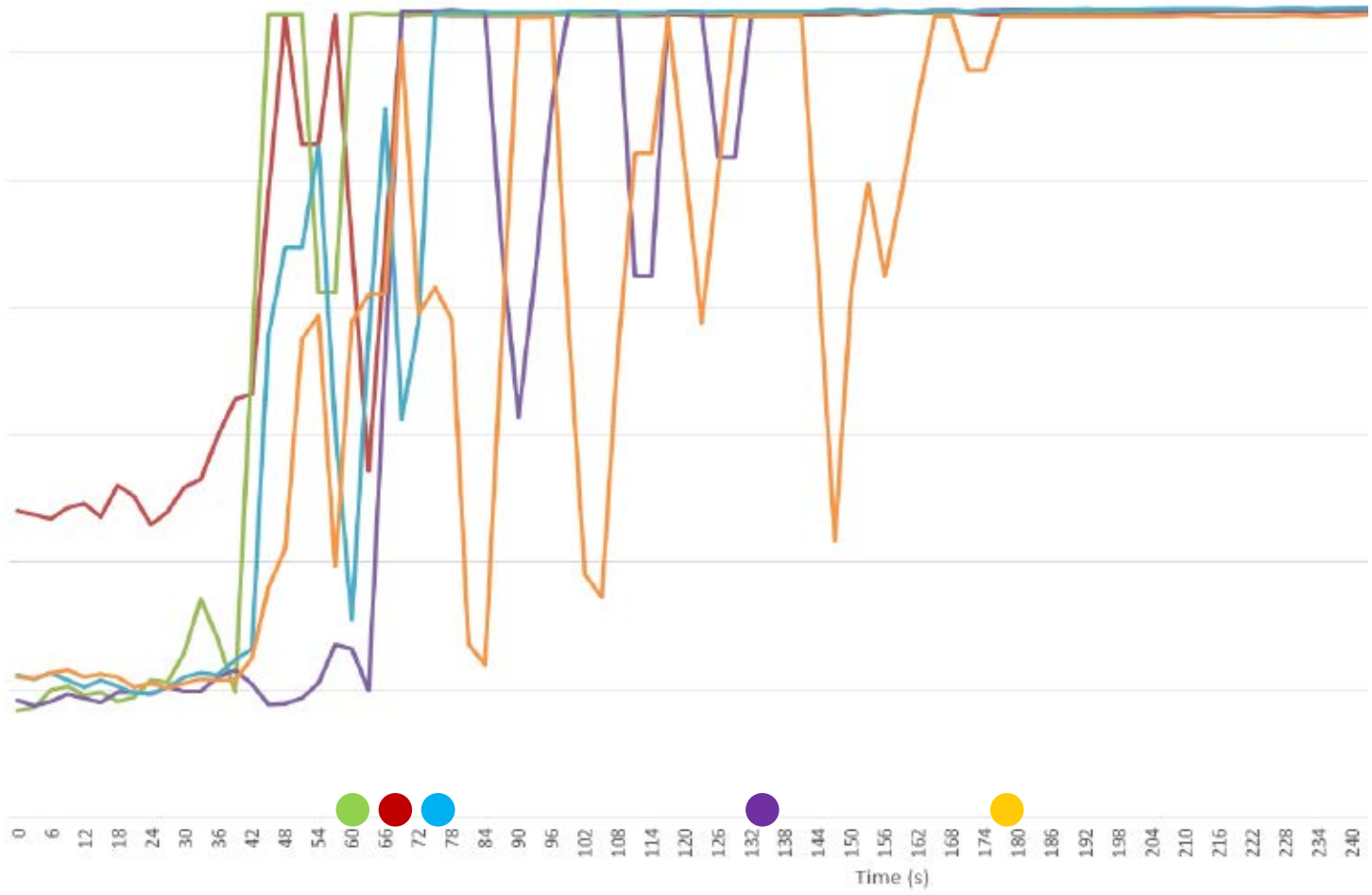


Progress

- Sourced low cost sensors
- Developed proof of concept
- Optimized sensor location

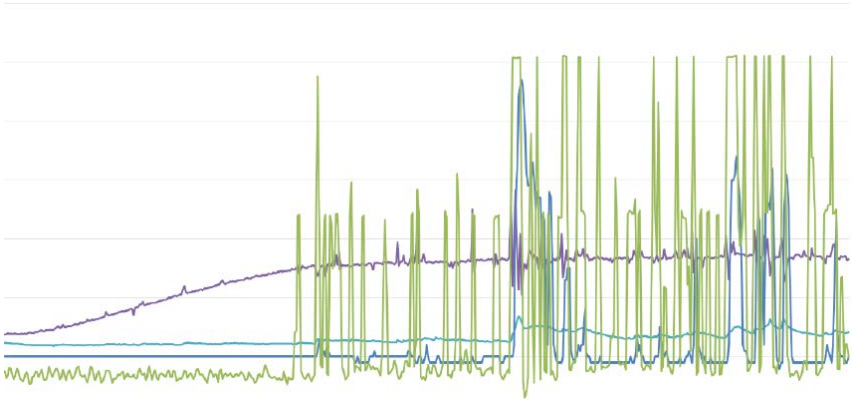


Sensor Location Affects Response Time and Signal Consistency



Challenges

- Durability
- Accuracy
- Responsiveness & False Positives
- Sensor redundancy
- Providing smooth responses to dynamic cooking events
- Perception/acceptability



Next Steps

- Sensor integration
- Control algorithm development
- Lab tests
- Field tests

Project Updates

Up Next...

Southface

Performance-Based IAQ and Optimized Ventilation

- Monitor four new-construction homes in Charleston, SC with “smart” energy recovery ventilators.
- Assess occupant comfort between continuous ventilation and time-varying ventilation modes toggling biweekly.
- Develop ERV field test protocol.
- Examine indoor air quality between the two ventilation methods using low-cost IAQ sensor packages for PM2.5, CO2, T/RH and radon.

Southface Energy Institute

Partners

- Underwriters Laboratory
- Beazer Homes
- Illinois Sustainable Technology Center
- Venmar
- Senseware

Topic Area

Smarter Indoor Air Quality Solutions

Success Metrics: Develop an ERV field test protocol, and validate that smart-ventilation that considers outdoor air conditions maintain occupant comfort, achieve annual HVAC energy cost savings (compared to central fan integrated supply systems) and agree with newly-developed BEopt models for time-varying ventilation in humid climates.

Performance-Based IAQ and Optimized Ventilation

Southface Energy Institute

Partners

- Underwriters Laboratory
- Beazer Homes
- Illinois Sustainable Technology Center
- Venmar
- Senseware

Topic Area

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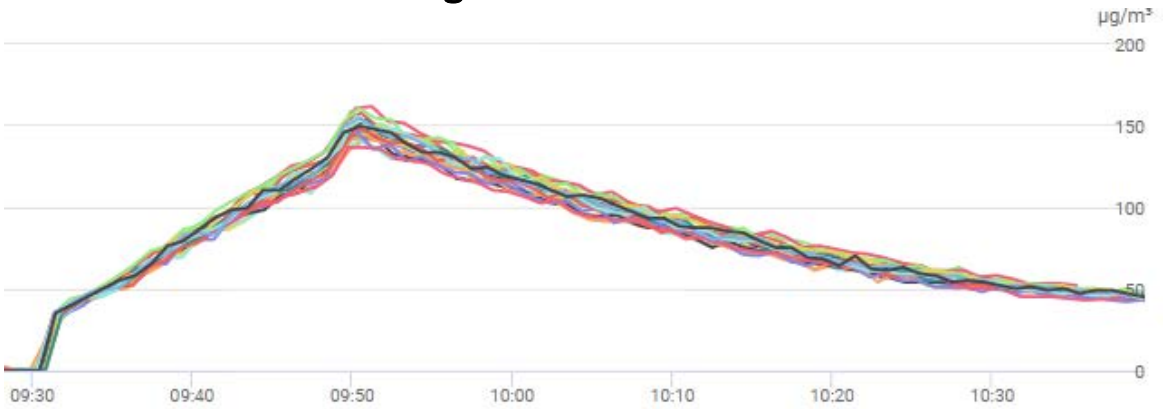
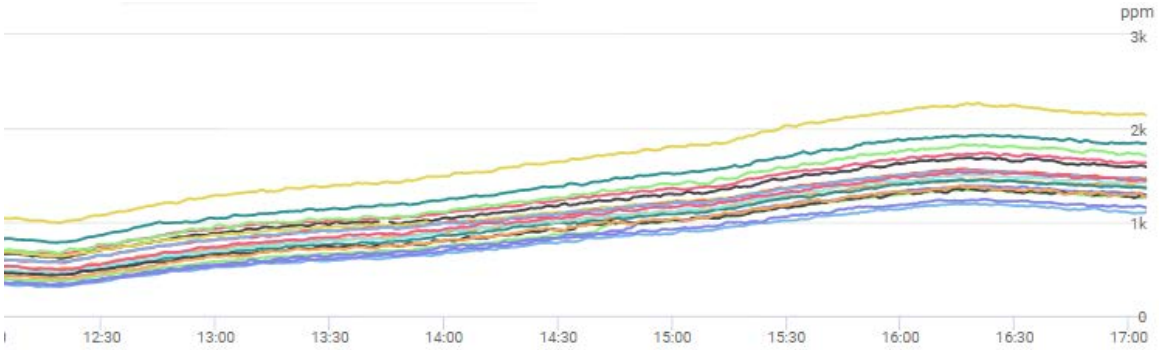
Tested Low-Cost IAQ Sensors in UL Chambers

PM2.5 Readings from all 22 PM Sensors



CO2 Readings from all 18 CO2 Sensors



Performance-Based IAQ and Optimized Ventilation

Southface Energy Institute

Partners

- Underwriters Laboratory
- Beazer Homes
- Illinois Sustainable Technology Center
- Venmar
- Senseware

Topic Area

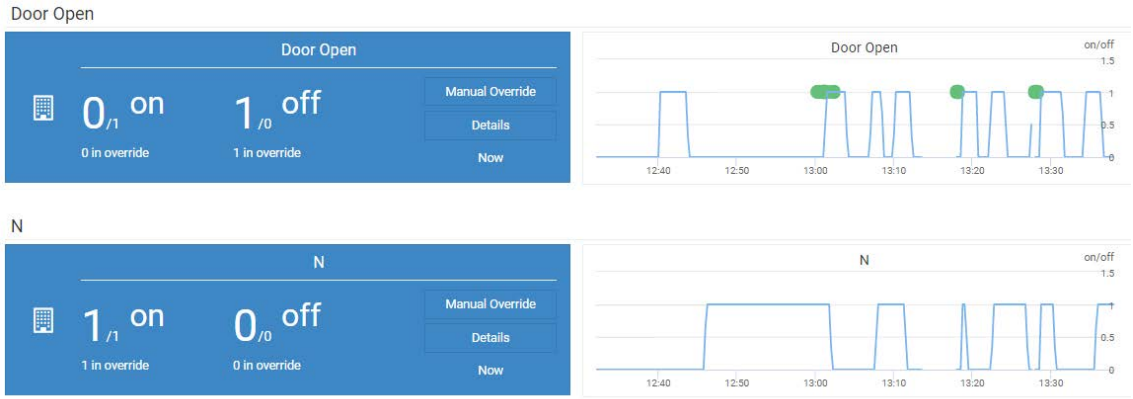
Smarter Indoor Air Quality Solutions

Success Metrics: Develop an ERV field test protocol, and validate that smart-ventilation that considers outdoor air conditions maintain occupant comfort, achieve annual HVAC energy cost savings (compared to central fan integrated supply systems) and agree with newly-developed BEopt models for time-varying ventilation in humid climates.

