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Creating Energy Independence

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Table of Contents

Abstract

From 2007 to 2009, the Building America Industrialized Housing Partnership worked with seven partners in the Gulf Coast region. This area sustained damage from Hurricane Katrina and was still in the recovery process. (Figure 1). The High Performance Affordable Housing Demonstration Home was created to give builders in the region a cost-effective model of high performance. This report summarizes our work with the seven partners to implement the proposed affordable, off-the-shelf, energy efficiency packages. The goal was to reach 30% and 40% whole house energy source savings (WHSES) calculated under the 2008 Building America Benchmarking Procedure, standard construction practices, and implementation challenges.

Figure 1: *Locations and number of the Gulf Coast Affordable High Performance Prototype Homes are indicated by the blue* markers. *Yellow markers show additional HFH affiliates worked with during the project, and the red marker indicates an incomplete project.*

Eleven houses were constructed during the project. Four of the houses were completed in 2008 and met the 30% savings goal; however, one of these homes did not meet the program's target duct leakage. Seven more houses were completed in 2009. Of these houses, three met the 40% goal and two met the 30% goal. The two remaining houses failed to reach their target goal. One house had duct leakage in excess of ENERGY STAR criteria, and the other one was not completed by project end which prevented final testing.

Executive Summary

This demonstration project is a Post Phase 3 research activity, ***Task 2.1.2*** under the Building America Industrialized Housing Partnership annual operating plan for 2008. The whole house source energy savings (WHSES) goal for the first prototypes was 30%, as calculated under the *2008 Building America Benchmarking Procedure*, *Standard Construction Practices, and Implementation Challenges* (Hendron, 2008.). This goal was to be achieved while also improving indoor air quality, durability, and comfort. Case studies of three Building America partners[1] in Florida who were already achieving 30% Whole House Source Energy Savings (WHSES) within the Building America Benchmarking revealed that 30% WHSES could be obtained for $1,500 - $2,000 by improving cooling and heating equipment efficiency, reducing cooling and heating loads, selecting ENERGY STAR appliances, and replacing incandescent with fluorescent lighting. Based on these results, BAIHP researchers developed the prototype package outlined in Table 1.

Table 1: *Prototype I Package*

Gulf Coast High Performance Affordable Demonstration Houses

Indoor Air Quality Features

- No atmospheric combustion heating or water heating equipment *(therefore, no combustion safety measures required)*
- Low radon potential *(therefore, no mitigation system recommended)*
- Indoor humidity and infiltration control strategies *(estimated natural ach < 0.35)*
    - House wrap, air sealing, and insulation checklist and inspection *(ENERGY STAR Thermal Bypass Checklist)*
    - Top plate and exterior wall penetrations sealed
    - For frame floors: bottom plate and floor deck penetrations sealed
    - Passive, positive pressure ventilation when Heat/AC operates
    - Heating and cooling equipment right-sized with ACCA Manual J
    - Kitchen and bath exhaust fans ducted to outside for humidity control
    - Interior air handler closet (sealed and separated from attic/crawl space)
    - R-13 wall insulation - dense pack cellulose or batt (fiberglass or recycled cotton) installed to meet RESNET Class I quality requirements
    - Sill seal under bottom plate
    - Can lights (when present) are air tight insulation contact (ATIC) Rated

Durability* Features

- Definitive drainage plane
- Air handler in conditioned space *(less harsh environment than attic)*
- Water heater located in interior or attached storage room
- Long life fiber cement siding
- Ship-lapped window and door flashing
- Kitchen and bath exhaust fans ducted to outside for humidity control
- 2’0” overhangs to direct water away from house

[1] See Appendix C for descriptions and economics from the three case studies.

▪ Slab raised to promote drainage away from foundation
Energy Efficiency Features (HERS Index ~73) ▪ R-30 blown cellulose attic insulation ▪ R-13 wall insulation meeting RESNET Class I requirements ▪ Low-E double pane windows ▪ At least 75% fluorescent lighting ▪ ENERGY STAR refrigerator *(412 kWh/year)* and ceiling fans (when present) ▪ High efficiency heat pump, *(at least SEER 14, HSPF 8.2)* ▪ Interior air handler closet (sealed and separated from attic and crawl space)** ▪ Radiant barrier decking ▪ Sealed air distribution duct system *(Qn,out = 0.03 or less)* ▪ Light colored exterior finishes ▪ Insulated exterior doors with double pane lites ▪ ENERGY STAR Thermal Bypass Checklist ▪ Mechanical system sized using ACCA Manual J or equivalent ▪ Building America Benchmark savings of 30% (HERS Index range 70-75)
**Disaster resistance measures are addressed by prevailing local codes and are outside the scope of this Department of Energy activity.*
Note: Some features are mentioned in more than one category.

Seven chapters of Habitat for Humanity International in the Gulf Coast region agreed to build two high performance prototype houses each as part of the Gulf Coast High Performance Affordable Housing Demonstration Project. These affiliates included Mobile County AL (Mobile), Baldwin County AL (Foley), East (Slidell) and West (Abita) St. Tammany, Baton Rouge and New Orleans LA, and Habitat of the Mississippi Gulf Coast (MSGC) in Biloxi MS. Each of the seven builders worked through a systems engineering process with researchers and made plans to build a prototype demonstration house. If the prototype was successful, participants were encouraged to exceed the specifications of the 30% WHSES package by reaching 40% WHSES with a second prototype.

Under this demonstration task, Building America paid the incremental cost of improving performance from code compliant to the targeted WHSES calculated using the 2008 Building America Benchmark procedure. The maximum cost for the improvement packages was set at $5,000 with a goal of $2,000. Deliverables on this task included the construction of at least eight demonstration houses with documented incremental cost data and two workshops for the Gulf Coast home building industry. Eleven houses in total were completed, four in 2008 and seven in 2009. Six of these houses met the 30% goal, and three houses achieved 40% WHSES. The two remaining homes failed to comply with the project’s goals, due to either excessive duct leakage or lack of final testing. Two Louisiana workshops were conducted in partnership with the affiliates and Louisiana State University’s Agricultural Center (LSU AgCenter) LaHouse Program. A workshop was also held in Mobile AL in partnership with the affiliate and the local Home Builders Association.

Table 2 shows a summary of the successful prototypes' energy use and costs. The range of BA Benchmark WHSES for the successful homes was 30.3% to 43.4% with the HERS Index value ranging from 60 to 73. Three of these houses Benchmarked at or above 40% WHSES, and the remaining houses Benchmarked at or above 30% WHSES. Researchers received expense data showing the incremental cost of $2,334 to $2,780 for 30% WHSES and $3,288 to $6,309 for 40% WHSES for all components of the package. Since none of the participants submitted pricing information for all components, researchers determined an average cost based on the various data points provided. These averages were reported as added estimated costs. Then they were combined with the reported cost data to calculate the total cost of the packages when partners had not provided the actual cost data for a measure. Annual cash flow to the homeowner was calculated by assuming $0.12 /kWh and a 30 year, 7% mortgage.

Table 2: *Prototype House Summary*

House	HERS Index	Total Annual Whole House Source Energy Use				Incremental Cost Information			
		Benchmark (Mbtu)	Prototype (Mbtu)	Savings (Mbtu)	Savings (%)	Reported Cost	Added Estimated Cost	Total Cost	Annual Cash Flow
Mobile House 1	69	54.01	35.94	18.07	33.5%	$1462	$886.50	$2348.50	$179.63
Mobile House 2	60	46.94	26.57	20.37	43.4%	$3176	$1016.50	$4192.50	$186.93
MSGC House 1	69	57.26	36.37	20.89	36.5%	$1491	$843	$2334	$238.46
MSGC House 2	71	58.14	38.87	19.27	33.1%	N/A	N/A	N/A	N/A
Slidell House 1	71	55.80	37.61	18.19	32.6%	$2408.80	$0	$2408.80	$206.67
Slidell House 2	73	55.80	38.89	16.91	30.3%	$2408.80	$0	$2408.80	$161.84
Foley House 1	68	63.41	41.53	21.88	34.5%	$1670	$1109.50	$2779.50	$231.83
Foley House 2	60	55.11	31.90	23.21	42.1%	$5000	$1308.63	$6308.63	$55.82
Abitta House 1	64	69.92	41.94	27.98	40.0%	$3096.34	$191.50	$3287.84	$339.67

The workshop in Mobile, Alabama was only comprised of participants from other Habitat for Humanity affiliates despite significant efforts in promoting the workshop to the general home building community. Two workshops in Louisiana, in partnership with the LSU AgCenter's La House program, drew participation from non-profit affordable housing builders in Louisiana and Mississippi including the general construction community. Researchers also presented information on the demonstration project to the general membership of ACCA in Mobile County.

Introduction to Building America

The Florida Solar Energy Center (FSEC) is a research institute of the University of Central Florida (UCF). FSEC leads the Building America Industrialized Housing Partnership (BAIHP) (www.baihp.org), one of the U.S. Department of Energy's Building America (BA) teams. BA teams partner with home builders across the country to conduct cost shared research that will accelerate the nationwide establishment of cost effective, production ready energy technologies. These partnerships also contribute to the development of technologies that can be widely implemented by new home producers to achieve 30% to 50% savings in whole house energy use. BAIHP focuses on affordable housing builders and factory builders (HUD code, Modular and Panelized).

Initially, BA researchers work through a "systems engineering" process (Figure 2) with the builder to evaluate the builder's current designs, specifications, details, and construction processes. Researchers also work with builders to set goals, identify high priority improvements, anticipate conflicts, and develop a quality control strategy.

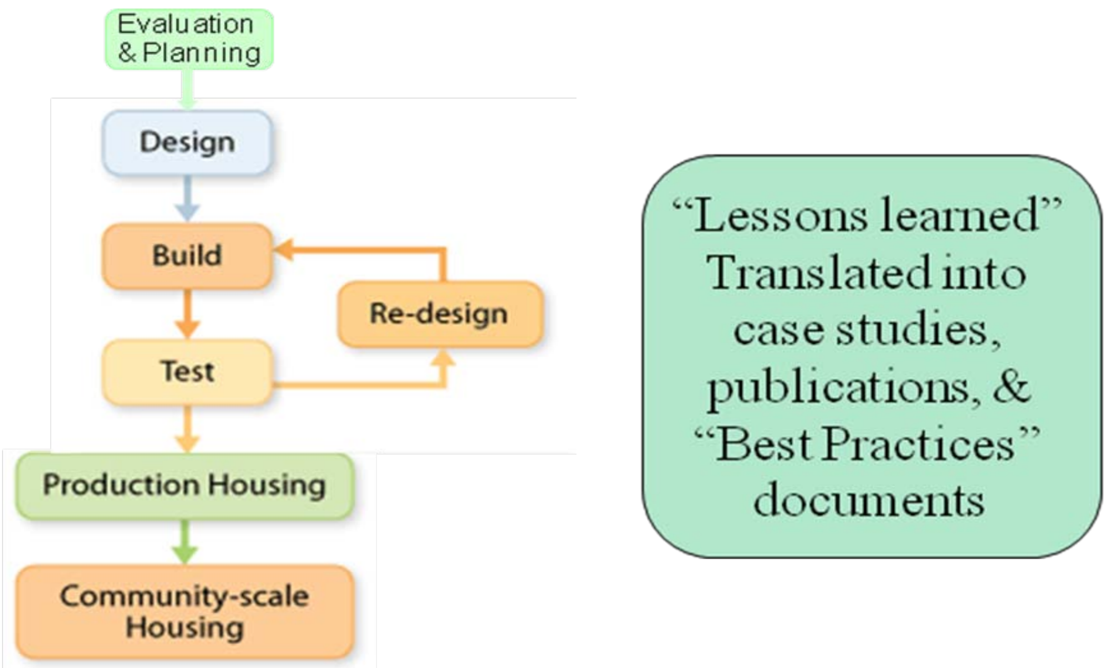

Figure 2: *The Systems Engineering Process*

The culmination of the systems engineering process is the production of a prototype house that embodies the changes deemed necessary to meet the builder's goal. For the affordable demonstration houses, the goal was 30% Whole House Source Energy Savings (WHSES) for the first prototypes, as calculated using the BA Benchmark procedure (Hendron, 2008.) To track progress toward aggressive multi-year, whole-house energy savings goals, Building America developed a Research Benchmark in consultation with other Building America teams. The Benchmark is generally consistent with mid-1990s standard practice, as reflected in the Home Energy Rating System (HERS) Technical Guidelines (RESNET 2002), with additional definitions and detail that allow analysts to evaluate advanced technologies in all residential end-use categories. Unlike the reference homes used for HERS, ENERGY STAR, and most energy codes, the Benchmark represents typical construction at a fixed point in time so it can be used as the basis for Building America's multi-year energy savings goals without the complication of chasing a "moving target." Link to U.S. DOE's Benchmarking information.

After building a prototype (Prototype I), refinements are sometimes needed in the package of improvements, the quality assurance approach, or the design. If necessary, these refinements will be implemented in a second prototype (Prototype II). If no refinements are needed, steps are then taken to achieve 40% WHSES in Prototype II. The final step is for the builder to implement the changes in their production process to build whole communities that meet the new high performance goal.

Through this process, Building America partners in the hot-humid climate zone have demonstrated cost neutral paths to achieving 30% WHSES, as calculated under the BA Benchmarking procedure, while maintaining or improving indoor air quality, durability, and comfort (McIlvaine, et. al., 2007.) Hundreds of homes across the southeastern region have been built to this performance standard *(See Appendix C).*

Introduction to the Gulf Coast High Performance Affordable Housing Demonstration Project

In a post-disaster environment, builders face many challenges and are often reluctant to embrace unnecessary change as they struggle to cope with disrupted supply chains, labor shortages, and new codes. There is also an urgent demand for housing after a disaster that begs the home building industry to produce homes at rates far exceeding pre-disaster production levels. These challenges often overshadow the desire to re-build better homes.

Under normal circumstances, Building America's contributions to the construction of prototype homes are limited to technical assistance and evaluation. Since the disastrous hurricane season of 2005, Building America has provided abundant technical assistance to builders in the Gulf Coast region; however it has not led to wide-spread adoption of higher performance specifications. This project goes beyond typical Building America assistance by providing funds for non-profit partner builders to cover their incremental costs for building demonstration houses that achieve 30% whole house source energy savings (WHSES) based on the2008 Building America Benchmark (Hendron, 2008.). The Benchmark is generally consistent with mid-1990s standard practice, as reflected in the Home Energy Rating System (HERS) Technical Guidelines (RESNET 2002), with additional definitions and detail that allow analysts to evaluate advanced technologies in all residential end-use categories.

The purpose of the Gulf Coast demonstration project was to educate builders about a cost effective approach to achieving higher performance buildings that could be easily adapted to the homes they built. Applicability to a wide range of housing types was a major consideration in choosing the package of improvements.

This demonstration project illustrates the feasibility of achieving 30% WHSES in the challenging affordable housing sector. To mitigate the risk associated with changing specifications and implementing new details, BA covered the cost of the improvement package and staff time in addition to the normal complement of BA technical assistance. This was a highly unusual provision and was only provided due to the unique opportunity to influence the massive rebuilding activity in the Gulf Coast region.

The Building America partners that build the demonstration houses documented the incremental cost of the high performance packages (beyond code compliance and customary practice), including staff time, and were reimbursed up to a maximum of $5,000 per house with the goal of keeping the incremental cost under $2,000. The cost goal and special consideration for the applicability of improvements to the general home building community were the guiding factors in the selection of the high performance improvement package.

After completing each demonstration house the builders were asked to provide cost data and a summary of the lessons they learned. This information was then shared with the broader home building community through the web page, workshops, and other communication avenues.

Proposed Prototype I Demonstration House Package

Case studies of three Building America partners[2] in Florida already achieving 30% Whole House Source Energy Savings (WHSES) within the Building America Benchmark revealed that 30% WHSES could be obtained for $1,500 - $2,000 by improving cooling and heating equipment efficiency, reducing cooling and heating loads, selecting ENERGY STAR appliances, and replacing incandescent bulbs with fluorescent lighting. Drawing from this previous work, researchers conducted Benchmarking exercises with designs from two of the demonstration project partners. The following set of specific improvements were identified as likely to achieve the targeted 30% WHSES and the broader indoor air quality, durability, and comfort goals that are part of all Building America activities.

Energy Efficiency Components of the Gulf Coast High Performance Affordable Housing Demonstration Project:

- R-30 attic insulation meeting RESNET Grade I requirements
- R-13 wall insulation meeting RESNET Grade I requirements
- R-30 floor insulation, or un-insulated slab-on-grade
- Low-E double pane ENERGY STAR qualified windows
- 75% or more fluorescent lighting
- ENERGY STAR refrigerator *(412 kWh/year or less)* and ceiling fans (when present)
- High efficiency cooling and heating equipment
    - *SEER 14, HSPF 8.2 heat pump* ***or better***
    - *Or AFUE 80% gas furnace with SEER 14 Straight AC* ***or better***

[2] See Appendix C for descriptions and economics from the three case studies.

- Interior air handler closet (sealed and separated from attic and crawl space)
- Radiant barrier decking
- Sealed air distribution duct system *(Qn,out = 0.03 or less)*
- Light colored exterior finishes
- Insulated exterior doors with double pane lites
- Continuous whole house air barrier
- ENERGY STAR Thermal Bypass Inspection Checklist
- Mechanical system sized using ACCA Manual J or equivalent

As part of the Benchmarking exercises, researchers found that this package of improvements produced a HERS Index ranging from 69 to73 when modeled with slab-on-grade or pier foundations and in different cities throughout the Gulf Coast region.

Some of these critical specifications were already in place as standard construction practices with the partners participating in the demonstration project. The standard practices of 2008's five partners are delineated in Appendix A and discussed in the baseline evaluation material in the next section.

Demonstration Houses and Workshops

Throughout 2007 and 2008, researchers recruited partners, developed the package of improvements, and set up a project web page at www.baihp.org/gulfcoast. By the end of 2008, four demonstration houses were completed in Mobile (1), Gulf Port (1), and Slidell, LA (2) with a fifth underway in Baton Rouge. Two houses attempted by New Orleans Area Habitat did not pass the Thermal Bypass Inspection due to poor installation of floor insulation. One of the houses built by Slidell failed to meet the Gulf Coast Demonstration Program's duct leakage target of Qn > 0.03; however it qualified for ENERGY STAR while meeting the project's 30% WHSES goal.

In 2009, Mobile and MSGC each built an additional demonstration house bringing the total to seven homes completed. New partners in 2009, Covington (Abita) LA and Baldwin County (Foley) HFH in coastal Alabama each produced two additional demonstration houses, bringing the total houses to eleven. Unfortunately, one of the houses in Covington failed both the project's and ENERGY STAR's duct leakage criteria. The home built by Baton Rouge was not completed by program's end. Although cost data was provided, no final testing was ever conducted.

Nine demonstration houses that exceeded the project's 30% WHSES criteria were completed. The program resulted in eight houses that met ALL project criteria (WHSES ≥30%, including three houses with WHSES ≥ 40%), two houses that did not meet the project's duct leakage criteria, and one house that remained unfinished with no final testing at project's end. Additionally, the project resulted in nine houses that were registered with the ENERGY STAR program.

In addition to the demonstration houses, deliverables for this task included workshops for home builders and sub-contractors in two locations in the Gulf Coast Region.

Researchers conducted a workshop in Mobile in November 2008, one in Baton Rouge in December 2008, and one in Covington LA in 2009. In Mobile, the Metro Mobile Home Builders Association promoted the workshop to 1,800 members. Researchers also promoted the workshop to the affordable housing community in the area through the state HUD office. However, attendance was not high enough to count this workshop as a successful effort. In Baton Rouge and Covington, the workshop was hosted in partnership with LSU AgCenter's La House program and promoted by the Capital District Home Builders Association (Baton Rouge) and the partner Habitat for Humanity Affiliates. Louisiana licensed builders who participated received four or six CEUs.

Workshops included a morning classroom session with a testing demonstration and site visit after lunch. In Mobile, attendees visited the Habitat affiliate's demonstration house and viewed the testing demonstration in a nearby house under construction. In Baton Rouge, the testing demonstration was conducted at La House with a site visit to one of the partner affiliate's house under construction to discuss the Thermal Bypass Checklist. In Covington, the testing demonstration and Thermal Bypass field trip were conducted in two of the partner Habitat affiliate's houses under construction. Construction staff from the Habitat affiliates' demonstration house partners was available to answer questions and discuss their experiences.

Summary of Partners Participating in the Demonstration Project

After discussing the demonstration project with many affordable housing providers in the region, seven Habitat for Humanity International affiliates (local chapters) agreed to participate (Figure 3). They are located in Mobile County AL (Mobile), Baldwin County AL (Foley), East (Slidell) and West (Abita) St. Tammany, Baton Rouge, and New Orleans LA, and Habitat of the Mississippi Gulf Coast (MSGC) in Biloxi. Habitat for Humanity International (HFHI) is a non-profit, affordable housing provider that operates through a network of over 1600 domestic affiliates.

Figure 3: *Locations and number of the Gulf Coast Affordable High Performance Prototype Homes are indicated by the blue* markers*. Yellow markers show additional HFH affiliates worked with during the project, and the red marker indicates an incomplete project.*

Habitat builds homes with volunteer construction crews. Usually the construction management staff and subcontractors for mechanical, electrical, and plumbing are paid. Each Habitat affiliate operates independently but builds homes in accordance with basic design criteria set by HFHI. Thus, there is much similarity in the size and design of the demonstration homes due to HFHI criteria (See Appendix B for floor plans and elevations for Demonstration houses).

Habitat homes are sold to qualified buyers who also contribute hundreds of hours of "sweat equity." In general, Habitat affiliates finance the homes using a 0% interest mortgage for 15-30 years depending on the family's ability to pay.

Because of the volunteer process and 0% loans, the actual cost to the Habitat affiliates for executing some of the performance improvements may be lower than achievable in standard for-profit construction. Additionally, the house size may influence overall cost since, at 1070 to 1200 square feet, Habitat builds homes that are substantially smaller than the America average.

Mobile County (AL) HFH

BAIHP conducted an initial site visit with this affiliate in November 2007. FSEC staff reviewed plans, conducted a thermal bypass evaluation and tested a completed home. Duct leakage was well within specification for ENERGY STAR, and BAIHP made minor recommendations for passing the thermal bypass inspection. Preliminary analysis showed the homes achieving a HERS Index of 95 and Benchmark savings of 13% WHSES. In an effort to bring specifications in line with ENERGY STAR for all their homes, the affiliate agreed to build two 30-40% WHSES prototypes.

The first prototype was completed in November of 2008 with a WHSES of 31% and a HERS Index of 69 (Figure 4). BAIHP presented the project to the general membership of the local chapter of the Air Conditioning Contractors of America (ACCA), and a workshop was produced in conjunction with the Home Builders Association of Metro Mobile on November 20, 2008. Despite direct mail promotion to over 1700 members of the HBA, attendance predominately consisted of local raters and other Habitat affiliates from south Alabama and the Florida panhandle. The workshop agenda and presentation are available on line at www.baihp.org/gulfcoast. The site visit portion of the workshop generated considerable discussion from attendees.

A second high-performance affordable prototype was completed in 2009 that included increased attic (R-38) and wall insulation (R-3 exterior), a SEER 15 ENERGY STAR heat pump, and an electric heat pump water heater with a COP of 2.3. These improvements were added to the previous prototype package to produce a BA Benchmark savings of 43.4% WHSES and a HERS Index of 60 (Figure 4). Ratings on the house were completed by a local rater and were also certified green by a local green building program. The affiliate is a participant in Habitat International's Partners in Sustainable Building program which provides a $5,000 grant for ENERGY STAR/green certified homes to offset the increased first cost of the home.

Figure 4: *Mobile County Habitat 30% Prototype (left) and 40% Prototype (right).*

New Orleans Area HFH (LA)

BAIHP performed multiple design reviews, provided energy efficiency and general building science technical assistance, and tested homes for ENERGY STAR thermal bypass compliance for this affiliate. Their homes initially achieved a HERS Index of 115. The main problem with the houses was extremely leaky return plenums and high infiltration. The air handler was located in an interior closet that was open to the attic. This setup provided combustion air for the atmospheric combustion gas furnaces. Return plenums were open to the walls of the closet with no attempt to create an air barrier. FSEC discussed methods of securing safe combustion while resolving the infiltration and leaky ducts issue. In 2007, New Orleans HFH committed to building one all-electric ENERGY STAR home and one gas/electric ENERGY STAR home.

In January 2008, BAIHP revisited this affiliate to conduct diagnostic duct testing and field testing of recommendations with Joe Ryan, a DOE contractor based in New Orleans. Results were excellent with duct leakage being brought into specification for ENERGY STAR certification along with significant improvement in whole house air tightness. Also in 2008, the affiliate switched to all radiant barrier roof sheathing. In the spring of '08, BAIHP conducted training for the construction staff on wall insulation, installation, and inspection for the thermal bypass checklist. Researchers also identified air sealing problems that needed to be resolved before the trial prototype home was constructed. In mid 2008, this partner committed to building two all electric 30% WHSES prototypes using the improvement package that BAIHP developed. The affiliate began construction on the side-by-side prototype homes (Figure 5). Unfortunately, the homes both failed the thermal bypass inspection in October of 2008. In particular, the floor insulation was not in contact with the air barrier, a very common problem in the region. Guidance on correcting the failed items was provided to the affiliate's construction staff. BAIHP also conducted floor insulation training with this group. Near the end of 2008, a large portion of the construction staff left the affiliate which brought our partnership activity to a standstill. It was anticipated that the affiliate would resume participation in the demonstration in 2009; however no further progress was made despite attempts to re-energize the partnership with the new staff members.

Figure 5. *New Orleans Area Habitat 30% Prototypes – both failed the TBIC.*

HFH of Greater Baton Rouge (LA)

In July 2007, FSEC began analysis of HFH of Greater Baton Rouge site-built homes. The homes built by this affiliate were already achieving a HERS Index of about 80 and WHSES of 25%. In November 2007, they agreed to build a 30%-40% WHSES prototype. In January of 2008, BAIHP visited the affiliate to work on specifications for the 30% to 40% WHSES. This process included identifying which floor plan and site would be used, identifying problems, coordinating with sub-contractors, and developing solutions on paper. Two homes passed the thermal bypass inspection for ENERGY STAR homes in February of 2008 but failed the final testing in March of that year.

Figure 6. *Baton Rouge Habitat 30% affordable demonstration house.*

Construction of a new 30% WHSES prototype began in March of ’08 (Figure 6). The major challenge for this affiliate was locating the air handler in the conditioned space. Numerous meetings with the HVAC sub-contractor were held to discuss the details. Ultimately the strategy was abandoned in the first attempted prototype because the truss layout had not been designed to allow adequate space for the supply plenum to enter the attic from the top of the air handler (AHU) closet. Shortly after this incident, the construction manager was replaced, and plans to build the prototype were put on hold. Throughout 2008, there were a number of management changes that delayed construction of a prototype home, but the affiliate began its third attempt at construction on a 30 % WHSES prototype in November of ’08.

