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

BUILDING TECHNOLOGIES PROGRAM

2011 Residential Energy Efficiency Technical Update Meeting Summary Report

Denver, Colorado – August 9-11, 2011

November 2011

Building America
U.S. Department of Energy

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2011 Residential Energy Efficiency Technical Update Meeting Summary Report

Prepared for:

Building America

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Office of Energy Efficiency and Renewable Energy

U.S. Department of Energy

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November 2011

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Unless otherwise noted, all figures were created by NREL.

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, but to address a small segment of key topics that were chosen for the meeting agenda.

PROGRAM BACKGROUND

Building America is part of the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Building Technologies Program (BTP). Building America focuses on conducting the systems research required to improve the efficiency of the 500,000 – 2,000,000 new homes built each year in the United States. With a clear focus on retrofitting, Building America is also working to improve the efficiency of the approximately 116 million existing homes.

Building America research accelerates the development of reliable and effective whole house packages of measures for highly energy efficient new and existing homes that are tailored for each major U.S. climate region. This research can be implemented on a broad basis, while also reducing risks, increasing durability, and providing a reasonable return on investment. These improvements are accomplished through multiscale research, systems development, systems integration, large-scale field implementation and evaluation, and effective communication of key research results and system-based strategies. The near and long term performance targets for Building America have been updated to help guide the energy efficiency of homes past code requirements and current standard practices, as well as to provide technical support for new residential initiatives including the BetterBuildings Program.

Since July 2010, the 15 research and deployment partnerships of the Building America program have begun 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 Building America website for more information about Building America teams, projects, partners and tools: www.buildingamerica.gov.

EXECUTIVE SUMMARY

The ***Summer 2011 Residential Energy Efficiency Technical Update Meeting*** was held on August 9-11, 2011, in Denver, Colorado, and brought together more than 290 professionals representing organizations with vested interest in energy efficiency improvements in residential buildings. This diverse and dynamic team presented research results and identified needs and opportunities for the U.S. Department of Energy's (DOE) Residential Buildings Program. Presenters represented the 15 DOE Building America teams, as well as associated industry partners. Attendees represented a variety of industries, including manufacturing, government, nonprofit, and private sector programs (see Meeting Participants section for a list of attending organizations).

Presenters covered up-to-date research results from dozens of Building America funded projects, including:

- Nationwide Energy Impact of Air Sealing and Ventilation
- Space Conditioning and Ventilation Strategies in Multifamily Buildings
- Hybrid Foundation Insulation Retrofits
- Deep Energy Retrofits for Roofs and Walls
- Condensing Boilers: Optimization of System Performance in Cold Climates
- Hygric Redistribution and Moisture Management
- Retrofit Audit Procedures
- Scalability of Self and Assisted Audits
- Market Realities and Change Management
- Effective Communication of Energy Efficiency Research Results
- Home Energy Score Pilot Results
- Characterizing Energy Efficiency Using Appraiser and Utility Data… and more.

This report provides a summary of the meeting, as well as research results from the Building America Program, as presented in the 25 meeting sessions.

Building America program updates are included in the following presentations:

- Residential Buildings Program, U.S. Department of Energy
- State and Local Initiatives
- Field Test Best Practices Online Tool
- Better Buildings Neighborhood Program Business Models: Lessons Learned

MEETING BACKGROUND

The U.S. Department of Energy's Building America Program holds two public meetings per year:

- The spring ***Residential Energy Efficiency Stakeholders Meeting*** focuses on hearing from building industry stakeholders on their perspective of key issues and needs related to advancing energy efficiency in housing to meet Building America goals and objectives.
- The summer ***Residential Energy Efficiency Technical Update Meeting*** focuses on hearing from Building America program participants about their projects, results, and needs.

The 2011 Residential Energy Efficiency Technical Update Meeting was held on August 9-11, 2011, in Denver, Colorado. The regional diversity of stakeholders attending this meeting provided a broad knowledge base and a catalyst for lively discussions (see Figure 1).

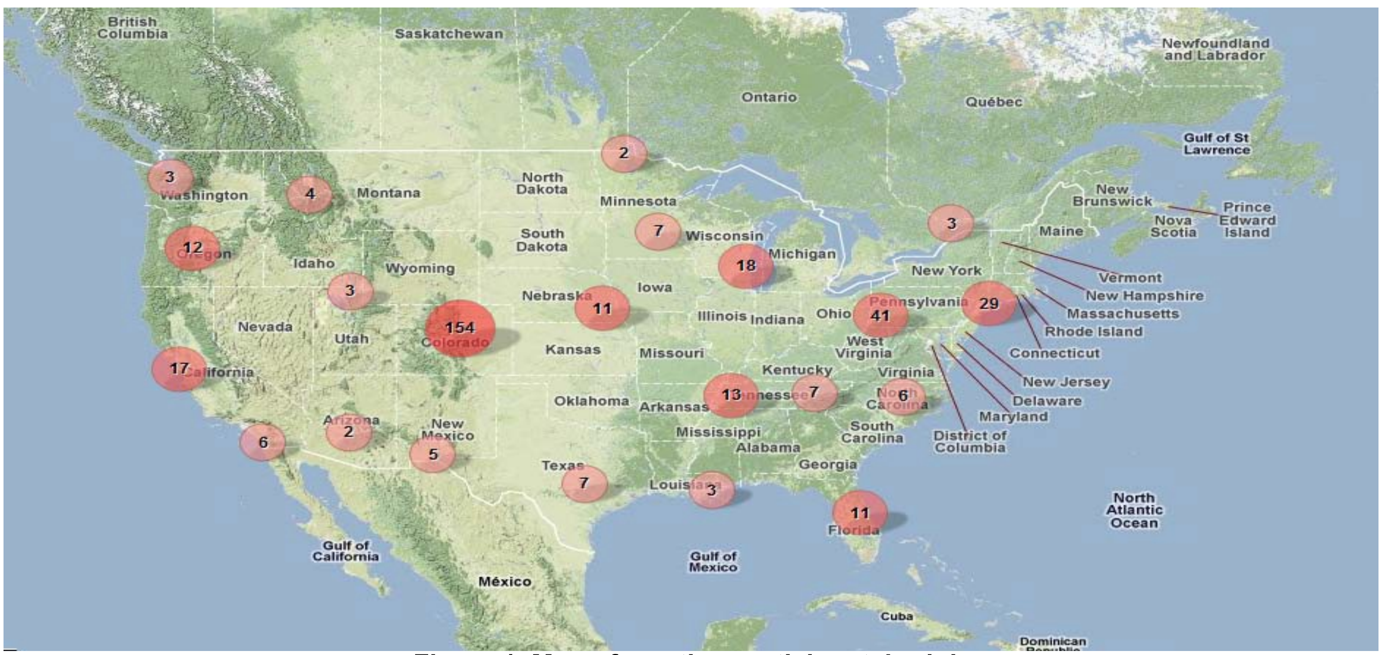

Figure 1. Map of meeting participants' origins

The next meeting in the series is the 2012 Residential Energy Efficiency Stakeholders Meeting, which will be held on February 29-March 2, 2012, in Austin, Texas.

This meeting summary report captures the key gaps and barriers to implementing residential energy efficiency strategies in the U.S. market, as identified in 25 sessions. The meeting brought together more than 290 professionals in the residential research and outreach industries to present on a wide variety of technical and market transformation topics, with the intent of creating a dialogue about research results, successes, challenges, gaps and barriers in the area of residential energy efficiency. To view presentations from this meeting, meeting archives, and future plans, visit the Building America website at www.buildingamerica.gov.

Each session was facilitated by a member of a U.S. Department of Energy Building America research team, with the intent of focusing the outcome of the session on identifying research results, as well as key gaps and barriers associated with the session topics. Feedback from the meeting has been documented in this report to be used to help set future research areas, and to identify technology gaps and barriers that hinder the deployment of high performance efficiency measures in both new and existing homes.

MEETING PARTICIPANTS

A.O. Smith Corporation	JELD-WEN, Inc.
AboutSavingHeat.com	Johns Manville
Apple Energy Group	Johnson Research LLC
Architectural Energy Corporation	KANservation
Architronic	La Mirada Homes
ARIES Collaborative	Lawrence Berkeley National Laboratory
Art of Engineering	Lightly Treading, Inc.
Aspen Aerogels	Longs Peak Energy Conservation
Avocet Design & Consulting, LLC	Marvin Windows and Doors
Belleview Neighborhood	Masco Home Services
Boise State University	Michigan State University
Booz Allen Hamilton	Midwest Energy Efficiency Alliance
Boulder County	Mitsubishi Electric Cooling and Heating
Boulder ZED Design Build	Mountain Energy Partnership
Building Affordable	NAHB Research Center
Building America Retrofit Alliance	National Renewable Energy Laboratory
Building Industry Research Alliance	Navigant Consulting
Building Media Inc.	Nevada Building Performance Professionals
Building Science Corporation	New West Technologies, LLC
Built Green, LLC	Newport Partners LLC
CARB/Steven Winter Associates, Inc.	Nexant, Inc.
Cardinal Glass Industries	NJIT Center for Building Knowledge
CDH Energy Corp	North American Insulation Manufacturers Association
Center for Energy and Environment	NorthernSTAR - University of Minnesota
Center for Sustainable Building Research	Oak Ridge National Laboratory
CertainTeed	Owens Corning
City of Aurora	Pacific Northwest National Laboratory
City of Boulder	Panasonic Home and Environment
City of Fort Collins	PARR/Gas Technology Institute
City of Raleigh	PECI
Clean Air Through Energy Efficiency Conference	Pella Corporation
Clean Efficient Energy Company, LLC	Penn State
Colorado Dept. of Local Affairs	PGT Industries
Community Solutions	Plumb Level Square
Confluence Communications	Populus
Connecticut Light and Power	R. L. Martin & Associates, Inc.
ConSol	Ray Ballard Services
Cowan Home Solutions	Redmond Construction LLC
Creative Construction Co.	Retrogreen Inc.
Custom Homes of the Rockies	Rocky Mountain Institute
DAI Design	Shelton Group
Davis Energy Group	SMARTdwell
Dow Building Solutions	SolarCity
DuPont	Southern California Gas Company
E Source	Southface Energy
Earthcore SIPs	Southwest Energy Efficiency Project
EchoFirst Inc.	Steve Easley & Associates
EcoSmart Homes	Structural Insulated Panel Association
Electric Power Research Institute	Superior Product Home Improvements
Empire Drafting and Design, LLC	Symbiotic Engineering
Energy Center of Wisconsin	The Energy & Environmental Building Alliance
EnergyLogic, Inc.	The Levy Partnership
EverSealed Windows, Inc.	The Pennsylvania State University
Ferris State University, Energy Center	The Wood Wizard
Florida Solar Energy Center	Town of Parker
Fort Collins Utilities	U.S. Department of Energy
Fraunhofer CSE	U.S. Environmental Protection Agency
Gas Technology Institute	UC Davis, WCEC
GEOS Smart Living	University of Colorado
Green Your Home Consulting	University of Florida
Hathmore Technologies, LLC	University of Nebraska
Hearth, Patio & Barbecue Association	University of Texas at El Paso
High Tech Enterprises	Utah Clean Energy
HPBA	Veterans Green Jobs
IBACOS, Inc.	Veterans Green/Energy Logic Solutions
Idea Academy	Vida Verde
Intermountain REA	Washington State University Energy Program
Interplay Energy	Wayne County
Intertribal COUP	Window & Door Manufacturers Association

MEETING SUMMARY: RESEARCH RESULTS AND OPPORTUNITIES

System Performance Improvements

Solving the technical system challenges of ever-increasing levels of energy efficiency requires significant research and pilot efforts involving many stakeholders. This track focused on summarizing key research activities related to system performance improvements.

Air Sealing and Ventilation

Air sealing and ventilation strategies are critical to improving energy performance and creating good indoor air quality for occupants. These sessions addressed models to assess energy benefits vs. indoor air quality ramifications, impacts of wind washing, humidity and dehumidification and health impacts of indoor air pollution, and included representatives from Lawrence Berkeley National Laboratory (LBNL), and Building America research teams Advanced Residential Integrated Energy Solutions (ARIES) Building America Partnership for Improved Residential Construction (BA-PIRC), Building Industry Research Alliance (BIRA), and Building Science Corporation (BSC).

Lawrence Berkeley National Laboratory (LBNL), Brett Singer: Nationwide Energy Impact of Air Sealing and Ventilation

This presentation summarized a model to assess the energy benefits of air sealing and potential indoor air quality ramifications for the existing population of U.S. homes. The model is physically based and uses housing stock data from the residential energy consumption survey (RECS). The ventilation and energy model will be combined with indoor pollutant models to examine interactions between ventilation, energy, and indoor air quality.

The following research results were identified:

- The energy impacts of air sealing and ventilation will vary by location, building characteristics, and household. The model validation presented by LBNL is using the REGCAP (REGister CAPacity) which is a more sophisticated but validated model that accounts for air flows, thermal energy, and moisture. The validation approach is using REGCAP model produced hourly via ACH feed into IVE, the IVE model generates incremental energy, which is compared against REGCAP results, and see if the two match well.