Tested Modified ERVs

ERV Modified by Venmar with Senseware Remote Switch

Control Dashboard and Status Graphs



Performance-Based IAQ and Optimized Ventilation

Southface Energy Institute

Partners

- Underwriters Laboratory
- Beazer Homes
- Illinois Sustainable Technology Center
- Venmar
- Senseware

Topic Area

Smarter Indoor Air Quality Solutions

- **Received IRB Approval**
- **Identified 4 houses in Charleston, SC to begin ERV installation**

Success Metrics: Develop an ERV field test protocol, and validate that smart-ventilation that considers outdoor air conditions maintain occupant comfort, achieve annual HVAC energy cost savings (compared to central fan integrated supply systems) and agree with newly-developed BEopt models for time-varying ventilation in humid climates.

Project Updates

Up Next...

Steven Winter Associates, Inc.

Ventilation Integrated Comfort System (VICS)

Steven Winter Associates, Inc.

Partners

- Mitsubishi Electric
- dPoint / Core Energy Recovery
- Therma-Stor

Topic Area

Optimized Low-Load Comfort Solutions

Success Metrics: Save 400-800 kWh/year in space conditioning energy compared to exhaust only ventilation. Lower cost of balanced, heat recovery ventilation.

Preliminary Results

- Steady-state, heating mode:

Ventilation cfm	OA DB	AHU scfm	HP Btu/h	ERV ε_{sens}	HP COP	ERV Watts
0	36°F	340	4,800	na	3.58	na
40	35°F	332	4,100	83%	4.12	3.1
70	35°F	311	5,200	73%	3.76	5.5
90	36°F	226	5,100	70%	2.88	8.0

- Winter testing ongoing, summer tests to come
- Design adjustments likely to increase versatility (but increase power consumption)
- Working with dPoint/Core, Mitsubishi, and Therma-Stor on next prototype
- Testing in home to begin Fall 2018

Project Updates

Up Next...

FLORIDA SOLAR ENERGY CENTER®
A Research Institute of the University of Central Florida

Integrated HVAC Control Methods for Supplemental High Efficiency Mini-Split Heat Pumps in Existing Homes

University of Central Florida, Florida Solar Energy Center

Partners

- Mitsubishi
- AirCycler

Topic Area

Optimized Low-Load Comfort Solutions

Success Metrics: Enable additional heating and cooling energy savings and improve thermal distribution via the integrated controller.

- Refine a new approach to using mini-split heat pumps in existing homes
  - Focus on using a single, centrally located mini-split heat pump as the primary system, while only using an existing, lower efficiency central system, as needed.
  - Develop an integrated controller to better coordinate operation of the mini-split and the central system.
- Develop best-practice guidance for optimum design, installation, system control, and central system replacement at end-of-life.

Project Updates

Up Next...

UNIVERSITY OF MINNESOTA

NorthernSTAR

A Building America partner in research, innovation, and real home solutions.

Affordable, Solid Panel "Perfect Wall" Building and Delivery System

NorthernSTAR and University of Minnesota

Partners

- Twin Cities Habitat for Humanity
- Urban Homeworks
- Thrive Builders
- City of Minneapolis
- Building Knowledge, Inc.
- Huber Engineered Woods
- Unico

Topic Area

Moisture Managed High-R Envelopes

Success Metrics: Partners to build six more houses this winter/spring. Bringing on a new community/building partner and developing a new engineering approach with our Denver partner.

- Began construction planning for two additional Twin Cities – Habitat for Humanity homes to compare constructability, cost, and performance of the solid panel to conventional wood stud frame.
  - They may be training a new enclosure contractor to compare learning curve, cost, and speed.
- Recently began construction for the first of two Urban Homeworks houses using previously trained contractor.
  - Solid panel erection observed by several partners and potential builders and/or enclosure contractors.
  - Structure completed in several days despite cold weather.
  - Apparent improvement in speed of panel construction.
- Initiated design and engineering work with Thrive Builders in Denver for four single-family homes.

Project Updates

Up Next...

BERKELEY LAB

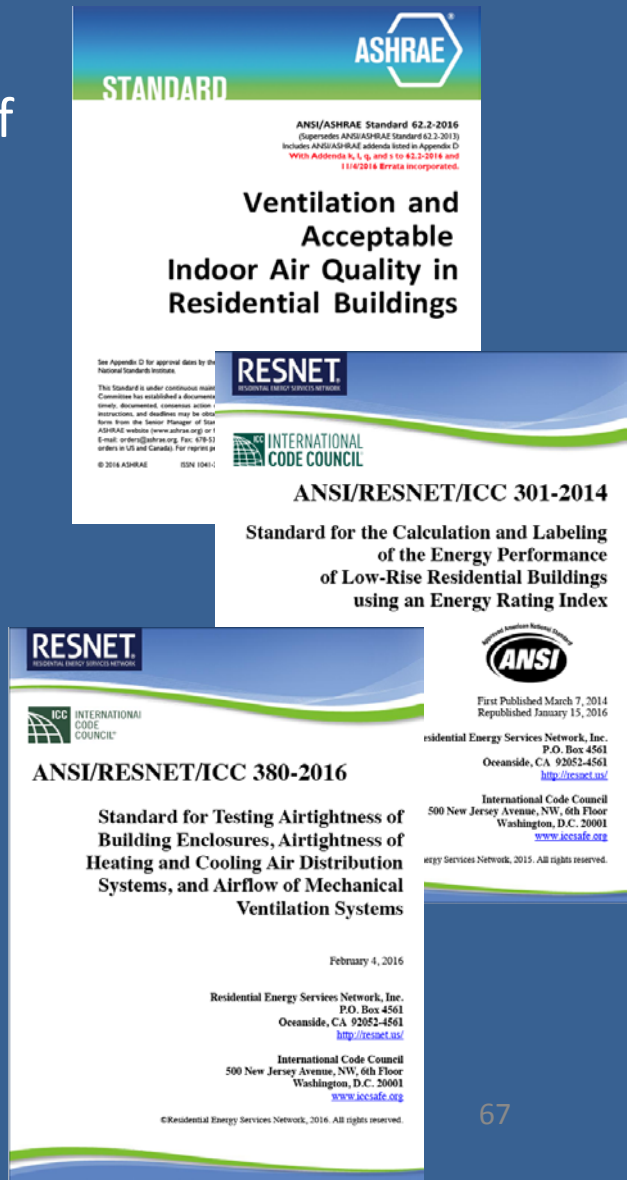
FY18 Building America Projects

LBNL Team: Iain Walker, Brett Singer, Brennan Less, Yang-Seon Kim, Rengie Chan, Vi Rapp, Woody Delp, Leo Rainer, Max Sherman

Key Partners: EPA, CEC, ASHRAE, RESNET, ASTM, GTI, AIVC, Aereco, IEA (Annex 68), NCHH

Industry Standards Technical Support

- ASHRAE 62.2
  - Rewrote core of standard for clarity and ease of use
  - Multi-family requirements
- RESNET
  - Multi-family improvements to RESNET Standards 301 & 380
  - Developing HVAC diagnostics
  - Duct testing
- ASTM
  - Published range hood test standard E3087
  - Development work with Texas A&M, TNO, Broan



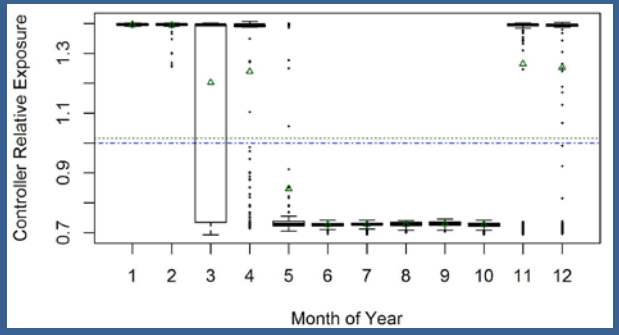
Success metrics: completed revision of ASHRAE 62.2 and RESNET 301 & 380

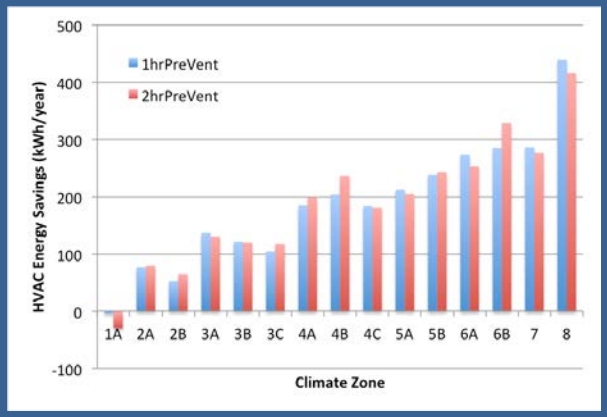
Smart Ventilation

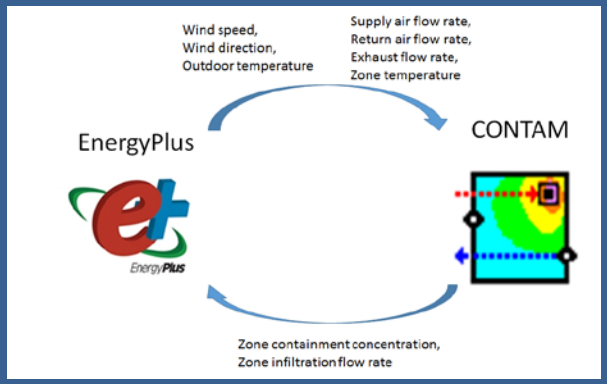
Co-Funded with CEC SVACH Project: svach.lbl.gov

- Simulation-based using CONTAM & EnergyPlus
- Controlled ventilation
  - Weather-based:, timer-based, cut-offs, running median, variable air flow, variable exposure targets
  - Occupancy – non-occupant contaminants, pre-vent flushing strategies
- Develop new IAQ Metrics
  - Zonal control – linked to occupancy with Aereco
  - Contaminant detection – exposure limit values, disability adjusted life years…
- With AIVC: developed international definition for “Smart Ventilation”

Success metric: energy saving ventilation controls optimized for different climates



