FLORIDA SOLAR ENERGY CENTER®

CONTRACT REPORT

Building America Industrialized Housing Partnership (BAIHP)

Annual Report – First Budget Period April 1, 2006 – February 28, 2007

FSEC-CR-1714-07
April (Revised June) 2007

Compiled by:
Stephanie Thomas-Rees and Subrato Chandra

Submitted to:
U.S. Department of Energy
Cooperative Agreement No. DE-FC26-06NT42767, UCF No. 2012-6034

1679 Clearlake Road, Cocoa, FL 32922-5703 • Phone: 321-638-1000 • Fax: 321-638-1010
www.fsec.ucf.edu

A Research Institute of the University of Central Florida

Building America Industrialized Housing Partnership (BAIHP)

Annual Report – Budget Period 1 (BP1)
April 1, 2006 – February 28, 2007

FSEC-CR-1714-07

Produced by the
BAIHP Team

Bob Abernethy, FSEC
Elizabeth Alford, UTSOA
Subrato Chandra, FSEC
Steven Baden, RESNET
Stephen Barkaszi, FSEC
David Beal, FSEC
David Chasar, FSEC
Carlos Colon, FSEC
Wanda Dutton, FSEC
Philip Fairey, FSEC
Ken Fonorow, FLHERO
Andrew Gordon, WSU
David Hoak, FSEC
Tom Hewes, ODOE
Safvat Kalaghchy, FSEC
Mike Lubliner, WSU
Eric Martin, FSEC
Janet McIlvaine, FSEC
Neil Moyer, FSEC
Mike Mullens, UCFIE
Danny Parker, FSEC
John Sherwin, FSEC
Dennis Stroer, Calcs-Plus
Stephanie Thomas-Rees, FSEC
Rob Vieira, FSEC
Susan Wichers, FSEC

Compiled by Stephanie Thomas-Rees and Subrato Chandra, FSEC

University of Central Florida/ Florida Solar Energy Center
12443 Research Parkway, Suite 207
Orlando, Florida 32826

April (Revised June) 2007

PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY
Under Cooperative Agreement
No. DE-FC26-06NT42767, UCF No. 2012-6034

ABSTRACT

This annual report summarizes the work conducted by the Building America Industrialized Housing Partnership (www.baihp.org) for the period 4/1/06 – 2/28/07. BAIHP is led by the Florida Solar Energy Center of the University of Central Florida. In partnership with over 50 factory and site builders, work was performed in two main areas – research and technical assistance.

In the research area -- through site visits and in house laboratory research we worked with builders educating and training them to adopt solutions to nearly eliminate moisture related problems. Through testing conducted in housing factories we documented the value of leak free duct design and construction which was embraced by our industry partners and has led to prototype research houses featuring interior ducts by two factory builders. Through laboratory test facilities and measurements in real homes we documented the merits of "cool roof" technologies and developed an innovative night sky radiative cooling concept currently being tested. We documented energy efficient home retrofit strategies after hurricane damage, developed improved specifications for federal procurement for future temporary housing, compared the Building America benchmark to HERS Index and IECC 2006, developed a toolkit for improving the accuracy and speed of benchmark calculations, monitored the field performance of over a dozen prototype homes and initiated research on the effectiveness of occupancy feedback in reducing household energy use.

In the technical assistance area we provided systems engineering analysis, conducted training, testing and commissioning primarily in hot-humid and marine climates. In 2006 we assisted in the construction of over 140 homes that exceed the 30% BA benchmark goals in hot-humid climates, over 160 homes that are near the 30% benchmark level in marine climates, over 4,400 Energy Star manufactured homes in the Pacific Northwest through the manufacturers participating in the Northwest Energy Efficient Manufactured Home program and over 19,000 other energy efficient manufactured homes by partners Palm Harbor Homes, Fleetwood and Southern Energy Homes. The estimated energy savings from these homes constructed in 2006 is over 209,000 million Btu/year and the estimated savings in utility bills to consumers exceed $3,600,000/yr. We worked with over twelve Habitat for Humanity affiliates / programs and helped them build over 83 Energy Star or near Energy Star homes. We have provided technical assistance to several show homes constructed for the International Builders' Show in Orlando, FL and assisted with other prototype homes in cold climates that save 40% over the benchmark reference. In the Gainesville, Fl area we have several builders that are consistently producing 15 to 30 homes per month in several subdivisions that meet the 30% benchmark savings goal. We have contributed to the 2006 DOE Joule goals by providing two community case studies meeting the 30% benchmark goal in marine climates.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government, nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agencies thereof.

TABLE OF CONTENTS

VIII. APPENDICES

ACKNOWLEDGEMENT

This work is sponsored, in large part, by the US Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, Building Technologies Program under cooperative agreement number DE-FC26-06NT42767. This support does not constitute an endorsement by DOE of the views expressed in this report.

The authors appreciate the encouragement and support from George James, Ed Pollock, and Chris Early, program personnel at DOE, and Bill Haslebacher, project officer at the National Energy Technology Laboratory. This work could not have been completed without the active cooperation of our industry partners and all collaborators. We greatly appreciate their support.

The FSEC Building America Industrialized Housing Partnership Project Steering Committee met at FSEC on February 6. Steven Chalk (in suit at far right in first row), the then director of building and solar technologies, led the U.S. Department of Energy delegation to the meeting. Photo: Nicholas Waters

INTRODUCTION AND SUMMARY

This annual report summarizes the activities of the Building America Industrialized housing Partnership (BAIHP, www.baihp.org) for the first budget period (BP1) spanning 4/1/2006 – 2/28/07. BAIHP is one of several U.S. Department of Energy (DOE) sponsored Building America teams (www.buildingamerica.gov) that perform cost shared activities to develop and deploy systems engineering based solutions to enhance the energy efficiency, comfort, durability of new and retrofit, site and factory built housing in the U.S.A.

The BAIHP team is led by the University of Central Florida's (UCF) Florida Solar Energy Center (FSEC) in collaboration with UCF Industrial Engineering (UCFIE) and other subcontractors Washington State University (WSU), Oregon Department of Energy (ODOE), University of Texas at Austin School of Architecture (UTSOA), Florida Home Energy and Resources Organization (FLHero), Residential Energy Services Network (RESNET) and Calcs-Plus, and leaders from the housing industry that build over 100,000 homes/yr.

This BAIHP team was formed as a result of a competitive solicitation issued by DOE-NETL (www.netl.doe.gov) in 2005. It is a successor to the previous BAIHP team also selected competitively in 1999.

The overall objective of the BAIHP project is to conduct cost shared research to accelerate the nationwide development of cost effective, production ready energy technologies that can be widely implemented by factory and site builders to achieve 30% to 50% savings in whole house energy use through a combination of energy efficiency and renewable energy measures. BAIHP will focus on factory builders (HUD code, Modular and Panelized), the housing segment not emphasized by the other BA teams. However, BAIHP will also work with site builders (primarily production and affordable housing) to explore synergies between the different housing segments, yielding a greater impact on the entire U.S. housing industry. BAIHP will employ BA systems engineering principles to enhance the energy efficiency, comfort, durability, indoor air quality, insurability, affordability, marketability and construction productivity of U.S. housing.

BAIHP's Goals

1. Perform cost shared research to reduce the energy cost of housing by 30% to 70% while enhancing indoor air quality, durability, resource efficiency and marketability.
2. Assist in the construction of thousands of energy-efficient industrialized houses annually and commercialize innovations.
3. Make our partners pleased and proud to be working with us.

What is industrialized Housing?

Industrialized housing encompasses much of modern American construction including:

- Manufactured Housing – factory-built to the nation wide HUD Code
- Modular Housing - factory-built, site assembled modules meeting local code
- Panelized/kit Housing – factory produced sub-assemblies put together on site to meet local codes
- Production Housing - site-built systematically, factory built components

Manufactured Homes are one of the most affordable types of single-family detached housing available anywhere in the world, generally costing less than $35/ft^2 plus land costs for centrally air conditioned and heated homes with built-in kitchens. Available in all parts of the country, manufactured homes are more popular in rural areas and in the southern and western US where land is still plentiful. Modular homes accounted for about 2% of 2005 housing starts. Many HUD Code home producers offer modular homes also which are built to local codes and take advantage of many factory production benefits.

Industry Partnerships

BAIHP has partners in many stakeholder groups of the U.S. housing including HUD Code home manufacturers; modular, multifamily, and production site builders; product and material suppliers. Research organizations and other non-profits have worked with BAIHP to collaborate on field work, ventilation studies, ASHRAE committee work, and training. Table I-1 lists current and past BAIHP Project Industry Partners. The geographic distribution of our partners is depicted on the map in Figure I-1. Industry Partners list is kept updated at http://www.baihp.org/partners/index.htm

Table I-1 BAIHP Industry Partners (Present and Past)

HUD Code Home Manufacturers	
Cavalier Homes	Homes of Merit
CAVCO Industries LLC	Karsten Company
Champion Homes (Redman)	Kit Manufacturing
Champion Homes (Silvercrest)	Liberty Homes
Clayton Homes	Marlette Homes
Fleetwood Homes	Nashua Homes
Fuqua Homes	Oakwood Homes
Golden West Homes	Palm Harbor Homes
Guerdon Enterprises	Skyline Corporation
Hi-Tech Homes	Southern Energy Homes
Homark Homes	Valley Manufactured Housing
Homebuilders North West	Western Homes
Modular and Panelized Builders	

Avis America Homes	Genesis Homes
Cardinal Homes	Nationwide Homes
Discovery Homes	Penn Lyon Homes
DuKane Precast Inc.	Royal Concrete Concepts
Epoch Corporation	The Homestore
Excel Homes	Trinity Construction Corp.
General Homes	
Production Builders	
All America Homes	G.W. Robinson Builder
American Energy Efficient Homes & Investments Inc.	New Generation Homes by Kingon Inc.
	On Top of the World
AMJ Construction	Patrick Family Housing, LLC
Arvida Homes	Pringle Development
Atlantic Design and Construction	Podia Construx
Bobek Building Systems, Inc	Regents Park (Condominiums)
Cambridge Homes	Rey Homes
Centex Homes	Tommy Williams Homes
Dye Company	WCI Communities
DR Horton	Winton/Flair Homes
GMD Construction Co.	
Affordable Housing Builders	
East Dakota Housing Alliance	Homes in Partnership
City of Gainesville, FL	HKW Enterprises
City of Lubbock, TX	Miami-Dade Hope VI Project
City of Orlando, FL	Sandspur Housing (Apartment builders)
Habitat for Humanity International	Williamsburg (townhouses)
Custom Builders	
All America Homes of Gainesville, Inc.	Pruett Builders, Inc.
Energy Structures & Systems, Inc.	Rainier Construction, Inc.
Fallman Design and Construction	Scott Homes
L.F. Custom Homes	Spain Construction
Marquis Construction & Development, Inc	Stitt Energy Systems
New Generation Homes by Kingon Inc.	Timeless Construction
NatMax	
Developers	
Castle & Cooke	Kashi Church Foundation, Inc.
East Bay Development Company of FL LLC (Formerly Midgard Associates)	
Research, Education, and Industry Association Partners	
Auburn University School of Architecture	Northwest Energy Efficient Manufactured Housing Program (NEEM)
Building Science Consortium	

Florida Green Building Coalition	Pacific Northwest National Laboratory
Florida International University, 2005 Solar Decathlon Team	Portland Cement Association
	RADCO, Inc
Florida Solar Energy Research and Education Foundation	RESNET
	Structural Insulated Panel Association
IBACOS, New American Home (Goehring Morgan Construction)	Stevens Associates (Home Ventilation Institute)
Not-So-Big-House, (Sarah Susanka, AIA)	Washington Manufactured Housing Assoc

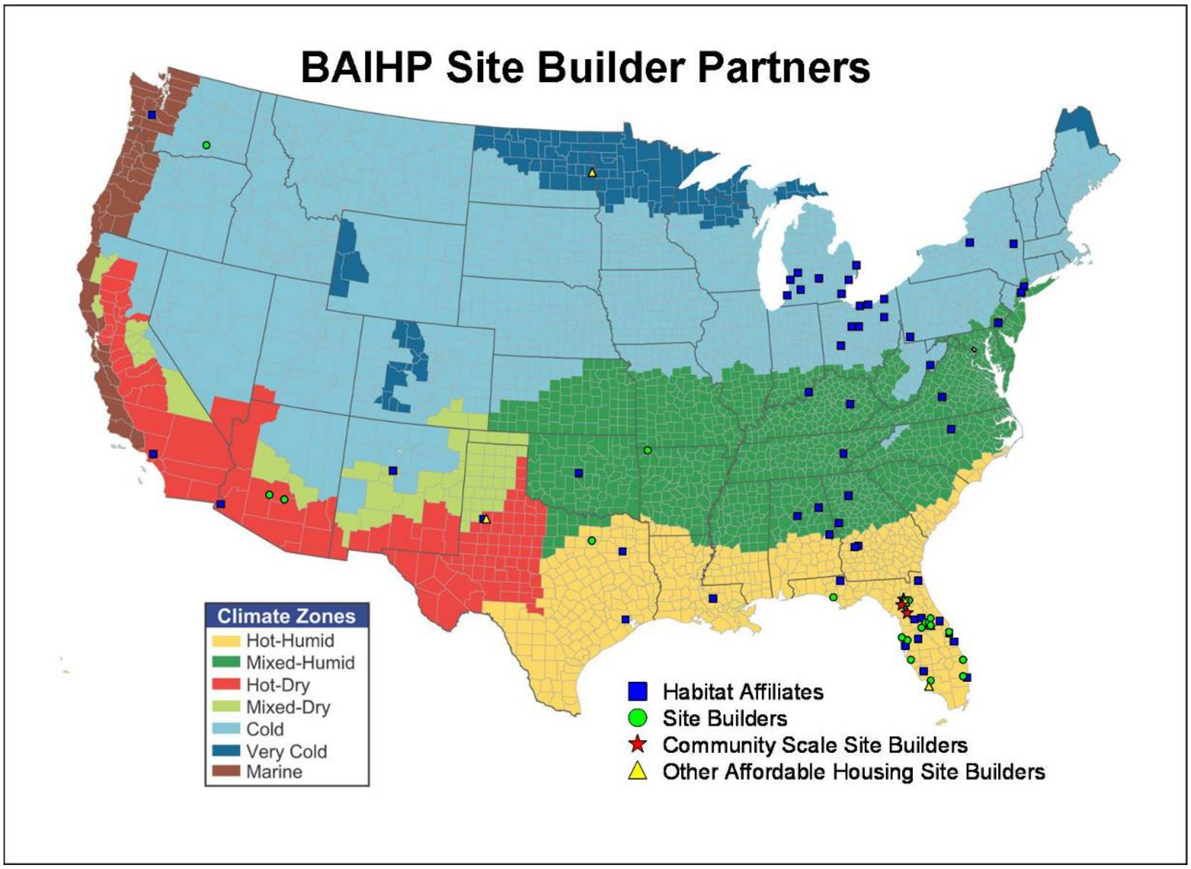


Figure I-1 BAIHP Research and Technical Assistance Sites

In BP1 the BAIHP team conducted activities in four major task areas:

Task 1: System Evaluations
Task 2: Prototype House Evaluations
Task 3: Community Scale Evaluations
Task 4: Other Activities

The activities in each area are summarized below:

Task 1: System Evaluations

Subtask 1.1 Improved Duct Systems

In BP1 BAIHP began working with two manufactured housing partners -- Cavalier Homes and Southern Energy Homes on two different approaches to interior duct system designs to bring all duct work inside the thermal envelope. A prototype was produced by Cavalier Homes featuring high side discharge with floor trunks. This home on a dealer lot is instrumented and data has been available since late November 2006. Data is available online at http://www.infomonitors.com/hsd/ . Prototype performance is excellent.

In addition began discussions with partner Southern Energy Homes to construct another prototype home with interior ceiling soffit duct system.   Both manufacturers are looking at alternate methods of crossover duct connections where that duct is also located within the conditioned space. Each has prototyped marriage line connections that eliminate crossover ducts in the crawlspace.

Figure I-2 Floor duct system with high side discharge outlets under construction being tested with duct tester

Figure I-3 Interior view of prototype house with high side discharge outlet

Subtask 1.2 Factory Integrated HVAC/DHW Systems

BAIHP team member DeLima Associates is currently developing an integrated space heating, cooling, water heating and air distribution system for HUD-Code manufactured housing, to be installed at the manufactured housing factory, eliminating site work. A prototype Comboflair unit manufactured by Unico system was installed in a model center Palm Harbor Home in Austin, TX. This home was unoccupied and FSEC designed and installed an automated system to generate interior sensible and moisture loads. FSEC has been monitoring data since January 2006. Data was posted online in a password protected website.

Subtask 1.3 Ventilation and Dehumidification

<u>Advanced Cooling with Dehumidifier Mode (ACDM) equipment Evaluation</u>
The FSEC Manufactured Housing Lab (MHLab) was used to conduct research associated ventilation and dehumidification. We partnered with Building Science Corp.(BSC) and evaluated their Advanced Cooling with Dehumidifier Mode (ACDM) equipment. This system was conceived in 2001 in an attempt to research ways to make a standard split-system cooling machine function as both a normal cooling machine and a dehumidifier. Instrumentation, data collection and equipment troubleshooting was performed by FSEC in BP1. Good data was collected at 1 min intervals and put on the FSEC web system for access by BSC.

<u>Humidity Liability Evaluation of ASHRAE 62.2</u>
The other major BP1 project conducted in the MHLab was an evaluation of the humidity liability of ASHRAE 62.2 level of mechanical ventilation (*ASHRAE62.2, 2004*). During Nov 2006 – Feb 2007 the MHLab operated three types of whole house mechanical ventilation -- None, 62.2 (which is 46cfm continuous for this house) and run time vent with 62.2 vent rate, i.e. 46 cfm supplied only when the heating or cooling system operated. Later experiments conducted in December and January showed that interior RH levels continued to stay high for no vent and run time vent cases, as well. The results for run time vent were unexpected as field data from a larger home in Ft. Myers, FL. with run time vent and occupied by a family of four showed good results. More research needs to be conducted to determine the humidity liability of ASHRAE 62.2 level of mechanical ventilation.

Subtask 1.4 Fortified® HUD Code Homes

In 2005 FSEC was asked to participate in the Institute for Business and Home Safety (IBHS) technical committee for HUD code homes. However, no significant activity occurred in this task area during BP1.

Subtask 1.5 Plug Load Reduction

Homes around the world currently have no means to judge household energy use other than their monthly utility bill. Unfortunately, this does not readily provide insight as to how or where the energy is being used. Existing studies show that providing direct instantaneous feedback on household electrical demand can reduce energy consumption by 10-15%. Reducing and shifting electrical demand is particularly important in Zero Energy Homes (ZEH), where it would be desirable to match solar electric PV output with household loads. To obtain current data on the magnitude of savings that can be expected, 23 homes have been fitted with a real time energy feedback device called "*The Energy Detective*" *(TED)* which costs ~$150. This is a small display unit, plugs into the wall and provides output on a digital display. In Miami, one user reported savings of 13% on their January bill.
The local NBC affiliate in Miami has taken a strong interest in this research and has broadcasted the results and made it available on the net, see
http://www.nbc6.net/video/11081023/index.html

Subtask 1.6 Setup and Finish Processes for Modular Homes

This task was conducted by the Housing Constructability Lab (HCL) of the UCF Industrial Engineering Department (UCFIE). Two activities were undertaken by the HCL group for two builders – Royal Concrete Concepts and Habitat for Humanity and the complete reports are included in Appendix A.

Royal Concrete Concepts
Royal Concrete Concepts (RCC) produces innovative concrete modules for both residential and commercial markets throughout Florida. RCC currently operates a mid-size, unenclosed production operation in West Palm Beach. The existing plant consists of four production "lines" supported by various uncovered storage areas and small enclosed stockrooms. The plant can produce a maximum of four modules per day. To meet increasing demand, RCC is developing a new high-volume plant in nearby Okeechobee, increasing production capacity by 2.5 times. The HCL research team was tasked to identify and develop innovative concepts for the supply chain – stretching from construction material vendors, through the warehouse, to the production line. To maximize impact, the scope was limited to three critical materials: rebar, polyethylene foam and steel interior/exterior studs. A summary of this research with recommendations was issued to the RCC senior management team. Assistance continues with RCC's new plant.

Habitat for Humanity
In March 2006, the UCF research team initiated efforts to assist Habitat for Humanity's Operation Home Delivery in the design of Habitat's first modular housing factory. The factory was envisioned as a high volume delivery method to replace homes destroyed by Hurricane Katrina. All designs were developed collaboratively with Habitat personnel in a series of workshops hosted at UCF. The team also recommended changes to the floor plans of the new modular home designs, making them more compatible with

conventional home designs. Work was completed by summer 2006 but Habitat decided not to follow this path of modular housing factories.

Subtask 1.7 Green Products and Processes

BAIHP Organized and moderated a conference session on this topic (identify and document green aspects of HUD code and modular manufacturer products as they relate to achievement of Building America performance goals and green certifications). This was at the GreenTrends conference. After receiving DOE feedback, this task area was of not high interest and efforts in this subtask were discontinued. Instead activities were pursued so that our builder partners could participate in existing green programs as they desired. We assisted partners to obtain such certifications including USGBC LEED-Homes, Florida Green Home Designation Standard, and Enterprise Foundation Green Communities.

Subtask 1.8 Cool Roofs

The Flexible Roof Facility (FRF) is a test facility in Cocoa, Florida designed to evaluate five roofing systems at a time against a control roof with black shingles and vented attic. Since 1989 the testing has evaluated how roofing systems impact summer residential cooling energy use and peak demand (Parker et al. 2005). In May of 2006 DOE recommended against conducting further research in this area as part of the FY07 AOP review process. BAIHP diverted efforts and continued testing for evaluation of various attic ventilation rates and their impacts on attic thermal performance. Data collection and facility maintenance continued but analysis has not been complete to date.

Subtask 1.9 Night Cool

Using a building’s roof to take advantage of long-wave radiation to the night sky has been long identified as a potentially productive means to reduce space cooling in buildings. The night cooling resource is large and enticing for residential energy-efficiency applications. Problems, limitations, solutions and data collection are researched and explained using instrumented side-by-side 10' x 16' test buildings located at the Florida Solar Energy Center.

During BP1 performance of *NightCool* was evaluated under both summer and autumn weather conditions. Daily *NightCool* system Energy Efficiency Ratios (EERs) averaged 31.0 Btu/Wh over the four summer-to-fall test periods – in line with simulations conducted earlier. The nightly system EERs varied from a low of 23.2 to a high of 43.2 Btu/Wh, the highest performance being seen during tests with higher return air temperatures and during periods with cooler and clearer nighttime conditions. As expected, performance was worse under cloudier humid conditions. Cooling rates also varied over the course of each evening, generally improving to a maximum point in the pre-down hours. The maximum nightly EERs varied between 35.4 (warm cloudy evening) to 69.1 Btu/Wh (clear and more cool conditions). In all cases, this level of performance compared favorably to an EER for the vapor compression air conditioner of about 9 Btu/Wh.

We plan to continue experimental and analytical work on the *NightCool* concept throughout 2007 concentrating on improving the dehumidification performance of the concept and collecting data for a wide variety of operating conditions. We have submitted a report to DOE titled, "*Experimental Evaluation of The NightCool Nocturnal Radiation Cooling Concept: Progress Report: Initial Thermal Performance Assessment of Test Buildings,*" and progress detailed in additional report available online at:
www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1692-07.pdf

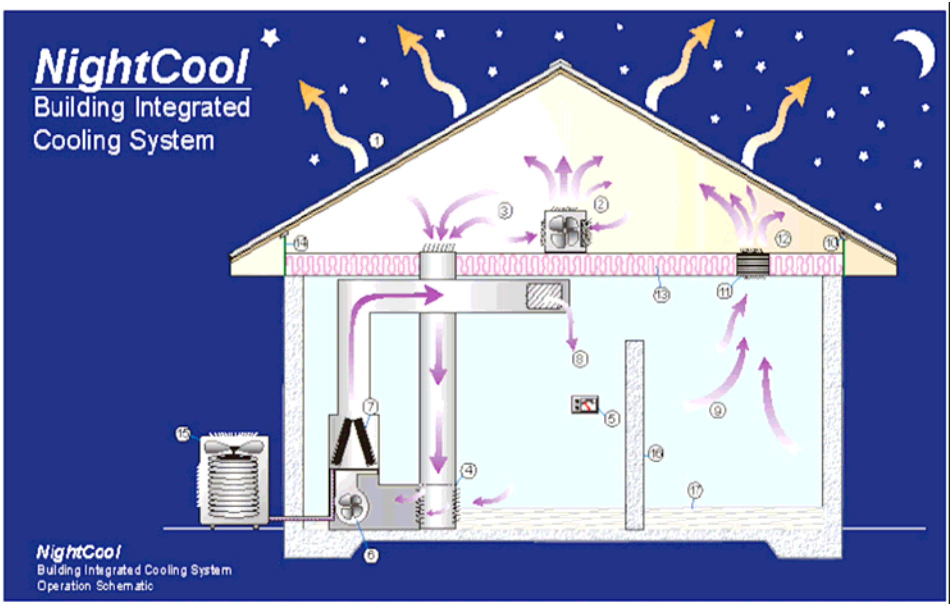


Figure I-4 Schematic of NightCool concept

Subtask 1.10 Solar Integrated Roofing Panels

This subtask was performed by one of our subcontractors – University of Texas at Austin, School of Architecture (UTSOA). UTSOA focused on developing scenarios for two different modular houses and testing options for photovoltaic arrays for both. They analyzed type, size, cost, energy production, ease of installation and public acceptance for both differing scenarios. The two models developed were The Back Home and The Bloom Home. UTSOA's complete report is included in Appendix B:

The Back Home

This is a house that could be rapidly deployed, but provide permanent affordable housing in areas of need. This model was developed in response to FEMA's Alternate Housing Pilot Program requirements, issued September 15, 2006. It is designed to meet health and safety requirements for hurricane prone areas. The house is 700 square feet and has one bedroom and one bath.

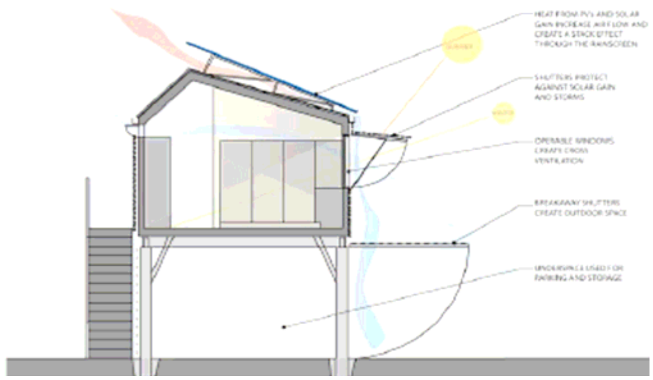


Figure I-5 The Back Home design strategies

The Bloom House

This is an evolution of the University of Texas Solar Decathlon 2007 competition house, designed to be marketed as part of an urban infill development to a median income family in Austin, Texas. This model is 1300 square feet, with three bedrooms and two baths. UTSOA designed the development layout as part of a conservation development in central Austin to test a strategy for implementation of photovoltaics in the larger housing market.

Figure I-6 The Bloom House conceptual design

Subtask 1.11 Related Systems Research

This section reports three subtasks carried over from the previous BAIHP project which ended in June, 2006. These tasks were all completed by September 2006 and reports were issued which are available online. The final report for the previous BAIHP project also summarized the efforts in these subtasks in the report submitted in October 2006 and available online at http://www.baihp.org/pubs/finalrpt/index.htm. A presentation on the report findings were made at the International Builders Show in February, 2007. Consequently we provide only brief notes on these carryover tasks in this report:

Retrofits of hurricane damaged homes (carryover task)
Task completed and report issued in September 2006.
Chasar, D., Moyer, N., and Martin, E., 2006. **"Energy Efficient Renovation of Storm Damaged Residences – Florida Case Studies,"** FSEC-1648-06, Florida Solar Energy Center, Cocoa, FL. September, 2006.
Report available online at http://www.baihp.org/pubs/deliverables/hurricane-retrofits9-13-06.pdf

Specifications for Improved FEMA homes (carryover task)
Task completed and report issued in September, 2006.
Thomas-Rees, S., Chandra, S., Barkaszi, S., Chasar, D. and Colon, C., 2006. "Improved Specifications for Federally Procured Ruggedized manufactured Homes for Disaster Relief in Hot/Humid Climates,**"** FSEC-CR-1645-06, Florida Solar Energy Center, Cocoa, FL. September, 2006.
Available online at
http://www.baihp.org/pubs/ImproveSpecificHomes/contract_report.pdf

Water Intrusion in Central Fl Homes (carryover task)
Task completed in and report issued in August , 2006.
Mullens, M., Hoekstra, R., Nahmens, I., and Martinez, F., 2006. "Water Intrusion in Central Florida Homes During Hurricane Jeanne in September 2004," UCF Housing Constructability Lab, University of Central Florida, Orlando, FL. August, 2006.
Available online at
http://www.baihp.org/pubs/deliverables/WaterIntrusionReport8-21-06.pdf

HUD-Code Energy Star Testing/Research (PHH co funding)
In addition to the carry over tasks, we provided technical assistance to Palm Harbor Homes under cost shared funding received from them to certify their HUD code Energy Star Homes and modular Energy Star homes.

Task 2: Prototype House Evaluations

In this section BAIHP document our efforts in providing design and technical assistance. BAIHP have also been instrumental in coordinating partnerships between organizations requesting help, renewable energy manufacturers and our prototype building partners. These prototypes can and have led to reproductions and/or case studies for community designs. In some projects the prototypes have been instrumented and the data analyzed to provide comparative statistics and evaluations. Three activities within this task are detailed in this section of the report.

Subtask 2.1A High Performance Prototype Homes Design Assistance

Locations – North Carolina, Arizona, Florida, Texas, Nebraska, Minnesota, North Dakota, Wisconsin
Developers, Builders and Organizations – Castle Cook, WCI, Richard Schackow, Don Ferrier, GMD Construction, Rainier Construction, Armed Forces Foundation, PATH, Habitat for Humanity, Federation of American Scientists, Marquis Construction, Selkirk Homes, Royal Concrete Concepts, Homark Homes, Southern Energy Homes, Cavalier Homes, ZCS Development, East Bay Development, Homes in Partnership
Number of Homes consulted on in BP1 total = 54: Castle Cook - 1, WCI - 1, Richard Schackow - 20, Don Ferrier – 1, GMD Construction – 3, Rainier Construction - 2, Armed Forces Foundation - 2, PATH – 1, Federation of American Scientists – 1, Marquis Construction – 3, Selkirk Homes – 10, Royal Concrete Concepts - 1, Homark Homes -1, Southern Energy Homes - 1, Cavalier Homes – 1, ZCS Development - 1, East Bay Development - 3, Homes in Partnership – 1
Energy Savings Range – Greater than Energy Star, Benchmark Savings (source energy) - 30% to 80%

Subtask 2.1B Instrumented Monitoring of Prototype Homes

Locations – Florida, Washington, West Virginia
Developers, Builders and Organizations – Solar Homes of Florida, Sierra Lakes, Scott Homes, Garst Homes, Habitat for Humanity
Number of Homes instrumented and monitored in BP1 total = 6: Solar Homes of Florida - 2, Sierra Lakes - 1, Scott Homes - 1, Garst Homes - 1 , Habitat - 1
Energy Savings Range – Greater than Energy Star, Benchmark Savings (source energy) - 30% to 60%

Subtask 2.2 International Builders' Show High Performance Prototype Homes Design Assistance

Location – Orlando, Florida
Developers, Builders and Organizations – National Association of Home Builders (NAHB), Palm Harbor Homes, TNAH builder, Renewed Home Builder, Charlie Clayton Construction
Number of Homes consulted on in BP1 total = 7: National Association of Home Builders (NAHB), Palm Harbor Homes, TNAH builder, Renewed Home Builder, Charlie Clayton Construction
Energy Savings Range – Greater than Energy Star, Benchmark Savings (source energy) - 30% to 60%, HERS Index Averages – 71.8* (Note HERS Index for Energy Star is 85 in this climate)
*2006 show homes were rated with EnergyStar scores, these were converted to Index to compute average

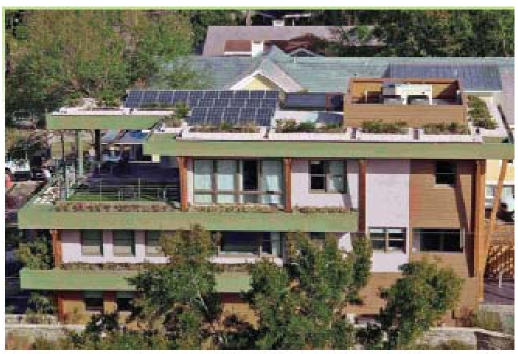


Figure I-7 The New American Home 2007

Figure I-8 The Renewed American Home 2007

Figure I-9 IBS Show Home 2007

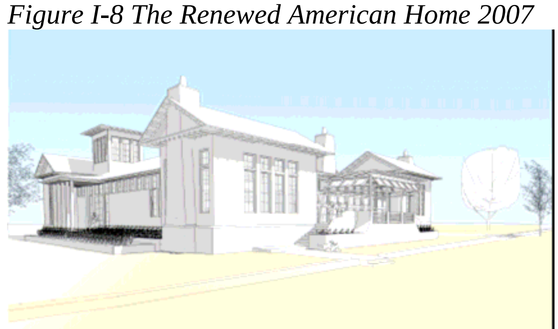


Figure I-10 IBS Show Home 2008

Task 3: Community Scale Evaluations

In this section we document our efforts in providing technical assistance to builders that are building entire communities of high performance housing in hot-humid and marine climates. Cost and market analysis have been performed for the hot, humid climate homes. The simple payback for the energy upgrades are in the range of 4 to 5 years. Market analysis of comparable homes indicate that the Building America builders are extremely cost conscious and are able to sell their homes at a price comparable to or less than the competition who sell typical homes close to code minimum levels of energy performance. The report describes in case study format the BAIHP work done in partnership with G.W. Robinson Builders and Tommy Williams Homes respective to community scale evaluations in hot humid climates. It also includes a summation of lessons learned and ongoing challenges in achieving the systems engineering approach to new home construction in hot, humid climates. WSU is working with Building America partners Oregon Department of Energy (ODOE), Champion Homes and Equity Residential in an effort to build over 850 energy efficient modular homes at Fort Lewis Army base in Washington State and details of their community scale evaluations in marine climate detailed in this section of the report, as well as, in WSU's annual report included in Appendix D.

Subtask 3.1 Hot Humid Climate

Location – All are in the area of Gainesville, FL. Alachua county.
Developers and Builders – G.W. Robinson Builders and Tommy Williams Homes
G.W. Robinson communities – Cobblefield, Turnberry Lake and Garison Way
Tommy Williams Homes Communities – Longleaf Village and Belmont
Number of Homes built in 2006 : G.W. Robinson – 101, Tommy Williams – 41
Energy Savings Range – Greater than Energy Star, Benchmark Savings (source energy) - 36% to 40%, HERS Index Averages – G.W. Robinson (~65), Tommy Williams (~70) (Note HERS Index for Energy Star is 85 in this climate)

Subtask 3.2 Marine Climate

Location – All homes are in Fort Lewis, WA (South of Tacoma, North of Olympia)
Developer – Equity and Lincoln Properties
Builder – Champion Homes of Oregon (a Modular builder)
Number of Homes built in BP1 – 167
Energy Savings Range – Energy Star level (per letter agreement from EPA). Benchmark Savings (source energy) – 25% to 30%

Task 4: Related Activities

Subtask 4.1 Habitat for Humanity Partnership

BAIHP has had a very productive relationship with Habitat for Humanity (HFH) and various local affiliates spanning over 10 years. In BP1 we assisted the following affiliates and supported various HFH programs like construction training, standard development performance testing. Each activity BAIHP participated in is explained in the subsection subtask 4.1 of this report. A brief summation of the activities are:

Habitat for Humanity International (HFHI)
BAIHP assisted in specifying efficient specifications and proper construction techniques and we were instrumental in the development of HFHI's Construction Standards which were released November 2006.