On December 5, 2008, in conjunction with the Baton Rouge HFH affiliate, the LSU AgCenter’s La House, and the Capitol District Home Builders Association, BAIHP conducted a workshop worth four CEUs for Louisiana contractors. The approximately 30 attendees included university students and faculty, raters, non-profit home builders, and for profit production builders.

The HFH of Greater Baton Rouge prototype home underwent a Thermal Bypass Inspection in January 2009 and passed the assessment. Work on the home was suspended when the buyer withdrew from Habitat's program early in 2009. Consequently, the prototype home was not completed by program's end.

Slidell (LA) - East St. Tammany HFH

In 2007, BAIHP researchers discussed ENERGY STAR requirements with the site supervisor and construction manager at this affiliate. Researchers made suggestions for improving the thermal envelope and air barrier, including a strategy for enclosing the air handler closet at the attic interface. Throughout 2007, the affiliate worked on improving these envelope issues including the air barrier separating the air handler closet from the attic. In January 2008, BAIHP tested several houses and found favorable results. This affiliate also worked with their utility's builder incentive program to improve their specifications. The initial HERS Index for this affiliate was approximately 95. They began construction of two 30% prototype houses in September of 2008. They passed the TBIC but needed improvements to their outside air system. The homes were completed in December of 2008 and were part of the 2008 Jimmy and Rosalind Carter Work Project (Figure 7). Final testing and rating were conducted in January of 2009 resulting in 32.6% and 30.3% WHSES savings. HERS Indices were 71 and 73 respectively. It is interesting to note that the only difference between the homes was the amount of duct leakage. The second, poorer scoring house missed the project's target duct leakage rate or Qn out > 0.03 but achieved ENERGY STAR standards with a qualifying Qn out of 0.06.

Figure 7: *East St. Tammany Habitat for Humanity in Slidell, Louisiana*

Biloxi (MS) - HFH of the Mississippi Gulf Coast (MSGC)

BAIHP researchers conducted analysis and Thermal Bypass Inspections for HFH of MS Gulf Coast homes in various stages of construction in June 2007. BAIHP researchers prepared a detailed report providing guidance on how to correct the many deficiencies found with regard to the Thermal Bypass Checklist. The affiliate expressed interest in achieving ENERGY STAR; however the demands of the 2007 Jimmy Carter Work Project precluded progress until 2008. In the spring of 2008, this affiliate was chosen to participate in the pilot phase of the HFHI Partners in Sustainable Building program. After attending training conducted by BAIHP and other building scientists for the pilot affiliates in October of 2008, the construction manager contacted BAIHP and committed to building two 30% WHSES prototype demonstration homes. The first home was completed in December of 2008 with final inspection, testing and rating in January of 2009. It achieved BA Benchmark savings of 36.5% with a HERS Index of 69. This affiliate completed their second prototype home in May of 2009 with a HERS Index of 71and BA rating of 33.1% (Figure 8).

Figure 8: *Mississippi Gulf Coast Habitat high performance affordable prototypes.*

Covington/Abita Springs (LA) – West St. Tammany HFH

In the fall of 2008, researchers met with the construction manager and conducted an initial evaluation of their homes including duct and whole house air tightness testing. Researchers outlined changes necessary to reach ENERGY STAR and the 30% WHSES prototype level. After consideration, the affiliate decided not to proceed with BA partnership at that time.

In 2009, the affiliate hired a new construction manager who had worked with the Gulf Coast Affordable Prototype Project in Slidell in 2008. Under his leadership the affiliate committed to building two 30% WHSES prototype houses, one slab-on-grade and one pier foundation (Figure 9). Testing on both houses was completed in September 2009. The slab-on-grade house's duct system was too leaky to qualify the house for ENERGY STAR (Qn=0.09). The pier foundation home achieved a BA WHSES of 40% with a HERS Index of 64. The home incorporated the BAIHP Gulf Coast Package along with increased attic insulation (R-38) and an ENERGY STAR SEER 15 heat pump.

Figure 9: *West St. Tammany Habitat high performance affordable prototypes.*

BAIHP again partnered with LSU AgCenter's LaHouse program and West St. Tammany HFH to present a workshop for home builders on June 23, 2009 in Covington, LA. Louisiana licensed builders who participated in the workshop received four or six CEUs.

Foley (AL) – Baldwin County HFH

In November of 2008, BAIHP researchers met with a HERS rater, Andy Bell, who was hired by the Alabama Association of Habitat Affiliates (a State level Habitat support organization) to work with HFH affiliates throughout the state. BAIHP and Bell visited the Baldwin County HFH affiliate and conducted testing of a finished house in Foley, located south of Mobile. The house and the duct system were within tightness specifications for building a 30% prototype. A prototype home was completed in 2009 (Figure 10) and incorporated a modified energy improvement package by using a galvalume or white metal roof instead of radiant barrier decking. Final inspection and testing of the first prototype was completed in June, 2009 and resulted in a BA WHSES of 34.5% and a HERS of 68.

The affiliate completed construction of their second prototype home in October of 2009. The home features the Gulf Coast Package with increased R-values, a white metal roof, and a solar hot water heater with an EF of 2.3. The home achieved a HERS Index of 60 with a Benchmark WHSES of 42.1%.

Figure 10: *Baldwin County HFH high performance prototypes.*

Table 3 summarizes the successfully completed Demonstration houses. The 2008 BA WHSES is shown as "Savings (%)" in the last column of the table.

Table 3: *Results of Completed Demonstration Houses*

House	HERS Index	Total Annual Whole House Source Energy Use			
		Benchmark (Mbtu)	Prototype (Mbtu)	Savings (Mbtu)	Savings (%)
Mobile House 1	69	54.01	35.94	18.07	33.5%
Mobile House 2	60	46.94	26.57	20.37	43.4%
MSGC House 1	69	57.26	36.37	20.89	36.5%
MSGC House 2	71	58.14	38.87	19.27	33.1%
Slidell House 1	71	55.80	37.61	18.19	32.6%
Slidell House 2	73	55.80	38.89	16.91	30.3%
Foley House 1	68	63.41	41.53	21.88	34.5%
Foley House 2	60	55.11	31.90	23.21	42.1%
Abita House 1	64	69.92	41.94	27.98	40.0%

Partners' Baseline Construction Practices

Part of the systems engineering process is to determine a baseline energy performance. Researchers conducted numerous site visits with each of the partners to evaluate standard practices and to introduce improvement concepts. Initially, researchers calculated a HERS Index and BA Benchmark WHSES for the typical construction practices of each partner.

The Habitat for Humanity partners typically build homes with conditioned areas of 1000-1200 square feet and three or four bedrooms. Appendix B includes floor plans and elevations for each partners' demonstration houses. Specific baseline characteristics are delineated in Appendix A. In general, the typical construction characteristics of the demonstration partners included:

Roof/Attic

- Shingles
- Radiant barrier decking
- Trusses (some raised heel)
- R-30 blown in fiberglass or batt ceiling insulation

Walls/Windows

- 2x4 wood frame construction
- Fiber cement siding
- House wrap with window flashing
- R-13 wall insulation (fiberglass batt, recycled cotton, or spray in cellulose)
- Double pane windows (clear or low-E)
- Sill seal or double bead of silicone caulk under sole plate

Floor/Foundation

- Uninsulated slab on grade with vapor barrier underneath
- Pier foundation with frame floor (w/R-19 batt or R-11 spray foam)

Appliances/Lighting

- ENERGY STAR Whirlpool refrigerator
- Fluorescent lighting in 10-75% of built in fixtures, including screw-in CFLs

Heating, Cooling, Water Heating

- Minimum efficiency cooling (SEER 13 straight cool or heat pump)
- Minimum efficiency heating (HSPF 7.7 heat pump, AFUE 80 gas furnace, or electric resistance furnace)
- Central return air plenum
- Air handler in attic, uninsulated interior closet open to the attic, or uninsulated interior closet separated from attic by air and thermal barriers
- Duct board supply plenum with R-4.3 or R-6 flex ducts to prefab junction boxes and boots
- Standard tank water heating

Baseline Testing Results and Recommendations

In addition to reviewing standard construction practices, researchers also conducted baseline air tightness testing with each partner. The results for whole house and duct system air tightness are shown in Table 4.

Table 4: *Baseline Testing Results*

			Whole House Air Tightness			Duct Air Tightness			
Date	**Affiliate**	**Area**	**CFM50**	**ACH50**	**Estimated Natural Infiltration**	**Total Leakage**	**Qn,total**	**Leakage to Out**	**Qn,out**
		ft2	**cfm**	**ach**	**ach**	**CFM25,tot**	**CFM25,tot / Area**	**CFM25,out**	**CFM25,out / Area**
12/6/07	Baton Rouge	1670	1520	6.83	0.34	205	0.12	103	0.06
3/6/08	Baton Rouge	1100	1050	7.16	0.36	152	0.14	98	0.09
3/6/08	Baton Rouge	1100	1015	6.92	0.35	195	0.18	125	0.11
12/5/07	Mobile	900	900	7.50	0.38	NA	NA	45	0.05
10/12/07	MSGC	1222	1446	8.87	0.44	273.5	0.22	121.5	0.10
10/11/07	New Orleans	1034	1506	10.92	0.55	362.5	0.35	275	0.27
10/11/07	New Orleans	1034	1635	11.86	0.59	NA	NA	NA	NA
10/12/07	New Orleans	1025	1400	10.24	0.51	250	0.24	200	0.20
12/4/07	New Orleans Mid-point	NA	NA	NA	NA	100	NA	NA	NA
1/24/08	New Orleans	1100	1503	10.25	0.51	290	0.26	220.5	0.20
1/24/08	Slidell	1120	1324	8.87	0.44	112	0.10	78	0.07
Average		1130.5	1329.9	8.9	0.45	215.6	0.20	140.7	0.13
Median		1100.0	1423.0	8.9	0.44	205.0	0.20	121.5	0.10
Minimum		900.0	900.0	6.8	0.34	100.0	0.10	45.0	0.05
Maximum		1670.0	1635.0	11.9	0.59	362.5	0.35	275.0	0.27

Baseline whole house air tightness: The whole house air tightness test results (Figure 11) indicated higher infiltration than the average code compliant Florida home, which has been shown to have an average ACH50 of 5.2 (Swami, et al, 2006). The average of the entire baseline testing in all five locations was 8.9 air changes per hour at 50 pascals (ACH50). Even the tightest house tested (ACH50 of 6.8) did not approach the Florida average. For the demonstration houses, researchers were looking for significant improvement of whole house air tightness, not just for energy efficiency, but also to ensure good indoor air quality and increase the life of the building and components. For further reference, a sample of 102 homes in Gainesville that achieved the 30% WHSES goal had an average ACH50 of 4.4 (Fonorow, et. al. 2007).

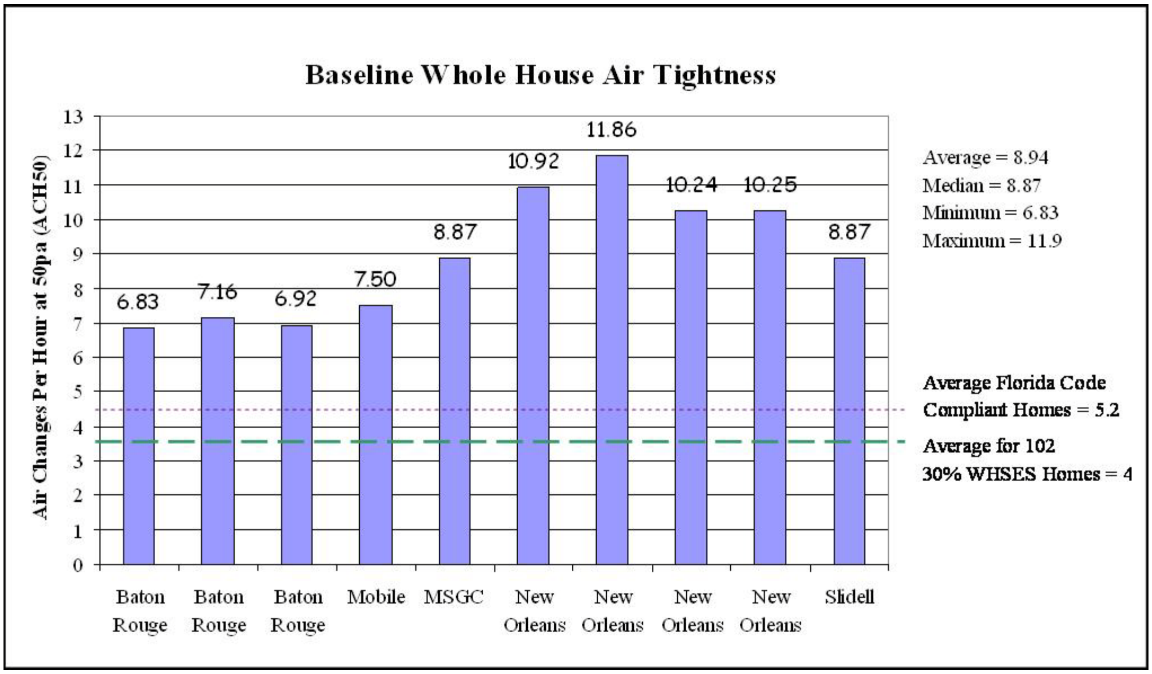

Figure 11. *Baseline whole house air tightness testing results*

All of the affiliates were using house wrap as part of the whole house air barrier (and wall drainage plane); however they were not sealing the top and bottom edges to the exterior wall sheathing. They were also filling penetrations for wiring and plumbing with foam or caulk in the top and bottom plates. Some exceptions were seen in New Orleans where researchers observed that penetrations through the bottom plates and floor decking, such as under the bathtub, were often left unsealed.

There were other major problems with the approach to the whole-house air barrier in New Orleans and, to a lesser extent, in Slidell and Covington. A typical area standard practice is to leave the AHU closet open to the attic to insure combustion air for a gas furnace. Quite often this practice is carried out in all-electric houses. Additionally, the central return plenum, located under the AHU platform, was open to the wall cavities of the AHU closets. In many cases, researchers observed penetrations in air handler closets that connected return plenums to the attic. This occurrence resulted in significant duct leakage.

In New Orleans, larger than usual quantities of air could be felt at all electrical outlets and switch plates on exterior walls. An examination of homes under construction revealed a hurricane strapping detail at the top plate that created a gap of about ¼ of an inch between the top plate and interior dry wall on all of the exterior walls. This created an air flow path between the attic and all of the exterior wall cavities. In addition, the AHU closet door was a standard interior door and did not provide an air barrier between the conditioned space and the above attic. During testing, air could be felt rushing around the door, and insulation was inadvertently pulled down from the attic into the closet.

BA Recommendations for whole house air tightness: The following recommendations were expected to reduce the estimated natural infiltration to 0.35 air changes per hour (ACH), the target for the demonstration houses.

- Seal all edges and seams of house wrap
- Eliminate gaps created by hurricane strapping on exterior walls
- Fill all penetrations in floor decking, ceiling drywall, top and bottom plates
- Completely separate the air handler closet from the attic
- Weather strip the attic access panel

Baseline duct air tightness testing: Like the whole house testing results, the baseline duct testing results from the five 2008 affiliates (Figure 12) were higher than expected with an average leakage to outside of 0.13 CFM per square foot of conditioned space measured at 25 pascals ($Qn_{,out}$). With the exception of two houses, all of the baseline tests exceeded the leakage limit set by the performance path of the ENERGY STAR program of $Qn_{,out} \leq 0.06$. For reference, the 102 houses in Gainesville achieving 30% WHSES on the BA Benchmark had an average $Qn_{,out}$ of 0.044 (Fonorow, et. al, 2007.)

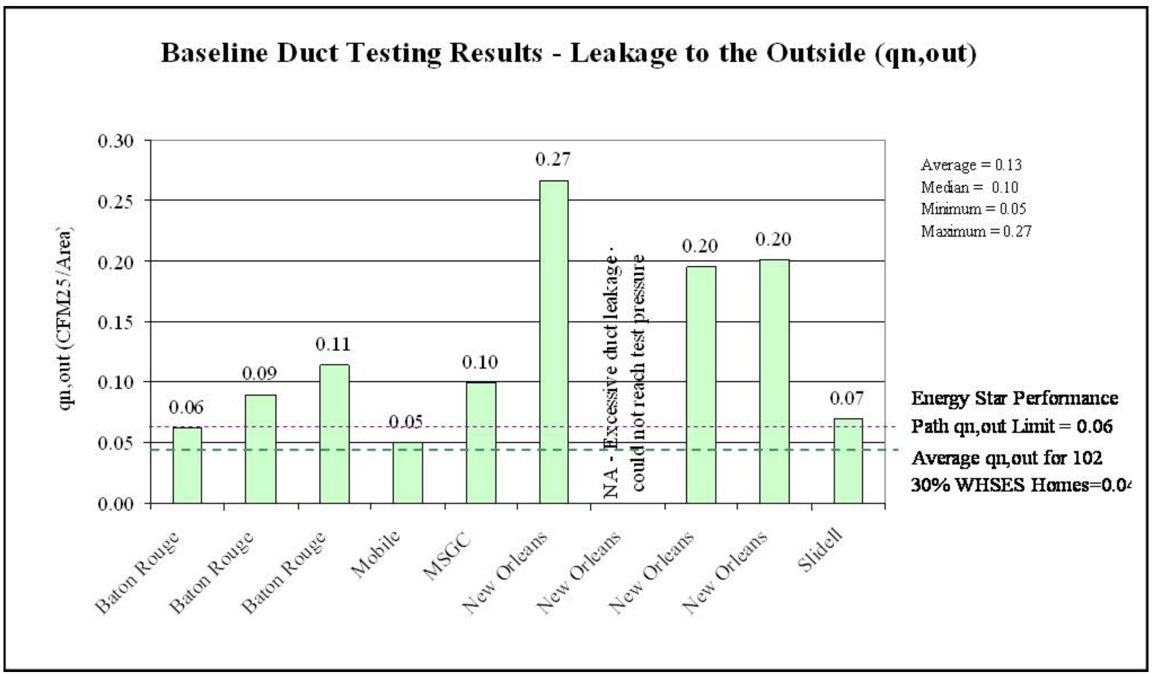

Figure 12: *Baseline duct testing results*

The houses observed during baseline testing placed their air handlers in either the attic, in an uninsulated interior closet open to the attic, or in the desired configuration: an uninsulated interior closet separated from attic by air and thermal barriers. The execution of this detail had a large impact on the measured duct leakage and whole house air tightness.

Houses with air handler closets had a central return plenum located under the AHU platform. This placement was often observed to be open to the wall cavities of the closet which connected the return plenums to the attic. Extensive duct leakage resulted from this configuration.

All of the Baton Rouge HFH duct systems included an attic mounted air handler. This installation compromised the attic floor insulation level; R-30 was blown in except under the air handler flooring where R-19 batt was installed with gaps and significant compression. Attic installed air handlers are a large mass located in a hot environment, therefore increasing the thermal load that the A/C must remove to provide effective cooling. Additionally, air handlers have been shown to have an average leakage of 30 cfm at 25 pascals (Cummings, et. al., 2003). In homes with air handlers in the attic all of this would be leakage to the outside. Likewise, the return duct was attic mounted and a significant leakage point was located at the connection between the return grill and the ceiling drywall. Moving the air handler to the conditioned space was expected to reduce Baton Rouge's duct Qn_{out} to between 0.03 and 0.06.

The Mississippi Gulf Coast (MSGC) and Alabama (Mobile and Foley) affiliates were already building an interior air handler closet and return plenum that were well isolated from the attic. This suggested that the MSGC high leakage (Qn = 0.10) was in the supply system which was not sealed with mastic. Before beginning their demonstration house, this affiliate elected to work with a mechanical contractor that uses mastic, which brought the leakage into the target range.

Mobile employs two mechanical contractors; one a RESNET certified home energy rater, and both consistently producing duct systems in the target leakage range. A similar level of quality duct work was found in Baldwin County.

The New Orleans test results all reflect leakage far in excess of typical duct systems. Working with Joe Ryan, a DOE contractor in New Orleans, BA researchers identified the open return plenums and air handler closets (described above) as the likely root of the excessive duct leakage. To further investigate the situation, researchers conducted a "mid-point" total leakage test (on 12/4/07) which characterizes the leakage of the supply ducts and the air handler. The system had total leakage of only 100 cfm, less than half the leakage of previous New Orleans results, all of which included the open return. To further validate the theory, a house was tested, repaired, and then retested on 1/24/08. The repair included sealing the return plenum with mastic and installing an air barrier in the top of the air handler closet. Both duct leakage and whole house infiltration dropped significantly (Table 5). Duct leakage to the outside was dropped to 0.06 cfm per square foot, the ENERGY STAR limit, which validated BA's recommendations.

Table 5: *New Orleans Baseline Testing and Repair Results*

			Whole House Air Tightness			Duct Tightness			
Date	**Affiliate**	**Area**	**CFM50**	**ACH50**	**Estimated Natural Infiltration**	**Total Leakage**	**Qn,total**	**Leakage to Out**	**Qn,out**
12/4/07	New Orleans Mid-point (w/AHU but no return plenum)	NA	NA	NA	NA	100	NA	NA	NA
1/24/08	New Orleans	1100	1503	10.25	0.51	290	0.26	220.5	0.20
1/24/08	New Orleans (Above House Repaired)	1100	1207	8.23	0.41	127.5	0.12	61	0.06

The as-found duct leakage in Slidell and Covington was high, and the AHU closets were open to the attic. The construction staff of the affiliate decided to undertake the task of applying mastic to the ducts, sealing the return plenum, and installing a ceiling in the air handler closet. Final testing of both affiliates' prototype houses showed that this method of duct sealing was not practical. In Slidell, one house had a Qn_{out} of 0.06, meeting ENERGY STAR but not meeting the project's 0.03 criteria. In Covington (Abita), one of the houses had a Qn_{out} of 0.09 and did not meet any program's leakage criteria. Further training and more effort would be needed on the affiliates' part to successfully seal the duct systems. Visual inspect indicated that effective duct sealing after installation would require the flex duct to be removed from the collars and collars removed from boxes. Then they would need to be reinstalled and sealed with mastic. A much better option would have been to require mastic sealed duct work from the HVAC contractor.

BA Recommendations for duct system air tightness: The following recommendations were expected to reduce the duct leakage to the outside down to 0.03 cfm per conditioned square foot at 25 pascals, the target for the demonstration houses.

- Install the air handler and central return plenum in the conditioned space
- Finish walls and ceiling of air handler closet to isolate space from attic and crawl space
- Seal penetrations in the air handler closet
- Avoid using building cavities as air flow paths
- Seal all duct system joints with fiberglass mesh and mastic
- Seal duct "boots" and grills to drywall

Further Improving Whole House and Duct Air Tightness: The desired level of air tightness and duct tightness is achieved through greater attention to the details of the whole house air barrier and its interface with the duct system. The primary targets for improved sealing were the air handler closet walls above the platform, the many joints of the central return plenum including those in the rough opening where the filter back grille unit seats, and the gaps separating the ceiling drywall from the supply plenum and supply boots and grills. If the attic access hatch or pull-down stair is not well-fitted, an improved gasket and/or cam device may be added to reduce whole house infiltration at this point.

Finally, back caulking the window unit and nailing flanges before they are set to connect the windows to the house wrap (air barrier) can also improve house air tightness.

The common construction of the central return plenum in the region is to finish the framed platform under the air handler with sheetrock. This is the accepted code-approved practice in all of the demonstration project jurisdictions. It appears that of the seven partners, only two of them deal with a code body that expressly requires the return plenum to have a fire resistant, sealed finish. Those two jurisdictions are the City of Mobile (Alabama) and East St. Tammany Parrish (Louisiana). In both jurisdictions, researchers discussed the details of the return plenum (and the passive outside air ventilation strategy) with the chief mechanical inspector.

ENERGY STAR as an Intermediate Step Towards 30% Goal

The three BA case studies of partners achieving 30% WHSES (Appendix C) document that each partner made incremental changes over a period of months or years. Achieving ENERGY STAR is a logical intermediate step on the path to 30% WHSES because it lays the building science foundation for controlling air and moisture flow, a fundamental premise of achieving high performance. It also introduces builders to the Home Energy Rating System (HERS).

Identifying this intermediate step is important not only for the demonstration partners but also for the builders we seek to influence with the demonstration project. The transformation from typical construction in the region to 30% WHSES requires significant change. While some organizations may prefer to make all of the changes at once, many will need to make incremental changes to allow time for adjustment. Suggesting a hierarchy for change will help builders plot a course that first lays a strong foundation for high performance and then builds on success.

Researchers recommend that builders hoping to emulate the demonstration project begin by working with a home energy rater to get an initial ENERGY STAR evaluation. That was the first step researchers took with each of the original 2008 demonstration partners. A baseline home energy rating was calculated based on the standard construction characteristics (see detailed list in Appendix A) gathered through site visits and testing. Researchers also provided feedback on how close each partner was to achieving ENERGY STAR under the National Performance Path (U.S. EPA, 2006.)

Researchers used Energy Gauge USA software to calculate the HERS Indices and Whole House Source Energy Savings (WHSES) under the 2008 BA Benchmark procedure.[3] As shown in Table 6, baseline HERS Indices ranged from 82 to 120, and baseline Benchmark WHSES ranged from 2.5% to 23.1%.

Given that the demonstration effort required a commitment of only two houses, researchers provided training to the partners on how to achieve ENERGY STAR

[3] Originally, analysis was conducted using the 2006 BA Benchmark procedure, but calculations were updated when the 2007 and 2008 procedures were released.

certification using the National Performance Path (U.S. EPA, 2006.) as both a goal for standard construction and also as the first step toward building the demonstration houses.

To raise awareness and improve on-site quality assurance, researchers worked with each partner's construction director and staff. They also conducted short seminars and on-site training at the New Orleans, Slidell, Covington, and Mobile affiliates. Baldwin County has a small construction staff, and the affiliate was already building an exemplary house As a result, very little training was required except for changes to the specifications. Our partner in Covington hired a construction supervisor in 2009 who had worked with us in Slidell in 2008, leading his affiliate on the path of ENERGY STAR and beyond. In Baton Rouge, the structure of the construction staff was in too much flux to arrange this training. Researchers worked with the final house leader and the liaison between the construction and administrative departments. The construction director at the Mississippi Gulf Coast affiliate conducted internal training after attending a 2.5 day workshop[4] associated with a HFHI sustainability program.

