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BSC Final Report: Lessons Learned from Building America Participation

February 1995–December 2002

Building Science Corporation
Westford, Massachusetts

Building Technology Program

U.S. Department of Energy
Energy Efficiency
and Renewable Energy

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INTRODUCTION

Over the past 5 years under the Building America program, the Building Science Consortium has worked with more than 25 builders in 121 developments, in 18 states, and in all six climate zones. This work has resulted in more than 7,000 ENERGY STAR™ homes built as of August 2002. At total build-out, this will result in:

- 13,167 ENERGY STAR Homes
- 2,984,174 MMBtus of energy saved per year
- 14,152,533 lbs. carbon emissions saved per year
- 110,834 lbs. SO_X emissions saved per year
- 155,841 lbs of NO_X emissions saved per year.

(For more detailed information see the latest Complete Data Report at: www.buildingscience.com/buildingamerica/data/default.htm.)

BSC builder technical assistance has ranged from performance testing to development and introduction of innovative assemblies, components, and techniques to one of the most extensive and widely visited electronic building science resources on the web (see www.buildingscience.com/_stats).

As part of the Building America program, Building Science Corporation has also worked with seven building product manufacturers or building industry service providers on the development of innovative products ranging from energy guarantee programs to new HVAC technologies.

The BSC Building America work has led to a large body of technical information, industry experience, and lessons learned, which can help move the residential building industry to higher performance practices and products. This report chronicles the how and why of the key BSC Building America outcomes. It is organized and put in the context of what the Building Science Consortium has learned from and with its building industry partners.

This report is organized into six major sections:

- Research and Development Achievements
- Approaches for Creating Effective Builder Partnerships
- Soliciting Involvement of Industry Partners
- Market Barriers Overcome
- Market Barriers Remaining
- Program Improvement Suggestions.

For each activity chronicled in each section, Lessons Learned are highlighted and characterized. In almost all cases, each activity chronicled is linked to a specific technical resource that BSC has made available to the general public (and the residential building community in particular) on its Web site: www.buildingscience.com. An added section of the report, *Lessons Learned - Summary*, weaves the Lessons Learned into a pattern or overall context that can be used to inform:

- Residential building industry members through ongoing dissemination efforts by the Department of Energy and the Building America teams
- Future work under the Building America program.

RESEARCH AND DEVELOPMENT ACHIEVEMENTS

This section is split into three subsections of R&D Achievement:

- **Industry-wide.** Innovative concepts that can and have been utilized by the residential building industry as a whole.
- **Broad-based successes.** Fully developed or implemented techniques/components/systems with more than one builder or with more than one community/development.
- **Specific successes.** Less-than-complete development of techniques/components/systems and/or implementation with only one builder/one community/one development.

Hygro-Thermal Regions Map

INDUSTRY-WIDE R&D ACHIEVEMENTS

The Six Climate Zones

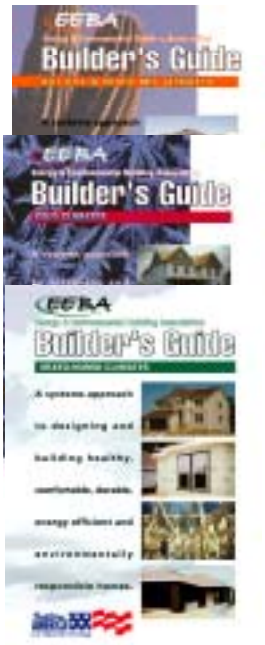
In recognition of the impact that climactic factors have on the design and construction of homes, particularly high performance homes, BSC developed the six climate zone system. For the first time, areas of the United States were clearly broken down by hygro-thermal region so that building envelopes and HVAC systems could be tuned to determinant climactic factors (see Web site at www.buildingscience.com/housesthatwork/default.htm). Given the industry-wide acceptance and use of this framework, it is pretty easy to overlook the importance of this concept and how critical it is as a backdrop for contextual systems thinking for residential building.

Lesson Learned

Systems thinking in residential building requires the analysis of how air, heat, vapor, and liquid water move on and through building envelopes and HVAC systems. This cannot be reasonably accomplished without acknowledgment and incorporation of how hygro-thermal conditions drive this analysis.

The EEBA Builder Guides

The most successful tool for moving builders, trade contractors, and product manufacturers to climate-specific systems thinking in the design and construction of homes is the *EEBA Builder's Guide* (for each of the six climates, see www.eeba.org/mall/builder_guides.asp). Details from this guide can be found throughout the major trade publications, laminated and posted at job sites, and even translated into Spanish for field use. The guides contain both the language and the images required to move building science theory into application by both design and field professionals.



Lessons Learned

"Show me" is a very common request from builders. BSC takes many calls a week on construction details for high performance, durable envelope assemblies that can now be handled by referral to the climate-appropriate EEBA Builder's Guide. The *EEBA Builder's Guide - Cold Climate* was also used extensively in the Project Specifications for the EcoVillage Cleveland Building America project.

Another lesson learned was applied to the *Houses That Work* section of the BSC Web site (see Web site at *www.buildingscience.com/housesthatwork/default.htm*). In this section, builders can freely access a single complete climate-appropriate envelope assembly. The lesson here is "Show me—in just one example, please."

Water Management Guide

Stemming from work on rigid insulation joint details with Dow Chemical (see page 19), additional BSC Building America partners—DuPont, Andersen Windows, and Fortifiber—expressed interest in the development of a technical information resource focusing on drainage plane details, addressing water as a liquid on the building shell. The result is a graphics-rich, step-by-step manual for handling water ("down and out") from rooftop to site—*The EEBA Water Management Guide*.

This effort has led to planned production for a series of five management guides; the other four will focus on moisture management (airborne, diffusion and capillary), air management, source management (material pollutant sources), and project management (systems thinking approach).

Lessons Learned

There is a continual tug-of-war between weaving complex principles together to show a systems-thinking or integrated perspective and breaking building science phenomena down into separate issues for clarity. Now that both the *EEBA Builder's Guides* (full integration at the climate-specific level) and *EEBA Water Management* series (specific principle shown in a full series of graphic details) are available, energy-efficient/resource-efficient/durable design and construction are presented for builders from both perspectives.

Building America Performance Targets

Every term in this phrase is critical to the concept of providing builders and other building industry members with criteria for design and construction that define exactly what it means to participate in BSC's Building America team. These criteria are mandatory for BSC builder partners and are:

- Specific to the goals of the Building America program in terms of resource- and energy-efficiency
- Performance-based so that builders can use a systems thinking approach to achieve an end, as opposed to prescriptive criteria that can discourage a systems-thinking approach
- Expressed in such a way as to distinguish between criteria that **must** be met and criteria that are strongly recommended. Embodied in these criteria are the inextricable links among standards of energy performance, indoor air quality, and durability. The systems approach that drives the Building America program is fully expressed in the BSC Building America Performance Targets (see the Web site www.buildingscience.com/buildingamerica/targets.htm).

BSC developed these targets and posted them on its Web site to inform both participating and inquiring builders. The success of these criteria is demonstrated by their adoption or use in the following building industry programs:

- The Platinum level of the Masco Environments for Living™ program (see www.eflhome.com)
- The building criteria for the Energy and Environmental Building Association (EEBA) (see www.eeba.org/technology/criteria.htm)
- The American Lung Association's Health House criteria (see www.healthhouse.org/iaq/tourtext.htm#Building_Criteria)
- The Building America green builder program in Central New Mexico (see the Web site at www.bapartner.org) in partnership with BSC member, EEBA.

Lesson Learned

Builders seek and respect clarity in terms of the meaning and level of commitment a program requires. The performance targets have enhanced the credibility of both BSC and Building America.

Building America Cost Trade-Off System

The "break points" or cost trade-offs approach is one of the greatest factors behind the successful deployment of Building America technologies. During systems-engineering analysis of the residential construction process, "break points" are identified; these are costs of warranty and call-back reduction strategies as well as energy-efficient features balanced by the reductions of other construction costs. These "break points" involve construction strategies or levels of energy efficiency that allow a specific component of a building to be downsized or deleted. For example, construction costs can be increased by changes and improvements to the building envelope that reduce warranty and call-back expenses, as well as reduce heat gain and heat loss. The improved building envelope performance allows the mechanical equipment to be downsized. The initial construction cost increases are offset by the reduced costs associated with the downsized mechanical system.

An extension of this approach is the "value rules" phenomenon. Several BSC Building America builders have experienced the following: selling more homes at a slightly higher cost to build, at a slightly higher selling price, with a slightly higher profit margin. The key is that if homebuyers are convinced of higher value, they will accept that a higher-priced home.

Example Cost Summary
Building America Metrics

Hot Dry Climate

Unvented roof	+ $750
NOT installing roof vents	- $500
High performance windows	+ $300
Controlled ventilation system	+ $150
Downsize air conditioner by 2 tons	- $1,000
Sealed combustion furnace	+ $400
TOTAL PREMIUM	+ $100

Example Cost Summary
Building America Metrics

Severe Cold Climate

Advanced Framing	- $250
High performance windows	+ $250
Controlled ventilation system	+ $150
Power vented gas water heater	+ $300
Simplified duct distribution	- $250
Downsize air conditioner by 1 ton	- $350
TOTAL PREMIUM	- $150

Lesson Learned

Builders like balance sheets. When they see the changes they must make to achieve high performance homes expressed in specific costs and savings, it's easier for them to consider making the jump to Building America performance targets. It certainly helps when slightly higher costs of construction can be covered by the sales division being able to sell the value of a high-performance home.

BROAD-BASED R&D ACHIEVEMENTS

Energy Bill Guarantee Programs

BSC worked with three consortium partners on the development of energy bill guarantee programs—Masco (Environments for Living™), GreenFiber (Engineered for Life™), and Artistic Homes (The Energy Use and Comfort Guarantee). In each case, the partner firm relied upon BSC's Building America performance targets in the development of their criteria for builder program participation.

They relied upon BSC energy modeling to establish the specifics of their financial guarantees. And, most importantly, all three programs explicitly recognize the inextricable connection among the Building America attributes of energy efficiency, indoor air quality, and durability. These programs have done more to deliver market value to the builder and the homebuyer (and product manufacturers!) than any other single element of the Building America program.

