BUILDING AMERICA PROGRAM EVALUATION

Volume II: Appendices

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Appendix A.

Building America Program Intent and Scope

Appendix A-1. Program Overview

A-1.1. Program History

Building America has its origins in a 1993 pilot project between DOE and a housing products unit at General Electric called IBACOS. In the early 1990s GE had tasked IBACOS with marketing its engineering plastics for home construction applications. As part of this work, IBACOS personnel and ex-rocket engineers at DOE discussed ways to introduce systems-engineering concepts into home-building as a way to integrate high-performance technologies into residential housing. These discussions culminated in a small DOE grant to IBACOS for a one-year, systems-oriented home-building collaboration in the building industry. DOE deemed this pilot project, the seed for Building America, successful enough to germinate the experiment into a broad housing technology innovation program.

Building America currently operates chiefly through five relatively autonomous and somewhat parallel "teams." In 1994 DOE issued an RFP for Building America participants and awarded basic one-year task ordering agreements to the four successful applicants: IBACOS, the Consortium for Advanced Residential Building (CARB), the Building Science Consortium (BSC), and the Hickory Consortium (Hickory). Through a closed re-solicitation, DOE issued new task ordering agreements to these four teams in June 1998 and continued them through mid-2003. A fifth team was added in 1999 when DOE merged its Industrialized Housing Program into Building America to bring previously absent research about manufactured housing into the program. Using another RFP process DOE issued a five-year financial assistance agreement for a team called the Industrialized Housing Partnership (IHP).

At the time of this writing, four of the five Building America teams had re-competed for task ordering agreements. Three of them (IBACOS, BSC, and CARB) were successful in their bids; the Hickory Consortium was not. In 2003 a new team named the Building Industry Research Alliance (BIRA), which looks more similar to the remaining three than Hickory, was added to the program.

A-1.2. Overview of Building Science and Systems Integration

The core concepts underlying innovation efforts in Building America are building science and systems integration (a.k.a. systems engineering). Building science is a little-known applied discipline focused on the thermodynamics of the built environment. This field serves as a source of knowledge for studying housing performance. The systems approach in Building America refers to holistic consideration of housing as whole structures. It encourages program participants to investigate opportunities for enhancing performance through combinations of advanced technologies; in this sense, the systems approach serves as a bailiwick for demonstrating technology and high-performance designs.

As illustrated in Figure A3, building science serves as a means for understanding housing thermodynamics: thermal and moisture gradients, presence and distribution of health stressors, the roots of these issues in housing design, and consequent effects on housing performance. In studying the thermal, hydrologic, and gaseous fluxes in built environments, building science provides a framework for describing the relationship between climate, technology, and housing performance. At a regional scale, building scientists have generalized findings about climate and building thermodynamics to categorize zones, as illustrated in Figure A4. In Building America, participants draw on this building science to study and improve housing performance in a climate-conscious manner. By relating fluxes of air, water, and heat to housing designs, program partners experiment with different technological options in an effort to develop deployable "technology systems packages" that improve the durability, energy efficiency, and occupant comfort, and reduce the environmental impacts of housing.

Figure A3. Housing Science

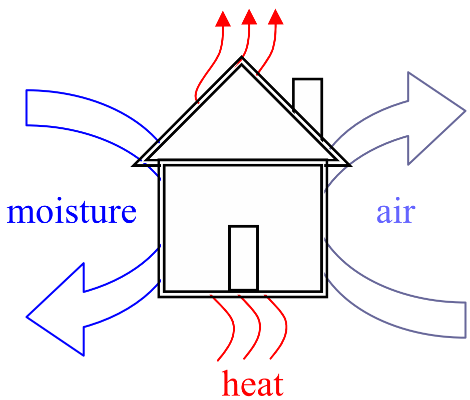


Figure A4. North America Climate Zones[1]

(Source: Building Science Corporation website.)

A systems view of housing design complements building science by providing a framework through which technical lessons can be integrated as advanced technology practices. Building America contracts define a systems approach as "any approach that comprehensively analyzes design, delivery, construction, business, and financing processes and performs cost and performance trade-offs between individual building components and construction steps that produce a net improvement in overall building performance." In Building America such systems engineering takes place on two levels: at the level of the house, and at the level of the industry. At the level of the house, projects consider the "interaction between the building site, envelope, and mechanical systems, as well as other factors" to recognize that "features of one component in the house can greatly affect others" (US DOE, 2003b). Drawing on the expertise of building scientists as well as "systems engineering and operations research," Building America projects rely on the systems-oriented thinking to identify technology and design changes that can improve the overall performance of housing.

[1] Taken from Building Science Corporation website: www.buildingscience.com (July, 2003)

At the level of the industry, Building America explores alternative and industrial organization to improve technological learning. The program suggests that its "systems engineering approach to home building…unites segments of the building industry that traditionally work independently of one another. It forms teams of architects, engineers, builders, equipment manufacturers, material suppliers, community planners, mortgage lenders, and contractor trades" (US DOE, 2003b). In fact, one of the requirements of the Building America contracts is the formation of teams with representation from different members of the housing industry. In this sense, Building America considers collaboration along supply chains and across spheres of economic activity to be a critical part of technological innovation. By drawing together markets actors in a "pre-competitive" phase of building design and construction, Building America intends to create a forum for sharing information typically difficult, if not impossible, to communicate through existing economic structures. However this focus on cross-organizational interactions does not reflect a focus on social or institutional learning. In Building America, the primary emphasis is on technical collaboration and knowledge production.

A-1.3. Program Scope At Time of Study

With the goal of improving the quality of residential housing in the United States, DOE has designed Building America to advance knowledge of housing design, housing technology, and construction practice. The following broad program statement indicates this orientation:

> The Building America Program is an industry-driven, cost-shared program sponsored by the US Department of Energy for applying systems engineering approaches that accelerate the development and adoption of innovative building processes and technologies. The goal of the program is to produce energy-efficient, environmentally sensitive, affordable, and adaptable residences on a community scale.
>
> The Building America teams bring together all segments of the building industry (designers, builders, developers, financial institutions, material suppliers, and equipment manufacturers). These industry groups have traditionally worked independently of one another, slowing development and adoption of new technologies. By working together using a systems engineering approach, decisions previously made independently can quickly be made with consideration for the entire design, manufacturing, and construction process, thereby increasing quality and performance without increasing cost.

In print materials and on the program's website (www.buildingamerica.gov), DOE further refines its goals for Building America. These range from improving housing quality to reducing environmental impacts, and from stimulating technology development to increasing the efficiency and competitiveness of housing. Figure A1 summarizes these goals, as included in Building America contracts (see Appendix D-2).

Figure A1. Building America Goals

- Accelerate implementation of advanced building energy systems in new residential construction through development and application of systems engineering with cross-cutting industry teams.

- Develop innovative technologies and strategies that enable the US housing industry to deliver environmentally sensitive, quality housing on a community scale while maintaining profitability and competitiveness of homebuilders and product suppliers.
- Deliver a 50% reduction in energy consumption (on average, depending on climate), 50% reduction in construction site waste, 25% increase in use of recycled materials, increase labor productivity, and reduce construction cycle time.

Although opinions about the exact purpose and scope of Building America differ somewhat both among teams and among government managers, there is no dispute that the overwhelming discourse about innovation and learning in the program is technical, not institutional or social. Thus, it is important to note that the program is not designed to actively engage code institutions, to develop standards, or to diffuse technologies from builder-to-builder. However, these activities exist at the periphery of the program through the actions of its participants.

A-1.4. Alternative Description of Projects

In section 4.1.2, we briefly introduced the types of Building America projects as DOE represents them. In our observations, we noted that the scope of projects undertaken by teams is slightly broader than what this list suggests. Among other things, the projects types listed in task ordering agreements neglect product development projects and detailed housing testing studies.

Another way to think about it is that each project is designed to explore one or more of three specific areas: the overall housing structure, an individual housing component, or the process of building housing. In projects focusing on structures, teams are to redesign housing and integrate advanced technologies to improve housing performance. Applying systems-oriented concepts and using actual housing as the site of learning, these team projects are designed to culminate in construction to demonstrate, test, and learn from housing redesigns. The second kind of project focuses on individual component technology. Potentially in collaboration with suppliers of building equipment or material, teams work to develop advanced housing products (e.g., ventilation systems, housing panels, modified trusses, etc.) or to study their performance. As part of these component technology projects, teams may conduct laboratory or pilot tests on new products. Successful demonstration of a concept or a product may result in the systems integration of a new technology into housing – the point at which technology development and housing redesign projects overlap. The third kind of project focuses not on physical artifacts but rather on the process of building housing. These projects can range from studying how to change techniques used in construction to engaging supply chain members and market competitors in new modes of interaction, such as roundtable meetings. For example, teams might work with site-builders to develop new mechanisms to coordinate technology changes among developers, builders, subcontractors, and local inspectors and permitters.

Figure A2. Matrix of Building America Project Activities

	housing	*housing product*	*housing process*
designing	drafting blueprints, planning communities	sketching performance characteristics	devising alternative relationships
building	constructing housing	developing higher performance products	creating new mechanisms for interaction
testing	short- and long-term household performance	laboratory testing or commissioning	surveys and partner feedback
coordinating	cooperation with developers and subcontractors	cooperation with manufacturers	cooperation with financiers and code officials
marketing	linking quality with energy efficiency	building brand awareness	promoting collaboration and learning
institutionalizing[2]	(changing the housing code)	(changing product standards)	(changing the fora for industry interactions)

The technological focal point is one dimension that differentiates projects. Another is the type of activities teams undertake. Figure A2 displays the various project foci and types in matrix form to provide a synopsis of the activities that take place in Building America. The first three rows (designing, building, and testing) reflect more technical trial-and-error learning (see Figure 6 in section 4.1.2): a team works together to design housing, build based on these designs, and then test the resulting performance; while completing these steps, the teams look for lessons, which feed back into the next set of designs. Design work (row 1) involves drafting housing or community blueprints, developing housing products, or devising alternative house-building processes. Building (row 2) involves constructing housing, developing new products, and creating new relationships and institutional structures to support housing improvements. Testing (row 3) involves short- and long-term measurement of household performance (in energy efficiency, durability, and indoor air quality), commissioning of equipment, or soliciting feedback from partners. The second three rows in Figure A2 (coordinating, marketing, and institutionalizing) constitute more sociological or economic research and development. (These activities also focus on learning more among team members than among the building scientists or program managers.) Coordinating (row 4) focuses on growing social capital and communicating technological knowledge, particularly from builders to construction trades or suppliers. Examples include workshops to educate subcontractors, dialogues with product manufacturers to discuss product specifications, or roundtable meetings to engage important market and nonmarket actors in discussions about reform. Marketing (row 5) involves efforts to build public awareness about high-performance housing. Examples include efforts to link energy efficiency with quality construction in builders' minds, to inform customers about the benefits of advanced technologies, and to encourage stakeholders to engage in collaborative learning. Institutionalizing (row 6) describes activities to diffuse practices via rules or the market. Examples include changing local building codes, creating product standards, developing markets, or starting labeling programs.

[2] These activities are beyond the scope of Building America. Although teams do engage in these activities at various levels, such efforts are generally not program-related. However, this distinction is hard to make universally.

Appendix A-2. Overview of Select Related Programs

A-2.1. Super Good Cents

The Super Good Cents Program began in 1990. In 2001, fifty percent of housing (or 100,000 homes) produced in the participating states was produced to Super Goods Cents standards.

The basic mechanism is a certification system. This system involves multiple steps: First, there is a training program for inspectors; second, there are quarterly inspections of the manufacturing facilities; third, there are random studies of installed homes to assure performance; fourth, there are forensic analyses of installed homes, as the Super Good Cents team is informed about failures (generally by phone). Each state operates a training program for inspectors. The training for the manufacturers occurs through the inspections. The housing certification becomes part of the housing documentation.

The ultimate goal of the Super Good Cents program is to design and deploy a zero-energy house. The program works by getting stakeholders (i.e., builders, manufacturers, technology transfer organizations) to buy into the process, begin constructing advanced housing and then innovating through their own experiences or through the collaborative research to improve the overall energy efficiency of the housing. Thus, the program involves an iterative learning process. The program stops short of technology diffusion and assumes that, as market actors begin to recognize and adopt advanced practices, market transformation will begin to occur.

Super Good Cents also has a housing research and specification program – a natural extension of the certification process. To paraphrase Mr. Lubliner, energy research in the real world cannot systematically separate research (testing and specification) from deployment (implementation and certification). That is, the research conducted on duct tightness informs house construction, which in turn affects the specification and certification systems. Similarly, the research design is informed by the lessons learned and trajectory of housing construction and certification.

- The Building America program provides funding for the research aspects of the Super Good Cents program. This money is pooled with other technical assistance efforts involved with learning about and implementing better housing.

A-2.2. Central New Mexico Building America Program

Conversation with Max Wade (Artistic Homes; Feb. 14, 2003)

- While Max was chairing the green builder program for the Central NM Home Builders Association, he was disappointed with the amount of progress being made.
- He noted market frustration and confusion; different standards for different green building labels offered an array of certification possibilities; the diversity was allowing builders to use virtually any change to label themselves "green builders." The labels do not offer clear product differentiation, and customers have trouble distinguishing the difference. (For example, Max commented about the inability of customers to distinguish the "silver" from the "platinum" levels in Green Fiber's Engineered for Life program.)
- Artistic Homes wanted one clear program with one set of standards that could clearly and definitively push the market forward – not multiple tiers that confuse buyers and mask the activities of the builders; the idea was to create a very clear, very honest program – in Max's words, "you either do it, or you don't" (i.e., you follow the criteria, or you don't get certified). Artistic Homes also wanted to establish an ambitious performance level and expected this to exceed those of other programs.

- In early 2000, Artistic Homes, who builds Artistic Homes (1800 homes/yr), partnered with the Building Science Consortium to redesign their homes; after the initial consultation, Artistic and BSC built two prototypes in mid-2000, and then constructed ten pre-production houses in late 2000.
- In 2001, Artistic Home worked with the local Home Builders Association (HBA) to create a pilot green building program; during this year the Building Science Consortium helped develop the green building standards, marketing, and educational material for the voluntary green building program. This program explicitly focused on the integrated housing system ("whole house") concept because, in their opinion, that was the only way to reap "all the benefits" (i.e., durability, energy efficiency, occupant comfort, healthiness, etc.).
- With the permission of DOE and other program participants, the program name was changed to the Central New Mexico Building America Program. While Max was serving on the board of EEBA in 2002, Artistic Homes helped to establish a local chapter as part of a negotiated agreement that EEBA would take over as facilitating manager of the program.
- In 2001 the program held monthly education classes for any interested stakeholders (builders, suppliers, customers, code officials, etc.). These classes were first given by Joe Lstiburek, later by John Toohey; and in 2002 Mark de Liberté (BSC-affiliated building scientists in MN) offered the classes bi-monthly. Max noted the attendance at 200-250 attendees.

- Q: What's the hook for builders?
- A: Many builders striving to improve their practice recognize that change doesn't come easily but still want to build better housing; the program is rigorous – every housing design is scrutinized and every house is tested – but the builders find benefit in the process; public education campaigns appear to be working as well; consumers (Max described them as "not as stupid as people suggest") are learning and demanding more about houses as products. The goal of the program is to create a distinct market transformation in 3-5 years.

- Q: How would you compare the program to the Built Green program in metro Denver?

- A: Built Green is the second biggest program but takes a very different approach. Built Green is a technology-based program (focused on upgrades to individual components); the Central NM Building America program is a performance-based program focused on the whole housing system.

- Q: Why has the Central NM Building America program been more successful than other green building programs?
- A: The program developers get credit for each and every change they made; in their opinion, doing so waters down the program and greenwashes the activities of builders without signaling a substantive, meaningful change.
- Other green building programs noted by Max Wade include the Green Fiber "Engineered for Life" program, Masco's "Environments for Living" program, Energy Star, and the Tuscon electric utility program. The local Building America program is stronger than the rest of these in central New Mexico.

- Q: What is your process of revision to your standards?
- A: So far, the program has established baseline performance levels, but they are hoping to push beyond that. For example, the program is currently exploring under-floor systems; everything in NM is typically built with just slab-on-grade.

- Q: Who "owns" the program? What will stop it from fading?
- A: There is no clear owner, just lots of people with a sense of ownership. It won't fade because people (like Max) fought long and hard to establish this program. EEBA is a third-party verifier; if they were unable or unwilling to continue, the program would find someone else to take this role.

- *Note*: according to this narrative, there were clear policy entrepreneurs: Max Wade (Artistic Homes) and Lindsay Oldfield (Central NM HBA).

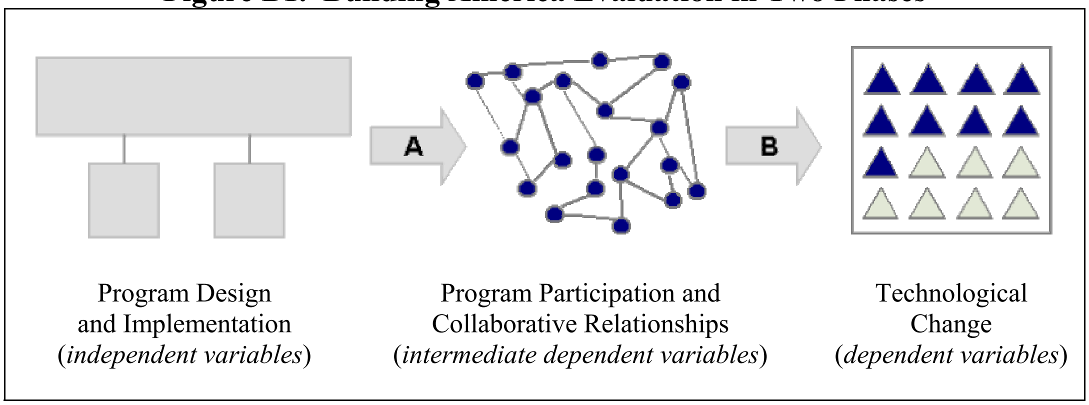
Appendix B.

Research Methodology

Introduction

We originally intended to develop the scheme in Figure B1 into a framework that would support statistical analysis of scientific hypotheses. In this pursuit and as listed in the parentheses at the bottom of the Figure B1, we created categories of variables to guide measurement of the three elements in our evaluation: program design, collaboration, and technology change. Despite this goal, the realities of the program made this approach only partially executable for two reasons. First, the program is much more complex in practice than it appears in print, and substantial background research was necessary to understand the structure of the partnership and the functioning of its teams. This need left less time to measure the behavior of program participants at each stage and to delve more deeply into the details of technology projects. Second, as discussed in more detail in the next section, data are not readily available nor easily collectable for many aspects of the program (and, hence, variables) needed to carry out such an analysis. As a result, we have repositioned our study to draw on the scheme in Figure B1 as a strategy for evaluation and not a hypothesis-testing scientific framework for carrying it out.

Figure B1. Building America Evaluation in Two Phases



The remainder of this appendix describes the research methodology based on a conventional distinction in scholarly research: qualitative versus quantitative data collection and analysis. Section B-1 describes the qualitative research, which has been used to explain the program structure, relationships in the partnership, and the nature of research outcomes. Section B-2 outlines the quantitative methodology, which has been used to examine the effect of participation on technology choice among builders who participated in the program.

Appendix B-1. Qualitative Research Methodology

Qualitative research was both a critical first step in our study as well as our means for learning about the program structure and research conducted by the teams. To learn about the partnership design and dynamics, we reviewed the team webpage and interviewed program managers and team leaders. We later used team contracts and reports to add to our understanding of the program structure and scope of activities. To learn about projects and their outcomes, we relied heavily on team contracts, reports, and webpages. Although we did learn a little during interviews, the scope of research over a seven-year period was too broad to make interviewing effective. Along the way, our interviews also helped us learn the opinions of key individuals about the effectiveness and ongoing challenges in these programs.

Timing
We conducted semi-structured interviews with program managers and team leaders between December 2001 and November 2002 and asked questions about the program during the period of 1995-2002. In addition, we reviewed team documents housed at NREL and the GFO for the period of 1998 through the third quarter of 2002. (All earlier documentation had been retired.) Reports from IBACOS Building America were withheld because they had all been marked confidential. (Although IBACOS invited us to review documents in their offices in Pittsburgh, PA, this travel did not fit within the scope of our work or budget.) We also reviewed team websites in 2001 and 2002 to collect information about their projects and partners.

Questions
The following list contains questions we used in interviews.

Team Activities and Composition
- What is your working model of a "team"? How much variance is there in the program?
- Do you use Building America terminology like "team" and "team leader"?
- Do "team members" know that they are on the same "team"?
- Do team members work together?

- How do builders come to participate in the program?
- Do they see themselves as working "in" Building America?
- What are the primary reasons that builders are participating?
- What are their primary concerns?
- Builder recruitment: what incentives bring them in, and what incentives keep them there?
- Is the participation of Building America builders and manufacturers committed with a contract or just a verbal agreement?
- How are the non-builder members of the team continuing players across projects?
- What is their commitment? How is it guaranteed? Do they ever refuse to cooperate? What happens then?
- Are there cost-sharing requirements? Do they engage in routine cost-sharing? How much, and how much is cost-sharing brought up?

- How does Building America fit into the larger scope of work that you are doing?
- Has your emphasis or incentive changed much in the last five years? How?

- What techniques have you used to stimulate builders and their contractors to collaborate with others instead of just competing at arms length about price?
- What techniques are you using to improve communication among participants?
- Why don't contractors choose to or want to commission equipment?

- How many homes are built based on a single demonstration project?
- Can you describe an organizational problem in your Building America projects?

Interactions with Government

- How have you interacted with DOE field offices about Building America: about what and how often?
- How have you interacted with state energy offices, particularly related to Building America: about what and how often?
- How have you interacted with local code officials?
- As a Building America representative, have you been involved in any code or standard development projects?
- How often does your team interact with technical staff at the labs? About what? Could these conversations take place without Building America? How does Building America change your interaction with the lab?
- How does DOE sponsorship help you?
- What has DOE told you about how your team will be evaluated? What performance measures do you expect them to use? What feedback have you been given so far?
- What role do DOE field offices play? How are they involved? How often?
- Does Building America have a State Energy Program? What role have state agencies been playing? Local agencies?
- How often have all-Building America team meetings been scheduled during the program? Have any teams launched joint projects with each other?
- What kind of NREL technical research has been conducted to address "disagreement about a technology that cuts across teams"? How many such projects have been undertaken?
- What are typical technical resources that teams seek from the lab? Do they obtain them from casual conversation, such as phone calls, or through formal channels, such as written requests?

Contract Management and Funding Questions

- When was the original RFP issued and the one for manufactured housing? How long is the contract under this RFP?
- When will the new RFP be put out? How long is the contract under this new Task Order Agreement? Are all teams re-competing now – even IHP?
- How much has been spent on Building America each year? (Does this figure include all the time spent by NREL and ORNL staff?) Can I get an annual breakdown?
- Team funding: under the Task Order Agreement, is there a standard amount of funding given to each team each year? How much? How much competitive funding issued as task orders has been available? Can I get an annual summary?
- How are the areas for task orders/statements of work determined? What procedure has been used to scope contracts/projects (i.e., how has NREL been negotiating the scope of work with teams)?
- How many projects/contracts does a team have at one time? Are they available for review?

- What documentation must teams provide to NREL? What information do builders consider proprietary in their documents submitted to NREL?
- How are you evaluating the performance of the teams? Who is performing well? Who is performing poorly? How do you know?
- What has DOE told teams about how they will be evaluated? What performance measures do you expect to use? What feedback have you given them so far?
- Teams often use the “toehold” approach to working with builders. How do you evaluate whether a team has done “enough” on a project to meet the Building America threshold for an acceptable research project?

Technical or Data-related Questions

- What are the “Building America metrics”?
- Monitoring Measurements: What is ΔQ? How are ACHs measured?
  (also rating systems: HERS, R-20, U-factor, SHCG, AEF, SEER-13)
- Who has data on the home tested in Atlanta for > one year?
- Are the data from monitoring homes in Civano available (e.g., in NREL’s database)?
- If I wanted to understand the differences between “distributed exhaust fans with timed controllers and outside air duct return, a new Hickory multi-port exhaust design, and high-efficiency energy recovery ventilators”, how would I find them in this program?
- What do you consider to be the biggest technical achievements in the program? Where are the greatest areas of underachievement?

Market Questions

- How are you helping builders market their Building America homes?
- To whom does your team market its partnership (i.e., which builders, suppliers, etc.)?
- Have you heard of any substantial efforts by participants to share the lessons of Building America with others outside the program?
- Teams mentioned that Masco, a large supplier to the building industry, has begun marketing “building systems” instead of individual housing technologies. How has Building America, through the teams and the labs, helped the company develop this idea? Who initiated the conversations?
- What is the Owens Corning System Thinking Builder Program?

Appendix B-2. Quantitative Research Methodology

In social science and policy analysis, the effective use of statistical methods can be especially challenging. Why can it be so hard to discern the true nature of causality that is the true nature of the cause-effect relationships that drive a system's behavior? Primarily, this is because it is often difficult, if not impossible, to set up a laboratory-type experiment with the associated rigorous controls. What are some of the potential mistakes that can be made in the assessment of causal factors? Even correct application of statistical methods can lead to incorrect rejection of the causal relevance of a variable.[3] The analyst may also be led to incorrectly conclude that a variable does play a causal role when in reality it does not.[4] Even if an analyst correctly concludes that a variable is significant, she can still get the level of its importance wrong (e.g. the associated coefficient is the incorrect magnitude). Having said all this, despite the potential pitfalls and limitations, quantitative analysis of policy impacts is important. The perfect should not be the enemy of the good, it is said. Some illumination is better than none at all. We seek to shed some light on the Building America program and the process of technological change, nothing more or less.

In this appendix, we describe the strategy we have developed for quantitative analysis of data collected in the study of the Building America program.

B-2.1 Overview

Our approach to quantitative modeling can be summarized as: Let the data guide model specification within the bounds of a loose theoretical framework. Here we give an overview of components of the strategy. First, as a preliminary step, we developed a conceptual model of the process of technological change in buildings. We draw upon a variety of works from the vast technological change literature here, but rely most heavily upon the distinguished work of Everett Rogers (1995). Development of a theoretical framework is discussed in the next section of this Appendix. Our work has also been informed by the "impact analysis" segment of the econometrics literature and the overlapping "determination of casual effects" segment of the statistical literature. This preparatory work has led us to think about potential problems of endogeneity. We define endogeneity below and explain our thinking about potential action to counteract it. In the end, with the current data set, we indicate that countermeasures to address endogeneity produce more noise than clarity, and we choose to estimate a standard Ordinary Least Squares model (OLS, i.e. the Classical Linear Regression Model).

What does "letting the data guide model development" really mean? What has been the process by which candidate independent variables have been included or excluded? Our efforts have sought to identify models that best fit the data in terms of amount of variation (in the dependent variable) explained and the significance levels of individual regressors. Put differently, we have

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[3] In other words, hypothesis-testing methods may indicate that a variable is not significant when it really is. This is known as a Type I error, incorrect failure to reject a null hypothesis. This is so because in regression analysis the typical null hypothesis for each independent variable is that the value of the associated coefficient is zero (e.g. not a causal factor).

[4] Put differently, hypothesis-testing methods may indicate a finding of significance when there is really none. In technical terms, this is known as a Type II error, since in regression analysis the typical null hypothesis for each independent variable is that the value is zero (e.g. not a causal factor). A Type II occurs when the statistician incorrectly fails to reject a null hypothesis that is in reality false.

sought models with the highest adjusted R-square values and the most highly significant independent variables. Such an approach can be criticized for producing findings that are particularly likely to be a result of spurious correlation, but, given the scope and constraints of this study, we conclude that this strategy is most appropriate.

A note on the formulation of dependent variables: We considered using an Ordered Probit model for qualitative dependent variables (such as the index for technological adoption) because this would be preferable on grounds of statistical and econometric theory. However, because OLS models consistently outperformed Ordered Probit models in terms of R-square values, and because OLS is known to be a particularly good estimator in small sample situations (such as ours), we focus on OLS results. We discuss this further below.

B-2.2 Theoretical Framework

As a first step to statistical-econometric modeling, we have thought about the complete (and unattainable) set of independent variables that one might like to have for each of the dependent variables we seek to better understand. First, we consider the processes and associated variables that generate technological deployment outcomes, that to say that we seek to illuminate the complete set of the determinants of adoption of innovations. The story we sketch largely follows the formulation of the problem by Rogers (2002, p.207).

Five categories of variables potentially affect a firm's adoption decision. Perhaps most obviously, the attributes of the innovation itself will influence the extent of its adoption. What are the innovation's relative advantages and how easily can a firm experiment with it? Attributes of the firm itself will also affect adoption decisions. The information structure within which the firm's personnel are embedded will play a role insofar as this will determine whether or not a firm has knowledge of an innovation and what its perceptions of the innovation's attributes are. Information structure is given special attention due to the importance communication has been given in the literature on technological change, but it might be considered a subset of the next category: the nature of the social system within which the firm operates. What are the attributes of the market in which the firm competes? What are the norms and beliefs of the community within which the firm exists? Finally, a firm's adoption decisions may be influenced by the efforts of what the literature calls change agents, programs such as Building America and others that seek to influence the trajectory of technology.

1. Attributes of the technology: Relative Advantage (in terms of profitability on average; perhaps there is a disadvantage in terms of risk), Complexity, Compatibility, Observability, Trialability
2. Attributes of firms: Location (for value of green marketing), Size, Profitability, Culture (openness to change vs. institutional inertia; presence of influential and innovative opinion leaders)
3. Information structures (access to information about innovation; degree of interconnectedness)
4. Attributes of the social system within which the firm operates (market structure; social norms)
5. Building America participation (or involvement with other change agents be they government or non-government)

Ideally, regression analysis is undertaken with all independent variables relevant to the process that has generated the dependent variable. Indeed this is an assumption underlying the classical regression model whereby the statistical-econometric model is specified by Ordinary Least Squares (OLS) estimation. Yet, in many cases this assumption (no omission of relevant independent variables) is very difficult or impossible to meet. Collecting all the data relevant to our study of Building America was infeasible. Our exploration of the multitude of variables acting at various scales makes this clear. Still, valuable insights can be gained in the absence of perfect analysis. Again, shedding some light is better than staying in the dark.

Returning to the notion of fitting the data within the bounds of a loose theoretical framework, the role of theory is this: We have sought to keep some variables from each of the five categories delineated above even as we have explored different potential model specifications. We feel theory and past empirical work both suggest they play a role in the process of technological change.

