Subcontractor Report

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Hickory Consortium 2001 Final Report

Hickory Consortium
Harvard, Massachusetts

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

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Introduction

The mission statement of the Hickory Consortium is to "Be a catalyst for environmentally sound, energy efficient, healthy, and affordable housing." To that end, we have focused our energies in support of four major objectives:

1. Create systems to improve the construction process

2. Create successful projects and test the results

3. Communicate the results

4. Create a Market Transformation.

As with all Building America Program consortia, *systems thinking* is the key to understanding the processes that we hope to improve. The Hickory Consortium (HC) applies this thinking to more than the whole-building concept. Our systems thinking embraces the meta process of how housing construction takes place in America. By understanding the larger picture, we are able to identify areas where improvements can be made and how to implement them.

From the start of its work with the Building America Program in 1995, the Hickory Consortium has been interested in exploring the housing market through *system dynamics modeling*. System dynamics modeling uses causal loops and descriptions of stocks and flows (both material and information) to examine the behavior of a complex system over time. The image of the overall housing production system that has emerged from this process has been invaluable in identifying the key areas in which actions by the group can have positive effects. Looking at the process from a top-down point of view allows us to see areas where leverage, correctly applied, can change the system. There are, of course, multiple systems within the overall building production process. To date, the Hickory Consortium has worked with many of these subsystems as well as with the overall system.

We believe that one of the key principles for catalyzing a change to energy-efficient building in all market sectors is the equation of quality with energy efficiency. The message that we continuously repeat to builders and manufacturers is that energy efficiency can't be obtained without embracing quality in construction and that there is no real quality without energy efficiency. New tools allow us to verify energy performance, which allows a demonstrable quantification of quality. This message has resonated with all of our affiliated developers and builders, as well as with our subcontractors, architects, and financial partners. Throughout the building process, when people stop to consider their role and the goal of their work, this message rings true. It represents a new way of looking at the building process and a new paradigm for excellence in building.

The effects of the paradigm described above are evident in each area of work performed by the Hickory Consortium in 2001. Though the approach varies between factory, site builder, modular builder, and developer, the underlying message and the ultimate effect on performance remain unchanged. Through a variety of interactions, we have been bringing this message to the building industry, resulting in continuous and permanent improvement among our partners.

Hickory Consortium Highlights 2001

Modular housing, although it has been on the market for many years, also represents a major departure from the way houses are usually built. In reality, however, most modular manufacturers have departed very little from the stick-built paradigm, even though construction takes place in a factory. Moreover, the button-up process, carried out by the builders who will finish the construction on site, is approached as though it were simply the last stages of a typical stick-built house.

To foster communication with the modular industry and to mainstream the innovations we have and will continue to develop, the Hickory Consortium has instituted a Quality Modular Building Task Force. This group, composed of the presidents of 12 of the largest and most influential manufacturers, meets annually to discuss issues of quality and energy. Many of these manufacturers have made dramatic changes in their production and on-site processes as a result of this interaction. The team's progress is discussed later in this report.

The Hickory Consortium has made great strides in understanding the factory process and real progress in finding opportunities to improve it. The factory flow has been modeled, and recommended changes have been identified and implemented. Many of these changes are being implemented in the newly renovated and expanded Cardinal Homes factory and the new Excel Factory, which opened in January 2002. A major effort in 2001 focused on quality management in the factory.

By recognizing the integrated system aspects of modular construction, the Hickory team has participated in the process of prototype design, which will improve efficiency and reduce the amount of on-site button-up work. In pursuing the dual goals of quality and energy efficiency, we have engaged in on-site measurement, observation of the process, and a Kaizen blitz quality improvement process with one of Excel/Avis's largest builders. The results and promise of the modular finish Kaizen process are discussed later in this report.

Hickory has begun assembling the knowledge and lessons learned through projects, observations, and systems dynamic modeling of the modular construction process in a format we call the Modular Construction Rubric. A rubric describes simply and clearly what's needed in each step leading to success and how to measure them, eliminating vagueness, mystery, and undefined goals. This will clarify the builder's understanding of the required steps for an economically successful, high-performance project. The end result of applying the rubric will be successful building projects that include high quality and energy efficiency, while saving the builder costs through production-efficiency improvements.

One of the tasks of the Quality Modular Building Task Force is to set the annual research agenda for the Hickory Consortium as it relates to modular building. One of the topics on the research agenda from the Modular industry representatives identified in 2000 was the need for performing a market research study to understand the builders' point of view. A summary of the study is provided elsewhere in this report.

A significant portion of the consortium's efforts have been in the area of technical innovation. In a later section, we will discuss our progress on HVAC systems and advanced system innovations.

In the area of urban housing, Hickory has been actively engaged in both low-income and market-rate developments in the inner city. The tremendous success of the Erie-Ellington Project (Figure 1) has led to numerous additional projects that seek to emulate the process and performance of those low-income housing units. Currently under construction is the Cambridge Park Place building: a large multistory apartment building that will likely be the first Leadership in Energy and Environmental Design (LEED)-certified apartment building in the United States. We have also actively participated in the Back of the Hill Project, a low-income housing project that will begin construction in 2002. Numerous other urban

low-income projects are in the works. Finally, we have begun working in Kansas City, Missouri, with several Community Development Corporations, the Metropolitan Energy Center, and the Kansas Building Science Institute to raise the level of awareness of energy-saving opportunities in Kansas City's low-income housing projects.

This report will also discuss the outreach activities we have been engaged in. A major focus will be on fostering enablers to energy-efficient housing and working with the local developers and financers to help them see opportunities and institutionalize energy-efficient practices in their businesses. Hickory has also attended and presented the Building America agenda and Hickory's research at many conferences; the conference listing is attached.

Finally, we will discuss a summary of the projects that Hickory has been working on, as well as the research agenda identified for 2002.

Figure 1. The Erie Ellington triplex in Boston, Massachusetts.

Modular-Housing Construction Process Rubric and the Kaizen Event

Because most of the actual construction is performed in the factory, the finish process for modular housing is often imagined to be much simpler than that of site-built housing. What actually happens on the site is far from simple and is often the primary source of imperfections in air sealing and system installations that reduce the energy efficiency, quality, and profitability of the modular product.

The consortium has reviewed builder's practices, evaluated training programs, observed and analyzed the set process (placing modules on the foundation and readying them for completion), constructed prototype modular houses, and tested completed houses for energy efficiency. The results show that a great deal could be improved. One important finding is that we currently don't offer builders a system for making the finish process easy to carry out. Improving this process will save costs, reduce mistakes, avoid scheduling conflicts, and allow us to implement better practices (such as marriage wall and duct sealing) without increasing costs.

Background: The Rubric

To meet this need, the Hickory Consortium is currently developing a Modular Housing Construction Process Rubric. The Rubric's goal is to provide an integrated approach to building modular housing and achieving significant energy savings. The Rubric will encompass all activities that are essential to successful projects and for which the builder is responsible.

A rubric is a set of guidelines that states the objectives and expectations required along with clear performance criteria. Rubrics focus on describing a stated objective (performance, behavior, or quality) and contain specific performance characteristics and metrics. Rubrics are becoming increasingly common as assessment tools in project-based learning, because the clearly defined objectives and expectations of performance set forth the desired behavior in plain language. The beauty of a rubric is that it describes simply and clearly what's needed in each of the steps leading to success and how to measure them, eliminating vagueness, mystery, and undefined goals. This will clarify the builder's understanding of all the required steps for an economically successful, high-performance project.

The Rubric is being designed as a guide primarily for the builder's use and will:

- Focus on the issues that confront the builder, clarifying and focusing attention on the key issues and decisions that are critical to the successful project.
- Lead the builder through a series of questions that pertain to each phase of the project so that he or she understands that different questions must be asked *AND* answered to achieve the savings and efficiencies that modular housing can offer.
- Highlight the significant differences between conventional and modular construction so the builder understands how to integrate the modular manufacturer with the needs of other parties typically involved (i.e., an architect, the buyer, regulatory agencies). This will help the builder properly prepare for and manage the trades on site.
- Suggest tools to facilitate better planning, design, energy savings, scheduling, marketing, and project management.

The Hickory Consortium has begun a constellation of investigations aimed at informing the development of this rubric as well as spotlighting the issues that currently plague the finish process of modular housing. In addition to the set and finish studies and testing of the built product mentioned above, we have been observing the entire finish process. We are also currently working with a systems dynamics model of the finish process that we hope will evolve into a useful simulation game for builders—the

modular flight simulator. This simulation game will let builders test their project management skills and try to maximize profit and quality.

The most important activity of the past year, which helped us develop an understanding of the site process and the steps to success, was the finish process Kaizen.

Overview of the Kaizen

A very significant project that supported the rubric's development was the Kaizen event carried out in July and August., The project involved a builder and crew in a rapid improvement event. The goal was to improve the builder's process and product by developing a shorter or smoother construction cycle and improving quality, safety, energy, and productivity. Kaizen events are highly focused, action-oriented, 3- to 5-day improvement workshops where an improvement team takes immediate action to improve a specific process. Several modular factories and many building products manufacturers have used Kaizens to improve their production processes. To our knowledge, the process has never been undertaken on a modular construction site for the builder's benefit. In fact, it took great foresight on the part of our consultant, Simpler Consulting, to envision how the process could be implemented on a modular construction site and on the part of the builder and employees of The Home Store of Whately, Massachusetts, who showed great vision and enthusiasm for the process.

The part of the building process chosen as the target for the Kaizen was the finish process, from the day of the module set to customer move-in. This is the area with the greatest need for both production-efficiency and energy-efficiency attention.

In a preparatory meeting, we established the typical standard work schedule for the Home Store's construction process. We set a goal of increasing worker productivity by 20%, reducing quality defects by 50%, reducing lead time by 50%, and improving energy efficiency by 50%. We also hoped to increase safety and reduce production time.

