High Performance Building Envelope Assemblies

2017 Building Technologies Office Peer Review

Enabling High Performance by Reducing Transition Risks

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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

Project Summary: Moisture Performance of High-R Walls

Timeline:

Start date: 08/01/2015

Planned end date: 7/31/2017

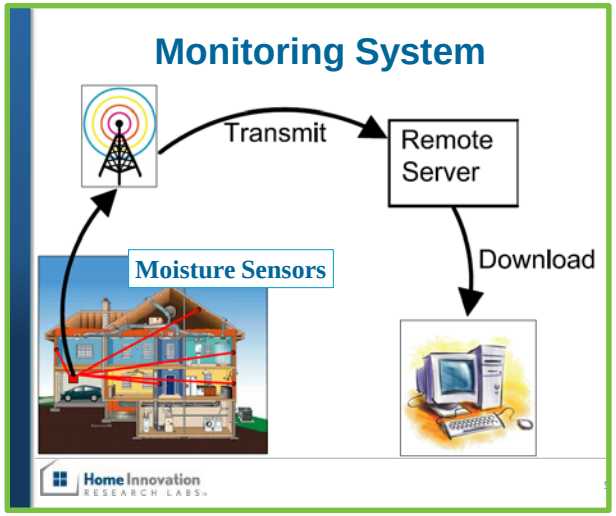
Key Milestones

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

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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:

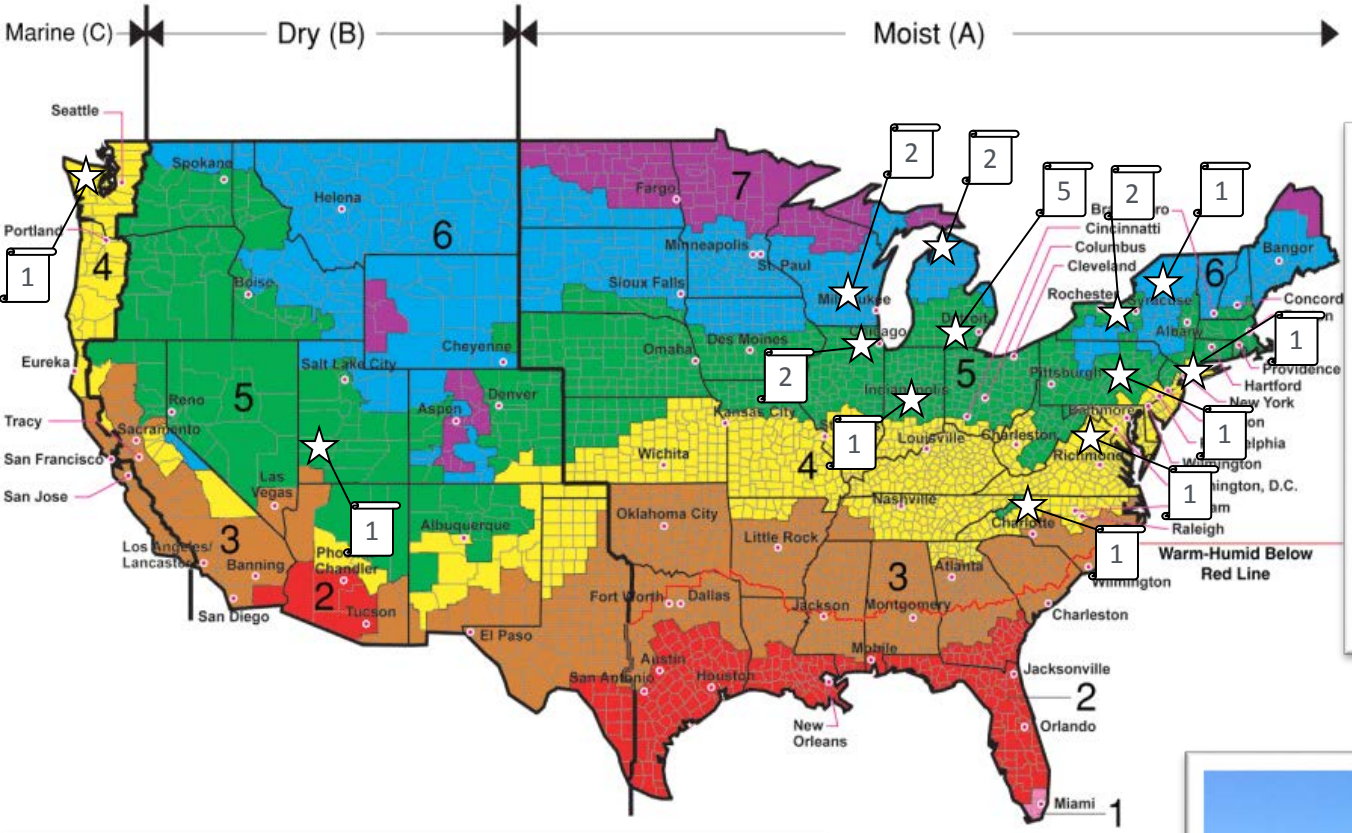
1) Over 100 inquiries from builders with interest to participate
2) A broad stakeholder group is engaged with the Advisory Group
3) 22 homes enrolled and instrumented
4) A draft standard method for field measurements has been developed
5) Blind-prediction WUFI simulations completed for future comparison