- The model comparison was performed on a 2500 square foot house with four bedrooms, two stories, slab foundation, central heating and cooling with ducts in the attic. Three different base cases were reviewed with two different runs across 16 California climate zones. Examined two thermostat setting base cases and changed effective leakage area and mechanical ventilation. IVE model does not account for the internal heat gains.

- IVE and REGCAP models match well until outside air temperature is close to indoor air temperature. Study across 158 scenarios show aggregate average difference of 2%.

- IVE model can apply to standards and programs to help understanding the energy benefit of air seal with added mechanical ventilation, the level of ventilation that can be justified by health benefits, and how to design ventilation to maximize health benefits, etc.

- Kitchen ventilation is used as local exhaust for local pollutants. ENERGY STAR® specifies for range hood cfm/W of fan energy, but that is not a performance specs on fans. Exhaust impacts air conditioner's energy. Extra energy on AC is more important than fan energy and capture efficiency may be more important than cfm/W.

BA-PIRC, James Cummings: Energy Savings from Wind Washing Retrofits in Two Story Homes

This presentation summarized the characteristics and thermal impacts of a particular type of wind washing in two-story homes in Florida. Repair techniques and cooling energy/demand savings were presented.

The following research results were identified:

- Wind washing falls into category of diminished thermal control in buildings caused by air movement over or through a thermal barrier.

- Results show when a floor space is not properly sealed, the wind either pushes room air into the attic or reverse depending on the wind direction. The resulting infrared images show that hot air flows from attic space into floor cavity. And the 600 square foot house can't be cooled by 2-ton AC.

- A second type of wind washing is caused by thermal buoyancy. An IR image shows when insulation batts are not tight to the gypsum board, a thermal loop is created with hot air flowing through the wall board and insulation batts.

- Example repair strategy in bonus room above garage, where there was no air boundary in between, room floor is cold and the room is warm. Garage ceiling was cold and attic space was warm. Repairs included creating an improved air and thermal boundary. The repair used open cell spray foam to seal the floor cavity and around supply duct in attic. Open cell foam allows vapor transmission and can cause moisture condensation and dripping on ceiling. Semi rigid 0.5 inch thick insulation (vapor barrier) is wrapped around the duct before foam in place. It works well and has been tested. The repair has two stages: seal the leakage on the large return duct generated 24.7% cooling energy savings, and wind washing repairs generated 33.15% cooling energy savings. The combined energy saving is 49.6%.

- Phase 1 study is in central Florida where 32 homes were inspected and monitored and repairs were made in six homes. Air flow can be by wind or stack effect (small height). Hot air flows up and cool air goes down to the lower level. IR image shows hot air sloshing around within the interstitial cavities of the house. Data show that wind washing repairs on 6 homes yielded cooling energy saving of 15.3%, or $146 cost savings and 12.6% peak demand (kW) reduction. Average wind washing repair cost is $686 per house including seal interstitial floor opening and adjacent knee wall with open cell foam.

- Wind washing repairs are a cost effective and potentially viable utility energy conservation measure.
- More research is required to study the cooling and heating season effects. Phase 2 of the study will field tests 24 homes, six of which are wind washing repairs.
- There is increased comfort and durability from these repairs, in addition to the energy savings.

LBNL, Max Sherman: ASHRAE 62.2 and Dehumidification

This presentation summarized ventilation issues impacting the need for dehumidification in a properly ventilated home. Ventilation is often considered a major culprit in mold problems in hot, humid climates, but it's only a minor part of the problem.

The following research results were identified:

- In most climates except in humid climate, 62.2 ventilation has small effects on indoor humidity. In a humid climate, 62.2 increased median humidity by 5%-10% but decreased high humidity events.
- Energy recovery ventilation (ERV) use does not change indoor humidity in hot, humid climates.
- Forced air system mixing/distribution did not lead to increased high humidity events.

BA-PIRC, Douglas Kosar: Laboratory Evaluations of ERV

This presentation summarized a series of laboratory test loop evaluations of whole house supplemental dehumidifiers and energy recovery ventilators that are underway. Results from ongoing dehumidifier performance mapping were briefly highlighted and then plans were outlined for pending unbalanced ventilator testing to address house depressurization that impacts the operation of widely utilized appliances that draw air from the conditioned space and exhaust to the outdoors.

The following research results were identified:

State-of-the-art supplemental dehumidification system types on the market have been evaluated using an Supplemental Dehumidification (SDH) test loop that complies with ASHRAE 174-2009 (new), ANSI/ASAM DH-1-2003, ASHRAE 37-2005. BA-PIRC calls for a black box model in EnergyPlus for desiccant wheel dehumidifiers. The current lab testing needs to accommodate the modeling inputs with many test conditions on process sides and regeneration sides. The SDH project can be used for EnergyPlus analysis to compare recuperative heat exchange and desiccant dehumidification augmented SDH equipment on annual operating issues of electrical energy use, added AC electrical energy use, and combined SDH and AC energy use.

BA-PIRC's research also addresses planned ERV performance testing with:

- Single rating point data and broader data mapping to capture bathroom and kitchen exhaust recovery.
- Issues of tight home construction and depressurization with passive ERV unbalancing and active ERV unbalancing.
- Appliance exhaust on depressurization levels and performance effects.

LBNL, Brett Singer: Health Impacts of Air Pollutants - Mitigation Assessment

This presentation summarized the methodology developed for quantifying health impacts and costs of air pollutant inhalation in residences. The method allows comparisons of benefits of improved indoor air quality against costs. The analysis has helped identify the highest priority indoor air pollutants for mitigation.

The following research results were identified:

ASHRAE ventilation standards are not related to any specific health protection targets. Models of outdoor and occupational air standards may not work for homes.

Key issues are that:

- Not all air pollutants can be controlled by ventilation.
- Health effects and impacts vary widely.
- Chronic vs. acute exposures - preceding analysis is for chronic issues only.
- Emission rates vary widely across homes.
- Major hazardous pollutants should be the focus of analysis.

LBNL reviewed four major hazardous pollutants that have measured values that exceed standards: Acrolein, PM2.5, NO2 and Formaldehyde. Disability Adjusted Life Years (DALYs) are used to evaluate costs of adverse health effects of pollutants. LBNL went over the damage of indoor air caused diseases with metric of DALYs, validating SHS methodology, and different pollutants caused DALYs per year. Excluding SHS and Radon, the main risk drivers are acrolein, PM2.5, formaldehyde. LBNL calls for standard to address hazard of polluted outdoor air along with needed ventilation.

BIRA, Mark Modera: Automated Sealing of Home Enclosures with Aerosol Particles

This presentation summarized how aerosol particles have been used successfully to seal ducts and may be similarly useful to seal enclosures. Preliminary experiments employ an 8' tall box with known leaks to simulate an enclosure into which the aerosol is introduced, and, with and without the use of mixing fans, the fraction of the particles that deposit in the leaks are measured and compared to those settling on the floor of the box.

This work describes a new method for sealing leaks in the building enclosure via injection of aerosol particles. A test cell was constructed to demonstrate the effectiveness of sealing.

The following research results were identified:

- Results vary depending on the flow rate of aerosol and the pressure of the room (8'x4'x8'). 40 square inches can be sealed in 5-20 minutes.
- Manual caulking and sealing of building enclosure can be expensive and ineffective.
- An aerosol sealant that automatically "seeks out" leaks can reduce cost and improve sealing.

Next steps:

Test smaller particles and lower operating pressures in real homes.

BSC, Kohta Ueno: Space Conditioning and Ventilation Strategies in Multifamily Buildings

This presentation summarized the performance of existing multifamily ventilation central systems, and explored alternative solutions in retrofit situations. This research project work is done using a multitude of approaches: engineering calculation and analysis, computer simulations, and field-testing of components and systems.

A ventilation retrofit of a large multifamily building posed many problems that required specialized solutions. The existing system was found to be over-ventilating with regard to ASHRAE 62.2. The retrofit included replacing the shaft ventilator with a lower-flow corridor unit, replacing unit ventilation grills with time-controlled exhaust fans and air sealing the individual units.

The following research results were identified:

- Kitchen ventilation had 25% leakage, Bath had 15%. Individual units had 8-10.5 ACH 50.
- Multifamily buildings with large shafts tend to induce stack effect ventilation. Many of the air flows required innovation measurement techniques.

- Compartmentalizing the individual units will decrease the impact of stack flows. This requires improving the air tightness of the individual units.

Next steps:

- Better sealing in the units.
- Modeling with CONTAM.
- Additional post-retrofit testing.

LBNL, Iain Walker: Residential Ventilation Controllers

This presentation summarized how a residential ventilation controller is being developed that reduces the energy impact of ventilation by accounting for other sources of ventilation. It also allows for lower ventilation when outdoor conditions are poor, avoiding peak conditions, or energy is expensive, while maintaining equivalent indoor air quality to a fixed air flow system.

Residential Ventilation Control is used to minimize ventilation fan operation. The control algorithm is geared to: avoid ventilating during peak hours when the outside air is hotter; avoid ventilating during unoccupied hours; limit peak exposure to old air; account for natural infiltration; and operate less while other exhaust flows are present.

The following research results were identified:

- System is successfully installed in one test home and showing promising results.
- Buildings sometimes use unnecessary fan energy to over-ventilate.

Next steps:

- Optimization of algorithm
- Embed algorithm in existing controllers (e.g. Home Energy Management systems)

Space Conditioning Distribution

Consortium for Advanced Residential Buildings (CARB), William Zoeller: SPF Encapsulated and Insulation Buried Duct Retrofit

This presentation summarized a closed-cell spray polyurethane foam encapsulation retrofit of existing attic located HVAC ducts in Jacksonville, Florida. Pre-retrofit data collection has been completed and post-retrofit monitoring is underway.

The following research results were identified:

- Encapsulating and/or burying ducts can be an effective way to reduce both leakage and conduction losses in distribution systems. Three test houses are being monitored (pre- and post-retrofit) and are showing promising results.
- Encapsulating and/or burying ducts effectively reduce losses in the distribution system. Ducts may need to be encapsulated to avoid condensate collecting on ducts.
- Duct losses account for a lot of energy usage in residential buildings.
- Encapsulating and/or burying ducts while sealing and insulating the attic can be achieved with minimal additional cost.

IBACOS, Dave Stecher: Simplified Space Conditioning in Unoccupied Test Homes

This presentation summarized the building of a new construction unoccupied test house and retrofitting an existing construction unoccupied test house in the mixed-dry climate. These projects will assess the thermal enclosure characteristics and space conditioning system thermal delivery characteristics necessary to enable the use of simple, lower-cost space conditioning systems in high performance houses.

The following research results were identified:

- This project is still in its conceptual phase, however it is hypothesized that ductless distribution systems that can provide comfort to the entire building can save on upfront costs, and eliminate distribution efficiencies. These systems need to be tested in lab homes to prove the concepts.
- Duct systems are expensive and can be inefficient. This work explores whether it is possible to provide comfort to the entire house (as new construction or retrofit) without ducting. Three systems are considered: 1) No ducting – depending on transfer grilles at room doors, 2) Ducts only in high occupancy rooms without existing exhaust, and 3) Fan-assisted through wall mixing.

Building America Partnership for Improved Residential Construction (BA-PIRC), James Cummings: Heat Pump Energy Savings and Demand Reduction with Attic and Indoor Duct Systems

This presentation summarized heating and cooling energy and demand savings of a variable capacity (34% to 100%) 3-ton heat pump compared to a fixed capacity 3-ton heat pump, based on full-house laboratory measurements with both attic and indoor ductwork.

The following research results were identified:

Testing was conducted to compare SEER 13 and SEER 21 units with an attic R-6 duct system and with a duct system in conditioned space. Indoor ducts are more important for SEER 21 units. A SEER 21 in conditioned space has 45% less peak demand than a SEER 13 system with an attic duct system. This work helps to quantify the interactions between equipment and distribution system improvements. There is a need to explore sensitivities to different levels of duct leakage and test the systems in humidity control and heating modes.

Foundation Insulation

Building Science Corporation (BSC), Kohta Ueno: Hybrid Foundation Insulation Retrofits

This presentation summarized hybrid foundation insulation approaches available that can deliver high levels of insulation economically, while solving many vexing moisture problems.

Hybrid foundation insulation approaches are available that can deliver high levels of insulation economically, while dealing with bulk water intrusion.

The following research results were identified:

- Field survey work of existing foundation insulated between 1996 and 2009 identified no damage.
- Sub slab insulation reduces risk of moisture issues (carpeting or stored boxes on slabs).
- Potential frost damage to foundations in very cold weather.
- Lack of guidelines to decide on the use of drainage layer.
- Existence of efflorescence/mortar erosion.
- Lack of capillary break requirements guidelines.
- Research and hygrothermal simulation work on efflorescence (mortar erosion and brick spalling) behavior after closed cell foam interior retrofits: does it reduce or effectively eliminate the problem, or does it cause any unanticipated problems?
- Sill beam durability: analysis of relative risks (exterior rain control detailing, splashback, capillarity, temperature reduction of sill beam), and effectiveness of remediation options (insulation that allows drying, additional rain control detailing, etc.).

