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

Building America Summer 2012 Technical Update Meeting Report

Denver, Colorado – July 24 - 26, 2012

October 2012

Building America
U.S. Department of Energy

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Building America Summer 2012 Technical Update Meeting Report

Prepared for:

Building America

Building Technologies Program

Office of Energy Efficiency and Renewable Energy

U.S. Department of Energy

Prepared by:

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About This Report

The research results, needs, and opportunities identified in this report do not represent the opinion or positions of the U.S. Department of Energy (DOE) or the National Renewable Energy Laboratory (NREL) and NREL and DOE do not necessarily agree with all of the points made by the meeting presenters. This report is not intended to be a complete summary of results, needs, and opportunities for Building America, but to address a small segment of key topics that were chosen for the meeting agenda.

Program Background

The U.S. Department of Energy's (DOE) Building America (BA) program is engineering the American home for energy performance, durability, quality, affordability, and comfort. BA is an industry-driven research program working with national laboratories and building science research teams to accelerate the development and adoption of advanced building energy technologies and practices in new and existing homes. The program works closely with industry partners to develop innovative, real-world solutions that achieve significant energy and cost savings for homeowners and builders.

Building America acts as a national residential test bed where different building system options are evaluated, designed, built, retrofitted, and vetted to ensure that requirements for energy efficiency, quality, sustainability, risk mitigation, and comfort are met. Research is conducted on individual measures and systems, test houses, and community-scale housing in order to validate the reliability, cost-effectiveness, and marketability of technologies when integrated into existing and new homes.

Since its inception in the mid 1990's, the research and deployment partnerships of the BA program (BA teams) have implemented projects that help dramatically improve the energy efficiency of American homes. These highly qualified, multidisciplinary teams work to deliver innovative energy efficiency strategies to the residential market and address barriers to bringing high-efficiency homes within reach for all Americans.

Visit the BA website for more information about BA teams, projects, partners, and tools: www.buildingamerica.gov.

Executive Summary

The ***Building America Summer 2012 Technical Update Meeting*** was held on July 24-26, 2012, in Denver, Colorado. More than 300 professionals representing organizations with vested interest in energy efficiency improvements in residential buildings registered for the event. This meeting served to create a forum to discuss issues related to energy efficiency in housing—specifically nine critical challenges without current definitive guidance—and to define recommendations from the BA program for housing industry stakeholders.

Presenters from BA teams and national laboratories focused on the following topics:

Issue 1 – How Do We First Do No Harm with High-R Enclosures?

Issue 2 – What Emerging Innovations are the Key to Future Homes?

Issue 3 – HVAC Proper Installation Energy Savings: Over-Promising or Under- Delivering?

Issue 4 – Are High-Efficiency Hot Water Heating Systems Worth the Cost?

Issue 5 – How Much Insulation is Too Much?

Issue 6 – Do Codes and Standards Get in the Way of High Performance?

Issue 7 – What are the Best HVAC Solutions for Low-Load, High Performance Homes?

Issue 8 – Better Technology Doesn't Always Win—How Can We Ensure That Doesn't Happen to High Performance Homes?

Issue 9 – What are the Best Ventilation Techniques?

Presentations and information on future meetings can be found on the BA website.

Meeting Participants

2nd Floor Renovations	Crown Jade Design and Engineering Inc.	J Neymark& Associates
A Tennyson LLC	Doug Keaty General Contractor	JELD-WEN Commercial Solutions
A&E Building Systems	Douglas County	Johns Manville
A.O. Smith Corporation	Dow Chemical	Johnson Research LLC
Acme Marketing	Drennen Custom Contracting	Kalyx Studio
AGL Resources	DuPont Building Innovations	KANservation
AHRI	Eagle Rock Supply	Kenai Manufacturing
Albuquerque Stair	Eco Construction	Kirkwood Community College
American Chemistry Council	EcoHome Magazine	La Mirada Homes
AppleBlossom Energy, Inc.	EcoSmart Homes	Lawrence Berkeley National Lab
Appraisal Institute	Ecotelligent Design	Lennar Homes
ARBI-Davis Energy Group	Efficiency.org	The Levy Partnership
Architectural Energy Corporation	Electric Power Research Institute	Lightly Treading, Inc.
Argil Inc.	Emerson	Louisiana Pacific Corp.
Art of Engineering	Empire Drafting and Design, LLC	Marvin Windows and Doors
ASERusa	Energy Center of Wisconsin	Masco Home Services
Aspen Aerogels, Inc.	Energy Design Update	McGraw-Hill Construction
ATELIER Andre	Energy Efficiency Business Coalition	Metro Senergy Consulting
Atmos Energy	Energy Logic	Midwest Energy Efficiency Alliance
avocet design & consulting llc	Energy Matters, LLC	MIT
B+Y Architects	Energy Stewards International	Moberly Public Schools
BARA	Energy Vanguard	Mountain Energy Partnership
Bauder Construction	Environmental Counsel Associates	NAHB Research Center
Bee Lang Homes	Environmental Health Watch	National Renewable Energy Laboratory
Belleview Neighborhood	Environmental Protection Agency	Navigant Consulting
BFIGCORP	EverSealed Windows, Inc.	Nevada ENERGY STAR Partners - GREEN
BGBG.ORG	Faegre Baker Daniels	New West Technologies, LLC
Bonneville Power Administration	Finished Works Construction, Inc.	Newport Partners, LLC
Boulder County	FlexCom Systems, LLC	Nexant
Boulder County EnergySmart	Florida Solar Energy Center	NJIT Center for Building Knowledge/BARA
Boulder County Housing Authority	Fort Collins Utilities	Northeast Energy Efficiency Partnerships
Boulder ZED Design Built	Fraunhofer CSE	NorthernSTAR - University of Minnesota
Building Science Corporation	Funding Partners	Norton Energy R&D
Built Green, LLC	Gas Technology Institute	Nothwest Energy Works
Burlington County Institute of Technology	GeoFireSafe International, LLC	Oak Ridge National Laboratory
C.O.A.D.	George Watt Architecture	Oramic, LLC
Calomino Consulting	Georgia-Pacific LLC	The Overton Firm
CDH Energy Corp / ARIES	Geos Smart Living	Owens Corning
Center for Energy and Environment	The Green Collar Institute at EETCKC	OZ Architecture
Center for Sustainable Building Research	Green Remodeling, LLC	Pacific Northwest National Laboratory
CertainTeed Insulation	GTI/PARR	Panasonic Eco Solutions
CHEX	Guardian Building Products	Passive House Alliance, Denver
Chris Vigil Construction	Hahn Eriksen Architects	Pella / EFCO
Cincinnati State Technical & Community College	Hanley Wood Business Media	PGT Industries
City and County of Denver	Hayes Insulation	Phase Change Energy
City of Aspen, CO	Hearth, Patio and Barbecue Association	Plumb Level Square
City of Aurora, CO	High Tech Enterprises	Populus
City Side Remodeling	Hunter Douglas Window Fashions	Preferred Weatherization Specialists
Clean Efficient Energy Company, LLC	Hutton Architecture Studio	ProActive Concepts
ClimateMaster	IBACOS	Progressive Energy Concepts
CMCCAA	iCAST	Protecto Wrap Company
The College of New Jersey	ICF International	PulteGroup
Colorado Code Consulting	Independent Electrical Contractors Rocky Mountain	R and R Heating & Cooling
Colorado Custom Stone, Inc.	Innovation Affinity Group	R. Pelton Builders, Inc.
Colorado Energy Office	Institute for Building Technology & Safety	RDK Engineers
Colorado Green Building Guild	InterNACHI	Re/Max Alliance
Confluence Communications	Interplay Energy	Reagan & Co. Inc.
Construction Instruction	IPA Ltd	Regal Beloit

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Riosuenoint'l
Rocky Mountain Institute
Ryland Homes
Sacramento Municipal Utility District (SMUD)
Smith Inspection Services L.L.C.
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SolarCity
Solid State Heating Corporation, Inc.
Southface Energy Institute
Southwest Nomad Group
SRA International
Steven Winter Associates, Inc.
Sustainable Ideas
SWEEP
T J Hill & Associates
TexEnergy / US Eco Logic
Timbersil Wood California
Town of Parker, Colorado
Train2Build
U.S. Department of Energy
U.S. Energy Institute
University of Colorado at Boulder
University of Georgia
University of Minnesota
Verdant Management
Verified Green, LLC
Veterans Green Jobs
Vida Verde
Whirlpool Corporation

Acknowledgements

The authors would like to thank the U.S. Department of Energy for hosting the meeting that is summarized in this report. We would also like to acknowledge the contributions of the Standing Technical Committee chairs for their work in the meeting. Finally, a special thanks to Confluence Communications for providing invaluable assistance to NREL in the production of the meeting and this report.

1 Day One: Standing Technical Committee Meetings

The Building America (BA) program strives to be the catalyst that transforms the residential building market, creating innovative home energy system solutions to achieve 50% energy savings in existing and new homes for all U.S. climate regions. Building America works to identify barriers to energy improvements and participates in research partnerships working for the development of robust and innovative solutions.

As part of this effort, BA Standing Technical Committees (STCs) capture and address specific research challenges, gaps in understanding, and new research opportunities identified by the BA program and its stakeholders. Committees include experts from the DOE, BA research teams, national laboratories, and industry organizations that offer specialized knowledge in the topic areas.

The BA STC meetings were held on July 24, 2012, and garnered more than 110 attendees from various backgrounds. Each meeting focused on developing solutions to significant challenges facing the BA program and our nation's energy efficiency programs. This section highlights key outcomes of each meeting.

More information on the goals of the STCs and summary reports for each research need can be found on the BA website at
http://www1.eere.energy.gov/buildings/building_america/strategic_plan.html

As a reminder, the STCs are open to all stakeholders and play a critical role in the BA research planning process. If you would like to participate, please contact the appropriate STC chair. Current information on each STC's activities can be found on the BA STC Google Group at https://sites.google.com/site/buildingamericastc/.

Test Methods and Protocols (Dane Christensen, NREL)

The focus of the Test Methods and Protocols STC Meeting was to consider high-level milestones developed previously and circulated in a document entitled "Building America Critical Path Innovations Leading to 50% Savings." These milestones characterize significant steps that must be achieved for the BA program to demonstrate its long-term energy conservation targets in the U.S. residential sector. Our purpose was to identify technical gaps and research needs that prevent building scientists and practitioners from achieving those milestones today. We discussed six milestones. The test methods-related gaps, barriers, and open research questions identified are listed below.

Milestone
In 2015, demonstrate minimally intrusive characterization of whole-house consumption, savings in new and existing homes for all major and significant minor loads, and operating conditions of any type.

Interim Steps

In 2012, identify technical requirements and develop a roadmap. Cross-reference requirements to existing products and coordinate with industry on product development. Identify gaps for proxy measurements and methods.

Gaps:

- Data collection analysis/management is very challenging. Consumption at the variety of end uses is sparse and requires different frequencies of data collection during use.
- What are major and significant minor loads? (i.e., need criteria for defining each).
- We lack sufficient understanding of state-of-the-art monitoring products/sensors that are developing quickly. Sensors are expensive and tough to install/setup. It is hard to measure a variety of loads with a single sensor package. Need to ensure we have appropriate tools to monitor each important load/fuel type.
- Devices/appliances do not self-report consumption/data.
- Different methods and parameters apply in existing vs. new construction; we need tools for both. Occupied homes have occupants.
- Less about analysis and more about what measurements can be done effectively: what are we measuring, how do we measure it, are there other hard-to-get measurements that we can get a good proxy for?
- We need to investigate clever techniques to measure rather than the brute force approach. Set the right frame (short-term/long-term) for protocols. What can we do in long-term monitoring without intervening in occupant lifestyle?
- We must minimize intrusiveness. Sometimes it is simplest to use occupants' Internet service; how to do this in an appropriate way? What are the possible negative results, (blame for problem due to testing, etc)?
- How do we disaggregate all testing information to identify the specific end uses?
- What is the ongoing communication process during the testing time for the occupants?
- Field validation: how do you monitor a particular home? (example: would monitoring design change based on using a single zone vs. multiple zones for HVAC monitoring/analysis?)
- We could benefit from a menu of options/checklist; does everybody know all the options? What will the interview process look like to vet the home?