B-2.3 Analysis and Statistics

One of the assumptions of the standard (OLS specified) classical linear regression model is that all independent variables are truly independent, that is to say that there is a one-way casual relationship whereby independent variables on the right hand side determine the value of the dependent variable on the left hand side. A violation of this assumption brings about the so-called endogeneity problem. The endogeneity problem occurs when one of the variables on the right hand side of a model (e.g. the equation to be estimated with the dependent variable on the left hand side) is not independent of other right hand side variables. In essence, one of the variables on the right hand side is a dependent variable that is itself a function of one or more of the other variables on the right hand side. Endogeneity induces correlation between right hand side variables and the disturbance (e.g. error) term and results in biased coefficients on explanatory variables. The literature on econometrics has devoted much attention to the issue of endogeneity as part of the effort to better understand and represent the nature of causal relationships. The favored technique for addressing this problem is known as the instrumental variable approach. The econometrician replaces the endogenous variable on the right hand side with an instrumental variable. For more reading on the instrumental variables technique, see the discussion in Kennedy (p.), or the more technical explanations in Greene (2000[5], p.370) or Johnston and DiNardo (1997[6], p. 153).

Endogeneity in Our Study. In the discussion called preliminaries, we gave our a priori assessment of the determinants of the adoption decision. Based on this assessment of the drivers of adoption, we expect to find a role for participation in BA in the decision process underlying technological choices. Inclusion of program participation variables merits special attention because in a separate statistical exercise we also view program participation as a dependent variable. We construct models to examine determinants of the extent and intensity of participation. Furthermore, we anticipate that some of the independent variables we expect to drive participation in BA will be the same as some of the right hand side variables in our adoption model. Thus, we have reason to suspect an endogeneity problem in use of participation variables in our technology adoption models.

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[5] Greene, William H. 2000 (4th ed.). *Econometric Analysis.* Prentice Hall: Saddle River, NJ.
[6] Johnston, Jack and John DiNardo. 1997 (4th ed.). *Econometric Methods*. McGraw Hill: New York, NY.

The Instrumental Variable as a Solution. By way of introduction, define impact analysis: Impact analysis has been used in the econometrics literature to refer to efforts at estimating the effect that government programs or policies have had on the targeted social outcomes. Other terms that have been applied to such work are program evaluation (in the policy and development literatures) or the assessment of the causal effects of a policy or program (in the statistics literature).

The impact analysis segment of the econometrics literature has addressed exactly the problem we face here, that is the problem of an endogenous program participation variable. The solution is called the instrumental variables approach to impact analysis. In retrospect, one can see the logic of this approach given that the instrumental variables approach has become a favored one in approaching the challenge of endogeneity in recent years.

A practical problem in instrumental variable work is picking the variable to serve as instruments themselves. As we write in advance of statistical work, no single variable stands out as a "perfect" instrument. In such situations, one can develop a composite instrumental variable using more than one underlying independent variables. This method is known as a Two-Stage Least Squares (2SLS).[7] Monte Carlo studies have shown the 2SLS estimator to be superior on most criteria to other instrumental variable methods in small-sample situations.[8] Angrist and Imbens[9] is an example of a 2SLS approach to impact analysis.

We should note that impact analysis is really best conducted with a control group of equal sample size to the treatment group, and Angrist and Imbens use such an approach as do most studies in the literature.[10] Resource constraints made collecting data for a control group infeasible for this study. Having acknowledged up front limitations of our dataset, we must emphasize that important insights may still be gleaned from the data.

Strategy for Selection. There is reason to believe that the best approach to the potential endogeneity problem is to ignore it in our case. In general, the introduction of more complex techniques has been shown to cause increased sensitivity to errors in specification and measurement – simpler models have been found to be more robust, especially in the case of small sample sizes.

Note that if instruments are not good, then using an instrumental variable approach may be worse than not taking action to address an endogeneity problem (accepting it). If the performance of the first stage equation in 2SLS is bad (low R-square is typically used as a measure of overall model performance), then we will have reason to suspect the resulting instrument is not good.

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[7] Here is an explanation of the two-stages of the 2SLS estimator for our case:

- Step 1: estimate a program participation variable model (equation), y = BX+ e; this gives a predicted value y-hat = B-hat * X
- Step 2: use these estimated values (e.g. y-hat) in the impact analysis regression equation, that is the ordered probit on the technology adoption variable or network-related variable.

[8] Kennedy, 1998, page 165.

[9] Angrist, JD and GW Imbens. "Two-Stage Least Squares Estimation of Average Causal Effects in Models with Variable Treatment Intensity," *Journal of the American Statistical Association,* June 1995, v90: 431-442.

[10] The terminology in this area of statistics, e.g. "treatment effects," has carried over from the study of effects of new treatments in medical research.

An instrument poorly correlated with the endogenous variable it is replacing (e.g. a "bad" instrument) does more harm than good.[11] Indeed, this was the case in our initial attempts at correcting our potential endogeneity program.

Other Possibilities. It may be may not be worth expending further resources exploring the endogeneity issue raised here. Nonetheless, here is a potential workplan for further investigation. As we have done here, start by estimating each model (technology adoption and program participation) separately by ordered probit and OLS respectively. Then use a Hausman specification test to check for endogeneity problems in technological adoption equations. Next consider the chance that models are not directly linked (through an endogeneity type relationship), but just through their error terms. Stack the (OLS style) technological change and program participation variables and run as a system of "Seemingly Unrelated Equations," known as SURE estimation. Compare results with earlier models. Then, try a Two-Stage Least Squares (2SLS) approach to correcting for endogeneity expected in the program participation variable.

Simultaneous Equations. In simultaneous equation estimation, the econometrician estimates multiple equations at the same time under the hypothesis that their dependent variables are jointly determined. For a time, before the prominence of the instrumental variable technique (a single equation approach), simultaneous equation estimation was considered the type of technique that distinguished econometricians from statisticians. Interestingly, there is no single definition of econometrics. Econometricians sought to address the weaknesses of observational data not gained in a control, laboratory environment that is frequently used in social scientific work. We have considered but decided against running participation and technology adoption together as system of simultaneous equations, at least for our initial work. It seems not hard to believe that, technology adoption level influences participation and vice versa, that in fact the two are jointly determined.

However, simultaneous equations can be criticized for the reasons other complex modeling approaches can be as explained above. Further, this approach can use up too many degrees of freedom. Lastly, simultaneous equations are more difficult for people to grasp since they are more complicated. This has policy implications. Policymakers and the public are more likely to consider and to accept as relevant research done with more readily accessible methods, that is to say methods that are easier to understand.

B-2.4 Ordered Profit versus Ordinary Least Squares

We considered at great length the question of the best type of model to use with index variables such as our technology adoption index. Here is what Kennedy says about such qualitative discrete dependent variables: "[Using] multinomial probit or logit would not be efficient because no account would be taken of the extra information implicit in the ordinal nature of the dependent variable. Nor would ordinary least squares be appropriate, because the coding of the dependent variable in these cases reflects only a ranking: the difference between a 1 and a 2 cannot be treated as equivalent to the difference between a 3 and a 4, for example. The ordered logit or probit model is used for this case." See page 236. Nonetheless, as explained above, OLS has very good small sample properties. This, and the much higher level of variance explained (adjusted R-square) lead us to put forth the OLS model as our main result.

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[11] Kennedy discusses the advantages of OLS as opposed to other techniques (2SLS, IV, Simultaneous equations) in some detail on page 163.

Appendix C.

Quantitative Data Analysis:
Analytical Framework, Modeling Approach,
and Statistical Results

Appendix C-1. Analytical Framework and Survey Data Summary

The first half of this appendix describes the analytical framework used to formulate a model for technology uptake among participants in the Building America program. The second half summarizes the survey data used to model the effect of Building America on builder technology choices. These data were collected from slightly more than half of identified builders (i.e., 70 of 130) who have participated in the program.

C-1.1 Technology Uptake: Technology Diffusion Model Overview

In analyzing Building America-related technology adoption, this study has drawn on the theoretical ideas of Everett Rogers (Rogers 1995). As described in Appendix B-2, the "diffusion of innovation" framework proposes five categories of variables to explain technology adoption decisions:

- attributes of the technology
- characteristics of the adopting organization (see C-1.1.1)
- the information structure for communicating about technology (see C-1.1.2)
- the social system in which the organization operates (see C-1.1.3)
- effects of change agents, such as a government technology program (see C-1.1.4)

The paragraphs below discuss the survey data in this context. (Appendix C-2 includes a categorization of program-related variables according to this framework.) Concerned primarily about modes of interaction, this study has omitted considerations of the characteristics of technologies themselves and focused only on the last four factors.

A survey of builder participants in Building America was implemented to collect data on the respondents' technology uptake and factors that explain change in technological capacity among participating builders. Information from the builder survey on technology uptake, along with survey responses on factors that are related to uptake (builder characteristics, information structure, social system, treatment or change agents), are presented and described below. The full survey and the coding scheme for its data are provided in Appendix D. The discussion below refers to questions from this survey. Compiled survey response data by question are provided in the Appendix E.

C-1.1.1 Builder Characteristics

Data was collected on the following characteristics of the builders: housing production approach, production volume (as a proxy for builder size), market niche (size and price), climate zone, amount of participation in other programs, and reasons for joining Building America. Based on survey responses, a majority of participants classify themselves as site-builders only (66%), slightly more than a quarter (27%) identify as housing manufacturers only, and a small fraction (7%) claim both to build and to manufacture housing (see Appendix E, question 7). The site-builders produce a highly variable quantity of housing but on average they build about 700 homes per year. In comparison, the average size (2087 square feet) and selling price ($233,000) of these homes is much more uniform. Although housing manufacturers vary substantially in the quantity of housing they build as well, with an average of 5738 homes per year, they build in much greater volume than site builders. Manufactured housing is also noticeably smaller on average (1165 square feet) and cheaper ($104,600) than stick-built housing. In terms of location of building, the builders are widely distributed through different climate zones (question 12): hot-dry (21%), hot-humid (28%), mixed (43%), cold (37%), and severe cold (9%).

Growing steadily between 1995 and 2002 (question 2), most of the population of program participants (84%) participate in other public building programs as well (see Table C1).

Table C1. Participation in Other Government Building Programs

Question: *Other than Building America, are there building-related government programs in which you are participating?*	number of affirmative responses (out of 71)
· Zero Energy House (ZEH)	4
· Energy Star	55
· Partnership for Advanced Technology in Housing (PATH)	10
· utility company program	11
· municipal program	4
· other federal program	6
· state program	8
· other	10

(Source: survey question 10.)

The greatest number (55) are involved in Energy Star (question 10), but only about half of these builders (56%) reported gaining certification for all of their Building America housing (question 14). Somewhat surprising given the high level of participation in Energy Star, builders cited assistance procuring a market label as the least important motivation for participating in Building America (question 15).

C-1.1.2 Information Structure for Communicating About Technology

The information structure refers to the capacities and mechanisms that builders possess for sharing knowledge, gaining access to expertise, or signaling others about their technology habits. This study considered two external factors (usage of market labels to signal customers, and the builder's network of social contacts) and one internal factor (organizational changes). Attention was focused on market labels from the largest nationwide program, Energy Star. As noted above, the majority of builders are involved in the Energy Star program, even though many of them have not gained certification for all their housing (questions 10 and 14).

In terms of relationship network, builders were asked about their lasting relations with a variety of actors. Based on data collected about their relationships (question 33), building scientists entered or became stronger in builders' relationship networks during involvement in Building America. This finding is not surprising given the central position that building scientists have in the partnership as team leaders. For example, the survey shows that the vast majority of participants (76%) joined Building America based on a suggestion or a request from a team leader. Irrespective of the time period in which they joined, only a quarter sought out the program and volunteered to participate of their own accord (question 9). This tendency toward recruitment is not surprising considering that, even though on average builders considered themselves to know the team leaders only "a little," most team leaders have drawn heavily on their relationship networks to find partners (question 16). Building Science Corporation stands out in this regard, since builders working with BSC felt that they already knew Building Science Corporation very well before participating in Building America.

In addition to their closeness to the building scientists, builders were asked about their involvement with other actors (i.e., other builder/developers, subcontractors, product supplier sales staff, product supplier design staff, employees at DOE, national laboratories, utility company staff, state and local officials, homebuilder associations, trade associations, financial community). Analysis of these data suggests that builders engaged other stakeholders during their involvement in the program, most strongly about technical matters.

Table C2. Relationship network Impacts of Building America

	Share technical information, improve housing performance, improve construction management, or develop a new/custom product			Discussions or work to change codes and regulations, change product standards, or develop new financing mechanisms		
	Before[12]	During	After	Before	During	After
Building Scientists	.35	1.00	.89	.22	.57	.46
Builders/Developers (other than your company)	.24	.46	.46	.20	.33	.30
Subcontractors	.50	.78	.72	.22	.41	.37
Product Supplier, Sales Staff	.46	.76	.72	.24	.41	.39
Product Supplier, Product Design Staff	.26	.59	.57	.26	.37	.33
Employees at the US Dept of Energy	.04	.30	.24	.00	.24	.15
National Laboratories (NREL, ORNL, LBNL)	.07	.22	.24	.00	.09	.09
Utility Company Staff (gas and/or electric)	.22	.41	.33	.15	.22	.17
State or Local Officials (energy or building code)	.30	.46	.39	.28	.46	.43
Homebuilder Association (such as NAHB)	.26	.35	.30	.17	.24	.20
Trade Associations (subcontractor trades)	.13	.20	.22	.09	.13	.13
Financial Community (such as mortgage companies)	.15	.35	.30	.15	.30	.24

(Key: percentage of builders reporting a significant relationship with actor on left. Source: survey question 33.)

The results of Table C2 above suggest that builders may have experienced a modest amount of relationship accretion with other actors. However, questions asked more directly about these interactions muddy the picture of this engagement. Despite some belief in the usefulness of interactions with other groups (see Appendix E, question 35), when builders were asked, "Did

[12] Mean values.

you work with groups with whom you normally do not?" they indicated only modest involvement with others (i.e., an average score of 2.8, where 1 = not at all, 2 = only a little, 3 = somewhat, 4 = very much; see Appendix E, question 34).

That builders experienced only marginal gains in working relationships with others is further reflected in their responses that Building America collaboration had modest effects on other working relationships: those with subcontractors, suppliers, and building code officials or inspectors. As Table C3 displays, program participation had a modest effect on builders' ability to coordinate changes in housing with subcontractors or suppliers or to respond to changes in local building codes.

Table C3. Influence of Building America on Builder Coordination

Question: *Did Building America make it easier to coordinate changes in housing with ______?*	Mean value
· subcontractors	3.42
· suppliers	3.44
Question: *Did Building America make it easier to respond to changes or obstacles in ___?*	Mean value
· local building code	3.55

(Key: 1 = made it much harder, 2 = made it harder, 3= no diff, 4 = made it easier, 5 = made it much easier. Source: survey questions 28-30.)

It seems reasonable to conclude that Building America collaborations may have helped builders engage other housing stakeholders to a modest degree, but that this involvement does not appear to have generated lasting relationships in the eyes of the builders nor provided them much traction (yet) for improving their technology practice.

Focusing on internal structures, we asked builders about organizational changes they made to capture the benefits of Building America (Appendix E, question 36). More than anything else, about three-quarters of respondents created quality assurance or training programs. Fewer changed the contact terms for subcontractors (42%), assigned individuals to work on changes to building codes (27%), or reassigned the responsibilities of site managers (18%). Very few (5%) changed financial incentives or contract bases.

Table C4. Organizational Adaptations to Capture Building America Benefits

Question: *Did your company make any of the following changes to capture benefits of Building America?*	no. of affirmative responses (out of 55)
· reassigned responsibilities for site managers	10
· changed the basis for payment	3
· offered new incentives to managers	3
· became more involved in changing building codes	15
· created training or coordination programs for subcontractors	38
· changed contract terms for subcontractors	23
· created or modified an inspection or QA/QC program	42
· other	5

(Source: survey question 36.)

In general, builders appear to have only modestly responded to Building America work with changes in organizational structure.

C-1.1.3 Social System in Which the Organization Operates

A builder's social system refers to the social context (e.g., dominant institutions, prevailing norms) in which the builder operates. The survey requested information on two aspects of builders' social system: their perception of market pressures and building codes, and their perceived credibility and trust in the advice of the partnership's technical experts.

First, markets and laws were examined because of their purported prominence in the decision making of builders. Regarding markets, builders were asked about their perception of their competitors (supply factors) and their customers (demand factors). Respondents reported perceiving small changes in the marketplace since 1995: a slight increase in higher-quality house-building among their competitors and a slightly smaller increase in consumer requests for advanced housing (questions 25 and 26). Regarding laws, builders were asked how much the building codes, which are often cited as creating bureaucratic barriers to innovation, impeded their ability to adopt new technologies. Although not insignificant, builders reported that building codes impede their use of advanced technologies infrequently – less than half of the time (question 27).

Table C4a. Market Factors in Builder Social System

	Mean value
Question: *Are more of your competitors building "Building America-quality" housing today than in 1995?*	2.29
Question: *Are more of your customers asking for "Building America-quality" housing today than in 1995?*	1.88

(Key: 1 = no more or fewer, 2 = only a few more, 3 = several more, 4 = almost all. Source: survey questions 25-26.)

Table C4b. Legal Factors in Builder Social System

	Mean value
Question: *How often does the building code hinder or discourage your use of advanced products or designs like those suggested in Building America?*	1.79

(Key: 1 = never, 2 = less than ½ the time, 3 = more than ½ the time, 4 = every time. Source: survey questions 27.)

Second, information was collected on builder attitudes about the credibility of the program's technical advice, as measured by their perception of the technical experts and their trust in the advice they receive. Because of the industry's risk-averse culture and reticence about technological change, it was anticipated that builders' willingness to collaborate and to adopt technology would depend on their perception of credibility and their trust in the advice of building scientists. In this sense, trust and credibility were treated as two sides of the same coin. No data are available about the impressions of the team leaders among builders who decided not to join the program, but among those who did, building scientists enjoyed an initial reputation as generally effective technical experts (question 17). On average, builder perception diverged slightly during the program but overall impressions of credibility increased slightly (question 18). The one standout in this regard is IBACOS. Although BSC and IHP enjoyed the highest initial credibility, IBACOS experienced the most substantial gain (i.e., from generally effective to nearly very effective) and was the only team whose members converged in opinion.

Table C5. Impressions of Building Scientist Credibility

	Mean value
Initial impressions of building scientist credibility	3.42
Impressions of building scientist credibility now	3.57

(Key: 1 = not effective, 2 = a little effective, 3 = effective, 4 = very effective. Source: survey questions 17-18.)

Compared to impressions of credibility, builders expressed more initial reluctance to trust the advice of the building scientists (question 19). Like credibility, participation in the program appears to have increased builders' abilities to easily trust the advice of the team leaders (question 20). In contrast to credibility, levels of trust converged rather then diverged. Again, although BSC and IHP enjoyed the highest initial levels of trust among their team members, IBACOS and CARB experienced the largest gains.

Table C6. Perceptions of Trust of Building Scientists

	Mean value
Initial trust in advice of building scientists	3.16
Trust in advice of building scientist now	3.53

(Key: 1 = did not trust, 2 = trust just a little, 3 = trust, 4 = fully trust. Source: survey questions 19-20.)

These data reveal a significant finding about builder perceptions about technology: collaboration appears capable of changing builder perceptions about the credibility of expert opinion and their trust in the advice of others. It is also worth noting that, somewhat in contradiction to rhetoric about the importance of market drivers in builder choices, survey data do not demonstrate that supply or demand is a primary motivation for builder interest in learning about advanced technology. Difficulty with building codes, also a commonly cited problem, does not emerge from the data as a significant barrier to advanced technology practice.

C-1.1.4 Change Agents

Analogous to what Rogers (1995) calls "change agents," Building America facilitation of technology diffusion constitutes an effort to condition builder technology choices or "treat" their behavior. The treatment factors considered included type of treatment (i.e., how involved), length of treatment (i.e., tenure with teams), and attitudes toward treatment. Because Building America contains myriad modes of participation, the survey collected data about ways that builders worked on or with teams (see question 11). The most common activities have been testing or monitoring of housing performance (76%) and developing an improved construction practice (74%). Notably, slightly more than half (53%) reported developing a new or improved housing product, but fewer (only 40%) reporting integrating a new housing product.[13]

[13] This logically unexpected difference may suggest a confusion in the question asked and answer provided.

Table C7. Modes of Builder Participation in Building America

Question: *Of the many the levels of participation, how has your company worked with a Building America team?*	no. of affirmative responses (out of 68)
· Discussed housing designs but did not build housing	10
· Discussed designs and built one or two prototype units	21
· Discussed designs and built a housing development	27
· Integrated a new housing product into housing	27
· Developed a new or improved housing product	36
· Developed an improved construction practice	50
· Tested or monitored housing energy performance	52
· Worked on changes in community development processes	9
· Modeled or simulated a manufacturing line	8
· Modified our manufacturing line(s)	8
· Other	4

(Source: survey question 11.)

Of particular interest given the concern about technology uptake into housing are the projects involving (re)design and/or construction of housing. To explain how builders have collaborated in construction projects, participation was grouped into three categories (which follow the Building America sequence for technology learning); (1) that which involved design reviews but did include building housing, (2) that which including housing redesign and prototype construction, and (3) that which involved construction of a housing development based on housing redesigns. Of all respondents, ten (15%) reported having worked with a Building America team only on design review. Another twenty-one (31%) continued past design review to build one or two prototypes. Slightly more than half of builders collaborating on redesigns (27 respondents, or 40% of total) reported working with team assistance on a housing development (i.e., more than two houses). In contrast, relatively few builders (around 12%) reported collaborating on manufacturing line changes or community development processes.[14]

In terms of length of participation, survey respondents reported working with teams for as little as a few months to as long as the entire eight years of the program. Although there is substantial variation, on average builders have worked with teams for three and a half years (question 2). To understand how participation may have impacted their technology practices, builders were asked about the impact of Building America participation on their ability to use new products or an integrated systems approach in their operations. As summarized in Table C8, builders report that their participation has modestly to moderately increased their technological capabilities.

Table C8. Ability to Use New Products or a Systems Approach

	Mean value
Question: *How did Building America change your ability to bring new products or appliances into your housing?*	3.67
Question: *How did Building America change your ability to use an integrated systems approach to building?*	4.03

(Key: 1 = made it much harder, 2 = made it harder, 3= made no difference, 4 = made it easier, 5 = made it much easier. Source: survey questions 31 and 32.)

[14] Somewhat surprisingly (and dubiously) only about two-thirds of these respondents were housing manufacturers. We are uncertain why those builders who consider themselves site-builders reported making manufacturing-related changes.

Overall, builders have a very favorable impression of Building America. On average builders described the program as very good. (More than half (62%) rated the program "excellent," and a majority of the rest (31% of total) called it "good.") Some expressed neutral support, but none of the survey respondents gave the program a negative rating (question 47).[15]

C-1.2 Technology Uptake: Modeling Results and Inferences

A key phenomenon that this study examined is the extent to which Building America participation (i.e., collaborative technology learning) affects the choices of its builder participants. Building America has both implicit and explicit means for stimulating technology adoption. Implicitly, through builder involvement in learning projects Building America provides builders with access to technical expertise (i.e., building science). This opportunity has the potential to affect builder practice by offering lower risk means for engaging in direct technology learning. However, an assumption is that the perception of opportunity mediates the ability of this changed access to expertise to affect technology usage; builders seem unlikely to engage in this collaborative learning unless they perceive it as an opportunity to leverage a competitive advantage in the marketplace. In contrast to such implicit means, team projects are an explicit means through which building scientists work to change builder practice. Housing redesign recommendations, government testing of housing performance, and ongoing technical assistance provided for, among other things, employee and subcontract training, all provide direct contact and experience capable of spurring builders to adopt advanced technologies.

C-1.2.1 Technology and Business Changes

One of the primary opportunities from a survey of builder participants is the ability to collect information about builder technology habits. This study's survey asked builders about their usage of sixteen different advanced housing technologies before, during, and after their collaboration on a Building America team. These data were collected to lay a foundation for examining how participation in collaborative learning programs, such as in Building America team projects, can shape choices for technology users.

Indices are a way to aggregate data for the purposes of analysis. In this case, the technology indices have been constructed to consolidate technology use patterns into a single variable that can be used as a dependent term in regression analysis. The indices quantify and scale builder technology usage based on habits before, during, and after participation in the partnership. A separate index was created for each technology, and a composite index was developed to aggregate the sixteen individual indices.

Indices are tricky to construct and often involve subjective choices about the ordering of data. The indices used in this analysis were constructed to as ordinal in nature so that they could support a more sophisticated modeling approach. Doing so required choices about how to interpret various technology use patterns and assumptions about how to scale them as degrees of technology uptake. The coding scheme developed and used in this analysis assigns the greatest weight to usage patterns when Building America collaboration has introduced a builder to an advanced technology and when a builder adopted it as standard practice. Lesser scores are

[15] Of potential significance here is the selection bias in our survey respondents. There is insufficient data to evaluate whether the survey captured a sample unrepresentative of all Building America participants, but it is worth noting that there may be participants with less positive opinions who did not bother to fill out a questionnaire.

assigned to builders already working with a technology before participating in the partnership and to builders adopting a technology less completely. A description of the coding scheme is offered in a footnote[16], as well as described in Appendix D-2.

The data collected on technology use and compiled into technology indices are summarized in Table C9. They are rank ordered according to the greatest degree of technology uptake into builder practice.

Table C9. Builder Use of Advanced Housing Components and Systems

Component or Systems Technology	Mean Value	Std. Dev.
· High Performance Envelope ***plus*** Downsized Heating or Cooling System	3.89	1.81
· *Reduced Air Infiltration or Sealing Package* ***plus*** *Mechanical Ventilation System*	3.72	2.02
· **Advanced Ventilation** (mechanical ventilation supply and/or exhaust system)	3.67	2.06
· **Tightened Ductwork** (duct sealing or hard-ducted returns)	3.67	2.06
· **Optimized Air Distribution** (ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts & transfer grilles)	3.56	2.01
· **Advanced Space Conditioning Equipment** (downsized, improved efficiency, or multi-speed units; combo hot water & hydronic heating; or programmable thermostats)	3.39	2.15
· *Duct Relocation and Sealing* ***plus*** *Downsized Space Conditioning System*	3.39	2.06
· **Advanced Insulation** (changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic)	3.11	2.32
· **Advanced Air Sealings and Reduced Infiltration** (upgraded sealing & caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances)	3.11	2.23
· **Advanced Framing** (stacked framing, 24" construction with 2x6s, SIPs, integrated sheer panels, or insulating sheathing)	3.11	2.00
· **Improved Air Quality** (low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification)	2.83	2.33

[16] The coding scheme is as follows: 5 ("created standard practice") = did not use before Building America, used during a Building America project, and use now as standard practice; 4 ("improved standard practice") = used before Building America, used during a Building America project, and use now as standard practice; 3 ("created partial practice") = did not use before Building America, used during a Building America project, and use now in some housing; 2 ("improved partial practice") = used before Building America, used during a Building America project, and use now in some housing; 1 ("introduced to practice") = did not use before, used during Building America project, generally have not started using in practice; and 0 = all other response patterns. This coding assumes that initial introduction involves steeper learning curve than improvement to existing uses. (For this reason, 5 is superior to 4, 3 is superior to 2.) For information about the coding scheme, see Appendix D-2.

· **Whole Building Energy Design** (systems engineering, systems integration, or cost-performance trade-off analysis)	2.72	1.93
· **Advanced Moisture Control** (foundation water sealing, added or eliminated wall vapor diffusion retarder, foundation water management, or crawl space water management)	2.56	2.38
· **High Performance Windows** (improved glazing and framing)	2.56	2.41
· *System Performance/Quality Control Testing* ***plus*** *Utility Bill Guarantee/Increased Homeowner Warranty*	1.94	2.24
· *Use of Solar Energy* ***plus*** *Increased Efficiency* *(solar heat or photovoltaic panels + energy efficient design)*	.67	1.46

(Key: see footnote. Source: survey question 21.)

These data suggest that, for a majority of the technologies, the average builder was introduced to technology or technique during a Building America project and has adopted it somewhat into practice. There are some notable standouts. On the high end, builders reported the greatest adoption of systems that control air infiltration or movement throughout the housing (e.g., high performance envelopes, improved ventilation systems, tightened ductwork). On the low end, builders reported the least adoption of quality control testing and solar technologies.

Builders were also asked about changes in the cost, time, waste volume, callbacks[17] and other factors important to productivity and profitability. These data were collected to provide insight into changing aspects of their business operations.[18] Tables 19a and 19b summarize these data.

Table C10a. Changes in Technology and Business Operations

Question: *How much have your ___ changed since working with Building America?*	Mean value
· building material costs	2.48
· construction costs	2.55
· construction or manufacturing time	3.04
· housing sale price	2.52
· time required to sell	3.12
· construction waste volume	3.39
· energy use of the housing	4.07
· overall housing value	2.32

(Key: 1= ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%. Source: survey questions 37-44.)

[17] A "callback" describes a post-construction fix or modification of an aspect of otherwise completed housing.
[18] These changes could be either endogenous or exogenous to Building America participation. Without a control group to normalize for industry-wide changes, it is not possible to attribute these changes to the program.

Table C10b. Percentage of Housing Receiving Callbacks

Question: *On what percentage of your housing have you received callbacks?*	Mean value
· Building America (i.e., at least 30% less energy)	3.46
· non-Building America	2.88

(Key: 1 = over 20%, 2 = 11-20%, 3 = 6-10%, 4 = 1-5%, 5 = none.
Source: survey questions 45-46.)

Based on the survey responses, Building America has had modest influence on changing waste volume, and has had a notable influence making it easier for builders to implement changes in energy use of their housing. Builders indicate that the program has had little or no influence on changing construction or manufacturing time and time required to sell a house. They report that the program has contributed to some increase in material and construction cost, sale price, and overall housing value.

C-1.2.2 Regression Model and Results

Again, using Rogers' framework to structure variables, an ordinary least squares (OLS) regression model was developed to analyze the effect of various factors on builder technology usage. Modeling data in this manner requires a dependent variable that can describe technology behavior. Although many questions in the survey concern technology experience (e.g., questions 31-32 and 37-46; see Appendix E), the regression analysis presented here focuses on data specifically related to use patterns for individual components and systems packages (i.e., question 21). Therefore, the technology index described above serves as the dependent variable in this analysis. (See appendix C-3 for additional detail about the linear model development.)

