Towards Sustainability: Green Building, Sustainability Objectives, and Building America Whole House Systems Research

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Abstract:

Green building is growing up in the United States.

EXECUTIVE SUMMARY

Towards Sustainability: Green Building, Sustainability Objectives, and Building America Whole House Systems Research

This paper discusses Building America whole house systems research within the broad effort to reduce or eliminate the environmental impact of building and provides specific recommendations for future Building America research based on Building Science Corporation's experience with several recent projects involving green home building programs.

Part 1, "Green Building and Sustainability," offers a working distinction between the terms 'green' and 'sustainable,' and identifies a framework of green building objectives. Building America research is then compared to national green building programs based on these green building objectives. Although Building America research goals are found to not address some aspects of green building, the program is found to excel in core areas including energy efficiency, durability and indoor environmental quality. Further, the program is characterized as 'very progressive' with regards to longer-term sustainability objectives based on its commitment to rigorous research; focus on industry transformation; and study of the environmental impact of energy use in a broad context.

Part 2, "Green Building and Building America Whole House Systems Research," discusses BSC's past experience and current projects involving one national green building program. Eight observations with relevance for future work involving green building programs are put forward:

1. Building America research goals do not address all green building objectives
2. Green building objectives should be addressed as early as possible in the design process
3. Green goals can assist project visibility
4. Building America research enables green building
5. Collaborative efforts with green building programs can encourage market transformation
6. Conflicting project goals must be managed
7. Maintaining objectivity and neutrality in technical recommendations may be difficult
8. Green building programs can offer an effective method of on-site quality assurance

Following these observations, four primary recommendations are made:

1. *Understand the context* – Building America teams should be aware of how their research efforts relate all major green building programs and, most importantly, to the sustainable design objectives outlined in Part 1.
2. *Maintain objectivity* – A clear view of Building America research goals must be maintained despite the apparent compatibility with major green building programs.
3. *Engage builders in green home building activity* – Despite the likely challenges, Building America teams should use green building programs to secure builder commitment to advanced research and promote project visibility.
4. *Broaden scope* – While emphasizing a depth of knowledge and experience, Building America teams should be open about the limited scope of BA research goals and seek to support the same rigorous approach in other areas of green building activity.

With due consideration given to the recommendations above, Building America research is found to be well positioned to derive mutual benefits from continued involvement with green building programs to move the residential housing industry towards sustainability.

OVERVIEW AND TASK DESCRIPTION

The Subcontractor shall prepare at least three technical papers for submission to an appropriate major technical conference or journal, describing the team's overall results from whole-house systems engineering research studies. The paper shall discuss the most promising advanced building system approaches to achieve 40-50% savings in residential space conditioning, hot water, and lighting loads relative to the Benchmark. The paper shall clearly identify the appropriate climate, building type, and building systems addressed by the recommendations. The paper shall summarize the building science knowledge and quality control tools that are required to successfully implement building design recommendations. The paper shall include examples of successful system solutions, examples of common mistakes to be avoided, and basic information about the potential impacts of making changes in the example solutions. The paper may be distributed through the DOE Building America Program Internet web site and hard copy format. The papers shall be delivered directly to the NREL Technical Monitor for peer review at least two weeks before the conference or journal submission deadline.

INTRODUCTION

Green building is becoming part of daily life in the residential construction industry. Over the past few years, the industry has seen a nationwide surge in green building programs for new housing. Consumers are being educated about the benefits of green building; product manufacturers are increasingly aware of the environmental benefits of their products; builders are learning about new techniques and technologies that purport to reduce environmental impact; and lenders, insurers, municipalities, code officials and design professionals are reinterpreting their roles in terms of green design objectives. Green building is growing up in the United States.

Such widespread change often creates uncertainty - knowing what to ask for and what to provide is a challenge. Homeowners' concern for green building issues is becoming more intense and sophisticated as their knowledge of environmental problems and possible solutions increases. Unlike mature industry products, however, residential green buildings are not themselves ready-made, tested and accepted. Builders must sell the environmental attributes of their products inside the market conditions established by consumer demand while at the same time adjusting methods of design, procurement and construction to meet changing standards. Green building is risky business.

Such widespread change and the associated risks, of course, also create opportunity. The combination of a changing marketplace and "external" ecological and social imperatives presents the residential construction industry with an opportunity to offer a new, valuable contribution to society and to make the internal changes to do so in a profitable way. Moreover, a rigorous understanding of environmental issues and the known responses to them is likely to be required if the United States is to address the current environmental problems in a meaningful and timely way.

For more than a decade, the U.S. Department of Energy's Building America research program has been working at the center of efforts to shepherd in this transformation of the residential building industry. Under the mantle "Research Towards Zero Energy" there has been a strong overlap between the program's research objectives and the fundamental concerns of the green building movement – key green concepts like energy and resource efficiency, durability and indoor air quality are core components of the Building America program. Building America interdisciplinary research teams have been leaders in developing knowledge and experience in these areas and communicating the results to a nationwide audience in the residential homebuilding industry.

This paper first discusses the broad context for action to reduce or eliminate the environmental impact of building, making distinctions between the terms 'green building' and 'sustainable building,' and providing a framework for understanding the many and overlapping environmental issues. National and international green building programs—including the Building America research program—are then compared on "building-related" issues and discussed relative to sustainability objectives.

In the second part of the paper, future considerations for integrating other fundamental sustainable building concerns into Building America research are discussed with recent Building Science Corporation Building America research as examples. Building America whole house research is described as being both well positioned to support sustainable building and limited in scope relative to several national green building programs.

PART 1: GREEN BUILDING AND SUSTAINABILITY

1.1: Understanding Green Building and Sustainability

The terms ‘green’ and ‘sustainable’ are often used interchangeably but there are fundamental differences between them. In a clear understanding of these differences lies the key to understanding the broad range of theories, agendas, programs, regulations, technologies, and techniques that are confusingly put together under the mantle of ‘sustainable building.’

In its most general sense, ‘green building’ is a label for the process of design and construction which aims to produce buildings that are less damaging to the environment—and the people that use them—than most buildings currently built today. These buildings must be measurably less damaging in significant ways of course, and unfortunately there are many examples of ‘green’ buildings that purport to be less damaging without supporting measurements, or that otherwise claim to be have integrated environmental concerns without addressing the most significant issues.

‘Sustainable building,’ however, refers more precisely to the goal of designing and constructing buildings that have no net impact on the environment, such that a total built environment composed of similar buildings could co-exist with the world’s ecological balance indefinitely.

Green building, then, focuses on incremental steps to solve known and measurable problems with our current practice, whereas sustainable building seeks models for an unidentified future state of society. Each term describes a distinct approach. Most of the environmentally responsible construction practiced today falls into the first category – we have few if any examples of sustainable buildings according to the above definition.

There are two important details that explain confusion about the fundamental difference between ‘green’ and ‘sustainable.’ The first is that environmental action as a whole is made up of many varied and sometimes competing objectives, which are pursued by different people or groups, according to different timeframes, and under different conceptions of the environmental problem itself. The second is that the environmental problem addressed by ‘green’ or ‘sustainable’ design is really an amalgam of issues, each affecting our society on different levels from the global to the personal, each therefore considered more or less important by different people, and each one more or less well understood in its internal complexities and external interactions.

Common misconceptions about the purpose of sustainable building efforts in the residential building industry and marketplace can be attributed to this lack of clarity about objectives. Understanding these competing objectives and concerns is a therefore necessary part of understanding how to do ‘green’ and ‘sustainable’ design. A framework to help unwind these issues is discussed in the following section.

1.2: The Ecological Crisis and Environmental Concerns

The major environmental concerns that relate to sustainable building, along with the groups having special interest, are listed in Table 1.1 below. While each concern impacts the others in some way, and although each group listed may have multiple areas of interest, the concerns presented tend to be treated by these groups as emblematic of their purpose.