Working closely with the factory's production manager, production engineer, the builder, and his production manager, the Hickory team (Mark Kelley, Ashley Richards, and Mike Mullens), met on site to evaluate the process and identify improvements. We immediately discovered several important areas of waste in both time and effort. There were a number of shipping or factory-related defects that were routinely repaired by the crew, and there were major inefficiencies in work habits, time to set up and tear down, travel time, break time, and scheduling. Several energy-efficiency problems were evident, including significant uninsulated areas, ineffective gaskets and air barriers, and poor air-sealing procedures at module connections and windows.

The process improvement effort began with a process called Value Stream Analysis. We evaluated the tasks done in terms of what skills are required, the hours those skills were needed, and the effects on cycle time. Using this process, we calculated that, at a minimum, a three-person crew was needed for efficient processing. Implementing the changes identified is clearly dependent on the manufacturer and builder committing to operating their respective businesses differently than they do today and in implementing changes that were uncovered during the Rapid Improvement Event. Specifically, these included changing the organizational structure of the business and committing to properly training production workers.

At both the modular factory and the erection site, quality control is a direct result of trained staff and an organizational structure that monitors quality at key points in the process. The organizational structure must be designed so the information flows freely from the office to the production line, the job site, and back again. Proper training of production staff cannot be overemphasized. Training includes not only learning proper techniques for completing a specific task, but also learning company philosophy and other policies and procedures, such as when to start work, length of lunch break, among other things. Any

breakdown in the communication or implementation process affects the entire system and has an increasingly profound effect on the desired results.

Both the factory and the builder agreed to implement a wide range of changes, both immediately and over the next few months. These improvements include relocating various loose items shipped inside the modules for more efficient use and removal, using rapid-dry wall compound, sealing windows with foam, changing band-joist insulation to fill the area completely, double sealing marriage walls, temporary stairs of steel grating material to keep dirt out of the house, using foam sill sealer, and many others.

Productivity improvements, including scheduling software, site setup, permanent workplace setup in the building, and, particularly, organizing the work to keep workers busy, could result in a 50% reduction in work per house, or a 100% increase in productivity for each team. Changing from the current work model of batch production to a one-piece flow model (working on one house at a time instead of all houses simultaneously) could reduce production time from 88 days to 18 days. This suggests that the teams could produce twice as many houses without adding personnel. After all the changes are implemented, productivity could increase by over 100%, defects could decrease by more than 50%, and production time could decrease by over 75%. These goals are realistic, but will require a great deal of effort on the part of the builder and his staff. Initially, we don't expect to see full realization of these goals, but we do foresee dramatic improvements.

In our most recent Task Force meeting, builder Andy Gianino of the Home Store reported that they were making considerable progress on those issues slated for change at the Kaizen. As a result of the Kaizen, many new policies and scheduling changes have been applied to their work. He noted that, although they have only begun the process, they have already seen the improvement in process time from 13 weeks to 8 weeks per house.

In pursuit of the overall goals, we hope to continue working with The Home Store, particularly in the thorny area of subcontractor control. Although electricians and plumbers are notoriously independent, we hope to find ways of applying the Partnering Process used by Hickory in other successful projects to enlist the cooperation of these vital links in the construction process chain. We hope that by helping them understand their importance to smooth project management and the benefit to themselves of cooperation and timeliness, they can be encouraged to treat the modular builder as a valued and favored customer.

Quality Modular Building Task Force

Background

The Quality Modular Building Task Force was convened by the Hickory Consortium in 1999 with the goal of working with the major players in the industry to improve the quality and performance of modular buildings without substantially increasing the manufacturing cost. The Task Force model was chosen to facilitate working together rather than separately. The Hickory Consortium's objectives are to

- Promote the values of high-quality, high energy and environmental performance, and resource-efficient modular building to leaders in the industry;
- Present the research and development (R&D) results and lessons learned by the Hickory Consortium and its partners;
- Identify an R&D agenda with industry leaders and obtain the commitment of leading modular manufacturers to that agenda;
- Identify Task Force members who will partner with the Hickory Consortium on specific projects; and,
- Leverage HC and Department of Energy (DOE) and Environmental Protection Agency (EPA) (ENERGY STAR® Homes) efforts with help from the major suppliers to the industry.

The Task Force has now met three times: in New Orleans, Louisiana, in 1999; in Annapolis, Maryland, in 2000; and in Salem, Massachusetts, in October 2001. The specific objectives of all the Task Force meetings were to define quality, identify challenges with respect to quality and performance, investigate solutions to problems, produce an action and R&D agenda, and identify ways to share resources and experience. In our judgement, the meetings were highly successful. Attendance by the invited manufacturers and suppliers was almost 100% at the New Orleans meeting, and six of the invited suppliers were financial sponsors. Feedback about both the format and content of the meeting was very positive. During the next year, three modular manufacturers, members of the newly created Task Force, joined the Hickory Consortium and began working with HC experts on specific projects.

Working relations between the Hickory Consortium and Task Force members became very open and productive that first year. HC began projects with supplier members of the Task Force, including NOMACO, U.S. Gypsum, and the Pella Corporation, as well as modular manufacturers. In addition, two leading modular manufacturers joined the Task Force during 2000: Unibilt Homes represented by President Doug Scholz, and General Housing Corporation represented by President Bradford Light. They became key participants in subsequent Task Force meetings.

Attendance and sponsorship of the Annapolis meeting was high. The meeting focused on results of the collaborative R&D projects conducted by HC experts with Task Force members during the year, particularly the studies of set techniques and quality measurement and management in the factory. Avi Friedman, a highly respected innovator and architect who heads the Affordable Housing Program at McGill University, was the featured speaker for the Task Force meeting and was very well received. Other key topics were mechanical ventilation and the ENERGY STAR Program. Penn-Lyon Homes agreed to be the ENERGY STAR "Champion" for the industry with the objective of making its entire line "ENERGY STAR ready."

Hickory Consortium and EPA staff members worked closely with Penn-Lyon, Excel, Cardinal, Epoch and other manufacturers during 2000-2001 on factory and on-site techniques to ensure energy efficiency, procedures for working with builders on ENERGY STAR, and ENERGY STAR marketing. HC wrote and produced a draft of the manual: "ENERGY STAR Labeled Homes: A Guide for Modular Manufacturers and Builders" and had it extensively reviewed by Task Force members and others. HC worked with Excel Homes on design issues; and Task Force member Bryant Heating and Cooling, a Division of Carrier Corporation, began several collaborative projects with the Hickory Consortium and modular manufactures on the Task Force. Two well-established modular manufactures joined the Task Force: Simplex Industries (Pennsylvania) and Muncie Homes (Indiana). On the supplier side, Superior Walls of America, a manufacturer of insulated concrete panels, also joined the Task Force.

Quality Modular Building Task Force 2001 Annual Meeting, Salem, Massachusetts

On October 4–5, HC hosted the third Annual Meeting of the Quality Modular Building Task Force in Salem, Massachusetts. The invitational meeting had excellent participation from both modular manufacturers and product suppliers, including the addition of two new modular companies: Stratford Homes of Stratford, Wisconsin, represented by President David Endy, and Muncie Homes of Muncie, Indiana, represented by Vice-President of Operations Joseph Cimakosky. Superior Walls of New Holland, Pennsylvania, a new product supplier, joined the Task Force as well, represented by Vice President Lee Hawthorne. This intentionally small working group consists of 12 modular manufacturers comprising approximately 50% of the modular housing completed in the United States and nine sponsor/suppliers of quality housing components offering energy conservation and sustainability benefits to housing manufacturers, builders, and homeowners.

This year's agenda topics covered updates on research conducted by members in joint tasks with HC members, all of which combine the goals of furthering modular housing's energy efficiency, while helping the industry achieve a greater market share through the resulting higher-quality product. This year's meeting discussed builder issues in some depth: how to reach new builders who are willing to build efficient houses, and training builders to manage and execute higher-quality projects that can earn ENERGY STAR certification (one obstacle to energy-efficient modular construction has traditionally been the homebuilder who assembles the homes on site). HC members reported on the Kaizen process implemented at an Avis America home site. It was acknowledged that heating, ventilating, and air conditioning (HVAC) is one of the biggest drags on project completion, and poor installation is detrimental to all quality housing goals. This led to an extensive discussion on potentially installing HVAC equipment in the modular factory, which has been a goal of the Hickory Consortium for some time.

Currently, the nation's two largest modular manufacturers, All-American and Excel/Avis America, both Task Force members, are engaged in working toward ENERGY STAR Homes compliance. Penn-Lyon Homes, another Task Force member, has committed its entire line to ENERGY STAR compliance, and Nationwide Homes has made a solid beginning with two ENERGY STAR developments in the South. Task Force members Sam Rashkin, ENERGY STAR Homes Program Manager, and Mark Kelley, of the Hickory Consortium, have been guiding these companies through the process.

HC member Michael Mullens' industrial engineering studies this year covered quality compliance systems in an industry of comparable complexity: yacht-building. Effective quality compliance is essential if, for example, HVAC systems are to be installed at the modular housing factory. Currently, quality systems in modular housing factories lag behind those in luxury boat building. Dr. Mullens pointed out that measurement against clear standards and an understanding of best practices, while logical steps to take, have in themselves to be interpreted and carried out rigorously and consistently to achieve results. Inspections can be controversial.