Builders

Pulte Home Corporation
Artistic Homes
Ryland Homes
Lee Homes
Habitat for Humanity

Resources

www.eflhome.com/efl_index.asp
www.us-gf.com/engineered.asp
www.artistichomessw.com/guarantee.htm

Lesson Learned

There is nothing more powerful than a market-based performance standard—a financial commitment links design, construction, and operation. Every party—builder, trade contractor, material supplier, and homeowner—has an investment in performance.

On-Site Grinding and Land Application of Clean Construction Waste

About two-thirds to three-quarters of the construction waste from any residential construction project is clean wood, clean gypsum board, and clean cardboard waste. That's by weight or volume. Everyone agrees that it's a shame to send that material to the landfill, both from a cost and environmental standpoint. But recycling infrastructure and markets are poorly developed in all but a very few areas of the country for wood and gypsum board waste, and markets for old corrugated cardboard (OCC) have been volatile with collection infrastructure often poorly suited to construction sites.

Working with BSC Building America partner Packer Industries, ground wood waste (often with OCC mixed in) is being used as a soil erosion control material and ground gypsum board as a soil amendment. Landfill capacity is conserved, wastes are turned into site resources, and disposal cost savings are captured by production builders. Packer Industries provides not only a technological solution, but assists the builder with both environmental and regulatory hurdles as well. In a particularly interesting turn of events, Packer Industries (with a vested interest only in waste production and processing) is taking the Building America systems thinking approach and promoting wood waste reduction as the first element of waste management.

Builders

Artistic Homes — Albuquerque, New Mexico
Pulte Homes — Minnesota
Hans Hagen — Minnesota, Wisconsin

Resource

www.buildingscience.com/resources/misc/wood_efficiency.pdf

Lesson Learned

The Building America principle of improved efficiency and cost savings applies as well to the tail pipe (waste management) as it does to the front end (advanced framing) of residential construction.

Unvented Conditioned Attic

There are two basic ways to achieve the BSC Building America performance target of locating all ducts in conditioned space—move the ducts or move the conditioned space boundary. Although not BSC's first choice, keeping HVAC equipment and ducts in attic space is a fact of life in some markets, driven by floor space and noise considerations. So BSC developed, modeled, tested, refined, and implemented the relocation of the conditioned space boundary from the top floor ceiling line to the roof line of homes, creating an unvented attic space conditioned either directly with supply registers or indirectly by duct leakage. There were a host of issues to consider in making this change:

- Energy performance for both heating and cooling in comparison to vented attic assemblies
- Peak temperatures achieved by various components of the roof assembly—exterior cladding, sheathing, etc.
- Building code and building department officials' assessment or acceptance of this new assembly
- Suitability and performance of the assembly in each of the six climate zones (for example, location of first condensing surface for different climate zones).

For each issue, the Building America process (modeling, pilot testing in one or two homes, analysis, refinement, and then implementation in production homes in a subdivision) led to performance that satisfied the builder, the building officials, and ultimately, the customer.

Builders

Pulte (Las Vegas, Tucson, Houston, Banning, Sacramento, Tracy, Phoenix)

Resource

www.buildingscience.com/resources/roofs/unvented_roof_summary_article.pdf

Lesson Learned

Unerring attention to construction details must be paid as a new approach is moved from one builder to another, particularly from one hygro-thermal region to another. Both examples below involved a change from a hot-dry to a hot-humid climate.

Example 1: A change from an air-tight stucco soffit to a clad soffit led to a breach in the air barrier, with subsequent moisture and condensation problems at this point of entry. This situation was resolved by using professional spray-applied air sealing to this area of the envelope assembly.

Example 2: A change from clay or cement tile roof cladding to asphalt shingles led to wicking of exterior liquid moisture (rain or dew) between roofing shingles with subsequent solar drive of this moisture into the thermal envelope below.

The lesson here is that any change in technique or materials must be evaluated for the way in which air, liquid, and vapor moisture and heat move on and through the envelope assembly, particularly when there is a change in location that involves climate or standard construction details.

Unvented Conditioned Crawlspaces

A little more than one-sixth of new homes in the United States are built on crawlspace foundations. Typical crawlspace construction calls for passive venting to the outside with cavity insulation for the first floor. No one is sure how this situation came about, but it certainly is not a basement configuration based on sound building science. A continuous air barrier and thermal envelope at this plane are nearly impossible because ducts and other utilities typically penetrate this plane and extend into the unconditioned crawlspace. In addition, research has shown the location, number, and total area of the typical crawlspace vents provide highly unreliable and often inadequate air exchange.

BSC worked out the details for converting this space to conditioned space, encouraging the building community (including code officials) to think of crawlspaces as simply "short" basements. In this way, all of the most common problems with crawlspaces—moisture and mold, radon and other soil gases, and heat loss from crawlspace ducting and discontinuous first floor air barrier and thermal envelope—are resolved. In other words, it is possible to satisfy BSC Building America performance targets if the crawlspace is unvented and conditioned.

BSC also conducted work under Building America on structural sub-basement crawlspaces typical of the Metro Denver area, where the combination of expansive clay soil conditions and full basements have led to moisture and performance problems. Applying principles of building science and working with Building America builders in the Denver area, BSC developed and tested sub-basement structural crawlspace treatments that integrate the need for control of soil gas and sub-basement moisture. The result is the most energy-efficient, healthy, and comfortable method—continuous poly barrier on the sub-basement crawl floor and a continuous 50-cfm exhaust fan with transfer grilles between the sub-basement crawlspace and full basement. The BSC approach uses less energy and achieves better air quality throughout the entire structure than any of the systems utilized or approved by local code.

Builders

Hidden Springs — Boise, Idaho

Prairie Crossing — Grayslake, Illinois

Habitat for Humanity — Denver, Colorado

Engle Homes — Denver, Colorado

GreenBuilt Homes — Cleveland, Ohio

Venture, Inc. — Flint, Michigan

Resource

Please see the BSC Web site (www.buildingscience.com/what's_new) for the latest information.

Lesson Learned

There are actually two lessons in this work. The first one is — always start with the larger question. In this case, why do you really want a crawlspace? BSC has worked with builders on substituting slab-on-grade construction for crawlspaces in many areas of the country where the real reasons for utilizing crawlspace foundations are perceived mechanical needs or market demand that may, in fact, not hold true.

The second lesson has to do with accomplishing change in the building industry. A large part of working with the building community is working with the local building officials. Bringing building science into the building industry means educating builders and local building departments.

All Ducts/Equipment in Conditioned Space

Ducts and equipment outside of the conditioned space create three problems. One, they make it challenging, if not improbable, to achieve high HVAC system efficiency. Two, they often lead to pressure imbalances that can affect health and safety of occupants. And three, these same pressure imbalances can affect building durability by introducing moisture into building assemblies. On the other hand, fitting the duct system within conditioned space presents design and engineering challenges. But herein lies the beauty of the Building America approach—when you combine a high-performance envelope with an innovative framing system, the engineer and the architect are freed from key constraints of conventional construction and the resulting simplified duct distribution system (see below) makes it much easier to move ducts and equipment into the conditioned space.

Artistic Homes took the Building America systems-thinking approach one step further in the field. They were having trouble getting the desired duct air sealing on the trunk duct tucked into the main hallway soffit. So, they decided the only way to keep this duct in conditioned space and seal it tight all the way around (the top side is nearly impossible to get to) was to assemble and mastic the trunk duct at ground level and then install it in the soffit. They accomplished this by getting the framer to build—but not install—the two 7-foot end-of-hallway partitions. After the trunk duct has been assembled and sealed with mastic and hung in the soffit, framers come back later and install the set-aside partitions. These partitions are clearly marked on the plans as "set-aside," and the actual partitions and their locations are marked with spray paint to remind all trades as to what they are, why they are not installed, and where they go when they finally are installed.

Builders

Pulte Home Corporation — Minnesota
Artistic Homes — Albuquerque, New Mexico

Resources

www.buildingscience.com/buildingamerica/casestudies/oakbrooke.htm

www.buildingscience.com/resources/misc/wood_efficiency.pdf
(particularly pages 2, 3, and 5)

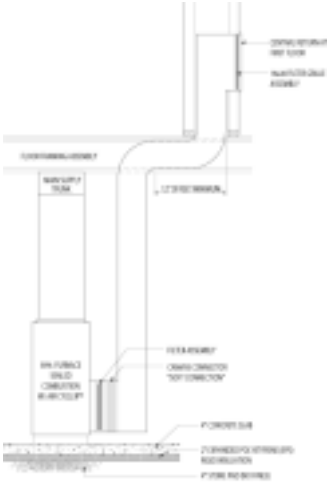
Lesson Learned

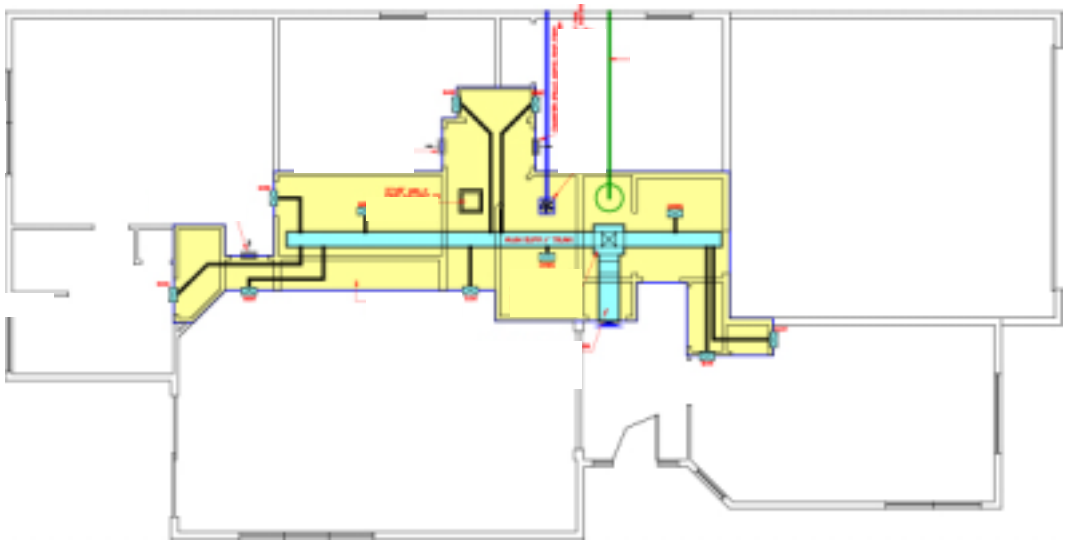
It often takes "outside-the-box" thinking on the part of several members of a building team to accomplish the desired result: systems engineering, systems design, systems installation, or field work. It's only when all team members "get the picture" and "build the vision" that the most elegant solutions rise to the top.