Table 1.1: Environmental Concerns, Impacts and Building-related Issues

Environmental Concern	Scale of Effect	Timeframe	Building-related Issues	Concerned Groups
Climate Change	Global, Regional	Centuries	-Global Ecological Impact -Energy Efficiency -Land Use -Materials and Resource Efficiency -Social Transformation	Widespread
Loss of Biodiversity	Global, Regional, Local	Years, Centuries	-Land Use -Water Management -Global Ecological Impact -Social Transformation	Municipalities, Individuals
Habitat Destruction, Aesthetic Impact	Regional, Local	Years	-Land Use -Water Management -Materials and Resource Efficiency -Community Development -Social Transformation	Municipalities, Individuals
Depletion of Non-renewable Resources	Global, Regional, Local	Centuries, Years	-Durability -Materials and Resource Efficiency -Energy Efficiency -Social Transformation	National Level, Industry
Pollution of Air, Earth and Water	Regional, Local	Years, Days	-Design and Delivery Process -Land Use -Durability -Indoor Environmental Quality -Water Management -Materials and Resource Efficiency -Social Transformation	Municipalities, Individuals
Poverty	Global, Regional, Local	Years, Days	-Affordability -Design and Delivery Process -Durability -Energy Efficiency -Community Development	Widespread

The "environmental concerns" identified in the matrix above are the context for green building activity. Each addresses particular aspects of residential design and construction that have identifiable environmental impacts. Green building efforts that address all of these concerns have a reasonable chance of successfully addressing the full range of environmental impacts of building. However, the scope of activity is very wide and the degree to which these environmental impacts can be identified and measured varies greatly.

Referring back to the difference between 'green' and 'sustainable' building, it should be clear that in tackling the challenges presented here we are primarily concerned with 'green' building—that is, taking incremental steps towards understanding these complex environmental concerns—and that 'sustainable' building would require greater knowledge and competency than is likely available. It should also be clear that an interdisciplinary approach will be required for this work.

The green building programs examined in Section 1.3 below represent a wide range of special interests, each having particular emblematic issues. It is common to find only several environmental concerns addressed by a green building standard or system.

1.3: Green Building Programs Comparison

There are more than 70 local or regional green home building programs in the United States[1] but far fewer national programs. Some of these major programs were created more than a decade ago but most were created in the last five years. Table 1.2 below shows how various programs compare to each other on a list of environmental issues that are typically considered important for green building.[2]

Table 1.2: Matrix comparing programs on major green building issues

	Land Use (LU)	Social Transformation (ST)	Global Ecological Impact (EI)	Design and Delivery Process (DD)	Durability (D)	Energy Efficiency (EE)	Materials and Resource Efficiency (ME)	Indoor Environmental Quality (IEQ)	Water Resource Management (WR)	Affordability (AF)	Community Development (CD)
USGBC LEED® for Homes	I	II	III	I	II	I	I	I	I	III	II
NAHB National Green Building Standard	III	II	III	I	II	I	I	I	I	II	III
EPA Energy Star for New Homes		II			II	I		I		III	
Masco Environments for Living®		II		II	I	I	II	II	II	II	
GAHBA/Southface EarthCraft House™		III		III	I	I	II	II	II	III	
ALA Health House®		III			II			I			
Architecture 2030 Challenge		III	I			I					
Passivhaus Institut Passivhaus Standard		II			II	I		I			
CHBA R-2000 / EnviroHome Program		III	III		III	I	III	II	III	III	
DOE Building America		II	III	I	I	I	II	I	III	I	

Legend

I	Primary focus, emblematic issue
II	Serious secondary consideration
III	Tertiary concern or inadequately addressed
(blank)	Issue not addressed by program

[1] The USGBC maintains a current list at www.greenhomeguide.org/green_home_programs/index.html

[2] The eleven issues listed here are collected from a wider survey of green home building programs. It should be noted that each of the issues could be broken down into more specific components. For example, Indoor Environmental Quality can be measured by the mental and physical health of the occupants and depends on ventilation, pollutant sources, lighting, access to daylighting, etc.

The matrix above shows a common focus on energy efficiency and indoor environmental quality. This corresponds to consumer preferences on building-related environmental issues.[3] Energy-efficiency and indoor environmental quality have intuitive benefits for the homeowner. The construction industry has a longer history of dealing with these two issues in particular than, for example, maximizing water use efficiency and using sustainable materials. These four issues, in turn, are directly related to the house itself, whereas community development and land use, for example, have less direct connections. More complicated issues such as contribution to climate change and loss of biodiversity may have more dire consequences in the long term but how the design, construction and use of the home influences these problems is more difficult to see.

Another observation from Table 1.2 above is that beyond energy efficiency and indoor environmental quality, there is little consistency between programs on the remaining green building issues. The U.S. Green Building Council's (USGBC) LEED for Homes and the NAHB National Green Building Standard address the greatest range of issues associated with green building. It is not a coincidence either that these two programs are the newest of the programs in the comparison. By the time the programs were introduced—in 2005 and 2006, respectively—general knowledge about green building had risen significantly and the list of green building concerns was well established.

Older programs such as the Canadian Home Builder's Association's (CHBA) R-2000 and DOE/EPA's ENERGY STAR programs were developed as advanced housing programs focused on energy efficiency and related durability issues. Both of these programs were later revised and expanded to include a broader range of issues.

Several programs also show a limited focus. The American Lung Association (ALA) Health House program is focused primarily on the quality of the indoor environmental, for example – an obvious special interest given that organization's mandate. Although not a complete green building program, the Architecture 2030 Challenge is important in that it very aggressively sets energy use targets based on a strategy to reduce the global impact of climate change rather than taking standard construction as a reference. The German Passivhaus Institut program, which is becoming better known in the United States, has a very similar focus to ENERGY STAR but sets a more aggressive energy use target.

The three remaining entries in the comparison matrix have common roots in the DOE Building America program – Masco's Environments for Living and EarthCraft House™, from the Greater Atlanta Home Builder's Association (GAHBA) and the Southface Institute, were both informed by the results of Building America research and benefited by the involvement of Building America research teams. The core elements of the Building America research program—energy efficiency, durability, indoor air quality and affordability—strongly overlap the core green building issues. The Building America research program also has a well-defined process for guiding innovation that makes it a leader in transforming the residential building industry.[4]

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[3] Energy efficiency and indoor air quality are the top two "very important" issues in a 2006 McGraw Hill market report on residential green building.
[4] For similar efforts, Building America was awarded NAHB's Green Advocate of the Year (Group/Organization) in 2005. http://www.eere.energy.gov/buildings/building_america/rh_0505_greenbldg_award.html

PART 2: GREEN BUILDING AND BA WHOLE HOUSE SYSTEMS RESEARCH

2.1: Research "Towards Sustainability"

Building America research addresses fundamental components of green building - namely, energy efficiency, durability, and indoor air quality. Further, along the conceptual divide between green building—which reduces our environmental impact in incremental steps—and sustainable building—which aims for no net environmental impact—Building America research has strong tendencies towards the latter, evidenced by a commitment to rigorous research, a focus on industry transformation, and study of the environmental impact of energy use in a broad context.

These characteristics make Building America research well positioned to not only interact with green building programs but to play an increasingly important role in setting direction for research towards sustainability.

The following section examines BSC's experience with three projects that interacted with the LEED for Homes rating system. They are:

- Ideal Homes ZEH, Oklahoma City, OK (2005)
- BA 40% Habitat for Humanity Houses, Westford and Bedford, MA (2007)
- BA 40% Houses, Greensburg, KS (2007)

For each project, observations are offered which have relevance for future Building America research involving green building programs and for Building America's potentially significant role in leading the residential building industry towards sustainability.

2.2: Past Experience – Ideal Homes ZEH, Oklahoma City, OK

The Oklahoma City Zero Energy Home (ZEH) project grew out of an established partnership between Ideal Homes[5] and the Department of Energy's Building America Program. Ideal Homes has a long history working with the Building America program, and has the distinction of successfully marketing the energy efficient features of their houses. Ideal has incorporated many of the high efficiency features into their production homes, and also continuously tests incorporating new technology into the production process.

In 2005, Ideal Homes completed the ZEH as part of a three-house set of prototypes testing advanced energy efficient technology, including: ground source heat pumps, a tankless water heater, a photovoltaic system, an enthalpy recovery ventilator (ERV), solar hot water, de-superheater hot water, and energy efficient lighting. The goal of these projects was to evaluate the feasibility of adding any of these systems to their production homes.

With the ZEH prototype, the focus on integrating energy efficient technology into market rate product at an acceptable cost yielded North America's first affordable Zero Energy Home.[6] The project was a major marketing success for Ideal Homes. Full descriptions of the project were featured by the Discovery Channel,[7] the popular HousingZone.com website,[8] and in dozens of other print and electronic publications.