Habitat for Humanity International (HFHI) Home in a Box
BAIHP assisted HFHI' s department of construction and environmental resources and the new operation home delivery department in developing Home in a Box program to provide a kit of parts deliverable to the Gulf States to help relieve housing and labor shortages due to Hurricane Katrina.

2007 Jimmy Carter Work Project, Los Angeles, CA
BAIHP[SC21] also provided training at national and regional conferences, focus builds, and "blitz" builds which included site testing in Florida, West Virginia, Colorado, Tennessee and other states mentioned in the report.

Lakeland, FL – 10 homes
This Habitat builds one of the highest performing homes among all affiliates consistently building homes above the 30% BA benchmark level. Homes were tested and rated by BAIHP in BP1.

Indian River County, FL – 4 homes
Worked with this affiliate and WCI homes to train and test 4 homes in partnership with a volunteer energy rater

Pinellas County, FL (PCHHFH) – 3 homes
BAIHP visited to evaluate their current construction techniques related to energy efficiency and make recommendations for a future construction project consisting of 1200 ft^2 per unit triplexes. The HERS Index as tested were EnergyStar compliant, 80, 83 and 84 (85 or less is EnergyStar certified). Two of Pinellas County HFH construction supervisors attended the training in Gautier, MS.

Baton Rouge, LA – 15 homes
In partnership with Habitat for Humanity International, Palm Harbor Homes and Oprah Winfrey conducted preliminary analysis, testing and Energy Star certification of 15 homes for the Baton Rouge Habitat for Humanity.

Gautier, MS – 4 homes
In partnership with Habitat for Humanity International and the local Habitat BAIHP conducted hands on energy efficiency training and participated in building 4 homes.

Dothan, AL – 12 homes
In partnership with Palm Harbor Homes and Oprah Winfrey conducted testing and Energy Star certification of 12 homes for the Dothan, AL Habitat for Humanity.

New Orleans, LA and the entire Gulf Coast - +20 homes
BAIHP developed partnership with the New Orleans, LA Global Green office to provide technical assistance (both by phone, email and in the field) to HFH affiliates and HFHI field staff.

Michigan Affiliates - +10 homes
A report was prepared in August 2006 and transmitted to Michigan affiliates summarizing recommendations to improve energy efficiency and indoor air quality in cold climate Habitat homes.

Olympia, WA – 3 homes
BAIHP assisted HFH on a 15 unit cottage project in Olympia, WA (3 completed in BP1). The goal is to achieve the 40% BA benchmark savings using a tankless gas combo hydronic floor heating system with ICFs and advanced framed 2x6 walls with R5 foam sheathing.

Figure I-11 HFH volunteers in home performance testing training

Figure I-12 Houston, TX Habitat for Humanity Partner

Subtask 4.2 Northwest Energy Efficient Manufactured Home (NEEM) Program Support

Oregon Department of Energy (ODOE) staff performed quarterly factory inspection visits, inspected problem homes, developed in-plant quality assurance detailed inspection manuals and periodically upgraded the standards to higher levels of energy efficiency. NEEM adopted the Oregon Residential Tax Credit standard for duct leakage as an airtight duct standard. The new NEEM standard is that total or net duct leakage shall not exceed 0.06 cfm50 X the floor area served by the system or 75 cfm50, whichever is greater. Ten out of 10 Oregon plants, four out of five Idaho plants, and one out of two Washington plants test all duct systems in each floor to ensure low leakage ducts using testing equipment. Other activities are explained in detail in subtask 4.2 of the report. Figure E-12 illustrates the number of homes built to NEEM standards and Energy Star compliancy during BP1.

ENERGY STAR produced April 1, 2006 to February 16, 2007	
Northwest Energy Efficient Manufactured Homes	
ENERGY STAR Gas	1,263
ENERGY STAR Electric	3,177
Total	4,440

Table E-1

Subtask 4.3 BA Program / Analysis Support

In this subtask we assisted NREL in the continued refinement of the Benchmark calculation methodology and BEOpt analysis tools through email exchanges and participation in conference calls.

We also conducted two subtasks carried over from the previous BAIHP project which ended in June, 2006. These tasks were all completed by September 2006 and reports were issued which are available online. The final report for the previous BAIHP project also summarized the efforts in these subtasks in the report submitted in October 2006 and available online at http://www.baihp.org/pubs/finalrpt/index.htm . The descriptive report titles and web links for the reports follow:

Fairey, P., Colon, C., Martin, E., and Chandra, S., 2006. “Comparing Apples, Oranges and Grapefruit: An Analysis of Current Building Energy Analysis Standards for Building America, Home Energy Rating and the 2006 International Energy Conservation Code,” FSEC-CR-1650-06, Florida Solar Energy Center, Cocoa, FL. September, 2006. Available online at http://www.baihp.org/pubs/deliverables/BA-HERS-IECC_9-12-06.pdf

Vieira, R., Gu, L., Sen Sharma, R., Colon, C., and Parker, D., 2006. “Improving the Accuracy and Speed for Building American Benchmarking,” FSEC-CR-1651-06, Florida

Solar Energy Center, Cocoa, FL. September, 2006. Available online at http://www.baihp.org/pubs/deliverables/ImprovingBenchmarkCalcs9-27-06.pdf

Subtask 4.4 System Research Completion Report

Participated in conference calls and prepared two case studies for the 30% marine report – NEEM program and NOJI Gardens. Details are found in the report issued by NREL.

Subtask 4.5 Documentation, Resource Development and Related Activities

The BAIHP team published 11 papers at various conferences and in addition prepared 10 contract reports. Over 25 presentations were made at various national and regional venues. The details are provided in the References section.

The web page www.baihp.org continues to be updated and revised periodically. All published papers and reports are placed on line.

BAIHP personnel from WSU (Lubliner) served as a co-chair for national conference ACEEE 2006 and BAIHP researchers continue active participation in ASHRAE, including working with other BAIHP partners to co-author five papers for the June 2007 ASHRAE symposium. In addition, Lubliner acted as chair of both the TC 6.3 Forced Air Systems subcommittee, and the Proposed Standards 193P committee. BAIHP researchers also participated on ASHRAE 62.2 committee activities, TC 9.5, and a coordinated effort between ASHRAE and ARI on latent cooling options. BAIHP staff also served as a judge for the NAHB-RC EVHA awards and on NFPA mechanical committees to provide input to HUD for updating manufactured housing standards.

RESNET activities

In BP1, subcontractor RESNET (www.resnet.us) worked in four main areas

- created a RESNET – Building America- Habitat for Humanity partnership to encourage raters to volunteer with Habitat affiliates around the country to build energy efficient homes. Details available at http://www.natresnet.org/rater/partnership/default.htm
- documented examples of high performance homes that are eligible for the $2,000 tax credit. Details at http://www.resnet.us/taxcredits/examples/default.aspx
- participated in preparatory activities for the DOE National Builders Challenge proposed initiative
- developed policy that was passed by the RESNET board to encourage financing of high performance homes.

Steering Committee Meeting- Feb 6, 2007

FSEC hosted a meeting of industry partners to obtain input on current and planned FY07 BAIHP research activities from 9am-4pm at FSEC February 6, 2007. Steve Chalk, Ed Pollock and Bill Haslebacher attended from DOE. About 20 builder and industry members as well as representatives of NREL and LBNL attended the meeting. Presentations were made by task leaders and subcontractors and may be downloaded from http://fsec.ucf.edu/download/br/baihp/2007steering/

Apart for some quick questions to clarify content, no significant comments were received on the presentations. The steering committee had no problems nor major suggestions to change the planned BAIHP FY07 work.

Program Impact

BAIHP concentrates its work in hot-humid and marine climates but is active in most regions of the U.S. as shown in the map above (Figure I-1). In 2006 we assisted in the construction of over 140 homes that exceed the 30% BA benchmark goals in hot-humid climates, over 160 homes that are near the 30% benchmark level in marine climates, over 4,400 Energy Star manufactured homes in the Pacific Northwest and over 19,000 other energy efficient manufactured homes by partners Palm Harbor Homes, Fleetwood and Southern Energy Homes. The estimated energy savings from these homes constructed in 2006 is over 209,000 million Btu/year and the estimated savings in utility bills to consumers exceed $3,600,000/yr.

I. SECTION 1 - TASK 1: SYSTEM EVALUATIONS

Subtask 1.1 Improved Duct Systems

It has been known for a long time that leaky ducts in residential attics are a major cause of excessive energy use in hot humid climates (Cummings et al. 1991). Leaky ducts in manufactured housing can contribute to mold growth, soft drywall and comfort problems in addition to high cooling and heating energy use (Moyer et al. 2001).

In BP1 we began working with two manufactured housing partners -- Cavalier Homes and Southern Energy Homes on two different approaches to interior duct system designs to bring all duct work inside the thermal envelope. A prototype was produced by Cavalier Homes featuring high side discharge with floor trunks. This home on a dealer lot is instrumented and data has been available since late November 2006. Data is available online at http://www.infomonitors.com/hsd/ . Prototype performance is excellent. Temperature uniformity was established by infrared scan (Figures 1-1 through 1-4)

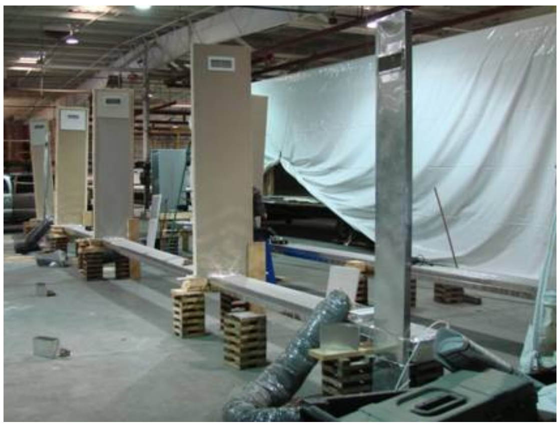


Figure 1-1 Floor duct system with high side discharge outlets under construction being tested with duct tester

Figure 1-2 Interior view of prototype house with high side discharge outlet

Figure 1-3 Cavalier Prototype under test

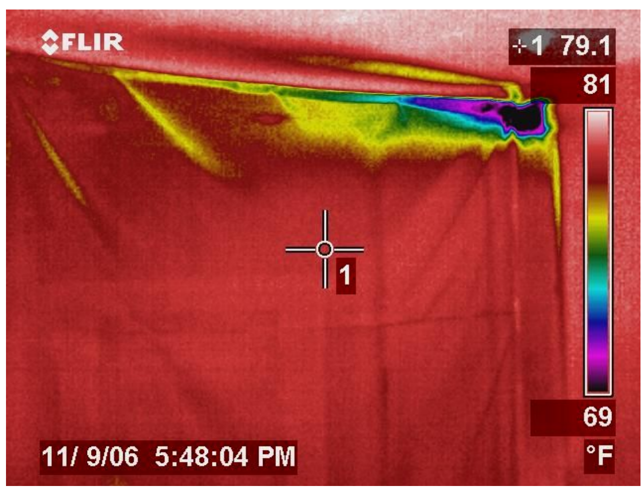


Figure 1-4 IR scan showing temperature uniformity inside the prototype

In addition we began discussions with partner Southern Energy Homes to construct another prototype home with interior ceiling soffit duct system. Both manufacturers are looking at alternate methods of crossover duct connections where that duct is also located within the conditioned space. Each has prototyped marriage line connections that eliminate crossover ducts in the crawlspace.

Successful adoption of interior duct systems in manufactured housing will result in significant energy savings and improvement in durability, comfort and indoor air quality.

Subtask 1.2 Factory Integrated HVAC/DHW Systems

BAIHP team member DeLima Associates is currently developing an integrated space heating, cooling, water heating and air distribution system for HUD-Code manufactured housing. This work is sponsored by the U.S. Department of Energy (SBIR grant), The Propane Education & Research Council (PERC) and Alabama Gas Company. The Comboflair system consists of a single-package heating/cooling unit (consisting of refrigerant coils, hydronic coil, compressor, blowers and hydronic pump), a water heater and an air duct system. The heating source is a natural gas or propane water heater that provides all space heating and domestic water heating needs. The air distribution system is a small-duct high-velocity system that minimizes duct losses. All equipment is installed at the manufactured housing factory, eliminating all site work. See Figures 1-5 through 1-6.

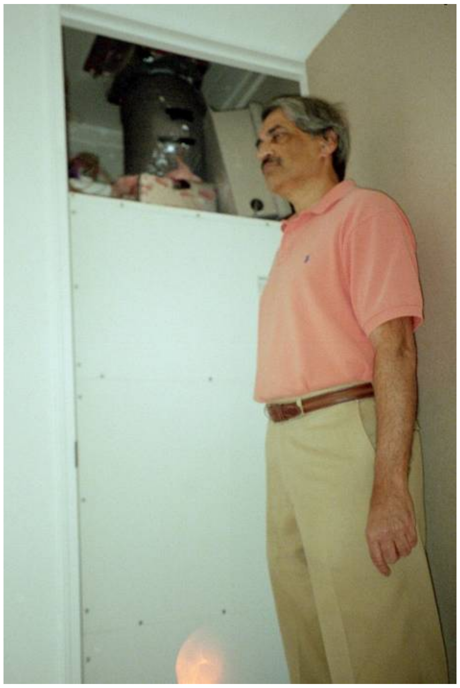


Figure 1-5 Interior view of the Comboflair System with Mr. Henry Delima, Comboflair project director

Figure 1-6 Exterior view of the Comboflair under test in Austin, TX at the Palm Harbor Home model center

A prototype Comboflair unit manufactured by Unico system was installed by them in a model center at Palm Harbor Homes in Austin, TX. This home was unoccupied and interior sensible and moisture loads were generated by an automated system designed and installed by FSEC. FSEC also installed a data acquisition system and has collected house and equipment data since January 2006. Data was posted online in a password protected website. According to Mr. Delima, “I must thank you for the outstanding job in monitoring the Austin test home. Unico now has considerable amount of data that can be used in further development and sizing of production models of Comboflair.”

Subtask 1.3 Ventilation and Dehumidification

Evaluation of Advanced Cooling with Dehumidifier Mode (ACDM) Equipment

The FSEC Manufactured Housing Lab (MHLab) was used to conduct research for ventilation and dehumidification strategies (Figure 1-7). The MHLab features two complete separate heating and cooling systems: an overhead duct system connected to a package unit air conditioner with electric resistance heating and a floor-mounted duct system connected to a split system air conditioner also with electric resistance heating.

Figure 1-7 The FSEC Manufactured Housing Lab

Figure 1-8 Completed ACDM Indoor unit in the MHLab crawlspace

During BP1 two major activities were conducted in the MHLab. During April through November 2006 we partnered with Building Science Corporation (BSC) and evaluated their Advanced Cooling with Dehumidifier Mode (ACDM) equipment. This system is an attempt to research ways to make a standard split-system cooling machine function as both a normal cooling machine and a dehumidifier. It was conceived by Building Science Corporation (BSC) in 2001. This system employs an indoor condenser/reheat coil, placed in the process air stream of a standard split-system, to allow continued removal of moisture while supplying room-neutral-temperature air, essentially converting the cooling system to a dehumidifier. This system was bench tested by BSC in their facilities in 2005 and tested at the MHLab in 2006 using the overhead duct system and replacing the package equipment with the

ACDM equipment which is based on SEER 14 Goodman HVAC components. The ACDM equipment was located in the conditioned crawl space of the MHLab (Figure 1-8).

The basic principle of design and operation follows. A thermostat and humidistat sense indoor space temperature and relative humidity. As the indoor temperature increases above the prescribed temperature setpoint, the compressor, the outdoor condenser fan, and the indoor air circulation fan are energized in normal cooling mode. As cool supply air decreases the indoor temperature below the prescribed indoor temperature setpoint, if the relative humidity is below the prescribed humidity setpoint, then the system shuts off; if the relative humidity is above the prescribed humidity setpoint, then dehumidifier mode is energized whereby the compressor and indoor air circulation fan continue, but the outdoor condenser fan shuts off, and a 3-way valve diverts refrigerant to an indoor condenser/reheat coil which heats the normally cool supply air to near room temperature conditions. In this way, moisture removal continues but reduction in room air temperature does not. When the indoor relative humidity falls below the humidity setpoint, all the equipment shuts off. Dehumidifier mode can also be energized without a prior cooling call, and a cooling call can be energized taking priority over an active dehumidification call.

Instrumentation and data collection and equipment troubleshooting was performed by FSEC. Good data was collected at 1 min intervals and put on the FSEC web system for access by BSC. The ACDM system performed well after troubleshooting was completed. BSC (Armin Rudd) should be contacted for further details.

<u>Humidity Liability Evaluation of ASHRAE 62.2</u>

The other major BP1 project conducted in the MHLab was to evaluate the humidity liability of ASHRAE62.2 level of mechanical ventilation (*ASHRAE62.2, 2004*). In 2004 ventilation experiments conducted with less than 62.2 levels of ventilation during the peak summertime showed good dehumidification performance for all ventilation and dehumidification systems tested (Moyer et al. 2004). During Nov 2006 – Feb 2007 the MHLab operated under three types of whole house mechanical ventilation -- None, 62.2 (which is 46cfm continuous for this house) and run time vent with 62.2 vent rate, i.e. 46 cfm supplied only when the heating or cooling system operated. The house was operated on an auto changeover thermostat designed to keep the house at 77ºF for cooling and 70ºF for heating. Internal loads simulated were typical for a family of 4 but the moisture generation went directly into the space (instead of being exhausted by spot ventilation fans).

The data collected in November when the MHLab was under 62.2 vent rate is shown in Figure 1-9 below.

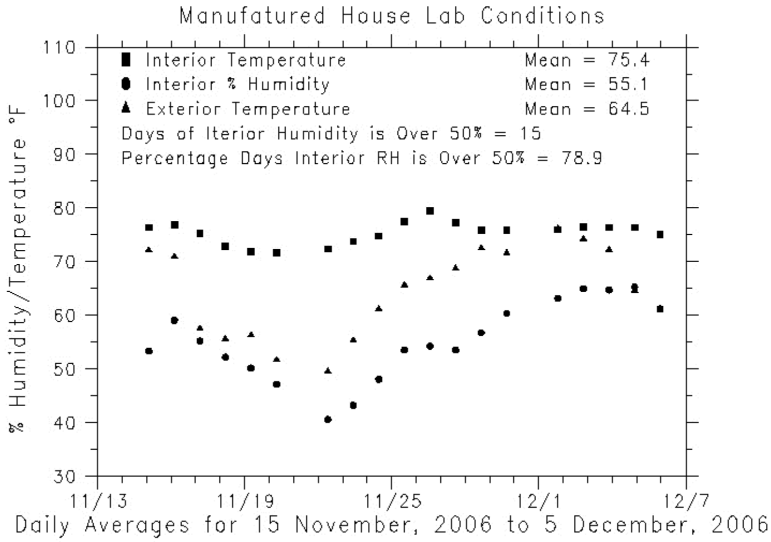


Figure 1-9 Interior and exterior conditions at the MHLab under ASHRAE 62.2 ventilation

Medical literature (Arlian et al. 2001) suggests indoor daily average RH be maintained below 50% RH for dust mite control, a major risk factor for asthma – especially in children. For this experiment, about 79% of the days the indoor RH exceeded that level suggested for dust mite control; it also exceeded 60% on average for a few days. Later experiments conducted in December and January showed that interior RH levels continued to stay high for no vent and run time vent cases as well. The results for run time vent were unexpected as field data from a prototype home in Ft. Myers, FL. with run time vent and occupied by a family of four showed good results. This house was bigger (~2,500 sq. ft. and with 4 bedrooms) and the run time vent rate was only 32 cfm. See Figure 1-10 below.

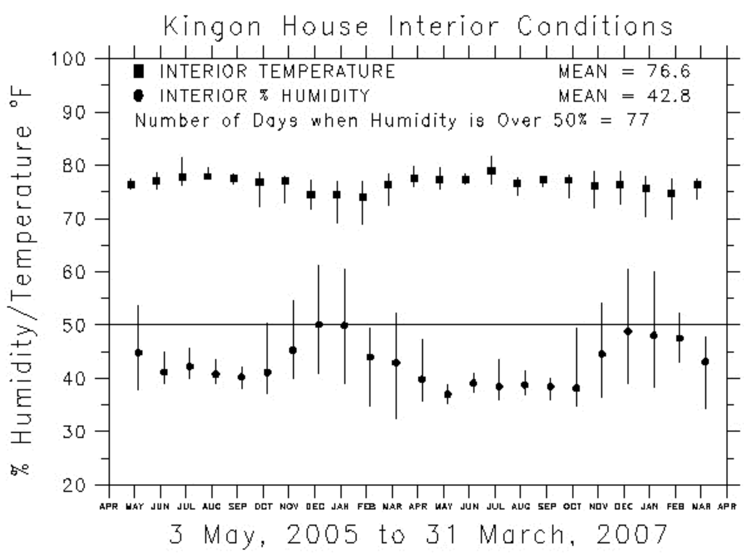


Figure 1-10 Interior T and RH for an occupied house in Ft. Myers, FL

For this house, the percentage of days that the interior RH was above 50% was only 11% of the time during this approximate 2 year long monitoring period.

More research needs to be conducted to determine the humidity liability of ASHRAE 62.2 level of mechanical ventilation.

Subtask 1.4 Fortified® HUD Code Homes

In 2005 FSEC was asked to participate in the Institute for Business and Home Safety (IBHS) technical committee for HUD code homes. However, no significant activity occurred in this task area during BP1.

Subtask 1.5 Plug Load Reduction

Homes around the world currently have no means to judge household energy use other than their monthly utility bill. Unfortunately, this does not readily provide insight as to how or where the energy is being used. Existing studies show that providing direct instantaneous feedback on household electrical demand can reduce energy consumption by 10-15%. Recently, such feedback devices are commercially available and dropping in price. Not only are these reductions potentially large as they comprise *all* end-uses, they may provide unique opportunities to realize goals for high-efficiency buildings. Reducing and shifting electrical demand is particularly important in Zero Energy Homes (ZEH), where it would be desirable to match solar electric PV output with household loads.

To obtain current data on the magnitude of savings that can be expected, 23 homes have been fitted with a real time energy feedback device called "*The Energy Detective*" *(TED)* which costs approximately $150. This is a small 3.5 x 5" display unit which plugs into the wall and receives power line carrier signals from a sending unit installed in the central breaker panel. Output is available on a digital display as shown in Figure 1-11.

Initial results from two users are summarized below – One user used another type of feedback device called the *Energy Viewer*.

Figure 1-11 TED The Energy Detective

Homeowner Using *Energy Viewer*

- Baseload without major appliances on was very large—up to 350 watts. The house is a "Smart Home" with a dozen *X-10* (home automation system) devices. The *X-10* switches were found to use about 5 W each.
- Was able to quickly recognize the large nature of the load associated with swimming pool pump operation (1,410 Watts operating four hours per day).
- The household did develop increased awareness of the energy use associated with clothes drying – 5.8 kW when operating.
- Demand of the electric heat pump showed use of resistance electricity on start-up in winter morning hours after setback.
- Home entertainment center is a major energy user with 220 Watts (5.2 kWh/day) of constant energy use even with the television and sound system off. TiVO digital recorder uses 28 Watts continuously. A media PC server used 144 W constantly.
- Home office and computer system draws 25 W continuously even when not operating.

Homeowner Using *TED*

- Learned that baseload electricity use was over 160 Watts with all major appliances off.
- From an initial examination, it was found that a potter's wheel had been left on in the porch (for months) drawing 20 Watts. The heating and cooling system transformer used 10 Watts even when not on and the household entertainment center drew 20 Watts when off. Also the home office system (computer, monitor, printer, DSL cable box) drew 25 Watts when off. A powered sub-woofer consumed 10 W even when unused.
- User dropped over one kWh a day from his household loads with little effort other than locating standby loads and providing a means to deactivate them:
    - Entertainment center and sub-woofer when not in use (power strip)

    - Computer and peripherals when not in use (occupancy-activated power strip)
    - Rechargeable tools in garage (power strip)
    - Standby power dropped from 160 W to 70 W
- Learned that even with very hot supply water from the solar water heater (135ºF) a new *Energy Star* dishwasher activates a one kW element during its use in both the *Normal* and '*Smart'* cycles. Moreover, in contrast to older dishwashers, the new generation machine had no way to disable the supplemental resistance booster heater.
- Watering the lawn within 10 feet of the outdoor condenser unit during the heat of the afternoon dropped air conditioning power by 80 - 140 Watts without direct spray on the unit.
- Observed unexpected electrical loads during the operation of gas appliances. This revealed that the gas dryer uses 700 Watts of electricity when drying clothes. Similarly the gas range uses 400 Watts of electric power when the oven is on, but none with stove-top burners.

In Miami one user reported savings of 13% on their January bill. This was broadcast by the local NBC affiliate in Miami, FL and aired February 21, 2007.

In summary, it appears that feedback devices do have promise to reduce household energy use by raising awareness.

Subtask 1.6 Setup and Finish Processes for Modular Homes

This task was conducted by the Housing Constructability Lab (HCL) of the UCF Industrial Engineering Department. The complete UCFIE report is included as Appendix A. Two activities were undertaken by the HCL group for two builders – Royal Concrete Concepts and Habitat for Humanity.

<u>Royal Concrete Concepts</u>

Royal Concrete Concepts (RCC) produces innovative concrete modules for both residential and commercial markets throughout Florida. RCC currently operates a mid-size, unenclosed production operation in West Palm Beach. The existing plant consists of four production "lines" supported by various uncovered storage areas and small enclosed stockrooms. The plant can produce a maximum of four modules per day. To meet increasing demand, RCC is developing a new high-volume plant in nearby Okeechobee. The new plant will have 10 unenclosed production lines capable of producing 10 modules per day, increasing production capacity by 2.5 times. The new operation will be supported by a 20,000 square foot on-site, fully enclosed warehouse with two covered 2,500 square foot sheds; one on each end of the warehouse. The new warehouse will have conventional loading docks and a rail spur for receiving and shipping. The Housing Constructability Lab (HCL) research team was tasked to identify and develop innovative concepts for the supply chain – stretching from construction material vendors, through the warehouse, to the production line. To maximize impact, the scope was limited to three critical materials: rebar, polyethylene foam and steel interior/exterior studs.

In December 2006, the HCL research team presented a summary of this research to the RCC senior management team. Recommendations were well received and the RCC team agreed to review and implement the recommendations. The HCL research team continues to assist RCC with their new plant.

<u>Habitat for Humanity</u>
In March 2006, the UCF research team initiated efforts to assist Habitat for Humanity’s Operation Home Delivery in the design of Habitat's first modular housing factory. The factory was envisioned as a high volume delivery method to replace homes destroyed by Hurricane Katrina. The team assisted Habitat in the selection of an existing facility, identifying retrofits necessary for modular home production (e.g., removing columns), designing layout alternatives that incorporated lean production concepts and detailing each production activity. All designs were developed collaboratively with Habitat personnel in a series of workshops hosted at UCF. The team also recommended changes to the floor plans of the new modular home designs, making them more compatible with conventional home designs. Work was completed by summer 2006 but Habitat decided not to follow this path of modular housing factories.

Subtask 1.7 Green Products and Processes

Organized and moderated a conference session on green products and processes (identifying and documenting green aspects of HUD code and modular manufacturer products as they relate to achievement of Building America performance goals and green certifications). This session was at the 3rd annual statewide GreenTrends conference in Gainesville, FL, on May 3, 2006. Participating speakers included a representative from the Palm Harbor Homes Plant City plant and a representative from Royal Management, a Building America partner constructing poured concrete modulars. Also participating was a representative from Resolution 4 Architecture, a design firm that has developed the “Modern Modular” concept - a systematic methodology of design that leverages existing methods of prefabrication and results in high performance residential construction. Each speaker discussed how prefabrication methods are leveraged to create high performance green products.

Discussions with these and other manufacturers continued to develop a plan to investigate and document specific practices. An abstract on this research was accepted for presentation at the USGBC GreenBuild conference in November.

In May 2006 after receiving DOE feedback on FY07AOP that this task area was of not high interest, efforts in this subtask were discontinued. Instead activities were pursued so that our builder partners could participate in existing green programs as they desired. We assisted partners to obtain such certifications including USGBC LEED-Homes, Florida Green Home Designation Standard, and Enterprise Foundation Green Communities. These activities are described in sections 2 and 4 of this report.

Subtask 1.8 Cool Roofs

The Flexible Roof Facility (FRF) is a test facility in Cocoa, Florida designed to evaluate five roofing systems at a time against a control roof with black shingles and vented attic (Figure 1-12). Since 1989 the testing has evaluated how roofing systems impact summer residential cooling energy use and peak demand (Parker et al. 2005).

Figure 1- 12 The FSEC Flexible Roof Facility (FRF)

In May of 2006 DOE recommended against conducting further research in this area as part of the FY07 AOP review process. Consequently, a very limited effort was expended in this subtask in BP1.

BAIHP continued testing for evaluation of various attic ventilation rates and their impacts on attic thermal performance. The test cell configurations are described below (from right to left).

Roofing systems tested at the
FSEC Flexible Roofing Facility, Summer of 2006

Cell#	Description	Justification within experiment
6	White metal roof, 1:300 ventilation	Best performing roofing system
5	Reference Black Shingles, 1:300 ventilation area	Standard requirement for building codes
4	Black shingles, 1:150 vent area	Added attic ventilation area
3*	Black shingles, Sealed	New approach to reduce attic humidity
2*	Black shingles, 1:300, soffit	Evaluate impact of soffit vs. ridge venting
1	Black shingles, 1:300, ridge	Evaluate impact of soffit vs. ridge venting

Table 1-1

* Cells 2 & 3 were used in testing proprietary materials for a US manufacturer. Not part of BAIHP contract

Data collection and facility maintenance continued on all six cells including the two cells sponsored by industry to obtain data on innovative roof/attic configurations. Data analysis was not completed in BP1.

Subtask 1.9 Night Cool

Using a building's roof to take advantage of long-wave radiation to the night sky has been long identified as a potentially productive means to reduce space cooling in buildings. The night cooling resource is large and enticing for residential energy-efficiency applications. On a clear desert night, a typical sky-facing surface at 80°F (27°C) will cool at a rate of about 70 W/m2. In a humid climate with the greater atmospheric moisture, the rate drops to about 60 W/m2 (Clark, 1981). Fifty percent cloud cover will reduce this rate in half. For a typical roof (225 square meters), this represents a cooling potential of 6,000 - 14,000 Watts or about 1.5 - 4.0 tons of cooling potential each summer night if all roof surface night sky radiation could be effectively captured. However, the various physical properties (lower roof surface temperatures, fan power, convection and conductance) limit what can be actually achieved, so that considerably less than half of this cooling rate can be practically obtained. Even so, in many North American locations, the available nocturnal cooling exceeds the nighttime cooling loads.

A big problem with previous night sky radiation cooling concepts has been that they have typically required exotic building configurations. These have included very expensive "roof ponds" or, at the very least, movable roof insulation with massive roofs so that heat is not gained during daytime hours. To address such limitations, an innovative residential night cooling system was designed. The key element of the *NightCool* configuration is that rather than using movable insulation with a massive roof or roof ponds, the insulation is installed conventionally on the internal ceiling. The system utilizes a metal roof over a sealed attic with a main to attic zone air circulation system.

During the day, the building is de-coupled from the roof and heat gain to the attic space is minimized by the white reflective metal roof. During this time the space is conventionally cooled with a small air conditioner. However, at night as the interior surface of the metal roof in the attic space falls well below the desired interior thermostat set-point, the return air for the air conditioner is channeled through the attic space by means of electrically controlled louvers with a low power variable speed fan. The warm air from the interior then goes to the attic and warms the interior side of the metal roof which then radiates the heat away to the night sky. As increased cooling is required, the air handler runtime is increased. If the interior air temperature does not cool sufficiently the compressor is energized to supplement the sky radiation cooling. The massive construction of interior tile floors (and potentially concrete walls) store sensible cooling to reduce daytime space conditioning needs. The concept may also be able to help with daytime heating needs in cold climates by using a darker roof as a solar collector. There is potential for mating the concept with Building Integrated Photovoltaics (BIPV) for combined heating, cooling and solar electric power production.

The empirical evaluation of the concept is being accomplished by using two highly instrumented side-by-side 10' x 16' test buildings located at the Florida Solar Energy Center. One of the test buildings is configured like a conventional home with a dark shingle roof and insulated ceiling under a ventilated attic. The experimental building features a white reflective roof on battens with a sealed attic where the air from the interior can be linked to the sealed attic and roof radiator when the roof temperature drops below the room target cooling temperature. See Figure 1-13

Figure 1- 13 Two small test buildings for the Night Cool concept

During BP1 performance of *NightCool* was evaluated under both summer and autumn weather conditions. Four experimental configurations were evaluated:

- No *NightCool* cooling with the experimental attics sealed to the interior (Null test): September 2nd - 4th, 2006.
- *NightCool* by convective air movement to the building only (open aperture to the attic so that cooled night air could drop out of the attic into the interior to be replaced by warmer air below): August 26th - 28th, 2006.
- No air conditioning in either test building, but *NightCool* activated with fan circulation in experimental test building: September 27th - 28th, 2006.
- Air conditioning in both test buildings, but when favorable attic temperature conditions are met, *NightCool* activated with fan circulation in experimental test building: October 20th – November 6th, 2006.

The last experiment, with supplemental air conditioning and *NightCool* operating in the experimental facility was evaluated under varied summer and autumn weather conditions. The experiments show that the experimental prototype performed better thermally under passive configurations. With the *NightCool* linkage to the main zone disabled (null test) the average nighttime temperatures in the unconditioned experimental and control test buildings from 8 PM to 8 AM was 82.0°F and 82.6°F respectively when the outdoor air temperature averaged 74°F. This shows the experimental building runs slightly cooler at night, largely because of the lower attic temperatures across the insulation and the effectiveness of the R-30 SIPs panels in the ceiling against the R-30 fiberglass batts in the control. Otherwise, thermal performance was similar.

However, in the second configuration with an attic hatch opened to the attic to allow warm air to naturally convect into the attic and heavier cool air to naturally convect to the interior below, the *NightCool* building showed superior performance. The experimental building's interior ran 1.9°F cooler during nighttime hours without any mechanical air movement to aid heat transfer. This is about three times the temperature drop seen without any nighttime cooling and a good demonstration of nocturnal cooling within the concept without any fan power. Detailed data was also obtained on the system with air conditioning used in the control and the experimental unit during daytime, and with the *NightCool* fan circulation system used during evenings. A daytime temperature of 78°F was maintained in both test buildings. Measured cooling energy savings varied from 17% under warm, cloudy conditions to 53% during milder periods. This was true even though the *NightCool* system maintained an average temperature 1°F lower than the control building. Daily *NightCool* system Energy Efficiency Ratios (EERs) averaged 31.0 Btu/Wh over the four summer-to-fall test periods – in line with simulations conducted earlier. The nightly system EERs varied from a low of 23.2 to a high of 43.2 Btu/Wh, the highest performance being seen during tests with higher return air temperatures and during periods with cooler and clearer nighttime conditions. As expected, performance was worse under cloudier humid conditions. Cooling rates also varied over the course of each evening, generally improving to a maximum point in the pre-down hours. The maximum nightly EERs varied between 35.4 (warm cloudy evening) to 69.1

Btu/Wh (clear and more cool conditions). In all cases, this level of performance compared favorably to an EER for the vapor compression air conditioner of about 9 Btu/Wh.

The delivered cooling rate averaged 2 - 4 Btu/hr/ft2 (6 -13 W/m2) of roof surface each evening, implying that NightCool in a full scale 2,000 square foot home would cool at a rate of 4,000 - 8,000 Btu/hr. Over a typical 10 hour operating period, this would produce 3 to 7 ton-hours of sensible cooling. The favorable experimental data collected so far indicates that NightCool can be a promising system technology for 50% or higher benchmark homes in hot-arid, hot-dry/mixed, mixed and humid climates. We plan to continue experimental and analytical work on the NightCool concept through out 2007 concentrating on improving the dehumidification performance of the concept and collecting data for a wide variety of operating conditions. We have presented the concept and data from NightCool test sheds to the cool metal roofing coalition. This industry group has enthusiastically endorsed the concept and plans to work with us in implementing the concept in future prototype homes.