Dictated by the number of cases available from the survey, the linear model can support a limited number of explanatory variables as regressors. To accommodate this limitation, the data were allowed to guide development of the overall model. Considering several specifications, the model pursed includes the greatest number of significant explanatory variables while also reasonably covering the different categories that Rogers suggests induce changes in technology usage. Based on thirty-six complete cases, the final model supports the following as significant explanatory variable:

Builder characteristics

- housing size in square feet (HS)
- production method (PM)
- involvement in other housing programs (OP)

Information structure

- pre-existing relationship network (RN)
- relationship introductions (RI)

Treatments or change agents

- participation in building projects (BP)
- factory studies (FS)
- technology development (TD)

It is worth noting that no factors related to the builder's social system were found to be significant in the model. Table C11 below lists the coefficients associated with the OLS model, their standard errors, and levels of statistical significance.[19]

Table C11. Linear Regression Model Results

Regressors	Regression Coefficient	Standard Error	Level of Significance
Housing Size (HS), avg square footage in 1000s (q5avg, range 925-4500)	-7.0	3.2	0.038
Production Method (PM), dummy variable (q7niche, manufacturing only = 1)	-22.3	5.8	0.001
Involvement in Other (Housing) Programs (OP) (q10all, range from 0-8)	3.4	1.7	0.060
Pre-existing Relationship Network (RN) (q33bef, range from 0-24)	1.8	0.5	0.002
Relationship Introductions (RI) (q33new, range from 0-24)	1.7	0.6	0.007
Participation in Building Projects (BP) (q11part1, range from 0-3)	5.7	1.9	0.006
Participation in Factory Studies (FS) (q11part2, range from 0-2)	11.5	4.3	0.013
Participation in Tech Development (TD) (q11part 3, range from 0-3)	4.8	2.3	0.044
constant	14.4	12.0	0.241
Technology Change Index (Y) (potential range 0-80, empirical range 0-74)	R^2 = 0.81 MSE = 11.5		

Equation 1 translates these OLS results into a mathematical model, which relates the explanatory variables to the technology adoption index. This model explains 81 percent of the variation in the composite technology index.

$$Y = 14.4 - 7.0 \cdot HS - 22.3 \cdot PM + 3.4 \cdot OP + 1.8 \cdot RN + 1.7 \cdot RI + 5.7 \cdot BP + 11.5 \cdot FS + 4.8 \cdot TD \quad (1)$$

Comparison of the range of influence over the dependent variables demonstrates the relative importance of the various factors for influencing builder technology adoption (see Table C12). The subsequent sections interpret these effects and their relevance to learning in the building industry.

Table C12. Relative Influence on Technology Adoption (Composite Index)

Explanatory Variable	Range in Y	Range of Influence on Y (observed)
Pre-existing Relationship Network (RN)	0-16	28.8
Relationship Introductions (RI)	0-16	27.2
Housing Size (HS)	925-4500	25.0

[19] All of the regressors are significant at a standard acceptable level of significance equal to 0.05 with the exception of Involvement in Other Housing Programs, which has a probability of unlikelihood equal to 0.06. Even though this is slightly greater than standard limits, we have accepted it as a valid regressor in the model.

Participation in Factory Studies (FS)	0-2	23.0
Production Method (PM)	0-1	22.3
Involvement in Other (Housing) Programs (OP)	0-6	20.4
Participation in Building Projects (BP)	0-3	17.1
Participation in Tech Development (TD)	0-3	14.4

C-1.2.2 Influence of Building Characteristics on Technology Adoption

The linear model produces three inferences about the influence of builder characteristics on the adoption of advanced housing technologies:

- The negative coefficient on the housing size (HS) variable suggests that, all else being equal, *as housing size increases builders find it more difficult to incorporate advanced technologies*.
- Somewhat in opposition to this finding, the negative coefficient on the production method (PM) variable suggests *site builders, who produce larger housing on average than housing manufacturers, have had relatively greater success adopting advanced technologies during involvement in Building America*.
- Regardless of housing size or production method, *the more builders are involved in other housing programs (OP), the greater the amount of technology they have adopted*.

In terms of builder characteristics, the regression results show roughly equal effects for production method and housing size, the factors included in the model. *The results suggest that uptake of advanced technologies among site-builders has been substantially greater than those for housing manufacturers* (22.3). The style of collaboration with housing manufacturers (i.e., the consultancy-oriented projects of the IHP and the stakeholder-focused efforts of the Hickory Consortium) provide a plausible explanation for these differences. Additionally, this difference is also potentially explained by the need of these teams to work with these builders to improve quality management and production efficiency as stepping stones to improving housing design and performance. As a result of these two factors, less opportunity has been available to collaborate about a range of advanced technologies, and adoption for *housing manufacturers* lags as a result. In terms of housing size, the magnitude of the coefficient (25.0) indicates *that builders have found more opportunity or ease adopting advanced technologies in more modestly-sized housing*. This finding stands somewhat in contrast to the effect of production method, since housing manufactures build smaller housing on average than larger builders. Consequently, it is not possible to find much insight from this coefficient and suggest that, quite possibly, the effect of housing size is more complicated than a linear model can capture accurately.

C-1.2.3 Influence of Information Structure on Technology Adoption

The information structure variables (pre-existing relationship network and relationship introductions) suggest a similar effect as the building characteristic variable. The following are the main inferences:

- The positive coefficient on the pre-existing relationship network (RN) variable suggests that, *ceteris paribus*, *builders with a larger, more diverse network of working relationships adopted more advanced technologies during their participation in Building America*. This finding is consistent with literature on technology learning that suggests that a more robust network increases an actor's capacity to learn about, understand, and respond to innovations.

- The positive coefficient on the relationship introduction (RI) variable suggests that *builders who expanded their set of working relationships during involvement with a Building America team adopted more advanced technologies* is consistent with this finding.

As summarized in Table C9 based on their rank order effects on Y, the relative effects of the information structure explanatory variables suggest a very strong role for relationship networks in technology adoption. *Possession of a strong, pre-existing network of working relationships (28.8) as well as the introduction of (even temporary) new relationships (27.2) has the strongest inferred influence on overall technology usage*. That involvement in other housing programs also has a strong effect (20.4) reinforces the idea that social ties, such as those developed through collaboration, aid in technology learning.

C-1.2.4 Influence of Treatments or Change Agents on Technology Adoption

The regression analysis supports the following inferences about the relationship between program involvement and technology adoption:

- The coefficients on all three participation indices (i.e., the treatments or change agents) are positive. This finding suggests that program involvement, whether building projects (BP), factory studies (FS), or technology development projects (TD), induces builder uptake of technology into practice.
- The positive effect for each of the intermediate program variables (BP, FS, TD) may suggest a potentially additive return to technology adoption from participation: *the more a builder collaborates with a Building America team, the more technology that builder adopts*.

The relative effects attributable to treatments ("change agents"), although smallest in magnitude of the explanatory variables[20], reveal that *greater levels of involvement in building projects (17.1), factory studies (23.0), and technology development (14.4) correlate with greater levels of technology adoption*. If accepted as metrics of collaboration intensity and their effects, these variables and their coefficients support the value of cooperative designs for accelerating learning, at least for some participants.[21]

In all, the statistical results suggest that, *particularly for the technologically risk-averse, collaborative programs may help accelerate technology adoption*. Our inference is that, by activating or growing relationship networks, collaboration can provide technology users with better access to resources and prepare them to change their practices. Such conclusions suggest

[20] It may be worth pondering whether the challenge of defining and, therefore, measuring "projects" contributes to a seemingly weak inference.

[21] Notably, the effect of factory studies is greater than that for building projects or technology development. Given the strength of the data set, we do not place much credence in this difference. However, we suggest that if factory studies have accelerated adoption faster than building projects or technology development work, it is most likely because factory-built housing has a steep learning curve and rapidly changes technology adoption as builders progress along it.

that collaborative program designs can offer real benefits, provided the programs themselves can be accredited with the changes in relationship networks.

C-1.2.5 Impediments to Uptake of Recommended Technology

In addition to exploring the various factors that influence the uptake of technology among participants in the Building America program, builders were asked why they followed (or did not follow) the technology recommendations they were given. *Builders cited the ability to perceive real change in housing performance – either as increased energy efficiency or reduced failures – as the strongest reason for changing technology practice* (see Appendix E, question 22). They gave the next greatest weight to the resources provided by building scientists and indicated that learning opportunities and market forces (e.g., effect on sales or market certification) were more modest in importance. The difference between these drivers and noted deterrents is striking. In terms of reasons for not adopting, concerns about expense and speed were given much greater weight than other factors (question 23). This finding matches the Hickory Consortium research as well: "Builders see themselves as punished by market indifference when they have innovated out of step with mainstream market demands. They perceive an invisible boundary beyond which it is not financially safe to step, and that boundary is defined by their ideas of the wishes of the largest number of customers as well as logistical feasibility" (ibid., page 5). The difference between these findings suggests builders may engage technologies with high hopes but make conservative choices when concerns about market forces, either real or perceived, enter the picture.

C-1.2.6 Cautions and Surprises

Because the regression model provides only preliminary insights, not structural conclusions, the conclusions need to be viewed with some degree of caution. Numerous questions and potential explanations of the processes underlying the Building America process have not been investigated through the survey nor explained with the model. Several examples are noted below.

The regression analysis could not reveal that trust or credibility made a difference. Section 6 and C-1 of this report suggest that establishment of trust and credibility among parties (in particular the technology adopters) helps to cement successful collaboration. Despite the apparent success of some teams with high initial and final levels of building scientist credibility and builder trust (e.g., BSC), the regression analysis could not confirm this claim.[22]

Participant building rates did not significantly explain variations in technology usage. Team leaders suggested that companies building a moderate amount of housing per year (i.e., between a few hundred to a thousand houses) are best suited to Building America collaboration. They explained that these organizations generally have adequate resources (compared to small builders) but lack incentive misalignment (as exists in large corporations) to adopt new

[22] We note that measuring "trust" and "credibility" is rather difficult, and it is hard to generate good data about these social characteristics. It is also likely that the builders who participated in Building America (and, thus, we surveyed) were those with high levels of trust and perceptions of building scientist credibility. If so, there is little ability to differentiate effects based on these factors.

technologies into practice.[23] However, data collected on participant building rates (i.e., the number of constructions per year – see question 4 in Appendix E) did not significantly explain variations in technology usage.

Length of participation with a Building America team did not correspond to greater levels of technology adoption. One might anticipate, as this modeling approach did, that length of participation with a Building America team (i.e., length of treatment) would correspond to greater levels of technology adoption. However, data collected on tenure of collaboration (question 2) was significant in the linear model.

Market factors were not found to have a significant effect. Despite the stated importance of market signals, builder perception of supply and demand pressures (questions 25 and 26) did not correlate with changes in technology usage. In fact, *compared to the technology gains in the program, builders perceived market drivers to be rather weak*. This mismatch suggests an important role for other social forces in technology choices and practice. One such factor is builder perception of their technology practice. This finding is somewhat surprising given the rhetorical emphasis on economic factors, but it echoes team leader comments that a sense of social purpose is an important driver behind builder business and technology decision making. In light of this finding, a comment in the Hickory Consortium study reveals that, absent market signals, the builders may conceive of advanced housing differently than team leaders and program managers. As the Hickory Consortium notes, “Many builders consider the houses they sell to be energy-efficient simply by the installation of higher-efficiency equipment” (Hickory Consortium 2001, page 3).

Several additional, available variables are not included in the regression analysis due to the size of the data set. These unexplored variables include builder perceptions about their ability to use new products (question 31) or to implement a systems perspective (question 32). The regression analysis also does not include technology-related effects (questions 37-44). A larger data set is needed to examine the full effects of all of these factors.

[23] As example, here is text from a team report: “After initially signing on large builders and large manufacturers, CARB has learned that small- and medium-sized companies can be very responsive to the goals of the program. CARB has in the last few years targeted smaller builders and found this a successful strategy, as reflected by the outstanding performance of Mercedes and Cambridge. Some large industry team members have been replaced by others, but each project has also brought with it a cluster of manufacturers, suppliers, and subcontractors, many of whom have been valuable additions to the team. Notable for continuing active involvement are Owens Corning, Honeywell, Whirlpool, and Simpson Strong Tie, among large company team members.” (CARB 2000)

Appendix C-2. Categorization of Variables

The table below categorizes data collected from the builder survey into "variables." These variables form the basis for the quantitative modeling and inferences about technology uptake among builder participants. The codes in parentheses correspond to the variables names given to the different data. (See Appendix D-2 for more detail.)

Table C13. Variables by Type

Exogenous Factors	**Level of Treatment**	**Outcomes**
- co. size (proxy): housing constr. rate (Q4, Q4all)	- tenure of participation in the program	- techn adoption (Q21, d21_tech, Q21bad)
	- number of years co. involved (Q2sum)	
- market segmentations	- number of employees involved (Q8)	- amount of housing built (Q13, Q13all)
- wtd avg of housing size (Q5)		
- wtd avg of selling price (Q6)	- mode of participation in the program	- Δ market factors
	- variation in building, on site (Q11part1)	- material cost (Q37)
- urban vs. suburban (Q7a, Q7b)	- variation in building, mfg (Q11part2)	- construction cost (Q38)
- site-built vs. mfd (Q7niche)	- variation in tech devmt (Q11part3)	- sale price (Q40)
		- time required to sell (Q41)
- climate zone (Q12)	- trust, credibility, and attitude about program	- overall value (Q44)
	- attitude about the program (Q47)	
- participation in similar programs	- perception of credibility, after (Q18)	- Δ technical factors
- participation in other programs (Q10sum)	- Δ perception of credibility (d18_17)	- construction time (Q39)
- Energy Star participation (Q10b, Q14sum)	- perception of trust, after (Q20)	- waste volume (Q42)
	- Δ perception of trust (d20_19)	- energy performance (Q43)
- trust, credibility, and previous relationship		- changes in callbacks (d46_45)
- invitation to participate (Q9)	- technology choices/motivations	
- prev. relations w/ building scientist (Q16)	- reasons for using tech (Q22)	- Δ org or org capacity
- pre-existing feelings of credibility (Q17)	- reasons for not using tech (Q23)	- changes in orgn or mgmt (Q36)
- pre-existing trust (Q19)	- reasons for stopping using tech (Q24)	- improved coordination (Q29, Q30)
		- better regulatory response (Q28)
- reasons for participating in the program (Q15)	- network changes	- capacity to use new tech (Q31, Q32)
	- expansion (d33_ _abc)	- Δ relationships → Δ tech (Q35)
- market and government stimuli	- introduction (d33_ _ab)	
- supply competition/push (Q25)	- retention (d33_ _bc)	- comments about program (Q48)
- customer demand/pull (Q26)	- work with new folks (Q34)	
- building code/reg impediment (Q27)		
	- tech changes	
	- introductions (d21_ 12)	
	- number of housing projects (Q13)	

Appendix C-3. Linear Regression Model Development

The general linear model we have used to study adoption behavior relies on the composite technology index as a dependent variable. The relationship between technology usage and builder experiences is reflected in the general form

$$Y_i = \beta_{x1} \cdot X_1 + \beta_{x2} \cdot X_2 + \ldots + \beta_{xi} \cdot X_i + \varepsilon_i \qquad (1)$$

where Y represents a composite technology change index (outcome), the Xs represent individual activity vectors (explanatory variables) theorized to describe changes in Y, and ε represents unexplained variation. As the dependent variable in our model, the technology change index serves as measure of adoption for each technology for each builder. As explained below, we considered two analytical approaches for the technology index: a composite approach, and an individual technology approach.

Composite Index.
As the dependent variable in our model, the composite index (tech_chg) serves as an overall adoption measure for each builder. We have computed this index by summing the individual technology indices for sixteen housing components and system packages, which are listed in Figure C14.

Figure C14. Housing Component and Systems Packages

Technology Name	Examples Provided on Survey to Define Technology
Advanced Framing	stacked framing, 24" construction with 2x6s, SIPs, integrated sheer panels, or insulating sheathing
Advanced Moisture Control	foundation water sealing, addition or elimination of wall vapor diffusion retarder, foundation water management, or crawl space water management
Advanced Insulation	changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic
Advanced Air Sealings and Reduced Infiltration	upgraded sealing and caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances
Advanced Ventilation	mechanical ventilation supply and/or exhaust system
Advanced Space Conditioning Equipment	downsized, improved efficiency, or multi-speed units; combo hot water and hydronic heating; or programmable thermostats
High Performance Windows	improved glazing and framing
Improved Air Quality	low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification
Optimized Air Distribution	ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts and transfer grilles
Tightened Ductwork	duct sealing or hard-ducted returns
Systems Package No. 1	High Performance Envelope ***plus*** Downsized Heating or Cooling System
Systems Package No. 2	Duct Relocation and Sealing ***plus*** Downsized Space Conditioning System

Systems Package No. 3	Reduced Air Infiltration or Sealing Package ***plus*** Mechanical Ventilation System
Systems Package No. 4	Use of Solar Energy ***plus*** Increased Efficiency solar heat or photovoltaic panels + energy efficient design
Systems Package No. 5	System Performance/Quality Control Testing ***plus*** Utility Bill Guarantee/Increased Homeowner Warranty
Whole Building Energy Design	systems engineering, systems integration, or cost-performance trade-off analysis

As illustrated in Figure C3, each individual technology index is designed to take on a value from zero (which indicates no adoption of the technology) to five (which indicates complete Building America-associated technology adoption) to indicate varying levels of technology uptake. This coding scheme contains two judgments worth pointing out. The first concerns the significance of innovation. Embedded in this scheme is an assumption that a builder who is introduced to a technology through Building America collaboration has engaged in a more profound degree of innovation than a builder who has previously used it in practice. The second is the equivalency of innovation. The rough resolution of answers about technology usage (see Appendix E, question 21) conveys nothing about the level of engagement or degree of challenge associated with adoption of a particular technology. Instead, the survey data rely on the builder's judgment about what constitutes an "advanced" technology and what constitutes new or improved usage. With no means for expunging any discrepancies, we have simply accepted their answers at face value. However, we draw on these indices with the understanding that their inability to account for degree of difficulty (in innovation) and context-dependencies (like builder's pre-existing practice) limits the definitiveness of inference from them.

Figure C15. Individual Technology Index Scale

Index Value	Used Before	Used or Improved During	Used After (all the time)	Used After (~½ the time)	Used After (no)
5		✓	✓		
4	✓	✓	✓		
3		✓		✓	
2	✓	✓		✓	
1		✓			✓
0					

As an aggregate of the sixteen individual technology indices, the composite technology index ranges from a minimum value of zero to a maximum value of ninety. A value for Y equal to zero is intuitive: this case represents a builder who has not used nor adopted any technologies as a result of Building America collaboration. The non-zero values for Y require more explanation. Increasing values are intended to represent increasing levels of technology innovation. In addition to the judgments embedded in the individual indices from which it is composed, the composite index has another characteristic that confounds inference: the ability of alternative combinations of technology changes to sum to the same value. For example, a builder whose answer patterns for "advanced framing" and "advanced moisture control" were each assigned a score of three would have a combined score for the overall index of six. A different builder assigned a five for “advanced framing” and a one for “advanced moisture control” would also have a composite score of six. Is adoption of advanced framing and advanced moisture control (3+3) equivalent to rigorous adoption of advanced framing and mere introduction to advanced moisture control (5+1)? This question is tough to answer without more information. Despite their seeming equivalency, we cannot argue that equally-scored answers constitute equal levels of innovation. Thus, in addition to other assumptions and the need to believe that builders have filled out the survey accurately, the logical leap of faith is that these differences largely wash out. Stated differently, our linear model assumes that, in composite, the technology change index accurately assigns higher scores to builders who have adopted more new or improved technologies through the program.

Defining the left-hand side of our linear model (see equation 1), this constructed technology change index represents technology adoption outcomes. The right-hand side contains factors to explain differences in uptake. Figure C16 below was developed to specify a model to regress the dependent technology index variables created from survey question 21. The table below follows the categories that borrowed from Rogers’ book. Using these groupings, we have arranged the variables from our survey into “control” and “treatment” groups. This organization may seem somewhat strained in some places. In particular, the treatment of Building America as a “change agent” suggests that the program is an intervention into the diffusion of technology. Yet Building America is a program intended for conducting research; we are investigating how its collaborative design also spurs technology diffusion. There are some direct means through which technology diffusion may occur, such as through expert analysis and assisted improvement to a builder’s housing design. However, the collaborative design may also shift a builder’s network (information structure) and perception of technology (social system) – two social effects that may indirectly influence technology diffusion. Our goal is to see if we can show if/how the indirect influences affect technology diffusion. Therefore, we have not included all of our “treatment” variables in the “change agents” box. Our approach will compare the regression coefficient to see how much we can learn about the relative importance.

Figure C16. Potential Explanatory Variables

	Control	Treatment
Attributes of Technology	(none)	(none)
Builder Attributes	- housing mfg dummy (q7niche) - builder size (q4all) - housing size (q5avg) - housing price (q6avg) - company motivat’ns (q15) - other prog particip’n (q10all) - climate zone (q12)	(none)
Information Structure	- market labels (q14sum) - invitation (q9)	- code responsiveness agility (q28) - sub coordination agility (q29) - supplier coordination agility (q30) - new partners (q34) - helpful partners (q35) - org changes (q36all) - network effects (q33)
Social	- demand pull (q26)	- Δ trust (d20_19)

System	- supply push (q25) - reg impediments (q27) - trust, before (q19) - credibility, before (q17)	- Δ credibility (d18_17) - other program partcpn (q10sum) - familiarity with team lead (q16) - Δ callbacks (d46_45) - trust, after (d20) - credibility, after (d18)
Change Agents	(none)	- years involved (q2sum) - number of BA houses (q13all) - new product use agility (q31) - systems perspective ease (q32) - reasons for using (q22) - building projects index (q11part1) - mfg projects index (q11part2) - tech devmt index (q11part3) - reasons for not using (q23) - reasons for not continuing (q24)

Dictated by the number of cases available from our survey, the linear model can support only a handful of explanatory variables as regressors. To accommodate this limitation, we have allowed data to guide development of the overall model. Considering several specifications, we have pursued a model that includes the greatest number of significant explanatory variables while also reasonably covering the different categories that Rogers suggests induce changes in technology usage. Based on thirty-six complete cases, our final model supports the following as significant explanatory variables (see equation 2 and Figure C17): housing size, production method, involvement in other housing programs (builder characteristics), pre-existing social network, relationship introductions (information structure), and participation in building projects, factory studies, and technology development (treatments).[24]

$$Y = 14.4 - 7.0 \cdot HS - 22.3 \cdot PM + 3.4 \cdot OP + 1.8 \cdot RN + 1.7 \cdot RI + 5.7 \cdot BP + 11.5 \cdot FS + 4.8 \cdot TD \qquad (2)$$

This model explains 81 percent of the variation in the composite technology index. The builder attributes (housing size, production method, and involvement in other programs) suggest the following effects. The negative coefficient on the housing size (HS) variable suggests that, all else being equal, as housing size increases; builders find it more difficult to incorporate advanced technologies. Somewhat in opposition to this finding, the negative coefficient on the production method (PM) variable suggests site builders, who produce larger housing on average than housing manufacturers, have had relatively greater success adopting advanced technologies during involvement in Building America. Regardless of housing size or production method, the more builders are involved in other housing programs (OP), the greater the amount of technology they have adopted. The information structure variables (pre-existing relationship network and relationship introductions) suggest a similar effect. The positive coefficient on the pre-existing relationship network (RN) variable suggests that, *ceteris paribus*, respondents with a larger, more diverse network of working relationship adopted more advanced technologies during their participation in Building America. This finding is consistent with literature on technology learning that suggests that a more robust network increases an actor's capacity to learn about, understand, and respond to innovations. Consistent with this finding, the positive coefficient on the relationship introduction (RI) variable suggests that builders who grew their set of working

[24] We found no factors related to the builder's social system significant in our model.

relationships during involvement with a Building America team adopted more advanced technologies. Given the benefits of collaboration that these information structure variables suggest, it is not surprising that the coefficient on the three participation indices (i.e., the treatments or change agents) is also positive. Each of these intermediate, program variables suggest that, whether involved in building projects (BP), factory studies (FS), or technology development projects (TD), the more a builder collaborated with a Building America team, the more technology that builder adopted.

Figure C17. Linear Regression Model Results

Regressors	Regression Coefficient	Standard Error	Level of Significance
Housing Size (HS), avg square footage in 1000s (q5avg, range 925-4500)	-7.0	3.2	0.038
Production Method (PM), dummy variable (q7niche, manufacturing only = 1)	-22.3	5.8	0.001
Involvement in Other (Housing) Programs (OP) (q10all, range from 0-8)	3.4	1.7	0.060
Pre-existing Relationship Network (RN) (q33bef, range from 0-24)	1.8	0.5	0.002
Relationship Introductions (RI) (q33new, range from 0-24)	1.7	0.6	0.007
Participation in Building Projects (BP) (q11part1, range from 0-3)	5.7	1.9	0.006
Participation in Factory Studies (FS) (q11part2, range from 0-2)	11.5	4.3	0.013
Participation in Tech Development (TD) (q11part 3, range from 0-3)	4.8	2.3	0.044
constant	14.4	12.0	0.241
Technology Change Index (Y) (potential range 0-80, empirical range 0-74)	R^2 = 0.81 MSE = 11.5		

With respect to the program, the regressors in this model include both exogenous and endogenous factors. For example, housing size (HS), production method (PM), and the pre-existing relationship network (RN) are characteristics of participants that existed external or exogenous to their participation in Building America. The endogenous or change factors include the indexes that describe builder participation in building projects (BP), factory studies (FS), and technology development (TD). Potentially straddling the line between exogenous and endogenous is the measure of builder involvement in other housing programs. Like the other exogenous factors, participation in other programs may be external, except for its influence on a builder's to select (or be selected for) partnership in Building America. However, involvement in one program may also stimulate, or at least facilitate, cross-enrollment in others.

Figure C18. Characteristics of Included Regressors

Regressors	Builder Characteristic	Information Structure	Social System	Treatment	Exogenous	Endogenous
Housing Size (HS)	✓				✓	
Production Method (PM)	✓				✓	
Involvement in Other (Housing) Programs (OP)	✓				✓	✓
Pre-existing Relationship Network (RN)		✓			✓	
Relationship Introductions (RI)		✓		✓		✓
Participation in Building Projects (BP)				✓		✓
Participation in Factory Studies (FS)				✓		✓
Participation in Tech Development (TD)				✓		✓

As summarized in Figure C19 based on their rank order effects on Y, the relative effects of the non-treatment, explanatory variables suggest a very strong role for social networks in technology adoption. Introduction of new relationships (27.2) as well as possession of a strong, pre-existing network of working relationships (28.8) have the strongest influence on overall technology usage. That involvement in other housing programs also has a large effect (20.4) reinforces the idea that social ties, such as those developed through collaboration, aid in technology learning. In terms of builder characteristics, we observed roughly equal effects for production method and housing size, the factors included in the model. The results suggest that uptake of advanced technologies among site-builders has been substantially greater than those for housing manufacturers (22.3). We believe that the style of collaboration with housing manufacturers (i.e., the consultancy-oriented projects of the IHP and the stakeholder-focused efforts of the Hickory Consortium) provide a plausible explanation for these differences. Additionally, this difference is also potentially explained by the need of these teams to work with these builders to improve quality management and production efficiency as stepping stones to improving housing design and performance. As a result of these two factors, less opportunity has been available to collaborate about a range of advanced technologies, and adoption lags as a result. In terms of housing size, the magnitude of the coefficient (25.0) indicates that builders have found more opportunity or ease adopting advanced technologies in more modestly-sized housing. This finding stands somewhat in contrast to the effect of production method, since housing manufactures build smaller housing on average than larger builders. Consequently, we do not find much insight from this coefficient and suggest that, quite possibly, the effect of housing size is more complicated than a linear can capture accurately. Of greatest interest are the relative effects attributable to treatments. Although smallest magnitude, these indices of participation reveal that greater levels of involvement in building projects, factory studies, and technology development work correlate with greater levels of technology adoption. If accepted as metrics of collaboration intensity and their effects, these variables and their coefficients support the value of cooperative designs for accelerating learning, at least for some participants.[25]

[25] Notably, the effect of factory studies is greater than that for building projects or technology development. Given the strength of the data set, we do not place much credence in this difference. However, we suggests that, if factors studies have accelerated adoption faster than building projects or technology development work, it is likely because factory-built housing has a steep learning curve and rapid changes technology adoption as builders progress along it.

Figure C19. Relative Influence on Technology Adoption (Composite Index)

Explanatory Variable	Range in Y	Range of Influence on Y (observed)
Relationship Introductions (RI)	0-16	27.2
Pre-existing Relationship Network (RN)	0-16	28.8
Involvement in Other (Housing) Programs (OP)	0-6	20.4
Production Method (PM)	0-1	22.3
Participation in Factory Studies (FS)	0-2	23.0
Housing Size (HS)	925-4500	25.0
Participation in Building Projects (BP)	0-3	17.1
Participation in Tech Development (TD)	0-3	14.4

<u>Individual Technology Indices</u>.
After generating the linear model for the composite index, we returned to the unaggregated data for further insights. Using the same technique and coding scheme for the composite index, we developed indices for each of the individual technologies and aggregated results across all builders. We then applied the same set of explanatory variables to sixteen individual technology adoption indices. This approach was used in an attempt both to confirm the results from the general linear model (equation 2 above, based on the composite index) and to consider the difference in importance among explanatory variables.

Because the characteristics and applications of each technology make it unique, we suspected that each index could inspire not just different coefficients for the same linear model, but a different linear model altogether. Not surprisingly, our modeling attempts imply this modeling limitation. Applying the same linear equation to the data for each technology resulted in many fewer significant relationships between the dependent variable (technology index) and the explanatory variables derived from the composite index.

Table C20 lists the explanatory variables from equation 2, their range of variance in the data set, the range of observed, significant coefficients from regression on the individual technology indices (Y), and the number of times a particular regressor was significant when the general linear model (equation 2) was applied. As evident in this table, the ability to explain changes in individual technologies is far weaker than the ability to explain aggregated changes in technology. This shortfall suggests that either each technology index is unique enough to require individual model development, or that insufficient data are available to analyze the relationship robustly with the derived linear model (equation 2). Given more time and data, the preferred approach would be to develop a linear model for each individual technology index. Doing so was beyond the scope of this project.