In 2013, demonstrate wireless data logger systems. Develop and demonstrate NILM disaggregation prototypes. Demonstrate and characterize proxy measurements.

Gaps:

- Limited budget, so monitoring tools must be affordable; currently inexpensive tools are unreliable.
- Proxy measurements are not well characterized in many cases.

- We need to limit "useless information" gathering by designing better experiments.
- Develop clever techniques to replace "brute force" monitoring.
- Long-term monitoring in existing homes is very intrusive.
- Disaggregation sensors (NILM) are too new and unproven; we need to aggressively pursue these to understand their capabilities and limitations.
- Prescriptive vs. performance specifications for field test protocols and sensor packages; which way is best to go for maintaining high technical quality at moderate cost? Developing new sensor packages from scratch for every test is challenging.

In 2014, develop tool for savings analysis based on vast expansion of end-use types. Continue refinement of NILM and wireless data system. Identify and prioritize significant minor loads that represent efficiency and control opportunity.

Milestone
In 2015, develop and demonstrate method to characterize low-risk retrofit opportunities for below-grade and ground-contacting elements of new and existing buildings via analysis, including a full assessment of the large inherent uncertainties associated with below-grade conditions, validated by field testing.

Interim Steps
In 2012, develop a research plan and specify uncertainties in driving boundary conditions and analysis gaps. Define test method and sensor gaps.

Gaps:

- Need to identify what boundary conditions are needed (and where that boundary is).
- Need to understand the dominant uncertainties in the analysis, to direct test method development.

In 2013, develop initial models (in TRNSYS or similar) and validate via comparison testing with research-grade tools. Instrument a test house to collect field test data for model validation.

Gaps:

- Limited budget, so monitoring tools must be affordable; currently, inexpensive tools are unreliable.
- What are the measurement needs for the analysis STC? For example, how do we measure ground moisture content, and evaluate it?
- Developing a generalized strategy to evaluate heat transfer through foundation elements. Need strategies for each of the foundation types, differing soils conditions.
- Do we know how to ask the right questions? What is the goal—risk mitigation?
- If the testing method is too expensive and time consuming to make the data worthwhile, what do we do?

In 2014, port models into EnergyPlus. Repeat validation with other tools/models to ensure EnergyPlus implementation is accurate. Validate against field data sets. Develop models for basement retrofit technologies.

Gaps:

- What quantity of datasets is needed to appropriately validate the models?

Milestone

In 2015, enhance BEopt and the Building America House Simulation Protocols so that multifamily residential buildings (including single-family attached) can be modeled and optimized to determine cost-effective new construction designs and retrofit packages at the 50% energy savings level in new and existing homes.

Interim Steps

In 2013, release a version of BEopt and published version of Building America House Simulation Protocols with capabilities and guidelines for modeling single-family-attached buildings.

Gaps:

- Measurement of air leakage in multifamily buildings is very challenging and costly. What are the impacts of performing guarded measurements vs. collecting dP to calculate leakage between walls? We need to develop a streamlined protocol to measure air leakage model inputs and may need multiple protocols for evaluating IAQ, energy impacts, and thermal comfort.
- We don't understand the physics of different fire separation assemblies (a.k.a. party walls).
- Will model be for whole building or individual units?
- Measuring occupancy for individual units; there are no tools for this.

In 2014, release a version of BEopt and published version of Building America House Simulation Protocols with capabilities and guidelines for modeling larger multifamily buildings.

Gaps:

- How do we characterize shared common areas and energy use (pools, hall lights, guard stations)?
- We need a methodology for characterizing multifamily shared mechanical systems; need to test usage patterns and losses, distribution, recirculation, controls, outdoor conditions.
- Will our approach to a multifamily building depend on how the building is metered?
- How do whole building retrofits affect individual units?

How do individual retrofits affect neighbors?

Milestone
In 2015, develop publically-accessible empirical test suites for software tools and calibration methods that are based on: a) large sets of audit and utility billing data (including pre- and post-retrofit); and b) research-quality data collected in laboratory and field tests in new and existing homes.

Interim Steps
In 2012, identify potential sources of pre- and post-retrofit audit and billing data. Develop experimental plan for obtaining data to test interior temperature modeling for existing homes (set-points, temperature variation room-to-room).

Gaps:

- How to capture utility use data information? Make it public? Develop a feeder-level monitoring tool kit?
- We need an avenue to protect data so that utilities will share. What's in it for the utility?
- Create a standardized structure to capture utilities' data. What can we learn from it? What information do we need?
- How to access tax assessor data and evaluate accuracy of this data.
- Identify what data already exists and what data we need to collect. Perform a comprehensive background study on what data is available and determine if it is useful.
- How can we connect to the real estate market and capture data from the MLS?

In 2013, have an initial empirical test suite of houses from the Building America Field Data Repository and complete field trials with working group of residential software developers. Collect laboratory and field test data for interior temperature modeling tests.

In 2014, add pre-/post-retrofit test cases to the empirical test suite, if sufficient data are available, and complete the initial test suite for interior temperature modeling.

Milestone
In 2015, demonstrate market-ready space conditioning equipment for low load homes that delivers 10%-20% heating energy savings over current best practice in new homes.

Interim Steps
In 2012, document optimum sizing and resulting savings for cold climate heat pumps. ACCA Manual S committee is not including this approach to energy savings in their standard revision. Reduced latent capacity resulting from shorter run times is a concern regardless of climate, but select climates can benefit from the approach with 10%-15% savings. Results showing additional savings through proper commissioning and limiting defrost to 5kW should also be documented.

Gaps:

- We don't have a definition of "current best practice."

- We need to measure energy associated with current delivered comfort, i.e., measure current system performance in a service-oriented fashion.
- What is take-back from achieving better comfort?
- How to characterize improvements in distribution systems?
- How to measure "whole-house comfort?"
- What is the breakpoint for "low load" homes, internal vs. external environment dominated?
- Do we need better regional load/sizing calculation strategies?
- Evaporative coolers and other climate-focused systems must be considered.
- Sizing for heating/cooling/ventilation systems simultaneously is challenging.
- Do we need to study zone control strategies?
- How do we measure and model interior uninsulated walls?
- Develop field protocols to estimate performance maps for selected equipment/combinations of equipment (i.e., installed system performance maps when individual equipment performance maps are unavailable).

In 2013, demonstrate 10%-15% savings through use of combination hydronic systems utilizing ENERGY STAR® water heaters. Building America research is achieving savings from such systems in the lab. Savings should also be documented when systems are deployed in test homes.

Gaps:

- When a system is not commissioned, how does its energy use change?
- Is savings due to equipment efficiency vs. system efficiency (including whole house)?

In 2014, develop algorithm for optimization of heat pump transition point temperature as a function of climate, auxiliary fuel, heating load, and system capacity, and simulate range of expected savings. Savings expected to be at least 10%.

Milestone

In 2015, use data-driven analysis to provide heat pump water heater (HPWH) manufacturers with necessary data to optimize product design from a systems integration perspective. Achieve 50% energy savings relative to electric storage water heaters in preferred applications. Deliver best practices report with quality assurance guidelines to utility partners that provide confidence and ensure average performance targets will be met in both new and existing homes.

Interim Steps

In 2012, develop additional field studies for CY2013 to assess indoor location space conditioning impacts in all climates, humidity control benefits, and assess location impacts on annual performance for HPWHs.

Gaps:

- How do we decide where heat pump water heaters live: conditioned vs. unconditioned?
- We need a protocol for (standardized) monitoring of HPWHs.
- How do we find out what we need to know relevant to the house?
- Do we need to assess the quality of the installation? What are the impactful metrics?
- Are heat pumps the most efficient water heaters? Do we need to fill this gap?
- Commissioning standards: what are they and how should they be judged?
- We may want to create a test protocol for distribution systems.
- How to monitor draw uses and end uses cost effectively? Develop test standards.

In 2014, deliver field study data and conclusions to key stakeholders (expected to include manufacturers); include best practices regarding preferred applications of HPWHs (climate/load/unit location).

Implementation (Deane Evans, NJIT, and Stacy Hunt, Confluence Communications)

Overview/Key Meeting Points

During the Implementation (I-STC) meeting, Deane Evans and Stacy Hunt (co-chairs from the BARA team) facilitated a working discussion focused on creating specific, actionable recommendations for the BA program related to the Valuation of Energy Efficiency for use in research planning activities. The I-STC chairs presented a "straw man" based on previous I-STC and BA discussions and research related to the topic (captured in an I-STC update issued in July 2012).

The following key points bracket the recommendations proposed in this update:

1. It is recognized that other federal agency initiatives—namely ENERGY STAR for New Homes and the Home Energy Score initiative as well as DOE HQ—have significant vested interest in exploring a more direct and forthright connection to the appraisal industry. The focus of BA work should be to ensure the adoption of Building America research results and to help collaborate with other initiatives to inform research planning for the BA program and to ensure effective valuation of BA measures and homes that meet BA performance targets.
2. Significant work has been done by BA teams related to the *Valuation of Energy Efficiency*. The goal is not to repeat this work, but to focus on critical issues and opportunities that prevent the widespread implementation of BA research results. The intent is to outline needs, identify current projects and initiatives that help to address these needs, and to identify specific areas where BA must develop solutions in order to ensure effective implementation of BA research results.
3. There are two significant issues related to the consistent *Valuation of Energy Efficiency*:

4. Lack of comparables and valuation data (whole house and specific measures)
5. Lack of energy efficiency appraisal training and education (associated with tools to help appraisers value home performance)
6. The difference between the *Valuation of Energy Efficiency* when valuing new construction versus valuing upgrades to an existing home may be significant and should be discretely addressed in any future research and development activity. The relationship between "adjusted age" and energy upgrades should be considered carefully, as the age of a property plays into valuation significantly.
7. Focus of future research and development activities should be the *Valuation of Energy Efficiency* on a whole-house performance basis, not related to specific measures. However, details about specific energy measures when quantified in the context of overall home performance (i.e., reduction in utility bills, increases in building durability) are useful to appraisers in substantiating their valuation of a home. Thus, future work should address both whole-house energy performance using labeling programs as a basis for valuation and the valuation of specific energy measures, "innovations," or upgrades.
8. Appraisers and underwriters are two discrete stakeholder audiences that must be explored and addressed to ensure the effective implementation of BA research results related to the *Valuation of Energy Efficiency.* Current I-STC work explores only the appraisal portion of the process, but will extend to explore the underwriting issue.
9. The *Residential Green and Energy Efficient Addendum* (Appraisal Institute) is currently the tool used by appraisers to help document the valuation of energy efficiency. This tool should be used as basis for the data format to implement BA research results in the appraisal community.

I-STC Building America Recommendations—Valuation of Energy Efficiency
The following recommendations for the BA program were developed as a result of the July 24, 2012, I-STC meeting:

1. Using the Residential Green and Energy Efficient Addendum as a basic framework:
    - Develop and implement a strategy to produce appraisal/value data as part of all relevant research results. Specifically, tie a section of each measure guideline developed by the program to the appropriate section in the Residential Green and Energy Efficient Addendum and provide all relevant cost/performance data to help the appraiser substantiate the increased value associated with this measure.
    - Integrate a draft *Residential Green and Energy Efficient Addendum* with current verification software, for use during the home performance contracting process, and in the DOE Challenge Home Initiative.
2. Partner with the Appraisal Institute (and other appropriate) to:
    - Augment existing education programs to inform appraisers on how to use the tools developed by BA that support the *Residential Green and Energy Efficient Addendum*.

- Promote the use of the *Residential Green and Energy Efficient Addendum* to appraisers and homeowners/homebuyers).

3. Explore the opportunity to partner with the State of Colorado (Colorado has significant related initiatives underway) to evaluate other key issues and opportunities in addressing the *Valuation of Energy Efficiency* and to stay engaged in current thinking on the topic.

I-STC Next Actions

The following actions were identified as a result of the July 24, 2012, I-STC meeting:

1. Understand the underwriting process, the role of the underwriter, and the connection between BA research results and the underwriting process. As part of the basis of discussion, residential "utility bill guarantee programs," such as MASCO's Environments for Living Program, should be explored to provide business-case information for underwriters about the comparative value of energy efficiency.
2. Evaluate current research on real market value of ENERGY STAR homes as compared with "standard" construction to determine if enough national data exists to make generalizations about increased value in home performance.
3. Continue the process of discussing the adoption of Building America research results by utility-based programs, with the intent of developing research recommendations.