Subtask 1.10 Solar Integrated Roofing Panels

This subtask was performed by one of our subcontractors – U. Texas at Austin, School of Architecture (UTSOA). UTSOA focused on developing scenarios for two different modular houses and then testing options for photovoltaic arrays for both. They analyzed type, size, cost, energy production, ease of installation and public acceptance for both differing scenarios. Two models were developed.

> <u>The Back Home</u>
> This is a house that could be rapidly deployed, but provide permanent affordable housing in areas of need. This model was developed in response to FEMA's Alternate Housing Pilot Program requirements, issued September 15, 2006. It is designed to meet health and safety requirements for hurricane prone areas. The house is 700 square feet and has one bedroom and one bath.
>
> <u>The Bloom House</u>
> This is an evolution of the University of Texas Solar Decathlon 2007 competition house, designed to be marketed as part of an urban infill development to a median income family in Austin, Texas. This model is 1300 square feet, with three bedrooms and two baths. UTSOA designed the development layout as part of a conservation development in central Austin to test a strategy for implementation of photovoltaics in the larger housing market.
>
> The full UTSOA report is contained as Appendix B to this report.

Subtask 1.11 Related Systems Research

In this subtask we conducted three subtasks carried over from the previous BAIHP project which ended in June, 2006. These tasks were all completed by September 2006 and reports were issued which are available online. The final report for the previous BAIHP project also summarized the efforts in these subtasks in the report submitted in October 2006 and available online at http://www.baihp.org/pubs/finalrpt/index.htm . Consequently we provide only brief notes on these carryover tasks in this report below:

Retrofits of hurricane damaged homes (carryover task)
Task completed and report issued in September 2006.
Chasar, D., Moyer, N., and Martin, E., 2006. "Energy Efficient Renovation of Storm Damaged Residences – Florida Case Studies," FSEC-1648-06, Florida Solar Energy Center, Cocoa, FL. September, 2006.
Report available online at http://www.baihp.org/pubs/deliverables/hurricane-retrofits9-13-06.pdf

Specifications for Improved FEMA homes (carryover task)
Task completed and report issued in September, 2006.
Thomas-Rees, S., Chandra, S., Barkaszi, S., Chasar, D. and Colon, C., 2006. "Improved Specifications for Federally Procured Ruggedized manufactured Homes for Disaster Relief in Hot/Humid Climates**,"** FSEC-CR-1645-06, Florida Solar Energy Center, Cocoa, FL. September, 2006.
Available online at
http://www.baihp.org/pubs/ImproveSpecificHomes/contract_report.pdf

In addition, material submitted to the Florida SERT (State Emergency Response Team) for FEMA competitive grant information request for alternative disaster housing solutions.

Water Intrusion in Central Fl Homes (carryover task)
Task completed in and report issued in August , 2006.
Mullens, M., Hoekstra, R., Nahmens, I., and Martinez, F., 2006. "Water Intrusion in Central Florida Homes During Hurricane Jeanne in September 2004," UCF Housing Constructability Lab, University of Central Florida, Orlando, FL. August, 2006.
Available online at http://www.baihp.org/pubs/deliverables/WaterIntrusionReport8-21-06.pdf

A presentation on the report findings were made at the International Builders Show in February, 2007

HUD-Code Energy Star Testing/Research (PHH co funding)

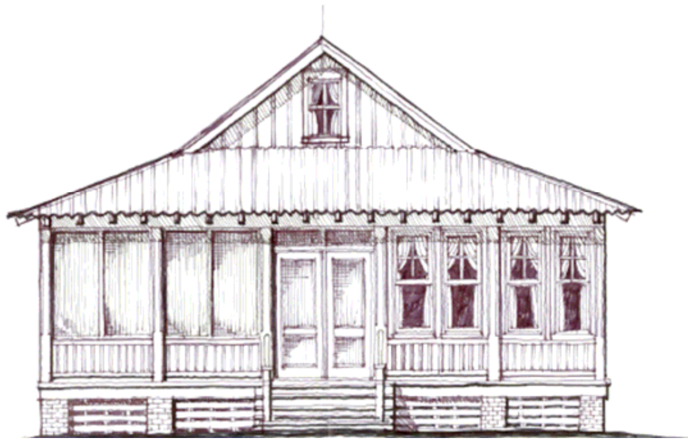
In addition to the carry over tasks, we provided technical assistance to Palm Harbor Homes under cost shared funding received from them to certify their HUD code Energy Star Homes and modular Energy Star homes. Activities summarized below.

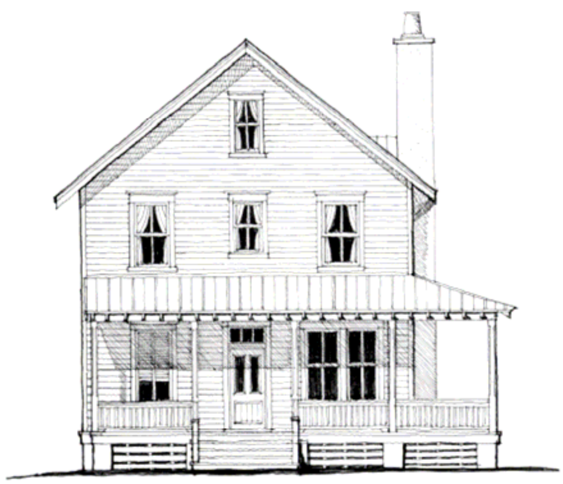
- Tested first labeled home for Austin plant which passed. Next test require for Austin after 51st home is produced. Tested other homes that failed inspections.
- Visited Austin and Plant City plants during construction of Habitat for Humanity homes destined for Baton Rouge, LA and Dothan, AL. Perform EPA-required Thermal Bypass Inspection Checklist (TBIC) inspections. Advised plants on changes needed to meet TBIC which becomes mandatory January 1, 2007.
- In partnership with Habitat for Humanity International, Palm Harbor Homes and Oprah Winfrey conducted preliminary analysis, testing and Energy Star certification of 15 homes for the Baton Rouge, LA Habitat for Humanity and 12 homes for the Dothan, AL Habitat.

Figure 1-14 Bottom plate airseal inspection – thermal bypass inspection checklist item

Figure 1-15 Insulation compression inspection –thermal bypass inspection checklist item

II. SECTION 2: PROTOTYPE HOUSE INVOLVEMENT AND EVALUATIONS





II. Section 2: Prototype House Involvement and Evaluations

In this section we document our efforts in providing design and technical assistance to over 22 organizations in 8 states. We have also been instrumental in coordinating partnerships between organizations requesting help, renewable energy manufacturers and our prototype building partners. This section also documents instrumented monitoring in prototype home construction projects which included activities involving 6 organizations. BAIHP continues to support demonstration home projects and were active in the 2007 International Builders' Show and are actively providing support for 2008 International Builders' Show. Handouts outlining the energy efficient, high performance and green features of both homes were disseminated at the show (2006 and 2007, see Appendix C.)

Subtask 2.1A High Performance Prototype Homes Design Assistance

This section describes in case study format the BAIHP work conducted on whole house systems engineering test houses (prototype) using the following general process--begin with a review of preliminary drawings and perform energy analysis using detailed hourly simulation software. Examine opportunities to bring the air handler and the ductwork within the thermal envelope and determine proper location of all ventilation inlets and exhaust outlets. Propose appropriate moisture tolerant wall and roof systems. Propose envelope and HVAC equipment choices (including solar energy equipment) options to meet builder budget and efficiency targets. Suggest Healthy and Green options. Finalize design and specifications after discussions with builder. Perform detailed room by room load and duct size calculations to size the heating / cooling equipment and ductwork using ACCA procedures. Provide mechanical drawings that include ductwork layout, mechanical equipment specifications and details to the builder and the HVAC sub. During construction, periodic site visits were made ensuring quality, especially in the areas of window flashings, thermal and air barrier continuity, sealing of ductwork and envelope.

In homes that included long term data monitoring, instrumentation wiring was installed. Envelope and duct tightness was determined by blower door and duct test equipment. Commissioning of all systems was also completed to ensure proper operation to design. After educating the homeowner about the uniqueness of the house and the BA project, data is continuously collected, monitored and is posted on the BAIHP web site. Data collection also continues to be compared to the performance of other homes' results and unique information is disseminated to the builders, researchers and other interested stakeholders.

Armed Forces Foundation (AFF), North Carolina and Arizona

In December 2006, the Armed Forces Federation initiated discussions with FSEC along with other organizations to assist with a pilot project to provide accessible housing to injured veterans. AFF have two customers, one in North Carolina and one in Arizona they are currently planning for and have requested that DOE programs provide technical and financial support for the integration of solar energy and energy efficiency in the houses. NREL and FSEC will provide analyses for the details. FSEC has solicited Palm Harbor Homes, a Building America partner, to design and build the home, which incorporate the needs of the customers and solar energy and energy efficiency measures. This pilot project could produce a replicable product marketable to other Palm Harbor Homes customers.

WCI Communities, Naples, FL

BAIHP staff developed, scheduled and delivered a training seminar on Zero Energy Homes to the architecture division of partner WCI Communities in January. The partner is planning construction of a ZEH in 2007. Four potential house plans were analyzed for performance potential, and recommended efficiency and renewable energy packages were prepared for the builder to consider.

Ferrier Builders, Dallas, TX

Multiple design reviews, recommendations and consultations. Ferrier Builders was accepted into the BAIHP program in fall 2006. They are an award winning custom home builder in the Dallas, TX area who builds exclusively with SIP panels. BAIHP provided analysis and recommendations for a large (~5,000 sq. ft.) home with pv. The home construction did not start in BP1.

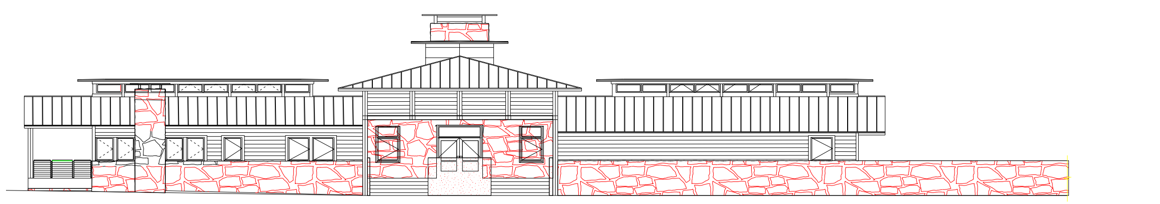


Figure 2- 1 Elevation for Ferrier Builders prototype home in Dallas, TX

PATH Concept Home, Omaha, NE

BAIHP performed benchmark analysis for the Path concept home to determine source energy savings over the BA benchmark. The Path home demonstrated benchmark source energy savings of 28.7% and HERS Index 79 with specified SEER 13, HSPF 8.5 HVAC equipment and Low-E 0.35 SHGC / 0.35 U windows. To achieve a BA 30% energy savings level (HERS 77), the use of SEER 14 and 9.0 HSPF equipment was recommended to PATH. This home is 2-story, 2,021ft2 with ICF foundation basement (unconditioned.)

Figure 2-2 Elevation for PATH concept home in Omaha, NE

Richard Schackow Solar Home Community Prototype, Gainesville, FL

BAIHP working with developer Richard Schackow to design and build a prototype for 20 Zero Energy Homes (ZEH) in Gainesville, Florida. These homes will be some of the most efficient residences ever constructed in Florida and include solar electric power and very low energy use appliances This project represents the first community level ZEH program in Florida.

Figure 2-3 Site for Zero Energy and Near Zero energy Community, Gainesville, FL

Castle Cook, Oakland Park, Orlando, FL

BAIHP have continued to work with Castle & Cooke developers on design of a sales office/model home for the Oakland Park Development in Orlando, FL. An architectural charrette for the community took place in August 2006 resulting in conceptual designs like the ones in Figure 2-4. There are 675 homes planned for this community with standard designs meeting 30% savings over BA benchmark. The scope also incorporates FGBC certification and high performance features like unvented attics, ducts in conditioned spaces, high efficiency HVAC equipment and whole house dehumidification systems.

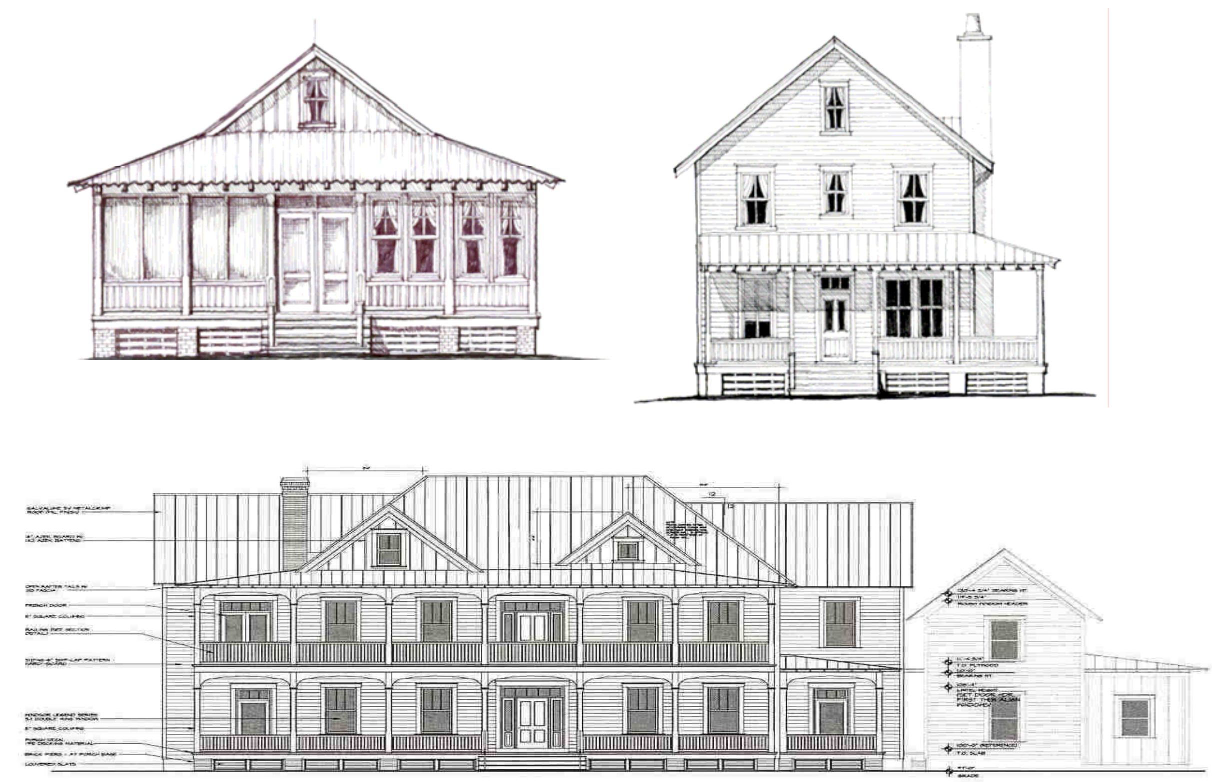


Figure 2- 4 Conceptual Designs developed for Oakland Park, Orlando, Fl

David Axel Home, Oviedo, FL

BAIHP provided feedback on house construction and combustion appliances for Dave Axel home. A site visit was made and construction documentation continues to be monitored.

Figure 2- 5 Construction Detail

Figure 2-5 HVAC equipment installed

GMD Construction (Divosta), Palm Beach Gardens and Jupiter, FL

BAIHP provided technical assistance to Guy DiVosta with GMD construction in Palm Beach Gardens, FL. Mr. DiVosta was interested in improving the overall energy efficiency of his home designs and providing solar thermal or PV systems as options. GMD Construction (Divosta) received a lighting assessment and plan from California Lighting Technology Center (CLTC), which included extensive use of CFLs and occupancy sensors.

GMD Construction also consulted BAIHP on a home that had some indoor comfort problems.

GMD construction was recently awarded a school construction project and is investigating the opportunities for including PV in that project.

GMD also requested technical review of plans for a 31 home development in Jupiter, FL.

BAIHP Manufactured Housing (MH) Lab, Cocoa, FL

BAIHP provided plans and pictures to CLTC for lighting assessment of MHLab, similar to Divosta. CLTC provided a modification plan for MHLab lighting and changes have occurred to implement CFL and LED technology in kitchen, living room and outdoor lighting.

Federation of American Scientists, Houston, TX

The Federation of American Scientists have requested assistance from BAIHP in the construction of a home. The project location is in Houston, TX and known as Rasbach House. A slab has been poured. BAIHP assisted with redesign of SIP panel walls and with HVAC designs and calculations.

Marquis Construction, Crimi Home, Masaryktown and Dade City, FL

Steven Crimi is the homeowner and sub-contractor for a home located in Masaryktown, Florida (west central FL). The shell was constructed by Marquis Construction, a Building America partner. He intends to integrate PV and DC circuit for LED lighting. This home uses SIP wall and roof panels, AAC floor, has a weather tight crawlspace that serves as a return for the whole house. BAIHP has been involved with pv, lighting and whole house indoor air quality design recommendations.

Figure 2- 6 Weather tight and insulated crawlspace

Figure 2- 7 Channels in roof construction to allow ventilation of potential heat generated from pv

Marquis Construction also completed two all SIP homes that FSEC tested and submitted energy rating files to Calcs-Plus for tax credit and rating. The homes HERS-06 Indexes were 62 and 68.

Figure 2- 8 Back view of Marquis Construction home in Dade City, FL

Figure 2-9 Testing Marquis Construction home in Dade City, FL (HERS Index 62)

<u>Selkirk Homes, ND</u>

BAIHP finalized Energy Star ratings on (4), phase IV homes and mailed certificates. BAIHP also submitted preliminary analysis of (6) phase V homes including EPACT06 tax credit qualifications.

<u>Royal Concrete Concepts (RCC), Pt. St. Lucie, FL</u>

BAIHP worked with Royal Concrete Concepts to incorporate PV on concrete modular residential buildings while still in the factory. We have conducted performance testing on their panelized home and RCC is aiming to have their home become the first certified USGBC LEED Home in Florida. They have 18 production lines that facilitate the structural strength of the panels to reach minimum 8,000 psi in 28 days and resist impact of a 2x4 at up to 84 mph. Other features of this prototype design are good R-values, tight envelopes and ducts in conditioned space. Calcs-Plus assisted in updating load and energy calculations.

Figure 2-10 Royal concrete concepts modular section

Figure 2-11 Structure & chase details

<u>Homark Homes of Minnesota</u>
Homark Homes has produced 8 Energy Star HUD-code homes placed in MN, ND and WI. First home is scheduled for testing in summer 2007.

<u>Southern Energy Homes, Double Springs, AL</u>
<u>Cavalier Homes, Opelousas, LA</u>
Southern Energy Homes and Cavalier Homes, manufactured home builders have requested assistance to provide diagnostics and possible retrofit solutions for moisture related issues in their homes. Design proposal for placing ducts in conditioned space was explored and a site visit included a mock up of design that encouraged further testing and analysis. Cavalier Homes and Southern Energy Homes on two different approaches to interior duct system designs, desire to bring all duct work inside the thermal envelope. The prototype images and testing data are detailed in Section 1, subtask 1.1.

<u>ZCS Development, Rockledge, FL</u>
ZCS Development is developing a 100 unit subdivision named Sierra Lakes in Rockledge, FL that includes all steel and foam construction with a sealed attic. Steel members are produced on-site with a mobile manufacturing unit. Energy and HVAC analysis was conducted and a BIPV design was provided to offset annual energy use to near-zero energy. The first model (Wesley) construction is near completion, BIPV mounting racks are in place for a 5kW array and monitoring instrumentation has been installed. BAIHP is assisting with development of low energy lighting package, active solar hot water system and PV powered pool pump. Other features include roof deck sprayed insulation values of R-22 (including garage), steel reinforced foam core walls with thermal values of R-24, ducts in sealed attic space, SEER 17.0/HSPF 9.2 HVAC equipment, 60% fluorescent lighting, Low-E windows (0.32 SHGC/ U-Val 0.4)

and instantaneous water heater (in addition to solar hot water heater). Analysis estimates the home can achieve benchmark energy savings of 69.4% with 4.8 kW of PV and the same home would achieve a 45.1% savings level if were to exclude the PV system. This model home surpasses the 30% savings level due to high performance envelope measures and high efficiency air conditioner (SEER 17). This development received media attention in *Florida Today (*Florida Today, "*New homes boast energy efficiency: Developer uses recycled steel instead of concrete, wood"*, January 4, 2007.)

Figure 2-12 Sierra Lakes, Wesley Model

Figure 2-13 Steel trusses produced on site

Homes in Partnership

This developer and partner desired to build Energy Star certified affordable housing. BAIHP worked with and made recommendations to meet Energy Star and beyond in support of Enterprise grant application. Status to date is awaiting confirmation on installation of programmable thermostats in (7) Pine Level homes before releasing ratings.

Figure 2-14 Pine Level Home undergoing performance testing

East Bay Development Group (EBDC), Calloway and East Bay FL
BAIHP visited partner East Bay Development Group in Calloway, FL in late July 2006 to inspect prototype modular homes that will be used to create high performance, affordable communities. Two buildings were inspected, and one was performance tested with favorable results. Recommendations were supplied to the partner to consider when finalizing specifications which will be supplied to the manufacturer.

The East Bay project in Calloway consists of 8 floor plans in which BAIHP performed HVAC load calculations/worse case analysis and system design. The floor plans are called the Richmond model, Nashville model, Savannah model 14’ wide, Savannah model 16’ wide, St Charles model 14’ wide, St Charles model 16’ wide, Augusta model 14’ wide, Augusta model 16’ wide (see Figure 2-15). BAIHP also investigated ground source heat pump equipment as per the owner’s direction but recently the owners desire to switch to air to air equipment. Air to air equipment was selected and EnergyGauge USA data has been input and analyzed. The HVAC floor plans are ready for review by Nationwide Homes (manufactured home builder). This project includes two communities of 270 modular homes with ducts in conditioned space and outside air ventilation with supplemental dehumidification.

Figure 2- 15 EBDC Callaway, FL

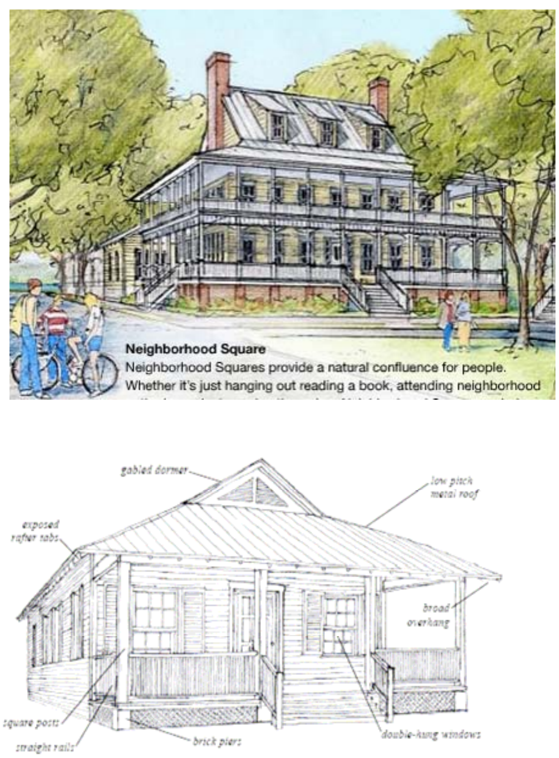


Figure 2- 16 EBDC East Bay, FL

EBDC has also requested assistance in another development encompassing over 2600 homes and community spaces in East Bay. This development has adopted their own code, East Bay code that includes Green design and EnergyStar. East Bay Code encourages high performance and green design standards like ducts in conditioned space, Energy Star lighting/appliances and estimates benchmark savings of 30% - 50%. Calcs-Plus assisted in energy analysis.

Rainier Construction, Maitland, FL

Rainier Construction was welcomed as a new BA partner. A home Rainier had completed construction on “pre-BA Partnership” was performance tested to create a benchmark for this contractor. Rainier’s first BA home is currently under construction and is known as Oyler Residence. A pre-permit submittal meeting was conducted to ensure all disciplines were aware of high performance, energy efficient objectives for this project. City of Maitland plan reviewers were also prepared prior to permit submittal of atypical strategies that may raise flags. This initial preparation was designed to save delays during plan review and construction. This home is also designed to be Energy Star, is expected to reach the 40% benchmark savings and apply for FGBC certification. Calcs-Plus performed HVAC equipment and duct layout design.

Figure 2- 17 Oyler Residence stem wall under construction (February 2007)

FLHero, Gainesville and Ocala FL

FL Hero, a Building America subcontractor, conducted whole house systems engineering, evaluations/recommendations, QA site visits, commissioning and problem solving on the following (some of these projects included multiple tasks within their scopes of work and some activities involved both prototype and community scale evaluations):

- GW Robinson Builder - Cobblefield, Turnberry, Garison Way, Canterbury Farms, in Gainesville, FL - Continued working with GW staff and in-house real estate representatives to continue development of collateral marketing material that highlights the features, benefits and value of the BA Systems approach. The goal is to better educate potential buyers of the value of using the BA approach, as well as, the effective use of the HERS index. Multiple design reviews, ongoing site visits for QA and implementation and completion of the requirements of the Thermal Bypass Inspection Checklist (TBIC). Coordinated a meeting between the developer and owner of a local solar company to discuss barriers and opportunities for solar DHW.
- Williams Bros. Construction - Belmont, Longleaf in Gainesville, FL - Design and ongoing site visits for QA, commissioning and tax credit analysis. Performed a site visit at a home at framing stage with the builder and project managers to highlight possible areas of performance improvements. Began implementing the requirements of the Thermal Bypass Inspection Checklist (TBIC).
- Spain & Cooper Construction in Gainesville, FL - Willowcroft - Multiple design reviews conducted for this builder.
- HKW Enterprises in Gainesville, FL - Williamsburg - Multiple design reviews and tax credit analysis. Performed smoke test on duct system with developer and mechanical contractor present. Ongoing site visits for QA and commissioning conducted.
- On Top of the World in Ocala, FL - Commissioning of multiple homes. Met with builder/developer and his key staff personnel to familiarize them with the requirements of the Thermal Bypass Inspection Checklist (TBIC), using the Energy Star PowerPoint presentation given by Sam Rashkin, to determine the most appropriate course of action to meet the specifications.
- Kent Harris Construction in Lake City, FL - Completed process to design appropriate air distribution systems for this manufactured home project. AH’s and duct system will be installed in an unvented attic
- Coastal Smart Construction - Citrus County, FL - Finalized plans and specifications.
- Pringle Development - Eustis, FL - Contacted by Pringle Development, an over 55 community builder. Became a BA Partner. Conducted site visit and toured their typical homes. Multiple Design Reviews, meeting & analysis for the purpose of developing a package of features including modifications to performance standards in SOW to insure meeting requirements for Energy Star. Ongoing site visits for QA and completion of the TBIC and commissioning. Continued implementing the requirements of the TBIC.

- Trunnel Construction - Gainesville, FL - Preliminary meeting with builder & developer to discuss the construction of “Green In-fill Development.”

<u>Miscellaneous Building America Partner Activity Related to Design and Technical Assistance and Instrumentation and Monitoring</u>

- Welcomed Minority Development Resource Group as a new partner. The company provides turnkey building envelopes and systems utilizing several energy efficient technologies including insulated concrete forms. A meeting was held with Dr. Erich Bourgault to discuss Building America review of the packages they offer and opportunities for improvement.
- Met with a potential new partner, Solaris Communities, to discuss development of a small high performance community of zero energy homes in Pt. St. Lucie, FL. Prototype building design was discussed including use of photovoltaics, high performance envelopes and systems, and an advanced energy management/home automation system.
- Initial contacts were made with Johns Manville regarding their Spider insulation system for possible applications for roof deck underside or frame floor undersides. The system incorporates blown fiberglass with a binding agent to allow adhesion to the horizontal or sloped surfaces.
- Helped IBACOS to modify channel maps for PM3 and PM4 (Pine Mountain) data loggers: Helped IBACOS create a new account/web site to monitor the "Tindall Home, Columbus, NJ" data logger named TIN.
- BAIHP personnel met with Jim Vallette of Unity Homes and Mike Mullens (UCF) to discuss plans for new Mississippi manufacturing plant targeting Gulf Coast reconstruction. FSEC PV personnel provided details on solar energy options.

Subtask 2.1B Long Term Instrumentation and Monitoring Projects

Energy Structures & Systems, Inc., Stuart, FL

Energy Structures & Systems, Inc. (ESSI) was welcomed in the BA program and FSEC conducted field inspections and commenced instrumentation on three homes being constructed in the Stuart, FL area. The homes feature unvented attics, AAC walls, solar water heater, roof integrated and stand-off PV, outside air ventilation, high efficiency a/c, fluorescent lighting, gossamer fans, xeriscaping and native plants etc. Houses are planned to have roof integrated PV systems installed, but as of yet, there is no PV on site.

Figure 2-18 Homes with sola hot water and BIPV on detached garage (not installed yet)

Chasar home, Cocoa, FL

BAIHP continues to monitor energy, indoor and attic conditions in Chasar home. Soffits sealed to create sealed attic space.

Ken Kingon, Fort Myers, FL

Regular data collection was continued. The data was analyzed for accuracy and completeness. Refer to subtask 1.3 with Figure 1-10 detailing data.

ZCS Development, Rockledge, Fl
In addition to technical design assistance, BAIHP also installed monitoring instrumentation to the first model (Wesley), which is near completion. This home incorporates mounting racks for a 5kW array.

WSU, Olympia Washington
Washington State University also participated in projects relating to Task 2 by supporting two homes that included monitoring and field testing, Garst Home and Stamets Residence. Their involvement is explained in Appendix D, in which one home attracted media attention in addition to partnering with product manufacturers to discuss performance improvements. WSU is currently involved with Scott Homes Olympia community project which has included site visits to evaluate construction and HVAC and assessments of combination Icynene ceiling and SIPs wall system, with HRV installed within the conditioned knee wall space. Case study information collection is also underway. WSU's BAIHP efforts are summarized in a powerpoint presentation located at:
www.fsec.ucf.edu/download/br/baihp/2007steering/Luby%20BAIHP%20Feb07%20final.ppt

Figure 2-19 PV panel installation, Garst Residence

Subtask 2.2 International Builders' Show Homes (all in Orlando, FL)

In BP1 FSEC's involvement with the National Association of Home Builders International Builders' Show spans for the shows in 2006-2008. We were involved with the Palm Harbor Homes participation in the outdoor show home exhibits and the National Association of Home Builder's show case homes built off site. These homes demonstrate the latest technology and products to builders and the general public as there were over 115,000 attendees that see these homes. Product manufacturers use these projects as marketing avenues for displaying new products or even show casing how to guides for installation of products. The 2007 single family show case home built by Palm Harbor Homes was pre-sold to a developer that will relocate the unit on raised stilts to a hurricane prone area, Siesta Key, FL. BAIHP intends to instrument this home and monitor it as it has a pv panel, inverter with battery back-up and solar hot water heater installed. These show homes are great opportunities to solicit builders to integrate more energy efficient and improved performance strategies in their homes as certifications and energy ratings can allow for a marketing edge.

The 2006 single family show home built by Palm Harbor Homes is now permanently located in Auburndale, Florida and was highlighted in the 2006 Polk County Builders Association Parade of Homes. The 2007 single family show home built by Palm Harbor Home included 3.25kWp PV and solar hot water system and was sold to a developer with plans to place the home on stilts in Siesta Key, Fl. We plan to monitor this project and document its performance when the home is relocated.

Additional venues of the International Builders' Show that BAIHP provided assistance with is the National Homes Builders Association and Builders Publication's site built demonstration projects. Our involvement within BP1 spans years 2006, 2007 and 2008. We assisted IBACOS with construction documentation and home performance testing of the 2006 and 2007 The New American Home (TNAH). We also provided the FGBC green home certifications for the 2007 Renewed American Home and The New America Home. Our latest involvement within BP1 is construction documentation of 2008 TNAH and the "Tradewinds Home" being constructed by Charlie Clayton Construction in Baldwin Park, a TND community in Orlando, FL

2006 International Builders' Show Homes

Building America partner, Palm Harbor Homes, has been responsible for construction of homes within Reed Publications show space. In 2006 PHH displayed 3 homes that FSEC provided oversight on green and energy efficient features. The three homes were tested and certified for EnergyStar compliance and FGBC green home standard. The details of these show homes can be found at: http://www.baihp.org/casestud/ph_homes/index.htm

The Bellaire Model was sold to a developer and permanently located on a lake view property in Auburndale, FL. The developer commissioned Palm Harbor Homes to construct a 1,250 square foot addition to the home and it was showcased in the Polk County Builders Association Parade of Homes.

1,682 sq. ft. Palm Harbor Home, the Wilmington – First Time Buyer

Energy Efficiency Features
• Expanding foam insulation throughout
• Low-E vinyl windows U=.39, SHGC=.39
• High efficiency heat pump, SEER 13, HSPF 8
• ENERGY STAR® Appliances
• Extensive use of compact fluorescent lighting
• Home Energy Rating Scale (HERS) Score = 90 Out of 100

Indoor Air Quality Features
• VOC Source Control including zero VOC paint
• Central vacuum system
• Duct System Sealed with mastic and fiberglass mesh and performance tested

Other Green Building Features and Certifications
• Resource efficient construction and construction waste management
• Water efficient appliances and fixtures
• Fire protection system
• Durable, low maintenance design
• Certified Florida Green Home by the Florida Green Building Coalition, Inc

2,500 sq. ft. Palm Harbor Home, the Palencia – NextGen Peace of Mind

Energy Efficiency Features
• Expanding foam insulation throughout
• Radiant barrier roof sheathing
• Low-E vinyl windows U=.32, SHGC=.31
• SEER 15 Puron air conditioner and 94.1 AFUE high efficiency gas furnace
• Tankless water heater
• ENERGY STAR® Appliances
• Home Energy Rating Scale (HERS) Score = 90.6 Out of 100

Indoor Air Quality Features
• Energy Recovery Ventilator for fresh air ventilation
• Advanced whole house air purification and filtration
• VOC source control including zero VOC paint

Disaster Resistance Features
• Built to Institute for Business and Home Safety's Fortified…for safer living program
• In-home storm shelter
• Impact resistant glass and storm shutters
• 4 ft. x 10 ft. roof sheathing with taped seams
• Galvanized metal screw-down shingle
• Corrosion resistant plumbing and fire protection system
Other Green Building Features and Certifications
• Resource efficient construction and construction waste management
• Water efficient appliances and fixtures
• Durable, low maintenance design
• Certified Florida Green Home by the Florida Green Building Coalition, Inc.
• US Green Building Council LEED for Homes Pilot Program Participant

2,865 sq. ft. Palm Harbor Homes, the Bellaire – Move up Buyer

Energy Efficiency Features
• Low-E vinyl windows U=.34, SHGC=.35
• R-33 vented ceiling
• High efficiency heat pump, SEER 13, HSPF 8
• ENERGY STAR® Appliances
• Extensive use of compact fluorescent lighting
• Home Energy Rating Scale (HERS) Score = 89.6 Out of 100

Indoor Air Quality Features
• VOC Source Control including zero VOC paint
• Central vacuum system
• Duct System Sealed with mastic and fiberglass mesh and performance tested

Other Green Building Features and Certifications
• Resource efficient construction and construction waste management
• Water efficient appliances and fixtures
• Fire protection system
• Durable, low maintenance design
• Certified Florida Green Home by the Florida Green Building Coalition, Inc.

2007 International Builders' Show Outdoor Homes

FSEC again supported Palm Harbor Homes with their outdoor show case homes at the 2007 International Builders' Show. There were two high performance homes, one single family and a tri-plex unit. We attended sponsor meetings ensuring that donated products met objectives of Energy Star rated and FGBC green certified homes for the show. FSEC's PV Division also assisted in our involvement and helped procure donated renewable energy products like 3.25 kWp BP Solar PV System, GridPoint Inverter and Battery-Based Backup Power & Energy Management equipment and a solar domestic hot water system for the single family home, GenX.