Figure C20. Technology Adoption Model (Individual Indices)[26]

Explanatory Variable	Range of Explanatory Variable	Range of Influence on Y (observed, significant)		No. of times a significant regressor
		Min	Max	
Housing Size (HS)	9.25-45	-1.03	-0.84	2
Production Method (PM)	0-1	-3.40	-1.51	7
Involvement in Other Programs (OP)	0-6	0.42	0.81	2
Pre-existing Relationship Network (RN)	0-16	0.13	0.22	8
Relationship Introductions (RI)	0-16	0.14	0.22	7
Participation in Building Projects (BP)	0-3	0.49	1.31	6
Participation in Factory Studies (FS)	0-2	1.30	2.07	4
Participation in Tech Development (TD)	0-3	0.89	0.89	1

Applying the same model to different subsets of the data is risky, and this shorthand approach may be unable to confirm or refute inferences and or modeling results. In this case, we interpret our model as too weak to offer insight about individual technologies. Therefore, we offer the results here as a suggestion of techniques that could be used, but we have not analyzed them for inferences about technology behavior. Further consideration of these data would require a larger data set to investigate the confounding influences of omitted variables, measurement error, and endogenous, explanatory variables. <u>This need confirms the importance of a large, higher-quality data sets for program evaluation and of the importance of programs to collect them</u>.

[26] The range of the individual technology indices is only 0-16, compared to the composite index range of 0-80.

Appendix C-4. Regression Output Tables

Table C1. Composite Technolgy Uptake Regression Results

			housing size, avg sq. footage in 1000s (q5avg)			housing manufacturing dummary variable (q7niche)			other housing program involvement (q10all)			pre-existing relationship network (q33bef)			relationship introductions (q33new)			level of involvement in building projects (q11part1)			level of involvement in factory studies (q11part2)			level of involvement in tech devmt (q11part3)			constant		
	R^2	MSE	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	
Composite Technology Uptake Index	0.81	11.45	-7.015	3.213	0.038	-22.269	5.847	0.001	3.402	1.731	0.060	1.831	0.532	0.002	1.676	0.578	0.007	5.748	1.908	0.006	11.477	4.293	0.013	4.819	2.276	0.044	14.387	12.010	0

KEY
b = coefficient for regressor
ese = estimated standard error of regression coefficient
sig = t-statistic derived probability

Table C2. Individual Technolgy Uptake Regression Results

			housing size, avg sq. footage in 1000s (q5avg)			housing manufacturing dummary variable (q7niche)			other housing program involvement (q10all)			pre-existing relationship network (q33bef)			relationship introductions (q33new)			level of involvement in building projects (q11part1)			level of involvement in factory studies (q11part2)			level of involvement in tech devmt (q11part3)			constant		
	R^2	MSE	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	sig	b	ese	
Advanced Framing	0.67	1.33	-0.073	0.373	0.845	-1.014	0.678	0.147	0.423	0.201	0.045	0.122	0.062	0.058	0.198	0.067	0.006	0.347	0.221	0.129	0.020	0.498	0.968	-0.172	0.264	0.521	-0.325	1.393	0
Advanced Moisture Control	0.37	2.04	-0.785	0.572	0.181	-1.250	1.040	0.240	-0.021	0.308	0.947	-0.011	0.095	0.911	-0.056	0.103	0.593	0.761	0.340	0.033	-0.399	0.764	0.605	0.395	0.405	0.338	2.282	2.137	0
Advanced Insulation	0.61	1.62	-1.027	0.454	0.032	-1.331	0.825	0.118	-0.197	0.244	0.428	0.038	0.075	0.619	0.109	0.082	0.193	0.955	0.269	0.001	0.055	0.606	0.928	0.293	0.321	0.369	2.805	1.696	0
Advanced Air Aealings or Reduced Infiltration	0.36	2.05	-0.843	0.577	0.155	-0.115	1.050	0.914	0.110	0.311	0.725	0.078	0.096	0.419	0.038	0.104	0.721	0.545	0.343	0.123	0.860	0.771	0.274	0.892	0.409	0.038	1.559	2.156	0
Advanced Ventilation	0.55	1.80	-0.564	0.506	0.274	-2.602	0.920	0.009	-0.014	0.272	0.959	0.209	0.084	0.019	0.219	0.091	0.024	-0.019	0.300	0.950	1.427	0.676	0.044	0.556	0.358	0.132	1.999	1.891	0
Advanced Space Conditioning Equipment	0.49	1.83	-0.579	0.513	0.268	-2.402	0.933	0.016	0.115	0.276	0.680	0.195	0.085	0.030	0.088	0.092	0.347	0.174	0.305	0.573	1.097	0.685	0.121	0.366	0.363	0.322	1.990	1.917	0
High Performance Windows	0.71	1.41	-0.844	0.396	0.042	-0.675	0.721	0.357	0.277	0.213	0.205	-0.047	0.066	0.482	-0.009	0.071	0.904	1.313	0.235	0.000	1.301	0.529	0.021	0.566	0.281	0.054	0.442	1.481	0
Improved Air Quality	0.57	1.74	-0.020	0.487	0.967	-1.701	0.887	0.066	0.413	0.262	0.128	0.149	0.081	0.076	0.208	0.088	0.025	0.175	0.289	0.550	0.372	0.651	0.572	0.296	0.345	0.399	-0.316	1.821	0
Optimized Air Distribution	0.63	1.56	-0.765	0.437	0.091	-3.359	0.795	0.000	0.386	0.235	0.112	0.189	0.072	0.015	0.060	0.079	0.451	-0.062	0.259	0.812	2.074	0.584	0.001	0.060	0.309	0.847	3.404	1.633	0
Tightened Ductwork	0.53	1.74	-0.484	0.490	0.332	-2.682	0.891	0.006	0.413	0.264	0.129	0.220	0.081	0.012	0.113	0.088	0.211	-0.402	0.291	0.178	2.054	0.654	0.004	0.498	0.347	0.163	2.408	1.831	0
Systems Package No. 1 (windows + conditioning equipment)	0.56	1.76	-0.272	0.493	0.585	-2.704	0.897	0.006	0.028	0.266	0.917	0.193	0.082	0.026	0.208	0.089	0.027	-0.070	0.293	0.812	0.543	0.659	0.417	-0.188	0.349	0.596	2.212	1.843	0
Systems Package No. 2 (air distribution + conditioning eqmt)	0.62	1.57	-0.701	0.441	0.124	-2.364	0.803	0.007	0.319	0.238	0.191	0.204	0.073	0.010	0.169	0.079	0.043	-0.014	0.262	0.957	0.282	0.590	0.636	0.197	0.313	0.534	1.915	1.650	0
Systems Package No. 3 (↓infiltration or ↑sealing + ventilation)	0.58	1.78	-0.316	0.498	0.532	-0.856	0.907	0.354	0.355	0.268	0.197	0.150	0.083	0.081	0.185	0.090	0.049	0.713	0.296	0.023	1.348	0.666	0.053	0.575	0.353	0.115	-0.861	1.863	0
Systems Package No. 4 (solar energy + increased efficiency)	0.45	1.12	0.079	0.313	0.804	0.309	0.570	0.592	0.295	0.169	0.091	0.035	0.052	0.502	0.141	0.056	0.019	0.159	0.186	0.400	0.068	0.418	0.871	0.395	0.222	0.086	-1.892	1.170	0
Systems Package No. 5 (QA/QC + utility bill guarantee)	0.73	1.10	-0.133	0.309	0.670	-0.381	0.562	0.504	0.807	0.166	0.000	0.133	0.051	0.015	0.046	0.056	0.412	0.486	0.183	0.013	0.260	0.413	0.534	0.372	0.219	0.101	-1.965	1.154	0
Whole House Energy Design	0.65	1.40	-0.386	0.394	0.335	-1.507	0.716	0.045	0.011	0.212	0.960	0.178	0.065	0.011	0.128	0.071	0.083	0.675	0.234	0.008	0.396	0.526	0.458	-0.086	0.279	0.761	0.645	1.472	0

Appendix D.

Builder Survey Instrument and Coding Scheme

Building America Program Study

Harvard University

Statement of Confidentiality. *We will keep the answers you provide on this questionnaire strictly confidential. Although we have labeled the top of your survey for tracking purposes, we will only use the data you provide to assess the program. Your name and [company name] name will not be associated with it.*

If you have any questions or concerns about the information we request, please email us at chad_white@ksg.harvard.edu or leave a message with Dawn Hilali at (617) 384-8164.

Please provide the following information about yourself.

1. Your name: ______________________________ job title/position ________________________________

2. During which years has ***[company name]*** worked with Building America? (Please mark all years that apply.)

☐ 1995 ☐ 1996 ☐ 1997 ☐ 1998 ☐ 1999 ☐ 2000 ☐ 2001 ☐ 2002

3. During how many of these years did you personally work with Building America? ___________________________

The next questions ask for some data about the size of your company and its construction operations.

4. On average, how many houses or multi-family units does ***[company name]*** build, manufacture, or oversee every year?

_______ houses ________ multi-family units

5. On average, what is the square footage of this housing? (Feel free to use multiple entries to indicate different market segments.)

__________ square feet (___% of total) __________ square feet (___% of total) __________ square feet (___% of total)

6. What is the average selling price of this housing? (Again, feel free to use multiple entries if needed.)

$ ___________ (___% of total) $ ___________ (___% of total) $ ___________ (___% of total)

7. Please describe the market niche of *[company name]*. (Please mark all that apply.)

☐ urban
☐ suburban
☐ site-built (or stick-built) housing
☐ manufactured housing (including modular)
☐ other (specify:____________________)

8. How many people from *[company name]* worked with a Building America team? (including yourself) ___________

9. How did *[company name]* become involved with Building America?

☐ We were asked or encouraged to participate.
☐ We sought out Building America on our own.

10. Other than Building America, are there building-related government programs in which you are participating?

☐ Zero Energy House (ZEH)
☐ Energy Star
☐ utility co program (specify: _____________________)
☐ municipal program (specify: _____________________)
☐ Partnership for Advancing Technology in Housing (PATH)
☐ other federal program (specify: ______________________)
☐ state program (specify: ____________________________)
☐ other (specify: _____________________________________)

The questions on this page ask about the ways that your company worked with a Building America team.

11. Of the many the levels of participation, how has *[company name]* worked with a Building America team?
(Please mark all project types that apply.)

- ☐ Discussed housing designs but did not build housing
- ☐ Discussed designs and built one or two prototype units
- ☐ Discussed designs and built a housing development
- ☐ Tested or monitored housing energy performance
- ☐ Worked on changes in community development processes
- ☐ Integrated a new housing product into housing
- ☐ Developed a new or improved housing product
- ☐ Developed an improved construction practice
- ☐ Modeled or simulated a manufacturing line
- ☐ Modified our manufacturing line(s)
- ☐ Other (specify: ____)

12. For (or in) which climate zone(s) have you worked with Building America on advanced housing? (Please check all that apply.)
(HDD = heating degree days. CDD = cooling degree days.)

- ☐ Severe-Cold (7000+ HDD)
- ☐ Cold (4000-7000 HDD, Less than 2000 CDD)
- ☐ Mixed (< 4000 HDD, Less than 2000 CDD)
- ☐ Hot-Dry (> 2000 CDD)
- ☐ Hot-Humid (> 2000 CDD)

If [company name] built or oversaw the building of systems-integrated housing while working with a Building America team, please answer the next two questions. If you did not, please skip to question 15.

13. How many houses or multi-family units have you produced or overseen with advice or assistance from a Building America team?

________ houses ________ multi-family units

14. What percentage of this Building America housing bears the Energy Star label?
☐ none ☐ 1-25% ☐ 25-50% ☐ 50-75% ☐ 75-99% ☐ all

15. When first considering working with Building America, how important were the following factors in the choice to participate?	most important	very important	important	not important	don't know
· Conducting research with building scientists/experts	[4]	[3]	[2]	[1]	[0]
· Consulting to solve a problem, to reduce callbacks, or to lower cost	[4]	[3]	[2]	[1]	[0]
· Accessing new information about design or products	[4]	[3]	[2]	[1]	[0]
· Building more energy efficient, healthier housing	[4]	[3]	[2]	[1]	[0]
· Improving housing value to make housing sell better	[4]	[3]	[2]	[1]	[0]
· Marketing housing as "Building America" or "Energy Star"	[4]	[3]	[2]	[1]	[0]
· Other (specify:______________________________)	[4]	[3]	[2]	[1]	[0]

	very well	well	a little	not much at all	don't know
16. How well did you or the other important decision makers at *[company name]* know the building scientists with [*team name 2*] before working with them through Building America?	[4]	[3]	[2]	[1]	[0]

	very effective	effective	a little effective	not effective	don't know
17. When *[company name]* began working with Building America, how effectiveness did you perceive the program's building scientists to be?	[4]	[3]	[2]	[1]	[0]
18. What is your impression of their effectiveness now?	[4]	[3]	[2]	[1]	[0]

	fully trust	trust	trust just a little	did not trust	don't know
19. When *[company name]* began working with Building America, how much could you trust the advice from these building scientists?	[4]	[3]	[2]	[1]	[0]
20. How much do you trust the advice from these building scientists now?	[4]	[3]	[2]	[1]	[0]

21. *Use of Advanced Housing Components and Integrated Systems*

The table in this question asks for information about the advanced housing components and integrated systems that you or your (sub)contractors have used (1) before, (2) during, and (3) since your first project with a Building America team. Each row represents a different type of housing technology, and each column represents a different time period.

Please work across each row. In column (1) mark the box if you used the component or practice on the left before working with a Building America team. In column (2) mark the box if you used a newer or improved version or if you used it for the first time during and because of your work with a Building America team. In column (3) mark the box that identifies how often you use the newer or improved version since your first project with a Building America team. (If you have never used the item on the left, please leave the entire row blank.)

Here is an example: if you did not use "Advanced Framing" before working with a Building America team, then do not check the box in column (1) of the first row. While working with a Building America team, if you used Advanced Framing that was either new to you or an improved version of one that you already used, then check the box in column (2). Since then, if you have used the technique on occasion (for example, about half of the time), check the second box in column (3). Then move on to the next row.

	(1)	(2)	(3)		
	Used **before** working with Building America team	Started or improved use **during and because of** work with Building America team	Use it now as **standard practice in most housing** (as appropriate for climate zone)	Use it now **in some housing**	Generally **have not started** using it (or only on rare occasions)
Advanced Framing (stacked framing, 24" construction with 2x6's, SIPs, integrated sheer panels, or insulating sheathing)	☐	☐	☐	☐	☐
Advanced Moisture Control (foundation water sealing, added or eliminated wall vapor diffusion retarder, foundation water management, or crawl space water management)	☐	☐	☐	☐	☐
Advanced Insulation (changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic)	☐	☐	☐	☐	☐
Advanced Air Sealings and Reduced Infiltration (upgraded sealing & caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances)	☐	☐	☐	☐	☐
Advanced Ventilation (mechanical ventilation supply and/or exhaust system)	☐	☐	☐	☐	☐
Advanced Space Conditioning Equipment (downsized, improved efficiency, or multi-speed units; combo hot water & hydronic heating; or programmable thermostats)	☐	☐	☐	☐	☐
High Performance Windows (improved glazing and framing)	☐	☐	☐	☐	☐
Improved Air Quality (low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification)	☐	☐	☐	☐	☐
Optimized Air Distribution (ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts & transfer grilles)	☐	☐	☐	☐	☐
Tightened Ductwork (duct sealing or hard-ducted returns)	☐	☐	☐	☐	☐
High Performance Envelope *plus* Downsized Heating or Cooling System	☐	☐	☐	☐	☐
Duct Relocation and Sealing *plus* Downsized Space Conditioning System	☐	☐	☐	☐	☐
Reduced Air Infiltration or Sealing Package *plus* Mechanical Ventilation System	☐	☐	☐	☐	☐
Use of Solar Energy *plus* Increased Efficiency (solar heat or photovoltaic panels + energy efficient design)	☐	☐	☐	☐	☐
System Performance/Quality Control Testing *plus* Utility Bill Guarantee/Increased Homeowner Warranty	☐	☐	☐	☐	☐
Whole Building Energy Design (systems engineering, systems integration, or cost-performance trade-off analysis)	☐	☐	☐	☐	☐

Please answer the next questions 22 through 24 by thinking about the answers you provided to question 21.

22. When you received recommendations about new or improved housing technologies from a Building America team, why did you use them?	most important	more important	important	not important	don't know
· The building scientist provided the necessary data to support changes.	[4]	[3]	[2]	[1]	[0]
· The changes solved a problem, reduced callbacks, or lowered costs.	[4]	[3]	[2]	[1]	[0]
· It was an opportunity to learn about products and practices.	[4]	[3]	[2]	[1]	[0]
· The changes made our housing more energy efficient and/or greener.	[4]	[3]	[2]	[1]	[0]
· The changes made our housing sell better.	[4]	[3]	[2]	[1]	[0]
· The changes helped get the "Building America" or "Energy Star" label.	[4]	[3]	[2]	[1]	[0]
· Other (specify:______________________________)	[4]	[3]	[2]	[1]	[0]

23. If, during your project, you did <u>not</u> follow a recommendation from a Building America team, how much did the following factors matter?	most of all	very much	somewhat	not much	don't know
· Recommended changes appeared too expensive or time-consuming.	[4]	[3]	[2]	[1]	[0]
· Recommended changes appeared inconsistent with our business plan.	[4]	[3]	[2]	[1]	[0]
· It seemed too hard to get subcontractors to go along with them.	[4]	[3]	[2]	[1]	[0]
· The changes seemed in conflict with existing building code.	[4]	[3]	[2]	[1]	[0]
· The changes seemed too hard to coordinate with available suppliers.	[4]	[3]	[2]	[1]	[0]
· Other (specify:______________________________)	[4]	[3]	[2]	[1]	[0]

24. If you used an advanced product or technique <u>only</u> during your Building America project, what stopped you from continuing to use it afterward?	most of all	very much	somewhat	not much	don't know
· It did not achieve the results we expected.	[4]	[3]	[2]	[1]	[0]
· The changes were more expensive or time-consuming then expected.	[4]	[3]	[2]	[1]	[0]
· The changes were too difficult without building scientists assistance.	[4]	[3]	[2]	[1]	[0]
· It was too hard to get subcontractors to go along with them.	[4]	[3]	[2]	[1]	[0]
· Existing building code made the suggested designs difficult to use.	[4]	[3]	[2]	[1]	[0]
· Existing supplier relationships could not support the changes.	[4]	[3]	[2]	[1]	[0]
· Other (specify:______________________________)	[4]	[3]	[2]	[1]	[0]

	almost all	several more	only a few more	no more or fewer	don't know
25. Are more of your competitors building "Building America-quality" housing (more durable and using at least 30% less energy) today than in 1995?	[4]	[3]	[2]	[1]	[0]
26. Are more of your customers asking for "Building America-quality" housing today than in 1995?	[4]	[3]	[2]	[1]	[0]

	every time	more than ½ the time	less than ½ the time	never	don't know
27. How often does the building code hinder or discourage your use of advanced products or designs like those suggested in Building America?	[4]	[3]	[2]	[1]	[0]

	made it much easier	made it easier	made no difference	made it harder	made it much harder	don't know
28. Did Building America make it easier to respond to changes or obstacles in the <u>local building code</u>?	[5]	[4]	[3]	[2]	[1]	[0]
29. Did Building America make it easier to coordinate changes in housing with <u>subcontractors</u>?	[5]	[4]	[3]	[2]	[1]	[0]
30. Did Building America make it easier to coordinate product or design changes with <u>suppliers</u>?	[5]	[4]	[3]	[2]	[1]	[0]
31. How did Building America change your ability to bring new products or appliances into your housing?	[5]	[4]	[3]	[2]	[1]	[0]
32. How did Building America change your ability to use an integrated systems approach to building?	[5]	[4]	[3]	[2]	[1]	[0]

33. *Relationships with Others*
We want to learn how the people with whom *[company name]* communicates or works changed through your experience with the Building America program. To collect this information, we would like you to fill out the table below.

The rows of the table contain names of groups relevant to Building America. The two columns contain ways of interacting with these groups and are divided into time periods before, during, and since your Building America collaboration. Column (1) describes interactions about technical aspects of building, such as sharing information, improving housing performance, improving construction management, and developing a new or custom product. Column (2) describes interactions to impact the laws or markets for housing, such as working to change codes and regulation, change product standards, or develop new financing mechanisms.

Our suggestion is to fill out the table by working across a row. For each row, you should begin by considering whether your company has worked or communicated with the listed group at some point in time. If not, then simply skip to the next row. If so, then please use columns (1) and (2) to indicate whether you have done so before, during, and since you worked with Building America. As a general rule, we ask that you check a box only when you can remember interacting with a group more than once during a specified time period. You may talk every day with some groups, such as subcontractors. However, you might not have normally talked with them about customizing products (column 1), and we would like to learn whether your Building America experience changed this.

As an example, consider the first row. If your company did not work with a building scientist to design housing, solve problems, or test performance before working with Building America, then leave the "before" box blank. If your company worked with building scientists during a Building America project, then check the "during" box. If your company's work with building scientists has continued, then check the "since then" box. The same procedure would be used for the boxes in column (2) and all other rows.

		(1) Share technical information, improve housing performance, improve construction management, or develop a new/custom product			(2) Discussions or work to change codes and regulations, change product standards, or develop new financing mechanisms		
		Before	During	Since then	Before	During	Since then
(A)	Building Scientists						
(B)	Builders/Developers (other than your company)						
(D)	Subcontractors						
(E)	Product Supplier, Sales Staff						
(F)	Product Supplier, Product Design Staff						
(G)	Employees at the US Dept of Energy						
(H)	National Laboratories (NREL, ORNL, LBNL)						
(I)	Utility Company Staff (gas and/or electric)						
(J)	State or Local Officials (energy or building code)						
(K)	Homebuilder Assoc'n (such as NAHB)						
(L)	Trade Associations (subcontrator trades)						
(M)	Financial Community (such as mortgage companies)						

	very much	somewhat	only a little	not at all	don't know
34. Through work with Building America, did you work with groups with whom you normally do not? (If not, skip question 35.)	[4]	[3]	[2]	[1]	[0]
35. How much did these new interactions change your ability to use new products or practices in your housing?	[4]	[3]	[2]	[1]	[0]

36. Did *[company name]* make any of the following changes to capture benefits of Building America? (Please mark all that apply.)

- ☐ reassigned responsibilities for site managers
- ☐ changed the basis for payment
- ☐ offered new incentives to managers
- ☐ became more involved in changing building codes
- ☐ created training or coordination programs for subcontractors
- ☐ changed contract terms for subcontractors
- ☐ created or modified an inspection or QA/QC program
- ☐ other (specify: ___________________________________)

	↓ more than 20%	↓ 1- 20%	no change	↑ 1-20%	↑ more than 20%	don't know
37. How much have your building <u>material costs</u> changed since working with Building America?	[5]	[4]	[3]	[2]	[1]	[0]
38. How much have your <u>construction costs</u> changed since working with Building America?	[5]	[4]	[3]	[2]	[1]	[0]
39. How much has your <u>construction or manufacturing time</u> changed since working with Building America?	[5]	[4]	[3]	[2]	[1]	[0]
40. How much has the <u>sale price</u> of your housing changed since working with Building America?	[5]	[4]	[3]	[2]	[1]	[0]
41. How much has the <u>time required to sell</u> your housing changed since working with Building America?	[5]	[4]	[3]	[2]	[1]	[0]
42. How much has your construction <u>waste volume</u> changed since working with Building America?	[5]	[4]	[3]	[2]	[1]	[0]
43. How much has the <u>energy use of the housing</u> you build changed since working with Building America?	[5]	[4]	[3]	[2]	[1]	[0]
44. How much has your <u>overall housing value</u> changed since working with Building America? (value = durability, affordability, and energy efficiency)	[5]	[4]	[3]	[2]	[1]	[0]

If you sell the housing you build, please answer the questions 45 and 46. Otherwise, please skip to question 47.

	none	1-5%	6-10%	11-20%	over 20%	don't know
45. On what percentage of your Building America housing (at least 30% less energy) have you received callbacks?	[5]	[4]	[3]	[2]	[1]	[0]
46. On what percentage of your non-Building America housing do you normally receive callbacks?	[5]	[4]	[3]	[2]	[1]	[0]

47. Overall, what is your opinion of Building America?
☐ excellent ☐ good ☐ fair ☐ poor ☐ very poor

48. How could Building America program be more useful? Please use the space below (or additional pages) to give us with suggestions, recommendations, or tell us anything else you think we should know about the program.

Thank you very much for your time and patience filling out this survey!
If you would like to receive a copy of our report from this study, please indicate here: ☐

Appendix D-2. Survey Codebook

(*) variables denoted with this symbol have been created through computation from survey data

Variable Name	Question from Survey	Code
Company	Name of Building Company	text
Code	Team Name Abbreviation(s), Builder No.	text
Respondent Information		
Q1a	1. Your Name: ________________	text
Q1b	1. Job Title/Position in Company: __________________	text
Company Tenure with Program		
Q2_	2. During which years has ***[company name]*** worked with Building America? (Please mark all years that apply.)	
Q2a	☐ 1995	0 = no, 1 = yes
Q2b	☐ 1996	0 = no, 1 = yes
Q2c	☐ 1997	0 = no, 1 = yes
Q2d	☐ 1998	0 = no, 1 = yes
Q2e	☐ 1999	0 = no, 1 = yes
Q2f	☐ 2000	0 = no, 1 = yes
Q2g	☐ 2001	0 = no, 1 = yes
Q2h	☐ 2002	0 = no, 1 = yes
Q2sum	(*) Involvement, total years; calculated sum of Q2a:Q2h	integer, 1-8
Q2period	(*) Period of Involvement (bundles of years)	1 = early (1995 – 1997) 2 = middle (1997 – 2000) 3 = late (2000 – 2002) 4 = whole (1995 – 2002)
Respondent Involvement Check		
Q3	3. During how many of these years did you personally work with Building America?	real, continuous
Housing Construction Rate (proxy for company size)		
Q4_	4. On average, how many houses or multi-family units does **[company name]** build, manufacture, or oversee every year?	
Q4a	- Number of single-family houses built per year: _____	integer, continuous
Q4b	- Number of multi-family units built per year: _____	integer, continuous
Q4all	(*) Calculated sum of Q4a + Q4b	integer, continuous

Variable Name	Question from Survey	Code
Market Niche		
Q5_1	5. On average, what is the square footage of this housing? (Feel free to use multiple entries to indicate different market segments.)	
Q5a1	(a) __________ square feet (___% of total)	integer, continuous
Q5b1	(b) __________ square feet (___% of total)	integer, continuous
Q5c1	(c) __________ square feet (___% of total)	integer, continuous
Q5_2	5. (corresponding percentage of total housing)	
Q5a2	(a) percentage for Q5a1	real, 0-1
Q5b2	(b) percentage for Q5b1	real, 0-1
Q5c2	(c) percentage for Q5c1	real, 0-1
Q5avg	Housing Size, Averaged - weighted average: $\sum (Q5\_1 \cdot Q5\_2)$	integer, continuous
Q6_1	6. What is the average selling price of this housing? (Again, feel free to use multiple entries if needed.)	
Q6a1	(a) $ __________ (___% of total)	integer, continuous
Q6b1	(b) $ __________ (___% of total)	integer, continuous
Q6c1	(c) $ __________ (___% of total)	integer, continuous
Q6_2	6. (corresponding percentage of total housing)	
Q6a2	(a) percentage for Q6a1	real, 0-1
Q6b2	(b) percentage for Q6b1	real, 0-1
Q6c2	(c) percentage for Q6c1	real, 0-1
Q6avg	(*) Housing Price, Averaged - weighted average: $\sum (Q6\_1 \cdot Q6\_2)$	integer, continuous
Q7_	7. Please describe the market niche of ***[company name]***. (Please mark all that apply.)	
Q7a	☐ urban	0 = no, 1 = yes
Q7b	☐ suburban	0 = no, 1 = yes
Q7c	☐ site-built	0 = no, 1 = yes
Q7d	☐ manufactured	0 = no, 1 = yes
Q7e1	☐ other	0 = no, 1 = yes
Q7e2	Q7e1 other, explained	text
Q7niche	(*) Coded variable to consider	0 = site-built 1 = mfd housing (incl. modular) 99 = faulty data

Variable Name	Question from Survey	Code
Company Participation		
Q8	8. How many people from ***[company name]*** worked with a Building America team? (including yourself): _______	integer, continuous
Q9_ Q9a Q9b	9. How did ***[company name]*** become involved with Building America? ☐ We were asked or encouraged to participate. ☐ We sought out Building America on our own.	 0 = no, 1 = yes 0 = no, 1 = yes
Q10_ Q10a Q10b Q10c1 Q10d1 Q10e Q10f1 Q10g1 Q10h1	10. Other than Building America, are there building-related government programs in which you are participating? ☐ Zero Energy House (ZEH) ☐ Energy Star ☐ utility co program (specify: ___________________) ☐ municipal program (specify: __________________) ☐ Partnership for Advancing Technology in Housing (PATH) ☐ other federal program (specify: ________________) ☐ state program (specify: ________________________) ☐ other (specify:______________________________)	 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes
Q10_2	10. ("other" programs, explained) - descriptor each for Q10c2, Q10d2, Q10f2, Q10g2, & Q10h2	 text
Q10all	(*) Calculated sum of Q10a-Q10h	integer, continuous
Q11_ Q11a Q11b Q11c Q11d Q11e Q11f Q11g Q11h Q11i Q11j Q11k1	11. Of the many levels of participation, how has ***[company name]*** worked with a Building America team? (Please mark all project types that apply.) ☐ discussed designs (only) ☐ integrated a new product ☐ built one or two prototypes (only) ☐ developed a new product ☐ built a development ☐ developed a new construction practice ☐ tested/monitored energy performance ☐ modeled or simulated a mfg line ☐ community development process ☐ modified a mfg line ☐ other	 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes
Q11k2	Q11k1 other, explained	text
Q11part1	(*) Level of Participation Variable 1. Created as index from Q11a, Q11c, and Q11e to reflect three grades of builder involvement in the program: (1) discuss designs, (2) built prototypes, and (3) built development.	3 = built development (Q11e) 2 = built prototypes (Q11c) 1= discuss designs (Q11a) 0 = none
Q11part2	(*) Level of Participation Variable 2. Created as index from Q11h and Q11j to reflect two grades of mfd builder involvement in the program: (1) modeled or simulated a mfg line or (2) modified a manufacturing line.	2 = modified a mfg line (Q11j) 1 = modeled a mfg line (Q11h) 0 = none
Q11part3	(*) Level of Participation Variable 3. Created as index from Q11b, Q11d, and Q11f to reflect two grades of technology: (1) integrated a new product (Q11b) and (2) developed a new housing product (Q11d) or a new construction practice (Q11f).	3 = dev'd product AND practice 2 = dev'd product OR practice 1 = used new product 0 = none

Variable Name	Question from Survey	Code
Climate Zone		
Q12_	For (or in) which climate zone(s) have you worked with Building America? (Please check all that apply.) (HDD = heating degree days. CDD = cooling degree days.)	
Q12a Q12b Q12c Q12d Q12e	☐ Severe-Cold (7000+ HDD) ☐ Hot-Dry (> 2000 CDD) ☐ Cold (4000-7000 HDD, Less than 2000 CDD) ☐ Hot-Humid (> 2000 CDD) ☐ Mixed (< 4000 HDD, Less than 2000 CDD) severe cold	0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes
Housing Construction in conjunction with Building America **(note: check NREL database)**		
Q13_	13. How many houses or multi-family units have you produced or overseen with advice or assistance from a Building America team?	
Q13a Q13b	- Number of single-family houses: _____ - Number of multi-family units: _____	integer, continuous integer, continuous
Q13all	(*) Calculated sum of Q13a + Q13b	integer, continuous
Market Labeling		
Q14_	14. What percentage of this Building America housing bears the Energy Star label?	
Q14a Q14b Q14c Q14d Q14e Q14f	☐ none ☐ 1-25% ☐ 25-50% ☐ 50-75% ☐ 75-99% ☐ all	0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes
Q14sum	(*) Index from Q14a:Q14f	0 = none 1 = 1-25% 2 = 25-50% 3 = 50-75% 4 = 75-99% 5 = all 99 = missing

Variable Name	Question from Survey	Code				
Company Motivations for Participating						
Q15_	15. When first considering working with Building America, how important were the following factors in the choice to participate?	most important	very important	important	not important	don't know
Q15a	- conducting research	4	3	2	1	0
Q15b	- solving a problem, reducing callbacks	4	3	2	1	0
Q15c	- accessing new information	4	3	2	1	0
Q15d	- building better housing	4	3	2	1	0
Q15e	- improving housing value (market edge)	4	3	2	1	0
Q15f	- qualifying for market label	4	3	2	1	0
Q15g1	- other (specify: ________________)	4	3	2	1	0
Q15g2	Q15g1 other, explained	*text*				
Risk-related Variables: Prior Relationship, Credibility, and Trust						
Q16	Onset level of familiarity between key company personnel and building scientist/team leader	4 = very well 3 = well 2 = a little 1 = not much at all (0 = don't know)				
Q17	17. When ***[company name]*** began working with Building America, how effectiveness did you perceive the program's building scientists to be?	4 = very effective 3 = effective 2 = a little effective 1 = not effective (0 = don't know)				
Q18	18. What is your impression of their effectiveness now?	4 = very effective 3 = effective 2 = a little effective 1 = not effective (0 = don't know)				
Q19	19. When ***[company name]*** began working with Building America, how much could you trust the advice from these building scientists?	4 = fully trust 3 = trust 2 = trust just a little 1 = did not trust (0 = don't know)				
Q20	20. How much do you trust the advice from these building scientists now?	4 = fully trust 3 = trust 2 = trust just a little 1 = did not trust (0 = don't know)				

Technology Adoption

21. Use of Advanced Housing Components and Integrated Systems

The table in this question asks for information about the advanced housing components and integrated systems that you or your (sub)contractors have used (1) before, (2) during, and (3) since your first project with a Building America team. Each row represents a different type of housing technology, and each column represents a different time period.