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.

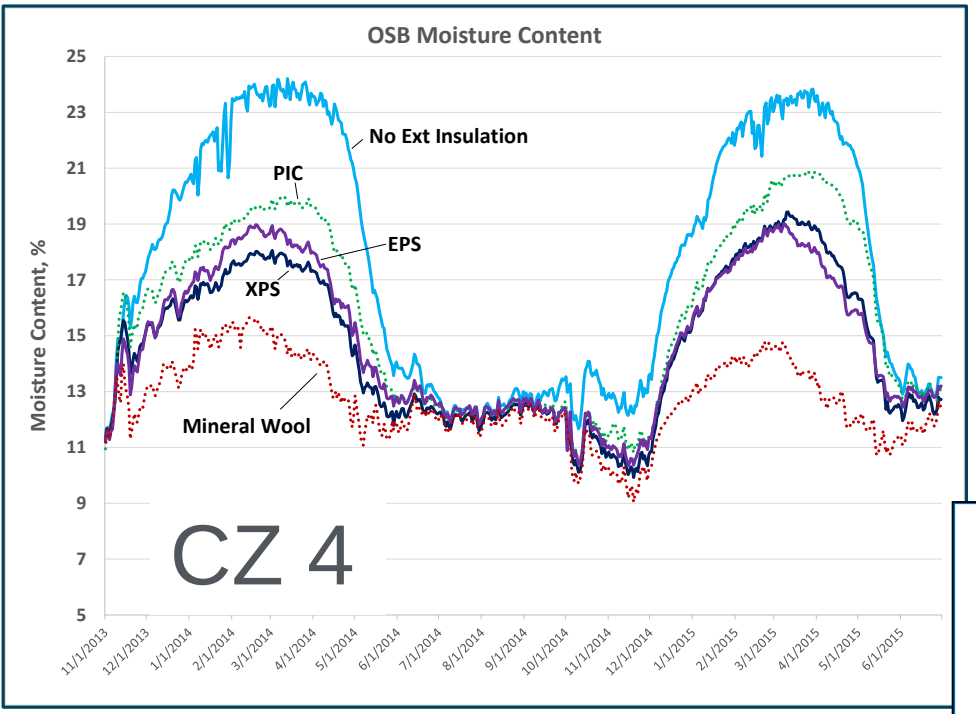
Instrumented Homes Map



North Slope, Northwest Arctic, Southeast Fairbanks

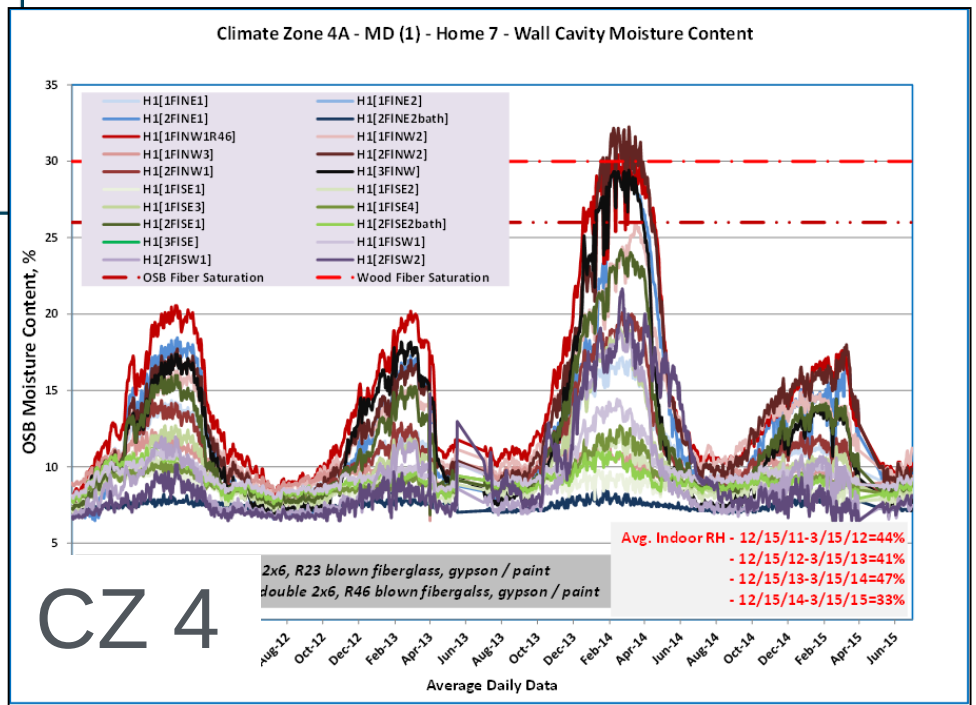
Precursor Data from Previous HI Studies

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:

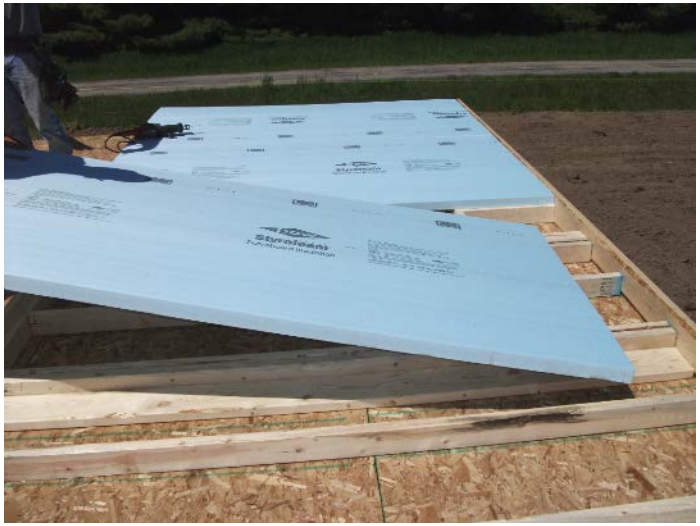
1) Improved level of confidence for practitioners using high-R wall solutions