Table 6: *Building America Benchmark Calculations for Baseline Construction Characteristics*

Category	Component	HFH of Greater Baton Rouge	New Orleans Area HFH (Gas)	New Orleans Area HFH (Electric)	East St. Tammany HFH (Slidell)	Mobile County HFH	Mississippi Gulf Coast HFH
Home Energy Rating	**Base Line HERS Index (MBtu)**	**82**	**102**	**120**	**85**	**91**	**110**
Whole House Site Energy Use (MBtu)	"Benchmark House"	63.338	74.102	55.637	57.301	53.392	56.961
	Base Line "Prototype House"	48.679	64.793	54.222	44.672	44.156	52.773
	Savings	14.659	9.309	1.415	12.629	9.236	4.188
	% Site Savings	**23.1%**	**12.6%**	**2.5%**	**22.0%**	**17.3%**	**7.4%**
Whole House Source Energy Use (MBtu)	Baseline "Benchmark	213.13	167.08	187.22	192.81	179.66	191.67
	Base Line "Prototype House"	163.8	144.34	182.45	150.32	148.58	177.58
	Savings	49.33	22.74	4.77	42.49	31.08	14.09
	% Source Savings	**23.1%**	**13.6%**	**2.5%**	**22.0%**	**17.3%**	**7.4%**

Steps Needed to Reach ENERGY STAR

Typical of the region, all of the partners were using R-30 ceiling insulation and at least R-13 wall insulation, though four of the partners needed to improve insulation quality. Duct leakage, discussed above, also needed improvement. Two of the partners met the HERS Index criteria for achieving ENERGY STAR because they had already incorporated radiant barrier decking, ENERGY STAR windows, and a minimum efficiency heat pump (instead of electric resistance heating). However, many of the partners were unable to pass all of the criteria on the ENERGY STAR Thermal Bypass Inspection with their standard construction practices. The Baton Rouge affiliate had participated in a state-wide program of the Louisiana Department of Natural Resources, now defunct, that awarded grant money to builders achieving ENERGY STAR under the 1999 HERS Guidelines. The Slidell affiliate participates in a local utility program that gives

[4] J. McIlvaine was an instructor at this workshop and recruited the Mississippi Gulf Coast affiliate to participate in the demonstration project.

incentives for peak-reducing energy efficiency improvements. Other builders with experience in these programs may be good candidates for Building America partnerships to reach 40% WHSES in the region.

BA Recommendations to Partners on Achieving ENERGY STAR

- To pass the Thermal Bypass Inspection
  - Maintain contact between insulation and primary air barrier
  - Seal penetrations in air barrier (drywall, top/bottom plates, and floor decking)
  - Seal edges and seams of house wrap
  - Install sill seal or equivalent under bottom plate
  - Install air barrier between ceiling insulation and porch ceiling
  - Insulate and weather strip attic access panel/stairs
  - Improve insulation quality
  - Switch to ICAT recessed lighting fixtures
- Request a Manual J calculation
- Satisfy the ENERGY STAR product requirement with ENERGY STAR windows
- To meet the duct leakage to the outside requirement (6 or less cfm per 100 square feet of conditioned space at the test pressure of 25 pascals) and implement the duct system improvements outlined above, specifically:
  - Install the air handler and central return plenum in the conditioned space
  - Finish walls and ceiling of air handler closet
  - Seal penetrations in the air handler closet
  - Avoid using building cavities as air flow paths
  - Seal all duct system joints with fiberglass mesh and mastic
- To lower HERS Index, in addition to duct, air handler, and infiltration changes
  - Install radiant barrier roof decking
  - Install compact fluorescent lamps in up to 20% of screw base fixtures (take additional credit for any pin base fluorescent fixtures)
  - Install Heat pump or 80-85 AFUE furnace
  - Install ENERGY STAR rated windows

Indoor Air Quality, Durability, and Comfort Improvements

In addition to energy efficiency, the demonstration project includes goals for indoor air quality, durability and comfort. The highest of these goals is to ensure combustion safety. Although none of the final demonstration houses had gas heating or water heating, one of the original New Orleans houses was slated to be a gas house, accounting for about 50% of their 100+ home Musician’s Village build. Natural gas is very common in the Gulf Coast region, and homeowners may replace existing electric units with gas equipment in the future. Ensuring combustion safety is even more essential in high performance houses. It is essential that combustion safety be addressed before the builder makes any changes in their standard construction practices, including the changes needed to reach ENERGY STAR. Unintentional changes in air flow dynamics can adversely affect the operation of minimum efficiency, atmospheric combustion gas furnaces and water heaters. The result can lead to toxic and moisture laden exhaust in the conditioned space.

One way to ensure there is no spillage or back drafting is to specify direct or forced vent furnaces and water heaters. While these items are not currently required by the ENERGY STAR performance path, they will improve a home's HERS Index because they also have higher efficiency ratings.

The detailing of the demonstration houses is designed to:

- Minimize infiltration to reduce levels of pollen, dust, and insect dander (common allergy/asthma triggers)
- Control indoor relative humidity to 50% or less
- Control the flow of bulk water over the building envelope and away from the foundation
- Maintain pressure in closed bedrooms below +2pa with respect to the main body of the house
- Protect heating and cooling equipment by installing it in conditioned space

Meeting these goals requires a plan for controlling air and moisture movement. The Manual J system sizing, whole house air barrier, and duct tightness requirements of the ENERGY STAR program are fundamental to achieving these goals, particularly by limiting pathways for outside air, attic air, and insects into the home. Roach dander, oak and pine pollen, and dust mite detritus are common allergy/asthma triggers (Chandra, et al., 1996.)

Dust mites proliferate at relative humidity levels above 50%. Keeping relative humidity at 50% or slightly lower also improves occupant comfort, allowing for a higher thermostat set point. Relative humidity increases through moisture generated by cooking and bathing. Using ducted exhaust fans in the kitchen and bathroom(s) can reduce whole house relative humidity. After the demonstration houses were completed, owners were instructed not to run their air handlers in the "Fan On" position, which reintroduces moisture that the air conditioner has removed from the house.

Keeping rain water, blowing rain, and irrigation water out of the building assemblies is essential for durability. This goal is not always possible, so assemblies should be able to dry to the inside, the primary direction of moisture flow in the hot, humid climate. The demonstration houses did not have any interior vapor flow retarders. To keep water away from water sensitive wood products, the demonstration partners used house wrap as both an air barrier and a drainage plane. Initially, some of the partners were not installing exterior wall sheathing above the top plate (the top of the conditioned space.) While the ENERGY STAR guidelines focus on alignment of the house air barrier with the insulation, the house wrap should cover all exterior wall sheathing when it is also serving as a drainage plane behind vented cladding. In the project homes, researchers found that window and door flashing was not always being installed in a ship-lap fashion with the house wrap. This correction was a high-priority because window and door penetrations are the most likely areas for water damage. Site grading to promote flow of water away from the house was already being done by most of the partners though it was not indicated on construction documents.

None of the partners were installing passive return air pathways from any bedrooms. The durability issue here was related to the accidental depressurization of the main body of the house when bedroom doors were closed, preventing air from returning when the central heating or cooling equipment was operating. The depressurization pulls moisture laden air through the floor, ceiling, and/or walls to compensate for the air that is trapped in the bedrooms. The consequence of this dynamic is multi-fold. The hot, humid air pulled through the building envelope may meet surfaces at dew point or promote mold growth in unconditioned cavities. It requires more energy to condition than re-circulated air. Hot, humid air is often pulled directly into the return plenum through unsealed gaps and joints, bypassing the filter and depositing dust and pollen in the air handler. All of these consequences have a negative impact on energy use, indoor air quality, durability, and comfort.

The rooms most likely to need passive pressure relief are those with multiple supply registers behind a single bedroom door, such as a master bedroom with a bathroom and a conditioned closet. Because the demonstration houses were small affordable homes, this occurrence was not as common as it would have been in the general production housing or custom housing markets. During preliminary evaluations, it was an issue in Mobile where the master bedroom included a half bath. The affiliate installed a passive jump duct connecting the bedroom with the main body of the house in their demonstration house. Pressure testing verified that the 2 pascal pressure difference was not exceeded.

Recommendations to partners for meeting the IAQ, durability, and comfort goals

- Continuous drainage plane over all exterior wall sheathing integrated with window flashing
- Site grading to promote water flow away from the house
- Capillary break at the ground
- Exhaust fans in kitchen and bath ducted outside
- Passive return air pathways where interior doors separate more than one supply register from the central return **OR** the pressure in the room is more than 2 pascals different than the main body during air handler operation

Reaching the 30% Whole House Saving Goal

Achieving ENERGY STAR was pursued as an intermediate step and a reasonable level of efficiency for the partners to adopt for standard construction. The goal of the demonstration project was to exceed ENERGY STAR by approximately 15%, reaching the 30% WHSES under the 2008 BA Benchmarking procedure. To accomplish this objective, researchers identified several additional energy improvements that were consistent with our partners' priorities. In addition to saving more energy, further moisture and air flow control was provided by adding an inexpensive passive outside air ventilation strategy.

- Use at least 75% fluorescent lighting (combination of pin base and screw base)
- Install ENERGY STAR ceiling fans (when present)

- Select higher efficiency cooling and heating equipment
  - SEER 14, HSPF 8.2 heat pump or better, or
  - SEER 14 straight AC with AFUE 90+ gas furnace or better
- Choose light colored exterior finishes
- Choose exterior doors with low-E double pane lites (when glass present)
- Install passive, supply only, run-time ventilation with manual damper and filtration
- Reduce whole house infiltration to less than 1 cfm per square foot at the 50 pascal test pressure (to produce estimated natural infiltration to 0.35 air changes per hour or less)
- Reduce duct leakage to Qn_{out} = 0.03 or less

Specifications and Quality Assurance: The first five items listed above are straight forward changes in specification. They must be integrated into procurement procedures and, where applicable, into scopes of work for sub-contractors. Although these changes do not impact on-site work significantly, it is important to have a quality assurance procedure in place to ensure that the specifications are being met. With the demonstration house partners, this was a special project, so the project managers took responsibility for verifying that what was installed matched what was specified.

This step is particularly important when specifying equipment or installation details that differ from typical construction. While the sub-contractor's staff responsible for developing bids may be well aware of the change in specs, there is a chance that this information will not be fully communicated to the installation crew. This issue occurred in one of our demonstration houses even though the owner of the company was fully aware of the details required. Tying payment of invoices to field verification can be an effective mechanism for ensuring that specifications are met; however, it does not ensure that they will be met the first time. Re-installation sets the schedule back and disrupts the work of other crews. In an effort to prevent field errors initially, we are recommending that the specifications and installation details be posted on site where the installation crew will see them and, if possible, that a project manager meet the sub-contractor's crew on site to review these before work begins. This strategy can address another cause of field errors that occurs when the crew does not have the correct materials, tools, or equipment with them. Having a project manager there to discuss the installation may prevent the crew from installing what they have instead of what is specified.

Passive, supply only run-time ventilation with manual damper and filtration: Additional improvement in moisture control is provided with a passive outside air ventilation strategy commonly referred to as "run-time" ventilation. A small duct delivers outside air from a filtered intake in the soffit or porch ceiling directly to the return plenum. It is situated as close to the air handler as possible. A small amount of outside air, approximately 40 cfm (see Appendix D for calculation details), is drawn through the duct when the air handler is running. The outside air mixes with house air and becomes part of the stream of air flowing through the air handler and on to the rest of the house. The air handler dehumidifies this air directly before it is introduced into the rest of the house. The effect, in essence, is that more air is being supplied to the house than is being removed through the return grill. The result is a slight positive pressure with respect to the outside. This slight positive pressure prevents infiltration of outside air through the envelope, a major source of moisture in the hot humid climate. This installation also provides some pressure relief during exhaust fan operation or similar events. An accessible manual damper is provided allowing occupants the option of closing the outside air pathway if needed, such as if there is a fire in the area. For full details see Appendix D.

The run time ventilation was the most unfamiliar element of the package for our partners and their mechanical contractors. In the first round of demonstration houses, this detail was executed with varying degrees of success. The primary challenges were the interface of the outside air duct with the soffit and the provision of filtration at that point, the size and configuration of the outside air duct and damper, the air duct interfering with air handler/wall clearances, and whether or not to insulate the outside air duct.

Researchers specified a filter back grille for the outside air intake. Only one of the four houses completed at the end of 2008 had a grille, and it was not a filter back grille. The other three terminated the outside air duct in the soffit, which will not provide adequate outside air flow. All of the mechanical contractors did provide a close mesh insect screen over the intake end of the duct. The mechanical contractors cited concern that owners would not change a filter at the soffit and also the lack of local availability as the primary reasons for not meeting this specification. An alternative installation of the filter in the designed space under the air handler could rectify this situation by replacing the outside filter back grill. If this route is pursued, the HVAC contractor must not run the copper or condensate lines in front of the filter access, which is the typical compact installation. The air handler closet may have to be slightly reconfigured to accommodate the re-routed lines.

Researchers specified 2-inch thin wall PVC or 4-inch flex duct for the outside air duct based on laboratory experiments with prototype systems (see Appendix D). Two of the houses built in 2008 had the PVC outside air duct, one had the flex duct, and one had the hard pipe. Initially, two of the systems were installed without a damper and had to be revamped.

Test Results for the Prototype I Demonstration Houses: All of the partners implemented the specification changes, and by implementing the above recommendations in the demonstration houses, our partners were able to meet the goals for whole house and duct air tightness. In the second demonstration house built in Slidell, the duct leakage to out exceeded the BA target of $Qn \geq 0.05$ but did conform to the ENERGY STAR criteria of ≥ 0.06. The second house in Covington had a Qn of 0.07 and missed both targets. Baton Rouge was unable to find homeowners for their house by the end of the program, so the house was never tested. The final testing results of nine demonstration houses are shown in Table 7.

Table 7: *Demonstration House Testing Results*

			Whole House Air Tightness			Duct Tightness			
Date	House #	Area	CFM50	ACH50	Estimated Natural Infiltration	Total Leakage	Qn,total	Leakage to Out	Qn,out
		Ft2	cfm	ach	ach	CFM25,tot	CFM25,tot / Area	CFM25,out	CFM25,out / Area
11/20/08	Mobile House 1	1073	842	5.89	0.22	NA	NA	35	0.033
10/03/09	Mobile House 2	902	448	3.73	0.12	N/A	N/A	20	0.022
12/19/08	MSGC House 1	1143	912	5.98	0.17	117.5	0.10	26	0.023
06/27/09	MSGC House 2	1169	1119	7.18	0.31	N/A	N/A	38	0.033
12/19/08	Slidell House 1	1120	1052	7.04	0.25	133	0.12	43	0.038
12/19/08	Slidell House 2	1120	1175	7.87	0.35	138	0.12	61	0.054
06/26/09	Foley House 1	1248	916	5.50	0.22	125	0.10	52	0.042
11/13/09	Foley House 2	1056	495	3.51	0.11	N/A	N/A	35	0.033
11/29/09	Abita House 1	1262	805	4.78	0.15	147	0.12	60	0.048

HERS Ratings and Benchmarking for the Demonstration Houses

Researchers calculated the HERS Index and WHSES Benchmark, shown in Table 8 and Figures 13 and 14, for nine demonstration houses completed. The 30% WHSES goal was met in six of the demonstration houses, and 40% WHSES was achieved in three of the houses.

Table 8: *Demonstration House HERS Indices and Benchmark Whole House Source Energy Savings (WHSES)*

		Total Annual Whole House Site Energy Use				Total Annual Whole House Source Energy Use			
House #	HERS Index	Benchmark (Mbtu)	Prototype (Mbtu)	Savings (Mbtu)	Savings (%)	Benchmark (Mbtu)	Prototype (Mbtu)	Savings (Mbtu)	Savings (%)
Mobile House 1	69	54.01	35.94	18.07	33.5%	181.73	120.92	60.81	33.5%
Mobile House 2	60	46.94	26.57	20.37	43.4%	157.95	89.41	68.54	43.4%
MSGC House 1	69	57.26	36.37	20.89	36.5%	192.68	122.38	70.3	36.5%
MSGC House 2	71	58.14	38.87	19.27	33.1%	195.64	130.81	64.83	33.1%
Slidell House 1	71	55.80	37.61	18.19	32.6%	187.78	126.56	61.22	32.6%

Slidell House 2	73	55.80	38.89	16.91	30.3%	187.78	130.85	56.93	30.3%
Foley House 1	68	63.41	41.53	21.88	34.5%	213.37	139.75	73.62	34.55
Foley House 2	60	55.11	31.90	23.21	42.1%	185.45	107.33	78.12	42.1%
Abita House 1	64	69.92	41.94	27.98	40.0%	235.27	141.11	94.16	40.0%

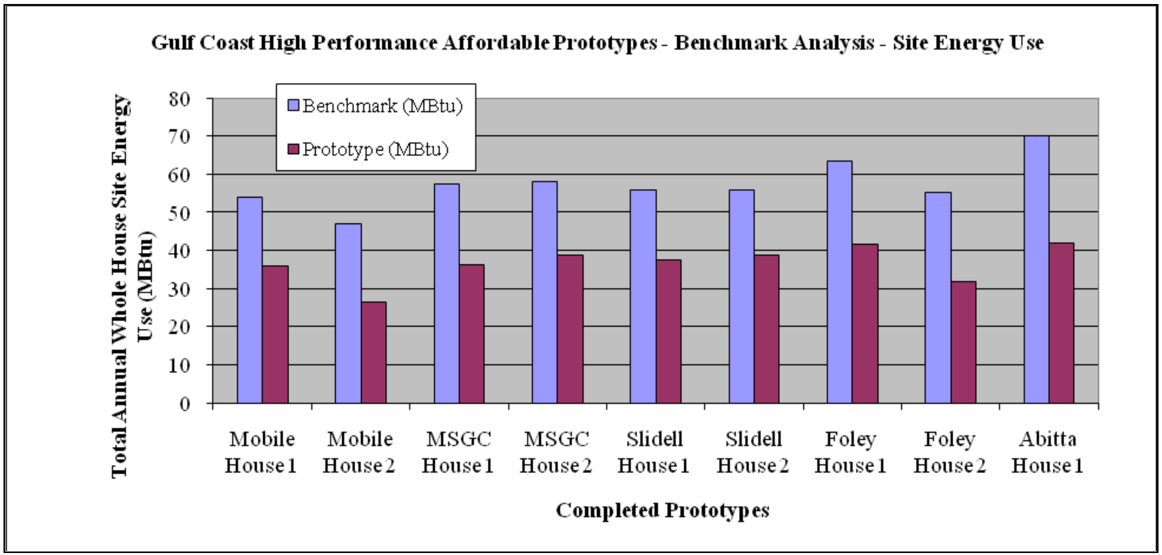

Figure 13: *Benchmark Site Energy use*

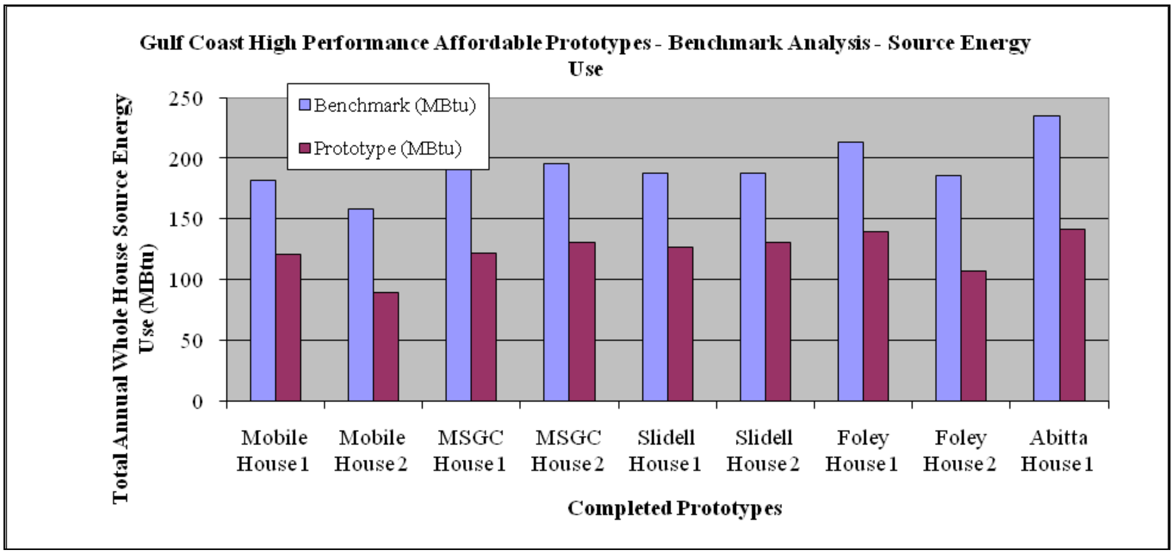

Figure 14: *Benchmark Source Energy use*

Energy Code Considerations

BAIHP began working with this project prior to Louisiana's July 2007 adoption of the 2006 International Energy Conservation Code. Louisiana made one exception to the code: return and supply duct insulation is only required to be R-6 instead of R-8. Alabama and Mississippi do not have a mandatory energy code.

Cost Data and "Lessons Learned" Submitted by Partners

Under this demonstration project, BAIHP established a sub-contract with each partner to pay the incremental cost of improving performance from code compliant to the goal of 30% whole house source energy savings (WHSES - 2008 Building America Benchmark). In addition to the hard cost associated with equipment and labor, the sub-contract covered staff time for implementing the improvements and for learning how to apply them. The maximum cost for the improvement packages was set at $5,000 with a goal of $2,000. The sub-contract included an itemized list of costs with supporting documentation and a summary of lessons learned by the construction director.

All affiliates reported costs for different items, but no affiliate reported costs for all items. Some of the recommended efficiency improvements were already being implemented by some or all of the affiliates; however, improvements varied from locale to locale. To account for this variability, all costs for a particular improvement were averaged, and this average was used in lieu of missing reported data to standardize costs. There were two basic "packages", Prototype 1 (30% WHSE) and Prototype 2 (40% WHSES). 40% WHSES was achieved in two ways: by addressing hot water heating or by maximizing the Prototype 1 package. Table 9 summarizes the average costs of Prototype 1 (30% WHSES), Table 10 the hot water method of 40% WHSES, and Table 11 the 40% WHSES Prototype 1 improvement.

Table 9: *Average Incremental Costs, 30% WHSES*

Average Standard	30% Improvement	30% Incremental Cost	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$128.80	$6.44	$10.28
standard decking	rbs decking (46)	$138.00	$6.90	$11.01
HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 14 HP	$680.00	$34.00	$54.26
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$571.00	$28.55	$45.57
Standard vent fan	vent to out fan (2)	$110.00	$5.50	$8.78
Standard Ceiling Fans	ESTAR Ceiling Fans (4)	$317.00	$15.85	$25.30
Incandescent Lighting	Screw CFL Lighting (20)	$31.00	$1.55	$2.47
	Pin CFL Lighting			
Miscellaneous				
Materials		$202.00	$10.10	$16.12
Additional Labor		$231.00	$11.55	$18.43
TOTAL		**$2,408.80**	**$120.44**	**$192.22**

Table 10: *Average Incremental Costs for 40% WHSES with hot water improvement*

Average Standard	40% Improvement Hot Water	40% Incremental Cost	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$128.80	$6.44	$10.28
standard decking	rbs decking (46)	$138.00	$6.90	$11.01
Hot Water and HVAC** **including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 14 HP	$680.00	$34.00	$54.26
Electric Tank	Heat Pump or Solar	$2,259.00	$112.95	$180.27
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$571.00	$28.55	$45.57
Standard vent fan	vent to out fan (2)	$110.00	$5.50	$8.78
Standard Ceiling Fans	ESTAR Ceiling Fans (4)	$317.00	$15.85	$25.30
Incandescent Lighting	Screw CFL Lighting (20)	$31.00	$1.55	$2.47
	Pin CFL Lighting			
Miscellaneous				
Materials		$202.00	$10.10	$16.12
Additional Labor		$231.00	$11.55	$18.43
TOTAL		**$4,667.80**	**$233.39**	**$372.49**

In keeping with the method used for DOE's Stage Gate process, the incremental first costs associated with the Mobile Demonstration Houses are reported in Table 12. Actual reported costs are highlighted in RED. Other costs are estimated by the average costs shown in Table 9. The total reported cost was $2,348.50. Habitat for Humanity finances the purchase of the homes they build at 0% interest. This incremental cost adds $117.43 annually over the life of a 20 year, 0% mortgage commonly used by Habitat affiliates. When amortized over the life of a more typical 30 year, 7% mortgage, it adds $187.69 annually.

To track progress toward aggressive multi-year, whole-house energy savings goals, Building America initially developed a Research Benchmark in consultation with the Building America teams. The Benchmark is generally consistent with mid-1990s standard practice, as reflected in the Home Energy Rating System (HERS) Technical Guidelines (RESNET 2002), with additional definitions and detail that allow analysts to evaluate advanced technologies in all residential end-use categories. Unlike the reference homes used for HERS, ENERGY STAR, and most energy codes, the Benchmark represents typical construction at a fixed point in time. It can be used as the basis for Building America's multi-year energy savings goals without the complication of chasing a "moving target." Link to U.S. DOE's Benchmarking information.

Table 11: *Average Incremental Costs for 40% WHSES via Package Improvements*

Average Standard	40% Improvement Envelope	40% Incremental Cost	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$128.80	$6.44	$10.28
standard decking	rbs decking (46)	$138.00	$6.90	$11.01
	R-3 wall sheathing	$340.00	$17.00	$27.13
R-30 attic	R-38 attic (1050)	$83.00	$4.15	$6.62
HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 15 HP	$1,080.00	$54.00	$86.18
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$571.00	$28.55	$45.57
Standard vent fan	vent to out fan (2)	$110.00	$5.50	$8.78
Standard Ceiling Fans	ESTAR Ceiling Fans (4)	$317.00	$15.85	$25.30
Incandescent Lighting	Screw CFL Lighting (20)	$31.00	$1.55	$2.47
	Pin CFL Lighting			
Miscellaneous				
Materials		$202.00	$10.10	$16.12
Additional Labor		$231.00	$11.55	$18.43
TOTAL		**$3,231.80**	**$161.59**	**$257.90**

As the Benchmark home represents mid 90s building science, a further comparison is needed to truly see the energy impact of the prototype house on regional standard building practice. To this end, a "Regional Standard Practice" building was generated from the prototype buildings. Each prototype software model was changed to the following specifications and designed to meet 2004 International Energy Conservation Code.