The work addresses a previously identified gap related to foundation thermal performance. Specifically, at the Enclosures Standing Technical Committee (STC) meetings the following areas of interest have been identified:

- Bulk water leaks in basements
- Foundation moisture control
- Foundation strategies
- Sill beams

Next steps:

- Frost damage to foundations in very cold (DOE Zones 6 and 7)—"Where is the edge?"
- Decision to use drainage layer—"historically dry" basement, etc.
- Efflorescence/mortar erosion—sufficiently slowed by reduced evaporation?
- Sill beam drying in interior retrofits; capillary break requirement guidelines?

NorthernSTAR Building America Partnership, Patrick Huelman: High R Foundations: Opportunities and Obstacles

This presentation summarized how proper foundation insulation is a critical step for high performance in both new and existing homes and how the higher levels of insulation for the foundation can have significant cost, construction, and moisture implications.

Proper foundation insulation is a critical step for high performance in both new and existing homes. How will the higher levels of insulation for the foundation impact insulation and application choice, cost, construction sequencing, and non-energy performance (eg. moisture, durability, and indoor air quality).

The following research results were identified:

The project is not at a phase to be able to summarize research results, however the following barriers and issues were identified:

- Below grade heat transfer models are both crude and cumbersome especially for deep basements.
- There are currently no validated and user-friendly below grade hygrothermal models in the United States.
- Boundary conditions (indoors, soil, and grade line) are not well characterized, especially for existing homes.
- Homeowners don't recognize the risk with interior insulation and basement finishing.
- Is uncontrolled dampness and mold growth behind interior insulation an indoor air quality liability?

Summary of key opportunities:

- Exploring external insulation opportunities in existing homes:
    - Insulation depth

  - Excavationless option
  - Insulation formulations

Next steps:

- Exploring the key opportunities above.
- Use of existing models to evaluate interior insulation systems in preparation for experimental testing in 2012.
- Moving forward on the market potential and means and methods research for excavationless exterior insulation retrofit.

High-R Enclosures

Fraunhofer Center for Sustainable Energy Systems (CSE), Jan Kosny and Oak Ridge National Laboratory (ORNL), Achilles Karagiozis: Deep Energy Retrofits for Roofs and Walls in New England

This presentation summarized the engineering challenges in energy retrofits of historical flat roofs and the inclusion in deep retrofit projects of different configurations of high R-value aerogel and vacuum insulations combined with novel labor-saving installation techniques in a form that would be energy efficient, flexible for different retrofit scenarios, durable, and cost competitive.

This presentation focused on the methods and challenges for deep energy retrofits for historical buildings in New England. The major project areas included flat roofs, attics, vaulted ceilings and walls. A successful retrofit in Seattle was also presented.

The following research results were identified:

- One method to achieve high-R walls in retrofits is to combine aerogel insulation blankets sandwiched between gypsum board, R-10 per inch blown-in insulation in cavities, and vacuum insulations. This can achieve R-40 to R-50 walls with little thickness added. Materials from single manufacturer could results in ~25% savings.
- Buildings in New England could have multiple owners (triple deckers), old materials, almost no insulation, complex structures and architecture.
- New England offers a lot of opportunities for high-R value wall retrofits. This region has a large number of buildings (triple-deckers and colonials) with similar floorplans and roof constructions that were built about the same time.

Next steps:

- Thermal and hygrothermal analysis, energy simulations, and cost analysis.
- Testing and final development of R-10 blown insulation.
- Explore combining and integration of several technologies from one supply chain.

NAHB Research Center Industry Partnership for High Performing Homes (NAHBRC Partnership), Vladimir Kochkin: High-R Walls: Moisture Characteristics of Frame Wall Systems

This presentation summarized the NAHB Research Center's (NAHB-RC) laboratory research on high-R enclosures and will detail the first steps and initial laboratory testing, including dynamic out-of-plane wind and rim header testing. These practices lead to improved energy efficiency, moisture resistance, durability, and ease of installation as well as contain increasing construction costs. The session also discussed the impact of the practices on the energy performance.

The presentation summarized test results that demonstrated how walls made from rigid foam insulation (XPS) are affected by wind pressure.

The following research results were identified:

- Multiple wall assemblies were tested. Negative pressure was applied, since the negative pressure on the back side of a house is higher than the side exposed to the wind directly. It was found that the full wall assembly could withstand between 100 psf and 120 psf. The framing in the full assembly broke first, but the overall wall 'system' was found to be fairly balanced in terms of what would break first. Also, vinyl siding was found to contribute to the capacity of the wall because of connections.

- The work addresses a previously identified gap because it provides a better understanding of wind pressures on various wall assemblies.

Next steps:

Test 24'' on-center framing, thicker foam insulation, and structurally insulated panels (SIPS).

Advanced Residential Integrated Energy Solutions (ARIES), Emanual Levy: Factory Built Advanced Design

This presentation summarized a project designed to leverage the advantages of industrialized construction in driving down the costs of moving to very low energy use. Interim results of the team's concurrent engineering process will be presented together with a look at the inherent advantages offsite building can provide in accelerating efficiency innovations.

New energy standards for manufactured, factory-built homes are driving improvements on the performance of wall assemblies. Several possibilities and the challenges associated with them were presented.

The following research results were identified:

- This performance improvement testing will take place in three phases. The first phase is to ID existing technologies that could be applied quickly. This includes SIPS or a stud wall with integrated insulated board. The second phase is technology development, and the third phase is implementation and testing. Current work is still in phase I.

- Changes to wall assemblies must be able to be manufactured in a factory. This could involve redesigning equipment and optimizing factories. Meeting cost requirements will also be a challenge.

- An opportunity exists for a single manufacturer to create a 'unified' wall assembly that is optimized for a single purpose. This could lower cost and improve the efficiency and structural capacity of the wall.

Next steps:

Continue with Phase II and Phase III of project.

Building Science Corporation (BSC), Joseph Lstiburek: Hybrid Insulation Systems

This presentation summarized how combinations of materials and approaches provide optimum performance. Integration is necessary and the hybrid walls proposed utilize a combination of exterior insulation, diagonal metal strapping, spray polyurethane foam, and cavity fill insulation to provide effective thermal, air, moisture, and water barrier systems in one assembly while providing structure.

This presentation highlights the need for hybrid wall assemblies that combine materials and approaches to obtain optimum performance.

The following research results were identified:

- The suggested approach is Advanced Wood Framing, 2"x6" 24'' on center, with insulated sheathing, spray foam to provide air sealing, and cellulose or fibrous cavity fill insulation. This combination would provide thermal and air sealing with structural support.
- No single manufacture provides all components of the wall assembly.
- Designing and building a wall with an integrated approach would combine the functions of the walls and improve its performance. This would provide thermal and air sealing with structural support.

Next steps:

- Structural testing of wall assemblies will happen soon.
- Report will be submitted at the end of this year.

Hydronic Systems

Alliance for Residential Building Innovation (ARBI), Bill Dakin: Radiant Cooling as a Hot Climate Strategy for Improving EER

This presentation summarized preliminary results from the application of a hybrid chilled water cooling delivery system in Tucson, Arizona, using a "reverse-cycle" chiller connected to a distribution system that consists of a small fan coil piped in series with the radiant floor. Both standard operation and pre-cooling strategies are being tested to evaluate and compare seasonal efficiency and energy consumption.

The primary objective is to evaluate the construction process and performance of alternative HVAC systems, such as air-to-water heat pump (AWHP) systems. This includes reviewing:

- The ability to provide more efficient space conditioning while improving zoning and comfort through radiant delivery.
- Potential for eliminating or downsizing air distribution systems and reducing distribution system losses.
- Ability to raise cooling temperature setting through lower mean radiant temperature.

The following questions are being addressed during this research:

- How does the distribution efficiency of the mixed-mode system compare to a traditional forced air delivery system with ducts in unconditioned space?
- What are the average effective cooling energy efficiency ratios (EERs)?
- How does the cost-effectiveness of AWHP compare to high efficiency air-to-air systems?
- What are climate limitations of AWHP systems with mixed-mode distribution?
- Is the fan coil and latent cooling it provides necessary for dehumidification and to prevent floor condensation during design load conditions?
- Can TRNSYS reliably predict performance of the two systems tested?
- How effective is night time pre-cooling in improving efficiencies and reducing cooling energy use?

Currently, there are two test sites that are evaluating this technology:

- La Mirada Homes in Tucson, Arizona: A high efficiency building envelope that includes SIPs construction and an AWHP, which is delivering heating and cooling through a fan coil and then to the floor. Preliminary monitoring data is available on this house.

- Cana House in Chico, California: A variable compressor three-function heat pump that is also providing water heating. The monitoring equipment for this house is currently being installed.

Two cooling strategies are being compared:

- Night slab cooling (cool and coast): a 78º cooling set point, but at night it is lowered 5º so it is run to cool the slab not using the fan coil. This pre-cools the house and the building mass. It will coast through the day.

- Constant 77º set point: equal to average temperature of "cool and coast."

TRNSYS modeling is being used to evaluate these components; current modeling shows that the trends compare well to monitored data but more calibration is needed.

When the fan coil operates it provides about 45% of the cooling. With the cool and coast strategy, operating efficiencies have improved 30%. This has the advantage of being able to operate this during off-peak times, and offers potential occupant comfort benefits because the space on average is cooler overall. Insulating the floor is critical to maintaining the performance of this technology.

Next steps:

- If this technology looks cost effective and promising, then our goal is to do a measure guideline on this.

- We will be doing modeling to give an evaluation of what climates these work best in.

Consortium for Advanced Residential Buildings (CARB), Lois Arena: Condensing Boilers: Optimization of System Performance in Cold Climates

This presentation summarized goals for the next hydronic heating system research phase including creating system designs that will reduce recovery time, increase condensing frequency and reliability, and reduce installation complexity. Research was conducted in three phases. Following are objectives and key findings of each phase:

Phase 1 focused on monitoring and evaluating six existing homes in order to analyze the frequency of condensing with condensing boilers installed in homes with baseboard radiators. The goal was to determine the factors that were most likely to affect performance, identify typical operating conditions in existing installations, and analyze how the boilers were functioning (cycling frequency; typical flow rates). During this phase, recommendations were made for design and operation of three new homes to see if condensing could be maximized. Finally, the monitoring plan was evaluated and revisions and refinements made for Phase II.

Key findings included**:**

- Primary/secondary loop plumbing configuration contributes to higher than optimal return water temperatures to the boiler, as does higher than recommended flow rates.
- Baseboard lengths being installed in these homes are consistent with the lengths needed for a low-temperature, low-flow system.
- Maximum boiler output temperature is typically set to 180°F or higher and the boiler supply temperatures to the domestic hot water tank were set at 180°F or higher for five of the six homes.

Phase 2 was bench-top research conducted with Tom Butcher at Brookhaven National Laboratory to test whether the boiler would blow up without a primary loop. There is a primary- secondary loop installed in condensing boiler application that contributes to a higher return water temperature than is optimal for condensing. This configuration, required by most manufacturers, reduces the efficiency of the equipment as it is installed. Manufacturers claimed the boiler would blow up without the primary loop.

Key findings established:

- It is very difficult to blow up the boiler.
- Low mass boiler tested can be operated with flow rates significantly lower and temperature rises significantly higher than the manufacturer's recommendations.
- The boiler pressure should be maintained at the high end of its allowable range.

The Phase 3 goal was to verify the installed performance based on the design recommendations and develop guidelines for installers outlining factors for optimizing efficiency: best control settings, pump selection/sizing, and plumbing configurations. The basic recommendations based on research in the first phase were: the maximum boiler supply temperature should be set to 160°F; the flow rate through each zone should be 1 gpm; baseboard sizing was based on an average water temperature of 150°F; 30 gallon, indirect storage tanks controlled by boiler's controller; and the primary loop should be removed.

Key findings:

Recovery from setback:

- Extremely slow in all homes monitored.
- Location of outdoor reset sensor is important to system performance.
- Appears to get worse with increasing outdoor temperatures.
- Differential setting can affect recovery time.

- 2-story configuration may be contributing to lag on first floor.

Flow rates were higher than specified:

- Contractors don't have standard, simple methods for measuring and/or setting flow rates.
- Until recently, low-flow residential pumps for which the flow can be set have been difficult to find.
- Different boiler manufacturers have different recommendations for minimum flows through the heat exchanger and installers are reluctant to design systems with very low flows.

Summary of key opportunities to address barriers:

- Working with manufacturers on designs that everyone can use without voiding warranties.
- Working on eliminating primary loops and developing controls that deal with the recovery issue.

Next steps:

The next round of research will be for three new homes with different systems (low-mass boiler, variable speed pumps and high max boilers). Research will be conducted in close collaboration with boiler and pump manufacturers, project managers and plumber for test homes, and hydronic designers.