Figure 2-20 3.25kWp Photovoltaic Panel on roof top of GenX

Figure 2-21 GridPoint Invert and battery Back-up Energy Management System

3,397 sq. ft. Palm Harbor Homes, the Bellaire – GenX

Energy Efficiency & Renewable Energy Features

- Low-E vinyl windows
- R-33 ceiling with radiant barrier roof decking
- 14 SEER / 8.4 HSPF heat pump
- ENERGY STAR® Appliances
- Extensive use of compact fluorescent lighting
  3.25 kWp BP Solar PV System with GridPoint Inverter & Instant, “Clean” Battery-Based Backup Power & Energy Management
- Solar Domestic Hot Water System
- Exceeds ENERGY STAR® Homes Standards with a
- Home Energy Index (HERS) = 71

Indoor Air Quality & Noise Reduction Features

- VOC Source Control including zero VOC paint
- Demand Ventilation with Dehumidification
- Central vacuum system
- Duct System Sealed with mastic and fiberglass mesh and performance tested
- Low-sone bathroom exhaust fan
- Soundproofing

Other Green Building Features and Certifications

- Resource efficient construction and construction waste management
- Water efficient appliances and fixtures
- Universal Design for handicap accessibility
- Durable, low maintenance design
- Certified Florida Green Home by the Florida Green Building Coalition, Inc.
- Progress Energy Home Advantage Premium Energy Saver/Energy Star Qualified

The three unit town home, called the EchoBoomer, that PHH homes built for the 2007 International Builders' Show also included energy efficient features and green building design strategies. BAIHP coordinated specification compliance and conducted on site performance testing.

Palm Harbor Homes, Town Homes – EchoBoomer
(3) Units
• 1 unit = 1,840 square feet • 2 units = 1,360 square feet each

Energy Efficiency & Renewable Energy Features

- Low-E vinyl windows
- R-33 ceiling with Honeywell Foam Insulation
- High efficiency heat pump
- ENERGY STAR® Appliances
- Extensive use of compact fluorescent lighting

- Exceeds ENERGY STAR® Homes Standards with a Home Energy Index (HERS) = 76 (left unit), 80 (middle unit),75 (right unit)

Indoor Air Quality & Noise Reduction Features

- VOC Source Control including zero VOC paint
- Central vacuum system
- Duct System Sealed with mastic and fiberglass mesh and performance tested
- Low-sone bathroom exhaust fan

Other Green Building Features and Certifications

- Resource efficient construction and construction waste management
- Water efficient appliances and fixtures
- Durable, low maintenance design
- Certified Florida Green Home by the Florida Green Building Coalition, Inc.
- Progress Energy Home Advantage Premium Energy Saver/Energy Star Qualified

We also compiled data sheets for dissemination that described both homes at the 2007 IBS (Appendix C). These sheets can be viewed at:
http://www.baihp.org/casestud/ph_homes2007/genx.pdf
http://www.baihp.org/casestud/ph_homes2007/echoboomer.pdf
Cost data was also compiled and shared with DOE.

Show home assistance is a small portion of our work with Palm Harbor Homes. We continue to offer technical support and assist with modular energy star labels and federal tax credit qualifications. We provide assistance to HWC Engineering (PHH 3rd party inspector) with incorporation of Thermal Bypass Checklist and reviewing possible use of new RESNET approved sampling protocol.

PHH plant located in Plant City built 18 houses for the Dothan, AL Habitat for Humanity affiliate. BAIHP personnel followed along during the construction to determine the factory's ability to comply with the thermal bypass check list, required for energy Star compliance. Current regulations do not require the homes to pass all items on the check list, so this provided an excellent opportunity for PHH to hone their ability to produce energy Star qualified homes after Jan. 1, 2007, when all items on the thermal bypass check list must be done correctly to conform to the Energy Star standards. We are working with PHH to rectify the issues not in compliance with the checklist, i.e. (many air barrier failures, incorrect use of can lights, etc.)

<u>2007 The New American Home</u>

Each year the National Association of Home Builders also demonstrates site built housing. The 2007 The New America Home was located in a historical area adjacent to The Renewed America Home, both of which FSEC assisted IBACOS by providing progress documentation, performance home testing, energy star ratings and green building certifications for both homes. Energy rating file was completed and submitted to Calcs-Plus for $2,000 tax credit and Energy Star rating. (HERS-06 = 51)

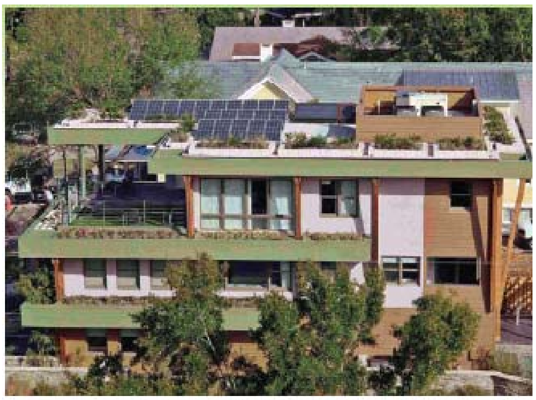


Figure 2-22 2007 TNAH (with the Renewed American Home roof in background)

Figure 2-23 2.25kWp Photovoltaic power system on roof top of 2007 TNAH

<u>2007 The Renewed American Home</u>

Figure 2-24 2007 TNAH (with the Renewed American Home roof in background)

Figure 2-25 2007 TNAH (with the Renewed American Home roof in background)

Built in 1909, the 2,462-square-foot "Renewed American Home" was completely renovated and expanded. The house was moved from its original site at the corner of Broadway Avenue and Ridgewood Street to the adjacent lot to make way for The New American Home. The final construction resulted in 5,860 sq. ft. conditioned, 4 bedrooms, 5 ½ bathrooms, with a library, additional basement and a detached garage with living space above. Additional features include latest in residential automation and home control for all low voltage systems, universal design, gas fired dehumidifier, EnergyStar® certified HERS-06 Index = 65 and FGBC certified. Eric Martin participated in an interview with HGTV regarding the Building America and green building process that was employed by the home.

2008 The New American Home

We are currently assisting IBACOS with construction documentation of the 2008 New American Home in the Lake Nona area.

Figure 2-26 2008 The New America Home under construction

2008 Builder Magazine Show Home

BAIHP will be sole energy efficient and high performance consultant in the International Builders Show Builder Magazine Show Home “Tradewinds” for 2008 built by Charlie Clayton Construction. The home will be located in Baldwin Park, FL. The design intends to include natural ventilation as a passive cooling strategy some months of the year. BAIHP’s primary role will be to provide a mechanical design and to provide other high performance recommendations. Coordination, technical support and recommendations continue. Features include Low-E vinyl windows with hurricane impact glass, ‘Cool’ roof, expandable spray foam insulation throughout, High efficiency heat pump (SEER 15, SEER 14.5), digital thermostats & RH display, homeowner website and pool solar hot water system. In addition to good indoor air quality and noise reduction strategies implemented, the builder would like this home to be one of the first LEED for Residential Certified recipients.

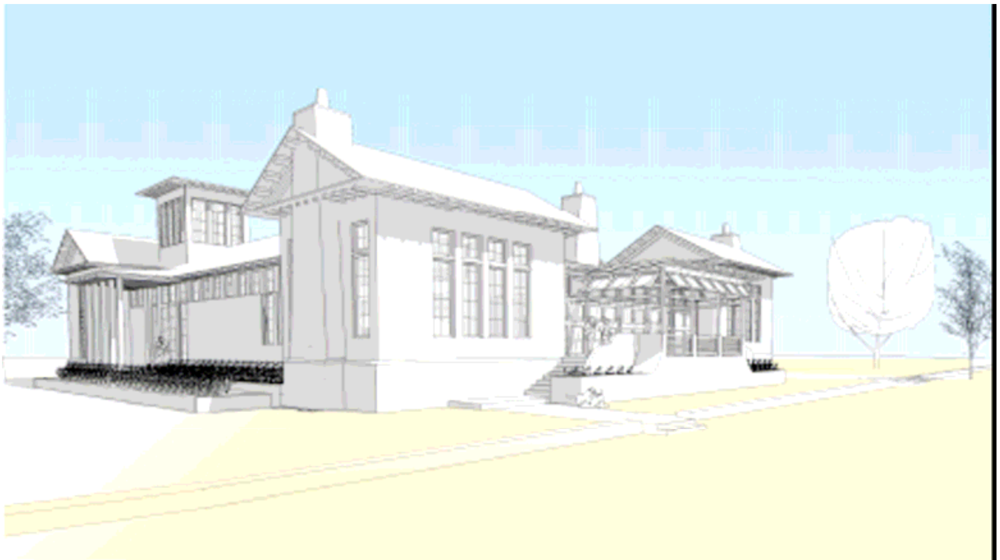


Figure 2-27 7,316 square foot home 'Tradewinds' home for 2007 IBS Builder Magazine

<u>2008 Vision House</u>

Met with a representative from the Vision House Orlando project – a show home planned for the 2008 IBS. The home will be in Lake County, and is sponsored by Green Builder Magazine. The home is targeting a high performance, systems engineered design, and has requested BAIHP assistance.

III. SECTION 3: COMMUNITY SCALE DEVELOPMENTS

Tommy Williams Homes

Phase 2 in Belmont. Pink sites are Tommy Williams Homes.
For a sales comparison with the other builder (purple sites) in this community, see next section "Energy Efficiency and Cost Neutrality" below.

In this section we document our efforts in providing technical assistance to builders that are building entire communities of high performance housing in hot-humid and marine climates.

<u>Hot Humid Climate (See subtask 3.1 write up below)</u>
Location – All are in the area of Gainesville, FL. Alachua county.
Developers and Builders – G.W. Robinson Builders and Tommy Williams Homes
G.W. Robinson communities – Cobblefield, Turnberry Lake and Garison Way
Tommy Williams Homes Communities – Longleaf Village and Belmont
Number of Homes built in 2006 : G.W. Robinson – 101, Tommy Williams – 41
Energy Savings Range – Greater than Energy Star, Benchmark Savings (source energy) - 36% to 40%, HERS Index Averages – G.W. Robinson (~65), Tommy Williams (~70) (Note HERS Index for Energy Star is 85 in this climate)

<u>Marine Climate (see subtask 3.2 write up below)</u>

Location – All homes are in Fort Lewis, WA (South of Tacoma, North of Olympia)
Developer – Equity and Lincoln Properties
Builder – Champion Homes of Oregon (a Modular builder)
Number of Homes built in BP1 – 167
Energy Savings Range – Energy Star level (per letter agreement from EPA) .
Benchmark Savings (source energy) – 25% to 30%

Subtask 3.1 Hot Humid Climate Communities

This section describes in case study format the BAIHP work done in partnership with G.W. Robinson Builders and Tommy Williams Homes

G.W. Robinson Builders Case Study

Communities: Cobblefield – Build out 265 homes, 260 built (as of March 2007)
Turnberry Lake - Build out 186 homes, 61 completed (as of March 2007)
Garison Way – Build out 110 homes, 23 completed (as of March 2007)

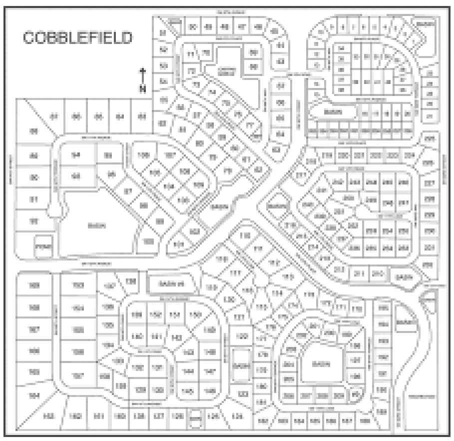
Developer/Builder: G.W. Robinson

Locations: Near Gainesville, FL (Alachua County)

Background and Summary
In 2000 GW Robison decided to build the healthiest, most energy efficient and "Green" subdivision possible for move up buyers and became a BA partner in 2001. Ken Fonorow of Florida H.E.R.O. worked with the builder to develop and implement a new set of specifications first in the Cobblefield community, then in the Turnberry Lake community and now in a third community Garison Way. This builder has chosen to incrementally improve his specs over the years and currently builds all homes with the recent most specs. All his homes have HERS Index values between 63 and 68 (average ~65) and Building America Benchmark savings range from 35% to 41%.

G.W. Robinson homes (Figures 3-1 and 3-2) are typically 2,000 to 5,000 square feet with a selling price in 2006 of $300,000 to over $1,000,000 with a sales price average of $165/sf. This builder's homes are enjoying solid sales in the current down turned market environment of 2006-2007.


Figure 3-1 Homes in Cobblefield (l) and Turnberry Lake (rt.)



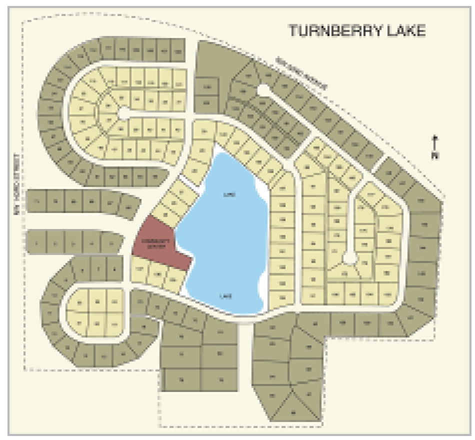


Figure 3-2 Site plans for Cobblefield (l) and Turnberry Lake (rt.)

Energy Efficiency and Cost Neutrality Analysis

When Fonorow began working with G.W. Robinson, his homes were compliant with the Florida Energy Code. Over time the specifications improved and the current specifications are summarized in Table 3-1. All of the homes built to these specifications achieve a HERS '99 score of 88.6 or better (HERS Index scores of 68 or lower).

Table 3-1 also shows the specs for typical new homes built in the Gainesville, Florida market and the estimated added costs for the BA specs that G.W. Robinson has implemented. Then the costs to the homeowner are estimated and a monthly cash flow analysis is shown at the bottom of the table. The bottom line is a monthly mortgage cost of $13.44 and an estimated monthly energy savings over typical construction of $41 yielding a net positive cash flow of over $27 per month. The simple payback for a cash buyer will be 4.1 years. Note that this cost neutrality analysis is done with respect to typical new construction specifications in the regional market, not with respect to the benchmark home.

All of the homes are individually performance tested as part of a commissioning (quality assurance) process. Simulation analysis shows these homes to be approximately 35% to

41% better than the benchmark with savings in all categories except appliances and plug loads (plotted in Figure 3-3 for a sample home saving 38.9% overall)

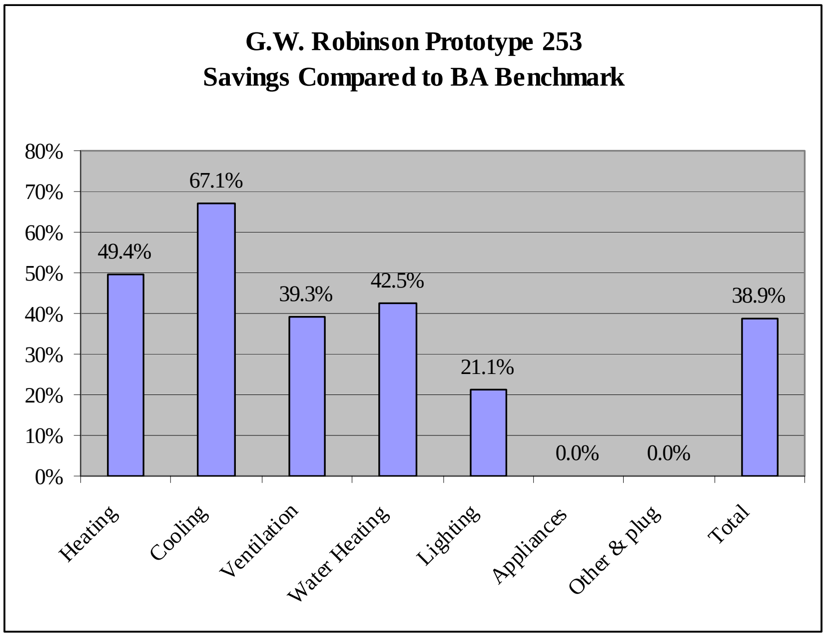


Figure 3-3 Source energy end use savings

Table 3-1 Energy Features of a 2,786 sq. ft. 1 story 3BR, 2.5 Bath home with specifications typical for the region compared to GW Robinson Home with BA specifications meeting the 30% Benchmark savings target				
Note: Cost Difference shown in this table is relative to Typical practice NOT Benchmark				
Category	Typical Specs	BA Specs		Incremental Cost
Manuals J and Manual D Calculation, Commissioning, and Rating				$400
Wall Insulation	R-11	R-13 Cellulose		$494
TBIC Compliance	No	Yes		$300
Wall Framing	standard 2x4	advanced 2x4 w/Ca corners, Ladder T's		$0
Windows	2-pane Aluminum	2-pane Vinyl Low-E		*-$128*
Heating System	80% Gas	93% Gas		$400
Capacity	100KBtu	60Kbtu		
Cooling System	SEER13	SEER14		$350
Capacity	5tons	3.5tons		*-$1,500*
Ventilation System	None	Run Time		$300
Air Handler Location (Costs $500, added appraised value $1500)	Garage	Interior		*-$1,000*
Duct Leakage	6% to out	4% to out		$165
House ACH50	6	4.5		$200
Attic Radiant Barrier	No	Yes		$806
Lighting	10%cfl	50% CFL		$50
Hot W pipe Ins	None	1/2" foam		$100
Water Heater(Gas)	60%	83% tankless		$900
			Added cost to Builder =	$1,837
			Added cost to Consumer @1.1=	$2,021
			Added mo. pmt @7%, 30yrs=	**$13.44**
Energy Savings Summary				
	Typical Specs	Cost ($)	BA Specs	Cost ($)
HERS Index	94		65	
Total kwh@12c/kwh	12792	$1,535	10408	$1,249
Total therms@$1.48/therm	373	$552	231	$342
Total Annual Energy Cost		$2,087		$1,591
Average Monthly Energy Cost		$174		$133
Monthly Energy Savings			$41	

Notes: Wall insulation @20c/sq. ft. extra. Actual price for vinyl low-e windows are cheaper. See below for Air handler cost benefit.

Value Added Innovations

Fonorow has worked with this builder to develop a number of innovative techniques. One involves the position of the air handler. Previously, the builder located the air handler in the garage as is typical conventional practice in Florida. Fonorow recommended moving the air handler to a closet in the conditioned space. This was accomplished without changing the floor plan by moving the exterior wall to form a closet around the air handler separating it from the unconditioned garage (figure 3-4). This adds approximately 15 square feet of conditioned space with an appraised value of about $1,500. The first cost of the detail adds about $500 to the total cost of the project for a net gain of $1,000. Another innovation in the air handler closet results in an improved air barrier between the closet and the attic overhead. Figure 3-5 shows the view looking up at the ceiling of the air handler closet before the air handler has been set. The supply trunk line on the right will be attached to the top of the air handler while the return trunk on the left will be connected to the return plenum below the up-flow air handler.

Figure 3-4 Exterior walls around air handler isolate closet from garage, create valuable conditioned square

Figure 3-5 Air barrier in top of air handler closet created with duct board by the mechanical contractor at the time that the ducts are installed.

Typically, this closet would get a drywall ceiling just like all the other closets in the house. There are several problems associated with this. First of all, drywall isn't typically available on site during the mechanical rough in when these trunk lines are put in place. Even if it is available, it's difficult to cut precisely and mechanical contractors are not accustomed to working with it. And leaving this detail to the drywall crew (later in the construction process) jeopardizes the air tightness of the closet.

Fonorow's innovation here was to switch materials for the ceiling. Note in the picture (Figure 3-5) that the top of the closet is made of duct board, just like the trunk lines. The material is readily available during the mechanical rough in, is easier to cut than drywall, and the mechanical contractor is accustomed to working with it. While this innovation does result in a vapor barrier at the wrong side, it does result in less infiltration into the air handler closet where there is often very high negative pressure due to small leaks in air handler cabinet itself. Fonorow is currently working on an improvement using duct board with a foil facing on both sides or simply doubling up on the duct board with foil facings out so that there is vapor barrier on both sides.

Outside Air Ventilation
In energy efficient homes in general, the natural infiltration rate tends to be low, occasionally resulting in odor or wintertime high humidity complaints from the homeowner. A general concern about energy efficient homes in the hot-humid climate is the magnitude of the remaining latent load (from infiltration and breathing) coupled with humidity in outside air ventilation.

In the hot-humid climate, outside air ventilation brings humidity to the conditioned space increasing the latent cooling load in the house. Air conditioners are better equipped to lower sensible heat than latent heat (warm moist air).And sensible heat is easier to reduce (with insulation and shading) than latent heat. Thus energy efficient homes in the hot-humid climate often have a very low sensible cooling load while still having a fairly typical latent cooling load.

Some measures such as exhaust fans ducted to outside help control the latent cooling load by removing warm moist air as it is produced (source control) and the use of a variable speed motor in the air handler which provides the opportunity to reduce the air flow rate across the evaporator coil resulting in enhanced dehumidification.

Figures 3-6 Outside air ventilation system details

Fonorow also developed a passive ventilation system which is in use by G.W. Robinson and other builders in the Gainesville market such as Tommy Williams (see the next case study). When the air conditioning or heating system is running, the negative pressure in the return plenum draws outside air through a duct linking the return plenum to a filtered outside air inlet mounted in the soffit or a porch ceiling (figures 3-6). The inlet is downstream of a filtered grill mounted to a standard one foot square boot. There is an in-line, pressure actuated damper with a manual override to prevent flow of outside air when it would be undesirable (for example when there is a fire in the area).

This outside air ventilation strategy has been implemented in over 500 homes in the Gainesville area including homes from G.W. Robinson and Tommy Williams Homes (see other case study). None of the homes have had problems with odor retention (from cooking, etc) or indoor humidity. In an evaluation of 54 homes built with the Fonorow design the mechanical vent rate averaged of 34 CFM when the air handler operated. Note that this is significantly lower than indicated by ASHRAE Standard 62.2.

Durability, Indoor Air Quality, and Landscaping

While recognizing that a home's most significant environmental resource impact will be the energy needed for its ongoing operation, this builder also addressed the issues of durability, health, maintenance, landscaping and irrigation.

To enhance durability, each home is treated with Bora-Care®, a termiticide whose active ingredient is Disodium Octoborate Tetrahydrate (DOT), which is a mixture of borax and boric acid. A 50+ year cementitious lap siding is installed over a continuous drainage plane. The entire exterior of the home receives three coats of paint which carries a ten year warranty. Thirty year architectural shingles have been selected. To help insure better indoor air quality low volatile organic compound (VOC) paint is used in the interior, all gas burning fireplaces receive outside combustion air and all rigid duct board material used in the distribution system is a coated style to help separate the air stream from any raw fiberglass. Where applicable, alkaline copper quaternary (ACQ) wood is used, which is arsenic and chromium free.

After protecting wooded areas whenever possible, homes are landscaped with drought tolerant indigenous species which are grouped according to their watering needs. Irrigation is provided through a municipal reclaimed water system where water that would normally be discharged via a deep well injection system is routed to the subdivision to meet the irrigation needs. It is important to note that this service is being provided to homeowners by the developer for $10 a month while a homeowner who uses the potable water for irrigation often pays $40-50 a month.

Quality Assurance: Systems Engineering and Site Inspections

The BA integrated systems engineering approach was used in both of these communities to optimize the performance of homes within a financial framework which enhanced the builder's profits.

After the initial analysis to determine the specifications for the communities, Florida H.E.R.O.'s systems engineering approach included an evaluation of each design (floor plan, elevations and specifications) to identify opportunities for improvements and ensure specifications were called out correctly. Next, Florida H.E.R.O. did a room-by-room ACCA Manual J load calculation to determine the heating and cooling equipment size and a duct system design based on ACCA Manual D calculations. Finally the duct system plan is drawn and a scope of work is developed for the mechanical contractor.

For quality assurance, site visits are conducted to complete the new Energy Star Thermal Bypass Inspection Checklist which includes an inspection of the air barrier continuity, thermal barrier (insulation) integrity, and duct system layout. Deficiencies are reported back to the developer/builder and meeting with the trades often occur to correct deficiencies and conduct training.

Lessons Learned

Following is a summation of lessons learned and ongoing challenges in achieving the systems engineering approach to new home construction:

- The first step in this process requires a clear and consistent commitment of the final decision maker, be it the builder or the developer. The support of this "champion" is necessary to maintain improvement and quality assurance efforts. Lip service will not result in high performance homes.
- A scope of work including specific *performance* criteria gives sub-contractors a clear idea of what is expected from them and provides a mechanism for linking payment to work quality. An example would be to include in the contract language, a provision requiring that the mechanical system will have no greater then 10% total leakage and 5% to out when using the standard cfm25 duct test.
- Effective communication of performance expectations to the person(s) responsible for implementation in the field must be performed, often in conjunction with education and demonstration activities.
- Ongoing quality assurance field inspections by either the project manager or an independent third party must be conducted to ensure consistency over time.
- Final commissioning of each home, including performance testing is an integral component of a systems approach, as it provides a timely feedback loop to the builder.
- In order for the builder to achieve sales goals, the sales representatives must be knowledgeable about the features and benefits that have been built into the home. Thorough and repeated sales training and advertisement is critical to success.
- Cost control is essential. This builder is able to offer BA homes for about the same price than typical efficiency homes.

Tommy Williams Homes Case Study

Communities: Longleaf Village: Build out: 225   Completed: 120
(Total Community Build out: 500. 275 lots allocated to a non-Building America builder.)

Belmont - Build out: 136 homes   Completed: 66
(Total Community Build out: 275. 139 lots allocated to a non-Building America builder.)

Builder: Tommy Williams Homes

Location: Near Gainesville, FL in Alachua county.

Background
Tommy Williams (Figures 3-7, 3-8, and 3-9) has been building homes for 26 years and embraced the Building America high performance approach in 2004. Home sizes in the Longleaf and Belmont communities are 1,300 to 2416 square feet with a 2006 selling price of $205,000 to $315,000 and averaging ~ $147/sq. ft.

Figure 3- 7 Tommy Williams Homes

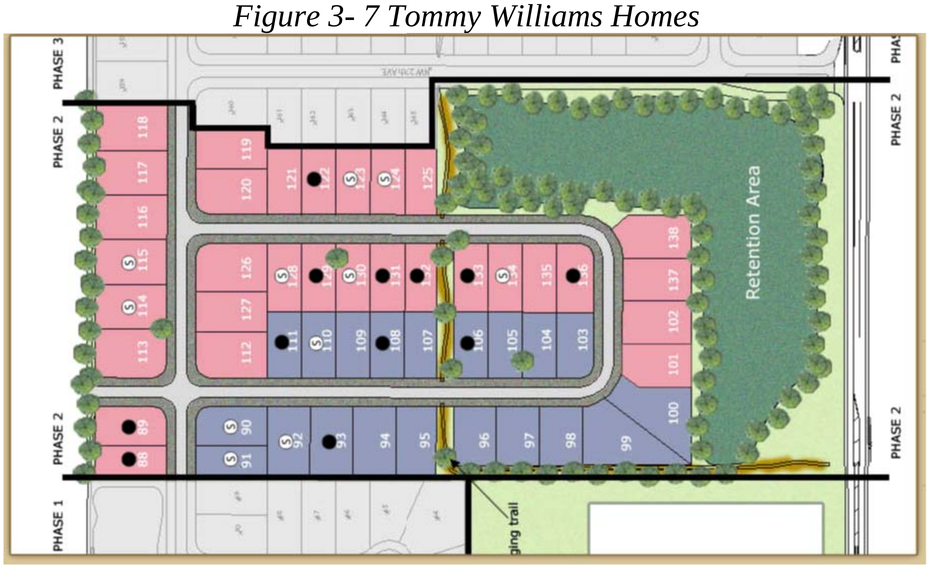


Figure 3-8 Site plan for Phase 2 in Belmont. Pink sites are Tommy Williams Homes. For a sales comparison with the other builder (purple sites) in this community, see next section "Energy Efficiency and Cost Neutrality" below.

Energy Efficiency and Cost Neutrality

Tommy Williams and his organization went from building Florida Energy Code minimum homes to being committed to build over 250 homes in two sub-divisions with HERS '99 scores of 88.6 or above (HERS Index 72 or below, average ~70).

Energy features are delineated in Table 3-2. Most of the homes built by this builder qualify for the $2,000 Federal Energy Tax Credit and are individually performance tested as part of a commissioning process. Benchmark analysis shows these homes to be an average of 36-40% better than the benchmark with savings in heating, cooling, and lighting (Figure 3-10).

Figure 3-9 Floor plan for Tommy Williams Homes' Mattair Model

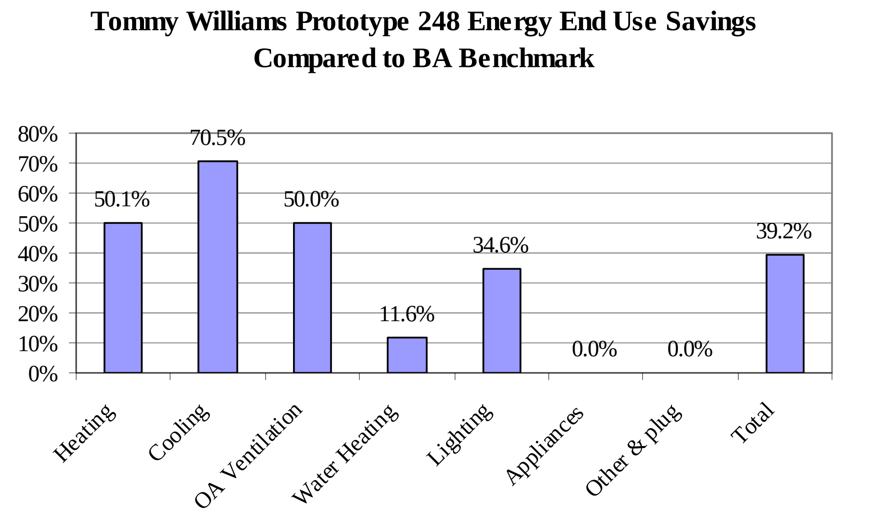


Figure 3-10 Estimated annual source energy savings by end use. Note significant reduction in heating and cooling energy use

Table 3-2 Cost analysis of energy features in a 1,809 sq. Ft. 1 story 3BR, 2 bath home with specifications typical for the region compared to a Tommy Williams **Home with BA specifications meeting the 30% Benchmark savings target**

Note: Cost Difference shown in this table is relative to Typical practice NOT Benchmark

Category	Typical Specs	BA Specs		Incremental Cost
Manuals J and Manual D Calculation, Commissioning, and Rating	Specs	Specs		$400
Wall Insulation	R-11	R-15 Spider		$370
TBIC Compliance	No	Yes		$250
Wall Framing	standard 2x4	advanced 2x4 w/Ca corners, Ladder T's		$0
Windows	2-pane Aluminum	2-pane Vinyl Low-E		*-$71*
Heating System	HSPF 7.7 Heat Pump	HSPF 9 Heat Pump		$0
Capacity	42KBtu	36KBtu		
Cooling System	SEER13	SEER15.25		$1,000
Capacity	3.5tons	3tons		*-$500*
Ventilation System	None	Run Time		$300
Air Handler Location (Costs $500, added appraised value $1500)	Garage	Interior		*-$1,000*
Duct Leakage	6% to out	4% to out		$165
House ACH50	6	4.5		$200
Lighting	10%cfl	75%cfl		$50
			Added cost to Builder =	**$1,164**
			Added cost to Consumer @1.1=	**$1,280**
			Added mo. pmt @7%, 30yrs=	**$8.51**
Energy Savings Summary				
	Typical Specs	Cost ($)	BA Specs	Cost ($)
HERS Index	92		70	
Total kwh@12c/kwh	9624	$1,155	7650	$918
Total therms@$1.48/therm	166	$246	166	$246
Total annual bill		$1,401		$1,164
Av monthly bill		$117		$97
Monthly bill Savings			**$20**	

In Table 3-2, the costs to the builder were estimated to the best of our knowledge and cost to the homeowner calculated at a 10% profit margin for the builder. The savings compared to a typical practice home is $20/month at an added monthly payment of $8.51 resulting in a net positive cash flow of over $11 monthly. The simple payback for a cash buyer is ~5.3 years.

Value Added Innovations
With this builder, Fonorow has implemented the same innovative techniques described more fully in the G.W. Robinson case study. These include moving the air handler to a conditioned closet created in the garage and making the ceiling of the air handler closet out of duct board instead of drywall.

Both builders are also using advanced framing techniques that result in lower framing fractions (Figures 3-9 and 3-10) enhancing comfort and performance. The spray in Spider® insulation is a fiberglass product that fills stud bays more evenly than batt insulation.

Tommy Williams' sub-contractors work from a formal scope of work that details what is expected of them with quantitative performance requirements when possible. This in addition to a sub-contractor meeting during the early stages of the project helps establish expectations for high performance quality.

Figure 3-11 Details reduce framing fraction and improve comfort.


Figure 3-12 Close up of ladder detail at the intersection of an interior wall. "Rungs" provide drywall nailing surface without compromising insulation.

Outside Air Ventilation
Fonorow also developed a passive ventilation system that supplies filtered outside air to the return plenum when the air handler is running (heating or cooling) which is in use by Tommy Williams and other builders in the Gainesville market such as G.W. Robinson (see GW Robinson case study for full discussion of ventilation issues). The filter back intake grille for the outside air is located in soffit of the front porch where it is easily accessible by the homeowner (Figure

3-13.) A flex duct connects the intake register boot to the return plenum of the mechanical system to be mixed with return air from the house (Figure 3-14.) Outside air is only drawn when the mechanical system is running. It is outfitted with a pressure

Figure 3-13 Outside air intake boot in porch ceiling at front door.

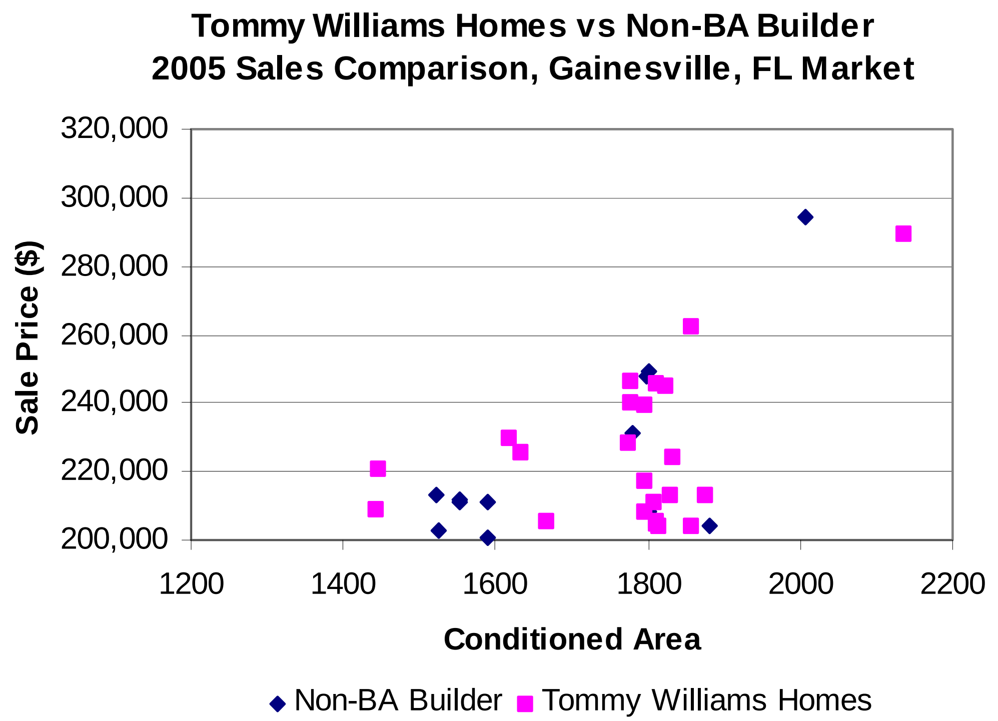
Figures 3-14 Outside air ventilation duct terminating into return plenum

actuated damper with a manual override.