- R-30 attic, R-13 wall, R-19 floor (frame floor only) insulation
- Single pane vinyl windows (SHGC=0.8 U=0.95)
- Heat Pump SEER 13 HSPF 7.7
- Duct Leakage $Q_{n\ out}$ 0.08
- Infiltration 0.35 ACH

Table 12: *Mobile Demonstration House Incremental First Costs (reported by the builder)*

Mobile Co. Standard	30% Improvement	30% Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$256.00	$12.80	$20.46
Standard Decking	RBS Decking	$136.00	$6.80	$10.87
Standard Exterior Doors	Hi-R Exterior Doors	$206.00	$10.30	$16.46
***HVAC** including duct upgrade and fresh air inlet*				
SEER 13 HP	SEER 14 HP	$650.00	$32.50	$51.95
SEER 13 HP	SEER 15 HP			
Hot Water				
Electric Tank Hot Water	Heat Pump Hot Water			
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$320.50	$16.03	$25.61
Standard vent fan	vent to out fan (2)	$104.00	$5.20	$8.31
Incandescent Lighting	Screw CFL Lighting	$95.00	$4.75	$7.59
Incandescent Lighting	Pin CFL Lighting			
Miscellaneous				
Materials		$6.00	$0.30	$0.48
Additional Labor		$575.00	$28.75	$45.95
TOTAL		**$2,348.50**	**$117.43**	**$187.69**

Building America's goals are reductions in source energy (i.e. at the power plant). The energy savings of the demonstration houses are summarized in Table 12 for Mobile 30% BA Benchmark Prototype and all other demonstration houses in Appendix F. Estimated source energy savings for individual load components of the prototype house are expressed as a percentage of end use reduction or percentage of total load reduction. End use reductions are for individual component's savings, and total load reductions represent the individual component's impact on overall savings.

Table 13: *Annual estimated energy usage for Mobile CO House 1*

Mobile Co 30%	Annual Source Energy			Estimated Source Energy Savings			
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard
Space Heating	22.88	15.25	9.35	59.2%	38.7%	7.4%	3.8%
Space Cooling	46.59	30.52	14.60	68.7%	52.1%	17.6%	10.2%
DHW	33.30	31.47	31.48	5.5%	0.0%	1.0%	0.0%
Lighting	19.13	19.78	6.56	65.7%	66.8%	6.9%	8.5%
Appl. & MEL	59.62	58.82	56.39	5.4%	4.1%	1.8%	1.6%
Ceiling Fan	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%
OA Vent Fan	0.22	0.24	2.54	-1064%	-953%	-1.3%	0.0%
Total Usage	**181.74**	**156.08**	**120.93**	**33.5%**	**22.5%**	**33.5%**	**22.5%**
Site Generation	0.00	0.00	0.00			0.0%	0.0%
Net Energy Use	**181.74**	**156.08**	**120.93**	**33.5%**	**22.5%**	**33.5%**	**22.5%**

Table 14: *Annual estimated savings for Mobile House 1*

Mobile Co 30%	Annual Site Energy			Estimated Site Energy Savings				Annual Utility Bill Reduction ($0.12/kwh)	
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total			
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard	Prototype WRT Benchmark	Prototype WRT Standard
Space Heating	6.80	4.53	2.78	59.2%	38.7%	7.4%	3.8%	$141.45	$61.67
Space Cooling	13.85	9.07	4.34	68.7%	52.1%	17.6%	10.2%	$334.23	$166.27
DHW	9.90	9.35	9.36	5.5%	0.0%	1.0%	0.0%	$19.02	-$0.07
Lighting	5.68	5.88	1.95	65.7%	66.8%	6.9%	8.5%	$131.25	$138.11
Appl. & MEL	17.72	17.48	16.76	5.4%	4.1%	1.8%	1.6%	$33.72	$25.32
Ceiling Fan	0.00	0.00	0.00	0%	0.0%	0.0%	0.0%	$0.00	$0.00
OA Vent Fan	0.07	0.07	0.75	-1060%	-947%	-1.3%	-1.5%	-$24.23	-$23.98
Total Usage	**54.01**	**46.38**	**35.94**	**33.5%**	**22.5%**	**33.5%**	**22.5%**	**$635.45**	**$367.32**
Site Generation	0.00	0.00	0.00			0.0%	0.0%	$0.00	$0.00
Net Energy Use	**54.01**	**46.38**	**35.94**	**33.5%**	**22.5%**	**33.5%**	**22.5%**	**$635.45**	**$367.32**
Added Annual Mortgage Cost (20 Yr @ 0%) w/o Site Generation								**$117.43**	**$117.43**
Net Annual Cash Flow to Consumer w/o Site Generation								**$518.02**	**$249.89**
Added Annual Mortgage Cost (30 Yr @ 7%) w/o Site Generation								**$187.69**	**$187.69**
Net Annual Cash Flow to Consumer w/o Site Generation								**$447.76**	**$179.63**

The prototype savings are estimated compared to both the BA Benchmark house and the Regional Standard Practice (defined above). Since this work is directed at new construction, the costs can further be rolled into the original mortgage and amortized over the length of the mortgage. In this particular project, all partners were Habitat for Humanity affiliates who self-finance their houses at 0% interest, typically for 20 years. For the for-profit-builder, savings are also presented for a 30 year, 7% note. Again, results are expressed as a percentage of end use reduction or as a percentage of total load reduction. Annual savings are based on the total incremental costs of the improvements amortized at both 0% for 20 years and 7% for 30 years compared to estimated energy savings (all electric houses, $0.12 kWh) for the improvements (summarized in Table 10,11, and 12 for Mobile).

The range of BA Benchmark WHSES for the demonstration homes is 29.0% to 43.0% with the HERS Index value ranging from 60 to 73 (Table 15). Three of these houses Benchmarked at or above 40% WHSES, with the remaining houses Benchmarking at or above 30% WHSES. Researchers received expense data showing incremental costs of $2,334 to $2,780 for 30% WHSES and $3,288 to $6,309 for 40% WHSES (Table 9), for all components of the package. None of the participants submitted pricing information for all components of the package, so an average was determined for all of the costs from the various data points submitted. These averages were reported as added estimated costs and were combined with the reported cost data to calculate the cost of the packages when actual cost data for a measure was not provided by the partner (Table 15). Annual cash flow to the homeowner was calculated by assuming $0.12 /kWh and a 30 year, 7% mortgage.

Table 15: *Prototype House Summary*

House	HERS Index	Total Annual Whole House Source Energy Use				Incremental Cost Information			
		Benchmark (Mbtu)	**Prototype (Mbtu)**	**Savings (Mbtu)**	**Savings (%)**	**Reported Cost**	**Added Estimated Cost**	**Total Cost**	**Annual Cash Flow**
Mobile House 1	69	54.01	35.94	18.07	33.5%	$1462	$886.50	$2348.50	$179.63
Mobile House 2	60	46.94	26.57	20.37	43.4%	$3176	$1016.50	$4192.50	$186.93
MSGC House 1	69	57.26	36.37	20.89	36.5%	$1491	$843	$2334	$238.46
MSGC House 2	71	58.14	38.87	19.27	33.1%	N/A	N/A	N/A	N/A
Slidell House 1	71	55.80	37.61	18.19	32.6%	$2408.80	$0	$2408.80	$206.67
Slidell House 2	73	55.80	38.89	16.91	30.3%	$2408.80	$0	$2408.80	$161.84
Foley House 1	68	63.41	41.53	21.88	34.5%	$1670	$1109.50	$2779.50	$231.83
Foley House 2	60	55.11	31.90	23.21	42.1%	$5000	$1308.63	$6308.63	$55.82
Abitta House 1	64	69.92	41.94	27.98	40.0%	$3096.34	$191.50	$3287.84	$339.67

Conclusions

The recommended package of improvements and implementation procedures adopted by the partners successfully met the demonstration goal 30% Whole House Source Energy Savings (WHSES) as defined by the 2008 Benchmarking (Hendron, 2008.) procedure. Further improvements allowed the package to achieve 40% WHSES. All paths showed positive cash flow for the consumer based on reported and averaged costs and an electrical cost of $0.12/kWh. Table 16 below summarizes the successfully completed Demonstration houses. Each house's HERS Index, details of their Benchmarking, and incremental cost information consisting of reported costs plus additional estimated costs, and finally, the estimated yearly cash flow to the homeowner assuming $0.12 /kWh and a 30 year, 7% mortgage are presented.

Table 16: *Demonstration Home Summary*

House	HERS Index	Total Annual Whole House Source Energy Use				Incremental Cost Information			
		Benchmark (Mbtu)	**Prototype (Mbtu)**	**Savings (Mbtu)**	**Savings (%)**	**Reported Cost**	**Added Estimated Cost**	**Total Cost**	**Annual Cash Flow**
Mobile House 1	69	54.01	35.94	18.07	33.5%	$1462	$886.50	$2348.50	$179.63
Mobile House 2	60	46.94	26.57	20.37	43.4%	$3176	$1016.50	$4192.50	$186.93
MSGC House 1	69	57.26	36.37	20.89	36.5%	$1491	$843	$2334	$238.46
MSGC House 2	71	58.14	38.87	19.27	33.1%	N/A	N/A	N/A	N/A
Slidell House 1	71	55.80	37.61	18.19	32.6%	$2408.80	$0	$2408.80	$206.67
Slidell House 2	73	55.80	38.89	16.91	30.3%	$2408.80	$0	$2408.80	$161.84
Foley House 1	68	63.41	41.53	21.88	34.5%	$1670	$1109.50	$2779.50	$231.83
Foley House 2	60	55.11	31.90	23.21	42.1%	$5000	$1308.63	$6308.63	$55.82
Abitta House 1	64	69.92	41.94	27.98	40.0%	$3096.34	$191.50	$3287.84	$339.67

A complete Building America Stage Gate analysis is included in Appendix G. Based on the success of the first prototypes all but one of the affiliates involved modified their standard building practices. One of the deliverables of the project was a summary of "lessons learned". It is included in Appendix E. Many of the affiliates that participated in the project chose to adopt all aspects of the proposed package as standard practice for their affiliates.

The Gulf Coast region was somewhat behind the curve in building energy efficient buildings. Much of the region had no energy code (Alabama and Mississippi still do not) and no resources or services necessary to foster better building energy performance. The proposed packages were challenging to implement due to regional building practices that needed to be changed first.

Standard building practices in the area needed to be addressed prior to introducing the proposed improvements, as the area's standard practice would undermine performance enhancements. Leaky duct systems and envelopes, poorly installed insulation, open air handler closets, floor insulation that did not touch the floor, grossly oversized space conditioning equipment and a myriad of other faulty building practices needed to be addressed prior to pushing for increased efficiency measures. There was a very entrenched "this is the way we always did it" work ethic in the area; however most participants had at least some knowledge of advanced building techniques, allowing BAIHP's packages to be acceptable at least as a path that could be followed.

Researchers found that the builder partners and other builders who participated in the workshops were not accustomed to thinking about establishing a whole house air barrier, a sealed duct system including the return plenum, neutral or slightly positive house air pressures, or a continuous drainage plane behind vented or water absorbing exterior wall cladding.

Training on these core concepts was essential to ensure successful implementation. It was conducted through classroom and site instruction. The most effective training exercises were those that included a demonstration of house air flows including blower door and duct tightness testing, pressure mapping, and the use of a table top air flow model. Setting an intermediate goal of achieving ENERGY STAR was a good way of establishing acceptable practice and measurable expectations for the house air barrier, insulation quality, and duct leakage. Though some builders in Louisiana were familiar with the idea of measuring duct leakage and infiltration because of a now defunct state grant program that gave incentives for achieving ENERGY STAR under the 1999 standards, the majority of builders we encountered had never seen the testing procedures.

The project concentrated on the Gulf Coast region that was damaged by Hurricane Katrina in 2004. This region typically built houses with naturally vented combustion furnaces and water heaters. This practice leads to deliberately open-to-the-attic air handler closets that provide combustion make-up air to the furnaces. Due to the unique nature of Habitat building, this method proved to be a big issue since there was often no drywall on-hand to seal the closet during drying-in. As a result, closets were sealed with particle board or plywood. Of the final seven partners, three of them were building air handler closets that were well isolated from the attic. One partner placed their air handler in the attic. Three others were putting their AHUs in an interior closet space; however, they were not enclosing the top of the closet. Typically, the walls of the closet were not finished in these homes. Looking into the closet and the central return plenum below the platform, one would see the attic above and wall framing members from the top plate all the way down to the bottom plate. In some cases, there was an effort to separate the return plenum from the space above the platform. By talking to mechanical inspectors, researchers learned that the practice of leaving the closet open to the attic was a conventional practice to ensure that atmospheric combustion gas furnaces had adequate combustion air. These were very common in the region. The three partners that were already building a well isolated closet installed and finished sheet rock in the whole closet including the ceiling before building the AHU platform. This process required the builder to have a few sheets of drywall on site before it would normally be delivered. In addition, it required the mechanical contractor to cut a hole in the ceiling for the return plenum and to also work in restricted quarters.

The partner who had been putting the AHU in the attic found that the change required a revision of the floor plan; mechanical, electrical, plumbing, and truss designs/drawings including modification of the door schedule and procurement package. An extra site visit with each contractor was required to identify exactly how the wiring, plumbing, trusses, and ducts would be installed. This builder's first attempt was unsuccessful because they failed to change the truss layout to accommodate the supply plenum that rose from the closet to enter the attic. At project end, they were still working on their second attempt. The affiliate concluded that the energy savings was not large enough to justify re-design of their houses.

In New Orleans, researchers tested and then repaired a leaky air handler closet and return plenum. They found that it was a factor in very high duct leakage and whole house infiltration. This detail is fundamental in gaining control over the house air flow needed to reach high performance goals for energy efficiency, indoor air quality, and durability.

There was also a noticeable distrust and dislike of heat pumps from some of the HVAC contractors interviewed during the project, including claims of excessive freeze-up and defrosts operation during heating due to the high ambient humidity. This bias was caused by the normal HVAC problems of over-sizing and poorly constructed duct systems combined with perceived problems due to normal operation. This problem was overcome by finding contractors who were comfortable with heat pumps.

Researchers found that the builders often needed significant coaching on how to detail the interior air handler closet, seal the duct system and unducted return plenum, establish a continuous whole house air barrier, and improve the quality of insulation installation. Setting ENERGY STAR as a first goal ensures that these fundamental improvements are made before builders strive for higher energy savings.

The primary quality assurance measure required to meet the 30% WHSES was a scope of work and commissioning of the mechanical system. All of the demonstration homes needed at least minor changes in the affiliate's original building specifications and methods. The outside air ventilation system was unfamiliar to all of the mechanical contractors. The improvements related to changes in the construction process also required some staff training to ensure that opportunities were not missed. Specifically, the house wrap details, air sealing details, and window and door flashing details needed to be covered in depth with the staff involved in those tasks. With a for-profit builder, the training would probably entail working through these details with the insulation contractor in the same manner that is needed with the mechanical contractor.

Thermal Bypass Checklist compliance was problematic for raised floor houses with batt floor insulation. Given that the project was completed in areas damaged by Katrina, there were code mandated flood requirements that required at least vented crawlspaces, and in many cases, post and pier construction. Consequently, the floors of the houses needed to be insulated; however this process was rarely performed well enough to meet the Thermal Bypass Checklist criteria of aligning the air and thermal barriers. In crawlspace houses, two solutions were employed: 1) inset stapling the kraft paper on the insulation (paper side facing the crawlspace) so that the insulation stayed in contact with the floor of the house and 2) foam insulation. In homes with post and pier construction, the inset stapling idea was not applicable due to fire concerns and the exposed kraft paper; however several participants in the program used spray foam under all of their raised houses. The use of fiberglass clips to support the insulation between floor joists was an unheard of detail, making adoption of the technique difficult.

Problems occurred with poorly installed ducts that were too leaky. In one instance, they were too leaky to qualify for ENERGY STAR, and in another case the leakage caused the house to fall short of the Qn < 4% goal. Both of these partners attempted to go behind their HVAC contractor and seal the duct system themselves.

When BAIHP began working with this project, Louisiana had not adopted the energy code that went into effect in July of 2007. This code was the 2006 International Energy Conservation Code with one exception. Return and supply duct insulation was only required to be R-6 instead of R-8. Alabama and Mississippi did not have a mandatory energy code.

Only one code issue occurred during the project. It related to the fresh air inlet that was directed into the return of the air handler. The applicable Code required a specific access dimension to allow the installation and removal of the air handler, which was being blocked by the fresh air inlet due to the small size of the air handler closets. This issue was resolved by moving the location of the fresh air duct in the closet. It was also required that the portion of fresh air duct exposed in the return be made of a non-flammable material and not PVC, as found. This problem was overcome by truncating the duct flush with the return platform, preventing any exposed duct.

The demonstration homes met all other applicable building codes. The researchers met with the chief mechanical inspector in Slidell, at the inspector's request, and in the City of Mobile after a presentation to the Mobile Area ACCA Chapter. Packages used **all** standard, off the shelf, components with proven durability and reliability, and were designed to add no additional maintenance burdens to the homeowner.

Though none of the partners were building demonstration homes with gas heating, the recommendation was to enclose the air handler closet and provide a 90%+ efficient gas furnace which had safety features to prevent exhaust spillage, back drafting and flame rollout. This recommendation was not well-received among the partners or the builders we met in workshops because of the high initial cost. Indeed, it would have significantly impacted the cash flow economics because the heating season is short. Plans were made to address this issue before making a blanket recommendation to the builders in the region for tightening infiltration and duct leakage, particularly because the conventional construction of the central return plenum was an unducted framed platform where the AHU rested. These are often connected to the space around the AHU by penetrations in the platform which could significantly depressurize the combustion zone.

This market needs an inexpensive gas fired alternative to atmospheric combustion furnaces that will ensure combustion safety in the manner that the 90%+ gas furnaces do. Many consumers prefer gas heat as opposed to heat pumps, but the heating load is not sufficient enough to justify the incremental cost of the high efficiency gas models.

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Appendix A: Baseline Construction Characteristics for Builder Partners Participating in the Gulf Coast High Performance Affordable Housing Demonstration Project

Table A-1: Baseline Construction Characteristics for Builder Partners Participating in the Gulf Coast High Performance Affordable Housing Demonstration Project

Category	Component	HFH of Greater Baton Rouge	New Orleans Area HFH (Gas)	New Orleans Area HFH (Electric)	East St. Tammany HFH (Slidell)	Mobile County HFH	Mississippi Gulf Coast HFH
General	Filename	HFH-LA-BR Baseline	HFH-LA-NO-Baseline-Gas	HFH-LA-NO-Baseline-Electric	E St Tam Slidell Baseline	HFH-Mobile-Base7%CFL	MSGC Baseline-Magnolia-Tested
General	Plan		P1	P1	Merrill		Magnolia
General	Bedrooms	4	3	3	3	3	3
General	Bathrooms	1	1	1	1	1.5	1.5
General	Conditioned Area	1303	1025	1025	1120	1073	1222
Roof	Configuration	Gable	Gable	Gable	Gable	Hip	Gable
Roof	Decking	Radiant Barrier Decking	Standard Decking	Standard Decking	Radiant Barrier Decking	Radiant Barrier Decking	Standard Decking
Roof	Finish	Shingles	Shingles	Shingles	Shingles	Shingles	Shingles
Roof	Overhang	Assumed 12"	Assumed 12"	Assumed 12"	12"	16"	Assujmed 1'0"
Roof	Structure	Raised Heel Trusses	Truss construction	Truss construction	Truss construction	Truss construction	Truss construction
Attic	Ceiling Insulation	R-30 Fiberglass Batts	R-30 Blown Fiberglass	R-30 Blown Fiberglass	R-30 Blown Fiberglass	R-30 Blown Fiberglass	R-30 Blown Fiberglass
Attic	Attic Access	Pull down stair, insulated, no gasket	Hatch, uninsulated, no gasket	Hatch, uninsulated, no gasket	Pull down stair, insulated, no gasket	Hatch, uninsulated, no gasket	Hatch, uninsulated, no gasket
Walls	Structure	16" on center, 2x4 wood frame	16" on center, 2x4 wood frame	16" on center, 2x4 wood frame	16" on center, 2x4 wood frame	16" on center, 2x4 wood frame	16" on center, 2x4 wood frame
Walls	Insulation	R-13 Recycled Cotton	R-13 Fiberglass Batt	R-13 Fiberglass Batt	R-13 Fiberglass Batt	R-13 Blown-in Cellulose	R-13 Fiberglass Batt
Walls	Insulation Grade	II	II	II	II	I	III
Walls	Drainage Plane	House Wrap	House Wrap	House Wrap	House Wrap	House Wrap	House Wrap
Walls	Finish	fiber cement siding	fiber cement siding	fiber cement siding	fiber cement siding	fiber cement siding	fiber cement siding
Windows	Panes	Double pane	Double pane	Double pane	Double pane	Double pane	Double pane
Windows	U-Value	0.34	0.35	0.35	0.36	0.38	0.68
Windows	SHGC	0.3	0.3	0.3	0.3	0.31	0.6
Windows	Frame Material	Vinyl	Vinyl	Vinyl	Vinyl	Vinyl	Metal
Windows	Window to Floor Area Ratio	13.60%	15.20%	15.20%	10.20%	10.25%	9.32%
Floor	Foundation and Floor	Uninsulated Slab on Grade	Pier with R-19 fiberglass batt	Pier with R-19 fiberglass batt	Pier with R-19 spray foam	Uninsulated Slab on Grade	Uninsulated Slab or Pier with R-19
Floor	Floor Insulation Grade	NA	III	III	I	NA	NA
Fans	Kitchen and Bath Exhaust Fans	Ducted to outside	Ducted to outside	Ducted to outside	Not ducted to outside	Ducted to outside	kitchen not ducted
Fans	ceiling fans	6 non-Energy Star ceiling fans	No ceiling fans	No ceiling fans	No ceiling fans	No ceiling fans	No ceiling fans
Appliances	Refrigerator	Energy Star Refrigerator	Energy Star Refrigerator	Energy Star Refrigerator	Energy Star Refrigerator	Energy Star Refrigerator	Whirlpool Energy Star Refrigerator
Lighting	Can Lights?	none	none	none	none	1 ICAT unit	*none*
Lighting	Lighting	75%	10% Fluorescent	10% Fluorescent	6.70%	6.70%	7.10%

Table A-1: Baseline Construction Characteristics for Builder Partners Participating in the Gulf Coast High Performance Affordable Housing Demonstration Project *(Continued from previous page)*

Category	Component	HFH of Greater Baton Rouge	New Orleans Area HFH (Gas)	New Orleans Area HFH (Electric)	East St. Tammany HFH (Slidell)	Mobile County HFH	Mississippi Gulf Coast HFH
HVAC	Equipment Type and Fuel	Air Source Electric Heat Pump SEER 13, HSPF 8	Straight Cool with AFUE 80 gas furnace	Straight Cool with electric resistance heating	SEER 13 Heat Pump	Straight Cool with Electric resistance heating	SEER 13 Straight Cool with Electric resistance heating
HVAC	cooling size	2.5 Tons				2 Ton	
HVAC	Ventilation	none	none	none	none	none	none
HVAC	Duct materials	R6 flex	R6 flex	R6 flex	R6 Flex	R4.3 Flex	R4.3 Flex
HVAC	Air Handler location	Attic	Interior closet *connected to* the attic	Interior closet *connected to* the attic	Interior closet *connected to* the attic	Interior closet *separated from* attic	Interior closet *separated from* attic
HVAC	Thermostat	Non-Programmable	Non-Programmable	Non-Programmable	Non-Programmable	Non-Programmable	Non-Programmable
Water heating	Fuel, Type	Electric, Tank Type	Gas, Tank Type	Electric, Tank Type	Electric, Tank Type	Electric, Tank Type	Electric, Tank Type
		EF=0.9	Gas EF=0.6	Electric EF=0.88	EF=0.88	EF=0.93	EF=0.9
Water heating	Location	attic	laundry room	laundry room	interior closet	laundry or storage room	AHU Closet
Infilatration	CFM50*	NA	NA	NA	1324	842	1446
Estimated Infiltration	ACH50*	7.15	11.05	11.05	8.87	5.885368127	8.87
Duct Leakage	Duct Leakage (total)*	NA	NA	NA	112	NA	273.5
Test Results	(out)*	78.18	256.25	256.25	78	35	121.5
Test Results	qn,out*	0.06	0.25	0.25	0.07	0.03	0.099
Thermal Bypass Inspection	Pass/Fail	Fail	Fail	Fail	Fail	Fail	Fail
Home Energy Rating	**Base Line HERS Index (MBtu)**	**82**	**102**	**120**	**85**	**91**	**110**
2008 BA Benchmark Calculations							
Whole House Site Energy Use (MBtu)	Baseline "Benchmark House"	63.338	74.102	55.637	57.301	53.392	56.961
	Base Line "Prototype House"	48.679	64.793	54.222	44.672	44.156	52.773
	Savings	14.659	9.309	1.415	12.629	9.236	4.188
	% Site Savings	**23.1%**	**12.6%**	**2.5%**	**22.0%**	**17.3%**	**7.4%**
Whole House Source Energy Use (MBtu)	Baseline "Benchmark House"	213.13	167.08	187.22	192.81	179.66	191.67
	Base Line "Prototype House"	163.8	144.34	182.45	150.32	148.58	177.58
	Savings	49.33	22.74	4.77	42.49	31.08	14.09
	% Source Savings	**23.1%**	**13.6%**	**2.5%**	**22.0%**	**17.3%**	**7.4%**

** Baseline calculations may have been done with estimates prior to actual testing, however estimates have been verified as consistent with test results.*

Appendix B: Typical Floor Plans and Elevations

Figure B-1: Habitat for Humanity of Greater Baton Rouge – Demonstration House Plan