Simplified Duct Distribution Systems

One of the most common callback complaints experienced by production builders has been comfort. Systems engineering analysis identified leaky ductwork, particularly on the return side, as the most significant cause of comfort complaints. BSC systems engineering came up with the solution—a hard-ducted central return with pressure-relief transfer grilles or jump ducts.

A key part of the design is the 12- to 18-inch horizontal off-set, with two 90-degree changes in direction, which provide excellent sound and vibration dampening. Note that a high-performance building envelope is the starting point for considering an innovative simplified duct distributon system.





Builders

Town & Country Homes — Chicago, Illinois

Pulte Home Corporation — Minnesota

Engle Homes — Denver, Colorado

Artistic Homes — Albuquerque, New Mexico

Hans Hagen Homes — Minnesota, Wisconsin

Resources

www.buildingscience.com/resources/mechanical/transfer_grills.htm

www.buildingscience.com/resources/mechanical/509a3_cooling_system_sizing_pro.pdf

Lesson Learned

Good design and engineering often lead to a system that is simpler, less expensive, and of higher performance.

Central-Fan-Integrated Supply Ventilation System

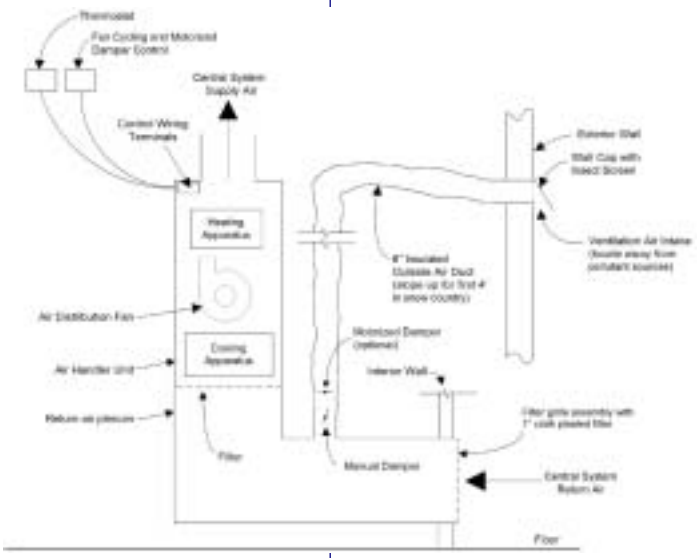
When BSC began designing high performance homes, two things were clear:

- High-performance homes require mechanical ventilation for dilution of internal pollutants, as well as moisture
- Cost-effective, reliable systems for mechanically introducing fresh air did not exist.

BSC was attracted to an outside air duct connected to the return side of the plenum because it achieved good distribution utilizing existing ducts. This type of system would, however, rely upon central fan operation for effectiveness, and this raised issues of controlling fan operation so that it would not:

- Under-deliver fresh air during shoulder season conditions (reduced or no delivery of conditioned air)
- Over-deliver fresh air during periods of more consistent or continuous central fan operation (particularly problematic during cooling in hot humid climates in terms of increasing latent load)
- Cycle in such a way that was energy inefficient or that shortened central fan service life.

So, a BSC engineer developed and eventually commercialized a central-fan-integrated controller. The science of efficient operation of this system involves a lot more than a smart controller, it requires the right-sized duct, introduced at the optimal location in the return plenum, and in many climates requires the integration of a motorized damper on the fresh air duct. This system today represents the simplest, most cost-effective method to consistently deliver the right amount of fresh air for human health and safety in all homes, but particularly, high-performance Building America homes.



Builders

Central-fan-integrated supply ventilation systems are employed in nearly every BSC Building America home. The system is also being used by other Building America builders, particularly builders working with Building America team leader, IBACOS.

Resources

www.buildingscience.com/resources/mechanical/ventilation_centralfan.htm

www.buildingscience.com/resources/mechanical/aircycler_freshair.htm

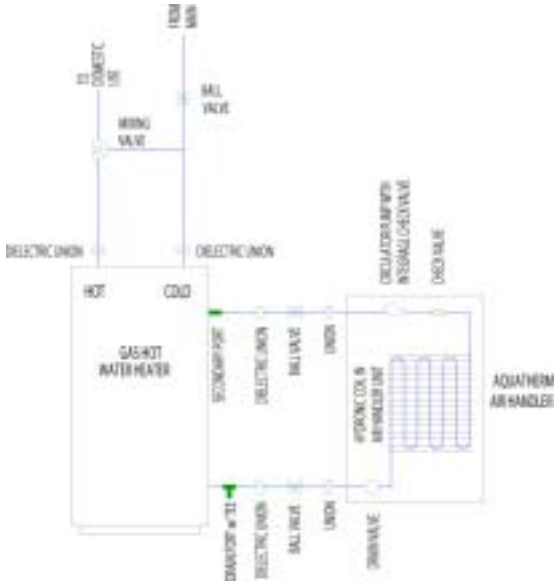
Lesson Learned

Systems thinking fosters innovation. Just because a cost-effective technology or building component does not exist, does not mean that it is not possible. The Building America program provided the conditions for the development and eventual successful commercialization of a key component of production high performance homes, the AirCycler™.

Combo Heating Systems

If the space heating loads are reduced via good building design (not uncommon in affordable, high-performance production homes or townhomes), using one system to handle both space heating and hot water loads is possible. A conventional tank water heater can be fitted with a heat exchanger coil for delivery of forced hot air. Special t-stat controls govern demand draw, ensuring that the more immediate need for domestic hot water outranks space heating demand when coincidental combined load approaches the delivery capacity of the tank water heater. The keys to this approach are a thorough systems analysis of the loads involved and exacting installation follow-through.

Because this is a non-standard system, home combo systems present significant design, training, and installation issues exacerbated by the lack of technological development and technical support for key components of the system. Only the most sophisticated and diligent of production home builders can successfully manage this system.



Builders

Artistic Homes — Albuquerque, New Mexico

Pulte Home Corporation — Las Vegas, Nevada (Cypress Point) and Houston, Texas (Creek Bend Estates)

Lee Homes — Village Green, Los Angeles, California

Hans Hagen – Townhomes — Minnesota, Wisconsin

Resources

www.buildingscience.com/resources/mechanical/combo_systems.pdf

Lessons Learned

There are a couple here. Systems that involve more than one trade (plumbing and HVAC) present a bigger project management and coordination challenge than systems that involve only one trade. For Artistic Homes, this meant actually taking their trade contractors to Las Vegas to see combo systems in Pulte homes and having their contractors talk to Pulte's. The Artistic trades eventually went from the biggest skeptics to the biggest proponents of the system, but not without time and digestion and accumulated experience.

Sometimes the builder is ahead of the manufacturer. The concept of combo systems is an elegant one but the key components and the way in which they must work together are still not fully developed.

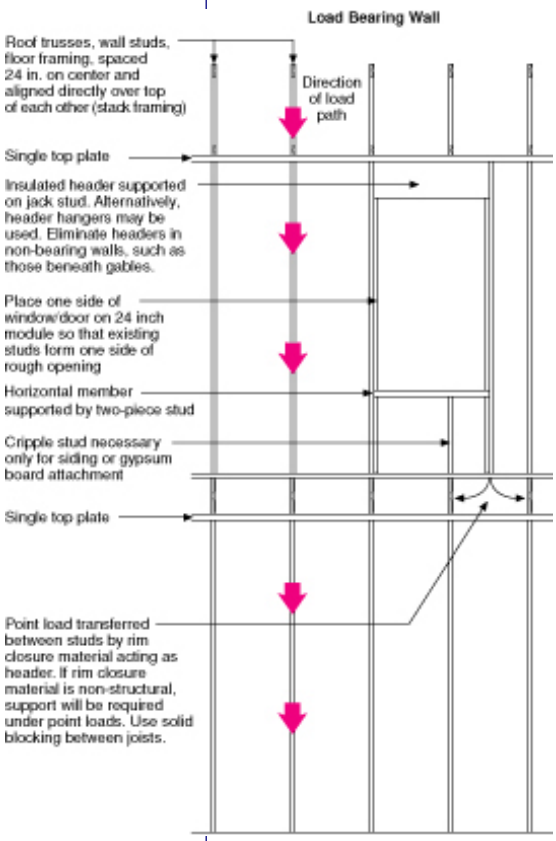
Advanced Framing Systems/Packages

Advanced framing is a pillar of the Building America systems engineering approach. Rarely are changes in design and construction so universally compelling as advanced framing. Benefits include the following:

- Improved thermal performance
- Reduced call-backs (particularly drywall cracking)
- Reduced materials costs (less material in the framing package)
- Reduced labor costs
- Easier accommodation of mechanicals (particularly HVAC ducting in floor assemblies)
- Reduced waste disposal costs.

BSC is proud of the fact that approximately half of BSC builders and their developments embrace advanced framing systems, but it's difficult to reconcile its absence in the other half. Despite the professional technical assistance offered to every BSC Building America builder, there are more than a few that choose to stick with conventional framing. Each of the obstacles below is more an issue of perception or interpretation than an issue of substance:

- Resistance from the framing contractor – Although the inability to make the change (crews that either do not understand or cannot read detailed framing plans) is not uncommon, more frequently it is unwillingness rather than inability to employ advanced framing.
- Resistance from the sales staff/homebuyer – "Wood is good; therefore, more wood must be better," makes it difficult to convince the consumer of the benefits of advanced framing, particularly on interior walls, where there is no quantifiable energy benefit.
- Resistance from local building inspectors – Despite the fact that fewer and fewer local codes actually preclude many advanced framing techniques, every builder must still convince the inspector on the job or reviewing the plans about advanced framing.



Builders

Pulte Homes — Houston, Phoenix, Tucson, Northern California, Sacramento, Southern California

Prairie Holdings Corporation — Grayslake, Illinois

Town & Country Homes — Vernon Hills, Illinois and Minnesota

Venture, Inc. — Flint, Michigan

Artistic Homes — Albuquerque, New Mexico

Lee Homes — Los Angeles, California

Habitat for Humanity — Orlando, Denver

Resources

www.buildingscience.com/resources/misc/wood_efficiency.pdf

Lesson Learned

BSC staff members hate to say this about advanced framing, but half a cup is better than none. Advanced framing has been around for more than 25 years. BSC should not be surprised that it will take more than 5 years to move the second half of BSC production builders to advanced framing, given that the industry as a whole is taking more than five times as long for any significant market penetration of this approach.

