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

Building America Building Science Education Roadmap

April 2013

Contents

INTRODUCTION

Applying Collective Impact to Building Science Education

One of the most significant findings from the Building America Building Science Education Summit is that there is an extraordinary list of assets engaged in this issue. This includes over a hundred individual resources involved in research, education, certification/training, advocating, conferences/events, providing technical content, and analysis tools. Yet progress has been painfully slow, and a daunting challenge remains to establish building science in education institutions and across the housing industry. Without success in this endeavor, an increasingly essential infrastructure of professionals with broad building science knowledge will not be available to ensure high-performance new and existing homes.

This summit was a first step to engage the diverse players to work together more effectively as a group than individuals. This concept is the subject of a research paper by John Kania and Mark Kramer called '***Collective Impact'*** that was published in the Winter 2011 edition of the Stanford Social Innovation Review. The authors' research revealed examples of "remarkable exception" for implementing large-scale social change and a common basis for their success: "commitment of a group of important actors from different sectors to a common agenda for solving a specific social problem."

This Roadmap is the first step in applying a similar collective impact strategy to building science education. The rubber meets the road as we move from a report to implementation. If we are to follow the principles in Kania and Kramer's paper, we will need to develop:

- A Final Common Agenda
- Shared Measurement Systems
- Mutually Reinforcing Activities
- Continuous Communication
- Backbone Support Organizations

The Department of Energy looks forward to facilitating this process as part of its Building America program. But the important social change goal can only be achieved with a broad commitment to actively participate in the process. Please join us.

Sam Rashkin
Chief Architect, Building Technologies Office

BACKGROUND

The U.S. Department of Energy invests in high-performance new and existing home innovations through its world-class research program called Building America. The key goal for this program is to support market transformation to zero net-energy ready new homes that are so efficient (e.g., about 50% above the latest code) that a small renewable energy system can offset most or all annual energy consumption and high-performance home retrofits that save 20-30% of total energy consumption. There is a four-prong strategy for achieving this goal:

1. Develop advanced technologies and practices to ensure cost-effective high-performance;
2. Prove performance with whole-house packages of advanced technologies and practices;
3. Provide guidance and tools needed to apply and refine proven innovations; and
4. Enable innovations by removing any infrastructure barriers to market transformation.

After tracking Building America accomplishments since the program's inception, one infrastructure need that has emerged is the lack of building science education to ensure an adequate supply of skilled professionals who can apply proven innovations and recognize the value of high-performance homes. DOE addressed this issue with a Building America Building Science Education Summit on November 7, 2012 at the National Association of Home Builders Research Center. The goal of this facilitated meeting was to bring together over 30 leaders in building science training, education, research, program implementation, and leadership from across the country to develop a strategic building science education roadmap. The meeting topics were organized as follows:

1. Define the ***problem*** by identifying the audiences lacking adequate building science education;
2. Identify the ***assets*** for building science education currently available;
3. Put forth a ***vision*** for building science education goals by 2030;
4. Identify the ***actions*** it would take to achieve the 2030 building science education goals including probable assets for leadership and support; and
5. Initiate a ***follow-up plan*** for moving forward.

This final report documents the results of this meeting after developing some broader organization and structure.

SUMMIT PARTICIPANTS

Facilitators

Sam Rashkin, Chief Architect, DOE Building Technologies Office
Sarah Mabbitt, Energetics

Name	Position	Organization
Building Science Educators		
Ben Bigelow	Professor of Construction Science	Texas A&M University
Tony Grahme	Professor of Green Building Technology	Univ. of Georgia
Patrick Huelman	Professor of Biosystems Engineering	Univ. of Minnesota
Joe Laquatra	Professor of Design and Env. Analysis /Department Extension Leader	Cornell University
Arn McIntyre	Director, Energy Center	Ferris State Univ.
Robert Reed	Director, Midwest Energy Efficiency Research Consortium (MEERC)	Univ. of Missouri
Georg Reichard	Professor of Building Construction	Virginia Tech
Bill Rose	Research Architect, Building Research Council	Univ. of Illinois at Urbana-Champaign
Mike Mazor	Adjunct Associate Professor	Michigan State University
Building Science Researchers		
Michael Baechler	Senior Program Manager	PNNL
Pam Cole	Scientist	PNNL
Tom Kenney	Senior Manager	NAHB Research Center
Janet McIlvaine	Senior Research Analyst	FSEC
Cheryn Metzger	BA Research Coordinator	NREL
Stacy Rothgeb	BA Research Coordinator	NREL
Building Science Organizations/Product Manufacturers		
Keith Aldridge	Exec. Director	Advanced Energy Corp.
James Brew	Principal	Rocky Mountain Institute
Amy Fazio	CEO	ACI
Jessica Hunter	Principal	Rocky Mountain Institute
Alexis Karolides	Principal	Rocky Mountain Institute
Brian Lieburn	Senior Advisor – Residential	DOW Building Solutions
Chris Little	Senior Advisor - Residential	BASF
Sydney Roberts	Home Services Program Man.	Southface
Craig Savage	Director	Building Media, Inc.
Karen Thull	Exec. Director	EEBA
Paul Totten	Senior Project Manager	SGH /NIBS/BETEC/Catholic University of America
Linda Wigington	Director Deep Energy Retrofit Initiatives	ACI
Government Programs Promoting Building Science		
Elizabeth Cocke	Director Afford. Hsg. Research & Tech. Div.	HUD
Eric Werling	Bldg. America Coordinator	DOE
Housing Industry Leaders		
CR Herro	Environmental Manager	Meritage Homes
John Sader	President	Sader Power Enterprises
Building Science Advocates		
Rose Grant	Program Director	State Farm Insurance
Sam Taylor	Building Science consultant	Sam Taylor

KEY RESULTS

Problem

Building science education is lacking across the entire spectrum of players involved in constructing and improving new and existing homes. This includes housing industry professionals, organizations, teachers, students, affordable housing stakeholders, and transaction process institutions.

Assets

There are an impressive array of assets serving building science education including certification/training programs, technical content, research centers, conferences/events, advocate organizations, university/college resources, and tools. However, they are substantially disconnected without a strategic vision and plan.

Vision

There are four main goals for building science education by 2030 including:

- Ensured high quality of building science education;
- Awareness of high-performance home benefits by key stakeholders;
- Mature delivery infrastructure for building science education; and
- Recognition of the value of high-performance homes in the transaction process.