Product suppliers had the opportunity to present their newest lines or what is in the pipeline in the near future. Shaw Industries presented their Glueless Melamine simulated wood flooring, which improves indoor air quality, conserves wood, and features superior durability. Pella Windows is seeking to enter the vinyl window market with a non-polyvinyl chloride (PVC)-based vinyl-like product. Trus Joist discussed its Laminated Strand Lumber, which can transform poorer-grade green lumber into a very strong product with superior strength and dry lumber performance, skipping the energy-intensive drying process. Bryant Heating and Cooling (Division of Carrier Corporation) presented their Puron products, non-chlorofluorocarbon (CFC) or hydrochlorofluorocarbon (HCFC)-utilizing cooling products that keep pace with the increasing restrictions on the old coolants, while providing greater efficiency and comfort. More than 200,000 units operating on Puron have already been installed.

Guest speaker Steve Loken of the Center for Resourceful Technologies spoke about the steady dematerialization, or ephemeralization, of the building materials used in the United States. We are learning to do much more with less material.

Sam Rashkin, ENERGY STAR Homes Program Manager, told the group about the steady and substantial expansion of the ENERGY STAR program, with a dozen national builders now signed on. He called for careful training of modular builders for quality performance.

The Task Force is coming into its own as a forum for exchanging ideas, R&D, and quality information, and for moving the industry as a whole. Participants who were reticent at the first meeting have begun to speak confidently without concern for keeping trade secrets, as they realize that this forum offers the opportunity for raising the caliber of all modular housing. The key to the Quality Modular Building Council's success is the fact that all of the participants have begun to understand the relationship between quality and energy. All of the participants have incorporated some of the ideas and improvements discussed, which is gratifying, and some have decided to act on these principles and raise the quality and energy performance of their entire product line.

University of Central Florida (UCF) Contributions to the Quality and Energy Efficiency of Modular Housing

In Fiscal Year 2001 (FY01), the University of Central Florida (UCF) Housing Constructability Lab research team made significant contributions to improving the quality of modular housing in America. In the factory, the research team recommended stronger enterprise-level quality management, as well as factory designs that reflect lean manufacturing principles. On the construction site, a Kaizen rapid-improvement event yielded a shortened construction cycle and improved quality, safety, energy, and productivity. Results from each effort are described below.

At the request of the Quality Modular Building Task Force, a group of 12 modular manufacturing industry leaders, the research team formulated a set of best-quality practices for the modular industry. Recommendations were based on an extensive benchmarking study that examined the best current practices of modular manufacturers, stick builders, and general manufacturers. The recommended quality practices impact all dimensions of housing quality, including the architectural design and features offered, structural integrity, function (including energy efficiency, indoor air quality [IAQ], and comfort) and aesthetics. The quality practices were presented to the Quality Modular Building Task Force in October 2001 and were well received. Since then, the team has been invited to visit two companies representing four modular manufacturing plants. During each visit, the team met with key management staff, discussed recommendations in detail, and answered a wide range of questions regarding implementation. Both companies plan to use the recommendations to improve their existing quality management systems in FY02. The research team will continue to support their efforts. To highlight the importance of energy-related performance metrics in a strengthened quality management program, the research team will perform blower door and duct blaster tests across the industry. These results will allow manufacturers to benchmark the air tightness of their homes against the best in the modular industry as well as stick-built homes.

Recognizing that the factory itself can be a key contributor to product quality, the research team worked closely with Excel Homes to incorporate lean manufacturing principles into the design of Excel's new Ghent, West Virginia, manufacturing facility. Excel is one of the nation's largest modular home manufacturers and a Building America Hickory Consortium industry partner. To manufacture a high-quality custom home, the production system must be flexible, responsive, and efficient, capable of producing a mix of custom home designs without the heroic efforts that typically degrade both quality and efficiency. The research team developed and tested various lean principles using the Generic Modular Manufacturing Simulation System (GMMSS). Consequently, several major improvements were incorporated in the new factory. Additional cranes were added to facilitate the flow of framed subassemblies to the line. Pairwise line movement was instituted, reducing line disruption by 50 percent. Roofing (sheathing and shingling) and ceiling drywall activities were moved off-line. The off-line workstations allow drywall activities to be performed in a pit at the same time roofing activities are being performed at floor level. This reduces production cycle time and enhances safety. Finally, a customization bay was added to allow more extensive, value-added customization without degrading line movement. Again, each improvement will enhance quality. The new plant began operation in 2002.

The research team also addressed housing quality and energy efficiency in the last stage of the supply chain, the modular homebuilder on the construction site. The team participated in a Kaizen rapid-improvement event to improve the finish process for The Home Store, a large-scale modular builder. The Kaizen event was a continuous, highly focused, action-oriented, 5-day improvement exercise, where a team took immediate action to refine the finish process. The improvement team, composed of staff members from the builder, the modular manufacturer, a lean manufacturing consultant, and our research

team, developed recommendations to drastically reduce the finish cycle time from 13 weeks to 3 weeks, improve safety, enhance quality, improve energy performance, and increase productivity. Energy-saving recommendations included: changing band joist insulation to better fill cavities, double-sealing marriage lines with gaskets and foam and providing backers to provide better foam seal, and using a foam sill sealer. In the October 2001 Task Force meeting, the President of The Home Store reported that they were making considerable progress, and many new policies and scheduling changes have been applied. He noted that although they have only begun the process, they have already reduced cycle times from 13 weeks to 8 weeks per house. The research team plans to measure airtightness in winter 2002 to estimate resulting energy improvement.

Market Research

Background

In spring 2000, Hickory Consortium member Josephine Carothers, of Carothers Market Research, completed telephone surveys with a number of stick and modular builders as tasked at the 1999 Quality Modular Task Force meeting. She presented the results from this survey at the Annapolis Task Force meeting in October 2000. Task Force members voiced an interest in doing some market research to find out why stick builders are not building modular homes. Comments were made that the industry seems to have hit a ceiling of 8%–10% of the market share for new homes and cannot go beyond that. Task Force members asked: What do we need to do to make modular attractive to builders?

In 2001, the Hickory Consortium took this market research further and held focus groups with builders to further explore the issues. Four focus groups of approximately 10 homebuilders each were held in Richmond, Virginia; Charlotte, North Carolina; Farmington Hills, Michigan (a suburb of Detroit); and Paramus, New Jersey (part of urban/suburban northern New Jersey). A moderator was hired to facilitate the groups. Builders were randomly chosen from lists of homebuilders screened according to the following criteria that describe builders most likely to be influenced by the Hickory Consortium's activities—builders that were currently engaged in homebuilding and building at least 5 and less than 100 houses annually.

Topics were chosen with the idea of encouraging builders to speak freely about their businesses in order to find potential leverage places from which to foster change in the direction of energy conservation. Their decision-making on how and when to innovate, what problems they face in business, and their points of view and experience concerning energy-saving construction were the topics chosen. Each participant was asked to fill out a brief construction-practices questionnaire to obtain their actual building practices regarding energy use in the homes they build.

Results

Following are the highlights of the results:

- Comparing the discussions on energy to the responses on the construction-practices questionnaire, it seems that many builders consider the houses they sell to be energy-efficient simply because they install higher-efficiency equipment.
- More than 75% of the builders indicated on the questionnaire that they install high-efficiency HVAC equipment.
- Most builders have heard of indoor air quality issues, but very few have a practice to deal with it. Similarly, they are aware that an increasing number of homebuyers have allergy issues, but they are uncertain how to respond.
- Builders cite cost as a barrier to green-building practices. Builders who have offered green-building features believe the market has not responded well for the extra trouble it took.
- Awareness of the ENERGY STAR program was most prevalent in New Jersey, while a Detroit builder was the only one in the study using it as a prime selling point. Most other builders knew little about it.

The builders in this study indicated three main drivers of builder innovation:

- Market demands, such as demand for low-maintenance housing, or shifts in fashion or size;
- New products that promise to save money, time, energy, or promote durability; and
- Problems such as air conditioning a crawl space to balance humidity or using poured concrete foundations to save on callbacks due to basement water.

Conclusions and Recommendations

The research demonstrated that most builders are risk-averse and tend to follow rather than to make trends. 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 and logistical feasibility. The task ahead is to ensure that the switch to energy-conscious construction is as safe as possible on both of these fronts.

- Use builders' points of view and experiences to determine at what points in the building process to provide pertinent information and what form that information should take.
- The public is still not receiving genuinely efficient housing, even while builders are making claims for such. The ENERGY STAR Program and modular housing provide a viable avenue for the public to obtain conservation housing, constructed by trained personnel and holding third-party certification, which will help fill the gap. Public education on what constitutes an energy-efficient house could also act as a corrective and incentive force for builders.
- Manufacturers and production builders of energy-efficient housing should create and require builder-training programs.
- Consider finding and registering "energy-expert" builders; then give them a listing of what other successful energy-conserving builders do in terms of marketing and customer relations, including customer education about energy-efficiency.

Advanced System Development Opportunities

Background

This year, the Hickory Consortium continued to focus its research on advancing energy systems. HC has continued to research and evaluate several components and systems in the area of integrated space conditioning systems, hot water systems, on-site power systems, control systems linked with home networks to optimize performance of energy systems, and other advanced systems. HC has identified nine candidate systems to perform an initial evaluation and feasibility study. Details on these systems have been presented in previous Building America reports. This group will be narrowed down to two systems that will have a detailed investigation performed on them. Based upon the detailed investigation, one of the systems will be selected to pursue further development and testing.

Initial Investigation Candidates

Nine candidates were selected for initial evaluation:

Hybrid Ventilation

Hydro-Air System with Bill-Mate Metering

Ice-X Battery Radiant Cooling Systems

Component Window Panels

Residential Fuel Cells with Heat Recovery

Track 21AQ, Air Quality Sensor, Tamarack Technologies

GFX—Gravity Film Xchange Drainwater Heat Recovery System

Icynene, Unvented Roof Technology

HomePrime, Web-based Building and Information Services

Selection process

Each of the nine candidates was evaluated and scored against a weighted set of criteria.