2) Increased market penetration for high-R walls
3) Use of insulation in factory-built panelized walls

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

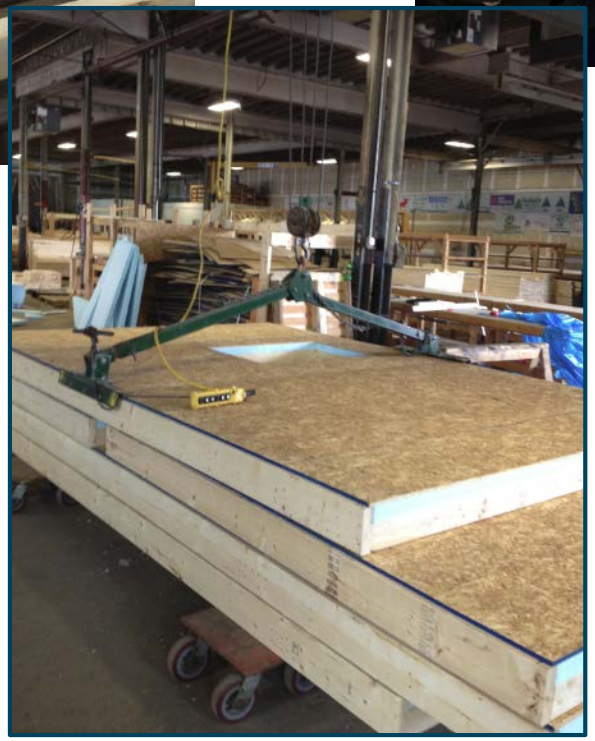


Standard OSB Exterior, Stud Cavity, Foam Interior

OSB is nailed over foam sheathing

Field Installation

Panelized Home (EP&B)



Structural Testing – Braced Walls / Shear Walls

Project Summary: Attic Retrofit Using Nailbase Panels

Timeline:

Start date: 08/01/2015

Planned end date: 7/31/2017

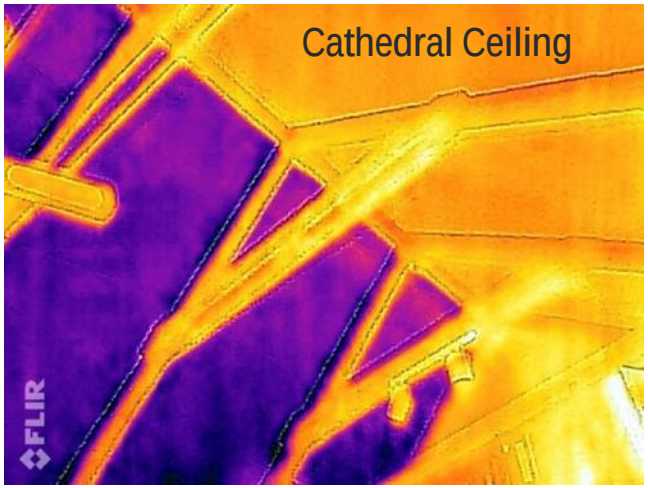
Key Milestones

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:

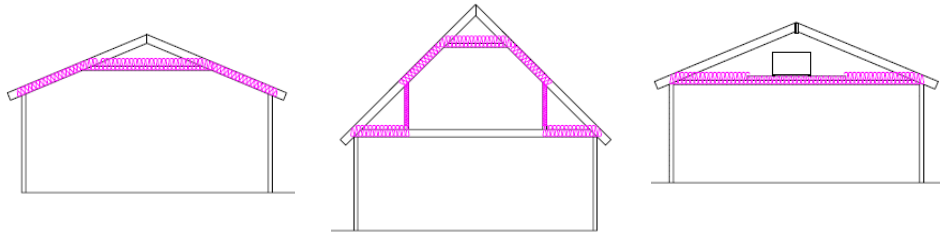
Structural Insulated Panel Association	American Chemistry Council
GAF	DuPont
Dow; Owens Corning	Forest Products Laboratory

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



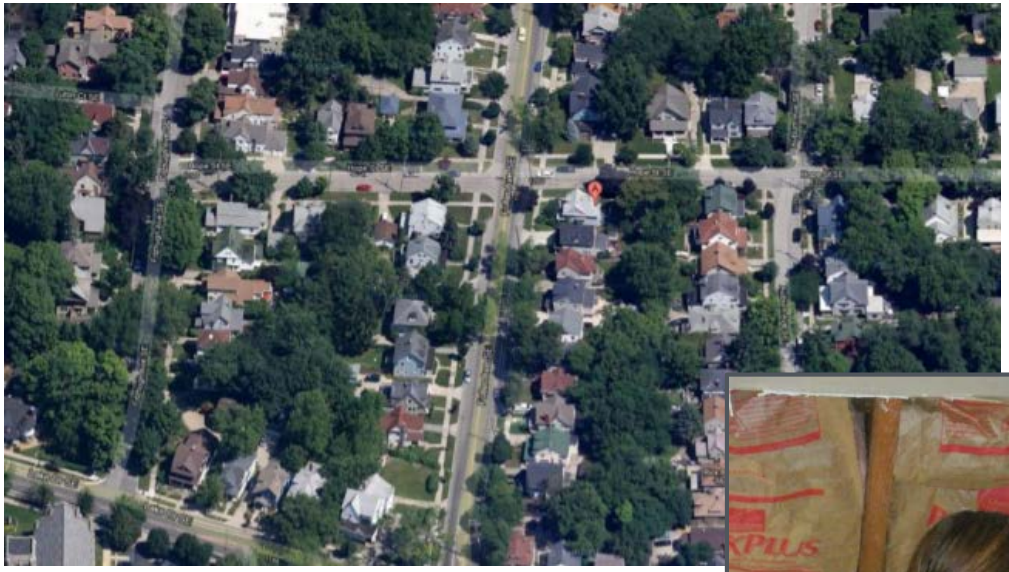
Target Market and Audience:
Remodeling and roofing contractors in all climate zones across the U.S.