Please work across each row. In column (1) mark the box if you used the component or practice on the left before working with a Building America team. In column (2) mark the box if you used a newer or improved version or if you used it for the first time during and because of your work with a Building America team. In column (3) mark the box that identifies how often you use the newer or improved version since your first project with a Building America team. (If you have never used the item on the left, please leave the entire row blank.)

Here is an example: if you did not use “Advanced Framing” before working with a Building America team, then do not check the box in column (1) of the first row. While working with a Building America team, if you used Advanced Framing that was either new to you or an improved version of one that you already used, then check the box in column (2). Since then, if you have used the technique on occasion (for example, about half of the time), check the second box in column (3). Then move on to the next row.

Q21_ _	Technology Usage before, during, & since Building America	
Technology	*Component Technologies*	
Q21a_	(a) advanced framing	
Q21b_	(b) advanced moisture control	
Q21c_	(c) advanced insulation	
Q21d_	(d) advanced air sealings or reduced infiltration	
Q21e_	(e) advanced ventilation	
Q21f_	(f) advanced space conditioning equipment	
Q21g_	(g) high performance windows	
Q21h_	(h) improved air quality	
Q21i_	(i) optimized air distribution	
Q21j_	(j) tightened ductwork	
	Systems Packages of Technologies	
Q21k_	(k) package no 1. (windows + conditioning equipment)	
Q21l_	(l) package no. 2 (air distribution + conditioning equipment)	
Q21m_	(m) package no. 3 (↓infiltration or ↑sealing + ventilation)	
Q21n_	(n) package no. 4 (solar energy + increased efficiency)	
Q21o_	(o) package no. 5 (QA/QC + utility bill guarantee)	
	Systems Integration	
Q21p_	(p) whole house energy design	
Timing	*Time Period of Use*	
Q21_1	(1) before	0 = no, 1 = yes
Q21_2	(2) during	0 = no, 1 = yes
Q21_3a	(3a) after, always	0 = no, 1 = yes
Q21_3b	(3b) after, sometimes	0 = no, 1 = yes
Q21_3c	(3c) after, not really	0 = no, 1 = yes
Q21bad	(*) Dummy variable added to exclude answers from question 21. Exclusion based on perceived misunderstanding of question format. (Surveys with only one check mark made per row.)	0 = good 1 = bad

Variable Name	Question from Survey	Code
Comparative Variables Indexes: changes in perceived effectiveness, trust, and callbacks		
d18_17	(*) Change in Perceived Effectiveness of Building Scientist, (calculated as difference between Q18 and Q17)	-3 to 3
d20_19	(*) Change in Trust about Recommendations from Building Scientists (calculated as difference between Q20 and Q19)	-3 to 3
d46_45	(*) Change in Callbacks on Building America Housing relative to conventional housing (calculated as difference between Q46 and Q45)	-3 to 3

Technology Impacts: introduction + adoption in a single index		
d21tech_ _ d21tech_a d21tech_b d21tech_c d21tech_d d21tech_e d21tech_f d21tech_g d21tech_h d21tech_i d21tech_j d21tech_k d21tech_l d21tech_m d21tech_n d21tech_o d21tech_p	(*) Technology Usage Index: index created from Q21 (a) framing (b) moisture control (c) advanced insulation (d) air sealings or reduced infiltration (e) ventilation (f) space conditioning equipment (g) high performance windows (h) improved air quality (i) optimized air distribution (j) tightened ductwork (k) package no 1. (windows + conditioning equipment) (l) package no. 2 (air distribution + conditioning equipment) (m) package no. 3 (↓infiltration or ↑sealing + ventilation) (n) package no. 4 (solar energy + increased efficiency) (o) package no. 5 (QA/QC + utility bill guarantee) (p) whole house energy design	5 ("created standard practice") = not before, during, now in most housing 4 ("improved standard practice") = before, during, and now in most housing 3 ("created partial practice") = not before, during, and now in some housing 2 ("improved partial practice") = before, during, and now in some housing 1 ("introduced to practice") = not before, during, and not now in housing 0 = all others Note: this coding assumes that initial introduction involves steeper learning curve than improvement to existing uses. For this reason, 5 is superior to 4, 3 is superior to 2.

Technology Change: introduction + adoption in a composite index		
tech_chg	(*) Technology Usage Index: index created from summation of indices tech21_a through tech21_p	integer, continuous (range 0-90)

Variable Name	Question from Survey	Code
Technology Impacts: <u>introduction only</u>		
d21_12	(*) Technology Usage (onset only)	2 = not before, during 1 = before, during 0 = all others
d21a12	(a) framing	
d21b12	(b) moisture control	
d21c12	(c) advanced insulation	
d21d12	(d) air sealings or reduced infiltration	(assumption: initial introduction involves steeper learning curve than improvement to existing uses)
d21e12	(e) ventilation	
d21f12	(f) space conditioning equipment	
d21g12	(g) high performance windows	
d21h12	(h) improved air quality	
d21i12	(i) optimized air distribution	
d21j12	(j) tightened ductwork	
d21k12	(k) package no 1. (windows + conditioning equipment)	
d21l12	(l) package no. 2 (air distribution + conditioning equipment)	
d21m12	(m) package no. 3 (↓infiltration or ↑sealing + ventilation)	
d21n12	(n) package no. 4 (solar energy + increased efficiency)	
d21o12	(o) package no. 5 (QA/QC + utility bill guarantee)	
d21p12	(p) whole house energy design	
Technology Impacts: <u>adoption only</u>		
d21_23	(*) Technology Usage (after program)	3 = during, now in most housing 2 = during, now in some housing 1 = during, not now 0 = all others
d21a23	(a) framing	
d21b23	(b) moisture control	
d21c23	(c) advanced insulation	
d21d23	(d) air sealings or reduced infiltration	
d21e23	(e) ventilation	
d21f23	(f) space conditioning equipment	
d21g23	(g) high performance windows	
d21h23	(h) improved air quality	
d21i23	(i) optimized air distribution	
d21j23	(j) tightened ductwork	
d21k23	(k) package no 1. (windows + conditioning equipment)	
d21l23	(l) package no. 2 (air distribution + conditioning equipment)	
d21m23	(m) package no. 3 (↓infiltration or ↑sealing + ventilation)	
d21n23	(n) package no. 4 (solar energy + increased efficiency)	
d21o23	(o) package no. 5 (QA/QC + utility bill guarantee)	
d21p23	(p) whole house energy design	

Variable Name	Question from Survey	Code				
Factors Affecting Degree of Participation/Technology Choices						
Q22_	22. When you received recommendations about new or improved housing technologies from a Building America team, why did you use them?	most important	very important	important	not important	don't know
Q22a	- building scientist provided necessary data	4	3	2	1	0
Q22b	- solved a problem, reduced callbacks	4	3	2	1	0
Q22c	- provided opportunity learn about new technology	4	3	2	1	0
Q22d	- changes made housing better	4	3	2	1	0
Q22e	- changes made housing sell better	4	3	2	1	0
Q22f	- changes helped secure label	4	3	2	1	0
Q22g1	- other (specify: ________________)	4	3	2	1	0
Q22g2	Q22g1 other, explained	*text*				
Q23_	23. If, during your project, you did <u>not</u> follow a recommendation from a Building America team, how much did the following factors matter?	most of all	very much	somewhat	not much	don't know
Q23a	- too expensive of time-consuming	4	3	2	1	0
Q23b	- inconsistent with business plan	4	3	2	1	0
Q23c	- too hard to coordinate with subcontractor	4	3	2	1	0
Q23d	- conflict with building code	4	3	2	1	0
Q23e	- too hard to coordinate with supplier	4	3	2	1	0
Q23f1	- other (specify: ________________)	4	3	2	1	0
Q23f2	Q23f1 other, explained	*text*				
Q24_	24. If you used an advanced product or technique <u>only</u> during your Building America project, what stopped you from continuing to use it afterward?	most of all	very much	somewhat	not much	don't know
Q24a	- did not achieve results expected	4	3	2	1	0
Q24b	- more expensive or time-consuming than expected	4	3	2	1	0
Q24c	- too hard to implement without building scientist help	4	3	2	1	0
Q24d	- too hard to coordinate with subcontractors	4	3	2	1	0
Q24e	- conflicts with building code	4	3	2	1	0
Q24f	- too hard to coordinate with suppliers	4	3	2	1	0
Q24g1	- other (specify: ________________)	4	3	2	1	0
Q24g2	Q24g1 other, explained	*text*				

Variable Name	Question from Survey	Code
Market Forces		
Q25	25. Are more of your competitors building "Building America-quality" housing (more durable and using at least 30% less energy) today than in 1995?	4 = almost all 3 = several more 2 = only a few more 1 = no more or fewer (0 = don't know)
Q26	26. Are more of your customers asking for "Building America-quality" housing today than in 1995?	4 = almost all 3 = several more 2 = only a few more 1 = no more or fewer (0 = don't know)
Regulatory Impediments		
Q27	27. How often does the building code hinder or discourage your use of advanced products or designs like those suggested in Building America?	4 = every time 3 = more than ½ time 2 = less than ½ time 1 = never (0 = don't know)
Building America Effects on Technological and Coordinative Agility		
Q28	28. Did Building America make it easier to respond to changes or obstacles in the local building code?	5 = made it much easier 4 = made it easier 3 = made no difference 2 = made it harder 1 = made it much harder (0 = don't know)
Q29	29. Did Building America make it easier to coordinate changes in housing with subcontractors?	
Q30	30. Did Building America make it easier to coordinate product or design changes with suppliers?	
Q31	31. How did Building America change your ability to bring new products or appliances into your housing?	
Q32	32. How did Building America change your ability to use an integrated systems approach to building?	

Relationship Network
33. We want to learn how the people with whom ***[company name]*** communicates or works changed through your experience with the Building America program. To collect this information, we would like you to fill out the table below.

The rows of the table contain names of groups relevant to Building America. The two columns contain ways of interacting with these groups and are divided into time periods before, during, and since your Building America collaboration. Column (1) describes interactions about technical aspects of building, such as sharing information, improving housing performance, improving construction management, and developing a new or custom product. Column (2) describes interactions to impact the laws or markets for housing, such as working to change codes and regulation, change product standards, or develop new financing mechanisms.

Our suggestion is to fill out the table by working across a row. For each row, you should begin by considering whether your company has worked or communicated with the listed group at some point in time. If not, then simply skip to the next row. If so, then please use columns (1) and (2) to indicate whether you have done so before, during, and since you worked with Building America. As a general rule, we ask that you check a box only when you can remember interacting with a group more than once during a specified time period. You may talk every day with some groups, such as subcontractors. However, you might not have normally talked with them about customizing products (column 1), and we would like to learn whether your Building America experience changed this.

As an example, consider the first row. If your company did not work with a building scientist to design housing, solve problems, or test performance before working with Building America, then leave the "before" box blank. If your company worked with building scientists during a Building America project, then check the "during" box. If your company's work with building scientists has continued, then check the "since then" box. The same procedure would be used for the boxes in column (2) and all other rows.

Variable Name	**Question from Survey**	**Code**
Q33_ _ _	Work with before, during, and after Building America	
Q33A_ _	(A) Building Scientists	
Q33B_ _	(B) Builders/Developers	
Q33D_ _	(D) Subcontractors	
Q33E_ _	(E) Product Supplier, Sales Staff	
Q33F_ _	(F) Product Supplier, Product Design Staff	
Q33G_ _	(G) US Dept of Energy (employees at)	
Q33H_ _	(H) National Laboratories (NREL, LBNL, ORNL)	
Q33I_ _	(I) Utility Company Staff (electricity or natural gas)	
Q33J_ _	(J) State or Local Officials (energy or building code)	
Q33K_ _	(K) Homebuilder Assoc'n (such as NAHB)	
Q33L_ _	(L) Trade Associations (subcontrator trades)	
Q33M_ _	(M) Financial Community (such as mortgage companies)	
Q33_1_	(1) Share technical information, improve housing performance, improve construction management, or develop a new/custom product	
Q33_2_	**(2) Discussions or work to change codes and regulations, change product standards, or develop new financing mechanisms**	
Q33_ _a	(a) before	0 = no, 1 = yes
Q33_ _b	(b) during	0 = no, 1 = yes
Q33_ _c	(c) after	0 = no, 1 = yes
Q33bad	(*) Dummy variable added to exclude answers to question 33. Exclusion based on perceived misunderstanding of question format.	0 = good 1 = bad

Variable Name	Question from Survey		Code
Relationship Network: <u>expansion</u> (introduction + retention)			
d33_ _abc	(*) Network capacity (attention to network expansion)		3 = not before, during, since then 2 = not before, not during, since then 1 = not before, during, not since then 0 = all others
d33A_abc	(A) Building Scientists		
d33B_abc	(B) Builders/Developers		
d33D_abc	(D) Subcontractors		
d33E_abc	(E) Product Supplier, Sales Staff		
d33F_abc	(F) Product Supplier, Product Design Staff		
d33G_abc	(G) US Dept of Energy (employees at)		
d33H_abc	(H) National Laboratories (NREL, LBNL, ORNL)		
d33I_abc	(I) Utility Company Staff (electricity or natural gas)		
d33J_abc	(J) State or Local Officials (energy or building code)		
d33K_abc	(K) Homebuilder Association (such as NAHB)		
d33L_abc	(L) Trade Associations (subcontractor trades)		
d33M_abc	(M) Financial Community (such as mortgage companies)		
d33_1abc		(1) technical	
d33_2abc		(2) legal	
Relationship Network: <u>introduction</u>			
d33_ _ab	(*) Network capacity (attention to new working relationships)		1 = not before, but during 0 = all others
d33A_ab	(A) Building Scientists		
d33B_ab	(B) Builders/Developers		
d33D_ab	(D) Subcontractors		
d33E_ab	(E) Product Supplier, Sales Staff		
d33F_ab	(F) Product Supplier, Product Design Staff		
d33G_ab	(G) US Dept of Energy (employees at)		
d33H_ab	(H) National Laboratories (NREL, LBNL, ORNL)		
d33I_ab	(I) Utility Company Staff (electricity or natural gas)		
d33J_ab	(J) State or Local Officials (energy or building code)		
d33K_ab	(K) Homebuilder Association (such as NAHB)		
d33L_ab	(L) Trade Associations (subcontractor trades)		
d33M_ab	(M) Financial Community (such as mortgage companies)		
d33_1ab		(1) technical	
d33_2ab		(2) legal	
Relationship Network: <u>retention</u>			
d33_ _bc	(*) Network capacity (attention to retention differences)		1 = during, since then 0 = all others
d33A_bc	(A) Building Scientists		
d33B_bc	(B) Builders/Developers		
d33D_bc	(D) Subcontractors		
d33E_bc	(E) Product Supplier, Sales Staff		
d33F_bc	(F) Product Supplier, Product Design Staff		
d33G_bc	(G) US Dept of Energy (employees at)		
d33H_bc	(H) National Laboratories (NREL, LBNL, ORNL)		
d33I_bc	(I) Utility Company Staff (electricity or natural gas)		
d33J_bc	(J) State or Local Officials (energy or building code)		
d33K_bc	(K) Homebuilder Association (such as NAHB)		
d33L_bc	(L) Trade Associations (subcontractor trades)		
d33M_bc	(M) Financial Community (such as mortgage companies)		
d33_1bc		(1) technical	
d33_2bc		(2) legal	

Variable Name	Question from Survey	Code
Network Effects		
Q33bef	(*) A measure of relationship network capacity before working with a Building America team. A summation of q33_1a and q33_2a (i.e., q33bef = Σq33_1a + q33_2a)	integer, continuous (range: 0-24)
Q33new	(*) Changes in relationship capacity, measured as new contacts made during participation in Building America. This variable is a summation of q33_1ab and q33_2ab (i.e., q33intro = Σq33_1ab + q33_2ab)	integer, continuous (range: 0-24)
Relationship Effects		
Q34	34. Through work with Building America, did you work with groups with whom you normally do not?	4 = very much 3 = somewhat 2 = only a little 1 = not at all (0 = don't know)
Q35	35. How much did these new interactions change your ability to use new products or practices in your housing?	4 = very much 3 = somewhat 2 = only a little 1 = not at all (0 = don't know)
Organizational Changes		
Q36_	36. Did ***[company name]*** make any of the following changes to capture benefits of Building America? (Please mark all that apply.)	
Q36a	☐ reassigned responsibilities for managers	0 = no, 1 = yes
Q36b	☐ changes the basis for payment	0 = no, 1 = yes
Q36c	☐ offered new incentives for managers	0 = no, 1 = yes
Q36d	☐ became more involved in changing building codes	0 = no, 1 = yes
Q36e	☐ created a training or coordination program for subs	0 = no, 1 = yes
Q36f	☐ changed contract terms for subs	0 = no, 1 = yes
Q36g	☐ created or modified an inspection or QA/QC program	0 = no, 1 = yes
Q36h1	☐ other (specify: __________)	0 = no, 1 = yes
Q36h2	Q36h1 other, explained	*text*
Q36all	(*) Sum of organizational changes: Q36a-h	

Variable Name	Question from Survey	Code
Outcomes from Building America Participation (continued)		
Q37	37. How much have your building material costs changed since working with Building America?	5 = ↓ more than 20% 4 = ↓ 1-20% 3 = no change 2 = ↑ 1-20% 1 = ↑ more than 20% (0 = don't know)
Q38	38. How much have your construction costs changed since working with Building America?	
Q39	39. How much has your construction or manufacturing time changed since working with Building America?	
Q40	40. How much has the sale price of your housing changed since working with Building America?	
Q41	41. How much has the time required to sell your housing changed since working with Building America?	
Q42	42. How much has your construction waste volume changed since working with Building America?	
Q43	43. How much has the energy use of the housing you build changed since working with Building America?	
Q44	44. How much has your overall housing value changed since working with Building America? (value = durability, affordability, and energy efficiency)	
Changes in Callbacks (Liability and Future Costs)		
Q45	45. On what percentage of your Building America housing (at least 30% less energy) have you received callbacks?	5 = none 4 = 1-5% 3 = 6-10% 2 = 11-20% 1 = over 20% (0 = don't know)
Q46	46. On what percentage of your non-Building America housing do you normally receive callbacks?	
Overall		
Q47_ Q47a Q47b Q47c Q47d Q47e	47. Overall, what is your opinion of Building America? ☐ excellent ☐ good ☐ fair ☐ poor ☐ very poor	 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes 0 = no, 1 = yes
Q47int	(*) Opinion of Building America (recode)	4 = excellent 3 = good 2 = fair 1 = poor 0 = very poor
Bonus	Wants to receive copy of our study	0 = no, 1 = yes

Appendix D-3. Compiled Survey Data by Question

To examine changes in participating builder technology habits, we prepared a questionnaire to send to builders who had been significantly involved in at least one Building America project between 1995-2002. The purpose of this survey (see Appendix C-1) was to collect builder information about their businesses, their involvement in Building America, and their technology usage. Team leaders provided us with a list of 132 builders, developers, and housing manufacturers with whom they had worked since their teams were chartered. This list contained company name, contact name, address, and phone number but no demographic information about the business. We mailed our survey to builders in September of 2002 and collected responses until January of 2003. We received 71 completed questionnaires (a response rate of 54%). The tables below summarize the information we collected. The question numbers match those in the survey and the survey codebook.

2. During which years has your company worked with Building America? (Please mark all years that apply.)

	Yes	*No*	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) participated in 1995	5	65	.07	.26	0.0	1.0	70
b.) participated in 1996	8	62	.11	.32	0.0	1.0	70
c.) participated in 1997	11	59	.16	.37	0.0	1.0	70
d.) participated in 1998	14	56	.20	.40	0.0	1.0	70
e.) participated in 1999	29	41	.41	.50	0.0	1.0	70
f.) participated in 2000	49	21	.70	.46	0.0	1.0	70
g.) participated in 2001	61	9	.87	.34	0.0	1.0	70

*Index***.** Total years involved in the program.	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
sum.) summation of question 2 answers (range 0-8)	3.41	1.91	1.0	8.0	70

3. During how many of these years did you personally work with Building America?

	Mean	*Std Dev.*	*Min*	*Max*	*N*
	3.15	1.95	0	8	70

4. On average, how many houses or multi-family units does your company build, manufacture, or oversee every year?

	Mean	*Std Dev.*	*Min*	*Max*	*N*
a.) houses	3204	8306	0	40000	69
b.) multi-family units	245	1054	0	7000	69
all.) houses + multi-family units	3449	8708	1	40000	69

		Mean	*Std Dev.*	*Min*	*Max*	*N*
site-builders[27]	houses	706	2044	0	13000	44
	multi-family units	91	158	0	700	44
	houses + multi-family units	798	2060	1	13000	44
housing mfrs[28] (including modular)	houses	5738	11193	2	40000	23
	multi-family units	259	1122	0	5400	23
	houses + multi-family units	5995	11256	2	40000	23

[27] The corporate-wide answers for Pulte Homes have been excluded from these data.
[28] These statistics include builders who indicated that they are involved in any kind of housing manufacturing, even if they are also involved in site building.

5. On average, what is the square footage of this housing? (Feel free to use multiple entries to indicate different market segments.)

	Mean	*Std Dev.*	*Min*	*Max*	*N*
a.) first segment	1900	842	600	5000	69
b.) second segment	2073	596	1000	3500	42
c.) third segment	2482	885	1100	4000	29
weighted average in square footage, all segments	2003	703	925	4500	69

site builders	average size (sq. feet)	2087	729	925	4500	42
housing mfrs	average size (sq. feet)	1165	430	1165	2900	23

6. What is the average selling price of this housing? (Again, feel free to use multiple entries if needed.)

	Mean	*Std Dev.*	*Min*	*Max*	*N*
a.) first segment (in $1000s)	201.0	162.4	24.5	750	66
b.) second segment (in $1000s)	198.0	106.8	34.5	455	33
c.) third segment (in $1000s)	267.3	168.1	41.0	700	23
weighted average selling price (in $1000s), all segments	202.1	136.9	35.0	563	66

site builders	average price ($1000s)	233.6	136.1	35.0	562.5	41
housing mfrs	average price ($1000s)	104.6	11.0	11.0	488.5	21

7. Please describe the market niche of you company. (Please mark all that apply.)

	Affirmative Response	*N*
a.) urban	27	71
b.) suburban	42	71
c.) site-built (or stick-built)	44	71
d.) manufactured	23	71
e.) other: 1.50 Time Borrowers, Active Adult, Affordable (2), All homes that need Rating/Testing, Conservation Community, Custom, Energy Efficiency/Comfort/Durability, Infill, Low to moderate income buyers, New Urban/Sustainable, New Urbanist, Panelized, Rehabilitation, Rental (3), Rural, Tear down substandard/build back, Vacation	16	71

*Index***.** Dummy variable for manufactured housing builders.

	Manufactured Housing Only	*N*
(1 = housing mfr only[29], 0 = all others)	18	71

8. How many people from your company worked with a Building America team? (including yourself)

Mean	*Std Dev.*	*Min*	*Max*	*N*
6.97	8.58	1	50	70

9. How did your company become involved with Building America?

	Affirmative Response	*N*
a.) We were asked or encouraged to participate.	54	71
b.) We sought out Building America on our own.	17	71

10. Other than Building America, are there building-related government programs in which you are participating?

	Affirmative Response	*N*
a.) Zero Energy House (ZEH)	4	71

[29] This dummy variable takes a value of 1 for builders who only manufacture housing.

b.)	Energy Star	55	71
c.)	utility company program: ACT FLA POWER, Energy Advantage Southwest Gas, Gas iElectric, Home owned utility LPFL, MPSC (Michigan Public Service Commission, P.V. Grant/Miss Ran Trust, PG+E, PGE Comfort, Super Good Cents, TEP Guarantee Program	11	71
d.)	municipal program: Affordable Housing, Various Counties, HUO money is used, Pontiac Home/Pontiac CDBG, Reclaimed Water Southwest Gas Energy Program	4	71
e.)	Partnership for Adv. Tech in Housing (PATH)	10	71
f.)	other federal program: HOME, HUD FTWB, LIHEAP (Dept Health & Human Services), NREL Monitoring	6	71
g.)	state program: State of Alaska AHFC/BEES, Building America Partner Program, Community Partners, Department of Community Affairs Sustainable Development Pilot Program, E-Star, Built Green, Illinois Energy Efficient & Affordable Housing, MSHDA PP, NYSERTA	8	71
h.)	other: Built Green, Earth Craft House/Green Program for metro Atlanta (2), Environments for living/MASCO (2), FHA/VA for loans, HBA Built Green, Million Rooftops Solar, Oakland County CDBG & Oakland County Home	10	71

Index. Other than Building America, are there building-related gov't programs in which you are participating?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
all.) summation of question 10 answers (range: 0-8)	1.52	1.14	0	6	71

11. Of the many the levels of participation, how has your company worked with a Building America team? (Please mark all project types that apply.)	*Affirmative Response*	*N*
a.) Discussed housing designs but did not build housing	10	68
b.) Integrated a new housing product into housing	27	68
c.) Discussed designs and built one or two prototype units (only)	21	68
d.) Developed a new or improved housing product	36	68
e.) Discussed designs and built a housing development (prototype assumed)	27	68
f.) Developed an improved construction practice	50	68
g.) Tested or monitored housing energy performance	52	68
h.) Modeled or simulated a manufacturing line	8	68
i.) Worked on changes in community devmt processes	9	68
j.) Modified our manufacturing line(s)	8	68
k.) Other (Field Technical Assistance to General Contractor, Conducted focus group meetings with builders, Developed a baseline of existing product and also did two high-performance pilot homes implementing the new techniques, On-going relationship - Developed Building Skills)	4	68

Index. Of the many the levels of participation, how has your company worked with a Building America team?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
part1.) site collaboration index (from 11a, 11c, and 11e, range: 0-3)	1.93	1.09	0	3	69
part2.) mfg collaboration index (from 11h and 11j, range: 0-2)	0.21	0.51	0	2	68
part3.) technology devmt index (from 11b, 11d, and 11f, range: 0-3)	1.38	1.06	0	3	71

12. For (or in) which climate zone(s) have you worked with Building America on advanced housing? (Please check all that apply.) (HDD = heating degree days. CDD = cooling degree days.)

	Affirmative Response	*N*
a.) Severe-Cold (7000+ HDD)	6	67
b.) Hot-Dry (> 2000 CDD)	14	67
c.) Cold (4000-7000 HDD, Less than 2000 CDD)	25	67
d.) Hot-Humid (> 2000 CDD)	19	67
e.) Mixed (< 4000 HDD, Less than 2000 CDD)	29	67

13. How many houses or multi-family units have you produced or overseen with advice or assistance from a Building America team?