Innovative Shear Panel

There are many areas of the country where wind shear forces necessitate structural sheathing on exterior walls and other areas where earthquake shear resistance requirements essentially mandate costly, proprietary shear components. Often, these same shear requirements preclude two important Building America concepts—continuous rigid exterior insulating sheathing on exterior walls and advanced framing (24-inch OC spacing and single top plates) of exterior walls.

BSC was convinced that a low-cost shear panel could be developed that would accommodate continuous rigid insulating sheathing in place of structural sheathing and advanced framing. Working with the Civil Engineering Research Laboratory, various panel configurations were lab-tested under the most stringent, up-to-date, and realistic stress protocols. The result was an inset shear panel made up of readily available building materials that can be either site- or shop-manufactured and provide shear resistance for areas with seismic and high-wind shear requirements. Currently, BSC has filed for an ICBO Evaluation Service report, the first and most important step toward broad-based code approval.

Builders

Pulte (Tracy, California)
Morrison Homes (NAHB 2001 Builder Show home)
Health-E Enterprises (Fairburn Commons — Atlanta, Georgia)
Spruce Construction (Juneau, Alaska)

Resource

www.buildingscience.com/resources/walls/shear_panel_test_results.pdf

Lesson Learned

Sometimes thinking "outside the box" actually means thinking "inside the box." The inset shear panel is yet another systems engineering solution that furthers Building America performance targets, even when environmental conditions place additional structural constraints.

System-Integrated Dehumidification

The Building America performance targets call for a more thermally efficient envelope and a reduction in uncontrolled air leakage. In order to compensate for a reduction in air leakage, controlled ventilation is provided. In hot/humid climates, the simultaneous reduction in heat gain and addition of controlled ventilation leads to a reduction in sensible load and an increase in the latent (moisture) load as a fraction of total cooling load. The resulting sensible-to-latent-heat ratio cannot be comfortably managed with currently available air conditioning equipment. This can lead to humidity problems and issues of comfort, occupant health, and durability.

Some form of supplemental dehumidification is necessary in homes with thermally efficient building envelopes in hot and humid climates. The most promising technological approach is the integration of dehumidification with ventilation. BSC set up field research to test six different dehumidification set-ups, including both integrated and stand-alone systems, in terms of their performance, installed costs, and operating costs. The results of this research are encouraging—relatively low-tech, low first-cost set-ups have provided good dehumidification and reasonable operating costs.

Builder

Pulte Home Corporation — Houston, Texas

Resource

Please see the BSC Web site (www.buildingscience.com/resources/mechanical/conditioning_air.pdf) for the latest information.

Lesson Learned

It's nice when your intuition is supported empirically. In this case, research supported the suspected solution, a solution that provided the best overall value:

- Lowest first cost
- Good moisture control performance

SPECIFIC R&D ACHIEVEMENTS

Reduced Call-backs

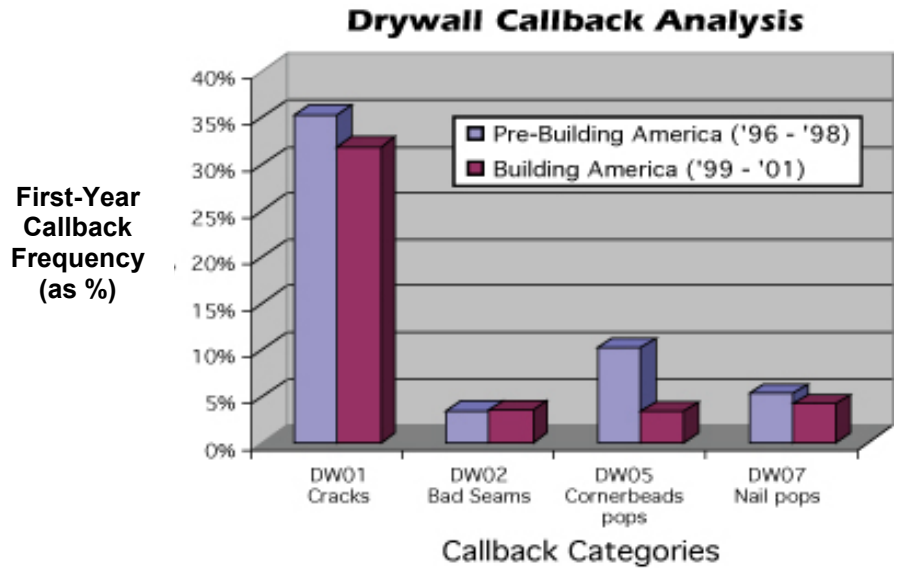
Although anecdotal reports of reduced call-backs for Building America homes abound, few builders have been willing to actually analyze for this phenomenon or publicly report on it. One builder, however, Pulte Homes of Tucson, has been very forthcoming about the impact that Building America has had on their call-backs. This division of Pulte Homes moved from warranty and call-back struggles that made the local news in the late 1980s to *NAHB's Builder of the Year* and the *Energy Value in Housing Award* in 2001.

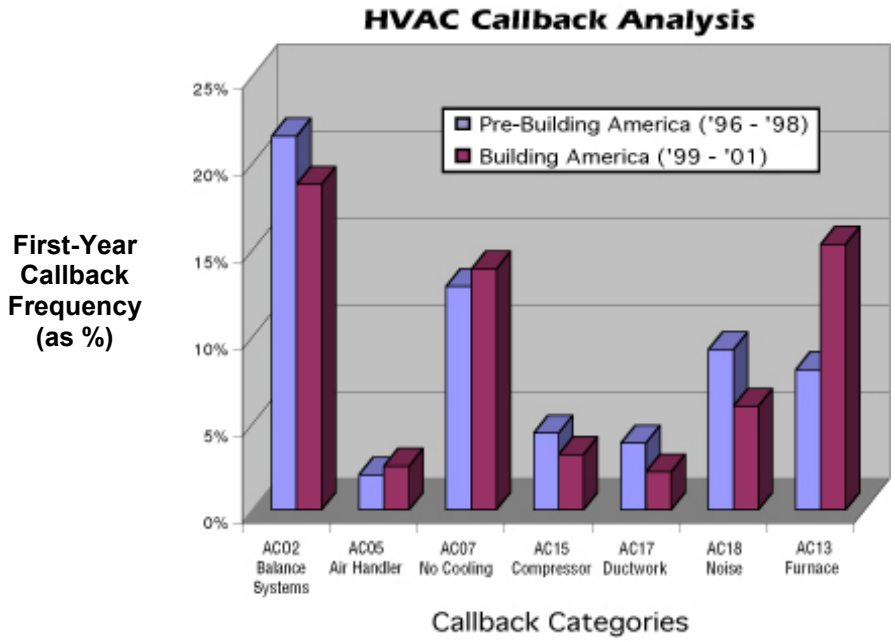
Pulte Tucson accomplished this turnaround in large part due to the following changes under the Building America program:

- Conditioned attic with all ducts and HVAC equipment in conditioned space
- 24-inch OC 2-by-6 framing with R4 EPS continuous insulating sheathing
- Low-e^2, spectrally selective, high performance windows
- Post-tensioned slab (to deal with issues related to unstable soils)
- 90%+ sealed combustion gas furnace and high-efficiency water heater in garage
- Mechanical ventilation with room-to-room air exchange.

The first-year call-back categories analyzed—selected HVAC and drywall specifically related to Building America program changes—yielded a modest, but significant, call-back reduction of just under 10%.

It should be noted here that the most dramatic HVAC call-back reductions reported by Building America HVAC contractors come from incorporating commissioning procedures (Sierra Air working for Pulte Homes in Las Vegas). They use key elements of the HVAC commissioning program, Check Me™ (see the Web site www.proctoreng.com/checkme/what.html). As a result of this BSC work with Sierra Air, BSC developed HVAC commissioning procedures. These procedures are recommended as part of the Building America program performance targets, but only employed company-wide by one BSC builder, Artistic Homes.





Builder

Pulte Homes – Tucson

Resource

www.buildingscience.com/resources/mechanical/air_conditioning_equipment_efficiency.pdf

Lessons Learned

Sometimes the most significant financial advantage is the less obvious, indirect one. In this case, the biggest financial boosts to the production builder from a change to Building America practices were the reduction in call-backs and increased customer referrals, both well worth their weight in any increased first cost.

This research with Pulte Tucson has really only scratched the surface of the call-back reduction phenomenon under the Building America program. Additional research is needed, particularly to assess the impact of comprehensive HVAC commissioning and comprehensive advanced framing on Building America-related call-backs.

Rigid Insulation Rain Control Joint Treatments

BSC is constantly looking for components of roof, wall, and foundation assemblies that support more than one of the key functions—thermal envelope, air barrier, proper level of vapor retarder, and drainage plane. A key example of this is rigid insulation used for exterior wall assemblies. If all joints and assembly/flashing interfaces can be sealed watertight, the continuous exterior sheathing becomes a continuous drainage plane as well as the thermal envelope and an effective air barrier (see diagrams).

Working with BSC Building America partners Town & Country Homes and Dow Chemical, both field and lab tests led to the following drainage plane details for rigid insulation sheathing:

- **Interior and exterior corners** — sheathing tape or mesh tape and mastic
- **Horizontal joints** — polyethylene sheet flashing (tucked behind top insulation, running over bottom insulation)
- **Vertical joints** — shiplap joints (if product is available) or sheathing tape or mesh and mastic
- **Step flashing** — flexible membrane strip covering top edges of metal step flashing with sheathing tape covering top edge of flexible membrane strip.

