U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America U.S. Department of Energy

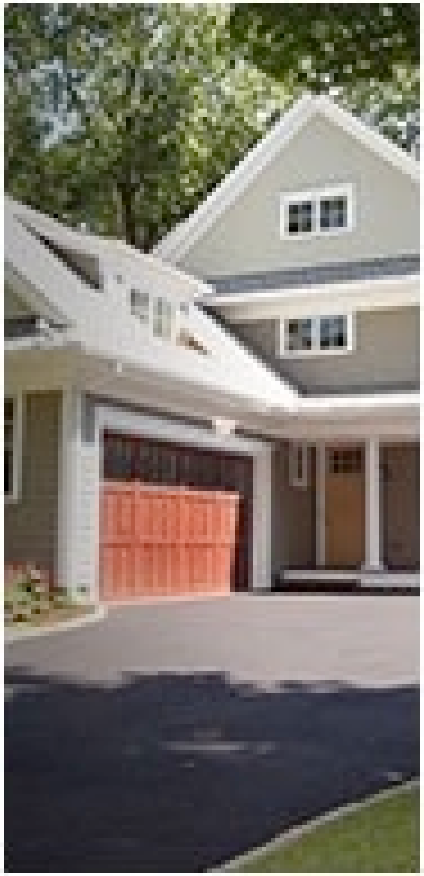
Building America

Quarterly Team Project Update – BTO Peer Review

March 14, 2017

U.S. Department of Energy
Eric Werling
Lena Burkett

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



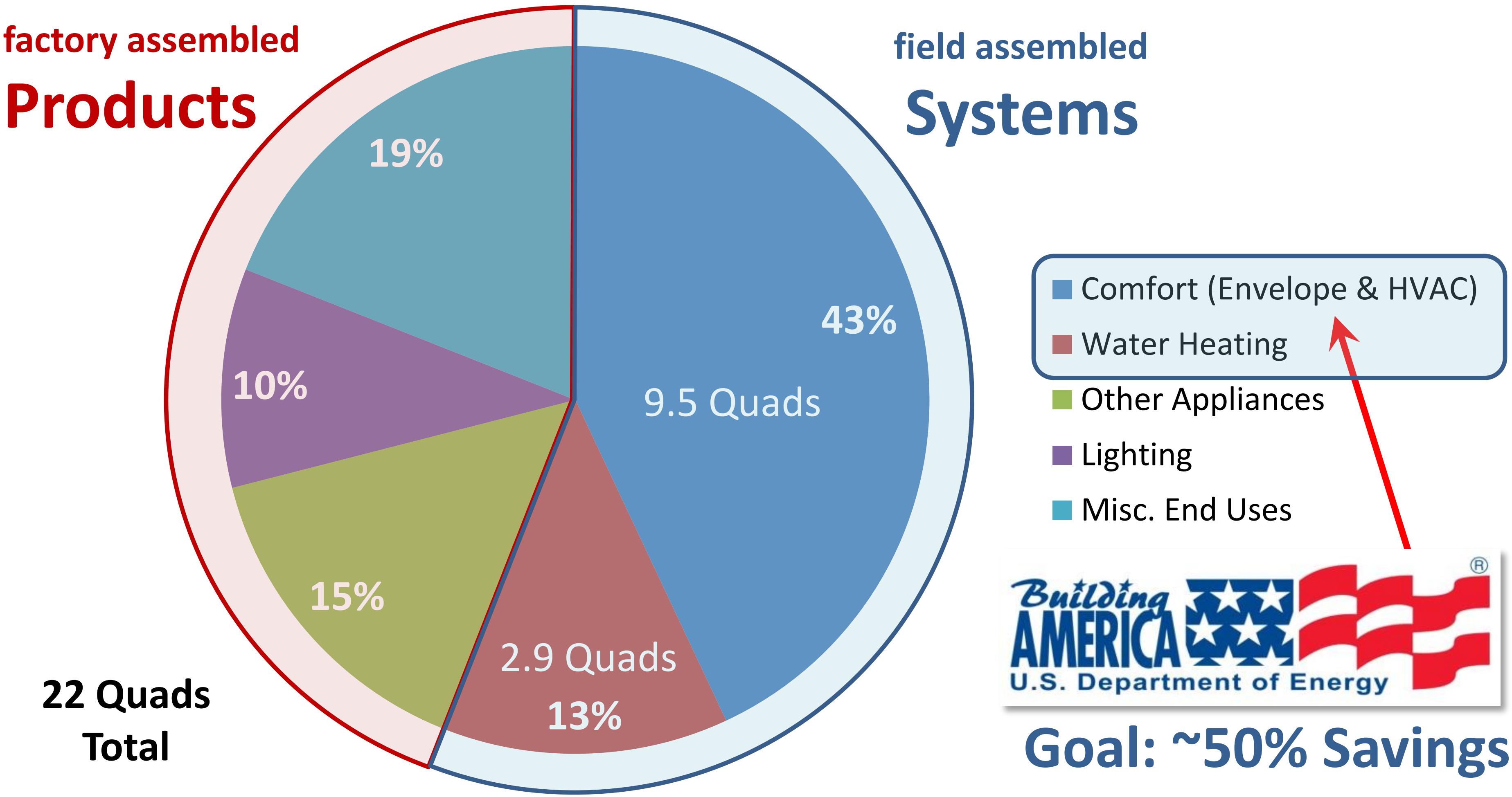
Building America Program Overview

ERIC WERLING
Building America Program Director
Building Technologies Office

Building America Program Overview

DOE's Building America Program conducts applied housing research on energy efficiency, focused on integrated building systems, i.e., heating, cooling, and water heating end uses. Results benefit many building industry segments and the public. The program has produced more than **100 innovations** and accelerated the adoption of whole house energy-saving technologies and practices such as increased air-tightness, insulation, ventilation, and HVAC system performance optimization. Since 1995, this work has helped households across the nation **save up to $54 billion**. Building America enjoys strong industry support, and DOE estimates as much as ***$170 in homeowner savings for every $1 spent by the program***.

Building America Aims to ***Cut Energy Use of U.S. Homes in Half*** by Helping Industry Improve "Integrated" (Field Assembled) Systems



U.S. Residential Buildings Primary Energy Consumption

* Source: U.S. EIA

Building America

Vision	Improved homes for Americans, that **cut bills in half**, improve **health/comfort**, & increase **jobs/profits** for housing industry based on **better home performance/value**
Goal	Demonstrate by 2020 integrated building & HVAC technologies that affordably **reduce EUI 60% for new homes** and **40% for existing homes** in all U.S. climates
Objective	Develop/Demonstrate/Disseminate building science & engineering **best practices** that **improve home performance** and **lower risks**, market tested through **industry partnership**

BTO MYPP Goals

- By 2020, develop and demonstrate cost-effective bundles of technologies and practices in each of the seven climate zones that can reduce the energy use intensity of new single-family homes by at least 60% and existing single-family homes by at least 40%, relative to 2010 with a focus on reducing heating, cooling, and water heating loads.
- By 2020, demonstrate performance of individual technologies and solutions that provide at least 10% heating and cooling energy savings (relative to 2010 levels).

Dec. 2015

The Residential Integration Program accelerates energy improvements in existing and new residential buildings by reducing technical and market barriers to spur investment and achieve high performance homes.

External Influences: DOE budget, Construction industry, Energy prices, Real estate market, Market incentives, State/local policies, Regulation

Objectives → Activities / Partners → Outputs → Short Term Outcome → Mid-Term Outcome → Long Term Outcome

Objectives

- Demonstrate & integrate energy efficient technologies & practices in representative homes
- Prove energy saving solutions & programmatic designs on a national scale with market partners
- Accelerate market adoption by increasing understanding of effective energy saving solutions

Activities / Partners

- Competitive R&D funding focused on demo, testing & validation by Building America & national lab researchers in field homes
- Resources development with national labs for building prof. & service providers
- Support business model demo to upgrade or construct high perf. homes with market partners across climates
- Outre… natio… adopt… solutions in common transactions.
- Tool development & demo of the value of energy efficiency in the market with market partners
- Educational support to promote quality workforce

Outputs

- Space conditioning, water heating & IAQ focused Building America upgrade packages & techniques for existing & new homes across climates
- Guidance for energy savings beyond recent building energy codes & industry standards for stakeholders
- Best practice online Better Buildings & Buildings America Solution Centers
- Demonstrated home upgrades …
- Targeted campaigns to propel adoption of low cost home upgrade improvements
- Home Energy Score tool
- Building science curriculum, student competitions & workforce development

Short Term Outcome

- Innovator building professionals equipped with validated energy saving solutions for integrating highly energy efficient tech or practices into homes
- Industry standard orgs. & voluntary programs equipped with validated technical specs & guidelines to make homes highly efficient
- … business practices to increase scale of energy efficiency investments
- Wide array of industry stakeholders & building professionals aware of strategies to increase energy efficiency

Mid-Term Outcome

- Leading building professionals improve or construct high performance homes above model energy codes
- Industry standard orgs adopt technical specs to accelerate new tech & practices in building energy codes
- Energy efficiency programs facilitate market demand for energy efficiency & foster …ue energy
- …onals install proven energy saving solutions in the broader market
- Industry stakeholders widely promote value of energy efficiency in products, services, & typical market transactions with homeowners

Long Term Outcome

- The building industry regularly constructs high performance homes that are ready for renewable energy systems or significantly improves the energy efficiency of existing homes across climates.
- Homeowners are motivated to invest in more energy efficient homes spurred by increased value in the residential market.

Impact

- 40% savings in existing homes demo'd; 60% savings in new homes demo'd; 10% savings thru individual measures
- Proved in 1 million existing homes & 50K ZER new homes
- Market Partnerships reach 90% of homes; 5% savings thru individual measures with partners
- Reduce the energy used for space conditioning & water heating in single family homes by 40% by 2025 from 2010 levels
- Reduce avg. EUI in all bldgs. 30% by 2030

This is the RBI Program Logic Model, with Building America focus areas highlighted

The Residential Integration Program accelerates energy improvements in existing and new residential buildings by reducing technical and market barriers to spur investment and achieve high performance homes.

Editable version

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Objectives

- **Demonstrate & integrate energy efficient technologies & practices in representative homes**
- Prove energy saving solutions & programmatic designs on a national scale with market partners
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Activities / Partners

- Competitive **R&D funding focused on demo, testing & validation by Building America** & national lab researchers in field homes
- Resources development with national labs for building prof. & service providers
- Support business model demo to upgrade or construct high perf. homes with market partners across climates
- Outreach to stakeholders on a national scale to increase volume of adoption at common transaction points.
- **Tool development & demo of the value of energy efficiency in the market with market partners**
- Educational support to promote quality workforce

Outputs

- **Space conditioning**, water heating **& IAQ Building America upgrade packages & techniques for existing & new homes across climates**
- Industry **guidance for energy savings beyond recent building energy codes & industry standards**
- Best practice online Better Buildings & **Buildings America Solution Centers**
- Demonstrated home upgrades & new construction in HPwES & ZER Homes
- Peer sharing via Better Building Residential Network
- Resources & campaigns to propel adoption of low cost home upgrade improvements
- Home Energy Score tool
- **Building science curriculum**, student competitions & workforce development

Short Term Outcome

- **Innovator building professionals equipped with validated energy saving solutions** for integrating highly energy efficient tech or practices into homes
- **Industry standard orgs. & voluntary programs equipped with validated technical specs & guidelines** to make homes highly efficient
- Energy efficiency programs & building professionals have access to resources & business practices to increase the scale of energy efficiency investments
- Wide array of industry stakeholders & building professionals aware of strategies to increase energy efficiency

Mid-Term Outcome

- **Leading building professionals improve or construct high performance homes** above model energy codes
- **Industry standard orgs adopt technical specs to accelerate new tech** & practices in building energy codes
- Energy efficiency programs facilitate market demand for energy efficiency & foster markets that value energy efficiency
- Building professionals install proven energy saving solutions in the broader market
- Industry stakeholders widely promote value of energy efficiency into products, services, & typical market transactions with homeowners

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Building America Business Case

High-Performance Home Impacts:*

- **~$350 Billion – $1+ Trillion** Utility Bill Savings
- **~$20 - $100+ Billion** Annual Health Related Benefits
- **~$90 – $270 Billion** Annual Construction Revenue
- **~120,000 – 360,000** Persistent New Jobs

* Impacts based on internal DOE analysis assuming 30% market penetration of high-performance new and existing homes by 2025

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Housing Industry Problems/Barriers (Opportunities)

- Housing industries under-invest in R&D:
  - <0.4% of Industry Revenue goes to R&D and
  - virtually 0% private investment in integrated whole house performance improvement solutions
- Perceived risks of innovation are high:
  - Uncertainty about envelope moisture durability of houses built to current standards with modern building materials
  - System integration and cost tradeoff challenges
  - Indoor air quality and ventilation system performance concerns
- Housing infrastructure lacks sufficient resources to effectively manage performance risks:
  - No/Low-tech performance measurement technologies; inability to measure/predict/manage installation quality & operational performance
  - Lack of consistent code approval for proven innovations
  - Insufficient training & education for trades

Building America Program Strategy

- Engage industry stakeholders in RD&D, to ensure market relevance and accelerate innovation.
- Develop practical and profitable solutions for builders and home improvement contractors.
- Demonstrate optimal performance and cost effectiveness in real world homes.
- Link RD&D with market deployment programs.
- Help industry manage technical and business risks through best practice guidance & tools.
- Help resolve market barriers such as codes and standards conflicts, with applied building science knowledge & guidance.

Building America Delivers High Performance Home Innovations

for Energy Efficient New and Existing Homes:

1. Moisture Managed High-R Envelopes

- Reduce Heating/Cooling Loads & Improve Durability

  High performance homes with increased insulation, reduced infiltration, reduced risk of condensation, & adequate drying potential inside building assemblies

2. Optimized Low-Load Comfort Solutions

- Effectively Manage Airflow & Indoor RH for Comfort

  High efficiency comfort systems for homes with low thermal loads, including optimal efficiency, managed air flow and RH control at all part load conditions

3. Smarter Indoor Air Quality Solutions

- Control Fresh Air Supply & Contaminant Removal

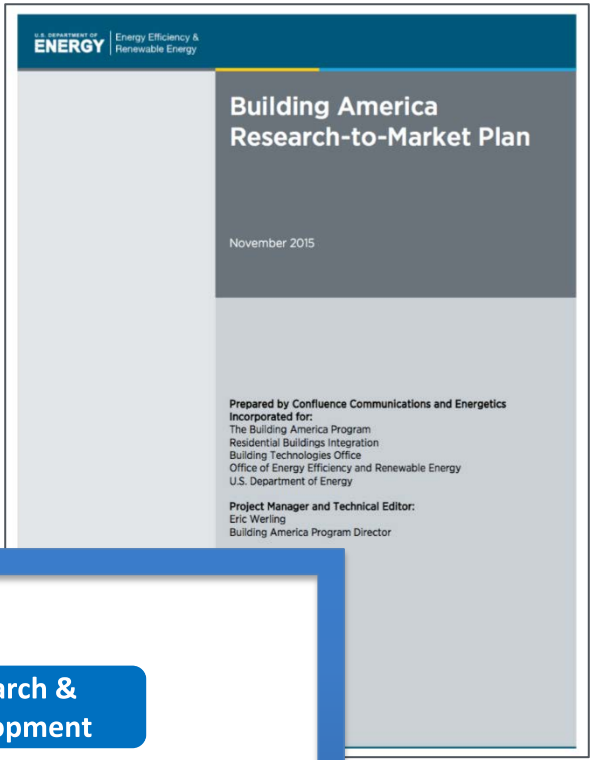
  Added tightness with improved source control, dilution, and high efficiency filtration, with little or no energy penalty

Building America Technology to Market Roadmaps

A. High Performance, Moisture Managed Envelope Systems

B. Optimal HVAC Systems for Low Load Homes

C. Optimal Ventilation and IAQ Solutions for Low Load Homes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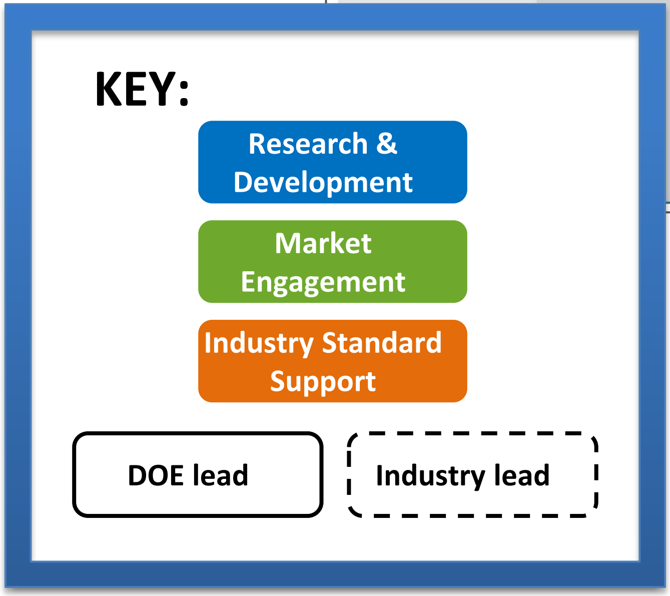
Building America Research-to-Market Plan

November 2015

Prepared by Confluence Communications and Energetics Incorporated for:
The Building America Program
Residential Buildings Integration
Building Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

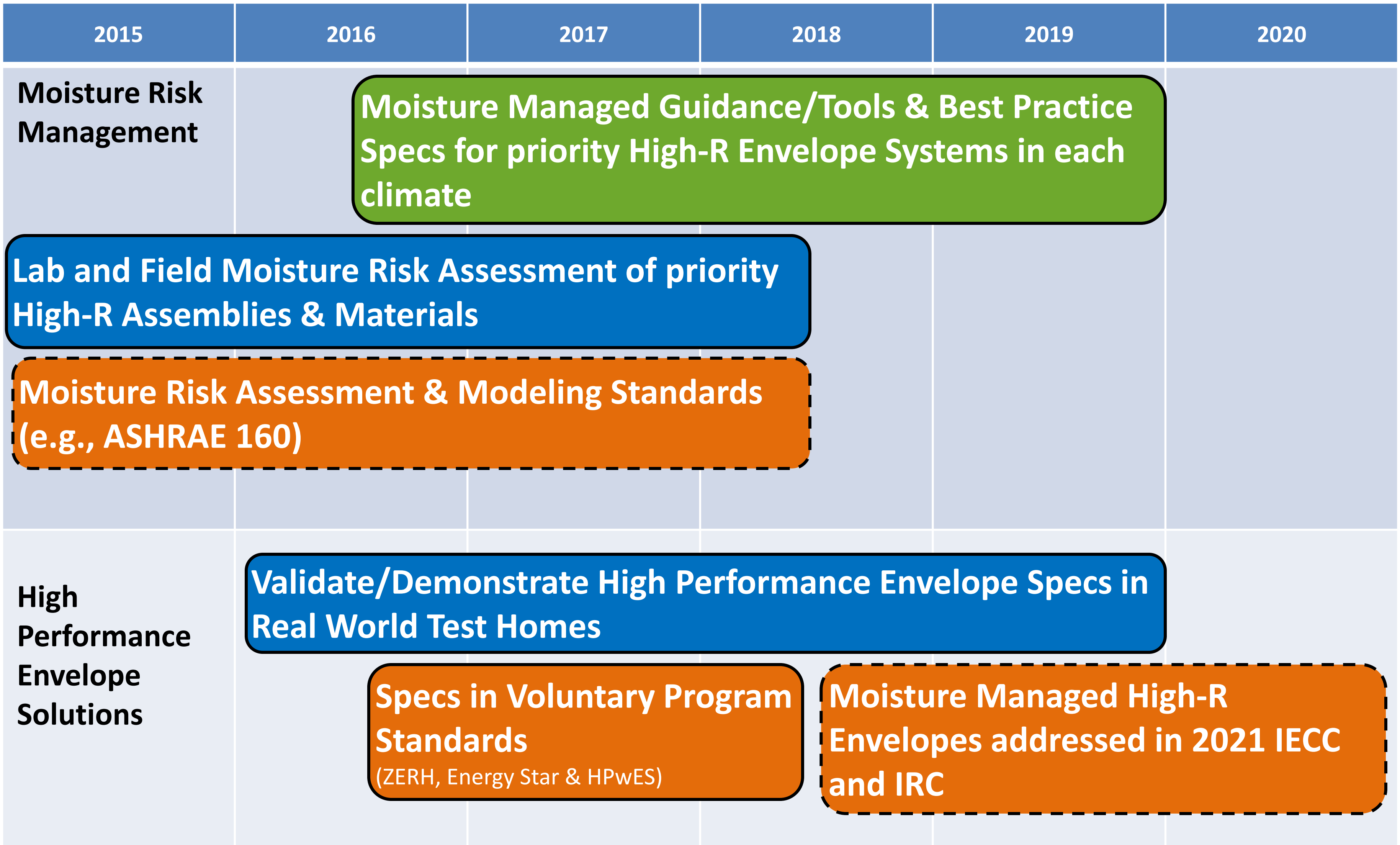
Project Manager and Technical Editor:
Eric Werling
Building America Program Director



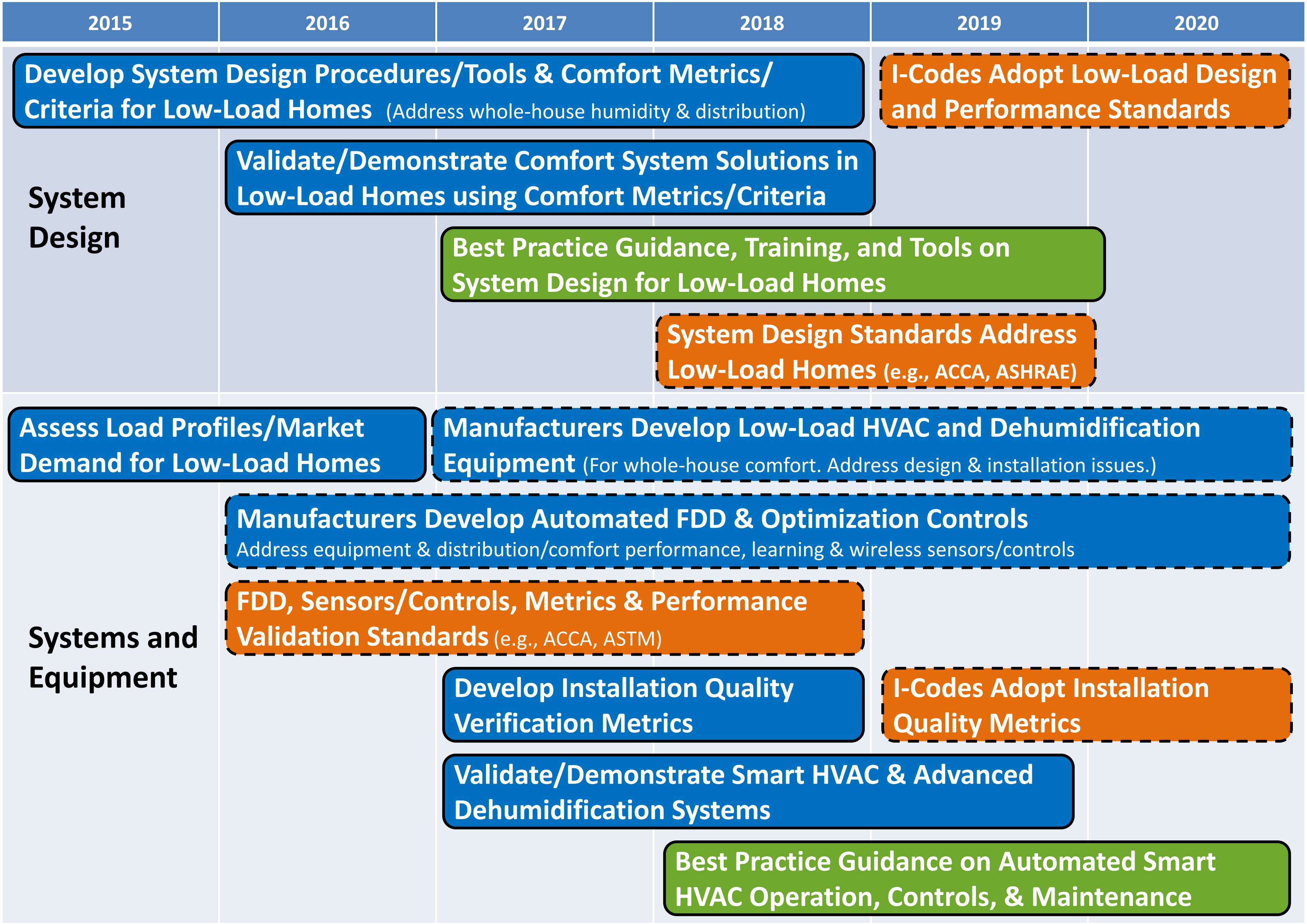
Roadmap Objectives:

- Improve Standard Practice
- Manage Risks
- Optimize Performance
- Practical, Profitable Solutions

A. High Performance Moisture Managed Envelopes



B. Optimal Comfort Systems for Low-Load Homes



C. Optimal Ventilation & IAQ Solutions

2015 | 2016 | 2017 | 2018 | 2019 | 2020

Targeted Pollutant Solutions

- **Manufacturers Develop Targeted IAQ Solutions**
  include smart range hoods, advanced air cleaning & humidity control systems
- **Validate/Demonstrate Targeted IAQ Solutions**
- **Targeted IAQ Solutions Addressed in HVI Certification, ASHRAE 62.2, & 2021 I-Codes**

Smart Ventilation

- **Manufacturers Develop Smart Ventilation Equipment & Real Time Controls** (using indoor/outdoor conditions & home operation data)
- **Validate/Demonstrate Smart Ventilation & Real Time Controls**
- **Smart Ventilation Specs**
  for IAP, ZERH, ENERGY STAR, & HPwES
- **Smart Ventilation Addressed in ASHRAE 62.2, 2021 I-Codes, & HERS**

IAQ Valuation

- **Develop IAQ Baselines & Valuation Metrics,**
  develop thresholds/targets, measure targeted pollutants
- **IAQ Guidance & Assessment Tools**
  for New Home Designs & Retrofit Strategies
- **ASHRAE 62.2 transition to IAQ Equivalence & Smart Systems**

Building America Research Activities in FY17

- Ongoing Research Projects to Address Roadmap Objectives (FY15-16 funded FOAs & FY17 Lab AOPs):
  - Envelope Projects: 5 Partnership Teams & 2 Nat'l Lab projects
  - HVAC Projects: 4 Teams & 1 Nat'l Lab projects
  - IAQ Projects: 3 Teams and 3 Nat'l Lab projects
- Select/Negotiate/Award 6 to 10 new FY17 funded FOA Awards (FOA# DE-FOA-0001630)
  - Topic 1: Additional Projects to Address Remaining Roadmap Objectives
  - Topic 2: Baseline Indoor Air Quality Study of New Occupied Homes
- FY18 Research Planning:
  - Develop Technology to Market Roadmaps for Existing Homes
  - Stakeholder engagement
  - FY18 FOA Development
  - FY18 Nat'l Lab R&D Planning

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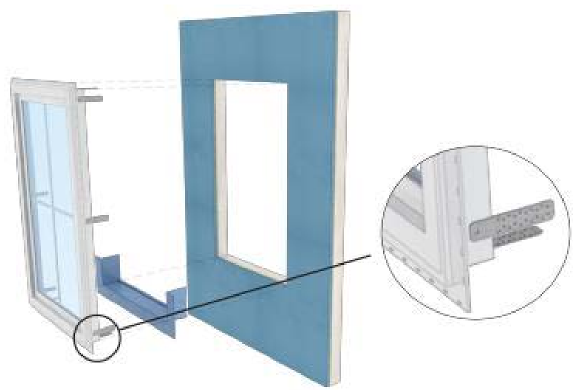
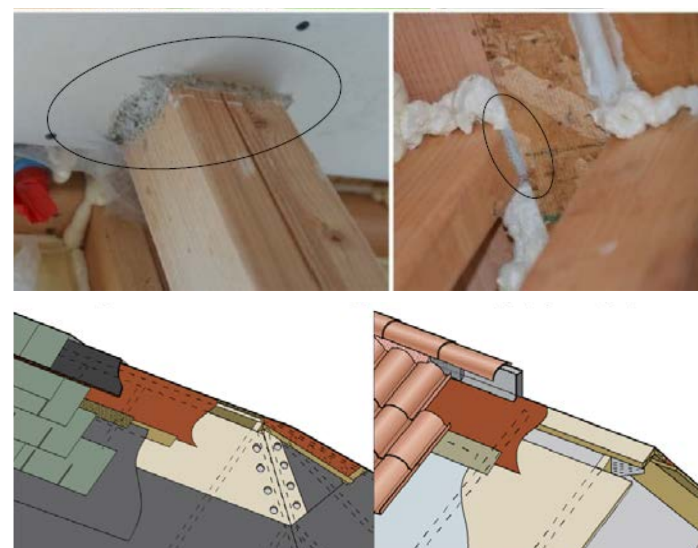
Current Industry Partnership Team Projects (FY15-16 funded):
HIGH PERFORMANCE MOISTURE MANAGED ENVELOPE SOLUTIONS

PROJECT LEAD	PROJECT TITLE
Home Innovation Research Labs, Inc.	A Constructible and Durable High-Performance Walls System: Extended Plate and Beam
University of Minnesota - Twin Cities	Achieving Affordable Zero Energy Ready Homes with an Advanced Solid Panel Wall System
Center for Energy and Environment	Aerosol Sealing in New Construction
Home Innovation Research Labs, Inc.	Attic Retrofits Using Nail-Based Insulated Panels
Home Innovation Research Labs, Inc.	Moisture Performance of High-R Wall Systems
Building Science Corporation	Monitoring of Unvented Roofs with Diffusion Vents and Interior Vapor Control in a Cold Climate
Home Innovation Research Labs, Inc.	Structural Support of Windows in Walls with Continuous Insulation

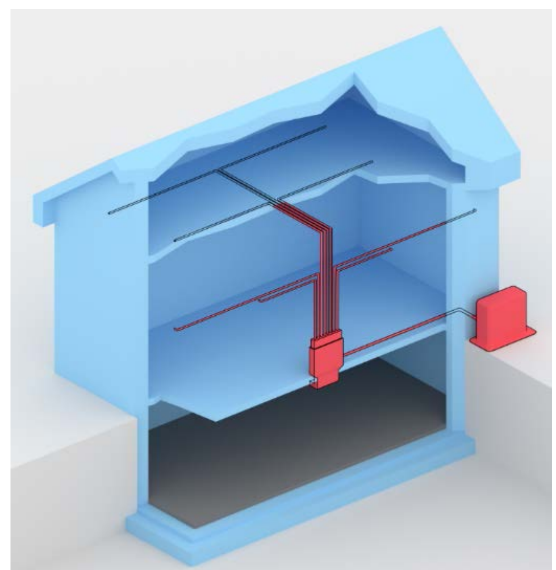




Current Industry Partnership Team Projects (FY15-16 funded):

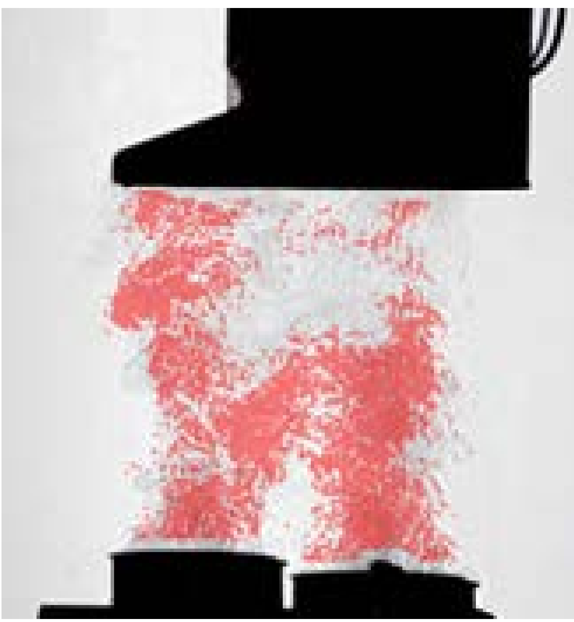
OPTIMAL COMFORT SYSTEMS FOR LOW LOAD HOMES

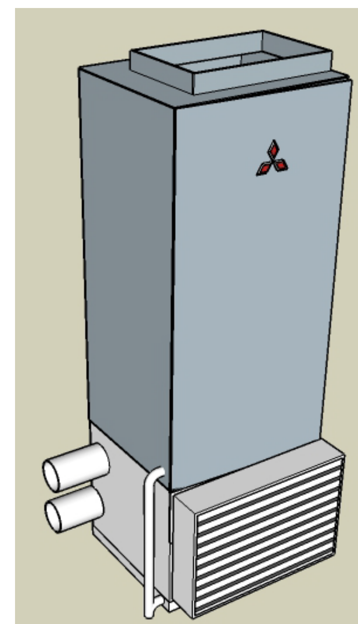
PROJECT LEAD	PROJECT TITLE
IBACOS (Integrated Building and Construction Solutions)	A "Plug-n-Play" Air Delivery System for Low-Load Homes and Evaluation of a Residential Thermal Comfort Rating Method
University of Central Florida	Building America Partnership for Improved Residential Construction (Lab and Field Testing of High Efficiency HVAC Systems for Low-Load Homes)
The Levy Partnership, Inc.	Integrated Design: A High Performance Solution for Affordable Housing
Fraunhofer USA, Inc.	Physics-based Interval Data Models to Automate and Scale Home Energy Performance Evaluations
Steven Winter Associates, Inc.	Ventilation Integrated Comfort System



Current Industry Partnership Team Projects (FY15-16 funded):
OPTIMAL VENTILATION & INDOOR AIR QUALITY (IAQ) SOLUTIONS

PROJECT LEAD	PROJECT TITLE
University of Central Florida	Building America Partnership for Improved Residential Construction (Temperature and Humidity Controlled Smart Ventilation)
Newport Partners	Development of the Industry's First Smart Range Hood
Gas Technology Institute	Energy Savings with Acceptable Indoor Air Quality Through Improved Air Flow Control
Southface Energy Institute	Performance-Based Indoor Air Quality and Optimized Ventilation
Steven Winter Associates, Inc.	Ventilation Integrated Comfort System





Building America Industry Support Activities in FY17

- **Whole house energy analysis tools & standards**:
  - Develop EnergyPlus/Open Studio interface and state-of-the-art energy analysis capabilities for residential buildings (public domain)
  - Nat'l Lab support to RESNET Std committee on HERS software accuracy
- **Building envelope knowledge & tools**:
  - Launch *Building Science Advisor v1*, a decision support tool for builders to understand & manage moisture risks of wall designs
  - DOE & Nat'l Lab support to ASHRAE Std committee on envelope moisture analysis
- **HVAC market research & analysis support:**
  - HVAC market characterization for energy efficient homes
  - Industry stakeholder engagement on HVAC QI (ACCA, ASHRAE, etc.)
- **IAQ knowledge & tools:**
  - Develop & vet draft Home IAQ score (like HERS)
  - DOE & Nat'l Lab support to ASHRAE Std committee on residential ventilation & IAQ
- **Building America Solution Center:**
  - Complete existing home guidance taxonomy
  - Develop new guidance from R&D results

Relationships with other Departments

- Building America Solution Center designed to provide technical guidance to **EPA Energy Star Homes & Indoor airPLUS program partners** based on Building America R&D
- Building America collaborates with **EPA, HUD, & NIST** on related R&D objectives, including shared stakeholder engagement, FOA merit reviewer participation, and inter-agency research planning
- **DOE Building America Program, HUD Healthy Homes Office, and EPA Indoor Environments Division** have a current inter-agency agreement on Healthy Efficient Homes, co-funding a collaborative R&D agenda
- Building America partnership team (Building Science Corporation) provided primary design services for the **NIST** Zero Energy Home Test Facility.
- Building America Teams and Nat'l Labs provide technical support/guidance on building science to numerous programs and agencies, including **DOE WAP, FEMP, EPA, HUD, FEMA, & DOD**

How do we measure progress? One measure…

Climate	EUI 2010 Baseline (kBtu/ft²/yr)	New Home 60% Reduction EUI Target (kBtu/ft²/yr)	Number of Case Studies Achieving Target or Better
Very Cold/Cold	112.9	45.1	4
Hot-Dry/Mixed-Dry	115.4	46.2	1
Hot-Humid	124.9	50	2
Mixed-Humid	117.4	47.0	1
Marine	111.8	44.7	0

Climate	EUI 2010 Baseline (kBtu/ft²/yr)	Existing Home 40% Reduction EUI Target (kBtu/ft²/yr)	Number of Case Studies Achieving Target or Better
Very Cold/Cold	112.9	67.7	9
Hot-Dry/Mixed-Dry	115.4	69.3	0
Hot-Humid	124.9	74.9	1
Mixed-Humid	117.4	70.4	0
Marine	111.8	67.1	2

Industry Quotes

The Building America Program is filling an essential role in the marketplace—one that would be extremely difficult for the private sector to perform. I believe that investments by the federal government in this program reap huge rewards at the local level in terms of energy savings, comfort, and consumer protection.

—Ron Flax, Sustainability Examiner for Boulder County Land Use (Colorado)

"Pulte has been working with the Building America Program since it began. Building America has helped our business research and develop strong new high-performance products that keep us competitive and offer our homebuyers exceptional efficiency and quality."

—Robert Broad, PulteGroup Southern California/Southern Nevada Division

Industry Quotes

"We used the U.S. Department of Energy's Building America program and its work with the energy efficiency industry to bring state-of-the-art construction innovations and resources to the public."

—Carolyn G. Goodman, Mayor of Las Vegas, Nevada

"Building America provides a much needed resource to our business and the industry. As a new home builder, we rely on the program to develop and demonstrate innovative technologies before we take the risk of putting them into our construction practices. Without Building America, the construction industry would have great difficulty adopting new practices."

—Tom Wade, Palo Duro Homes

Up Next…

FLORIDA SOLAR ENERGY CENTER®

A Research Institute of the University of Central Florida

Partnership for Improved Residential Construction

2017 Building Technologies Office Peer Review

Full-Scale Residential Research Laboratories at FSEC
Top: *Flexible Residential Test Facility*: smart ventilation studies in side-by-side control and experiment houses. **Bottom:** *Manufactured Housing Lab*: experiments with variable capacity HVAC systems.

Occupied Field Study Houses
WSU smart ventilation study home in Washington (top, left) and FSEC optimal comfort system study homes on the east (top, right) and west (bottom) coasts of the Florida peninsula.