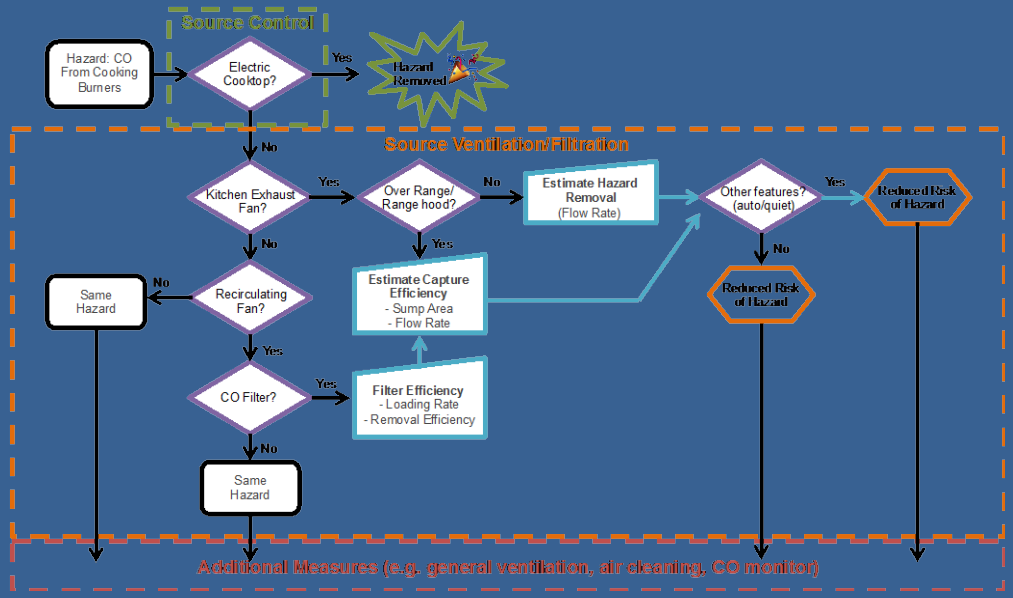




IAQ Score

- Scoring framework presented to stakeholders (RESNET, 62.2, etc.)
  - Lower score = lower risk of IAQ problems
  - Considers common hazards and details of controls
- Working calculator tool enables additions and score updates
- Next step is expert input for scores; on-hold pending FY18 budget

Example: Score CO hazard from cooktop burner



Success: Scoring tool 1.0 released to home performance community

New Home IAQ Study

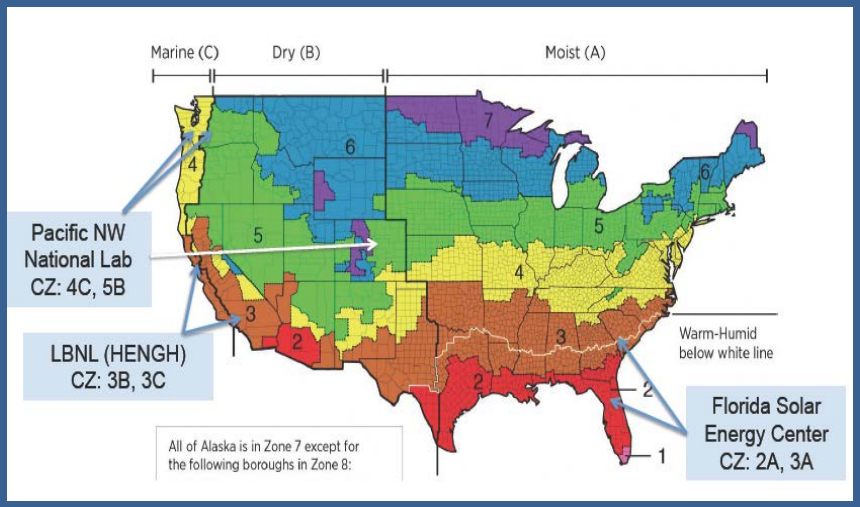
Occupied homes, 2013 or newer
- 4 climate zones, 32 homes each
- 1/3 with & w/o ventilation

LBNL: field protocols & database, helping w/human subjects protocol

FSEC & PNNL: Recruit & Field Work
- Document ventilation equipment
- Measure airflows
- Monitor IAQ and equipment use
- Activities and occupancy

Connect to data in LBNL survey

Analyze data to inform standards



Parameter	Time Resolution	Example Instrument	Resolution	Accuracy
$PM_{2.5}$	1 min.	MetOne BT 645 (in) ES-642 (outdoor)	1 ug/m^3 (LoQ ~ 3-5ug/m^3)	5%
$PM_{2.5}$ gravimetric	Time-integrated	MSP PEM + pump (w/ flow control & logging)	LoQ <1 ug/m^3 (>2 lpm for 1wk)	5% (pump flow)
Low-cost $PM_{2.5}$	1-5 min.	Foobot, Purple Air, etc	TBD	TBD
CO_2	1 minute	Extech SD800	1 ppm	5%
NO_2, NO_x	Time-integrated	Ogawa passive sampler	2 ppb	25%
Formaldehyde, acetaldehyde	Time-integrated	SKC UMEx 100 passive sampler	1 ppb (Formaldehyde)	25%
T, RH	1 min.	Onset HOBO Pro v2	0.1 °C, 1% RH	T: 1%; RH: 2.5%

Success = Database of New Home IAQ & ventilation performance

California Study of New Gas Homes

Occupied homes, 2011 or newer

- 70 total; ~50 to date
- Operate code-required ventilation
- Keep windows closed

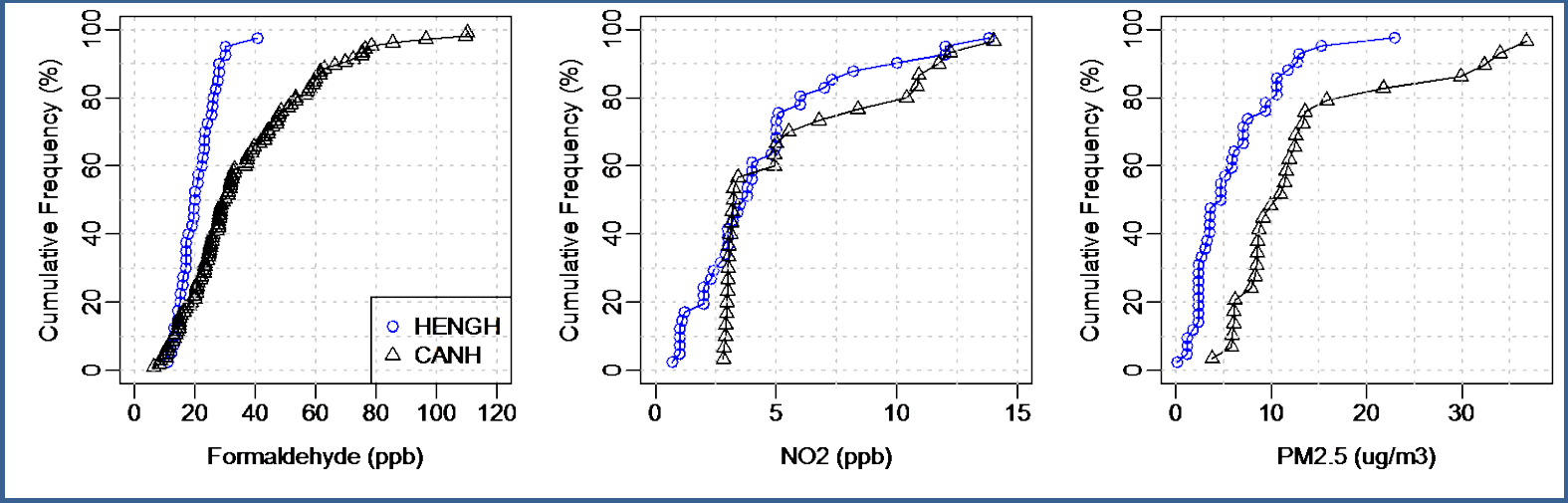
Ventilation airflows ~ 50% above code minimum

Most homes had ventilation off

Compare to CA homes built 2002-05

- Formaldehyde lower and less variable -
  > Low-emitting material regulations working!
- Indoor NO2 similar
- Indoor $PM_{2.5}$ much lower

Cooking dominant indoor source of $PM_{2.5}$



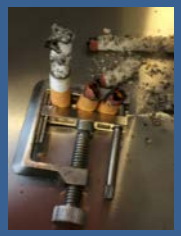
Success = Database of New Home IAQ & ventilation performance

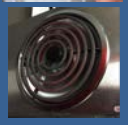
Consumer IAQ Monitor Laboratory Evaluation

Compare to Reference Monitors for Common Residential PM Sources

Burned incense, candles and cigarettes

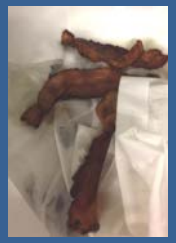


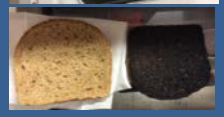


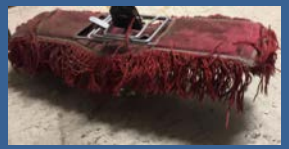
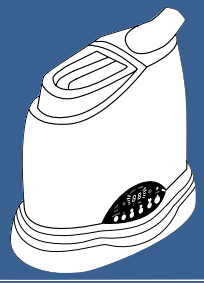



Heated pots of water, an oven, a hair dryer, and an electric burner

Cooked green beans, bacon, pancakes, toast, and a pizza, and heated canola oil





Released AZ test dust, shaked a dust mop, and operated an ultrasonic humidifier using unfiltered tap water

Consumer IAQ Monitor Laboratory Evaluation

Compare to Reference Monitors for Residential $PM_{2.5}$

Four monitors detected most sources and quantitatively measured large sources.

➔Appear suitable to manage IAQ.

Two monitors detected many sources but not quantitatively.

One monitor not informative.

SPK

PA

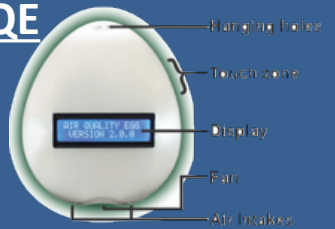
FOB

AB

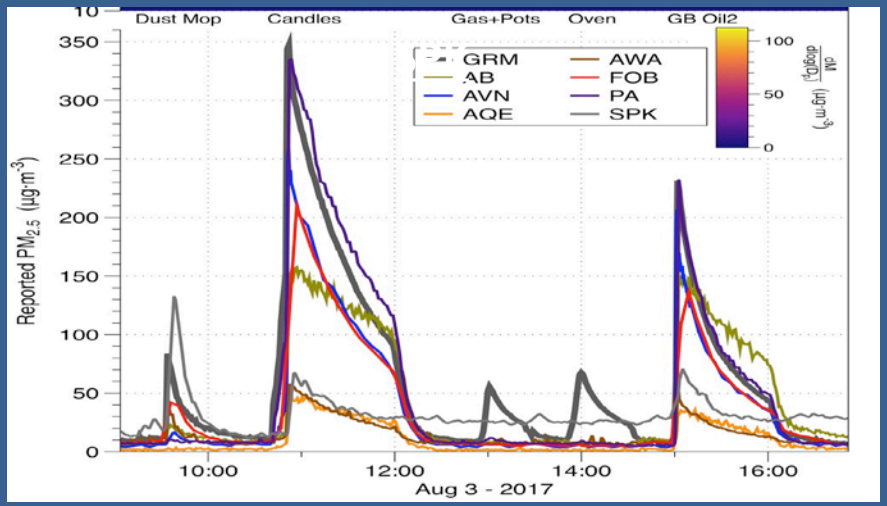
AVN

AWA

AQE



Example Data



- Results should be verified in homes
- What fraction of $PM_{2.5}$ detected?
- How durable are the devices?

Success = Guidance to Home Performance Pros & Consumers: what works?

Project Updates

Up Next...

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

- Race to Zero Student Design Competition
- Humidity in Low-Load Homes
- HVAC Installation Quality
- Advanced Analytics

U.S. Department of Energy Race to Zero Student Design Competition

- Inspires collegiate students to become the next generation of building science professionals through a design challenge for zero energy ready buildings
- Major boon to participants:
  - Learn critical skills for designing, analyzing, and documenting high-performance buildings
  - Receive no-cost building science training from recognized experts and educators
  - Gain experience working in a multidisciplinary team
  - Make professional connections to launch their careers.