The benefit for the USA by following this road map is quite simple:

- **Great buildings** – higher occupant productivity; lower operational and maintenance costs; much smaller carbon footprint
- **Great careers** – spectrum of roles and experience levels; making life better for others; job is hard to offshore

Actions

Near-, Mid- and Long-Term actions needed to achieve the building science education vision have been identified including key assets for leading and supporting them. These actions will require an effective oversight group to ensure success. A Building Science Education Task Force with representatives from each of the highest priority assets is recommended for this purpose.

Follow-up Plan

To maximize the value from the education summit, the key actions that need to move forward include completing the Building America Building Science Education Roadmap; promoting existing building science resources to stakeholders, coordinating existing university and college resources, and establishing a Building Science Education Task force.

PROBLEM

The following key audiences are not adequately served with Building Science education:

Housing Industry Professionals

- Architects/Designers
- Building Performance Managers(multi-family)
- Builders
- Engineers
- Sustainability Consultants
- Trades

Professional Organizations

- Air Conditioning Contractors of America (ACCA)
- American Institute of Architects (AIA)
- American Institute of Building Designers (AIBD)
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)
- Apprenticeship Programs
- Leading Builders of America (LBA)
- Mortgage Bankers Association
- National Association of Home Builders (NAHB)
- National Association of Realtors (NAR)
- Professional Degree Accreditation Bodies

Teachers

- Higher Education Teachers
- Builder/Trades Continuing Education Trainers
- K-12 Teachers

Students

- K-12
- Higher Education
- Consumers

Affordable Housing Stakeholders

- HUD
- Habitat for Humanity
- Low Income Tax Credit Administrators
- Philanthropic Organizations

Transaction Process Institutions

- Underwriters
- Appraisers
- Insurance Companies
- Realtors/Sales Agents

ASSET CATEGORIES

- Research Centers
- University/Colleges
- Certification/Training Programs
- Advocate Organizations
- Conferences/Events
- Technical Content
- Tools

ASSET DETAILS

Research Centers

- Building America (BA)
- Building America Consortia Teams (e.g., BSC, IBACOS, SWA, FSEC, ARIES, BA-PIRC, ARBI, Northern Star, PARR)
- Cold Climate Housing Research Center
- Electric Power Research Institute (EPRI)
- Florida Solar Energy Center (FSEC)
- National Laboratories (LBNL, PNNL, ORNL, NREL)
- National Institute of Standards and Technology (NIST)
- National Association of Home Builders Research Center (also part of Building America) (NAHBRC)
- Pennsylvania Housing Research Center (Penn State)
- Western Cooling Efficiency Center (WSEC)

University/Colleges

- Associated Schools of Construction (ASC)
- BETEC Education Committee
- Building America/NASULGC (now APLU) Building Science 101 Curriculum
- Building Science Student Chapters
- Building Science programs integrated into professional degrees (e.g., Waterloo, Univ. MN,)
- Building Science programs integrated into two-year degrees (e.g., Univ. of GA, Appalachian St.)
- Criteria for Excellence in Building Science Education
- National Consortium of Housing Research Centers' (NCHRC or "University Consortium")
- Building America Joint Committee on Building Science Education
- Annual Award for Excellence in Building Science Education
- Task Group on Criteria for Excellence in Building Science Education
- Society of Building Science Educators (SBSE)
- USGBC Green Builders Student Organization

Certification/Training Programs

- American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Appraisal Institute Green Rater Certification Training
- Building Performance Institute (BPI)
- DOE Challenge Home Training (CH)
- EPA ENERGY STAR for Homes (ESH)
- EPA Indoor airPLUS (IAP)
- EPA WaterSense (WS)
- DOE Guidelines for Home Energy Professionals
- Institute for Business and Home Safety (IBHS) Fortified Home (FH)
- Air Conditioning Contractor Association (ACCA)

ASSET DETAILS *continued*

- Masco Environments for Living
- NAHB Green Building Standards/Training
- Passive House
- Regional Utility Energy Efficiency Programs/Training
- RESNET HERS Rater Training/Certification
- Southface Earthcraft Green Building Training
- Southface Building Science/Code Training
- USGBC Leadership in Energy and Environmental Design
- U.S. Department of Agriculture Rural Development (USDA)
- Weatherization Program/Training

Advocate Organizations

- Advanced Energy Corporation (AEC)
- Affordable Comfort Incorporated (ACI)
- Air Conditioning Contractors of America (ACCA)
- Alliance to Save Energy (ASE)
- American Council for an Energy Efficient Economy (ACEEE)
- American Institute of Architects (AIA) – Building Science Education Committee
- American Society of Civil Engineers – Architectural Engineering Institute (AEI)
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)
- America Society of Mechanical Engineers (ASME)
- Building Enclosure Councils (BEC – NIBS/AIA)
- Building Enclosure Technology and Environment Council (BETEC)
- Building Performance Institute (BPI)
- Council of Large Public Housing Authorities
- EcoBroker
- Efficiency First (EF)
- Energy and Environmental Building Alliance (EEBA)
- High-Performance Product Manufacturers
- HUD Low-Income Housing Programs
- Indoor Air Quality Association (IAQA)
- International Energy Agency (IEA)
- Institute for Business and Home Safety (IBHS)
- Institute for Market Transformation (IMT)
- National Association of Home Builders (NAHB) national organization and regional chapters
- National Home Performance Council (NHPC)
- National Institute of Building Science (NIBS)
- North American Technician for Excellence (NATE)
- Residential Energy Efficiency Leaders Network
- Residential Energy Services Network (RESNET)
- Regional Utility Energy Efficiency Alliances (NEEP, NEEA, SWEEP, SEEEA, MEEA, SECO)
- Rocky Mountain Institute (RMI)
- Southface
- U.S. Green Building Council (USGBC)

ASSET DETAILS *continued*

Conference/Events

- ACCA Annual Conference
- ACEEE Summer Study on Energy Efficiency in Buildings
- ACI Annual/Regional Conferences
- Building America Technical Meeting Series
- Building Enclosure Council Meetings (BETEC/NIBS) – offered in over 25 cities in the US
- Building Enclosure Science and Technology Conferences (NIBS)
- Canadian Building Science and Technology Conferences
- DOE's Building Conferences
- EEBA Annual Conference
- HARDI Annual Conference
- IAQA Annual Conference
- NAHB International Builders Show
- NIBS Annual Conference, including BETEC Symposium
- Regional Building Science Conferences (Midwest, Wisconsin, Minnesota, NESEA)
- RESNET Annual Conference
- Roof Construction Institute Building Science and Construction Conferences
- Solar Decathlon
- USGBC GreenBuild