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Eric Martin, martin@fsec.ucf.edu
Florida Solar Energy Center, University of Central Florida

Project Summary

Timeline:
Start date: August 1, 2015
Planned end date: July 31, 2017

Key Milestones:
1. Complete setup, begin data collection; December 2015
2. Preliminary evaluation of research questions; July 2016
3. Complete data collection; June 2017

Budget:

Total Project $ to Date (2/23/2017):
- DOE: $714,576
- Cost Share: $159,615

Total Project $:
- DOE: $1,000,000
- Cost Share: $250,000

Key Partners:

Comfort Systems	*Ventilation / IAQ*
Unico	Wash. State Univ.
Panasonic (heat/cool)	Panasonic (vent)
Mitsubishi	Nest Labs
Habitat for Humanity	Air Cycler

Project Outcome:
1) *Optimized Comfort Systems* - Demonstrate system approaches for energy efficient management of temperature and relative humidity in low load homes in humid climates. *MYPP goal: 10% heating/cooling energy savings from individual technologies.*

2) *Optimal Ventilation / IAQ* – Demonstrate approaches to optimize delivery of mechanical ventilation in response to variable risk factors. *MYPP goal: 10% heating/cooling energy savings from individual technologies.*

Purpose and Objectives – Optimized Comfort Systems

Problem Statement: Energy efficient home construction and remodeling leads to reduced sensible load, but latent loads remain unchanged. As a result, conventional space cooling equipment runs less, and may no longer manage moisture and comfort adequately.

Target Market and Audience:

Target Market: High performance new construction and renovation in humid climates. Cooling energy use = 0.13 Quads (site energy basis).

Audience: Early adopter builders, remodelers and mechanical contractors that need solutions now. Product manufacturers who can provide mass-market solutions.

Purpose and Objectives – Optimized Comfort Systems

Impact of Project: Demonstrate ability of emerging space cooling equipment to maintain RH < 60% with less reliance on supplemental dehumidification, resulting in 10% cooling energy savings and meeting immediate needs of early adopters. Identify desirable operational characteristics that can be used to advance conventional equipment to meet similar, growing needs of mass market. Success also helps enable best practice mechanical ventilation in humid climates.

Project Outputs: Project specific data leading to guidance on applicability of emerging systems for early adopters and recommendations for manufacturers to improve performance of both advanced and conventional cooling equipment.

a. <u>Near-term outcomes:</u> Partner builders incorporate innovations as standard.
b. <u>Intermediate outcomes :</u> Increase general humid climate Zero Energy Ready Home (ZERH) compliance and engage manufacturers of conventional equipment to consider solutions.
c. <u>Long-term outcomes:</u> Humid climate HVAC systems become standard product offerings, and considerations for RH control performance included in equipment certification. Seeking similar, regional market transformation as we have seen with use of heat pumps vs. electric resistance, and Energy Star windows.

Approach – Optimized Comfort Systems

Approach: Testing relative humidity (RH) control of variable capacity heat pumps. Systems offer potential for better RH control via ability to vary compressor speed, refrigerant flow, and coil air flow.

- Conducting lab test of centrally ducted system with small duct high velocity distribution (Central Florida – CZ 2a), *Partners: Unico*.
- Conducting field tests of ducted mini-split and ductless multi-split systems (Central Florida – CZ 2a), *Partners: Habitat for Humanity, Mitsubishi, Panasonic*.

Key Issues:

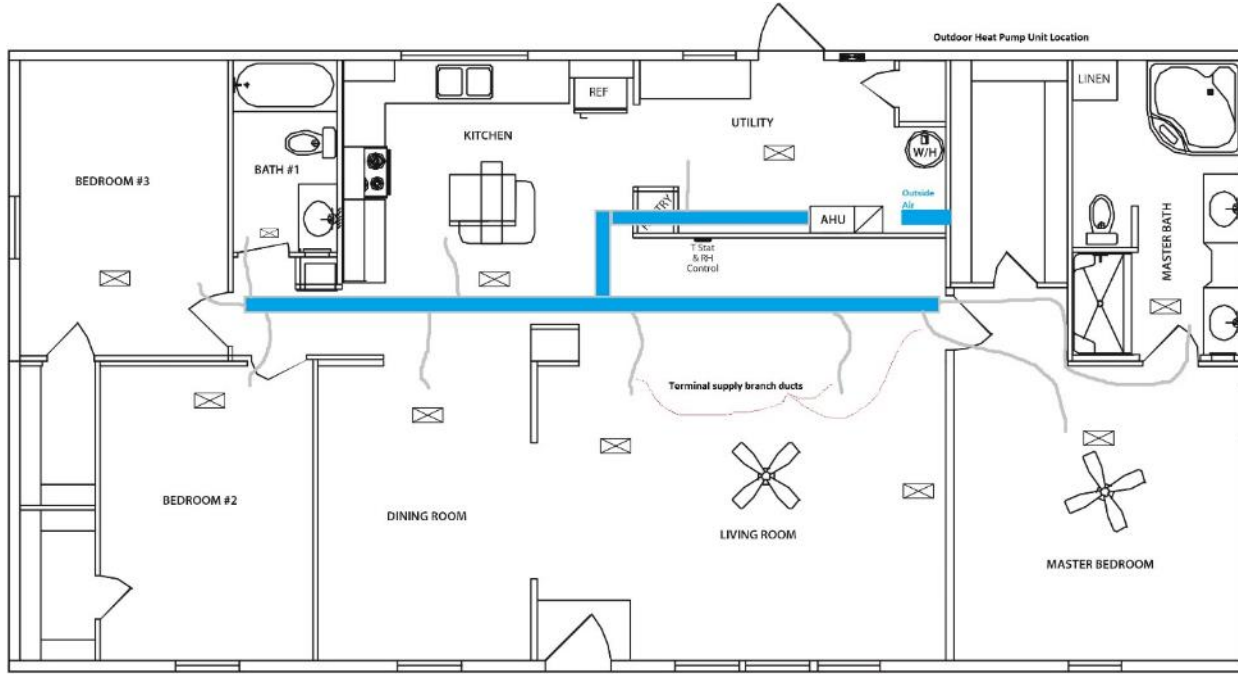
- Need for supplemental dehumidification to maintain RH < 60% in low load, mechanically ventilated houses.
- Integration of mechanical ventilation as part of system package.

Distinctive Characteristics:

- Interior ducts can also be a barrier for ZERH. Approach involves strategies that reduce/eliminate duct losses through use of compact and/or ductless distribution.
- Investigating how distribution strategies perform in terms of evenness of comfort throughout the homes.

Small Duct High Velocity (SDHV), Variable Capacity Heat Pump

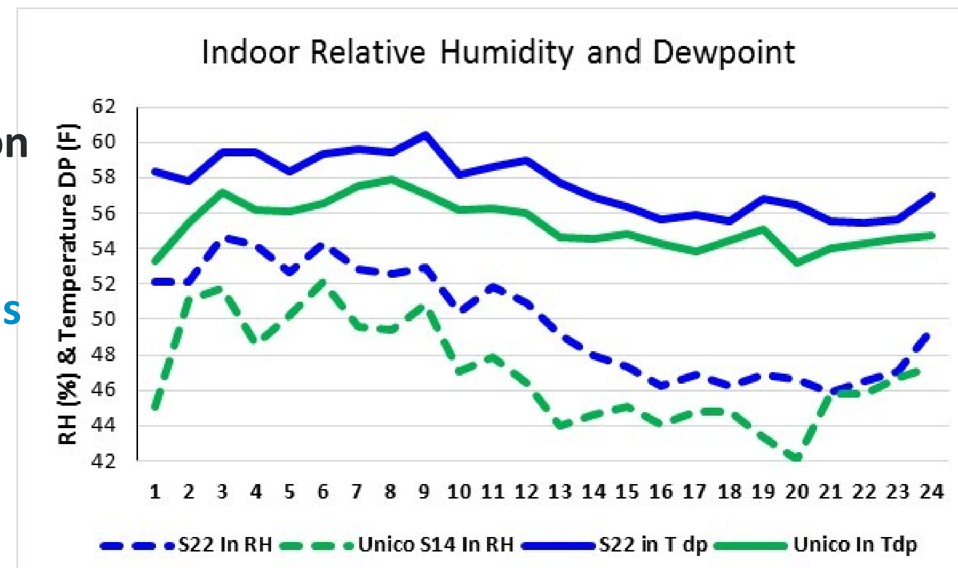
Lead: Chuck Withers



Supplemental Dehumidification Energy:

SEER 22 = 0.44 kWh/d (previous testing)

SDHV = 0.22 kWh/d (current testing)

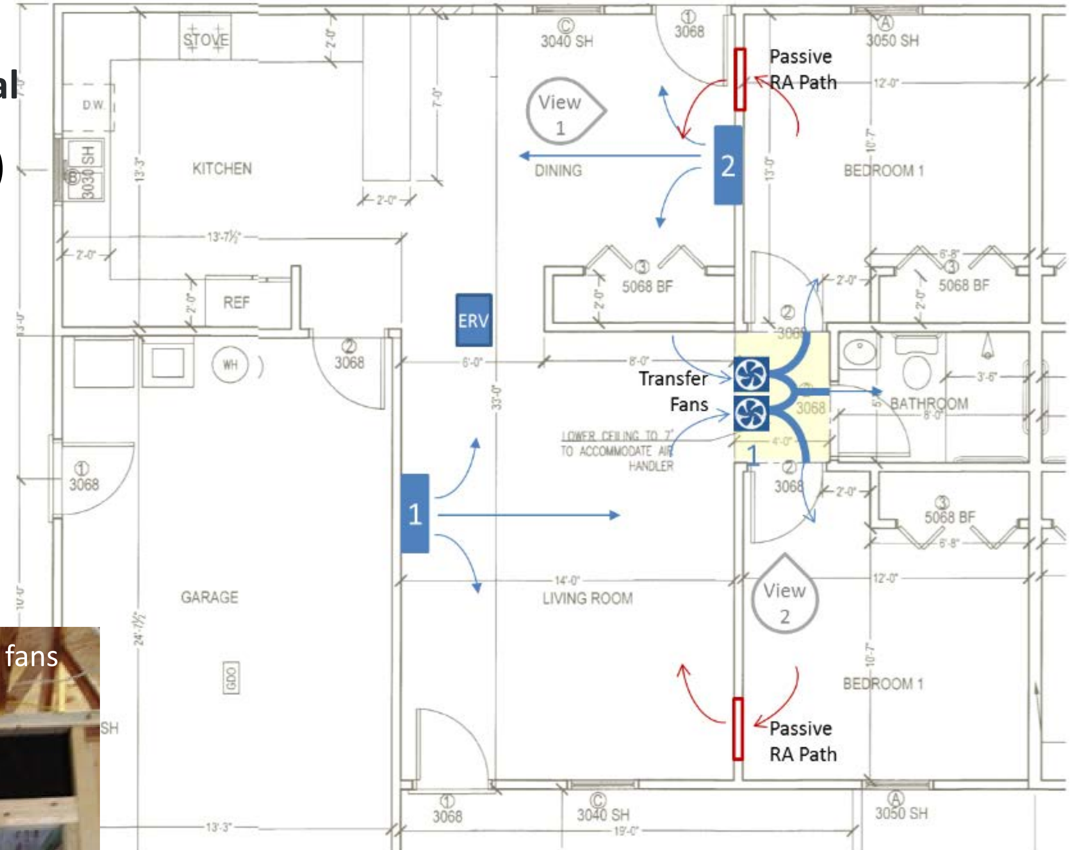


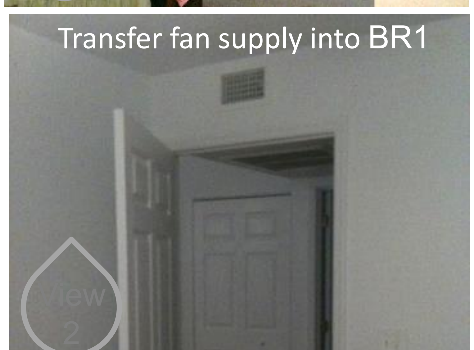
Ductless Multi-Split

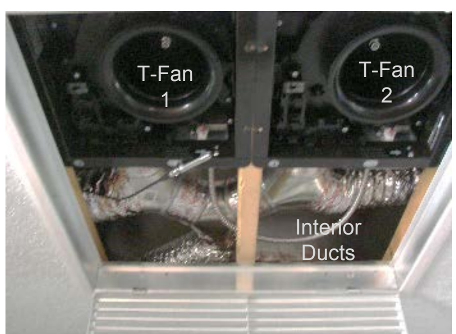
Lead: Janet McIlvaine, Dave Chasar, David Beal

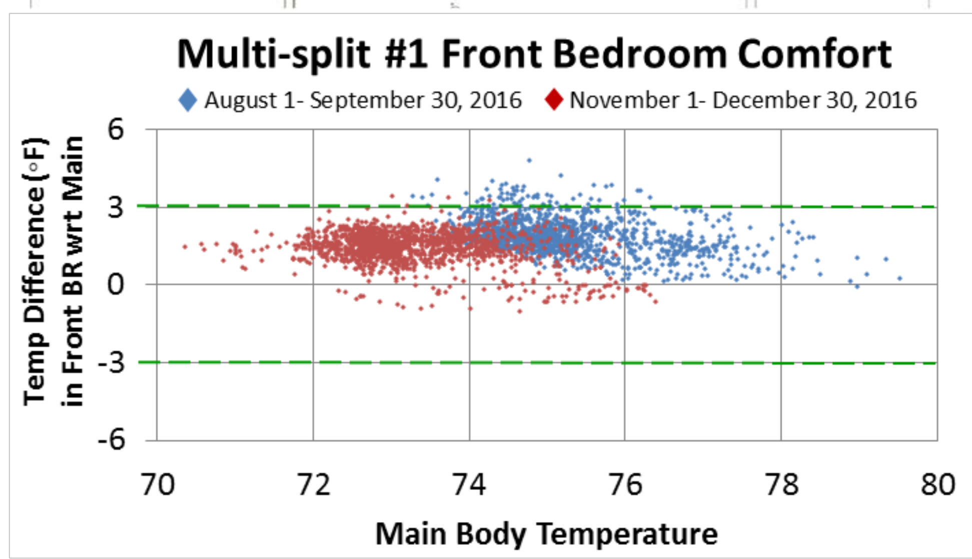
SE Volusia Habitat for Humanity (Florida)

- Duplex (1,075 ft^2 per unit)
- Panasonic bundled package
  - 2 fan coil units in main body
  - 2 transfer fans circulate air to BRs
  - ERV for mechanical ventilation







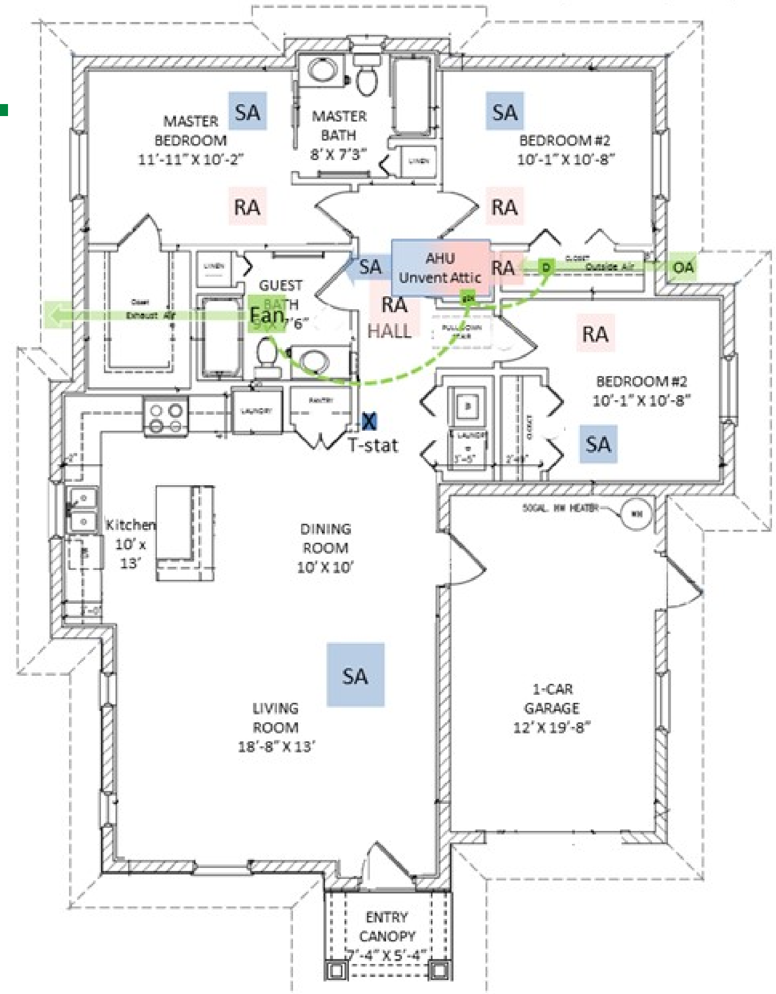


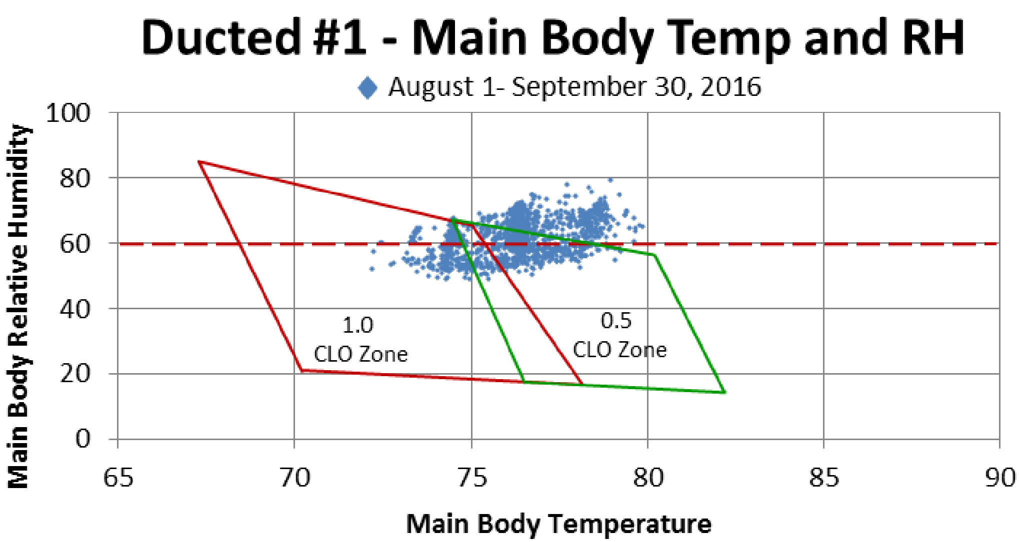
Ducted Mini-Split

Lead: Janet McIlvaine, Dave Chasar, David Beal

South Sarasota Habitat for Humanity (Florida)

- 2 single family detached houses (1,290 ft^2 per unit)
- Mitsubishi mini-split with cassette AHU
  - Fully ducted supply and return
  - Unvented attic
  - Hybrid supply/exhaust system for mechanical ventilation.





Progress / Accomplishments – Optimized Comfort Systems

Accomplishments:

1) Ductless systems with transfer fans distribute comfort within ACCA Manual RS guidelines (bedrooms ± 3^{o}F from set point) for > 95% of all hours for all months.
2) Small duct, high velocity central system able to maintain RH < 60% with only incidental need for supplemental dehumidification (50% less than previous SEER 22 system tested), due to consistently low cfm/ton. Dry mode requires no dehumid.
3) Variable capacity systems tested do not appear to operate at lowest stated capacities for extended periods (>15 minutes). Mini/Multi systems often default to high coil temp.
4) 3 of 4 Mini/multi-split homes have 50-70% of cooling hours > 60% RH; 25-35% of cooling hours > 65% RH.

Market Impact: Partner Habitat affiliates have transitioned to the ducted mini-split system as standard, with ~30 homes built to date. Accelerating impact by:

1. Engaging with 3 equipment manufactures to identify and implement modifications to improve performance.
2. Engaging builders/contractors through conferences, focused training activities.
3. Working together with Habitat and manufacturers as they develop and standardize regional HVAC packages available through Gifts in Kind program.

Awards/Recognition: Partner Habitat affiliates have won DOE Housing Innovation Awards in 2014, 2015, and 2016.

Purpose and Objectives – Optimal Ventilation / IAQ

Problem Statement: Mechanical ventilation is a critical component of a comprehensive strategy for good IAQ. However, the potential for continuous delivery of outdoor air to impact energy use and comfort presents a barrier to installation and operation of compliant systems.

Target Market and Audience:

Target Market: High performance new construction and renovation in all climates. Heating/cooling energy use = 1.46 Quads (site energy basis).

Audience: Product manufacturers for commercialization of solutions; ASHRAE Standard 62.2, ZERH / Energy Star, and codes to enable adoption of solutions; and builders and contractors for implementation of solutions.

Purpose and Objectives – Optimal Ventilation / IAQ

Impact of Project: Demonstrate ability of smart ventilation systems to better manage energy and comfort risks, while ensuring compliant acute and chronic exposure to pollutants. Success will lead to increased market penetration, increased effectiveness of installed systems, and 10% heating/cooling energy savings.

Project Outputs: Project specific data leading to commercialization of smart ventilation systems and guidance for compliant operation.

a. Near-term outcomes: Single variable systems operated in compliant fashion.
b. Intermediate outcomes : Multi-variable systems and advanced single variable systems available commercially. Enables increased penetration of ZERH, Energy Star, etc.
c. Long-term outcomes: Combined with improvement of low-cost IAQ sensors, apply smart ventilation principles to performance based IAQ standards and mechanical ventilation systems. Risks related to delivery of outdoor air no longer a barrier to adoption of mechanical ventilation and compliant operation.

Approach – Optimal Ventilation / IAQ

Approach: Testing smart mechanical ventilation systems that vary outdoor air flow in response to various risk factors.

- Lab test of system varying relative exposure (flow) real time, proportional to outdoor temperature and relative humidity (Central FL, CZ 2a – hot humid).
- Field test of system delivering two levels of flow in response to 1) outdoor temperature and 2) occupancy (Washington, CZ 4c - marine), *Partners: Panasonic, Nest Labs.*
- Field test of hybrid supply (CFIS)/exhaust system (Central Florida, CZ 2a – hot humid), *Partners: Habitat for Humanity, AirCycler*.

Key Issues:

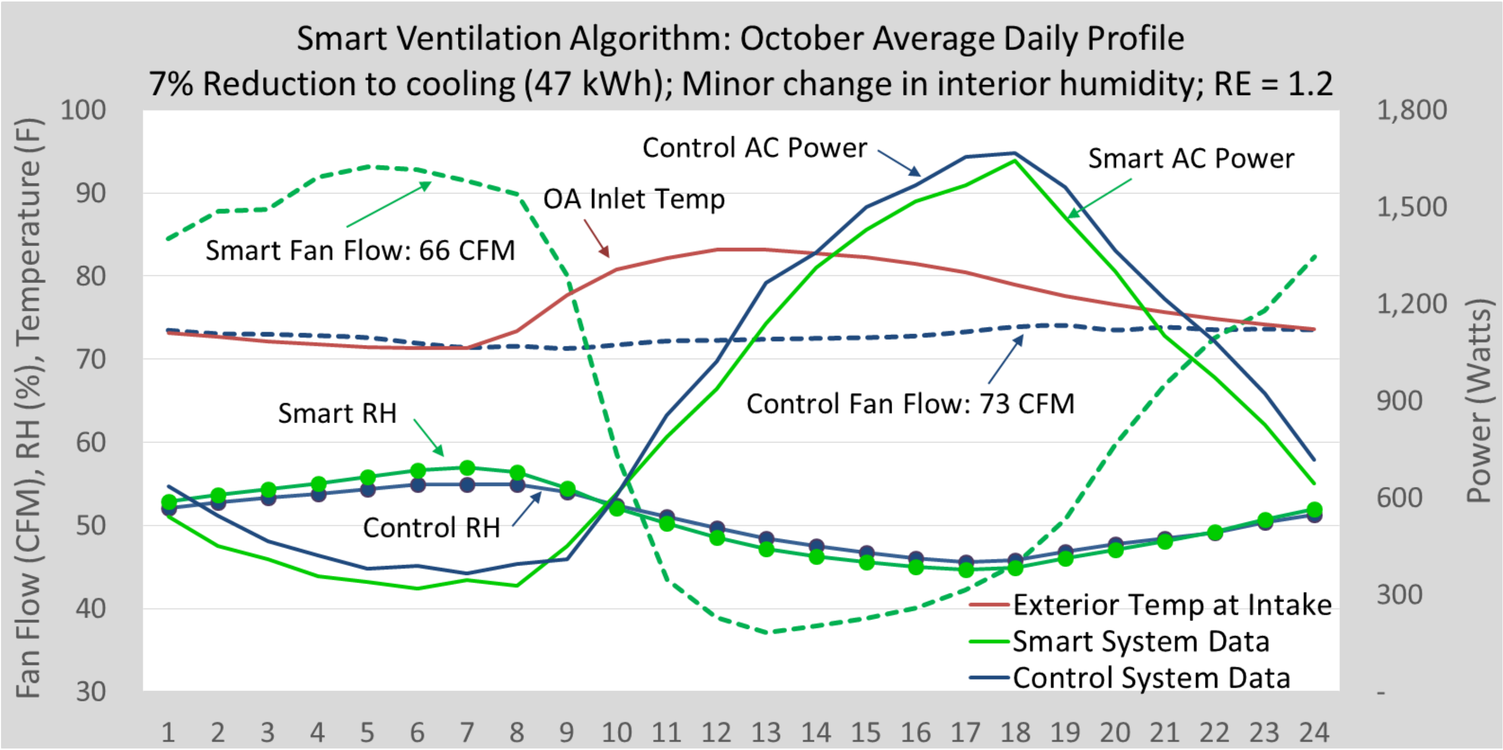
- Deliver improved (or equivalent) comfort, while consuming less (or an equivalent amount of) energy, compared to continuous ventilation.
- Deliver relative exposure to pollutants in accordance with ASHRAE 62.2-2016.

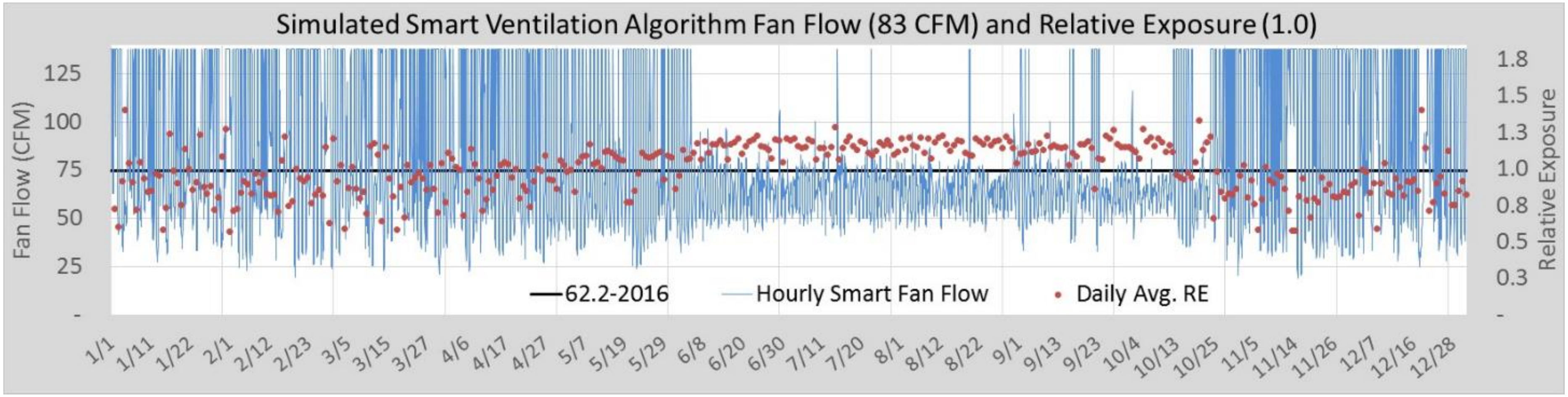
Distinctive Characteristics:

- Engaging ventilation equipment manufacturers and other stakeholders, including ASHRAE Standard 62.2 committee, to enable market penetration.

Smart Ventilation Algorithm Lab Test

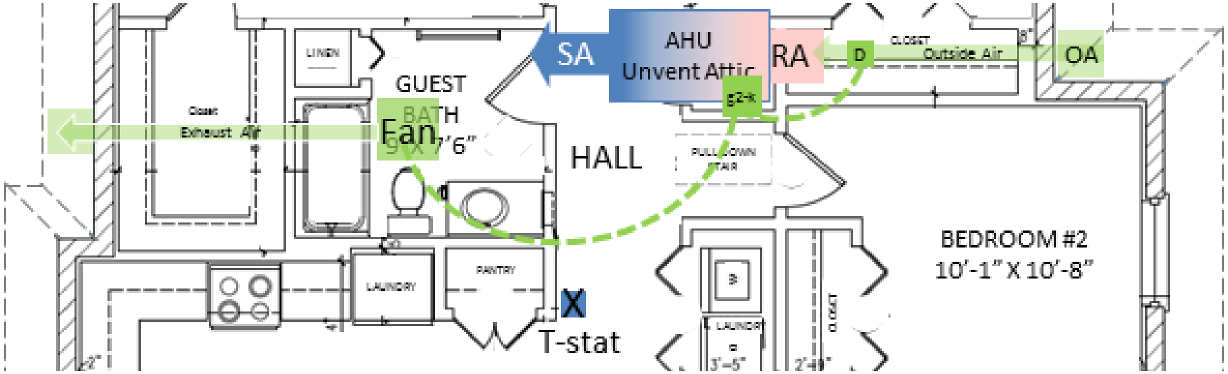
Lead: Danny Parker, Karen Sutherland





Hybrid Supply/Exhaust Ventilation Field Test (Florida)

- System prioritizes central fan integrated supply (CFIS) ventilation when actively heating/cooling.
- Balance needed for ASHRAE 62.2 compliance made up with efficient exhaust fan.
- Will ASHRAE 62.2 compliance be achieved if mini-split causes CFIS flow to vary?



Temperature/Occupancy Controlled Ventilation Field Test (WA)

Lead: Michael Lubliner, WSU

- Deep Energy Retrofit. Exhaust ventilation. ACH50 = 5.
- Investigating resulting indoor comfort, indoor air quality, and energy impacts among 40 cfm continuous exhaust ventilation and:
  - 0 cfm when outdoor temperature < 57F, 90 cfm when outdoor temp > 57F, taking advantage of stack induced natural ventilation.
  - 0 cfm when unoccupied, 40 cfm when occupied.

Progress / Accomplishments – Optimal Ventilation / IAQ

Accomplishments:

1) Smart ventilation algorithm delivering 1.3 kWh/d cooling energy savings = 6.3% average monthly cooling energy savings (ranging from 1-18%). Minor indoor RH impacts.
2) Temperature based ventilation control estimated to save 9% heating energy (230 kWh/y) with no indoor RH impacts.
3) Hybrid supply/exhaust system provides relative exposure <1 when mated with variable capacity heat pump.
4) Started dialogue within ASHRAE 62.2 related to relationship between occupancy and pollutant emission rates, potentially enabling additional energy savings and/or IAQ improvement.

Market Impact: Partner Habitat affiliate has built ~6 homes with the hybrid supply/exhaust system. Accelerating impact by:

1. Providing input to/review of ASHRAE 62.2 user manual containing examples of applications involving compliant, smart ventilation systems.
2. Engaging manufacturers and other stakeholders to identify commercialization issues and remaining gaps including system costs, commissioning, fault detection, and interoperability of components across communication platforms.
3. Investigating use of measurements from low cost IAQ sensors (TVOC, CO_2) as a surrogate for occupancy. Participating in Energy Star Web Connected Thermostat efforts to enable smart ventilation control.

Project Integration and Collaboration

Project Integration: Collaborating and coordinating with:

- Builders and contractors (local Habitat affiliates and Habitat International) to assist with validation and adoption of innovations.
- Voluntary programs (Zero Energy Ready Home) to communicate potential solutions to barriers and enable adoption by leading building professionals.
- Industry standard organizations (ASHRAE 62.2) to inform the market on best practice.
- HVAC manufacturers to develop and commercialize mass market solutions (Including some not yet mentioned: Trane, Honeywell, Aprilaire, QuFresh).

Partners, Subcontractors, and Collaborators:

- Subcontractor: WSU – Leads smart ventilation activities related to occupancy, marine/cold climates, and commercialization.
- Partners: Panasonic, Nest, Energy Conservatory, Unico, Mitsubishi, AirCycler, and Habitat for Humanity.
- Collaborators: LBL, PARR Building America Team, NREL

Communications:

- Expert meeting, conference papers, and panel sessions on smart ventilation.
- Education of local, regional, and national Habitat stakeholders through roundtables, conferences, and webinars.

Next Steps and Future Plans (current scope / future)

Optimized Comfort Systems:

- Implement RH control enhancement in homes with Mitsubishi ducted mini-split. Discussing similar enhancements with Panasonic and Unico.
- Adjust transfer fan air flow in homes with ductless multi-split.
- Perform simulations to quantify impact of supplemental dehumidifier energy at RH set points < 60%.
- Engage with EnergyStar HVAC certification on inclusion of criteria for RH control performance.

Optimal Ventilation/IAQ:

- Continue dialogue on occupancy control within ASHRAE 62.2. Simulate energy savings potential with large scale occupancy data from Nest Labs.
- Analyze data on interior conditions in occupancy controlled residence and correlate data from multiple, low cost IAQ monitors against tracked occupancy.
- Adjust smart vent algorithm parameters in Florida lab to ensure compliant relative exposure, shift emphasis to RH control.
- Hybrid supply/exhaust system: Determine if fraction supplied by exhaust increases proportionally as outdoor dew point decreases, and if expected energy savings are being realized.
- Engage with ASHRAE 62.2 regarding acceptable occupancy detection and IAQ sensors, and requirements for fault detection and alerts.

REFERENCE SLIDES

Project Budget

Project Budget: FY 2016 funds primarily spent on experimental set up and preliminary data collection. FY 2017 funds primarily spent on final data collection and reporting.

Variances: Original deliverables planned for March 2017, but early delays in one task enable data collection to continue through June 2017 with deliverable reports planned for July 2017.

Cost to Date: 70% of the budget has been expended to date (as of 2/23/2017).

Additional Funding: No additional funding has been received from other sources.

Budget History					
August 2015– FY 2016 (past)		FY 2017-July 2017 (current/planned)		FY 2018 (N/A)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$514,523	$124,371	$485,477	$125,629	$0	$0

Project Plan and Schedule

- Initiation date: 8/1/2015. Project planned completion date: 7/31/2017.
- Original builder partner for Florida smart ventilation field measurements dropped from project. Change in builder partner and system type prevented “complete set-up” milestone for this task only from being achieved on original date of 12/2015.
- Go/no-go decision points evaluated preliminary results in 7/2016.

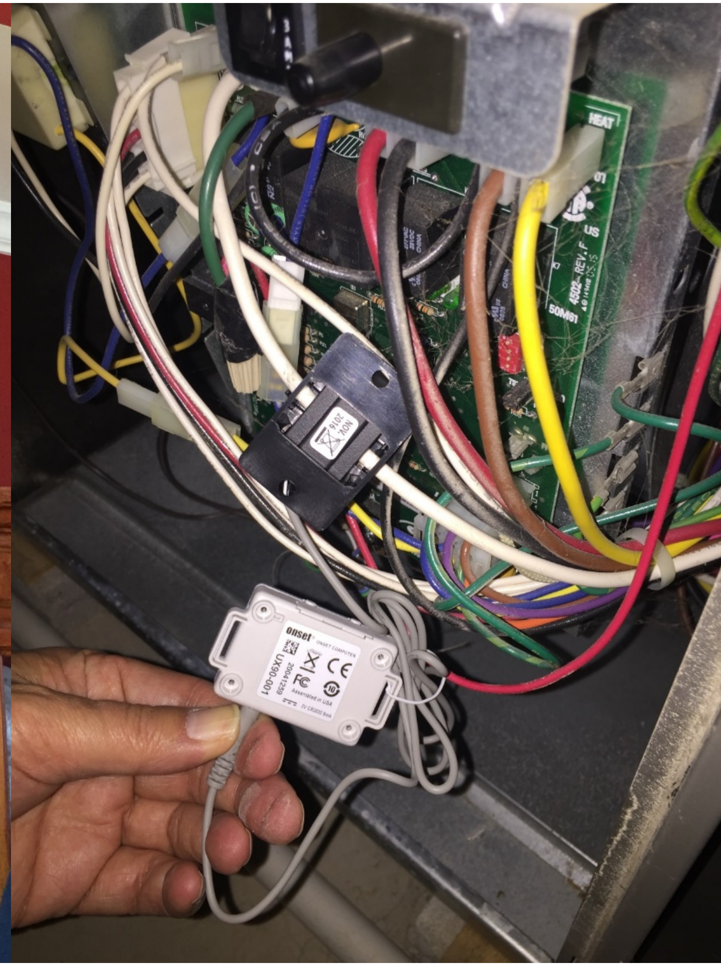
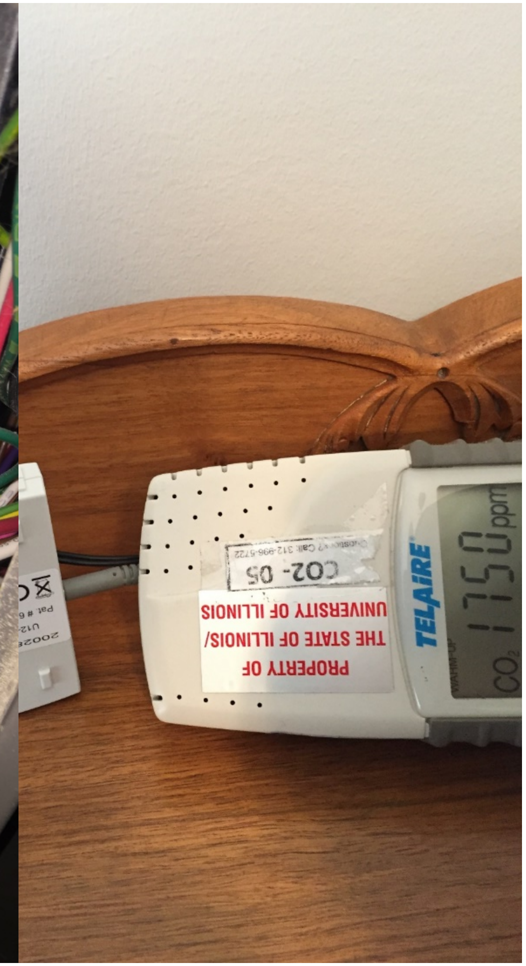
Project Schedule												
Project Start: August 2015	Completed Work											
Projected End: July 2017	Active Task (in progress work)											
	Milestone/Deliverable (Originally Planned)											
	Milestone/Deliverable (Actual)											
	FY2015				FY2016				FY2017			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Q4 Milestone: Approval of Experimental Plan												
Q1 Milestone: Complete Set-Up / Instrumentation												
Q2 Milestone: Smart Vent Expert Meeting												
Q3 Milestone: Complete Cost Comparisons												
Q4 Milestone: Evaluate Research Questions												
Current/Future Work												
Q3 Milestone: Complete Data Collection												
Q4 Milestone: Deliver Final Report												

Up Next…

GAS TECHNOLOGY INSTITUTE

Energy Savings with Acceptable Indoor Air Quality Through Improved Air Flow Control in Residential Retrofit

2017 Building Technologies Office Peer Review

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Paul W. Francisco, pwf@Illinois.edu
University of Illinois at Urbana-Champaign
(GTI/PARR team)

Project Summary

Timeline:

Start date: September 1, 2015

Planned end date: March 30, 2019

Key Milestones

1. Expert and Practitioner Meetings; 5/2016
2. Go/No-Go Budget Period 1; 8/2016
3. Recruitment; Underway, homes are currently being monitored

Budget:

Total Project $ to Date:

- DOE: $195,596
- Cost Share: $93,979

Total Project $:

- DOE: $750,000
- Cost Share: $250,000

Key Partners:

Gas Technology Institute (GTI; prime)
University of Illinois at Urbana-Champaign (UIUC)
Midwest Energy Efficiency Alliance (MEEA)
Priority Energy

Project Outcome:

This project aims to demonstrate that, through systematic management of airflows, indoor air quality and/or energy savings can be increased with no penalty to the other. This will help to reduce EUI while optimizing home performance and validate improved practices that can be applied across a variety of climate zones.