RACE TO ZERO
U.S. DEPARTMENT OF ENERGY
STUDENT DESIGN COMPETITION

Building AMERICA
U.S. Department of Energy

National Renewable Energy Laboratory

Partners

- Multiple industry sponsors
- Industry jurors

Topic Areas

Moisture Managed High-R Envelopes, Optimized Low-Load Comfort Solutions, and Smarter Indoor Air Quality Solutions

Success Metrics: 2018 competition has seen significant participation growth: 84 participating teams representing 68 collegiate institutions from nine countries.

Building Science Vision

- ✓ **Inspire** and develop the next generation of building science professionals
- ✓ **Advance** and enhance building science curriculum in universities

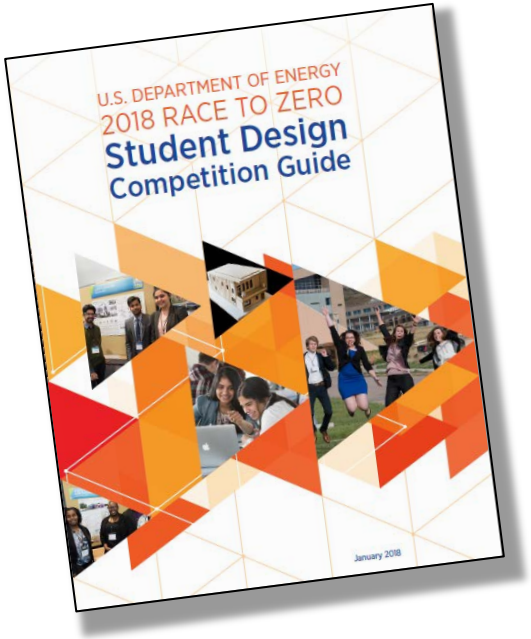
Race to Zero Overview

- Annual Competition (started in 2014)
  - Easily integrated in existing curriculum of 1-2 semesters
- Critical Skill Development
  - Building science training
  - Collaborative teamwork experience
  - Comprehensive integrated design
  - Market ready solutions (design + cost + construction)
- Two-Day Competition Event at NREL
  - Collegiate team presentations to expert jurors
  - Networking
  - Thought leaders
  - Career connections

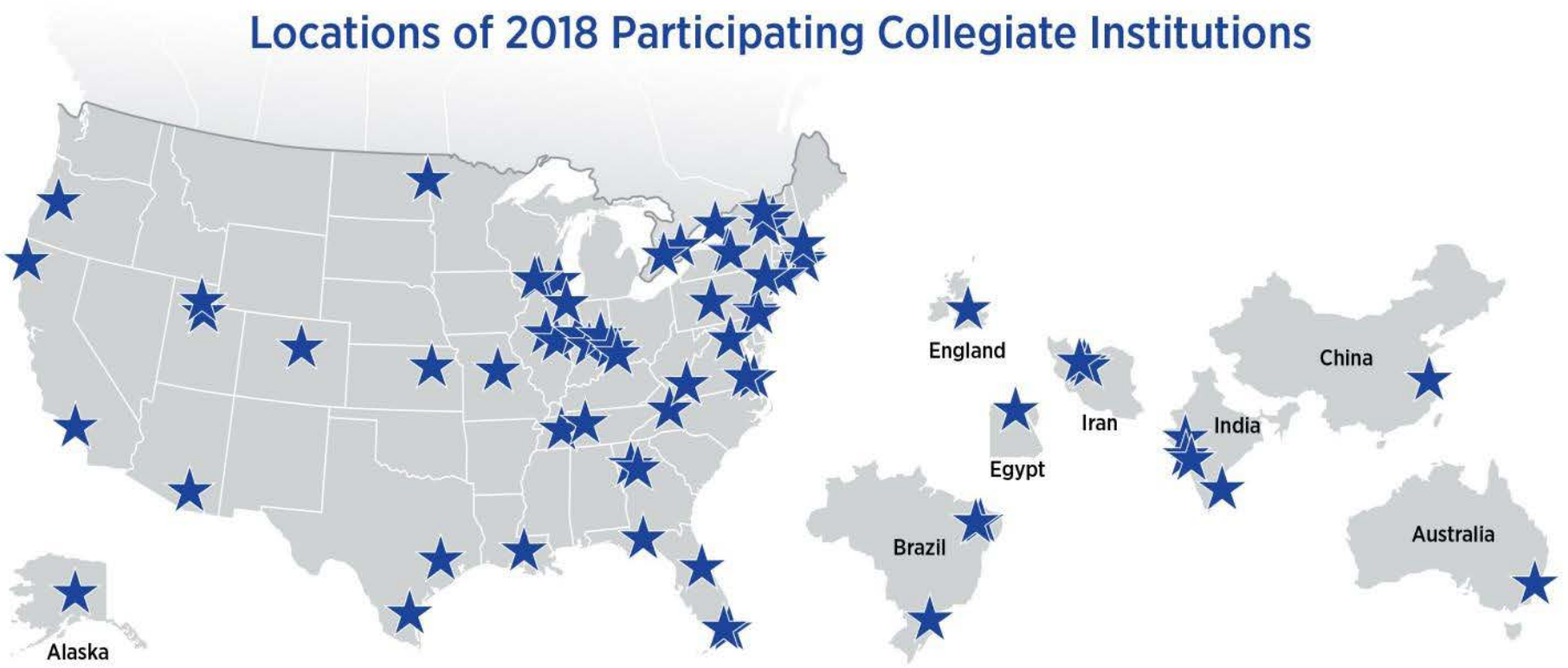
2017 Finalists and Jurors

2018 Competition

- 84 teams, representing 68 collegiate institutions
- Finalists, 40 teams compete at **NREL April 20-22**
- Five competitions
  - Suburban Single-Family
  - Urban Single-Family
  - Attached Housing
  - Small Multifamily
  - Elementary School



2018 Competition



Humidity in Low-Load Homes

National Renewable Energy Laboratory

Partner

- Oak Ridge National Laboratory

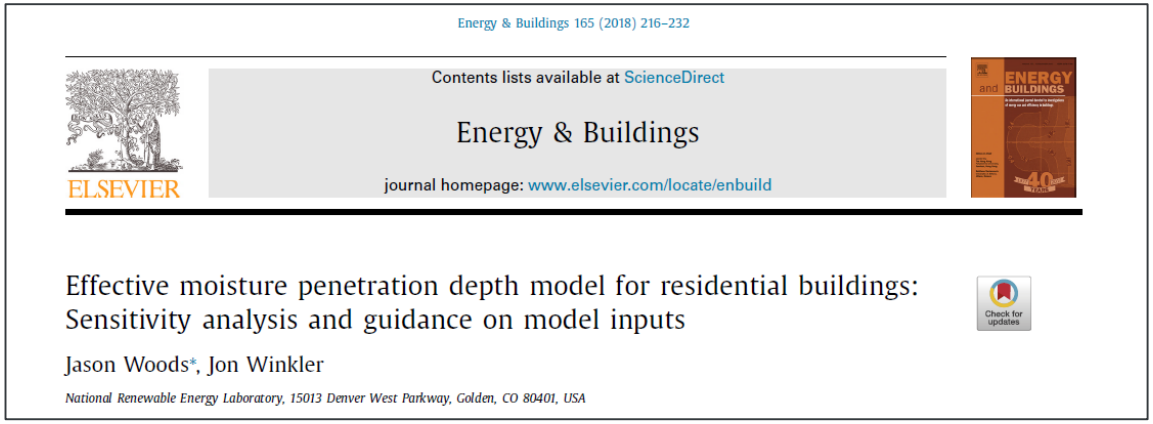
Topic Area

Optimized Low-Load Comfort Solutions

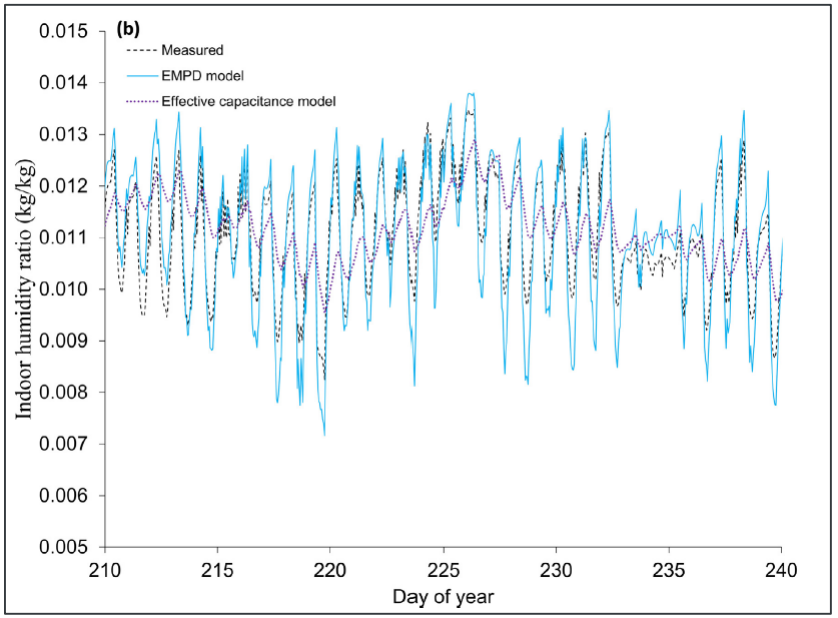
Success Metrics: This research supports the development of best practices and voluntary industry standards aimed at improving the quality of HVAC system installations in residential buildings.

- Use EnergyPlus™ to quantify the impact variations in internal moisture loads and air conditioner configuration can have on indoor relative humidity and recommended equipment capacity.
- Use stochastically-derived latent and sensible internal gain profiles to determine the sensitivity of internal gains on indoor relative humidity.
- Evaluate the impact that air conditioner oversizing and air flow rate have on indoor relative humidity.
- Determine recommended blower-off delays to better control indoor relative humidity in low-load homes.
- Investigate how well appropriately-sized equipment in a low-load home can handle atypical loads not accounted for by current equipment selection procedures.