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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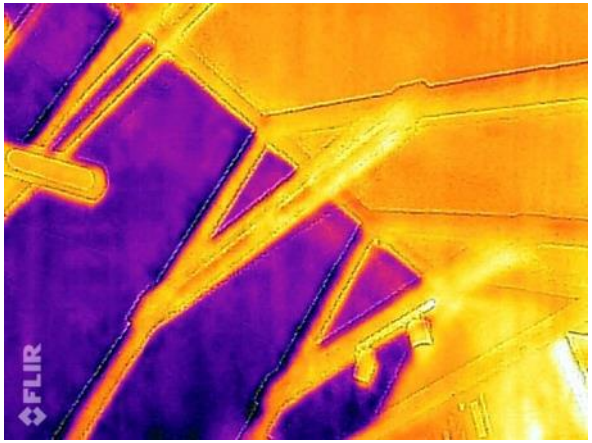
Observational Research

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

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

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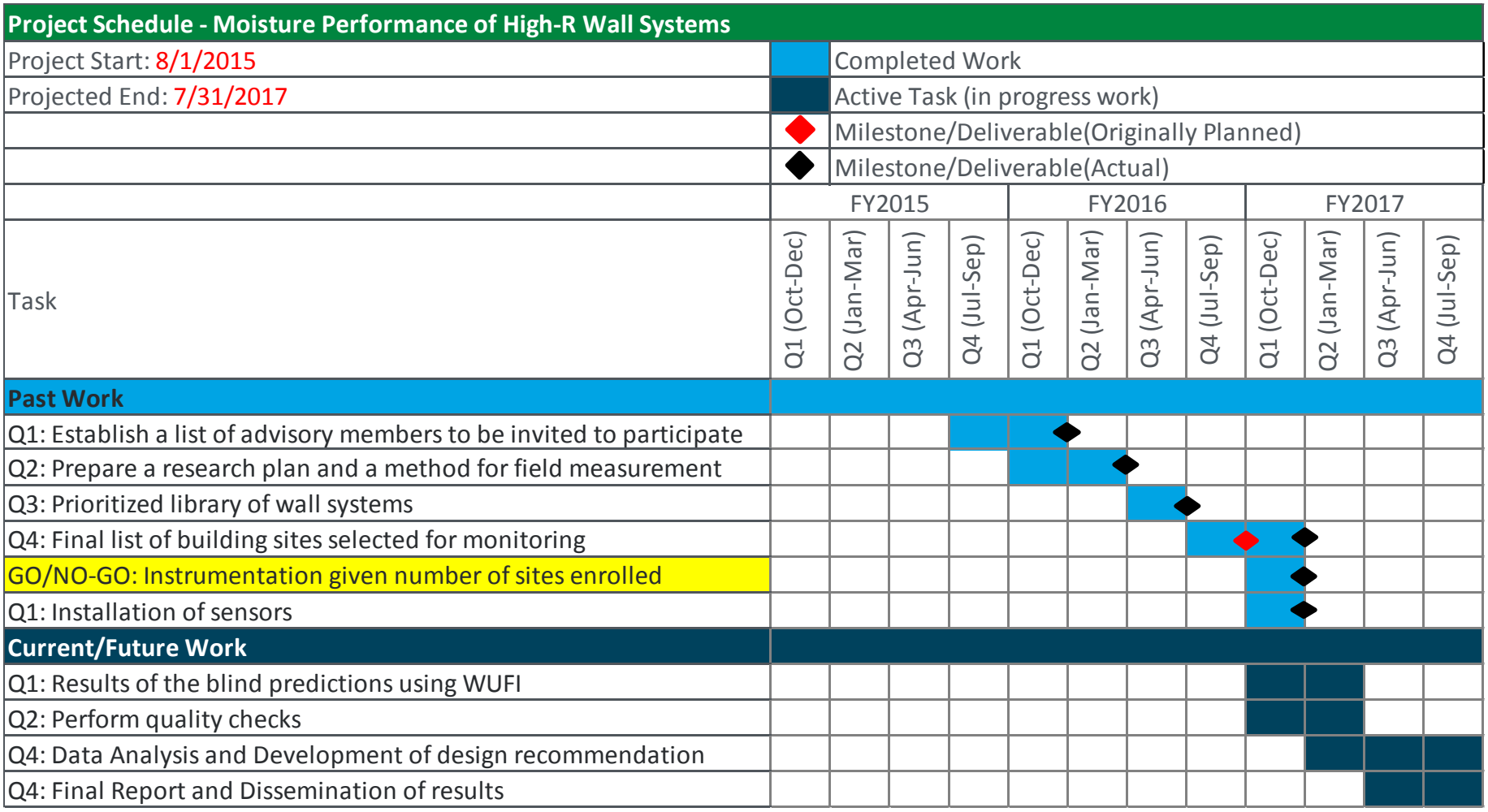
REFERENCE SLIDES