Goals/Impact/Status

- Support retrofit savings from air sealing of approximately 7% (based on impact evaluations of retrofit programs)
  - Air sealing corresponds to potential of about 1.5 quads per year across existing homes (based on MYPP)
  - Corresponds to about $17B in potential consumer energy cost savings (based on MYPP)
- Assume that concerns about IAQ sacrifice 10% of potential air sealing savings in 1% of homes
  - Potential benefits approximately $17M
- For project cost of $750,000, leads to ROI of about 23:1
- Project recently underway in field
  - No field conclusions yet
  - 2016 Accomplishments: Practitioner and Expert Meetings and Test Plan completed

Purpose and Objectives

Problem Statement: Concern about indoor air quality (IAQ) frequently limits energy efficiency upgrades. Airflows within the home are often considered independently. This project aims to demonstrate that systematic management of airflows increases the ability to deliver energy savings without sacrificing IAQ. This addresses the BTO MYPP on Residential Buildings Integration Strategies while serving to unlock the energy savings potential of air sealing in existing homes.

Target Market and Audience: The target market is existing buildings, and supports the goal to reduce energy usage by 25% which would result in a national savings of 5 quads. The audience is the home performance contractor.

Impact of Project: The final product of this project is a protocol for contractors to use to deliver maximum energy savings without negatively impacting IAQ.

a. Near-term: Early adopters have the tools to provide integrated energy and IAQ packages
b. Medium-term: Standards and programs adopt these tools
c. Long-term: Integrated energy and IAQ packages become standard practice

Approach

Approach: We are evaluating how to address IAQ concerns in order to maximize energy savings. We are conducting a case-control study in collaboration with local home performance contractors to adopt a systematic approach that considers multiple air flow streams and measures multiple contaminants.

Key Issues: Energy savings are often sacrificed due to concerns about IAQ. Some interventions may improve one metric while causing problems in another. Airflow management is also typically not viewed systematically, which can result in suboptimal energy and IAQ outcomes.

Distinctive Characteristics: This project involves field measurements of multiple contaminants in a case-control approach.

Delivery of Project Outcomes

- Project will provide data on impact of measures
- Refine measure package and recommendations based on results
- Finalize measure package with guidance document/decision tree for broader use
- Deliver package through conferences, workshops, and trainings

Expert and Practitioner Meeting Outcomes

- Refined list of contaminants to be measured
- Refined ventilation strategies to be considered
- Identified minimum requirements for participant homes
  - Maximum leakage levels
  - Basement foundations
- Identified critical characteristics for matching of treatment and control homes
- Refined testing schedule
- Identified recruitment paths
- Identified potential contractor participants

Energy/IAQ Measurements

- Indoor Air:
  - Formaldehyde (continuous indoor generation)
  - Radon (soil/exterior generation)
  - CO_2 (human generation)
  - Humidity (human and outdoor generation)
  - Particles when possible (periodic indoor and outdoor generation)

- Energy:
  - Heating/cooling
  - Ventilation

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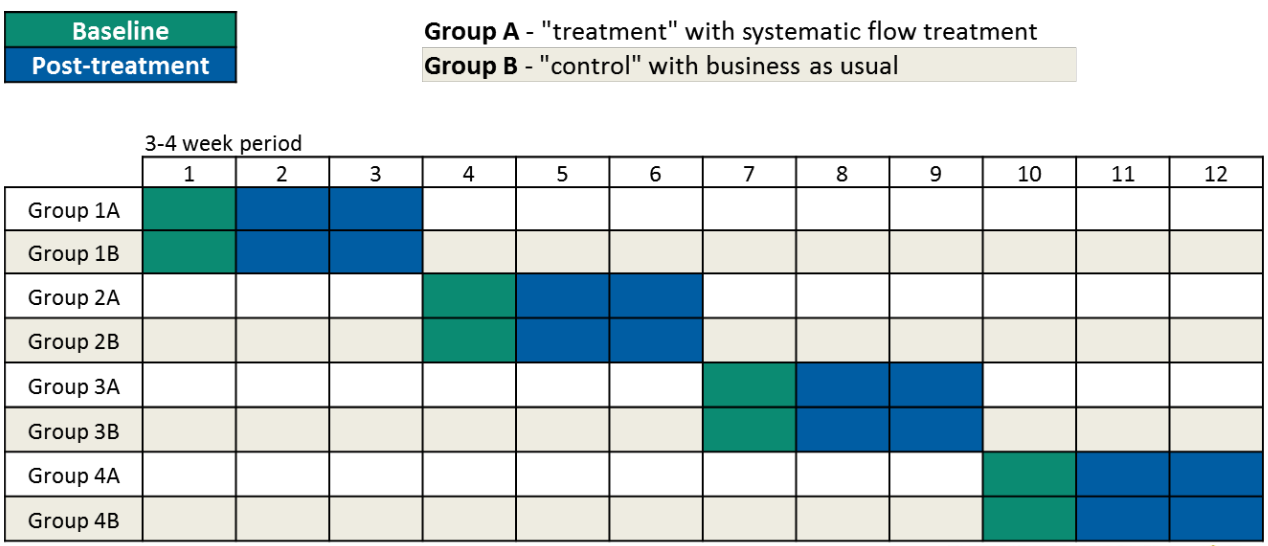
Airflows Considered

- Infiltration
  - Heating/cooling losses; addressed by air sealing
- Ventilation
  - Provide controlled air exchange; desire to minimize energy use for ventilation
- Duct leakage
  - Leakage to outside is an energy penalty
  - Unbalanced duct leakage causes pressure differentials
    - Impacts infiltration and can cause IAQ problems
- Air handler flow
  - Impacts comfort
  - Impacts humidity control in summer
  - Restricted ducts impact energy use

Testing schedule

Anticipated Site Visits:

- V1 – Audit/Qualify (partner)
- V2 – Install Instruments for Baseline Sampling (team)
  - V2+1 Wk – Return HCHO and Radon samples
- V3 – Treatment or Control Measures (partner)
  - V3+1 Wk – Return HCHO and Radon samples
- V4 – Removal (team)



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Treatment/Control

- Treatment gets all applicable measures
- Control gets "business as usual" per program, plus ASHRAE 62.2-2016
- Must match on a few characteristics, e.g. similar starting airtightness, foundation type
- Test at approximately same time

Progress and Accomplishments

Accomplishments: Two stakeholder workshops

- Expert Meeting - helped refine the project design
- Practitioner Meeting - identified challenges and solutions to project implementation
- Approval of Test Plan - this took longer than expected; the result was an improved project design but an overall project delay
- Partner contractor training, recruitment, and field testing now underway

Market Impact: We have worked closely with a retrofit contractor. The contractor has been trained on the methods and potential benefits. By working with a home performance contractor we are able to accelerate impact by demonstrating not just the theory but the practicality of implementation.

Awards/Recognition: None to date; project is underway without final results

Project Integration and Collaboration

Project Integration: The project team includes multiple members who have strong connections to industry, including the industry team lead (GTI), a weatherization training center (UIUC/ICRT), and a regional energy efficiency alliance (MEEA). The project is also working closely with a home performance contractor, Priority Energy. The connections of the project team with practitioners will expedite adoption of the project outcomes.

Partners, Subcontractors, and Collaborators: Subcontractors under GTI include UIUC/ICRT, MEEA, Chitwood and Associates, and the National Center for Healthy Housing. UIUC/ICRT is leading the scientific effort; MEEA is coordinating with practitioner collaborators and organizing stakeholder workshops. Chitwood and Associates provides contractor insight. NCHH provides a tie to the environmental health industry. The collaborator, Priority Energy, is conducting the field interventions.

Next Steps and Future Plans

Next Steps and Future Plans: Future project activities include completing recruitment and testing on a total of 40 homes, including 20 treatment and 20 control homes. Analysis of the data will indicate the extent to which the systematic airflow management techniques lead to improved energy savings/IAQ outcomes. This will be followed by presentations at stakeholder conferences and appropriate modifications to training and energy efficiency program policies.

REFERENCE SLIDES

Project Budget

Project Budget: $1,000,000; DOE: $750,000; Cost Share: $250,000

Variances: NA

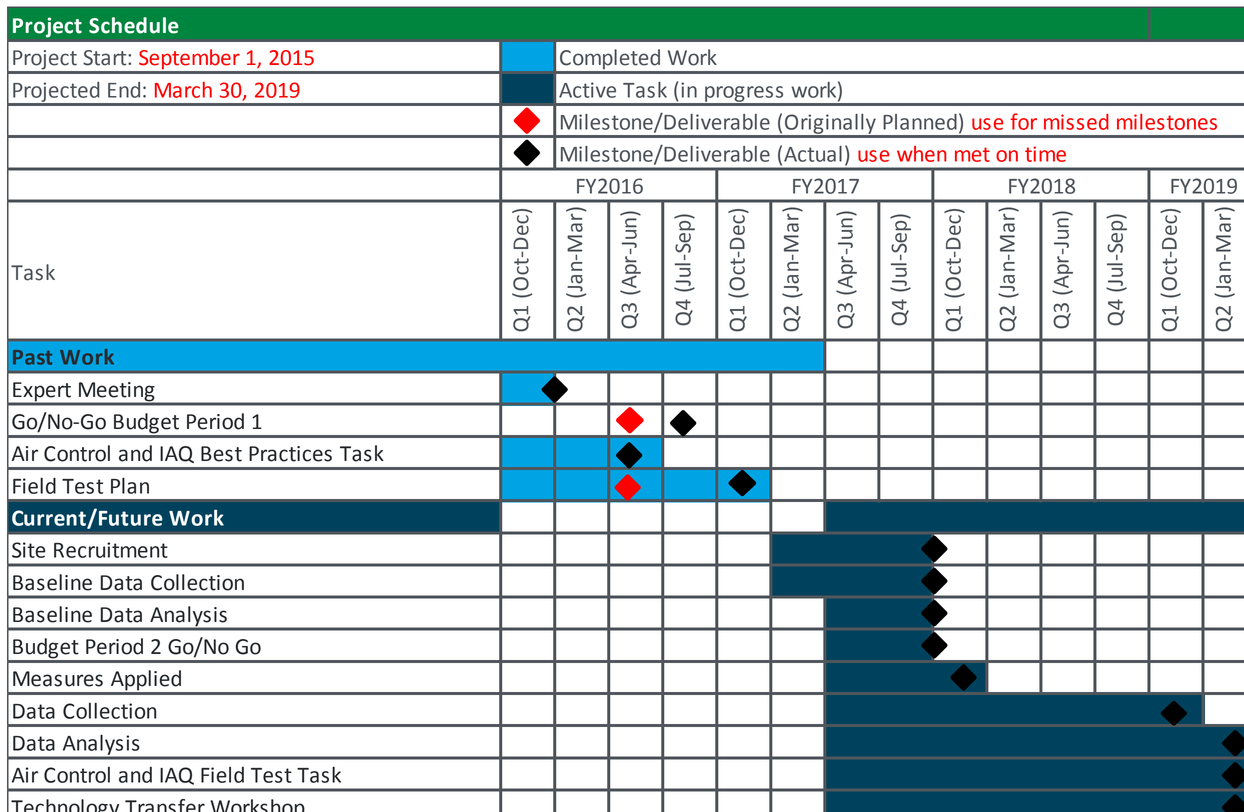
Cost to Date: $289,575; DOE: $195,596; Cost Share: $93,979

Additional Funding: NA

Budget History					
September 1, 2015 – FY 2016 (past)		FY 2017 (current)		FY 2017, 2018, 2019 – March 30, 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$165,902	$91,424	$29,694	$2,555	$554,404	$156,021

Project Plan and Schedule

- See below for original initiation date and project planned completion date, schedule, milestones, go/no-go decision points, and current and future work
- The Field Test Plan was delayed to include input from both Expert and Practitioner Meetings along with longer than expected engagement and review with key stakeholders
- The Air Control and IAQ Best Practices Task and Budget Period 1 Go/No-Go decision were delayed due to delay in finalizing Field Test Plan
- Future task and milestones due dates were extended to recognize Budget Period 1 delays (fully approved and executed). All delayed milestones and tasks are complete and project is back on schedule.



Up Next…

The Levy Partnership

Integrated Design: A High Performance Solution for Affordable Housing

2017 Building Technologies Office Peer Review

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Jordan Dentz, JDentz@levypartnership.com

The Levy Partnership, Inc.

Project Summary

Timeline

- Start: July 2015
- Planned end: June 2018

Key Milestones

- Unoccupied home meets comfort and performance criteria; July 2016
- Occupied home meets comfort and performance criteria; July 2017

Budget

Total Project $ to Date:

- DOE: $495,717
- Cost Share: $157,158

Total Project $:

- DOE: $749,987
- Cost Share: $277,000

Key Partners:

- Habitat for Humanity
- Systems Building Research Alliance
- Mitsubishi Electric
- Panasonic
- State Industries
- Whirlpool
- DOW
- Clayton Homes
- Affordable Housing Alliance
- Champion Enterprises
- Owens Corning
- Lippert Industries
- Knauf
- Next Step Network, Inc.

Project Outcome:

- **60% energy savings in single story affordable homes in mixed and cold climates**
- **Integrated HVAC and envelope using point source space conditioning**
- **Actionable guidelines for industry tied to partner implementation**

BTO Needs and Objectives: Target Markets

BTO Objective: Develop and deploy technologies and systems that reduce building energy consumption by 60%; stimulate market by partnering with major market players.
RBI Markets: single family, multifamily, **manufactured housing**

High-performance home, so energy efficient,

all or most annual energy consumption
can be offset by renewable energy.

MANUFACTURED HOMES

- **Built in 120 plants; 5,000 dealers**
- **Uniform construction: 1-story, small**
- **~70% of unsubsidized affordable housing**
- **75% owner occupied**
- **10% of new homes (70-100k/yr)**
- **7 million homes use 0.47 quad/yr**
- **Highest $/sf energy cost**

HABITAT FOR HUMANITY

- **Site built largely by volunteers**
- **1-2 story and modest size**
- **Affordable**
- **Owner occupied**
- **1,400 affiliates**
- **3,000-4,000 homes/yr**

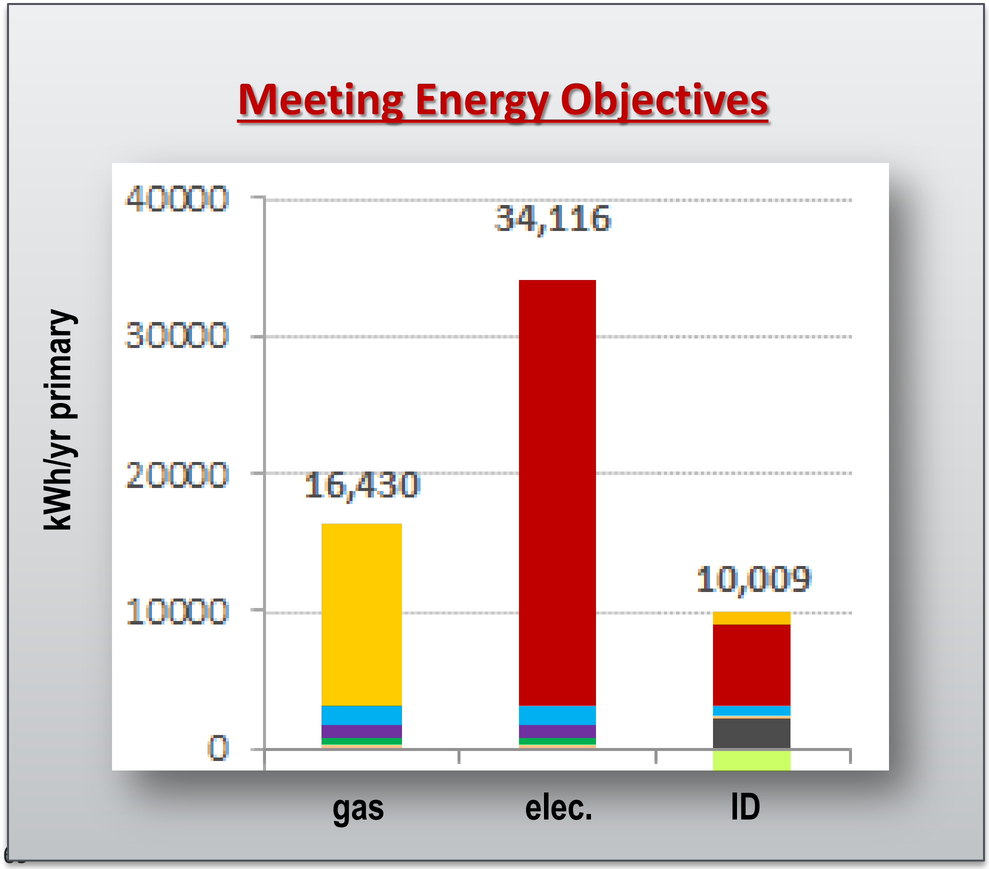
Purpose and Objectives: Benefits and Impact

60% space conditioning energy savings, at similar cost.

30 trillion BTUs saved over 10 years

$6 million annual utility bill savings*

ROI 400:1 over 10 years



Road to Impact

- **Output: Demonstrated solutions for affordable, high performance homes; clear guidelines for plants and builders**
- **Measurement: Number of homes built using guidelines**

*Assuming 30% market penetration

Approach: Project Plan and Timeline

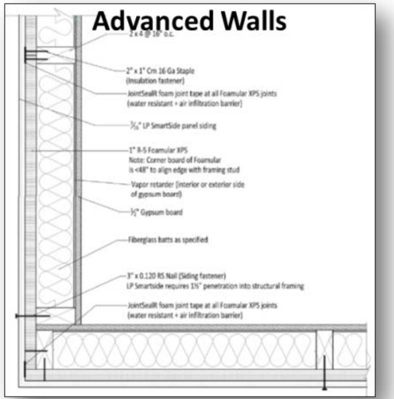
July 2015	Launch Project
Jan. 2016	2nd gen. lab home built
Jan. 2016	Complete testing 1st gen. lab home
July 2016	
Jan. 2017	2nd gen. lab home occupied
Jan. 2017	Habitat projects selected & designed
July 2017	Habitat houses occupied
Jan. 2018	
July 2018	Complete Project; Industry Hand-off
July 2018	Data collected; guidelines drafted

We Are Here

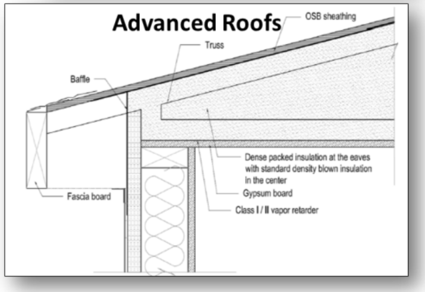
Lab Homes → **Verification in Occupied Homes** → **Industry**

Approach

Approach: Extreme collaboration with targeted market segments to demonstrate successful approaches to low energy homes. Accelerate movement in this direction by eliminating builder uncertainties and providing clear guidance for point source space conditioning with superb thermal envelopes.



Key Issues: Affordability and assurance that the solution will succeed in terms of comfort metrics, buildability and energy savings. The market is inching in this direction but needs validated solutions to rally around.



Distinctive Characteristics: Unique aspects of our approach include collective Impact: the commitment of a group of actors from different sectors to a common agenda for solving a specific problem, using a structured form of collaboration. Technologies include ultra-efficient thermal envelope, low capacity ductless heat pump, innovative distribution system.

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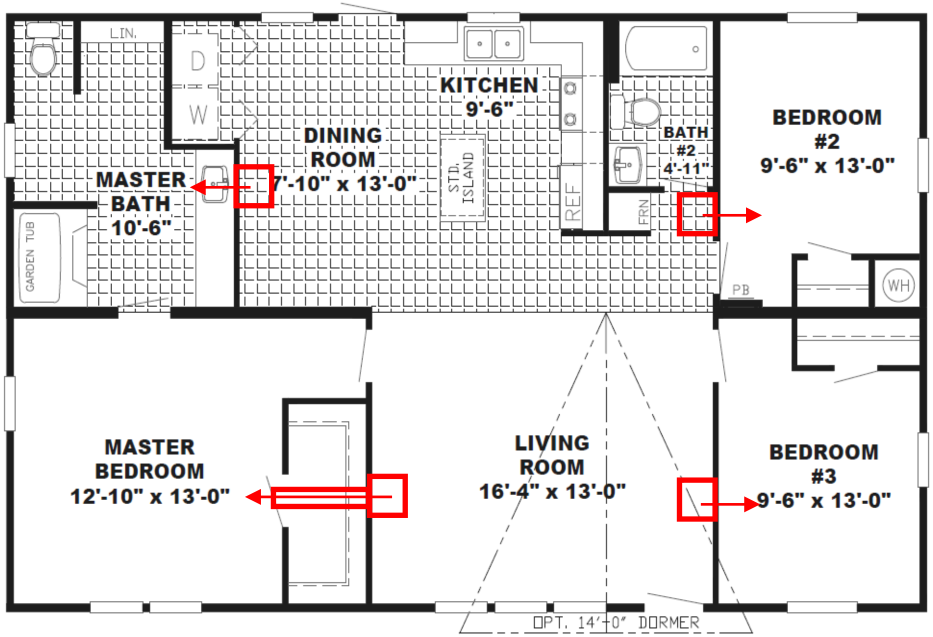
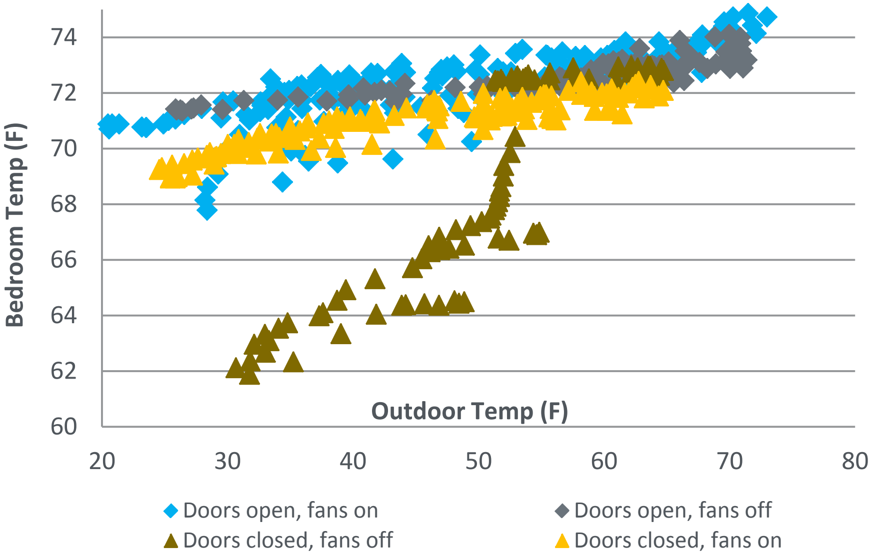
Approach: Point Source Space Conditioning

Point source space conditioning with transfer fans proven viable in Building America lab home (Russellville, AL).





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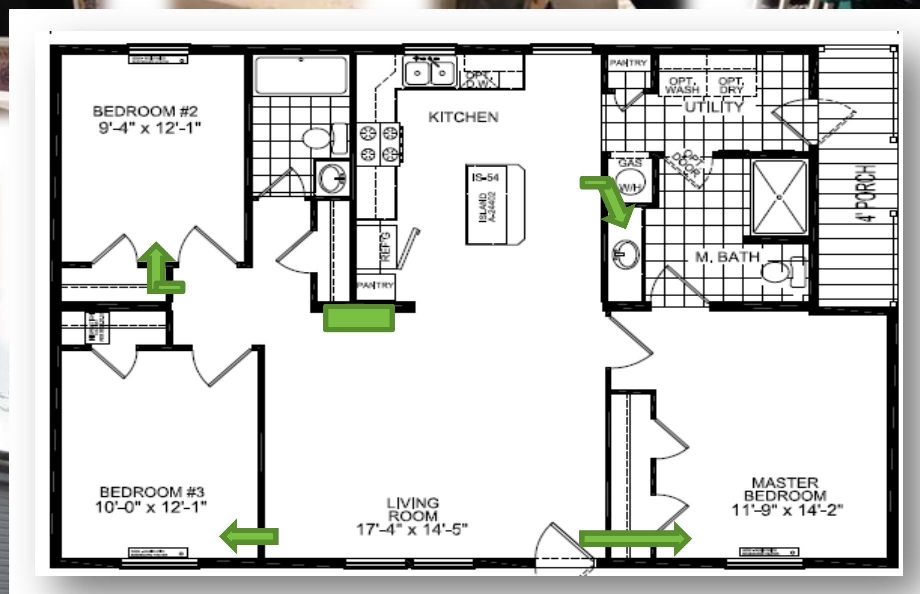
Progress and Accomplishments: 2nd Generation ID Home

2nd generation lab house in mixed climate (Eatontown, NJ) incorporating lessons learned from Russellville plus new features. Monitoring: 10-month unoccupied and 12 months occupied ongoing







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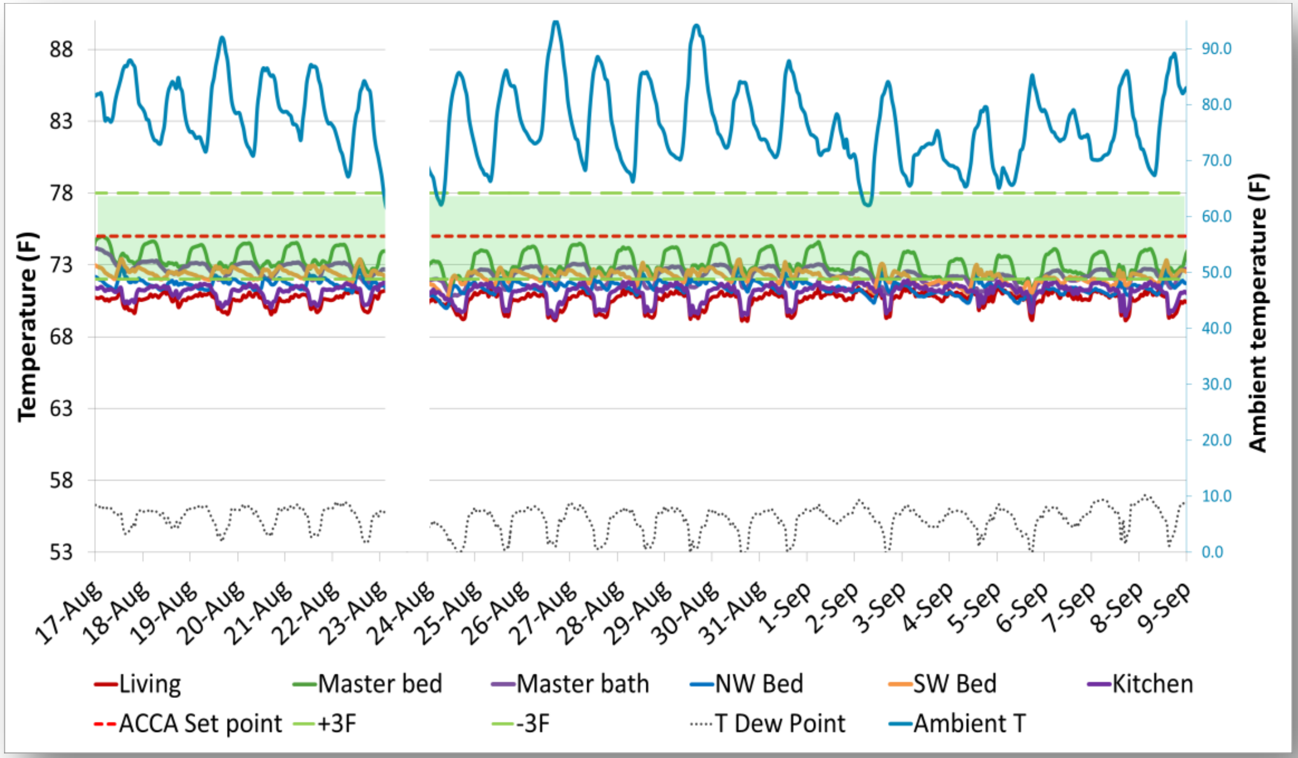
Progress and Accomplishments: Cooling Season

- **Energy targets met**
- **Temperatures mostly in compliance**



- **Relative humidity exceeded target for large portions of cooling period – an issue endemic to low load houses, regardless of distribution system approach**
- **"Dry" mode reduced RH, but not enough, and temperature increased**
- **Reducing setpoint helps…but too cool**

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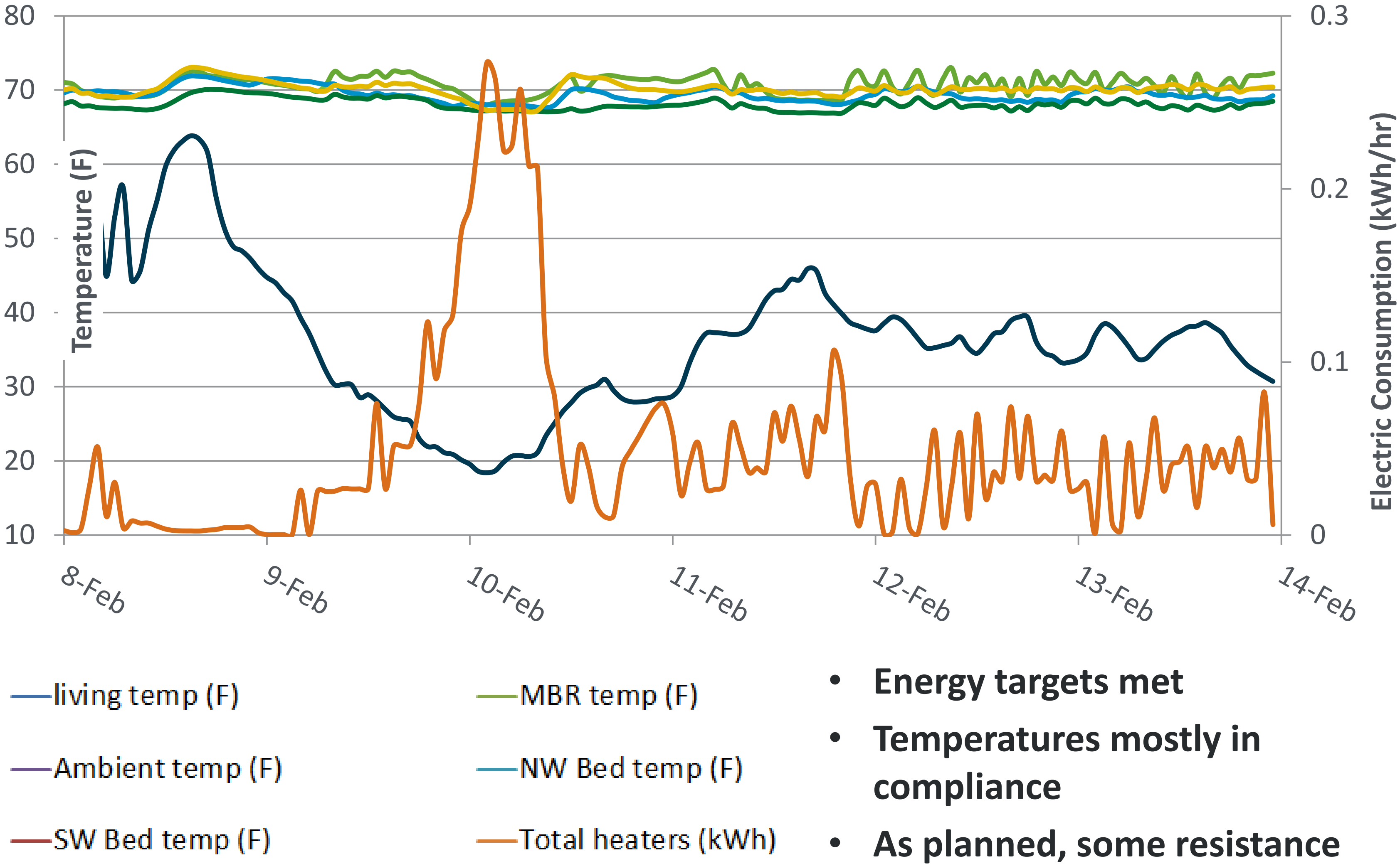
Progress and Accomplishments: Heating Season



- **Energy targets met**
- **Temperatures mostly in compliance**
- **As planned, some resistance heat needed in bedrooms**

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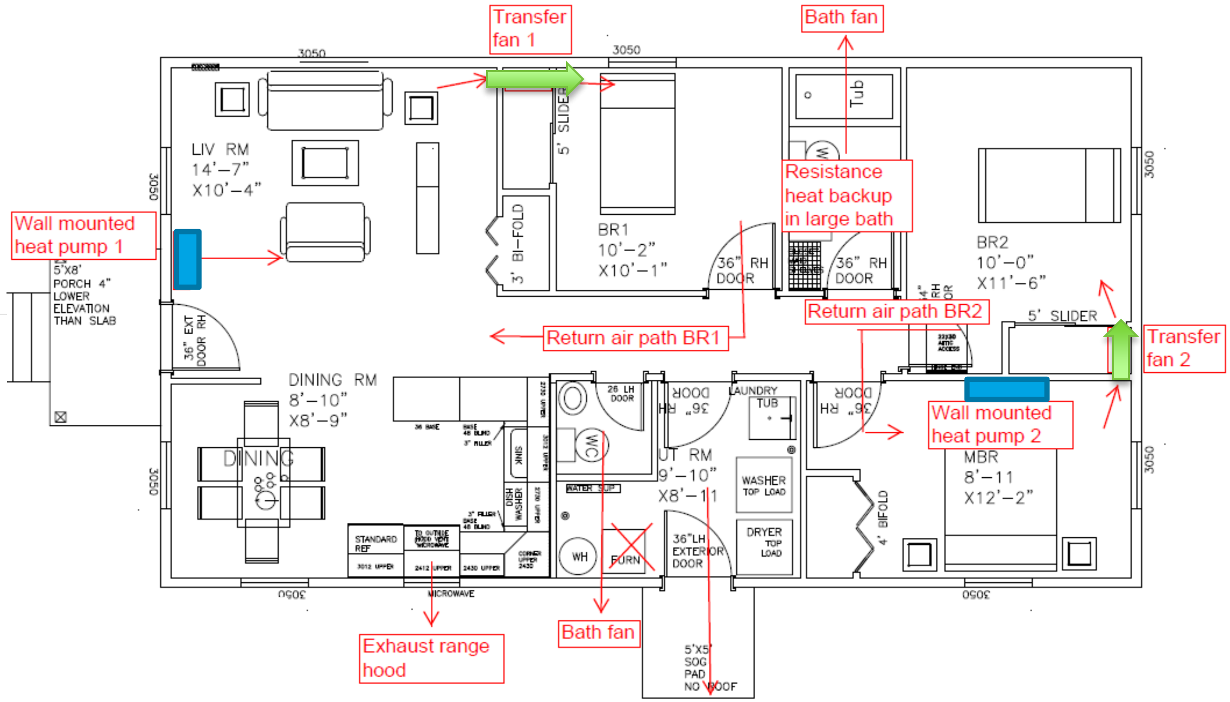
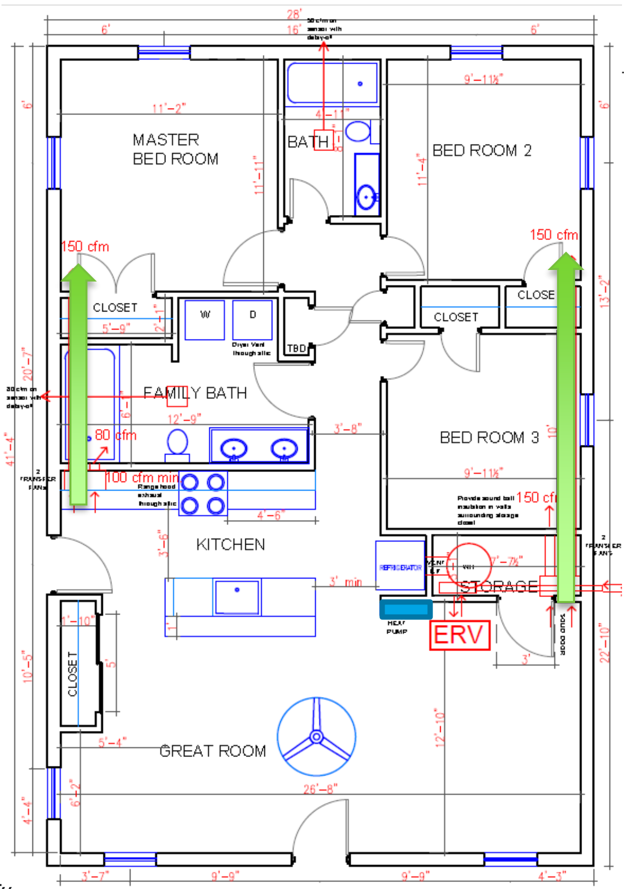
Progress and Accomplishments: Habitat Projects Ongoing

- **New Habitat houses designed**
- **Scheduled for completion spring/summer 2017**
- **Occupied monitoring**





Progress and Accomplishments: Market Impact

- Collaborative approach with broad representative group from each respective industry steering the work
- Potential adopters involved from Day 1
- Already making an impact on other efforts, including:

Offshoot project:
Two ID home demonstrations in New York with Titan Homes
Funded by NYSERDA

Next generation of FEMA emergency housing units being developed by TLP with ID approach

Market uptake:
At least one mfg. seriously considering ID; working on one project now.