Humidity in low-load homes



New, validated Effective Moisture Penetration Depth(EMPD) model added to EnergyPlus, facilitating assessment of humidity in low-load homes



Humidity in low-load homes

Contents lists available at ScienceDirect

Energy & Buildings

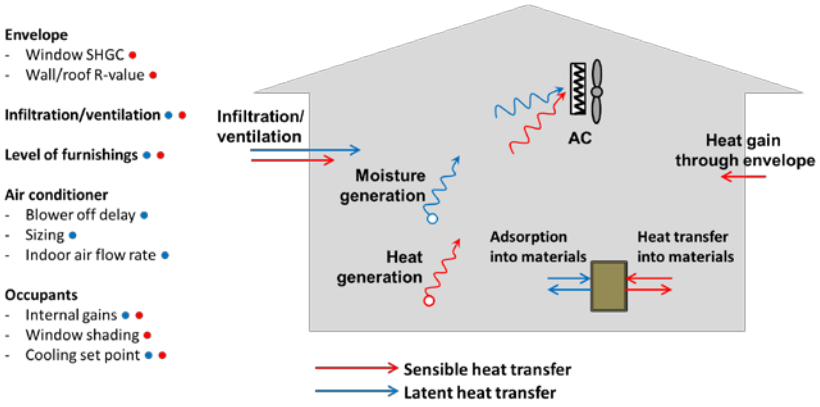
journal homepage: www.elsevier.com/locate/enbuild

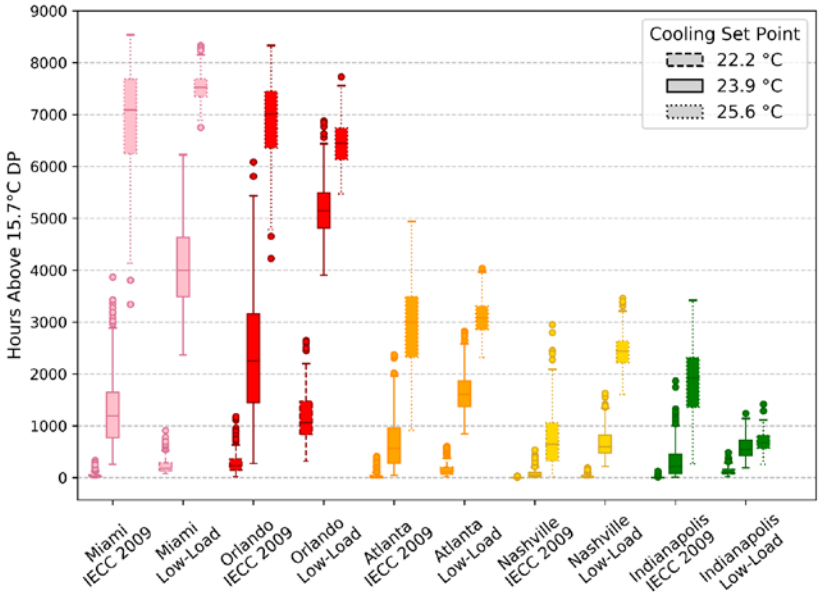
Effect of occupant behavior and air-conditioner controls on humidity in typical and high-efficiency homes

Jon Winkler [a,*], Jeffrey Munk [b,*], Jason Woods [a]

[a] National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO 80401, United States
[b] Oak Ridge National Laboratory, 1 Bethel Valley Rd, Oak Ridge, TN 37830, USA

Forthcoming journal article documenting study of humidity excursions in low-load homes.





HVAC Installation Quality

National Renewable Energy Laboratory

Partners

- RESNET
- EPA

Topic Area

Optimized Low-Load Comfort Solutions

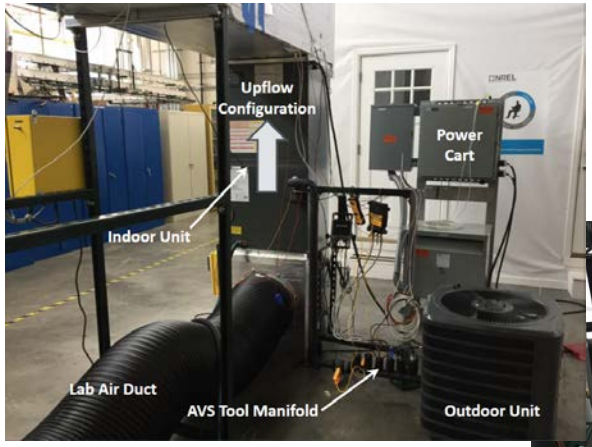
- Use NIST installation quality performance curves and FY17 literature review findings to assess the impact of residential HVAC installation faults and assess future research needs to improve installation quality.
- Complete and publish results from laboratory research on ability of smart installation tools to accurately discern faults. Initiate pilot study with system installers and third-party verifiers to validate installation quality verification

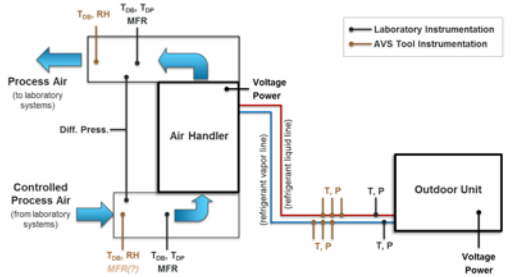
Success Metrics: This research will inform development of HVAC design guidance and standards, the Building Science Advisor, and Building America Comfort Roadmap priorities.

HVAC AVS lab experimental rig

How well do **Automated Verification Systems** for HVAC installation work?

Fault detection experiments underway.





Faults of interest

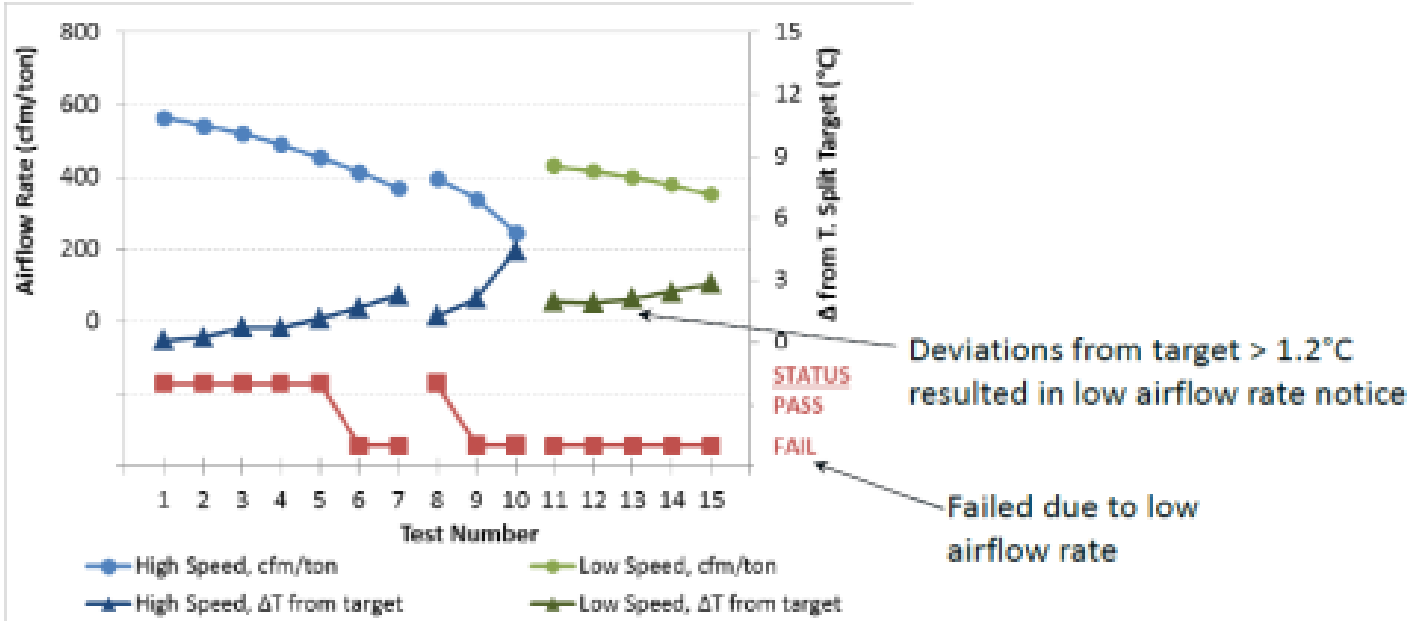
- Indoor airflow rate
- Refrigerant charge
- Non-condensable gases
- Outdoor airflow rate

Systems tested

- North Park Innovations iManifold
- Fieldpiece HG3 System Analyzer
- Emerson ComfortGuard

HVAC AVS lab experimental rig

Preliminary results are being produced and compiled. Publication expected in the Fall



Advanced Analytics – Residential

Building AMERICA
U.S. Department of Energy

National Renewable Energy Laboratory

Partners

Office of Energy Policy and Systems Analysis, U.S. Department of Energy

Topic Areas

Moisture Managed High-R Envelopes, Optimized Low-Load Comfort Solutions, and Smarter Indoor Air Quality Solutions

Success Metrics: NREL's suite of comprehensive, open-source building energy tools help achieve state-of-the-art, energy-efficient buildings that can make the grid more efficient, resilient, and reliable.

- **ResStock™** helps states, municipalities, utilities, and manufacturers identify which home improvements save the most energy and money.
  - Allows extremely granular evaluations of energy efficiency retrofit options.
  - State-specific fact sheets and technical report available

ResStock

- **OpenStudio®**—a cross-platform collection of software tools—makes building energy modeling easier for architects and energy audits easier for utilities.
  - Creates feature-rich applications for building energy modeling, reducing risk for developers.
  - OpenStudio 2.3.0 released in October 2017

- **EnergyPlus™** is a whole-building energy simulation program engineers, architects, and researchers use to model energy consumption and water use in commercial and residential buildings and data centers.
  - Provides detailed, validated physics-based algorithms to accurately model performance.
  - EnergyPlus 8.8.0 released in September 2017

EnergyPlus

Housing stock characteristics database + **Physics-based computer modeling** + **High-performance computing**

Housing stock characteristics database

+

Physics-based computer modeling

+

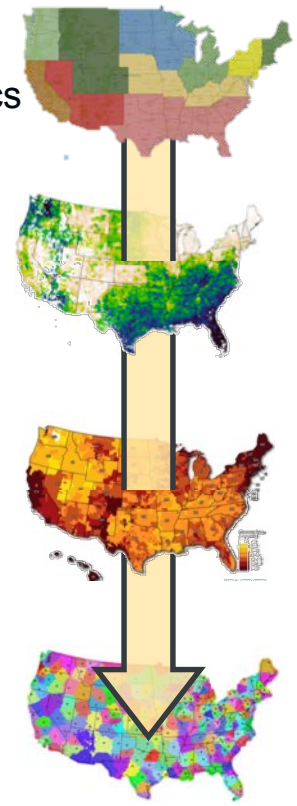
High-performance computing

Building Characteristics

Census Data

Costs

Climate Locations



EIA	**Res. Energy Consumption Survey (RECS)**
NAHB	**Homebuilder Surveys**
IECC	**Historical Energy Codes**

Other national, regional, and local audit databases

Census	**American Community Survey (ACS)**

EIA	**Electricity and fuel costs**
NREL	**OpenEI.org Utility Rate Database**
NREL/Navigant	**Measure Cost Database**