Technical Content

- ACI/Efficiency First job board/matching service
- ASHRAE Handbooks
- BestofBuildingScience.com
- Building America Best Practice Guides
- Building America Solution Center (BASC)
- Building Science Web sites (e.g., BuildingScience.com)
- DOE Workforce Guidelines
- EEBA Builder Guides
- ENERGY STAR for Home Version 3 Field Guides
- IBHS Fortified Home Guide
- ORNL Disaster Recovery Guidebook
- PATH ToolBase
- Solar Decathlon Education Resources
- Trade Journals (Home Energy, JLC, Fine Homebuilding, Energy Design Update)
- Whole Building Design Guide (NIBS)

ASSET DETAILS *continued*

Tools

- Builder I.Q.
- Cloud-based Checklists
- Green Appraisal Form
- Green Building Educator's Toolkit
- History of Failures
- Immediate Access to Post-Disaster Response and Rehab Efforts
- MLS Green ToolKit
- National Training and Education Resource (NTER)
- Residential Investment Grade Resource Standard (RIGRS)
- TED, TED-X

2030 Vision

Building Science Education by 2030 will be adequate to ensure:

High Quality Building Science Education and Practices

- Consistent, clear, common definition for ***Building Science*** is established
- Clearly defined skill sets for educators are established
- Clearly defined credentials to teach Building Science are established
- A credential for Building Science professional is established
- All construction documents must be approved by a Building Science credentialed professional
- Building science content targets appropriate levels: (practitioner, supervisor, policy-maker)
- Manufacturers ensure installers integrate building science principles

Mature Delivery Infrastructure for Building Science Education

- There are adequate qualified building science professionals
- Trades are qualified in building science best practices
- University and community college construction, architecture, and engineering programs fully integrate building science
- Building science content is integrated in K-12 science text books and curriculum
- Building science content is incorporated in construction training programs
- A major building science conference brings professionals/content together each year
- A certification harmonizes and recognizes various educational efforts

Awareness of High-Performance Home Benefits by Key Stakeholders

- Building science is recognized as a discipline nationally
- Labels in the market place clearly educate consumers on building science attributes (i.e. user manuals, interior labels for the home that identify performance attributes)
- Consumer guidance on homeownership effectively addresses benefits of high-performance
- High-performance homes are easily identified
- Data on energy use is provided to the public
- Home performance feedback systems are integrated in homes like a ‘check engine’ warning light
- Affordable housing providers recognize the value of high-performance homes for low-income families

Recognition of the Value of High-Performance Homes in the Transaction Process

- Home performance is integrated in MLS systems nationwide
- Home performance is included in education provided to homeowners at point-of-sale
- Financial institutions integrate cost and performance benefits when setting interest rates
- Insurers integrate the risk reduction value of high-performance when setting rates
- Appraiser recognize the value of high-performance homes
- Sales professionals effectively convey the value proposition for high-performance homes

KEY ACTION CATEGORIES

- Improve Quality of Building Science Education and Practices
- Increase Awareness of High-Performance Home Benefits
- Build Delivery Infrastructure for Building Science Education
- Educate Transaction Process About High-Performance Value

Timeframe Classification for Actions:

Near-Term : 2013-2018
Mid-Term: 2018-2024
Long-Term: 2024-2030

9.1 Key Actions: Improve Quality of Building Science Education and Practices

Action	Lead	Assets
Near-Term Actions [2013-2018]		
Terminology and Standards: • Develop a definition for building science • Identify and set proficiency levels (practitioner, supervisor, policy-maker) • Map proficiency levels to existing certifications • Establish building science Knowledge, Skills, Abilities (KSAs) for key construction trades • Promote Building Science Professional certification	Task Force BA	Research Centers Univ./Colleges Advocate Organizations
University/College Programs: • Establish criteria for excellence in building science education (define/set expectations) • Form committee to develop academic coursework and training curriculum tied to proficiency levels starting with a kick-off meeting similar to that for workforce guidelines. • Establish a peer-review process for building science curriculum • Test model curriculum through a pilot series and then finalize curriculum • Develop an educator proficiency rating system • Develop SWAT team to approach accreditation boards to require building science content • Bring organizational representatives on university advisory boards	NCHRC	Univ./Colleges Research Centers Technical Content Draft Crit. For Excellence Workforce Guidelines
Building Science Content: • Form a national manufacturers' committee to sponsor an online building science academy that ensures their products are properly installed in accordance with building science principles • Develop comprehensive national CEU building science training requirements for builders, contractors, trades	EEBA ACI	Technical Content Certif./Training Programs Advocate Organizations
Mid-Term Actions [2018-2024]		
Promote credentialed building science professional approval of construction documents to states	EEBA ACI	Advocate Orgs. Univ./Colleges
Require building science for accreditation of architectural and engineering education programs	NCHRC	Advocate Orgs. Univ./Colleges
Builder/contractor licenses require a building science proficiency exam/certification	BPI, ASHRAE	Advocate Orgs. Technical Content
Long-Term Actions [2024-2030]		
Professional license exams include a building science component	AIA ASHRAE	Advocate Orgs.

9.2 Key Actions: Increase Awareness of High-Performance Home Benefits

Action	Lead	Assets
Near-Term Actions [2013-2018]		
Targeted Audience Outreach : • Promote the builder/contractor business case for high-performance • Establish a caucus to promote benefits of mandatory building science in federal projects • Convene a meeting of educators and policy-makers to integrate workforce guidelines into existing state and federal training curriculum • Working with FEMA, ARMY COE, develop a Disaster Response Guide ensuring high-performance homes • Promote budget savings with high-performance homes to Department of Defense • Prepare and promote materials linking building science to philanthropic organizations' missions	BA BETEC, NIBS	Advocate Organizations Research Centers Conferences/Events Technical Content
University/College Programs: • Develop university business case outlining increased job opportunities for students with building science skills • Develop and promote information attracting students to pursue building science education	NCHRC, BETEC	Univ./Colleges Advocate Orgs.
General Public Awareness: • Promote high-performance homes/building science Ted Talk • Launch 'Energy Fact Check' consumer web site to address myths/misinformation about high-performance homes and lessons learned from real projects • Integrate benefits of high-performance homes in media stories • Work with utilities to include comparative energy score on utility bills based on empirical energy use	ACI, EEBA DOE BA Regional Util. EE Alliances	Research Centers Certificate/Training Programs Advocate Organizations Technical Content
Mid-Term Actions [2018-2024]		
Transaction Process Awareness: • Work with local governments to ensure home performance metrics are disclosed at sale • Work with lenders to routinely offer homeowners EEMs when purchasing resale homes to improve home performance	IMT	Advocate Orgs. Univ./Colleges
Long-Term Actions [2024-2030]		
Ensure home performance 'feedback' systems are integrated in new and retrofitted homes	DOE	Certificate/Training Programs Advocate Orgs.