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Progress and Accomplishments: Lessons Learned

Technical lessons learned include the following:

- Transfer fans can mix the temperatures well, but 100+ cfm per room is needed
- Backup heat in bedrooms: 15% site energy, approximately 6% of load
- RH, as expected is an issue for low-load homes
- VRF heat pumps may remove less moisture than non-VRF AC because they run at lower capacities and don’t condense as much moisture when operating
- Solutions may include new heat pump features, more precise equipment sizing and/or supplemental dehumidification

Project Integration and Collaboration: Habitat

- Habitat Research Foundation formed 2015 with Building America expert meeting
- Representatives from affiliates throughout the Northeast and HFHI
- Habitat supplier contributors involved in test houses
- HRF Steering Committee oversees BA project and is poised to adapt and disseminate results

The Levy Partnership

Habitat for Humanity

Building America U.S. Department of Energy

ARIES Collaborative

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Project Integration and Collaboration: Factory Builders

Left to Right: Emanuel Levy, TLP; Brian Lieburn, DOW; Kevin Clayton, Clayton Homes; Bryan Mallon, DOW; Jim Morey, DOW; Sam Rashkin, DOE; David Brewer, Southern Homes at ARIES Lab House in Russellville, AL

Communications: Updates at industry meetings and conferences and publications.

- Stakeholders participate and guide the work
- Regular stakeholder conference calls
- All major decisions owned by steering committee
- Participation of many companies, not just those involved in the prototyping
- More than 70% of industry
- In-kind contributions
- Demos/prototyping/testing at industry facilities

Project Integration and Collaboration: Partners

Building America U.S. Department of Energy

NREL National Renewable Energy Laboratory

ZERO Energy Ready Home U.S. Department of Energy

California Energy Commission

TVA

MHI Manufactured Housing Institute

Systems SBRA Building Research Alliance

Habitat for Humanity

Clayton homes

Champion Manufactured Beautifully

SE homes

Owens Corning

Dow

ARIES Collaborative

Knauf

Lippert Components Inc

Panasonic

Mitsubishi

Dimplex Innovative Heating and Cooling

Johns Manville

Senco

GE Appliances

Whirlpool Corporation

Next Steps and Future Plans

Understand how occupants interact with the home – 1 year monitoring at each house:

- Eatontown Manufactured Home: spring 2017 – spring 2018
- Worcester Habitat: summer 2017 – summer 2018
- Susquehanna Habitat: summer 2017 – summer 2018

Develop guidelines based on test house results and calibrated energy models:

- Manufactured housing industry
- Habitat for Humanity

Disseminate guidelines to industry via:

- MH industry meetings and publications and direct to manufacturers
- Habitat bi-annual conference, newsletters, HRF board members and HFHI Sustainable Building Specialists

REFERENCE SLIDES

Project Budget

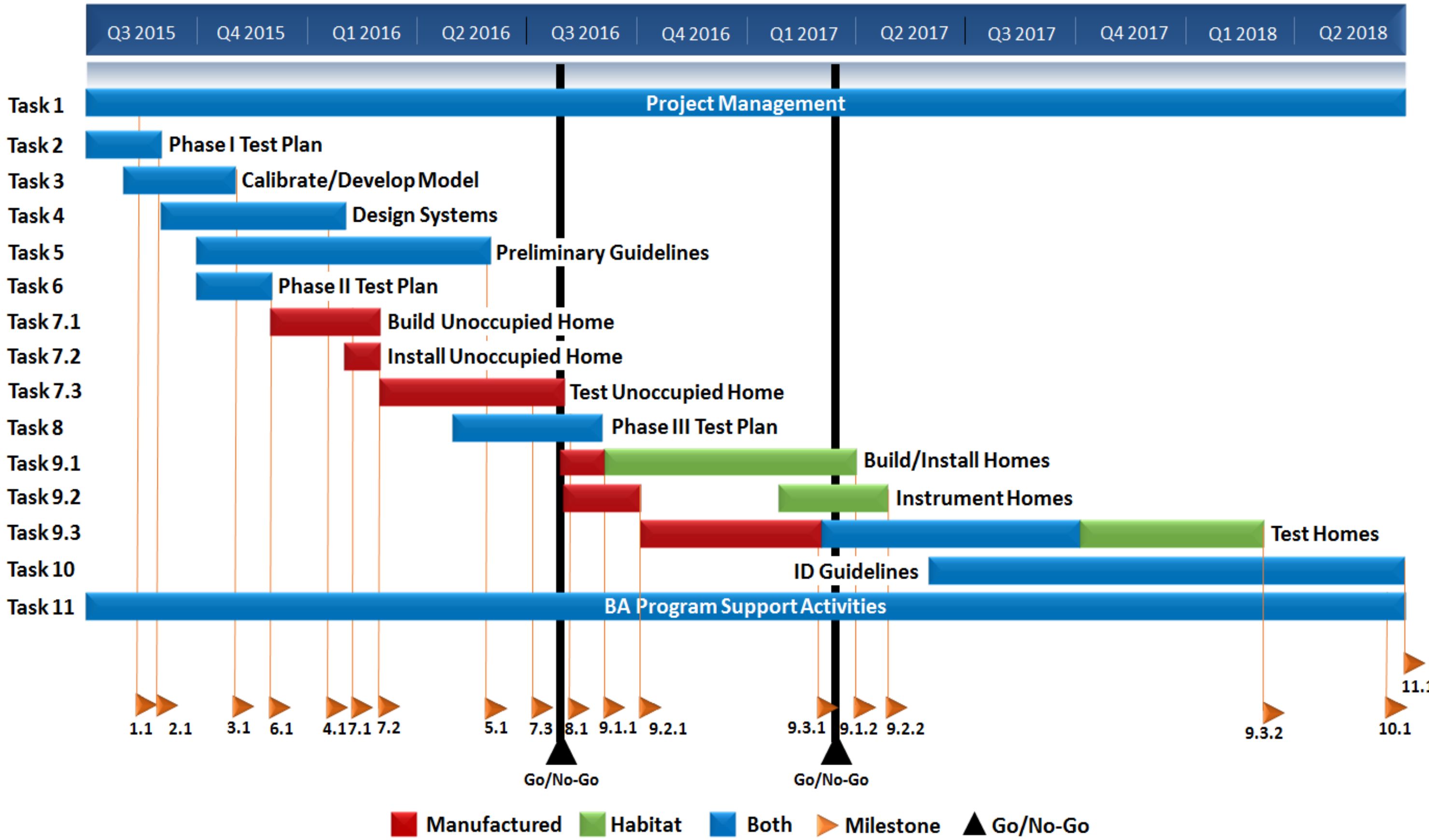
Project Budget: $1,026,987 total budget including $277,000 in cost share
Variances: None.
Cost to Date: $625,875 of $1,026,987 (64%) expended to date
Additional Funding: $277,000 cost share from industry in-kind and cash contributions; $341,747 NYSERDA-funded complimentary project in NY

Budget History					
July 2015 – FY 2016 (past)		FY 2017 (current)		FY 2018 – June 2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$403,150	$122,008	$155,991	$85,992	$190,846	$69,000

Project Plan and Schedule

- Go/No-go 1: Unoccupied home meets comfort and performance criteria: ACCA Manual RS, ASHRAE 55-2010 and 62.2, source space conditioning and ventilation energy savings ~50% compared to baseline : **July 2016**

- Go/No-go 2 Occupied home 1 meets same comfort and performance criteria: **Moved from Feb 2017 to July 2017 due to postponement of home sale/occupancy**



Up Next…

IBACOS®

| innovation |

A "Plug and Play" Air Delivery System for Low Load Homes

2017 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Ari Rapport, arapport@ibacos.com
IBACOS, Inc.

Project Summary

Timeline:

Start date: 08/01/2015

Planned end date: 01/31/2017

Key Milestones

1. Complete Cost Analysis, 01/31/2017
2. Develop Design Methodology, 01/31/2017
3. Secure Builder and Manuf Interest, 01/31/2017

Budget:

Total Project $ to Date:

- DOE: $600,085.00
- Cost Share: $220,845

Total Project $:

- DOE: $600,085.00
- Cost Share: $220,845

Key Partners:

Housing Innovation Alliance

Project Outcome: The Project Goal is to develop a simplified residential air delivery system that is a solution to air distribution and comfort delivery issues in low-load production-built homes.

Outcomes include the following:

- A straightforward, intuitive design method and companion guidance documents
- Justification and suggested language for needed code and standard changes
- Commitment from a manufacturer partner to pursue product development and a builder partner to demonstrate the technology based on the project's findings

Purpose and Objectives

Problem Statement:

- The residential HVAC market is struggling to achieve effective HVAC system design, installation, and commissioning in lower-load homes
- Heating and cooling to each space is not optimally delivered from smaller-capacity equipment with traditional air distribution systems
- Traditional duct systems have a host of problems, including installation labor, leakage, constriction, and energy loss
- These issues can inhibit low-load homes from achieving broader industry performance goals, including energy efficiency and comfort

Target Market and Audience:

- Market: new construction low-load homes (0.01 quads/year)
  - 2012 IECC enclosure, 2,000-3,000 ft^2 "sweet spot"
- Audience: Home builders, HVAC contractors and system designers, HVAC equipment manufacturers and component suppliers, and material suppliers

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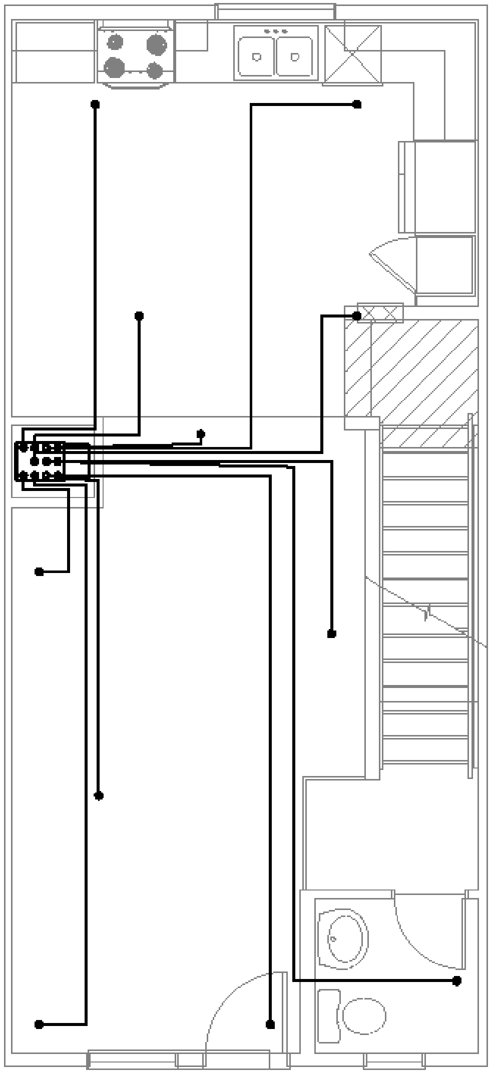
Purpose and Objectives

Impact of Project: Project Outputs

- Characterize the performance parameters for plastic small diameter rigid ducts and fittings and other, off-the-shelf duct products
- Characterize the installed "comfort" (temperature) impact of Plug and Play system
- Define the range of application for the system in terms of home size, load, load density, and climate
- Analyze the cost and installation impacts
- Compare the performance and cost to traditional air distribution system approaches
- Develop installation guidance
- Develop a documented design methodology
- Secure interest from a builder and manufacturer



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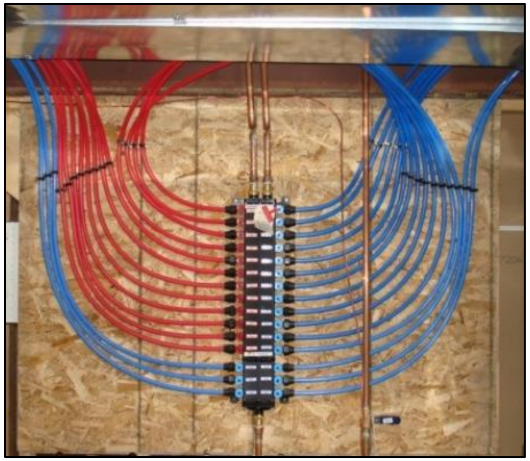
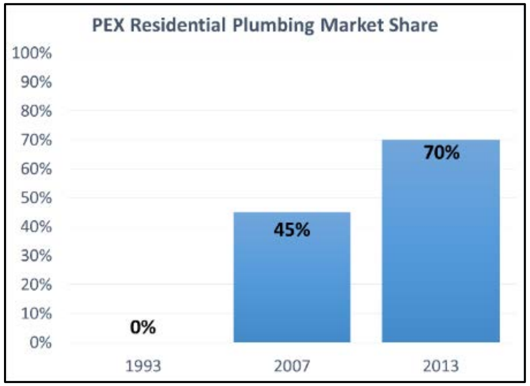
Purpose and Objectives

Impact of Project:

- Could revolutionize ducted air distribution like PEX piping impacted plumbing distribution
  - PEX costs 25% - 45% less, installed
  - Rapid claim to majority market share
- Potential for significant cost savings vs. conventional systems, with performance benefits
  - More discrete room-by-room zoning opportunities
  - Improved comfort - energy is effectively used
  - Simplified design and installation
  - Facilitates integration into conditioned space
- Alternative to all conventional and small diameter air distribution systems on the market
- Residential ductwork is a $1.2 Billion market annually
  - 10% new constr. market penetration in 5 years
  - 25% penetration in 10 years, plus retrofit market
- As costs decrease, market penetration increases





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Purpose and Objectives

Objectives → Activities / Partners → Outputs → Short Term Outcome → Mid-Term Outcome → Long Term Outcome

Objectives
- Demonstrate & integrate energy efficient technologies & practices in representative homes
- Prove energy saving solutions & programmatic designs on a national scale with market partners
- Accelerate market adoption by increasing understanding of effective energy saving solutions

Activities / Partners
- Competitive R&D funding focused on demo, testing & validation by Building America & national lab researchers in field homes
- Resources development with national labs for building prof. & service providers
- Support business model demo to upgrade or construct high perf. homes with market partners across climates
- Outreach to stakeholders on a national scale to increase adoption of energy efficiency solutions in common transactions.
- Tool development & demo of the value of energy efficiency in the market with market partners
- Educational support to promote quality workforce

Outputs
NOW
- Space conditioning, water heating & IAQ focused Building America upgrade packages & techniques for existing & new homes across climates
- Guidance for energy savings beyond current building energy codes & industry standards for stakeholders
- Best practice online Better Buildings & Buildings America Solution Centers
- Demonstrated home upgrades & new construction in HPwES & ZER Homes
- Peer sharing via Better Building Residential Network
- Targeted campaigns to propel adoption of low cost home upgrade improvements
- Home Energy Score tool
- Building science curriculum, student competitions & workforce development

Short Term Outcome
1-3 Yrs
- Innovator building professionals equipped with validated energy saving solutions for integrating highly energy efficient tech or practices into homes
- Industry standard orgs. & voluntary programs equipped with validated technical specs & guidelines to make homes highly efficient
- Energy efficiency programs & building professionals have access to resources & model business practices to increase scale of energy efficiency investments
- Wide array of industry stakeholders & building professionals aware of strategies to increase energy efficiency

Mid-Term Outcome
3-5 Yrs
- Leading building professionals improve or construct high performance homes above model energy codes
- Industry standard orgs adopt technical specs to accelerate new tech & practices in building energy codes
- Energy efficiency programs facilitate market demand for energy efficiency & other markets that value energy efficiency
- Building professionals install proven energy saving solutions in the broader market
- Industry stakeholders widely promote value of energy efficiency in products, services, & typical market transactions with homeowners

Long Term Outcome
- The building industry regularly constructs high performance homes that are ready for renewable energy systems or significantly improves the energy efficiency of existing homes across climates.
- Homeowners are motivated to invest in more energy efficient homes spurred by increased value in the residential market.

Impact
- 40% savings in existing homes demo'd; 60% savings in new homes demo'd; 10% savings thru individual measures
- Proved in 1 million existing homes & 50K ZER new homes
- Market Partnerships reach 90% of homes; 5% savings thru individual measures with partners
- Reduce the energy used for space conditioning & water heating in single family homes by 40% by 2025 from 2010 levels
- Reduce avg. EUI in all bldgs. 30% by 2030

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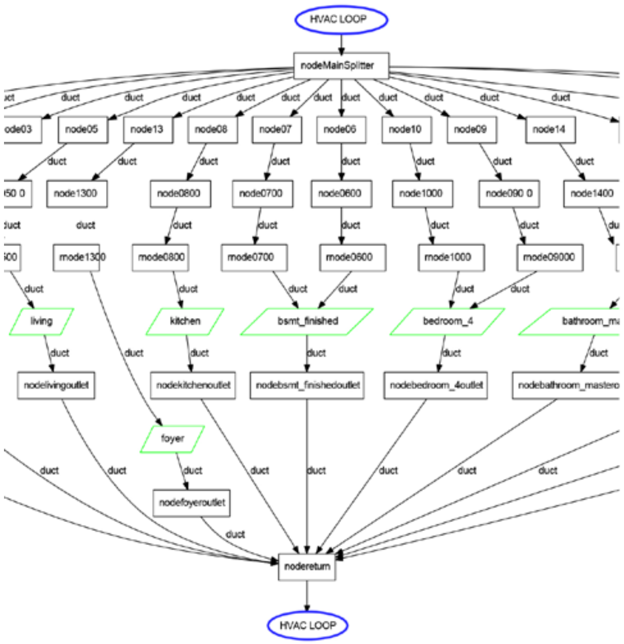
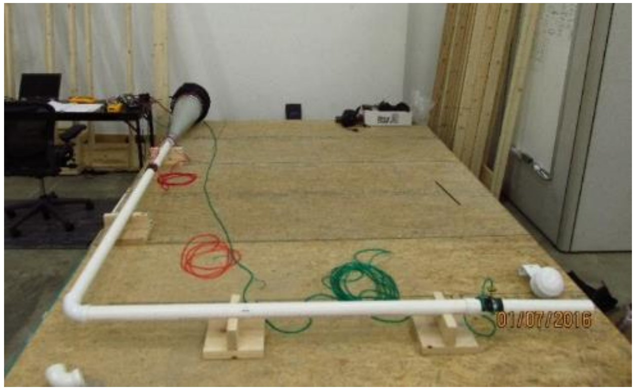
Approach

Approach:

- Use benchtop tests, mock ups, lab house tests, and performance simulation to do the following:
  - Develop a new "Plug and Play" design methodology (NO BALANCING DAMPERS)
  - Define its application parameters
  - Evaluate installation, constructability, and cost
  - Test this design against a conventional system
- Engage the market

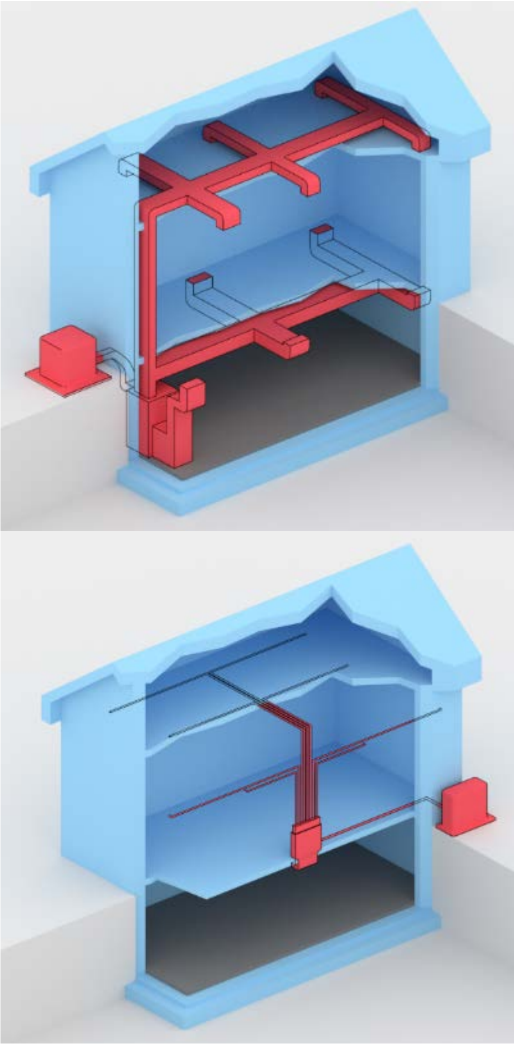




Approach

Key Issues: Conventional Duct Systems

- Difficult to access all duct runs for maintenance and dampering
- Current labor pool is unwilling, unskilled, or unavailable to practice good duct design and installation
- Traditional duct systems are often:
  - Oversized for low loads
  - Leaky, requiring secondary sealing
  - Routed though unconditioned space
  - Not well-integrated into home
  - Dirt collectors
- Comfort and performance suffers
- Too many SKUs



Approach

Distinctive Characteristics:

- A home-run manifold of small diameter (2-3 inch) ducts to work with small-capacity equipment to deliver predictable performance for low-load homes
- Intended to use off-the-shelf products as a kit-of-parts with fewer SKU's to install a simplified duct system with less error/waste than conventional systems
- Conventionally-skilled tradespersons and home designers will have a quick, efficient and credible method for designing an air delivery system that responds to the unique qualities of lower-load homes and emerging comfort systems, providing reliable design results.

Progress and Accomplishments

Accomplishments:

- Completed a design methodology
  - Using ACCA Manual J loads and airflows
  - Based on plastic ducts but completed analysis of alternate duct materials
  - Evaluated range of applications for Plug and Play duct system
- Simulation
  - Created a detailed multi-zone model using Energy Plus Airflow Network
  - Calibrated model to unoccupied lab home data
  - Evaluated "comfort" performance of Plug and Play duct system compared to traditional systems
- Compared installation material & labor costs to traditional duct system
- Engaged Codes community around use of plastic ducts

Plug-and-Play Home Run Manifold Design Tool

v 0.1

Project

Nominal CFM	26	(based on 30' L, 60 Pa)
Available Pressure	0.35	in. wc. (from manual S) (minus 0.1" for manifold)
Heating factor	0.0231	Btuh / CFM
Cooling factor	0.0268	Btuh / CFM

#	Room	Htg Load (Btuh)	Clg Load (Btuh)	CFM	Len (ft.)	Elb	Ducts
1	Master Bedroom	2365	2316	55	29	5	2
2	Bath 2	642	220	15	12	3	1
3	Bedroom 2	2025	1500	47	15	4	2
4	Powder	798	620	18	22	3	1
5	1st Floor	6489	4486	150	16	3	5
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
	Total:	12319	9142	285	94	18	11

Select Material

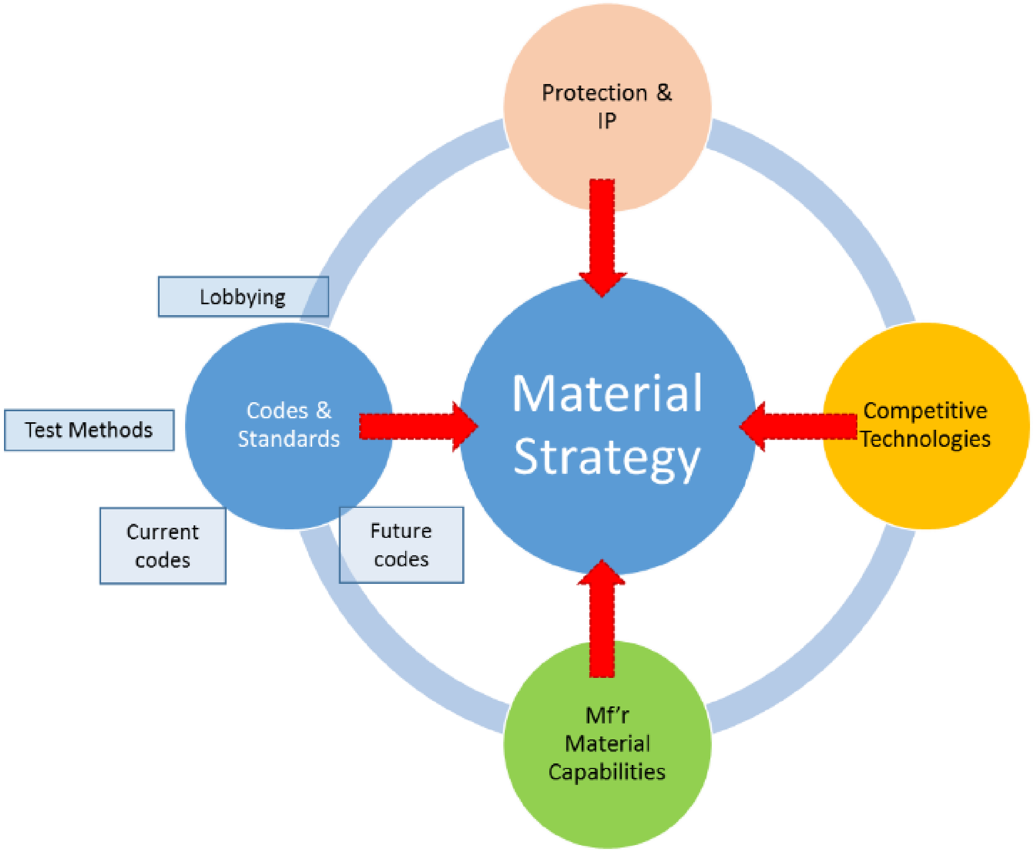
2" PVC

EL of 90	2	
Pipe Diameter	2.0	
Coefficients -- 2" PVC	CFM = (Pa/C*L)^(1/n)	
C	0.01146	
n	1.70239	

Progress and Accomplishments

Market Impact:

- Ongoing engagement with homebuilders – interest to demonstrate or pilot the technology when available
- Engaging potential commercialization partners
- Pursuing code approval of plastic ducts while exploring the use of existing, off-the-shelf duct materials
- Defining target house types and climate zones
- Developing cost comparisons and value story
- Engaging Standards organizations



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Progress and Accomplishments

Awards/Recognition: None

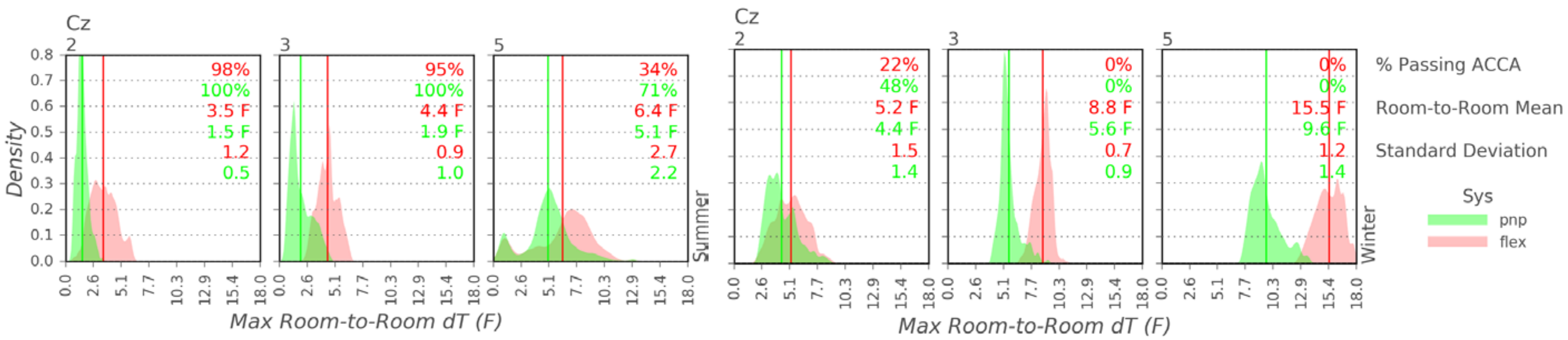
Lessons Learned:

- All homes could use 3.0” flexible ductwork.
- 2.5” smooth ductwork provides sufficient airflow for a 2200 sq. ft. home in climate zones 2-5.
- Smaller homes (<1200 sq. ft.) or very low load homes built (i.e. Passive House) can use 2.0” smooth ductwork.
- A simplified design method is possible with proper load calculations and uniform duct diameters & materials.

Progress and Accomplishments

Lessons Learned:

- Plug and Play achieves equal or better thermal uniformity in homes than a traditional duct system.
  - Exception when large disparity between heating and cooling loads and airflow needs in the house
- The EnergyPlus Airflow Network is a powerful tool to simulate the dynamic effects of air delivery systems



Progress and Accomplishments

Lessons Learned:

- The Plug and Play duct system is cost competitive to traditional duct systems, installed

Duct System	Hours	Labor Cost @ $33.35 hr.	Material Cost	SKU'S	Length of duct	Cost of ductwork system
Traditional	**18** (including 6 hr bulkhead)	**589**	**487**	**6**	35' trunk + 50' flex	**$ 1,076**
2.5" PVC	**10** (including 6 hr bulkhead)	**330**	**686**	**6**	210'	**$ 1,017**
2" PVC	**6**	**195**	**440**	**6**	250'	**$ 635**

Notes:

- PVC costs were off-the-shelf pricing
- Time and motion study was conducted in a 1,200 ft^2 2-story townhome
- 2.5" PVC is used only for furnace combustion pipes so off-the-shelf prices are escalated
- Schedule 40 pipe is not required for air distribution; schedule 10 to 15 would be more adequate which could reduce the material costs by half

Progress and Accomplishments

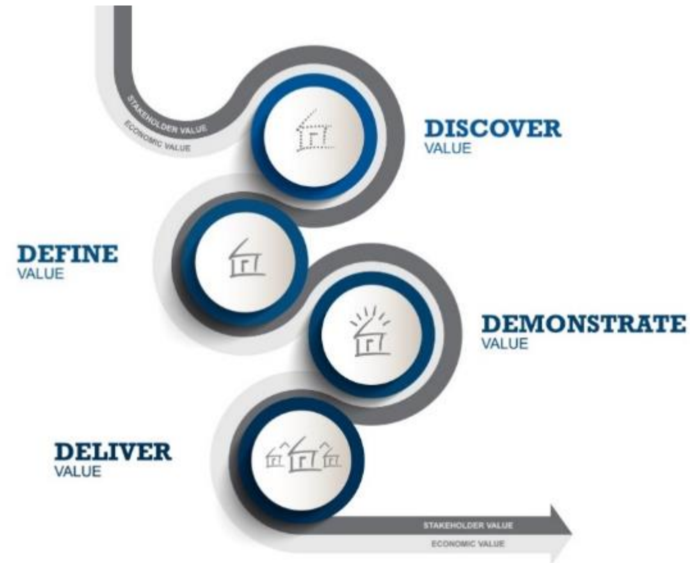
Lessons Learned:

- Code acceptance of plastic duct materials hinge on their function as a pathway between discrete zones (rooms) in a home
  - An automatic shutoff at the furnace could be a solution
  - Shutoff dampers between rooms is another option
  - Ultimately, a plastic meeting UL 181 Class 1 requirements for flame spread and smoke is ideal

Project Integration and Collaboration

Project Integration:

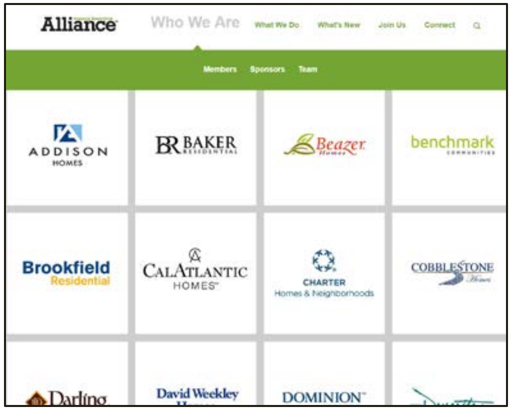
- Innovation Pathway
  - Model for collaboration to discover, define, demonstrate and deliver innovative solutions with economic and stakeholder value
- Builder Engagement
  - Connect with builder clients and partners to socialize the technology concept and project outcomes
- Manufacturer Engagement
  - Explore commercialization partnerships
- National Lab Engagement
  - Critical collaboration on development of simulation aspects (i.e. EnergyPlus Airflow Network)
- Industry Codes & Standards Organizations
  - ASHRAE, ICC



Project Integration and Collaboration

Partners, Subcontractors, and Collaborators:
Housing Innovation Alliance (a.k.a. "Alliance")

- 75+ homebuilder members
- Represent 200,000 housing units annually
- A dozen innovative building industry product suppliers and manufacturers
- Collaborative homebuilding solutions
- Multi-venue feedback loop
- http://www.housinginnovationalliance.com/



Alliance partnership provides ongoing venue for communication of project outputs, socialization among Top 100 homebuilders, manufacturer engagement, and opportunities for product demonstration and a path to market.

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Project Integration and Collaboration

Communications:
- Housing Innovation Alliance
- ASHRAE
- Pennsylvania Housing Research Center
- U.S. Department of Energy

Next Steps:
- Complete final project report and peer reviews
- Close out project documentation

Future Opportunities:
- Secure commercialization partner to develop technology and deliver to market
- Develop companion components: dampers, plenum/manifold, diffusers
- Develop design & commissioning standards
- Demonstrate product technology in field test homes and pilot projects
- Explore retrofit market integration

REFERENCE SLIDES

Project Budget

Project Budget: $820,930: $600,085 Federal + $220,845 Cost Share
Variances: A no-cost time extension was granted in June 2016 to extend the project timeline from July 31, 2016 to January 31, 2017.
Cost to Date: 100% of project budget expended through January 31, 2017.
Additional Funding: None

Budget History					
Aug. 1, 2015 – FY 2016 (past) THRU 9/30/16		FY 2017 (current)		FY 2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$529,866.77	$220,845.00	$600,085.00	$220,845.00	None	None

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Project Plan and Schedule

Project Schedule													
Project Start: August 1, 2015		Completed Work											
Project End: January 31, 2017		Active Task (in progress work)											
		Milestone/Deliverable (Originally Planned)											
		Milestone/Deliverable (Actual)											
	FY2015				FY2016				FY2017				
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	
Past Work													
Q4 Milestone: Conduct Lab Tests													
Q5 Milestone: Complete Cost Analysis													
Q5 Milestone: Performance Simulation Analysis													
Q4 Milestone: Propose Design Methodology to Standards Groups													
Q3 Milestone: Secure Manufacturer Interest													
Q5 Milestone: Secure Builder Interest													
Q6 Milestone: Final Report													

Project start delay

Milestone delays due to NCTE

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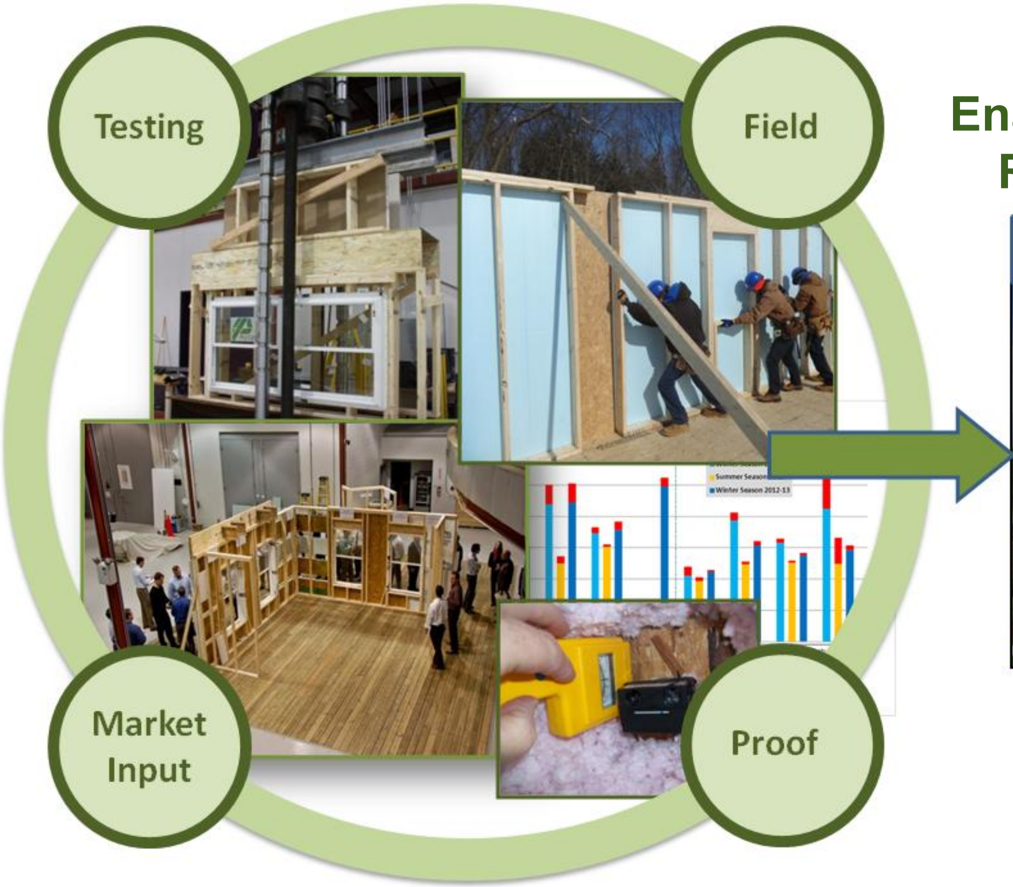
Up Next…

Home Innovation RESEARCH LABS™

High Performance Building Envelope Assemblies

2017 Building Technologies Office Peer Review



Enabling High Performance by Reducing Transition Risks

Production Homes

Vladimir Kochkin
vkochkin@homeinnovation.com

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Home Innovation RESEARCH LABS™

High Performance Building Envelope Assemblies

- **Four Distinct Projects:**
  a. Moisture Performance of High-R Wall Systems (2015-2017)
  b. Extended Plate and Beam (EP&B) Wall System (2015-2017)
  c. Attic Retrofit Using Nail-Base Insulated Panels (2015-2017)
  d. Durability of Windows in Walls with Continuous Insulation (2016-2018) [*separate ppt presentation*]
- **Overarching Principles for All Projects**
  a. Provide solutions for energy efficient durable enclosures at established target levels of thermal resistance
  b. Tackle cross-cutting issues and provide a forum for broad stakeholder involvement
  c. Enable compliance with code and above-code programs
  d. Resolve construction conflicts and evaluate field-ready details
  e. Demonstrate and validate constructability and performance

Building America Role

Image Basis: Building Energy Codes Program: National Benefits Assessment, 1992-2040, https://www.energycodes.gov/sites/default/files/documents/BenefitsReport_Final_March20142.pdf

Building America Business Case

High-Performance Home Impacts:*

- **~$350 Billion – $1+ Trillion** Utility Bill Savings
- **~$20 - $100+ Billion** Annual Health Related Benefits
- **~$90 – $270 Billion** Annual Construction Revenue
- **~120,000 – 360,000** Persistent New Jobs

* Impacts based on internal DOE analysis assuming 30% market penetration of high-performance new and existing homes by 2025

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Project Summary: Moisture Performance of High-R Walls

Timeline:

Start date: 08/01/2015

Planned end date: 7/31/2017

Key Milestones

1. Identify key wall configurations – June 2016
2. Recruit builders – September 2016
3. Instrument homes – December 2016

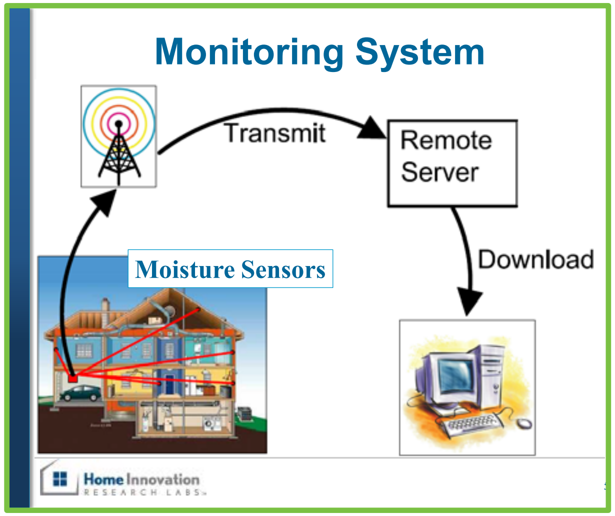
Budget:

Total Project $ to Date:

- DOE: $265,000
- Cost Share: $77,000

Total Project $:

- DOE: $333,026
- Cost Share: $90,000



Key Partners:

American Chemistry Council	Forest Products Laboratory
National Association of Home Builders	Broad-based Advisory Group of Stakeholders
Participating Builders	Vinyl Siding Institute
Oak Ridge National Laboratory	

Project Outcome:

- Moisture performance library of energy efficient walls for Climate Zones 4-6
- Relative humidity library for energy efficient homes
- Identified marginal wall designs and recommended improvements
- Design criteria and code change recommendations

Purpose and Objectives (Moisture in High-R Walls)

Problem Statement: Concerns regarding the durability of high-R walls in energy efficient homes remain one of the key barriers to broad market adoption of high performance wall technologies

Target Market and Audience: Residential designers and builders with wood-framed projects in Climate Zones 3-8 (>70% of all housing starts in the country).