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[5] More information about Ideal Homes can be found at: http://www.ideal-homes.com/
[6] The selling price for the house was less than $200,000.
[7] http://dsc.discovery.com/news/2006/05/31/zeroehome_tec.html

Late in the development process for this project, the decision was made to participate in the USGBC's LEED for Homes Pilot Program and the home became one of the first to be rated under that system. Although the ZEH was counted as a major success by Building America standards, the house achieved only a "Certified" (or lowest) rating under the LEED-H system.

There were two factors that contributed to this initially counterintuitive result, both of which have some bearing on future Building America research projects involving green building programs such as LEED for Homes.

1. Building America research goals do not address all green building objectives

   In some LEED for Homes categories—namely, Energy and Atmosphere, and Indoor Environmental Quality—the ZEH scored almost top marks. Others—including Location and Linkage, Sustainable Sites, Water Efficiency, Materials and Resources, and Homeowner Awareness—are only partially or not explicitly addressed by the Building America program.[9] Specifically, the Ideal ZEH's rating suffered from the following:

   - Did not avoid construction on farmland (2 possible points)
   - Did not address landscaping (14 possible points)
   - Did not install very high efficiency fixtures and irrigation system (10 possible points)
   - Did not follow the ENERGY STAR Indoor Air Package (although many measures were implemented as part of the BSC Building America Performance Criteria – approximately 6 missed points)
   - Did not install ENERGY STAR Advanced Lighting Package or Very Efficient Clothes Washer (4 possible points)
   - Did not apply for any special Innovation credits (although the affordable ZEH concept would certainly have qualified for one – 4 possible points)

   In total, these missed opportunities add up to 40 possible points, which would have made the difference between the "Certified" and "Platinum" (highest) rating.

2. Green building objectives should be addressed as early as possible in the design process

   Many of the points that the ZEH did not get could have been added through purchases made by the builder. In this case, Ideal Homes was committed to the development of a ZEH within market pricing and "point-chasing" would have added to the cost of the house. However, the cost associated with some of the missed points could have been reduced or eliminated if attention was given to them early enough in the process. Several techniques to reduce cost that are already used in other Building America projects could have been employed. These include:

   - Identifying and applying cost savings as trade-offs against desired system performance improvement costs
   - Determined research effort to locate alternate products or systems with equivalent performance characteristics, employing testing and analysis where necessary

[8] http://www.housingzone.com/article/CA6332828.html

[9] Although in Building Science Corporation's work with Building America there are examples of each of these area being addressed in full – and even cases within the LEED for Homes system where BSC and Building America publications are used as best practice recommendations (Durability Planning, Advanced Framing Techniques, and the Homeowner's Manual).

- Justification of increases in initial capital investment through life cycle costing and clear statements of expected benefits
- Identification of minor process changes that can be made to remove obstacles to desired performance and quality improvements
- Use of federal, state or local government incentives
- Partnership with manufacturers and other industry stakeholders to change market conditions, including supply, cost, and product characteristics

Some or all of the above mentioned techniques could have been employed if the LEED for Homes points had been included in the project goals and enough time had been allowed early enough in the design process.

It should also be mentioned here that although the more recent projects discussed below cite the marketing appeal of green building programs as a primary reason for builders to pursue them, this was not the case with the ZEH completed just a couple of years before. The ZEH was successfully marketed by Ideal Homes based on the "Towards Zero Energy" concept promoted by the Building America program. Public attention has focused on a broader definition of green building that places Building America research objectives as a subset of issues addressed. This paper has observed (in Part 1 above) that the trend towards broadening the scope of green building has also introduced confusion and an increased risk disconnecting well-intentioned action from the systematic study of known, effective solutions.

The next two projects discussed describe Building America research activities in the current, broad understanding of green building.

2.3: BA 40% Habitat for Humanity Houses, Westford and Bedford, MA

In 2007, Building Science Corporation worked with Habitat for Humanity of Greater Lowell[10] on a project involving one house in Westford, MA and seven houses in Bedford, MA. The one-and-a-half story, full basement, 1800 square foot houses were designed as part of BSC's research into high R-value enclosures.

Based on analysis relative to the Building America Benchmark, the house plan achieves 42.5% savings on whole house energy use. The enclosure and mechanical system specification for this house is listed in Table 2.1 below.

The Habitat plan was also designed to meet BSC's Building America Performance Criteria, which include requirements for the specification stage, the field testing stage, and further recommended items.[11] The specifications include requirements for whole house energy use, ventilation flows (as per ASHRAE Standard 62.2), ventilation intake locations, combustion safety, minimum window performance standards, appliance efficiency, and lighting efficiency. Testing requirements are presented as well. Many of these Performance Criteria have a direct parallel in the national green building programs.

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[10] More information about Habitat for Humanity of Greater Lowell can be found at: http://www.lowellhabitat.org/index.php?section=1

[11] The BSC Building America Performance Criteria can be found at: http://www.buildingscienceconsulting.com/buildingamerica/targets.htm

Table 2.1: Westford/Bedford, MA Habitat for Humanity House Technology Package

Building enclosure	
Ceiling	R-26 4" polyisocyanurate on roof deck (x2 2" layers) with R-40 loose-fill cellulose (2x12 bays; 11.25")
Walls	R-19 2x6 OVE frame w. R-26 4" polyiso (x2 2" layers)
Foundation	Basement R-26 4" polyiso walls (x2 2" layers)
Windows	Double Pane Vinyl Spectrally Selective LoE_ U=0.33, SHGC=0.40 (minimum requirements)
Infiltration	2.5 sq in leakage area per 100 sf envelope 1127 CFM 50 (3.6 ACH 50) Plan 1
Mechanical systems	
Heat	92% AFUE gas furnace
Cooling	14 SEER air conditioner split system
DHW	0.85 EF water heater (e.g., instantaneous)
Ducts	R-4.2 flex runouts in conditioned space
Leakage	none to outside (5% or less)
Ventilation	Aprilaire VCS 8126 or similar supply-only system integrated with AHU; 25 W system power 50 CFM @ 33% Duty Cycle: 10 minutes on; 20 minutes off
Return Pathways	Transfer grilles/jump ducts at bedrooms
PV System	no information
Solar Hot Water	no information

For the Habitat group, green building was pursued primarily as a means of generating interest in the project and securing funding. For Habitat, secure project funding must be resolved before construction can begin. Being able to generate excitement and at the same time improving the quality of the house delivered to the homeowner, makes advanced housing an attractive prospect. In this case, a target rating of LEED-H "Certified" was set after work was started on the BA plans.

BSC conducted a preliminary and unofficial LEED for Homes rating on the house plans, making the following assumptions:

- No points were taken for *Sustainable Sites* credits (i.e., landscaping) with the exception of non-toxic pest control measures, which are part of the BSC Building America Performance Criteria,
- No points were taken for *Water Efficiency* credits, and
- Prerequisites were assumed to be met in all cases.

For the 1800 square foot, 5-bedroom example house plan, the proposed technology package scored 48 points, which would meet the "Certified" level of the LEED for Homes rating system (for the preliminary rating, the points threshold for Certified was 38 and for Silver was 53). Appendix A includes the detailed checklist LEED-H rating but a summary is included here:

- 7 of 10 points for *Location and Linkages*, given for the characteristics of the building site,
- 22 of 38 points for *Energy and Atmosphere*, based on an anticipated HERS index of 65 and an efficient plumbing layout,
- 4 of 14 points for *Materials and Resources*, taken for advanced framing techniques and reduced construction waste,

- 9 of 20 points for *Indoor Environmental Quality*, received for improved ventilation and combustion safety, and
- 6 additional points for design process and durability measures.

A number of additional measures were suggested to complement the Building America core areas of focus and meet minimum point totals in the Water Efficiency category. An additional 15-25 points could be achieved by these suggestions, which included low environmental impact landscaping, environmentally preferable construction materials and finishes, commissioning and performance testing, and homeowner education.

With the 48 "base" points for the Building America technology package and the suggested additional measures, the proposed LEED for Homes rating was revised to the "Gold" level with "Platinum" being within range.

The BSC experience with the Westford/Bedford, MA Habitat for Humanity houses offers important lessons for future Building America research projects:

1. Green goals can assist project visibility

   For the Habitat houses, the interest generated by the green objectives contributed to the financial viability of the project. Habitat for Humanity has special requirements in this respect that are not shared by production builders. However, increased media exposure in a tight building market would be an obvious advantage for most builders. For Building America research, the opportunity to assist builders in developing competency in this area may help secure builder commitment for future research projects.

   The Westford/Bedford, MA project also provided a platform for Building America Industry Partners to showcase products and systems with green characteristics. Supporting this interest with Industry Partners can be directly compatible with Building America research goals.