9.3 Key Actions: Build Delivery Infrastructure for Building Science Education

Action	Lead	Assets
Near-Term Actions [2013-2018]		
Industry Event: Organize one major Excellence in Home Performance Conference and Expo, possibly Integrating related existing home performance conferences.	ACI EEBA	Existing Related Conferences/Expos (ACI, EEBA, RESNET, ACCA, IAQA, NIBS, BETEC, E3)
Information Sharing: • Initiate a Building Science Educators Forum [national or regional] to share lessons learned, develop curriculum, implement competitions, etc. • Architectural and engineering programs are promoted with fully integrated building science and listed in college selection resources and all major building science web sites • Identify and catalog qualified building science educators and programs and post online to attract more university programs	NCHRC, BETEC	Univ./Colleges Certificate/Training Programs Technical Content Research Centers Advocate Organizations
Resource/Program Development: • Work with NAHBRC to set up Regional/National Affordable High-Performance Home Design Competition to establish building science course at universities and colleges • Develop/expand national building science student chapter organizations • Establish centralized building science online courses • Meet with Department of Education to integrate building science in appropriate middle- and high-school courses • Develop K-12 education toolkits (activities, story books, textbook content, science fair activities, etc.)	DOE BA	Univ./Colleges Advocate Organizations Technical Content
Mid-Term Actions [2018-2024]		
Building Science Accountability: • Special recognition provided to construction, design, and engineering schools most proficient in building science • Work with K-12 physics textbook approval board to require building science content	NCHRC, BETEC ASC	Univ./Colleges
Long-Term Actions [2024-2030]		
Every home builder, contractor, and large trade subcontractor has credentialed building science expertise in-house or on retainer.	RESNET BPI	Advocate Organizations

9.4 Key Actions: Educate Transaction Process about High-Performance Value

Action	Lead	Assets
Near-Term Actions [2013-2018]		
Market Transformation Advocacy: • Advocate for FHA loan officer incentive structure to provide and promote EEMs for home performance retrofits • Define specific appraisal metrics beyond 'comps' that integrate value of high-performance homes • In coordination with the SAVE Act, develop and promote national economic policy for including NPV benefits of high-performance homes in appraisal and underwriting practices • Develop and promote policy that requires providing a home performance assessment at point of sale • Promote inclusion of energy assessment/ certification information in MLSs across the nation; engage the National Assoc. of Realtors • Convene meeting with leading lending underwriters on the reduced risk with high-performance homes • Convene meeting with leading insurers on reduced risk associated with high-performance homes	IMT DOE DOE	Advocate Orgs.
Business Case For High-Performance Homes: • Develop case studies demonstrating the value of high-performance homes • Develop 'best practice' sale training guidance for realtors and sales agents • Engage stakeholders to define verifiable metrics for high-performance homes	BA	Research Centers Advocate Organizations Univ./Colleges Conferences/Events
Mid-Term Actions [2018-2024]		
Analysis on high-performance homes value performed in areas where MLS flags these homes	BA	Research Centers Advocate Orgs.
High-performance home value training required component for appraisers license exam	IMT	Advocate Orgs.
High-performance value training required component for realtor license exam	NAHB, LBA	Advocate Orgs.
Long-Term Actions [2024-2030]		
Market-based reduced mortgage rates for high-performance homes	IMT	Research Centers Advocate Orgs.
Market-based reduced insurance rates for high-performance homes	LBNL	Research Centers Advocate Orgs.

EDUCATION SUMMIT FOLLOW-UP PLAN

Action	Lead	When
Complete Building Science Education Roadmap: • Prepare draft roadmap • Solicit stakeholders for roadmap review from Summit participants • Vet with Education Summit participants and identified stakeholders • Set up tracking tool for capturing reviewer comments • Process all comments on tracking tool • Complete final roadmap integrating review comments	BA BA BA PNNL PNNL BA	3/13
Promote Building Science Resources to Stakeholders: • Survey Education Summit participants for the best building science resources • Review existing building science curriculum including Building Science 101 Model Curriculum	BA	2/13
Coordinate Existing University/College Resources • Engage all existing university/college building science education assets in a meeting to align interests • Inform existing building science educators about into the SWS schema for the Guidelines certifications	BA	4/13
Establish a Building Science Education Task Force: • Survey Education Summit participants for high-priority assets • Solicit a key decision-maker from each high-priority asset to serve on the Task Force • Set up initial meeting of Education Task force to review the completed roadmap • Ongoing Task Force meetings to review progress/refine roadmap	BA	5/13

Suggested task force role:

- Oversee the completion and approval of final roadmap
- Identify mutually reinforcing activities for building science education
- Set up committees for activities
- Recruit key assets to lead committees
- Set up share measurement systems
- Facilitate continuous communications
- Update roadmap annually

Appendix A—History of the Building America Building Science Education Effort

The Building America/NASULGC project (FY 2004-2007) received significant DOE funding with "Summer Workshops" hosted by the University of Kentucky over a three year period. It produced a Building Science 101 outline with 14 modules. It was fostered by Dr. Jim Fischer, Asst. Secretary's Office (former Dean of Clemson University) and Ed Pollock. Funding issues lead to project closure. Subsequently, the DOE-EE Asst. Secretary's office sought to increase the educational impact of the Solar Decathlon. One result was the Building America Building Science Education project and the January 2011 "Excellence in Building Science Education Workshop", including the launch of the Building America Building Science Education website. The focus of that effort was to establish the mechanisms to share "excellent" curriculum and content for building science education, and foster the development of such curricula and content. The recommendations of the workshop and forum were to establish an institutional presence in Building America and also within the university organizations to facilitate sharing of curriculum and content. Further, an awards program was established for "excellence in building science education". At that time, the University Consortium and the Associated Schools of Construction (ASC) began, with DOE assistance, working together to improve their collaboration. This included an agreement to establish a "joint committee on building science education". Numerous meetings at the 2011 and 2012 ASC annual conferences took place resulting in at least slow progress towards establishing a formal collaboration between the organizations and an institutional presence in the university organization fostering excellence in building science education. Also, within Building America, delays were experienced in establishing a Building Science Education Committee under Building America, and updating the website based on forum recommendations. Recently, the Building America Building Science Education project received significant DOE and university support:

- Under the University Consortium, a task group was formed following the February 2012 annual meeting at the IBS on Criteria for Excellence in Building Science Education Curricula.
- Adjunct to the annual meeting at IBS, the first Excellence in Building Science Education Annual Award (and lifetime achievement award) were presented. Subsequently, in the summer of 2012, a selection was made for the second annual award.
- A meeting on building science education was held in July of 2012 in Denver, and the Building America Building Science Education committee was established.
- Following meetings in Boston, in July 2012, plans proceeded for a summit meeting to develop a roadmap for both the education activities and a competition among the universities to stimulate proficiency in building science.