Partnership for Advanced Residential Retrofit (PARR), Larry Brand: Steam System Balancing

This presentation summarized the energy-saving opportunity for steam system balancing and tuning and the ten-unit field test planned for the upcoming heating season in Chicago as a part of the PARR and CNT Energy Savers program. This project, currently in its preliminary stages, focuses on identifying energy efficiency issues with steam systems in older multifamily buildings in the Chicago area, and developing steam balancing as a viable alternative to replacing systems, in order to achieve better efficiency and comfort for residents. It also includes educating the building owners and operators about the benefits of this measure and helping them to understand how to properly use the control systems they have.

Research questions addressed in this project include:

- How do steam balancing measures affect the temperature dynamics within units?
- Which individual steam balancing measures are most cost-effective?
- Which measures should be further promoted to increase awareness about their contribution to system balancing?

- Are certain steam balancing measures more effective with certain building types?

The scope of this project will include:

- Ten test buildings, all with 1-pipe steam systems.
- Retrieve pre-upgrade measurements and data for monitoring.
- Develop detailed scopes of work.
- Oversee general contracting; obtain RFPs from three contractors for each measure, and inspect the work.
- Collect post-upgrade temperature data, analyze utility bills for pre- and post-upgrade measurement, and calculate energy savings.

Summary of key opportunities:

- Develop quick retrofit measures that improve efficiency of systems and can be implemented easily and cost-effectively.
- Coordinate with and educate building owners and maintenance staff about proper operation of boiler controls.

Long Term Wall Durability

Building Science Corporation (BSC), Joe Lstiburek: Hygric Redistribution and Moisture Management

This presentation summarized how hygrothermal simulations have shown that adding ½" foil-faced rigid insulation under a replacement cladding during a retrofit is likely to lead to moisture problems in cold climates because it's a cold-sided vapor barrier, but in practice, many home retrofits have been constructed like this without apparent problems.

The project is still in the early stages. The following research is underway:

- Drainage and drying testing on wall balance is currently underway and should be finished prior to the draft report.
- Lateral redistribution testing on wall balance is scheduled to start mid-August and there will be preliminary results for draft report; further testing will be conducted prior to final report.
- Low R-value impermeable exterior insulation research program being determined. Testing began in mid-August with preliminary results ready for the draft report; further testing will be conducted prior to final report.
- Draft report in progress; due September 15th.
- Final report following review; due November 15th.

Summary of barriers or issues identified:

- Disagreement between hygrothermal simulation performance and field investigations with low R-value impermeable insulating sheathings.
- Hypothesis: Retrofits with low R-value impermeable sheathings work because they act as a dehumidifier for the wall.
- Concerns that using exterior insulation over a drainage plane and wood sheathing may cause durability concerns of wood sheathing.
- Hypothesis: A drainage plane can be installed between exterior insulation and wood sheathing without any durability concerns if detailed correctly. Some building materials may decrease risk of moisture-related issue.

Consortium for Advanced Residential Buildings (CARB), Lois Arena: Moisture Monitoring in Exterior Walls

This presentation summarized how, with the increased use of foam insulation, various vapor barrier applications, the drastic increase in retrofit activities, and the increasing thickness of the wall, moisture issues could potentially become much bigger problems than they have been in the past. Several different configurations of high-R wall assemblies in climate zones 4-7 with warm/moist summers are being analyzed and monitored.

The research evaluated potential for moisture problems in three wall assemblies:

- Brick walls with interior insulation.
- Super insulated walls at least 12" thick: R-40 and R-60.
- Code-built walls using spray foam insulation and fiberglass batts.

Modeling activity will be conducted this year

- WUFI
- THERM

Field Monitoring – beginning 2012

- Brick rehab
- High-R walls: R-40 and 60
- Code walls: hybrid insulation w/ spray foam and fiberglass

Changes in construction due to:

- Drastic increase in retrofit activities.
- Programs like PH and NZEH challenges.
- Increased use of hybrid insulation strategies.
- New insulation products.
- Code changes

Changes include:

- Increased use of foam insulation.
- Increasing thickness and R-value of walls.
- Increased use of hybrid insulation strategies.
- Changes in vapor retarder/barrier strategies.

Questions to be answered:

- How does WUFI modeling compare to actual monitored moisture levels?
- What combinations of building and insulation products produce a durable, efficient wall assembly?
- Do any of the monitored wall systems show moisture accumulating? If so, where?
- If high moisture conditions exist, are levels and durations long enough to risk mold and/or decay?
- If high levels of moisture occur, can the cause be determined?
- Can differences in modeling and monitoring be explained?
- Are the R-values specified in Table 601.3.1 of the 2009 IRC sufficient to prevent condensation?

NAHB Research Center Industry Partnership for High Performing Homes (NAHBRC Partnership), Vladimir Kochkin: High-R Walls

This presentation summarized why moisture considerations are necessary to ensure durability and thermal performance. This session will outline moisture testing of test houses in the mixed-humid climate. The project includes a comprehensive research approach: monitoring of homes, test huts in climate zone 4, and WUFI modeling. The goal of this work is to understand and quantify the impact of energy efficiency features on the long-term moisture performance of wood-framed walls. Oriented strand board (OSB) is used as performance indicator. OSB is hygroscopic material.

The following research results were identified:

Climate Zone 4 based on WUFI simulations:

- Vapor retarders affect OSB winter MC.
- Both 2x4 and 2x6 gave a similar performance.
- Walls with foam dry slower than those without.
- Walls without foam dry to the outside.
- For walls with foam, drying rate to the interior depends on the season.
- Indoor relative humidity makes a difference on OSB winter MC for walls with class III vapor retarder.

High-R walls are important to achieving:

- Higher levels of energy performance.
- 2012 IECC increased code minimum R-values.
- Higher R-values needed to achieve beyond-code efficiency goals.

Wall cavity moisture performance has been raised as a concern by builders. What is different?

- Permeability of wall materials.
- Increased overall wall R value.
- Location of insulation in a wall.
- New insulation materials and use of combinations of insulating materials.
- Air-tightness of the wall.
- Interior moisture load (RH).

Speed and Scale

New and unique challenges arise when transitioning energy efficient design and construction strategies from single test homes or test communities to the market. This track focused on strategies to overcome barriers to market transformation to create replicable, impactful results.

Audit Procedures

Partnership for Advanced Residential Retrofit (PARR), Ryan Kerr: Retrofit Audit Procedures

This presentation summarized the rationale for performing energy audits, RESNET and BPI, energy simulation, work scopes, health and safety, and the opportunities to reduce audit costs while enhancing desired outcomes. The final report will include recommendations for improved cost-effective retrofit audit procedures.

This project is in the initial phases and the majority of the work and results are not yet complete.

The following research results were identified:

- Site assessment must identify potential hazards. Most often, an expensive visit to the home is required and radon testing and mitigation requires multiple trips to the house.
- Moisture issues are rampant and mold can be found in many homes, but how much is "too much?" A specific direction is needed and there is lots of gray area.
- Blower door diagnostic testing is highly variable and contractors find tighter homes than third-party raters.
- Information is often lost between the auditor and the contractor. The nuances of the home need to be transferred better and reduce the opportunity for error.
- Certain features and types of housing use lots of energy, but are poor candidates for energy upgrades.
- Common pricing is important for consumers but there is variation seen in the market.
- Process evaluation: Best to reduce customer touch points yet keep quality and health issues up. Also beneficial is optimizing models to handoff to contractors.

National Energy Leadership Corps (N.E.L.C.), David Riley: Audit Taxonomy

This presentation summarized the development of a taxonomy of audit types that characterizes variable forms of self, assisted, traditional, and deep home energy assessment processes which enable the use of new tools and advanced types of energy improvement measures. The project will define and address different audit types/scopes with goal to identify best methods to affect energy efficiency upgrades.

The following research results were identified:

- Segmentation of each of the four audit types can help define strengths and weaknesses related to each; this hypothesis will be confirmed through work.
- Improve handoffs by focusing on homeowners.

N.E.L.C., Steve Taylor: Scalability of Self and Assisted Audits

This presentation summarized how the investigation is designed to identify and classify the tools, audit techniques, and existing technologies available to the homeowner and industry professional to prepare a homeowner for a successful energy efficiency upgrade. The goal is to develop a one to two page homeowner survey where key problems are identified.

The following research results were identified:

- Tradeoffs of whole house approach: complete audit gives the best results, but conflicts with the industry "do one thing well" approach.
- There is a need for tools to help people get started; the coaching/assisted audit may need to be updated.
- Some organizations have used assisted; BPI is so extensive that this is the expectation. Assisted self-audit doesn't always measure up, however, and there is a need for communication to make people see the value.
- Performance outcomes, linked to ROI, can help people reconcile different audit methods with their expectations.

Business Models

National Renewable Energy Laboratory (NREL), Marcus Bianchi: Retrofit Business Models

This presentation summarized current and emerging retrofit business models and identified technical barriers, gaps, and opportunities to support the implementation of these business models. The retrofit business models discussed in the session were identified through literature review and interviews with subject matter experts such as large contractors, consultants, program managers, manufacturers, and real estate providers.

The following research results were identified:

- Four basic business models were identified:
  - Consultant, auditor, rater: identifies energy areas to address.
  - Trade contractor: includes a variety of trades that participate in home energy upgrades.
  - General contractor: contract the different trades for work and perform quality control and assurance.
  - Home performance energy upgrade contractor: provides the audit, contracts with the trades to deliver the upgrades and quality control.
- Building science is complex: information is overwhelming for homeowners. Develop simple and clear educational campaigns targeting homeowners; create building science museums and informational kiosks about energy upgrades.
- Problem of specialization: trades have a specialized way of doing things and they see their trade as the only solution to the particular problem.
- Insufficient mentoring or follow-up after initial training for home performance contractors. Solution: create continuous learning, mentoring, or apprenticeship opportunities for contractors. Could use Web tools or social media to create a virtual community to help field questions.
- Building characteristics and utility bill data are not available for testing software tools. Solution: address software inaccuracy issues; develop certification procedures for software tools and use data from very well-instrumented houses.
- Initial house assessment is time-consuming.
- Comprehensive energy efficiency upgrades may be expensive.
- No standard practices to install additional insulating sheathing when re-siding a house.

- Reducing miscellaneous electric loads is challenging due to occupant behavior.
- Expand the Field Date Repository: create open data repositories where homeowners can add information; work with utilities to create energy use averages available by specific territories.
- Create plans for staged energy upgrades for homeowners to follow.
- Research technical solutions for issues and best practices to adopt, and document in field guides developed for different climate zones.
- Educate the homeowner about how their behavior impacts energy use.

Next steps:

A report summarizing feedback from stakeholders on current business models, gaps, barriers and opportunities related to home energy upgrades is being created. This report will be peer reviewed and published and will contribute to the Building America Strategic Plan document.

DOW, Jeff Alcott and DOW, Elena Enache-Pommer: Market Realities and Change Management

This presentation summarized the use of the Six Sigma design process to define the value chain and develop a Voice of the Customer collection plan to uncover the critical customer requirements that will help guide the development of this new sustainable "business model" to increase the adoption rate of residential energy efficiency upgrades.

The research objective is to develop a sustainable business model that increases the adoption rate of energy efficiency upgrades by using Building America knowledge. This model should create, capture, and deliver value for the end user and reflect what the customers want, how they want it, and how to organize the Building America information to meet those needs. The project is designed for Six Sigma, which is the development process that identifies and uses customer needs and data-based decisions to drive a sustainable solution. The project stages include:

- Define the opportunity statement, goals, objectives, timeline, and resources. Solution design concepts will be ready by the end of 2011. By the middle of 2012, proposed solution and implementation plan will be in place.
- Collect and analyze voice of the customer data. Identify homeowners, contractors, distributors, as the decision makers. Will conduct 50 face to face interviews with value team decision-makers and 50 phone interviews (50% finished with this process). Once the interviews are completed, the customer data will be analyzed to articulate the customer needs. Design measures will be defined and prioritized to find out whether we are meeting the need.

- Formulate and qualify solution concepts by taking critical customer requirements and performing a functional analysis and then generating concepts. The Building America knowledge will be added into the concepts.

- Establish and validate the ideal solution by conducting a functional capability assessment and conducting a pilot of this solution.

- Execute plans to sustain the momentum.

Building Industry Research Alliance (BIRA), Rob Hammon: Moving Hot -dry Builders from Standard to Best Practice (Pulte)

This presentation summarized a cost-effective, marketable set of energy-efficiency measures that create 30% energy savings in the hot-dry climate compared to the Building America Benchmark. Pulte is currently building and selling homes at this 30% savings level and exploring what might be required to meet the Building America 50% energy savings

The partners involved in this project include BIRA, ConSol, Pulte Homes, Arizona State University, and APS utility company. Pulte is working to get their homes to zero net energy in 2014-15 timeframe. Pulte reached 30% beyond the current Building America benchmark. To get to this goal, the envelope (vertical walls, ceiling, and windows), the airflow, duct conditioned space, and increased efficiency of all of the equipment and the lighting were improved. Reaching the 50% target will require more money and taking risks with innovative technologies. The BEopt simulation results show that as the homes start climbing toward 50% savings goal, they are going to go past cost effectiveness and returns will diminish.