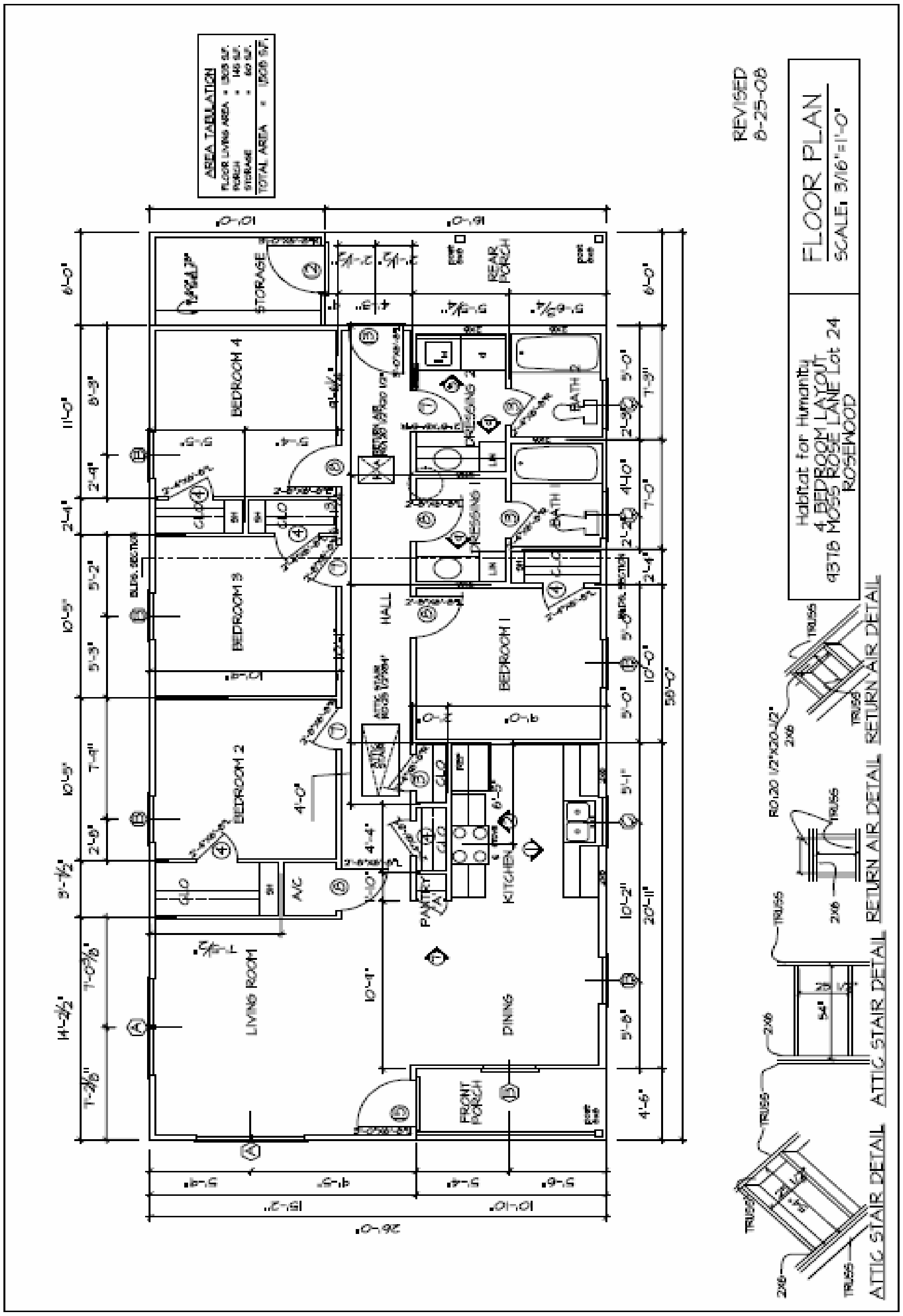


Figure B-2: Habitat for Humanity of Greater Baton Rouge – Demonstration House Elevations

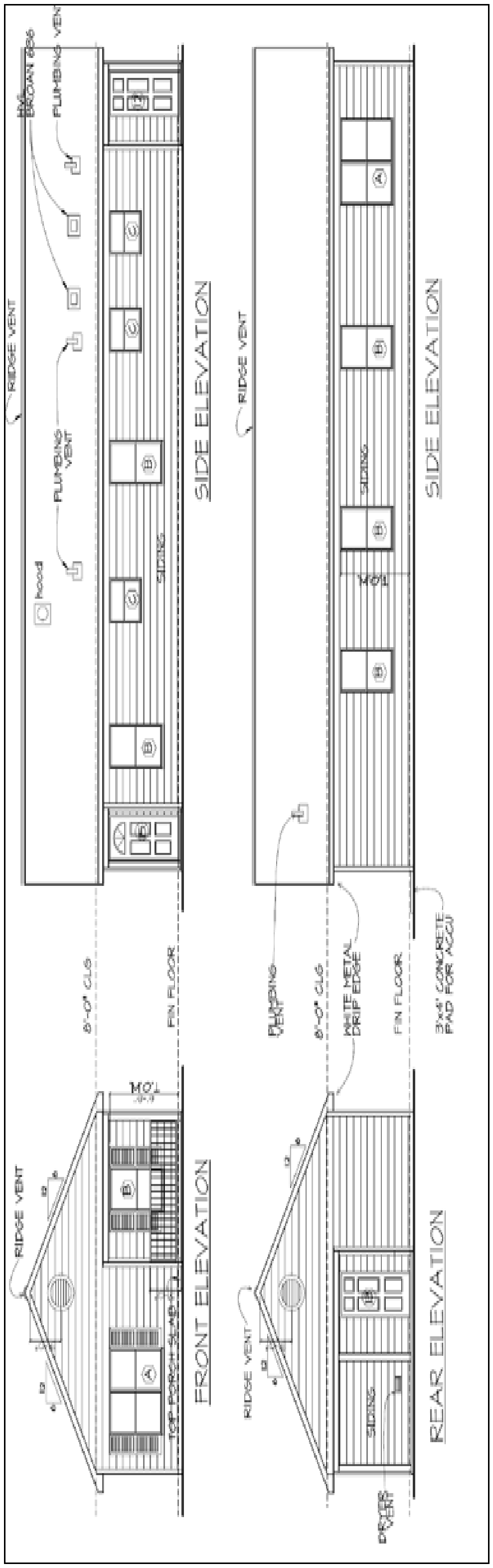


Figure B-3: East St. Tammany Habitat for Humanity – Demonstration House Plan

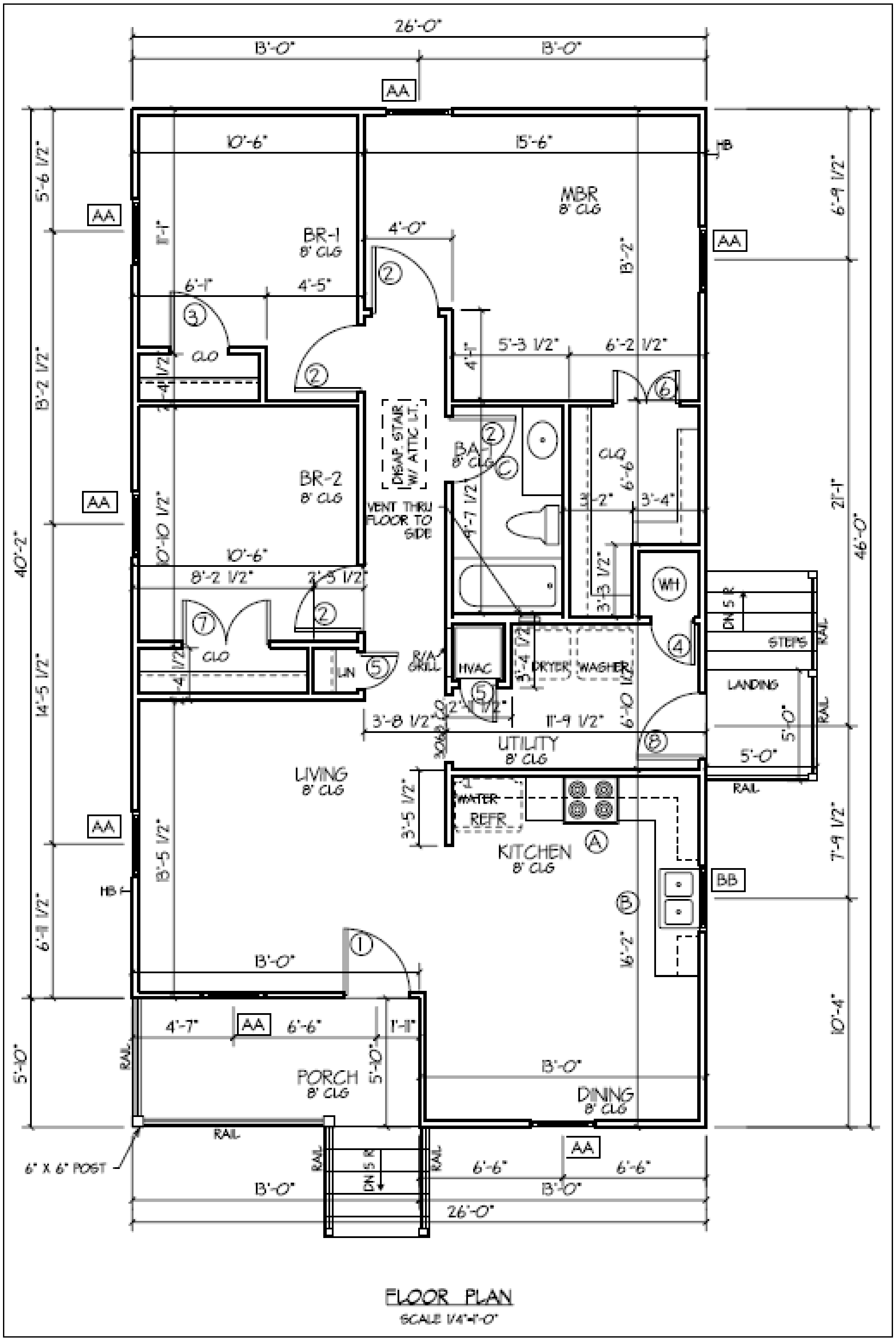


Figure B-4: East St. Tammany Habitat for Humanity – Demonstration House Elevations

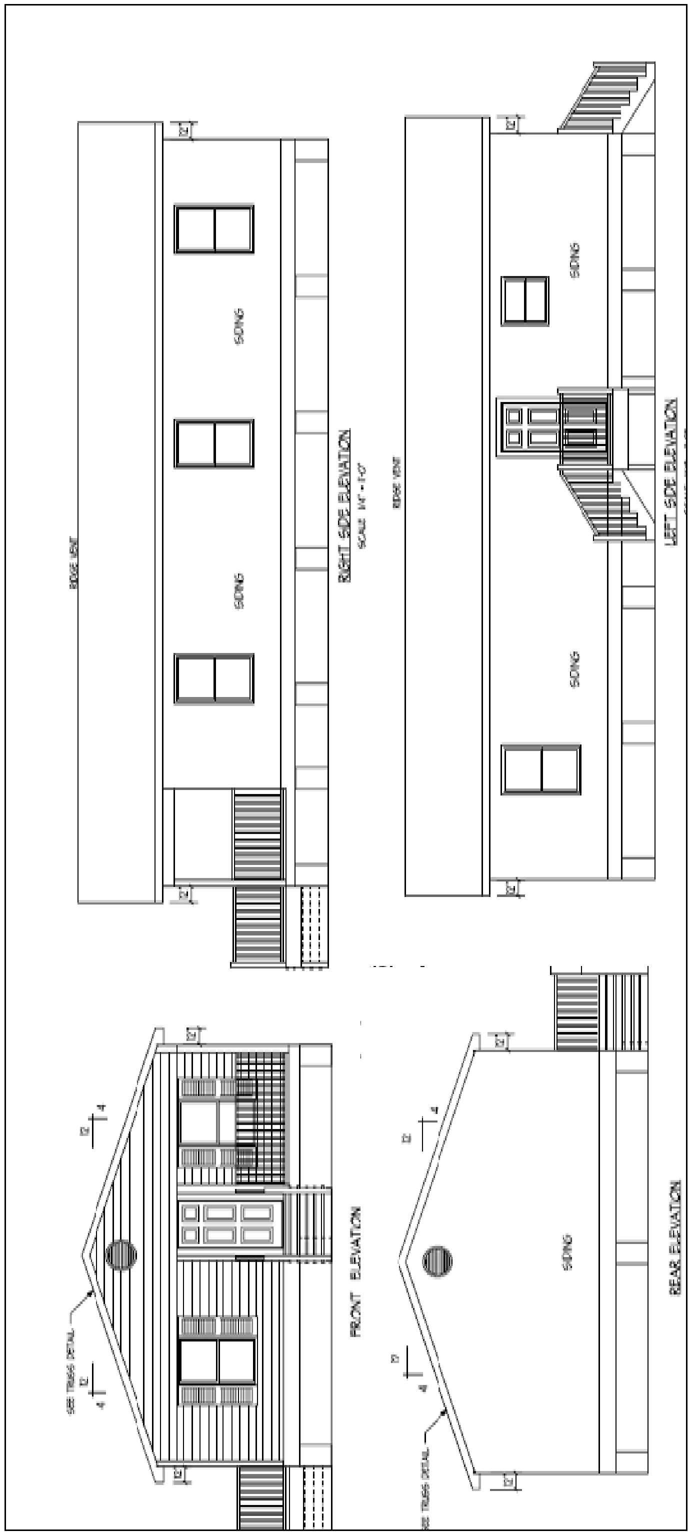


Figure B-5: Mobile County Habitat for Humanity – Demonstration House Plan

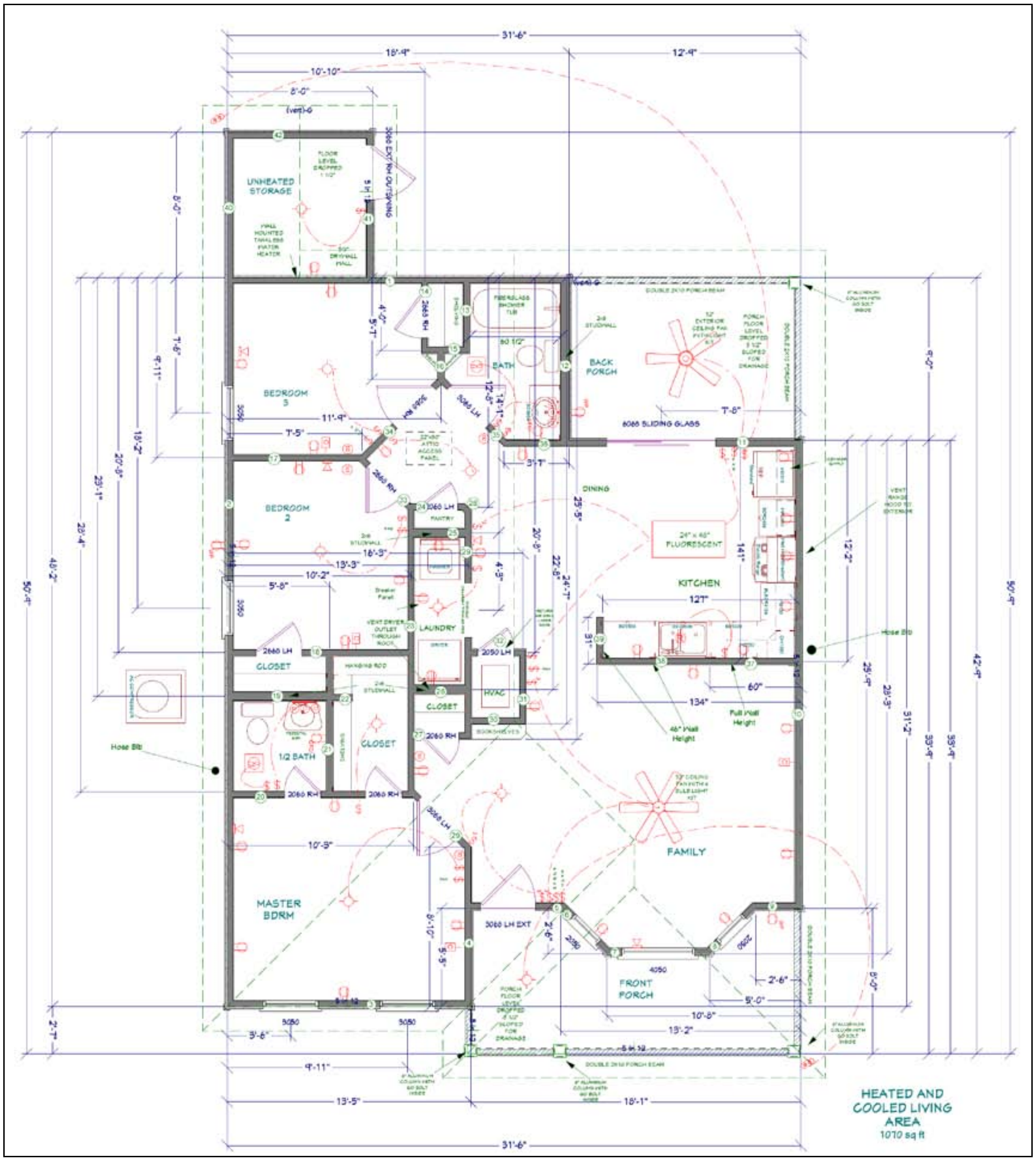


Figure B-6: Mobile County Habitat for Humanity – Demonstration House Elevations

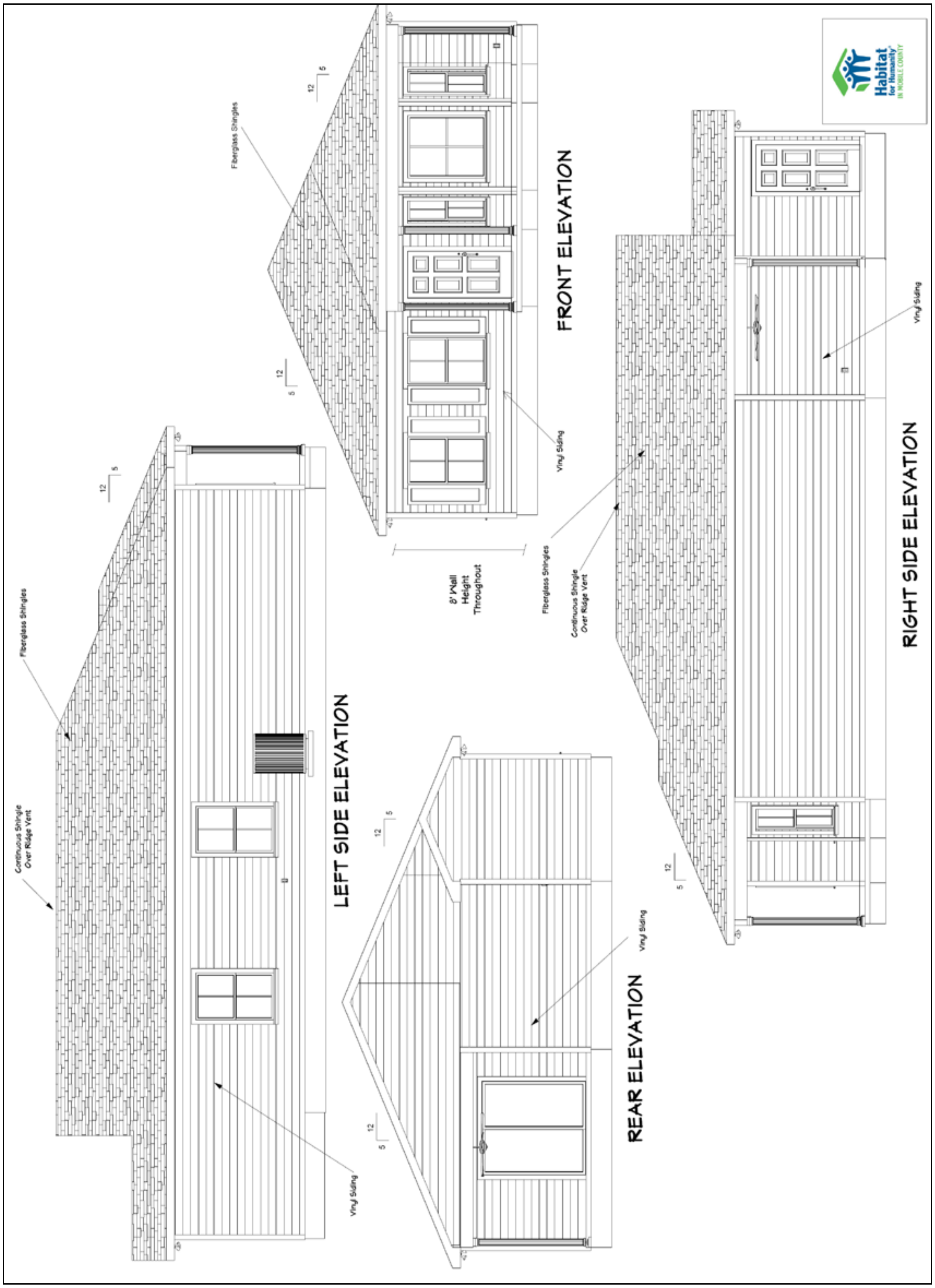


Figure B-7: Mississippi Gulf Coast Demonstration House Plan

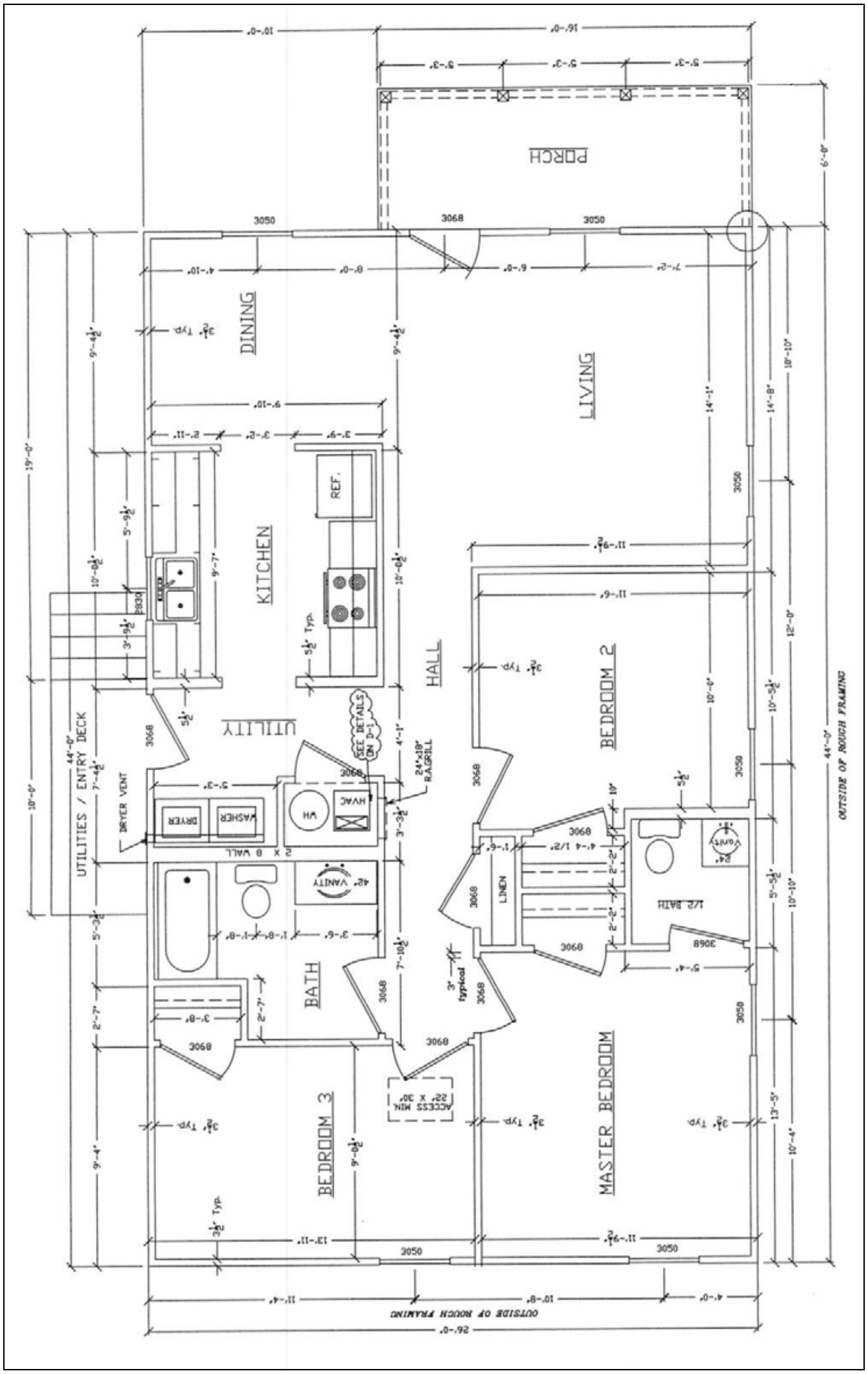


Figure B-8: Habitat for Humanity of the Mississippi Gulf Coast – Demonstration House Elevations