Market Reception

Tommy Williams is one of the two builders working in the Belmont subdivision. The other builder is not a Building America partner. One realty company handles all sales. 2005 and 2006 sales data for both builders are shown in Figure 3-15. These data were compiled from the public records of the county.

The sales data reveal that Tommy Williams had more sales than the non BA builder and there was no statistically significant difference between the price per square foot for both builders. In 2006, the average selling price for the BA builder was actually slightly less at \$147/SF compared to \$149/SF for the conventional builder but again, the difference was not statistically significant. The 2005 data also do not show a statistically significant difference between the BA and the non-BA builder. The 2006 prices, however, were on average about \$25/SF higher than 2005. It is clear that the BA builder, because of his building and management practices is delivering more efficient homes for the same \$ to the homeowner and enjoying a larger market share. In 2006 the BA builder sold 26 compared to 12 homes for the non BA builder in this Belmont subdivision.



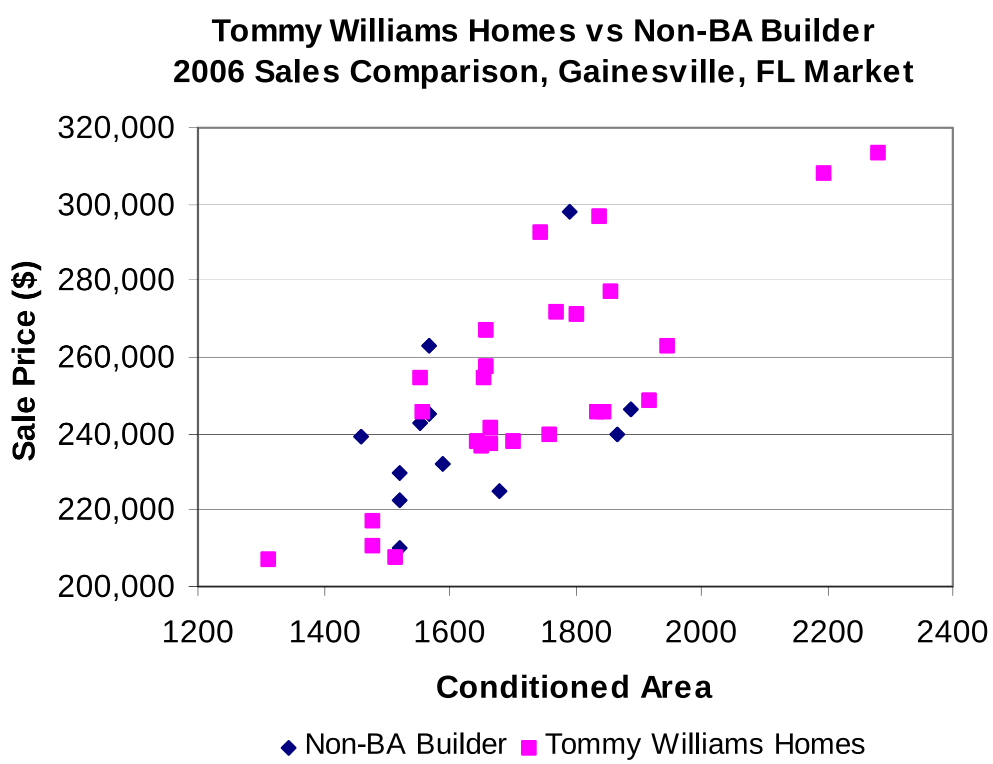


Figure 3-15 Sales data for Tommy Williams (squares) and non-BA builder in same subdivision (diamond) for 2005 (top) and 2006 (bottom).

Subtask 3.2 Marine Climate Community

Figure 3-16 Two story Modular housing assembly - Fort Lewis Army Base, Washington

WSU is working with Building America partners Oregon Department of Energy (ODOE), Champion Homes and Equity Residential in an effort to build over 850 energy efficient modular homes at Fort Lewis Army base in Washington State. These factory-built homes are constructed to ENERGY STAR Homes Northwest (NEEM) standards, and feature .90 AFUE furnaces, efficient windows, and ENERGY STAR appliances.

The project is administered as a mixture of ENERGY STAR manufactured and site-built programs. During BP1 ODOE inspected the homes in-plant and provided quality assurance throughout the construction process. WSU provided on-site quality assurance for the final inspection of the home, and evaluations of the HVAC performance.

Phase 1 of the project, which started in 2005, produced 174 units (homes are single story duplex, two story duplex, or two story triplex). Phase 2, currently underway, will result in an additional 150 units. Phase 3 will be started and completed in 2007, and will result in 135 units, for a total of 459 units by the end of 2007.

Initial testing of Fort Lewis HVAC systems by BAIHP staff indicated leakage rates of worse than 400 CFM_{50}. Hands-on efforts by BAIHP staff resulted in leakage rates of less than 100 CFM_{50}.

Current Fort Lewis homes benchmark at the 25-30% level. BAIHP worked with Equity and Champion to build a demonstration duplex with a .94 AFUE Carrier furnace with ECM motor and AeroSeal™, Panasonic Whisper Green fans as well as ENERGY STAR lighting (GU24 fixtures), a Noritz tankless hot water system, and active crawlspace ventilation. These demonstration units are expected to benchmark at or above the 40% level.

BAIHP are also working with Equity staff and Minol on an effort to conduct a community scale billing analysis of phases 1 and 2 (including the demonstration homes.) Discussions with Equity on field testing, new technology research and PR event planning are ongoing. A informational case study sheet was developed in the Building America Best Practices Series: Volume 5 – *Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Marine Climate* Version 1, 8/2006. This sheet can be viewed online at:
http://www.eere.energy.gov/buildings/building_america/pdfs/38449.pdf

IV. SECTION 4: RELATED ACTIVITIES

Typical US Habitat for Humanity home; average costs $60,000

Volunteers construct Habitat for Humanity homes

IV. SECTION 4 – Task 4: OTHER ACTIVITIES

BAIHP has been involved in various activities over the course of Budget Period 1 relevant in the research towards zero energy homes. Subtask 4.1 highlights activities associated with Habitat for Humanity at the international level, as well as, the local affiliate level. Activities include testing homes, training volunteers, design review and recommendations, standard development, activity and analysis reports, instrumentation and monitoring. BA team members and subcontractors like Washington State University, Oak Ridge National Laboratory, RESNET and others, have actively partnered to develop a true synergy of community partnerships. BP1 proved to be an effective use of resources as over 12 HFH affiliates and/or programs were personally assisted, over 83 homes improved through direct support and over 40 staff/volunteers helped by electronic or verbal advice.

Subtask 4.2 involved working with HUD code manufacturers and Northwest Energy Efficient Manufacturing (NEEM) Housing program to improve efficiency and marketability through various activities. These activities were primarily directed toward projects located in marine-cold and hot-humid climates, climates that other Building America contractors are not currently focused on. BAIHP made factory and field site visits to test homes, ensuring low leakage ducts; we promoted better efficiencies in equipment and promoted solar ready concepts; we continued to train and educate factory personnel resulting in 4,440 EnergyStar manufactured units in BP1.

In subtask 4.3 BAIHP continued to assist National Renewable Energy Laboratory in refining the Benchmark calculation methodology and BEOpt analysis tools. Carryover tasks are included in this section. The final report for the previous BAIHP project, which ended in June 2006, was submitted in October 2006 and is available online at: http://www.baihp.org/pubs/finalrpt/index.htm

In BP1 subtask 4.4 initiated preparation, research and completion of two case studies for the 30% marine report – NEEM program and NOJI Gardens.

Subtask 4.5 highlights a few of the conference papers (11), contract reports (10), and presentations given at various national and regional venues (over 25). Full details are provided in the References section of this report. This section also highlights other activities that may be relevant to projects with multiple tasks associated with them or are relevant in the research towards zero energy homes.

Subtask 4.1 Habitat for Humanity (HFH) Partnership

In Budget Period 1 BAIHP involvement continued its decade long partnership with HFH to provide technical assistance support to habitat international's department of construction and environmental resources and the new operation home delivery department. We provided technical assistance to at least 8 HFH affiliates including: those in the gulf coast recovery area, those participating in the Congress Building America program, and those affiliates identified by HFHI as those that are building up production capacity. BAIHP will continue providing training at national and regional conferences, focus builds, and "blitz" builds. These affiliates play a role as pace setters in their communities and regions. Goals of BA technical assistance to HFH affiliates is to move "standard practice" toward Energy Star and beyond, achieve high performance in affordable housing to spur change, standardized the production processes and make recommendations that are volunteer friendly, proven techniques, cost effective, and readily available.

In addition to technical support and training BAIHP instrumented and monitored HFH homes for long term data collection and analysis. In collaboration with ORNL, Loudon County (Franklin, TN) HFH zero energy homes are being monitored and instrumentation has begun. A HFH home in West Virginia is monitored to determine the performance of radiant floor heating systems.

The report titled: "Energy and Indoor Air Quality Recommendations for Cold Climate Habitat for Humanity Homes," was submitted during BP1 that involved six HFH affiliates in Michigan participating in the 2005 Jimmy Carter Work Project (JCWP) and HFHI's Congress Building America (CBA) program. This report can be found online: http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1647-06.pdf

Figure 4-1 HFH volunteers in home performance testing training

Figure 4-2 Houston, TX Habitat for Humanity Partner

Building America has been supporting Habitat for Humanity for over a decade and shared principles like operating affordability, durability, reliability, occupant health, safety, comfort, quality of life, and stewardship of resources has motivated this partnership. A detailed presentation given during the February steering committee about the BAIHP and HFH partnership can be viewed online at: http://fsec.ucf.edu/download/br/baihp/2007steering/Janet-Habitat-Feb07.ppt

Subtask 4.1A High Performance Habitat for Humanity Design Assistance

Detailed activity of technical design, specification and standards development, performance testing and sustainable construction techniques training, with respect to affiliate and special programs, are highlighted in this section.

Habitat for Humanity (HFH), Home in a Box, Nationwide

In BP1 BAIHP was involved with Habitat for Humanity International (HFHI) and Habitat for Humanity local affiliate nationwide. We continued to provide technical assistance and support to Habitat for Humanity International's department of construction and environmental resources and the new operation home delivery department. The operation home delivery department has developed Home in a Box program to provide a kit of parts deliverable to the Gulf States to help relieve housing and labor shortages due to Hurricane Katrina disaster. In addition to BAIHP assistance in specifying efficient specifications and proper construction techniques to high profile projects we were instrumental in the development of HFHI's Construction Standards which were released November 2006.

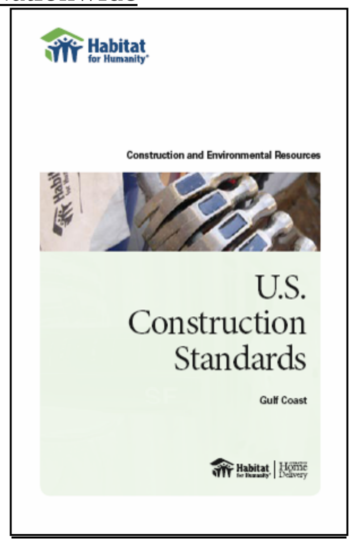


Figure 4-3 HFHI's Construction Standards which were released November 2006

2007 Jimmy Carter Work Project, Los Angeles, CA

BAIHP also provided training at national and regional conferences, focus builds, and "blitz" builds. These include site testing in Florida, West Virginia, Colorado, Tennessee and other states mentioned in this section. We also became involved in 2007 Jimmy Carter Work Project in Los Angeles where 100 homes will be built in one week in October of this year. This involvement provides training which includes analysis, testing, and HERS ratings; development of checklists and visual aids to guide proper installation of insulation, air sealing, flashing, drainage plane, air barrier, etc. to HFH volunteers.

Figure 4-4 Jimmy Carter Work Project

Lakeland (FL) Habitat for Humanity

BAIHP works with local affiliates like Lakeland Habitat for Humanity. Since 2000 Lakeland HFH has adopted an energy efficiency program and a total of 51 Energy Star homes have been built by Lakeland HFH. The first energy efficient home they built qualified as an Energy Star and won a special $20,000 grant for energy efficiency from the Walt Disney Corporation. BAIHP subcontractor Ken Fonorow (Florida H.E.R.O.) provided plan reviews for the house, specification recommendations, and energy-efficiency testing once the house was completed. With technical support from Fonorow and FSEC, FSEC conducts periodic testing and rating of Lakeland Habitat homes (12 houses over the past five years) to verify specifications. Currently Lakeland Habitat plans to build at the rate of 7 to 10 homes /yr at scattered sites throughout the area. Five homes were tested and rated by BAIHP in BP1.

Figure 4-5 A Interior air handler, return plenum, and supply duct chase.

Figure 4-6 Low-E windows are enhanced by two foot overhangs, porches, and site shading.

Figure 4-7 Radiant barrier reduces heat transfer from the roof, a major component of the cooling load.

The current specifications (Table 4-1) save over 30% in whole house energy in comparison to the Building America Benchmark. In addition to energy improvements, Lakeland HFH also incorporates outside air ventilation using an inexpensive, passive strategy that can be implemented by any builder in the hot humid climate. To achieve 30% (Figure 4-8) whole house energy savings, the principal strategy is to reduce cooling energy use – the largest component of annual energy use. This was done through a combination of cooling efficiency improvements. While some of the features that reduce the cooling load also reduce the heating load, some actually increase it slightly. For example, sealed ducts reduce both the cooling and heating loads; whereas, low-E windows reduce the cooling load but increase the heating load by reducing winter time heat gain through the windows. At the 30% savings level in the hot-humid climate, these winter time disadvantages are not significant. However, they may become more significant as we strive toward zero energy homes.

A review of the peak cooling load (Figure 4-8, from Manual J system sizing calculation for the Benchmark house) helps analysts and builders prioritize improvements. Notice in the BA Benchmark house (blue) that conductive heat gain to the duct system, window heat gain, and ceiling heat gain are the major envelope related components of the peak cooling load. To minimize these,

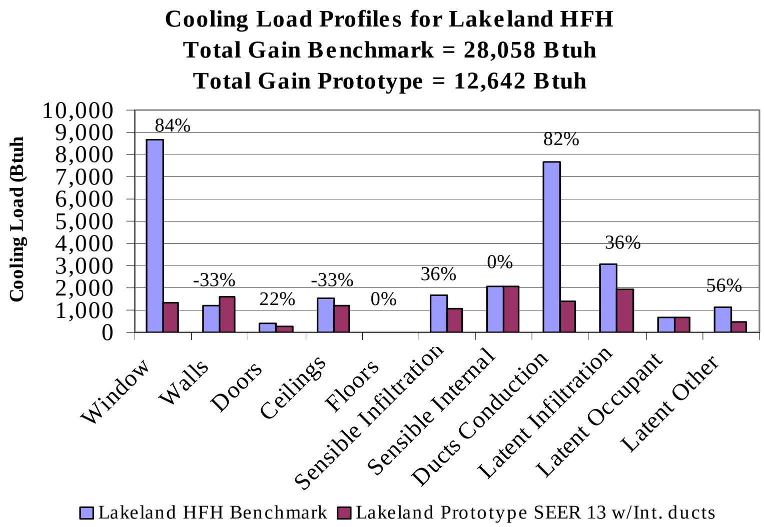


Figure 4-8 Lakeland Habitat peak cooling load reduction with savings noted in each category.

Lakeland Habitat uses interior ducts and air handler closet, low-E windows with shading where possible, and radiant barrier under the roof decking (figures 4-5, 4-6, 4-7). Lakeland Habitat HERS '99 scores range from 88.6 to 91.2 with an average of 89.3.

Roof/Ceiling	Radiant barrier, R-30 ceiling insulation, standard vented attic.
Windows	Double pane, vinyl frame, low-E windows, 24-inch overhangs, site shading and east-west orientation (when possible) to limit direct solar gain
Air Distribution System	Interior air handler closet and ducts in conditioned space (furred down duct chase) with joints and seams sealed with water-based mastic and fiberglass mesh, randomly tested to ensure duct leakage below 6%
Water Heating	Water-heater timers
Ventilation	Passive outside air ventilation ducted to the return side of the air handler with a filter-backed intake grill mounted in the soffit (at back door or porch). Ducted exhaust fans in the kitchen and bathroom(s) to improve indoor humidity control.
Cooling/Heating	14 SEER heat pump (up from 10 SEER in 1999)

Whole House Air Tightness	Extensive air sealing of building envelope after dry in. Random tests for whole house air tightness. In 2007 began implementing the Energy Star Thermal Bypass Inspection Checklist.
Appliances	Energy Star refrigerator

Table 4-1 Energy efficient features standard in Lakeland Habitat for Humanity homes

Indian River County, FL (Vero Beach Area)

One goal the BAIHP has for HFH is to establish a network of volunteer HERS raters for each affiliate so that habitat homes can be performance tested as a standard practice to their program. We worked with the Indian River County HFH, who received a grant from local developer WCI Homes, and trained and tested 4 homes. A volunteer energy rater was matched with this affiliate for performance testing. This affiliate built the first FGBC certified habitat home.

Figure 4-9 Habitat for Humanity-WCI home, Vero Beach, FL

Pinellas County, FL

At the request Pinellas County (PC) HFH, BAIHP visited to evaluate their current construction techniques related to energy efficiency and make recommendations for a future construction project consisting of 1200 ft^2 per unit triplexes. PCHFH desires to make these homes Energy Star compliant. The HERS Index as tested were EnergyStar compliant, 80, 83 and 84 (85 or less is EnergyStar certified); improvement recommendations were also made and included comparison of ICFs to CMU block construction techniques. Two of Pinellas County HFH construction supervisors attended the training in Gautier, MS.

Baton Rouge, LA
In partnership with Habitat for Humanity International, Palm Harbor Homes and Oprah Winfrey BAIHP conducted preliminary analysis, testing and Energy Star certification of 15 homes for the Baton Rouge Habitat for Humanity.

Gautier, MS
In partnership with Habitat for Humanity International and the local Habitat BAIHP conducted hands on energy efficiency training where 50 volunteers attended and participated in building 4 houses during a "Blitz Build" (accelerated construction pace) venue.

Dothan, AL
In partnership with Palm Harbor Homes and Oprah Winfrey conducted testing and Energy Star certification of 12 homes for the Dothan, AL Habitat for Humanity (at least 6 more expected during BP2).

Figure 4-10 Palm Harbor Homes built in Alabama for Oprah Winfrey-HFH partnership

New Orleans, LA and the entire Gulf Coast
BAIHP has developed a partnership with the New Orleans, LA Global Green office to provide technical assistance to all local Habitat for Humanity affiliates. Sent out joint FSEC- Global Green letter to affiliates in March 2007. We have and continue to respond to inquiries from the Habitat affiliates in Slidell, LA and Covington, LA. We also, provided extensive plan review, energy analysis, and recommendations to Habitat for Humanity International's new Construction Standards for the Gulf Coast Habitat affiliates. Standards were released in November 2006. We provided on-call technical assistance to HFHI field staff.

Gulf Coast Reconstruction Efforts

BAIHP was involved in various activities to support reconstruction in the Gulf Coast, most involvement was related to HFH, which was explained with regards to respective locations above. This summary below highlights the HFH activities geographically and other Gulf Coast reconstruction activities.

Figure 4-15 BAIHP reconstruction efforts

1. Baton Rouge, LA (Aug. 2006- Feb. 2007): In partnership with Habitat for Humanity International, Palm Harbor Homes and Oprah Winfrey conducted preliminary analysis, testing and Energy Star certification of 15 homes for the Baton Rouge Habitat for Humanity.
2. Baton Rouge, LA (summer/fall 2007): Planning to instrument the LousianaHouse demonstration home (http://www.louisianahouse.org/) being built on the LSU campus under the direction of professor Claudette Reichel.
3. Opelousas, LA (Nov. 2006 – current): In partnership with Cavalier Homes, built prototype test home with high side discharge interior duct system. This home is on a dealer lot and is instrumented. Live data online at http://infomonitors.com/hsd/
4. Gautier, MS (near Ocean Springs, MS) (February 2007): In partnership with Habitat for Humanity International and the local Habitat conducted hands on energy efficiency training where 50 volunteers attended and participated in building 4 houses
5. Dothan, AL. (Nov 2006- April 2007): In partnership with Palm Harbor Homes and Oprah Winfrey conducted testing and Energy Star certification of 18 homes for the Dothan, AL Habitat for Humanity

6. <u>New Orleans, LA and the entire Gulf Coast (Nov 2006- Current):</u> Developed partnership with the New Orleans, LA Global Green office to provide technical assistance to all local Habitat for Humanity affiliates. Sent out joint FSEC- Global Green letter to affiliates in March 2007. Have responded to inquiries from the Habitat affiliates in Slidell, LA and Covington, LA

7. <u>Entire Gulf Coast Region (Sept 2005-Nov 2006)</u> Provided extensive plan review, energy analysis, and recommendations to Habitat for Humanity International's new Construction Standards for the Gulf Coast Habitat affiliates. Standards were released in November 2006. Provided on-call technical assistance to HFHI field staff beginning September after Hurricane Katrina made landfall.

<u>Michigan Affiliates</u>

A report was prepared in August 2006 and transmitted to Michigan affiliates summarizing recommendations to improve energy efficiency and indoor air quality in cold climate Habitat homes. This report resulted out of site visits to multiple homes in Michigan in 2005 as part of the Jimmy Carter Work Project 2005. The report included recommendations for a ducted return air plenum that pulls air only form the conditioned space - not form connected floors, walls, or ceilings. Note frame for filter back grill like the one pictured in Figure 4-12

Figure 4-11 JCWP-CBA House built by Lansing (MI) Habitat for Humanity

Figure 4-12 Detail of a ducted return air plenum

<u>Olympia, WA</u>

BAIHP staff is working with BAIHP partner Habitat for Humanity on a 15 unit cottage project in Olympia, WA. The goal is to achieve the 40% BA benchmark savings using a tankless gas combo hydronic floor heating system with ICFs and advanced framed 2x6 walls with R5 foam sheathing. Three homes are currently constructed. BAIHP staff is working with Habitat staff to conduct an Energy Gauge analysis of the community. WSU staff is also providing technical assistance and outreach to other Northwest Habitat affiliates.

Subtask 4.1B Long Term Instrumentation and Monitoring Habitat for Humanity Projects

Detailed activity of instrumented and monitored for long term data collection Habitat for Humanity projects with respect to their locations is outlined below.

Loudon County, TN

BAIHP is continuing to monitor and collect data on two near zero energy Habitat houses with ORNL located in Loudon County. During the second quarter, Zero Energy House 5 data logger was reprogrammed to accommodate IBACOS hot water experiment designed to minimize water and energy waste.

Franklin, WV

BAIHP installed ground and slab instrumentation for radiant floor heating in Habitat house being constructed in Franklin, West Virginia. Instrumentation so far consists of temperature probes embedded in the ground 1 and 3 meters from the slab, on the sides of the slab, and at three interior locations under and in the slab; the middle of the house, 1 meter form the edge of the slab, and in between these two locations to determine the performance of radiant floor heating systems.

Figure 4-13 Rigid insulation being installed on rock bed within ICF stem wall

Figure 4-14 Radiant floor system installed prior to slab pour

Subtask 4.2 – HUD Code Energy Star

Oregon Department of Energy Staff performed quarterly factory inspection visits, inspected problem homes; developed in-plant quality assurance detailed inspection manuals and periodically upgraded the standards to higher levels of energy efficiency to provide support to Northwest Energy Efficient Manufactured Home (NEEM) Program. NEEM adopted the Oregon Residential Tax Credit standard for duct leakage as an airtight duct standard. The new NEEM standard is that total or net duct leakage shall not exceed 0.06 cfm50 X the floor area served by the system or 75 cfm50, whichever is greater. Ten out of 10 Oregon plants, four out of five Idaho plants, and one out of two Washington plants test all duct systems in each floor to ensure low leakage ducts using testing equipment. As of June 1, NEEM inspectors are requiring a written response to non-compliant energy details found during quarterly inspections.

Energy Star built-in appliances are being installed in each Energy Star home. Other activities include, but are not limited to:

- NEEM completed utility cost effectiveness for Energy Star homes
- 59 regional utilities and two states now offer incentives and tax credits for NEEM homes
- NEEM met with the industry in September 2006 to discuss two specification proposals and other important issues
- NEEM wrote a two- page summary and distributed to the industry Energy Star manufactured home about federal tax credits update
- NEEM promoted heat pumps, high efficiency gas furnaces, Energy Star lighting
- NEEM promoted solar ready concepts
- NEEM distributed specification clarification on
    - Whole-house ventilation HUD rule
    - Foundation ventilation specification change
    - Spec change proposal from industry setup requirement of elbows on crossovers

ENERGY STAR produced April 1, 2006 to February 16, 2007	
Northwest Energy Efficient Manufactured Homes	
ENERGY STAR Gas	1,263
ENERGY STAR Electric	3,177
Total	4,440

Table 4-2

A presentation of WSU efforts for HUD Code enhancements given to steering committee is available online at:
www.fsec.ucf.edu/download/br/baihp/2007steering/Luby%20BAIHP%20Feb07%20final.ppt

Subtask 4.3 BA Program / Analysis Support

In this subtask we assisted NREL in the continued refinement of the Benchmark calculation methodology and BEOpt analysis tools through email exchanges and participation in conference calls.

FSEC and RESNET also continued to support DOE and NREL in the area of tax credit implementation procedures.

We also conducted two subtasks carried over from the previous BAIHP project which ended in June, 2006. These tasks were all completed by September 2006 and reports were issued which are available online. The final report for the previous BAIHP project also summarized the efforts in these subtasks in the report submitted in October 2006 and available online at http://www.baihp.org/pubs/finalrpt/index.htm . The descriptive report titles and web links for the reports follow:

Fairey, P., Colon, C., Martin, E., and Chandra, S., 2006. "Comparing Apples, Oranges and Grapefruit: An Analysis of Current Building Energy Analysis Standards for Building America, Home Energy Rating and the 2006 International Energy Conservation Code," FSEC-CR-1650-06, Florida Solar Energy Center, Cocoa, FL. September, 2006.
Available online at http://www.baihp.org/pubs/deliverables/BA-HERS-IECC_9-12-06.pdf

Vieira, R., Gu, L., Sen Sharma, R., Colon, C., and Parker, D., 2006. "Improving the Accuracy and Speed for Building American Benchmarking," FSEC-CR-1651-06, Florida Solar Energy Center, Cocoa, FL. September, 2006.
Available online at
http://www.baihp.org/pubs/deliverables/ImprovingBenchmarkCalcs9-27-06.pdf

Subtask 4.4 System Research Completion Report

Participated in conference calls and prepared two case studies for the 30% marine report – NEEM program and NOJI Gardens. Details are found in the report issued by NREL.

Subtask 4.5 Documentation, Resource Development, RESNET Tasks, and Related Activities

Documentation and Resource Development
The BAIHP team published 11 papers at various conferences and in addition prepared 10 contract reports. Over 25 presentations were made at various national and regional venues. The details are provided in the References section.

The web page www.baihp.org continues to be updated and revised periodically. All published papers and reports are put on line.

BAIHP personnel from WSU (Lubliner) served as a co chair for national conference ACEEE 2006 and BAIHP researchers continue active participation in ASHRAE, including working with other BAIHP partners to co-author five papers for the June 2007 ASHRAE symposium. In addition, Lubliner acted as chair of both the TC 6.3 Forced Air Systems subcommittee, and the Proposed Standards 193P committee. This latter effort will be significant to producing a standard for a method of testing (MOT) for determining duct cabinet leakage. BAIHP researchers also participated on ASHRAE 62.2 committee activities, TC 9.5, and a coordinated effort between ASHRAE and ARI on latent cooling options. WSU (Lubliner) also served as a judge for the NAHB-RC EVHA awards and on NFPA mechanical committees to provide input to HUD for updating manufactured housing standards.

Steering Committee Meeting- Feb 6, 2007
FSEC hosted a meeting of industry partners to obtain input on current and planned FY07 BAIHP research activities from 9am-4pm at FSEC February 6, 2007. Steve Chalk, Ed Pollock and Bill Haslebacher attended from DOE. About 20 builder and industry members as well as representatives of NREL and LBNL attended the meeting. Presentations were made by task leaders and subcontractors and may be downloaded from http://fsec.ucf.edu/download/br/baihp/2007steering/

Apart for some quick questions to clarify content, no significant comments were received on the presentations. The steering committee had no problems or major suggestions to change the planned BAIHP FY07 work.

Program Impact

BAIHP concentrates its work in hot-humid and marine climates but is active in most regions of the U.S. In 2006 we assisted in the construction of over 140 homes that exceed the 30% BA benchmark goals in hot-humid climates, over 160 homes that are near the 30% benchmark level in marine climates, over 4,400 Energy Star manufactured homes in the Pacific Northwest and over 19,000 other energy efficient manufactured homes by partners Palm Harbor Homes, Fleetwood and Southern Energy Homes. The estimated energy savings from these homes constructed in 2006 is over 209,000 million Btu/year and the estimated savings in utility bills to consumers exceed $3,600,000/yr. Figure 4-16 reveals savings since BAIHP has been part of the DOE.

Total number of homes improved: **136,252**

Total energy saved: **$22,635,864**

* statistics are as of December 2006

Figure 4-16 BAIHP Program Impact

RESNET Tasks

In BP1, subcontractor RESNET (www.resnet.us) worked in several areas / projects: U.S. Department of Energy National Builders Challenge, Habitat for Humanity and energy efficient mortgage product. Each of these tasks is explained in detail below.

Habitat for Humanity

- RESNET has developed a work plan for the RESNET-Building America-Habitat for Humanity partnership to encourage raters to volunteer with Habitat affiliates around the country building energy efficient homes. RESNET's tasks are:
- Promote the partnership by hosting a page on its web site on the partnership
- Promote the partnership by covering the partnership in "What's New at RESNET" e-news feature quarterly by reiterating the steps that raters must take to participate in the partnership and by sharing comments from the RESNET rater volunteers.
- Identify RESNET members working in the areas where Habitat affiliates have requested where the top 20 producing Habitat affiliates build
- Identify RESNET members working in the areas affiliates have requested assistance in response to Habitat's partnership postings
- Assist Building America with writing a template for RESNET volunteers to summarize their experience with the partnership, maintain a separate web page where RESNET volunteers can summarize their experience with

the partnership and another page where RESNET volunteers can download the template after they have conducted their volunteer activities.

- Use the RESNET/Building America partnership experience to communicate with important stakeholders in the housing industry by writing two news releases about the benefits of energy efficiency, ratings, and collaborative public/private efforts for energy efficient affordable housing.
- Keep a log of member volunteers that have contacted RESNET by date and name
- Assist Building America with writing a summary of the partnership for the Building America web site.
- The RESNET web page has been updated to reflect the new effort. The page is posted at http://www.resnet.us/rater/partnership/default.htm

U.S. Department of Energy National Builders Challenge

RESNET staff attended the steering committee meeting of the U.S. Department of Energy's National Builder Challenge in Washington, DC on November 20, 2006. RESNET executive director was appointed to chair the working group on defining the national index. This will assist with DOE's effort to promote energy efficient home construction by providing a consistent national performance metric

Survey of Tax Compliant Homes

In BP1 RESNET conducted a survey of raters that have verified homes for the new federal tax credit for energy efficient homes. The purpose of the survey was to provide "real life examples for builders on what it takes to qualify for the tax credit." The goal is to have at least one example in each of the IECC climate zones. RESNET received homes that were certified by raters for the tax credit in the states of Colorado, Indiana, Massachusetts, Minnesota and Wisconsin on posted them on the RESNET web site at http://www.resnet.us/taxcredits/examples/default.aspx

RESNET presented examples of homes that made the federal tax credits at the 2006 Energy and Environmental Building Association Conference at the National Association of Home Builders October 2006 Energy Committee meeting.

RESNET documented examples of high performance homes that are eligible for the $2,000 tax credit. Details at http://www.resnet.us/taxcredits/examples/default.aspx

RESNET continues to recruit raters to submit more examples of homes that have been certified for the tax credit.

Fannie Mae Including High Performance Manufactured Homes in Energy Efficient Mortgage Product

- In an effort to make the energy efficient mortgage product more viable the RESNET Board of Directors adopted a policy statement on energy mortgages.
- ***RESNET urges Congress to adopt as federal policy that by 2020 new homes be 50% more efficient than today's home. The policy would also be that as government chartered corporations Fannie Mae and Freddie Mac have a responsibility to assist in meeting the goal and must prepare a plan to Congress on how they will assist in meeting this policy objective and report annually on progress.*** **–** Since the federal lending institutions are chartered by Congress they have a responsibility to assist the nation in meeting its goal of dependence on imported oil. This is a logical conclusion of the new homes tax credit that was established in the Energy Policy Act of 2005.

V. DELIVERABLES

Parker, D.S., and Sherwin, J. R., 2006. "Experimental Evaluation of the NightCool Nocturnal Radiation Cooling Concept: Performance Assessment in Scale Test Buildings," FSEC-CR-1692-07 January 2007. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1692-07.pdf

Parker, D.S., and Sherwin, J. R., 2006. "Experimental Evaluation of The *NightCoo*l Nocturnal Radiation Cooling Concept: Progress Report: Initial Thermal Performance Assessment of Test Buildings," FSEC-CR-1657-06 September, 2006. (Not available online at this time.)

Lubliner, M. and Hadley, A. "Side by Side tests of HUD code Homes," Project: Zero Energy Manufactured Home Project (ZEMH), Builder: Kit Manufacturing, Clearwater Homes Location: Nez Perce Reservation, Cherry Lane, Idaho September 27, 2006. http://www.baihp.org/pubs/deliverables/ZEMH9-27-06.pdf

Vieira, R., Gu, L., Sen Sharma, R., Colon, C., and Parker, D., 2006. "Improving the Accuracy and Speed for Building America Benchmarking," FSEC-CR-1651-06, September 27, 2006. http://www.baihp.org/pubs/deliverables/ImprovingBenchmarkCalcs9-27-06.pdf

Chasar, D., Moyer, N., and Martin, E., 2006. "Energy Efficient Renovations Storm Damaged Residences Florida Case Studies," FSEC-CR-1648-06 September 8, 2006. http://www.baihp.org/pubs/deliverables/hurricane-retrofits9-13-06.pdf

Fairey, P., Colon, C., Martin, E., and Chandra, S., 2006. "Comparing Apples, Oranges and Grapefruit: An Analysis of Current Building Energy Analysis Standards for Building America, Home Energy Ratings and the 2006 International Energy Conservation Code," FSEC-CR-1650-06 September 2006. http://www.baihp.org/pubs/deliverables/BA-HERS-IECC_9-12-06.pdf

McIlvaine , J. S. Chandra, S. Barkaszi, D. Beal, D. Chasar, C. Colon, K. Fonorow, A. Gordon, D. Hoak, S. Hutchinson, M. Lubliner, E. Martin, R. McCluney, M. McGinley, M. McSorley, N. Moyer, M. Mullens, D. Parker, J. Sherwin, R. Vieira S. Wichers. 2006. " Final Project Report for the Building America Industrialized Housing Partnership April 1999 through June 2006." FSEC-CR-1663-06. Florida Solar Energy Center, Cocoa, Florida. October 2006. http://www.baihp.org/pubs/finalrpt/index.htm

Beal, D. and McIlvaine, J. 2006. "Energy and Indoor Air Quality Recommendations for Cold Climate Habitat for Humanity Homes," FSEC-CR-1647-06 August 2006. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1647-06.pdf

Fonorow, K., Chandra, S., Martin, E., McIlvaine, J., "Energy and Resources Efficient Communities through Systems Engineering: Building America Case Studies in Gainesville, FL.", Proceedings of the 2006 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Asilomar, CA., August 2006. http://www.baihp.org/pubs/aceee_fonorow/ACEEEpaper.pdf

Thomas-Rees, S., Chandra, S., Barkaszi, S., Chasar, D. and Colon, C., 2006. "Improved Specifications for Federally Procured Ruggedized Manufactured Homes for Disaster Relief in Hot/Humid Climates," FSEC-CR-1645-06 Revised - September 2006. http://www.baihp.org/pubs/ImproveSpecificHomes/contract_report.pdf

Mullens, M., Hoekstra, R., Nahmens, I., and Martinez, F., 2006. "Water Intrusion in Central Florida Homes During Hurricane Jeanne in September 2004," UCF Housing Constructability Lab, University of Central Florida, Orlando, FL. August, 2006. http://www.baihp.org/pubs/deliverables/WaterIntrusionReport8-21-06.pdf

VII. MEDIA/NEWS RELEASES

NBC, “How Can ‘TED’ Help You”, aired February 21, 2007, interviewee Danny Parker, file:///C:/Documents%20and%20Settings/sthomas/Local%20Settings/Temporary%20Internet%20Files/OLK19/www%20nbc6%20net_greenisgreen_11074628_detail.html#

Builder, "The New American Home 2007", January 2007, pp. 118-144.
Home Energy, "Road Blocks to Zero-Energy Homes", by Rich Brown and Danny Parker, January/February 2007, Volume 24.1, pg. 24.