   It is important to note that advanced housing technology through the Building America program was initially sought after by the Lowell Habitat group as both a learning experience for the organization and for increased public exposure – both justified by perceived value for the organization. The LEED-H rating was an effective add-on to this initial strategy. The somewhat greater value perceived in pursuing the LEED-H rating reflects an implicit acknowledgement that the green building program was a "better fit" with the interests of funding sources for the project.[12]

2. Building America research enables green building

   Although, the goals are the Building America research program are a subset of those typically addressed by green building standards, the focus on energy efficiency, resource efficiency, occupant safety, health, comfort, and durability is strongly compatible with those standards. For the Westford House, the Lowell Habitat group prepared a marketing document entitled "101 Ways We are Building Green" of which more than half of the

[12] More explicit acknowledgement was given in the acceptance of significant fees paid by the LEED for Homes Provider for the certification service (especially when the overlap with Building America research activities is considered).

features were directly attributable to the energy efficiency and durability components of the Building America technology package.

2.4: BA 40% Houses, Greensburg, KS

In 2007, Building Science Corporation participated on DOE/NREL's residential re-construction team in Greensburg, Kansas.[13] The town of Greensburg was effectively destroyed in May 2007 by a tornado rated as category EF-5 on the Enhanced Fujita Scale. The town and county were declared a disaster area and many federal and state agencies (including FEMA, DOE, EPA and USDA) sent response teams to the area. As part of the residential team, the BSC and IBACOS Building America research teams were asked to provide support for energy efficient re-construction.

Based on BEopt analysis conducted by NREL, technology packages were developed to reach 30%, 40% and 50% savings targets. BSC produced a sample plan set as a concrete and buildable example of the 40% package and developed a Demonstration House Incentive Program (DHIP) with Industry Partners to support the construction of 10 houses to BA specifications. The DHIP technology package is summarized in Table 2.2 below.

Table 2.2: Greensburg Demonstration House Incentive Program Technology Package

Building enclosure	
Ceiling	R-50 blown cellulose
Walls	R-19 blown cellulose 2x6 OVE walls + R-7.5 1.5" XPS
Rim Joist	2" High Density Spray Foam R-12
Basement	R-13 2" foil faced polyisocyanurate
Windows	Double Pane Vinyl Spectrally Selective LoE2
	U=~0.35, SHGC=~0.33
Infiltration	2.5 sq in leakage area
	per 100 sf envelope
Mechanical systems	
Heat	92% AFUE Furnace
Cooling	2 ton 16 SEER air conditioner split system
DHW	0.82 instantaneous gas water heater
Ducts	Located in conditioned basement with central return on first floor
Leakage	none to outside (5% or less)
Ventilation	Aprilaire VCS 8126 Supply-only system integrated with AHU
	50 CFM 33% Duty Cycle: 10 minutes on; 20 minutes off
Return Pathways	Transfer grilles/jump ducts at bedrooms

NREL residential team in Greensburg formed a mutually-supportive relationship with Greensburg Greentown, a local non-for-profit organization formed to provide residents with information and support to rebuild Greensburg as a model green community.[14] Greensburg Greentown acted on behalf of the City of Greensburg as the coordinator for town-wide events, including several

[13] More information about the DOE/NREL/Building America residential team's activities can be found at: http://greensburg.buildingscience.com
[14] More information about Greensburg Greentown can be found at: http://www.greensburggreentown.org/

"Green Building Fairs" and the set-up of a housing resource center; as well as, nationally-covered events, such as the launch of a Discovery Channel documentary of the building of a the "Greenest Town in America." From the outset, then, BSC's example house plans and DHIP were considered to be part of the larger effort towards sustainable housing in Greensburg.

To demonstrate the relationship between the Building America 40% technology package and green building objectives that partner organizations were more familiar with, BSC conducted a preliminary and unofficial LEED for Homes rating on the example house plans. As in the Westford, MA house described above, several assumptions were made:

- No points were taken for *Location and Linkages* credits (i.e., building site location),
- No points were taken for *Sustainable Sites* credits (i.e., landscaping) with the exception of non-toxic pest control measures,
- No points were taken for *Water Efficiency* credits, and
- Prerequisites were assumed to be met in all cases.

For the 1200 square foot, 3-bedroom example house plan, the BA 40% technology package scored 36 points, which would meet the "Certified" level of the LEED for Homes rating system. Appendix B includes the detailed checklist LEED-H rating but a summary is included here:

- 17 of 38 points for *Energy and Atmosphere*, based on an anticipated HERS index of 65 and an efficient plumbing layout,
- 4 of 14 points for *Materials and Resources*, taken for advanced framing techniques and reduced construction waste,
- 9 of 20 points for *Indoor Environmental Quality*, received for improved ventilation and combustion safety, and
- 6 additional points for design process and durability measures.

The suggestion supported by this evaluation was that the Building America 40% technology package could offer a reliable core for a green building program in Greensburg. To complete the breadth requirements for the LEED program, additional measures would need to be taken in the landscaping and water efficiency areas to meet minimum point totals. Including these minimums, approximately 35 points could be added to the core total of 36 by addressing reconstruction in an urban setting, on-site renewable energy generation, environmentally preferable construction materials and finishes, commissioning and performance testing, and homeowner education. Greensburg Greentown was encouraged to organize other partners' contributions to address these key areas. By using the Building America package as a base and integrating other green building measures, the BSC Greensburg example house plan would achieve a very respectable "Gold" rating under the LEED for Homes system.

In the course of implementing the Demonstration House Incentive Program in Greensburg, several key issues were encountered that have significance for future Building America research projects:

1. Collaborative efforts with green building programs can encourage market transformation

   The re-construction effort in Greensburg was an unusual situation in that all levels of government and many other stakeholders were acting to transform the market place. However, the relationships that were established between groups (inside and outside government agencies) with a sustainability agenda should serve as a model for other, open market situations. In particular, public interest in sustainability can be usefully leveraged to increase builder interest and commitment, while BA research and support offers much needed rational grounding for green building activities.

2. Conflicting project goals must be managed

   The relationship between BA research teams and sustainability interest groups in Greensburg was not an easy one. BA research teams' focus on cost neutrality and a limited range of green building issues was perceived as being "not going far enough" by groups hoping to accomplish more comprehensive change. As a result, NREL, BSC and IBACOS were forced to expend considerable effort on establishing credibility for BA research work.

   An argument was made in Part 1 of this paper that BA research focuses on core areas of green design that can be measured and verified, and therefore can be known to be effective efforts to reduce environmental impact. It was also pointed out that the general level of knowledge and agreement about what constitutes green building is inconsistent across different sectors of the residential building industry. This was certainly true of the industry cross-section of stakeholders acting in Greensburg. However, it would be unfair to attribute BA teams' initial hardship to others' lack of knowledge – DOE, NREL, and BSC began work in Greensburg assuming that they contributions would be recognized as important and valuable. Given the response, it is clear that some effort must be made to position BA research relative to the broader spectrum of sustainability objectives and to demonstrate the depth of technical knowledge gained through whole house research.

   Another, separate, goals-related conflict that was managed by DOE, NREL, and BA research teams throughout the project was differing interest in sustainability objectives for both Greensburg residents and local partner builders. For the part of the BA research teams, public disinterest and builder skepticism is a constant and expected challenge. Through years of working with builders conducting advanced housing research, BA teams have developed effective methods of communication and technical support, and a clear understanding of issues faced by builders. BA teams can also confidently discuss the value of their research for homeowners. However, the close linkage to sustainability interest groups in Greenburg gave teams less flexibility in overcoming goal-related conflicts – possibility at the cost of begin able to reach residents and builders wishing to distance themselves from the green initiatives but otherwise interested in advanced housing.

3. Maintaining objectivity and neutrality in technical recommendations may be difficult

   An objective stance towards different technical proposals for green housing in Greensburg was challenging to maintain amid the intense marketing conducted by building material manufacturers, suppliers and the general media. The Greensburg green initiative was a microcosm of the current climate in the green building industry, where objective consideration of green issues is often overwhelmed by aggressive marketing of green products and services. Charged with providing objective technical advice to residents and builders, NREL and BA research teams were frequently in the position of having to explain or contradict claims made by other groups with a different agenda or with a product to sell. The lack of knowledge amongst homeowners, builders and other industry stakeholders has created a situation where those with a specific agenda are often trying to define green building in a way that is favorable to their own interest – not dissimilar to normal activity in the homebuilding industry, but of particular concern for BA teams trying to orient their activity according to a broad context for environmental action.