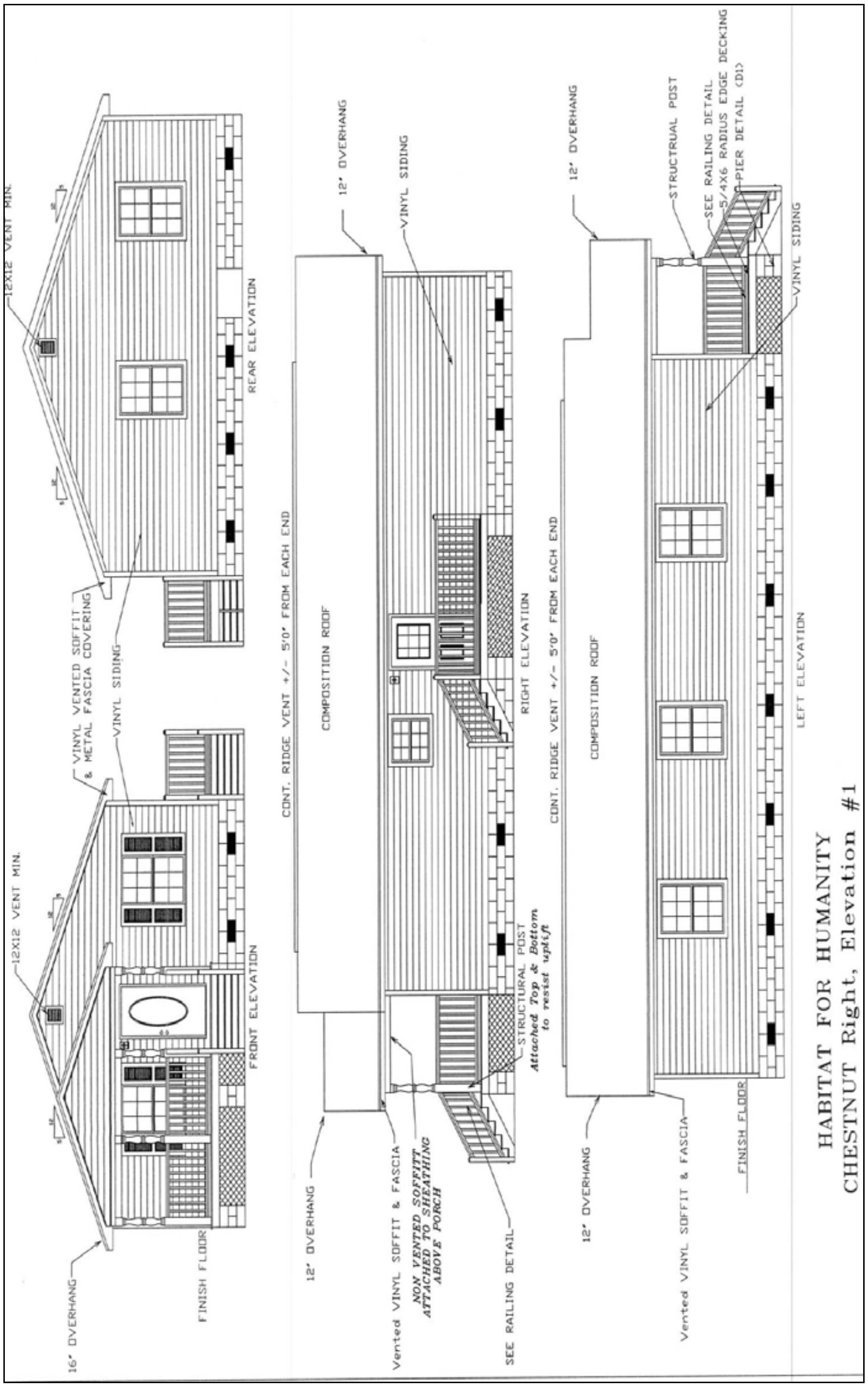


Figure B-9: HFH of West St. Tammany Floor plan

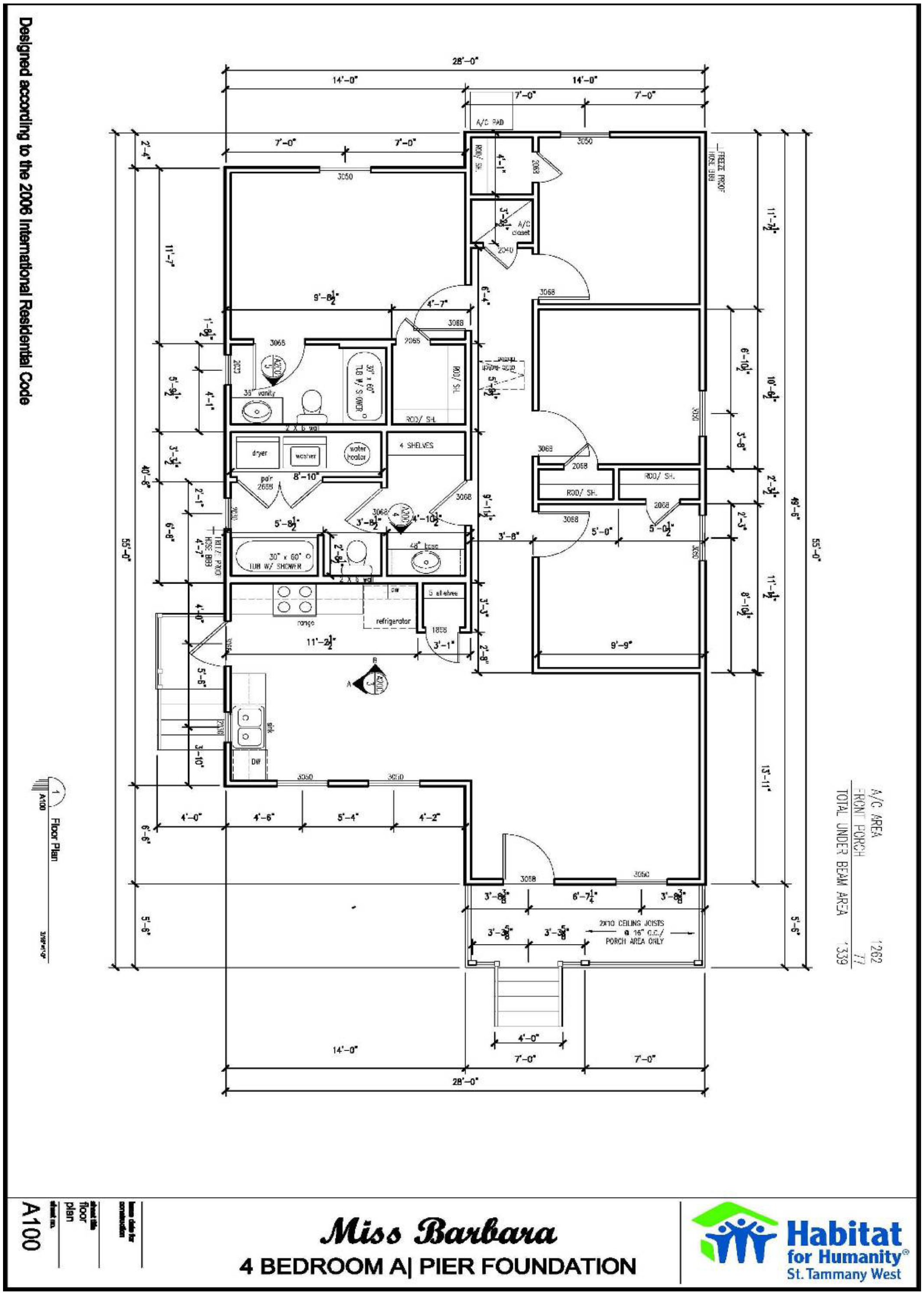


Figure B-10: HFH of West St. Tammany Elevations

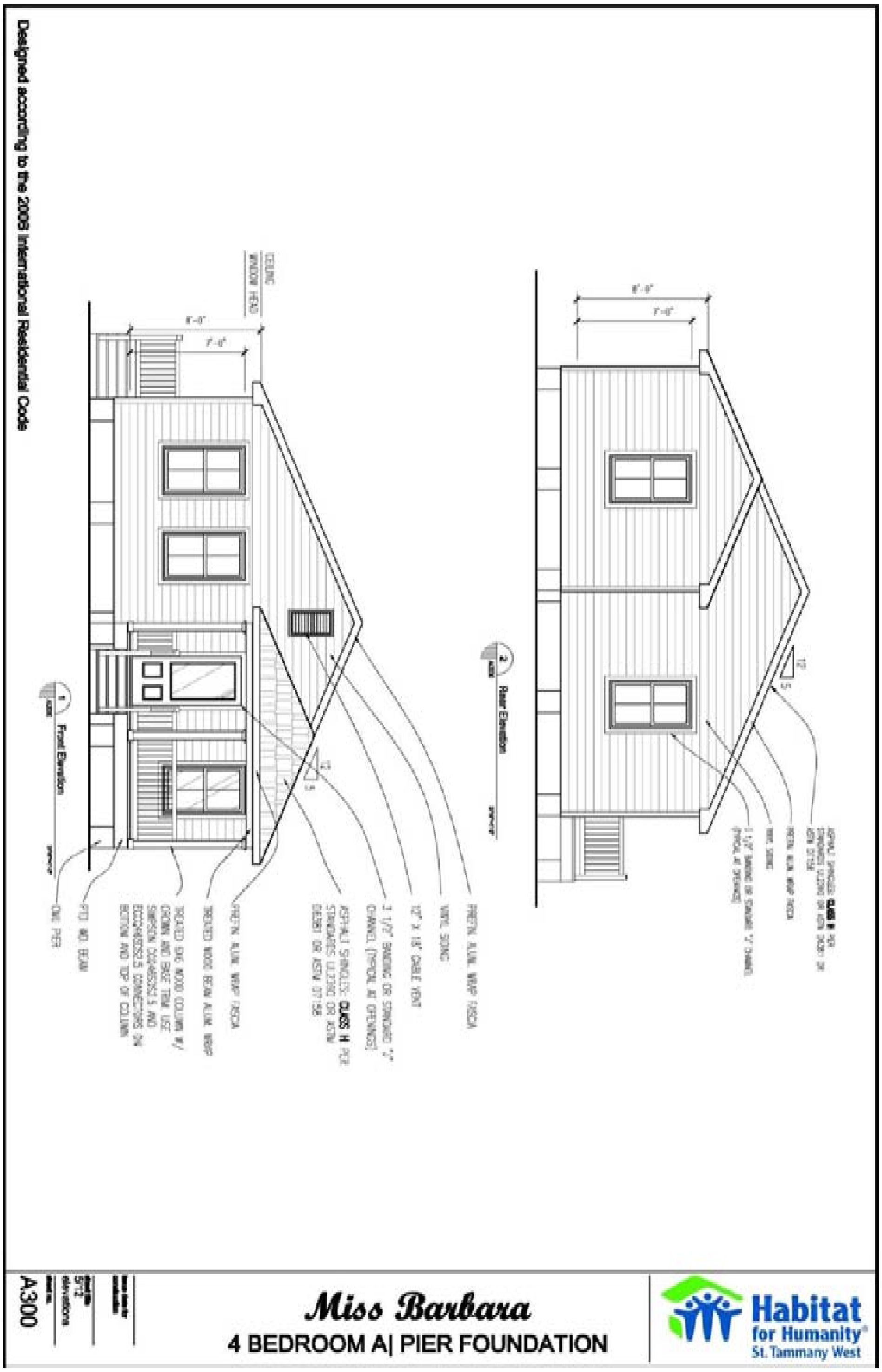
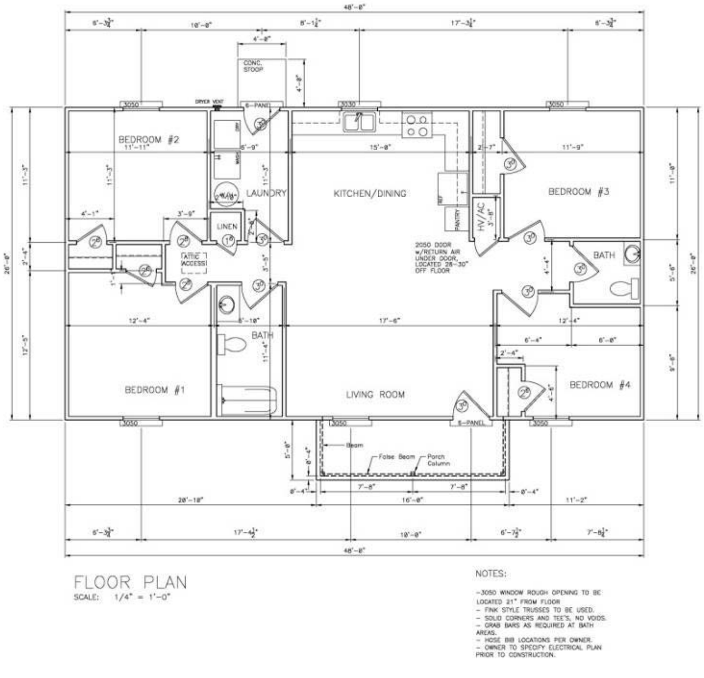
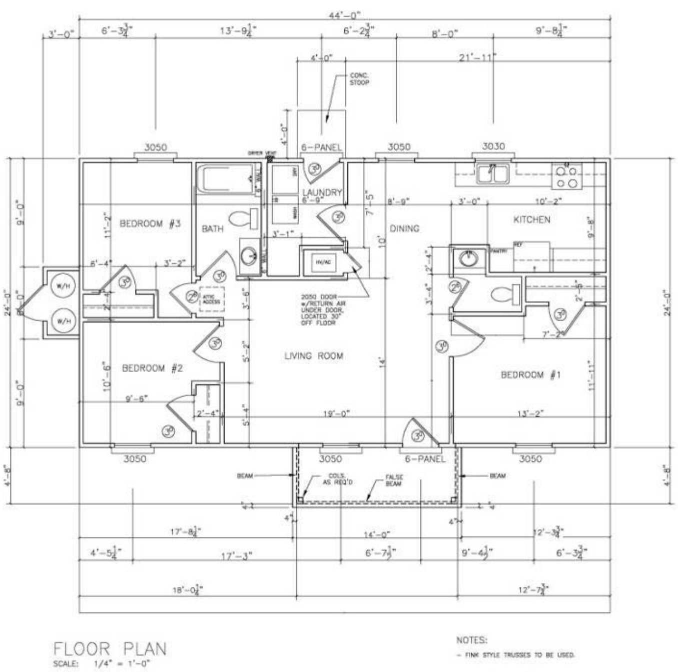


Figure B-11: Baldwin CO HFH Floor plans





Appendix C: Brief Case Study Materials for Building America Partners Achieving 30% Whole House Source Energy Savings in the Hot Humid Climate

As part of reporting to Building America (BA), the Florida Solar Energy Center assisted with the development of material showing that BA builder-partners were meeting the Stage Gate criteria for communities of homes achieving 30% whole house source energy savings (WHSES) under the 2006 Building America Benchmarking procedure. The report included a summation of recommended best practices for builders striving to meet that goal. The report is an internal Department of Energy document used for program evaluation and for determining if the Building America teams are meeting the milestones and goals of the overall Building America program. It is being used as the basis for a new version of Volume 1 of the Building America Best Practices series. The following material is excerpted from FSEC's case studies on three builder partners. They are presented here as background material to show what experience the researchers drew from in developing the package of improvements for the Gulf Coast High Performance Affordable Housing Demonstration Project. One-page summaries and detailed case studies of these three builders are available online:

<u>One-Page Fact Sheets</u>

- G.W. Robinson Builders, Inc.: http://www.baihp.org/casestud/baday/G W Robinson Builders.pdf
- Tommy Williams Homes Fact Sheet http://www.baihp.org/casestud/baday/Tommy Williams Homes.pdf
- Lakeland Habitat for Humanity http://www.baihp.org/habitat/pdf/Lakeland-Case-Study.pdf

<u>Detailed Case Studies</u>

- G.W. Robinson Builders, Inc. and Tommy Williams Homes http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-430-07.pdf
- Lakeland Habitat for Humanity http://www.baihp.org/habitat/pdf/Lakeland-Habitat-Case-Study.pdf

Summary for G.W. Robinson Builders, Inc.

- Location: Gainesville, Florida
- 400+ Houses completed and sold
- Lead – Florida H.E.R.O. (Ken Fonorow)

Figure C-1: Typical size G.W. Robinson Builders, Inc. home.

G. W. Robinson (GWR) 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 in his "move up buyer" subdivisions. GWR homes (Figure C-1) are typically 2,000 to 5,000 square feet with a selling price in 2006 of $300,000 to over $1,000,000. Average sales price is $165/sf. This builder has chosen to incrementally improve his specifications over the years. All GWR homes being built in 2006 had HERS Index values between 63 and 68 and a Building America Benchmark savings range from 35% to 41%. The package of improvements that deliver this level of savings is shown in Table C-1. Table C-2 shows the estimated incremental improvement cost to be $2,021. When factored over the life of a 30 year, 7% mortgage, this cost adds $161 to the mortgage annually. The estimated annual energy savings of $863 generates a positive first year cash flow of $702.

Table C-1: G. W. Robinson Builders, Inc. Improvement Package (in 2006)

- **Heating/Cooling Equipment**
  - SEER 15 Air conditioner, 93% AFUE Gas Furnace
  - ACCA Manual J system sizing
  - Ducts sealed with mastic and tested
  - Interior air handler closet
- **Water Heating Equipment**
  - EF=0.84 Tankless gas water heater
- **Heating/Cooling Load Reduction**
  - ENERGY STAR windows (double pane, vinyl frame, low-e)
  - R-30 with radiant barrier vented attic
  - 2 x 4 advanced framing w/R-13 cellulose
  - Wide overhangs on patio doors and windows
  - Extensive air sealing and continuous whole house air barrier
- **Indoor air quality, durability, and comfort features**
  - Ducted kitchen and bath exhaust fans
  - Passive, positive pressure outside air ventilation
  - Drainage plane and flashing details
  - Passive return air pathways from bed rooms
  - Low VOC paints
- **Verification**
  - Thermal Bypass Inspection
  - Blower door and duct leakage testing

Table C-2: First Year Cash Flow Analysis for Typical G.W. Robinson Home	First Cost	Annual Cost (7%, 30 yr mortgage)

Total Incremental Cost (includes 10% mark up)	$2,021	$161
Estimated Annual Energy Savings *(wrt typical construction, not the Benchmark)*		$863
Net 1st Year Cash flow		$702

Summary for Tommy Williams Homes

- Location: Gainesville, Florida
- Over 200 homes built and sold
- Lead – Florida H.E.R.O. (Ken Fonorow)

Tommy Williams (Figure C-2) 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 2,416 square feet with a 2006 selling price of $205,000 to $315,000. Average cost per square foot was approximately $147. Tommy Williams and his organization went from building Florida Energy Code minimum homes to building over 250 homes in two sub-divisions. HERS '99 Index scores of 88.6 or above increased in efficiency to HERS Indices of 72 or below. Analysis shows these

Figure C-2: Tommy Williams Homes model center

homes to be an average of 35-40% better than the Building America Benchmark using the 2006 procedure. The typical package of improvements used by Tommy Williams is shown in Table C-3. Table C-4 shows the estimated incremental improvement cost to be $1,280. When spread over the life of a 30 year, 7% mortgage, this adds $102 to the mortgage annually. The estimated annual energy savings of $402 generate a positive first year cash flow of $300.

Table C-3: Tommy Williams Homes Improvement Package (in 2006)
• **Heating/Cooling Equipment** – SEER 15, HSPF 9 Heat Pump – ACCA Manual J system sizing – Ducts sealed with mastic and tested – Interior air handler closet
• **Heating/Cooling Load Reduction** – ENERGY STAR windows (double pane, vinyl frame, low-e) – R-30 with radiant barrier vented attic – 2 x 4 advanced framing w/R-15 spray in fiberglass "spider" insulation – Extensive air sealing and continuous whole house air barrier
• **Indoor air quality, durability, and comfort features** – Ducted kitchen and bath exhaust fans

– Passive, positive pressure outside air ventilation – Drainage plane and flashing details – Passive return air pathways from bed rooms
• **Lighting** – 75% Fluorescent
• **Verification** – Thermal Bypass Inspection – Blower door and duct leakage testing

Table C-4: First Year Cash Flow Analysis for Typical Tommy Williams Home	First Cost	Annual Cost (7%, 30 yr mortgage)
Total Incremental Cost (includes 10% mark up)	$1,280	$102
Estimated Annual Energy Savings *(wrt typical construction, not the Benchmark)*		$402
Net 1st Year Cash flow		$300

Summary for Lakeland Habitat for Humanity

- Location: Lakeland, Florida
- Over 50 homes built and sold
- Lead – FSEC Janet McIlvaine

Lakeland Habitat for Humanity adopted an energy efficiency program to meet ENERGY STAR for New Homes standards under the leadership of Executive Director Claire Twomey in 2000. Between then and 2006, Lakeland Habitat built 51 affordable homes, making incremental improvements to achieve 30% in WHSES compared to the 2006 Building America Benchmark. HERS scores(1999) averaged 89.3, translating to HERS Indices (2006) of 70-75. The typical package of improvements used by Lakeland Habitat for Humanity is shown in Table C-5. Home size is typically 1050-1200 square feet with three or four bedrooms. Homes (Figure C-3) are sold to buyers at 0% interest, and buyers contribute hundreds of hours of labor on Habitat homes to earn “sweat equity.”

Figure C-3: Homes built by Lakeland (FL) Habitat for Humanity

Table C-6 shows the estimated incremental improvement cost to be $1,500. When factored over the life of a 30 year, 0% mortgage that Habitat typically writes, this cost adds $50 to the mortgage annually. The estimated annual energy savings of $182 generates a positive first year cash flow of $132. If this were a typical 30 year, 7%

mortgage, the improvement package cost would add $119 to the mortgage annually, and the buyer would see a $62.24 first year positive cash flow. Because Lakeland Habitat for Humanity is a non-profit affordable housing provider, they are eligible for municipal grant money awarded for building energy efficient homes. They receive $5,000 per home which covers the cost of the improvement package and adds $3,500 to the general building fund. The full energy savings are passed on to the buyer – a $182 first year positive cash flow.

Table C-5: Lakeland Habitat for Humanity Improvement Package (in 2006)

- **Heating/Cooling Equipment**
  - SEER 14, HSPF 8.5 Heat Pump
  - ACCA Manual J system sizing
  - Ducts sealed with mastic and tested
  - Interior air handler closet
- **Water Heating**
  - Water Heater Timer *(does not affect HERS Index or Benchmark)*
- **Heating/Cooling Load Reduction**
  - ENERGY STAR windows (double pane, vinyl frame, low-e)
  - R-30 with radiant barrier vented attic
  - RESNET Grade I, R-13 fiberglass insulation
  - Extensive air sealing and continuous whole house air barrier
- **Indoor air quality, durability, and comfort features**
  - Ducted kitchen and bath exhaust fans
  - Passive, positive pressure outside air ventilation
  - Drainage plane and flashing details
  - Passive return air pathways from bed rooms
- **Verification**
  - Thermal Bypass Inspection
  - Blower door and duct leakage testing

Table C-6: First Year Cash Flow Analysis for Typical Lakeland Habitat for Humanity Home	First Cost	Annual Cost (0%, 30 yr mortgage)	Annual Cost (7%, 30 yr mortgage)	Annual Cost with grant funds
Total Incremental Cost (no mark up)	$1500	$50	$119	$0
Estimated Annual Energy Savings *(wrt typical construction, not the Benchmark)*		$182	$182	$182
Net 1st Year Cash flow		$132	$62.24	$182

Appendix D: Original and Revised Outside Air Ventilation System Calculations and Design Guidelines

Components of Ventilation System for
Gulf Coast High Performance Habitat for Humanity Demonstration Houses

- OA intake located in soffit near side door or porch ceiling (with step ladder access for changing/cleaning filter)
- Heavier gauge filter back grille for OA intake connected to…
- Standard box/boot with collar appropriate for connecting to…
- 2” thin wall PVC pipe or 4” flex (if length exceeds 25’ use 6” flex) Note, seal around PVC or flex where it penetrates the ceiling of air handler closet with expanding foam, mastic and mesh, or caulk. Connect pipe/duct to…
- Manual damper with fittings in an accessible location with pipe/duct continuing to…
- Collared opening in return plenum. Seal joint at pipe/duct to collar with mastic and fiberglass mesh.

A motorized damper or gravity fed back draft damper may (with override control) be substituted for the manual damper.

Pipe/Duct Sizing Rationale:
Using ASHRAE Calculation Formula for Recommended Flow:
7.5cfm/person + 10cfm/1000sq ft
Estimating the number of people using the number of bedrooms plus one, we get the following recommended flows:

2 Bed Room 950-1050 sq ft
Flow=32 cfm (Approximately 30cfm)

3 Bed Room 1050-1150 sq ft
Flow=41cfm (Approximately 40cfm)

4 Bed Room 1150-1250 sq ft
Flow=49 cfm (Approximately 50cfm)

The size pipe/flex recommended above will accommodate these levels of flow. The manual damper may be adjusted to reduce or increase the flow if occupant desires.

Components of Ventilation System for
Gulf Coast High Performance Habitat for Humanity Demonstration Houses

General Guidance on Passive Outside Air (OA) Ventilation System:
An OA duct is installed during the mechanical rough in. It runs from an OA intake mounted in a nearby soffit through the attic to the top of the air handler (AHU) closet. It makes one 90 degree turn and passes through a closely cut hole in the ceiling of the AHU closet down to another closely cut hole in the platform that supports the air handler. Respecting code required clearances, the duct runs from the ceiling into the return plenum. (*See guidance on each element of the system below.*) The OA must pass through a filter before entering the air handler. This can be done at the OA intake or at the air handler. There must be an accessible manual damper with visible "closed" and "venting" marks to allow occupants to over ride the OA ventilation system when conditions warrant, such as when there is a fire in the area. During design, check with local code officials to determine clearances of all the elements in the handler closet.

Outside Air (OA) Intake Register

Figure D-1: At a minimum, outside air intake register mounted in vented vinyl soffit with OA duct positioned in soffit above.

- OA intake shall provide free flowing outside air (not attic air) to the OA duct. The intake should be located in a soffit or on an exterior wall with weather protection similar to a dryer exhaust duct (Figure D-1). It should be within 25 feet of the air handler closet with tight-mesh insect screen mechanically secured over the end of the OA duct.
- At a minimum, the OA duct shall terminate at a register to allow a free flow of air from the outside, not the attic, into the duct. It is preferable that the OA duct terminates in a standard box/boot mounted in the soffit framing, with a mechanically fastened connection to the duct and a standard size register mounted in the soffit.

Outside Air Duct
- 2" thin wall PVC pipe or 4" flex
- Minimize bends in the OA duct to one 90
- Seal around PVC or flex where it penetrates the ceiling of air handler closet with expanding foam, mastic and mesh, or caulk. Connect pipe/duct to…
- Manual damper with fittings in an accessible location with pipe/duct continuing to…
- Collared opening in return plenum. Seal joint at pipe/duct to collar with mastic and fiberglass mesh.

A motorized damper or gravity fed back draft damper may (with override control) be substituted for the manual damper.

Pipe/Duct Sizing Rationale:
Using ASHRAE Calculation Formula for Recommended Flow:
7.5cfm/person + 10cfm/1000sq ft
Estimating the number of people using the number of bedrooms plus one, we get the following recommended flows:

2 Bed Room 950-1050 sq ft
Flow=32 cfm (Approximately 30cfm)

3 Bed Room 1050-1150 sq ft
Flow=41cfm (Approximately 40cfm)

4 Bed Room 1150-1250 sq ft
Flow=49 cfm (Approximately 50cfm)

The size pipe/flex recommended above will accommodate these levels of flow. The manual damper may be adjusted to reduce or increase the flow if occupant desires.

Filtration of the outdoor air can be achieved by installing a filter-back grill in the soffit. This places a further maintenance burden on the homeowner (a filter outside under the eaves) but provides filtered air when the air handler is running, as well as filtered air when the fresh air vent is responding to a negative pressure in the house and providing passive make-up air.

A second, easier method of filtering the outdoor air is accomplished by installing a filter under the air handler in the factory designed spot for the filter. This method uses the existing air handler filter (no filter back grill in eave or in the house at the return) but does not provide filtration when the fresh air vent is providing passive make-up air. Further, using this filter requires that the HVAC installer not install the refrigerant or condensate lines in front of the filter access panel.

Recommendations compiled by:
Janet McIlvaine with input from Neil Moyer and David Beal
Research Analysts, Buildings Research Division, Florida Solar Energy Center
DOE Building America Program, Liaison to Habitat for Humanity
1679 Clearlake Road, Cocoa, FL 32922
321-638-1434 phone, 321-638-1439 fax
janet@fsec.ucf.edu please include “Habitat” in your subject line

Appendix E: Deliverables – Costs and Lessons Learned

MOBILE COUNTY HABITAT FOR HUMANITY BUILDING AMERICA HIGH PERFORMANCE DEMONSTRATION HOME COST ANALYSIS AND INVOICE

Habitat For Humanity In Mobile County
851 E. I-65 Service Rd. South
Suite 301
Mobile, Alabama 36606
United States
251-476-7171

For the Project:

3 BEDROOM Building America High Performance Demonstration Home

Project Address: 509 Doby Court
Mobile, AL

Development: Hillsdale

Lot Number: Lot 13

Summary of costs associated with Building America High Performance Demonstration Home to establish the incremental cost difference on prescribed changes.

Name	Unit	Rate	Standard Specifications	Building America Specifications	Incremental Cost Difference
HVAC SYSTEMS					
HVAC SUBCONTRACT	Lump Sum		$2600.00	3250.00	650.00
Jump Duct Materials	Ea		0.00	50.00	50.00
Insulate Attic Access			0.00	6.00	6.00
Radiant Barrier Decking	68 pcs	2.00	0.00	136.00	136.00
Labor Time					
Jump Duct Install	1 Crew Hour	25.00	0.00	25.00	25.00
100% Compact Fluorescent Bulbs			37.92	133.00	95.08
Management Time	4 Days	275.00	0.00	1100.00	1100.00
Total Due					**$2062.08**

Included in HVAC Subcontract:
- Building America Package
- 14 SEER Heat pump, HSPF 8.5
- Vent Bath Fans to Soffit
- Fresh air intake with damper and filter at air handler unit

Included in Standard HVAC Subcontract
- 13 SEER
- Bath Vents to Attic
- No Fresh air ventilation

Jump Duct materials on this house were donated by another HVAC company, so cost is approximated.