Florida Today, "New homes boast energy efficiency: Developer uses recycled steel instead of concrete, wood", January 4, 2007.

Structural Insulated Panel Association, "Florida Solar Energy Center Specifies SIPs for FEMA Manufactured Homes", September 1, 2006, Number 06-22.
http://www.sips.org/content/news/index.cfm?pageId=168

VIII. REFERENCES, BAIHP PUBLICATIONS, PRESENTATIONS, TRADE PUBLICATIONS, TRAINING & PATENTS

References:

Arlian, Larry G., PhD, and Thomas A. E. Platts-Mills, MD, PhD. March 2001. The biology of dust mites and the remediation of mite allergens in allergic disease. Journal of Allergy and Clinical Immunology. March 2001 (Vol. 107, Issue 3 (Supplement), Pages 406-413.)

ASHRAE 62.2 2004. Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings. ANSI/ASHRAE Standard 62.2-2004, ASHRAE

Clark, Gene, 1981. “Passive/Hybrid Comfort Cooling by Thermal Radiation,” Passive Cooling: American Section of the International Solar Energy Society, Miami Beach, 1981.

Cummings, J.B., Tooley, J.Jr., Moyer N. (1991), "Investigation of Air Distribution System Leakage and Its Impacts in Central Florida Homes", Prepared for the Governor's Energy Office, FSEC-CR-397-91, January 31, 1991.

Moyer, N., Beal, D., Chasar, D., McIlvaine, J., Withers, C, & Chandra, S. (2001). “Moisture Problems in Manufactured Housing: Probable Causes and Cures.” ASHRAE - IAQ 2001 Conference Proceedings, San Francisco, CA.

Moyer, N., Chasar, D., Hoak, D., Chandra, S. (2004). "Assessing Six Residential Ventilation Techniques in Hot and Humid Climates," Proceedings of ACEEE 2004 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington, DC, August 2004.

Danny Parker, Jeffrey Sonne, John Sherwin, (2005) "Flexible Roofing Facility: 2004 Summer Test Results", Prepared for U.S. Department of Energy Building Technologies Program, FSEC-CR- 1514-05, July 2005.

BAIHP Publications:

Papers with Presentations

2006 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Asilomar, CA., August 2006

Fonorow, K., Chandra, S., Martin, E., McIlvaine, J., "Energy and Resources Efficient Communities through Systems Engineering: Building America Case Studies in Gainesville, FL."

Danny Parker, David Hoak, Alan Meier, Richard Brown, "How Much Energy Are We Using? Potential of Residential Energy Demand Feedback Devices"

Fairey, P. and D. Goldstein, "Getting It Right Matters: Why Efficiency Incentives Should Be Based on Performance and Not Cost."

Baden, S., P. Fairey, P. Waide, P. de T'serclaes and J. Laustsen, "Hurdling Financial Barriers to Low Energy Buildings: Experiences from the USA and Europe on Financial Incentives and Monetizing Building Energy Savings in Private Investment Decisions."

Moyer, N., "Ducts in Conditioned Space"

Brown, Richard, Parker, Rittlemann, William, Homan, Greg, "Appliances, Lighting, Electronics, and Miscellaneous Equipment Electricity Use in New Homes."

15th Symposium on Improving Building Systems in Hot and Humid Climates. Orlando, FL. July 24-26, 2006

Thomas-Rees, S., Chandra, S., Barkazsi, S., Chasar, D., Colon, C., "Improved Specificiations for Federally Procured Ruggedized Manufactured Homes for Disaster Relief in Hot/Humid Climates"

Chasar, D., Chandra, S., Parker, D., Sherwin, J., Beal, D., Hoak, D., Moyer, N., McIlvaine, J., "Cooling Performance Assessment of Building America Homes"

Beal, D. and Chasar, D., "Measured Crawlspace Conditions in a HUD-code Home"

Moyer, N. "Diagnosing Moisture Problems"

Mcilvaine, J. "Minimum Standards for Rebuilding in the Gulf Coast Region – Building America Recommendations to Habitat for Humanity" (no paper)

Presentations (Does not include presentations at BA quarterly meetings or presentations with papers/publications):

BAIHP Steering Committee, Cocoa, FL February 6, 2006

Presentations available for download at http://fsec.ucf.edu/download/br/baihp/2007steering/

EEBA, Williamsburg,VA October 11-13, 2006

Parker, D., "Miscellaneous Energy Use and Energy Feedback Research in Energy Efficient Housing"

RESNET 2007 Conference , San Diego, CA, February 18-20, 2007

Presentations: Abstracts and presentation downloads available at http://www.resnet.us/conference/2007/agenda.htm . BAIHP presentations included:

- Monetizing Building Energy Performance in Private Investment Decisions
  Presenter: Steve Baden, RESNET
- The RESNET HERS Index – The Path to Zero Energy Homes
  Presenter:
  - Philip Fairey, Florida Solar Energy Center
- Carbon Trading – The Role of Building Energy Performance
  Presenters:
  - Steve Baden, RESNET
  - Thomas Hamilton, Quality Built
  - Kelly Parker, Guaranteed Watt Savers
- Round Table Discussion of Construction Errors Identified during the Rating Process
  Presenters:
  - Ken Fonorow, Florida H.E.R.O.
  - Dennis Stroer, Calcs-Plus
- Time Has Come Today – A New Look at Energy Efficient Mortgages
  Presenters:
  - Steve Baden, RESNET
  - David Goldstein, Natural Resources Defense Council

- Lessons Learned from Building America: Effective Zoned Systems
  Presenters:
  - Ken Fonorow, Florida H.E.R.O
  - Dennis Stroer, Clacs – Plus
- Lessons Learned from Building America: Mechanical Ventilation – How Much is Enough? Can There be Too Much?
  Presenter:
  - Subrato Chandra, Florida Solar Energy Center
  - Armin Rudd, Building Science Corporation

- ENERGY STAR Qualified Homes and Manufactured Housing: HUD Code and Modular Homes
  Presenters:
    - David Lee, Environmental Protection Agency
    - Emanuel Levy, Manufactured Housing Research Alliance
    - Neil Moyer, Florida Solar Energy Center
- Codes, Ratings, Energy Star and Tax Credits, Oh My!
  Presenters:
    - Philip Fairey, Florida Solar Energy Center
    - Dave Roberts, Architectural Energy Corporation
- ACCA Manual J Load Calculation - An Overview for the Energy Rater
  Presenter:
    - Dennis Stroer, Calcs-Plus

Affordable Comfort Conference, Austin, TX, May 24, 2006
Chandra, S. and Thomas-Rees, S., "High Performance Manufactured Housing"
40 minutes, ~20 attendees

Structural Insulated Panel Association, Annual Conference, Austin, TX, April 11, 2006
McIlvaine, J., "Introduction to 2006-07 Energy Efficient New Home Tax Credits"
45 minutes, ~150 attendees

BuildSmart Expo, New Orleans, LA, April 22, 2006
McIlvaine, J., "Energy Urgency,"
1 hour, Keynote address, ~100 attendees

National Association of Community Development, Hollywood, FL, June 23, 2006
McIlvaine, J., "Energy Efficiency Opportunities in Affordable Housing"
30 minutes, ~15 attendees

Ventilation expert meeting, Quebec City, Canada , June 27-29, 2006
Chandra, S., "Ventilation Data From Florida Homes and Lab Facility"
~20 attendees

Green Buildings Conference, FIU, Miami, FL November 3, 2006
Chandra, S., "Sustainable Housing in Florida: An Overview"
~50 attendees

Sustainable Housing, Houston, TX., November 15, 2006
Chandra, S. "Sustainable Housing"
~60 attendees

Sustainable Housing, Corpus Christi, TX., November 30, 2006
Chandra, S. "Sustainable Housing"
~ 15 attendees

Sustainable Housing, Brownsville, TX December 12, 2006
Chandra, S. “Sustainable Housing”
~25 attendees “Sustainable Housing”

FRACCA Annual Conference, Tampa, FL, April 2006.
Martin, E. “Buildings that Work for Florida”
2 hour workshop, ~50 attendees total

GreenTrends Statewide Green Building Conference and Trade Show, Gainesville, FL, May 2006.
Martin, E. “Greening Affordable Housing.”
3 hour workshop, ~30 attendees total

Florida Housing Coalition Annual Conference, Orlando, FL, September 2006.
Martin, E., “*Greening Affordable Housing*.”
3 hour workshop, ~60 attendees total

USGBC North Florida Meeting, Jacksonville, FL, October 2006.
Martin, E., LEED for Homes.
1 hour presentation, ~20 attendees total

GreenBuild International Conference and Expo,. Denver, CO, November 2006
Martin, E. “Manufacturing Green Housing: Benefits of an Industrialized Approach.”
1/2 hour presentation, ~80 attendees total

Trade /BA Publications:

Mullens, M., I. Nahmens, and R. Hoekstra, "Lessons Learned from Lean Practice: Case Study of a Precast Concrete Panelizer," Submitted to Engineering Management Journal. Submitted 3/06

Syal, M., M. Hastak, M. Mullens, and A. Sweaney, "U.S.-India Collaborative Research Directions in Urban Housing and Supporting Infrastructure", ASCE Journal of Architectural Engineering, 12(4)163-167, December 2006.

Nasereddin, M. and M. Mullens, "Automated Simulator Development: A Strategy for Modeling Modular Housing Production", Automation in Construction. Accepted for publication 4/14/06

Mullens, M. and M. Arif, "Structural Insulated Panels: Impact on the Residential Construction Process," The Journal of Construction Engineering and Management, 132(7) 786-794, July 2006.

Brown, R., and Parker, D. "Roadblocks to Zero Energy Homes," HomeEnergy, December 2006

Baechler, M.; Lubliner, M.; et. al. "Fort Lewis Army Base." Building America Best Practices Series: Volume 5 – Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Marine Climate.

Baechler, M.; Lubliner, M.; et. al. "Sam and Christine Garst Build a House." Building America Best Practices Series for High Performance Technologies: Solar Thermal & Photovoltaic Systems in the Marine Climate.

Training:

HFHI Conference Call Training April 18, 2006

McIlvaine, J., "Moisture Issues,"
1 hour, audio available on HFH intranet, ~25 callers from 15 affiliates

HFHI National Leadership Conference, Charlotte, NC, August 4, 2006

McIlvaine, J., "Green Building – Habitat Style"
1.5 hours, ~75 attendees

Florida Green Home Designation Certification Course (5 offerings in FL) April 2006-October 2006

Trainer: Martin, E.
6 hour workshop, ~120 attendees total

Mercedes Homes Green Building Workshop, Tampa, FL, *April 2006*

Martin, E., LEED for Homes

2 hour course, ~12 attendees total

Architectural Charrette for Oakland Park, Orlando, FL, *August 2006.*

Martin, E., "Green Building Design Strategies."

2 hour course, ~12 attendees total

Patents:

Parker, D. and Sherwin, J. "High Efficiency Air Conditioner Condenser Fan," U.S. 7,014,423 B2, 21 March 2006.

Parker, D., Sherwin, J., "High Efficiency Air Conditioner Condenser Twisted Fan Blades and Hub," Application No. 29/231,433, Allowance received 17 October 2006.

VIII. APPENDICES

Appendix A University of Central Florida, School of Industrial Engineering Annual Report

UCF Housing Constructability Lab

(http://hcl.engr.ucf.edu/)

2006 Annual Report to
Building America Industrialized Housing Partnership

Prepared by

Dr. Michael A. Mullens, PE Associate Professor
Dr. Robert Hoekstra Associate Professor
Isabelina Nahmen Graduate Research Assistant
Department of Industrial Engineering & Management Systems
University of Central Florida
4000 Central Florida Blvd., PO Box 162993
Orlando, FL 32816-2993
Telephone (407) 823-5703, FAX (407) 823-3413
mullensm@mail.ucf.edu

Royal Concrete Concepts

Royal Concrete Concepts (RCC) produces innovative concrete modules for both residential and commercial markets throughout Florida. RCC currently operates a mid-size, unenclosed production operation in West Palm Beach. The existing plant consists of four production "lines" supported by various uncovered storage areas and small enclosed stockrooms. The plant can produce a maximum of four modules per day. To meet increasing demand, RCC is developing a new high-volume plant in nearby Okeechobee. The new plant will have 10 unenclosed production lines capable of producing 10 modules per day, increasing production capacity by 2.5 times. The new operation will be supported by a 20,000 square foot on-site, fully enclosed warehouse with two covered 2,500 square foot sheds, one on each end of the warehouse. The new warehouse will have conventional loading docks and a rail spur for receiving and shipping. The Housing Constructability Lab (HCL) research team was tasked to identify and develop innovative concepts for the supply chain – stretching from construction material vendors, through the warehouse, to the production line. To maximize impact, the scope was limited to three critical materials: rebar, polyethylene foam and steel interior/exterior studs.

HCL researchers took a *Lean Production* approach to the effort. First, the team observed the operations throughout the supply chain including reordering, transport, receiving, warehousing, kitting, staging (on the lines), usage and waste. The process was documented on value stream maps (Figure 1), one for each critical material.

Opportunities for improvement were also identified for further analysis. Second, the team documented the usage of each material by home type and location (i.e. walls, floor or roof) (Table 1) and projected future order quantities and material flow levels.

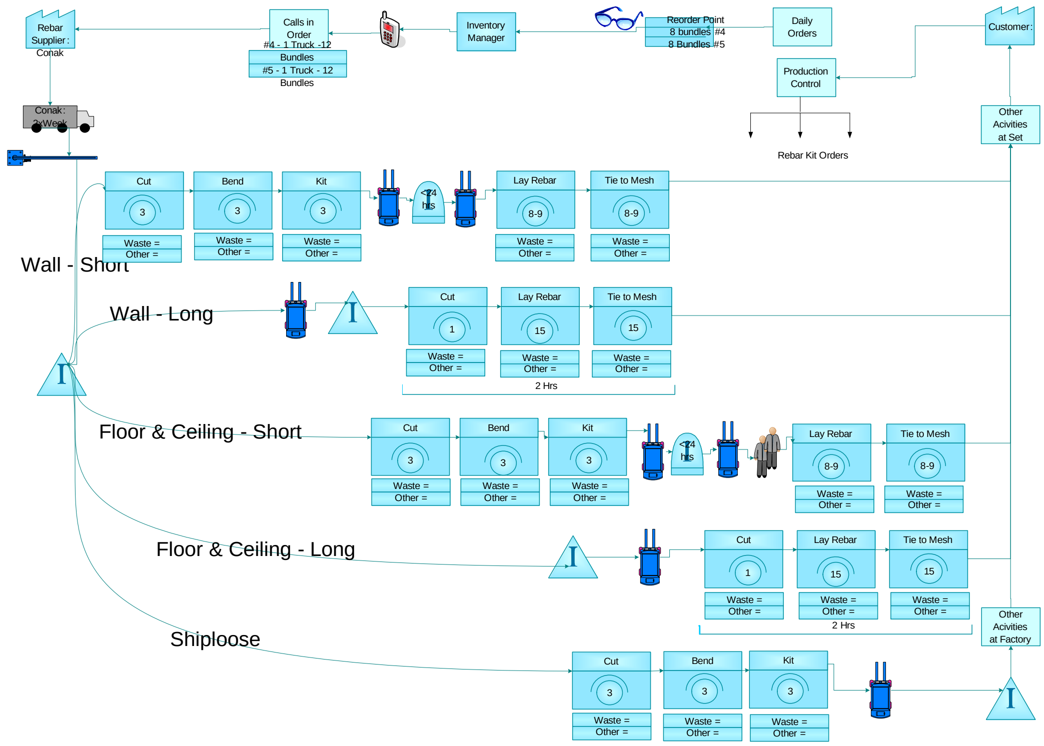


Figure 1. Value Stream Map of Current Rebar process

		Commercial	Madison A	Madison B	Lexington	Park Model	Walkway
Wall	#4	1,050	1,049	1,182	1,049	703	262
	#5	454	424	462	424	284	106
Floor	#4	0	0	0	0	0	0
	#5	1,061.5	1,428	1,228	1,428	957	357
Roof	#4	0	144	166	144	96	36
	#5	808.5	519	420	519	348	130
Footers	#4	0	0	0	0	0	0
	#5	649	753	644	753	505	188
Total (ft)	**#4**	**1,050**	**1,193**	**1,348**	**1,193**	**799**	**298**
	#5	**2,973**	**3,124**	**2,754**	**3,124**	**2,093**	**781**
	Total (ft)	**4,023**	**4,317**	**4,102**	**4,317**	**2,892**	**1,079**

Source: Takeoffs from Commercial, Madison A/B drawings – assumed Lexington ~ Madison A; Park ~ 2/3 Madison A; Walkway ~ ¼ Madison A

Table 1. Rebar usage (ft/home) by home type and location

Recommended innovations included a kanban-style lean procurement and replenishment strategy that will slash inventory levels and facilitate reordering, automated equipment to efficiently in-source rebar and poly foam processing operations, and a lean, high density warehouse design that improves storage capacity and smoothes material flow to the production lines. The rebar improvements described below are typical for each of the three critical materials:

1. Utilize kanban pull system to simplify and synchronize reordering with actual production. Inventory levels are reduced as shown in Table 2.
2. Procure and install automated shear machine ($117,400) in new warehouse to cut rebar to size, improving quality and reducing annual labor cost by about $100,000.
3. Replace kitting with kanban pull system for delivery to line. This eliminates double handling associated with kitting, reduces replenishment trips from warehouse to line by a factor of three, improves availability of material on the line, and provides better access to material by designating fixed staging locations on the lines (Figure 2).

	Current Inventory (Days)	Proposed Inventory (Days)
#4 Rebar	24	2.5
#5 Rebar	4.9	2.5

Table 2. Current and Proposed Rebar Inventory Levels

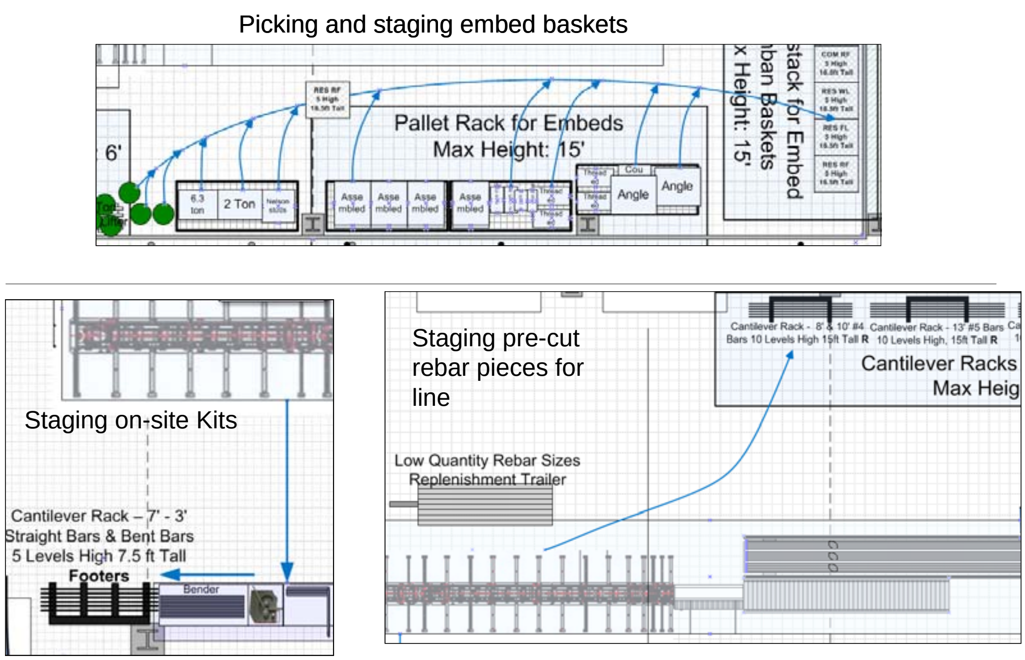


Figure 2. Warehouse Rebar Storage- improved flows

The recommended design for the new lean warehouse (Figure 3) incorporates reduced inventory levels associated with the kanban reordering strategy, high density storage, new material fabrication equipment and a layout that smooths flow within the warehouse.

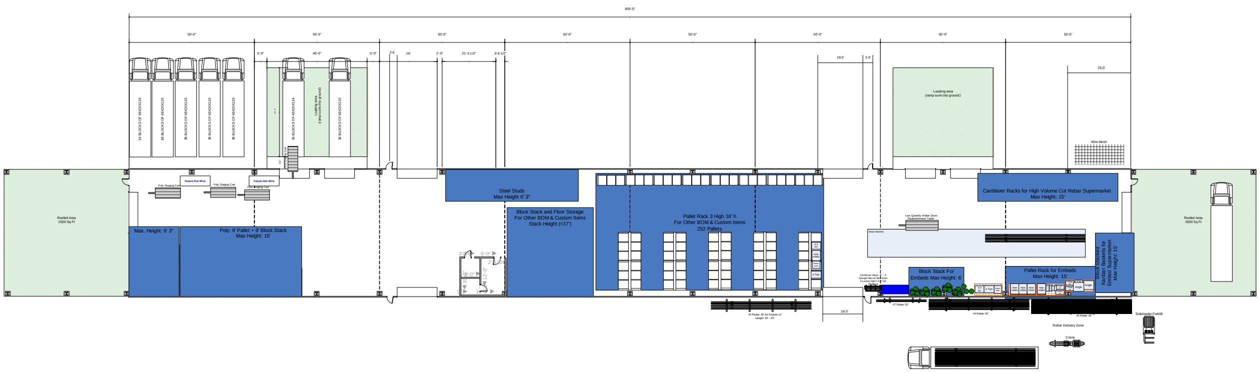


Figure 3- Proposed Configuration of New Warehouse

In December 2006, the HCL research team presented a summary of this research to the RCC senior management team. Recommendations were well received and the RCC team agreed to review and implement the recommendations. The HCL research team continues to assist RCC with their new plant.

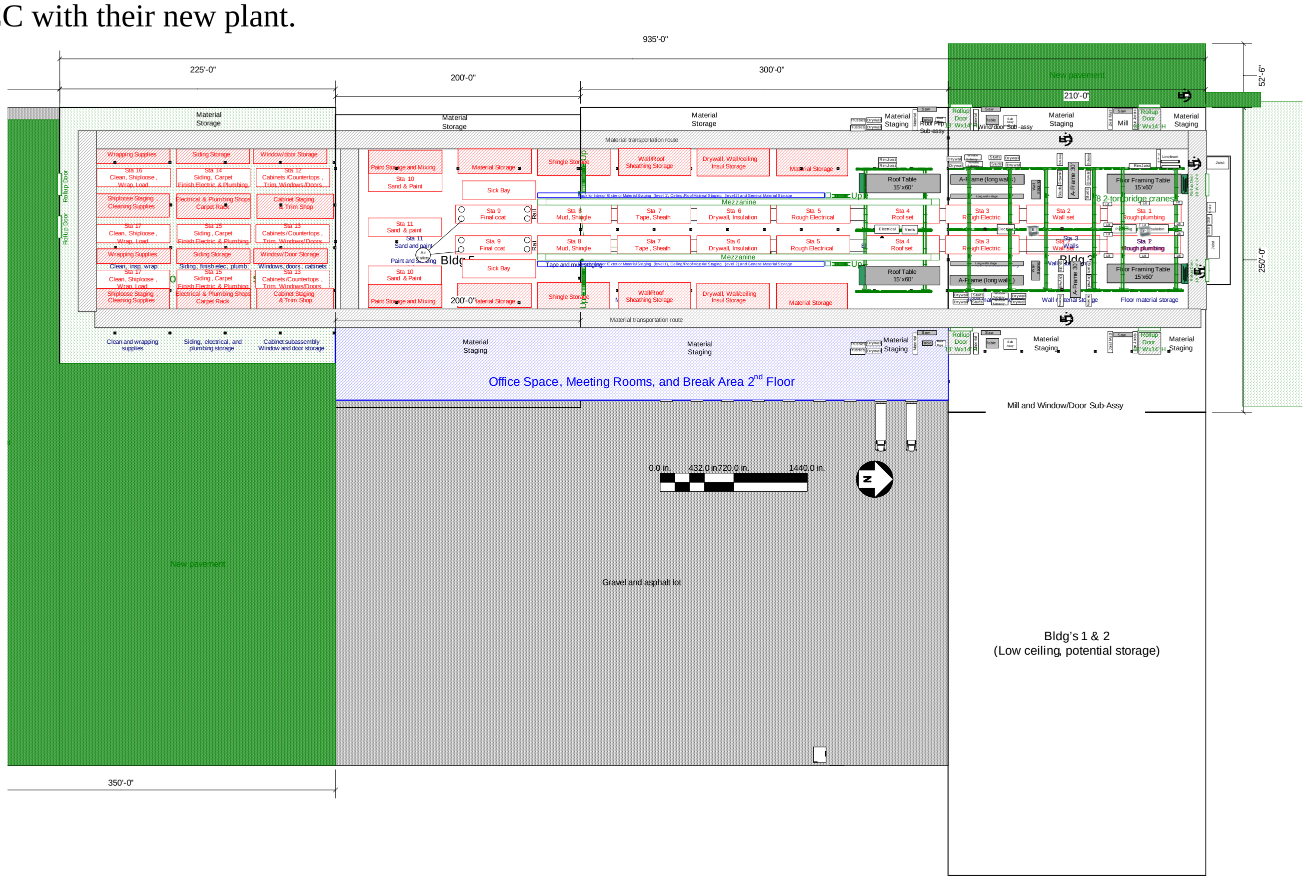


Figure 4. Proposed Habitat Factory Layout

Habitat for Humanity

In March 2006, the UCF research team initiated efforts to assist Habitat for Humanity's Operation Home Delivery in the design of Habitat's first modular housing factory. The factory was envisioned as a high volume delivery method to replace homes destroyed by Hurricane Katrina. The team assisted Habitat in the selection of an existing facility, identifying retrofits necessary for modular home production (e.g., removing columns), designing layout alternatives that incorporated lean production concepts (Figure 4), and detailing each production activity. All designs were developed collaboratively with Habitat personnel in a series of workshops hosted at UCF. The team also recommended changes to the floor plans of the new modular home designs, making them more compatible with conventional home designs. Habitat decided to delay their ambitious schedule for the modular factory and instead purchase modular homes (based on Habitat plans) from existing modular manufacturers.

Theses, Reports, Publications and Presentations

Mullens, M., I. Nahmens, and R. Hoekstra, "*Lessons Learned from Lean Practice: Case Study of a Precast Concrete Panelizer*," Submitted to *Engineering Management Journal*. *Submitted 3/06*

Syal, M., M. Hastak, M. Mullens, and A. Sweaney, "U.S.-India Collaborative Research Directions in Urban Housing and Supporting Infrastructure", *ASCE Journal of Architectural Engineering,* 12(4)163-167, December 2006.

Nasereddin, M. and M. Mullens, "Automated Simulator Development: A Strategy for Modeling Modular Housing Production", *Automation in Construction*. Accepted for publication 4/14/06

Mullens, M. and M. Arif, "Structural Insulated Panels: Impact on the Residential Construction Process", *The Journal of Construction Engineering and Management*, 132(7) 786-794, July 2006.

Mullens, M., B. Hoekstra, I. Nahmens, and F. Martinez, *Water Intrusion in Central Florida Homes During Hurricane Jeanne in September 2004*, Report to U.S. DOE, University of Central Florida Housing Constructability Lab, August 2006.

Outreach, Student Association and Other Activities

Isabelina Nahmens and Felix Martinez, Graduate Research Assistants in the Housing Constructability Lab, were awarded 1st prize in the 2006 IIE Construction Division Student Paper Competition for their paper "QUALITY vs. SPEED OF NEW CONSTRUCTION IN CENTRAL FLORIDA".

Dr. Mullens accepted an invitation to serve on the Editorial Board for the *Journal of Construction Innovation: Information, Process and Management.*

Many presentations given to our research partners in the Building America program and our industry partners throughout the U.S. homebuilding industry.

Appendix B University of Texas, School of Architecture Annual Report

1.0 Introduction

Our work has focused on developing scenarios for two different modular houses and then testing options for photovoltaic arrays for both. We analyzed type, size, cost, energy production, ease of installation and public acceptance for both differing scenarios. Results are summarized at the end of the report. Several of our conclusions concern site planning relevant to layout of houses with photovoltaic panels. The two models we developed were:

The Back Home
This is a house that could be rapidly deployed, but provide permanent affordable housing in areas of need. This model was developed in response to FEMA's Alternate Housing Pilot Program requirements, issued September 15, 2007. It is designed to meet health and safety requirements for hurricane prone areas. The house is 700 square feet and has one bedroom and one bath.

The Bloom House
This is an evolution of the University of Texas Solar Decathlon 2007 competition house, designed to be marketed as part of an urban infill development to a median income family here in Austin, Texas. This model is 1300 square feet, with three bedrooms and two baths. We designed the development layout as part of a conservation development in central Austin to test a strategy for implementation of photovoltaics in the larger housing market.

2.0 The Back Home

The Back Home was developed in response to the influx of evacuees from Hurricane Katrina into Texas. Over 144,000 households (more than 400,000 people) were displaced by Hurricane Katrina to Texas. Of those, 84,000 households have reported that they are staying in Texas. In addition, 75,000 homes of lower income families in Texas sustained major damage due to Hurricane Rita. This added to an existing housing crisis in the state. This seemed to be a timely program to take on in our research. As we began our work, FEMA issued a Request for Proposals for their Alternate Housing Pilot Program. We took the FEMA design requirements as our mandate. The central feature of the house was that it could be delivered to an area of need quickly, but could be durable enough to stay long-term.

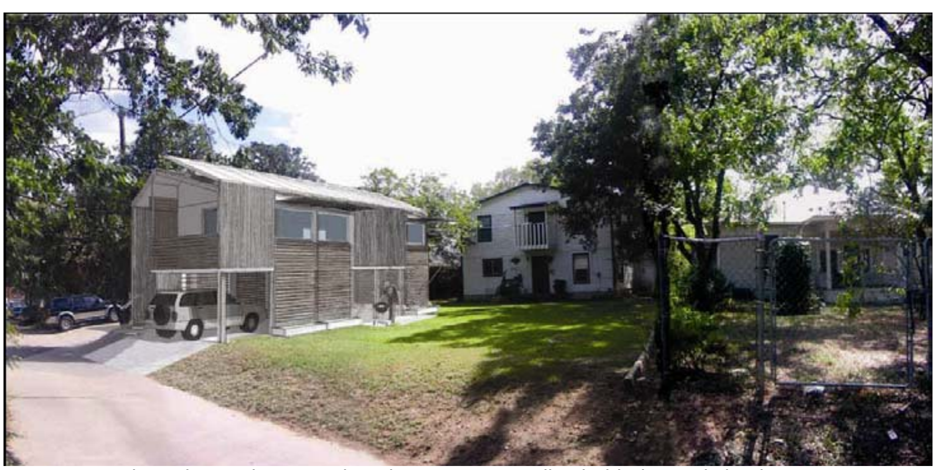


Fig.1 The Back Home placed next to a rear alley behind an existing house

2.1 Site Planning
The first thought was about how best to integrate disaster-relief housing into a devastated community. We had seen pictures of the standard FEMA trailer placed in the front yards of houses, and read complaints that they seemed to contribute to the degradation of the community. Our thesis was that if the support house could be put at the back of the lot, it would be better absorbed into the fabric of the community--the Back Home. A family could live in the house while the main house was being repaired. When the main house was livable, the family could move back in, and the Back Home would remain, to become an auxiliary dwelling unit; a rental apartment or room for extended family (a 'granny flat'). The unit could also function as home office. This would serve to give ongoing support to the family and bolster the community.
We presented the Back Home at two different conferences for feedback. The first was with the Texas Department of Housing and Community Affairs, and included their staff as well as representatives of community groups from areas in southeast Texas where there is a significant need. The second conference was a meeting of the Texas Low-Income Housing Information Center, and their network of community partners in Houston.

Based on their comments, we determined that placing homes at the rear of damaged houses would not typically be practical unless there was a rear alley. Debris in the driveway, or position of garages at the back of a driveway would be impediments to installation. In response we developed a version of the house that would work along the street front. The size of the house would require an open lot; it would not work in front of an existing house. We believe that this would provide an option for infill housing. We are also showing the house as a duplex, which would be one way to bring its cost down.

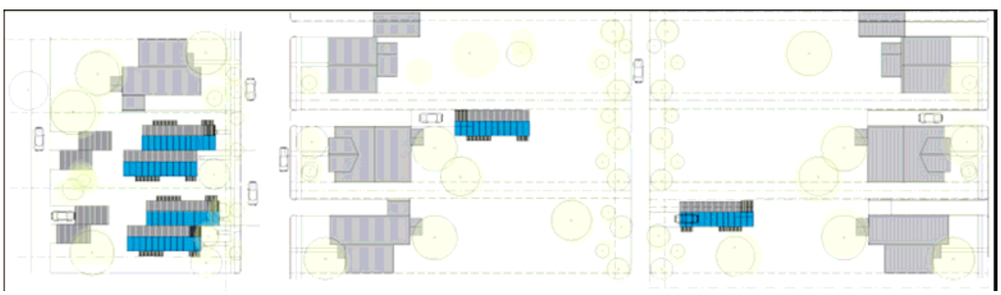


Fig.2 Site Plan showing options of use of the Back Home

The Back Home modular house design is made to fit into a variety of contexts. With a simple offset gable roof and porch, it is appropriate for older communities in shape and scale. It is made of a base module wrapped in a second layer of cladding or rain screen material. This layer can be changed to reflect to typical materials and building customs in a given community.

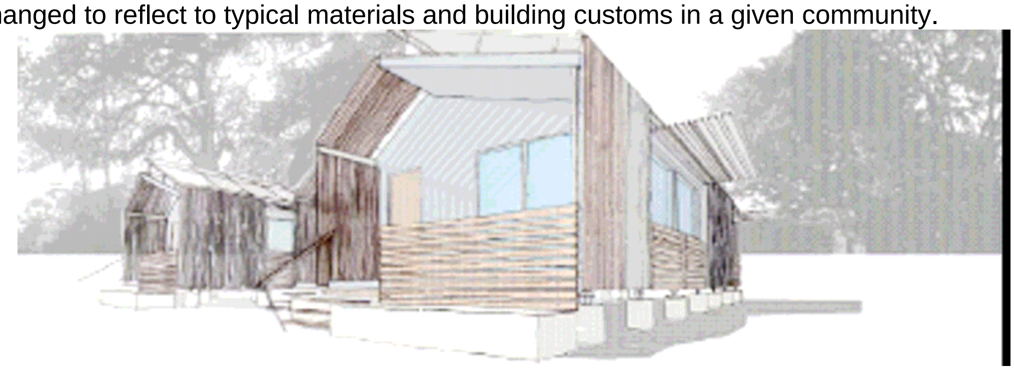


Fig.3 The Back Home in the front of an urban infill lot

2.2 Design
The house was designed to well exceed current FEMA trailer standards. The current FEMA trailer model is 256 square feet; while our base model is 700 square feet. We believe the larger

size is important if the house is to be livable beyond the period of emergency; even more so in our area, where families tend to be larger. We also took advantage of wider Texas/Louisiana highway limits, and designed the house to be 16’ wide. The Back Home is compact, but the open floor plan and daylighting makes it comfortable for longer-term living. While the public area is open to make it feel spacious, separate private zones are included for the bedroom. We also include much more storage space than is currently included in FEMA trailers. This would give a place to put away belongings and contribute to a sense of security and organization. The layout of the Back Home modular unit can accommodate modification for handicap accessibility.