	Mean	*Std Dev.*	*Min*	*Max*	*N*
a.) houses	761	3042	0	20000	44
b.) multi-family units	62	102	0	400	24

14. What percentage of this (question 13) Building America housing bears the Energy Star label? (Answers only for those claiming participation in question 10.)

	Affirmative Response	*N*
a. none	7	48
b. 1-25%	7	48
c. 25-50%	2	48
d. 50-75%	2	48
e. 75-99%	3	48
f. all	21	48

Index. What percentage of this (question 13) Building America housing bears the Energy Star label?

	Mean	*Std Dev.*	*Min*	*Max*	*N*
(created from question 14; 0 = none, 1 = 1-25%, 2 = 25-50%, 3 = 50-75%, 4 = 75-99%, and 5 = all)	3.49	1.97	0	5	39

15. When <u>first considering</u> working with Building America, how important were the following factors in the choice to participate? (1 = not important, 2 = important, 3 = very important, 4 = most important)

	Mean	*Std Dev.*	*Min*	*Max*	*N*
a.) Conducting research with building scientists/experts	2.85	.96	1	4	67
b.) Consulting to solve a problem, to reduce callbacks, or to lower cost	2.95	1.01	1	4	66
c.) Accessing new information about design or products	3.00	.78	2	4	66
d.) Building more energy efficient, healthier housing	3.51	.78	2	4	66
e.) Improving housing value to make housing sell better	2.98	.94	1	4	66
f.) Marketing housing as "Building America" or "Energy Star"	2.38	1.06	1	4	66
g.) Other (Addressing moisture levels in our homes, Assistance with local inspectors, Avoid the risk of unhealthy homes or upset customers, Learn new energy saving ideas, Meeting a consumer demand, Permanently change construction practice in the future, Training Builders)	3.00	.46	3	4	8

16. How well did you or the other important decision makers at your company know the building scientists with your team before working with them through Building America? (1 = not much at all, 2 = a little, 3 = well, 4 = very well)	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
Overall	2.17	1.24	1	4	71
· IBACOS	1.85	1.07	–	–	13
· BSC	2.68	1.36	–	–	22
· CARB	1.71	1.25	–	–	7
· IHP	1.70	.82	–	–	10
· Hickory Consortium	2.11	1.27	–	–	9

17. When your company began working with Building America, how effective did you perceive the program's building scientists to be? (1 = not effective, 2 = a little effective, 3 = effective, 4 = very effective)	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
Overall	3.42	.61	2	4	67
· IBACOS	3.20	.68	–	–	15
· BSC	3.62	.50	–	–	21
· CARB	3.14	.69	–	–	7
· IHP	3.58	.51	–	–	12
· Hickory Consortium	3.40	.70	–	–	10

18. What is your impression of their effectiveness <u>now</u>? (1 = not effective, 2 = a little effective, 3 = effective, 4 = very effective)	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
Overall	3.57	.74	1	4	66
· IBACOS	3.73	.46	–	–	15
· BSC	3.64	.73	–	–	22
· CARB	3.14	1.07	–	–	7
· IHP	3.55	.69	–	–	12
· Hickory Consortium	3.42	.90	–	–	11

Index. Change in perceived effectiveness (q18-q17)	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
Overall	.20	.73	-3.0	2.0	66
· IBACOS	.53	.74	–	–	15
· BSC	.00	.84	–	–	21
· CARB	.00	.82	–	–	7
· IHP	.00	.45	–	–	11
· Hickory Consortium	.30	.48	–	–	10

19. When your company began working with Building America, how much could you trust the advice from these building scientists? (1 = did not trust, 2 = trust just a little, 3 = trust, 4 = fully trust)

	Mean	*Std Dev.*	*Min*	*Max*	*N*
Overall	3.16	.64	2.0	4.0	67
· IBACOS	3.00	.65	–	–	15
· BSC	3.32	.65	–	–	22
· CARB	2.86	.69	–	–	7
· IHP	3.27	.47	–	–	11
· Hickory Consortium	3.20	.79	–	–	10

20. How much do you trust the advice from these building scientists now? (1 = did not trust, 2 = trust just a little, 3 = trust, 4 = fully trust)

	Mean	*Std Dev.*	*Min*	*Max*	*N*
Overall	3.53	.53	2.0	4.0	68
· IBACOS	3.60	.51	–	–	15
· BSC	3.59	.50	–	–	22
· CARB	3.43	.79	–	–	7
· IHP	3.55	.52	–	–	11
· Hickory Consortium	3.36	.50	–	–	11

Index. Change in level of trust (q20-q19)	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
Overall	.37	.57	0.0	2.0	67
· IBACOS	.60	.74	–	–	15
· BSC	.27	.46	–	–	22
· CARB	.57	.79	–	–	7
· IHP	.27	.47	–	–	11
· Hickory Consortium	.20	.42	–	–	10

All Teams

21. Use of Advanced Housing Components and Integrated Systems	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) **Advanced Framing** (stacked framing, 24" construction with 2x6's, SIPs, integrated sheer panels, or insulating sheathing)	1.50	1.96	0	5	54
b.) **Advanced Moisture Control** (foundation water sealing, added or eliminated wall vapor diffusion retarder, foundation water management, or crawl space water management)	1.56	2.17	0	5	54
c.) **Advanced Insulation** (changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic)	2.30	2.29	0	5	54
d.) **Advanced Air Sealings and Reduced Infiltration** (upgraded sealing & caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances)	2.91	2.25	0	5	54
e.) **Advanced Ventilation** (mechanical ventilation supply and/or exhaust system)	2.72	2.31	0	5	54
f.) **Advanced Space Conditioning Equipment** (downsized, improved efficiency, or multi-speed units; combo hot water & hydronic heating; or programmable thermostats)	2.31	2.18	0	5	54
g.) **High Performance Windows** (improved glazing and framing)	1.81	2.27	0	5	54
h.) **Improved Air Quality** (low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification)	1.83	2.26	0	5	54
i.) **Optimized Air Distribution** (ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts & transfer grilles)	2.48	2.18	0	5	54
j.) **Tightened Ductwork** (duct sealing or hard-ducted returns)	2.81	2.25	0	5	54
k.) High Performance Envelope ***plus*** Downsized Heating or Cooling System	2.17	2.26	0	5	54
l.) Duct Relocation and Sealing **plus** *Downsized Space Conditioning System*	2.04	2.18	0	5	54
m.) Reduced Air Infiltration or Sealing Package **plus** *Mechanical Ventilation System*	2.41	2.30	0	5	53
n.) Use of Solar Energy **plus** *Increased Efficiency (solar heat or photovoltaic panels + energy efficient design)*	.41	1.27	0	5	54
o.) System Performance/Quality Control Testing **plus** *Utility Bill Guarantee/Increased Homeowner Warranty*	1.20	1.93	0	5	54
p.) ***Whole Building Energy Design*** *(systems engineering, systems integration, or cost-performance trade-off analysis)*	1.74	2.01	0	5	54

(KEY: see next page at bottom)

Tech_Chg

Index. Total technology adoption, as summed across all housing components and systems packages.	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(created from question 21; summation for all technologies a through p; possible range: 0-90.	28.87	22.14	0	74	53

IBACOS

21. Use of Advanced Housing Components and Integrated Systems	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) **Advanced Framing** (stacked framing, 24" construction with 2x6's, SIPs, integrated sheer panels, or insulating sheathing)	1.50	1.68	0	5	12
b.) **Advanced Moisture Control** (foundation water sealing, added or eliminated wall vapor diffusion retarder, foundation water management, or crawl space water management)	2.25	2.34	0	5	12
c.) **Advanced Insulation** (changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic)	3.25	2.26	0	5	12
d.) **Advanced Air Sealings and Reduced Infiltration** (upgraded sealing & caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances)	3.67	2.06	0	5	12
e.) **Advanced Ventilation** (mechanical ventilation supply and/or exhaust system)	3.67	2.10	0	5	12
f.) **Advanced Space Conditioning Equipment** (downsized, improved efficiency, or multi-speed units; combo hot water & hydronic heating; or programmable thermostats)	3.08	2.23	0	5	12
g.) **High Performance Windows** (improved glazing and framing)	2.50	2.47	0	5	12
h.) **Improved Air Quality** (low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification)	2.58	2.23	0	5	12
i.) **Optimized Air Distribution** (ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts & transfer grilles)	2.67	2.15	0	5	12
j.) **Tightened Ductwork** (duct sealing or hard-ducted returns)	3.75	1.96	0	5	12
k.) High Performance Envelope ***plus*** Downsized Heating or Cooling System	1.83	2.21	0	5	12
l.) Duct Relocation and Sealing **plus** *Downsized Space Conditioning System*	2.08	2.15	0	5	12
m.) Reduced Air Infiltration or Sealing Package **plus** *Mechanical Ventilation System*	3.25	2.30	0	5	12
n.) Use of Solar Energy **plus** *Increased Efficiency (solar heat or photovoltaic panels + energy efficient design)*	.42	1.44	0	5	12
o.) System Performance/Quality Control Testing **plus** *Utility Bill Guarantee/Increased Homeowner Warranty*	1.50	1.98	0	5	12
p.) ***Whole Building Energy Design*** *(systems engineering, systems integration, or cost-performance trade-off analysis)*	2.17	2.08	0	5	12

KEY: technology adoption index

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0 = all other response patterns

BSC

21. Use of Advanced Housing Components and Integrated Systems	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) **Advanced Framing** (stacked framing, 24" construction with 2x6's, SIPs, integrated sheer panels, or insulating sheathing)	3.11	2.00	0	5	18
b.) **Advanced Moisture Control** (foundation water sealing, added or eliminated wall vapor diffusion retarder, foundation water management, or crawl space water management)	2.56	2.38	0	5	18
c.) **Advanced Insulation** (changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic)	3.11	2.32	0	5	18
d.) **Advanced Air Sealings and Reduced Infiltration** (upgraded sealing & caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances)	3.11	2.230	0	5	18
e.) **Advanced Ventilation** (mechanical ventilation supply and/or exhaust system)	3.67	2.06	0	5	18
f.) **Advanced Space Conditioning Equipment** (downsized, improved efficiency, or multi-speed units; combo hot water & hydronic heating; or programmable thermostats)	3.39	2.15	0	5	18
g.) **High Performance Windows** (improved glazing and framing)	2.56	2.41	0	5	18
h.) **Improved Air Quality** (low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification)	2.83	2.33	0	5	18
i.) **Optimized Air Distribution** (ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts & transfer grilles)	3.56	2.01	0	5	18
j.) **Tightened Ductwork** (duct sealing or hard-ducted returns)	3.67	2.06	0	5	18
k.) High Performance Envelope ***plus*** Downsized Heating or Cooling System	3.89	1.81	0	5	18
l.) Duct Relocation and Sealing **plus** *Downsized Space Conditioning System*	3.39	2.06	0	5	18
m.) Reduced Air Infiltration or Sealing Package **plus** *Mechanical Ventilation System*	3.72	2.02	0	5	18
n.) Use of Solar Energy **plus** *Increased Efficiency (solar heat or photovoltaic panels + energy efficient design)*	.67	1.46	0	5	18
o.) System Performance/Quality Control Testing **plus** *Utility Bill Guarantee/Increased Homeowner Warranty*	1.94	2.24	0	5	18
p.) ***Whole Building Energy Design*** *(systems engineering, systems integration, or cost-performance trade-off analysis)*	2.72	1.93	0	5	18

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CARB

21. Use of Advanced Housing Components and Integrated Systems	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) **Advanced Framing** (stacked framing, 24" construction with 2x6's, SIPs, integrated sheer panels, or insulating sheathing)	1.00	2.000	0	4	4
b.) **Advanced Moisture Control** (foundation water sealing, added or eliminated wall vapor diffusion retarder, foundation water management, or crawl space water management)	.00	.000	0	0	4
c.) **Advanced Insulation** (changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic)	1.75	2.062	0	4	4
d.) **Advanced Air Sealings and Reduced Infiltration** (upgraded sealing & caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances)	2.25	2.630	0	5	4
e.) **Advanced Ventilation** (mechanical ventilation supply and/or exhaust system)	1.00	2.000	0	4	4
f.) **Advanced Space Conditioning Equipment** (downsized, improved efficiency, or multi-speed units; combo hot water & hydronic heating; or programmable thermostats)	1.75	2.062	0	4	4
g.) **High Performance Windows** (improved glazing and framing)	2.00	2.449	0	5	4
h.) **Improved Air Quality** (low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification)	.00	.000	0	0	4
i.) **Optimized Air Distribution** (ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts & transfer grilles)	.75	1.500	0	3	4
j.) **Tightened Ductwork** (duct sealing or hard-ducted returns)	.75	1.500	0	3	4
k.) High Performance Envelope ***plus*** Downsized Heating or Cooling System	.75	1.500	0	3	4
l.) Duct Relocation and Sealing **plus** *Downsized Space Conditioning System*	1.75	2.062	0	4	4
m.) Reduced Air Infiltration or Sealing Package **plus** *Mechanical Ventilation System*	1.00	2.000	0	4	4
n.) Use of Solar Energy **plus** *Increased Efficiency (solar heat or photovoltaic panels + energy efficient design)*	1.25	2.500	0	5	4
o.) System Performance/Quality Control Testing **plus** *Utility Bill Guarantee/Increased Homeowner Warranty*	.25	.500	0	1	4
p.) ***Whole Building Energy Design*** *(systems engineering, systems integration, or cost-performance trade-off analysis)*	.75	1.500	0	3	4

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IHP

21. Use of Advanced Housing Components and Integrated Systems	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) **Advanced Framing** (stacked framing, 24" construction with 2x6's, SIPs, integrated sheer panels, or insulating sheathing)	.00	.00	0	0	10
b.) **Advanced Moisture Control** (foundation water sealing, added or eliminated wall vapor diffusion retarder, foundation water management, or crawl space water management)	.00	.00	0	0	10
c.) **Advanced Insulation** (changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic)	.50	1.58	0	5	10
d.) **Advanced Air Sealings and Reduced Infiltration** (upgraded sealing & caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances)	2.20	2.30	0	5	10
e.) **Advanced Ventilation** (mechanical ventilation supply and/or exhaust system)	1.60	2.37	0	5	10
f.) **Advanced Space Conditioning Equipment** (downsized, improved efficiency, or multi-speed units; combo hot water & hydronic heating; or programmable thermostats)	1.30	1.77	0	5	10
g.) **High Performance Windows** (improved glazing and framing)	.90	1.91	0	5	10
h.) **Improved Air Quality** (low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification)	1.00	2.11	0	5	10
i.) **Optimized Air Distribution** (ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts & transfer grilles)	2.70	2.31	0	5	10
j.) **Tightened Ductwork** (duct sealing or hard-ducted returns)	3.00	2.26	0	5	10
k.) High Performance Envelope ***plus*** Downsized Heating or Cooling System	1.10	2.08	0	5	10
l.) Duct Relocation and Sealing **plus** *Downsized Space Conditioning System*	1.10	2.08	0	5	10
m.) Reduced Air Infiltration or Sealing Package **plus** *Mechanical Ventilation System*	1.20	2.04	0	5	10
n.) Use of Solar Energy **plus** *Increased Efficiency (solar heat or photovoltaic panels + energy efficient design)*	.00	.00	0	0	10
o.) System Performance/Quality Control Testing **plus** *Utility Bill Guarantee/Increased Homeowner Warranty*	.60	1.58	0	5	10
p.) ***Whole Building Energy Design*** *(systems engineering, systems integration, or cost-performance trade-off analysis)*	.80	1.75	0	5	10

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0 = all other response patterns

Hickory

21. Use of Advanced Housing Components and Integrated Systems	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) **Advanced Framing** (stacked framing, 24" construction with 2x6's, SIPs, integrated sheer panels, or insulating sheathing)	.00	.00	0	0	8
b.) **Advanced Moisture Control** (foundation water sealing, added or eliminated wall vapor diffusion retarder, foundation water management, or crawl space water management)	.87	1.81	0	5	8
c.) **Advanced Insulation** (changed insulation location, slab edge or basement insulation, or higher R-value in wall, floor, ceiling, and/or attic)	1.75	2.05	0	5	8
d.) **Advanced Air Sealings and Reduced Infiltration** (upgraded sealing & caulking, continuous air barrier, improved marriage wall seals, or sealed combustion appliances)	3.25	2.12	0	5	8
e.) **Advanced Ventilation** (mechanical ventilation supply and/or exhaust system)	1.50	1.85	0	5	8
f.) **Advanced Space Conditioning Equipment** (downsized, improved efficiency, or multi-speed units; combo hot water & hydronic heating; or programmable thermostats)	.63	1.19	0	3	8
g.) **High Performance Windows** (improved glazing and framing)	.63	1.41	0	4	8
h.) **Improved Air Quality** (low-emitting materials, high efficiency air filters, radon control, combustion appliances outside the thermal envelope, or whole-house dehumidification)	.87	1.81	0	5	8
i.) **Optimized Air Distribution** (ductwork and/or air handlers inside conditioned space, improved duct layout or shortened runs, single central return, or "jump" ducts & transfer grilles)	.63	1.19	0	3	8
j.) **Tightened Ductwork** (duct sealing or hard-ducted returns)	.50	1.07	0	3	8
k.) High Performance Envelope ***plus*** Downsized Heating or Cooling System	1.00	1.93	0	5	8
l.) Duct Relocation and Sealing **plus** *Downsized Space Conditioning System*	.38	1.06	0	3	8
m.) Reduced Air Infiltration or Sealing Package **plus** *Mechanical Ventilation System*	1.00	1.41	0	3	8
n.) Use of Solar Energy **plus** *Increased Efficiency (solar heat or photovoltaic panels + energy efficient design)*	.00	.00	0	0	8
o.) System Performance/Quality Control Testing **plus** *Utility Bill Guarantee/Increased Homeowner Warranty*	.63	1.77	0	5	8
p.) ***Whole Building Energy Design*** *(systems engineering, systems integration, or cost-performance trade-off analysis)*	1.00	1.93	0	5	8

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22. When you received recommendations about new or improved housing technologies from a Building America team, why did you use them? (1 = not important, 2 = important, 3 = very important, 4 = most important)	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) The building scientist provided the necessary data to support changes.	2.80	.85	1	4	59
b.) Changes solved a problem, reduced callbacks, or lowered costs.	2.97	1.04	1	4	60
c.) It was an opportunity to learn about products and practices.	2.55	.77	1	4	65
d.) Changes made our housing more energy efficient/greener.	3.16	.85	1	4	67
e.) The changes made our housing sell better.	2.63	1.01	1	4	59
f.) Changes helped get "Building America" or "Energy Star" label.	2.45	1.10	1	4	65
g.) Other (Avoid upset customers or risk, More affordable housing, Project Criteria – Efficient, make housing sell better - energy cost is still low that consumers are worried more about health)	2.75	.5	2	3	4

23. If, during your project, you did <u>not</u> follow a recommendation from a Building America team, how much did the following factors matter? (1 = not much, 2 = somewhat, 3 = very much, 4 = most of all)	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) Recommended changes appeared too expensive or time-consuming.	2.78	.96	1	4	55
b.) Recommended changes appeared inconsistent with our business plan.	1.45	.77	1	4	49
c.) It seemed too hard to get subcontractors to go along with them.	2.10	1.00	1	4	52
d.) The changes seemed in conflict with existing building code.	1.50	.82	1	4	44
e.) The changes seemed too hard to coordinate with available suppliers.	1.86	.89	1	4	49
f.) Other (Field application often had to be worked out again – theory vs. experience, Followed all recommendations, Impractical technique – lack of acceptance, Local inspector would not allow change, Market ability of new technology - public perception low, New systems require time to incorporate, No market demand, Reducing A/C tonnage to recommended level, Time for ROI long)	3.71	.49	3	4	7

24. If you used an advanced product or technique <u>only</u> during your Building America project, what stopped you from continuing to use it afterward? (1 = not much, 2 = somewhat, 3 = very much, 4 = most of all)	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
a.) It did not achieve the results we expected.	1.72	1.00	1	4	29
b.) Changes were more expensive or time-consuming than expected.	2.57	1.04	1	4	35
c.) Changes were too difficult w/o building scientists assistance.	1.53	.80	1	4	32
d.) It was too hard to get subcontractors to go along with them.	2.12	.96	1	4	33
e.) Existing building code made suggested designs difficult to use.	1.17	.47	1	3	29
f.) Existing supplier relationships could not support the changes.	1.55	.77	1	4	31
g.) Other (All systems now standard and we continue to upgrade, We did not stop using (2), We plan to continue using BA approach, We need the engineering from BA, sold but we still need help on solar side because small builders can't afford)	2.50	2.12	1	4	2

25. Are more of your competitors building "Building America-quality" housing (more durable and using at least 30% less energy) today than in 1995?
(1 = no more or fewer, 2 = only a few more, 3 = several more, 4 = almost all)

Mean	*Std Dev.*	*Min*	*Max*	*N*
2.29	.86	1	4	58

26. Are more of your customers asking for "Building America-quality" housing today than in 1995?
(1 = no more or fewer, 2 = only a few more, 3 = several more, 4 = almost all)

Mean	*Std Dev.*	*Min*	*Max*	*N*
1.88	.86	1	4	64

27. How often does the building code hinder or discourage your use of advanced products or designs like those suggested in Building America?
(1 = never, 2 = less than ½ the time, 3 = more than ½ the time, 4 = every time)

Mean	*Std Dev.*	*Min*	*Max*	*N*
1.79	.73	1	4	62

28. Did Building America make it easier to respond to changes or obstacles in the local building code?
(1 = made it much harder, 2 = made it harder, 3= no diff, 4 = made it easier, 5 = made it much easier)

Mean	*Std Dev.*	*Min*	*Max*	*N*
3.55	.75	2	5	64

29. Did Building America make it easier to coordinate changes in housing with subcontractors?
(1 = made it much harder, 2 = made it harder, 3= no diff, 4 = made it easier, 5 = made it much easier)

Mean	*Std Dev.*	*Min*	*Max*	*N*
3.42	.79	2	5	65

30. Did Building America make it easier to coordinate product or design changes with suppliers?
(1 = made it much harder, 2 = made it harder, 3= no diff, 4 = made it easier, 5 = made it much easier)

Mean	*Std Dev.*	*Min*	*Max*	*N*
3.44	.64	2	5	66

31. How did Building America change your ability to bring new products or appliances into your housing?
(1 = made it much harder, 2 = made it harder, 3= no diff, 4 = made it easier, 5 = made it much easier)

Mean	*Std Dev.*	*Min*	*Max*	*N*
3.67	.58	3	5	70

32. How did Building America change your ability to use an integrated systems approach to building?
(1 = made it much harder, 2 = made it harder, 3= no diff, 4 = made it easier, 5 = made it much easier)

Mean	*Std Dev.*	*Min*	*Max*	*N*
4.03	.67	3	5	64

ALL TEAMS: technical working relationships

Column a

33. Relationship with Others (1): to share technical information, to improve housing performance, to improve construction management, or to develop a new/custom product	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
A.) Building Scientists	.35	.48	0	1	46
B.) Builders/Developers (other than your company)	.24	.43	0	1	46
D.) Subcontractors	.50	.51	0	1	46
E.) Product Supplier, Sales Staff	.46	.50	0	1	46
F.) Product Supplier, Product Design Staff	.26	.44	0	1	46
G.) Employees at the US Dept of Energy	.04	.21	0	1	46
H.) National Laboratories (NREL, ORNL, LBNL)	.07	.25	0	1	46
I.) Utility Company Staff (gas and/or electric)	.22	.42	0	1	46
J.) State or Local Officials (energy or building code)	.30	.47	0	1	46
K.) Homebuilder Association (such as NAHB)	.26	.44	0	1	46
L.) Trade Associations (subcontractor trades)	.13	.34	0	1	46
M.) Financial Community (such as mortgage companies)	.15	.36	0	1	46

Column b

33. Relationship with Others (1): to share technical information, to improve housing performance, to improve construction management, or to develop a new/custom product	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
A.) Building Scientists	1.00	0	1	1	46
B.) Builders/Developers (other than your company)	.46	.50	0	1	46
D.) Subcontractors	.78	.42	0	1	46
E.) Product Supplier, Sales Staff	.76	.43	0	1	46
F.) Product Supplier, Product Design Staff	.59	.50	0	1	46
G.) Employees at the US Dept of Energy	.30	.47	0	1	46
H.) National Laboratories (NREL, ORNL, LBNL)	.22	.42	0	1	46
I.) Utility Company Staff (gas and/or electric)	.41	.50	0	1	46
J.) State or Local Officials (energy or building code)	.46	.50	0	1	46
K.) Homebuilder Association (such as NAHB)	.35	.48	0	1	46
L.) Trade Associations (subcontractor trades)	.20	.40	0	1	46
M.) Financial Community (such as mortgage companies)	.35	.48	0	1	46

Column c

33. Relationship with Others (1): to share technical information, to improve housing performance, to improve construction management, or to develop a new/custom product	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
A.) Building Scientists	.89	.31	0	1	46
B.) Builders/Developers (other than your company)	.46	.50	0	1	46
D.) Subcontractors	.72	.46	0	1	46
E.) Product Supplier, Sales Staff	.72	.46	0	1	46
F.) Product Supplier, Product Design Staff	.57	.50	0	1	46
G.) Employees at the US Dept of Energy	.24	.43	0	1	46
H.) National Laboratories (NREL, ORNL, LBNL)	.24	.43	0	1	46
I.) Utility Company Staff (gas and/or electric)	.33	.47	0	1	46
J.) State or Local Officials (energy or building code)	.39	.49	0	1	46
K.) Homebuilder Association (such as NAHB)	.30	.47	0	1	46
L.) Trade Associations (subcontractor trades)	.22	.41	0	1	46
M.) Financial Community (such as mortgage companies)	.30	.47	0	1	46

ALL TEAMS: institutional working relationships

Column a

33. Relationship with Others (2): discussions or work to change codes and regulations, change product standards, or develop new financing mechanisms	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
A.) Building Scientists	.22	.42	0	1	46
B.) Builders/Developers (other than your company)	.20	.40	0	1	46
D.) Subcontractors	.22	.42	0	1	46
E.) Product Supplier, Sales Staff	.24	.43	0	1	46
F.) Product Supplier, Product Design Staff	.26	.44	0	1	46
G.) Employees at the US Dept of Energy	.00	.00	0	1	46
H.) National Laboratories (NREL, ORNL, LBNL)	.00	.00	0	1	46
I.) Utility Company Staff (gas and/or electric)	.15	.36	0	1	46
J.) State or Local Officials (energy or building code)	.28	.46	0	1	46
K.) Homebuilder Association (such as NAHB)	.17	.38	0	1	46
L.) Trade Associations (subcontractor trades)	.09	.28	0	1	46
M.) Financial Community (such as mortgage companies)	.15	.36	0	1	46

Column b

33. Relationship with Others (2): discussions or work to change codes and regulations, change product standards, or develop new financing mechanisms	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
A.) Building Scientists	.57	.50	0	1	46
B.) Builders/Developers (other than your company)	.33	.47	0	1	46
D.) Subcontractors	.41	.50	0	1	46
E.) Product Supplier, Sales Staff	.41	.50	0	1	46
F.) Product Supplier, Product Design Staff	.37	.49	0	1	46
G.) Employees at the US Dept of Energy	.24	.43	0	1	46
H.) National Laboratories (NREL, ORNL, LBNL)	.09	.28	0	1	46
I.) Utility Company Staff (gas and/or electric)	.22	.42	0	1	46
J.) State or Local Officials (energy or building code)	.46	.50	0	1	46
K.) Homebuilder Association (such as NAHB)	.24	.43	0	1	46
L.) Trade Associations (subcontractor trades)	.13	.34	0	1	46
M.) Financial Community (such as mortgage companies)	.30	.47	0	1	46

Column c

33. Relationship with Others (2): discussions or work to change codes and regulations, change product standards, or develop new financing mechanisms	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
A.) Building Scientists	.46	.50	0	1	46
B.) Builders/Developers (other than your company)	.30	.47	0	1	46
D.) Subcontractors	.37	.49	0	1	46
E.) Product Supplier, Sales Staff	.39	.49	0	1	46
F.) Product Supplier, Product Design Staff	.33	.47	0	1	46
G.) Employees at the US Dept of Energy	.15	.36	0	1	46
H.) National Laboratories (NREL, ORNL, LBNL)	.09	.28	0	1	46
I.) Utility Company Staff (gas and/or electric)	.17	.38	0	1	46
J.) State or Local Officials (energy or building code)	.43	.50	0	1	46
K.) Homebuilder Association (such as NAHB)	.20	.40	0	1	46
L.) Trade Associations (subcontractor trades)	.13	.34	0	1	46
M.) Financial Community (such as mortgage companies)	.24	.43	0	1	46

ALL TEAMS: working relationships

33. Relationships with Others (survey format)	(1) Share technical information, improve housing performance, improve construction management, or develop a new/custom product			(2) Discussions or work to change codes and regulations, change product standards, or develop new financing mechanisms		
	(a) Before	(b) During	(c) Since then	(a) Before	(b) During	(c) Since then
(A) Building Scientists	.35	1.00	.89	.22	.57	.46
(B) Builders/Developers (other than your company)	.24	.46	.46	.20	.33	.30
(D) Subcontractors	.50	.78	.72	.22	.41	.37
(E) Product Supplier, Sales Staff	.46	.76	.72	.24	.41	.39
(F) Product Supplier, Product Design Staff	.26	.59	.57	.26	.37	.33
(G) Employees at the US Dept of Energy	.04	.30	.24	.00	.24	.15
(H) National Laboratories (NREL, ORNL, LBNL)	.07	.22	.24	.00	.09	.09
(I) Utility Company Staff (gas and/or electric)	.22	.41	.33	.15	.22	.17
(J) State or Local Officials (energy or building code)	.30	.46	.39	.28	.46	.43
(K) Homebuilder Association (such as NAHB)	.26	.35	.30	.17	.24	.20
(L) Trade Associations (subcontractor trades)	.13	.20	.22	.09	.13	.13
(M) Financial Community (such as mortgage companies)	.15	.35	.30	.15	.30	.24

Index. A measure of relationship network capacity <u>before</u> working with a Building America team.	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
bef.) summation of question 33 responses in column a (range: 0-24)	4.52	4.51	0	16	46

*Index***.** Changes in relationship capacity, measured as new contacts made during participation in Building America	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
new.) summation of question 33 responses in column b given a negative response in column a (range: 0-24)					

*Index***.** Relationship network expansion, measured in terms of new and retained contacts from participation	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
post.) summation of question 33 responses in column b given a negative response in column a (range: 0-??)					