Appendix B—Building Science 101 Model Curriculum

Module/Learning Objectives	Level of Detail in Module by Audience		
	Consumers	GenEd/Community College	Trades
1. Energy Issues and Building Solutions Learning Objectives: • Define terms of building science, ecological systems, economics of consumption • Relate building science perspective, ecology, social science • Explain historical energy and environmental issues related to buildings • Compare Site and source energy • Examine the health, safety and comfort issues in buildings • Examine the general context for building solutions (zero energy green home with durability as the goal) • Explain a basic overview of alternative energy (total solar flux) – do we have enough energy • Examine cash flow to homeowners • Demonstrate ability to find, evaluate and synthesize knowledge regarding building performance and sustainability • Define Business case – career opportunities • Explain appropriate technology and systems (and how to research them with every lesson) • Define interconnections/inter-relationships among building systems	High	High	High
2. Introduction to Sustainable Design & Building Performance Learning Objectives: • Describe how a building works as a system • Explain the flow of air, heat, liquid water and water vapor • Describe the importance of climate-specific design details • Relate IEQ issues to health • Relate Building performance to overall sustainability • Describe the characteristics of available fuel choices • Examine the roles and responsibilities of the building team • Explain the need for respect within the building team	High	High	High
3. Flows: Air, Heat, Water, Vapor (Site related)	Medium	Medium	High

<table>
<tr><td>Learning Objectives:
• Comprehend specific issues related to pressure- and temperature-induced flows
• Grasp the significance of water flows and their roles in building details related to the drainage plane and other building elements
• Recognize the need to manage relative humidity (condensation)
• Understand the air change rate and its relationship to above concepts
• Describe how heat, air, and moisture flows are linked (use hanging mobile)
• Show examples of buoyant forces and the tendency for warm air to move in a particular way
• Water flow
  – Show capillary effect of wood, concrete and glass
  – Discuss moisture storage of building materials as time and temperature specific
  – Design to ensure drying; dry-ability = durability; 4D’s – deflection, drainage, drying and durability
• Describe the relationship between relative humidity and health, r.h. and condensation (temperature) and r.h. and durability (again condensation)
• Recognize by source the pressures acting to move air in a building (air leakage forces)
• Quantify amount of heat loss (or gain) (average) attributable to air leakage
• Explain how to control air, heat and moisture flow in buildings
• Recognize psychometric chart and the cause of condensation
• Define dew point and give an example of its occurrence and result</td><td></td><td></td><td></td></tr>
<tr><td>4. Building Materials and Their Properties</td><td rowspan="2">Medium</td><td rowspan="2">Medium</td><td rowspan="2">High</td></tr>
<tr><td>Learning Objectives:
• Differentiate between different materials based on their porosity and the impact it has on properties, such as wetting and drying, capillarity, etc.
  – Define and be able to use:
  – Vapor perm ratings
  – Air perm ratings
  – r-values/u-values – look at all materials, including glazing
• Differentiate between individual material ratings and the performance of installed materials in the context of the completed assembly
  – Thermal by-pass
  – Resistance as r-value</td></tr>
</table>

– radiation • Practice waste reduction and use regionally appropriate and ecological materials • Predict effect of mass and phase change on building performance • Compare life span of materials Account for embodied energy			
5. Climate and Designing with Nature Learning Objectives: • Identify hydro-thermal regions • Apply heating and cooling degree day concept and summer and winter design conditions to construction details • Discuss relationships among temperature, precipitation, and construction techniques • Give examples showing the importance of climate-appropriate design and construction detail • Explain the relationship between solar geometry and building/window orientation • Define daylighting methods and give examples of applications • Describe methods to control solar gain (shading) to occupants benefit • Describe how wind influences design location of intake and exhaust • Describe methods to apply natural ventilation to occupants' benefit • Identify building details related to seismic conditions, hurricane-resistance, wind, fire, corrosion and other climate-specific factors that affect structural durability	High	High	High
6. Building Design, Systems Engineering Learning Objectives: • Explain systematic relationships among conditioning source, distribution network, and (location and selection) and terminal units with building envelope. • Identify sources of thermal by-pass (residential air leakage) • Name appropriate control methods for thermal by-pass • Discuss reasons why work and storage spaces should be isolated from living space • Name methods to accomplish isolation • Describe the method for insulating and isolating attics and crawl spaces (maybe move to 8?) • Identify methods used in performance diagnostics	High	High	High
6b. Building Design, Systems Engineering and Commissioning	Low	Low	High

Learning Objectives: • Demonstrate correct use of blower door, duct blaster, and similar diagnostic tools • Define the role of design details, specifications, and trade contractor scopes of work with respect to quality and high performance • Explain the process of building commissioning • Given typical commissioning records, interpret system performance • Explain importance of maintaining commissioning records			
7. Site: Drainage, Pest Control, Landscaping	High	Medium	High
Learning Objectives: • Relate water run-off to site grading • Explain the practices to manage residual toxins, termites, rodents, and other pests • Discuss proper placement of vegetation, mulch, and other decorative land cover • Relate soil properties to soil conditioning • Describe the effects of irrigation on the durability of the building			
8. Foundation: Moisture Control and Energy Performance	Medium	Medium	High
Learning Objectives: • Describe foundation construction techniques essential for the prevention of moisture and management of soil gas entry (radon) • Relate foundation systems to overall building energy performance • Explain climate-specific use of alternative foundation insulation systems			
9. Building Envelope: Moisture Control and Energy Performance	High	High	High
Learning Objectives: • Learn roof and wall assembly materials and techniques essential to water management (including flashing) • Learn roof and wall assembly materials and techniques essential to air infiltration • Learn roof and wall assembly materials and techniques essential for the prevention of vapor intrusion and drying of interstitial spaces • Learn climate- and design-specific use of alternative glazing systems • Become familiar with insulation selection criteria, advantages and disadvantages of various types of insulation • Explain what happens when insulation gets wet			