Builder

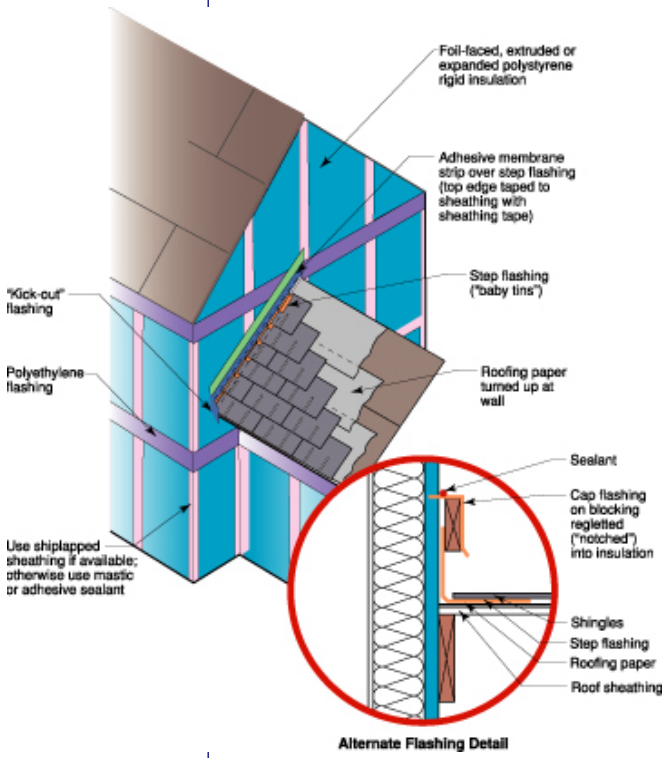
Town & Country Homes — Vernon Hills, Illinois

Resource

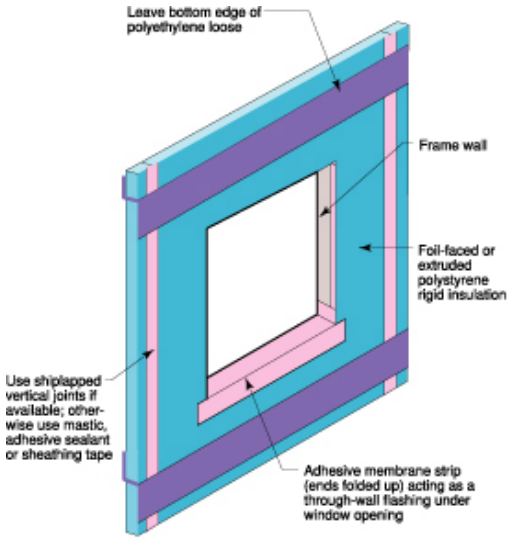
EEBA Water Management Guide (page 35 and page 38)
EEBA Builder's Guide — Cold Climate (figures 5 and 6, page 124)

Lessons Learned

Level of detail should always be commensurate with level of risk, in this case water penetration. While the shiplap vertical joint may be a superior solution to other vertical joint details, the risk of water penetration did not warrant manufacturing changes to rigid insulation edges.



Alternate Flashing Detail



Taped Rigid Insulation as Drainage Plane

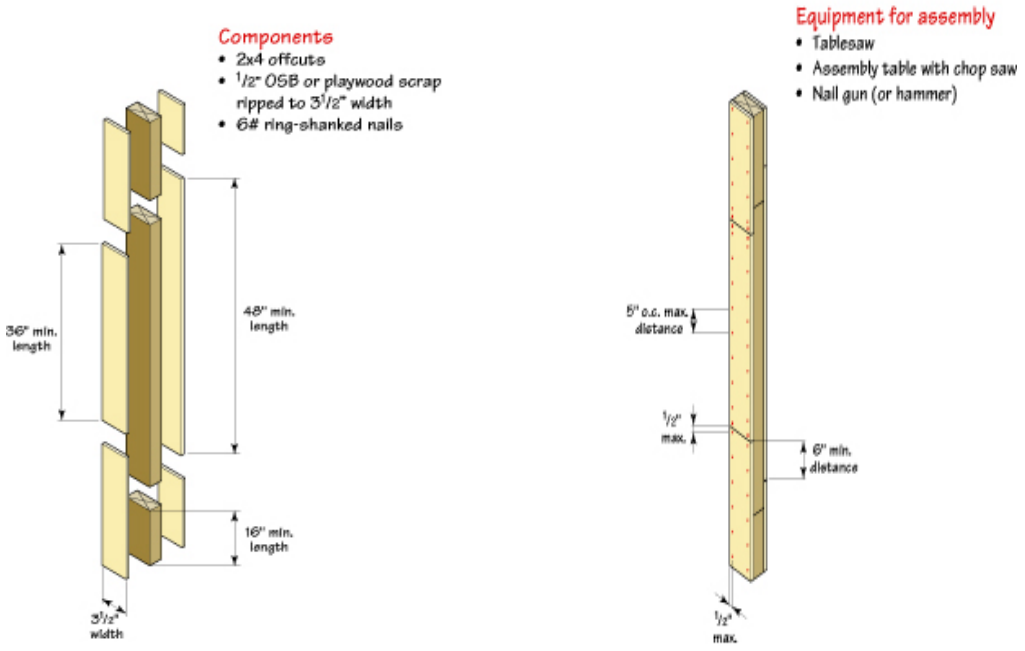
- Flanged window inserted into opening, flanges back-caulked between rigid insulation and flange except at bottom
- Tape or adhesive membrane strip installed over flanges to further seal flanges to rigid insulation. Seal on three edges only (top and the two sides)
- Foil-faced insulations should have foil facing installed to exterior if only faced on one side

Scrap-Engineered Environmental (SEE) Stud

One of BSC's Building America builders, Artistic Homes, lost its only outlet for its company-wide wood recycling program. Artistic contacted BSC, feeling that there must be some way of using, rather than discarding, the scrap OSB and 2-by-4s. Artistic's home designs generally take all loads to exterior walls, leaving all interior wall framing members as non-load bearing, hence technically, non-structural. What if the scrap OSB and two-by materials could be used to build non-structural framing members (in a OSB face [2-by-4 core] OSB face sandwich; see diagram), reducing waste and lumber purchase?

The feasibility of SEE studs depends on a combination of technical, regulatory, and economic issues. While the technical specifications for SEE studs have been developed, the various codes do not address non-load-bearing walls and framing members in nearly the same way. Little progress has been made to date on code acceptance of SEE studs for Artistic Homes (under the Uniform Building Code), but a sample wall has been built for building code official review for the Building America project at the EcoVillage Townhomes at 58th St. in Cleveland Ohio (under BOCA).

It is ironic that scrap lumber and sheathing waste for Artistic Homes and the EcoVillage project—both using a comprehensive advanced framing package—provide an insufficient supply of wood waste to meet the demand for non-load bearing studs. The economic feasibility of on-site SEE stud production is dependent on the economies of scale that a production building setting provides. It is likely that real-scale production of SEE studs will require the even greater economies of scale that shop manufacturing provides at some collection point, such as a C&D recycling facility, truss or panel plant, or lumber supply center.



Builders

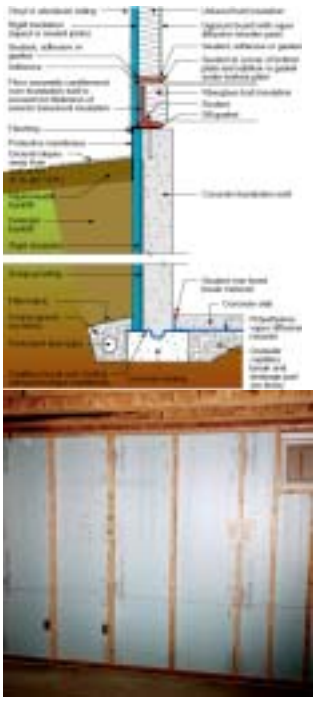
Artistic Homes — Albuquerque, New Mexico
DAS Construction — Cleveland, Ohio

Resource

www.buildingscience.com/resources/walls/SEE_stud_specs.pdf

Lesson Learned

If steel can be gauged for optimal value engineering of non-load bearing studs, why can't wood? In a sense, this is what the SEE stud does. But just as with any innovation, it must pass muster from a practicality, economic, and code standpoint.



Basement Insulation Systems

For a variety of cost and ease-of-construction issues, many if not most basements in new homes are insulated on the interior. And homes that start out with no basement insulation always end up with interior basement insulation when the basement is finished off and converted into full living space.

The addition of interior insulation (often with a vapor retarder or barrier interior face) along with other components— vapor barriers, wood framing, drywall, paint, etc.—have led to significant changes in the way that heat and moisture move through the basement wall assembly. And these changes are almost always for the worse. Mold, rot, and odor problems exist in new energy-efficient homes with what BSC contends are inappropriate insulation or wall assemblies in basements.

To address this issue, BSC has developed code-compliant (in terms of fire rating) interior insulation strategies that permit moisture from the soil and curing concrete to move through and out of the concrete and the interior insulation. In this way, high performance homes maintain their energy performance, basements can be finished off as living space, and moisture, mold and odor problems are controlled.

Builders

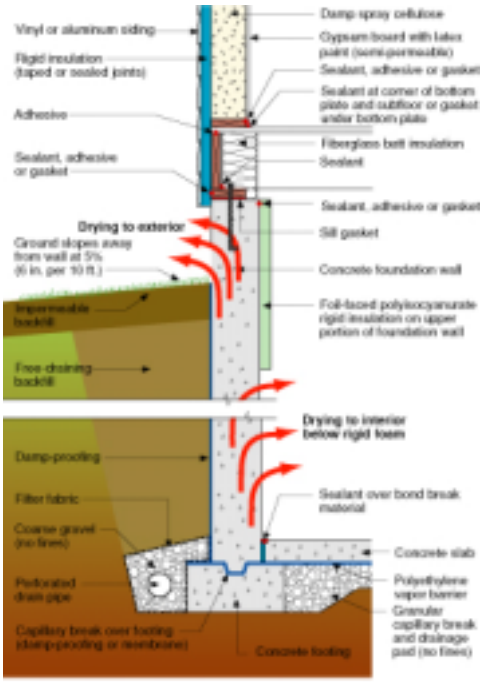
Pulte Home Corporation — Detroit, Michigan

Resource

www.buildingscience.com/resources/foundations/basement_insulation_systems.pdf

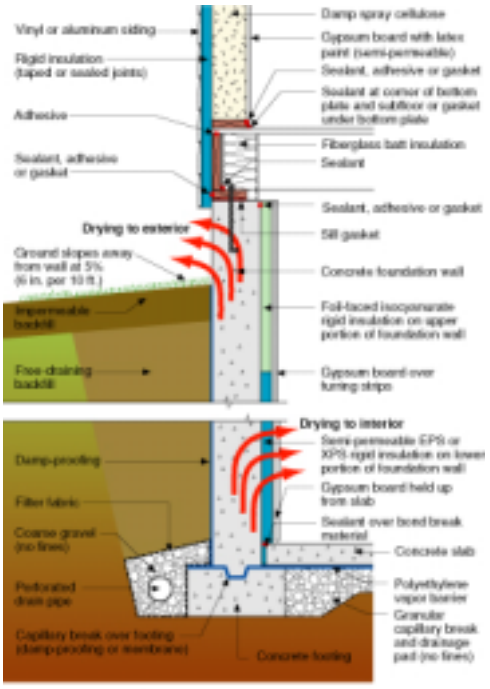
Lessons Learned

A focus on just one performance attribute of a material is antithetical to systems thinking, yet this approach is pervasive in construction practice, product manufacturing and marketing, and building codes. Basement insulation is a perfect example. A systems approach applies as well to material selection as it does to design. This is a lesson we should *not* be relearning but, too often, do.