ALL TEAMS: network expansion index (q33

Index (q33_1abc). Relationship with Others (1): share technical info, improve housing performance, improve construction management, or develop a new/custom product.	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
A.) Building Scientists	1.50	1.33	0	3	66
B.) Builders/Developers (other than your company)	.66	1.12	0	3	65
D.) Subcontractors	.72	1.14	0	3	65
E.) Product Supplier, Sales Staff	.80	1.21	0	3	65
F.) Product Supplier, Product Design Staff	.86	1.26	0	3	65
G.) Employees at the US Dept of Energy	.59	1.00	0	3	65
H.) National Laboratories (NREL, ORNL, LBNL)	.48	1.02	0	3	65
I.) Utility Company Staff (gas and/or electric)	.52	1.00	0	3	65
J.) State or Local Officials (energy or building code)	.48	1.00	0	3	65
K.) Homebuilder Association (such as NAHB)	.35	.86	0	3	65
L.) Trade Associations (subcontractor trades)	.20	.69	0	3	65
M.) Financial Community (such as mortgage companies)	.45	1.02	0	3	65

Index (q33_2abc). Relationship with Others (2): discussions or work to change codes and regulations, change product standards, or develop new financing mechanisms	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
A.) Building Scientists	.85	1.15	0	3	65
B.) Builders/Developers (other than your company)	.40	.90	0	3	65
D.) Subcontractors	.60	1.09	0	3	65
E.) Product Supplier, Sales Staff	.54	1.11	0	3	65
F.) Product Supplier, Product Design Staff	.32	.87	0	3	65
G.) Employees at the US Dept of Energy	.45	.97	0	3	65
H.) National Laboratories (NREL, ORNL, LBNL)	.8	.82	0	3	65
I.) Utility Company Staff (gas and/or electric)	.25	.71	0	3	65
J.) State or Local Officials (energy or building code)	.58	1.09	0	3	65
K.) Homebuilder Association (such as NAHB)	.31	.79	0	3	65
L.) Trade Associations (subcontractor trades)	.15	.62	0	3	65
M.) Financial Community (such as mortgage companies)	.45	1.00	0	3	65

KEY: relationship network (expansion index)
3 = immediate gain (no working relationship before, working relationship during, working relationship since then)
2 = lagged gain (no working relationship before, no working relationship during, working relationship since then)
1 = introduction only (no working relationship before, working relationship during, no working relationship since then)
0 = no perceivable network gain (all other response patterns)

34. Through work with Building America, did you work with groups with whom you normally do not?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = not at all, 2 = only a little, 3= somewhat, 4 = very much)	2.80	.90	1	4	65

35. How much did these new interactions change your ability to use new products or practices in your housing?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = not at all, 2 = only a little, 3= somewhat, 4 = very much)	3.03	.85	1	4	59

36. Did your company make any of the following changes to capture benefits of Building America? (Please mark all that apply.)	*Affirmative Response*	*N*
a.) reassigned responsibilities for site managers	10	55
b.) changed the basis for payment	3	55
c.) offered new incentives to managers	3	55
d.) became more involved in changing building codes	15	55
e.) created training or coordination programs for subcontractors	38	55
f.) changed contract terms for subcontractors	23	55
g.) created or modified an inspection or QA/QC program	42	55
h.) other (became a housing rater, started an employee training program, hired on staff employees to test homes, raised our minimum specifications on HVAC equipment, superintendent training and education)	5	55

*Index***.** Extent of organizational adaptation.	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
all.) summation of question 36 answers (range 0-8)	3.41	1.91	1.0	8.0	70

37. How much have your building material costs changed since working with Building America?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%)	2.48	.71	1	4	65

38. How much have your construction costs changed since working with Building America?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%)	2.55	.78	1	5	64

39. How much has your construction or manufacturing time changed since working with Building America?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%)	3.04	.61	2	5	62

40. How much has the sale price of your housing changed since working with Building America?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%)	2.52	.64	2	4	63

41. How much has the time required to sell your housing changed since working with Building America?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%)	3.12	.33	3	4	58

42. How much has your construction waste volume changed since working with Building America?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%)	3.39	.55	2	5	62

43. How much has the energy use of the housing you build changed since working with Building America?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%)	4.07	.78	1	5	56

44. How much has your overall housing value changed since working with Building America?
(value = durability, affordability, and energy efficiency)
(1 = ↑ more than 20%, 2 = ↑ 1-20%, 3= no change, 4 = ↓ 1-20%, 5 = ↓ more than 20%)

Mean	*Std Dev.*	*Min*	*Max*	*N*
2.32	.94	1	5	59

45. On what percentage of your Building America housing (at least 30% less energy) have you received callbacks?
(1 = over 20%, 2 = 11-20%, 3 = 6-10%, 4 = 1-5%, 5 = none)

Mean	*Std Dev.*	*Min*	*Max*	*N*
3.46	1.37	1	5	28

46. On what percentage of your non-Building America housing do you normally receive callbacks?
(1 = over 20%, 2 = 11-20%, 3 = 6-10%, 4 = 1-5%, 5 = none)

Mean	*Std Dev.*	*Min*	*Max*	*N*
2.88	1.23	1	5	34

47. Overall, what is your opinion of Building America?	*Affirmative Response*	*N*
a.) excellent	42	68
b.) good	21	68
c.) fair	5	68
d.) poor	0	68
e.) very poor	0	68

*Index***.** Overall, what is your opinion of Building America?	*Mean*	*Std Dev.*	*Min*	*Max*	*N*
(1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = excellent)	4.54	.63	3	5	68

48. How could Building America program be more useful? Please give us with suggestions, recommendations, or tell us anything else you think we should know about the program.

Appendix E.

Overview of Teams, Contracts, and Funding

Appendix E-1. Overview of Teams

This appendix describes the Building America Teams. Descriptions of Building America's design can give the impression that its standing teams are self-similar, neatly bundled organizations, whose membership and purpose are well established and relatively easily coordinated. Empirical observation of teams reveals that, although they share the common challenge of recruiting partnership and carrying out housing projects, teams differ in organization, management style, and degrees of interaction among partners. As mentioned in section 5, teams share a mission – to generate and disseminate knowledge about ways to improve housing performance – but differ in both strategy and structure. Additionally, because the team projects and composition evolve over time, the sketches presented here are best interpreted as snapshots in time.

The primary issue that team variation creates for evaluation is a difficulty producing a shared definition of what a team and a project is. The remainder of Appendix E-1 provides detailed overviews of each team to offer some perspective about these differences.

E-1.1 Integrated Building and Construction Solutions (IBACOS)

IBACOS began as a research consortium among several large manufacturing companies and was part of the DOE pilot program that eventually became Building America. Now free-standing, IBACOS, Inc is a for-profit enterprise dedicated to improving the quality of US housing. The company conducts both privately- and publicly-funded research on building and construction technologies and operates an engineering and consulting business. With two-thirds of its business funded by Building America, all divisions of IBACOS are involved in some capacity with the program.

As both a team and a company, IBACOS's learning strategy focuses on a close feedback relationship between technology research and technology implementation in housing. Its Building America funding is split roughly equally between technology R&D on the one hand and technology deployment projects (such as prototype construction) on the other. IBACOS's technology R&D projects seek to advance the performance frontier for housing, while its construction projects support this R&D program.

Virtually all of IBACOS's privately-funded research projects complement the publicly-funded Building America projects. For example, a heating and cooling systems manufacturer may donate equipment that is tested with funds from DOE. What most differentiates IBACOS from the other teams is the way that it fosters collaboration between suppliers and builders. Many suppliers do not view builders as a technologically advanced market. IBACOS helps suppliers to recognize the large role that builders play in appliance selection and stimulates them to learn, through IBACOS, about builders' interests and responses to housing and household equipment.

E-1.2 Building Science Consortium (BSC)

Building Science Consortium (BSC) is led by the Building Science Corporation (BSCorp), a small architectural and building science consultancy with six employees. With renowned expertise in building forensic (failure) analysis, BSCorp offers housing and technology services in building efficiency, durability, and quality. BSCorp relies on a network of consultants across the country to help execute projects. BSC subcontracts work to these consultants to provide on-site assistance to builders. This arrangement has permitted the team to work with a very large and diverse set of builders, materials and equipment suppliers, and technology transfer organizations.

BSC recruits its builder partners and develops projects incrementally. After providing builders with advice about how to solve a particular problem (e.g., numerous callbacks because of mold), BSC collaborates with them on system design studies and prototype construction projects. This collaborative process of "guided discovery" to solve particular problems—such as drywall cracking—generally makes builders receptive to recommendations for improved housing design. If the builder is willing, BSC continues working with them from the prototype project through the production and community scales of housing construction. During these scale-up phases, BSC continues its efforts to improve the design. A housing development generally takes one to three years to build, and BSC works with a particular builder to design plans for the approximately one hundred houses in each development.

Recognizing the tendency to revert to the most familiar way of doing things, BSCorp places particular emphasis on developing innovative strategies that not only increase housing performance, but are also replicable. Throughout its collaborations, BSC focuses on convincing builders that higher housing performance provides many benefits beyond a better environment: more durable housing, fewer callbacks, and greater profitability. In addition to the training it provides through these building projects, BSC has invested substantial resources in workshops that disseminate technologies and techniques to the broader community of builders. They have also conducted housing technology research products, written technical guidebooks to help the industry move practice forward, and developed a publicly-available website.

E-1.3 Consortium for Advanced Residential Buildings (CARB)

The Consortium for Advanced Residential Buildings (CARB) is led by Steven Winter and Associates, an architecture and building science firm with seventy employees. Steven Winter and Associates also serves as the technical consultant for this consortium. CARB has worked with many builders and usually has about six active projects at any given time. Compared to other teams, CARB's builder partners are relatively large. CARB often works with multiple divisions of its builder partners on different projects, so its reach is somewhat broader than these numbers suggest.

CARB's strategy is to produce evidence that technological innovations will work in practice. The team leader believes that builders are risk-averse. CARB focuses on developing partnerships at the top levels of organizations, and establishing credibility to secure collaboration in prototype construction projects.

CARB does not redesign housing incrementally (i.e., compared to other teams "toe-hold" strategy). Instead, CARB seeks to re-engineer the total system that a builder uses to make a house. This methodology requires substantial buy-in from the builder from the outset. Compared with other teams, CARB is more of a systems integrator of existing advanced technology than a developer of new discrete technologies.

E-1.4 Industrialized Housing Partnership (IHP)

The Industrialized Housing Partnership (IHP) is operated by the Florida Solar Energy Center (FSEC), a research extension of the University of Central Florida[30]. IHP differs from the other five Building America teams both administratively and financially. The Golden Field Office (GFO) oversees it, and it has a more generous 80-20 cost-shared financial assistance agreement, not a 50-50 contract. The team supplements its DOE income with funding from the Florida Energy Office in the Florida Department of Community Affairs, the Northwest Energy Efficiency Alliance (NEEA), and industry partners.

FSEC has a small staff and relies extensively on subcontracted housing specialists to extend the reach of IHP. The team has also developed a long-standing partnership with Washington State University's (WSU) Energy Program, which conducts research and provides guidance for a public-private program in the Pacific Northwest called "Super Good Cents." Thus, the technical leadership of IHP is centered at FSEC includes subcontracted building experts and research staff at WSU.

FSEC neither refers to itself as the "team leader," nor to IHP as a "team." FSEC consider its "team" to be the collection of consultants who advise builders about design and construction. Its industry partners are considered "clients," rather than team members. Builders and manufacturers are likely to interpret the term "Building America team" to referring to the network of technical organizations which provide government-funded consulting services and view themselves as "working with the folks from Building America." Terminology aside, IHP primarily works with builders and housing manufacturers. Although suppliers have been somewhat involved, in IHP they work to forge marketing relationships to builders, and do not participate in housing research. IHP concentrates on improvement to industrialized housing, which includes manufactured, HUD-code, and modular housing, as well as other mobile buildings, such as portable classrooms. In a December 2001 report, they list the following goals for their team:

- Cost-effectively reduce the energy use of industrialized housing by up to 50% while enhancing the indoor air quality, building durability, and construction productivity
- Assist in the construction of thousands of energy efficient industrialized houses annually (with over 11,000 homes constructed in the first two years)
- Make our partners pleased and proud to be working with us.

To attain these goals, IHP carries out housing design research, testing and monitoring studies, and builder technical assistance. Shaped by the requirements of their funding agreements and FSEC's academic affiliations, IHP conducts more housing performance studies and longer-term research projects than other Building America teams.

[30] Prior to creating a specific role for manufactured and modular housing in Building America, DOE operated an Energy Efficient Industrialized Housing (EEIH) program for years, funding it through an annual line-item. In 1999, DOE decided to add industrialized housing to Building America and put out a competitive solicitation for a team to influence the design and construction of this housing segment. Already a participant in EEIH, the Florida Solar Energy Center won the contract for this team.

IHP works concertedly with housing manufacturers on ways to improve not just the quality (e.g., energy-efficiency, durability) of their buildings but also their production efficiency on the factory floor. The purpose is to teach manufacturers how to test and learn from their own designs. FSEC explains that its client-needs orientation keeps IHP focused on providing work of value to their partners.

E-1.5 Hickory Consortium

The Hickory Consortium was led by a board of directors composed largely of self-employed professionals,[31] rather than a single company. In 2002 DOE chose not to renew the Hickory Consortium's contract with Building America. Until then, DOE issued funds to one of the board members, who served as the official team leader, and the Hickory Consortium reallocated this funding to other members. This decentralization allowed the Consortium's agenda to be broader than those of the other teams, but it was also less integrated.

The Hickory Consortium's Building America projects emphasized affordable and environmentally superior housing. They largely worked on urban infill community (multi-family) housing or co-housing in the greater Boston Area. They also invested in studies of modular housing manufacturers, an industry segment with potential but without a strong economic footing.[32] In addition to collaborating with builders to redesign, build, and test housing performance, and working with suppliers to develop enabling technologies, Hickory sought to build institutions with the potential to transform modular manufacturing and urban redevelopment.

Much of Hickory's institutional work concentrated on creating fora in which housing industry actors could collaborate. For instance, Hickory helped to set up the Quality Modular Task Force (QMTF). In addition to Hickory's board members, the QMTF includes eleven modular manufacturers (who constitute fifty percent of US modular house manufacturing capacity), nine suppliers to those manufacturers, and, on an intermittent basis, consultants, trade journalists, and educators. The group has held quarterly to semi-annual meetings, which allow builders to discuss concerns technology concerns that they can not communicate about through the market. A Hickory report states that "[QMTF members and participants] said that the opportunity to meet together, apart from national meetings of industry associations, and share information was one of the key reasons they are interested in the Task Force. They said they had no other opportunities like this."

Similarly, in its work with developers of multi-family housing projects, Hickory sponsored a series of roundtable meetings that complemented its effort to diffuse building systems design concepts. The goal of these discussions was to identify ways to open learning channels in the building process to communicate about, correct, and learn from mistakes. As another avenue to improve organizational intelligence, Hickory conducted research projects on tools for builders. For example, the team conducted research on the life-cycle impacts of construction materials and developed schema to identify low environmental impact product choices. Labeling them

[31] The team leaders has included building engineering consultants, architects, housing manufacturers, an HVAC experts, urban planners, and marketing professionals.

[32] Modular housing manufacturing is the construction of housing subassemblies in a factory and the later installation (generally by another company) at a building site.

"EcoDynamic Specifications," Hickory developed these tools to help builders purchase higher quality, environmentally superior materials.

Like the other teams, the Hickory Consortium has engaged in a variety of technology innovation-spurring projects, ranging from systems dynamics modeling to industrial engineering studies of shop floors to trial-and-error prototype design. However, compared to the other teams, the Hickory Consortium built fewer prototypes and oversaw the construction of fewer housing units. In part, this smaller number of building projects was a function of their smaller team size, smaller Building America funding level, and technology development efforts. However, the real difference, and perhaps the reason why their contract was not renewed, is the team's lesser emphasis on iterative learning from building projects and greater emphasis on improving institutional capacity, shared communication, and information webs for learning.

E-1.6 NREL Team[33]

Building America contains a sixth team, which was not included in this analysis because its mission and scope was so different from the other teams. Led by NREL, this "building prototype" team serves a different set of builders: those who build custom, high-performance houses. The NREL team's projects thus involve more "radical" technologies like passive solar design or renewable energy systems and focus on research and development with little or no emphasis on deployment of new technologies. The team composition also differs from the other teams in that the home buyer is generally present and involved through the home design and building process.

[33] This "NREL Team" initiative could constitute a "sixth team." However, the extent of this team's activities have been relatively minor compared with the other five Building America teams, and for this reason they were omitted from this program study.

Appendix E-2. Team Task Ordering Agreement

This appendix discusses the contracts established between DOE and the industry teams. The terms of this contract discussed in this section cover only the four industry teams that NREL oversees: IBACOS, BSC, CARB, and the Hickory Consortium. The contract relationship between the GFO and the team called IHP is less specific.

Subcontract: standard task ordering agreement with "specific deliverables, quantities, due dates, reporting requirements, and addresses [as specified] in the Statement of Work for each Task Order."

Process (as specified in the TOA)

1. NREL requests a proposal from (team) for each Task Order.
   a. technical proposal (acceptance of statement of work and a technical discussion about how the subcontractor proposes to accomplish it)
   b. proposed timeline, including deliverables
   c. cost proposal (direct materials, direct labor, fringe benefits, labor overhead, special equipment, travel, consultants, lower-tier subcontractors, other direct costs, general and administrative expense)
   d. organizational conflicts of interest
2. NREL review of proposal and negotiation between NREL and Subcontractor
3. NREL issuance of Task Order (binding subcontract)

The text below is excerpted from the team task ordering agreements written with NREL. Any emphasis in the text has been added.

Statement of Work (Appendix A of Team Task Ordering Agreement)

1.0 Objective
The objective of the Building America Program is to apply systems engineering approaches to the development of advanced residential buildings, including production techniques, products, and technologies that result in higher quality, energy-efficient housing. The primary market sector for this effort is new residential buildings that are single-family detached houses and attached townhomes.

2.0 Purpose
The purpose of this work effort is to continue the DOE and NREL systems engineering partnership with [team leader name] and [team name] industry team, focusing on development of next generation energy systems in test/prototype houses, evaluation of cost and performance trade-offs in preproduction homes, and resolution of barriers to community-scale implementation of systems innovations.

3.0 Background
3.1 Building America Goals

- accelerate implementation of advanced building energy systems in new residential construction through development and application of systems engineering with cross-cutting industry teams

- develop innovative technologies and strategies that enable the US housing industry to deliver environmentally sensitive, quality housing on a community-scale while maintaining profitability and competitiveness of homebuilders and product suppliers
- deliver 50% reduction in energy consumption (on average, depending on climate), 50% reduction in construction site waste, 25% increase in use of recycled materials, increase labor productivity, and reduce construction cycle time

3.2 Program Description

Building America is an industry-driven, cost-shared program sponsored by DOE. Field support is provided by NREL. The program participants include residential builders, architects, designers, material suppliers, equipment manufacturers, subcontractor trades, financial institutions, and related organizations. Under the Building America Program, DOE has established (through NREL) multi-year cost-sharing agreements with four housing industry teams. These four teams are comprised of more than fifty companies and organizations including a number of Fortune 500 corporations and several top-ten US homebuilders. **DOE/NREL provides the funding for research, technology development, and evaluation through the Building America Program. All construction material and labor costs are funded by the private sector industry team members.**

The mission of the Building America teams is to accelerate the development of residential energy innovations using systems engineering approaches. A systems approach for development of advanced residential buildings is defined to be any approach that comprehensively analyzes design, delivery, construction, business, and financing processes and performs cost and performance trade-offs between individual building components and construction steps that produce a net improvement in overall building performance. A systems approach includes the use of systems engineering and operations research techniques and requires integrated participation of all the industry team members.

Each Building America project is expected to contribute to the development of a new paradigm for delivery of energy-efficient, quality housing based on the use of systems engineering approaches. The approaches should reduce the time required to bring new products and systems to market and the waste produced during housing construction while increasing energy performance, construction productivity, use of recycled materials, and the Unites States' globally competitive position in advanced housing materials and components.

The Building America Program is intended to complement, not duplicate, current development of advanced building systems. Accomplishment of the program objectives will best be achieved by team arrangements that utilize the outstanding US capability in building and construction technologies, including the creativity of small business.

3.3 Long-term Objectives

The long-term objectives of the Building America Program is to transfer major systems innovations developed by program participants to 15,000 houses within five years and 70% of new homes within ten years. It is estimated this will reduce energy use by 0.03 quads per year, produce savings of a quarter billion dollars per year in reduced utility bills for customers, and reduce carbon emission by 0.6 million metric tons annually.

3.4 Building America Program Strategy
The ultimate success of the Building America Program is based on the linkage that systems engineering approaches establish between:

- industry-driven development of next-generation building systems that improve housing performance, and
- system integration requirements that are identified by comprehensive cost and performance evaluations in test houses, preproduction houses, and community-scale developments.

The program achieves its goals through an iterative contracting process between the industry teams and DOE/NREL. Program results and potential barriers are reported on a regular basis through team meetings, site visits, discussions of intermediate test results, and semi-annual presentations to NREL and DOE. The program's early successes are attracting the interest of industry leaders who will apply the Building America approach to developments of hundreds of additional single-family and townhouse units. To take advantage of this interest, the Building America industry teams will continuously evolve and possibly increase their membership from the residential building industry so that the number of new buildings influenced by the program continues to grow.

The final products of each project will be performance measurement and cost/performance evaluations in test/prototype houses, preproduction homes, and community-scale developments. These measurements and evaluations will lead to development of innovative system concepts that can be applied on a production basis by the homebuilders involved in the program. Innovative system concepts include HVAC components, enveloped materials, mechanical and lighting systems, and design and construction strategies.

3.5 Key Customers and Stakeholders
The Building America Program systems engineering focus is designed to accelerate innovation by bridging the fragmentation between manufacturers, suppliers, designers, builders, and building trades. Residential construction and business practice innovations developed by each Building America team are first available to those industry members participating on the team. Program solutions and results are further disseminated to the industry at national building conferences (e.g., National Association of Home Builders, Energy Efficient Building Association, and the Westerns Building Show), in the energy efficiency and building trade press, and in the home section of regional newspapers. By catalyzing this technology integration process in the home building industry, the Building America Program ultimately benefits housing consumers through the development of energy-efficient, higher quality homes.

3.6 Key products resulting from Building America include

- new envelope and energy systems
- new production processes optimized between factory and site-building strategies
- increased energy efficiency in test houses, preproduction homes, and community-scale housing developments,
- performance data from field evaluations of test houses, preproduction homes, and community-scale housing developments, and
- case studies detailing results of performance and cost trade-off studies

4.0 Participation Requirements

4.1 Team Composition

The subcontractor team shall have sufficient breadth to include all major types of companies involved in design, construction, and delivery of typical US residential building including equipment, component, and material manufacturers. At a minimum, the team must have at least one industry member with demonstrated design capability, one industry member with building material expertise, and one industry member with building equipment design and manufacturing capability. **The subcontractor is encouraged to evolve, and possible increase, the breadth of industry team members during the project**. Team members are required to directly contribute to the overall performance requirements of the team, including completion of systems engineering studies, evaluations of housing systems and components, modification of building designs and material/equipment performance, evaluations of business practices, and price participation.

4.2 Price Participation

It is required that price participation by the team be 50% of overall project cost over the lifetime of the program. DOE/NREL's portion of the price shall not include capital equipment or construction labor. The price participation of the subcontractor, lower-tier subcontractor, or team member shall provide 100% of the funding for all construction materials and supplies, equipment and construction labor. In-kind price participation, such as currently owned equipment, supplies or real property (land and buildings) shall not be accepted as satisfying the requirements of price participation.

4.3 Systems Engineering Studies

The subcontractor and team are required to conduct comprehensive systems engineering studies that evaluate opportunities to improve housing performance and overcome barriers to adoption of housing innovations. Studies must cover the range from initial test house evaluations through to community-scale implementation in production housing. Studies must also include a series of design, test, redesign, and retest iterations using feedback from the testing phase to guide redesigns. Throughout this systems engineering process, the subcontractor is required to ensure that project participants receive the feedback required to modify their designs and production methods.

The subcontractor and team members shall evaluate their progress relative to the program's 50% energy performance goal using validated energy analysis and whole-house energy testing methods (subject to approval by DOE/NREL). The team members shall also provide access to unoccupied prototype and basecase houses as needed for testing and evaluation by NREL. As part of their cost and performance evaluations, the team members shall be encouraged to reinvest cost savings identified during systems engineering studies into advanced systems that improve the overall energy performance, sustainability, and comfort.

4.4 Team Coordination

The subcontractor shall coordinate with other Building America industry team leaders on team composition, team member participation, and related team activities to ensure that work proceeds on a collaborative basis. The industry teams are encouraged to work together on related projects when it makes the best use of their combined resources.

5.0 Scope of Work
This Task Ordering Agreement will support work by the Building America industry team leader on systems approaches to the development of advanced residential buildings. The industry team will conduct performance studies and analysis on full-scale system mockups, test houses, preproduction houses, and community-scale developments. The work will apply lessons from projects completed under the initial Task Ordering Agreement and extend the team's activities to include additional system concepts, project locations, and industry team members. The task orders to be negotiated under this Task Ordering Agreement will include, at a maximum, four years of systems engineering studies.

In performing activities under this Task Ordering Agreement, the subcontractor shall comply with applicable rules and regulations of Occupational Safety and Health Administration (OSHA) and state and local governments concerning environment, safety, and health. The subcontractor shall also obtain all applicable and required permits for the conduct of their work.

The work to be performed under the task orders will be based on individual proposals from the Building America industry team for "[project title]." Task Order proposals shall be submitted with a detailed description of the scope, objectives, background, project activities, schedule, and costs.

5.1 Technical Scope
Proposed work shall focus on analysis of system performance and cost trade-offs as they relate to whole-building performance and cost optimization, including interactions between advanced envelope designs, mechanical systems, electrical systems, and appliances.

These performance evaluations will require the construction of test houses, preproduction homes, and community-scale developments. It is expected that successful deployment of innovative building systems will require the development of new manufacturing and delivery systems to maximize overall quality and productivity. Proposed work must range from component development to community-scale production of whole buildings, including modification and retesting of components and systems based on feedback from builders, trades, and code officials.

Individual task order proposals shall address the impact that advanced housing systems will have on whole-building affordability, quality, energy performance, and resource use. Specific topics to be addressed include the following:

- energy efficiency
- acceleration of the innovation process in production housing
- home affordability and value
- utility and maintenance costs
- construction cycle time and trade labor productivity
- international competitiveness in housing technology
- integrated housing components designed to reduce manufacturing and construction costs
- new building practices and building components that…
  …reduce the generation of solid waste in the building process
  …eliminate the use of CFCs and other ozone-depleting substances
  …reduce environmental emissions from in-situ energy-consuming equipment and off-site material and product manufacturing processes
  …minimize the stress on US natural resources
- quality control strategies to ensure that system performance is not degraded during the construction process
- training on innovative systems for trades, builders, manufacturers, and code officials

5.2 Whole-Building Energy Performance
The performance of energy-efficient housing varies significantly depending on climate, design, construction quality, and occupants. Energy performance is determined by complex interactions between enveloped loads, internal gains, and building equipment. Energy and resource measurements ensure a high standard of performance in the advanced building system concepts developed by subcontractor team.

To provide rapid feedback in the systems engineering process, performance testing shall include short-term energy measurements of the building envelope, conditioning equipment, and appliances. Short-term energy performance tests shall be conducted soon after the test house or preproduction houses are complete, in side-by-side tests, under unoccupied conditions, and with technical support from NREL. Short-term energy performance measurements include shell loads, thermal capacitance, solar gains, effective leakage area (blower door), air exchange rate (tracer gas), duct leakage, infrared imaging, and HVAC system efficiencies. Energy performance analysis shall include an evaluation of reductions in energy loads and energy use benchmarked against the builder's standard practice and the HERS reference house.

As the program moves from evaluation of individual and preproduction test houses to community-scale construction, short-term testing will be complemented by long-term data collection and utility bill analysis. In addition, specific performance tests (i.e., indoor contaminant concentrations and moisture transport in insulation) shall be conducted by the subcontractor to evaluate the achievement of specific team performance objectives.

In addition to energy performance measurements, the team must also address the development of simple quality control test methods to help builders verify that advanced system concepts are correctly installed on a production basis. All measurement techniques shall include an analysis of estimated errors including systematic and experimental contributions to total error (random and bias errors). Access shall be provided to prototype and basecase residential buildings as needed for testing, auditing, and evaluation by NREL.

Proposals for specific task orders will be expected to address performance measurements in the following areas:

5.3 Resource Use
The project shall include measurements of the impacts of standard and advanced building systems on whole-building water use, use of recycled or alternative materials, and production of construction waste.

5.4 Productivity and Affordability
The project shall include measurements of impacts of standard and advanced systems on whole-building construction productivity and affordability. Cost impacts of system changes, including labor, material, and waste cost, shall be measured during construction to evaluate overall cost and performance trade-offs.

6.0 Project Activities
The following activities shall be included in specific task orders:

6.1 Strategic Planning and Reporting
The subcontractor shall develop strategic plans and establish the industry partnerships required to conduct systems engineering studies on advanced residential buildings. The subcontractor shall also provide general program planning and reporting support. Key industry team members shall attend DOE/NREL planning meetings to review progress and maintain technical coordination. The subcontractor shall produce a monthly report that summarizes progress in ongoing projects. The subcontractor shall establish strategic priorities for product development requirements and industry partner needs based upon results from systems research. The subcontractor shall track and report partner company programs that support implementation of advanced system concepts. The subcontractor shall review market trends and opportunities for advancing housing systems, especially in the area of energy efficiency. The subcontractor shall review the industry team progress relative to team member goals and Building America Program objectives.

6.2 Requirements for Development of Advanced Residential Building Systems
Using a systems approach, an evaluation of technical and market requirements for advanced residential building systems will be conducted. The evaluations completed under this task shall include determinations of expected cost and performance trade-offs produced by the advanced systems and expected interactions between components and systems when they are introduced into whole buildings. The evaluations shall also include specification of performance measurements and quality control testing to ensure that technical and market requirements have been met.