Impact of Project:

1. Project outputs:
    a) Demonstrated and validated performance of high-R walls
    b) Recommended improvements to design and field practices
    c) Proposals for codes and standards
    d) Input and calibration for BA Building Science Expert System
2. Contribution to BA and market goals:
    a. Opaque walls contribute up to 10% of energy savings (whole-house) or up to 20% of heating energy savings to support DOE goals for energy use reduction
    b. Accelerated adoption of walls with higher insulation values
    c. Accelerated adoption of 2012/2015 codes w/o envelope amendments

Approach (Moisture in High-R Walls)

Approach:

1. Identify key wall types and house characteristics for evaluation
2. Recruit builders of qualified homes
3. Instrument, document, and observe performance in occupied homes
4. Make recommendations based on documented performance

Key Issues:

1. Performance of frame walls with continuous insulation (CI)
2. Performance of hybrid walls (CI and an int. vapor retarder, VR)
3. Performance of cavity-only insulation walls with various VRs
4. Performance of rim joists
5. Relative humidity levels inside of high performance homes

Distinctive Characteristics: Documenting and validating the performance of real occupied homes built without special expert oversight

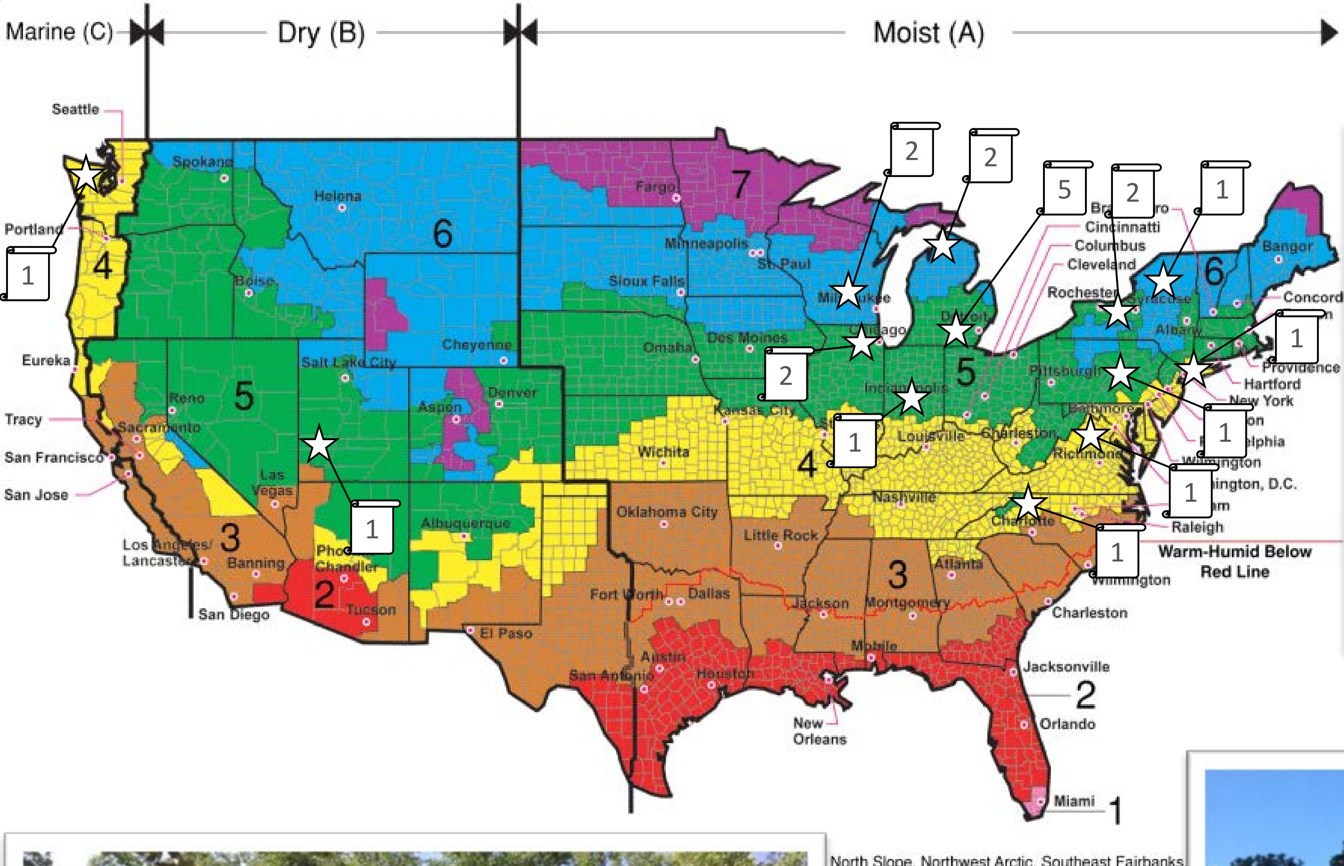
Progress and Accomplishments (Moisture in High-R Walls)

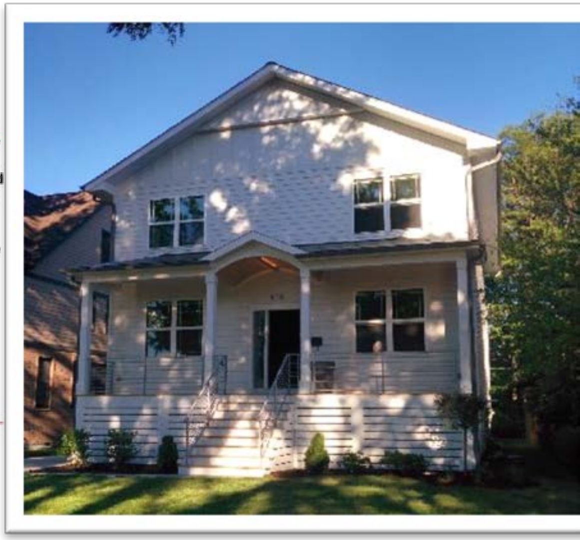
Accomplishments:
1) Over 100 inquiries from builders with interest to participate
2) A broad stakeholder group is engaged with the Advisory Group
3) 22 homes enrolled and instrumented
4) A draft standard method for field measurements has been developed
5) Blind-prediction WUFI simulations completed for future comparison

Expected Market Impact:
1) Improved level of confidence for builders using high-R wall solutions
2) Minimized risk of future durability issues in Climate Zones 3-7
3) Accelerated adoption of high performance homes
4) Accelerated adoption of 2012/2015 I-codes without envelope amendments
5) Through broad stakeholder engagement, significant improvement in awareness across the entire building industry about proven durable solutions for high-R walls

Lessons Learned: Builders can be highly creative at combining various new and conventional building materials. Wide range of performances is observed.

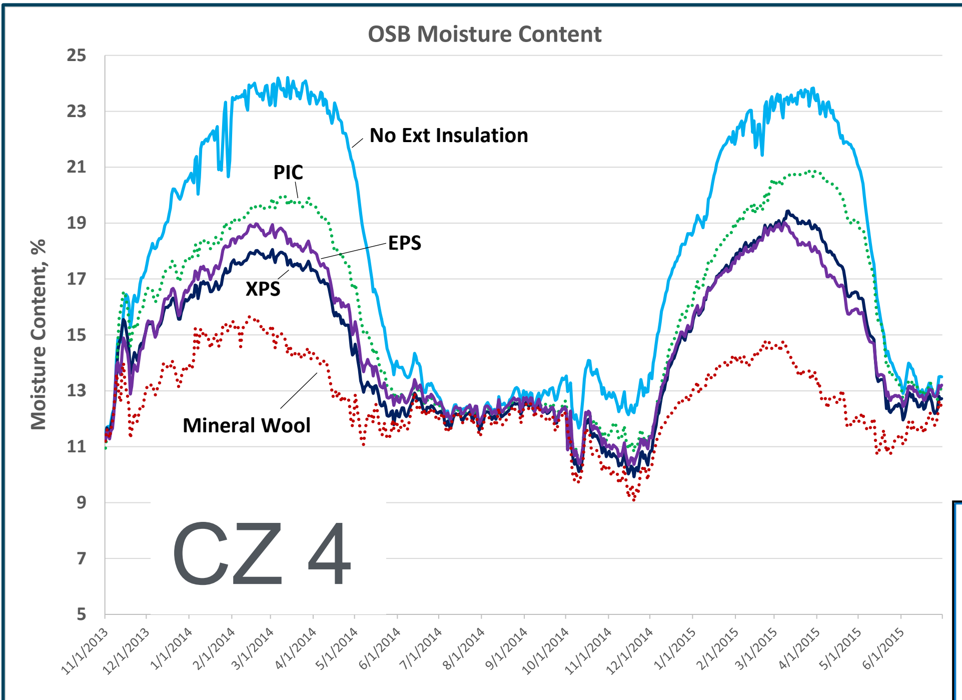
Instrumented Homes Map





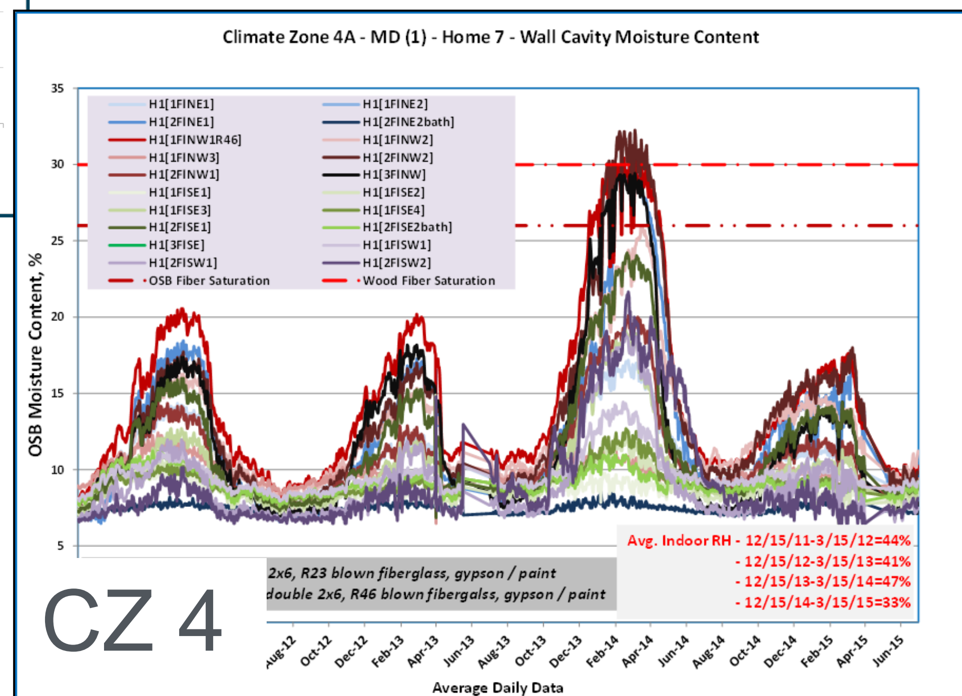
Precursor Data from Previous HI Studies

Do walls with ext. foam dry out?



2x4+R5 Walls w/o int. VR

Are indoor RH levels important for walls?



Project Summary: Extended Plate and Beam

Timeline:

Start date: 08/01/2015

Planned end date: 7/31/2017

Key Milestones

1. Conduct Structural Testing – March 2017
2. Field Demonstrations – Sept 2016
3. Builder Guide and Basis for Code Change – July 2017

Budget:

Total Project $ to Date:
- DOE: $180,000
- Cost Share: $65,000

Total Project $:
- DOE: $256,818
- Cost Share: $65,000

Key Partners:

American Chemistry Council	Forest Products Laboratory
Dow	DuPont
Owens Corning	NYSERDA

Project Outcome:

- A builder-ready solution for R23 or higher wall system built using conventional materials
- Lab and field validated performance data
- Increased market penetration for high-R walls
- Introduction of rigid foam sheathing into offsite wall panelization

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Purpose and Objectives (EP&B)

Problem Statement: Low market penetration of high-R walls above R21

Target Market and Audience: Residential designers and builders with product offerings in Climate Zones 4-8 (50% of all housing starts in the country).

Impact of Project:

1. Project outputs:
   a) A builder-ready solution for R23+ walls using conventional materials
   b) An EP&B Builder Guide
   c) Laboratory and field validated performance data
   d) Information package to support a code proposal

2. Contribution to BA and market goals:
   a. Opaque walls contribute up to 10% of energy savings (whole-house) or up to 20% of heating energy savings to support DOE goals for energy use reduction
   b. Accelerated adoption of walls above R20
   c. Introduction of foam sheathing to industrialized factory wall panelization

Approach (EP&B)

Approach:

1. Validate performance (structural and moisture)
2. Demonstrate the system (stick-built and panelized)
3. Develop simple guidance for builders
4. Prepare information to support a code proposal

Key Issues:

Wall with exterior foam sheathing have a steep learning curve and introduce constructability questions:

  a. Windows
  b. Drainage plane
  c. Cladding

Distinctive Characteristics: Achieves R23 or higher using standard materials by relying on a novel assembly sequence resulting in a wall that functions similar to a conventional system

Progress and Accomplishments (EP&B)

Accomplishments:
1) Structural performance is demonstrated (testing)
2) Moisture performance is demonstrated (modeling and field monitoring)
3) Two homes built (in addition to two previous field demonstrations)
4) Buy-in from product manufacturers
5) Builders' Guide developed

Expected Market Impact:
1) Improved level of confidence for practitioners using high-R wall solutions
2) Increased market penetration for high-R walls
3) Use of insulation in factory-built panelized walls

Lessons Learned:
1) Walls are one of the last energy efficiency measures builders are likely to tackle
2) Moisture performance of high-R walls is misunderstood
3) Field assembly of EP&B wall panels is nearly identical to that for standard 2x6 wall panels

Site-built Homes (EP&B)

Foam is installed against an extended bottom plate

Standard OSB Exterior, Stud Cavity, Foam Interior

OSB is nailed over foam sheathing

Field Installation

Panelized Home (EP&B)

Structural Testing – Braced Walls / Shear Walls

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Project Summary: Attic Retrofit Using Nailbase Panels

Timeline:

Start date: 08/01/2015

Planned end date: 7/31/2017

Key Milestones

1. Identify Test Homes and Conduct Assessment – March 2016
2. Field Demonstrations – January 2017
3. Performance Assessment and Standardized Solutions – July 2017

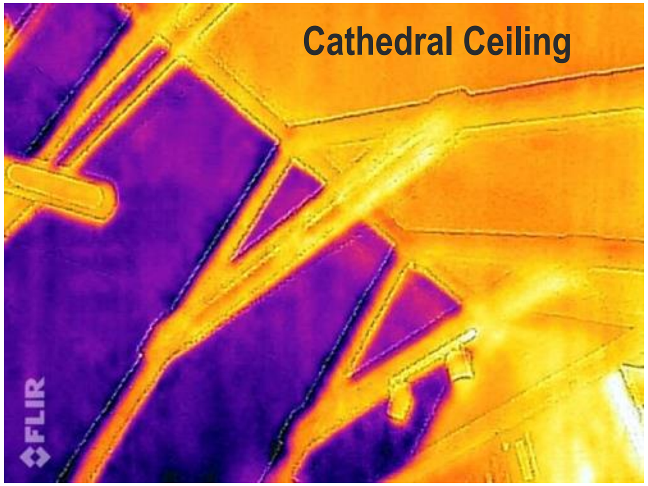
Budget:

Total Project $ to Date:

- DOE: $230,000
- Cost Share: $75,160

Total Project $:

- DOE: $283,871
- Cost Share: $75,160



Key Partners:

Structural Insulated Panel Association	American Chemistry Council
GAF	DuPont
Dow; Owens Corning	Forest Products Laboratory

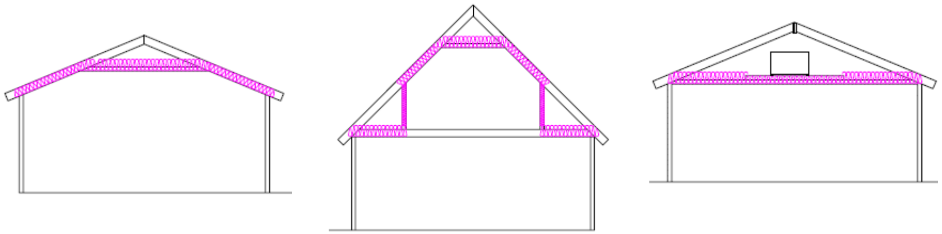
Project Outcome:

- Standardized attic retrofit solutions and details applicable to a large portion of older existing homes built prior to 1980s in Climate Zones 2-8
- Field validated performance of retrofitted conditioned attics (energy, moisture, comfort)

Purpose and Objectives: Attic Retrofit w. Nailbase Panels

Problem Statement: Lack of standardized solutions for attic retrofit for older homes where a simple "insulation pile-on" option is not applicable due to the attic configuration: cathedral ceiling; habitable attics; attics with equipment and/or storage; small attics

Target Market and Audience:
Remodeling and roofing contractors in all climate zones across the U.S.

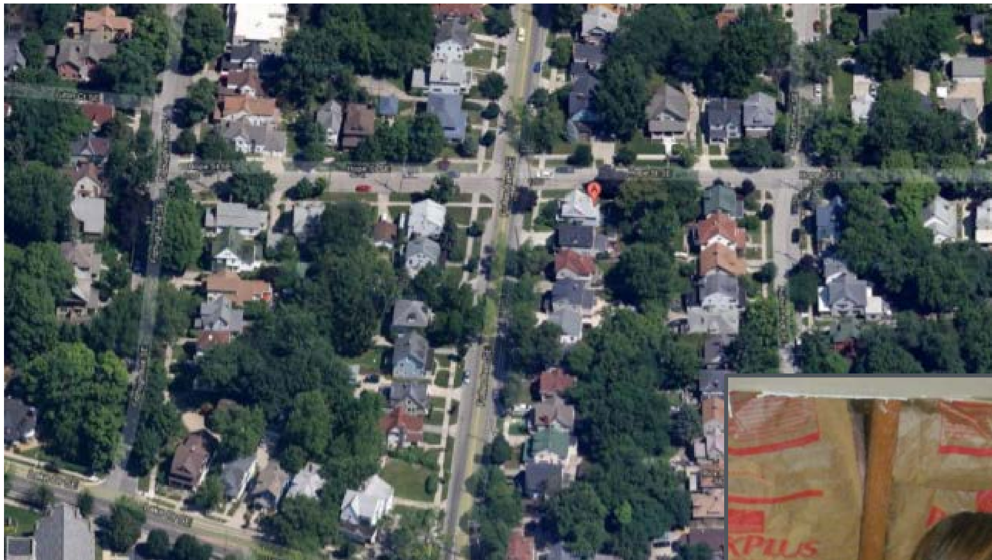


Impact of Project:

1. Project outputs:
   a) Builder-ready solutions for attic retrofits as part of a re-roofing project for various types of older homes
   b) Field-validated performance data supported with case studies of occupied homes
2. Contribution to BA and market goals:
   a. Up to 11+% of energy savings (whole-house) or up to 22% heating and cooling energy savings to support BA goals for energy use reduction
   b. A business case for adding energy efficiency to a re-roofing project for millions of older homes in the U.S.

Over half of 118M housing units in the U.S. predate 1980

2009 American Housing Survey (AHS) shows that nearly 90% of homes in the Midwest were built before energy codes were adopted



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Approach: Attic Retrofit using Nailbase Panels

Approach:

1. Identify suitable homes for field tests
2. Develop retrofit solutions and conduct observational research
3. Demonstrate and validate solutions in the field
4. Obtain feedback from trades and occupants
5. Develop standardized solutions

Key Issues:

1. Field details and integration with re-roofing
2. Moisture performance
3. Wide range of roof/attic configurations and climate zones

Distinctive Characteristics: Field demonstration of solutions for attic retrofit of older, highly inefficient housing using two occupied homes as case studies

Progress and Accomplishments: Attic Retrofit

Accomplishments:
1) Two homes have been identified, assessed, and specific solutions developed
2) WUFI modeling has been performed
3) A laboratory observational evaluation has been performed
4) Attics of two homes have been retrofitted and instrumented

Expected Market Impact:
1) Increased awareness of options available for attic retrofit in older homes
2) Increased awareness of benefits of high performance attics in existing homes
3) Increased use of energy efficiency improvements as part of re-roofing of existing homes

Lessons Learned:
1) It can be done; and with adequate planning it is a reasonable proposition
2) A step-up from a basic re-roofing project
3) Many older homes are very inefficient (even in cold regions) and can benefit from these types of improvements
4) Architecturally – retrofitted roof looks excellent

Roof / Attic Retrofit Demonstration Projects

Hot-Humid Climate - St. Simons Island, GA

Cold Climate – Ann Arbor, MI

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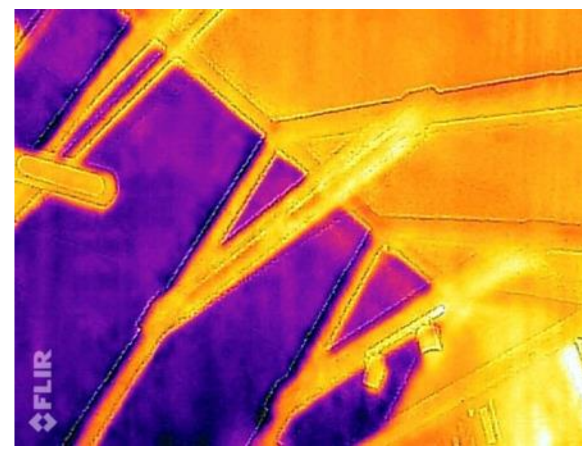
Observational Research

Purpose: Assess the constructability of the ventilation mat that is intended to allow outward drying from an unvented roof assembly and reduce shingle temperature.

Results:

- ➢ Overall takeaway was favorable
- ➢ Gap maintained at full thickness
- ➢ Shingles looked normal (not wavy)

Cold Climate – Ann Arbor, MI



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Cold Climate – Ann Arbor, MI

Before and After

Hot-Humid Climate - St. Simons Island, GA

Gable Wall Insulation

Collar-tie reinforcement

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Hot-Humid Climate - St. Simons Island, GA

Soffit detail

Lifting a nail-base panel

Panel installation

Roofing system

Project Integration and Collaboration

Project Integration: Home Innovation brings key stakeholders including associations to the table as co-sponsors (cash and product) and as advisory group members. Broad industry participation includes builders (including high production builders), insulation product manufacturers, and building science experts. Projects are broadly announced via various industry media channels. As an example of integration, the EP&B system was featured at the International Builders' Show directly by product manufacturers without our involvement. Hamilton Building Services made EP&B the focus of their booth at the 2016 Architecture Boston Expo (ABX).

Project Integration and Collaboration

Partners, Subcontractors, and Collaborators: In addition to several co-funders and advisory group members, Home Innovation works with the following collaborators:

1) Forest Products Laboratory – expertise in moisture performance of wood buildings
2) NYSERDA – energy-efficient systems for New York State
3) Dow, DuPont, Owens Corning – product support and building science expertise
4) Structural Insulated Panel Association – product support and construction expertise
5) Oak Ridge National Laboratory – a lead in a broader effort on moisture performance of high-R walls

Communications: NAHB's International Builders' Show, EEBA Conference, DOE Educational Webinars, ACC meetings

Next Steps and Future Plans

1) Development of recommendations and best practices for design and construction of high performance enclosures for new and existing construction
2) Development of recommendations for code change proposals and standards updates
3) Broadly disseminate results of the studies through various industry media channels and through stakeholders
4) Identify gaps in knowledges that require further investigation
5) Revise applicable guidance documents and Tech Notes
6) Monitor the rate of adoption of high-R walls via Home Innovation's Annual Builder Practices Survey

REFERENCE SLIDES

Project Budget – All Three Projects

Project Budget: see Table below; Total: $873,715 (DOE) $230,471 (Cost Share)
Variances: None
Cost to Date: See Table below
Additional Funding: None for the described scope of work
Projects: Total budget for 3 projects - Moisture performance of High-R walls; EP&B; Attic Retrofits.

Budget History					
FY 2015 – FY 2016 (past)		FY 2017 (current)		FY 2017 (remaining planned thru July 31)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$536,431	$122,758	$138,569	$94,402	$198,715	$13,311

Project Plan and Schedule: Moisture Performance of High-R Walls

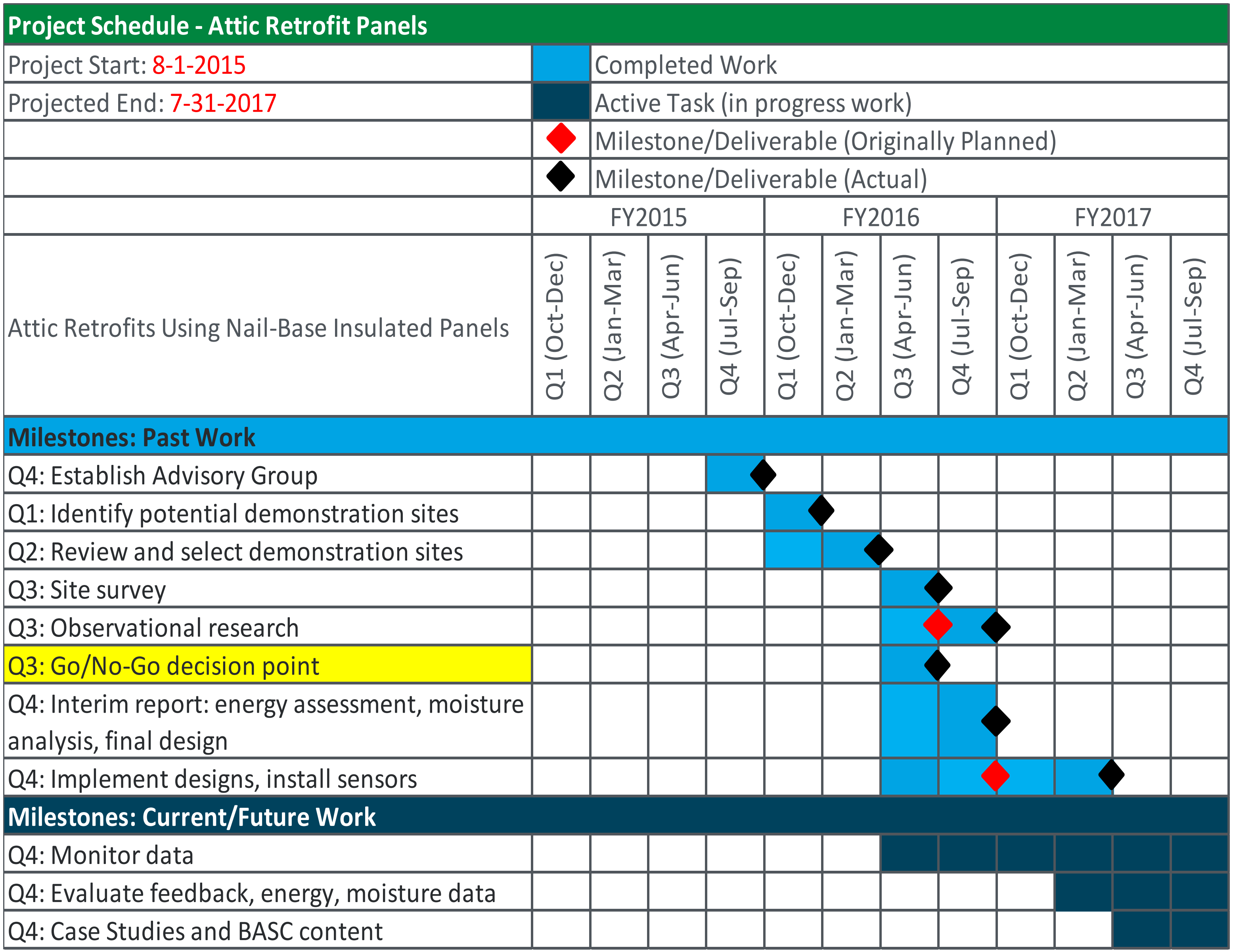
Project Schedule - Moisture Performance of High-R Wall Systems		
Project Start: 8/1/2015		Completed Work
Projected End: 7/31/2017		Active Task (in progress work)
		Milestone/Deliverable(Originally Planned)
		Milestone/Deliverable(Actual)

	FY2015				FY2016				FY2017			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Q1: Establish a list of advisory members to be invited to participate												
Q2: Prepare a research plan and a method for field measurement												
Q3: Prioritized library of wall systems												
Q4: Final list of building sites selected for monitoring												
GO/NO-GO: Instrumentation given number of sites enrolled												
Q1: Installation of sensors												
Current/Future Work												
Q1: Results of the blind predictions using WUFI												
Q2: Perform quality checks												
Q4: Data Analysis and Development of design recommendation												
Q4: Final Report and Dissemination of results												

Project Plan and Schedule: EP&B

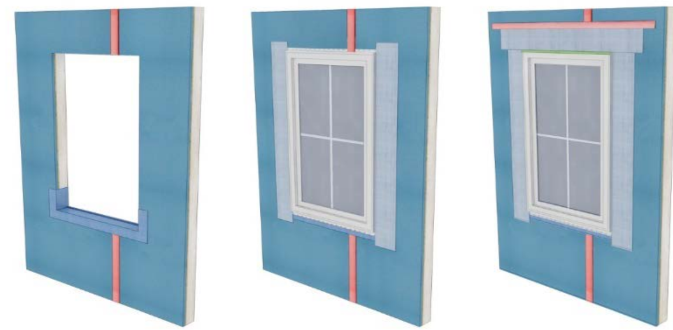
Project Schedule - Extended Plate and Beam Wall System												
Project Start: 08/01/2015	Completed Work											
Projected End: 07/31/2017	Active Task (in progress work)											
	Milestone/Deliverable (Originally Planned)											
	Milestone/Deliverable (Actual)											
	FY2015				FY2016				FY2017			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Q4 Two Demonstration Houses - Construction & Observation												
Go/No-Go												
Current/Future Work												
Q4 Structural Shear Wall Testing												
Q3 Moisture Performance - WUFI Simulation												
Q4 Moisture Performance - Instrumentation, Monitoring, Analysis												
Q4 Wall Construction Guide												
Q4 Documentation & Language to Support IRC Code Change Proposal												

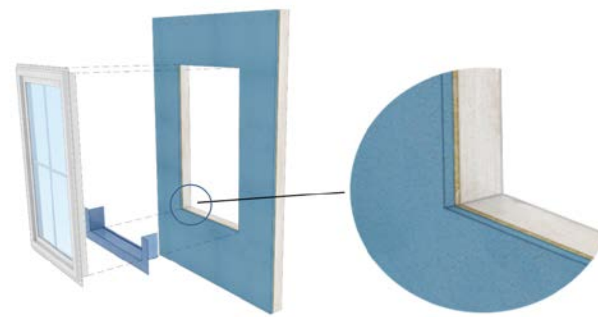
Project Plan and Schedule: Attic Retrofits



Durability of Windows in Walls with Continuous Insulation (CI)

2017 Building Technologies Office Peer Review





Vladimir Kochkin
vkochkin@homeinnovation.com

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Home Innovation RESEARCH LABS™

Project Summary

Timeline:

Start date: 01/08/2016

Planned end date: 7/31/2018

Key Milestones

1. Plan of Evaluation – March 2017
2. Testing Complete – March 2018
3. Solutions and recommendations – July 2018

Key Partners:

American Chemistry Council (ACC)
American Architectural Manufacturers Association (AAMA)
Window and Door Manufacturers Association (WDMA)
National Association of Home Builders

Budget:

Total Project $ to Date:

- DOE: $75,600
- Cost Share: $50,000

Total Project $:

- DOE: $399,908
- Cost Share: $100,000

Project Outcome:

1. A simplified set of window installation solutions that ensure durability of the water and air barriers at the window-wall interface for walls with exterior foam sheathing (i.e., continuous insulation)
2. Broad industry acceptance for the proposed solutions to facilitate code acceptance

Purpose and Objectives

Problem Statement: The window industry published a standard with conservative methods for installation of windows in walls with exterior foam sheathing that creates a significant barrier to the use of continuous insulation (CI).

Target Market and Audience: Residential designers and builders with light-frame projects in Climate Zones 3-8 (>70% of all single-family housing starts in the country) who are using or considering the use of exterior foam sheathing.

Impact of Project:

1. Project outputs:
   a. Laboratory-tested performance of windows in walls with various types of foam, foam thicknesses, and installation methods
   b. Recommended solutions for installation of windows in walls with CI
   c. Testing procedures for evaluation of the window-wall interface in walls with CI
2. Contribution to BA and market goals:
   a. Opaque walls contribute up to 10% of energy savings (whole-house) or up to 20% of heating load savings to support DOE goals for energy use reduction
   b. Accelerated adoption of walls with higher insulation values
   c. Accelerated adoption of 2012/2015 codes w/o envelope amendments

Approach

Approach:

1. Assemble a broad industry advisory group
2. Perform inventory assessment of windows and foam sheathing products
3. Develop/adopt an evaluation protocol
4. Conduct testing and evaluate results
5. Develop solutions and establish applicable limitations

Key Issues: The long-term performance of conventional window installation practices in walls with CI has not been verified leading to a concern that in certain installation configurations and exposure conditions it can lead to unacceptable performance

Distinctive Characteristics: Building broad industry consensus on evaluation protocols; focusing on an identified set of critical variables in terms of material properties and system configurations to validate performance

Progress and Accomplishments

Accomplishments:
1. Advisory Group met to discuss the gaps and provide direction for the project
2. An inventory of windows has been conducted
3. A draft evaluation protocol has been developed

Market Impact:
1) Improved level of confidence for practitioners using walls with CI
2) Minimized risk of potential durability issues for high performance homes in Climate Zones 3-8
3) Accelerated adoption of 2012/2015 I-codes without envelope amendments
4) Through broad stakeholder engagement, significant improvement in awareness across the entire building industry about proven durable solutions for high-R walls

Lessons Learned: The window industry requested that the evaluation be broadened to include performance attributes (in addition to structural aspects) related to temperature fluctuations, air tightness, and water leakage

Window Inventory

Awning

Casement

Garden

Jalousie

Hung (Single and Double)

Horizontal Slider/Glider

Dual Action

Pivoted

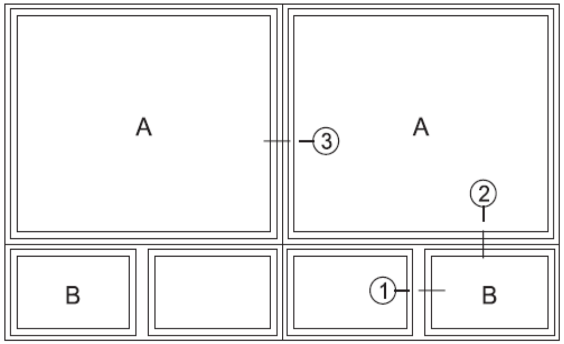
Fixed

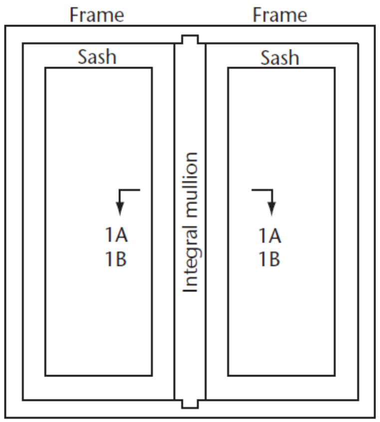
Vertical Slider

Window Inventory - Continued

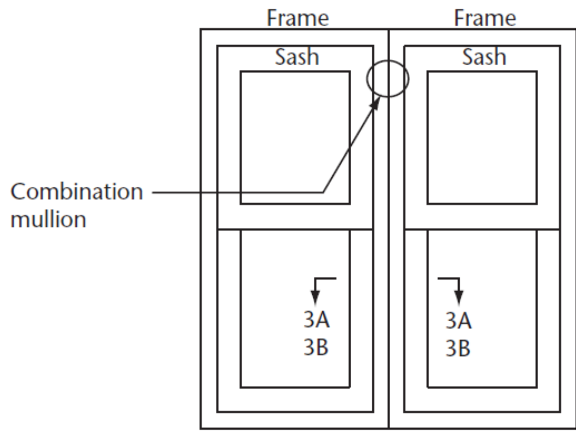
Mulled Assemblies

- Mullions: connecting members between two or more window units
- Vertical or horizontal
- Three types

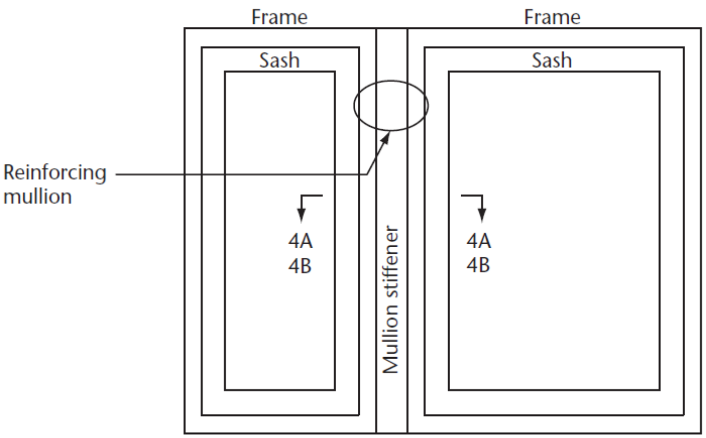




Integral



Combination



Reinforcing

Home Innovation Testing Facility

Wind Pressure

Air and Water Leakage

Temp Fluctuations

Project Integration and Collaboration

Project Integration: Home Innovation brings key stakeholders including associations to the table as co-sponsors (cash and product) and as advisory group members. Broad industry participation includes builders (including high production builders), window manufacturers, standard-writing bodies, insulation product manufacturers, and building science experts. As an example of engagement and integration, the photo below shows an industry meeting on evaluating practices for use of CI in walls that prompted the current project.