• Explain the purpose of a vapor retarder and the reasons for where it is placed • Distinguish between vapor retarder materials and weather barriers and their functions in buildings • Become familiar with appropriate climatic treatments for flashing (waterproofing) window penetrations • Explain the concept of drainage planes, gravity flow, roof penetration flashing, and how to keep the house dry • Describe the effect of voids and imperfections in insulation			
9b. Windows, Doors and Other Penetrations	High	High	High
Learning Objectives: • Describe radiation effect, conduction and convection heat flows through windows and doors • Discuss low E films, gas fills and low conduction spacers • Discuss NFRC labels and explain U/R value, visual transmittance, solar heat gain, coefficient & condensation resistance • Describe the sequence of a gravity-layered flanged window installation • Recall that there are two types of windows: windows that leak now, and windows that will leak • Describe appropriate materials for flashing that are waterproof, durable, compatible, formable and their mechanical properties • Analyze flashing requirements for drainage, continuity, end dams, drip effect and accommodate movement • Describe where to flash; wall assemblies, roof lines, top & bottom of doors and windows, penetrations, balconies, doors and decks • Recognize that some water will get past the cladding, always install a weather barrier that drains • Describe the importance of installing a weather barrier from the bottom of the building to the top, layered, shingle-fashion			
10. Mechanicals/Electrical/Plumbing: Systems Engineering, Energy Performance, Occupant Health, Safety, Comfort, and Envelope/Mechanicals Management, Part I	Low	Low	High
Learning Objectives: • Identify equipment and explain duct issues • Relate mechanical system design to architectural design • Explain best practices for selection, installation and maintenance of mechanical equipment • Describe efficiency standards and appliance ratings • Explain the concepts air conditioning • Describe hot water systems • Explain issues related to ducts for air distribution			

• Explain the use of controls and monitoring and their impact on energy performance • Describe the use of spot ventilation to control moisture at its source • Calculate ventilation rates using ASHRAE 62.2 • Describe the use and application of evaporative cooling			
11. Mechanicals/Electrical/Plumbing: Systems Engineering, Energy Performance, Occupant Health and Safety, Comfort, and Envelope/Mechanicals Management, Part II	High	High	High
Learning Objectives: • Explain the purpose function operation and maintenance of ventilation systems • Describe the conditions that cause and effects the result from back draft issues • Describe control and venting of combustion products and symptoms of failure • Recognize a sealed combustion system and discuss IAQ effects • Identify and use appropriate methods to seal penetrations (e.g. wires, pipes, ducts) • Demonstrate ability to seal and test duct work for air leakage • Explain the role of indoor relative humidity in building performance and the conditions-based need for dehumidification/humidification • Describe the operation, control and application of alternative heat pumps • Describe operation control and application of combustion appliances (e.g. wood burners, fireplaces and natural gas inserts) • Walk on water			
11b. Electricity Payload	High	High	High
Learning Objectives: • Recognize the Energy Star label and interpret its information • Introduce TED and tell us how to know him better and what he can do for us • Explain a “phantom” load and why it affects your utility bill • Define watt, kWh, BTU (British thermal unit) • Explain the three different electrical lighting types (compact fluorescent, incandescent, halogen, and LED) and their advantages and disadvantages • Estimate your own hot water use and describe how renewable energy sources might provide this energy service			

<table>
<tr><td>11c. On-site Generation

Learning Objectives:
• Describe the application of PV & wind generated power to the building load
• Discuss the use of solar thermal systems for water and space heating
• Discuss future technologies such as fuel cells and plug-in hybrid cars</td><td>Medium</td><td>High</td><td>High</td></tr>
<tr><td>12. Field Issues: Construction Management, Codes, and Other Regulatory Matters (0ptional)

Learning Objectives:
• Relate practical matters that affect implementation of design details, specifications or purchasing requirements, and scopes of work including construction labor issues and homebuyer concerns
• Describe code enforcement and zoning ordinance issues that may obstruct the construction of high performance housing and effective counter strategies
• Impact of codes/standards on building performance and sustainable design
• Discuss local public policy; Impact of policy, regulation and enforcement
• Review the process of policy development and change
• Relate that high performance construction is a team process, just because a general contractor or buyer wants high performance, it takes subcontractors and employees to understand the details and importance to succeed</td><td>Low</td><td>Low</td><td>High</td></tr>
<tr><td>12b. Benchmarking performance: meeting and exceeding the norm

Learning Objectives:
• Apply building simulation tools and techniques for measurement and prediction
  – Metrics of performance – how to measure performance and make adjustments
  – Ability to use tools to analyze buildings and make design decisions (energy, environment, etc.)
• Exceeding Code
  – Compare valuation methodologies for building performance and sustainable design (HERS, LEED for homes, local green building program, etc.)</td><td>Low</td><td>Low</td><td>High</td></tr>
<tr><td>13. Community Scale</td><td>Medium</td><td>Medium</td><td>High</td></tr>
</table>

Learning Objectives: • Describe relationship between single building & site land use, infrastructure and ecological impacts • Relate buildings to utility systems (electric, gas, water and sewerage) • Explore impact of peak loads on the utility system • Identify rate structure and potential effects on decision-making • Relate building location and density to community transportation options (cars, public transportation, biking and walking) • Discuss community-scale generation options (district heating and cooling, landfill gas generation, etc.)			
14. Putting it all Together: Experiential Learning in the Field / Office	Medium	High	High

Learning Objectives:
• Integrate class lessons with field demonstrations
  – Trade only: through a partnership with a high performance builder, shadow a construction manager for an assigned time during a one-week period
  – Participate in utility or third party audit
• Assess best practice via web-based case studies (new construction and retrofit)
  – Discuss differences and similarities
  – Discuss what works and what doesn't
  – Discuss design intent vs. as-built performance
• Create new information
  – Perform evaluation of local buildings and compare			