Next steps:

Evaluate prototype homes comparing predicted energy savings with actual utility data. Continue to provide technical support to Pulte to work toward 50% energy savings in their homes.

IBACOS Arlan Burdick: Transitioning HVAC Contractors to Whole House Performance Contractors

This presentation summarized a research effort to understand the business impacts and what change management strategies HVAC companies can use to quickly transition from a "traditional" heating and cooling contractor to one that provides whole house energy upgrades.

The following research results were identified:

- Found fundamental business activities of HVAC and energy upgrade companies are not all that different.

- Developed process map of HVAC company, highlighting transition areas.

Summary of barriers or issues identified:

- Business: need technical training, new equipment, and resources, assistance managing sub-contracting relationships, and strategic planning for the transition.
- Marketing: need to work on the customer and community education and engagement process to increase awareness of the industry.
- Assessment: create arrival process for the assessment, conduct on-site customer interview before the assessment, establish whole house assessment practices and procedures.
- Sales: need customer presentation package that ties into customer education and staged upgrades and an assessment report that can be used as a sales tool.
- Contract administration: conduct utility reporting management of the reporting process to receive utility or program rebates.
- Production: eliminate work scope/procedures and subcontractor management barriers.

Summary of key opportunities:

By making the information needed to successfully transition HVAC contractors to whole house energy upgrade contractors available to the contractors, the consumers' resources for receiving an energy upgrade will increase. Creating more contractors that are able to perform whole house energy upgrades will increase the number of energy upgrades performed.

Next steps:

- Characterize these "highest priority, most difficult to implement" processes.
- Identify the barriers or information gaps associated with these processes.
- Work with HVAC companies who are making the transition to understand what they need to overcome these barriers.
- Understand how to document and communicate results.
    - Manufacturers and distributors were suggested by experts as a trusted information source for HVAC contractors.
    - Webinars/presentations.

NAHB Research Center Industry Partnership for High Performing Homes (NAHBRC Partnership), Amber Wood: Retrofit Contractor "Start -up" Kit

This presentation summarized how the NAHB Research Center is developing an energy remodeling "start-up kit" for existing homes. This effort began with regional focus groups of remodeling contractors followed by national quantitative market research of remodelers to explore the topic area and collect data for analysis. This session outlined the results of the two series of focus groups as well as the subsequent development of the quantitative market research.

The following research results were identified:

- Most remodelers believe in growth potential for energy efficient upgrades; however, long-term success requires market-driven upgrades.
- Barriers include perceived value, limited scope of the remodeling project, and costs.
- Homeowners need to perceive a "reason why" they should invest in the upgrades. However, remodelers don't want to come across as "selling" but rather as recommending solutions that will benefit the homeowner.
- The slowdown in new construction and economic climate has shifted greater to focus to existing homes and to remodeling.
- Qualified remodelers and builders strive to differentiate themselves based on experience, knowledge and customer service, in addition to quality building practices.
- Remodelers need to educate themselves as to best practices and approaches and help to motivate homeowners.

Key opportunities:

- Most remodelers agreed that the most beneficial things for stimulating growth of energy efficient upgrades would include:
  - Development of a nationwide rating system for existing homes.
  - Establishing appraisal value for energy efficient upgrades.
  - Realtor education as to value energy efficient upgrades bring and how to sell the features.
  - Financing of energy efficient upgrades.
- For remodelers themselves, the following tools would be valuable:
  - Resources to shift consumer thinking, increase understanding of problems, understand benefits, etc.
  - Resources to increase awareness and understanding of the value of energy efficient upgrades.
  - Free/low cost energy audits for homeowners.

- Means of quantifying impact of energy efficient upgrades (e.g. pre/post testing, energy savings calculators, etc.)
- Connecting remodelers with energy auditors so they can develop a referral network.

Next steps:

- 2011 Research: Remodelers
  - First set of remodeler focus groups
  - Second set of remodeler focus groups
  - Qualitative remodeler research from focus groups
- 2012 Research: Homeowners
  - First set of homeowner focus groups
  - Second set of homeowner focus groups
  - Qualitative homeowner research from focus groups

Communication/Outreach

National Renewable Energy Laboratory (NREL), Cheryn Engebrecht: Building America Outreach Efforts

This presentation summarized the new types of outreach efforts that Building America is conducting. Using new partnerships and accessible documentation, our goal is to be the go-to resource for residential energy efficiency research results.

The following outreach efforts were identified:

- Redesigned BA website using EERE template.
- Streamlined processes to improve speed of delivery of results: document management system, product consistency, products targeting broader audiences (measure guidelines, case studies).
- Established new media outreach partners: Fine Homebuilding, Builder Partnerships, etc.
- Still facing issues of program visibility as well as awareness of and access to Building America research results.
- Next steps include continuous assessment/feedback about the effectiveness of the outreach efforts.

Pacific Northwest National Laboratory (PNNL), Michael Baechler: Building America Documentation

This presentation summarized the mechanics and function of programmatic documentation within the Building America program. The presentation also described the documentation resources that are available to the public and to specific target audiences within the renovation and construction industries.

Documentation includes:

- Best practice guides for three climate zones. Example chapters include *Installer Field Guides.*
- Case studies celebrate Building America team work and are broadly representative of team participation, climates, business models, house types, price points, innovation. These can be used to tell builders' stories.
- Special subject documents: air sealing, historic homes, Builders Challenge, HVAC renovations, BetterBuildings health and safety, etc.
- Still needed: renovation best practices; outreach roadmap for BT residential integration.

Building America Retrofit Alliance (BARA), Stacy Hunt: Effective Communication of Energy Efficiency Research Results

This presentation focused on key challenges and strategies in communicating energy efficiency research results from collaborative team efforts to key stakeholder audiences. The presentation also discussed the difference between general awareness outreach efforts and targeted, transaction-based outreach intended to effect behavioral change to improve energy efficiency in homes.

Research results can be overwhelming and there is a strong need to craft communication to target specific audiences.

Key opportunities:

- Segment and prioritize audiences.
- Identify and map transactions and trigger points.
- Distill information to relevant, actionable core messages and tools.
- Catalog detailed information.
- Characterization of housing retrofit market: traditional remodeling, casualty repair, etc.
- Outreach plan for Building America.
- Measure guidelines in multimedia formats.
- BEopt training modules.
- Optimize strategies for utilize demonstration homes.

Community Evaluation

[Building Science Corporation (BSC), Philip Kerrigan: New Construction Pilot - New Orleans, LA]

This presentation summarized how it is imperative that the calculated energy and cost savings from the computer model be verified by tracking actual energy consumption of occupied Building America-designed homes. This analysis serves to confirm the models or illustrate gaps

Monitoring has been completed in only on the first two phases of the homes. However, results were disappointing. Some houses performed well, while others used much more energy than predicted.

BEopt predicted average source savings of 26%, but only one home achieved that. Weather data was different than predicted, possibly affecting the outcome, and one home had excessive cooling due to a refrigerant leak as well as the dehumidifier being set too high. The builder discontinued installation of dehumidification system in later homes, but homes still were using more energy than modeled.

Barriers identified included:

- Cost and usability of dehumidification system
- Possible high base loads contributing to less than predicted energy savings
- Energy simulation models cannot simulate dehumidification; estimates were added to models.

Next steps:

- Explore watt meters to disaggregate end-use loads in order to identify discrepancies between modeled energy and actual use.
- Follow up with homeowner survey to determine the impact of occupant behavior has on the energy use of these homes.

[Oak Ridge National Laboratory (ORNL), Jeff Christian: TVA Residential Deep Retrofit Research from 3 to 100 Houses]

This presentation summarized the findings from three simulated occupancy houses and five occupied deep-retrofit houses in the mixed-humid climate. This work has led to a 200-house retrofit study focusing on the use of the Home Energy Score (HES) and another 20- house study with opportunities for 40%-50% deep retrofits that also have considerable peak load reduction capacity. Hard field measurements were presented on insulating and sealing attics and crawlspaces and variable speed heat pumps with inverter and advanced compressor technology.

The following research results were identified:

- Big benefit in retrofits came from insulating and sealing of the attic.
- Moisture in roof sheathing was not a problem when measured annually.
- Roof temperature on the underside did reach 170 degrees in the summer, which may be a problem.
- One retrofit project house sold in 2 months (average is 13 months).
- Air tightness hard to get as low as desired in retrofit houses.
- Thin film solar did not work as well as standard solar—30% energy savings for same investment.
- Opportunity to harness the aggressive retrofit efforts of TVA in their efforts to mitigate concerns of utility capacity.

NorthernSTAR Building America Partnership, Dave Bohac: Home Energy Score Pilot Results

This presentation summarized how the Home Energy Score (HES) was used to rate 150 pilot houses and review the results. This, included the field crew experience integrating the score with their field visits, homeowner reactions, the score's potential to predict and motivate energy efficiency upgrades, and how the score predicted the homes' energy use compared to utility data. The HES scale is 1 (less efficient) to 10 (most efficient).

The following research results were identified:

The study included 154 diverse homes. Most were two-story homes, but also included were one-story and 1.5-story homes. Of the total, 95% had a basement, 33% of the homes had R-4 or less in the walls but 50% had R-11 or better. Half of the pre-World War II homes had little or no insulation. In the attic, 26% had less than R-15 and about 25% had over R-30. Data was collected during home visits and the HES report was mailed or emailed.

Findings:

- There was close agreement between energy use predictions in electric homes for HES and utility bills on average. However, there was a lot of disagreement on an individual home basis. HES seems to over-predict energy use in gas homes.
- 1.5 story homes had larger discrepancies between utility bill and HES predictions – possibly due to complex architecture.
- 27% of homes were HES 1-4. 41% of homes were HES of 7-10 (although none started at 9 or 10).

- After completing upgrades, 44% of homes only received an increased HES of 0-1 (this was not helpful in motivating consumers).

- No local customization: basement wall insulation was a common recommendation but in that area, adding basement insulation is not often recommended in a retrofit due to dangers in creating moisture issues.

- Many attics were not recommended to increase insulation, which was a discrepancy from local practice which would typically recommend higher levels of insulation. Utility gives incentive for higher levels than R-30.

Existing Program Evaluation

Consortium for Advanced Residential Buildings (CARB), Lois Arena: Better Buildings Initiative and SmartRegs Ordinance in Boulder, CO

This presentation summarized SmartRegs energy efficiency requirements for rental properties that were adopted by the Boulder City Council on September 21, 2010 and became effective on January 3, 2011. The session discussed the identification of the immediate needs for successful implementation and evaluation of program effectiveness.

The goal for the Better Buildings Initiative was to improve 10,000 homes and 3,000 businesses by May, 2013. Currently there are over 2,500 homes right now in the Better Building program, 58% of which have performed major improvements.

SmartRegs applies to rental properties and will be required for renewal of rental property licenses by 2019. There have been 1,500 properties signed up through EnergySmart in the seven months since the program began, with 505 achieving compliance. This number reflects that the program has achieved its first year goal for SmartRegs compliance. The Better Buildings Initiative has a target of 10,000 homes with a goal of creating an audit that can be performed in two hours to move owners to action.

Summary of barriers or issues identified:

- Auditor experience
- Difficulty in getting utility bills for comparison to predictions
- Lack of desire of homeowners to get several bids
- Lack of marketing tools/educational materials for property managers to present to owners

Summary of key opportunities:

- Training materials needed:
    - Presentation slides and handouts
    - Speakers notes
    - Train-the-Trainer material
    - Classroom content
    - Hands-on field training
    - Spanish versions of the above

Next steps:

- Performing more case studies and follow up interviews to determine secondary effects.

Partnership for Advanced Residential Retrofit (PARR), Ryan Kerr: Catalog of Midwest Retrofit Programs

This presentation summarized how, through surveys, web research, EM&V reports, and phone calls, work is being done to catalog existing and planned comprehensive retrofit programs, ultimately highlighting top performing programs and program elements. The presentation covered project design, initial results, and discussed working with energy efficiency program administrators and implementers to address Building America goals.

The following research results were identified:

- Web-based research can be used to gather publically-available information.
- Using "Survey Monkey," gather information from utility administrators on program details that are not likely to be publically available, but that are readily available to the utility administrator, including program goals, budget, cost-effectiveness and evaluation studies and results of Midwestern whole home programs.
- Detailed questions created for the most successful 10–12 Midwestern whole home programs that will provide a "deep dive" into the program design and implementation to assess what program elements have contributed most to the program's success.

The team will compile information about recent and historic energy consumption along with building size, year of construction, type of construction, number of rooms, and number of baths into a single database, focusing on the Chicago metro area. Using frequency and energy use per dwelling criteria, the team will identify the top ten housing types. Modeling tools like BEopt and empirical data will be used to select the three housing types that offer the best opportunity for cost-effective 30% whole house source energy savings.