Partners, Subcontractors, and Collaborators: Home Innovation formed an Advisory Group that includes broad stakeholder representation

Communications: The project was announced at NAHB's International Builders' Show, ACC meetings, Home Innovation website; results will be broadly disseminated to industry partners as well as organizations that develop relevant standards and codes.

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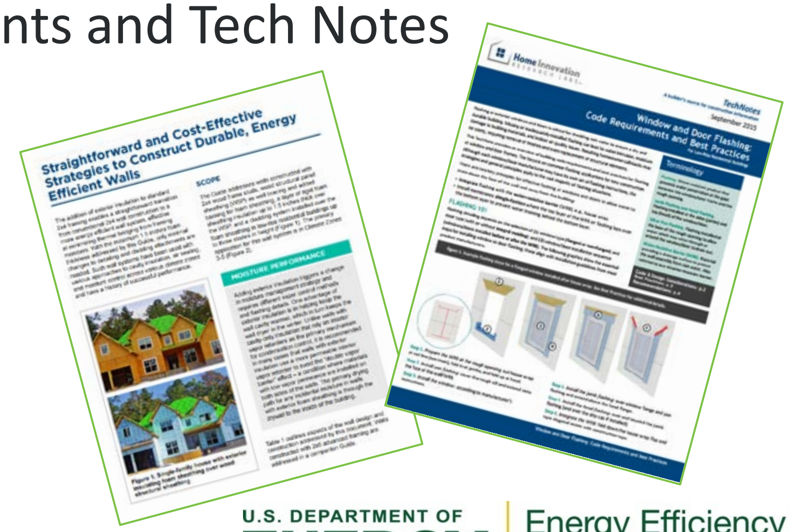
Next Steps and Future Plans

1) Finalize the evaluation protocol
2) Conduct laboratory testing
3) Perform evaluation of the results
4) Make recommendations for installation methods and define applicable limitations
5) Broadly disseminate results of the study through various industry media channels and through stakeholders
6) Revise applicable guidance documents and Tech Notes
7) Monitor the rate of adoption of walls with CI via Home Innovation's Annual Builder Practices Survey



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REFERENCE SLIDES

Project Budget – Windows in Walls with CI

Project Budget: see Table below; Total: $399,908 (DOE) $100,000 (Cost Share)
Variances: None
Cost to Date: See Table below
Additional Funding: None for the described scope of work

Budget History					
FY 2016 (past)		FY 2017 (current)		FY 2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$10,376	$0	$229,624	$75,000	$159,908	$25,000

Project Plan and Schedule: Windows in walls with CI

Project Schedule - Windows Installed Over Continuous Insulation		
Project Start: 8-1-2016		Completed Work
Projected End: 7-31-2018		Active Task (in progress work)
	◆	Milestone/Deliverable (Originally Planned)
	◆	Milestone/Deliverable (Actual)

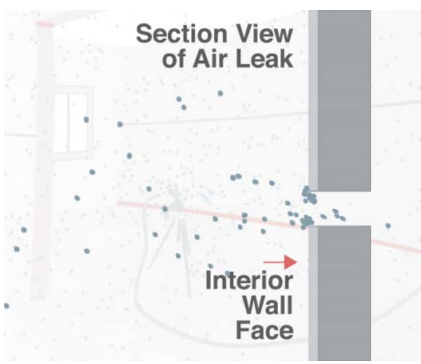
	FY2016				FY2017				FY2018			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Q1: Advisory Group Established					Completed ◆							
Q1: Window Inventory					Completed ◆							
Current/Future Work												
Q2: Literature Review - Research Plan					Active	Active						
Q2: Initial Test Matrix / Performance Criteria - Research Plan						Active						
Q4: Testing						Active	Active	Active				
Q4: Updated Test Matrix / Performance Criteria								Active				
GO/NO-GO: Further Testing Given Initial Results								Active				
Q2: Continued Testing								Active	Active	Active		
Q3: Evaluation of Results - Report											Active	
Q4: Set of Solutions for Dissemination												Active

Up Next…

cee
Center for Energy and Environment

Aerosol Sealing in New Construction

2017 Building Technologies Office Peer Review



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Dave Bohac, dbohac@mncee.org
Center for Energy and Environment

Project Summary

Timeline:

Start date: 8/1/2016

Planned end date: 7/31/2019

Key Milestones

1. Builder kickoff meetings; MN- 12/16, CA- 3/17
2. Identify sealing options; MN- 4/17, CA- 6/17
3. Seal 5 houses; MN- 8/17, CA- 10/17

Budget:

Total Project $ to Date (1/31/17):

- DOE: $44,244
- Cost Share: $11,089

Total Project $:

- DOE: $535,037
- Cost Share: $134,143

Key Partners:

University of California, Davis, WCEC (Western Cooling Efficiency Center)
Building Knowledge, Inc.
University of Minnesota, Cold Climate Housing Program
Aeroseal, LLC.

Project Outcome:

The project team will work with builders to optimize the integration of aerosol envelope sealing into the production building process. The sealing guides will enable builders to reduce air infiltration space conditioning energy use by over 50% which can reduce space conditioning energy use by over 10%.

Purpose and Objectives

Problem Statement: High performance moisture managed envelopes require more effective air barriers that require add cost, training, and quality control.

Target Market and Audience: Aerosol envelope sealing can improve the energy performance of all residential new construction. This project will focus on single family new construction, but many of the lessons learned could be applied to other residential units. Approximately 1 million new residential units were built in 2014. In 2009 40% of residential energy use was attributed to space heating and cooling which is impacted by air infiltration loads from leaky envelopes.

Impact of Project: This project will provide guides and builder case studies for optimal integration of aerosol envelope sealing for new home construction. The project team will work with builders in Minnesota and California to identify options for when to seal and what current sealing could be eliminated. The tightness and net cost of the aerosol sealed houses will be compared to results for their standard construction. The goal is to produce reliably tighter houses for equal or lower cost.

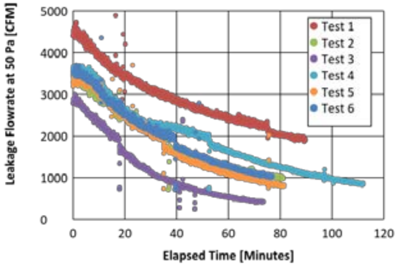
Aerosol Envelope Sealing

Technology:

- Pressurize enclosure for 1 to 2 hours while applying aerosol "fog"
- Sealant particles find and seal leaks as air escapes house
- Capable of simultaneously measuring, locating, and sealing leaks in a building envelope.

Benefits:

- Envelope tightness improved by 60% to 95%
- Reduced training and quality control for eliminated conventional sealing
- Reliable tightness to meet requirements, know when to "stop", and certification test



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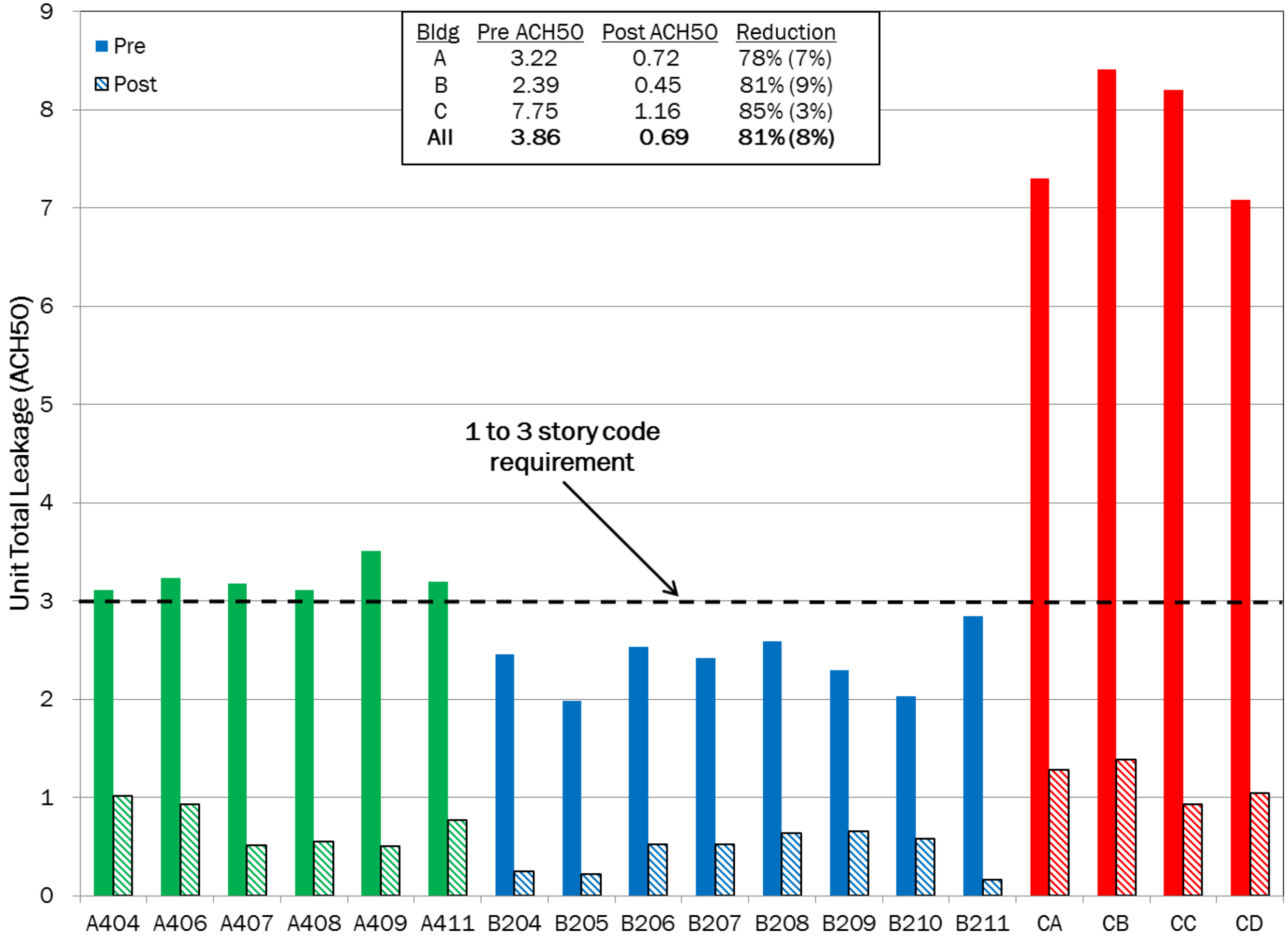
Leakage Results: 18 New Construction MF Units



Bldg	Pre ACH50	Post ACH50	Reduction
A	3.22	0.72	78% (7%)
B	2.39	0.45	81% (9%)
C	7.75	1.16	85% (3%)
All	**3.86**	**0.69**	**81% (8%)**

Average leakage: pre= 3.9 ACH50, post= 0.7 ACH50

54% to 95% below code requirement, average= 77%

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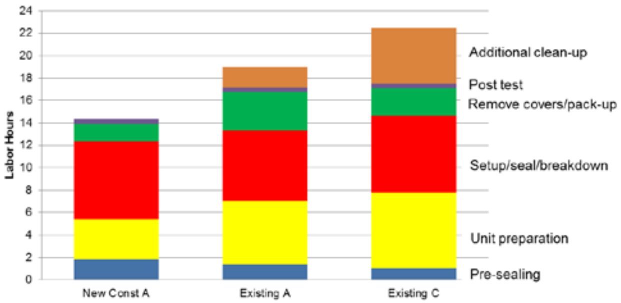
Approach

Key Issues:

- Previous Building America projects showed 60% to 95% improvements in envelope tightness.
- Sealing typically applied after drywall in place. No experience with ability to replace current sealing methods.

Approach:

- Iterative approach with multiple builders – when & what to eliminate
- Assess current sealing methods for a MN & CA builder and develop two approaches for each
- Net cost and tightness will be evaluated against standard methods
- Process repeated with second set of houses for first builders and a set of houses for additional builders.



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Progress and Accomplishments

Accomplishments:

- Planning complete: Test Plan and Project Management Plan
- Held kickoff meeting for Minnesota builders and starting outreach for California meeting
- Developing assessment protocol
- Field work delayed – did not want to apply sealing under most challenging conditions (e.g. Minnesota winter)

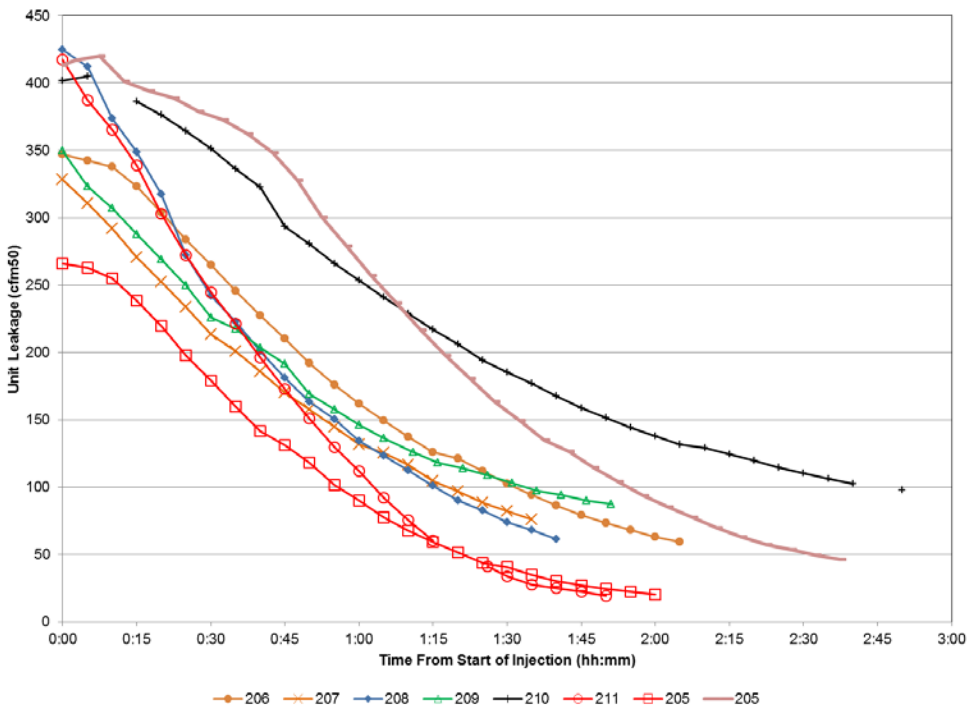
Market Impact:

- Working with manufacturer (Aeroseal) – direct application of results
- Aeroseal's duct sealing contractors seal about 15,000 systems/year & planning to develop envelope contractors by end of 2017
  - DOE Energy 100 award
  - ASHRAE 2016 Product of the Year Award
- Large and/or visible builders to improve credibility

Progress and Accomplishments

Lessons Learned (Builder Kickoff Meeting):

- Interested in sealing after mechanical penetrations/before insulation
- Eliminate 4 ml poly interior?
- Change rim joist spray foam approach?
- Seal ducts from outside > in?
- Likely to need help working with code officials to approve some changes
- Significant interest, but time for corporate approval & other priorities



MF New Construction

- 71% to 94% reduction
- Post ACH50: 0.16 – 0.66
- Post cfm50: 25 - 114

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Project Integration and Collaboration

Project Integration and Key Partners:

- UC Davis Western Cooling Efficiency Center developed technology and working on other efforts to promote aerosol sealing in other markets
- Aeroseal corporation will be conduit to contractors who perform work
- Building Knowledge is established air sealing and energy efficiency consultant for homebuilding industry
- University Minnesota Cold Climate Housing experienced builder trainer/educator

Communications:

- Presentations at ACEEE Summer Study, Better Buildings Better Business, & Home Performance Conference: primarily previous MF results but discussing current BA project

Next Steps and Future Plans

- Agreement with first MN builder
- Assess houses and develop sealing options 1st MN builder (March/April)
- Seal 1st five MN houses (May – August)
- CA effort ~ 2 months after MN
- California builder kickoff meeting (March/April)
- Seal 1st five CA houses (June – Sept)
- Repeat for second set of houses for first builders
- Repeat for houses for another builder in MN and CA

Waiting for the winter thaw

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REFERENCE SLIDES

Project Budget

Project Budget: The total project budget is $669,179 (DOE: $535,037; Cost Share: $134,143). About 7% of the funds will be used by Aeroseal staff to seal houses, 11% by Building Knowledge for builder engagement, and remainder split between CEE and WCEC to implement project. Current expenses were used primarily to generate the Test Plan and conduct first builder kickoff meeting.
Variances: Expenses in FY 2017 have been less than expected due to the decision to move back initial field work to warmer weather and delays in partner invoices.
Cost to Date: DOE: $44,244, Cost Share: $11,089; 8.3% of the project budget has been spent to date.
Additional Funding: Builder's staff time for project was uncertain and has not been included as cost share.

Budget History					
8/1/2016 – FY 2016 (past)		FY 2017 (current)		FY 2018 – 9/30/2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$11,218	$2,813	$224,169	$58,761	$200,103	$47,872

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Project Plan and Schedule

- Three year project that started August 2016 & planned to be completed July 2019.
- Final Test Plan and MN builder kickoff meeting complete.
- Split builder kickoff meetings for MN & CA, so CA meeting is being held later (closer to start of field work). Delayed initial sealing work to warmer weather- project put on 2 month hiatus.
- Work with first MN builder expected to start in March with sealing to start in April-May. CA work will start about 2 months after work in MN.
- First go/no-go decision point is to have first two builders recruited by July 2017.

Project Schedule		
Project Start: August 2016		Completed Work
Projected End: July 2019		Active Task (in progress work)
		Milestone/Deliverable (Originally Planned)
		Milestone/Deliverable (Actual)

	FY2016				FY2017				FY2018			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Q1 Milestone: Final version of Test Plan												
Q1 Milestone: MN builder kickoff meeting												
Q1 Milestone: CA builder Kickoff meeting												
Current/Future Work												
Q2 Milestone: MN builder 1 sealing options												
Q3 Milestone: MN builder 1 seal five houses												
Q? Milestone: CA builder 1 sealing options												
Q? Milestone: CA builder 1 seal five houses												

Up Next…

Building Science Corporation

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

2017 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Kohta Ueno, kohta@buildingscience.com
Building Science Corporation

Project Summary

Timeline:

Start date: October 2016

Planned end date: September 2019

Key Milestones

1. Instrumentation & Test Plan, November 2016
2. Needs Assessment-Manufactured Housing Roofs, July 2017
3. Winter 1 ("Normal") Report, September 2017

Key Partners:

DuPont	NAIMA
Owens Corning	Nu-Wool
Cosella-Dörken	
K. Hovnanian	

Budget:

Total Project $ to Date: $198,317

- DOE: $156,671
- Cost Share: $41,646

Total Project $: $544,687

- DOE: $430,302
- Cost Share: $114,385

Project Outcome:

In an effort to improve moisture-managed high-R envelopes to reduce heating and cooling loads, the moisture safety of roofs insulated with fibrous insulation in cold climates is being monitored. This will provide options for lower-cost unvented roofs, thus increasing market penetration. At 5% of new single-family housing start, this would be on the order of 40,000 units/year.

Purpose and Objectives

Problem Statement:

- Insulating at the roofline (unvented roofs): eliminate attic ductwork losses, improve airtightness, and reduce duct condensation risks
- Moisture-safe unvented roofs (spray foam): effective but costly
- Insulating roofs with lower-cost fibrous insulation: reduce costs for unvented roofs by factor of 2-3 (increase market penetration)
- Research aligns with the DOE goal of developing Moisture Managed High-R Envelopes.

Target Market and Audience:

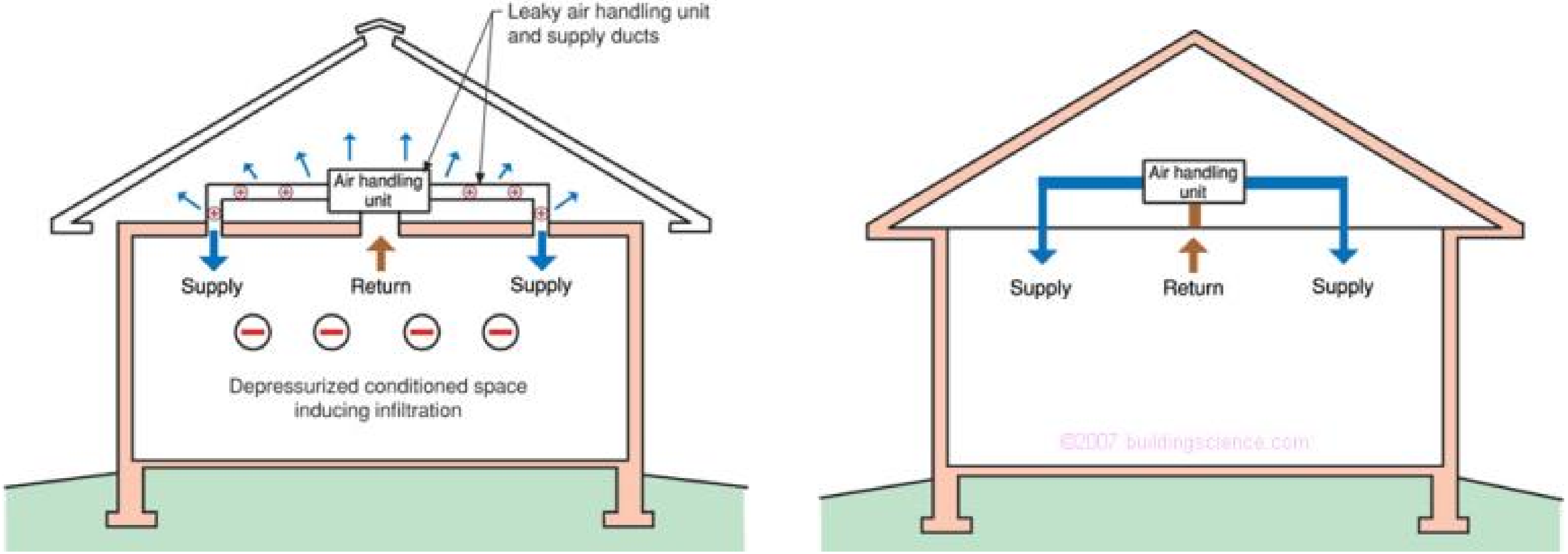
- Applications to roofs in new and existing housing
- Climate zones at least up to 5A
- Insulation manufacturers key to widespread implementation; are key stakeholders and cost share partners

Purpose and Objectives

Impact of Project:

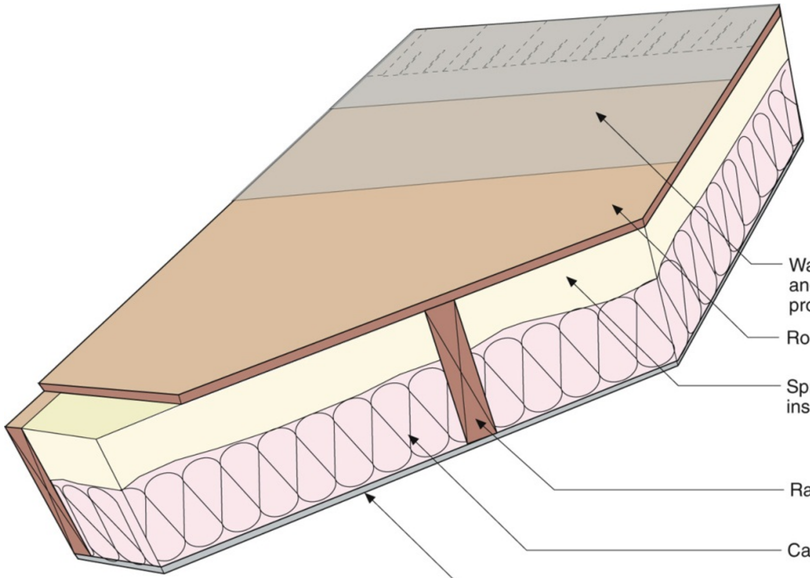
1. Planned project output:
   a. Validate moisture safety data of unvented roof assemblies
   b. Provide inputs for proposed building code changes
2. Project will measure moisture safety of high-R roof assemblies; experimental variables provide fine-tuning of recommended best practice; calculations estimate savings of >10% in HVAC energy use
   a. Near-term: acceptance of results by industry and development of proposed code language
   b. Intermediate outcomes: use of measure on smaller scale in high performance housing (industry thought leaders, NZE); process of incorporation into building codes
   c. Long-term outcomes: regular use of the code-compliant measure in standard construction, 40,000 units/yr. low est.

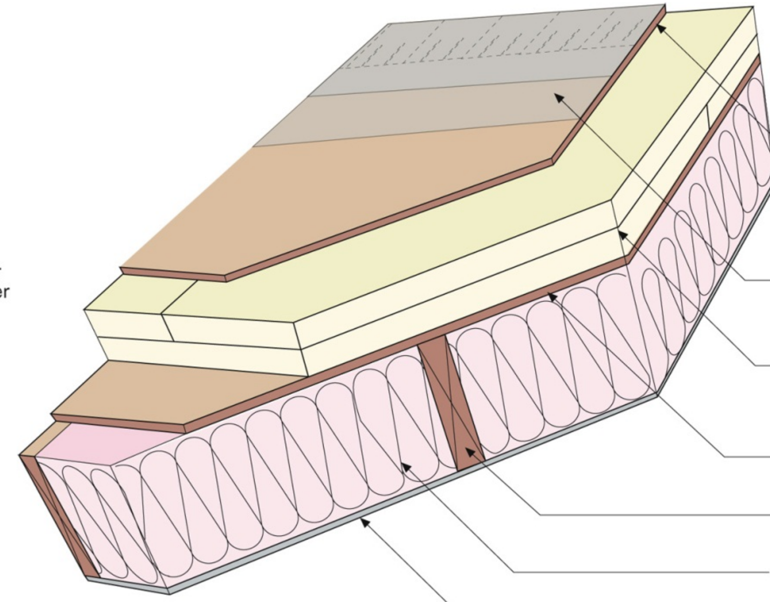
Background: Unvented Roofs



- Ducts in unconditioned attic = substantial energy losses
  - Industry reluctant to move ducts out of attic
- Solution: bring ducts into conditioned space
- Unvented/conditioned attic
  - Keeps ductwork in conditioned space, duct leak issues eliminated
  - Eliminates ice dam issues due to duct losses
  - Lowers risks for hot-humid climates ductwork and AHU condensation
  - Potential airtightness improvement

Background: Spray Foam/Exterior Insulation Roofs

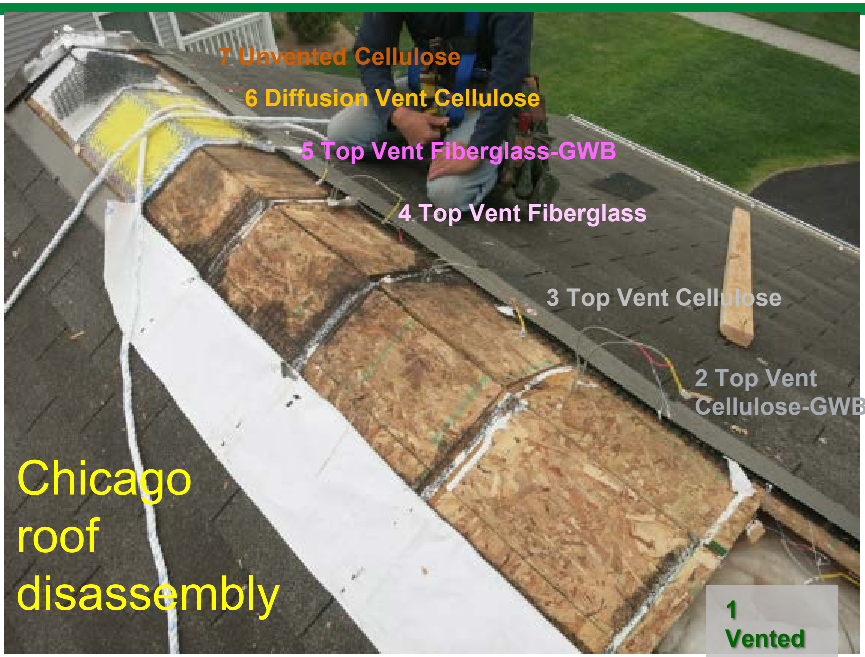




- Unvented roofs with fibrous insulation alone: moisture risks
- Poor performance of cathedral vented assemblies (air leakage)
- 2006 IRC onward: §R806.4 Unvented attic assemblies
  - Minimum R-value of “air impermeable insulation” (foam)
  - High cost of spray foam or rigid foam + nail base
  - Anti-foam sentiment in industry segments

Previous Building America Research

- Chicago (CZ 5A):
  - One winter, 50% RH
  - Unvented roofs-high risk
  - Cellulose lower risk than FG batt
- Houston/Orlando (CZ 2A):
  - 2 attics, multiple seasons
  - Diffusion vents allow greater drying, avoid moisture problems
- Europe/PassivHaus:
  - Allowing unvented roofs w. variable-perm vapor control, other constraints



Approach

Approach:

- Climate Zone 5A Test Hut: side-by-side test roofs constructed and monitored for moisture behavior over 3 winters
- Manufactured Housing Project: possible implementation of unvented roof assemblies with fibrous insulation, diffusion vent ridge

Key Issues:

- Constructability of fibrous insulation at roofline/unvented
- Costs vs. current practice—estimated factor 2-3 typical
- Moisture safety to be gauged by mold index model (from data)

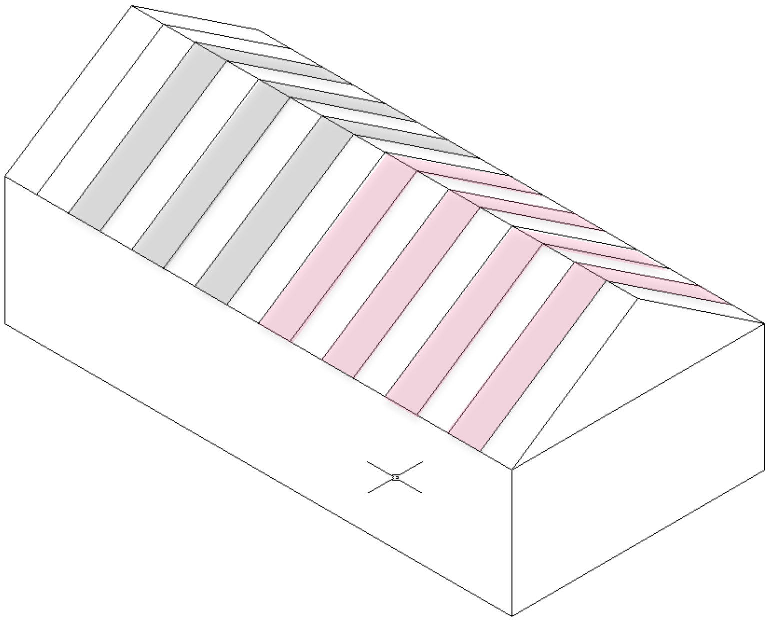
Distinctive Characteristics:

- Side-by-side assembly and north/south test hut approach
- Cooperation from manufacturers in multiple insulation industries; DOE providing third party unbiased research

Test Hut Experimental Approach

- Climate Zone 5A test hut
- Eight north-south roof bays
- ±R-50 (14-¾" framing, 2012 IECC)
- Test variables:
  - Vapor retarder: variable perm vs. fixed perm
  - Diffusion vent at ridge vs. no diffusion vent
  - Fiberglass vs. cellulose
  - "Control" comparison §R806.4 spray foam + fibrous
- Varying interior boundary conditions
  - Winter 1: "Normal" interior conditions (constant T, ~30% RH)
  - Winter 2: Elevated RH (50% constant)
  - Winter 3: Air leakage into rafter bays

Test Hut South Elevation



Progress and Accomplishments

Accomplishments:

- Test hut experimental and instrumentation plans reviewed and accepted by industry partners
- Test hut construction, instrumentation, and insulation complete (December 2016)
- Preliminary data being collected and analyzed (Winter 1)

Market Impact:

- Impact to be ensured by tracking of costs, ease of construction (vs. implementation hurdles in practice), and hygrothermal performance
- Actual vs. planned impacts: early in research, only preliminary data

Project Integration and Collaboration

Project Integration: BSC collaborating closely with industry partners (major insulation manufacturers): provide input on experiment, information on potential market opportunities, and material donations.

- NAIMA (fiberglass industry insulation trade group)
- NuWool (cellulose)
- Owens Corning (fiberglass, rigid board foam)
- Johns Manville (fiberglass, rigid board foam, spray foam)
- Saint-Gobain/CertainTeed (fiberglass, rigid board foam, spray foam)
- Roxul (mineral fiber)

Partners, Subcontractors, and Collaborators: Manufactured housing effort managed by Washington State University/Michael Lubliner

Communications: Year 1 results to be presented at energy industry or weatherization conference (EEBA or similar); communications with construction trade publications (*JLC, FHB*, Green Building Advisor)

Next Steps and Future Plans

CZ 5A Test Hut

- Three winters of test roof data
  - Normal, humidified, air leakage
- Decommissioning/disassembly
  - Actual test roof conditions after exposure
- Formulating building code language
  - Mass implementation only possible as a code-compliant option
  - Restrictions on use, standards to be met, application to various CZs
  - May require future hygrothermal modeling task

Manufactured Housing Project

- Stakeholder meeting and statement of needs
- Possible implementation of monitored test site

REFERENCE SLIDES

Project Budget

Project Budget: Three-year project, covering monitoring of climate zone 5A test hut and manufactured housing needs assessment & field work
Variances: n/a
Cost to Date: Roughly 20% of total budget spent to date
Additional Funding: Cost share provided by funding partners (Nu-Wool and NAIMA)

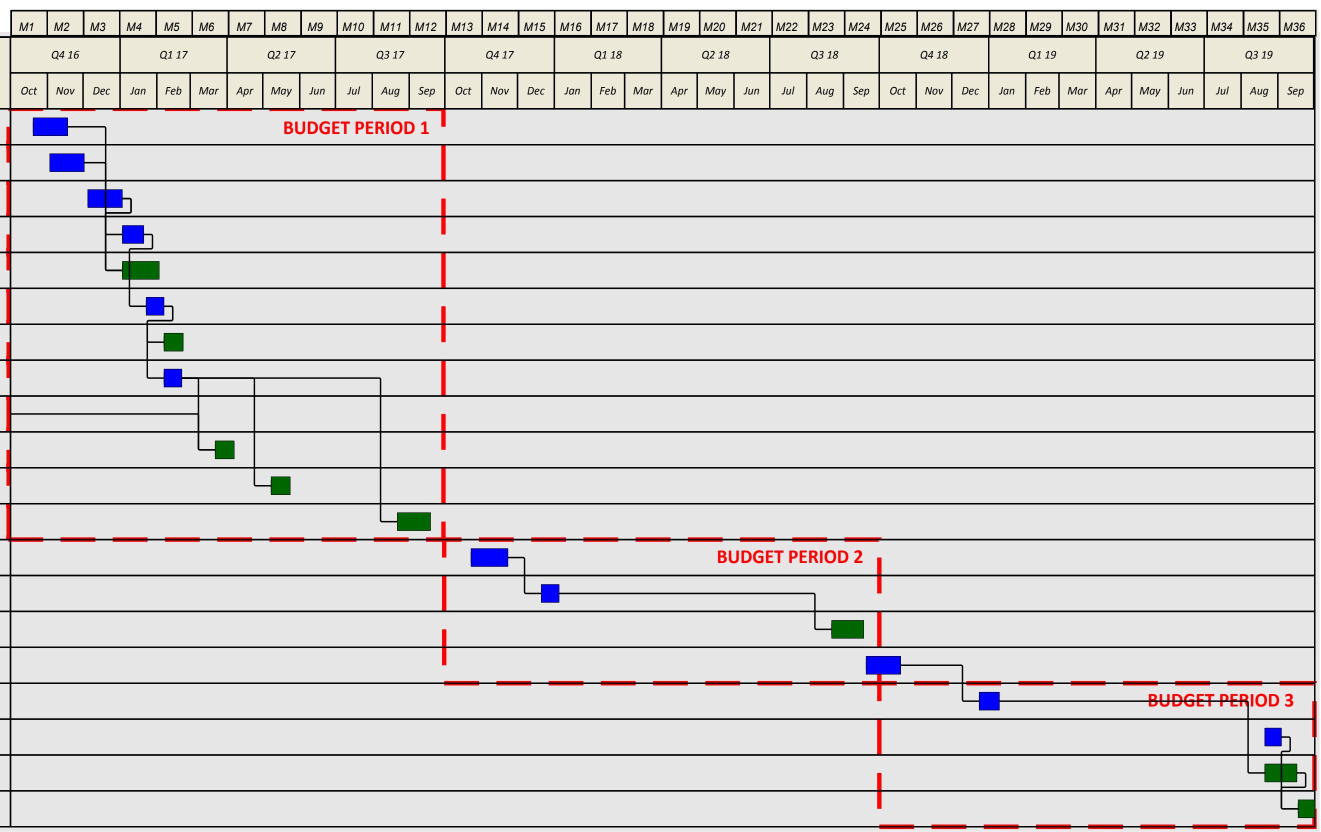
Budget History					
October 2016 – FY 2016 (past)		FY 2017 (current)		FY 2018 – September 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$156,671	$41,646	$134,334	$35,710	$139,297	$37,029

Project Plan and Schedule

- Start date: October 2016
- Planned end date: September 2019
- Westford Test Facility Results
  - 9/2017: Winter 1 (“Normal”)
  - 9/2018: Winter 2 (“Humidified”)
  - 9/2019: Winter 3 (“Air Leak)
- Manufactured Housing Roofs
  - 7/2017: Needs Assessment

- Go/no-go decision points
  - Westford Test Facility: are there viable assemblies based on moisture conditions in roof? (BP1, BP2)
- Westford Test Facility (CZ 5A Hut):
  - Currently collecting Winter 1 data
  - Data analysis
  - Commissioning testing (air leak)

ID	Task *Blue = Design/Implementation* *Green = Reporting*	Start	Finish
1	Roof Assembly Selection	10/20/2016	11/17/2016
2	Vetting Test House, Site Visit	11/3/2016	12/1/2016
3	Roof Instrumentation Package Design	12/5/2016	1/2/2017
4	Instrumentation Setup & Testing	1/3/2017	1/20/2017
5	Test Plan to Industry Partners	1/3/2017	2/2/2017
6	Pre-Insulation Instrumentation (“Rough”)	1/23/2017	2/6/2017
7	Insulation/Installation Documentation	2/7/2017	2/22/2017
8	Post-Insulation Instrumentation (“Final”)	2/7/2017	2/21/2017
9	Field Testing/Commissioning	2/8/2016	2/22/2016
10	Reporting: Instrumentation & Testing	3/22/2017	4/6/2017
11	Reporting: Initial Data (Sensor Function)	5/8/2017	5/22/2017
12	Reporting: Winter 1 Results	8/22/2017	9/18/2017
13	Develop and Test Humidification System	10/23/2017	11/21/2017
14	Install Humidification System	12/21/2017	1/4/2018
15	Reporting: Winter 2 Results, Humidifier	8/22/2018	9/17/2018
16	Develop and Test Air Leak System	9/20/2018	10/18/2018
17	Install Air Leak System	12/24/2018	1/8/2019
18	Decommissioning and Disassmbly	8/21/2019	9/3/2019
19	Reporting: Winter 3 Results, Air Leakage	8/21/2019	9/16/2019
20	Reporting: Final and Summary	9/18/2019	10/16/2019



Up Next…

Fraunhofer

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

New 2016 Project

2017 Building Technologies Office Peer Review



Fraunhofer USA

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Kurt Roth, Ph.D. kroth@cse.fraunhofer.org
Fraunhofer USA Center for Sustainable Energy Systems (CSE)

Project Summary

Timeline:

Start date: 9/21/2016 (contract received)

Planned end date: 7/31/2019

Key Milestones

1. Homes with one CT + furnace: classification accuracy 75%+ for target ECMs, predict runtime with ±25% accuracy (June, 2017)
2. Homes with multiple CTs + furnace: 75%+ classification accuracy for target ECMs, predict runtime ±25% accuracy (July, 2018)

Budget:

Total Project $ to Date:

- DOE: $71,893 (as of 2/22/2017)
- Cost Share: $33,683 (estimated, 32%)
- *Total Project: $99,836*

Contracted Project $:

- DOE: $1,050,158
- Cost Share: $492,061
- *Total Project: $1,542,219*

Key Partners:

Eversource Energy
Holyoke Gas & Electric
National Grid

Project Outcome:

Validate algorithms that automatically analyze communicating thermostat (CT) data to identify homes with at least one target energy conservation measure (ECM):

- Attic and/or wall insulation; air sealing, and heating system upgrade.