15. Homeowner Education (Communicating with the Consumer)	High	High	High
Learning Objectives: • Identify tax incentives • Related building performance to financing and insurance: e.g. energy improvement mortgages • Explain the value of commissioning, punch lists, and home inspection • Develop/apply best practices: O&M manuals • Evaluate occupancy lifestyle impacts: e.g. TED • Selling energy efficiency • Analyze home energy audits • Encourage energy efficiency & technology: behavior via social diffusion • Trades only: promote and apply cleanliness of the job-site			
16. Conclusions, Implications, sources of further learning and continuing education	High	High	High
Learning Objectives: • Review and Reinforce materials covered and studio and field			

experiences • Discuss current research topics regarding high performance buildings • Restate the need for lifelong learning • Reflection • Diagram all of the energy inputs and losses from a building • List all systems involved in air circulation in a building • Identify most important factors affecting building comfort and safety • Identify all sources of energy inputs to the construction of a building • Explain how HPB can effect world energy issues • List ways to make a difference in current world energy imbalances			

Appendix C—The Need for Building Science Education White Paper (Joseph Laquatra, Cornell University)

As the demand for high-performance housing grows, so does the need for improvements in building science education. Even before the energy crisis precipitated by the 1973 Arab oil embargo, building codes in America were gradually addressing energy and moisture issues in prescriptive ways that were not evidence-based. As a result, problems ensued. Builders, engineers, architects, building code officials, and others involved in the home building industry have been learning how to avoid the problems through trial and error. This has led to widespread misconceptions that persist to this day, including beliefs that buildings should not be airtight or "overinsulated." Well-documented problems of mold-infested houses have exacerbated misunderstandings about methods for building high-performance homes.

Stricter building codes or builder licensing requirements are not necessarily the solutions to problems associated with misunderstandings about building science. Motivating professionals currently involved in the housing industry to learn through continuing education is a start, but the core problem must be addressed by including building science education in curricula related to architecture, engineering, construction management, and other fields. This paper will review early developments in the history of housing construction that led to discoveries related to building science, problems that followed, their resolutions, and current efforts to increase awareness of building science education.

Ireton (2012) provided a useful history of building science, beginning with the early years of insulating homes in the 1920s and 1930s, after which exterior paint started peeling. That resulted in painters refusing to paint insulated houses. Vapor retarders and attic insulation were prescribed by building codes; and paint continued to peel from exterior siding. Issues that were not understood included relative humidity levels inside houses and wind-driven rain that can penetrate siding. To this day, moisture movement inside houses and water intrusion into building enclosures are issues that are not well comprehended by builders, code officials, architects, and other housing professionals. Misconceptions abound and building failures continue because of moisture that can cause structural problems and create conditions that lead to pest infestations. In addition to affecting the health of structures, excess moisture affects the health of building occupants by creating conditions that are favorable to mold growth that exacerbates asthma and allergies (Institute of Medicine, 2004).

Besides moisture, other issues that affect the health of building occupants include indoor pollutants such as radon, volatile organic compounds, and combustion products. Understanding and controlling these pollutants requires a grasp of what has come to be known as building science, a growing field that takes a systems approach to understanding houses by focusing on the structure of a building, its occupants, and its contents (Florida Solar Energy Center, n.d.). In addition to a focus on pollutants, building science includes emphases on heat flows, air flows, and exterior water management. A house that is built by someone with a good understanding of building science should be durable, affordable, healthy, comfortable, and safe. But the term, building science, is not used consistently.

Rose (2012) noted a use of the term, "building science," in the *Proceedings of the University of Illinois Conference on Architectural Education* from 1949. Max Abramovitz is quoted as:

"I wonder if you realize how very few men are left today who are expert in building science." (Rose, 2012: 7)

Rose (2012) described the field as "science applied to buildings," and provides both broad and narrow definitions, with the former applying to all "physical, chemical and biological process affecting buildings," and the latter applying to "heat, air and moisture transport in buildings." He also noted that the term corresponds to what is called "building physics" in Europe. (Rose, 2012: 8)

Best Training School provides the following definition

"Building science is the collection of scientific knowledge that focuses on the analysis and control of the physical phenomena affecting buildings. This includes the detailed analysis of building materials and building envelope systems. The purpose of building science and understanding the training that supports it is to provide predictive capability to optimize building performance and understand or prevent building failures. Those failures may include not only structural weaknesses but also failures in securing the building envelope against moisture intrusion that may result in wood rot, mold, or, in most severe cases, destruction of the structural integrity of the building."
http://www.besttrainingschool.com/building-science.php (Retrieved October 10, 2010)

One thing missing from the above definition is the role of mechanical systems in a building's performance.

Lstiburek (2005) wrote that building science is an immature discipline with little visibility at universities. He compared it to structural engineering when it was a young discipline. But structural engineering did mature and brought about an understanding of loads, load resistance, and other concepts. As structural engineering matured, so too can building science.

At the university and community college levels in the United States, building science is becoming integrated into academic programs. Carnegie Mellon University's School of Architecture, for example offers graduate degrees in Building Performance & Diagnostics. The Department of Architecture at the University of California, Berkeley includes a minor in sustainable design that features courses in building sciences and sustainability. Onondaga Community College's programs in architecture and interior design include instruction in building science. An issue with current academic programs in architecture is that they are focused on large buildings, not houses. One academic program that does focus on housing is construction management, which is also known as construction science, construction technology, and construction engineering technology. What is the extent to which building science is becoming integrated into this program?

The American Council for Construction Education (ACCE) is the accrediting body for construction management academic programs in the United States. The ACCE manual, *Standards and Criteria for Accreditation of Postsecondary Construction Education Degree Programs,* lists courses that must be taught in Construction Management programs in order for them to be accredited. Building Science is not mentioned in the manual.

The Department of Technology and Environmental Design at Appalachian State University offers a Bachelor of Science Degree in Building Science with concentrations in Construction Management and Architectural Technology and Design. A specific course in Building Science in this program covers ways that buildings interact with the environment, moisture issues, indoor air quality, and the use of diagnostic devices including blower doors, duct leakage testing devices, air flow detection equipment, and indoor air pollutant testing tools. This program is not accredited by ACCE.

The Department of Building Science at Auburn University offers Bachelor and Masters degrees in Building Construction and is accredited by ACCE. But building science as described above is not covered in the undergraduate or graduate program. The Del E. Webb School of Construction at Arizona State University offers Bachelor, Masters, and Ph.D. programs in Construction Management and is accredited by ACCE. Building science is not covered in any of these programs.