Space Conditioning (Eric Martin, FSEC)

The Space Conditioning Standing Technical Committee met to discuss the five space conditioning endpoint milestones with associated interim milestones identified at the April Critical Path Planning Meeting. These include:

- Document BA Best Practice Guidelines for effective, reliable, and climate-specific whole house mechanical ventilation systems for new and existing homes.
- Demonstrate market-ready space conditioning equipment that delivers 30% cooling energy savings relative to current SEER 16 systems while delivering BA best practice ventilation and providing adequate moisture control to ensure enclosure durability and occupant comfort in new and existing homes.
- Document new construction community scale adoption of space conditioning distribution system solutions that ensure negligible conductive, radiant, and leakage losses in new and existing homes.
- Demonstrate market-ready space conditioning equipment for low load homes that delivers 10%-20% heating energy savings over current best practice in new homes.
- Demonstrate systems and strategies that achieve 10%-15% space conditioning energy savings by upgrading or supplementing existing heating/cooling equipment for existing homes where HVAC change-out is not cost effective.

After a brief discussion of committee activity and meeting objectives, attendees divided into working groups. In addition to a general review of the milestones for accuracy and completeness, each group was tasked to identify specific, unanswered questions and research needs around each milestone to be addressed in the 2012 to 2013 timeframe. Some groups also discussed factors that limit implementation of proven best practices. Groups also addressed two issues also of interest to the Hot Water STC: heat pump water heaters and combination space and water heating equipment. The Hot Water and Space Conditioning STCs briefly coordinated on these issues.

Hot Water (Marc Hoeschele, Davis Energy Group)

At the Hot Water Standing Technical Committee meeting, chairs provided an update on BA and outside research activities related to the topic and presented draft Building America Critical Path Milestones. The group held a brainstorming session about the milestones.

Key comments on the six currently identified milestones are summarized below:

1. Optimized Heat Pump Water Heater (HPWH) Design and Operation and Best Practice Guidelines
   - Real vs. rated EF: do we need better hot water load patterns to drive models?
   - An installation guide is needed.
   - What are the ways to mitigate noise impacts?
   - Need to characterize the space conditioning and dehumidification impacts for units located indoors or in basements.
   - NREL is working on HPWH field test protocol that includes assessing space conditioning impacts (available for review shortly).
   - Smart grid coordination is needed in the future.
2. High Efficiency Gas Solutions for Existing System Infrastructure
   - Charlie Adams (AO Smith) says they have been working on hybrid systems with small tanks coupled to tankless (NEXT product on the market). Adams wonders what more is to be done. Discussion on better understanding peak load events (burner/storage downsizing?) and what benefit improved controls could have on annual efficiency.
3. New Construction System Solutions (35%+ for Gas and to 50%+ for Electric)
   - Focus is on reducing distribution losses and adding efficient water heating equipment.
   - Industry outreach and education; need for improved VoTech training; trades need to better understand PEX installation (layout, avoid pipe oversizing).
   - Modeling credit for improved distribution layouts (how to translate results from detailed simulation tools (TRNSYS, HWSIM) to hourly models, such as BEopt?).
4. Best Practice Design and Implementation Guidelines for Combined Systems
   - Need combi system ratings (ASHRAE working on it, but not clear on the timeline).

- Best practices guidelines needed. According to Schoenbauer, a great deal of work is needed to achieve the 15% savings. Will the industry be able to reliably deliver these systems? Need to engage with industry to get optimally performing products.
- Modeling: Lots of variables:
  - Need radiant systems and hydronic fan coils in BEopt.
  - For radiant systems, what are the standard layouts?
  - For hydronic fan coils, is there a standard layout? Pipe length/sq ft, etc.?
- What are the cost tradeoffs for different delivery options? What are multifamily system costs?

5. Optimized Multifamily Recirculation Systems Solutions
   - Continuous recirculation is standard in high rise multifamily buildings. CARB (Robb Aldrich) is working on multifamily recirculation on two gut rehabs (12 and 22 unit projects).
6. System Integration Evaluations for Solar Water Heat
   - Cost, maintenance issues, and battle over roof space are the key barriers.
   - Builders may be gun-shy towards solar.
   - Multifamily buildings offers better cost effectiveness since there is a bigger load to serve.
   - Improved understanding of seasonal hot water load variations. Appears that SRCC overestimates summer loads, resulting in higher than "real" solar fractions.
   - Niche specialty contractors contribute to high costs.

Automated Home Energy Management (Lieko Earle and Bethany Sparn, NREL)

The majority of individuals who attended the Automated Home Energy Management (AHEM) STC meeting on July 24 in Denver are not regular participants in the committee. As such, it was a challenge to get the conversation going in the right direction, but, in the end, the brainstorm sessions benefitted from the diversity of perspectives. The following items were agreed upon as key next steps and questions to be researched:

Toward Milestone 1: Validate effective whole house control strategies that maximize comfort and energy savings in new and existing homes.

- Identify savings potential when optimizing cooling system—look at first stage vs. second stage, extending cycle for steady state operation.
- Determine savings potential of fault detection diagnostics (FDD) tools.
- Should/can ventilation be demand-controlled?
- Complete inventory of what sensors are available vs. what sensors are needed.

- How can whole-house monitoring identify AHEM energy savings opportunities?
- Evaluate the interoperability between existing devices.

Toward Milestone 2: Identify and break down barriers to market adoption of technologically sound AHEM solutions for new and existing homes.

- Is there an AHEM industry group?
- Define first who would be primary audience for AHEM taxonomy.
- Recognize that these are not just products—they can include analysis and algorithms.
- Taxonomy could be focused on identifying core functionalities rather than particular devices.
- Strategize how to incent manufacturers to collaborate (since they have similar work but have some proprietary piece)?
- Need to work on standardization of communication protocol.
- It's time for another AHEM expert meeting (like the one NREL hosted in fall of 2009) to compare notes on the current state of technology.

Toward Milestone 3: Determine the opportunities for using controls to curb inadvertent energy use in homes and quantify the energy that can be saved in new and existing homes.

- What are the loads? Range of devices? When should they be completely turned off? These questions can be answered through monitoring.
- What are the technologies available for control? (e.g., advanced power strips)
- Define power source types: always on, easily switched, automatically switched (timer, motion), “smart,” other?
- Talk to Continental Automated Buildings Association (CABA).

Toward Milestone 4: Analyze control strategies for energy impact during demand response events and evaluate related utility cost and energy savings in new and existing homes.

- Order priority of appliances (ranked by highest demand?).
- Peak performance prioritization—which appliances run coincident to peak?
- Leverage security industry, which can drive innovation.
- Investigate smart controls by climate region.
- Match construction type and design parameters for effectiveness of precooling.
- Identify and evaluate potential unintended consequences.

Analysis Methods and Tools (Ben Polly, NREL)

The Analysis Methods and Tools (AMAT) STC met to identify gaps related to the critical path milestones that were defined by the committee in early 2012.

Ben Polly, the chair of the AMAT STC, began the meeting with an overview of the critical path milestones, and reviewed the working definition for a "gap" related to a critical path milestone. He emphasized that gaps are research questions and barriers that, if not addressed, could prevent us from achieving the milestone. Gaps are not just questions that will be answered along the way by researchers who complete projects that address the milestone. Rather, they are critical questions that must be answered to properly define the technical scope of any work that will be proposed and performed to meet the milestone. They may also represent barriers that must be tracked at the STC-level to ensure coordination across the BA program and with outside groups so that the barriers can be overcome.

After the overview, the group broke out into three working groups. Each working group was responsible for defining gaps corresponding to a particular critical path milestone. More specifically, gaps were defined for the 2012 and 2013 interim milestones. The groups discussed the topics for about thirty minutes, recording ideas on flip charts provided in the meeting. One representative from each group then reported the major outcomes (defined gaps) for discussion as an entire group. After a short break, this process was completed for three additional topics, one of which was a topic suggested at the meeting for consideration as an additional critical path milestone.

Overall the meeting was a successful first step in identifying gaps for the critical path milestones. The chair will summarize the key gaps defined in the meeting and send those to the committee for further contributions and review. Detailed notes for the meeting will be made available on the AMAT STC website.

Enclosures (Joe Lstiburek and Katie Boucher, BSC)

The goal of the Enclosures STC meeting was to identify the questions that need to be answered in order to achieve the following six critical milestones that will need to be achieved in order to reach 50% energy savings:

1. By end of 2015, adopt code language defining the requirements for attaching cladding over typical thicknesses of insulating sheathing (i.e., 1", 1.5", 2", and 4") for both 16" and 24" o.c. framing.
2. By end of 2015, adopt code language defining the requirements for insulating the underside of wood floors using insulating sheathing.
3. By end of 2015, develop a method of retrofitting monolithic slab-on-grade foundations.
4. By end of 2015, approve fire-tested wall assemblies, including insulating sheathing over wood framing for use in new and existing low-rise and mid-rise multifamily buildings.
5. Published durable high-R enclosure system selection guidelines by climate for new construction and majority of wall constructions and enclosure retrofits in existing homes.

6. By end of 2015, address the Weatherization Program practice of promoting and using methods that violate existing codes such as dense packing unvented cathedral ceilings.

It is important to note that the goal of the meeting was not to actually solve the problems or answer the questions, but to identify the questions that need to be answered. In order to achieve this goal, Joseph Lstiburek presented each of the milestones and facilitated a group discussion. Following each milestone discussion, attendees were asked to answer the following two questions:

1. What was the most important question discussed?
2. What questions still remain?

Attendees responded to these questions using comment forms distributed at the beginning of the meeting. The comment forms were collected at the end of the meeting and will be used as an aid when updating the milestone language.

Prior to the in-person meeting, the committee held two conference calls to discuss Milestones 1 and 2. Since the meeting, one additional call was held to discuss Milestone 3. Milestones 4, 5 and 6 will be discussed over the next three months. Meeting presentations and meeting notes have all been posted to the committee website.

2 Days Two and Three: General Session

Building America (BA) teams represent world-class building science expertise for high performance homes. Program customers, including builders, contractors, HERS raters, designers, and consultants face significant challenges in determining consistent recommendations for key building-related issues. The Summer 2012 Building America Technical Update Meeting presented a diverse array of expert perspectives on nine key issues followed by a facilitated discussion to narrow down the best BA guidance that can be provided at this time. The intent of the panel format was to evaluate the status of solutions to key questions currently limiting implementation of high performance homes with the intent of arriving at a set of expert BA recommendations for these key issues.

The following section of the report provides details on each session, including:

- Background for the specific issue, to provide context
- Proposed solutions, developed by session presenters prior to the meeting
- Expert recommendations, gathered live from each meeting session.

This report is not intended to be an exhaustive capturing of the details of each session, but a summary of key points and recommendations.

Full presentations are available online at www.buildingamerica.gov.

Issue 1 – How Do We First Do No Harm with High-R Enclosures?

Background
In this session, presenters addressed this question:

What materials and approaches provide the "perfect," cost-effective, production-level, high-R enclosures for all major U.S. climate regions that ensure no moisture damage?

Presentations were developed based on these desirable characteristics for high performance enclosure solutions:

- Easily adaptable elements for different climates, allowing for standardized construction approaches across all climates
- Minimizes possibility of condensation within walls
- Can be easily adapted to allow use of a broad range of cladding systems
- Minimizes increase of labor and material cost compared to current reference production wall systems defined by IECC 2012
- Reliably integrates window installation and flashing, drainage plane, air barrier, and shear strength requirements
- Controls groundwater and soil gas entry into the conditioned space

- Reliably predicts durability and performance of enclosures by advanced analytical and experimental hygrothermal test protocols
- Controls groundwater and soil gas entry into the conditioned space
- Dries within an acceptable period of time after water intrusion events via a combination of vapor diffusion and/or convection
- Durability and performance of enclosure can be reliably predicted by advanced analytical and experimental hygrothermal test protocols.

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Moisture Performance through Field Testing For High Performing Homes; Vladimir Kochkin
The hygrothermal adaptation of higher insulated and air sealed framed wall systems has been and continues to be evaluated both in software simulation and in field testing. The field research effort is focused on identifying and compiling the moisture performance details specifically for high performance frame wall systems using field tests in occupied homes in various climate zones and in test buildings in climate zone 4. The NAHB Research Center Industry Partnership described this study and presented preliminary data from a few houses during this past winter (2011/2012). Ultimately, the project will detail actual moisture performance of wall systems in a variety of climate zones that meet or exceed the minimum insulation levels and air tightness requirements of the 2012 IECC.