4. Green building programs can offer an effective method of on-site quality assurance

   Some green building programs require documented verification of specified "green" measures and require that this documentation be provided by a qualified third-party. In addition, all green building programs make performance claims to homeowners that lead to a higher degree of public scrutiny. Both of these factors can work to ensure a higher level of on-site quality assurance for Building America research projects involving a green building program.

   There are some important considerations, however, that can limit the effectiveness of this approach. For example, LEED for Homes requires that a durability plan and checklist be completed but the durability measures chosen may or may not correspond to measures recommended by Building America systems engineering. If recommendations are made early enough in the process, the durability checklist can be revised to include Building America criteria. Another limitation can be the training and experience of the third-party responsible for the inspections.

   Some green building programs include a variety of mandatory and optional performance tests. These test reports can be a useful source of information for research projects if efforts are made to ensure that test methods used are compatible with Building America requirements. Also, some optional testing (such as outdoor air flow rate and room-by-room supply – IEQ credits 4.3 and 6.3 in the LEED-H system, respectively) could be chosen on green building projects to support Building America research.

2.5: Recommendations for Whole House Research

The previous discussion of BSC Building America research projects listed the following relevant observations for future work involving green building programs:

1. Building America research goals do not address all green building objectives
2. Green building objectives should be addressed as early as possible in the design process
3. Green goals can assist project visibility
4. Building America research enables green building
5. Collaborative efforts with green building programs can encourage market transformation
6. Conflicting project goals must be managed
7. Maintaining objectivity and neutrality in technical recommendations may be difficult
8. Green building programs can offer an effective method of on-site quality assurance

With consideration given to the context for green building proposed in Part 1 of this paper, these observations can be condensed into four key recommendations:

1. Understand the context

   Building America teams should be aware of how their research efforts relate to all major green building programs and, most importantly, to the sustainable design objectives outlined in Part 1.

   Given the overlap in goals, it should be considered highly likely that the majority of Building America research work will become involved in green building programs. Teams will need to be able to explain their technical recommendations relative to these programs and will need to be able to provide suitable documentation to satisfy green building program requirements. Beyond this, Building America teams will be expected to provide expert advice on how to best reach goals within green building programs and to provide guidance on how to interpret the programs' requirements amid competing sustainability objectives and the normal pressures of the homebuilding industry.

2. Maintain objectivity

   A clear view of Building America research goals must be maintained despite the apparent compatibility with major green building programs.

   Although the standards set by green building programs appear to have a direct overlap with the objectives of Building America research, there are significant differences that should not be overlooked. In general, green building programs are developed using a consensus approach, which aims to put forward prescriptions that are clear, relatively easy to achieve and agreeable to the parties involved in the process. In some cases, where the development process has been less than rigorous, technical requirements in the green building program may be distorted or simply incorrect. In other cases, requirements may have been reduced in complexity or potency and will fall far short of measures demanded by leading edge research. Building America teams will need to maintain an objective view despite political and technical challenges, and an increasingly prevalent "points-based" approach to whole house design.

   An additional caution: In the Building America program there is an openness towards new techniques and technologies that address the core objectives of energy efficiency, durability and affordability. However, incompatible decision-making processes driven by differences in opinion on green building objectives may make some green homes inappropriate projects for Building America research teams.

3. Engage builders in green home building

   Despite the probable challenges, Building America teams should use green building programs to secure builder commitment to advanced research and promote project visibility.

   In each of the BSC projects discussed above, significant benefits were realized for the Building America Builder Partner working with a green building program. In cases where the builder partner is already interested in advanced research, especially the higher energy savings levels, Building America teams can offer the marketability of the green housing product as an added benefit of whole house systems research. Recall that in recent years, the growth of major green building programs has changed conditions in the market place so that core Building America research objectives are very likely to be interpreted in terms of 'green' or 'sustainable' construction – and as a subset of these broader issues at that.

   For builders that have mild or inconsistent interest in advanced research, participation in the Building America program can be proposed as a proven mechanism for reaching green building goals. Specifically, Building America teams can enable the transition to green building through systems evaluations, whole house energy analysis, support for product delivery process change, and the establishment of effective quality assurance programs.

4. Broaden Scope

   While emphasizing a depth of knowledge and experience, Building America teams should be open about the limited scope of BA research goals and seek to support the same rigorous approach in other areas of green building activity.

   Drawing upon research conducted by DOE National Laboratories and Building America team project experience, Building America research projects should be prepared to address water resource management and building material selection. Teams should be able to support site, landscape and community development activities, especially as they impact building design and energy use. In particular, Building America teams should lend experience with systems engineering to these areas.

   At the green building policy level, Building America teams should play a more active role in defining effective green building activity by establishing acceptable performance levels, critiquing the environmental merits of proposed technical solutions, and assisting with the development of reliable and realistic mechanisms for industry change.

CONCLUSIONS

As Building America research teams move towards higher whole house energy savings, there is a high likelihood that projects will become more involved with national or locally-based green building programs. For builders, green building programs are becoming an increasingly significant part of the residential building market and this trend is likely to continue. Building America's strong focus on core green building areas—as well as the research teams' rigorous approach to technology development, focus on industry transformation, and study of the environmental impact of energy use in a broad context—allows for connections to be made to green building activities with benefits for all parties involved. In order to take best advantage of this opportunity, Building America research teams should consider the four primary recommendations are made in this paper:

1. *Understand the context* – Building America teams should be aware of how their research efforts relate all major green building programs and, most importantly, to the sustainable design objectives outlined in Part 1.
2. *Maintain objectivity* – A clear view of Building America research goals must be maintained despite the apparent compatibility with major green building programs.
3. *Engage builders in green home building activity* – Despite the likely challenges, Building America teams should use green building programs to secure builder commitment to advanced research and promote project visibility.
4. *Broaden scope* – While emphasizing a depth of knowledge and experience, Building America teams should be open about the limited scope of BA research goals and seek to support the same rigorous approach in other areas of green building activity.

REFERENCES

2030, Inc. / Architecture 2030. "The 2030 Challenge." http://www.architecture2030.org/2030_challenge/index.html.
(More information about this program can be found at www.architecture2030.org)

American Lung Association. "Health House Builder Guidelines" ALA, 2006.
(More information about this program can be found at www.healthhouse.org)

EarthCraft House. *EarthCraft House and Low-rise Multifamily Technical Guidelines.* Version June 2005.
(More information about this program can be found at www.earthcrafthouse.com)

Environmental Protection Agency. *"Guidelines for ENERGY STAR Qualified New Homes."* http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.homes_guidelns
(More information about this program can be found at www.energystar.gov)

Masco Services Group Corp. "Environments for Living: Program Requirements and Performance Criteria." www.elfhome.com/04_programspecs.shtml
(More information about this program can be found at www.elfhome.com)

McGraw Hill Construction. "Residential Green Building SmartMarket Report" 2006 Residential Green Building Issue.

National Association of Homebuilders. *National Green Building Standard – Draft Standard Version No. 1*, August 10, 2007.
(More information about this program can be found at www.nahbrc.org/greenguidelines)

Passivhaus Institut. *Passive House Planning Package.* www.passiv.de
(More information about this program can be found at www.passiv.de)

U.S. Green Building Council. *LEED for Homes Pilot Rating System – Version 1.11a*, January 2007.
(More information about this program can be found at www.usgbc.org/leed/homes)

APPENDICES

A. LEED-H Example Checklist – BA 40% Habitat for Humanity House, Westford, MA

B. LEED-H Example Checklist – BA 40% Houses, Greensburg, KS

C. LEED-H Example Durability Plan – BA 40% Habitat for Humanity House, Westford, MA

APPENDIX

A. LEED-H Example Checklist – BA 40% Habitat for Humanity House, Westford, MA

Project Checklist
LEED for Homes

Builder Name:	***Habitat for Humanity Building America House***
Home Address (Street/City/State):	***Westford, MA***

Input Values: No of Bedrooms: ***5*** Floor Area (SF): ***1800***

Minimum No. of Points Required: Certified: ***38*** Silver: ***53*** Gold: ***68*** Platinum: ***83***

Detailed information on the measures below are provided in the companion document "LEED for Homes Rating System"