These are only a few examples of the current state of building science education, but they serve to demonstrate that widespread awareness of building science does not yet exist. In an article that is now 13 years old, Uniacke (1994) wrote that he expects to see serious defects in the thermal performance of newly constructed houses. He cited a lack of access to good information on the part of builders and architects as being largely responsible for the situation. He argued that integrating building science into construction management academic programs at the community college level would be an effective remedy to the problem because of ease of access and value. When Uniacke wrote the article, his institution was called Yavapai Community College. It is now Yavapai College. A check of its website on the Associate of Applied Science Degree in Residential Building Technology revealed that energy efficiency is emphasized in some program areas (http://www.yc.edu/academics/degrees-and-certificates/associate-of-applied-science---residential-building-technology/28).

Uniacke (1994) stressed other advantages of integrating building science in community college curricula. One is that building in the local climate can be emphasized. Another is that building professionals, at least at this college, could take courses without being graded. The particular course that Uniacke (1994) described a two-tiered approach to teaching building science. The first tier relates to the goal: to build a house that is energy efficient, affordable, healthy, safe, comfortable, and durable. The second tier covers evidence and theory including definitions, procedures, product information, and construction details. In his class he made use of the blower door and other diagnostic tools, used over 600 visual aids, expert guest lecturers, construction site tours, and other enhancements that made his class so popular that attendees began sending their employees to it.

A 2005 collaboration between the U.S. Department of Energy (DOE) and the Association of Public and Land-grant Universities (APLU) produced an outline for a university-level, semester-long course in building science, "Building Science 101." This course outline contains the following modules:

- Energy issues and building solutions
- Introduction to sustainable design & building performance
- Flows: air, heat, water, vapor
- Building materials and their properties
- Climate and designing with nature
- Building design, systems engineering and commissioning
- Site: drainage, pest control, landscaping
- Foundation: moisture control and energy performance
- Building envelope: moisture control and energy performance
- Windows, doors and other penetrations
- Mechanicals/electrical/plumbing: systems engineering, energy performance, occupant health, safety, comfort, and envelope/mechanicals management, part I
- Mechanicals/electrical/plumbing: systems engineering, energy performance, occupant health, safety, comfort, and envelope/mechanicals management, part II
- Electricity payload
- On-site generation
- Field issues: construction management, codes, and other regulatory matters (optional)
- Benchmarking performance: meeting and exceeding the norm
- Community scale
- Putting it all together: experiential learning in the field/office
- Homeowner education (communicating with the consumer)

The full course outline can be viewed here:
http://www1.eere.energy.gov/buildings/residential/ba_science_education.html#curricula

Numerous resources on building science exist and include books, peer-reviewed journals, websites, and organizations. The DOE Building America program has set a goal of supporting the transformation of the

design/construction industry to one that routinely designs and builds quality, high performance homes that are safe, healthy, durable, comfortable, and energy efficient. To achieve this goal DOE recently developed a Building America Building Science Education committee. One activity of this group is to work with a joint committee of the Associated Schools of Construction (ASC) and the National Consortium of Housing Research Centers (NCHRC). A long-term goal of this project is to facilitate the inclusion of building science courses as part of the accreditation process of construction management academic programs by ACCE.
In 2011 DOE worked with the NCHRC to establish an annual Excellence in Building Science Education Award program to recognize efforts of university, college, or community college faculty in this area.

Although progress is being made in building science education, it is not happening fast enough. System failures, including water leaks and mold growth in houses, are prevalent. Forty-seven percent of homes in the U.S. are reported to have problems related to dampness and mold (LBNL, 2012). Mullens, Hoekstra, Nahmens, and Marinez (2006) reported that 20% of homes built in 2003 in Central Florida experienced water leaks from the exterior during Hurricane Jeanne in 2004.

The construction of high performance energy efficient homes now requires specialized knowledge and skills that were not required of builders 40 years ago. Properly installed housewrap, window flashing, and air-tightening measures all contribute to a house that performs well. But the nature of the housing industry in the U.S. makes it difficult to ensure that everyone involved in building homes understands these issues well. Many different trades, including carpentry, plumbing, electricity, and others are involved in construction. Straube (2012) is quoted as saying that the construction site supervisor should be the first person to receive training in building science.

Changing building codes to reflect the latest knowledge in the field is not the answer to this problem, because the code process is a political one and because codes lag science by 10 to 15 years (Ireton, 2012). Requiring licenses for building contractors, coupled with continuing education would only work partially, because of all the trades involved in building. Licensing is another political issue. Not all states require this. Some that have tried to impose it as a requirement have met stiff resistance from home builder associations. The current generation of home builders requires continuing education in building science, but not all builders are motivated to pursue this. In theory, home buyers could exert a push factor on the process by becoming informed about building science themselves, but this is not very likely to happen. The long-term solution is to include building science education in academic construction management programs.

References

Florida Solar Energy Center (n.d.). Building Science Basics. Retrieved November 10, 2012 at: http://www.fsec.ucf.edu/en/consumer/buildings/basics/index.htm

Institute of Medicine (U.S.). Committee on Damp Indoor Spaces and Health (2004). *Damp Indoor Spaces and Health.* Washington: The National Academies Press.

Ireton, K. (2012). The trouble with building science. *Fine Homebuilding.* Spring/Summer, No. 227: 70-75.

Lawrence Berkeley National Laboratory (LBNL) (2012). Prevalence of building dampness. Retrieved November 15, 2012 at: http://www.iaqscience.lbl.gov/dampness-prevalence.html

Lstiburek, J. (2005). Forward, in Straube, J. and Burnett, E. (2005). *Building Science for Building Enclosures.* Westford, MA: Building Science Press.

Mullens, M., Hoekstra, B., Nahmens, I., Martinez, F. (2006). Water intrusion in Central Florida homes during Hurricane Jeanne in 2004. Retrieved November 15, 2012 at: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&ved=0CGUQFjAI&url=http%3A%2F%2Fwww.ba-pirc.org%2Fpubs%2Fdeliverables%2FWaterIntrusionReport8-21-06.pdf&ei=dUqlUM6RHJOC9gSgkYEY&usg=AFQjCNGn0NTghWn00v2DP9d3R8eGegnTWw

Rose, W. (2012). Research, building science and architecture. Housing Knowledge Community Webinar Series. American Institute of Architects. Retrieved November 11, 2012 at: http://network.aia.org/AIA/Resources/ViewDocument/?DocumentKey=89904d0f-70dc-4c4f-906a-c44e1556ec19

Straube, J., in Ireton, *op. cit.*

Uniacke, M. (1994). Building science education in the community college. *Home Energy,* May/June. Retrieved November 14, 2012 at: http://www.homeenergy.org/show/article/year/1994/magazine/85/id/1047