How Do We First Do No Harm With High-R Enclosures?; Joseph Lstiburek
The perfect wall must have a water control layer, air control layer, vapor control layer, and thermal control layer outboard of the structure coupled with a ventilated and drained cladding system. These requirements are necessary for all U.S. climate regions. The production level adaptation of this wall is an advanced wood frame 2x6 assembly with structural sheathing, a water control layer, air control layer, and thermal control layer outboard of the structural sheathing and a ventilated and drained cladding. Interior vapor retarders are Class II or greater; interior vapor retarders of Class I should not be used in any U.S. climate region. Cost shifting and cost trade-offs can make this assembly either the same cost as conventional framing or within 5% of conventional framing, depending on climate zone and wind zone/seismic zone requirements.

Exterior Wall Retrofit Strategies with Exterior Insulating Sheathing; Richard Baker
In new and existing homes across all U.S. climate regions, it is generally recognized that adding exterior foam sheathing and other strategies (e.g., structurally insulated panels (SIPS), insulating concrete forms (ICFs), spray foam) reduces condensation potential inside the wall cavity and improves energy efficiency. Exterior foam and these other strategies can be difficult to detail and install, as well as expensive to implement, especially in retrofit situations where the vast majority of housing is existing 2x4 cavity wall construction. When modeling a retrofit wall system (including windows and doors), similar energy savings can be achieved by dense packing the walls and installing high-R windows. The New York State Energy Research and Development Authority (NYSERDA) is undertaking an exterior wall retrofit research project to more closely evaluate the costs associated with a variety of exterior insulation strategies. IBACOS is leading

one of these efforts to compare the energy consumption of exterior insulated building enclosures (rigid foam sheathing and spray foam with stand-off furring) without window replacement to dense-packed 2x4 wall cavities with new high-R windows. Ultimately, what the industry appears to need is not a "one size fits all" solution (i.e., the "perfect" solution) but a portfolio of regionally appropriate solutions (the "good" solutions) that can meet basic durability, comfort, and energy efficiency criteria based on the level of work that the homeowner is planning.

Expert Comments and Recommendations

The BA program is conducting ongoing research required to develop more robust enclosure guidelines, specifications, and construction details to ensure that high-R walls are both durable and cost effective. The following recommendations pose some of the most current thinking on how to effectively build high-R enclosures:

All Enclosures:

Deal with moisture and water issues first, then air seal and insulate.

Walls:

- The best wall system follows this basic premise: always align and connect the four primary layers. This should happen everywhere in the building enclosure from the way a wall is designed, a roof, slab, everything. All control elements are connected even with and around penetrations.
    - Water to water.
    - Air to air.
    - Vapor to vapor.
    - Heat to heat.
- A highly recommended wall system adds rigid insulation over an insulated advanced frame assembly (applicable for up to 4" of insulating sheathing). The layers of this system include:
    - Advanced framing—less expensive, works better.
    - OSB in corners, insulating sheathing everywhere else. Wherever you have insulating sheathing, you must have a gap to back ventilate and drain your cladding systems.
    - Rigid insulation over OSB. As rigid insulation gets greater than 1/2" thick, this becomes a potential structural concern with code approval. Research is developing data to resolve this issue.
    - Wrap and tape seams.
    - Flashings on window openings. Need good windows, installed properly (SHGC .2-.25). Most of the time, the problem isn't the window, it's connection of window to wall. Pan flash sill and conventional flashing at jambs and head.
    - Furring strips over wrapped insulating sheathing to ensure a drainage gap (1/2" min. 3/4" better).

  - This is the only technology that is going to work because we need to allow drying.
  - Cladding on OSB over furring strips.
- SIPs/ICFs have moisture control issues, but there are solutions. For example**,** ventilated cladding is a solution to this moisture problem. SIP roof panels have the same problem and solution.
- Liquid applied membranes are a great technology, especially when they become cost-effective and readily available. Won't work in areas that remain wet for longer periods of time like the bottom areas of the drainage plane.
- With ultra-efficient homes employing double-wall framing, the outside sheathing layer is so cold that it needs to be more permeable to ensure drying. Thus, OSB is not recommended in this application. Instead, more permeable sheathing such as plywood and exterior grade drywall should be used. Note that double wall construction is more risky in cold climates because of the inability to locate the dew point outside of the wall.
- Retrofitting existing walls with insulation needs to be carefully considered and rejected if it is not possible to provide a complete water management system.
- Insulating sheathing used as the backer for spray foam is a good strategy in retrofit scenarios.

Attics:

- While there is increasing interest in unvented attics with insulation installed at the roof sheathing, vented attics work best and minimize moisture control issues. It is common to put mechanical systems in the attic. Don't.
- That said, unvented attics can work and help locate HVAC ducts inside conditioned space, but they should include a furred vent space above the insulation in cold climates.
- SIP roofs have moisture control issues, but there are solutions. Use ventilated space over panel to address this moisture problem.

Foundations:

- Exterior foundation insulation provides poor moisture management and is expensive.
- Interior foundation insulation needs to ensure effective drying to the interior.
- Best strategy for slab on grade retrofit is insulated stem wall.
- Post-tension monolithic slab, insulating on the edge is futile, insulate on top.

Windows:

- There are two types of windows—windows that leak and windows that *will leak.* Build with this understanding.
- In retrofit scenarios, pull windows and reinstall to ensure that flashing connects with the wall drainage plane and water that gets into the window assembly drains to the outside. In addition, this allows for sealing the rough opening gap.

Codes and Standards:

- Building codes provide minimum requirements, not solutions for every situation.
- Need better guidelines; builders need specific solutions.
- Need to be careful—too much insulation can create moisture in wall structure, need to minimize condensation in walls.
- Code does not require vapor barrier on interior.
- Relative humidity maintained per ASHRAE 160.
- Related to radon, there is fear from outside the industry that a depressurized house and extreme air sealing will invite more radon into the home. Dealers and industry representatives have been worried that positive pressure will force vapor into the walls and create condensation and potentially draw radon into the living space. If you air seal and insulate at the roof, you should actually decrease radon. The best thing to do is ventilate under the slab because it is hard to combat the negative pressure built up of any house (regardless of climate, air sealing, etc.).
- Occasionally, walls will get wet and need to dry out. Do not over seal!

Issue 2 – What Emerging Innovations are the Key to Future Homes?

Background
In this session, presenters addressed this question:

What are the most important emerging innovations that will solve critical problems and capture new performance opportunities for future homes?

Presentations were based on these desirable characteristics for emerging solutions:

- Provides whole house savings at neutral cost compared to current solutions
- Increases home durability and comfort
- Reduces warranty and call back costs
- Reduces the cost or increases the performance of other systems.

Examples include high-R windows, heat pump clothes dryers, heat pump water heaters, "next gen" home automation systems, "next gen" home entertainment and home office products, ENERGY STAR-rated power supplies, air handlers with integrated ventilation and hydronic coils, etc.

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Ductless Hydronic Distribution Systems; David Springer

Field research and TRNSYS analysis suggest that distribution efficiencies for ductless hydronic systems of over 90% are easily achievable. The ARBI research team completed a technical report on the evaluation of ductless hydronic distribution systems. Findings from this technical report indicate that annual heating and cooling energy use (site and source) can be reduced by up to 27% when substituting pumps, pipes, and small fan coils for blower, refrigerant coil, and ducts and replacing a conventional 13 SEER heat pump and coil with a similarly rated air-to-water heat pump. The team is also monitoring and evaluating two homes in hot-dry climates using air-to-water heat pumps to deliver heating and cooling using radiant floor distribution. Performance data from one home during the summer of 2011 shows very favorable cooling system performance without the need for dehumidification or risk of floor condensation. These systems are applicable in all climate regions (fan coils are needed in humid climates) and can provide sensible and latent cooling and/or heating using a single hot and chilled water source such as a heat pump, or a high efficiency water heater (combined system) and separate chiller. Heat pump chiller-heaters can be supplied factory charged with refrigerant, thus avoiding problems of incorrect refrigerant charge in the field.

Home Energy Management Systems and Reduced Consumption; Duncan Prahl

The IBACOS research team has conducted energy analyses on more than 30 different house plans of existing homes across multiple U.S. climate zones for Lend Lease, a military housing provider. It is not surprising that, based on utility bills, the actual energy consumption in houses varied dramatically from modeled predictions. One project that Lend Lease has implemented on a limited scale that shows promise for persistent energy savings is the E3 Greentech Enterprises wireless home energy management system using cloud computing. Sensors provide data to the cloud where it is processed by E3's analytic software which then sends signals back to the house and uses the sensors to control various systems to reduce energy consumption. The E3 system learns how the occupants live in the house and use the systems and then develops ways to eliminate waste while maintaining the occupants' desired functionality. The E3 system also can identify failures and poorly performing equipment and can be used for demand control. IBACOS believes this type of solution is needed for large-scale deployment to automate savings by managing the operation of devices and systems instead of relying on occupants to be active participants.

Excavationless Foundation Insulation for Existing Homes; Garrett Mosiman

To be successful, a foundation insulation retrofit should reduce building energy use in a cost-effective manner while reducing risks associated with factors like water intrusion and moisture accumulation in vulnerable materials. The ideal solution would involve a quick and surgical excavation with minimal damage to landscape features and house components. Then the resulting trench would be filled with a material that would reduce heat loss through the basement walls while reducing moisture loading in the basement from the soil. An excavation technology capable of digging a very precise, narrow trench adjacent to an existing foundation has been identified, as well as three pourable materials suitable for use as below-grade insulation. These include cellular concrete, perlite concrete, and pourable polyurethane foam. All are, or can be, significantly resistant to moisture penetration.

Role of Highly-Insulating Windows in Achieving 50% Energy Savings in Residential Retrofits; Sarah Widder and Terry Mapes

An evaluation of highly insulating (R-5) windows was conducted in side-by-side lab homes. The whole house energy consumption and temperature distributions in the experimental home were compared to those in the baseline home, which has aluminum frame, double pane clear glass windows typical of most existing homes. These data will be used to quantify the energy savings and thermal comfort improvement from the R-5 windows in the lab homes during the heating and cooling season. Data collected on the homes will also be compared to predicted savings from the EnergyPlus model.

Expert Comments and Recommendations

BA is constantly evaluating new technologies and systems—innovations—to determine the conditions under which new systems cost less and perform better than current solutions or solve existing challenges. In some cases, innovations provide interesting alternatives to current solutions. In other cases, more work may be required before new systems are ready for "prime time." In both cases, it is the role of the BA program to explore and support the development of promising new technologies to advance the state of housing performance.

The following summaries represent the four emerging innovations presented during the meeting:

<u>Ductless Hydronic Distribution</u>

Ductless hydronic distribution provides:

- Increased distribution efficiency over air ducts, approaching 100% efficiency because it is easier to route inside conditioned space.
- More energy efficiency because of distribution efficiency, the utilization of pumps versus fans, and better sizing.
- Much easier to zone, increased comfort, equipment takes less space, no combustion safety issues, not much more complicated than a forced air system, but requires contractor education.
- Cons are that it is difficult to do cooling, there is limited availability of compact air handler products, requires engineering, and has a high cost of heat pump equipment.

<u>High Performance Windows</u>

- Low U-value, high solar heat gain coefficient (SHGC), low cost windows don't really exist yet, though there are companies working on this now that incentives for the hot climate windows have gone away.
- The role of highly-insulating windows in achieving 50% energy savings in residential retrofits is significant and follows two types—primary replacement and storm window additions.
- Retrofits are increasing, but window upgrades are not always pursued because of cost and lack of awareness of current products.
- BA needs to verify performance of highly insulating primary windows and low-e storm windows.

- Right now, it is difficult to get the cost down for high performance windows because there is a lack of regional distribution.
- BA needs to give more guidance on how to deal with historic window replacement.

Home Energy Management Systems

- Home energy management (HEM) systems can significantly reduce energy consumption, but the technology is still being optimized.
- People don't want to think, they want technologies that make their lives easier.
- Expert prediction is that everything with a plug is going to have a chip in it and the smart meter will be the gateway.
- Ideally, everything works together with minimal interaction from occupant.
- The most compelling technology today is the Nest, but it's simply a thermostat and not a HEM system.
- BA should help quantify how much energy is actually saved with smart power strips.