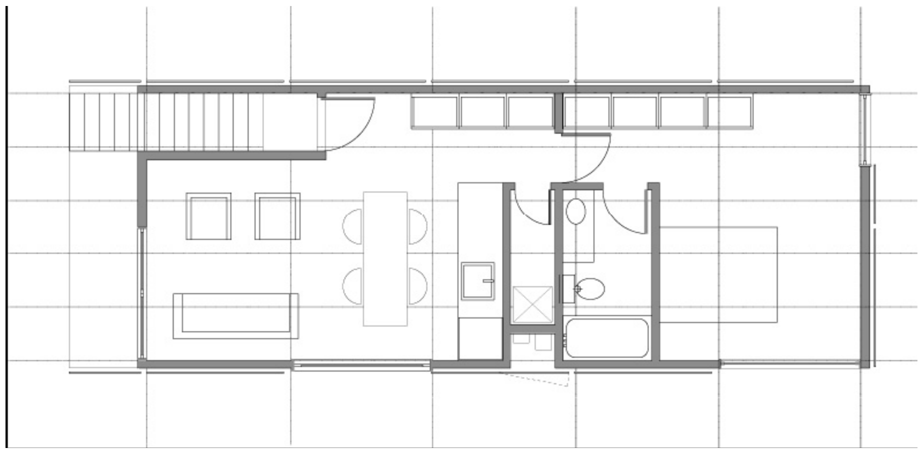


Fig.4 Floor Plan

We designed the house to work in two positions: either on pier and beam foundation at 18” above grade, or lifted to the second floor. The lifted option would be useful in areas where there are higher base flood elevations, or where people want garage apartments.

The Back Home uses energy efficient building materials, and passive solar design strategies. The rectangular proportion of the house and placement of doors and windows optimizes airflow through the house. Rooms have more windows for better ventilation. Operable awnings on the south side of the house shade south facing windows from summer sun and let in winter sun. The house uses a rainscreen to cool the exterior.

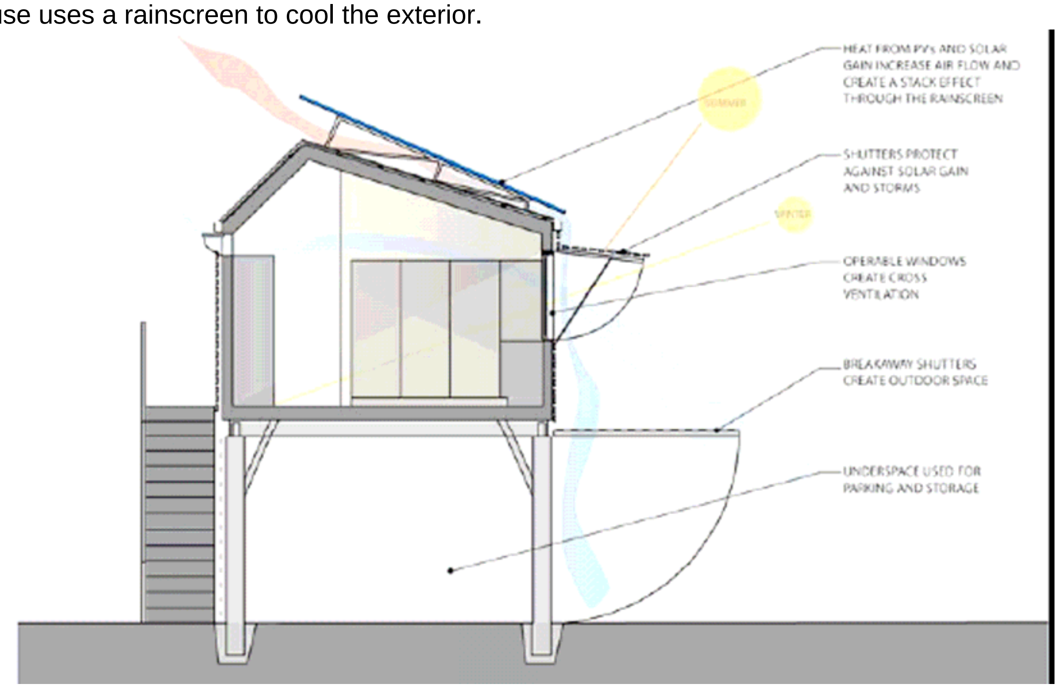


Fig.5 Passive solar design strategies

It can be assumed that there will be more hurricanes in the future, so we included a number of safety features in the design of the house that would make the house operational for several days during disaster conditions. The house is designed to resist high winds and uplift. The higher elevation would be appropriate for areas with higher base flood elevations. Cast-in place concrete footings provide solid foundations. Waterhog water tanks would provide water for several days, and help weight the house down. Screening around the bottom of the house would break away in flood conditions. It's metal SIP construction is mold resistant. HVAC is put within the attic space above an indoor mechanical closet, so that it remains operational during flood conditions. Shutters can be locked down for extra protection during storm. The photovoltaic array with battery back-up provide adequate power for basic life functions. Lastly, a sky hatch would allow for escape from the roof in high water conditions.

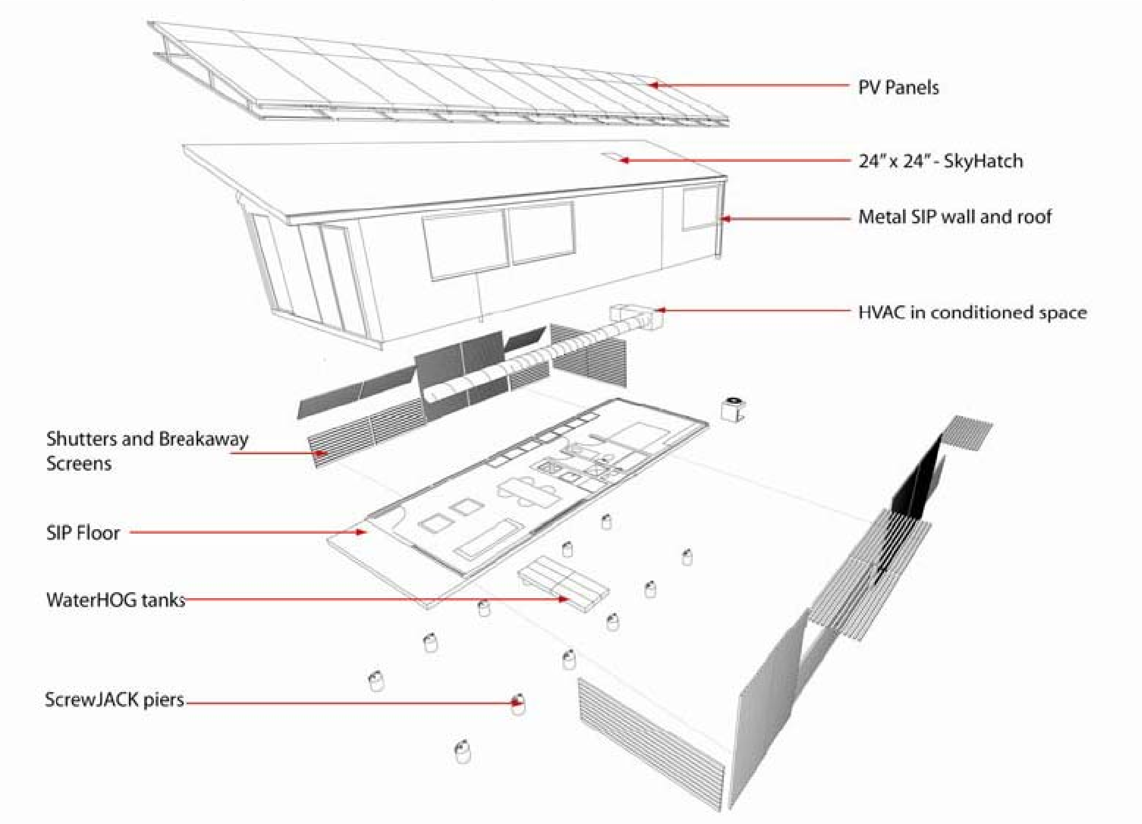


Fig.6 Emergency measures

2.4 Construction

During our research period, we investigated several potential industrialized building partners for the Back Home in our area. Through our work with the Solar Decathlon we were approached by a company that produces concrete sprayed SIPs. The durability, mold resistance and weight of the material seemed promising in hurricane-prone areas. We developed an initial model specific to this type of panel, but abandoned it when it was determined that the company had not completed proper testing. We then focused on two main construction strategies:

2.41 Modular Construction using Structural Insulated Panels:

We specified panelized structural insulated panels (SIPs) for their energy and material efficiency, and reduced life cycle cost (see FSEC's Contract Report "Improved Specifications for Federally Procured Ruggedized Manufactured Homes for Disaster Relief in Hot/Humid Climate by Stephanie Thomas-Rees et al). Assuming this house is built in a time of housing emergency, it would need to be built in a factory, to locate adequate workforce and to ensure timely delivery.

The house is based on a 4' module, and could be made with SIPs or standard 2x6 wall construction. The base module would be made in a factory, as well as the rainscreen on the house. The rainscreen is detailed to accommodate straps of the crane for moving the house.

This could also be something that's added onsite. We investigated two different ways that installation of photovoltaics could happen, both eliminating need for separate onsite installation crew.

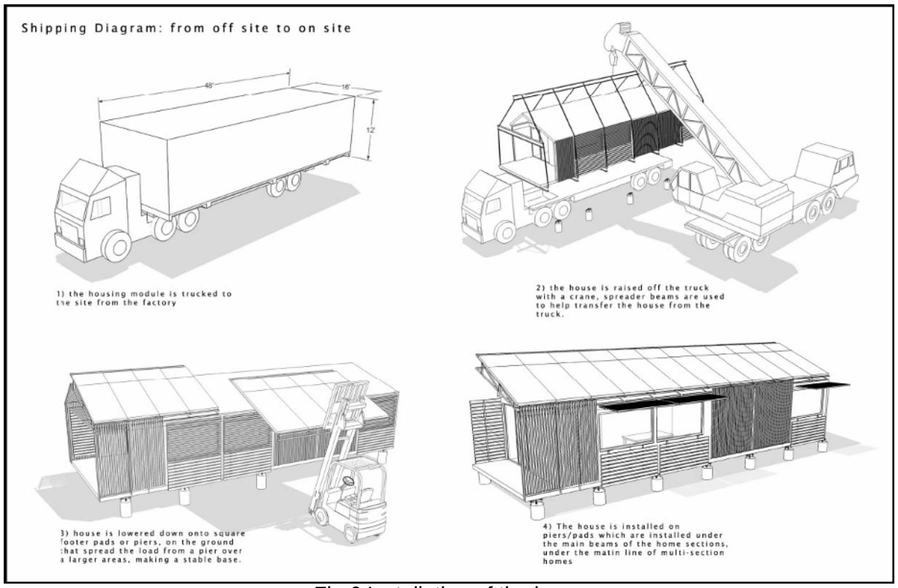


Fig.6 Installation of the house

Energy analysis was conducted on this house for sizing the photovoltaic array. This was based on The University of Texas at Austin's Solar Decathlon 2007 Marketable Prototype house, which was very similar to the Back Home in size and shape. The house was analyzed with wall, roof and floor construction of SIPs (R-value 25); double-glazed low-e windows (U=0.43); awnings over south facing windows, Energy Star appliances, solar hot water collectors, mini-split HVAC system (SEER13), and fluorescent lighting. The house was found to require 8080 kWh per year, based on use in Austin. (Unfortunately no simulation was conducted for a coastal area.)

2.42 Site-built House by Mobile Factory

We also identified another building/research partner in Dr. Stephen Mulva, director of Texas State University's Building Systems and Technology Institute. Unlike a modular or panelized approach which requires a centralized factory, this production system relies upon an onsite 'factory' mounted on a series of lightweight trailers, pulled by standard sized trucks. This is designed to minimize coordination with other agencies and services responding to a disaster. By leaving materials in their 'compact' state for transport and 'expanding' them onsite into a home, accessibility of the system in terms of size and weight is enhanced. This may be important if temporary roads and bridges are in use.

The mobile factory maximizes the ability to accommodate buildings of all sizes, yet at a remarkably low price point. The system avoids shipping 80-90% air (i.e., as in modular construction) or the maximum economic shipping radius of 300 miles (i.e., as in panelized construction). Traditional constructor and subcontractor roles are discarded, along with their inherent waste and transactional cost. Workers would require minimal specialized training (i.e. two weeks), and no prior construction experience. This is possible because the high quality of the completed home is dependent only upon the assemblies created by the onsite factory. As a result, upon sequenced production of walls, roof, floors, systems and cabinetry, a crew of 6 workers could complete construction of an 800 square foot 'high-design' home in three days.

Costs are kept down because there is no capital investment in the factory building. A 6-person crew can use $350,000 of onsite factory production modules to complete eight to ten units per month in disaster conditions, or about 100 units per year. When compared with a $4 to $7 Million conversion of an existing manufactured housing assembly line, or the construction of a $12 to $20 Million modular factory, the onsite factory produces between 1,500 and 4,500 units, respectively – given similar investment. The mobile factory could accommodate a range of house configurations, including the Back Home. Its houses are not limited by highway regulations. Construction for a house constructed with the Mobile Factory is based on the capabilities of the machinery. Each house rests upon either an advanced grillage foundation or helical piers. On top of the foundation system, a superstructure is created using a light-gauge metal framing with each member manufactured by an onsite production module. Thermal insulation and moisture protection is provided by expansive foams and stamped exterior cladding, respectively.

Wall finishes are avoided by using a new fiber technique. Installation of mechanical, electrical, and plumbing (MEP) systems will then take place concurrent with the installation of flooring systems. Vert-I-Pak HVAC units are installed, thus eliminating the need for external heat pump compressors and external concrete pads. Multiplexed, direct-current (DC) electronics are also used, allowing all lighting, motor function, entertainment, and communication signals and power to be sent along the same single wire. This also enables off-site diagnostics. Specialized PEX manifolds and home runs speed installation of plumbing. Finally, roofing is created by an onsite production module originally developed for the U.S. military. Starting with flat, coiled steel, this module creates barrel vaults as seamed panels. Mil-coat, a R-38 insulating paint developed by NASA provides insulation. This product is available for approximately $18 per gallon, or $0.13 per square foot, installed. As with all the materials used in this production system, the value proposition is high. Interior finish-out of each home incorporates many of the shell, fixture, bonding, and flat and contour panel technologies used for aircraft interiors. Cabinets, lavatories, and other 'compact and complex' portions comprise the only elements which are shipped to location using dedicated supply channels under contract with vendors such as FedEx or UPS. Energy simulation of a house with such a construction system would be conducted under further research.

3.0 The Bloom House MP

The Bloom House MP was another model developed under this grant. This house had a very different mandate than that of the Back Home. This house shows how the University of Texas Solar Decathlon 2007 competition house could be realized; a strategy for marketing a high performance house in central Texas in today's market. Using the analogy of a car show, if the house shown at the competition is the 'concept car,' this is the 'production model.' We started from the assumption that for the house to be marketable it would have to be comparable in price to other offerings in our area, so cost estimating was included in our design analysis. We also doubled the size of the competition house based on market research. The house is designed as part of a community of houses. For solar-powered houses to reach a larger segment of the population, we believe they will be brought to market by a developer. A developer or non-forprofit agency can take advantage of economies of scale if they are building multiple houses.

Looking at the house as part of a complete environment including land and infrastructure, allows us to strategize and design effectively to make a house with photovoltaic power marketable (i.e. affordable and comparable). We modeled our development for an urban infill project in central Austin.

Fig.7 In Blooms

3.1 Site Planning

We based our lot size on a development that is being realized here in Austin for the reuse of land at the old Mueller airport (http://www.muelleraustin.com/), described as “the new mixed-use urban village in the heart of Austin.” We employed their “yard house” lot size, which is a compact form of suburban house and yard. Lots are typically 20’ x65’, with a rear alley. This reduced lot size produces savings in land cost. It also makes more efficient use of yard; the side yard is more private than a typical suburban front yard; more usable.

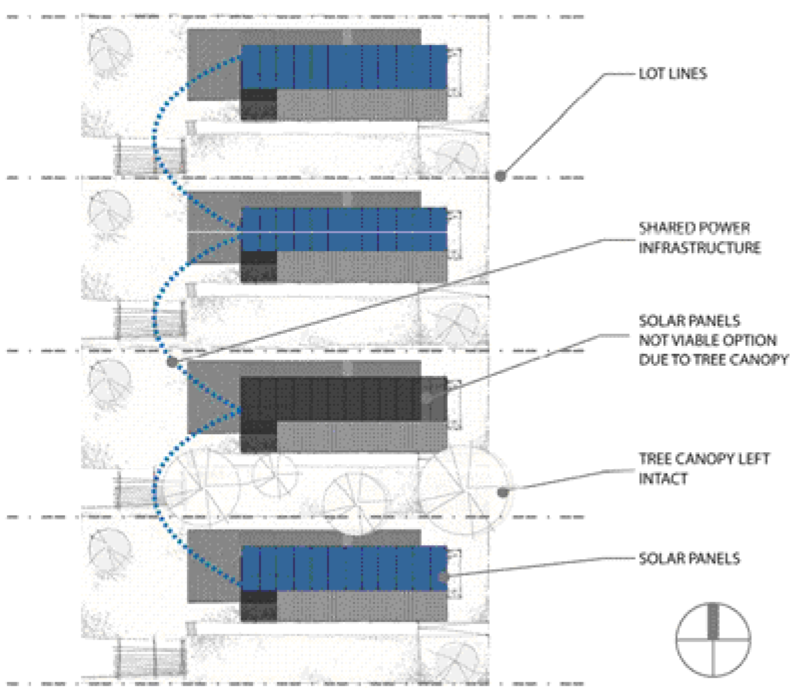


Fig.8 Site Plan

For planning, we thought of this as a conservation development or condominium, with collective ownership of land. This gets us around 'power wheeling' regulations in Austin. It is illegal in Texas to transmit power across property lines. In our work with the Solar Decathlon 2005 team, we had come up against this as a problem when our community partner wanted to install the house next to another house and share the power produced by its 8Kw system. (See http://www.austinchronicle.com/gyrobase/Issue/story?oid=oid%3A348064). In developments where there is joint ownership of land this roadblock goes away. The photovoltaic array could be owned collectively, just as the land is. In future work we will investigate implications for netmetering on such a scenario.

Another advantage to thinking on a larger scale for houses with solar panels is that lots need to be laid out to provide proper orientation. This site plan for the Bloom House (fig. 8) works for solar panels assuming long direction runs east-west. (Note that roofs on site plan are 'butterfly' roofs, so panels on the north side of the house slope to the south.)

3.2 Design

The Bloom House MP is laid out as a three-bedroom, 2 1/2 bath house. This is the most saleable type of house in our target area, according to our market research. A bedroom and bath are downstairs, with an open kitchen and living room. The kitchen has large south-facing windows that look out into the private side yard, and the living room looks out onto a small porch facing the street. Upstairs are master bedroom, with access to a deck; and another bedroom, bathroom and closets for HVAC and washer/dryer.

The house takes advantage of passive solar design strategies. Good daylighting is provided by a south-facing window that is shaded by the house overhang. The neighboring houses provide shade on the house and yard. A skylight on the north side of the stair lights the hall and bounces light into the kitchen area. The west and north sides of the house are almost completely closed, protecting those sides from cold north wind and the hot west sun.

Fig.9. Plan

Houses are laid out as townhouses; the house is a 'double-up'. This allows the smaller lot to work with a side yard, and lifts the solar panels up to the sun. Raising the solar panels has particular merit in areas with existing tree canopy. More trees can be left to shade the house if the roof is at a higher elevation.

Fig.10 Solar access is increased when house is raised

3.3 Construction

The Bloom House MP could be built as a onsite or in a factory. Its dimensions would allow delivery with two modules, one for each floor. However that would most likely mean doubling structure at the 1st floor ceiling/2nd floor, so for cost estimating the house is priced as panelized construction assembled on site.

The house is made using very similar construction to that outlined for the Back Home. Wall, roof and floor construction is SIPs with (R-value 25); double-glazed low-e windows (U=0.43); awnings over south facing windows, Energy Star appliances, solar hot water collectors, mini-split HVAC system (SEER13), and fluorescent lighting. It was assumed to be a fairly airtight house; the ventilation rate is 0.36 air changes/hour.

Energy simulation was conducted using the DOE-2 energy simulation tool, with eQUEST 4.6 graphic user interface by Dr. Atila Novoselac in the UT School of Engineering. We assumed the house would be used by a family of four. A variety of energy efficient measures were examined for energy savings and cost. The house was found to consume 9192 KwH per year.

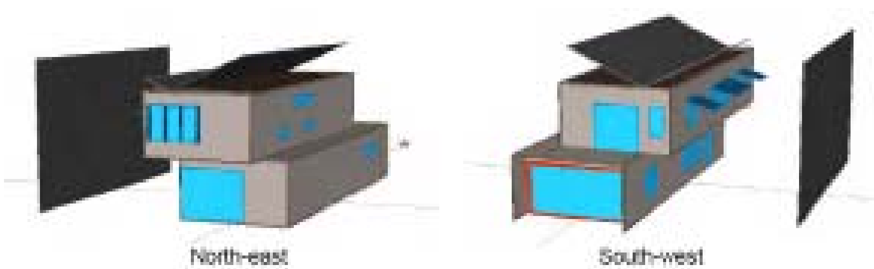


Fig.11 Energy simulation models

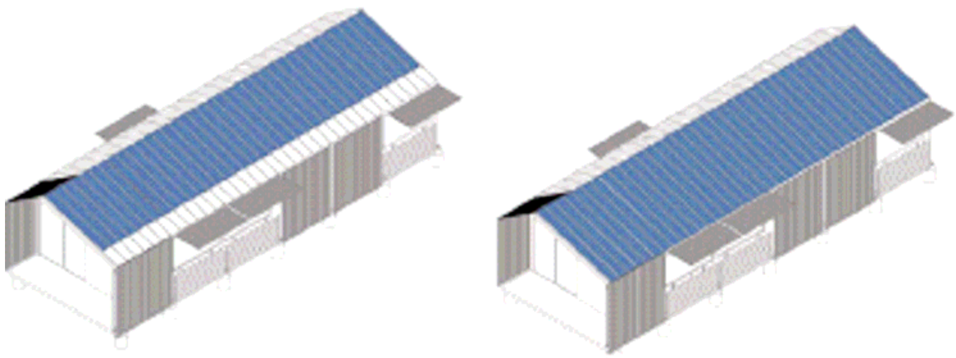
As marketability (=affordability=comparability) was our key consideration, we were pleased to meet local price points in our initial cost estimate of the house. We were arriving at a cost of $145/square foot for house, land, and photovoltaics, and our market research shows houses in comparable areas going for this without energy production.

4.0 Comparison of Photovoltaic Arrays

The roofs of the Bloom House MP and the Back Home are essentially identical, but inverted; one is a offset gable roof, one is a offset butterfly roof. We have investigated two types of photovoltaic systems, polycrystalline silicon modules in a frame product, and amorphous silicon modules in a laminate product. We used different sizing strategies for each type. For the polycrystalline panels we specified a 3.328 Kw system, which would reach the highest level of rebate offered by Austin Energy ($12,000 at $4.50/watt). We are using (16) Sharp 208 Watt polycrystalline modules. For the amorphous panels we used the total roof area available. Our roof length is 12' from peak to eave on the south side. We specified the product closest in length to that. We are using (36) Unisolar Laminate PVL-68 amorphous silicon modules, which are 9'-4" long. We also investigated a custom version that would be tailored to our specific roof. This would seem to be a reasonable proposal, assuming this would be a factory-assembly situation, where large quantities would be purchased. The Unisolar modules are 9 ½" long, so we could have a length of 12'-0" with 14 modules. This would create a 2.978 Kw system. However, Unisolar was resistant to go into depth about this option until a real job was eminent.

Table 4.1 Annual Energy Production

array	kWh	Energy Value
3.328 Kw; Sharp 208	4422	$414
2.45 Kw; Unisolar PVL-68	3253	$304
2.978 Kw; Unisolar PVL-82*	3957	$371



Unisolar PVL-68 Unisolar custom 12'-0" length

Fig.12 Amorphous silicone laminate roof options

4.1 Integration

We investigated the custom size for the laminate option because from a market acceptability standpoint, it is important. Obviously aesthetics are of lesser importance during times of power outage. However, if these houses are to be made for long-term usage, then the integration of the solar panels holds more attention. There seems to be fairly consistent comments from the public expressing concern about the look of photovoltaics on the main façade of the home. We base this hypothesis on feedback from the Solar Decathlon house, and on community design guidelines here in Austin. Some developments have outlawed anything on the roof. The Mueller Development mentioned previously encourages the use of photovoltaics, but says they should not be visible from the main street elevation. Given this, customizing the size of the laminate panels to fit size of the roof would give them a much more integrated look.

Photovoltaic panels on second floor structures are less visible from the street in general. This would hold true for the lifted version of the Back Home and for the Bloom House. The second story off-set butterfly roof of the Bloom House serves to provide a small awning on the south side of the house, and to hide the top of the roof. This allows for flexibility in sizing photovoltaics and solar hot water heaters.

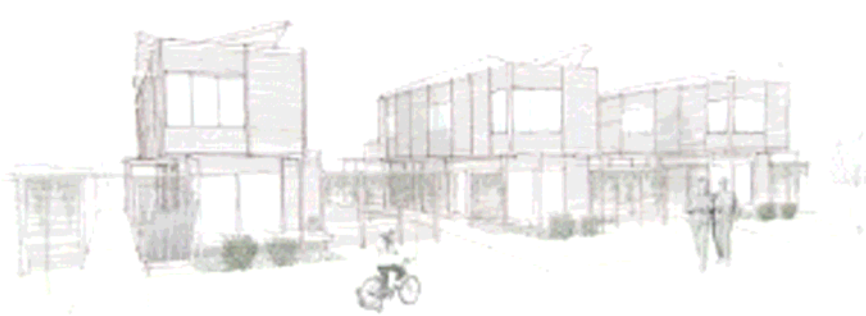


Fig.13 Systems on roof are hidden by offset butterfly roof on second storey

4.2 Factory Installation

We investigated installation of photovoltaics in a factory setting. We began by researching costs that would be eliminated if the array was assembled and put on the house in a factory. The following numbers were provided by Andrew McCalla of Meridien Energy Systems here in Austin. Fieldwork includes site transition costs such as travel, unloading, mileage, setting up and taking down for installation. Administrative costs include permitting, site analysis, rebate documentation, design and shipping coordination. Hardware costs are the costs of the mounting hardware. Costs of racks are described in a separate section. There are slight variations in field work and administrative costs from module to module; but the big savings in installation of the amorphous panels comes from elimination of fasteners. This study has yet to take into account costs to the factory for retooling their production to accommodate a photovoltaic shop, or the difference in labor costs between the well-trained work force currently doing custom installation of photovoltaics, and workers doing repetitive installations in a factory.

Table 4.2 Reduced Costs from Factory Installation of PV

	crystalline panels	amorphous panels
Field Work	$1,200	$1,600
Administrative	$1,100	$900
Hardware	$825	na
Total	$3,125	$2,500

4.3 Costs and Energy Value

We priced photovoltaic arrays for the two models as described, looking at both a grid-tied version, which would be more appropriate for the Bloom House MP, and an off-the-grid array for the Back Home. We also looked at pricing for Austin with and without rebates. Rebates do not cover batteries, so that provides a big incentive for a grid-tied system (which is their point.)

Table 4.4 System Costs

type	size: w	cost	battery	total	$/w
Sharp 208, off grid	3328	$18,750	$7,000	$25,750	$8
Sharp 208, grid-tied	3328	$18,750	na	$18,750	$6
Unisolar PVL-68, off grid	2448	$15,775	$7,000	$22,775	$9
Unisolar PVL-68, grid-tied	2448	$15,775	na	$15,775	$6

Table 4.5 System Costs Including Austin Energy Rebate

type	size: w	cost	battery	total	$/w
Sharp 208, off grid	3328	$18,750	$7,000	$25,750	$8
Sharp 208, grid-tied	3328	$18,750	na	$18,750	$6
Unisolar PVL-68, off grid	2448	$15,775	$7,000	$22,775	$9
Unisolar PVL-68, grid-tied	2448	$15,775	na	$15,775	$6

The reduction in price from factory installation leveraged with the rebate makes for very attractive pricing. When looking at payback and energy value, the grid-tied polycrystalline system actually winds up with a net credit. We used PV Watts to calculate energy value, with their default values. We used an online mortgage calculator (mortgage.com) to calculate additional costs of the panels, assuming they could be rolled into a base home mortgage (30 years at 7%).

Unfortunately there is no factory within the Austin Energy service area installing photovoltaics.

Table 4.6 System Costs Including Austin Energy Rebate

type	net cost	energy value per year	payback inyears	mortgage per year	net credit per year
Sharp 208, off grid	$25,750	$414	62	($792)	($378)
Sharp 208, grid-tied	$3,774	$414	9	($288)	$126
Unisolar PVL-68, off grid	$22,775	$248	92	($864)	($616)
Unisolar PVL-68, grid-tied	$4,759	$248	19	($360)	($112)

4.3 Mounting Photovoltaics

We have investigated three mounting options: a custom rack which could be made to particular specifications, an off-the-shelf mounting system and a laminate peel and stick modules.

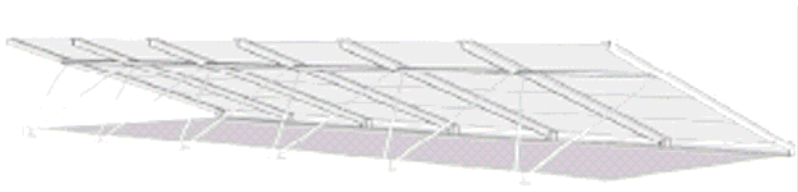


Fig. 14. Custom rack

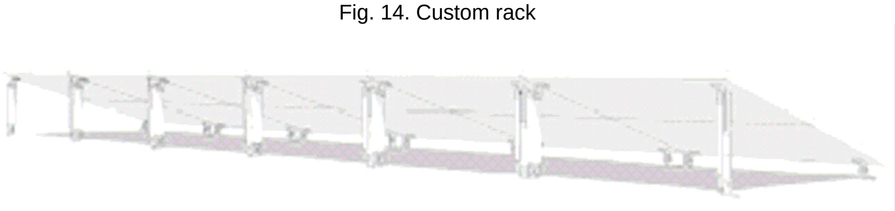


Fig. 15. Unirac Solar Mount Low Profile adjustable tilt-leg kit

Both rack options have the advantage of increasing the cooling of the house by shading it, and inducing airflow. The custom rack could be designed for easy deployment by forklift. This would decrease installation time on site; both because there is easy access to wiring, and because assemblies could arrive in multiples. This would have the advantage of allowing array assemblies to be brought to a house separately from the house itself. For the off-the-shelf system we have specified a Unirac system, which would provide some of the benefits of a custom rack, but at lower cost. The laminate stuck down directly to a standing seam roof would not require any additional structure for mounting, but loses the interchangeability.

Table 4.7 Costs of Mounting Racks

rack costs	
custom steel rack	$ 2,000
Unirac	$ 1,190
Unisolar PV laminate	-

5.0 Conclusion

While the polycrystallline array shows a net credit assuming rebates are included in the calculations, the amorphous panels are more cost effective with mounting is taken into consideration. Amorphous panels have many advantages for a photovoltaic array installed on a modular house in a factory setting. Their light weight and flexibility make them ideal for transport. Their low profile means they will not take away height from the height of the house. Their lower price would appeal to the modular market. The typical complaint about amorphous panels is that the material cost savings is eaten up by increased installation costs. In a factory setting, repetition could help bring the labor costs down, and make this an attractive option for bringing photovoltaic energy production to the housing market on a larger scale.

While custom racks no doubt add initial cost, we believe there are long-term advantages to this option for a large governmental agency, like FEMA. Photovoltaic array assemblies could be deployed as needed in areas with damaged infrastructure, either on houses or anywhere there was adequate sun.

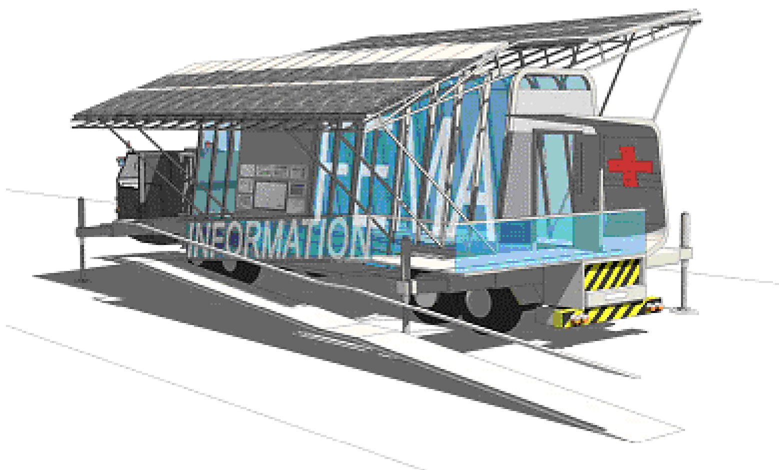


Fig. #16 FEMA relief vehicle with photovoltaic rack

Appendix C 2007 International Builders' Show Homes Fact Sheets

Higher quality copies of the International Builders' Show Homes Fact Sheets are located on the BAIHP website in the following locations:

http://www.baihp.org/casestud/ph_homes/index.htm
Palm Harbor Homes' First time Buyer Home
Palm Harbor Homes' "Move-up" Buyer Home
Palm Harbor Homes' "Peace of Mind" Home

http://www.baihp.org/casestud/ph_homes2007/index.htm
Palm Harbor Homes "GenX" Home
Palm Harbor Homes "EchoBoomer" Town Homes
The New American Home 2007

Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

Research that Works
www.buildingamerica.gov

Palm Harbor Homes' "First Time Buyer" Home

Based on Palm Harbor Homes' Wilmington Model, this 1,682 square foot home addresses the needs of the first time home buyer. This show home exposes what is behind the walls where everything from framing to wiring to insulation and mechanicals can be seen.

Energy Efficiency Features

- Expanding foam insulation throughout
- Low-E vinyl windows U=.39, SHGC=.39
- High efficiency heat pump, SEER 13, HSPF 8
- ENERGY STAR® Appliances
- Extensive use of compact fluorescent lighting
- Home Energy Rating Scale (HERS) Score = 90 Out of 100

Indoor Air Quality Features

- VOC Source Control including zero VOC paint
- Central vacuum system
- Duct System Sealed with mastic and fiberglass mesh and perfomance tested

Other Green Building Features and Certifications

- Resource efficient construction and construction waste management
- Water efficient appliances and fixtures
- Fire protection system
- Durable, low maintenance design
- *Certified Florida Green Home* by the Florida Green Building Coalition, Inc.

Palm Harbor Homes

Designer SERIES

For more information, contact:
Home Manufacturer
Discovery Custom Homes, a division of Palm Harbor Homes, 1-800-729-4363
Technical assistance:
Building America Industrialized Housing Partnership www.baihp.org
at the Florida Solar Energy Center/UCF www.fsec.ucf.edu

FLORIDA SOLAR ENERGY CENTER

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

Building Technologies Program
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Building America

U.S. Department of Energy

Research that Works

www.buildingamerica.gov

Research Toward Zero Energy Homes

Palm Harbor Homes' "Move-Up Buyer" Home

Based on Palm Harbor Homes' Bellaire Model, this 2,865 square foot home addresses the unique problems associated with narrow lot houses. Located in the Show Village, this home has achieved US EPA Energy Star® and Florida Green Home Designations.