The criteria used and weights follow:

Meets Building America Goals	20%
Energy Savings	20%
Cost Effectiveness	15%
Maturity of Technology	15%
Marketing Value	10%
Sustainability	20%

Within these headings were embedded subheadings that were also necessary to consider. For example, under the Energy Savings heading, both operating energy and embodied energy are considered. Because of its more significant impact, operating energy is weighted more heavily than embodied energy, holding 18 of the 20 total points available under this heading.

The candidates that scored the highest were the HomePrime (ranked #1) and the Track 21AQ, Air Quality Sensor, Tamarack Technologies (ranked #2).

HomePrime: Web-based Building Information System

Through a web-portal in each unit, the HomePrime system connects apartment occupants to an innovative communications network. This network integrates information about building systems, energy use, weather, local services, and other occupant amenities that previously have come from a variety of sources.

Track21AQ, Air Quality Sensor, Tamarack Technologies

The Track 21 is a gas sensor that activates an exhaust fan or fans for spot and whole-house ventilation. Usually located in a bathroom, it detects pollutant gases in the interior environment, as well as excess humidity, and then triggers the exhaust fan to expel them. There is also a manual override switch.

We have included the scoring matrix including the scores for all of the candidates in Table 1 and also an explanation of the scores received for the HomePrime system.

HomePrime Scores

Meets Building America Goals—20%

HomePrime scored 18 out of 20 possible points under this heading because of the number of research opportunities that the system could potentially generate. By addressing issues of individual transparent energy metering, energy information management, and accurate system control, this web-based system takes on a set of difficult advanced energy system research questions for next-generation green buildings.

Energy Savings—20%

HomePrime scored 17 of a possible 20 in this category. The potential savings are estimated to be significant, especially when applied to buildings that have been designed using a systems engineering approach. This is because HomePrime enables the capture of further energy savings that are not picked up in the design and construction of the building. In addition, monitoring the indoor environment and energy use ensures consistency, and even improvement, on performance goals.

Cost Effectiveness—15%

HomePrime scored 10 of a possible 15. Cost benefits for the customer are clear in terms of more transparent system operation, performance, and energy use. Installing the system will be fairly inexpensive, as many new buildings are being wired with this infrastructure as standard. However, the variables involved with sensor technology and costs to the builder are as yet undetermined.

Maturity of Technology—15%

HomePrime scored 10 of a possible 15. With the beta version of HomePrime nearly complete, it is expected that the fully versatile system will not be far behind. In addition, today's real estate market is calling for more complex building automation systems that include web-integrated components.

Marketing Value—10%

The HomePrime system scored a perfect 10 in this category. With the capability to measure, manage, share, and display meaningful energy and indoor environment information, HomePrime will have a distinct advantage over other building automation systems.

Sustainability—20%

HomePrime scored 19 of a possible 20 points. Should it live up to its full potential, this easy-to-use system will also contribute greatly to increasing durability and improving human health, while decreasing maintenance, operating energy, and related greenhouse gas emissions.

Table 1. Scoring Matrix, including the Scores for all of the Candidates

Selection Criteria			Hybrid Ventilation		Hydro-Air & Bill-Mate		Ice-X Battery		Component Window Panel		Residential Fuel Cells with HR		Track 21		GFX		Icynene Roofs		HomePrime	
	Weight		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Meets Building America Goals	20																			
Research Agenda		15	12	1.8	8	1.2	5	0.75	11	1.65	8	1.2	13	1.95	10	1.5	12	1.8	13	1.95
Philosophy		5	5	0.25	3	0.15	5	0.25	5	0.25	4	0.2	5	0.25	5	0.25	5	0.25	5	0.25
Energy Savings	20																			
Operating Energy		18	11	1.98	9	1.62	7	1.26	9	1.62	12	2.16	11	1.98	12	2.16	13	2.34	15	2.7
Embodied Energy		2	2	0.04	1	0.02	2	0.04	1	0.02	1	0.02	1	0.02	1	0.02	1	0.02	2	0.04
Cost-effectiveness	15																			
To customer		5	3	0.15	5	0.25	4	0.2	3	0.15	1	0.05	4	0.2	4	0.2	4	0.2	5	0.25
To builder		5	1	0.05	4	0.2	3	0.15	5	0.25	3	0.15	3	0.15	3	0.15	2	0.1	2	0.1
Ease of Installation		5	1	0.05	5	0.25	5	0.25	3	0.15	5	0.25	5	0.25	5	0.25	3	0.15	3	0.15
Maturity of Tech.	15																			
Market Readiness		10	7	0.7	10	1	10	1	2	0.2	6	0.6	8	0.8	10	1	9	0.9	7	0.7
Prior testing?		5	2	0.1	4	0.2	5	0.25	1	0.05	2	0.1	4	0.2	5	0.25	4	0.2	3	0.15
Marketing Value	10	10	7	0.7	3	0.3	3	0.3	5	0.5	8	0.8	7	0.7	5	0.5	6	0.6	10	1
Sustainability	20																			
Durability & Maint.		5	5	0.25	3	0.15	4	0.2	5	0.25	4	0.2	4	0.2	5	0.25	4	0.2	5	0.25
Ease of use		5	5	0.25	4	0.2	4	0.2	5	0.25	5	0.25	5	0.25	5	0.25	3	0.15	5	0.25
Health Impacts		5	5	0.25	4	0.2	3	0.15	3	0.15	3	0.15	5	0.25	3	0.15	4	0.2	5	0.25
Materials Impact		5	3	0.15	3	0.15	3	0.15	3	0.15	3	0.15	3	0.15	3	0.15	4	0.2	4	0.2
Total score		100	**69**	6.72	**66**	5.89	**63**	5.15	**61**	5.64	**65**	6.28	**78**	7.35	**76**	7.08	**74**	7.31	**84**	8.24
Rank				**5**		**7**		**9**		**8**		**6**		**2**		**4**		**3**		**1**

Detailed Investigation

A detailed investigation was performed of the two highest-ranking candidates. This investigation revealed that both candidates would be appropriate technologies for HC's research agenda in the upcoming year. Both candidates have high marks in nearly every category. The Trak 21's innovative focus on creating a control that is invisible to the user, while effectively and efficiently maintaining optimal indoor air quality would make it a complimentary piece of any advanced-energy-designed home or multifamily building. HomePrime would also add to the reach of an advanced energy approach, yielding information to the user and building operator about the building's performance. HC's partnerships are well suited for the development, implementation, and testing of each system, much of which is already underway with both the Trak 21 and the HomePrime System. However, the HomePrime system's potential to reduce operating energy was the deciding factor for its selection as the most worthwhile system to pursue.

Initial Development and Testing of Advanced System

Initial development and testing of the HomePrime system is currently underway in an HC-engineered apartment building in Cambridge, Massachusetts. This prototype system will serve as a basis for further development and testing of the indoor environment sensor technology, energy measurement devices, software, and user interface of the HomePrime System. An HC partner, Oak Tree Development, will be leading the effort with help from the MIT Home of the Future.

The most important component of the system, the communications infrastructure or backbone, is nearly complete. Connected to this are sensors and Internet connections in every apartment with digital interfaces that will display in real-time the energy impact of occupant climate and electricity choices. Each apartment will be provided with this information in an easy to understand computer interface. Building operators will use this information to optimize energy use for the whole building. This two-tiered information approach is expected to produce significant energy savings—by making occupants aware of the energy impact of their choices, especially if they are paying for it, and by giving building operators the information to enhance the performance of building HVAC systems. Testing this system will reveal the effectiveness of the sensors and energy measurement devices, the user interface, and information management software. Testing will also produce results about the magnitude of energy savings

Conclusion

The conclusions reached by performing the criteria selection matrix process were a reassurance of the competence and balance of HC's evolving research agenda. Finding that the two top-ranked technologies were innovations that HC has already spent time and resources on, gave new "energy" to these pursuits. Although Hickory will remain interested in the advanced energy systems that did not get chosen, this process has invigorated the partners working on the Trak 21AQ and HomePrime systems to continue their work with added confidence.

In terms of HC's top choice for advanced energy system research, the effectiveness of the HomePrime system on reducing operating energy will depend on several assumptions. The first is that occupants will become interested participants in monitoring the amount of energy they are using and will take steps to reduce that use. The second is that the information provided will be adequate to enhance energy management on a whole-building level. The partners involved with HomePrime are confident that the technology exists to make HomePrime a reality and that it only needs to be combined in the right way.

Heating, Ventilating, and Air Conditioning (HVAC)

Introduction

One of the primary goals of the Hickory Consortium is to improve the quality of the installed HVAC system and, in the process, improve the comfort and indoor air quality and reduce energy and installation costs. Warm-air heating systems are commonly poorly installed, usually due to poor workmanship on site or complexity of installation, plus lack of installer training. Recent studies have highlighted the importance of good installation, interior duct location, and tight ducts, but these are not common practices. At the same time, house construction speeds have increased, leaving little time for careful engineering or detailed installation. And because this has been going on for so long, many consumers have gotten used to these uncomfortable systems, though callbacks related to comfort still top the builder's lists of problems. The HomeRun system seeks to address both the installation problem and the need for individually zoned air delivery.

The HomeRun HVAC System™ (HRHS) is a heating and cooling distribution system designed to provide energy efficiency and comfort to the end user and simple installation to the contractor. The primary difference between the HRHS and traditional warm-air heating system is a "zoned" distribution system using individual fans to direct the conditioned air into as many as nine rooms or locations. Each room has its own controlling thermostat. HRHS constitutes a breakthrough in simplified, energy-efficient, high-comfort heating, cooling, and ventilating technology for homes. The advent of quiet, powerful, low-power and low-cost fans has made possible a new way of delivering heating and cooling to buildings. By devoting a small fan to each room, adequate airflow is assured; and each room can be independently controlled and zoned. Thus, installation is greatly simplified. Furthermore, with air infiltration reduced by better insulation and glazing, the old system of placing heat registers under windows has become obsolete, and much shorter ducts can be used.