CARB, Lois Arena: Clark County, NV NSP: Evaluation of Phase I and Plans for Next Round of Funding

This presentation summarized the evaluation of the success of Clark County's Neighborhood Stabilization Funds from the Department of Housing and Urban Development with respect to their original goals and to support the program in the next round. There were 184 homes completed in the first round. Audit and costs data were collected and analyzed for 40 homes and evaluated sample as a whole and by age group.

The following research results were identified:

- Some HVAC contractors don't understand requirements from BPI, ACCA Quality Install, ENERGY STAR.

- These contractors often underbid those who understood what is required.
- There is a need for training, support materials and support lines of communication for questions.

It may be that newer homes equal a more successful program. There will be less energy savings per house, however:

  - Can rehab more houses.
  - Employ more people.
  - Qualify more homeowners.
  - Allocate a bigger percentage of funds to energy efficiency.
  - Program-wide energy reductions would be about the same.

Next steps are to start the next round and find a target neighborhood:

- $50,000 per house cap.
- $20 million available this round vs. $30 million last round.
- 1960's to 1980's construction: 20 to 40 years older than homes evaluated in the last round.

Market Characterization

Building Energy Efficient Homes for America (BEEHA), Nathan Barry and BEEHA, Pierce Jones: Characterizing Energy Efficiency Using Appraiser and Utility Data
Part II.

This presentation summarized how monthly utility bills combined with property appraiser data offer the opportunity to directly quantify household energy consumption patterns. This session described how annual residential energy consumption baselines are being used to evaluate residential energy efficiency programs in Florida and Iowa.

The following research results were identified:

- Actual historical utility data on individual properties is necessary in predicting savings.
- Costs and investment payback remains the driving force of large-scale implementation.
- Performance varied across builders for HERS rated and Builders Challenge homes.
- Some investor-owned utilities do not share utility data, but there is confusion as to whether they are legally prevented from sharing this data or whether it is their choice.

Next steps:

- Data analysis of survey results, assessor data, and BTU/SqFt Ranking.
- Monitor homes on post-retrofit analysis.

DOW, Tim Mrozowski and DOW, Nat Ehrlich, Ph.D.: Market Characterization: Great Lakes

This presentation summarized the research approach and findings to date on characterization of selected housing markets in the Great Lakes region. This project creates a housing taxonomy for the region and identifies dominant archetypes and their characteristics, prevalence, and opportunities for retrofit.

The following research results were identified:

For taxonomy development, independent variables were build date, style, and size, while dependent variable were prevalence, need for upgrades, and homeowner demographics. Two dominant archetypes were identified for the Ann Arbor region: 2-story pre-1930 “Old West Side Charmers” and 1946-1970 post-war ranches. However, it was difficult to find ideally similar homes for field testing; some compromises had to be made when selecting homes and archetypes may not be uniform across a census region.

Next steps:

- Selecting homes for technical testing studies, relating archetypes to identifying retrofit measures, and completing field research work.

IBACOS, Kevin Broznya: Multifamily Energy Retrofit Specifications

This presentation summarized how, as more and more states are incorporating energy efficiency criteria into their affordable housing funding requirements, multiregional developers of affordable housing projects are working to understand the requirements and develop cost-effective standardized practices for complying with them. Model specifications that provide guidance on particular products, standards, and building practices help to take the guess work out of the equation for both building designers and trade contractors.

The presentation described the challenges of the energy burden being larger for low income housing than non-low income housing. However, the opportunity to improve energy efficiency in small multifamily low-income housing is great due to higher average consumption per square foot. With the development of model specification documents, that provide more clarity and guidance for the general contractor and trades, the goal is to create a greater level of consistency in execution of energy efficiency retrofits measures across the multiple regions a developer may work.

Next steps:

- Further evaluate incremental energy retrofit opportunities when other planned maintenance work is being performed.
- Identify what kinds of details may be necessary to enable phased approaches to retrofits.
- Develop guidelines and/or general decision trees on how to determine and address energy savings measures in differing types of multi-family buildings.

Advanced Residential Integrated Energy Solutions (ARIES), Hugh Henderson: HYDRONIC Retrofits for Low-Rise Multifamily Buildings

This presentation summarized the impact of using wireless temperature sensors in multiple apartments to control the central boiler plant. While most buildings use outdoor air temperature reset to modulate boiler supply temperatures, incorporated space sensors minimize overheating in apartments.

The objective of the research was to determine the impact of control strategies that use apartment temperatures for central boiler control on energy consumption, comfort, and cost and to compare energy performance, comfort, and cost to individual radiator valve controls in each apartment. Overall, the goal is to determine how best to utilize new wireless technologies to assist in energy efficiency.

The following research results were identified:

- This project is still in the initial phases.
- System hardware installation is underway, it is expected that the system will be operational with data collection possible by late September.

Summary of key opportunities:

A target to reduce heating costs by 15% to 25%:

- 20% savings = 4,539 therms per year ($5,447 at $1.2/therm)
- Initial assumption: cost to install the control system (PHASE 1) was $25,000
- Simple payback is 4-5 years. Payback is longer due to small size of building and multiple boiler rooms

Neighborhood Scale Strategies

Alliance for Residential Building Innovation (ARBI), Mark Berman: Driving Demand for Retrofits Through Neighborhood Outreach

This presentation summarized a study to determine if demand for residential retrofits is driven by targeted neighborhood outreach. This project is in its initial phase but will examine four pilot, neighborhood-scale programs:

- Stockton Energy Challenge: Single contractor
- Sonoma: Single contractor, targeting two neighborhoods, incentives for early adopters
- LA County: Two contractors, enlisting energy champions
- LA County: Multiple contractors, enlisting energy champions

The programs have commonalities such as financial incentives, use of traditional marketing and door-to-door canvassing, and use of Energy Upgrade California. However, there are differences between programs including levels of collaboration, financial incentives, HOA involvement and city and contractor participation.

IBACOS, Richard Baker: Using Community Associations to Catalyze Community Scale Retrofits

This presentation summarized the extent to which community resources can be leveraged to reduce customer acquisition costs for retrofit contractors, delivering a higher volume of business at lower costs to the homeowner. It was a review of community associations (CAs) and possible approaches for leveraging them to bring retrofit to scale.

Currently brainstorming ideas for leveraging CAs because:

- >24M housing units in CAs
- 4 out of 5 housing starts in CAs
- 60,000 CA managers
- 10,000 CA management companies

Summary of barriers or issues identified:

- How can community associations be leveraged?
- What motivates residents?
- How can CA help contractors?

Building Industry Research Alliance (BIRA), Tim Hillman: Neighborhood Outreach Utilizing Social Norms and Existing Social Networks

This presentation summarized neighborhood outreach through a push method utilizing social norms and existing social networks and through generation of specific meter level energy usage trends, comparisons to similar houses, efficient neighbors, and neighborhood comparisons employing housing stock characteristics and electric and water consumption data.

The project was conducted with Anaheim Public Utilities (APU) to provide customers comparative bill information. The targeting was a specific neighborhood of approximately 3,200 homes, 25% of which have sufficient equity to improve their homes.

The following research results were identified:

- Mailers and print ads led to roughly 30 homes sign up for retrofits.
- Working with schools to deliver targeted messages to kids.
- Translate targeted marketing messages successes to other markets.

System Tune-Up

Larry Brand from Partnership for Advanced Residential Retrofit (PARR) and Bill Dakin from Alliance for Residential Building Innovation (ARBI) presented several studies looking at lab and field tests designed to assess the effectiveness of energy upgrades through tune-ups, servicing, or replacement of heating and/or cooling equipment. One study will examine the best field conditions for equipment to meet rated performance.

PARR, Larry Brand: Installed Performance of High-Efficiency Gas Furnaces

This presentation summarized the ASHRAE standard, the test plan for measuring AFUE according to the standard under varying conditions, and the results to date for this new project. Residential energy models generally use the rated AFUE for high-efficiency gas furnaces or make a minor adjustment for oversizing and do not always achieve the installed efficiency.

The lab test study will be done using ASRHAE standard 103-2007 to examine high efficiency gas furnaces and identify what conditions need to be present in the field in order for these units to achieve their rated performance.

The following research results were identified:

- The study will examine three furnaces (90% AFUE single stage, 93% AFUE two stage, and a 98% AFUE step modulating furnace) to identify conditions necessary to achieve rated performance of high efficiency gas furnaces in the field.
- Cycle time in the standards set oversizing degree. Oversize standard is 70%—study will also look at 100% and 120%.
- External static test—0.2 inches (will also study at 0.3 inches, 0.5 inches, and .07 inches).
- Expected results:
    - AFUE rating will not change much in lab tests with changes in static pressure, but part load AFUE value will be lower.
    - High efficiency gas furnaces are cost effective, but performance is expected to vary significantly in the field.
    - High static pressure requires an adjustment to high fan speeds and more blower power.
- ASHRAE standard 103-2007 conditions create a very controlled environment not found in the field. In testing, unknowns such as the conditions of ducts and filters as well as pressure drops will present challenges.
- Recommendations for changes to the ASHRAE standard will be made.

ARBI, Bill Dakin: Avoiding Pitfalls of Air Conditioner Tune-ups and Replacements

This presentation summarized how successful air conditioning tune-ups and replacements require careful attention to detail with refrigerant charge procedures. Previous studies have shown that poorly calibrated instruments, presence of non-combustibles, human errors, and improperly maintained vacuum pumps can result in improper refrigerant charge adjustments, resulting in less than optimal performance.

This study will look at where efficiencies can be gained, as well as when servicing and when replacing is most appropriate; following up on a report from SoCal Edison on utility programs for duct and refrigerant charge retrofits.

The following research results were identified:

- There is expected potential savings to be found through servicing of existing equipment. At times, such as when the unit has reached its useful life, when refrigerate used is no longer available, after a home energy retrofit that reduces loads, or when high performance equipment is economically justified, replacement is necessary.
- There are potential retrofit savings in cooling. However, utility programs are seeing less than expected savings from these cooling retrofits—only 11% of expected savings relevant to refrigerant charge.
- Savings could be not there for various reasons:
    - Instrument inaccuracy
    - Human factors
    - Conditioning of evacuation equipment
    - Refrigerant overcharge
    - Evaporative fouling

Other findings:

- Return air paths in California have typically been undersized—CA is working to address this in the next code.
- Reduced air flow – flow hoods not reliable for accurate readings.
- Undersized return with high MERV filter can impact fan performance and air flow.
- Most standard techs don't evacuate refrigerant lines enough.

PARR, Larry Brand: HVAC Retrofit Program

This presentation summarized how the bottom-line performance of residential heating and cooling equipment can be measured in terms of energy provided to (or removed from) the space divided by energy consumed in the process. The MEEA HVAC Save program in Iowa is designed to collect data in 165 homes to determine this ratio and provide cost-effective system upgrade recommendations for the components that will benefit most from the investment. This presentation also covered the expected opportunity, the test plan, and results to date for this new project.

The following research results were identified:

Building America has looked at benefits from moving ducts into conditioned space. This study will examine the benefits of energy improvements on homes with ducts already in conditioned space. The study will also examine the reasons behind equipment not performing in the field such as oversizing, low air flow, distribution systems, equipment efficiency, high static pressures, and system not meeting the load. In addition, it will:

- Collect field data post-modification and see what corrections have the most savings potential.
- Collect energy data on homes that go through energy upgrades.
- Seek to work with contractors trained through SMEEA/ESI SAVE certification.
- Use ASHRAE standards 152 and 111.

Summary of barriers or issues identified:

- Typical systems are only 60-75% efficient.
- Most equipment is oversized.
- Figuring out how to measure in the field will be difficult.

A key opportunity this project presents is working with trained HVAC contractors to identify what issues and costs are associated with different measures.

Next steps:

- Follow-on testing and more detailed energy analysis of homes and comparison with results of lab tests.
- For houses with furnace replacement as an upgrade, the old furnace will be tested with ASHRAE 103 standard.

Engaging Stakeholders

Delivering new levels of energy efficiency in new and existing homes means involving and supporting key stakeholders and working with them to provide needed tools and information to their audiences. This track focused on strategies to engage stakeholders, utilize opportunities and overcome barriers to market transformation.

Software Tools and Databases

Pacific Northwest National Laboratory (PNNL), Heather Dillon: Building Component Cost Community Database

This presentation summarized the Building Component Cost Community database of costs associated with residential and commercial buildings. To capture the dynamic nature of the cost data, the database includes a community web-interface which will allow Building America partners and other industry experts to contribute data about the cost of high-performance building components.

This database summarizes cost data for both commercial and residential buildings. Faithful and Gould (national cost estimation firm) will provide component level cost data, and existing data from public sources is also included. In addition, DOE partners will be able to upload real cost data.

Summary of key opportunities:

- Web interface will allow Building America partners and other industry experts to upload cost information for high-performance building components.
- Feedback possible from the community on cost accuracies.