Energy Efficiency Features

- Low-E vinyl windows U=.34, SHGC=.35
- R-33 vented ceiling
- High efficiency heat pump, SEER 13, HSPF 8
- Energy Star® Appliances
- Extensive use of compact fluorescent lighting
- Home Energy Rating Scale (HERS) Score = 89.6 Out of 100

Indoor Air Quality Features

- VOC Source Control including zero VOC paint
- Central vacuum system
- Duct System Sealed with mastic and fiberglass mesh and performance tested

Other Green Building Features and Certifications

- Resource efficient construction and construction waste management
- Water efficient appliances and fixtures
- Fire protection system
- Durable, low maintenance design
- *Certified Florida Green Home* by the Florida Green Building Coalition, Inc.

Palm Harbor Homes

Designer Series

For more information, contact:

Home Manufacturer

Discovery Custom Homes, a division of Palm Harbor Homes, 1-800-729-4363

Technical assistance:

Building America Industrialized Housing Partnership www.baihp.org at the Florida Solar Energy Center/UCF www.fsec.ucf.edu

Florida Solar Energy Center

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

Building Technologies Program

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

Research that Works
www.buildingamerica.gov

NextGen "Peace of Mind" Show Village Home

Based on Palm Harbor Homes' Palencia Model, this 2,500 square foot home is designed to showcase best practices in home automation, energy efficiency, green building, and storm resistant construction. The home will also serve as a model for the first NextGen Certified™ planned community to be built by BrownStone Builders near Tampa Bay, Florida.

Energy Efficiency Features

- Expanding foam insulation throughout
- Radiant barrier roof sheathing
- Low-E vinyl windows U=.32, SHGC=.31
- SEER 15 Puron air conditioner and 94.1 AFUE high efficiency gas furnace
- Tankless water heater
- ENERGY STAR® Appliances
- Home Energy Rating Scale (HERS) Score = 90.6 Out of 100

Indoor Air Quality Features

- Energy Recovery Ventilator for fresh air ventilation
- Advanced whole house air purification and filtration
- VOC source control including zero VOC paint

Disaster Resistance Features

- Built to Institute for Business and Home Safety's *Fortified…for safer living program®*
- In-home storm shelter
- Impact resistant glass and storm shutters
- 4 ft. x 10 ft. roof sheathing with taped seams
- Galvanized metal screw-down shingle
- Corrosion resistant plumbing and fire protection system

Other Green Building Features and Certifications

- Resource efficient construction and construction waste management
- Water efficient appliances and fixtures
- Durable, low maintenance design
- *Certified Florida Green Home* by the Florida Green Building Coalition, Inc
- US Green Building Council *LEED® for Homes Pilot Program Participant*

Palm Harbor Homes

Designer SERIES
BY DISCOVERY CUSTOM HOMES

For more information, contact:

Home Manufacturer
Discovery Custom Homes, a division of Palm Harbor Homes, 1-800-729-4363

Technical assistance:
Building America Industrialized Housing Partnership www.baihp.org
at the Florida Solar Energy Center/UCF www.fsec.ucf.edu

FLORIDA SOLAR ENERGY CENTER

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

Building Technologies Program
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

Research that Works
www.buildingamerica.gov

Palm Harbor Homes "GenX" Home
2007 International Home Builders' Show
Orlando, FL

GenX Statistics
- 3,397 square feet

Energy Efficiency & Renewable Energy Features
- Low-E vinyl windows
- R-33 ceiling with radiant barrier roof decking
- 14 SEER/8.4 HSPF heat pump
- ENERGY STAR® Appliances
- Extensive use of compact fluorescent lighting
- 3.25 kWp BP Solar PV System with GridPoint Inverter & instant, "Clean" battery-backup power & energy management
- Solar domestic hot water system by SunBuilt
- Exceeds ENERGY STAR® Homes Standards with a Home Energy Index (HERS) = 71

Indoor Air Quality & Noise Reduction Features
- VOC source control including zero VOC paint
- Outside air ventilation with dehumidification
- Central vacuum system
- Duct system sealed with mastic and fiberglass mesh and performance tested
- Soundproofing

Other Green Building Features and Certifications
- Resource efficient modular construction and construction waste management
- Water efficient appliances and fixtures
- Universal Design for handicap accessibility
- Durable, low maintenance design
- *Certified Florida Green Home* by the Florida Green Building Coalition, Inc.
- Progress Energy Home Advantage Premium Energy Saver/Energy Star Qualified

Palm Harbor Homes

Designer SERIES
BY DISCOVERY CUSTOM HOMES

FLORIDA SOLAR ENERGY CENTER

Florida Solar Energy Center leads the Building America Industrialized Housing Partnership Consortium

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

Building Technologies Program
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

Research that Works
www.buildingamerica.gov

Palm Harbor Homes "EchoBoomer" Town Homes
2007 International Home Builders' Show
Orlando, FL

EchoBoomer Statistics
- (3) Units
- 1 unit = 1,840 square feet
- 2 units = 1,360 square feet each

Energy Efficiency Energy Features
- Low-E vinyl windows
- R-33 ceiling with Honeywell foam insulation
- 15 SEER/8.2 HSPF heat pump
- ENERGY STAR® Appliances
- Extensive use of compact fluorescent lighting
- Exceeds Energy Star Homes Standards with a Home Energy Index (HERS) = 76 , 80, 75*

*HERS index 76 for the large unit (left), 80 for the middle unit and 75 for the small unit (right)

Indoor Air Quality & Noise Reduction Features
- VOC source control including zero VOC paint
- Outside air ventilation
- Duct system sealed with mastic and fiberglass mesh and perfomance tested
- Low-sone bathroom exhaust fan

Other Green Building Features and Certifications
- Resource efficient modular construction and construction waste management
- Water efficient appliances and fixtures
- Durable, low maintenance design
- *Certified Florida Green Home* by the Florida Green Building Coalition, Inc
- Progress Energy Home Advantage Premium Energy Saver/Energy Star Qualified

Palm Harbor Homes

Designer SERIES

FLORIDA SOLAR ENERGY CENTER

Florida Solar Energy Center leads the Building America Industrialized Housing Partnership Consortium

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

Building Technologies Program
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

The New American Home® 2007 Orlando, Florida

Each year, The New American Home® demonstrates use of innovative building materials, cutting-edge design, and the latest construction techniques, providing production homebuilders with an example for producing more energy efficient, durable homes without sacrificing style. Cosponsored by The National Council of the Housing Industry and *BUILDER Magazine*, The New American Home® is not only the official showcase house of the annual International Builders' Show, but is also a for-sale product. The majority of features and innovations in the home are accessible to both builders and consumers for integration into their own homes.

Located in Orlando's Lake Eola historic district, The New American Home is within walking distance of downtown Orlando and is surrounded by upscale contemporary lofts, condominiums, and vibrant social and cultural activities. A modern interpretation of historic bungalow architecture, the three-story urban loft home is designed in a way that takes full advantage of the views, captures the favoring climatic factors, and provides a sense of privacy and comfort, while also paying homage to the social thread that binds the community. The project is a collaborative effort between custom homebuilder Homes by Carmen Dominguez, Bloodgood Sharp Buster Architects & Planners, and interior design firm Robb & Stucky Furniture and Design Studio. It features 3,733 ft^2 of living area, a shallow basement, a roof plaza, and a detached two-car garage with additional living space.

To ensure energy efficiency and innovation, two Building America teams have worked closely with the National Council of the Housing Industry. IBACOS Inc. provided design and engineering support, and the Industrial Housing Partnership provided performance testing and consulted with the builder regarding the use of solar photovoltaic systems. As a result, the home's three stories are conditioned using three strategically placed, high-performance HVAC systems. The shallow basement, first floor, and second floor are served by two heat pumps with 17.8 SEER performance, while the third floor is served by a 15 SEER gas/electric unit. Each unit and its associated ductwork are within conditioned space. A solar thermal hot water system preheats incoming water for tankless water heaters, which are fueled by natural gas – further adding to efficiency and comfort. A 2.4-kW photovoltaic system lightens the electric energy load by 9 kilowatt hours per day on average.

Other prominent features further contribute to energy efficiency and durability. The exterior was constructed with pre-cast, insulated concrete sandwich walls (equivalent thermal performance to R-26 wood-framed walls), and the home is built on a solid foundation of pre-cast concrete walls with R-5 exterior insulation. All of the windows and sliding doors are impact resistant and have low-emissivity coating to limit solar heat gain and provide storm protection. In addition, windows on the south- and west-facing sides are covered by overhangs that include a layer of vegetation (green roof concept). Last, but not least, fluorescent lighting and lower wattage incandescent lamps are saving electricity and providing cooler indoor conditions.

The energy features in The New American Home can be used in homes at any price point with equivalent energy savings.

Specifications

- Pre-cast, insulated structural concrete wall system
- Three high-efficiency heating and cooling units; heat pumps 9.0 HSPF
- Air-conditioning systems between 15 and 17.8 SEER
- Air-distribution system entirely within conditioned space
- Low-emissivity impact-resistant windows, U-value = 0.33, SHGC = 0.32
- 4-foot overhangs over most south- and west-facing windows
- Natural-gas-fueled instantaneous water heaters, EF = 0.82
- 2.4-kW solar photovoltaic system
- 49% whole-house energy savings (58% with PV system contribution)

Primary Project Goals

- Build a high-profile show home for the International Builders' Show by implementing Building America strategies to conserve energy and materials
- Introduce production builders to advanced HVAC strategies and advanced insulation and airtightness details

Performance Features

Thermal Shell

- Low solar gain windows with 4-ft overhangs on south and west orientations
- Pre-cast exterior concrete walls with STYROFOAM T-MASS technology
- Poured concrete foundation walls with R-5 exterior insulation
- Flat, unvented roof insulated to R-20 with layer of vegetation

Airtightness

- Penetrations and openings sealed to achieve 0.30 natural air changes
- Limited seams in concrete wall system add to airtightness

Moisture Control

- Shallow basement with waterproof membrane

HVAC

- Two air-source heat pumps, 9.0 HSPF and 17.7 SEER, serving basement, first, and second floors
- 15 SEER gas/electric unit serving third floor
- All ductwork within conditioned space

Hot Water

- Solar thermal system preheats natural-gas-fueled, instantaneous water heaters (EF = 0.082), which minimize piping and reduce standby losses

Electrical

- Solar PV systems lighten the load by 9 kilowatt hours per day on average
- ENERGY STAR®-rated dishwasher, clothes washer, refrigerator
- 29% fluorescent lighting

For more information, contact:

- Homes By Carmen Dominguez
  407-999-9002
- National Council of the Housing Industry
  1-800-368-5242 ext. 8519
- IBACOS
  1-800-611-7052
- Industrial Housing Partnership (IHP)
  407-384-2048

Energy Features and Benefits

Energy efficiency is among the top benefits of The New American Home® 2007. The home uses approximately 73% less energy for heating and cooling and 54% less energy for water heating compared to a house of comparable size in the Hot Humid climate region. Each component of the home was selected and integrated into the project through a systems approach of designing, testing, and redesigning. All of its components work together to achieve maximum performance. For example, the home's thermal qualities are achieved by properly sizing the mechanical equipment, using the right insulation materials and specifications, and designing the ductwork to fit within the conditioned space.

Extra measures were taken to ensure the foundation and shallow basement were waterproof.

Openings for windows and any other penetrations required careful design and placement in the pre-cast concrete system.

Steel framing was used for faster installation into concrete exterior, floors, and ceilings.

Pre-cast exterior concrete walls allow for faster building enclosure construction and a tighter envelope.

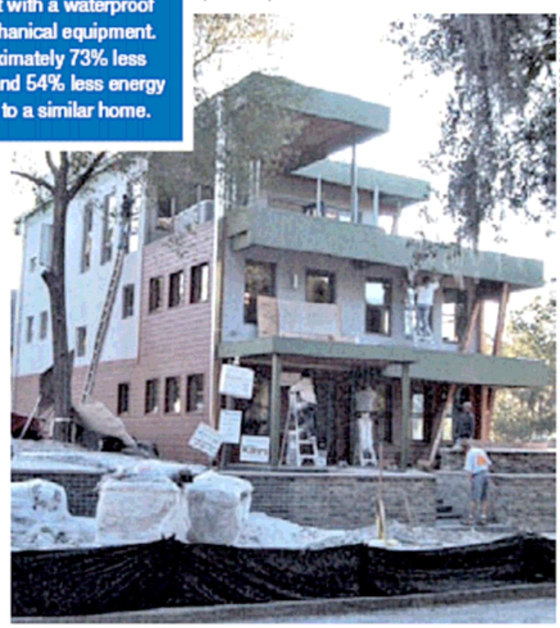
A shallow basement cleverly conceals mechanical equipment.

Fiber cement siding and stucco add warmth to the bungalow's exterior.

Pre-cast concrete overhangs provide area for vegetation and shade to reduce solar heat gain.

Each year for the International Builders' Show, The New American Home® transforms from a graded plot into a truly unique home in style and function. The one characteristic shared by each home since the Building America Program has participated in the project is energy efficiency. This year's home achieves high levels of efficiency through advanced HVAC equipment, careful installation of insulation and air sealing, and high-performance windows. Among its interesting features is a shallow basement with a waterproof membrane, which houses mechanical equipment. Overall, the home uses approximately 73% less energy for heating and cooling and 54% less energy for hot water, when compared to a similar home.

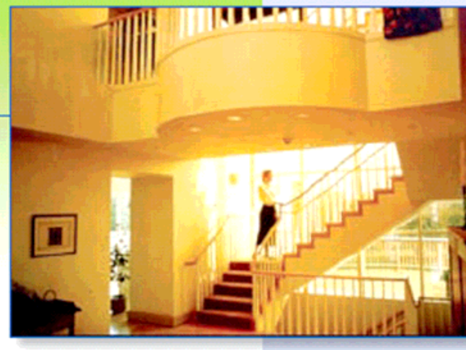
Balconies and overhangs expand the outdoor living space and provide additional shade.



A PV system powers the refrigerator directly, and the excess energy is either used elsewhere in the home or stored.

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Advantages to the Consumer



- Increases quality without increasing cost
- Increases comfort and performance
- Reduces utility bills
- Allows greater financing options

Advantages to the Builder

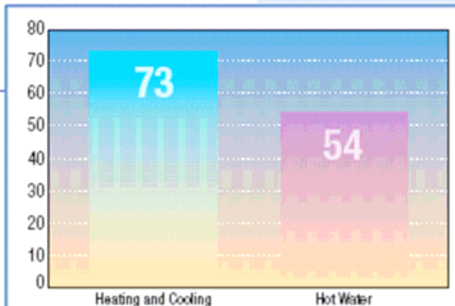
- Reduces construction costs
- Improves productivity
- Improves building performance
- Reduces callback and warranty problems
- Allows innovative financing as a result of predictably lower utility bills
- Gives builder a competitive advantage

Systems Engineering Cost Saving Trade-Offs

Second floor plan for The New American Home 2007.

- Advanced framing systems
- Tightly sealed house envelopes
- Shorter, less costly ductwork
- Engineered and planned infrastructure
- Smaller, less expensive mechanical systems
- Modular construction

Percentage of Energy Reduction



- 73% reduction in heating and cooling energy use
- 54% reduction in hot water energy use

Appendix D Washington State University Annual Report

Washington State University Extension Energy Program
Annual Report for Building America Industrialized Housing Partnership
April 2006 – February 2007

Task Area 2 – Test House Evaluations

Garst Residence

Figure 1 – PV panel installation, Garst residence – Olympia, WA

The Garst residence is a 2400 ft. home built in Olympia, Washington to the Building America 50% benchmark. The ENERGY STAR Homes Northwest and LEED qualified home features a ground source heat pump, solar design, including a 4.5 kW photovoltaic array and sunspace, as well as an energy recovery ventilator. Home construction began in Summer of 2005, and was completed in May of 2006.[2]

BAIHP staff from WSU and FSEC coordinated the design stage, field testing and monitoring efforts. Field testing indicated envelope leakage of 4.9 ACH_{50}. BAIHP staff were also able to provide troubleshooting of the ground source heat pump, lighting and HVAC design.

Data instrumentation of the home was completed in January 2007. BAIHP staff from WSU and FSEC are still in the process of fine tuning the data acquisition, which will be available through BAIHP's WEBGET system.

WSU coordinated with PNNL on development of a Building America Best Practices case study on the Garst residence (see publications section, below.)

In addition, the Garst home is featured as the cover story for the March 2007 issue of Solar Today. BAIHP staff provided comment and review for the article (see publications section, below.)

Stamets Residence

Figure 2 –Stamets residence – Olympia, WA

The Stamets residence is a 5000 ft.^{2} home, constructed in 2005-06 in Shelton, Washington. The home, which will achieve at least a 30% Building America benchmark, features a ground source heat pump with floor and ceiling radiant heating, solar design (including solar hot water and PV array), ENERGY STAR lighting and appliances, HRV and HEPA filtration, a heat pump water heater and condensing dryer.

BAIHP staff are working with the homeowner to coordinate installation of the ground source heat pump, as well as the solar hot water and PV systems in 2007-08. BAIHP staff are also coordinating testing and monitoring efforts. Evaluations underway or planned for 2007 include:

- HOBO dataloggers measuring hot water and floor/ceiling radiant zone heat, ambient temperature, relative humidity, and energy saving technologies
- Boiler/GSHP flip-flop testing to assure proper control strategies for radiant heating and domestic hot water demand.
- Evaluation of improvements to DHW recirculation controls
- Evaluate interactions between heat pump water heater and condensing dryer.
- Testing of HRV/HEPA system, including interaction with fireplace
- Heat flux measurement comparisons of ceiling and floor hybrid insulation systems

Due to prescriptive program requirements, this home does not currently meet ENERGY STAR Homes Northwest specifications. BAIHP staff have been working with the homeowner to add R-19 blown fiberglass in the ceiling and R-19 batts in the floor to bring the home in line with these specifications, providing further opportunities to evaluate Icynene “hybrid” assemblies.

Once all insulation, HVAC and renewable upgrades are made the home is expected to benchmark at over 40%.

Task Area 3 – Community Scale Evaluations

Fort Lewis Army Base – Fort Lewis, Washington

Figure 3 – Two story Modular housing assembly - Fort Lewis Army Base, Washington

WSU is working with Building America partners Oregon Department of Energy (ODOE), Champion Homes and Equity Residential in an effort to build over 850 energy efficient modular homes at Fort Lewis Army base in Washington State. These factory-built homes are constructed to ENERGY STAR Homes Northwest standards, and feature .90 AFUE furnaces, efficient windows, and ENERGY STAR appliances.

The project is administered as a mixture of ENERGY STAR manufactured and site-built programs. ODOE inspects the homes in-plant and provides quality assurance throughout the construction process. WSU provides on-site quality assurance for the final inspection of the home, and evaluation of the HVAC performance.

Phase 1 of the project, which started in 2005, produced 174 units (homes are single story duplex, two story duplex, or two story triplex). Phase 2, currently underway, will result in an additional 150 units. Phase 3 will be started and completed in 2007, and will result in 135 units, for a total of 459 units by the end of 2007.

Initial testing of Fort Lewis HVAC systems by BAIHP staff indicated leakage rates of worse than 400 CFM_{50}. Hands-on efforts by BAIHP staff resulted in leakage rates of less than 100 CFM_{50}.

Current Fort Lewis homes benchmark at the 25-30% level. BAIHP worked with Equity and Champion to build a demonstration duplex with a .94 AFUE Carrier furnace with ECM motor and AeroSeal™, Panasonic Whisper Green fans as well as ENERGY STAR lighting (GU24

fixtures), a Noritz tankless hot water system, and active crawlspace ventilation. These demonstration units are expected to benchmark at or above the 40% level.

BAIHP are also working with Equity staff and Minol on an effort to conduct a community scale billing analysis of phases 1 and 2 (including the demonstration homes.) Discussions with Equity on field testing, new technology research and PR event planning are ongoing.

Scott Homes

Figure 4 – Brotherton Farmhouse, 13th Avenue Bungalows by Scott Homes – Olympia, WA

Scott Homes is a production and custom home builder in Olympia, Washington, emphasizing green and energy efficient construction techniques. A Building America partner since 2005, Scott Homes are built with high efficiency shell and equipment measures, including SIP panels, and radiant heating with high efficiency gas combo heat/domestic hot water systems.

In 2005 – 2006 BAIHP staff met extensively with Scott Homes, assessing 10 of Scott Homes' existing and future projects, providing design consultation, preliminary assessment of tax credit qualification, and ENERGY STAR Homes Northwest technical assistance.

BAIHP staff identified key elements in the homes' specifications that were a barrier to compliance with ENERGY STAR, tax credit, and high Building America metrics. One significant element was the use of electric resistance boilers in the standard design; this created a significantly higher compliance threshold for ENERGY STAR, and made compliance for tax credit impossible.

Another element that led to difficulties with both ENERGY STAR and tax credit was the use of traditionally framed ceilings in combination with SIP walls. Envelope leakage rates were higher than anticipated for SIP construction, and made the homes ineligible for the ENERGY STAR BOP for electric resistance homes.

In 2006, BAIHP staff began working with Scott Homes on planning, testing and monitoring of the 13th Avenue Bungalows, the first four of what was originally planned as a 13 home community constructed in Olympia. These homes, designed to meet the Building America

40%+ metric, as well as ENERGY STAR Homes Northwest and the Federal Tax credit, include gas tank-less combo systems, radiant floors, SIP walls, ENERGY STAR lighting and appliances, HRVs and the Energy Detective energy monitor.

All four homes were constructed with a hybrid ceiling – Icynene foam and fiberglass batts. Testing of these homes indicated envelope leakage of 2.42 at ACH. By contrast, Scott homes with 100% SIPS construction tested with leakage rates of under 1.5 ACH. The SIP wall/framed ceiling homes indicated leakage rates of greater than 4.0 ACH. 505050

BAIHP staff deployed HOBO dataloggers in the homes to collect data to evaluate zone temperatures and HVAC performance in 2007. The homes include supplementary electric resistance heat in the upstairs bedrooms; one area of particular interest is how often the supplementary heat operates.

Habitat for Humanity

Figure 5 – Habitat for Humanity cottage project – Olympia, WA,

BAIHP staff are working with BAIHP partner Habitat for Humanity on a 15 unit cottage project in Olympia, WA. The goal is to achieve the 40% metric, using a tankless gas combo hydronic floor heating system with ICFs and advanced framed 2x6 walls with R5 foam sheathing.

Three homes are currently constructed. BAIHP staff are working with Habitat staff to conduct an Energy Gauge analysis of the community. WSU staff are also providing technical assistance and outreach to other Northwest Habitat affiliates.

Subtask 4.5 – Documentation, Resource Development and Related Activities

ASHRAE

BAIHP staff from WSU continue active participation in ASHRAE, including working with other BAIHP partners to co-author five papers for the June 2007 ASHRAE symposium – these papers are listed in the publications section, below.

In addition, BAIHP staff acted as chair of both the TC 6.3 Forced Air Systems subcommittee, and the Proposed Standards 193P committee. This latter effort will be key to producing a standard for a method of testing (MOT) for determining duct cabinet leakage. MOT standard development will begin in fall of 2007.

BAIHP staff co-authored the draft revised standard 62.2 guideline; this effort continues in 2007. BAIHP staff also participated on TC 9.5, and a coordinated effort between ASHRAE and ARI on latent cooling options.

Other BAIHP Partner coordination

- *ACEEE*: BAIHP staff chaired Residential Panel 1 for the 2006 Summer Study, where numerous Building America team papers were presented.
- *Fleetwood Homes*: Coordinated with BAIHP partners at Fleetwood on duct leakage testing research.
- *NFPA*: Worked with BAIHP partners to propose new HUD duct leakage standards in MHCSS for NFPA and HUD MHCC.
- *NIST*: BAIHP staff coordinated with BAIHP partner Energy Conservatory on testing at the NIST test site after retrofit efforts to reduce duct and envelope leakage. Tests indicate 80% reduction in duct leakage and 15% reduction in envelope leakage.

Press, References and Publications

Building America Case Studies

Baechler, M.; Lubliner, M.; et. al. “Fort Lewis Army Base.” Building America Best Practices Series: Volume 5 – *Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Marine Climate.*

Baechler, M.; Lubliner, M.; et. al. “Sam and Christine Garst Build a House.” Building America Best Practices Series for High Performance Technologies: *Solar Thermal & Photovoltaic Systems in the Marine Climate.*

ASHRAE

Baylon, D.; Hales, D.; Lubliner, M.; Peeks, B. “NEEM Mastic Study.” Accepted paper for 2007 ASHRAE Symposium (peer review comments addressed.)

Hadley, A.; Lubliner, M.; Parker, D. “HVAC Improvements in Manufactured Housing Crawlspace-Assisted Heat Pumps.” Accepted paper for 2007 ASHRAE Symposium (peer review comments addressed.)

Fairey, P.; Lubliner, M.; Lucas, R. “National Energy Savings Potential in HUD code Housing from Thermal and HVAC Equipment Improvements”; Accepted paper for 2007 ASHRAE Symposium (awaiting peer review.)

Lubliner, M.; Persily, A.; Nabinger, S. “NIST HUD-code retrofit study” Paper in draft, to be submitted for future publication TBD.

ASHRAE Proposed Standards 193P Subcommittee (chair) – “Method of Test for Determining The air-leakage rate of HVAC equipment – draft under development.

ASHRAE Standard 62.2 technical Subcommittee (co-author) “62.2 Guidelines.” – draft under development.

Home Energy Magazine

Hadley, A.; Lubliner, M. “Zero Energy Manufactured Home.” Article in draft; to be published in 2007.

Appendix E Oregon Department of Energy Annual Report

Oregon Department of Energy

Annual Report for Building America Industrialized Housing Partnership

April 2006 – February 2007

Task 2 – Test House Evaluations

The Northwest Energy Efficiency Manufactured Home (NEEM) program recruited retailers in the region that represented a variety of manufacturers to participate in a pilot program. We asked for the opportunity to do complete lighting retrofits on their model manufactured homes. We targeted retailers who left the model home lights on most of the time.

Conclusions: We were pleasantly surprised at the conclusion of the pilot project. In the past, we had attempted efficient lighting projects with poor results. The retail sales competition in a down climate was not conducive to a successful project. This time, however, the retailers wanted to participate and reacted positively to the efficient lighting installations.

The retailers had questions such as “What if people ask questions?” and “How should we be presenting the new bulbs?” After talking with our retail partners, we developed a program questionnaire sheet, personalized with each retailer’s logo and name. This questionnaire provided the retailers with an organized and simple way to observe themselves and customers walking through their homes.

Energy Star lighting was installed in 37 retail outlet homes to save on energy costs. In addition, two manufactures and 10 retailers are now offering an upgrade 100 percent and 50 percent CFL lighting package. Palm Harbor includes three CFL fixtures standard in their Earth Advantage home. Palm Harbor is considering increasing the percentage of the fixtures as part of an Oregon Department of Energy (ODOE) pilot program. In addition, one manufacturer installed at the factory and shipped 500 bulbs, a 50 percent CFL lighting package, in 20 Energy Star homes.

Random home field-testing

As part of the quality control process, we conducted field studies of a random sample of 41 Oregon and 30 Washington homes manufactured in 1992-93, 1997-98 and 2001-02. Observations during these field tests led the NEEM program staff to suspect that a significant amount of reported duct leakage was due to failure of various duct sealing tapes.

Starting January 1, 2004, NEEM specifications were revised to require all central forced air duct systems to duct mastic for all sealing. To evaluate the efficacy of mastic used to seal ducts combined with in-plant duct leakage testing in the program, we collected field data on 71 homes built after January 1, 2004, with duct systems sealed with mastic and compared it to data from previous studies in the region.

Study design/ recruit select home

The sample selection was one of convenience. We chose to test homes before they were occupied and/or focused on occupied homes built by manufacturers who were also known to be duct testing at least some of their homes at the factory. NEEM staff also tests ducts in the 19 participating plants on a quarterly basis. Ten of the regions 19 factories (including all of the major builders) were represented in the sample. Forty-one homes sited in Oregon were tested from September 2004 through March 2006. Homes tested were all sited, set up and either occupied or ready for occupancy. Thirty homes sited in Washington were tested between March 2005 and August 2005. Homes were visually inspected to confirm the use of mastic and identify obvious deficiencies.

Group	SGC Mfd Homes Built 2001-02 Medians (avgs)			SGC Mfd Homes Built 1997-98 Medians (avgs)	MAP 1992-93 (avgs except for triples)	
	Leakage @ 25 Pa (ft^3/min)	Leakage @ 50 Pa (ft^3/min)	Leakage @ 25 Pa (ft^3/min)	Leakage @ 50 Pa (ft^3/min)	Leakage @ 25 Pa (ft^3/min)	Leakage @ 50 Pa (ft^3/min)
All cases	131 (139) n=94	192 (209)	103 (151) N=47	159 (231)	(104)	(157)
Double section home	119 (132) n=69	180 (199)	97 (157) N=34	157 (240)	(101) n=124	(155)
Triple section home	176 (174) n=22	259 (265)	144 (134) N=13	223 (210)	122 n=11	169
Idaho	127 (151) n=20	187 (229)	106 (165) n=24	168 (254)	-	-
Oregon	135 (134) n=37	200 (198)	NA	NA	-	-
Washington	115 (132) n=39	179 (202)	103 (135) n=25	159 (208)	-	-

3

TABLE 1b
Exterior Duct Leakage (Current Study)

Group	SGC Mfd Homes Built after January 1, 2004 Medians (avgs)	
	Leakage @ 25 Pa (ft^3/min)	Leakage@ 50 Pa (ft^3/min)
All cases (Washington & Oregon)	51 (56) n=66	73 (80)
Single section home	53.0 (53.0) n=2	85.0 (85.0)
Double section home	49 (42) n=41	64 (71)
Triple section home	62 (65) n=21	88 (82)

TABLE 2
Leakage to Exterior Normalized to Conditioned Floor Area

Study	Mean %	Median %
Exterior duct leak @25 Pa/ft^2 of house area (Built after 1/1/2004, 66 homes)	3.4	3.0
Exterior duct leak @25 Pa/ft^2 of house area (2001-02 homes, 89 cases)	7.9	7.5
Exterior duct leak @25 Pa/ft^2 of house area (1997-98 homes, 49 cases)		5.9
Exterior duct leak @25 Pa/ft^2 of house area (1992-93 homes, 150 cases)	7.2	

Share results at semi-annual meetings of NEEM partners

The selection of homes in this study was not random, but it did include 10 of the region's 19 manufacturers and all of the major manufacturers in the NEEM program. Based on this limited sample, indications are that the revision to the specifications starting in January 2004 requiring the use of mastic to seal duct systems has produced a significant improvement in duct tightness over all previous samples in the region. Duct leakage to the exterior after set up was reduced by 43 percent over the next best reported value in the region.

The comparison between the homes that received in-plant duct testing and those that did not showed a distinct improvement in overall performance with an in-plant quality control step. Indeed, about half of the benefit from the change in specifications and the use of duct mastic seem to be attributable to the in-plant testing. This study suggests that in-plant testing is essential to achieving the benefits of the improved duct tightness and installation specifications.

The new NEEM standard is total or net duct leakage shall not exceed 0.06 cfm50 x floor area served by the system or 75 cfm50, whichever is greater.

Decommissioning of older mobile homes

ODOE staff involved in the NEEM Program made progress in introducing studies regarding the decommissioning of older mobile home in cooperation with our industry partners. The Umpqua

CDC and Heartwood ReSources was one of two studies that NEEM staff became involved in that looked at the economics of recycling older mobile homes. NEEM staff presented this study at an Indian weatherization conference. Funding for this project was provided by the Oregon Department of Environmental Quality, Douglas County Public Works Solid Waste Division and Umpqua Community Development Corporation

A Pilot Project for Sustainable Decommissioning

Of Manufactured Housing

A Study of Composition, Cost and Waste Stream Diversion Potential

Best Practices Manual

A Process for Deconstruction, Salvage and Recycling

Methods and Logistics

Umpqua CDC and Heartwood ReSources Roseburg, OR

Winter 2005 / 2006

Task 3: Community Scale Evaluations:

From April 2006 through February 2007, NEEM made final inspections on 167 homes in the Champion plant in Silverton Oregon. Of the Ft. Lewis homes delivered and finished, we duct tested 100 percent, installed compact fluorescent bulbs in 50 percent of the sockets and installed Energy Star built-in appliances in all the homes. ODOE set up a new process to receive and enter Ft. Lewis home performance test data (duct and blower door tests) with Auburn Sheet Metal technicians.

Champion and Ft. Lewis Communities LLC, Equity Housing, built an experimental duplex in December 2006 as part of Building America Industrialized Housing Partnership (BAIHP) project. It was sited and constructed at Ft. Lewis in January 2007. Ft. Lewis Communities LLC, Equity Housing, Washington State University, Champion Homes, and ODOE agreed to test and monitor two test units at Ft. Lewis. Panasonic Whisper Green fans will replace Panasonic 110 cfm. Fans are sized to ASHRAE 62.2 instead of WA VIAQ and were installed in bathrooms replacing the hallway whole house fan. The entire HVAC system will be sealed with Aeroseal. The ESTAR lighting fixtures are being installed in both units as well as T-8 strip lighting will be added above and below kitchen cabinet lighting.

ODOE Progress April 1, 2006 - February 28, 2007	
Ft. Lewis Energy Star homes site built by Champion of Oregon	167
Total	167

Task 4: Lessons Learned

Subtask 4.2 NEEM Program Support

Staff performed quarterly factory inspection visits, inspected problem homes, developed in-plant quality assurance detailed inspection manuals and periodically upgraded the standards to higher levels of energy efficiency. NEEM adopted the Oregon Residential Tax Credit standard for duct leakage as an airtight duct standard. The new NEEM standard is that total or net duct leakage shall not exceed 0.06 cfm50 X the floor area served by the system or 75 cfm50, whichever is greater. Ten out of 10 Oregon plants, four out of five Idaho plants, and one out of two Washington plants test all duct systems in each floor to ensure low leakage ducts using testing equipment. As of June 1, NEEM inspectors are requiring a written response to non-compliant energy details found during quarterly inspections.

Energy Star built-in appliances are being installed in each Energy Star home. Other activities include, but are not limited to:

- NEEM completed utility cost effectiveness for Energy Star homes
- 59 regional utilities and two states now offer incentives and tax credits for NEEM homes
- NEEM met with the industry in September 2006 to discuss two specification proposals and other important issues
- NEEM wrote a two- page summary and distributed to the industry Energy Star manufactured home about federal tax credits update
- NEEM distributed specification clarification on
    - Whole-house ventilation HUD rule

- Foundation ventilation specification change

6

- Spec change proposal from industry setup requirement of elbows on crossovers

ENERGY STAR produced April 1, 2006 to February 16, 2007	
Northwest Energy Efficient Manufactured Homes	
ENERGY STAR Gas	1,263
ENERGY STAR Electric	3,177
Total	4,440

Subtask 4.5 – Documentation, Resource Development and Related Activities
BAIHP project coordination:

• Co-authored and edited ASHRAE paper: "Effect of Mastic on Duct Tightness in Energy Efficient Manufactured Homes"
• Wrote NEEM Mastic Study for USDOE grant
• Authored lighting pilot study
• Presented decommissioning study to Indian Tribe Energy Programs

Other BAIHP Partner coordination:

• Coordinated with BAIHP partners at Fleetwood on duct leakage testing research
• Met with Oregon Building Codes on HUD-code manufactured housing technical issues
• Attended monthly Oregon In Plant Inspection Agency (IPIA) and Oregon State Administrative Agency (SAA) staff meetings
• Copied all in-plant and consumer complaints to State of Oregon IPIA/SAA
• Developed curriculum and taught six two-day classes for HUD code installers and local jurisdiction installation inspectors
• Met informally with Building America stakeholders, as well as DOE and HUD staff at USDOE
• Discussed building science related proposals for HUD code housing
• Worked directly with Panasonic, Broan/Nutone on fan options for HUD code