HC has been seeking a way to engineer most of the installation details into the equipment and remove them from the work site. With this approach, a larger portion of the cost is transferred to the equipment manufacturer, while greatly reducing the installer's portion. If successful, there will be much less work on site, and the total of all installation costs will be reduced. Importantly, reducing the number of steps and simplifying duct design can also reduce the errors often associated with installation.

Improved energy efficiency has been achieved by using a total zoned approach: every room is served by its own circulating fan. This means that the fans can be much smaller and the only energy used is that required to satisfy that room. Studies have shown that savings up to 30% can be achieved in systems with room-level zoning. Also, duct connections are fewer and all are within the conditioned space so system losses are greatly reduced. Note that the savings from zoning are in addition to those attributed to the interior location of ducts. Thermal distribution system efficiencies range from 65% to 95%, depending on their location and level of air sealing, but additional zoning savings come from reduced loads in cooler or warmer zones and from reduced fan and heat generator operation.

These improved systems lend themselves to modular home construction because most of the work can be performed in the factory. Moreover, modular homes can be substantially ducted within the modules with this system, making between module connections with piping rather than ducts. However, there are many opportunities and market segments that would also benefit from the smaller, zoned air system, such as apartments, condominiums and small homes, and these other markets may emerge as primary users in the long run. Below is a brief review of the development history of the HomeRun System through several prototypes, and a summary of work done on the system in 2001.

HomeRun Model 1

The first HomeRun system units consisted of modified First Co. air handlers with their circulating blowers removed. These were replaced with a fan module that was installed on top of the system. The fan module included nine small fans and backdraft dampers, each controlled by a room thermostat, and each connected to a separate flexible duct.

As with a conventional HVAC system, return air entered the system through the return duct, through the filter and into the air handler. When an individual room called for heating, the fan connected to that room would turn on, pushing the conditioned air through a backdraft damper, through the ducting, and out through the wall register into the room. The air was then drawn back through the central stairway and down to the return duct in the basement.

The registers were located high on inside walls in the rooms to more effectively supply both heated and cooled air. With excellent windows (i.e., warm glass-surface temperatures), there is little need for the traditional practice of covering the glass surface with a blanket of conditioned air; this has been verified by the owners of these units.

The backdraft dampers are necessary so that the air is drawn through the conditioning coil instead of back through a duct from another room or rooms. Evaluation of Model I showed that these backdraft dampers must be very easy to open when fans come on, to reduce resistance in the duct. Low flows from some fans were problematic; and several fans were replaced by more powerful models.

The controls for these first systems consisted of Honeywell Round thermostats in each room connected to a relay bank at the air handler. This relay bank allowed the low-voltage signal from the thermostat to control the line voltage operation of the fan and to allow the system to be switched over from heating to cooling with the selection of the setting on the master thermostat in the first-floor hallway.

HomeRun Model 2

The second version of the HomeRun systems did not vary functionally from the originals. They did include a microprocessor-based controller that took the place of the relay bank, and the fan housings were improved to simplify installing and replacing the fans. Different fans were also used to compensate for the low flows found in the original units and the long duct runs.

One innovation for these systems was to include telephone cable and telephone jack connectors to make the thermostat connections easier and less susceptible to installer error. Generally, this was a successful innovation, though some of the wires installed at the factory were too large for the connectors. The need for coordination between equipment manufacturer and modular manufacturer cannot be underestimated. The connectors did make installation easier and will make replacing components easier in the future.

In the Cambridge Co-housing project, where the Model 2 was prototyped, some of the townhouses (those without basements) had standard fan-coil systems. These units exhibited the typical problems with seasonal changes in balancing requirements. Manual dampers were used in an attempt to allow users to change the flow of air to the top rooms on a seasonal basis, but comfort levels were erratic. The townhouses with the HomeRun systems have by-and-large been more comfortable for the occupants.

Modular HomeRun

The Modular HomeRun system combines the advantages of both an HVAC system and a hydronic system. The air handlers are designed to be small enough to mount in a hallway ceiling. With four duct connections, as many as four rooms surrounding the air handler can be supplied with conditioned air.

The conditioning for the house can be accomplished by circulating hot or cold water from a central heating or chilling unit. Water from this source is directed to the coil in the air handler. Air from the hallway is drawn into the system through a filter, through the conditioning coil, and pushed into the room calling for heating or cooling by the appropriate fan, and through the register into the room.

The room sensor reads the temperature in the room. That temperature is returned to the unit control adjacent to the four rooms being controlled. The desired temperature for each of the spaces is set on the control. The coil temperature is also sensed. The fan speed is controlled by the smallest difference between the room temperature and the coil temperature or the room temperature and the set point. If the unit control is set for heating and the room temperature exceeds the set point, the fan will not run and a cooling call indicator will illuminate. The heating or cooling function is manually selected on the unit control. (This could become an automatic function when three of the four sensors are calling for a changeover.)

The air handler is a ceiling-mountable unit that allows air to move into it through a ceiling register, through a replaceable filter, through the coil, through one or more of the replaceable direct current (DC) fans, and out through a 6-inch duct fitting that includes a fabric backdraft damper. A connection can be made to the inlet chamber through a motorized damper to the outside. A control circuit in the unit control can be set to open the damper at various times for various lengths of time.

Internal water connections with the coil are made with polyethylene "snap-on" fittings, allowing connections to be made and broken easily.

By keeping the air handler "local," the duct runs can be much shorter and the resistance will be much less. This also reduces the power requirements of the fans. However, there is less ducting to insulate the end of the duct from the fan noise. These systems, therefore, will use variable-speed, DC fans.

The control strategy has also been changed. Instead of four individual room-mounted thermostats, a single, four-channel control center will be supplied. Perhaps the most difficult element of control is allowing the system to change over from heating to cooling. Determining the controlling thermostat made the logic unnecessarily complex. A single switch can be used to select the heating or cooling status when a single control center is used for all four locations.

Each delivery point will be supplied with a temperature sensor. At the control center, the temperature for that delivery point will be set. The coil temperature will also be sensed. The speed of the airflow through the delivery fan will be set by the difference between the room temperature, the set point, and the coil temperature. The flow will be set to the lowest rate. So, as the temperature in the room approaches its set point, the fan speed will decrease.

A bi-color indicator light-emitting diode (LED) will indicate if a room is calling for heat by glowing red. If the room is calling for cooling, the LED will glow green. This will clearly indicate if the system should be switched over for cooling.

The air handler will include a motorized damper for a fresh-air inlet. The on-timing will be set by a control on the control center.

Two "Y" valves will circulate the heated or cooled water to and from the tanks. This will allow the air handler to have only three water connections: supply, return, and drain.

The air handler itself will include an insulated box (to limit noise and the chance of condensation problems), a place for the filter, the coil with "snap-on" water connections, and slots for four DC fans with electrical connections. By removing the ceiling cover from the air handler, the filter, coil, and fans will be accessible and serviceable. In particular, the coil will be easily removable for cleaning and servicing. This modularity will be one of the most unique features of this system.

Development Status: Production drawings for the air handler housing are being revised. Once the drawings are completed, the prototype will be assembled and flow tested. The electronic logic diagrams are in process. Once that is complete, the circuit will be designed and prototyped.

A number of material selection decisions still need to be made, such as which fans to use, what size the filter should be in order to be a standard item, what sort of water connections should be used, and how the room sensors should be housed to simplify installation.

Multi-Air™

There are a variety of inexpensive ways to ventilate a house that has a central air HVAC system, but not all new housing uses forced-air delivery for heating and cooling. Many new houses, particularly in the north, have radiant or convective heat delivery systems and no cooling system. Further, with some of the central-air delivery systems, it is not always desirable to insert unconditioned outside air into the return side of the air-handling system. In these cases, there has been no economical way to deliver fresh air to all spaces. The mechanical ventilation system under development by Tamarack Technologies, Inc., with the support of the Hickory Consortium is designed to fill a niche among the products available for residential ventilation systems.

Where houses are tight (0.2 air changes per hour [ACH]) and small, the required ventilation rate of 60 cubic feet per minute (cfm) to meet the need for 0.35 ACH or four occupants can be met by the Multi-Air. The Multi-Air can also alleviate the problems associated with naturally aspirated appliances, radon, garage connections, and fireplaces. It puts the fresh air where it is most needed—in the bedrooms with closed doors. Its operating cost will be low and, although initial cost is not insignificant, installed cost will be below that of other distributed-fresh-air systems.

The general design and performance requirements of the Multi-Air were well known from the beginning. The motorized impeller was used because of its ability to move air effectively against considerable backpressure. In the original configuration, the motor was centered in its housing, but flow testing determined that locating the fan off-center, near a corner, actually improved the air flow by about 10 cfm.

Housing size was kept as small as possible to facilitate installation. Initial units had screw-mounted covers that proved too cumbersome for filter cleaning and replacement. The volume of the housing was increased slightly to allow a heating element to be installed if it proved necessary.

Conclusions

After thoroughly bench-testing the system, the Multi-Air system was installed in the Excel Model Home as a working prototype. HC plans to test the operation, performance, and ease of installation in that building in the winter of 2001 to 2002. HC also plans to evaluate the feasibility of bringing the product to market as early as 2002.

Projects

Kansas City, Missouri

HC members Mark Kelley and Bruce Hampton conducted a series of workshops on the systems principles used by HC to produce high-quality, energy-efficient, low-income housing. The workshops were presented to the Kansas City Builders Association; the Kansas City American Institute of Architects (AIA); 17 of the local Community Development Corporations (CDCs); and a group of interested state, local, utility, and financial interests. Considerable excitement has been generated relative to the prospect of producing better, more efficient housing in Kansas City.