Y / Pts	No	N/A	#	Credit	Measure		***Max Points Available***	Notes
				Innovation and Design Process (ID)	(Minimum of 0 ID Points Required)		**9**	
y			1.1	**Integrated Project Planning**	Preliminary Rating		Prerequisite	
1			1.2		Integrated Project Team		1	An integrated team is part of the BSC's Building America research.
			1.3		Design Charrette		1	
y			2.1	**Quality Management for Durability**	Durability Planning; (Pre-Construction)		Prerequisite	
y			2.2		Wet Room Measures		Prerequisite	
y			2.3		Quality Management		Prerequisite	
3			2.4		Third-Party Durability Inspection		3	These measures are part of the BSC's Building America specification.
			3.1	**Innovative / Regional Design**	Provide Description and Justification for Specific Measure		1	
			3.2		Provide Description and Justification for Specific Measure		1	
			3.3		Provide Description and Justification for Specific Measure		1	
			3.4		Provide Description and Justification for Specific Measure		1	
4				Sub-Total				
				Location and Linkages (LL)	(Minimum of 0 LL Points Required)	OR	**10**	
HOLD			1	**LEED-ND Neighborhood**		**LL2-5**	10	
2			2	**Site Selection**	Avoid Environmentally Sensitive Sites and Farmland	**LL1**	2	The LL points are estimated based on the location of the proposed building site in Westford.
			3.1	***Preferred Locations***	Select an Edge Development Site	**LL1**	1	
2			3.2	***OR***	Select an Infill Site	**LL1**	2	
			3.3		Select a Previously Developed Site	**LL1**	1	
1			4	**Infrastructure**	Site within 1/2 Mile of Existing Water and Sewer	**LL1**	1	
1			5.1	**Community Resources**	Basic Community Resources / Public Transportation	**LL1**	1	
			5.2	**& Public Transit** ***OR***	Extensive Community Resources / Public Transportation	**LL1**	2	
			5.3	***OR***	Outstanding Community Resources / Public Transportation	**LL1**	3	
1			6	***Access to Open Space***	Publicly Accessible Green Spaces	**LL1**	1	
7				Sub-Total				
				Sustainable Sites (SS)	(Minimum of 5 SS Points Required)	OR	**21**	
y			1.1	**Site Stewardship**	Erosion Controls (During Construction)		Prerequisite	
			1.2		Minimize Disturbed Area of Site		1	
y			2.1	**Landscaping**	No Invasive Plants		Prerequisite	
			2.2		Basic Landscaping Design		2	4-8 additional points could be added with an appropriate landscape design and installation (using a number of SS credits). Cost for this would vary but likely in the $2500 to $4500 range.
			2.3		Limit Turf		3	
			2.4		Drought Tolerant Plants		2	
			3	**Shading of Hardscapes**	Locate and Plant Trees to Shade Hardscapes		1	
1			4.1	**Surface Water Management**	Design Permeable Site		4	Could be higher depending on site conditions.
2			4.2		Design and Install Permanent Erosion Controls		2	Can be included in site design.
2			5	**Non-Toxic Pest Control**	Select Insect and Pest Control Alternatives from List		2	These measures are part of the BSC's Building America specification.
			6.1	**Compact Development**	Average Housing Density ≥ Units / Acre	**LL1**	2	
			6.1	***OR***	Average Housing Density ≥ 10 Units / Acre	**LL1**	3	
			6.3	***OR***	Average Housing Density ≥ 20 Units / Acre	**LL1**	4	
5				Sub-Total				
				Water Efficiency (WE)	(Minimum of 3 WE Points Required)	OR	**15**	
			1.1	**Water Reuse**	Rainwater Harvesting System		4	2 additional points are likely for outdoor rainwater use. A collection and storage system (about $1000) and an irrigation system (about $1500) are needed.
			1.2		Grey Water Re-Use System		1	
			2.1	**Irrigation System**	Select High Efficiency Measures from List		3	
			2.2		Third Party Verification		1	
			2.3	***OR***	Install Landscape Designed by Licensed or Certified Professional	**WE 2.2**	4	
3			3.1	**Indoor Water Use**	High Efficiency Fixtures (Toilets, Showers, and Faucets)		3	Minimum required. Donations could be solicited for these products, cost is in the $500 range for the house.
			3.2	***OR***	Very High Efficiency Fixtures (Toilets, Showers, and Faucets)	**WE 3.1**	6	
3				Sub-Total				

Project Checklist (cont'd)

HERS Index Value Achieved: 57
IECC Climate Zone: 5
EA 1.2 Pts Achieved: 19.2

Y / Pts	No	N/A	#	Credit	Requirement		Pts	Notes
				Energy and Atmosphere (EA)	(Minimum of 0 EA Points Required)	OR	38	
y			1.1	**ENERGY STAR Home**	Meets ENERGY STAR for Homes with Third-Party Testing		Prerequisite	
19			1.2		Exceeds ENERGY STAR for Homes	**EA 2-10**	34	Based on preliminary energy analysis (EnergyGage)
2			7.1	**Water Heating**	Improved Hot Water Distribution System		2	These measures are part of the BSC's Building America specification.
			7.2		Pipe Insulation		1	
1			11	**Refrigerant Management**	Minimize Ozone Depletion and Global Warming Contributions		1	If A/C is not installed (i.e., no refrigerate used) = 1 point. If A/C is installed, expect about $800 in additional cost for refrigerant charging.
22				Sub-Total (or Sub-Total from Adendum A - Prescriptive EA Credits)				
				Materials and Resources (MR)	(Minimum of 2 MR Points Required)		14	
y			1.1	**Material Efficient Framing**	Overall Waste Factor for Framing Order Shall be No More than 10%.		Prerequisite	
3			1.2		Advanced Framing Techniques		3	These measures are part of the BSC's Building America specification.
			1.3	***OR***	Structurally Insulated Panels	**MR 1.2**	2	
y			2.1	**Environmentally Preferable**	Tropical Woods, if Used, Must be FSC		Prerequisite	
			2.2	**Products**	Select Environmentally Preferable Products from List		8	2-6 additional points could be gained in for this credit depending on the interior finishes and construction materials chosen. BSC can prepare this specification. Expect $500-1000 per additional credit.
y			3.1	**Waste Management**	Document Overall Rate of Diversion		Prerequisite	
1			3.2		Reduce Waste Sent to Landfill by 25% to 100%		3	These measures are part of the BSC's Building America specification. The waste documentation process requires effort on the part of the construction manager but there are well known ways of diverting waste from landfill.
4				Sub-Total				
				Indoor Environmental Quality (IEQ)	(Minimum of 6 IEQ Points Required)	OR	20	
			1	**ENERGY STAR with IAP**	Meets ENERGY STAR w/ Indoor Air Package (IAP)	**IEQ2-10**	11	
y			2.1	**Combustion Venting**	Space Heating & DHW Equip w/ Closed/Power-Exhaust	**IEQ 1**	Prerequisite	
2			2.2		Install High Performance Fireplace	**IEQ 1**	2	Can receive this credit for NOT installing a fireplace at all.
1			3	**Moisture Control**	Analyze Moisture Loads AND Install Central System (if Needed)	**IEQ 1**	1	This measure is part of the BSC's Building America specification.
y			4.1	**Outdoor Air Ventilation**	Meets ASHRAE Std 62.2	**IEQ 1**	Prerequisite	
			4.2		Dedicated Outdoor Air System (w/ Heat Recovery)	**IEQ 1**	2	
			4.3		Third-Party Testing of Outdoor Air Flow Rate into Home		1	1-5 additional credits are possible with additional testing done by BSC as Building America research.
y			5.1	**Local Exhaust**	Meets ASHRAE Std 62.2	**IEQ 1**	Prerequisite	
			5.2		Timer / Automatic Controls for Bathroom Exhaust Fans	**IEQ 1**	1	
1			5.3		Third-Party Testing of Exhaust Air Flow Rate Out of Home		1	Part of the BSC's Building America research.
y			6.1	**Supply Air Distribution**	Meets ACCA Manual D	**IEQ 1**	Prerequisite	
			6.2		Third-Party Testing of Supply Air Flow into Each Room in Home		2	
y			7.1	**Supply Air Filtering**	≥ 8 MERV Filters, w/ Adequate System Air Flow	**IEQ 1**	Prerequisite	
			7.2	***OR***	≥ 10 MERV Filters, w/ Adequate System Air Flow		1	
			7.3	***OR***	≥ 13 MERV Filters, w/ Adequate System Air Flow		2	
			8.1	**Contaminant Control**	Seal-Off Ducts During Construction	**IEQ 1**	1	
			8.2		Permanent Walk-Off Mats *OR* Shoe Storage *OR* Central Vacuum		2	
			8.3		Flush Home Continuously for 1 Week with Windows Open		1	
y			9.1	**Radon Protection**	Install Radon Resistant Construction if Home is in EPA Zone 1	**IEQ 1**	Prerequisite	
1			9.2		Install Radon Resistant Construction if Home is not in EPA Zone 1	**IEQ 1**	1	This measure is part of the BSC's Building America specification.
y			10.1	**Garage Pollutant Protection**	No Air Handling Equipment OR Return Ducts in Garage	**IEQ 1**	Prerequisite	
			10.2		Tightly Seal Shared Surfaces between Garage and Home	**IEQ 1**	2	
			10.3		Exhaust Fan in Garage		1	
3			10.4	***OR***	Detached Garage or No Garage	**IEQ 1**	3	Part of BSC's plan.
9				Sub-Total				
				Awareness and Education (AE)	(Minimum of 0 AE Points Required)		3	
y			1.1	**Education for Homeowner**	Basic Occupant's Manual and Walkthrough of LEED Home		Prerequisite	
			1.2	**and/or Tenants**	Comprehensive Occupant's Manual and Multiple Walkthroughs / Trainings		1	
1			1.3		Public Awareness of LEED Home		1	Very likely part of promoting the project.
			2.1	**Education for Building Mgrs**	Basic Building Manager's Manual and Walkthrough of LEED Home		1	
1				Sub-Total				
55				**Project Totals** (pre-certification estimates)			***130***	