Unfinished Basement — Half-height insulation

- Lower portion of wall dries to the interior
- Upper portion of wall dries to the exterior



Finished Basement

- Drying continues to the interior
- Drying to the exterior

Insect Control and Foam Insulation

Insect control issues, particularly in the southeast, have taken a significant "bite" out of the construction of insulated foundation systems. Most notably, model code agencies have banned below-grade rigid insulation in the most severe termite zones in the United States.

The key to insect control and the use of rigid foam insulation is a multi-pronged approach— proper chemical management at the building perimeter, borate-treated foam and wood products, and proper water and moisture management in terms of design and construction details. BSC worked with builders and product manufacturers on two projects to develop and implement this multi-pronged approach. In one instance, an innovative perimeter slab insulation detail was developed using borate-treated foam, metal flashing, and cement board (see photo of Fairburn Commons slab foundation detail at the left). With partner Louisiana State University Agricultural Center and manufacturers LP and US Borax, BSC worked on design and construction details for LaHouse, an educational resource facility that will serve as a model for insect-control residential construction details throughout the Southeast.

In a related but separate development, the successful commercial introduction of the termiticide, Termidor™, is likely to have the most dramatic effect on the use of at-grade and below-grade foam insulation in termite-prone areas of the country. The effectiveness and environmentally benign nature of this new termiticide are likely to bring about re-acceptance of the use of foam insulation for foundations.

Builders

Health-E Enterprises, Fairburn Commons — Atlanta, Georgia

La House — Louisiana State University

Lesson Learned

An integrated approach—in this case one involving insect-resistant design, construction details, treated building materials, and a new termiticide—will almost always generate the most effective and economical solution to a building problem. It certainly helps when a product breakthrough, such as Termidor™, completely resets the stage!

Composite Housewrap

A breakthrough idea germinated as a result of water management experiments conducted on a test hut constructed by the BSC team: use DuPont StuccoWrap and Typar™ carpet backing (manufactured by DuPont in Europe) as a multi-layered housewrap in hard-coat stucco applications. The carpet backing has no polypropylene skin, unlike the most housewraps manufactured in the United States. The unfaced (and now vapor permeable) Typar™ carpet backing would act as a bond break between the hard-coat stucco and the StuccoWrap without impairing the drainage characteristics of the StuccoWrap.

Although a testing schedule for this multi-layered or composite housewrap was proposed, the work could not be scheduled during the current cycle of the Building America program. However, this initial research and product identification has verified product feasibility. Under the next cycle of Building America, BSC and manufacturing partner DuPont have proposed further development of this material. DuPont is looking for production capacity for testing and application according to the Building America R&D regime:

Test house → Pre-Production → Community Level

Builder

Building Science Corporation (test hut)

Resource

www.buildingscience.com/resources/walls/problems_with_housewraps.htm

Lesson Learned

The permutations are scary—you can use the wrong material in the wrong application, the right material in the wrong application, and the wrong material in the right application. Building science is about assessing all of the properties of individual materials and the collective properties of all materials in an assembly, and then making them work towards, rather than against, high performance.

Pulte Low-Energy Home

Two nearly identical homes were constructed for side-by-side evaluation at the Pulte Homes La Terraza community in northwest Tucson. One home, the reference house, was constructed according to BSC's minimum Building America metrics. The other—the Low-Energy Home—had the following additional energy features: Polaris 94% efficient combo water /space heater; 15 SEER A/C unit and air-handler with a more efficient electronically commutated motor (ECM); ENERGY STAR refrigerator, dishwasher, and clothes washer; and compact fluorescent interior lighting package. These features totaled a builder-reported additional cost of approximately $7,600. Collectively, these features had a target prformance of approximately 20% greater energy efficiency than the more conventional Building America house. Energy modeling predicted that the Low-Energy Home would demonstrate about 44% energy savings in comparison to a conventional home, for an annual savings of about $759. Using Fannie Mae's net present value calculation, this would result in adding between $8,500 and $10,500 to the appraisal value of the home.

Builder

Pulte Home Corporation, La Terraza — Tucson, Arizona

Resource

11.A.4 Report: Higher Performance Building Systems

Lesson Learned

To test the marketability of a high performance home, there must be equivalence in non-energy features. In this case, the Low-Energy Home carried the following unique marketing burdens:

- a three-car garage option, rather than the den (the den has proven to be highly preferred in this development)
- property lines shared with five other homes (all other homes in the subdivision share property lines with two, three, or four homes, but none share as many as five)
- location in development, such that headlights from cars entering the development shine directly into the front bedroom window.

High Performance Homeowner Manual

More than one BSC Building America builder has requested a homeowner manual tuned to their high performance products. BSC developed such a manual. Some of its elements that are specific to high performance homes are:

- Operating guidance on programmable thermostats, particularly with regard to the difference between setback strategies for cooling versus heating
- Operating guidance for mechanical ventilation, specifically the AirCycler™
- Layman explanation of right sizing and run times for high-efficiency HVAC equipment
- Listing of building features that promote durability and service life
- Guidance on the importance of matching paint, stain, and sealant properties to the material(s) to which they are applied
- Explanation and guidance on the importance of water and moisture management inside and outside the home.

BSC expects that requests for comprehensive, performance-based homeowner manuals will only increase, as builders increasingly discover manuals as another tool in the kit of managing homeowner performance expectations and managing builder liability.

Builders

Pulte Home Corporation
Artistic Homes

Resource

www.buildingscience.com/resources/homeowner/HVAC_performance_handout.pdf

Lessons Learned

Education and training for the high performance homeowner is a key part of any comprehensive systems approach.

The Zero Energy Cottage

BSC designed an ultra-efficient vacation or second home for the non-profit environmental organization, the Captain Planet Foundation. BSC also provided technical assistance in the outfitting of this home for two of its traveling venues—the Atlanta Home Show and the National Park Service Sustainability Fair.

BSC identified four key elements of the Zero Energy Cottage—performance of the envelope and HVAC equipment, solar power supply from photovoltaic and solar water panels, high efficiency appliances and lighting, and homeowner load management. One of the toughest challenges of any zero energy building is selecting and integrating loads from space heating, space cooling, dehumidification, and domestic hot water. Along with building design, the optimal combination of equipment to meet these needs is heavily dependent on climate. This is particularly true in terms of passive solar design, design for natural ventilation and daylighting, and integrating hot water with either space heating or cooling. The Zero Energy Cottage for the Captain Planet Foundation represents the BSC vision and deployment for a mixed humid climate.

Builder

Certified Living, Inc.

Resource

www.buildingscience.com/buildingamerica/casestudies/zero_energy.pdf

Lessons Learned

This project abounds in Lessons Learned:

- Systems integration and donation-driven demonstration project is nearly a contradiction in terms. Any zero energy building by definition must be finely tuned, with each element of design and specification critical to overall performance.
- Current modeling tools can't handle all of the elements that are key to zero energy buildings: passive design for heat gain and heat avoidance, natural ventilation, daylighting and active solar (PV and solar water).
- Once a super-efficient envelope and HVAC system have been integrated with a low-energy design, the energy performance of the home is driven by hot water consumption, appliances, and plug loads. In general, these loads are out of the builder/designer's hands and lie squarely in the homeowner's. Occupant behavior/awareness/tolerance can make or break the zero energy building.
- Although the solar industry has done a great job of packaging individual components—panels, mounting racks, inverters, and battery systems—into solar energy systems, there are still areas for improvement. For example, there was no clear system or contractor responsibility for securing either PV or solar water rooftop panels to SIPS roof panels.
- There is a lot of tension between breaking new ground with new technology and delivering reliability and service life on projects that push the envelope. For example, heat pump water heaters were considered for this project in this climate, but the lack of product selection and track record made it a tough choice.

US Green Building Council's (USGBC) Leadership in Energy and Environmental Design – Residential (LEED-R) Program

Representing the Building America program, BSC has taken a leadership role in the USGBC's development of LEED-R. There are three main reasons for this:

1. Many green building efforts do not amply embrace or express principles of building science in their technical criteria. This is particularly true in terms of indoor air quality (adequate ventilation, combustion safety, moisture control, and chemical source control) and resource efficiency (material selection and durability—in terms of the components of roof, wall and foundation assemblies—and advanced framing).
2. LEED-R is an effort without any real representation from the production builders in the high performance home business. BSC is a respected and trusted representative of this group.
3. Several of the local green building programs, with which Building America either has or is developing a relationship, are concerned about how LEED-R will coexist with their established efforts. BSC is a respected and trusted representative of this group.

In at least some substantial part, BSC staff has been instrumental in:

- Forging a relationship between the USGBC and EEBA
- Involving two Building America builders at the steering committee level of LEED-R (Hedgewood Properties of Atlanta, Georgia, and McStain Enterprises of Boulder, Colorado)
- Planning a meeting between LEED-R and local green building program representatives.

The result has been LEED-R development more firmly grounded in the high performance realm of the residential building industry.

Lessons Learned

There is a relationship between green building and building science; there simply has to be a champion of this relationship.

Resource

www.buildingscience.com/about/Green_Building_Treatise.pdf

Fannie Mae

BSC has been looking for ways to work with Fannie Mae, using their new energy-efficient mortgage (EEMs) products. There are a number of ways that Fannie Mae has tried to improve the delivered value of their energy-efficient mortgages and improve access and user friendliness for builders and their lenders. BSC has been working with two of its builders, Artistic Homes and Pulte Homes, to understand whatever obstacles there might be for Building America builders in obtaining the full value of Fannie Mae EEMs for their buyers.