A systems analysis of the products currently planned for construction in the Paige Point Project in Kansas City showed opportunities for major energy savings (over 50% of energy costs) at a very low initial investment. Efforts are underway to include some upgrades in the project even though groundbreaking took place just after the meeting. Future projects will offer greater opportunities through earlier intervention and more attention to project management.

The low-income housing currently being constructed in Kansas City has many shortcomings with respect to quality and energy efficiency. Though there is considerable will on the part of the CDCs and charitable organizations responsible for developing this housing, they lack the expertise for systems engineering, including improvements in design or managing projects to smoothly incorporate improvements. HC can provide all of these necessary ingredients and, in discussions with the developers, has begun to devise a plan for delivering these services at a distance. By combining forces with the Metropolitan Energy Center and the Kansas Building Science Institute, we are embarking on a cooperative effort to support the CDCs in all of these areas. Activities scheduled for 2002 include additional training, design review and systems engineering support, project management support, and quality assurance testing (blower door and duct testing) of completed buildings.

Cambridge Park Place, North Cambridge, Massachusetts

Cambridge Park Place Apartments is a 311-unit, multifamily project located at the Alewife public transit stop in North Cambridge, Massachusetts. This transit-oriented development (TOD) utilizes and restores a 3.3-acre industrial site. Designed to have 35% improved energy performance over standard buildings of its type, Cambridge Park Place is currently under construction. It will be the largest residential green-design project in the United States, as well as the first large-scale residential project in the country to get a LEED specification.

The mid-rise project brings much-needed housing and neighborhood life to a neighborhood that has become dominated by commercial office buildings. The project incorporates 36 affordable units and 275 market-rate units, as well as some retail space. The project is in an ideal location for commuters going to central Cambridge and Boston, with a direct link to downtown Boston and the universities in Cambridge. Many shops and amenities in the Fresh Pond area are within walking distance. Bicycle paths from western suburbs also convene at the Alewife transit station.

The developer and the project team have used the Integrated Development Process (IDP), facilitated by HC member William Reed. IDP creates a process for collaboration and cross-fertilization of isolated specialties, leading to coordinated decisions and higher performance. A full description of IDP was provided in the first Progress Report on Cambridge Park Apartments. "The Integrated Development Process Chart" and "Phases of an Integrated Development Process," developed by William Reed, were included in the second report.

The overall goal of the Cambridge Park Place Apartments project has been to produce a high-performance building that meets environmental, energy-efficiency, and quality expectations, while competing in the multifamily housing market. Original project objectives, most of which have been ultimately met, include the following:

- Build high-quality, multifamily rental housing convenient to residents working in Boston and Cambridge
- Maximize the environmental benefits and cost performance of a building located in a dense urban area adjacent to mass transit
- Reduce overall energy demand and consumption by 30% to 40%
- Create healthy indoor air quality for tenants and staff
- Reduce construction waste and associated costs
- Reduce water use and related costs
- Reduce runoff from the site and store floodwaters on the site
- Reduce maintenance and operating costs over the life of the building for owner and tenants
- Achieve LEED Green Building certification at standard construction cost.

The Cambridge Park Place Apartments project at Alewife offers an opportunity to expand the impact of the Building America Program to a new residential building type. One multifamily building can bring hundreds of energy-efficient homes into the housing market. Cambridge Park Place Apartments also provides a unique opportunity to document the interrelationship between systems-based construction methods developed by the Building America Program and related programs such as the U.S. EPA Smart Growth Initiative, the U.S. EPA's ENERGY STAR Homes Program, the U.S. Green Building Council's LEED Green Building Rating System version 2.0, and the Integrated Development Process. Most directly, Cambridge Park Place Apartments provides the Building America Program with the following opportunities:

- Develop a systems-based approach to a new residential building type
- Demonstrate the viability and advantages of a high-performance building for the competitively priced, mid-rise residential housing market
- Add 311 units to the Building America Program
- Create a replicable sustainable design and development process.

The developer plans to take advantage of the marketing benefits of an overall well-designed, competitively priced, environmentally responsible, resource-efficient multifamily building. The final high performance of Cambridge Park Place Apartments, including lower electrical costs to tenants, high comfort levels in units with better air and temperature control, no toxic off-gassing, and reduced overall environmental impact, will be part of the marketing package when Cambridge Park Place Apartments are put on the rental market in 2002.

Erie Ellington, Boston, Massachusetts

The Erie-Ellington Homes development brought 50 beautiful, affordable homes and a community center to the Four Corners Neighborhood of Boston. In this inner-city Boston project, the Codman Square Neighborhood Development Corporation developed five parcels on Erie and Ellington Streets in Dorchester, Massachusetts, for affordable rental housing and a community building. The project is designed with sufficient scale to counter the blighting impact of the unusually large number of vacant lots

(24%) in the neighborhood that are both scattered between housing and clustered into a number of sizable tracts.

The five parcels in the project amount to 3.6 acres. Twenty-seven percent of the area will be occupied by buildings, 11% will be off-street parking (one car per household), and 61% will be open space. The units have been built to EcoDynamic™ Homes specifications and produced as panelized housing.

Erie-Ellington homes were designed to have the following features:

- Use 49% less energy than standard homes
- Use 41% less water
- Reduce air pollutants by 25%–60%
- Cost 25% less to build, and
- Reduce annual water, electricity, and heating operating expenses by 46%.

The key to the environmental performance of the design is whole-building design. To make design decisions, HC architects and engineers considered all of the components of a home and how they interact. A whole-building approach made it possible, for example, to use higher quality low-e windows. Good low-e windows cost a little more, but because they help conserve energy, engineers were able to design smaller equipment to heat each building. This saved the project money and energy.

The Erie-Ellington Homes project was a very exciting opportunity for the Hickory Consortium and the Building America Program to demonstrate the viability and advantages of "green" building for the affordable-housing market. Too often, homes designed to exacting environmental standards and using innovative, environmentally sound materials and components are expensive to build and purchase. In the Erie-Ellington Homes, we have demonstrated that affordability <u>and</u> environmental responsibility are not mutually exclusive.

Construction on these homes was completed in 2000, and the homes have been occupied for 1 to 1-½ years.

HC has conducted resident interviews and evaluation of the energy usage billing data. An energy analysis of billing water and energy use and energy costs show a better-than-predicted energy cost savings, approximately 50%, with a slightly lower-than-predicted energy use savings of 40%. The better-cost savings are due to greater electric energy savings (59% reduction compared to the base case), as compared to heat and hot water savings, while the electric costs have more than doubled in the past 2 years. Water use and water-heating reductions were lower than estimated, but heating energy use and heating cost savings were better than predicted. The combined heat and hot-water energy costs were within 3% of estimated costs when adjusted for fuel cost increases. Overall, the actual energy costs were better than the originally estimated costs when adjusted for utility price increases.

The resident survey revealed some minor heat distribution problems (which will be easily corrected), although residents are generally very positive about the comfort level in the buildings. Perhaps even more exciting, residents report a dramatic decrease in asthma for children who had asthma before occupying these housing units.

Back of the Hill Housing Project, Boston, Massachusetts

The Community Housing Initiative's "Back of the Hill" (BOTH) project is the second of three low-income housing projects in the Mission Hill area of Boston. This project, located on Heath and Hayden Streets, will be the first to apply the Building America systems-engineering approach and HC's Eco-dynamic specifications to the design and construction process. BOTH Phase II is a low-income housing project (73% of the residents will fall in the low-income category), with a mix of large multifamily, triplex, and duplex

units. The steeply sloping site presented unique challenges for the architect, and the central multifamily building has a good approach to providing off-road parking, while preserving and even enhancing the building's appearance.

Phase 2 of the Community Housing Initiative involves the new construction of seven wood-frame buildings containing a total of 34 dwelling units on a steep site in the Back of the Hill neighborhood. The project includes four two-family buildings, two three-family buildings, and one multifamily building with 20 units and a meeting room. There will be 24 off-street parking spaces. The existing one-story warehouse building on the site is to be completely demolished and removed, except for the rear wall and one side wall, which will remain as retaining walls.

The project is expected to start construction in the spring of 2002. Current activities are focusing on remediating low-level lead contamination in soils on the site. This is the standard concern with inner city developments, yet it adds considerable uncertainty to both the cost and schedule of the project. Once this remediation is complete, a firm construction schedule can be established.

The current status of the project is very encouraging from a cost and energy perspective. After completing the working drawings for the project, Architect Nick Elton sent the plans out for bids. The result was several good bids and a final bid approximately 1% below the budget—almost unheard of in today's market. Through systems engineering, heating and hot-water equipment was reduced in size, allowing some boilers to be eliminated and others to be downsized. We also incorporated polyisocyanurate foam insulation in an exposed floor over the parking lot entrance and in the roof of one of two identical duplexes. This will enhance the comfort and energy efficiency of the buildings and allow us to test the performance of this new roof system in direct comparison to a typical vaulted ceiling.

The Back of the Hill Project has incorporated nearly all of the recommendations from the Hickory Consortium's systems engineering analysis. The buildings will greatly benefit from the application of the systems engineering principles used by the Hickory Consortium in the Building America Program. Dramatic energy savings are expected at little or no cost through performance tradeoffs and utility incentives. These will also improve the environmental performance and the quality of the indoor environment. The specifications created and agreed to in the winning bid are thorough and specific to assure clear understanding of the goals and techniques and a positive effort at on-site follow through.

Testing these buildings presents an opportunity to evaluate the effectiveness of the modifications to the building envelope and systems that resulted from HC's systems engineering. Using polyisocyanurate insulation in the roof of one of two identical duplexes will provide a good situation for comparing the standard system to this new approach. Finally, the testing will allow HC to quantify systems losses in hydronic heat-delivery systems in multifamily housing. This is an area of some uncertainty in the design and choice of these systems, and the results will be broadly useful to designers and developers in the future.