Enable targeted and customized outreach by utility energy efficiency programs to:

1. Double the uptake of energy audits
2. Double the uptake of target ECMs
3. Provide remote EM&V of those retrofits

Project Motivation

Problem Statement:

- Space heating is the largest end use for homes in cold/very-cold climates
- Homes with poor/no insulation or inefficient heating systems have higher heating energy consumption
  - ~20-25 percent of homes
- Wall and/or attic insulation, air sealing, and HVAC system upgrades can significantly reduce space heating energy consumption
- Programs face high customer acquisition costs
- Slow market uptake of these proven measures
  - <1% of households/year in Massachusetts

Sources: DeMark Home Ontario. S. Edwards-Musa, Eversource Energy.

Project Objectives and Benefits

Project Objective: Develop a tool for utility energy efficiency (EE) programs that **analyzes communicating thermostat (CT) data** to **automatically identify** and **quantify the benefit** of **targeted and customized retrofit opportunities**

Customer and Utility Benefits:

- Double the deployment rate of the target energy conservation measures (ECMs)
- Decrease the cost of EE programs via targeting
- Reduce retrofit performance risks using remote EM&V
- Increase customer engagement

Ultimate Vision: CTs deployed in most homes identify high-impact opportunities to reduce HVAC energy consumption *and* ensure retrofit performance

Sources: DOE BTO (2012), Massachusetts TRM (2013).

Project Impact

Project Impact:

- *Basic* ECMs identified have a technical heating savings potential ~0.5 quad/year
  - *Consumer savings of **$4-5 billion per year***
    - *Potential* annual *ROI on DOE investment of 3-4,000+*
  - Further savings from space cooling savings, deeper retrofits

BTO Building America Goals Addressed:

Affordably achieve 40% EUI reduction for existing homes

- Increase market demand for high-impact, high-performance home retrofits
  - Addresses two largest end uses: Space heating and cooling
- Reduce risk: Ensure retrofits *achieve and maintain* high performance
- Leverage dramatic growth in CT installed base = very low incremental cost

Approach: Technical Challenges

What the thermostat reports:

Date	Time	System Setting	System Mode	Calendar Event	Program Mode	Cool Set Temp (F)	Heat Set Temp (F)	Current Temp (F)	Current Humidity (%RH)	Outdoor Temp (F)	Wind Speed (km/h)	Cool Stage 1 (sec)	Heat Stage 1 (sec)	Fan (sec)
3/29/2016	0:00:00	auto	heatOff		Sleep	82	63	70	39	43.8	16	0	0	0
3/29/2016	0:05:00	auto	heatOff		Sleep	82	63	69.9	39	43.8	16	0	0	0
3/29/2016	0:10:00	auto	heatOff		Sleep	82	63	69.8	40	43.8	16	0	0	0
3/29/2016	0:15:00	auto	heatOff		Sleep	82	63	69.8	40	43.8	16	0	0	0
3/29/2016	0:20:00	auto	heatOff		Sleep	82	63	69.8	40	43.8	16	0	0	0
3/29/2016	0:25:00	auto	heatOff		Sleep	82	63	69.7	40	43.8	16	0	0	0
3/29/2016	0:30:00	auto	heatOff		Sleep	82	63	69.6	40	42.7	22	0	0	0
3/29/2016	0:35:00	auto	heatOff		Sleep	82	63	69.4	40	42.7	22	0	0	0
3/29/2016	0:40:00	auto	heatOff		Sleep	82	63	69.3	40	42.7	22	0	0	0
3/29/2016	0:45:00	auto	heatOff		Sleep	82	63	69.1	40	42.7	22	0	0	0
3/29/2016	0:50:00	auto	heatOff		Sleep	82	63	69	40	42.7	22	0	0	0
3/29/2016	0:55:00	auto	heatOff		Sleep	82	63	68.9	40	42.7	22	0	0	0
3/29/2016	1:00:00	auto	heatOff		Sleep	82	63	68.9	40	42.7	22	0	0	0
3/29/2016	1:05:00	auto	heatOff		Sleep	82	63	68.8	40	42.7	22	0	0	0
3/29/2016	1:10:00	auto	heatOff		Sleep	82	63	68.7	40	42.7	22	0	0	0
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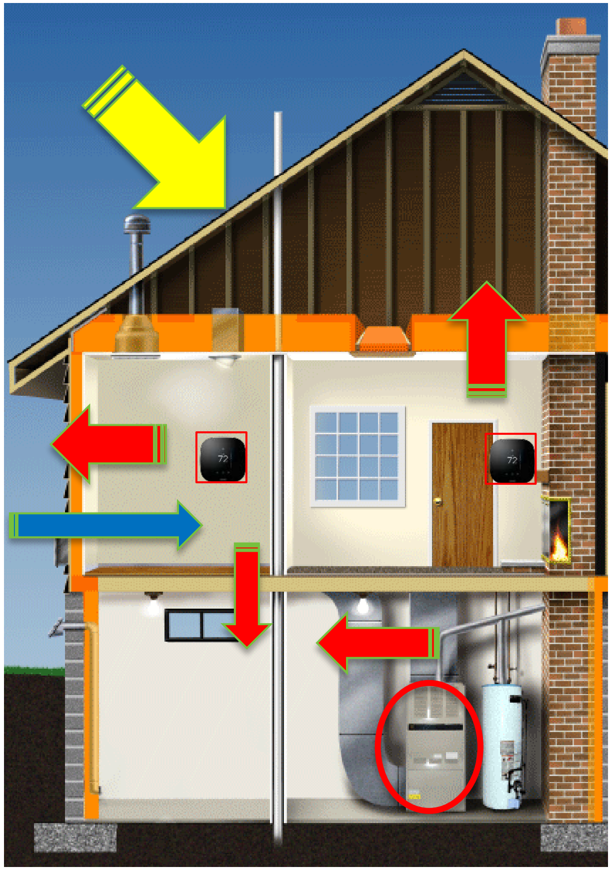
3/29/2016	1:25:00	auto	heatOff		Sleep	82	63	68.5	40	42.7	22	0	0	0
3/29/2016	1:30:00	auto	heatOff		Sleep	82	63	68.5	40	42.6	19	0	0	0
3/29/2016	1:35:00	auto	heatOff		Sleep	82	63	68.4	40	42.6	19	0	0	0
3/29/2016	1:40:00	auto	heatOff		Sleep	82	63	68.4	40	42.6	19	0	0	0
3/29/2016	1:45:00	auto	heatOff		Sleep	82	63	68.3	40	42.6	19	0	0	0
3/29/2016	1:50:00	auto	heatOff		Sleep	82	63	68.2	40	42.6	19	0	0	0
3/29/2016	1:55:00	auto	heatOff		Sleep	82	63	68.2	41	42.6	19	0	0	0
3/29/2016	2:00:00	auto	heatOff		Sleep	82	63	68.1	41	42.6	19	0	0	0

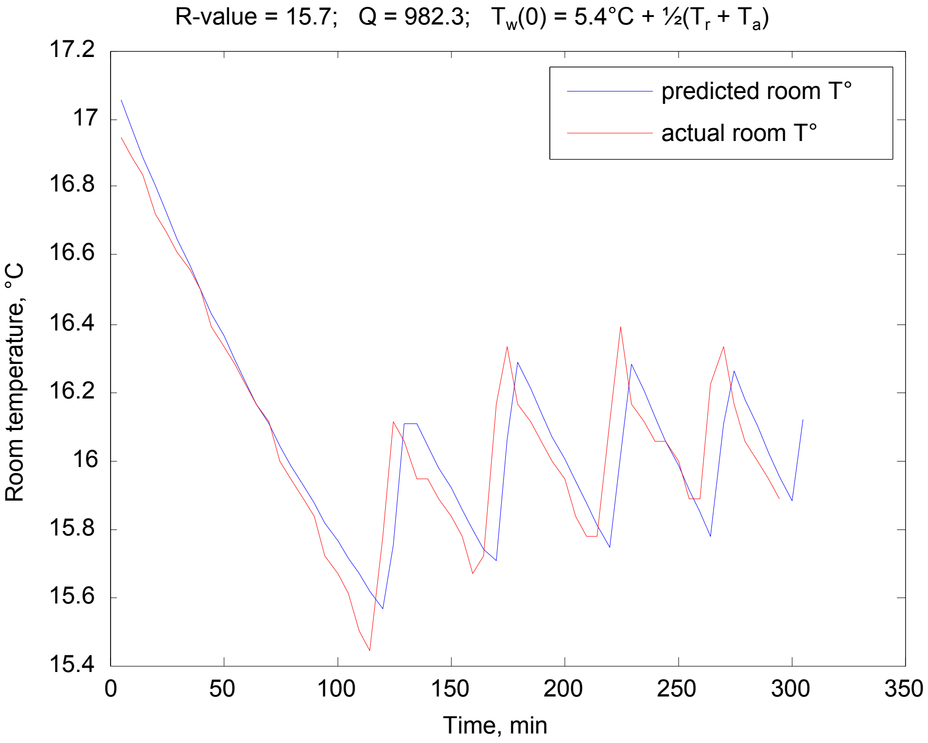


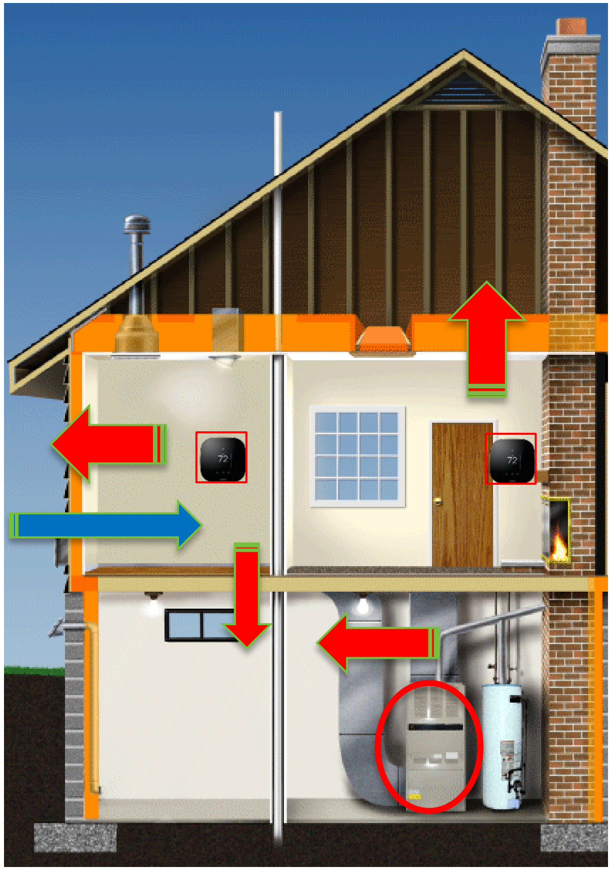
Sources: DOE, Ecobee, Fraunhofer CSE.

Approach: Technical Challenges

Example of parameter estimation by curve fitting using CT data from a single night.

???





Sources: DOE, Ecobee, Fraunhofer CSE.

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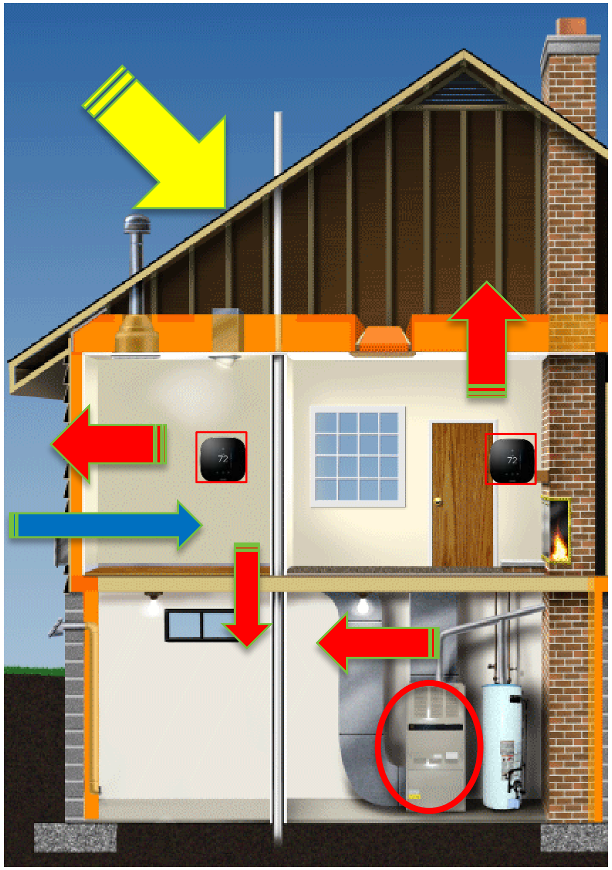
Approach: Technical Challenges and Approach

Key Challenges:

- Different physical parameters can create similar building thermal responses
- Different HVAC systems have different response times and characteristics
- Many homes have multiple CTs
- Thermal response “noise” from internal heat gains



Project Approach:

Analyze *real-world CT, interval, and home energy audit data* to successively refine home thermal response models to *accurately estimate home physical parameter*s that correspond to the target ECMs *in increasingly complex situations*.

Sources: DOE, Ecobee.

Approach: Technical Approach

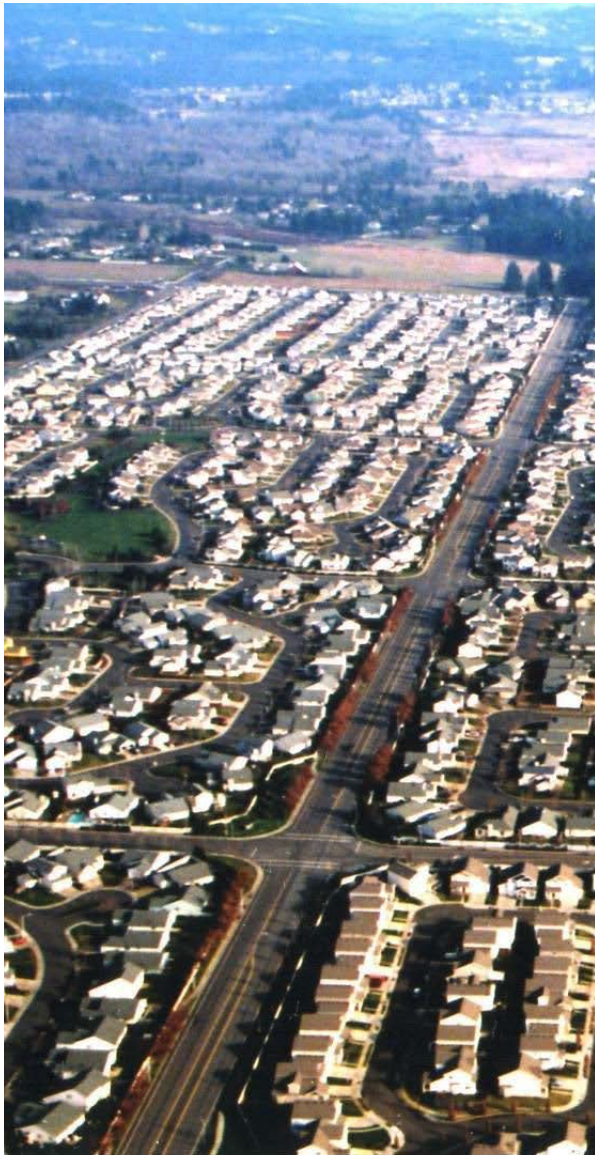
Basic Approach:

1. Energy balances on the enclosure and indoor air
2. Fit real-world CT data sets to gray-box thermal models to determine the physical parameters
3. Compare physical parameters to thresholds indicative of retrofit opportunity

Approach to Overcoming the Technical Challenges: Data, Data, and More Data

Superior data quality and quantity enables a ***hybrid gray-box thermal modeling and machine-learning approach*** to develop and train algorithms

- CT and Home Energy Audit data for several hundred + homes
- Deep "ground truth" data from 80 homes with CTs
  - Home energy audit with blower door testing
  - Interval gas (hourly) and electric (5-minute) data



Source: Clearmeadows Community Association, DOE.

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Approach: Scaling for Impact

1. Project Team: Two leading IOUs and innovative muni
   – Leverages data from existing CT programs
2. Project integrates randomized controlled trial (RCT) to validate key hypothesis of project:
   Do targeted outreach and customized EE offers double the uptake of home energy audits and targeted ECMs?
3. Project Deliverables to Scale Impact
   – CT Data Specification
   – Best Practices Guide for EE Program Integration
4. Near-term outcome: Integrate with Eversource and National Grid EE programs
5. Target Future Outcomes:
   – Leverage growth in CTs – projected ~25MM in 2019
   – CT data specification adopted by other utilities, EE programs, and EnergyStar
   – CT analytics used by other EE programs

EVERSOURCE ENERGY

nationalgrid

HG&E
EMPOWERING YOUR WORLD
gas | electric | telecom

Source: ACHRNews (2015).

Progress and Accomplishments – *Note: New Project*

- Reviewed literature on lumped parameter/gray box modeling and identification
  - Second-order model should be sufficient (considered higher-order)
  - Curve-fitting-based approach
- Derived closed-form solution to 2^{nd}-order gray-box differential equations
- Developed a program for parameter estimation in MATLAB
  - Fitting the closed-form solution for room T° to observed T° (from CT data)
  - Estimates R-value and heat flux using single or multiple nights of data
  - Can also estimate air leakage parameter with data from multiple nights
  - Preliminary testing with existing, proprietary CT data
- Developed a program for fuel consumption estimation in MATLAB
  - Based on PRISM (PRInceton Scorekeeping Method)
  - Calculates heating energy consumption rate
  - Given the estimated heat flux, calculates HVAC efficiency

Progress and Accomplishments – *Note: New Project*

- **Project Start – Sept. 16**
- **Draft CT Data Specs. – Jan. 17**
- Human Subjects Approval – March 17
- Data for 200+ homes: CTs + Audits – April 17
- Data for 80+ homes: CT + Energy Audits + Elec & Gas Interval – June 17
- BP1 Furnace Accuracy Milestone – June 17
- Prelim. EE Integration Plan - Sept. 17
- BP1 Boiler Accuracy Milestone – Nov. 17

BP1 Accuracy Milestones are for homes with *one CT and heating system*:

a) ±25% accuracy in HVAC runtime

b) 75%+ classification accuracy

BP2: Extend accuracy to homes with *multiple* CTs, energy savings estimates for ECMs.

Lessons Learned to Date:

- CT data access and resolution varies greatly among CT providers
- Energy audit information vs. data

Project Integration and Collaboration

Project Integration: Team comprises utility residential and evaluation teams

- Discussions with leading CT manufacturers about data resolution and sharing
- CPUC, NYSERDA, and PG&E have expressed interest in the project
- *Future:* Share and scale the project outcomes through leading utility EE forums

Partners, Subcontractors, and Collaborators: Core team has three utility members

- Data sharing: CT and home energy audit data, interval data
- Planning and execution of the RCT pilot to evaluate effectiveness
- Development of Best Practices Guide for integration of the algorithms with EE programs (for both increasing EE deployment and EM&V)

Communications:

- "Communicating Thermostats as a Tool for Home Energy Performance Assessment" – *Proc. 2017 IEEE Intl. Conf. on Consumer Electronics (ICCE).* Jan.
- 2017 Better Buildings Summit – Accepted invitation to present

Conclusions, Next Steps, and Future Plans

Conclusions:

- Systematic data-driven approach to develop algorithms
- Identifies high-impact retrofits for largest residential end use
- Increases market demand for impactful retrofits and validates performance
- Clear path to commercialization and scale through leading utility EE programs

Next Steps and Future Plans:

- Further refine algorithms for single-family homes with furnace + 1CT
- Secure Human Subjects approval
- Start working with larger Eversource and National Grid data sets
- Recruit 80 HG&E homes for project – deploy CTs, complete energy audits

Potential Project Extensions to Increase Project Impact:

- Validate effectiveness in more moderate climates
- Expand to space heating with heat pumps
- Expand to space cooling applications
  - Deeper integration of electric interval data

REFERENCE SLIDES

Project Budget

Project Budget: DOE Funds: $1,050,158, Team Cost Share: $492,061;
Total $1,542,219

Variances: None to date.

Federal Cost to Date: $71,893 as of Feb. 22, 2017; (7% of total federal funds)
Cost Share to Date: $33,683 estimated (32%)

Additional Funding: $492K in cost share from utility partners and Fraunhofer.

Budget History & Projections					
9/21/16– FY 2016 (past)		FY 2017 (current & planned)		FY 2018 – 7/31/19 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$18,398	$11,058	$331,760	$153,012	$700,000	$327,991
38% cost share		32% cost share		32% cost share	

Project Plan and Schedule

Project Start: 9/21/2016 (contract received, backdated to 8/1/2016)
Projected End: 7/31/2019

Completed work — **M** Expected Milestone
Active Task — **M** Updated Milestone
Future Task — **GNG** Go/No-Go Decision Point

	FY 2016 Q4 (July-Sept)	FY 2017 Q1 (Oct-Dec)	Q2 (Jan-March)	Q3 (Apr-June)	Q4 (July-Sept)	FY 2018 Q1 (Oct-Dec)	Q2 (Jan-March)	Q3 (Apr-June)	Q4 (July-Sept)	FY 2019 Q1 (Oct-Dec)	Q2 (Jan-March)	Q3 (Apr-June)	Q4 (July-Sept)
Past Work													
Q1 Milestone: Draft CT Data Specification		M	M										
Current/Future Work													
Q2 Milestone: Data from 80+ homes			M	M									
Q3 Milestone: Data from 200+ homes				M									
Q3 Milestone: Furnace + 1CT Algorithm Accuracy				M									
Q4 Milestone: Draft EE Program Integration Plan					M								
Q5 Milestone: Boiler + 1CT Algorithm Accuracy						M							
BP1 Go/No-Go Decision Point: 1CT Accuracy						GNG							
Q6 Milestone: 2CT Models Demonstrated							M						
Q7 Milestone: 2CT Model Accuracy									M				
Q8 Milestone: Retrofit Energy Savings Accuracy									M				
Q8 Milestone: Field RCT Test Plan Completed									M				
Q8 Miletstone: Final EE Program Integration Plan									M				
Q9 Milestone: Final CT Data Specification											M		
BP2 Go/No-Go Decision: 2CT Model Accuracy									GNG				
BP2 Go/No-Go Decision: Retrofit Energy Savings Accuracy									GNG				
Q10 Milestone: Field RCT Implemented											M		
Q11 Milestone: RCT Evaluation Completed												M	
Final Reporting: Final Project Report													FR
Final Reporting: Best Practices Guide for Scale Up													FR

Up Next…

NP
Newport Partners L.L.C.

Development of the Industry's First Smart Range Hood

2017 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Mike Moore, mmoore@newportventures.net
Newport Partners

Project Summary

Timeline:

Start date: October 1, 2016

Planned end date: September 30, 2019

Key Milestones

1. M1.1: Sensor & pollutant spec table; 1/16/17
2. M1.2: Identify and acquire sensors; 3/31/17
3. GNG: Develop control logic model; 6/30/17

Budget:

Total Project $ to Date:

- DOE: $5,892
- Cost Share: $3,123

Total Project $:

- DOE: $462,803
- Cost Share: $213,819

Key Partners:

Newport Partners L.L.C.

BROAN

NuTone

Project Outcome:

Develop, test, and demonstrate the industry's first Smart Range Hood.

Project Goal:

Integrate smart features in future, commercially available range hoods.

Purpose and Objectives

Problem Statement

1. Infiltration accounts for more energy use than any other building envelope component.
2. Tight, energy efficient dwelling units require mechanical ventilation to provide acceptable IAQ.
3. One of the largest sources of indoor air pollution is cooking.
4. Ineffective kitchen ventilation (“too noisy” or “not needed”) is a barrier to the construction of healthy, energy efficient dwelling units.

Objectives

1. Develop a Smart Range Hood that senses pollutants, with automatic operation
2. Improve residential IAQ, extend lives, and save billions of dollars in health-related costs annually

Purpose and Objectives, cont'd

Target Market and Audience: Single-family and multifamily dwelling units: infiltration energy use of 2.26 quads/yr (MYPP Table 6)

Impact of Project:

1. Project output: demonstration of smart, energy efficient range hood

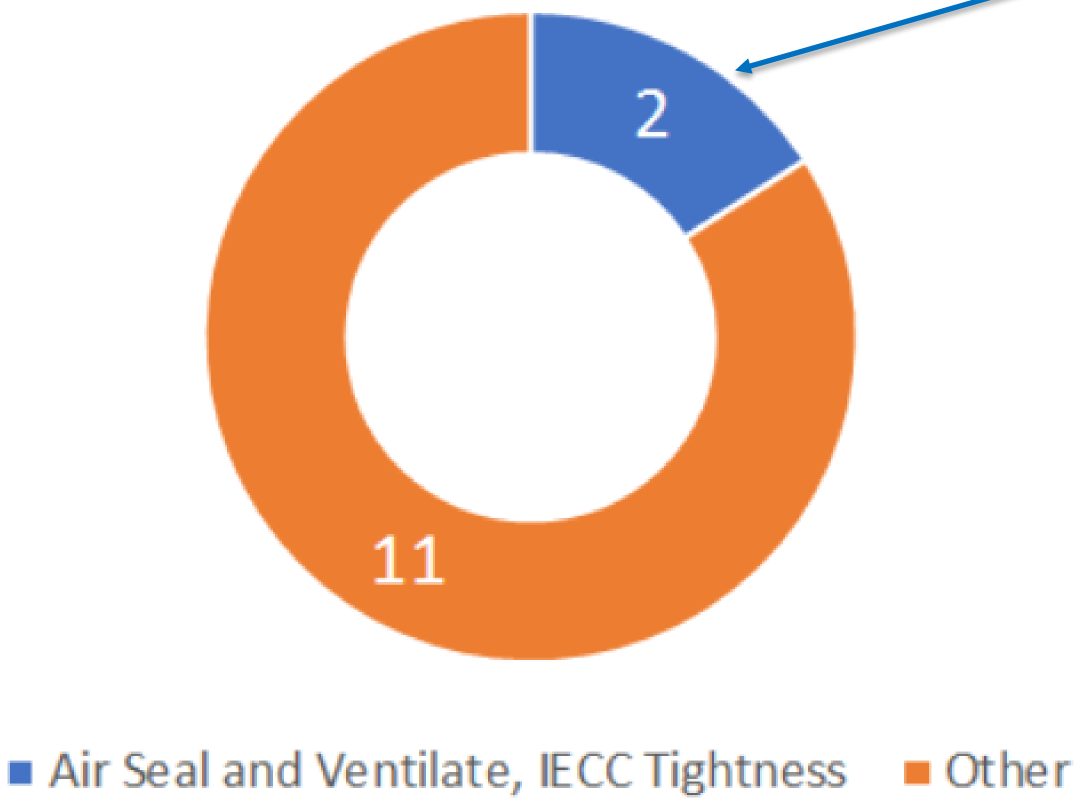
2. Energy savings potential of air sealing and mechanical ventilation: ~2 quads/yr (Sherman et al., 2013*)

3. Outcomes:
   A. Near: concept demonstration
   B. Intermediate: market introduction of products
   C. Long: 25% market penetration

*Sherman et al. 2013. Residential Energy Savings from Air Tightness and Ventilation Excellence. CEC-500-2014-014

Relevance

BTO Goal: 40% reduction in residential EUI by 2030 (~13 quads)



Air seal & ventilate:
could account for up to 2 quads (16%) of BTO's goal for the residential building sector

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Approach

Phase 1: Pre-Prototype → Phase 2: Prototype Development → Phase 3: Lab and Field Testing

Address critical market barriers

Problem	*Solution*
Too Noisy:	≤ 1 sone at 150 cfm
Poor Capture:	~100% CE
Not Operated:	auto response
Inefficient:	up to 5x more efficient than ENERGY STAR
High Cost:	pricing for intermediate market

Distinctive Characteristics: quiet, superior capture efficiency, energy efficient, responsive to pollutants

Key Issues: Sensor accuracy, control algorithms, user acceptance

Progress and Accomplishments

Accomplishments (New project with ~ 1% of budget spent):

1. Developed Pollutant and Sensor Matrix: concentration thresholds and ranges, sensor accuracy and costs

2. Identified Low-Cost, Accurate Sensors

PM2.5

Acrolein

CO

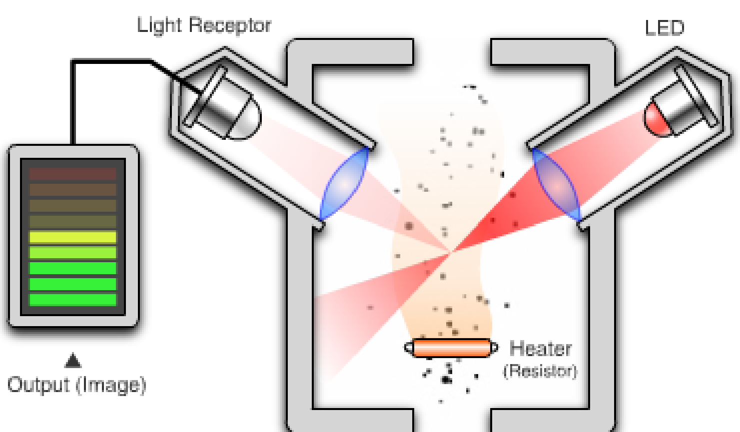
Formaldehyde

CO_2

H_2O

Temp

NO_2



Images c/o Shinyei Technology

Progress and Accomplishments, cont'd

3. Addressed Regulatory Barrier:
   A. Currently, ASHRAE 62.2 does not permit auto-ON controls without occupant OFF control (no such barrier in I-codes)
   B. Proposed change to permit such controls
   C. approved by 62.2 committee in January by a vote of 21-0-2.

62.2 New Text (in process):

automatic control: a control that operates without the need for manual or remote occupant intervention and operates as a function of one or more input variables or conditions, including but not limited to time, humidity, temperature, occupancy, appliance operation, and contaminant concentration.

Demand-controlled mechanical exhaust systems shall be provided with at least one of the following controls:
1. A readily accessible occupant-controlled ON-OFF control.
2. An *automatic control* that does not impede occupant ON control.

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Progress and Accomplishments, cont'd

Market Impact: On-track to address critical market barriers and achieve goals

Awards/Recognition: None to date

Lessons Learned: No unanticipated barriers

Project Integration and Collaboration

Project Integration:

- Manufacturer Partner: Broan-NuTone is the largest U.S. manufacturer of residential range hoods
- Ventilation Codes and Standards: Newport has proposed more successful changes to ICC and ASHRAE 62.2 than any other group in last 5 years

Partners, Subcontractors, and Collaborators:

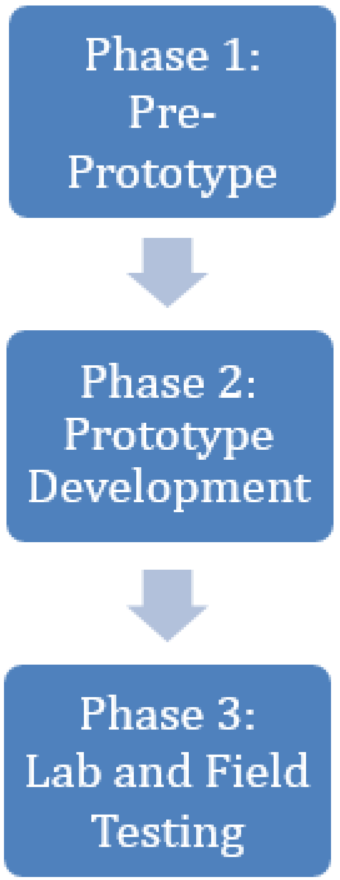
- Manufacturer: Broan-NuTone
- Collaborators: Lawrence Berkeley Lab – project review/comments

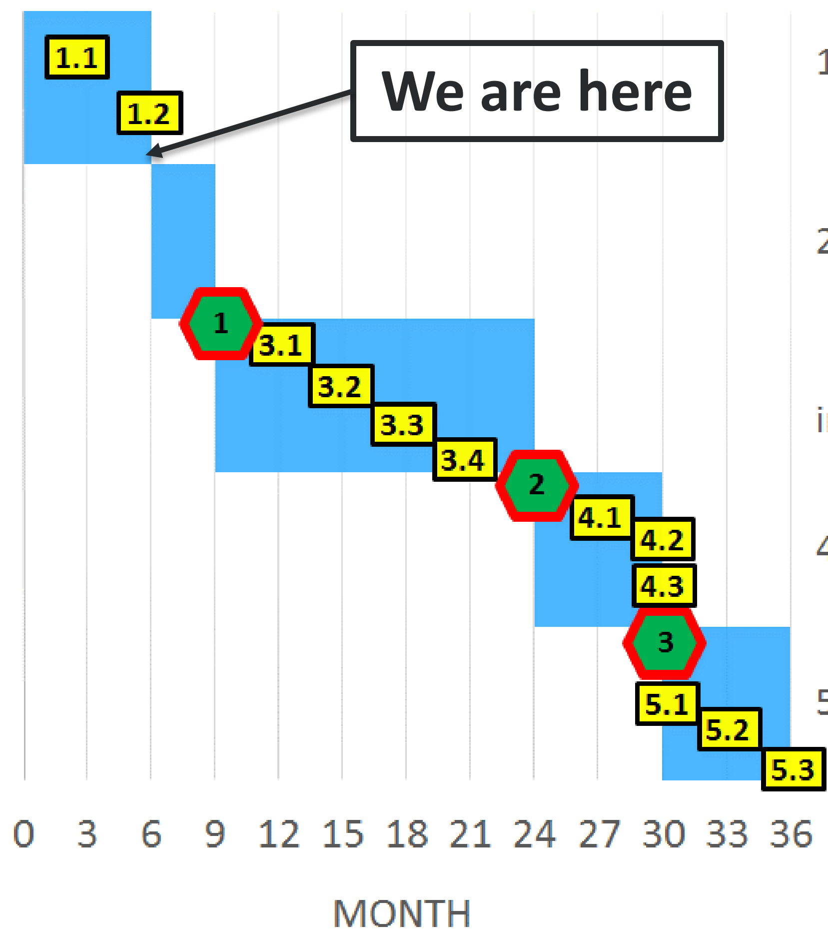
Parallel Efforts

- LBL: ASTM Capture Efficiency Test Method
- Home Ventilating Institute: Likely to develop CE certified rating program

Communications: None to date. ASHRAE meetings expected to be regular outlet

Next Steps and Future Plans





TASK

1. Identify criteria specifications for sensors and source sensors
2. Develop control logic
3. Develop prototypes with integrated sensors and controls
4. Conduct lab tests
5. Field-test prototype

REFERENCE SLIDES

Project Budget

Project Budget: $462,803
Variances: None
Cost to Date: $5,892 (~1% of total)
Additional Funding: None

Budget History					
FY 2017 (planned)		FY 2018 (planned)		FY 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$94,918	$47,617	$121,741	$88,296	$246,144	$77,907

Project Plan and Schedule

Period of performance: October 1, 2016 - September 30, 2019

Milestone	Description	Federal Year Due Date
M1.1	Develop sensor specification table with primary pollutants and key criteria	2017 Q2
M1.2	Source affordable sensors that also achieve high performance	2017 Q2
M1.3	Develop project management plan (PMP)	2017 Q2
GNG1	Develop logic models that addresses auto-operation and 62.2 compliance.	2017 Q3
M2.1	Develop lab test plan	2017 Q4
M3.1	Develop first prototype of sensor and control module	2018 Q1
M3.2	Develop second prototype of sensor and control module	2018 Q2
M3.3	Develop a first-generation prototype with integrated sensors and controls	2018 Q3
M3.4	Develop a second-generation prototype with integrated sensors and controls	2018 Q4
GNG2	Test and verify the response of the second gen prototype to a typical cooking scenario.	2019 Q1
M4.1	Conduct lab tests for capture efficiency using the latest ASTM draft capture efficiency test	2019 Q2
M4.2	Conduct lab test for sound per HVI 915	2019 Q3
M4.3	Conduct lab test for auto operation with respect to pollution sensing and response	2019 Q3
M4.4	Develop field test plan, including human subjects review (HSR)	2019 Q2
M5.1	Conduct first field test and report on performance	2019 Q3
M5.2	Conduct second field test and report on performance	2019 Q4
M5.3	Conduct third field test and report on performance	2019 Q4
M5.4	Final technical report and case study	2020 Q1
M6.1, M6.4, M6.7	Attend Building America stakeholder, expert or program planning meeting	2017, 2018, 2019
M6.2, M6.5, M6.8	Participate in Building America technical peer review process (up to 3 annually)	TBD
M6.3, M6.6, M6.9	Present results in webinars and conferences (up to 2 annually)	2017, 2018, 2019
M6.10	Participate in BTO Peer Review	TBD

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Building America U.S. Department of Energy

Up Next…

UNIVERSITY OF MINNESOTA

Affordable Solid Panel “Perfect Wall” System

2017 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Pat Huelman, phuelman@umn.edu
University of Minnesota

Project Summary

Timeline:

Start Date: July 1, 2016 (New Project)

Planned End Date: June 30 2019

Key 2017 Milestones

- Milestone 3: Complete optimized plans and specs for 2 house designs; March '17
- Milestone 4: Select and train one builder to execute MonoPath system: March '17

Key Partners:

MonoPath	Unico
Twin Cities Habitat for Humanity	Huber Engineered Woods
Urban Homeworks	
Thrive	
Building Knowledge	

Budget:

Total Project $ to Date:

- DOE: $57,258
- Cost Share: $21,388

Total Project $:

- DOE: $897,860
- Cost Share: $232,578

Project Outcomes:

- Targeting Building America goals to demonstrate reduction of EUI by 60% in new homes by 2020.
- Validate design and construction of an affordable "Perfect Wall" moisture-managed building envelope system that will achieve ZERH specs.
- The whole house system is easily adaptable by affordable housing programs on a national basis through ease of construction and lower cost.