- Fannie Mae Form 1224 – Fannie Mae has been working on including the net present value of all energy improvements in the appraised value of the home, a very significant benefit. BSC worked with Fannie Mae, RESNet, and the designers of the energy software, REMRate, on standardizing and streamlining how Form 1224 works, including recognition of key Building America features (such as conditioned attics, conditioned crawlspaces, and all ducts and equipment in conditioned space).
- Artistic Homes – The Moya Group, the lending firm associated with Artistic, has access to an experimental EEM made available to Central New Mexico through the Dallas regional Fannie Mae office. Although Artistic Homes has found value in this mortgage product for some of their buyers, they have found it only marginally competitive with existing mortgage products from FHA and VA.
- Pulte Home Mortgage – Pulte has not been able to find significant increased value for the homebuyers from the new Fannie Mae EEMs, in comparison to other mortgage products to which they have access. One of the main stumbling blocks is the inability of Pulte to capitalize on the added value of the energy improvements in the appraisal value. The timing of Pulte's appraisal process with respect to the home sales process precludes their buyers from being able to use that added value in their Loan-To-Value (LTV) final ratio and allowing them to afford additional features.

Builders

Artistic Homes

Pulte Home Corporation

Resources

www.natresnet.org/lenders/fnm_comparison.pdf

Lessons Learned

Fannie Mae has no more ability to offer a reduced-interest rate in their EEMs than in any of their other mortgage products. And yet, that was the hope of many in the building industry when Fannie Mae first began their green building initiative with NAHB. Fannie Mae needs to build up a history of EEMs within their business, be able to quantify how these loans perform with respect to their other products, and then use this data to justify even better EEM product offerings. The competition with FHA and VA loans for first-time buyers with marginal credit scores and little down payment makes it tough for the Fannie Mae EEM to deliver to this particular market slice (perhaps closely identifying many of Artistic Homes buyers). On the other hand, buyers with really good credit scores and at least a 20% down payment are hard to convince of the advantage of adding their energy savings to their income (a situation with many Pulte homebuyers). The moral is that some, but not all Building America builders and their buyers will find significant enough value in Fannie Mae EEMs to make broad use of these mortgage products.

Perhaps the most telling lesson about the ability of EEMs to affect change in the mortgage industry comes directly from a Fannie Mae representative: the biggest cost/risk in secondary lending is mortgage default. And while reducing operating costs nibbles at the edges of this issue, the big bites in defaults are still losing your job, losing your life, or losing your marriage. It would take a much broader Building America program to address these issues.

APPROACHES FOR CREATING EFFECTIVE BUILDER PARTNERSHIPS

Perhaps the most important factor contributing to BSC success under the Building America program has been the strength of BSC builder partnerships. BSC's success with builder partnerships is evidenced by the number of builders that BSC has had to turn down as partners during the latter years of the Building America program. Here are what we consider the key elements of that success:

- **Under-promise and over-deliver** – From the beginning, BSC adopted the philosophy with its builders of exceeding expectations, particularly in terms of technical assistance. It is often tough to overcome the builder preconception of a government industry initiative—"We are from the government and we are here to help you." BSC won its builders' respect and trust by delivering on commitments to find ways to reduce or maintain first costs, increase value, and achieve energy savings.
- **Real world technical assistance** – Another key element of winning builder partner respect and trust was the technical and field experience of BSC staff. BSC builder partners have come to expect that anyone from BSC sent out into the field on a job site has the technical credibility and field experience to hold their own with superintendents, trade contractors, and technicians. It's easy to overlook how important this "job-site" credibility is with builders.
- **Matching expectations to technical feasibility** – When working with builders on innovations and changes to the way they build, the best way to attain a "can-do" attitude—as opposed to a "you-want-to-do-WHAT?" attitude—is to know the line between challenging and daunting. This only comes from experience in both building science and home construction, and many of the BSC staff have both.
- **Timely delivery of technical assistance** – It's easy for consultants to be less than sensitive to the scheduling demands of the home building business. BSC knew on what issues builders had scheduling leeway and what issues they needed immediate delivery. Examples include plan review, energy modeling results, installation specs, etc.
- **Broad-based expertise** – BSC, while being a relatively small consulting firm, has expertise in enough arenas of construction that builders felt that they could rely on sound guidance or assistance on everything from design to energy modeling, from moisture dynamics to construction waste management.
- **Hanging in when the going gets tough** – When an innovation does not work quite the way that the builder or the consulting firm intended or expected, builders respect firms that follow through and stick with the situation until it is resolved. In our case, there were times when this even meant using non-Building America company resources to correct problems in prototype housing. But once again, builders will hang tough with you, if you hang tough with them.
- **Energy bill guarantee programs** – This is perhaps the most important partnership development within the Building America program. These programs are market-based, building science-based programs that deliver real value to the builder (both in terms of technical information and marketing) *and* have a life of their own. The strength and rigor of these programs is based upon the science, experience, and data that Building America has developed with the industry.
- **National and regional network of service** – The network of local and regional building science service providers that BSC has extends the reach of the firm with little loss in expertise or efficiency, given the depth and consistency of interaction between these firms and BSC. Examples include Advanced Energy Corp. (North Carolina), Southface Energy Institute (Georgia), Florida Solar Energy Center (Florida), BCI Testing (Arizona), Shelter Supply (Minnesota), and LDC Consulting (New Mexico).
- **The EEBA Builder's Guides** – This resource is a key element of the process BSC has for developing a relationship with builders. It connects and grounds all of the training and builder education efforts that are the heart of the Building America program. And again, builders trust and respect a firm that created and continues to update a resource well-tailored to their needs in the design office, at the superintendent's trailer, and out on the job site.

- **The Building America performance targets** – It's a lot easier for both the builders and the consulting firm to set and meet expectations when the "requirements" for participation are clear-cut. BSC over the years has worked hard to make these performance targets explicit so that builders know exactly where they stand in terms of making a Building America commitment. Again, builders respect this straightforward, meaningful approach to building high performance homes.

SOLICITING INVOLVEMENT OF INDUSTRY PARTNERS

In many ways, the approaches that prove successful with builders are no different than the approaches that prove successful with industry partners. The 10 bullets in the previous section apply equally well to industry partners such as building product manufacturers. What is most interesting is the increasing need for the team approach that Building America embodies. At a time when an unprecedented number of new building products and systems are being introduced to the residential building industry, many if not most manufacturers have reduced their technical support and field presence. BSC has found that manufacturers are just as hungry as builders for "third-party" qualified analytical field and technical support and analytical perspective.

Manufacturer interest in the building science that Building America embodies is being driven by both positive and negative market forces—homebuyers want energy savings and don't want mold and moisture problems. More and more manufacturers, as well as builders, are beginning to understand that a systems thinking approach will give them the positive public exposure they desire and go a long way towards avoiding the negative press they so ardently seek to avoid.

An effective vehicle for soliciting BSC industry partnerships has been the Energy & Environmental Building Association (EEBA). Its annual conference, innovative builder membership, and technical resources draw in manufacturing and other industry partners to the Building America program and the systems approach that it represents.

The most promising development under the Building America program for applying private sector resources toward a systems approach to energy efficiency has been the energy bill guarantee program. Nothing has solicited more comprehensive industry partnerships than this development. It is the most elegant way to bring about builder/trade contractor/ manufacturer/homeowner cooperation for the performance of a home. It is interesting to note that BSC recognized the importance of energy bill guarantees as far back as its original Building America proposal:

"Specifically, the technical objectives of our proposal are to … increase the market share of the builder members of our team through marketing and finance innovations such as guaranteed energy bills."

BSC was instrumental in the development of the Engineered for Life™ program with industry partner Green Fiber; the Environments for Living™ program with industry partner Masco; and the "Energy Use and Comfort Guaranteed" program of home building partner Artistic Homes.

MARKET BARRIERS OVERCOME

Each of the approaches described below has been critical to moving the Building America builder and their buyers beyond standard expectations for energy, comfort, health and safety, and durability to the high performance standards as expressed by the BSC Building America performance targets (see www.buildingscience.com/buildingamerica/targets.htm).

The Cost Trade-off Approach

Historically, production builders have followed this motto:

"I have to figure out a place to save money to be able to devote resources to higher performance so that the first cost my homebuyer sees is ideally lower or just the same."

To satisfy this axiom, BSC developed the cost-trade off method, showing builders how things such as downsized mechanical systems and advanced framing savings could be used to support high performance windows, more insulation, and better HVAC equipment. The cost trade-off method proved very successful, not in overcoming the market barrier (i.e., the cost barrier with buyers), but the underlying design

and construction barriers. (See, for example, the Pulte – Minnesota case study: www.buildingscience.com/buildingamerica/casestudies/oakbrooke.htm.)

Going Beyond Cost Trade-offs to Value

BSC has been successful in moving Building America builders beyond the issue of cost to that of delivered value. The message sent out by various divisions of Pulte Homes has resonated throughout the industry:

Build and sell more homes at a slightly increased construction cost, but at a higher retail price with a higher profit margin. (See, for example, the Pulte – Banning case study: www.buildingscience.com/buildingamerica/casestudies/sun_lakes.htm.)

You can only do this if the buyer perceives higher delivered value. And again, the best vehicle for expressing that higher value to the buyer has been the energy bill and comfort guarantee programs such as Masco's Environments for Living™ and GreenFiber's Engineered for Life™.

Value Back to the Builder: Reduced Call-backs

High performance homes can deliver value back to the builder as well, in the form of reduced call-backs and associated builder expenditure (See, for example, the Pulte – Tucson case study: www.buildingscience.com/buildingamerica/casestudies/copper_moon.htm.). It's important to emphasize that the success of Building America has been a comprehensive approach to market barriers requiring the education and subsequent commitment of all elements of a production home builder's company—design, engineering, field construction, sales, and marketing.

MARKET BARRIERS REMAINING

The previous section not withstanding, there are high performance concepts/strategies/systems that remain difficult to sell to the builder, the buyer, or both.