NREL	**TMY3 weather data**

Housing stock characteristics database

+

Physics-based computer modeling

+

High-performance computing

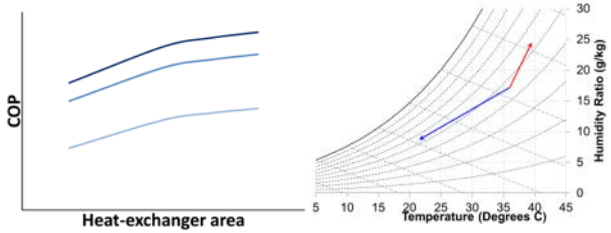
U.S. DOE Tools

OpenStudio

EnergyPlus

Ability to simulate emerging technologies

Emerging technology



System performance characterization

ResStock

Detailed open-source component models

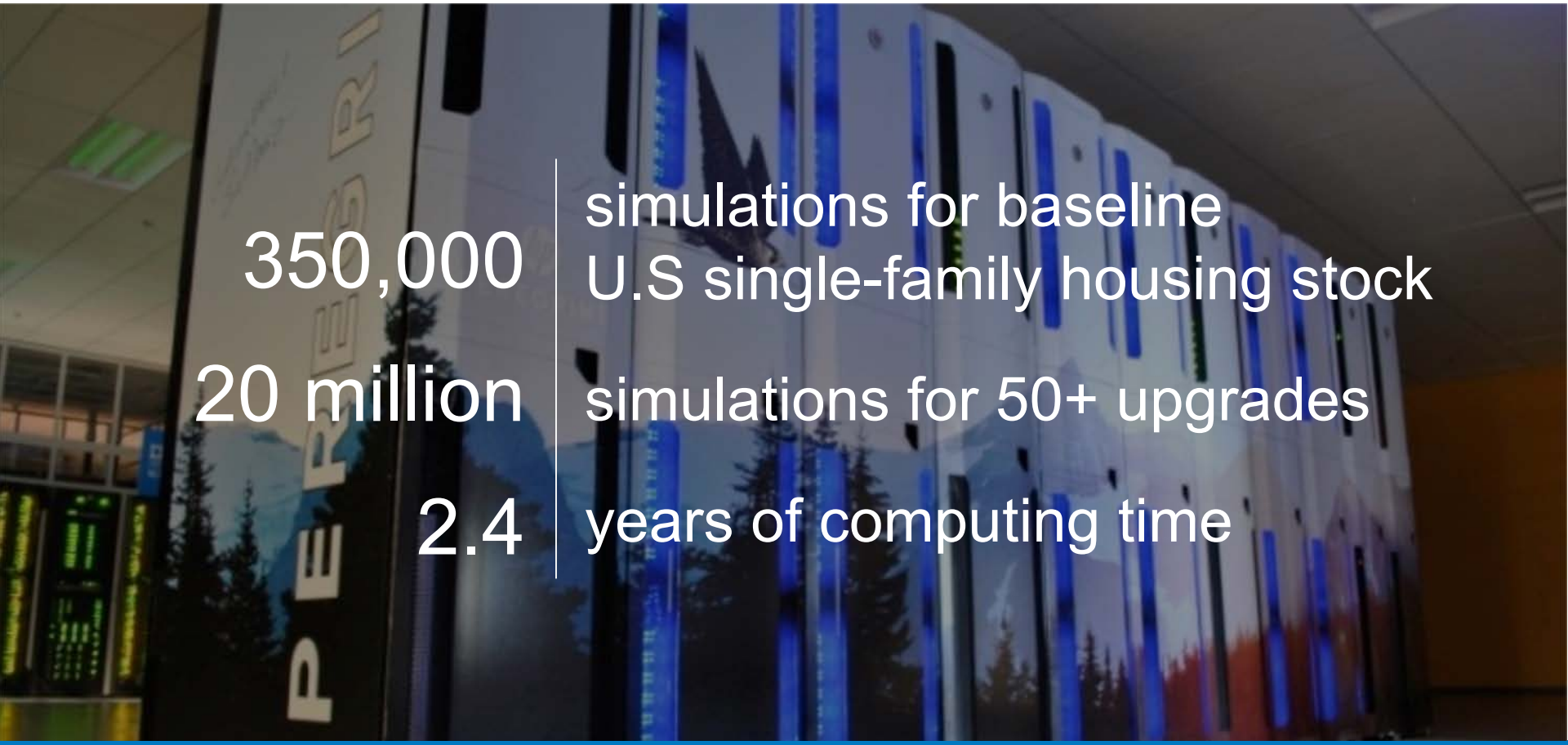
Housing stock characteristics database

+

Physics-based computer modeling

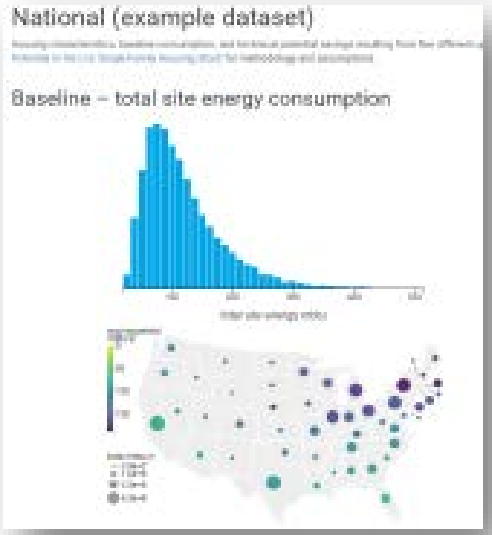
+

High-performance computing



350,000	simulations for baseline U.S single-family housing stock
20 million	simulations for 50+ upgrades
2.4	years of computing time

resstock.nrel.gov

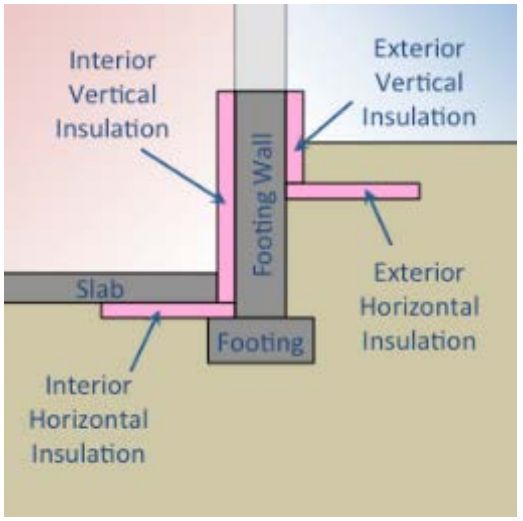


ResStock FY18 Work

- Add multifamily stock
- Add demographic data to facilitate analysis targeting income-qualified households
- Demand and loadshape analysis to support Grid-interactive Efficient Buildings (GEB)

EnergyPlus Highlight: Kiva Foundation Model

- Big Ladder implementation in E+ 8.7
- 2-dimensional finite difference calculations
- Fast
  - < 5 seconds
- Accurate
  - Comparable to 3-dimensional simulation
  - Tested against BESTEST ground coupled cases
- Flexible
  - Handles basements (including walkout), slabs (in- and on-grade), and crawlspaces
  - User-specified insulation materials and configurations

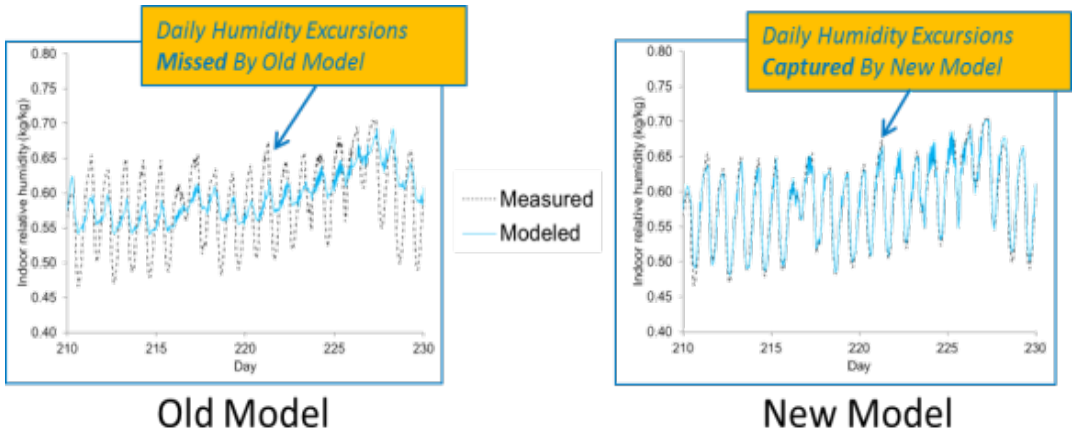


EnergyPlus Highlight: Airflow Network Model

- Airflow Network evaluations/assessments
  - Ducts (ORNL 2014)
  - Infiltration, interzonal airflow, and ducts (NREL 2016)
  - Attics, radiant barriers, and duct radiation (Fraunhofer 2017)
- Substantial set of capabilities
  - Wind/stack-induced infiltration
  - Duct conduction, convection, radiation, and leakage
  - Vented attics and crawlspaces
  - Radiant barriers in attics
  - Natural ventilation
  - Mechanical ventilation
  - Interzonal airflow (multi-zone)
  - Airflow interactions of above

EnergyPlus Highlight: Moisture Buffering Model

- Effective Moisture Penetration Depth (EMPD) model
- Improved absorption/desorption modeling
- Increased accuracy in predicting humidity excursions
  - Validated against field data measurements
- NREL implementation of enhanced model in E+ 8.7
- Capability needed for tighter, low-load homes

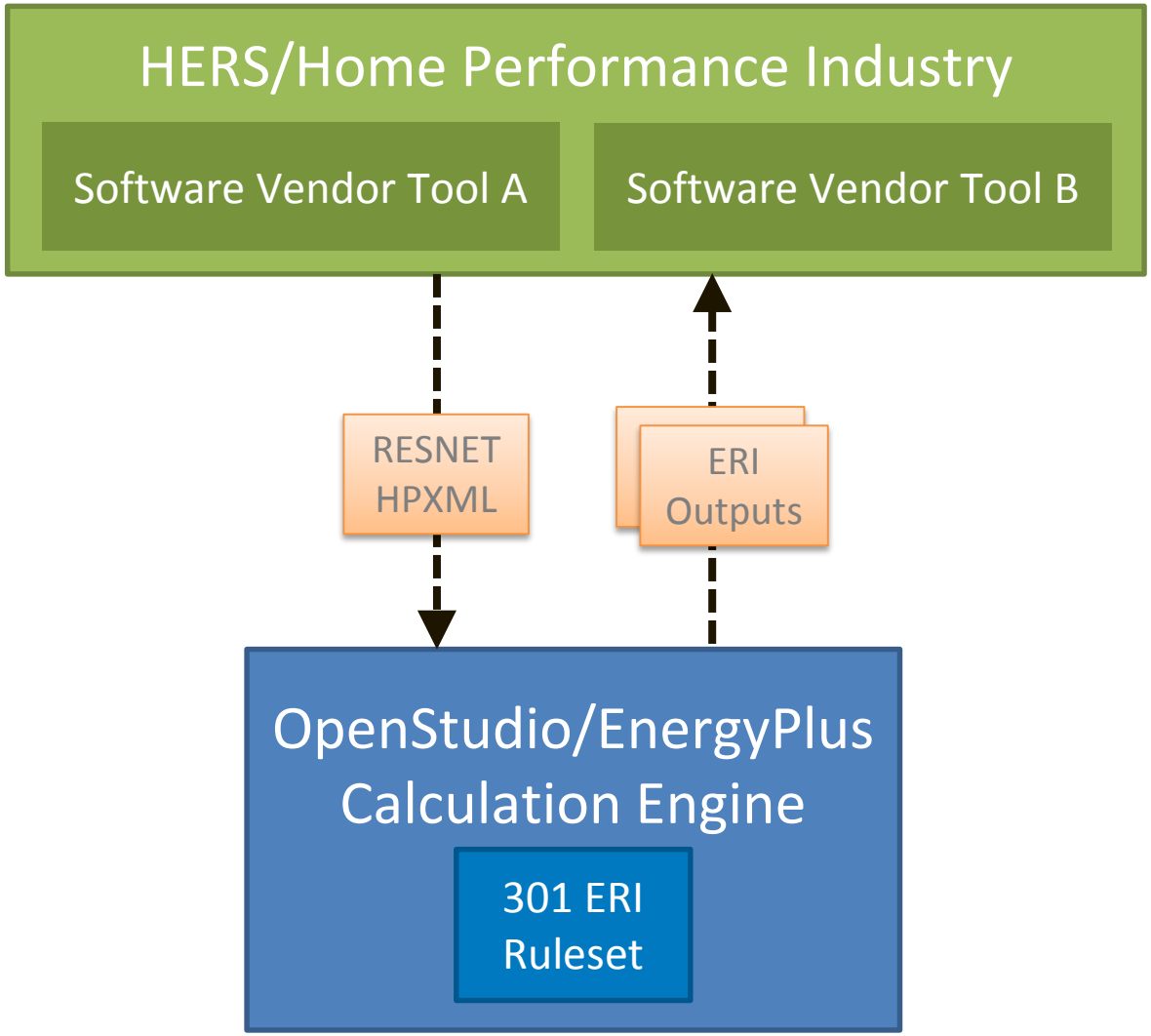


Old Model

New Model

Field Validation

Residential Workflow: Energy Rating Index



EnergyPlus FY18 Work

- Add Airflow Network enhancements: Fans, multiple air loops, radiant barriers, etc.
- Complete User Controls for Multiple Air Loop HVACs in One Zone
- Complete Eigen Solver for Airflow Network
- Add PVWatts model

Project Updates

Up Next...