APPENDIX

B. LEED-H Example Checklist – BA 40% Houses, Greensburg, KS

Project Checklist

LEED for Homes

Builder Name:	***Sample Building America House***
Home Address (Street/City/State):	***Greensburg, KS***

Input Values:
No of Bedrooms: ***3*** Floor Area (SF): ***1200***

Minimum No. of Points Required:
Certified: ***36*** Silver: ***51*** Gold: ***66*** Platinum: ***81***

Detailed information on the measures below are provided in the companion document "LEED for Homes Rating System"

Y / Pts	No	N/A	#	Credit	Measure		Max Points Available
				Innovation and Design Process (ID)	(Minimum of 0 ID Points Required)		9
y			1.1	**Integrated Project Planning**	Preliminary Rating		Prerequisite
1			1.2		Integrated Project Team		1
			1.3		Design Charrette		1
y			2.1	**Quality Management for**	Durability Planning; (Pre-Construction)		Prerequisite
y			2.2	**Durability**	Wet Room Measures		Prerequisite
y			2.3		Quality Management		Prerequisite
3			2.4		Third-Party Durability Inspection		3
			3.1	**Innovative / Regional Design**	Provide Description and Justification for Specific Measure		1
			3.2		Provide Description and Justification for Specific Measure		1
			3.3		Provide Description and Justification for Specific Measure		1
			3.4		Provide Description and Justification for Specific Measure		1
4				Sub-Total			
				Location and Linkages (LL)	(Minimum of 0 LL Points Required)	OR	10
HOLD			1	**LEED-ND Neighborhood**		**LL2-5**	10
			2	**Site Selection**	Avoid Environmentally Sensitive Sites and Farmland	**LL1**	2
			3.1	***Preferred Locations***	Select an Edge Development Site	**LL1**	1
			3.2	***OR***	Select an Infill Site	**LL1**	2
			3.3		Select a Previously Developed Site	**LL1**	1
			4	**Infrastructure**	Site within 1/2 Mile of Existing Water and Sewer	**LL1**	1
			5.1	**Community Resources**	Basic Community Resources / Public Transportation	**LL1**	1
			5.2	**& Public Transit** ***OR***	Extensive Community Resources / Public Transportation	**LL1**	2
			5.3	***OR***	Outstanding Community Resources / Public Transportation	**LL1**	3
			6	***Access to Open Space***	Publicly Accessible Green Spaces	**LL1**	1
0				Sub-Total			
				Sustainable Sites (SS)	(Minimum of 5 SS Points Required)	OR	21
y			1.1	**Site Stewardship**	Erosion Controls (During Construction)		Prerequisite
			1.2		Minimize Disturbed Area of Site		1
y			2.1	**Landscaping**	No Invasive Plants		Prerequisite
			2.2		Basic Landscaping Design		2
			2.3		Limit Turf		3
			2.4		Drought Tolerant Plants		2
			3	**Shading of Hardscapes**	Locate and Plant Trees to Shade Hardscapes		1
			4.1	**Surface Water Management**	Design Permeable Site		4
			4.2		Design and Install Permanent Erosion Controls		2
2			5	**Non-Toxic Pest Contro**	Select Insect and Pest Control Alternatives from List		2
			6.1	**Compact Development**	Average Housing Density≥ Units / Acre	**LL1**	2
			6.1	***OR***	Average Housing Density≥ 10 Units / Acre	**LL1**	3
			6.3	***OR***	Average Housing Density≥ 20 Units / Acre	**LL1**	4
2				Sub-Total			
				Water Efficiency (WE)	(Minimum of 3 WE Points Required)	OR	15
			1.1	**Water Reuse**	Rainwater Harvesting System		4
			1.2		Grey Water Re-Use System		1
			2.1	**Irrigation System**	Select High Efficiency Measures from List		3
			2.2		Third Party Verification		1
			2.3	***OR***	Install Landscape Designed by Licensed or Certified Professional	**WE 2.2**	4
			3.1	**Indoor Water Use**	High Efficiency Fixtures (Toilets, Showers, and Faucets)		3
			3.2	**OR**	Very High Efficiency Fixtures (Toilets, Showers, and Faucets)	**WE 3.1**	6
0				Sub-Total			

Project Checklist (cont'd)

HERS Index Value Achieved: 65
IECC Climate Zone: 4

EA 1.2 Pts Achieved: 15.5

Y / Pts	No	N/A	#	Credit	Description		Points
				Energy and Atmosphere (EA)	(Minimum of 0 EA Points Required)	OR	**38**
y			1.1	**ENERGY STAR Home**	Meets ENERGY STAR for Homes with Third-Party Testing		Prerequisite
15			1.2		Exceeds ENERGY STAR for Homes	**EA 2-10**	34
2			7.1	**Water Heating**	Improved Hot Water Distribution System		2
			7.2		Pipe Insulation		1
			11	**Refrigerant Management**	Minimize Ozone Depletion and Global Warming Contributions		1
17				Sub-Total (or Sub-Total from Adendum A - Prescriptive EA Credits)			
				Materials and Resources (MR)	(Minimum of 2 MR Points Required)		**14**
y			1.1	**Material Efficient Framing**	Overall Waste Factor for Framing Order Shall be No More than 10%.		Prerequisite
3			1.2		Advanced Framing Techniques		3
			1.3	***OR***	Structurally Insulated Panels	**MR 1.2**	2
y			2.1	**Environmentally Preferable**	Tropical Woods, if Used, Must be FSC		Prerequisite
			2.2	**Products**	Select Environmentally Preferable Products from List		8
y			3.1	**Waste Management**	Document Overall Rate of Diversion		Prerequisite
1			3.2		Reduce Waste Sent to Landfill by 25% to 100%		3
4				Sub-Total			
				Indoor Environmental Quality (IEQ)	(Minimum of 6 IEQ Points Required)	OR	**20**
			1	**ENERGY STAR with IAP**	Meets ENERGY STAR w/ Indoor Air Package (IAP)	**IEQ2-10**	11
y			2.1	**Combustion Venting**	Space Heating & DHW Equip w/ Closed/Power-Exhaust	**IEQ 1**	Prerequisite
2			2.2		Install High Performance Fireplace	**IEQ 1**	2
1			3	**Moisture Control**	Analyze Moisture Loads AND Install Central System (if Needed)	**IEQ 1**	1
y			4.1	**Outdoor Air Ventilation**	Meets ASHRAE Std 62.2	**IEQ 1**	Prerequisite
			4.2		Dedicated Outdoor Air System (w/ Heat Recovery)	**IEQ 1**	2
			4.3		Third-Party Testing of Outdoor Air Flow Rate into Home		1
y			5.1	**Local Exhaust**	Meets ASHRAE Std 62.2	**IEQ 1**	Prerequisite
1			5.2		Timer / Automatic Controls for Bathroom Exhaust Fans	**IEQ 1**	1
1			5.3		Third-Party Testing of Exhaust Air Flow Rate Out of Home		1
y			6.1	**Supply Air Distribution**	Meets ACCA Manual D	**IEQ 1**	Prerequisite
			6.2		Third-Party Testing of Supply Air Flow into Each Room in Home		2
y			7.1	**Supply Air Filtering**	≥ 8 MERV Filters, w/ Adequate System Air Flow	**IEQ 1**	Prerequisite
			7.2	***OR***	≥ 10 MERV Filters, w/ Adequate System Air Flow		1
			7.3	***OR***	≥ 13 MERV Filters, w/ Adequate System Air Flow		2
			8.1	**Contaminant Control**	Seal-Off Ducts During Construction	**IEQ 1**	1
			8.2		Permanent Walk-Off Mats *OR* Shoe Storage *OR* Central Vacuum		2
			8.3		Flush Home Continuously for 1 Week with Windows Open		1
y			9.1	**Radon Protection**	Install Radon Resistant Construction if Home is in EPA Zone 1	**IEQ 1**	Prerequisite
			9.2		Install Radon Resistant Construction if Home is not in EPA Zone 1	**IEQ 1**	1
y			10.1	**Garage Pollutant Protection**	No Air Handling Equipment OR Return Ducts in Garage	**IEQ 1**	Prerequisite
			10.2		Tightly Seal Shared Surfaces between Garage and Home	**IEQ 1**	2
			10.3		Exhaust Fan in Garage		1
3			10.4	***OR***	Detached Garage or No Garage	**IEQ 1**	3
9				Sub-Total			
				Awareness and Education (AE)	(Minimum of 0 AE Points Required)		**3**
y			1.1	**Education for Homeowner**	Basic Occupant's Manual and Walkthrough of LEED Home		Prerequisite
			1.2	**and/or Tenants**	Comprehensive Occupant's Manual and Multiple Walkthroughs / Trainings		1
			1.3		Public Awareness of LEED Home		1
			2.1	**Education for Building Mgrs**	Basic Building Manager's Manual and Walkthrough of LEED Home		1
0				Sub-Total			
36				**Project Totals** (pre-certification estimates)			***130***