6.3 Test and Production Houses
Test and preproduction houses shall be built to measure energy performance, construction characteristics, and interactions between advanced system concepts, including an evaluation of the integration success of the design and construction process. The measurement approaches used in the test and preproduction houses shall provide the ability to make direct performance, productivity, and cost comparisons between conventional and advanced system designs.

6.4 Advanced Production and Delivery Processes
The subcontractor shall evaluate and resolve potential barriers to adoption of advanced residential building systems, including construction processes, training requirements, operation and maintenance issues, codes and standards, and other building industry infrastructure issues that limit widespread adoption of advanced system concepts. It is anticipated that this evaluation will require the construction of multiple-house developments as part of the industry team price participation consistent with the limitation on use of DOE/NREL funds. This task shall include measurements of the performance impacts of advanced production and delivery processes. The evaluations completed under this task shall include a recommendation for the optimum commercialization path for the advanced systems developed under the program including definition of requirements for industry partners, training, codes and standards, performance, cost, and financing.

6.5 Technology Transfer
The subcontractor shall propose and implement strategies for transferring systems technologies and advanced residential building systems developed by the team to a broad residential construction industry audience. Tasks may include seminars, plan reviews, demonstration programs, and other technology transfer activities. The subcontractor shall include a method for tracking the impact and effectiveness of these activities.

7.0 Deliverables
Deliverables will be specified in the statement of work for each task order issued under this TOA. Following are examples of deliverables that will be included within individual task orders.

7.1 Strategic Planning and Reporting
The subcontractor shall report on the development of new project opportunities, evolve and possibly expand participation of industry team members, conduct strategic planning and project review meetings with team members and DOE/NREL, attend program reviews and technical updates, and prepare and update time-phased activity plans. Specific deliverables and activities include:
- monthly reports
- strategic planning and team meetings summaries
- participation in program reviews (including handout materials)
- conference presentations
- project schedules

7.2 Requirements for Development of Advanced Residential Building Systems
The subcontractor shall report on evaluations of all products, systems, and processes needed to complete fully integrated and flexible advanced housing systems that meet user and industry needs. Reports should specify performance targets and discuss all design, fabrication, cost, and performance measurements that are required to integrate advanced housing products, components, and systems. Results of these activities include:
- reports on system design iterations and expected performance benefits of advanced systems
- technical papers
- reports on next generation systems
- reports on technical and market barriers to adoption of advanced systems
- reports that evaluate the results of large-builder, small-builder, and technology-based initiatives

7.3 Results of Test and Preproduction House Design, Construction, and Evaluation
The subcontractor shall prepare reports on the design, construction, and evaluation of advanced system concepts in test and prototype houses, including design drawings, evaluation of the construction process, cost comparisons, and results of test/prototype house performance measurements. Information to be produced includes
- system and house test plans
- system and house performance evaluations
- system and house cost evaluations
- case studies on systems and houses
- reports on consumer and builder value produced by systems approach

7.4 Advanced Production and Delivery Process
The subcontractor shall develop production and delivery processes that facilitate adoption of advanced systems conceptions produced under previous tasks. This development process will include resolution of barriers that limit community-scale adoption of advanced systems concepts and evaluation of impacts on the housing performance characteristics. Reports should include recommendations for optimum manufacturing and delivery processes required to accelerate adoption of advanced technologies. Deliverables include
- reports describing advanced production and delivery processes

- design, cost, and performance requirements for community-scale implementation
- integration of advanced system concepts with building and zoning codes

7.5 Technology Transfer

The subcontractor shall develop and implement strategies for transferring systems technologies and advanced residential building systems developed by the team to a broad residential construction industry audience. Specific activities and results include:

- industry/technology conference planning and evaluation
- internet materials
- advisory outreach

7.6 Task Order Price Summary (TOPS)

The subcontractor shall submit an initial TOPS within one month after the award of each task order. The subcontractor shall also submit a TOPS halfway through and at the conclusion of each task order award. The planned and actual cost commitments shall be broken down to reflect cost/price commitments being funded by the DOE/NREL under the subcontract and those cost commitments funded by the project team members. If the variance between planned and actual commitments is greater than 10%, the subcontractor shall also submit a letter explaining the variances and indicate any potential or current problems and the impact to subcontract performance. This report shall also include:

- update of team membership status
- team member commitment letters
- summary of price participation provided by the team members
- update of housing inventory report

Appendix F.

Team Reporting and Project Summary Examples

Appendix F-1. Example of Team Reporting

This appendix offers two examples, both from the team CARB, of periodic internal Building America reporting about projects and progress. The reader is encouraged to read this section to understand the depth and breadth of information being communicated.

F-1.1. CARB work with Builder A (hot-humid climate)

The following are the monthly summaries from late 1998 through mid 1999 that describe CARB work with builder partner Builder A.

> 8.31.98
>
> Early in July project manager Don Clem met with Joe Campus of Builder A in (hot-humid climate) to discuss potential areas of exploration for the Builder A Building America prototype. During the trip information was gathered on Builder A's typical buyer demographics, the current building methods practiced by Builder A, and the designed areas for change in Builder A's product. A one story slab on grade home of approximately 1700 square feet, called the Bristol, was decided upon as the basis for the prototype. Results of NREL's on-site testing of a comparable model from July 7-14 also helped to focus the areas of the CARB effort with Builder A. Through the discussions with the builder, and results from the testing, it is anticipated that indoor air quality, accessibility, and the use of green materials will be part of the focus of this CARB effort. Builder A may also be interested in looking at community-scale issues, such as neo-traditional town planning. Marketing issues related to these areas of investigation are also to be considered. The Builder A prototype is scheduled to being construction in January of 1999.
>
> 9.18.98
>
> As discussions continue with Builder A indoor air quality and healthy home issues have been investigated further. Consideration was given to possibly building the Builder A prototype as an American Lung Association Health House. The Health House program has stringent requirements, which the CARB team felt would drive up the cost of the prototype beyond a reasonable limit for a first-time homebuyer. There was also discussion of the typical buyer of Builder A. It seems that most are young couples and families, and relatively few are of retirement age. For Builder B to incorporate the innovations of the Building America prototype into a standard model, these innovations need to be marketable. Ideas were brought up that while young couples may not be particularly concerned with IAQ in relation to themselves, they would be with regard to their children. This brought about a general discussion of the issues of indoor air quality and green materials as they relate to energy efficiency and home buyer desirability. SWA decided to survey different green builder programs in the nation as well as different indoor air quality programs. This overview is intended to be used to inform IAQ issues in all of the CARB prototypes. The handling of on-site waste and the potential for increased recycling is also slated to be investigated with Builder A.

10.5.98
Further development of the Builder A home plan has resulted in a design with fewer exterior corners, more easily framed partitions, and more efficient accommodation of the HVAC system. An issue project architect Don Clem would like to investigate in this home is the effect of bringing the ductwork inside the thermal envelope. Part of the distribution system will be brought down into the house through the use of boxed out soffits, while other areas will have ductwork buried in insulation in the attic. This way a comparative test of efficiency can be executed within the same house. The prototype will also use a dehumidification system, which will significantly reduce the latent load to be handled by the AC system. After reviewing different green builder programs, the Denver Green Builder Program will most likely be used as a guideline for the materials used in the Builder A prototype. Next steps for this project are to present candidate concepts and optional floor plans to the builder prior to the CARB meeting in Houston.

11.5.98
Project manager Don Clem presented an update on the Builder A project at the [October 14 and 15 CARB meeting in Houston]. Thomas Stokes, the sales manager for Builder A in Mobile, AL gave an overview of Builder A's current practices and their desire to embrace innovation in the CARB prototype. The prototype will be based on Builder A's Bristol model, an approximately 1200 square-foot single story home built on a slab. Currently, Builder A builds a 16" o.c. double top plates and roof trusses. Mr. Stokes related that in the past Builder A used panelized construction with less than ideal results and created a strong resistance to this method in their area. Don Clem discussed several of the candidate concepts for the Builder A project, including SIPs, steel framing, autoclaved aerated concrete (AAC) and engineered wood. The current mechanical system used by Builder A is a gas furnace and electric air conditioner, both of standard efficiency, with ductwork in the attic. Possible options being considered for the HVAC system were presented by Dianne Griffith and include a combination system, an air source heat pump, a ground source heat pump, and an AC unit specifically designed for dehumidification. Dehumidification is a real concern for Builder A, being that the latent load in (hot-humid climate), where the prototype will be built, is significant. Mr. Clem wants to study the issue of condensation in attic insulation when the ductwork is placed below the insulation. To do this he is proposing that two-thirds of the ductwork in the prototype be brought down into the conditioned space, while one third remain in the attic and be placed below the insulation. The insulation surrounding the buried ductwork will be monitored for moisture to see if, in fact, condensation does develop. Builder A has expressed a great interest in "green" building materials an indoor air quality. A matrix comparing Builder A's current practices with the Denver Built Green program was presented as a way to evaluate possible changes in materials selections Builder A might want to make for greater adherence to this widely recognized program. The Builder A prototype is scheduled to begin in January.

12.5.98
Project manager Don Clem is planning to meet with Joe Campus at the Builder A office in (hot-humid climate) in early December. Ideas that were presented at the Houston CARB meeting have been further researched and refined for review by Mr. Campus.

1.5.99
CARB met with Joe Campus at Builder A and presented a redesigned floor plan of Builder A's Bristol model. Builder A was pleased with the design and requested that additional elevations be developed for it. Builder A is still very interested in dealing with green issues in the prototype and will continue to develop their own "green" program with the help of the CARB team. CARB is going to look at the cost and efficiency issues associated with gas versus electric energy in the prototype, being that gas is quite expensive in the (hot-humid climate) area ($1.15/therm). Discussions have begun with Simpson Strong Tie to consider what changes can be made to Builder A's typical framing practices to reduce the amount of lumber used while still adhering to stringent wind load requirements. The prototype is planned to begin construction in March.

2.5.99
Builder A has been sent follow up plans with suggested design revisions that have been incorporated into the "(new housing model)." It is still anticipated that the Builder A prototype will be started in the early spring.

3.5.99
Further refinements to the Builder A plan have resulted in the use of a Unico mechanical system with a heat pump. The Unico system allows small 3" diameter ducts to run within interior walls for air distribution. A main trunk link is being incorporated into a plant shelf at 8' above the finished floor. From this trunk line, room supplied will be fed through partition walls. This allows this slab-on-grade prototype to have all the ductwork within the conditioned space without boxing out soffits below the ceiling line to accommodate them.

4.15.99
The Builder A prototype is being examined for resistance to wind loading and hurricane uplift by CARB team member Simpson Strong Tie. The prototype may also use a new wind-resistant siding product made by Owens Corning. CARB is planning to use Studor plumbing vents and self-contained electrical devices (SCDs) for added labor savings in the field. Further refinements to the Builder A plan have resulted in the use of a Unico mechanical system with a heat pump. The Unico system allows small 3" diameter ducts to run within interior walls for air distribution. A main trunk line is being incorporated into a plant shelf at 8' above the finished floor. From this trunk line, room supplies will be fed through partition walls. This allows this slab-on-grade prototype to have all the ductwork within the conditioned space without boxing out soffits below the ceiling to accommodate them.

F-1.2. CARB work with Builder B (cold climate)

The following are the monthly summaries from late 1998 through mid 1999 that describe CARB work with builder partner Builder B.

8.31.98

Builder B, a medium-sized builder member of the CARB team, was visited by SWA to collect information on the builder's areas of interest and potential ideas for improvement of their current practices from an energy standpoint. At this initial meeting, a model was decided upon for reworking by the CARB team. This model…is a two-story, three or four bedroom house ranging from 1500 to 1800 square feet. The CARB team is reworking the plan considering structural, mechanical, and layout issues, as well as energy efficiency.

9.18.98

SWA was visited by Builder B's New Product Development Specialist early in August. The goal of the meeting was to show him the three prototype schemes developed at SWA based on the existing Builder B (redesigned) model. Each design had to be able to accommodate a centralized mechanical distribution system, be adaptable as either a three or four bedroom house, have a cathedral ceiling in the family room, and an improved thermal envelope. Secondary goals for the plan included consolidating the plumbing preferably on interior walls and incorporating cold weather construction techniques. Many different materials were to be considered for the prototype, including autoclaved aerated concrete for the foundation, structural insulated panels possibly in combination with steel studs for the walls, engineering wood I-joists for the floors, structural insulated panels for the roof, and recycled-content windows. Plans of each scheme were presented and discussed at length during this day of meetings. With regard to mechanical systems, Builder B noted that their homes are often built with heating only, rather than automatically including air conditioners because of the generally cool (cold climate) summers. This would need to be considered in the design of the system. It was also realized that because home design could have three or four bedrooms, the mechanical system would have to be easily adaptable to that load change. Following the meeting, the Builder B representative returned to (cold climate) with plans and elevations of all three schemes, for discussion within his office. Builder B settled on one of the schemes within two weeks, at which time SWA met with them to discuss further refinement of the design. By the end of August, more detailed discussions regarding the mechanical system, layout adjustments, and potential construction materials and assembles were taking place.

10.5.98

The Builder B design is adaptable for both low and high density development. Essentially it can be used as a single family detached or a duplex or fourplex unit. The prototype will be built as a single family detached home. The exterior walls will be made of structural insulated panels, as well as certain roof sections and the floor of the master bedroom suite over the garage. As part of a passive cooling strategy, there will be an operable skylight in the stairway hall ceiling to optimize stack effect ventilation. The house will use a high efficiency 2-stage gas furnace. The foundation wall will be a precast wall system as a cold weather construction strategy, much in the way that a precast system was used for (another builder partner's) basement. Construction documents are slated to be done in October and construction to begin on December 1, 1998.

11.5.98
Project manager Paul Romano presented an update on the Builder B project at the [October 14 and 15 CARB meeting in Houston]. He reviewed Builder B' objective for the prototype, including their desire to be a regional leader in "green" construction materials and practices and to develop a prototype that was similar to their best-selling model, value engineered for cost savings. He went on to present the scheme that had been developed for the prototype showing its flexibility as either a 3 or 4 bedroom plan and its efficient use of circulation space. The section of the house showed the clever use of the stairway area, serving to bring in daylight and function as a passive cooling element with the use of an operable skylight in its ceiling. The careful consideration of daylighting throughout the house was demonstrated with Lightscape images. This software models daylighting in photo-realistic images, allowing for adjustment in fenestration layout during the design stage. The home will be construction over a precast basement wall system, with SIPs creating the above-grade envelope. Roof trusses will be used, as well as open web floor trusses. In the optional fourth bedroom over the garage, a SIP roof will be used, to allow for a cathedral ceiling in that space, and an SIP floor, providing both structure and insulation. The family room in the back will also have an SIP roof and will be built on a slab. The slab in the basement and below the family room will use fly ash aggregate and fiber reinforcing, eliminating the need for welded wire mesh reinforcing. Heating will be provided by a high-efficiency two-stage furnace. Air conditioning will not be installed. Builder B installs air conditioning in only 10 percent of their homes. Construction will begin on December 1.

12.5.98
The Builder B design has been finalized, with construction documents going out to Builder B the first week of December. The foundation will be poured in late December, with framing to being in early January.

1.5.98
Project manager Paul Romano met with Builder B and the key subcontractors to discuss construction of the prototype. He reviewed the technologies that will be used in order to familiarize the field people with the products and techniques that differ from their standard practices. As we found in the (another builder's) prototype, without proper implementation in the field, even the best ideas, designs, and technologies will not reap their full potential benefits.

2.5.98
Project manager Paul Romano performed on-site construction observation of the CARB prototype from mid- to late-January. The site was excavated on January 19, with the foundation set and first floor deck completed the following day. The basement, built with a prefabricated panelized concrete wall system, was set in 2 ½ house by a four-man crew,

including the crane operator. The floor system set on top of the basement wall consisted of open web wood joists, the span of which was optimized by the design of the floor size. SIP panels were set on top of the floor system, some with pre-installed Andersen windows. To the project manager's knowledge, this is the first time that this has been done. Paul plans on revisiting the site in mid-February for continued construction observation. Builder B will be building three homes as part of the CARB effort: the prototype referred to as CARB I, a slightly modified prototype with subtle architectural differences built with Builder B' conventional construction methods (CARB II), and the original design from which the prototype evolved (the Redesigned model). The three homes allow for disaggregation of the effect of technologies and architecture on energy use and construction costs.

3.5.99
Project manager Paul Romano presented construction slides of the Builder B prototype. The foundation was complete, and the first floor wall panels were being erected. The ventilation strategy was also discussed. The home will employ use of the air handler with a two-stage fan and fresh air dampened intake to provide fresh air distribution to all the rooms. The use of a damper at the fresh air inlet allows the introduction of outside air only when called for either by demand or time interval. Builder B was at the meeting and expressed their satisfaction with the reduction in construction time to complete the precast foundation and began setting the SIPs. The prototype is anticipated to be completed in late April; the schedule has slipped due to inclement weather.

4.15.99
CARB has been asked to redesign Builder B' entire single-family detached line following the success of their redesign of a Builder B's best selling model. These redesigns will consider market research data relevant to the anticipated buyers of these homes. The first design will be a bungalow that can sit on the redesigned Hampton foundation. This will allow for flexible site planning and foundations to be completed and home designs to be selected later in the sales process. The designs will be presented at the next CARB team meeting, which is scheduled for May 17. Work on the Hampton prototype continues, with the HVAC slated to be installed in mid-April. The prototype is anticipated to be completed by the CARB meeting.

Appendix F-2. Example of Effective Team Project and Outcome Summary

From 1999 CARB annual report (called the "Milestone Report", 7.2.99)

Builder/Project	Industry Partners	Objectives	Innovations	Lessons Learned
Builder A (hot-humid climate) single-story home	Unico, Andersen, Owens Corning, ThermaTru, Simpson Strong-Tie	Design and test starter home for Pensacola market featuring energy efficiency, accessibility, and "green" attributes	Plant shelf typically featured in high volume single story space used as part of the HVAC distribution system; hip roof designed for wind resistance; roof system creates more interior volume with simpler construction; Unico small diameter distribution within walls	Attempt to incorporate 24" o.c. framing was rejected by the builder because of perceived market resistance in the hurricane-prone area. Prototype is to begin construction in July, testing slated for October
Builder B (cold climate) 2-story starter home	Owens Corning, AFM, York, Andersen, Honeywell, Whirlpool	Research and test innovative shell, HVAC and other house elements to improve design, construction cycle, energy performance, etc.	Pre-installed windows in SIPS panels, two-zoned heating system with consolidated duct runs within conditioned space, programmable ventilation, two stage ECM furnace, "Fire Finish" fire resistant coating at ceiling SIP panel, recycling station, passive cooling stairwell using operable skylight above	SIP construction went swiftly; the builder is considering building the entire subdivision in SIPs if a supply problem is resolved. Testing of the HVAC and envelope is planned for the coming months.
Builder C (mixed-humid climate) condos	Tarkett, The Noble Co., Badger Cork, GreenStone, Icynene (note: not CARB members but donors to the process)	Research and test economical ways of mitigating impact noise on hard floor surfaces in multi-family dwellings	Combination of increased floor insulation and underlayment material optimized through acoustic testing and later interpolation	Filling the floor cavity up to 2/3 with insulation and using a resilient closed-cell foam underlayment increased the impact isolation class rating of the floor system by up to 4 points. Added mass was effective, but proved to be impractical in this application. An additional resilient channel was only marginally effective.
Builder D (cold climate) two-story home (high end)	A.O. Smith, Studor, Foster Miller, Weyerhaeuser, Andersen, US Brass, Honeywell	Meet the demands of a high-end home buyer within a simplified form of energy and resource efficiency	Integrated design/detailing process, structural simplicity, insulated collapsing forms under basements slab, non-vented uninsulated crawl space, continuous SIPs run past band joist, passive heating through double-height south-facing foyer, front/back upstairs/downstairs HVAC zoning, "smart" electric panel	SIP erection proved to be more complex than necessary, although the envelope is anticipated to be tight. HVAC coordination with structure was problematic. Efficiencies of the design will be applicable to future Builder G homes. Testing will take place in July.

Builder/Project	Industry Partners	Objectives	Innovations	Lessons Learned
Builder E (hot-humid climate) 2-story starter	Studor, York, Andersen, Simplex, Simpson Strong-Tie, ITW/Foalseal	Analyze the design and construction of an existing model; quantify its cost and performance. Use that data to re-engineer the home for improved energy performance at the same first cost and maintained marketability.	Air seal exterior skin, simplify building perimeter, eliminate furnace with hydronic coil, orientation-specific zoning, compact duct distribution	OVE framing and simplified HVAC systems savings can be applied to high performance windows and reduce overall first costs. Regional labor differences caused the site built roof of the control house to be cheaper than the truss-framed roof of the prototype. Framing at 24 o.c. anticipated to reduce framing time from 5 days to 3 on future homes. infiltration and duct leakage were improved from the control house. marketability was not adversely affected by the strategies used, the prototype sold before the control house.
Builder F (cold climate) cottages, condos	Honeywell, Whirlpool, Tamarack	Improve energy and cost performance of homes that are already very efficient	Downsized heating in cottages and cooling in condos, OVE floor framing, mastic-sealed ductwork, acoustic insulation between floors in condos, proposed programmable ventilation strategy	Acoustic testing information from Ryan prototypes was used to advise the installation of increased insulation thickness in the floor ceiling assembly of the condos. Early anecdotal evidence shows the insulation to be successful at reducing sound transmission between units. Ventilation strategies used in the (other builder) prototypes informed the strategy proposed for the cottages. Implementation of the strategy is planned for the cottages, and possibly a later phase of the condos.
Builder G (hot-humid climate) single-story home	Steel Framing Alliance, Owens Corning, Hebel	Research and develop alternatives to block construction but with the same consumer appeal. Seek to utilize the company's wood-framed panel plant with alternate framing technologies.	ICFs with exterior foam stripped to avoid termites, autoclaved aerated concrete, steel stud concrete panel system with possible use of neoprene thermal break on interior of steel studs	Construction of these prototypes will not begin until the fall of 1999. During the research phase of wall systems it was found that SIP panels would not be considered because of anticipated consumer resistance in the market. Termites are a major problem in the area.

Appendix G.

Program Recommendations

Appendix G-1. Selected Coordination Gaps and Recommended Fixes

Building America suffers from gaps in reporting, metrics, and data collection. The highlights include the following:

Reporting

- The program suffers from significant underreporting, especially in terms of the linkages between program intent and program outcome. Teams routinely underreport their experiences. DOE and NREL have been frustrated by team reports that disclose only cursory details about their projects. Many team reports describe actions taken but lack analysis or clear presentation of results.

- Both DOE and NREL staff suspect that team leaders fear that discussing problems openly and failures will make them vulnerable to performance criticisms during the funding and contracting processes. Team leaders must receive assurances that reporting of failures is equally as useful as reporting of successes. If Building America teams do not feel comfortable reporting the whole story, rather than explaining only the successes, then the innovation process is compromised because participants cannot learn from each others' mistakes.

- Team reporting about project intentions, experiences, and outcomes has fallen short of the thorough guidelines in the task ordering agreements. Although Building America conferences often discuss the goals, requirements, and accomplishments of the program (e.g., number of projects, cost-sharing, house performance), the level of goal attainment or the progress of the individual teams is not discussed.

- The inconsistency in project definition is troubling, both for program evaluation and for management of the partnership. A lack of uniformity in project labels makes it difficult to categorize and compile team projects. Program participants inconsistently and selectively apply project labels. As a result, there is no way to determine how many projects there have been. One of the biggest problems is the lack of clear line demarking a point at which team activities become "projects." Projects often do not have clear starts and stops; rather they follow the path of finding, securing, and maintaining cooperation among different parties.

- The absence of a transparent, consistent framework for project management and reporting makes it difficult to compare lessons from project to project. Thus, it becomes very difficult to understand how any project – or rather any set of actions taken under contract – contribute to innovation.

- In managing privacy concerns that teams have expressed in varying degrees, DOE has struggled to develop a reporting scheme that could get technology results into the public domain without compromising confidentiality concerns. In some cases, teams sent DOE abridged reports for the formal records and kept an unabridged version for their own uses (IBACOS created a password-protected area on their website for team members to access). Others attempted to prevent data from being withheld from DOE review. Instead of filtering information, some teams sent DOE unabridged reports but marked them confidential.

Metrics

- Although, in the program, energy-efficiency advances serve as the primary metric of program progress, program participants emphasized that energy performance was but one facet of technology innovation in the program. Other notable outcomes are – durability, economic value, occupant comfort, environmental impact reduction, etc.

- Building America lacks established, consistently-applied metrics. The program has struggled with determining how best to measure and communicate technological progress. Building America has defined a variety of categories to describe technological learning and progress: energy efficiency, housing durability, economic value, occupant comfort, waste reduction, environmental impact reduction, and technological capacity. However, metrics related to some of these categories are vague. Data are most regularly collected about energy performance, but even the energy data are not consistently or routinely compiled. As a result, sufficient data are neither available nor easily collectible to enable program managers or outside reviewers to produce a comprehensive picture of partnership efforts and outcomes using these program metrics. The program seems to have difficulty establishing a consistent set of measures about which housing is to be judged and projects are to report. Without establishment of a clear set of metrics, teams cannot be expected to compile systematic data about their projects and results.

Data collection

- Available data about program participants is incomplete, program data collection efforts are partial and inconsistent, and information about outcomes is unavailable or hard to compile. The only data that are routinely (although still intermittently) collected are energy-efficiency improvements, but it is noted that energy performance is but one facet of technology innovation in the program.

- Energy performance data is spotty and, for the most part, is inadequate for conducting an overall energy assessment for the program. Although teams routinely check housing performance, teams do not always maintain or share energy efficiency records. As a result, despite some intermittent efforts to compile statistics about housing built in conjunction with the program, DOE and NREL do not possess a complete database about energy performance. Further, NREL includes in its program housing database only those houses that meet the program's minimum thirty percent performance level, but the database does not possess energy performance data for all houses. Also, no information on energy performance is compiled about the housing constructed that failed to meet the baseline Building America requirements.

- Building America data collection and reporting have not been routine and consistent enough to apply a set of measures to all teams, across all projects. The only data routinely, although still intermittently, collected are energy performance improvements. Although data have been more evenly collected for certain factors (e.g., amount of housing constructed or housing energy performance), Building America data collection is still spotty about these and other measures. Other data, such as lists of all participating builders and complete data on building projects is not consistently collected and is very difficult to obtain. Participating builders -- For example, nobody in Building America keeps a list of all participants. No complete data set on building projects exists. These data could be partially compiled from team webpages, publications, and reports to NREL and the GFO; however, coverage of activities among teams and across documents is variable enough to make it very hard to paint a complete picture.

Program Participation

- Builders are not always unambiguously "in" the program or "on" a team. They may think of themselves as simply working with the team leader, who receives government funding to help them.

- Although the recruitment process used by teams has found some success, one could argue that the mechanisms are too limited to promote wider program participation. The recruitment process typically involves team leaders inviting or encouraging partners to participate, but the Teams use different strategies for doing this. Builders become involved in Building America projects when recruited by team leaders (the dominant mechanism), or when they approach team leaders because they are interested in solving a problem or improving their housing designs. Accordingly, the vast majority of participants (76% according to the survey) joined Building America based on a suggestion or a request from a team leader. Irrespective of the time period in which they joined, only a quarter sought out the program and volunteered to participate of their own accord. This tendency toward recruitment is not surprising considering that, even though on average builders considered themselves to know the team leaders only "a little," most team leaders have drawn heavily on their social networks to find partners.

Stimulation of Collaborative Networks

- In contrast to builders, currently suppliers (the building product manufacturers) are much less central to the model of Building America learning and to collaboration on the team. There is little evidence that teams have generated new, sustained modes of communication between builders and suppliers.

- Although teams work regularly with local governments through the permitting process, they have little interactions with national government regional offices or State agencies.

- Existing team-to-team collaboration is weak. Collaboration among teams remains peripheral within the Building America program, although some teams do communicate with each other about technical information, but generally not about business or management practices.

- Knowledge generated by individual teams is not being transferred adequately to other teams, and the public at large. Annual project negotiations between Team Leaders and NREL during the funding process appear to be the largest mode of team-government interaction and collaborative knowledge-sharing.

- Although many of the parties in Building America attend conferences, are active in associations, and comment on codes and standards, Building America does not have explicit mechanisms for interacting with trade associations, educational institutions, and lending institutions.

- Participating builders have established lasting relationships with building scientists (Team Leaders), but not developed sustained relationships with other actors (e.g., other builder/developers, subcontractors, product supplier sales staff, product supplier design staff, employees at DOE, national laboratories, utility company staff, state and local officials, homebuilder associations, trade associations, financial community). For activities involving sharing technical information, improving housing performance, improving construction management, or developing a new/custom product, building scientists entered or became stronger in lasting relationships with builders. In contrast, builders appear to have experienced little lasting relationship gain with other actors. Building America collaborations do not appear to have helped builders form lasting relationships with other actors, despite moderate introduction to new groups and reported useful of these interactions. Additionally, on average builders reported only modest gains in ability to coordinate changes with suppliers and subcontractors.

Other Outcomes

- According to the builder survey, the program appears to have slightly increased building construction time, material and construction costs, sales price, and sales factors. Builders indicate that the program has had little or no influence on changing construction or manufacturing time and the time required to sell a house. However, they report that the program has contributed to increases overall housing value.

The following specific suggestions for improvement are offered:

Resources

- More resources are needed at DOE for program coordination and reporting functions.

- As appropriate, DOE could provide teams with lab introductions or organizational maps to make it easier for them to locate lab resources and to begin meaningful, collaborative exchanges with a broader range of lab expertise (should teams demonstrate that labs can aid their collaborative learning). This opportunity does not obligate teams to confer with them, but facilitated access to national labs is intended to improve transfer of advanced technological knowledge into the partnership through the teams.

Program Coordination

- In recent years, Building America has created two means of idea exchange and synchronization: ongoing contract management and quarterly partnership meetings. Building America's periodic meetings have been a critical coordinating resource in this effort and should be a continuing part of the partnership.

- The program needs to establish additional coordination mechanisms beyond the broad steering ability of meetings and the more specific project oversight of contracting.

- DOE and NREL should provide feedback to Teams about metrics for judging team performance, and also improve transparency on their communication with third parties on issues that result in adjustment of program priorities.

- The Building America program should consider creating a new additional channel for enabling substantive interaction between government staff and program participants. This could focus on improving the degree of knowledge exchange between participants.