Nearly Excavationless Foundation Exterior Insulation Systems

- Inside insulation option common, easily done, but has issues:
    - Water management
    - Capillary break at sill.
- An outside insulation option has various hygrothermal benefits as the warmer wall can dry to interior and lack of capillary break is less important since the wall is drier.
- It is practical (2-3 day operation on a simple house) to dig up the yard to the footing and install an exterior insulation system. However, preliminary costs shown do not take into account replacement of landscape features.

Other Innovations to Watch

- Exterior shading options.
- Heat pump clothes dryer.
- Smart power strips.
- Wireless/GPS enabled zone controlled air handlers.
- More HVAC solutions like window air conditioners that minimize refrigerant needs and are factory-sealed without need for maintenance, easy-to-install and cost-effective.

Issue 3 – HVAC Proper Installation Energy Savings: Over-Promising or Under-Delivering?

Background
In this session, presenters addressed this question:

What energy savings are realistically achievable by following quality installation standards for installation, operation, and maintenance of residential HVAC?

Presentations were based on these desirable characteristics for installation and maintenance solutions:

- Simple checklists inspection and diagnostics installers can apply to verify correct installation and maintenance
- Simple consumer operation and maintenance guides
- Equipment sensing and self-diagnostics
- Contractor certification
- Clear documentation of the value and savings that result from proper installation and maintenance
- Increase in component and labor cost minimized compared to equivalent systems.

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Guidelines on Airflow and Charge Verification; David Springer
Home performance contractors frequently overlook HVAC maintenance or resort to replacement of equipment that may not solve the original problem, creating a missed opportunity. Several studies have shown that a significant percentage of air conditioning systems suffer from inadequate airflow resulting from undersized filters and/or ducts or incorrectly designed zoning systems and refrigerant problems including incorrect charge, non-condensables in the refrigerant, and other problems. The objective of an air conditioner installation and maintenance protocol should be to ensure that systems operate close to the efficiency at which they are rated by manufacturers. Given measurement uncertainty, a tolerance of 5% should be an achievable goal that can be accomplished by properly applying equipment sizing principals, closely following manufacturer installation instructions, and properly implementing diagnostic testing and remediation procedures. However, these measures should be cost effective. To respond to this need, the ARBI team completed a measure guideline that recommends an efficient two-step approach for the diagnosis and repair of existing air conditioning systems.

Improving Installed Furnace Performance — A 48-House Case Study; Tim Hanes
Nameplate furnace output is usually based on ideal conditions, not the ones found in the field. Proper fan speed adjustments, tuning, and duct sizing matter and can improve performance by as much as 30%. Adding a flow measuring device to the furnace tuning toolkit allows for

measurement of delivered energy to compare with the nameplate values. This project proposed the addition of that measurement, an analysis of performance vs. name plate, checklist targets for settable parameters, and a method to evaluate performance improvement. A furnace tune-up is a cost-effective measure in some homes at a price that is 1/10th the cost of replacement. Those upgrade dollars can then be focused on insulation, air sealing, and other measures. These are especially cost effective where recent mid-efficiency furnaces are in place but are not properly installed and costing up to 10% of the potential delivered energy from the system. The presentation covered the application of this technique to the 48 houses in the field study, providing pre-retrofit information and post-retrofit improvement assessments.

A PDI for Your HVAC System; Iain Walker

The installation of an HVAC system is more important than selection of higher performance equipment. What is needed is the equivalent of an automobile Pre-Delivery Inspection (PDI) for residential HVAC systems. This includes diagnostic tests for air flow, refrigerant charge, filter performance, fan power consumption, combustion, and so on. Along with focusing on energy performance, there is also more important value, from the occupant's perspective, in terms of comfort, indoor air quality, reliability, and durability. The reliability and durability aspects are also important for equipment manufacturers to ensure that their equipment is installed properly. The proposed solution is to develop a PDI checklist of inspections and diagnostics. This checklist is already mostly covered in contractor certification, such as BPI or NATE, or in home-energy rating requirements, such as RESNET. However, good standards and diagnostics for heating and cooling system air flows and ventilation air flows are missing components. In addition, many home performance contractors and certified technicians lack the explicit training required for some HVAC procedures, such as dealing with refrigerants or measuring electric power consumption, and these will need to be dealt with in some constructive way.

Expert Comments and Recommendations

Technology isn't always the problem; installation and quality assurance/quality control (QA/QC) methods can also contribute to reduced system performance. BA works extensively to develop installation and QA/QC guidance for the industry to reduce the instances of "designed vs. installed" performance issues. The following guidance was provided on key areas to ensure proper installation of HVAC equipment to improve expected performance:

- If we fixed (sealed/insulated/tested) all the ducts in the United States, we might save about $25 billion a year. Contractors need to change from low-bid service techs to high profit professionals. This will reward good contractors and offer a better public image. This would also provide equipment manufacturers with less warranty claims and a better public image.
- Measure the temperature split (between return and supply plenums) for quick and effective AC inspection. This split is easy to measure and is used to determine system health.
- Must properly train HVAC technicians, installers, and sales people. Public awareness of proper installation correlating value is a must, otherwise, with just training the technician, change won't happen. Promote participation in ENERGY STAR, ACCA QI, SAVE, and other programs focusing on HVAC installation.

- Develop a pre-delivery inspection (PDI) checklist and label (include target and system test results) for HVAC, make it law, regulate, and require it. Label and certify for tight equipment. By force of law, the HVAC industry must have a PDI with on-board diagnostics installed on all HVAC equipment to ensure it operates as expected.
- Need to create public awareness around these issues and national verification by qualified organizations—greatest obstacles are increased cost and getting homeowners to understand the value associated with the cost.

Issue 4 – Are High-Efficiency Hot Water Heating Systems Worth the Cost?

Background
In this session, presenters addressed this question:

What are realistic energy savings associated with the latest advanced and forthcoming water heating technologies and are they cost effective?

Presentations were based on these desirable characteristics for a high-efficiency water heating system:

- Long lifetime
- Reliable operation
- Dependable energy savings
- Ensured combustion safety
- Cost effectiveness.

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Water Heater Replacement Field Study Leading to Tankless Water Heater Option; Ben Schoenbauer
Space conditioning loads are typically the largest energy use in residential homes. Both new construction and existing homes are becoming tighter and better insulated to reduce this usage. Thus, the water heating energy usage becomes a bigger part of the energy use in a home, and water heating is typically very inefficient. Additionally, tightening homes increases the combustion safety risks associated with natural draft water heaters. Recent studies indicate that tankless water heaters can solve both of these issues. Non-condensing tankless water heaters can save 25%-50% of a home's hot water energy bills. A condensing model can save up to 60%. Tankless water heaters are power vented and most models have sealed combustion, reducing the dangers of back drafting in a tight, well insulated home.

In retrofit applications there are a wide range of install costs for tankless water heaters. In the best cases, tankless units can be installed for $2500, up to around $5000 in homes with difficult installations. In new construction (or in a retrofit application where a power vented water heater is required) the incremental costs can be significantly reduced. In these homes, a non-condensing tankless water heater can be installed for about the same cost as a power vented tank type water heater (models with an EF of 0.60-0.65 are typically installed). A condensing tankless water heater can be installed for $300 to $500 incremental cost.

The largest implementation issue for tankless water heaters occurs in retrofit installations. Tankless water heaters operate in such a different manner than the storage water heaters they are typically replacing, installs can be difficult. Changing gas lines, locating the intake air and exhaust pipes, installing a condensate drain pump, altering the plumbing pipes to connect to the new water heater, and moving the location of the water heater can all add cost and time to an installation.

Performance of Gas-fired Water Heaters in a 10-home Field Study; Dan Cautley
The Energy Center of Wisconsin recently performed a study of gas-fired water heater performance in 10 homes. In each home, the performance of an existing atmospherically vented water heater was monitored for a period of months, after which each water heater was replaced with a power vent or tankless unit with continued monitoring. Monitoring included water and energy use, the volumetric flow of room air through the venting system, and indicators of vent spillage. Savings for power vent and tankless water heaters were estimated at about $20 to $70 per year at 50 gallon per day hot water loads. The loss of conditioned air through an atmospheric venting system adds an estimated typical space heating load of 9 therms per year in a Wisconsin climate zone. Combustion products spillage is quite common, but usually corrects itself within a few minutes. In addition to cost, other considerations in the selection of a water heater technology include total hot water load, the need for a chimney for other appliances and/or a chimney liner, household experience with running out of hot water, the performance of tankless systems in providing continuous hot water at a regulated temperature (including the specific problem that dishwasher operation may not trigger tankless water heater burner operation), and combustion safety in some cases.

Cost-Effective Water Heating Solutions; Marc Hoeschele
Considerable data has been collected in recent years on the performance of advanced gas water heaters and the newly emerging heat pump water heaters. The data can be used to characterize performance under various applications and usage scenarios, recognizing that water heater recovery load magnitude and use patterns have a significant impact on seasonal operating efficiency. Future residential water heating loads will likely decrease as appliances, fixtures, and distribution systems become more efficient. The ARBI team has recently completed guidelines that identify cost-effective water heater solutions based on load, climate, utility rates, rebates, and estimated incremental cost. With this information, the guidelines inform the user on the cost effectiveness of various advanced water heater solutions.

Expert Comments and Recommendations
Technical solutions without economic viability don't make it in the market. BA works to evaluate performance and cost benefits and create guidance for the industry on whether innovations are ready for "prime time," both in practice and in the market. The following guidance was given regarding the current state of high performance hot water systems:

- At this time, high efficiency gas water heating systems may not be worth the extra cost, especially in warm climates with higher ground water temperatures and lower hot water heating loads. HPWHs may have very favorable economics in areas with high electric rates and mild climates.
- Water heating efficiency improvements can contribute to whole-house energy savings if incremental system costs can be reduced to reflect incremental energy savings.
- Installed cost relative to standard systems are still too high. This may have to do with familiarity by plumbers, local competitive pricing, and lack of economies of scale. Cost trends with certain systems are headed in the right direction. Additional research is required to standardize and reduce installation costs.
- International markets are more successful because of economies of scale and desired use in space-constrained applications.
- There is a need to look at systems as a whole, including distribution. System interaction with whole house is not entirely understood and accounted for.
- Concern about carbon monoxide problems, which are caused mainly by undersized vents and lack of combustion air.
- On-bill financing is an important technique for improving water heating efficiency, since many cannot afford to pay the incremental cost for efficiency upfront.
- Solar water heating systems look most promising for multifamily applications, since the loads are higher and a central system offers some cost savings relative to a single family system.
- Point of use water heaters may be a good application for small loads located far from the water heater.
- If you can't replace the water heater, look to load reduction options like low-flow fixtures and more efficient distribution systems as additional alternatives to achieve energy savings.

Issue 5 – How Much Insulation is Too Much?

Background
In this session, presenters addressed this question:

How do we define the cost-effective limit for improvements in enclosure efficiency?

Presentations were based on these desirable characteristics for solutions for determining the cost effectiveness of efficient enclosure systems:

- Comparison of cost savings to cost of grid-supplied energy
- Comparison of cost to finance energy upgrades to reductions in operating cost
- Comparison of cost of efficiency savings to the cost of savings from renewable generation

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Decision-Making Approaches for Enclosure Insulation Levels; John Straube
As the market becomes capable of delivering almost any range of enclosure R-value, making the decision of what R-value to specify has become more important. To avoid squandering resources and the need to retrofit a home again in the near future, a robust decision-making process is needed. This session presented the critical flaws with most economic models (highly uncertain cost inputs, no non-economic inputs) used in making this decision as well as alternative approaches (such as minimum thresholds, comfort and durability requirements, and marginal cost evaluations). Although more refined decision-making is the most common approach used to select enclosure component R-values, such methods are poorly understood or researched, and more study is required to ensure robustness.

Optimizing High Levels of Insulation; Ren Anderson
The residential efficiency marketplace can be very frustrating if you are a diligent comparison shopper interested in getting the most bang for your buck. Is doubling your wall R-value really a better investment than buying that new 200 mpg motorcycle? Is living good better than living the good life? While perfect answers to life's persistent questions may not always be possible, consistent information about the core cost/performance tradeoffs associated with different efficiency investments can provide an excellent starting point for making informed decisions about the relative value of the different energy choices leading to the development of high performance homes.