With cooperative participants and their support to assure clear understanding of techniques, there is every reason to expect a better project process and a better housing product than is normally the case for low-income projects. The potential benefits of this project are tremendous, to the owners, occupants, the community, and all of the people who contribute to this phase of the Back of the Hill Project.

Research Agenda for 2002

Systems Improvements/Whole Integrated Design Research Agenda

- Develop a systems-based approach to a new residential building type on the 311-unit Cambridge Park Place project, and demonstrate the viability and advantages of a high-performance building for the competitively priced, mid-rise residential housing market.
- Create a replicable sustainable design and development process for residential building design and construction to enable LEED certification.
- Perform research on basement insulation in support of Hickory's Urban Rehab Housing projects.

Hardware Improvements/Advanced Systems Research Agenda

- Continue design and development of the Modular HomeRun and numerous material selection decisions, such as which fans to use, what size the filter should be in order to be a standard item, what sort of water connections should be used, and how the room sensors should be housed to simplify installation.
- Monitor and test performance of the installed Multi-Air system installed in the Excel Model Home. Perform product viability assessment to evaluate the feasibility of bringing the product to market as early as 2002.
- Continue research and development of the two chosen candidates from Hickory's advanced system research – HomePrime system and Trak21AQ.

Modular Research Agenda

As part of the annual Quality Modular Building Task Force, we will work with the industry leaders to develop the Modular Research Agenda for HC for the next year. This will guide HC's work with the modular industry in the areas of components and process improvements. This year, the topics are as follows:

- Develop systems for bringing HVAC systems into the modular factory.
- Continue development, testing, and deployment of the Construction Rubric for on-site set and finish activities for modular home construction. Perform the Kaizen process with different manufacturers' products and different builders.
- Develop and disseminate a Builder Training program. Pursue and disseminate the Construction Rubric.
- Continue to work with modular manufacturers to introduce quality management concepts into the modular housing industry.
  - Develop a performance measurement plan for key drivers (including energy drivers)
  - Develop a benchmarking plan that allows task force members to benchmark against competitors
  - Develop an employee involvement/teaming plan to empower employees.
- Continue to educate the manufacturers: Energy efficiency is the result of good quality.

Outreach

Developers Roundtable

The purpose of the Developers Roundtable is to focus developer interest on issues and techniques related to green building and encourage green project development. The Developers Roundtable is a joint project of Hickory Consortium and the Green Roundtable.

To date, there have been three Developers Roundtables on Green Building. The first two meetings identified a need for a financing vehicle for green builders and developers. This has driven the current focus of the meetings to “Financing Green Development," which is working with members of the finance and real estate sector on promoting and enabling green-building projects. The Hickory Consortium is bringing together a small working group to help financers give incentives green building—specifically to develop innovative lending products for green residential/mixed-use projects. By helping to create these “Green Building” lending products, Hickory Consortium believes that we will enable the development of residential and mixed-use projects being built with green building design.

Hickory Member Stella Tarnay is facilitating the meetings and is working with area representatives from financial institutions, developers, and senior building professionals, to identify stakeholders, engage them in conversation to identify issues and needs for lenders, and find out how HC can be supportive.

Presentations and Conferences

HC members participated in, presented at, and hosted numerous conferences throughout the year. The conferences listing, participation, and descriptions are included as Attachment 1 of this report.

Summary

In summary, HC had a very effective year, with many exciting projects. The efforts we have put into educating the community and industry on the importance of quality and energy savings are evident.

We have further cemented our strong relationships with the Modular Manufacturers on the Task Force. Many of the Modular Manufacturers are firmly behind incorporating quality principles into their businesses. The manufacturers are also beginning to demonstrate an understanding of the relationship between energy and quality. As we help them test their homes, design their factories, and work on improving the building processes in their factories, we have seen them make real changes in their businesses. The manufacturers are beginning to demonstrate the belief that incorporating Building America ideals will result in a better product and a competitive advantage for their businesses and industry. We are witnessing the influence that HC and the Building America program is having on the industry, most tangibly through the Modular factory we have helped design for Excel Homes. We will continue to work closely with our industry partners over the next year to execute the Modular Research Agenda.

We have made great progress in Heating and Ventilation Systems, with the Multi-Air system installed in a prototype home. HC plans to test the operation, performance, and ease of installation in that building this winter, with the goal of bringing the product to market as soon as 2002. Promising results on the Modular HomeRun system will guide the continued development of that system.

Our advanced systems research agenda is rich with promise. One of the most exciting aspects of the HomePrime system is the concept of the consumer of energy being engaged knowledgeably in the process; this is a very important and potentially powerful step in energy conservation. By providing the information to the homeowner, intelligent decisions can be made to change their behavior and effect reduced energy use and, ultimately, reduced cost.

HC will also be expanding its influence and outreach in the coming year to cultivate a national presence. The first step is the Kansas City project, which looks very promising. We will continue to focus on the urban market, including expanding our focus to include urban rehabilitation.

We plan to continue our work to bring the message that energy efficiency can't occur without embracing quality in construction. There is no real quality without energy efficiency.

Appendix 1. Hickory Consortium Presentations and Conferences Listing

February 2001

Modular Focus Group. In February and March of 2001, HC member Josephine Carothers convened four focus groups of stick builders on modular building. The purpose of the groups was to identify attitudes and resistance among stick-builders to modular building. Residential builders in Virginia, North Carolina, and Michigan participated. Sessions were facilitated by an independent facilitator and observed by Josephine Carothers. They were also videotaped for further review and analysis.

National Homebuilders Show. In February 2001, HC members Paul Raymer and Dan LeBlanc presented recent advances in HVAC technology at a booth at the annual National Homebuilders Show in Atlanta, Georgia. Their booth attracted much attention, and Raymer and LeBlanc used the opportunity to ask visitors about their approach to ventilation and to educate them about the need for fresh-air supply.

Vermont Star Homes Show. In February 2001, HC member Paul Raymer displayed new HVAC products and technologies at the Vermont Star Homes Show. The booth attracted a lot of discussion regarding the in-process Vermont ventilation codes.

Massachusetts Green Leadership Luncheon. In February, HC member Stella Tarnay participated in a leadership luncheon for 20 green building organizations in Massachusetts and presented recent HC and Building America Program advances.

March 2001

Green Prints Presentation. HC member Bruce Hampton presented the Erie-Ellington project and Building America Program at the Green Prints Conference in Atlanta, Georgia.

Developers Roundtable and Presentation. In March, HC member Stella Tarnay convened and facilitated a regional meeting of developers and financers interested in green building. The purpose of the meeting was to identify green-building issues relevant to developers and to identify opportunities for HC involvement. HC members Gwen Noyes and Art Klipfel of the Oaktree Green Development gave a presentation on the Cambridge Park Place project. The meeting was co-sponsored by The Green Roundtable, a local chapter of the U.S. Green Building Council.

NESEA Conference and Award. HC members Mark Kelley, Stella Tarnay, Bill Reed, and Jesa Damora participated in the Northeast Sustainable Energy Association's Building Energy Conference at Tufts University in Medford, Massachusetts. Mark Kelley presented on the topic of whole-building design and the Building America Program, and Bill Reed gave a presentation on high-performance buildings. Stella Tarnay and Jesa Damora networked on behalf of HC and the Building America Program. During the conference, the HC team was awarded First Prize in the Residential Category for sustainable building. Conference tours also featured a stop at Cambridge Co-housing, hosted by HC members and Oaktree Development principals Gwen Noyes and Art Klipfel.

LEED Workshop. As part of her NESEA conference participation, HC member Stella Tarnay participated in the full-day LEED training workshop, at which she became knowledgeable about the LEED certification process on behalf of HC. She was also able to present the Building America Program and HC approaches to building.

San Ramon, California, Trade Show. In March, HC member Paul Raymer of Tamarack participated in a trade show in San Ramon where there was a great deal of interest in a wide variety of ventilation issues. This meeting facilitated conferences and work on the HomeRun control and heat transfer systems with several experts.

GBIO Meeting. In March, HC members Stella Tarnay and Jesa Damora met with representatives of the Greater Boston Interfaith Organization, an influential organization for affordable housing, and members of the Climate Action Initiative. They presented HC's approach to home design and building and suggested steps for further interaction.

NAHB Green Building Conference. HC member Mark Kelley gave a presentation on the Building America Program and the Erie-Ellington Homes project at the annual National Association of Home Builders Conference on Green Building in Seattle, Washington.

Energy Efficiency Training. HC members Mark Kelley and Anna Lee Court gave a full-day training on energy efficiency to Epoch's builders and staff in Pembroke, New Hampshire. The training included energy strategies for modular building and finishing, DOE's Building America Program systems-based approach, and ENERGY STAR.

April 2001

Stephan Bradley Presentation. In April, HC member Bill Reed gave a presentation on high-performance buildings to Stephan Bradley Associates, a major architectural firm in Boston and project architect for HC's Cambridge Park Place Apartments.

DOE Meeting. On April 10–11, HC members Stella Tarnay, Mark Kelley, Steve Stuntz, Paul Raymer, and Bruce Hampton participated in the Building America Program teams meeting hosted in Washington, D.C., by DOE. They presented recent HC initiatives and advances, both in the technical arena and in market outreach.

EnviroDesign 5 Conference. In April, HC member Stella Tarnay represented Hickory Consortium at the EnviroDesign Conference in Atlanta, Georgia. She made excellent contacts with building design industry professionals, including the chief of green building initiatives for the City of Chicago and several housing developers in Atlanta.

Boston Duplex Project. HC members Jennifer Pinck and Bruce Hampton presented the plans for an eight-unit infill project on Howard Street in Boston to members of the Dudley Street Neighborhood Initiative community group in April, the first green housing project to be proposed in the neighborhood.