The Low-Energy Home's Lack of Success

Despite the broad success Building America production builders have had with the sales and marketing of homes with 30% to 35% energy savings in comparison to standard production homes, limited forays by the same builders into higher levels of energy efficiency have proved difficult. For example, the Pulte Tucson Low-Energy Home only sold after more than 9 months on the market and only after much, if not all, of the cost premium incurred by the builder had been parlayed into closing incentives on the home. (The nearly identical monitoring project home built to Building America standards was only on the market for a short period of time). Pulte felt sure that they could find homebuyers willing to shoulder the nearly $10,000 premium on the Low-Energy Home because of its performance value. But, according to the development's sales manager, other attributes of this particular home (three-car garage versus den, location dead-on to incoming development traffic, five adjacent homes) completely overshadowed the energy value of the home to prospective buyers.

The real market test for homes with greater than a 50% energy savings represented by a significant market premium will not come from single forays of challenging properties. It will come from the more significant commitment of a whole development of Low-Energy Homes—those with marketing, financing, energy bill guarantees, warranty, and even homeowner insurance premiums that truly reflect the greater value that these homes can deliver.

Financing Advantage – The EEM

For almost a decade, Fannie Mae and other leaders in the home mortgage industry have been developing energy-efficient mortgage (EEM) products that attempt to deliver real advantage to the buyer of high performance homes. Their focus has been on:

- Adding the operational cost savings of high performance homes to the income of the buyer
- Reducing down-payment requirements for qualifying buyers
- Capturing the added value of energy improvements in the home's appraisal
- Simplifying how each of the above is captured and managed by parties to the loan, including the lender, energy rater, appraiser, and private mortgage insurance (PMI) firm.

Working with BSC, RESNet, and builders such as BSC builders Artistic Homes and Pulte Homes, Fannie Mae has made progress on the above, particularly with two new mortgage products they

are about to announce. Of particular importance, these new products have the following attributes:

- **Simpler for the lender** – there are now just two products
- **Simpler for the energy rater** – the manner in which the net present value of the energy improvements is calculated and documented for the loan have been vastly simplified
- **Simpler for the PMI** – the LTV ratio has been established to eliminate issues lenders had with private mortgage insurance firms on calculating their rates
- **Easier** – carried on Fannie Mae's Desktop Underwriting software.

Time is an important element in terms of Fannie Mae's efforts to move this item from "market barriers remaining" to "market barriers overcome." Lenders need a bit of time in the marketplace with these two new products to assess their real value to high performance home builders and buyers. And perhaps just as important, Fannie Mae needs to build up some credit history on the performance of these two EEMs and then determine how they might increase power in the marketplace if the products come through with their expected superior performance for Fannie Mae.

The power of the EEM to reduce market barriers for high performance homes is still in a bit of the chicken-and-egg stage. Builders need sharper mortgage products to help distinguish the value of their high performance homes in the marketplace, and secondary lenders such as Fannie Mae need a deeper and broader base of actual EEMs in the marketplace to prove their superior performance to lenders.

One last element of EEMs that remains to be explored is the potential relationship between secondary lenders such as Fannie Mae and energy bill guarantee programs such as Masco's *Environments for Living*™ and GreenFiber's *Engineered for Life*™. The issue of who absorbs the cost of the energy rating (ranging from $150 to $400) has been a stumbling block for EEMs and for all builders in the EFL programs. They readily absorb this cost because of the perceived marketing value of a third-party energy bill guarantee. Therefore, there should be a way for these two business entities to co-promote their products to the ultimate benefit of high performance home builders and buyers. BSC is working on this issue in the last few months of the current cycle of Building America.

The Last Hurdle – Capturing the Durability Advantage

Durability has some distinct differences from energy efficiency. Durability is more difficult to define exactly, it is more difficult to measure and quantify, and it is more difficult to set standards for, particularly in terms of establishing a baseline. We just don't have a very good understanding or expression of how long houses or their components typically last or how environmental and other factors interact to affect overall building or individual material durability.

But here is what we do know:

- Durability stands squarely on the three-legged stool of quality—quality building design, quality materials, quality installation.
- Durability also stands squarely on homeowner maintenance, repair, and replacement. These are important operating costs to the homebuyer, and control or reduction of these costs could be translated into a real market advantage to the builder.
- Some builders are in their own way considering the concept of extended "product" responsibility, envisioning their business to be the supply of a continuous stream of services to a home over time, rather than just ending at or shortly after the home sale.
- Homeowners are concerned about the health risks and builders the liability associated with moisture and mold (both are facing exorbitant premiums or even unattainable insurance), a phenomenon directly associated with durability.

BSC began the exploration of capturing the market advantage of more durable homes with two builders: Artistic Homes and Pulte Homes. In particular, this exploration involved the concept of GREEN—Guaranteed Resource- and Energy-Efficiency Now (see the Web site www.buildingscience.com/resources/presentations/green.pdf). With Artistic Homes, this resulted in a detailed survey and analysis of building defects and homeowner maintenance and repair. With Pulte Homes it resulted in initial discussions of working with a major insurance firm on preferential home insurance premiums for high performance homes. But, in neither case, did

the initial work result in a real translation into market advantage for the builder or financial advantage to the high performance homeowner. The market barrier of capturing the advantage of more durable homes remains and requires further exploration.

Mold – the Double-Edged Sword

Here is the bad news: mold in buildings is fueling fear, litigation, builder and homeowner insurance program withdrawals, and media hysteria. And energy efficiency is being linked to mold—and often rightly so.

Here is the good news: building science and systems thinking are being viewed by the building industry as the answer to the mold problem—and rightly so.

The Building America program is uniquely positioned to use this rather sudden and sweeping industry interest as a driver for promoting building science and systems thinking. The key is that mold management is risk management. That makes it more of a new market advantage, than a remaining market barrier—one that is likely to have a major impact on Building America's success in coming years. (For more information, see www.buildingscience.com/resources/mold/default.htm.)

LESSONS LEARNED — SUMMARY

Each of the research and development activities BSC conducted within the Building America program resulted in specific lessons learned, as expressed in the first section of this report. But there are overarching lessons that have formed the Building America experience for BSC. These are organized below into three categories—building science, field, and general lessons learned.

Building Science Lessons

- Systems thinking in residential building requires the analysis of how air, heat, vapor, and liquid water move on and through building envelopes and HVAC systems. This cannot be reasonably accomplished without acknowledgment and incorporation of how hygro-thermal conditions drive this analysis.
- Each component of a building assembly should be assessed for its individual properties, particularly with respect to the movement of water, vapor, air, and energy. Product manufacturers need to supply and builders need to request (demand) detailed information on properties such as vapor permeability on all building products.
- Each component of a building assembly should be assessed for its contribution to the properties of the total assembly, particularly with respect to the movement of water, vapor, air, and energy. Again, product manufacturers and builders need to focus on how products perform in typical building assemblies, not just how the products perform individually.
- In high performance homes in hot-humid climates, the latent-to-sensible load ratio is such that dehumidification must be a separate and yet integral element of the HVAC system.
- As we move from energy efficiency improvements of 30% to more than 50%, we have a lot to learn about hot water, appliances, lighting, and plug loads. This is particularly true with regard to how domestic hot water can be integrated with either space heating or cooling, and how we accurately model natural ventilation, day lighting, and solar energy systems.

Lessons from the Field

- A systems approach and systems solutions almost always involve cooperation and communication among the trades. Particularly with HVAC contractors, the lack of this cooperation and communication is a real stumbling block in achieving high performance.
- Moving builders and framing contractors to advanced framing requires a progression of education and assistance—plan review and building redesign, Builder's Guide digestion, integration of HVAC, detailed drawings, and follow-up in the field. What is second-nature and obvious to the "converted" is painful and difficult to the newly initiated.
- Builders operating in more than one of the six climate zones must pay careful attention to the transfer of high performance techniques, systems and components as they move these from one climate zone to another.

- The really top-notch Building America builders get buy-in on the importance and meaning of high performance from every level of their organization—company management, field management, design and engineering, trade contractors, and sales and marketing.
- Performance testing of every home at the beginning of the Building America experience provides critical feedback in "getting it right." Performance testing of every home after that provides critical feedback in "keeping it right."

General Lessons

- The best Building America partner companies— builders, manufacturers, etc.— are those large enough to have or create economies of scale, but also small enough or managed in such a way that the company can make decisions and, subsequently, changes in a straightforward and timely way. BSC's best builder relationships always included this characteristic.
- Energy bill guarantees are simply the most elegant and most effective vehicle for marketing the benefits of Building America high performance homes.
- There are topics and times when the building science message must be translated for the homeowner as well as the builder (the AirCycler™ is a perfect example).
- Manufacturers need to know, establish, and publicize all the performance properties of the products as a matter of course, not as a matter of inquiry.
- Moving builders from simply the "first cost" to the "value" criterion for making changes in the way they build is an important part of high performance homebuilding.

PROGRAM IMPROVEMENT SUGGESTIONS

Building America has been one of the most successful residential building technology development and transfer programs ever. The five teams have participation from every sector of the business and area of the country. Real changes have been instituted company-wide by real builders and real manufacturers to provide real benefits to homebuyers and the environment.

But there are, of course, ways in which the Building America teams could be even more effective, particularly by strengthening commitments from builder partners.

- **Builder financial commitment** – Builders need to make a deeper commitment in the form of actual financial resources rather than just in-kind contribution towards Building America work. This would separate out the really committed from the "window-shopping" builders, allowing the team leaders to focus on those builders who are really willing to deliver. In addition, a stronger builder commitment to long-term monitoring of Building America homes is required to ensure that we get the hard-core proof-of-concept data needed. Incidentally, this very approach was the one that BSC took with its builder and manufacturer partners in its Building America proposal for the next cycle of Building America work.
- **Depth of builder commitment** – It is surprising to BSC the number of builders who have truly valued and benefited from the building science/systems thinking of Building America without taking the step of developing the same expertise in-house. Perhaps the commitment required of Building America builders should be extended to some sort of mandatory formal training in building science by at least one member of the builder's company. Perhaps Building America and EEBA's Master Builder program could team up with the building science expertise of BSC to establish this requirement.
- **Breadth of builder commitment** – The lateral transfer (division to division) of the Building America program within regional and national production builders is an important phenomenon. It is a phenomenon that we need to studiously encourage, given how important comprehensive systems thinking is when the Building America approach is transferred from one hygro-thermal zone to another.

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- **Emerging Technologies**
  Research and development of the next generation of energy-efficient components, materials, and equipment
- **Technology Integration**
  Integration of new technologies with innovative building methods to optimize building performance and savings

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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