National Renewable Energy Laboratory (NREL), Ben Polly and NREL, David Roberts: NREL Efforts to Improve Software Accuracy

This presentation summarized several NREL initiatives to isolate, identify, and reduce sources of inaccuracy in residential building modeling software. The initiatives include comparisons of software results to large empirical datasets, uncertainty analysis, and subsystem modeling improvements.

The following research results were identified:

- Software typically over-predicts energy use of old, leaky homes.

The following software and types of software were examined:

- House Simulation Protocols

- National Residential Efficiency Measures Database
- Field and laboratory tests
- Field Data Repository
- Comparative analysis
- BEopt test suite.

Lawrence Berkeley National Laboratory (LBNL), Wanyu Rengie Chan: LBNL's Air Leakage Database

This presentation summarized preliminary analysis of the air leakage distribution of whole house building envelope tightness. Data collected and recently added to the database include blower door measurements from weatherization and retrofit programs from across the United States and new construction programs from several states. The results reported are preliminary.

The following research results were identified:

- In both new and old construction, the air change rate ACH50 peaked near 5 but drops off sharply to the lower side and more gradually on the high side.
- Blower door results from new construction: most ACH50 between 1.5 and 6.5. Change in median ACH50 between pre/post retrofit is 16~40%.
- Full analysis plan includes:
    - Looking at differences by regions, states, and/or programs.
    - Characterizing envelope air leakages of new construction.
    - Comparing pre- and post-retrofit data.

Testing Methods and Protocols

Fraunhofer Center for Sustainable Energy Systems (CSE), Kurt Roth: IEQ/IAQ and Energy Performance of Very Low-Energy Homes

This presentation summarized the monitoring of two single family homes built as very low energy homes, one of them all-electric, the other one with an instantaneous gas heater. In addition to energy consumption and the thermal performance of the buildings, indoor comfort is being analyzed and evaluated in detail by recording parameters related to indoor thermal comfort and indoor air quality.

The following research results were identified:

- Energy for space heating remains dominating load, followed by the hot water heater.
- In a good insulated envelope, a single point heat source can be used without comfort issues.
- Net zero energy homes are likely occupied by "aware" users who sometimes live with very low indoor temperatures during winter months.
- Mechanical ventilation is crucial in airtight buildings, but available solutions need improvements.

Building America Partnership for Improved Residential Construction (BA-PIRC), Philip Fairey: FSEC's Flexible Residential Test Facility

This presentation summarized the construction of two side-by-side, 1,536 square foot, 3-bedroom, slab-on-grade, lab homes designed and intended to be highly flexible with respect to the evaluation of potential retrofit options in hot-humid climates. To the degree allowable by existing codes, both homes are constructed with minimum efficiency component characteristics in order to represent "retrofitable" existing homes in hot-humid climates.

The homes had single pane fenestration, evenly distributed throughout, no concrete block wall insulation, R-19 ceiling insulation (current code minimum), SEER-13/HSPF-7.7 heat pumps (code minimum), and computer controlled heat and moisture gains scheduled by time of day.

The construction is now complete for both homes and the HVAC systems installed and operational. Other systems are underway:

- Instrumentation and data acquisition systems ~70% completed
- Weather station ~20% completed
- Automated lighting, appliance and occupancy system ~20% completed

The preliminary test plan for this project has been submitted for review.

NorthernSTAR Building America Partnership, Patrick Huelman: Testing Protocols and Procedures

This presentation summarized how successful retrofits require a clear understanding of the home's baseline condition, identification of any preexisting conditions, and confirmation that the home was left in better condition than it was found. This session reviewed protocols and procedures that should be employed during "test in" and "test out."

Due to funding delays, this project is just getting underway, so comments represent preliminary thoughts from project team. The focus is on whole house performance issues, not just energy efficiency.

The following research results were identified:

- Energy, durability, and air quality issues are interactive and must be solved simultaneously. Generally, better results are achieved with a performance-based approach.
- A performance-based approach reduces the risk of improving one area at the risk of another area and performance testing reduces callbacks and liability.
- There exists a need to standardize procedures and messaging to mitigate homeowner confusion and mistrust.

Test Houses

Pacific Northwest National Laboratory (PNNL), Subrato Chandra, PNNL, Sarah Widder, and Oak Ridge National Laboratory (ORNL), Roderick Jackson: 50 Pilot Deep Retrofits - Case Studies, Lessons Learned, Challenges Ahead; *Residential Retrofits in Atlanta*.

This presentation summarized a pilot study to provide technical assistance to 50 homes that are undertaking deep energy retrofits to save at least 30% of the whole house energy consumption. The presentation will discuss the current project status, selected case studies, lessons learned, and some of the challenges ahead for deep energy retrofits.

The following research results were identified:

- Energy efficiency upgrades were planned/performed for various residential buildings. The projected savings associated with these retrofits ranged from 30%-75%.
- In one case study, the most successful recruitment tool was a website pre-screen.
- Deep energy retrofits are easier to achieve when major remodeling work is planned.
- Deep energy retrofits are expensive and paybacks are typically longer than homeowner stays in home.
- Work with institutions that own residential properties to improve efficiency (can accept long paybacks and fund deep energy retrofits).
- Software predictions of post-retrofit energy usage can be compared to metered energy usage. If different, investigate why.

Summary of opportunities to collaborate:

- There may be opportunities for Building America to partner with colleges and universities that have signed the American College & University Presidents Climate Commitment.

Lawrence Berkeley National Laboratory (LBNL), Iain Walker: Deep Energy Retrofits

This presentation summarized how home energy reductions of 70%-90% are attainable using existing technology, sound construction practice, and careful project planning as well as how in-depth monitoring of deep energy retrofits provides insight into successful strategies and technologies that lead to energy reductions in occupied homes.

The following research results were identified:

- In order to achieve energy reductions approaching the 70% level in California homes, almost every system and component in the house will have to be improved.

- Deep savings are achievable using a variety of current technologies, including Passive Haus retrofit.
- Simpler approaches are better than complex ones. As an example, in one house a complex DHW/heat pump system failed, while in another inexpensive electric baseboard heaters effectively met the small remaining space conditioning loads.

Summary of barriers or issues identified:

- It is difficult to achieve 70% savings in homes where occupants display low energy user behavior pre-retrofit.
- Conversely, post-retrofit low energy user behavior is essential to success; energy savings will not be achieved if occupants make high energy choices.
- Enclosure air tightness levels could still be improved.

NAHB Research Center Industry Partnership for High Performing Homes (NAHBRC Partnership), Amber Wood and NAHBRC Partnership, Robert Stephenson: Greenbelt and Fort Benning (retrofit)

This presentation summarized energy efficient existing home remodeling through a pilot program of 28 units and detailed many considerations for energy efficient remodeling projects regarding the building envelope. In addition, the cost analysis of choosing the energy upgrades to include and the material, installation, and maintenance costs ensures the most cost-effective solution for energy efficient upgrade.

The following research results were identified:

- A sampling quality assurance approach can make gut-rehab projects more cost-effective.
- Analysis of worst case unit yielded projected source energy savings of 42% (BEopt) and a reduction in HERS from 176 to 88 (REM/Rate).
- Some additional opportunities include 100% hardwired fluorescent lighting, R5 exterior insulation, 14 SEER (8.6 HSPF) heat pump.

Summary of barriers or issues identified:

- Solutions valid only for gut rehab projects.
- Utility incentives drive builder decisions.
- Economic case and model for improvement in rental housing.

Next steps:

- Compares savings predictions to actual savings
- Monitor envelope upgrades
- Perform HVAC upgrades
- Monitor overall upgrades.

Testing Methods and Protocols

Building Energy Efficient Homes for America (BEEHA), Jonathan Shi: Building Envelope Energy Performance Estimation Methods

This presentation summarized how to use logged HVAC operation patterns together with weather conditions for estimating a building envelope's energy performance. Nebraska has developed a 3-D thermal modeling technique that uses IR imaging, laser scanners, and a pan-tilt unit.

The following research results were identified:

- The approach allows inverse modeling approach from the outside of the house (versus inside, e.g. blower-door) to assess building envelope characteristics and infiltration. It provides a non-intrusive method to audit.
- This project is underway and researchers are currently conducting field tests to assess usability of this approach.

DOW, Brian Holton: Field Efficiency Test Methods for Legacy Forced Air HVAC Equipment

This presentation summarized the development of a practical, accurate, and reliable method of field-testing legacy residential gas-fired furnaces and air conditioning equipment to determine efficiency degradation. The field-test methods will be used to improve the accuracy of energy and cost impact analysis programs.

The November, 2010, Building America meeting identified the need for research to address software accuracy, software validation and other modeling inputs. This research can lead to improved energy savings predictions by improving the accuracy of simulation input. The same group also placed high priority on field evaluations of retrofit systems and existing systems.

The following research results were identified:

The test method presented focuses on determining operating capacity and efficiency of the equipment itself, to compare manufacturers' efficiency ratings with reality. The methods have been largely developed; the next step is to put them into practice. A trial run of field test methods will be conducted in labs and then in three to five residences.

Fraunhofer Center for Sustainable Energy Systems (CSE), Jan Kosny: Phase Change Materials

This presentation summarized simple experimental methods for assessment of energy performance characteristics of insulation sheathings, thermal insulations, and complex arrays of containers containing phase change materials (PCM).

The following research results were identified:

PCM could be more effective than conventional insulation. They are used all over the world, but widespread use in United States is slow due to misunderstandings about how and where to use them appropriately. However, the United States is leading the development of PCMs, so it could be the leader in applications.

Summary of barriers or issues identified:

- The largest barriers are the cost of PCMs and their reputation based on past failures.
- Computer simulations that are currently available are inadequate to handle PCMs accurately because they would need to model a dynamic process, not steady-state.

Next steps:

- Dynamic testing of PCM-enhanced materials used in the United States.
- Development of E+ and BEopt models for PCM.
- Development of configuration recommendations for PCM applications in U.S. climates.
- Models to optimize temperature range and PCM load as function of application thermal conductivity, location, thickness.

Windows

Building Science Corporation (BSC), Kohta Ueno: Repair, Rehabilitation, and Replacement

This presentation summarized a review of current industry knowledge of the window retrofit options, including benefits and risks associated with the modification of existing window system. This research also identified concerns related to building durability and performance, and proposed strategies to mitigate the concerns identified. This project is still in process.

The following research results were identified:

- Comfort issues are often the drivers of energy retrofits/window replacements. However, existing work tends to consider windows as a standalone component, not as a part of an assembly/wall system. Several methods can be used to improve or augment window performance. There is a need to understand cost/performance tradeoffs for each.

- Many retrofit documents describe window sash seals, but not other air leakage paths; these details will be developed. There is a strong need to ensure air barriers are continuous and seals are provided. This is also true for water barriers. Retrofitting sill pans or fixing water issues can be difficult when not doing full window replacement.

- As with water infiltration, risk of condensation is a real concern. For example, interior storm windows may develop condensation on interior due to air leakage. Interior storms must be significantly more airtight (factor of 5 or 10) to avoid condensation issues.

Summary of key opportunities:

- Retrofit measure guidelines and energy efficiency solutions that fit business models and meet cost and performance targets.

NorthernSTAR Building America Partnership, John Carmody: Guidelines for Energy Efficient Windows

This presentation summarized the work in progress of the "Window Guidelines for New Construction" being developed for the Building America Program. Window selection tools were reviewed.

The following research results were identified:

- Windows represent at least 10% of addressable energy efficiency opportunities and there has been extensive of innovation in windows because of this.

- The Efficient Windows Collaborative's Window Selection Tool is based on RESFEN (RESidential FENestration) software. It allows users to select new or existing construction, climate where the window will be installed and other filters. The results show the energy efficiency of multiple window types available.

- Another way to inform consumers is fact sheets that include information on the alternative factors and benefits that drive window replacement, not just energy performance.

- Electrochromic/thermo/photochromic windows are coming to the marketplace. These windows represent a big investment by DOE.

Building America Retrofit Alliance (BARA), Theresa Weston: PNNL Window Guide

This presentation summarized the Window Retrofit Guide being developed to communicate the dos and don'ts when retrofitting windows. Window retrofits can all be considered custom projects. Considerations start with whether the whole window or the window operable sash is being replaced, and whether the retrofit is being done at the same time as a cladding replacement. Existing construction and climate must be considered in product, material and installation method selection. Care must be taken to provide for long-term durability by establishing continuity of air, moisture, and thermal management with the wall system to extent possible considering the retrofit scope.

The following research results were identified:

- This guide is still currently under development. The project fills a gap identified in a previous meeting held in Atlanta, Georgia, earlier this year. The goal is to develop a framework where, while each window replacement is fairly custom, it can be treated with similar process.

- Damaged windows, such as deposits between panes, are just one reason for retrofitting. There is a need to correct the underlying cause of damage and defects, not just the damage itself. With window replacements, there exists the opportunity to make these improvements.