May 2001

City of Boston DND. In May, HC members Bruce Hampton and Mark Kelley met with the staff of Boston's Department of Neighborhood Development and the Boston Health Department to follow up on a presentation they gave in 2000 and to review and upgrade the requirements for new home construction in the city. This upgrade will require better windows, healthy materials, ventilation, air sealing, insulation, and equipment. All of approximately 1,000 houses built in the city must submit proposed specifications that meet these requirements.

Affordable Comfort. In May, HC member Mark Kelley presented an overview of the Erie-Ellington Homes project and lessons learned at the Affordable Comfort Conference in Milwaukee, Wisconsin. The presentation was part of a session entitled Green Homes in Green Communities.

June 2001

Developers Roundtable. In June, HC member Stella Tarnay convened the second meeting of the Developers Roundtable on Green Building. HC associate member Bill Reed gave a presentation on the LEED Certification program and the U.S. Green Building Council. The Roundtable is jointly sponsored by HC and The Green Roundtable, the regional chapter of the U.S. Green Building Council.

CNU Conference. In June, HC member Stella Tarnay represented the Hickory Consortium at the Congress for New Urbanism's annual conference in New York City. She co-chaired the salon on sustainability and green building and introduced the Building America Program's systems-based approach to a new audience.

Smart Growth Task Force. HC member Stella Tarnay represented Hickory Consortium at the Smart Growth Task Force meeting of the Citizens Housing and Planning Association, the leading affordable housing advocate in New England.

DOE Public Hearing. HC members Stella Tarnay and Josephine Carothers testified on behalf of Hickory Consortium and the Building America Program at the regional DOE public hearing on the new U.S. Energy Policy, testifying to the progress that has been made in residential energy use through the Building America Program.

Boston City Public Hearing. HC member Stella Tarnay testified on behalf of the Hickory Consortium and the benefits of environmentally responsible construction at a public hearing called by Boston City Council for a proposed green-building initiative.

Kansas City. In June, HC members Mark Kelley and Bruce Hampton made four presentations on systems-based design and engineering to 18 Kansas City-area Community Development Corporations and a group of city, utility, housing, and professional organizations, including the local chapter of the AIA and the Kansas City Homebuilders Association, which is working on starting a green building program.

July 2001

Codes Conference. HC member Paul Raymer participated in the National Codes Conference in Burlington, Vermont, an important venue for upgrading ventilation codes in various states. He represented HC advances and the Building America Program at the event.

North American Cohousing Conference. HC member Stella Tarnay moderated a panel on environmentally sustainable building at the North American Cohousing Conference in Berkeley, California. She also presented the Erie-Ellington case study and provided information on the Building America Program to co-housing professionals and participants.

Pacific Coast Builders Conference. HC member Paul Raymer participated in the Pacific Coast Builders Conference in San Francisco, California. His booth attracted a large number of builders interested in ventilation issues and indoor air quality.

August 2001

USGBC Annual Summit. HC member Dan LeBlanc participated in the 4th Annual U.S. Green Building Council in Tuscon, Arizona. He represented the Hickory Consortium and the Building America Program in summit discussions.

Sustainable Communities Think Tank. HC member Pliny Fisk represented the Center for Maximum Potential Building and Hickory Consortium at the Sustainable Communities Think Tank in Aspen, Colorado. The Think Tank was funded by the National Science Foundation.

September 2001

Automated Builders Conference. On September 7, HC member Steve Stuntz gave a presentation on factory systems and HC advances at the Automated Builders Conference in Pittsburgh, Pennsylvania. He also introduced HC and the Building America Program.

New Ecology Conference. HC members Mark Kelley, Bruce Hampton, and Jesa Damora presented the Erie-Ellington Homes project and systems-based methodology to a group of affordable housing professionals at the New Ecology Conference: The Greening of Community Development, held at the Massachusetts Institute of Technology in Cambridge.

October 2001

Urban Land Institute. On October 4, HC members Gwen Noyes, Bruce Hampton, Stella Tarnay, and Jesa Damora participated in the national Fall Meeting of the Urban Land Institute (ULI). Gwen Noyes gave a presentation to ULI's Environmental Council on the Cambridge Park Place project, Bruce Hampton gave a presentation on Erie-Ellington Homes to the Council, and Stella Tarnay introduced the Hickory Consortium and the Building America Program.

Task Force Meeting. On October 4–5, HC convened the third annual meeting of the Quality Modular Building Task Force in Salem, Massachusetts. HC members Mark Kelley, Josephine Carothers, Mike Mullens, Steve Stuntz, Ash Richards, Anna Lee Court, and builder Andy Gianino gave presentations on quality systems and improved plant design for modular factories, building materials, the Kaizen process, suppliers issues, and the new ENERGY STAR manual. The group also discussed upcoming research agendas.

Developers Roundtable on Green Building. On October 11, HC member Stella Tarnay convened the third Developers Roundtable on Green Building. The focus of the meeting was financing and included a presentation by HC member Art Klipfel of Oaktree Green Development and Erie-Ellington's original developer, Ann Houston. Private and public developers were present, as were the heads of several City agencies and financial institutions.

Ohio AIA Conference. HC member Pliny Fisk gave the keynote address at the Annual Ohio AIA Conference in Cincinnati.

EEBA Conference. HC member Mark Kelley gave a presentation on the Kaizen process and the Building America Program at the EEBA Excellence in Building Conference in Orlando, Florida, on October 25–28.

November 2001

Build Boston. HC members Mark Kelley, Bruce Hampton, and Gail Vittori gave presentations on Practical Sustainability and Greening Urban Housing at the annual Build Boston Convention and Conference in November.

Bibliography

Court, Anna Lee. 1999. *Minutes of the First Meeting of the Quality Monitor Building Task Force,* September 30 – October 1, 1999, St. Marie Hotel. New Orleans, Louisiana.

Hampton, Bruce. 2001. GreenVillage Co. Project Promotes Building for the Longterm. *Automated Builder*, April.

Hickory Consortium. 2001. Northeast Green Building Awards, sponsored by the Massachusetts Renewable Energy Trust. *Environmental Building News*, April.

Hickory Consortium. 2002. *Milestone Report: Final Evaluation of Hickory Consortium's Fifth Prototype GreenFORMs™: The GrowHome*. November 30, Cambridge, Massachusetts, Task Order KAR-5-18413-05 Deliverable 5.B.1.

Hickory Consortium. 2000. *Update of Heating/Cooling Systems*. December 4, Cambridge, Massachusetts. Task Order KAR-8-18413-05 Deliverable 5.A.1.

Hickory Consortium. 2001. *Progress Report: Construction Management System for On-Site Modular Housing Assembly.* April 3, Cambridge, Massachusetts. Task Order KAR-8-18413-07 Deliverable 7.B.2.

Hickory Consortium. 2001. *Report of the Hickory Consortium's Building America Initiative for the Period*, April 1 – April 30, 2001. May, Cambridge, Massachusetts, Task Order KAR-8-18413-08 Deliverable A.2.

Hickory Consortium. 2001. *Guide to Producing ENERGY STAr Homes for Modular Manufacturers and Their Builders*. August, Cambridge, Massachusetts. Task Order KAR-8-18413-05 Deliverable C.3b

Hickory Consortium. 2001. *Report of the Hickory Consortium's Building America Initiative for the Period, October 1 - October 31, 2001*. November, Cambridge, Massachusetts.

Hickory Consortium. 2001. *Final Report: Results of the Modular Housing Site Process Kaizen.* October 19, Cambridge, Massachusetts. Task Order KAR-8-18413-07 Deliverable 07.A.2.

Hickory Consortium. 2001. *Report: Update on Heating/Cooling Systems*. October 19, Cambridge, Massachusetts. Task Order KAR-8-18413-07 Deliverable 7.C.1.

Hickory Consortium. 2001. *Report: A Study of Homebuilders*. October 19, Cambridge, Massachusetts. Task Order KAR-8-18413-06 Deliverable 6.B.1.

Hickory Consortium. 2000. *Milestone* Report on the Quality Modular Building Task Force Meeting Results and Research Plan. November 10, Cambridge, Massachusetts. Task Order KAR-8-18413-06 Deliverable 6.B.2b.

Hickory Consortium. 2001. *Letter Report: Design Development, Performance Test and Evaluation Plan for the Mission Hill Project*. December 11, Cambridge, Massachusett. Task Order KAR-8-18413-08 Deliverable 8.C.1.4.

Hickory Consortium. 2002. *Milestone Report: Quality Modular Building Task Force Meeting Results and the Research Agenda.* January 2, Cambridge, Massachusetts. Task Order KAR-8-018413-08 Deliverable 8.B.2.

Hickory Consortium. 2002. *Information Report of the Hickory Consortium's Building America Initiative for the Period, December 1 – December 30, 2001*. January 18, Cambridge, Massachusetts. Task Order KAR-8-18413-08.

Hickory Consortium. 2001. *Letter Report: Modular System Design and Test Plans.* December 28, Cambridge, Massachusetts. Task Order KAR-8-18413-08 Deliverable 8.C.1.1.

Hickory Consortium. 2001. *Letter Report: Hickory Consortium Final Report.* December, Cambridge, Massachusetts. Task Order KAR-8-18413-08, Deliverable 8.C.1.6.

Tamarack Technologies. 2001. Multi-Air System Provides Filtered, Fresh Air. *Energy Design Update*, April.

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13. ABSTRACT *(Maximum 200 words)*

As with all Building America Program consortia, *systems thinking* is the key to understanding the processes that Hickory Consortium hopes to improve. The Hickory Consortium applies this thinking to more than the whole-building concept. Their systems thinking embraces the meta process of how housing construction takes place in America. By understanding the larger picture, they are able to identify areas where improvements can be made and how to implement them.

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