Attic access cost based on donated Dow blueboard insulation, but includes weather stripping cost.

Light Bulb Specifications for standard housing

100W incandescent
Incandescent vanity bulbs
PAR 30 Halogen floodlights

13.96 PAR 30
3.98 Vanity Globes
9.98 Vanity Globes
9.98 100W Incandescent
Total $37.92

The prescribed changes were not difficult to implement in our program, as most changes involved subcontracted HVAC work. Important along those lines are a written set of HVAC specifications and scope of work to be exactly followed by HVAC company. These forms can now be produced based on lessons learned from the pilot home. Other Changes such as radiant barrier decking and 100% CFL bulb replacement took no additional labor and were a matter of simply changing product specifications. Many basic ENERGY STAR best practices have already be implemented as standard practice by the affiliate. Construction management time was factored in to on the prototype home as an administrative and educational cost only to this house, and would not be a cost reflected in future projects. This includes time spent on project working directly with Janet and David, and also time spent in educating staff members on required and best practices. The final financial analysis proves very promising in terms of first year positive cash flow with saved energy cost, and the goals of improving indoor air quality and durability. The cost of the changes with the one time management cost taken out amounts to $962.08. I am recommending that Habitat for Humanity in Mobile County adapt the recommended changes on all houses as standard practices.

Brian Stanley
Construction Direction
Habitat For Humanity In Mobile County
251-476-7171 Main Office
251-476-7978 Main Fax
251-454-0418 Cell habitatbrian@mchsi.com

MOBILE COUNTY HABITAT FOR HUMANITY BUILDING AMERICA HIGH PERFORMANCE DEMONSTRATION HOME SUMMARY REPORT

Habitat for Humanity in Mobile County
851 E. I-65 Service Rd. South
Suite 301
Mobile, Alabama 36606
United States
251-476-7171

For the Project:

3 BEDROOM Building America High Performance Demonstration Home

Project Address: 6732 Jaimee Circle
Development: Fort Lake Trace

PROJECT SUMMARY

The second high performance home specifications were easily implemented by the Mobile affiliate. Since the first house, HVAC system specifications as far as fresh air ventilation, jump duct, and spot ventilation had been made standard practice, as well as attic access insulation. Changes to the high performance home from the prototype included a 15 seer equipment upgrade, which was just a matter of specifying it to the HVAC contractor. Other changes such as the pin based cfl fixtures had no direct effect on the affiliate except for getting new bids out for the fixtures. Changing to pin based cfl had no effect on the electrical labor subcontract. Recommended in the package was utilizing ½" Dow Blueboard over the OSB sheathing to increase wall R value and reduce thermal bridging effect of the framing members. I failed to relay this recommendation the construction staff and the house was constructed without the blueboard. This would have been at no cost on the materials and would have required little effort based on our volunteer labor, and would have been implemented if the oversight had not occurred. The heat pump water heater used a larger 65 gallon electric tank, as compared to our normal 50 gallon. The Geyser HPWH installation took less than an hour and was easily completed by Habitat construction staff. The water heater elements were totally disconnected from the tank, and the heat pump provides all the water heating. There was concern about the ability of the HPWH to provide enough water without the larger tank and under higher use situations. Upon further research, the first hour rating is 62.5 gallons, 12.5 gallon per hour recovery @120 degrees. It was not necessary to disconnect the elements from the tank. The HPWH would have replaced the lower element as the primary heating source, but the upper element could have been left operational and would have worked as designed to supplement heat as needed, with much less worry of running out of hot water. With this knowledge, I would have felt comfortable with a standard 50 gallon tank in this two bedroom home. Another interesting point would have been to duct air from the attic to the HPWH, since the hotter and more humid the air, the greater efficiency of the unit. Also, since the unit can provide ½ ton of air condition and dehumidification, it would be interesting to duct this free byproduct back into the HVAC system.

I believe that the High Performance House Project and its prototype were a successful one for the affiliate, as we picked up many energy efficient and cost saving features that will be placed in our standard housing specifications, as their low cost, high benefit and quick ROI make them a wise decision in our affordable housing program.

Brian Stanley
Construction Direction
Habitat for Humanity in Mobile County

Standard		**Hi-perfromance**		**Difference**
SEER 14 (standard)	$3,395.00	SEER 15	$3,965.00	$570.00
R-30 attic	$599.00	R-38	$570.00	-$29.00
incandescent light	$168.00	all florescent fixtures	$555.59	$387.59
hot water	N/A	add-on hot water heat pump	$1,018.00	$1,018.00

Habitat for Humanity of Baldwin County

Mailing Address: 12678 County Road 65 North · Foley, AL 36535
(251)-943-7268 · FAX (251) 943-7269
Website: www.baldwinhabitat.org Email: Info@baldwinhabitat.org

INVOICE

Bill To: Florida Solar Energy Center
Building America Industrialized Housing Project
1679 Clearlake Rd
Cocoa, FL 32922

Invoice Number 01107576
Date 12/28/2009

Task 1 – 13498 Rooster Lane	Materials	$1351.90
	Labor	$ 318.00
	Total	**$1,669.90**
Task 2 – 1700 S. Oak Street	Materials	$4,408.38
	Labor	$582.00
	Total	**$4,990.38**

Total Amount Due ------------------------------------ $6,660.28

Habitat founder Linda Fuller says,
“We can’t eliminate poverty housing using only 50% of the population.”

Habitat for Humanity of Baldwin County
Energy Saving Costs

Task 2 - 1700 S. Oak Street, Foley - Job 76

Description	Standard	Energy Upgrade	Difference	Subtotals
Materials				
Roof Trusses	1,270.00	1,525.00	255.00	
R-38 Insulation		85.00	85.00	
Metal Roof	1,400.45	1,598.50	198.05	
Water Heater		3,500.00	3,500.00	
Bath Fans	88.00	99.48	11.48	
Bath Fans	88.00	174.67	86.67	
House Wrap Tape	0.00	41.44	41.44	
Extra Caulk		68.40	68.40	
Exterior Door	147.66	229.26	81.60	
Exterior Door	142.24	222.98	80.74	4,408.38
Labor				
Site Supervisor			108.00	
Construction Manager			306.00	
Assist. Const. Manager			168.00	582.00
Totals	3,136.35	7,544.73	4,990.38	4,990.38

Task 1 - 13498 Rooster Lane, Foley - Job 75

Description	Standard	Energy Upgrade	Difference	Subtotals
Materials				
Roof Trusses	1,750.00	2,020.00	270.00	
Heat Pump Upgrade			600.00	
Styrofoam Sheating		340.20	340.20	
Exterior Door	140.00	210.85	70.85	
Exterior Door	140.00	210.85	70.85	1,351.90
Labor				
Site Supervisor			108.00	
Construction Manager			126.00	
Assist. Const. Manager			84.00	318.00
Totals	2,030.00	2,781.90	1,669.90	1,669.90

Habitat for Humanity St. Tammany West
Building America High Performance Demonstration Home Cost Analysis

70421 Lake Reelfoot Dr., Covington LA
4BR “Ms. Barbara” Floor Plan

70415 Lake Reelfoot Dr., Covington LA
3BR “Modified Kollister” Floor Plan (on slab)

The changes prescribed by the Building America Program were not at all difficult to implement. Things like upgraded insulation, better doors and windows, radiant barrier decking and ENERGY STAR appliances didn’t take any extra time or effort beyond specifying the difference from the code compliant product. Using Dow’s instructional handout made the installation of window flashing and great stuff very volunteer friendly and will increase the durability and energy efficiency of our homes. We had to take some time with the HVAC contractor to let them know exactly what we wanted in terms of SEER, EER, and the fresh air intake, but they were open to the changes. One big lesson we learned was to ‘box in’ the HVAC closet before the rough-in as long as there would be room for the subcontractor to seal the unit to the air return. It was much more difficult to ‘box in’ the HVAC closet after the unit and drywall were installed.

Working with Janet and David has helped out construction staff think of the entire house as a system rather than individual parts. Once staff members understand that concept they are able to do a much better job with air sealing and insulating. It was also nice to have the blower door tests to verify how much difference these small attentions to detail make in the long run. I will strongly suggest that our affiliate makes the new processes and materials standard procedure.

Habitat for Humanity St. Tammany West			Invoice	Task #1
1400 North Lane				
Mandeville, LA 70471				
985-893-3172			11/13/2009	
Florida Solar Energy Center				
Building America Industrialized Housing Project				
1679 Clearlake Rd				
Cocoa, FL 32922				
321-638-1433				
Project Address: 70415 Lake Reel Foot, Covington LA				

Name	Unit	Standard Specifications	Building America Specifications	Incremental Cost Difference Per Unit	Incremental Cost Difference Total
Radiant Barrier Decking	58	$9.97	$13.60	3.63	$ 210.54
Exterior 6 Panel Door	1	$88.00	$223.08	135.08	$ 135.08
Exterior Sunburst	1	$184.00	$364.10	180.1	$ 180.10
3050 Windows	6	$62.00	$93.00	31	$ 186.00
2030 Windows	2	$40.00	$123.00	83	$ 166.00
Exterior Wall Insulation (square feet)	1232	$0.23	$0.47	0.24	$ 295.68
HVAC System	1	$4,195.00	$5,405.30	1210.3	$ 1,210.30
Additional Hours for HVAC	1	$0.00	$ 20.00	20	$ 20.00
Refrigerator	1	$549.00	$619.00	70	$ 70.00
Ceiling Fans	4	$17.78	$77.94	60.16	$ 240.64
Additional Hours to Seal HVAC	4	$0.00	$13.50	13.5	$ 54.00
Straight Flashing	1	$0.00	$36.99	36.99	$ 36.99
Additional Hours for Flashing	2	$0.00	$13.50	13.5	$ 27.00
Spray Foam Gap and Crack	9	$0.00	$9.99	9.99	$ 89.91
Additional Hours for G&C	1	$0.00	$13.50	13.5	$ 13.50
Spray Foam Window and Door	7	$0.00	$12.49	12.49	$ 87.43
Additional Hours for W&D	1	$0.00	$13.50	13.5	$ 13.50
Additional Management Time	4	$0.00	$20.00	20	$ 80.00
Total Incremental Cost					**$ 3,116.67**

				Invoice	Task #2
Habitat for Humanity St. Tammany West					
1400 North Lane					
Mandeville, LA 70471					
985-893-3172				11/13/2009	
Florida Solar Energy Center					
Building America Industrialized Housing Project					
1679 Clearlake Rd					
Cocoa, FL 32922					
321-638-1433					
Project Address: 70421 Lake Reel Foot, Covington LA					

Name	Unit	Standard Specifications	Building America Specifications	Incremental Cost Difference Per Unit	Incremental Cost Difference Total
Radiant Barrier Decking	56	$9.97	$13.60	3.63	$ 203.28
Exterior 6 Panel Door	1	$88.00	$223.08	135.08	$ 135.08
Exterior Sunburst	1	$184.00	$364.10	180.1	$ 180.10
3050 Windows	7	$62.00	$93.00	31	$ 217.00
2030 Windows	3	$40.00	$123.00	83	$ 249.00
Floor Insulation (square feet)	1262	$0.23	$1.11	0.88	$ 1,110.56
Exterior Wall Insulation (square feet)	1232	$0.23	$0.47	0.24	$ 295.68
HVAC System	1	$4,195.00	$5,405.30	1210.3	$ 1,210.30
Additional Staff Hours for HVAC	1	$0.00	$20.00	20	$ 20.00
Refrigerator	1	$549.00	$619.00	70	$ 70.00
Dishwasher	1	$218.00	$230.00	12	$ 12.00
Ceiling Fans	5	$17.78	$74.25	56.47	$ 282.35
Additional Hours to Seal HVAC	4	$0.00	$13.50	13.5	$ 54.00
Straight Flashing	1	$0.00	$36.99	36.99	$ 36.99
Additional Hours for Flashing	2	$0.00	$13.50	13.5	$ 27.00
Spray Foam Gap and Crack	9	$0.00	$9.99	9.99	$ 89.91
Additional Hours for G&C	1	$0.00	$13.50	13.5	$ 13.50
Spray Foam Window and Door	7	$0.00	$12.49	12.49	$ 87.43
Additional Hours for W&D	1	$0.00	$13.50	13.5	$ 13.50
Additional Management Hours	4	$0.00	$20.00	20	$ 80.00
Total Incremental Cost					**$ 4,387.68**

ENERGY STAR LESSONS LEARNED – HFHMGC

A little over a year ago we made the decision to begin to build some of our houses to Energy Star standards. We did not know what to expect or what we would necessarily have to do to accomplish this. We started by have a couple of our existing homes tested by a HERS rater and the results were not ideal. With HERS indexes around 110 we knew we would have to change some things to achieve the ratings of 85 or better that we would need to qualify as Energy Star.

We began researching the requirements, doing some cost analysis and decided to build or first Energy Star home. As the home was built and the testing was done we realized that this was actually easy. With a final result of a HERS rating of 69 we have decided to build more and eventually all our homes to Energy Star standards. The following are some of the lessons we learned.

Building an Energy Star home actually takes minimal effort as far as labor is concerned. By educating our site supervisors and contractors as to the requirements we need and expect as far as equipment installation and building techniques, I seriously doubt we added more than a day to the entire build schedule. Building a tighter envelope included things like sealing all penetrations with caulk or foam no matter where or how small and proper installation of the air barrier. Better insulation techniques played a big part in the process. Eliminating all air voids, compression of bats, proper cut-ins and proper sizing all amounted to huge gains for the rating and the future home owner's utility bills. By sealing all plug and switch boxes, all vents and access panels we effectively tightened the envelope well beyond the minimum standards needed.

As far as equipment and material requirements, we upgraded from a SEER 13 to a SEER 14 unit and added a passive air intake. Low E windows with Energy Star ratings and radiant barrier roof decking also added big gains. Rounding out the additions with CFL lighting, an Energy Star refrigerator and increasing the blown in insulation to R-30 in the attic gave us a great Energy Star home.

All said and done we have learned that with very little effort and only a small monetary increase we can build our homes to Energy Star standards. We anticipate up to a 30% savings for the home owner in their utility bills. The equipment will run more efficiently increasing the life expectancy of that equipment. Less outside air infiltration and better moisture control means better indoor air quality and hopefully a better quality of life for the home owner.

What did we learn from all of this? With little effort we can benefit the home owners, benefit ourselves and benefit our world.

Bracky Cooper
Construction Manager HFHMGC

1636 Popps Ferry Road
Suite M-13
Biloxi, MS 39532

Invoice

Date	Invoice #
4/28/2009	1240

Bill To

Florida Solar Energy Center
ATTN: David Beal
Building America Ind. Housing Project
1679 Clearlake Road
Cocoa, FL 32922

Terms	Project
Net 10	2201 21st Ave, Gulfport, MS

Description	Amount
UPGRADE FROM CONVENTIONAL HEAT PUMP SYSTEM TO ENERGY STAR:	
R-6 Duct Board, R-6 Insulated Boxes, R-6 Flex	250.00
Programmable Thermostat	20.00
Variable Speed Air Handler (RHLL Series)	165.00
Fresh Air Duct Material and Labor	150.00
Tax on above items	40.95
OTHER UPGRADED ITEMS:	
R-19 (.335) to R-30 (.538) Underfloor Insulation - 1,144 sf x .203/sq, plus tax	248.49
15/32 OSB (5.99) to 15/32 Tech Shield (9.23) - 54 boards x 3.24/board, plus tax	187.21
Standard Windows to Low "E" - (7) 3050 (+30.31 ea)	212.17
Standard Windows to Low "E" - (1) 2830 (+16.43 ea)	16.43
Affiliate labor, 16 hours @ 15.00/hour	240.00
INVOICE AMOUNT ADJUSTED PER CREDIT MEMO #1412, 8/6/09 PER VICTOR ALFSEN - REVISED INVOICE TOTAL $1,094.55.	
	Total Due $1,530.25

David Beal
Florida Solar Energy Center
Building America Industrialized Housing Project
1679 Clearlake Rd
Cocoa, FL 32922
321-638-1433
Fax: 321-638-1439, Attn: Beal

Lessons Learned

As the Construction Director for a participating partner in the Building America Industrialized Housing Project, I oversaw the completion of two homes meeting the program's criteria. I learned, and was able to teach others, about various methods of inexpensively increasing energy efficiency. The affordable measures we undertook increased our efficiency and often cost little to no additional money. Instead, we learned how to best install the materials we already used and became aware of other inexpensive tactics yielding energy savings that surpass the cost of installation. The presentation of the criteria was helpful in that it was organized in order of impact, allowing us to understand what made the greatest amount of difference. Our affiliate has permanently adopted many of the requirements for this program, further increasing our efficiency for rather minimal amounts of money. Through the partnership we learned a good deal and much of that is attributable to our contacts at the Florida Solar Energy Center.

The greatest lesson learned is that with a relatively small time and monetary commitment, homes can be made dramatically more energy efficient. The result of this efficiency is a conservation of resources, mainly money and time. Through this partnership our affiliate tried to target the best values of energy efficiency ideas. Having to complete these tasks expressly for the Building America Program was the impetus we needed to begin thinking more directly and intentionally about energy efficiency, even making it the main talking point for our affiliate's homes.

The energy auditors and their guidance were one of the greatest assets of this program. For the past year our affiliate has worked with David Beal and Janet McIlvaine, who have answered numerous questions and taught us the latest methods of building efficiently. When first tested, our homes actually faired well regarding energy efficiency. However, there were a few issues; the most serious being the HVAC closet having no barrier between it and the attic. With the help of Janet and David we were able to solve this problem with scrap lumber and a minimal amount of mastic UL-180. This is a prime example of affordably solving a problem. In other areas we tweaked our existing methods, for instance we began to caulk the top and bottom of the housewrap to seal the envelope. The amalgamation of this knowledge and the willingness of our staff made this project achievable. The program also gave specifics into each compartmentalized task, such as insulation, but David and Janet synthesized this information into a system where each part of the house affects another. Beginning to think in this manner, in positive and negative pressure, in controlling humidity which affects the A/C unit and so forth, gave us a more realized picture of energy efficiency and how disparate materials and installation can affect numerous other things in a house through chain reactions.

With the knowledge gleaned throughout the months of participation in this program I feel we have realized a new standard in our home building. That standard in basic terms is to reap the most benefit for the least amount of money. In this instance, I think the program lends itself especially well to the non-profit world where labor is often free as performing tasks correctly almost unanimously takes longer than doing it to simply pass code. I do not see a future for rental properties or speculation homes as energy costs will be covered and most likely ignored by the residents. I think the best way to disseminate this information would be to educate and inform future homeowners/homebuyers with classes so they can be made aware of the importance and relative ease of making their home 30% more energy efficient. If future tenants can link their future monetary commitments to correctly installed insulation and sealed bottom plates, we can begin to think about building in terms of how soon and begin to think in how well, how tight.

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Item	Passing Code	DOE 30%	Difference	Time
Straight Flashing	0	75.96	75.96	2 hours
Great stuff	0	74.85	74.85	2 hours
Windows	804.18	933	128.82	0 hours
HVAC	3900	4580	680	2 hours
Shingles	0	0	0	0 hours
Siding Color	0	0	0	0 hours
Caulk for house wrap	0	23.94	23.94	1 hour
Insulated door	149	149	0	0 hours
Mastic	0	12.04	12.04	2 hours
CFLs	25	55.96	30.96	0 hours
Attic access	0	15	15	4 hours
Hood vent	39	94	55	2 hours
Refridgerator	378	949	571	0 hours
Radiant barrier OSB	251.62	390.08	138.46	0 hours
Ceiling fans	163.44	480	316.56	0 hours
Proper Insulation	0	0	0	5 hours

Lessons Learned

As mentioned before, our affiliate has been using energy efficient building practices for quite some time; so, incorporating these additional techniques was fairly easy. The two biggest changes were redesigning the layout of the home by moving the air handler to the first floor and the work done by our HVAC subcontractor, Buddy's Heating and A/C. One thing about moving the air handler down to the first floor is that it does take up room from the actual living area making the layout of the rooms slightly smaller. Also, we later learned that since we already use radiant barrier in our homes, which are less than 2000 square feet, that it is not necessary to move the air handler to the main floor. So, I do not believe that we will continue to keep the air handler in the homes that are smaller in size. Also, we purchased attic vent baffles from a local insulation company, and that seemed repetitive since we already place a piece of DOW blueboard over the vent/soffit opening which acts in the same purpose.

The additional costs to implement these practices were very minimal, and most of the additional cost went towards building the mold-resistant closet for the air handler. There were no additional costs for the custom-made trusses despite the fact that they used 2x6 top and bottom chords. Also, the HVAC labor and material for Lot #24 ended up being $100 less than the other four bedroom homes in the same subdivision. In installing the HVAC system, Buddy's Heating and Air used an R8 rating. Louisiana code is R6. Considering equipment differences, our HVAC subs used a condenser heat pump instead of the standard condenser as well as an expansion valve in the coil which offers better capacity.

Our affiliate will continue building energy efficient homes. Much like the affiliate in Mobile, Alabama, these changes are simply a matter of changing product specifications, which is something that we will continue doing. It's these simple changes that we hope will create better, safer homes for our homeowners. Perhaps we may look towards the possibility of LEED certification in the future.

Appendix F: Improvement Analysis, Package, Benchmark, and 2004 International Energy Conservation Code complaint "Regional Standard"

Improvement Analysis
Because there was a wide variation in standard/baseline construction among the partners, researchers conducted an improvement analysis with respect to the 2004 IECC. The goal was to make the analysis more applicable to builders outside the demonstration project.

Researchers developed simulation models in Energy Gauge USA, compliant with the 2004 IECC, using a slab on grade design from the Mobile County affiliate and a pier foundation design from the New Orleans affiliate. Researchers then simulated each element of the 30% improvement package in these two models. The results of this improvement analysis (see slides below) were presented individually with an implementation discussion to builder and subcontractor audiences at three workshops in the region.

Mobile Co. Standard	30% Improvement	30% Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$256.00	$12.80	$20.46
Standard Decking	RBS Decking	$136.00	$6.80	$10.87
Standard Exterior Doors	Hi-R Exterior Doors	$206.00	$10.30	$16.46
HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 14 HP	$650.00	$32.50	$51.95
SEER 13 HP	SEER 15 HP			
Hot Water				
Electric Tank Hot Water	Heat Pump Hot Water			
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$320.50	$16.03	$25.61
Standard vent fan	vent to out fan (2)	$104.00	$5.20	$8.31
Incandescent Lighting	Screw CFL Lighting	$95.00	$4.75	$7.59
Incandescent Lighting	Pin CFL Lighting			
Miscellaneous				
Materials		$6.00	$0.30	$0.48
Additional Labor		$575.00	$28.75	$45.95
TOTAL		**$2,348.50**	**$117.43**	**$187.69**

Mobile Co 30%	Annual Source Energy			Estimated Source Energy Savings			
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard
Space Heating	22.88	15.25	9.35	59.2%	38.7%	7.4%	3.8%
Space Cooling	46.59	30.52	14.60	68.7%	52.1%	17.6%	10.2%
DHW	33.30	31.47	31.48	5.5%	0.0%	1.0%	0.0%
Lighting	19.13	19.78	6.56	65.7%	66.8%	6.9%	8.5%
Appl. & MEL	59.62	58.82	56.39	5.4%	4.1%	1.8%	1.6%
Ceiling Fan	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%
OA Vent Fan	0.22	0.24	2.54	-1064%	-953%	-1.3%	0.0%
Total Usage	**181.74**	**156.08**	**120.93**	**33.5%**	**22.5%**	**33.5%**	**22.5%**
Site Generation	0.00	0.00	0.00			0.0%	0.0%
Net Energy Use	**181.74**	**156.08**	**120.93**	**33.5%**	**22.5%**	**33.5%**	**22.5%**

Mobile Co 30%	Annual Site Energy			Estimated Site Energy Savings					
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total		Annual Utility Bill Reduction ($0.12/kwh)	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard	Prototype WRT Benchmark	Prototype WRT Standard
Space Heating	6.80	4.53	2.78	59.2%	38.7%	7.4%	3.8%	$141.45	$61.67
Space Cooling	13.85	9.07	4.34	68.7%	52.1%	17.6%	10.2%	$334.23	$166.27
DHW	9.90	9.35	9.36	5.5%	0.0%	1.0%	0.0%	$19.02	-$0.07
Lighting	5.68	5.88	1.95	65.7%	66.8%	6.9%	8.5%	$131.25	$138.11
Appl. & MEL	17.72	17.48	16.76	5.4%	4.1%	1.8%	1.6%	$33.72	$25.32
Ceiling Fan	0.00	0.00	0.00	0%	0.0%	0.0%	0.0%	$0.00	$0.00
OA Vent Fan	0.07	0.07	0.75	-1060%	-947%	-1.3%	-1.5%	-$24.23	-$23.98
Total Usage	**54.01**	**46.38**	**35.94**	**33.5%**	**22.5%**	**33.5%**	**22.5%**	**$635.45**	**$367.32**
Site Generation	0.00	0.00	0.00			0.0%	0.0%	$0.00	$0.00
Net Energy Use	**54.01**	**46.38**	**35.94**	**33.5%**	**22.5%**	**33.5%**	**22.5%**	**$635.45**	**$367.32**
Added Annual Mortgage Cost (20 Yr @ 0%) w/o Site Generation								**$117.43**	**$117.43**
Net Annual Cash Flow to Consumer w/o Site Generation								**$518.02**	**$249.89**
Added Annual Mortgage Cost (30 Yr @ 7%) w/o Site Generation								**$187.69**	**$187.69**
Net Annual Cash Flow to Consumer w/o Site Generation								**$447.76**	**$179.63**

MCHFH Standard	40% Improvement	40% Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$256.00	$12.80	$20.43
Standard Decking	RBS Decking	$136.00	$6.80	$10.85
Standard Exterior Doors	Hi-R Exterior Doors	$206.00	$10.30	$16.44
HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 14 HP			
SEER 13 HP	SEER 15 HP	$1,220.00	$61.00	$97.36
Hot Water				
Electric Tank Hot Water	Heat Pump Hot Water	$1,018.00	$50.90	$81.24
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$320.50	$16.03	$25.58
Standard vent fan	vent to out fan (2)	$98.00	$4.90	$7.82
Incandescent Lighting	Screw CFL Lighting			
Incandescent Lighting	Pin CFL Lighting	$388.00	$19.40	$30.96
Miscellaneous				
Materials				
Additional Labor		$550.00	$27.50	$43.89
TOTAL		**$4,192.50**	**$209.63**	**$334.56**