Heat Pump Water Heaters

Building Industry Research Alliance (BIRA), Rob Hammon: Gas vs. Add-On HPWH vs. Hybrid HPWH in an Occupied Home

This presentation summarized how the energy use and hot water production of three different water heating systems–gas (propane) storage, an add-on heat pump water heater (HPWH), and an integrated HPWH–were compared in situ under similar ambient and water-draw situations at different times of the year for three different ambient conditions (cold, moderate, and hot) and corresponding different incoming water temperatures.

The following research results were identified:

- Three different 50 gallon water heating systems—propane storage water heater, Air-Tap add-on heat pump water heater (HPWH) on a propane water heater and GE HPWH—were monitored and compared in situ under similar water draw situations at different times of the year with typical, high and abnormal water usage.
- Field monitoring included most required parameters on ambient air and water draw conditions. But ambient air relative humidity was not recorded and immersion thermocouples were not installed for internal tank temperature measurements.
- General performance concluded under monitoring:
  - There was no shortage of hot water.
  - HPWHs all worked fine in heat pump only mode.
  - GE HPWH outperformed the AirTap add-on unit.
  - Average payback period for GE over propane is 1.8 years, for AirTap is 2.4 years.

National Renewable Energy Laboratory (NREL), Kate Hudon and NREL, Bethany Sparn: Results from Heat Pump Water Heater (HPWH) Laboratory Experiment

This presentation summarized the performance evaluation of five integrated heat pump water heaters (HPWH) based on results obtained at the Advanced Thermal Conversion Laboratory on the NREL campus.

The following research results were identified:

- Five heat pump water heaters (rated EF between 2-2.35) were tested in the Advanced Thermal Conversion Laboratory in NREL. The five HPWH have variants in condenser geometry, compressor size and backup elements. DOE standard test, operating mode test, performance map test and draw profile tests, and reduced air flow were conducted.

- DOE standard test results were similar to manufacturer's ratings; the set point temperature differed on the first hour rating for some units.

- Operating mode test results showed each HPWH has different control logic: a) either upper, lower, or the combination of the both thermistors are used to control heating or b) it used various control strategies for electric resistance elements.

- Coefficient of performance (COP) performance test showed a general trend of COP increasing with increasing air temperature and decreasing with increasing water temperature and icing limits on heat pump operating range for some units with low temperature air and water conditions.

- Drawing profile test showed that using morning and evening draws, 80 gal tank HPWHs have can maintain "hot" outlet temperature using heat pump, and smaller tank HPWH cannot maintain the temperature and relies on electric elements to operate.

- A TRNSYS model was developed to demonstrate energy savings potential for HPWH technology in various climate regions against electric water heaters. Results show that this technology is a viable option in most climates and is expected to provide significant energy savings when compared to typical electric resistance water heaters.

Consortium for Advanced Residential Buildings (CARB), Srikanth Puttagunta: Field Evaluation of Heat Pump Water Heaters in 14 New England Homes

This presentation summarized the in-situ performance of 14 heat pump water heaters (HPWH) installed in the Northeast. The second largest individual load in homes is quite often water heating, so with this increased importance, new domestic water heaters have been developed and are being installed.

The following research results were identified:

- Fourteen HPWH were evaluated for National Grid, NSTAR and Cape Light Compact with GE (50gal), AO Smith (50 and 80 gal) and Stiebel-Eltron (80 gal) units. Rated Energy factor, average COP (1.8 across 10 sites) and first hour rating were all monitored and reported.

- The impact of hot water demand in terms of daily draw volume (gallons/day) was plotted against HPWH coefficient of performance (COP). Sites with low COP values were found to have problems such as low ambient temperatures, concentrated draws, low or high hot water demand, and dirty filters. Heat pump heating rate was also tested on all units.

- In general, 50 gallon HPWH were recommended for use. But the field study indicated 60 and 80 gallon units have higher COP and can maintain hot water outlet set points.

- NREL lab tested air flow in the range of 100-500cfm with about 0.5-1ton of cooling. As the house becomes more and more high performance, the effect of HPWH becomes more significant.

Automated Home Energy Management Systems

Fraunhofer Center for Sustainable Energy Systems (CSE), Kurt Roth: In-Home Energy Displays: Consumer Adoption and Response

This presentation summarized the results of the home energy management preferences survey conducted to identify barriers and benefits associated with obtaining, installing, and using home energy displays (HED). The session also gave an overview of the project and its goal to establish specifications for the effective attributes of HEDs and data-driven evaluation of long-term energy savings from field tests of HEDs in approximately 100 homes (including control groups). In particular, prior studies suggest that initial energy savings do not persist due to a lack of sustained engagement with inhabitants. Survey and design assessment work done to evaluate what characteristics of HEDs are of greatest value and most engaging to users was presented.

The following research results were identified:

- Most people likely to spend very little time using HED.
- Usability ratings are good predictor of length of use.
- Approaches to residential energy management providing multimedia options are the most likely to be successful.
- Phone apps still can't rival web portals, even though they are highly desired.
- HEDs need to be more engaging overall to compete with web and phone based media.
- Current results stress the need for more work in the energy domain on user interface design, as well as what elements of visual energy feedback lead to the most energy savings.

CSE, Kurt Roth: Field Evaluation of Programmable Thermostats

This presentation summarized the project with a focus on the current task, the selection of high-usability programmable thermostats, and recruitment/selection of the field test site for their deployment. The project's goal is to evaluate users' experience with programmable thermostats in the field, particularly comfort levels and energy consumption achieved with high-usability thermostats as compared to a baseline "standard" thermostat that doesn't have high-usability ratings. Prior research, most notably at LBNL, has found that a significant portion of households do not effectively use programmable thermostats. The hypothesis, identified by LBNL researchers, is that thermostat usability is responsible for the relative ineffectiveness of thermostats. Planning for field testing is underway, and the team will randomly deploy high or low usability thermostats in ~100 units of a multifamily building and evaluate whether or not there are significant differences in how they are used to save energy (e.g., significant differences in implementing nighttime setbacks). The data acquisition solution for each housing unit was also described.

Finally, the Fraunhofer Team also was the first team to go through the Internal Review Board (IRB) procedure for human subjects testing, and described navigating that process.

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ABOUT THE BUILDING AMERICA TEAMS

Advanced Residential Integrated Energy Solutions (ARIES)

Lead: The Levy Partnership, Inc., New York, NY

Focus: Accelerate the development and commercialization of innovative and cost-effective approaches for dramatically reducing energy use of the nation's affordable housing, both existing and new. The team is broadly representative, including more than 50 organizations drawing from all stakeholders in the affordable housing community.

Alliance for Residential Building Innovation (ARBI)

Lead: Davis Energy Group, Davis, CA

Focus: Evaluate and demonstrate innovative technologies and residential construction techniques. ARBI focuses on research to motivate homeowners to invest in home energy upgrades, and develops and tests alternative marketing approaches to achieve large-scale implementation of energy improvements in targeted communities.

Building America Retrofit Alliance (BARA)

Lead: Building Media, Inc, a wholly owned subsidiary of E. I. du Pont de Nemours and Company, Wilmington, DE

Focus: Combines technical expertise and real-world construction experience with communications and outreach expertise to bridge the gap between research and market integration. BARA focuses exclusively on the home renovation and retrofit market, with emphasis on developing, deploying and promoting technically sound, cost-effective measures to radically improve home performance.

Building America Partnership for Improved Residential Construction (BA-PIRC)

Lead: Florida Solar Energy Center (FSEC), University of Central Florida, Orlando, FL

Focus: Cost-effective efficiency solutions for new and existing homes in hot-humid and marine climates. FSEC manages residential energy research facilities including the Manufactured Housing Laboratory, the Flexible Roof Facility, the Building Science Lab, the Hot Water Systems Laboratory, and the Climate-Controlled Air Conditioning Laboratory. The Flexible Research Test Facility, currently under construction, will provide two side-by-side lab homes for controlled retrofit experiments. For more information, visit the BA-PIRC website.

Building Energy Efficient Homes for America (BEEHA)

Leads: University of Nebraska-Lincoln, Lincoln, NE, and the University of Florida, Gainesville, FL

Focus: Explore and deliver systems-engineered solutions for new and existing homes using simulation and building systems research laboratories. In addition to achieving anticipated energy savings, special efforts will be placed on cost-effectiveness, scalable deployment ability and marketability of each solution.

Building Industry Research Alliance (BIRA)

Lead: Consol, Stockton, CA

Focus: Energy and peak reduction in homes and communities by evaluating technologies and market delivery approaches for neighborhood-scale implementation. The research will evaluate a variety of technologies and strategies to decrease energy use and peak demand in new and existing communities, and to increase implementation of energy-efficiency retrofits. For more information, visit the BIRA website.

Building Science Corporation (BSC)

Lead: BSC, Somerville, MA

Focus: Leading developer of energy efficient enclosure, ventilation and dehumidification systems for durable, high performance homes. BSC has worked with dozens of industry partners during the past decade and is responsible for the construction of more than 10,000 Building America houses and 100,000 ENERGY STAR houses (through its partner MASCO and the Environments for Living® program). BSC provides advanced solutions to technical challenges, code barriers and market requirements for new and existing homes. Learn more at the BSC website.

Consortium for Advanced Residential Buildings (CARB)

Lead: Steven Winter Associates, Inc., Norwalk, CT

Focus: Improving new and existing homes (specializing in multifamily and affordable housing) by leveraging new technologies, underutilized technologies, and innovative market delivery strategies. Researching advanced building systems and whole house performance, and transferring that knowledge to the marketplace in order to elevate home performance industry-wide. Visit the CARB website to learn more about the team and projects.

Fraunhofer Center for Sustainable Energy Systems (CSE)

Lead: Fraunhofer Center for Sustainable Energy Systems, Cambridge, MA

Focus: Deploy large-scale energy savings by integrating efficiency and renewable energy systems in new and existing homes. Extensive experience in whole house system integration research, from simulation through commissioning.

Habitat Cost Effective Energy Retrofit Program

Lead: Dow Chemical Company, Midland, MI

Focus: Application of innovative retrofit technologies in partnership with Habitat for Humanity affiliates primarily in the cold and mixed-humid climate regions. Improve retrofit methodologies by validating cost-effective strategies through test homes and identifying technology gaps that must be addressed.

IBACOS

Lead: IBACOS, Pittsburgh, PA

Focus: Develop and demonstrate integrated systems of design, procurement, construction, quality assurance and marketing needed to transform residential building retrofits and new construction. Visit the IBACOS website to learn more about the team and projects.

NAHB Research Center Industry Partnership for High Performing Homes (NAHBRC Partnership)

Lead: NAHB Research Center, Upper Marlboro, MD

Focus: Integrated, system-based technology advancement center with the primary mission of removing technological, regulatory, and cost barriers to building innovation by leveraging its access to remodelers and home builders. Visit the NAHB Research Center website to learn more.

National Energy Leadership Corps (N.E.L.C.)

Lead: Pennsylvania State University, State College, PA

Focus: A new approach to home and homeowner energy audits and assessments that facilitate multiple levels of energy efficiency measures for existing homes including modest and low-cost improvements, extensive energy retrofits, occupant interactions, and the introduction of advanced energy controls and renewable energy technologies.

NorthernSTAR Building America Partnership

Lead: University of Minnesota, St. Paul, MN

Focus: High-performance, energy-efficient solutions for new and existing homes in cold and severe cold climates, using a holistic integration of information and technologies across three key systems: the building system, the construction/delivery system, and the market/user system.

Partnership for Advanced Residential Retrofit (PARR)

Lead: Gas Technology Institute, Des Plaines, IL

Focus: Apply strong experience in design, development, integration, and testing of advanced building energy equipment, components and systems in laboratory and test house settings to improve performance, quality and market acceptance of whole house residential energy efficiency retrofits in cold climates.

ABOUT THE NATIONAL LABORATORIES

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division (EETD) performs analysis, research, and development leading to improved energy technologies and reduction of adverse energy-related environmental impacts. EETD conducts research in advanced energy technologies, atmospheric sciences, energy-efficient building technologies; energy analysis; and indoor environmental quality.

National Renewable Energy Laboratory

As DOE's primary laboratory for renewable energy and energy efficiency R&D, the National Renewable Energy Laboratory (NREL) conducts research to accelerate industry adoption of advanced technologies in both the residential and commercial buildings marketplace. NREL is the national technical leader for the Building America Research Program.

Oak Ridge National Laboratory

Oak Ridge National Laboratory's (ORNL) Buildings Technology Center (BTC) supports the development of technologies that improve the energy efficiency and environmental compatibility of buildings. ORNL partners with universities and private industry to develop and deploy energy-efficient buildings system technologies. A major focus of the BTC is Building America, including the development of manuals for builders and homeowners to guide them toward energy-efficient homes. The BTC is also home to a Building America Research Team.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) develops multidisciplinary solutions that enhance the energy efficiency of the nation's buildings. PNNL is the lead national laboratory for DOE's energy codes and standards, including support of the International Energy Conservation Code. PNNL's market transformation activities help to develop markets for emerging technologies such as solid-state lighting and highly insulating windows. PNNL supports Building America through documentation and resource development.

EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
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