Cost Analysis Approach for Codes; Todd Taylor
The U.S. Department of Energy has established a goal of 50% improvement in the 2015 International Energy Conservation Code (IECC) relative to the 2006 IECC. The DOE, through its Building Energy Codes Program, is developing code change proposals to increase the code's efficiency cost effectively. Toward that end, the DOE has developed a residential energy and cost analysis methodology. The methodology includes single and multifamily prototype building definitions for energy analysis, energy simulation assumptions and rules, an efficiency measure cost database/repository, and an economic assessment protocol. The economic assessment protocol results in three evaluation metrics applicable at various levels of geographic aggregation: life cycle cost, consumer cash flow, and simple payback. This presentation discussed the development and public vetting of the methodology, described its key characteristics, explained how the DOE will apply it to develop its own code proposals and evaluate the proposals of others, and discussed its use in evaluating new codes to assist states in their code adoption processes.

Expert Comments and Recommendations
BA experts agree that the question isn't how much insulation is needed, but how much thermal control is needed? To answer this question, we must consider thermal bridging, thermal mass, and air leakage. There are minimal levels of thermal control needed for comfort and condensation reduction, but standards outlining optimal levels of insulation are currently lacking. The following guidance was provided on how to evaluate optimal levels of insulation, in the context of overall envelope performance:

- Insulation performance is currently suboptimal due to thermal bridging and air leakage; installation must be addressed in addition to insulation levels.
- Homeowners should consider the price of energy over the life of the mortgage (25 year) and heat loss relative to insulation value. There is a declining rate of return. To understand current investment in insulation, you need understand future savings to current costs.
- Need to consider trade-offs and look at cash flow—mass market penetration requires lowest capital cost option.
- There are some mixed markets where code minimum requirements make sense and exceeding requirements does not, and others where there are huge opportunities for increased insulation (hot humid, hot dry, cold). Best practice guidance by market would be useful.
- Codes might need to evolve from prescriptive to performance/house-specific and may need to address installation quality. Payback information by climate would be useful to states.

Issue 6 – Do Codes and Standards Get in the Way of High-Performance?

Background
In this session, presenters addressed this question:

What gaps and barriers in codes, standards, and rating systems limit achievement of 50% homes?

Presentations were based on these desirable characteristics for solutions resolving gaps and barriers in codes, standards, and rating systems:

- Identification and documentation of building science driven risks and associated costs
- Solution description in a form that can be adopted by consensus technical committee
- Documentation of solution benefits.

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Challenges with Existing Home Mechanical Systems Codes: Examples from Florida; Janet McIlvaine
Researchers have worked with affordable housing partners in 80 Florida retrofits in foreclosed homes ranging in efficiency improvement from 6% to 60%. All of the houses had mechanical systems with one centrally located return. The scopes of work that partners develop to solicit bids generally include language stating that all work shall be done in compliance with prevailing codes. Florida residential codes have absorbed building science strategies to improve whole house performance and reduce risk of building failures related to mismanagement of air, heat,

and moisture transport. For the mechanical system, these manifest as requirements for system sizing, design, and component selection; passive return air pathways; duct construction and sealing; avoidance of building cavities for air transport; and access around air handlers. These apply to all new homes, but not existing homes. This missed opportunity to improve system and whole house performance usually does not arise more than once in a decade. Since completion of the field study, researchers have worked with three partners to incorporate specific, code-parallel language into bid documents to ensure new construction standards are met, and documenting risks and barriers associated with requirements which would preclude widespread implementation.

Prescriptive Codes: A Cure or A Curse?; Pat Huelman
Historically, most residential building codes and standards have been prescriptive-oriented. While they may be simpler to implement and easier to verify, they have difficulty dealing with complex, dynamic, and interactive systems, such as those in high performance houses. They also tend to be written around current technologies and practices. This approach has frequently led to overly conservative and restrictive solutions. Ultimately, it does not support breakthrough or leap-frog technologies. And, in the end, there are limited assurances that the desired performance outcomes are achieved.

Impact of Codes on Potential PVC Duct System Solution; Duncan Prahl
Thin wall polyvinyl chloride (PVC) pipe is inherently a desirable material for short-run, low-volume air distribution systems in small diameters (4 inches). It is very cost competitive with sheet metal, is easy to cut and assemble in the field, and combined with solvent welding creates inherently airtight joints. In 6-inch diameters, polyethylene (PE) flexible corrugated pipe (used commonly for drainage) is cost competitive with standard insulated flex duct, is less prone to crushing or kinking, and would have a significantly longer projected service life. The I-Codes (IRC 2012 Section M1601.1.1; IMC 2012 Section 603.5) indicate ducts shall be constructed with Class 0 or Class 1 duct material and shall comply with UL181. UL Class 0 are air ducts and air connectors having surface burning characteristics of zero; UL Class 1 are air ducts and air connectors having a flame-spread index of not greater than 25 without evidence of continued progressive combustion and a smoke-developed index of not greater than 50. PVC and PE do not meet both of these requirements. Presumably, Class 0 or Class 1 duct is required so that, in the event of a fire and the ducts are burning, flame and noxious smoke will not be actively transported throughout the building. If this is the intent, then code language could be written that allows ducts to be of any material provided that the HVAC system was interconnected to a smoke alarm system so that when the smoke alarm was activated, the air distribution system would shut down.

Expert Comments and Recommendations
BA experts are highly engaged in the code development process and have extensive experience working in the field to understand code barriers to the use of new systems and design strategies. The following observations were made about codes and standards and their relationship to high performance construction techniques:

- Fundamentally, in this order, codes should at least:
    - Not require the wrong thing

- Not prevent the right thing
- Discourage the wrong thing
- Encourage the right thing.

- Current code is not always the problem, often it's the interpretation of code. Better guidance for builders and code officials based on BA research results may be all that is needed in many cases.
- Prescriptive codes are not well suited to complex, dynamic high-performance systems. Prescriptive codes are for single measures, performance codes are required for homes built with true building as a system/building science approach. Need performance-based code. However, it is still critical to ensure house-as-a-system building science measures because better insulated and tighter construction assemblies can have less tolerance for drying, and more risk for combustion safety issues.
- New construction codes are reasonable. Codes for existing construction are challenging.
- Sometimes, code isn't the issue; it's the sub-organizations referencing the code and their standards (i.e., BPI, ASHRAE, ANSI, ENERGY STAR, LEED).

Issue 7 – What are the Best HVAC Solutions for Low-Load, High Performance Homes?

Background
In this session, presenters addressed this question:

What components and controls are required to implement the "perfect," cost-effective, production-level low-load space conditioning systems for all major U.S. climate regions?

Presentations were based on these desirable characteristics for space conditioning system solutions:

- Uniform distribution of comfort and ventilation air
- Easy adaptation of system components for different climates, allowing for standardized system design approaches across all climates
- Can be designed to meet the capacity requirements for 50% homes
- Occurrences of lengthy episodes of high indoor relative humidity (RH) during periods with low sensible loads limited
- Meets current mechanical code
- Minimizes increases in labor and material cost compared to standard systems
- Places ducts and air handlers in conditioned space
- Based on actual vs. rated performance characteristics
- Is flexible enough to meet a broad range of individual comfort preferences.

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Sensible and Latent Load Control with Centrally Ducted Variable Capacity Space Conditioning Systems in Low Sensible Load Environments; James Cummings
Air conditioning (AC) systems are typically sized to meet the maximum cooling load during the hottest period of the (nearly) hottest day. Therefore, during 90%+ hours of the cooling season, the AC system is significantly oversized. It would be useful if the AC system could modulate its cooling capacity so that it remains operating for extended periods rather than cycling off after short "on" periods. This can improve both system efficiency and latent cooling performance. In homes with low sensible loads, latent cooling loads from induced ventilation and from internal moisture generation (e.g., respiration, perspiration, cooking, showers, dishwashing, plants, etc.) can exceed the latent cooling capacity of the AC system. It would be useful, therefore, if the system could modulate its sensible heat ratio (SHR) so that a reduced level of sensible load can produce an increased latent cooling capacity. A new generation of variable capacity AC and heat pump systems can satisfy both of these. One such product varies its capacity from 34% to 100% of maximum capacity and also has thermostat control algorithms, which modulate cfm/ton rates and allow greatly reduced SHR. These products can provide SEER ratings in the range of 20 to 24.5, which can allow further enhancement to the already high energy efficiency of the house (or other building).

HVAC for Low-Load Homes; John Straube
Homes with very low heating and cooling demands are becoming common as a result of improved enclosure characteristics (insulation level, airtightness, and solar control) as well as changing housing characteristics (more multifamily housing, smaller housing size). Although this offers the potential of energy and cost savings, the range of optimal HVAC solutions begins to shift. In essentially all cases, the demand for domestic hot water becomes a larger proportion of the total energy load. This presentation reviewed the benefits, limitations, and caveats of using a number of systems, from air- and water-source heat pumps to mini-splits and tankless, instantaneous water heaters.

Dual Integrated Appliances (Combi Systems); Ben Schoenbauer
In new and existing homes, improved building envelopes have led to decreased space heating loads. At the same time, high efficiency water heating product lines with higher firing rates are being installed in an increasing number of homes. Instead of a separate furnace and a water heater, a packed combination system can be used to meet both space heating and water heating loads with a single, high efficiency thermal engine. These power or direct vented systems help solve the combustion safety issue. In addition, systems are now available that include whole house ventilation and advanced control of distribution air flow, water circulation flow, and temperature set-points, which can further improve efficiencies.

Minimized Space Conditioning Distribution Strategies for Low-Load Homes; Dave Stecher
The goal of this research is to define the characteristics of minimized space conditioning distribution strategies for low-load houses (retrofit or new construction) that meet industry comfort measures. The IBACOS team will assess the ability of each system to meet existing standards for temperature uniformity and stability. In the Fresno, California, Retrofit Unoccupied

Test House (hot-dry/mixed-dry), IBACOS installed a central space conditioning unit with no ducted distribution. The system as configured represents the characteristics of the lowest-installed-cost market-available space conditioning equipment. Complete elimination of distribution ductwork is a key factor in the low installed cost of the system. The primary implementation issue with such a system is the risk of under-conditioning rooms that can be separated by doors from the space in which conditioned air is supplied. To help combat this issue, IBACOS had market-available, passive high- and low-wall vents installed in interior partition walls to enable air transfer to these rooms when the partition doors were closed. In the winter of 2011–2012, IBACOS performed computational fluid dynamics and other mathematical modeling to complement data collected from the test house. Field test data indicate the inability of these passive high- and low-wall vents as installed to provide sufficient air transfer to meet existing standards for temperature uniformity and stability. Due to the inability of this lowest cost strategy to meet existing standards for temperature uniformity and stability, the next least-cost options are being determined so that their performance will be evaluated. This field work and corresponding mathematical modeling will be used to draw larger conclusions for a variety of climatic regions and house configurations.

Expert Comments and Recommendations

The BA program evaluates the complete interactions between building systems, whole-house design, and manufactured products, and partners with industry to encourage the development of new systems to address the novel challenges of high performance homes. Such is the case with new HVAC systems to deal with the "problem" of extremely low loads. In lieu of new products to address the issue, BA experts provided the following guidance:

- In some cases, appropriately sized systems can cost more, particularly for high performance homes. This is an area where the new construction market can help to achieve cost reductions via increased demand and corresponding economies of scale. Innovations in this area will not be driven by the replacement of retrofit market.
- Anecdotal evidence from manufacturers says it is more expensive to build a smaller furnace and perceived demand isn't great enough to instigate the production of these products. The problem isn't a technical challenge, but a market challenge.
- Decent heating solutions are available; the problem is air conditioning. Sensible and latent load control can be achieved with centrally ducted variable capacity space conditioning system in low sensible load environments.
- Some believe the building science community should attempt to meet latent control objectives first with high efficiency A/C systems that are optimized for RH control and implement dehumidifiers only as a last resort because they are a very energy inefficient means for providing latent cooling (the most energy efficient dehumidifiers have a space heating COP of about 2.9).
- Need smaller air handling units for low load homes and manufacturers are simply not making them.
- Combination systems (dual integrated appliances) are good solutions.
- Minimized space conditioning distribution strategies for low-load homes are needed along with good design guidance.