Purpose and Objectives

Problem Statement:

Adopting a fully-optimized, high-performance building envelope approach, such as the "perfect wall", requires overcoming significant builder resistance, installation challenges, and cost implications.

- This project addresses these challenges by working with multiple partners to build, compare, and measure the new system on numerous houses.
- The validation of this innovative wall system and delivery approach will demonstrate its fit with Residential Building Integration goals.

Target Market and Audience:

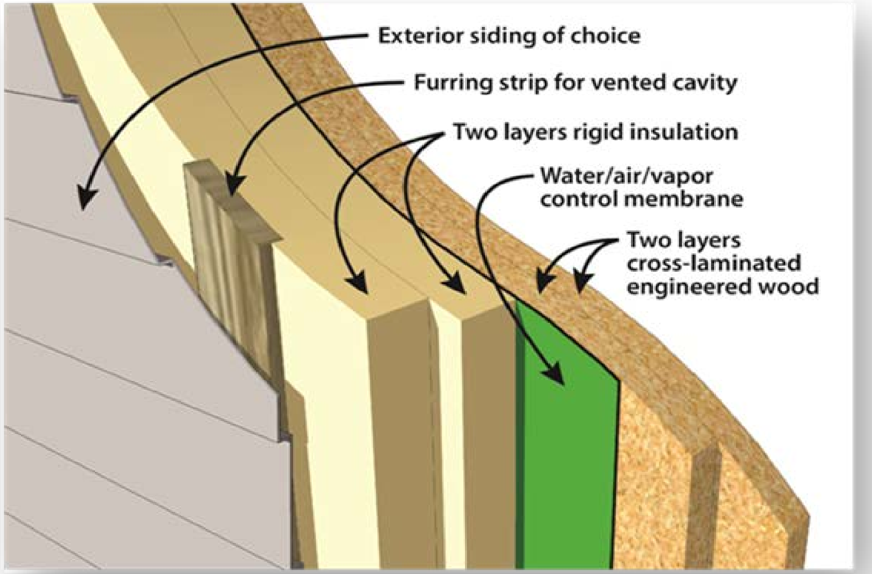
The affordable housing market (single and multiple family) is generally 10% of the total new homes built. The recent housing crisis left hundreds of cities with thousands of vacant lots.

- This project will present these entities with high-performance houses built stronger, faster, better, at a lower cost.
- These homes are sold at market rate with subsidy to make them affordable. This factor takes the homes out of the speculative market and into a "programmed sale" market.

Purpose and Objectives

Impact of Project:

A better way to build high-performance at a lower cost. Following the RBI Logic Model of market adoption acceleration, this building process delivers improved quality control with less-skilled labor to facilitate market acceptance.



- Build 23 houses in two locations to test, measure, and validate performance, cost, constructability,, and market acceptance.
- Train 2 to 4 builders to construct homes that will demonstrate a business model and market viability that can help reach the BTO MYPP RBI goals for whole house solutions and Zero Energy Ready Homes at scale.
- Since the MonoPath building system works in all climate zones, this approach can be readily moved into other national affordable housing markets (e.g. Habitat for Humanity, Neighbor Works), which follows and supports the RBI Program Logic Model.
- The City of Minneapolis is currently developing a model to build more efficiently on a large number of City owned lots. This method could work in any city, producing thousands of affordable homes, and be deployed after the grant to many cities (e.g., Chicago, St. Louis, Oklahoma City, Detroit).

Approach

Approach: Build 23 real-world houses through the existing affordable housing industry processes.

- Test, evaluate, and train to produce and replicate two designs and multiple houses.
- Validate the innovative building structure and delivery process through demonstration, verification, and comparative analysis.

Key Issues: Builders aren't adopting an optimized "perfect envelope" approach due to perceived complexity and cost. They resist giving up "stick" building which keeps them from achieving more effective thermal and moisture management.

Distinctive Characteristics: Three critical aspects for "perfect homes":

- Control layers must go outside of structure.
- Studs framing is problematic; structural engineered panels are easier and lower cost.
- Single envelope contractor ensures QA/QC and reduced cost.

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Progress and Accomplishments

Accomplishments: We are a new project and are currently ahead of our milestone timeline. We already have 2 builders committed and 2 house designs completed.

Market Impact: Building for this project will start in Spring ’17. However, there were 11 prototypical houses built prior to this project. Using that knowledge base, there is confidence that proceeding was warranted. All of the houses sold quickly in the urban neighborhoods. Builders, contractors, inspectors understand the system. Our partners will build most houses this season with a few in Spring ‘18.

- Market impact efforts include educating local and national “affordable housing” groups about the house along with its building and delivery system.
- We will measure performance, constructability, cost, and market delivery.
- We will develop protocols for training, detailed cost analysis, and energy as soon as we have complete the comparative (stud vs. panels) analysis.

Lessons Learned: It is difficult to change the building industry perception of the house as a composite of many layers, parts, and contractors. The new system must be presented for instruction and deployment with this in mind.

Project Integration and Collaboration

Project Integration: Field work by the P.I., project manager, 5 staff, and 3 project coordinators. The staff (project management team) meets twice per month, and we meet monthly with our building/developers. The staff develops the timeline and division of work, and then works individually with our builder/developer partners.

Partners, Subcontractors, and Collaborators:

Field Partners:

- ***2 non-profit builder/dev***
  - Habitat for Humanity
  - Urban Homeworks
- ***2 for-profit builders***
  - Morrissey Builders
  - New Look
- ***1 for-profit developer***
  - Thrive (Denver)

Industry Partners:

MonoPath, LLC provides design, engineering, training, and building process expertise for MonoPath houses.

Building Knowledge, Inc. is a rater and trainer for ZERH.

Huber Engineered Woods manufactures panels and provides expert advice for their products.

Unico: Advises with HVAC issues.

Communications: Presented our project formally to a national training for affordable housing builders affiliated with Neighbor Works. We have presented to various housing groups with the City of Minneapolis, including council members and planning department.

Next Steps and Future Plans

Next Steps:
- Fully execute our current project plan.
- Provide support for builder training and system integration.
- Implement our test plan for performance, constructability, costs.
- Conduct an analysis on market delivery and acceptance.

Future Plans:
- Expand this technology and delivery system model to a wider base of affordable housing developers and/or single enclosure contractors in our current markets.
- Continue our conversations with national affordable housing networks that can provide entry to other locales that have a critical need for high-performance, affordable housing.
- Explore opportunities to develop an HVAC+DHW approach and delivery systems that can complement this enclosure system.

Project Budget

Project Budget: This new project started on July 1, 2016 and has a Total Cost of $1,130,439 ($897,860 DOE Share) over 3 years. The funding level is larger for front-end design and construction oversight and is smaller for the monitoring and analysis in the final year. We have successfully completed project set up, Test Plan, and Project Management Plan. We have started partner engagement and design.
Variances: Funding levels in Q1 and Q2 were slightly less than budgeted.
Cost to Date: $78,646 ($57,258 DOE Share); 15% of BP1 and 7% of Total Project.
Additional Funding: Nothing beyond cost share at this time.

Budget History					
FY 2016 (past)		FY 2017 (current)		FY 2018 – FY 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$ 0	$ 0	$399,777	$104,704	$498,084	$127,782

Project Plan and Schedule

Project Timeline:

Start Date: July 1, 2016

End Date: June 30, 2019

Phase		Milestone Schedule For our project, the quarters start on July 1, 2016 which is our fiscal year. So Q1 is July 1 to Sept 30. Sorry for any confusion.		FY2017				FY2018				FY2019			
				Q1 (Jul-Sep)	Q2 (Oct-Dec)	Q3 Jan-Mar)	Q4 (Apr-Jun)	Q1 (Jul-Sep)	Q2 (Oct-Dec)	Q3 Jan-Mar)	Q4 (Apr-Jun)	Q1 (Jul-Sep)	Q2 (Oct-Dec)	Q3 Jan-Mar)	Q4 (Apr-Jun)
		Past Work													
1	**M**	Complete the Project Management Plan.	M6		◆										
1	**M**	Complete the Research Test Plan.	M6		◆										
		Current Future Work													
End Budget Period 1		Go/No-Go 1: 1) Complete construction documents for each of two single-family house designs, with modeled OSB moisture levels verified to not exceed 18% and energy use verified to meet or exceed ZERH targets. 2) At least one builder trained to execute MonoPath house construction.	M12				◆								
2	**M**	Complete optimized sets of construction documents for one multi-family (3-plex) design, including energy and moisture analysis.	M15					◆							
2	**M**	Complete optimized sets of construction documents for each revised design, and complete energy and moisture analysis for revised designs as needed.	M15					◆							
	M	At least one additional builder trained to execute MonoPath house construction.	M15					◆							
2	**M**	Construction process documentation per protocol developed in Task 4 complete for all houses completed to date.	M15					◆							
2	**M**	Energy monitoring protocol deployed in all complete houses, with	M18						◆						
2	**M**	Enclosure and system commissioning per protocol developed in Task 5.0 complete and documented for all complete houses. HERS ratings and ZERH certification complete for all complete houses.	M18						◆						
2	**M**	Data required for comparative analysis is secured in a consistent format for all houses at a level appropriate for their level of completion.	M21						◆						
End Budget Period 2		Go/No-Go 2: 1) One additional builder trained to build SEP-ETMMS houses. 2) Minimum of four houses either complete or under construction. 3) All measurement and monitoring protocols are deployed in houses in a manner consistent with their level of completion.	M24								◆				
3	**M**	Construction process documentation per protocol developed in Task 4 complete for all houses completed to date.	M27									◆			
3	**M**	Energy monitoring protocol deployed in all complete houses, with data collection verified.	M30										◆		
3	**M**	Enclosure and system commissioning per protocol developed in Task 5.0 complete and documented for all complete houses. HERS ratings and ZERH certification complete for all complete houses.	M30										◆		
3	**M**	Comparative analysis studies complete and documented.	M30										◆		
3	**M**	Complete the final report and documentation.	M30										◆		

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Up Next…

Southface

Performance-Based IAQ and Optimized Ventilation

2017 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Sydney G. Roberts, Ph.D.
sroberts@southface.org
Southface Energy Institute

Project Summary

Timeline:

Start date: October 1, 2016

Planned end date: September 30, 2018

Key Milestones

1. Sensors tested in lab chamber; 06/31/2017
2. Monitoring packages deployed in homes; 08/31/2017
3. Humidity control ERV installed in new construction homes; 08/31/2017

Budget:

Total Project $ to Date:

- DOE: $42,794
- Cost Share: $14,325

Total Project $:

- DOE: $661,417
- Cost Share: $214,134

Key Partners:

UL Environment	Beazer Homes
University of Illinois	Kerley Family Homes
LBNL	Greater Atl HBA
Venmar	WrightSoft
Senseware	LG Squared

Project Outcome: *Enable adoption of high performance home technologies by proving maintained/improved IAQ*

- Establish performance metrics for low-cost IAQ sensors.
- Enable smart, connected technologies which optimize IAQ, energy and comfort.
- Improve valuation of IAQ technologies by measuring impacts pollutant levels and energy consumption.

Purpose and Objectives

Problem Statement: High performance homes are at increased risk of IAQ, humidity and comfort challenges. In order to improve indoor air quality (IAQ) in homes, while also ensuring comfort and reducing energy consumption, ventilation manufacturers should develop technologies which respond to pollutant levels and optimize fresh air exchange. Establishing performance requirements for IAQ pollutant sensors is essential to acceptance of such approaches.

Target Market and Audience: Sensor/monitor manufactures, standards development organizations and home builders. Fifty percent (50%) adoption of the humidity control ERV in new construction in the South will save 340,000 MMBtu/yr over central fan integrated systems.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Purpose and Objectives

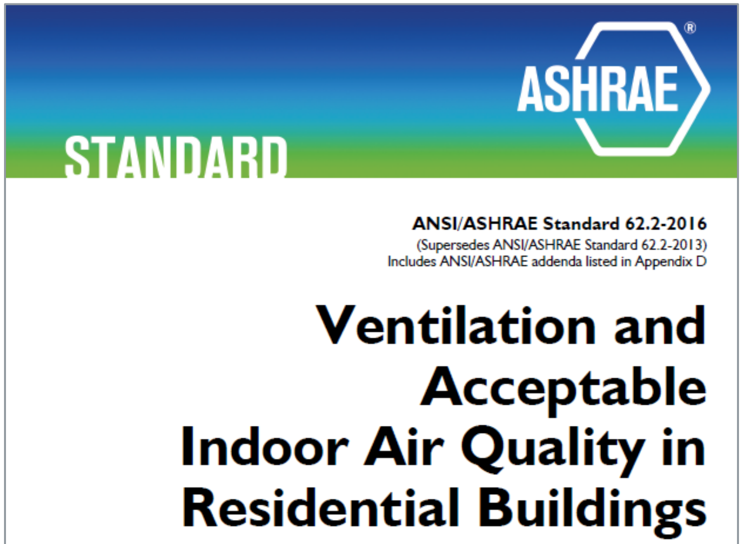
Impact of Project: *Success will result in improved IAQ at lower total cost of ownership*. Outputs will enable sensor, monitor and equipment manufacturers to coordinate with standards development and program administrators to transition from prescriptive to performance metrics. Project will also demonstrate impact of humidity-control ERV in hot-humid climate zone.

Program Goals:

a. Approach for establishing sensor performance requirements.
b. IAQ pollutants benchmarked in new and existing homes using low-cost sensors.
c. Proven and documented innovative ERV overcoming builders’ barriers to ventilation and increased air tightness in the South.
d. Pathway to allowing a performance-based (smart) ventilation standard.

- ➢ Reduce EUI by decreasing energy consumption for HVAC
- ➢ Integrated, systems approach to enclosure air tightness, IAQ, and comfort systems

What Is “Good” Air Quality?


STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.2-2016
(Supersedes ANSI/ASHRAE Standard 62.2-2013)
Includes ANSI/ASHRAE addenda listed in Appendix D

Ventilation and Acceptable Indoor Air Quality in Residential Buildings

See Appendix D for approval d
National Standards Institute.

This Standard is under continu
Committee has established a d
timely, documented, consensu
instructions, and deadlines ma
form from the Senior Manag
ASHRAE website (www.ashra
E-mail: orders@ashrae.org. F
orders in US and Canada). For

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Approach

Approach:

- Establish performance requirements for IAQ sensors with industry/standards engagement
- Benchmark pollutants in new and existing homes using low-cost sensors/monitors
- Demonstrate, test and validate energy saving ventilation technology in test homes

Key Issues:

- Prescriptive vs. Performance
  - May be over ventilating – wasting energy

Distinctive Characteristics:

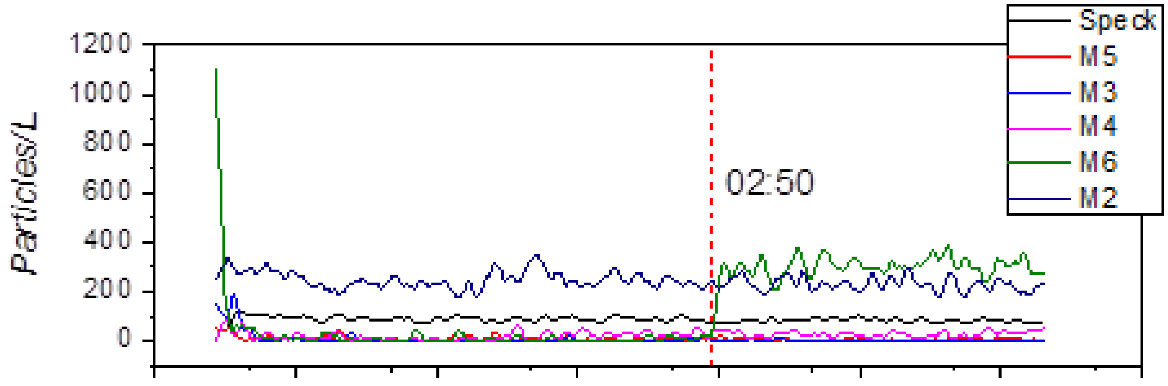
- Define Key Performance Indicators
- Innovative ERV
- Address market uncertainty around sensors and ventilation

Progress and Accomplishments

Accomplishments: Engaged with market-leading partners, including Beazer Homes, Venmar, WrightSoft and Senseware. Also leveraging intradepartmental relationships with LBNL and EPA.

Market Impact: Demonstrated $PM_{2.5}$ sensor/monitor performances in UL Environment chamber.

Lessons Learned: Software challenges for modeling ERV extend beyond humidity control to include HVAC design (Manual J), and are an issue for all E/HRV's.



Southface-built $PM_{2.5}$ and Speck monitors in clean test chamber

Project Integration and Collaboration

Project Integration: Collaborate with LBNL on IAQ Score development/pilot; sub-contractor University of Illinois is member of GTI Building America team; NREL on innovative modeling approach.

Partners, Subcontractors, and Collaborators: UL Environment, University of Illinois, Venmar (Broan/NuTone), Beazer Homes, Kerley Family Homes, LBNL, WrightSoft, Senseware, Greater Atlanta Home Builders Association, LG Squared.

Communications: RESNET and Home Performance Coalition National Conferences.

Next Steps and Future Plans

Next Steps and Future Plans:

Establish IAQ Sensor requirements

Assemble and test sensor package

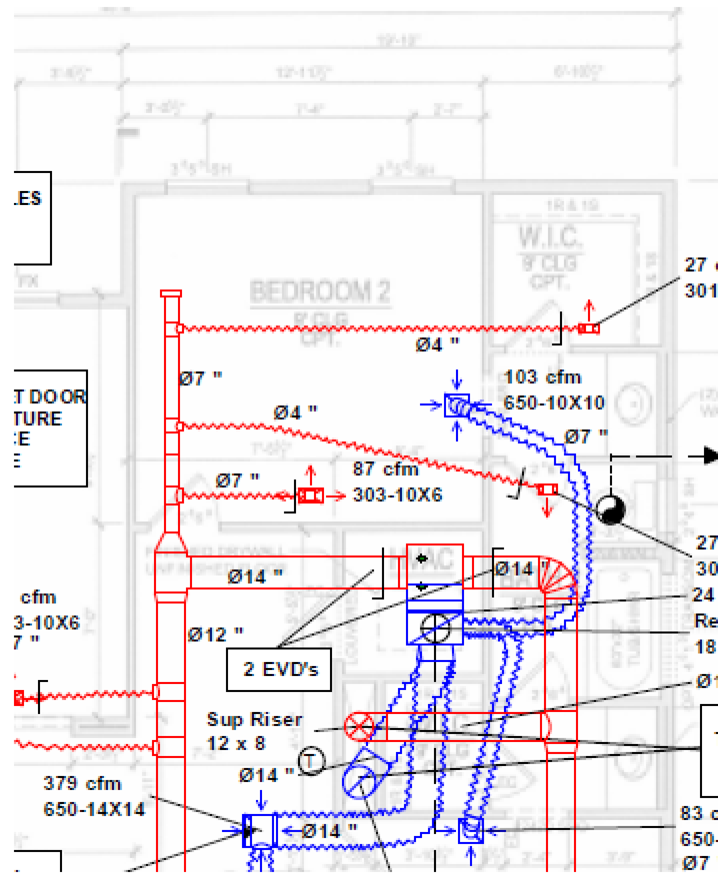
New Construction Test Homes: measure impact of ERV vs. CFIS and pilot IAQ Score

- 2 Homes in Charleston
- 2 Homes in Atlanta

Existing Home Test Homes: measure impact of energy upgrade

- Collaboration with GTI Team

Potential for Future Exploration of Measurement-Based Scoring/Certification



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REFERENCE SLIDES

Project Budget

Project Budget: DOE: $661,417; Cost Share: $214,134
Variances: Finalizing contracts with UL Environment and University of Illinois.
Cost to Date: $42,794 has been invoiced to date. Southface invoices DOE quarterly.
Additional Funding: Southface is grateful for the contributions of LBNL, NREL and other Federal partners.

Budget History					
10/01/2016 – FY 2016 (past)		FY 2017 (current)		FY 2018 – 09/31/2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$42,794	$14,325	$363,438	$119,509	$255,185	$80,300

Project Plan and Schedule

Timeline 10/01/2016 – 09/31/2018

TASKS TO BE PERFORMED - PHASE 1		Budget Period 1												Budget Period 2												
TASK		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Milestones
1.0	**develop IAQ Assessment Protocol/Sensor Package**	Q1			Q2			Q3			Q4			Q5			Q6			Q7			Q8			
	1.1 Conduct literature review	–	–	–	–	→																				
	1.2 Initial sensor perfromance requirements developed	–	–	–	–	→																				
	1.3 Monitoring packages assembled and calibrated	–	–	–	–	→																				
	1.4 Monitoring packages tested at Southface Eco Office	–	–	–	–	→																				
																										1.1 Monitoring packages assembled and programmed
																										1.2 Working units calibrated in controlled environment
																										1.3 Working units tested on Southface campus
2.0	**IAQ Benchmarking**																									
	2.1 Submit test plan																									
	2.2 Select test homes monitoring packages																									
	2.3 Recruit test homes																									
	2.4 Meassure test home building performance parameters							–	–	–	–	→														
	2.5 Deploy and maintain sensors							–	–	–	–	→														
	2.6 Monitor, retrieve, and redeploy sensors as needed							–	–	–	–	→														
	2.7 Process and analyze IAQ and performance data							–	–	–	–	→														
																										2.1 Monitoring packages deployed in first cohort
																										2.2 Monitoring packages deployed in second cohort
3.0	**Assess "Smart" Ventilation on IAQ and Energy**																									
	3.1 Recruit at least 2 test homes	–	–	–	–	–	–	–	–	–	–	→														
	3.2 Partner with builders on HVAC systemdesign	–	–	–	–	–	–	–	–	–	–	→														
	Go/No-Go 1.1 MOU signed with 2 homebuilders																									

Project Plan and Schedule, continued

TASKS TO BE PERFORMED - PHASE 1		Budget Period 1												Budget Period 2												
TASK		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Milestones
4.0	**Technical and Project Management**																									
	4.1 Ongoing project management and reporting	–	–	–	–	–	–	–	–	–	–	→														
	4.2 Test plan development																									
																										4.1 PMP accepted by DOE
5.0	**Project Management and Reporting**																									
	5.1 Attend Building America meeting	–	–	–	–	–	–	–	–	–	–	→														
	5.2 Participate in BA peer review	–	–	–	–	–	–	–	–	–	–	→														
	5.3 Present results of BA projects (webinars/conferences)	–	–	–	–	–	–	–	–	–	–	→														
	5.4 Participate in BTO Peer Review	–	–	–	–	–	–	–	–	–	–	→														
	Go/No-Go Decision Points																									
	Go/No-Go 1.2 Twenty sensor packages deployed																									
6.0	**IAQ Benchmarking**																									
	6.1 Recruit additional homes if necessary													–	–	–	–	–	–	–	–	–	–	→		
	6.2 Measure test home building parameters													–	–	–	–	–	–	–	–	–	–	→		
	6.3 Deploy and maintain monitoring packages													–	–	–	–	–	–	–	–	–	–	→		
	6.4 Monitor, retrieve, and redeploy packages as needed													–	–	–	–	–	–	–	–	–	–	→		
	6.5 Process and analyze IAQ and performance data													–	–	–	–	–	–	–	–	–	–	→		
																										6.1 Data from monitored existing homes analyzed
																										6.2 Data from monitored new construction homes analyzed

Project Plan and Schedule, continued

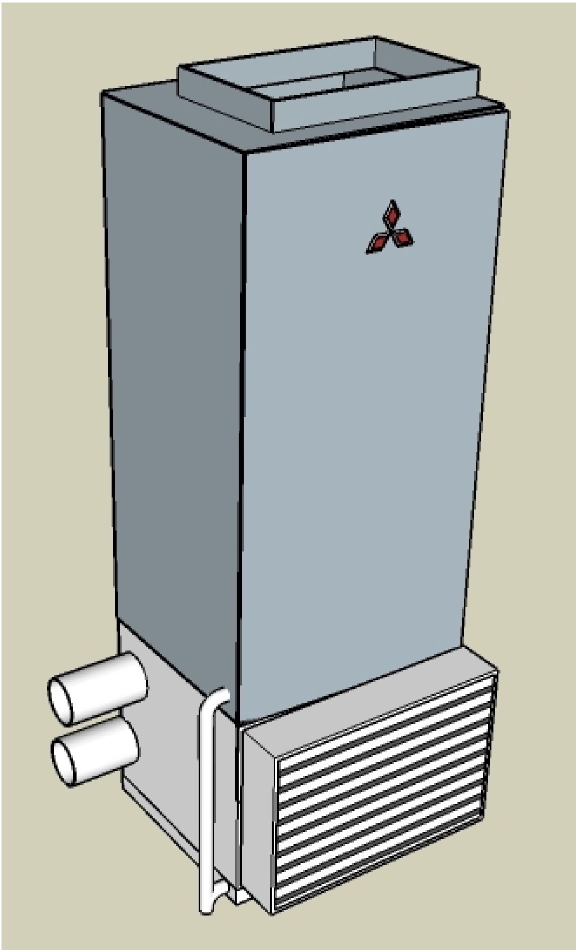
TASKS TO BE PERFORMED - PHASE 1		Budget Period 1												Budget Period 2												
TASK		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Milestones
7.0	**Assess "Smart" Ventilation on IAQ and Energy**																									
	7.1 Recruit additional homes if necessary													–	–	–	–	–	–	–	–	–	–	→	■	
	7.2 Measure test home building parameters													–	–	→	■									
	7.3 Deteremine package needed for IAQ measurements													■												
	7.4 Develop test plan for ERV performance measurement													–	→	■										
	7.5 Deploy monitoring in test homes													–	–	→	■									
	7.6 Request 12-month utility data for test homes													–	–	–	–	–	–	–	–	–	–	→	■	
	7.7 Monitor, retrieve, and redeploy monitoring packages													–	–	–	–	–	–	–	–	–	–	→	■	
	7.8 Analyze IAQ and energy metrics, and compare data													–	–	–	–	–	–	–	–	–	–	→	■	
																									■	7.1 Determine IAQ impact of "smart" ventilation strategies
8.0	**Technical and Project Management**																									
	8.1 Ongoing project management and reporting													–	–	–	–	–	–	–	–	–	–	→	■	
9.0	**Building America Program Support**																									
	9.1 Attend Building America meeting													–	–	–	–	–	–	–	–	–	–	→	■	
	9.2 Participate in Building America peer review													–	–	–	–	–	–	–	–	–	–	→	■	
	9.3 Present results in technical webinars and conferences													–	–	–	–	–	–	–	–	–	–	→	■	
	9.4 Participate in BTO Peer Review													–	–	–	–	–	–	–	–	–	–	→	■	

Up Next…

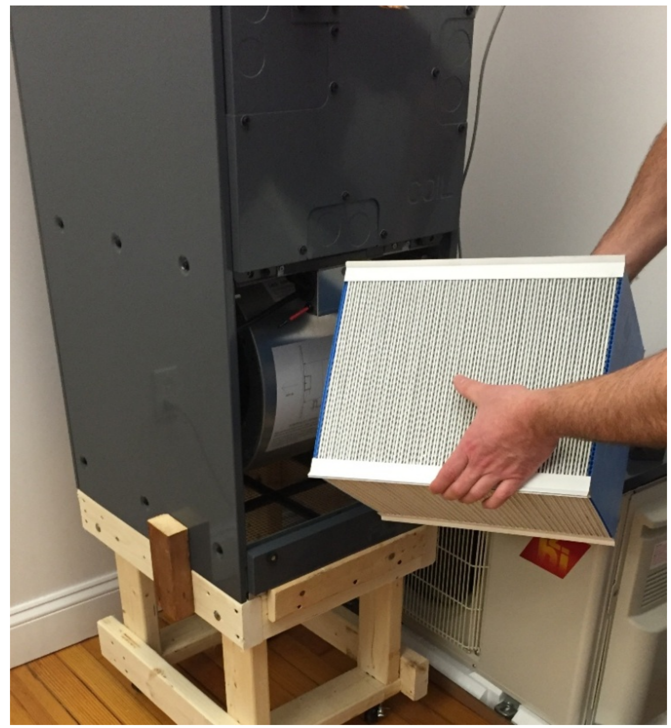
Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

Ventilation Integrated Comfort System (VICS)

2017 Building Technologies Office Peer Review



Integrating energy recovery ventilation with efficient heating and cooling.



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Robb Aldrich, raldrich@swinter.com
Steven Winter Associates, Inc.

Project Summary

Timeline:

Start date: August 2016
Planned end date: July 2019

Key Milestones

1. Completion of fully functional prototype for testing in unoccupied space
   Jan. 2018 (GO/NO-GO)
2. Installation of prototype in occupied home
   Aug. 2018

Budget:

Total Project $ to Date (1/31/17):

- DOE: $107,569
- Cost Share: $35,327

Total Project $:

- DOE: $902,438
- Cost Share: $231,246

Key Partners:

Mitsubishi Electric	Several builders & developers of high-performance homes.
dPoint Technologies	

Project Outcome:

- Enable **heating, cooling,** and whole-building **ventilation** in a single system.
- Address **IAQ concerns** in air-tight homes achieving 40%-60% savings
- Help achieve the 40%-60% savings by reducing thermal **ventilation loads**
- Reducing **cost** by 30-50% over separate HRV/ERVs

Purpose and Objectives

Problem Statement: (MYPP) BA is solving challenges related to:

- "optimal comfort systems for low-load homes"
- "optimal ventilation systems and [IAQ] solutions for low-load homes"
- "solutions for homes with a high latent load (high moisture)"

Demonstrate & integrate energy efficient technologies & practices in representative homes → Competitive **R&D funding focused on demo, testing & validation by Building America** & national lab researchers in field homes → **Space conditioning**, water heating **& IAQ Building America upgrade packages & techniques for existing & new homes across climates**

Balanced, heat recovery ventilation is becoming a more obvious choice in very tight, efficient homes. It remains very expensive and can be challenging to integrate effectively.

How can we efficiently, practically, and affordably combine heating, cooling, and whole-building ventilation?

Target Market and Audience:

- Homes with design loads < 10-12 kBtu/h (multiple systems for higher loads)
- Thousands of SF homes (ZERH, Passive House, etc.) and growing
- MOST new MF apartments, ~350,000 starts in 2016 (FreddieMac)

Purpose and Objectives (cont'd)

Impact of Project:

Final Product: Fully functional prototype evaluated in occupied home

- Projected energy savings compared to exhaust only (65 CFM)
  - ~**500 kWh/y** in DC, ~**1,000 kWh/y** in Chicago (efficient heat pump)
  - **0-10%** reductions towards **40-60%** goals, but addresses **IAQ** & moisture concerns.
- Cost of adding heat/energy recovery ventilation ***30-50% less*** than with a separate, ducted HRV/ERV.
- Improved IAQ (balanced, filtered, distributed OA), improved heat pump efficiency and better humidity control.

After the Project:

Last Year of Project	1-2 years after project	3-5 years after project
• Agreement with manufacturer(s)	• Pre-production prototypes, testing & certification (UL, AHRI, HVI, etc.)	• Manufacture and distribution, 5–10k/y

Approach

New homes that achieve 60% energy savings have:

- Greater need for balanced, distributed ventilation
- Very small design H/C loads
  - ➢ They need much smaller H/C systems
- In general, H/C manufacturers have not responded to this demand
- Exception: efficient, variable-speed ASHPs
- New Mitsubishi product: 1-ton, full static AHU.

Opportunity: With smaller heating/cooling equipment, air flow rates needed for H/C are *closer* to those needed for whole-building ventilation.

Key Issues: Many current H/ERV installations have poor integration, inconsistent controls, questionable delivery of outdoor air, and/or have high energy use. And they are *expensive*.

Distinctive Characteristics: Integrated system. One duct system, little extra space, smart controls, lower cost.

Progress and Accomplishments

Accomplishments: Active 6 months. On or ahead of schedule.

- Market Assessment Milestone (November 2016)
- Prototype Design/Performance Specification Milestone (February 2017)
- Construction of first prototype under way.

Market Impact: Interviewed eight east-coast builders/developers (built hundreds of efficient homes in 2016).

Have you used ERVs/HRVs?

- Not standard for any, but most had some experience
- "**Nightmare**" used by three builders
- Most suspect codes/programs will require in the future

Half of the builders were very interested in VICS concept. "When can we try one?"

Appeal: Integrated system, low capacity, lower cost, better humidity control.

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Builder/Developer Interviews

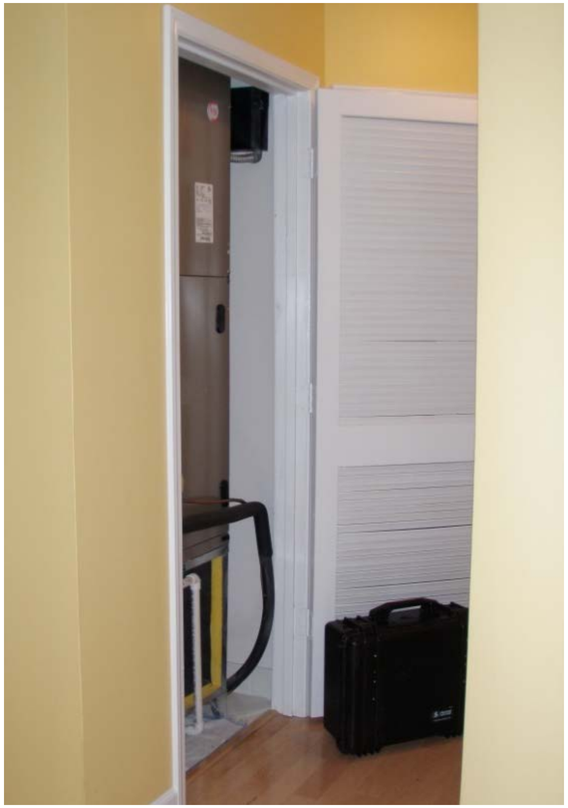
What barriers/challenges prevent you from using balanced, heat recovery ventilation?

- **COST**. Uniformly largest barrier. ~$3,000/home installed.

Other barriers/challenges:

- No/questionable energy benefits
- Space constraints
- Wall penetrations
- Maintenance
- Reliability
- Not required by codes/programs

Lessons Learned: Size is a critical design factor. More challenging to achieve pressure/flow characteristics in a small package.



Project Integration and Collaboration

Project Integration: R&D - close communication with manufacturing partners. Weekly (at least) communication with Mitsubishi engineers.

Partners, Subcontractors, and Collaborators:

- **Mitsubishi** – extremely interested, supportive, and responsive. Provided equipment, controls support, design/integration advice, etc.
- **dPoint** – visited our office, support re. configuration, flow, pressure dynamics, etc.
- **Builders/developers** – interviews, some eager to try a prototype

Communications: Limited outreach; still in R&D. Several inquiries based only on DOE press release alone. "When can we get one?" Significant interest. Working on provisional patent in parallel.

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Next Steps and Future Plans

Next Steps and Future Plans:

- Construction of first prototype under way. Benchtop testing Spring-Summer 2017.

- **GO/NO-GO** decision before installation of second prototype in unoccupied building during Winter 2017-18.

- Installation and testing of third prototype in occupied home mid 2018.

Beyond Current DOE Project

- Currently working on provisional patent.
- With initial prototype results, talk with manufacturers late 2017-2018.
- Explore integration with wider range of heating/cooling equipment.

REFERENCE SLIDES

Project Budget

Project Budget: 3-year project divided into two 18-month Budget Periods , BP1 August 1, 2016 – January 31, 2018.

Variances: No significant variances to date. Supply costs are higher than initially proposed, but less than $5,000 variance.

Cost to Date: 26% of the Total Approved BP1 budget of $542,651. Cost Share contribution to date is 24.7%.

Additional Funding: None

Budget History					
Aug. 1, 2016 – FY 2016 (past)		FY 2017 (current)		FY 2018 – July 31, 2019 (FY 2019) (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$11,960	$6,702	$698,757	$175,000	$191,721	$49,544

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Project Plan and Schedule – Budget Period 1

Project Schedule		
Project Start: 8/1/2016		Completed Work
Projected End: 7/31/2019		Active Task (in progress work)
		Milestone/Deliverable (Originally Planned)
		Milestone/Deliverable (Actual)

Task	Q1 (Aug-Oct 2016)	Q2 (Nov 2016-Jan 2017)	Q3 (Feb-Apr 2017)	Q4 (May-Jul 2017)	Q5 (Aug-Oct 2017)	Q6 (Nov 2017-Jan 2018)	Q7 (Feb-Apr 2018)	Q8 (May-Jul 2018)	Q9 (Aug-Oct 2018)	Q10 (Nov 2018-Jan 2019)	Q11 (Feb-Apr 2019)	Q12 (May-Jul 2019)
Past Work												
Q1 Milestone: Project Management Plan												
Q1 Milestone: Test Plan												
Q2 Milestone: Market Assessment												
Current/Future Work												
Q3 Milestone: Design Specifications												
Q4 Milestone: Alpha Prototype - Interior Components												
Q5 Milestone: Sensor/Control Strategies												
Q5 Milestone: Prototype Benchtop Testing												
Q6 Milestone: Go/No-Go Decision for Successful Indoor Components of Prototype												
Q7 Milestone: Alpha Protytpe Completion (Operational with Outdoor Components)												

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Project Plan and Schedule – Budget Period 2

Project Schedule												
Project Start: 8/1/2016		Completed Work										
Projected End: 7/31/2019		Active Task (in progress work)										
		Milestone/Deliverable (Originally Planned)										
		Milestone/Deliverable (Actual)										
Task	Q1 (Aug-Oct 2016)	Q2 (Nov 2016-Jan 2017)	Q3 (Feb-Apr 2017)	Q4 (May-Jul 2017)	Q5 (Aug-Oct 2017)	Q6 (Nov 2017-Jan 2018)	Q7 (Feb-Apr 2018)	Q8 (May-Jul 2018)	Q9 (Aug-Oct 2018)	Q10 (Nov 2018-Jan 2019)	Q11 (Feb-Apr 2019)	Q12 (May-Jul 2019)
Current/Future Work												
Q7 Milestone: Alpha Protytpe Completion (Operational with Outdoor Components)												
Q9 Milestone: Alpha Prototype Performance Evaluation												
Q9 Milestone: Cost and Manufacturability Opportunities												
Q10 Milestone: Completion of Beta Prototype												
Q12 Milestone: Demonstration in Occupied Home Draft Technical Report												
Q12 Milestone: Demonstration in Occupied Home Final Technical Report												