APPENDIX

C. LEED-H Example Durability Plan – BA 40% Habitat for Humanity House, Westford, MA

Builder Name: **Habitat for Humanity of Greater Lowell**

Lowell Habitat for Humanity - Westford, MA **18 Williams Avenue, Westford, MA 01886**

Approaches

For each of the high and moderate risk areas indicated above, list the durability responses or, if none are used, provide a brief statement explaining why not. Add lines as needed.

1.0 Water -- Exterior Sources	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)
1.1 Groundwater - Silt-protected perimeter drainage installed; sub-slab gravel bed with connection to exterior perimeter drain; sump system installed; dampproofing installed on exterior foundation walls.	Typical Wall Section, Foundation Plan, Specifications	☐	☐	☐
1.2 Surface Water - Ground sloped away from building and marked on plans.	**Site Grading Plan??,** Specifications	☐	☐	☐
1.3 Rain - Continuous drainage plane installed and integrated with flashings; vented and drained cladding over 3/4" airspace on furring strips; full window pan flashings; building overhangs specified to shelter walls; roof drainage system with appropriate deflectors and flashings used; full roof shingle underlayment used. Maintanence instructions included in homeowner manual	Typical Wall Section, Specifications	☐	☐	☐
1.4 Capillary Rise - Liquid-applied capillary break applied over footing to inhibit capillary rise of ground-sourced moisture from the footing into the foundation. Prevents groundwater from moving through the building assembly and coming into contact with moisture sensitive materials. Basement slab over non-capillary active 2" extruded polystyrene (XPS) rigid insulation over 4" stone pad (no fines)	Typical Wall Section, Foundation Plan, Specifications	☐	☐	☐
1.5 Ice Damming - Ice and water shield applied to the lowest 3' of roof (shingle underlayment under remainder of roof), "compact" (unvented) roof design with multiple layers of airtightness (interior gypsum, roof sheathing, two layers 2" polyisocyanurate with staggered joints, roof sheathing)	Typical Wall Section, Roof Plan, Specifications	☐	☐	☐

2.0 Water -- Interior Sources	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)
2.1 Spills and Equipment Malfunction - high risk water sources (washing machine, water heater, HVAC unit) all located on unfinished basement level (concrete floor; water can be swept to sump). Kitchen and bath--anything?? Single-throw shut off valves installed for all water using appliances, fixtures and equipment??	Floor Plans, Specifications	☐	☐	☐
2.2 Meltwater from shoes - linoleum surfaces in entry areas	Floor Plans, Specifications	☐	☐	☐

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Approaches

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3.0 Water Vapor Flow	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)
3.1 Interstitial Condensation (Below-Grade Enclosure) - interior rigid insulation to control surface temperature, air barrier, not using moisture sensitive materials	Typical Wall Section, Specifications	☐	☐	☐
3.2 Interstitial Condensation (Above-Grade Enclosure) - exterior insulation to control temperature of condensing surface and vapor resistance of interior paint finish (plus air barrier of interior gypsum board). Additional buffering provided by hygric mass of cellulose stud bay insulation.	Typical Wall Section, Specifications	☐	☐	☐
3.3 Dryable Assemblies - enclosure assemblies are designed to dry to the interior through the vapor-permeable painted gypsum board	Typical Wall Section, Specifications	☐	☐	☐

4.0 Air Flow	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)
4.1 Air Barrier System (Below-Grade Enclosure) - concrete as air barrier in basement; sill plate sealed to concrete with sill gasket	Typical Wall Section, Specifications	☐	☐	☐
4.2 Penetrations (Below-Grade Enclosure) - all penetrations (windows, drains and stacks, concrete control joints) are sealed with sealant and/or low expansion foam	Typical Wall Section, Specifications, Penetration Details	☐	☐	☐
4.3 Air Barrier System (Above-Grade Enclosure) - Interior air barrier composed of gypsum board connected via sealant to framing at perimeter and penetrations; connected to rim joists and ceiling-wall interface using spray urethane foam, as well as sealant and construction adhesive at joints. Additional air barrier resistance provided by two layers of 2" polyisocyanurate rigid insulating sheathing, with staggered joints, and taped joints on exterior layer.	Wall Sections, Enclosure Details, Specifications	☐	☐	☐
4.4 Penetrations (Above-Grade Enclosure) - All penetrations passing through air barrier sealed to air barrier, and where thermal expansion could or shifting could occur (i.e., vent stacks), a flexible seal has been detailed.	Typical Wall Section, Specifications	☐	☐	☐
4.5 Air Sealing of Intersitial Cavities - Fire-stopping and sealant are used to seal connections between interior partitions and exterior walls and behind tubs, shower units and fireplaces to prevent unintentional air leakage	Typical Wall Section, Enclosure Details	☐	☐	☐

5.0 Heat Flow	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)
5.1 Clear Enclosure Sections - Increased insulation levels substantially over code requirements (R-19 + R-26 = R-44 walls nominal; roof R-40 + R-26 = R-66 nominal)	Typical Wall Section, Specifications	☐	☐	☐
5.2 Thermal Bridging - Insulated sheathing has been specified to provide a minimum layer of insulation over all thermal breaks in the framing; spray foam at rim joists to ensure continuous installed R-value; constant section of roof insulation (no compression at eaves in design)	Typical Wall Section, Specifications	☐	☐	☐
5.3 Control Window Surface Temperatures - low-e, argon filled, vinyl frame glazing units (U=0.35 maximum)	Specifications	☐	☐	☐

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Approaches

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6.0 Solar (Ultraviolet) Radiation	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)
No special measures required. *Rationale: Critical enclosure control layers are protected by cladding materials. Degradation due to ultraviolet radiation does not pose a durability risk for this project.*				

7.0 Wildfire	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)
No special measures required. *Rationale: Project is situated within an existing suburban community. Nearby forest areas are sufficiently separated from developed areas that wildfire does not pose a durability risk for this project.*				

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Approaches

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8.0 Pests	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)
8.1 All XPS insulation in contact with grade (below basement slab) to be termite resistant product (e.g., DOW BLUEGUARD). Vented above-grade wall drainage cavity protected by insect screen.	Specifications			

Other	Location in Drawings, Specs, and/or Scopes	Pre-work Acknowledgement (Builder/trade)	Completion Acknowledgement (Builder/trade)	Construction Verified (Rater)

About this Report

This report was prepared with the cooperation of the U.S. Department of Energy's, Building America Program.

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