- Should minimize the need for supplemental dehumidification but this integrated function can increase equipment cost.
- Need to consider domestic hot water when looking at low load HVAC as burner capacity is comparable. If a condensing hot water system is used, the space conditioning system must be designed to ensure a low enough return temperature to maintain condensation.
- Distribution systems pose a problem as they must be designed for larger capacity even if not needed—we need non-standard equipment.
- Ductless systems may work in smaller homes, but don't address need for ventilation, filtration, or mixing.
- The multifamily market is an excellent place to start as there's a real market opportunity there for manufacturers and this may drive technical solutions that can be used in the residential market.

Issue 8 – Better Technology Doesn't Always Win—How Can We Ensure That Doesn't Happen to High Performance Homes?

Background
In this session, presenters addressed this question:

What market delivery solutions are most effective in communicating and validating the value of high performance home innovations?

Presentations were based on these desirable characteristics that document market value:

- Value to key participants in the value chain
- Acceptance of innovation by experts and market leaders
- Incremental whole house benefits that exceed incremental costs
- Innovation that meets code and warranty requirements
- Implementation guidelines compatible with production builder construction practices
- Program participation that enhances builders' business metrics.

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Winning with Co-opetition; Emanuel Levy
Conventional wisdom is that the best strategy for getting better technologies accepted in the market is to find a business partner with the goal of using the technology to be more competitive, capturing market share. This is the thinking that shapes how many in the research community approach new technology development. This presentation suggested that having a business partner motivated by competitive advantage is, in many instances, counterproductive, and may stymy commercialization. Rather than appeal to the competitive instincts for industry, the

presentation argued that creating a cooperative research group of otherwise competing companies—an approach referred to as "co-opetition"— is a better formula for winning in the market and may ultimately provide a more appropriate structure for spending public funds.

Communicating the Value of EE Research Results; Darren Harris
Ensuring that the value of high performance home innovations is not lost or downplayed is critical to getting BA research results and innovations accepted and broadly implemented. However, communicating and validating innovations is not always as simple as it might seem, particularly when there are multiple stakeholders involved. Successfully doing so requires consideration, planning, and communication. A variety of communication tools can help to make sure the value of the innovations hits the right audiences and gains the desired attention. Web content, video, articles, white papers, and case studies can all be used as market delivery solutions. However, a combination of these types of communication will provide the best audience coverage. Media partnerships can help broadcast the message across multiple channels at a minimal cost. This presentation looked at developing successful partnerships with local stakeholders and media outlets to ensure broad acceptance of BA research results.

Successful Marketing Practices of 30% Community Scale Builders; Stephanie Thomas-Rees
Merely claiming energy use reduction is not enough for builders to sell a high performance product. Successful builders have implemented strategies that can be outlined in three steps: 1) show the customer that the features have benefits, 2) use show-and-tell type illustrations or mock ups to create a "hands on," bonding experience with the customer, and 3) develop/enlist incentives, promotions, programs, and third party certifications that are offered to the customer. Recorded home sale statistics with respect to specifications of both BA builders and non-BA builders were presented and further support that without advertising, marketing, or expending adequate resources to accompany their "value" added features, success is not realized.

Expert Comments and Recommendations
The following key comments and recommendations on the issue were gathered during the meeting:

- Encourage cooperative agreements between builders and have them use their collective purchasing power to convince manufacturers to produce suitable products, where they don't already exist.
- Start with community-scale in mind, using resources like local government programs and investors. Use obvious cash flow benefits up front in discussions. More energy efficient homes mean lower bills for struggling families, higher likelihood of loan payback, etc.
- Use marketing and sales techniques effectively, don't discount them.

Issue 9 – What are the Best Ventilation Techniques?

Background
As building envelopes are built better, key innovations will be for systems that can provide improved indoor environmental quality (IEQ) robustly and with low energy impact. To do so, such systems must be responsive not only to occupants' needs but also to the building and to

external conditions such as weather, outdoor air quality, and utility needs (e.g. smart grid). However, there is a lot of variation in expert recommendations.

In this session, presenters addressed these questions: How do we address ventilation in all climates? What is the best compromise between occupant health and safety and energy efficiency? What is the most cost-effective approach? How much to ventilate? When to ventilate? What about ASHRAE 62.2? Do we agree?

Proposed Solutions
Presenters developed the following abstracts prior to the meeting and provided the following recommendations regarding their topic:

Emerging Innovations for IEQ; Max Sherman
As building envelopes are built better, key innovations will be for systems that can provide improved indoor environmental quality (IEQ) robustly and with low energy impact. To do so, such systems must be responsive not only to occupants' needs but also to the building and to external conditions such as weather, outdoor air quality, and utility needs (e.g., smart grid). The Residential Integrated Ventilation Energy Controller (RIVEC) was used as an example of such a potential technology. RIVEC modifies the ventilation rate of a home based on internal and external drivers to optimize energy use while still providing the same effective ventilation. Other, less developed IEQ innovations were also mentioned such as the development of high performance range hoods and new dehumidification systems.

Thoughts on ASHRAE 62.2; Joe Lstiburek
ASHRAE 62.2 does not encourage good ventilation systems and, in fact, promotes inefficient ventilation systems that result in poor indoor air quality. A critique of exhaust, balanced and supply ventilation systems and the basis of source control and dilution of contaminants are presented in a historical context. Recommendations on moving forward are provided.

Expert Comments and Recommendations
This session raised many interesting questions, which were discussed in depth by experts. Research is ongoing in order to provide more justification for either side of the argument. The following presents raw notes from the session, capturing our experts' varying positions on ventilation:

Max Sherman

- Providing good indoor environmental quality is what buildings are all about
- Better buildings need ventilation because air doesn't flow without it
- Failures to ventilate will become more of a problem as buildings get bigger
- ASHRAE 62 is the only national consensus standard document there is - follow 62.2, resistance if futile. Makes no sense for someone to suggest guidance that is contrary to 62.2
- Ventilation is more like a structural requirement, not like comfort, should not be up to occupants
- A good solution is a double duty fan: local and whole house exhaust

- Have a good range hood, no standards, but cooking may be biggest source of contaminants
- If we could rate range hoods as to how good they capture pollutants, we could do good ventilation there
- Design for a good filter (MERV11); can have significant pressure drops
- Exhaust fans tend to work—they are low cost, don't tend to clog, and exhaust contaminants directly
- Not a market readiness issues w/ 62.2, perhaps some w/ next step (re: range hoods)
- More consistent ventilation w/ exhaust because it's unbalanced, less sensitive to enclosure leakage than balanced systems
- Depressurization in super-tight houses, exhaust only does not control where air is coming from (not problem in leaky house)
- No particular advantage of supply-only systems in hot humid climate zones
- In extreme climates, an energy recovery ventilator (ERV) or heat recovery ventilator (HRV) can be cost effective if done right
- Technologies not quite ready for "prime time" include:
    - Automated range hoods
    - Chemical air cleaning
    - Smart ventilation controllers
    - IAQ controllers
    - Ultralow pressure drop filters (nanotech development under way).

Joe Lstiburek

- Don't promulgate standards that can't be achieved by reasonable people doing reasonable things
- Passivhaus standard of 0.6 is excessive: People don't realize how difficult 0.6 is. We've built houses to 0.5 with balanced vent, but dryer exhaust doesn't work, bath exhaust doesn't work.
- To get to 3 air changes per hour (ACH) you follow the thermal bypass checklist. A little more work, "not an extraordinary amount" and you get to 1.5, but not sure it makes sense.
- Built tight (3 ACH), ventilate right—production level
- Ventilate right:
    - Balanced, energy recovery, distribution, source control
    - Dilution not solution to indoor formaldehyde pollution
- Worst: leaky, with exhaust ventilation and no distribution

- Only benefit is this (exhaust only ventilation) is that it's cheap, if you want cheap put in that double duty fan.

Other observations:

- 10 minutes of vent distribution adequate in Joe's experience w/ exhaust
- May be able to couple single-point exhaust with some supply
- Multipoint exhaust is a step up from single point
- 100 cfm exhaust vs. 100 cfm balanced exhaust will have diff effectiveness
- Recommend humidity range: 25% RH winter, 70% RH in summer (current 20-60, arbitrary and capricious)
- New ASHRAE change impact is from 50-90 cfm (7.5 cfm + 0.1 to 0.3 cfm/sq ft)
- BSC designs systems to meet 62.2, regularly at 1.5 times, but cx systems at 60% because they are balanced with distribution, then give control to occupant (structural analogy is wrong, sizing of HVAC is correct analogy, standard procedure to size then let occupant control)
- Joe believes 62.2 discourages good systems currently
- Exhaust system has to operate at 2x rate as balanced system
- Haven't seen good studies on pollutants on house
    - Need $20-30 million for big study in American houses and health effects
    - Current pollutant numbers aren't based on real science.

Discussion between panelists and the audience:

- There was agreement that a 3 ACH is not "too tight"
- Does not vary by climate
- So easy for production builder to get to 3, don't argue about it, just do the checklists.

Sam (facilitator): We have two very different expert opinions on ventilation guidance.

Joe: Didn't say exhaust only 62.2 doesn't work, just not as good. Both systems will work, questions of cost, effectiveness, and energy impacts (nobody dies, nothing rots, we're ok).

Max: Don't agree with Joe's ½ number, we have data to show that, he proposed to 62.2. Infiltration credit: originally in, wanted to get back to no credit standard (originally at 0.3 ACH).

In response to the 0.1 or 0.3 sq ft requirement:

In Quebec city: majority of community thought infiltration was unreliable.

7.5 + 0.1/sq ft = 10-12 cfm, Max was concerned because people expect ~15 cfm, workaround is 0.2 infiltration credit

- Until the HERS industry started blower doors showing the infiltration credit wouldn't apply according to Sherman-Grimsrud model, so infiltration credit won't apply.
- If credit goes away, then need to increase vent rate.
- Some people happy credit went away, but not happy with number.

Joe: I believe infiltration is unreliable and should not be counted, Max does.

Joe: Annual average exposures are the wrong way of doing things.

Sherman-Grimsrud good for average energy, not for determining indoor air quality.

- Both saying to follow 62.2, all the systems we've proposed will work.
- "Have not done the necessary homework as an industry" to determine what the rates need to be.

Failure modes:

Blockage of supply, ERVs in wet rooms.
Blockage a real concern, make sure inlet is inspectable and fixable.

Joe: Exhaust systems don't know where air is coming from, which I think big deal, need to think about filters on supply/balanced.

- What is the best option for clean environment: place where you can pick where air coming from and can filter, or place where you have no idea? Systems require maintenance.
- Most reliable approach, connect to your AC or furnace or better yet, figure out a way to connect to your hot water!

Joe: If I was a production builder I wouldn't do ERV, do exhaust w/ mixing our OA to return side w/ ECM motor mixing a big deal because it homogenizes comfort.

Joe: In hot humid climate, Joe thinks already at edge at 7.5 + 0.1/sq ft, we're over and need dehumidification.

Joe: What about passive vent options? We don't have a history of this, done in Europe. Worth exploring and researching. Need sustainable vent systems without lots of fan power or when power goes out. Radon: don't want to depressurize, need to consider other things.

3 Stakeholder Recommendations for Building America

Meeting participants had the following recommendations for additional support from the BA program:

Issue 1 – How Do We First Do No Harm with High-R Enclosures?

- Need solid builder guides, specific solutions guidance; codes cannot do it all. Should include a checklist or tools to conduct an if/then cost/tradeoff analysis of varying energy measures.
- Update vapor retarder guidance for a broader range of enclosure systems so that innovative systems can be used without risk of failure.

Issue 2 – What Emerging Innovations are the Key to Future Homes?

- BA needs to verify performance of highly insulating primary windows and low-e storm windows. Right now, it is hard to get the cost down because there is a lack of regional distribution.
- Study shading impacts on cooling; interior shades vs. exterior sun shade options.
- Evaluate how ductless hydronic compares to low cost heat pumps with high seasonal energy efficiency ratio (SEER) and high heating seasonal performance factor (HSPF).
- Create guidance on how to deal with historic window replacement.

Issue 3 – HVAC Proper Installation Energy Savings: Over-Promising or Under- Delivering?