OAK RIDGE National Laboratory

Durability Analysis using ORNL Heat, Air, and Moisture Chamber

Oak Ridge National Laboratory

Partners

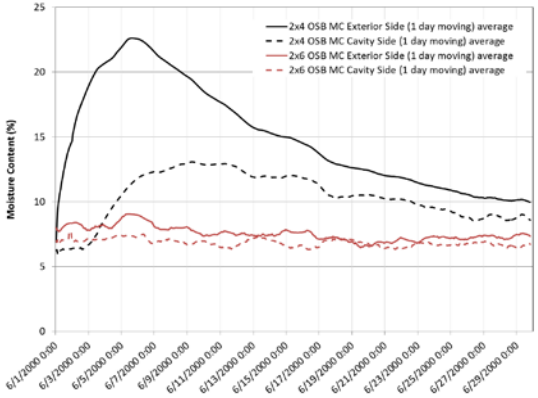
- Home Innovation Research Labs

Topic Area

Moisture Managed High-R Envelopes

Success Metrics: BSA users will be able to easily access credible building science expertise to make informed decisions about moisture risk management and real-world performance of high-R walls.

- Conducted tests in the ORNL HAM chamber (2x4 and 2x6 wood-framed IECC 2015 walls)
  - Diffusion only Chicago Winter
  - Diffusion only Chicago Summer
  - Wetting event during Chicago Summer



- Validating WUFI simulation models based on HAM chamber tests is ongoing.
  - Winter diffusion simulation agreed well with measured chamber data:
    - OSB Temperature simulated with 1.5 °C RMSE
    - OSB Moisture Content simulated with 0.7% RMSE
- Upcoming work:
  - Chamber test other wall structures: SIPS and Masonry Block
  - Validate WUFI models with convection through wall and solar insolation

Building Science Advisor (BSA)

Oak Ridge National Laboratory

Partners

- Building Science Corporation
- Home Innovation Research Labs

Topic Area

Moisture Managed High-R Envelopes

Success Metrics: Provide a user-friendly online tool that takes the guesswork out of complex high-performance wall design decisions.

- Developed an initial database of walls evaluated for moisture durability based on expert experience.
  - Includes wood-framed walls for all climate zones
- Developed an alpha version of BSA.
  - Over 100 users gave feed-back on tool.

- Currently addressing user comments for an upcoming beta release in 2018:
  - Revising look and easier navigation of the website
  - Extending database with more wall types and materials
  - Improving moisture durability evaluation logic
  - Adding more guidance and images to aid user education

Sensitivity Analysis of Indoor Humidity in Low-Load Homes

Oak Ridge National Laboratory

Partners

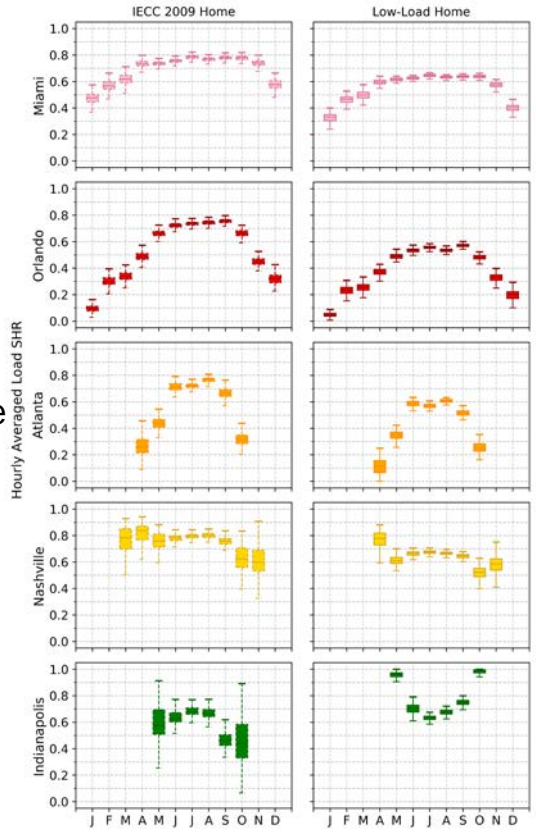
- National Renewable Energy Laboratory

Topic Area

Optimized Low-Load Comfort Solutions

Success Metrics: Provide design information required by HVAC manufacturers to develop systems capable of providing comfort in low-load homes.

- Used EnergyPlus to evaluate how internal loads and HVAC controls affect indoor humidity
  - Used dual layer EMPD model for moisture buffering
  - Used program in energy management system (EMS) to model off-cycle evaporation of condensate on the evaporator coil.
- Building America Webinar presentation held in December 2017
- Energy and Buildings journal publication accepted
- Utilizing simulation framework to evaluate the breakdown of sensible and latent loads in different efficiency homes
  - Peak total cooling loads
  - Peak dehumidification loads
  - How are loads changing as homes improve?



Project Updates

Up Next...

Pacific Northwest
NATIONAL LABORATORY

Building America Research Dissemination – Building America Solution Center

Pacific Northwest National Laboratory

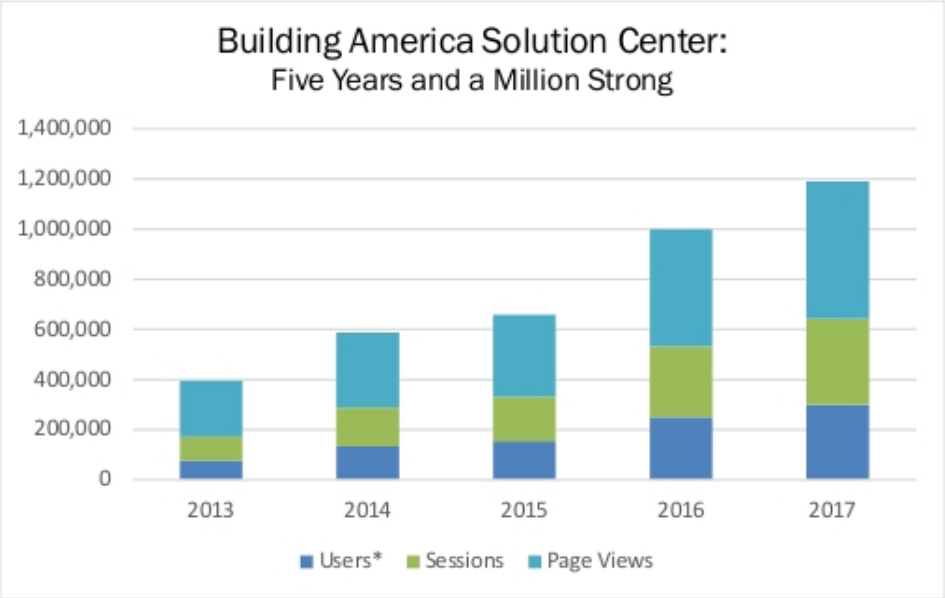
Partners

- Building America Research Teams
- Labs

Topic Areas

Research Dissemination

- The Building America Solution Center (BASC) is a web-based tool that includes technology and best practice information related to both new and existing homes. This project includes ongoing maintenance of the BASC platform and the incorporation of new results as they are produced by Building America researchers.



Success Metrics: Growth from 77,000 users in 2013 to almost 300,000 in 2017. BASC celebrated it's 5th Anniversary in January, 2018.

Building AMERICA
U.S. Department of Energy

Pacific Northwest National Laboratory

Partners

- Building America Research Teams
- Labs

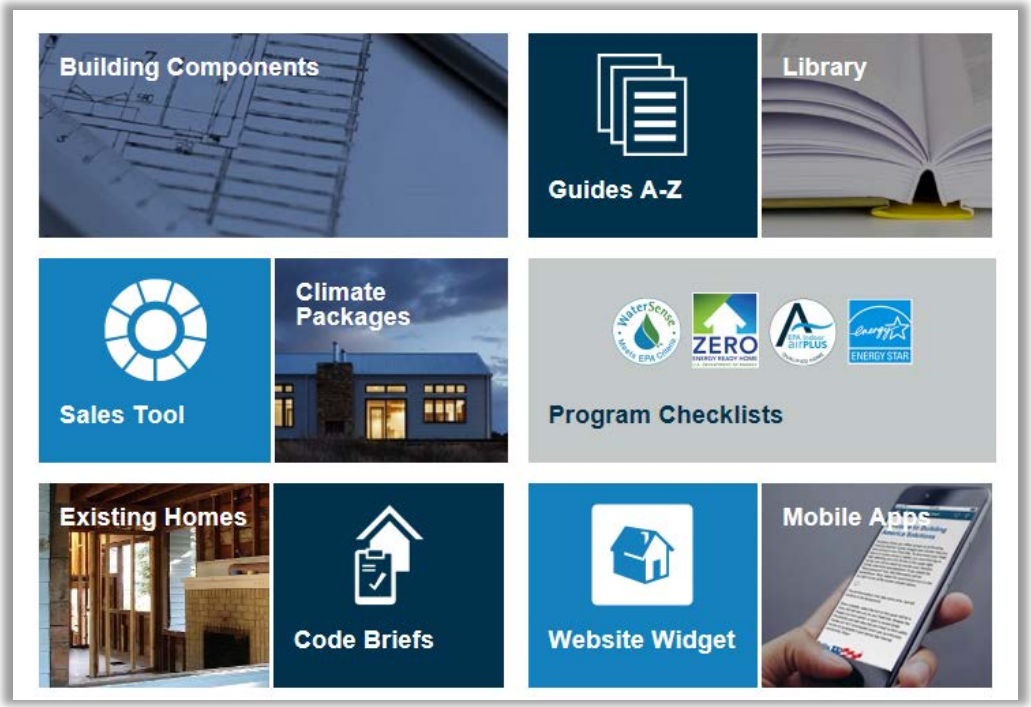
Topic Areas

Research Dissemination

Happy 5th Anniversary BASC!