Project Budget – All Three Projects

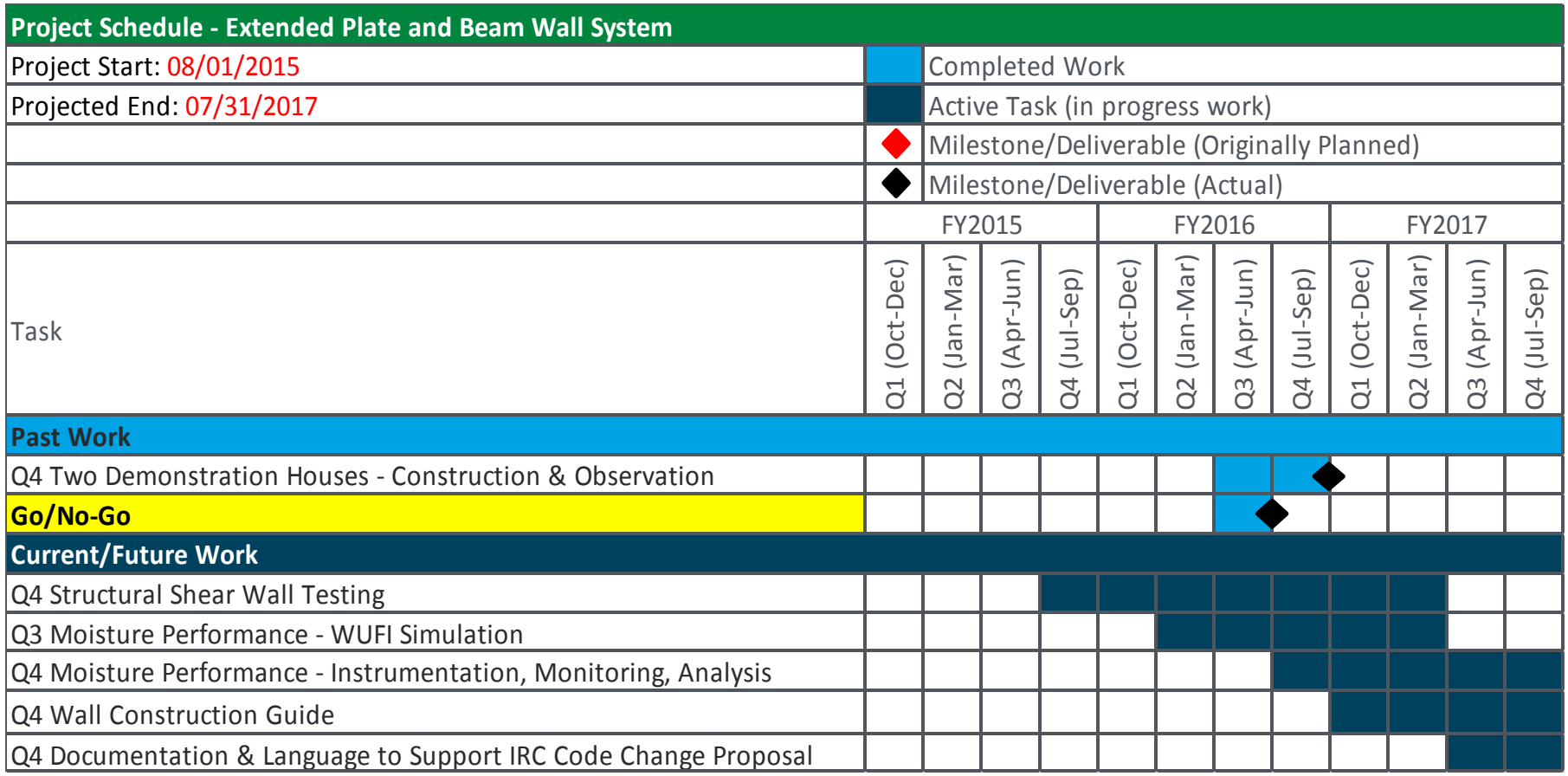
Project Budget: see Table below; Total: $873,715 (DOE) $230,471 (Cost Share)
Variances: None
Cost to Date: See Table below
Additional Funding: None for the described scope of work
Projects: Total budget for 3 projects - Moisture performance of High-R walls; EP&B; Attic Retrofits.

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 Plan and Schedule: EP&B



Project Plan and Schedule: Attic Retrofits