- Refrigerant systems are complex—true problems are often difficult to identify. There are few simple and reliable diagnostic procedures for refrigerant charge and there is poor quality of diagnostics due to uncalibrated test equipment, poorly trained technicians, and poor procedures. New approaches are needed.
- Could develop a checklist and label to certify proper equipment installation.

Issue 4 – Are High-Efficiency Hot Water Heating Systems Worth the Cost?

- Evaluate smaller units to support smaller loads (smaller water heating loads from energy star appliances and low flow shower heads and water faucets).
- Emerging low-cost solar water heating systems look promising for multifamily applications. Installation costs and maintenance costs are still big barriers to broad use of high performance systems. Innovations in these areas will provide large benefits.

Issue 5 – How Much Insulation is Too Much?

- Need recommended Best Practices Guidance based on current and future costs.

- Additional innovations are required to reduce the cost and increase the reliability of fasteners for cladding over insulating sheathing and high performance approaches to 2x4 framing systems.

Issue 6 – Do Codes and Standards Get in the Way of High-Performance?

- BA to continue to inform codes of validated, cost-effective, low-risk techniques to save energy.
- Could produce a Building America guide for code officials. This guide would show code officials how novel approaches to building science do not go against code. The Measure Guidelines and Strategy Guidelines already provide a good foundation for this.
- BA code commentary to coordinate with ICC.

Issue 7 – What are the Best HVAC Solutions for Low-Load, High Performance Homes?

- BA should work with multifamily developers and work with manufacturers to make that important connection.

Issue 8 – Better Technology Doesn't Always Win—How Can We Ensure That Doesn't Happen to High-Performance Homes?

- Be mindful of the impact of compelling technical sales information and tools to communicate value of energy efficiency and innovation to contractors and their customers.

Issue 9 – What are the Best Ventilation Techniques?

- Complete additional work to gain clarity, consensus, and guidelines.

4 Presenter Biographies

Dr. Ren Anderson manages the NREL Residential Research Group, a crosscutting team of 30 scientists and engineers that evaluates the impacts of innovative energy systems on residential energy demand. Ren is a recipient of patents focusing on advanced heat and mass transfer devices for building and vehicle applications and has received several awards, including the President's Award for Exceptional Performance in 1993, Outstanding Accomplishment Award for the Thermal Test Facility in 1996, and an NREL Director's and DOE EERE Assistant Secretary's Award in 2008 for his support of rebuilding efforts in Greensburg, Kansas.

Richard Baker supports and leads projects that help homebuilders prevent and control risk. In this role at IBACOS, he conducts proactive, in-field quality assessments for builders, produces reports on the best and worst practices, and compiles details to enable builders to make improvements. He has studied green construction practices through the U.S. Green Building Council (USGBC) and National Association of Home Builders (NAHB). He is an NAHB Certified Green Professional and an Accredited Verifier for the NAHB National Green Building Program. Rich received his master's and bachelor's degrees in architecture from the State University of New York at Buffalo.

Dan Cautley manages and conducts research investigating the energy performance of buildings at the Energy Center of Wisconsin. His work focuses on the field performance of building systems—walls, windows, foundations—and mechanical systems and appliances.

James Cummings has worked with Florida Solar Energy Center (FSEC) for over 20 years and has extensive experience lecturing, training, and developing training materials and programs on the topics of energy use, air flows, duct leakage, diagnostic methods, and indoor air quality. He developed diagnostic test methods and protocols for characterization of airflows, building air barriers, and building zone pressure mapping and carried out field and lab research identifying the nature, extent, and consequences of duct leakage and other forms of uncontrolled air flow in residences and commercial buildings.

Tim Hanes has been working in the energy efficiency world for the past 14 years. He is the vice president of ESI, Inc., as well as a partner of Cenergy, LLC, the largest home energy consulting firm in the state of Iowa. As a RESNET certified rater, Tim specializes in the whole house approach to energy efficiency. With the NCI Air Balancing certification, Tim has been able to implement HVAC system performance testing and analysis into Cenergy's service offering. Tim is regularly consulted by industry professionals on his approach to field testing and analysis of HVAC systems. He is a certified geothermal installer and a member of the Iowa Ground Source Heat Pump Association (IGSPA). Tim is also a trainer for NCI and is frequently asked to speak at energy-efficiency related conferences and events around the country.

Darren Harris has more than 15 years of experience in marketing, business development, and public relations in the building products industry. His experience overseeing operations for a startup media company, his expertise creating and developing online demonstration projects, and his skill in forming partner-ships with government agencies, building product manufacturers, and associations makes him a valuable resource to clients. Darren has prior experience as public relations manager for The Engineered Wood Association trade group and worked as a reporter and editor at McGraw-Hill's Construction Information Group in Seattle.

Marc Hoeschele, PE, is an engineering manager at Davis Energy Group (DEG). He specializes in technology evaluations, systems monitoring, and California Title 24 codes and standards development. Marc has developed a research emphasis in domestic water heating and advanced residential space conditioning and currently heads BA's Hot Water Standing Technical Committee. Marc joined DEG in 1984 after earning a master's degree from the University of California at Davis and a bachelor's degree in civil and environmental engineering from Cornell University.

Pat Huelman is an associate professor in residential energy and building systems in the Department of Bioproducts and Biosystems Engineering at the University of Minnesota and serves as coordinator of the Cold Climate Housing Program. He is the lead faculty for the Residential Building Science and Technology undergraduate degree, a principal investigator for hygrothermal testing at the Cloquet Residential Research Facility, and is directing the NorthernSTAR Building America Team.

Vladimir Kochkin: As Director of Applied Engineering for the NAHB Research Center, Vladimir Kochkin oversees engineering research programs covering structural, environmental, and energy performance of residential construction. He also manages the ANSI process for the development of the National Green Building Standard. He serves on or is active with various building code and standard development committees. Vladimir also manages laboratory testing programs for innovative and conventional construction systems.

Emanuel Levy is President of The Levy Partnership, a building systems consulting firm and the team lead for the Building America Advanced Residential Integrated Energy Solutions (ARIES) consortium. He also serves as the Executive Director of the Systems Building Research Alliance (SBRA). Since 2000, SBRA has served as the U.S. EPA's national quality assurance provider for the ENERGY STAR manufactured and modular home programs, thus far awarding ENERGY STAR labels to nearly 30,000 factory built homes. Mr. Levy has advanced degrees in architecture from Syracuse University and Carnegie- Mellon University. He is a registered architect in New York State, has served as a member of the National Institute of Building Sciences Consultative Council, and is on the board of Next Step, a non-profit organization creating innovative and sustainable housing solutions for low-income families.

Joseph Lstiburek, B.A.Sc., M.Eng., Ph.D., P.Eng., is a principal of Building Science Corporation and an Adjunct Professor of Building Science at the University of Toronto. Dr. Lstiburek received an undergraduate degree in mechanical engineering from the University of Toronto, a master's degree in civil engineering from the University of Toronto, and a doctorate in building science at the University of Toronto. Dr. Lstiburek has been a licensed professional engineer since 1982. Dr. Lstiburek lives and works in Boston. He is an ASHRAE Fellow.

Terry Mapes is a Certified Energy Manager (CEM) who joined PNNL in 2009 and has had a primary role in more than 20 projects. In addition to his role as project manager for the Department of Energy's High Performance Windows Volume Purchase Program, he is currently involved in several projects within the Building Energy Codes Program.

Janet McIlvaine: Since 1990, Janet McIlvaine has been a research analyst at the Florida Solar Energy Center (FSEC) with an emphasis on energy efficiency for affordable housing. Since the fall of 2009, FSEC has been working on deep energy retrofits with local government and non-profit housing entities in central Florida. Partners have achieved 30% or more improvement in HERS Index in over 50 homes.

Garrett Mosiman is a research fellow at the Center for Sustainable Building Research at the University of Minnesota. He holds a bachelor of architecture degree from Rice University and a master's in architecture from the University of Minnesota. Prior to returning to school in 2006, Garrett worked for 10 years as a carpenter, architectural model builder, furniture maker, project manager, and architectural designer in Texas and Minnesota. His primary field of expertise is sustainable materials and their use in durable building assemblies that honor the principles of sound building science. Other areas of interest include light pollution mitigation, urban hydrology, architectural acoustics, and energy efficiency. Garrett has served in many roles at CSBR, with a primary focus on energy efficiency in residential and commercial buildings.

Duncan Prahl has over 11 years of experience at IBACOS assisting builders and developers with implementing high performance housing using Building America research results. His research focuses on process-related barriers in most builders' organizations with the goal of creating new process models for builders. He is a registered architect in New York.

Ben Schoenbauer is a research engineer at the Center for Energy and Environment (CEE) in Minnesota. At CEE, Ben has been conducting research projects dealing with residential and commercial energy efficiency for the past four years, including work as part of the NorthernSTAR Building America team. Ben has a master's degree in mechanical engineering from the University of Minnesota and a bachelor's degree in physics from St. John's University.

Max Sherman is a senior scientist at the Lawrence Berkeley National Laboratory (LBNL) and leads the Energy Performance of Buildings group. He is an ASHRAE Distinguished Fellow and focuses his research on energy and indoor air quality aspects of air inside homes including air tightness, ventilation, infiltration, and thermal distribution.

David Springer is president and co-founder of Davis Energy Group (DEG), a 31-year-old mechanical engineering firm specializing in building energy efficiency. He has managed DEG's participation in the Building America program for 10 years and currently leads the Alliance for Residential Building Innovation (ARBI) team. David has authored 18 papers and articles on energy subjects and holds six patents. He serves on two ASHRAE committees, SPC 152R (residential distribution) and TC 6.5 (radiant heating and cooling). He earned his B.S. from UC Davis in Biological Science in 1973.

Dave Stecher leads IBACOS's research effort in innovative space conditioning strategies for low load homes that are economical to install and provide equal or better occupant comfort than traditional methods. Dave has a bachelor's degree in mechanical engineering and 7 years of experience in low-load building design, implementation, and performance assessment.

John Straube is a principal of Building Science Corporation and a professor of building science in the Civil Engineering Department and School of Architecture at the University of Waterloo, Canada. Dr. Straube has acted as an educator, researcher, consultant, and expert witness on energy efficiency, durability, and IAQ. Current interests include the optimal system design of buildings, sustainable buildings, and moisture problem avoidance.

Z. Todd Taylor is a senior research engineer at the Pacific Northwest National Laboratory, specializing in building energy analysis, residential energy code development, large-scale building energy simulation, and analysis of large energy datasets. For more than 25 years, Todd has developed energy saving building codes including the International Energy Conservation Code, ASHRAE Standard 90.2, manufactured housing energy standards, federal residential standards, and Pacific Northwest regional codes.

Stephanie Thomas-Rees is a research architect in the Buildings Research Division at the Florida Solar Energy Center (FSEC), where she has been involved with high performance buildings research since 2001. She currently is a member of the Building America Partnership for Improved Residential Construction, sponsored by the U.S. Department of Energy, where she conducts research and provides technical assistance to the home building industry to improve the environmental performance. She is a board member of the Florida Green Building Coalition and Green Home Certifying Agent.

Dr. Iain Walker is a scientist at Lawrence Berkeley National Laboratory. He has more than 20 years of experience as a building scientist and consultant, conducting research on energy use, ventilation, moisture, performance simulation, and commissioning/diagnostic issues in residential buildings. His current work focuses on retrofits, zero/low energy homes, and HVAC systems in residential buildings through field and laboratory evaluations, modeling and simulation activities, and standards setting. He is Executive Editor and member of the board of Home Energy magazine. He is the task group leader for ASTM standards committees on building and duct system air leakage and seal-ant longevity. He is an ASHRAE fellow and serves on several ASHRAE Standards committees. He also serves on Building Performance Institute and RESNET Technical Committees as well as the Affordable Comfort conference planning committee and provides leadership and technical input to many local, state, national, and international bodies.

Sarah Widder works at the DOE's Pacific Northwest National Laboratory, where she focuses on the application of technology, standards, and regulations to meet sustainable design, energy efficiency, and greenhouse gas management goals. Some of her current projects involve researching innovative and cost-effective solutions for improving energy efficiency in residential buildings with the Building America Program. She is also helping DOE meet energy efficiency goals through more stringent standards for appliance energy consumption as well as performing analysis to understand the overall sustainability impacts of energy-related choices using life cycle assessment and other sustainability assessment tools.

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