Content snapshot:

- 230+ Guides
- 1,600+ Images
- 330+ Proven performance case studies
- 115+ CAD drawings
- 900+ Building Science references & resources
- 30+ Code compliance briefs
- 90+ Videos
- 40+ Sales briefs
- Research Tracker



Team and Partners

Pacific Northwest National Laboratory
DOE, CEC, NYSERDA, BPA

Topic Area

Research Coordination

Success Metrics for Beta Launch: Usefulness to program managers across the country

Research Tracker

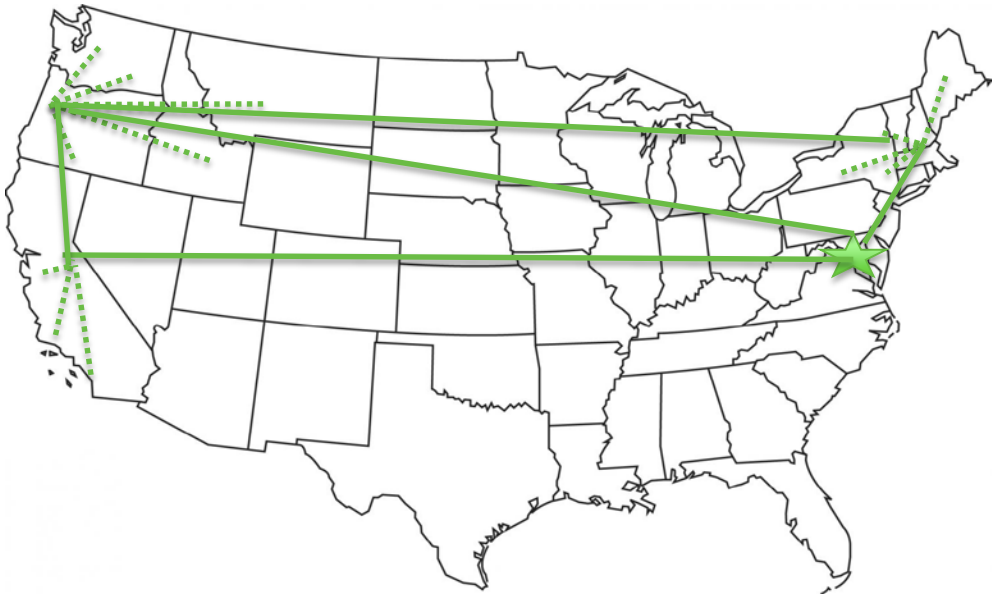
https://basc.pnnl.gov/research-tracker

Objective:

- Help ensure that projects are coordinated across major funding organizations across the country.

Update:

- 235 projects from across the country and counting

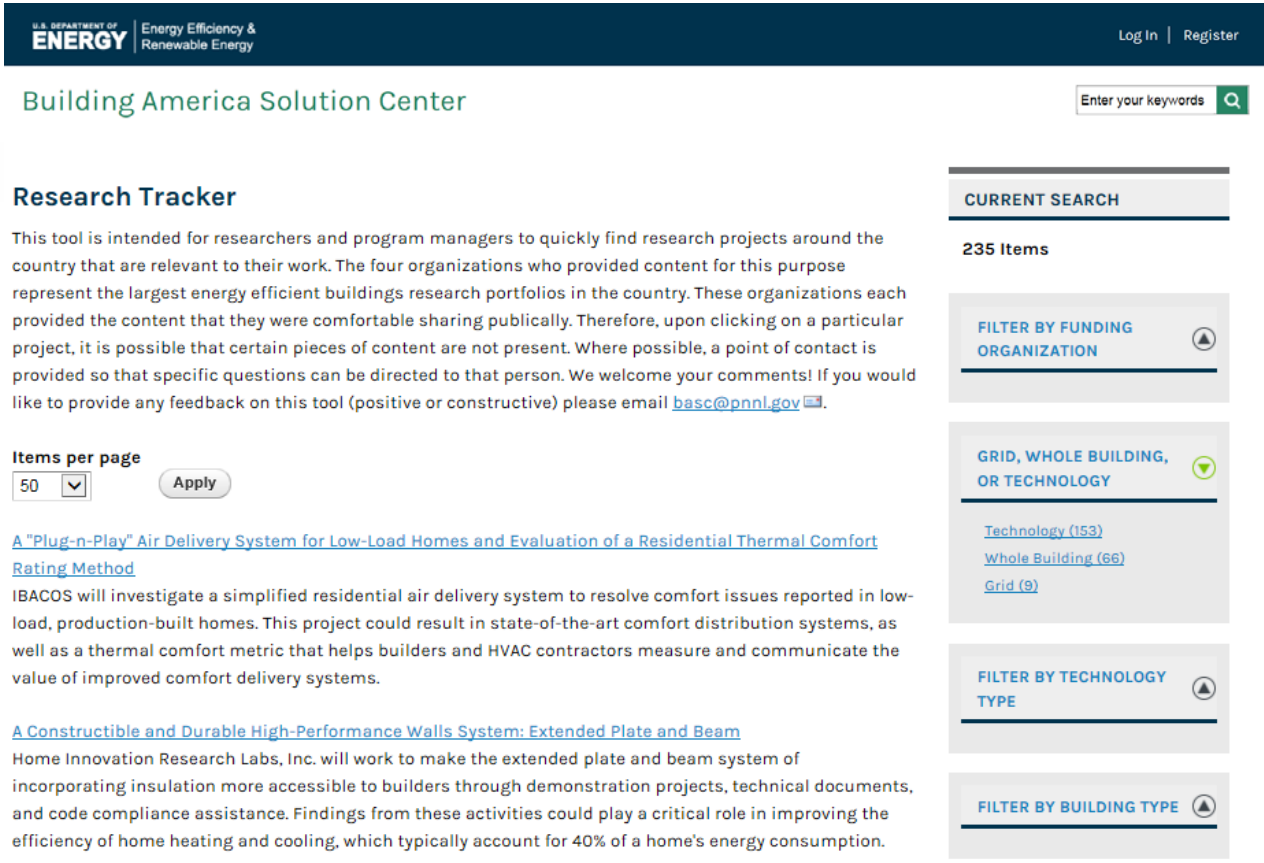


Team and Partners

Pacific Northwest National Laboratory
DOE, CEC, NYSERDA, BPA

Topic Area

Research Coordination



Demand Response Potential of Heat Pump Water Heaters

Team and Partners

Pacific Northwest National Laboratory
BPA, PGE, NEEA, Orlando Utilities Commission Program

Topic Area

Water Heaters

Success Metrics: Reduced uncertainty in HPWHs as a grid resource

Objective: Validate performance of connected HPWHs

- Peak load shifting and battery-equivalent storage of energy
- Grid and household resiliency
- Energy efficiency potential and load reduction
- CTA 2045 integration and validation

Update:

- ~200 water heaters deployed in NW region
- Partnership with Orlando Utilities Commission (OUC) established

Team and Partners

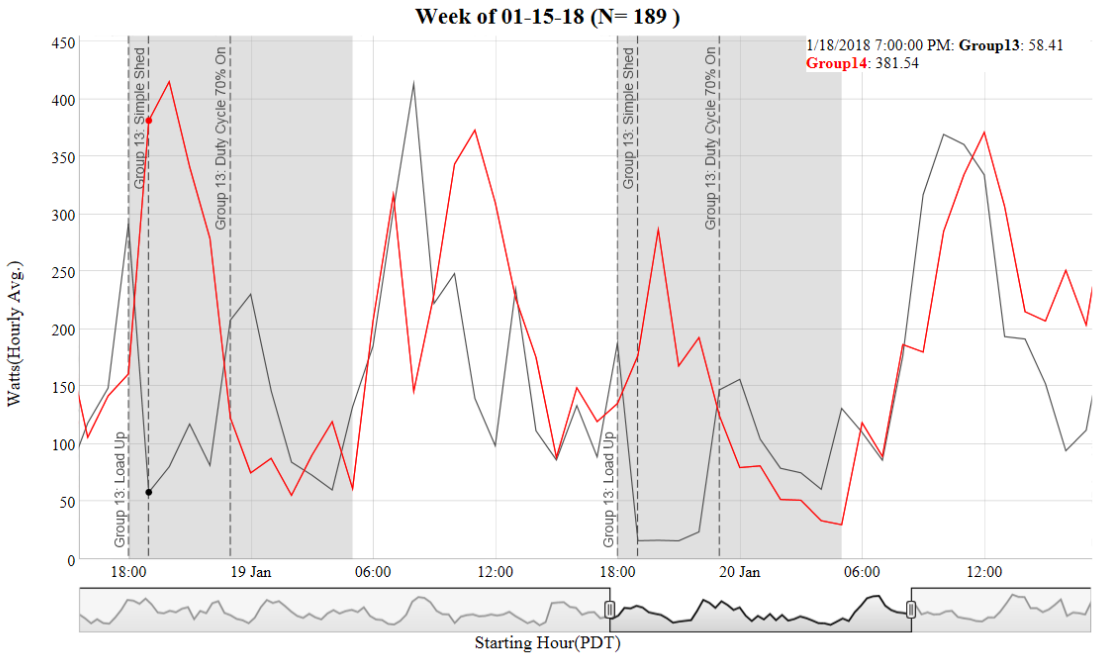
Pacific Northwest National Laboratory

BPA, PGE, NEEA, Orlando Utilities Commission Program

Topic Area

Water Heaters

Example of Energy Shifting Potential



Building AMERICA
U.S. Department of Energy

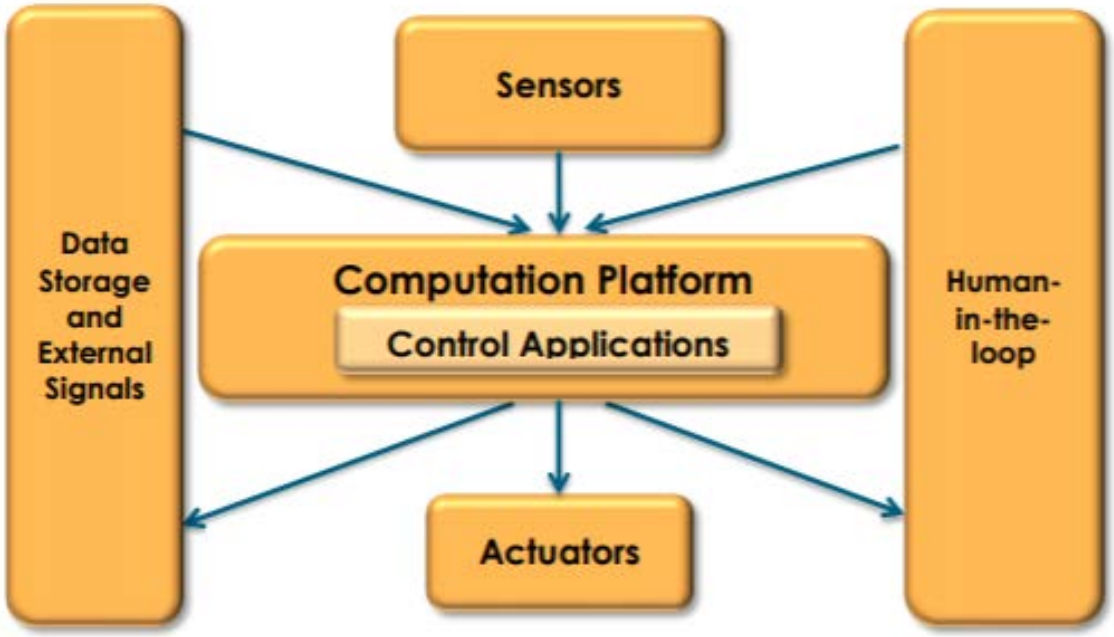
Team and Partners

Pacific Northwest National Laboratory

Topic Area

HVAC Controls

Review of Residential Comfort Control Products and Opportunities



https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-27141.pdf

Wrap Up

Next Meeting

May 8, 2018

Tuesday, 3-5 p.m. ET