Mobile Co 40%	Annual Source Energy			Estimated Source Energy Savings			
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard
Space Heating	19.70	15.70	8.35	57.6%	46.8%	6.2%	4.7%
Space Cooling	40.04	27.30	11.47	71.4%	58.0%	15.7%	10.1%
DHW	27.87	26.21	13.39	51.9%	48.9%	8.0%	8.2%
Lighting	17.55	18.16	4.89	72.1%	73.1%	7.0%	8.5%
Appl. & MEL	52.58	51.77	49.35	6.1%	4.7%	1.8%	1.6%
Ceiling Fan	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%
OA Vent Fan	0.22	0.18	1.96	-800.5%	-966.8%	-1.0%	0.0%
Total Usage	**157.95**	**139.32**	**89.41**	**43.4%**	**35.8%**	**43.4%**	**35.8%**
Site Generation	0.00	0.00	0.00			0.0%	0.0%
Net Energy Use	**157.95**	**139.32**	**89.41**	**43.4%**	**35.8%**	**43.4%**	**32.0%**

Mobile Co 40%	Annual Site Energy			Estimated Site Energy Savings				Annual Utility Bill Reduction ($0.12/kwh)	
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total			
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard	Prototype WRT Benchmark	Prototype WRT Standard
Space Heating	5.86	4.66	2.48	57.6%	46.8%	6.2%	4.7%	$104.79	$76.75
Space Cooling	11.90	8.11	3.41	71.3%	58.0%	15.7%	10.1%	$263.65	$165.43
DHW	8.28	7.79	3.98	51.9%	48.9%	8.0%	8.2%	$133.61	$133.92
Lighting	5.22	5.40	1.45	72.1%	73.1%	7.0%	8.5%	$116.87	$138.64
Appl. & MEL	15.62	15.39	14.67	6.1%	4.7%	1.8%	1.6%	$29.78	$25.32
Ceiling Fan	0.00	0.00	0.00	0%	0.0%	0.0%	0.0%	$0.00	$0.00
OA Vent Fan	0.07	0.06	0.58	-797%	-960%	-1.0%	-1.1%	-$16.09	-$18.56
Total Usage	**46.94**	**41.40**	**26.57**	**43.4%**	**35.8%**	**43.4%**	**35.8%**	**$716.17**	**$521.49**
Site Generation	0.00	0.00	0.00			0.0%	0.0%	$0.00	$0.00
Net Energy Use	**46.94**	**41.40**	**26.57**	**43.4%**	**35.8%**	**43.4%**	**35.8%**	**$716.17**	**$521.49**
Added Annual Mortgage Cost (20 Yr @ 0%) w/o Site Generation								**$209.63**	**$209.63**
Net Annual Cash Flow to Consumer w/o Site Generation								**$506.54**	**$311.86**
Added Annual Mortgage Cost (30 Yr @ 7%) w/o Site Generation								**$334.56**	**$334.56**
Net Annual Cash Flow to Consumer w/o Site Generation								**$381.61**	**$186.93**

Baldwin Co Standard	30% Improvement	30% Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Standard Windows	Low-E Windows(8)	$256.00	$12.80	$20.43
R-30 attic	R-38 Attic			
Galvalume metal roofing	White metal Roofing			
Standard Exterior Doors	Hi R Exterior Doors	$142.00	$7.10	$11.33
	R-3 Exterior wall insulation	$340.00	$17.00	$27.13
Standard Truss	Raised Heal Truss	$270.00	$13.50	$21.55
Hot Water and HVAC ***including duct upgrade and fresh***				
Total SEER	Total SEER 14	$600.00	$30.00	$47.88
Electric Tank	Solar Hot Water			
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$320.50	$16.03	$25.58
Standard vent fan	ESTAR vent to-out fan (2)	$98.00	$4.90	$7.82
Standard Ceiling Fans	ESTAR Ceiling Fans (5 and 1)	$347.50	$17.38	$27.73
Incandescent Lighting	Screw CFL Lighting	$87.50	$4.38	$6.98
Miscellaneous				
Materials				
Additional Labor		$318.00	$15.90	$25.38
TOTAL		**$2,779.50**	**$138.98**	**$221.80**

Baldwin Co 30%	Annual Source Energy			Estimated Source Energy Savings			
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard
Space Heating	26.81	17.74	10.13	62.2%	42.9%	7.8%	4.2%
Space Cooling	54.56	34.69	16.71	69.4%	51.8%	17.8%	9.8%
DHW	39.00	37.05	37.07	4.9%	-0.1%	0.9%	0.0%
Lighting	19.59	20.26	6.83	65.1%	66.3%	6.0%	7.4%
Appl. & MEL	65.88	65.88	62.65	4.9%	4.9%	1.5%	1.8%
Ceiling Fan	6.87	6.87	3.73	45.7%	46%	1.5%	1.7%
OA Vent Fan	0.23	0.24	2.40	-943%	-896%	-1.0%	0.0%
Total Usage	**212.93**	**182.72**	**139.51**	**34.5%**	**23.6%**	**34.5%**	**23.6%**
Site Generation	0.00	0.00	0.00			0.0%	0.0%
Net Energy Use	**212.93**	**182.72**	**139.51**	**34.5%**	**23.6%**	**34.5%**	**23.6%**

Baldwin Co 30%	Annual Site Energy			Estimated Site Energy Savings					
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total		Annual Utility Bill Reduction ($0.12/kwh)	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard	Prototype WRT Benchmark	Prototype WRT Standard
Space Heating	7.97	5.27	3.01	62.2%	42.9%	7.8%	4.2%	$153.99	$79.57
Space Cooling	16.21	10.31	4.96	69.4%	51.8%	17.7%	9.8%	$349.40	$187.90
DHW	11.59	11.01	11.02	4.9%	-0.1%	0.9%	0.0%	$17.80	-$0.25
Lighting	5.82	6.02	2.03	65.1%	66.3%	6.0%	7.3%	$117.77	$140.36
Appl. & MEL	19.58	19.58	18.62	4.9%	4.9%	1.5%	1.8%	$29.78	$33.72
Ceiling Fan	2.17	2.17	1.18	46%	45.7%	1.6%	1.8%	$30.81	$34.88
OA Vent Fan	0.07	0.07	0.71	-949%	-890%	-1.0%	-1.2%	-$20.03	-$22.54
Total Usage	**63.41**	**54.43**	**41.53**	**34.5%**	**23.7%**	**34.5%**	**23.7%**	**$769.27**	**$453.63**
Site Generation	0.00	0.00	0.00			0.0%	0.0%	$0.00	$0.00
Net Energy Use	**63.41**	**54.43**	**41.53**	**34.5%**	**23.7%**	**34.5%**	**23.7%**	**$769.27**	**$453.63**
Added Annual Mortgage Cost (20 Yr @ 0%) w/o Site Generation								**$139.98**	**$139.98**
Net Annual Cash Flow to Consumer w/o Site Generation								**$629.29**	**$313.65**
Added Annual Mortgage Cost (30 Yr @ 7%) w/o Site Generation								**$221.80**	**$221.80**
Net Annual Cash Flow to Consumer w/o Site Generation								**$547.47**	**$231.83**

Baldwin Co Standard	40% Improvement	40% Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Standard Windows	Low-E Windows(8)	$256.00	$12.80	$20.43
R-30 attic	R-38 Attic	$85.00	$4.25	$6.78
Galvalume metal roofing	White metal Roofing	$199.00	$9.95	$15.88
Standard Exterior Doors	Hi R Exterior Doors	$162.00	$8.10	$12.93
	R-3 Exterior wall insulation	$340.00	$17.00	$27.13
Standard Truss	Raised Heal Truss	$255.00	$12.75	$20.35
Hot Water and HVAC ***including duct upgrade and fresh***				
Total SEER 13	Total SEER 14	$232.50	$11.63	$18.55
Electric tank	Solar Hot Water	$3,500.00	$175.00	$279.30
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$320.50	$16.03	$25.58
Standard vent fan	ESTAR vent to-out fan (2)	$109.63	$5.48	$8.75
Standard Ceiling Fans	ESTAR Ceiling Fans (5 and 1)	$69.50	$3.48	$5.55
Incandescent Lighting	Screw CFL Lighting	$87.50	$4.38	$6.98
Miscellaneous				
Materials		$110.00	$5.50	$8.78
Additional Labor		$582.00	$29.10	$46.44
TOTAL		**$6,308.63**	**$315.43**	**$503.43**

Baldwin Co 40%	Annual Source Energy			Estimated Source Energy Savings			
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard
Space Heating	19.24	12.57	5.51	71.4%	56.2%	6.4%	3.9%
Space Cooling	50.25	32.94	15.71	68.7%	52.3%	16.2%	9.4%
DHW	33.33	32.10	9.39	71.8%	70.8%	11.2%	12.4%
Lighting	17.82	18.43	13.94	21.8%	24.4%	1.8%	2.5%
Appl. & MEL	58.74	58.74	55.13	6.1%	6.1%	1.7%	2.0%
Ceiling Fan	5.50	5.50	4.93	10.4%	10.4%	0.3%	0.3%
OA Vent Fan	0.22	0.23	2.41	-1006%	-948%	-1.0%	0.0%
Total Usage	**185.10**	**160.51**	**107.02**	**42.2%**	**33.3%**	**42.2%**	**33.3%**
Site Generation	0.00	0.00	0.00			0.0%	0.0%
Net Energy Use	**185.10**	**160.51**	**107.02**	**42.2%**	**33.3%**	**36.7%**	**29.3%**

Baldwin Co 40%	Annual Site Energy			Estimated Site Energy Savings				Annual Utility Bill Reduction ($0.12/kwh)	
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total			
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard	Prototype WRT Benchmark	Prototype WRT Standard
Space Heating	5.72	3.74	1.64	71.4%	56.2%	6.4%	3.9%	$126.75	$73.77
Space Cooling	14.93	9.79	4.67	68.7%	52.3%	16.2%	9.4%	$318.84	$180.05
DHW	9.91	9.54	2.79	71.8%	70.8%	11.2%	12.4%	$221.01	$237.33
Lighting	5.30	5.48	4.14	21.8%	24.4%	1.8%	2.5%	$35.78	$46.90
Appl. & MEL	17.46	17.46	16.38	6.1%	6.1%	1.7%	2.0%	$33.26	$37.66
Ceiling Fan	1.74	1.74	1.56	10%	10.4%	0.3%	0.3%	$5.62	$6.36
OA Vent Fan	0.07	0.07	0.72	-1003%	-954%	-1.0%	-1.2%	-$20.25	-$22.82
Total Usage	**55.11**	**47.81**	**31.90**	**42.1%**	**33.3%**	**42.1%**	**33.3%**	**$816.24**	**$559.25**
Site Generation	0.00	0.00	0.00			0.0%	0.0%	$0.00	$0.00
Net Energy Use	**55.11**	**47.81**	**31.90**	**42.1%**	**33.3%**	**42.1%**	**33.3%**	**$816.24**	**$559.25**
Added Annual Mortgage Cost (20 Yr @ 0%) w/o Site Generation								**$315.43**	**$315.43**
Net Annual Cash Flow to Consumer w/o Site Generation								**$500.81**	**$243.82**
Added Annual Mortgage Cost (30 Yr @ 7%) w/o Site Generation								**$503.43**	**$503.43**
Net Annual Cash Flow to Consumer w/o Site Generation								**$312.81**	**$55.82**

Slidell Standard	30% Improvement	30% Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$128.80	$6.44	$10.28
standard decking	rbs decking (46)	$138.00	$6.90	$11.01
HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 14 HP	$680.00	$34.00	$54.26
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$571.00	$28.55	$45.57
Standard vent fan	vent to out fan (2)	$110.00	$5.50	$8.78
Standard Ceiling Fans	ESTAR Ceiling Fans (4)	$317.00	$15.85	$25.30
Incandescent Lighting	Screw CFL Lighting (20)	$31.00	$1.55	$2.47
	Pin CFL Lighting			
Miscellaneous				
Materials		$202.00	$10.10	$16.12
Additional Labor		$231.00	$11.55	$18.43
TOTAL		**$2,408.80**	**$120.44**	**$192.22**

Slidell 30%	**Annual Source Energy**			**Estimated Source Energy Savings**			
Description	**BA Bench**	**Regional Standard Practice**	**Prototype House**	**Percent of End Use**		**Percent of Total**	
End Use	**Mbtu/y**	**Mbtu/y**	**Mbtu/y**	**vs. BA Bench**	**vs. Standard**	**vs. BA Bench**	**vs. Standard**
Space Heating	18.06	11.99	6.63	63.3%	44.7%	6.1%	3.3%
Space Cooling	54.11	38.28	19.56	63.8%	48.9%	18.4%	11.4%
DHW	32.09	30.35	30.36	5.4%	0.0%	0.9%	0.0%
Lighting	18.41	19.04	8.22	55.4%	56.8%	5.4%	6.6%
Appl. & MEL	59.04	59.04	55.81	5.5%	5.5%	1.7%	2.0%
Ceiling Fan	5.50	5.50	3.38	38.6%	39%	1.1%	1.3%
OA Vent Fan	0.22	0.18	2.39	-995%	-1198%	-1.2%	0.0%
Total Usage	**187.42**	**164.38**	**126.35**	**32.6%**	**23.1%**	**32.6%**	**23.1%**
Site Generation	0.00	0.00	0.00			0.0%	0.0%
Net Energy Use	**187.42**	**164.38**	**126.35**	**32.6%**	**23.1%**	**32.6%**	**23.1%**

Slidell 30%	Annual Site Energy			Estimated Site Energy Savings				Annual Utility Bill Reduction ($0.12/kwh)	
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total			
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard	Prototype WRT Benchmark	Prototype WRT Standard
Space Heating	5.37	3.56	1.97	63.3%	44.7%	6.1%	3.3%	$105.54	$56.01
Space Cooling	16.08	11.38	5.81	63.8%	48.9%	18.4%	11.4%	$318.87	$195.56
DHW	9.54	9.02	9.02	5.4%	0.0%	0.9%	0.0%	$15.93	-$0.07
Lighting	5.47	5.66	2.44	55.3%	56.8%	5.4%	6.6%	$94.04	$113.07
Appl. & MEL	17.54	17.54	16.59	5.5%	5.5%	1.7%	2.0%	$29.78	$33.72
Ceiling Fan	1.74	1.74	1.07	39%	38.6%	1.2%	1.4%	$20.87	$23.63
OA Vent Fan	0.07	0.06	0.71	-992%	-1191%	-1.2%	-1.3%	-$20.03	-$23.03
Total Usage	**55.80**	**48.96**	**37.61**	**32.6%**	**23.2%**	**32.6%**	**23.2%**	**$639.63**	**$398.89**
Site Generation	0.00	0.00	0.00			0.0%	0.0%	$0.00	$0.00
Net Energy Use	**55.80**	**48.96**	**37.61**	**32.6%**	**23.2%**	**32.6%**	**23.2%**	**$639.63**	**$398.89**
Added Annual Mortgage Cost (20 Yr @ 0%) w/o Site Generation								**$120.44**	**$120.44**
Net Annual Cash Flow to Consumer w/o Site Generation								**$519.19**	**$278.45**
Added Annual Mortgage Cost (30 Yr @ 7%) w/o Site Generation								**$192.22**	**$192.22**
Net Annual Cash Flow to Consumer w/o Site Generation								**$447.41**	**$206.67**

Covington Standard	40% Improvement	40% Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$352.00	$17.60	$28.09
standard decking	rbs decking (58)	$210.54	$10.53	$16.80
Standard Door (2)	Hi-R door	$315.18	$15.76	$25.15
R-11 (1232 ft2)	R-15 Wall	$295.68	$14.78	$23.60
HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 15 HP	$1,210.30	$60.52	$96.58
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$70.00	$3.50	$5.59
Standard vent fan	vent to out fan (2)	$104.00	$5.20	$8.30
Standard Ceiling Fans	ESTAR Ceiling Fans (4)	$240.64	$12.03	$19.20
Incandescent Lighting	Screw CFL Lighting (20)	$87.50	$4.38	$6.98
	Pin CFL Lighting			
Miscellaneous				
Materials		$214.00	$10.70	$17.08
Additional Labor		$188.00	$9.40	$15.00
TOTAL		**$3,287.84**	**$164.39**	**$262.37**

Covington 40%	Annual Source Energy			Estimated Source Energy Savings			
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard
Space Heating	33.68	21.07	10.21	69.7%	51.6%	10.0%	5.5%
Space Cooling	69.60	47.21	21.79	68.7%	53.8%	20.4%	12.8%
DHW	38.81	36.53	34.69	10.6%	5.0%	1.8%	0.9%
Lighting	19.72	20.39	5.49	72.1%	73.1%	6.1%	7.5%
Appl. & MEL	65.95	65.95	62.28	5.6%	5.6%	1.6%	1.8%
Ceiling Fan	6.87	6.87	3.82	44.4%	44%	1.3%	1.5%
OA Vent Fan	0.22	0.28	2.58	-1085%	-836%	-1.0%	0.0%
Total Usage	**234.83**	**198.29**	**140.86**	**40.0%**	**29.0%**	**40.0%**	**29.0%**
Site Generation	0.00	0.00	0.00			0.0%	0.0%
Net Energy Use	**234.83**	**198.29**	**140.86**	**40.0%**	**29.0%**	**40.0%**	**29.0%**

Covington 40%	Annual Site Energy			Estimated Site Energy Savings					
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total		Annual Utility Bill Reduction ($0.12/kwh)	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard	Prototype WRT Benchmark	Prototype WRT Standard
Space Heating	10.01	6.26	3.03	69.7%	51.6%	10.0%	5.5%	$216.60	$113.50
Space Cooling	20.68	14.03	6.48	68.7%	53.8%	20.3%	12.8%	$441.27	$265.60
DHW	11.53	10.86	10.31	10.6%	5.0%	1.7%	0.9%	$37.98	$19.20
Lighting	5.86	6.06	1.63	72.1%	73.1%	6.0%	7.5%	$131.28	$155.69
Appl. & MEL	19.60	19.60	18.51	5.6%	5.6%	1.6%	1.8%	$33.79	$38.25
Ceiling Fan	2.17	2.17	1.21	44%	44.4%	1.4%	1.6%	$29.97	$33.93
OA Vent Fan	0.07	0.08	0.77	-1082%	-837%	-1.0%	-1.2%	-$21.83	-$24.12
Total Usage	**69.92**	**59.06**	**41.94**	**40.0%**	**29.0%**	**40.0%**	**29.0%**	**$983.85**	**$602.04**
Site Generation	0.00	0.00	0.00			0.0%	0.0%	$0.00	$0.00
Net Energy Use	**69.92**	**59.06**	**41.94**	**40.0%**	**29.0%**	**40.0%**	**29.0%**	**$983.85**	**$602.04**
Added Annual Mortgage Cost (20 Yr @ 0%) w/o Site Generation								**$164.39**	**$164.39**
Net Annual Cash Flow to Consumer w/o Site Generation								**$819.46**	**$437.65**
Added Annual Mortgage Cost (30 Yr @ 7%) w/o Site Generation								**$262.37**	**$262.37**
Net Annual Cash Flow to Consumer w/o Site Generation								**$721.48**	**$339.67**

Gulfport Standard	30% Improvement	30% Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$229	$11.43	$18.24
standard decking	rbs decking (54)	$175	$8.75	$13.96
R-19 Floor	R-30 Floor (1144)	$232	$11.61	$18.53
Standard Door	High R door	$206	$10.30	$16.44
***HVAC** including duct upgrade and fresh air inlet*				
SEER 13 HP	SEER 14 HP	$615	$30.75	$49.08
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$320	$16.00	$25.54
Standard vent fan	vent to out fan (2)	$104	$5.20	$8.30
Incandescent Lighting	Screw CFL Lighting (20)	$87	$4.35	$6.94
	Pin CFL Lighting			
Miscellaneous				
Materials		$126	$6.30	$10.05
Additional Labor		$240	$12.00	$19.15
TOTAL		**$2,334**	**$116.69**	**$186.23**

Gulfport 30%	Annual Source Energy			Estimated Source Energy Savings			
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard
Space Heating	27.43	14.46	7.44	72.9%	48.5%	10.4%	4.3%
Space Cooling	54.48	39.22	21.10	61.3%	46.2%	17.3%	11.1%
DHW	32.78	30.72	30.72	6.3%	0.0%	1.1%	0.0%
Lighting	18.63	19.27	5.19	72.1%	73.1%	7.0%	8.6%
Appl. & MEL	59.15	59.15	55.92	5.5%	5.5%	1.7%	2.0%
Ceiling Fan	0.00	0.00	0.00	0.0%	0%	0.0%	0.0%
OA Vent Fan	0.22	0.22	2.01	-822%	-822%	-0.9%	0.0%
Total Usage	**192.69**	**163.03**	**122.38**	**36.5%**	**24.9%**	**36.5%**	**24.9%**
Site Generation	0.00	0.00	0.00			0.0%	0.0%
Net Energy Use	**192.69**	**163.03**	**122.38**	**36.5%**	**24.9%**	**36.5%**	**24.9%**

Gulfport 30%	Annual Site Energy			Estimated Site Energy Savings					
Description	BA Bench	Regional Standard Practice	Prototype House	Percent of End Use		Percent of Total		Annual Utility Bill Reduction ($0.12/kwh)	
End Use	Mbtu/y	Mbtu/y	Mbtu/y	vs. BA Bench	vs. Standard	vs. BA Bench	vs. Standard	Prototype WRT Benchmark	Prototype WRT Standard
Space Heating	8.15	4.30	2.21	72.9%	48.5%	10.4%	4.3%	$184.48	$73.31
Space Cooling	16.19	11.66	6.27	61.3%	46.2%	17.3%	11.1%	$308.06	$189.30
DHW	9.74	9.13	9.13	6.3%	0.0%	1.1%	0.0%	$19.04	-$0.04
Lighting	5.54	5.73	1.54	72.2%	73.1%	7.0%	8.6%	$124.08	$147.14
Appl. & MEL	17.58	17.58	16.62	5.5%	5.5%	1.7%	2.0%	$29.75	$33.68
Ceiling Fan	0.00	0.00	0.00	0%	0.0%	0.0%	0.0%	$0.00	$0.00
OA Vent Fan	0.07	0.07	0.60	-818%	-818%	-0.9%	-1.1%	-$16.52	-$18.71
Total Usage	**57.26**	**48.45**	**36.37**	**36.5%**	**24.9%**	**36.5%**	**24.9%**	**$734.60**	**$424.70**
Site Generation	0.00	0.00	0.00			0.0%	0.0%	$0.00	$0.00
Net Energy Use	**57.26**	**48.45**	**36.37**	**36.5%**	**24.9%**	**36.5%**	**24.9%**	**$734.60**	**$424.70**
Added Annual Mortgage Cost (20 Yr @ 0%) w/o Site Generation								**$116.69**	**$116.69**
Net Annual Cash Flow to Consumer w/o Site Generation								**$617.91**	**$308.01**
Added Annual Mortgage Cost (30 Yr @ 7%) w/o Site Generation								**$186.23**	**$186.23**
Net Annual Cash Flow to Consumer w/o Site Generation								**$548.36**	**$238.46**

Baton Rouge Standard	30% Improvement	Incremental Cost (Reported)	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$256	$12.80	$20.43
standard decking	rbs decking (50)	$165	$8.23	$13.13
Standard Door	High R door	$206	$10.30	$16.44
HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 14 HP	$290	$14.49	$23.12
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$321	$16.03	$25.58
Standard vent fan	vent to out fan (2)	$104	$5.20	$8.30
Incandescent Lighting	Screw CFL Lighting (20)	$88	$4.38	$6.98
	Pin CFL Lighting			
Miscellaneous				
Materials		$260	$13.00	$20.75
Additional Labor		$383	$19.17	$30.60
TOTAL		**$2,072**	**$103.58**	**$165.32**

Average Standard	30% Improvement	30% Incremental Cost	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$128.80	$6.44	$10.28
standard decking	rbs decking (46)	$138.00	$6.90	$11.01
HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 14 HP	$680.00	$34.00	$54.26
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$571.00	$28.55	$45.57
Standard vent fan	vent to out fan (2)	$110.00	$5.50	$8.78
Standard Ceiling Fans	ESTAR Ceiling Fans (4)	$317.00	$15.85	$25.30
Incandescent Lighting	Screw CFL Lighting (20)	$31.00	$1.55	$2.47
	Pin CFL Lighting			
Miscellaneous				
Materials		$202.00	$10.10	$16.12
Additional Labor		$231.00	$11.55	$18.43
TOTAL		**$2,408.80**	**$120.44**	**$192.22**

Average Standard	40% Improvement Envelope	40% Incremental Cost	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$128.80	$6.44	$10.28
standard decking	rbs decking (46)	$138.00	$6.90	$11.01
	R-3 wall sheathing	$340.00	$17.00	$27.13
R-30 attic	R-38 attic (1050)	$83.00	$4.15	$6.62
***HVAC** including duct upgrade and fresh air inlet*				
SEER 13 HP	SEER 15 HP	$1,080.00	$54.00	$86.18
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$571.00	$28.55	$45.57
Standard vent fan	vent to out fan (2)	$110.00	$5.50	$8.78
Standard Ceiling Fans	ESTAR Ceiling Fans (4)	$317.00	$15.85	$25.30
Incandescent Lighting	Screw CFL Lighting (20)	$31.00	$1.55	$2.47
	Pin CFL Lighting			
Miscellaneous				
Materials		$202.00	$10.10	$16.12
Additional Labor		$231.00	$11.55	$18.43
TOTAL		**$3,231.80**	**$161.59**	**$257.90**

Average Standard	40% Improvement Hot Water	40% Incremental Cost	Amortized Annual Cost (20 yr, 0%)	Amortized Annual Cost (30 yr, 7%)
Building Enclosure				
Single-pane Windows	Low -E Windows (8)	$128.80	$6.44	$10.28
standard decking	rbs decking (46)	$138.00	$6.90	$11.01
Hot Water and HVAC including duct upgrade and fresh air inlet				
SEER 13 HP	SEER 14 HP	$680.00	$34.00	$54.26
Electric Tank	Heat Pump or Solar	$2,259.00	$112.95	$180.27
Appliances				
Standard Refrigerator	ESTAR Refrigerator	$571.00	$28.55	$45.57
Standard vent fan	vent to out fan (2)	$110.00	$5.50	$8.78
Standard Ceiling Fans	ESTAR Ceiling Fans (4)	$317.00	$15.85	$25.30
Incandescent Lighting	Screw CFL Lighting (20)	$31.00	$1.55	$2.47
	Pin CFL Lighting			
Miscellaneous				
Materials		$202.00	$10.10	$16.12
Additional Labor		$231.00	$11.55	$18.43
TOTAL		**$4,667.80**	**$233.39**	**$372.49**

Appendix G: Gate 1 and 2 - Prototype House Evaluations for the Gulf Coast High Performance Affordable Demonstration Houses built in 2008

The following criteria is used by the Building America Program to evaluate Prototype Houses in the Stage Gate Evaluation process. These criteria were taken from the "Summary of Technical Reporting Requirements for 2009 BA AOP Proposals and Project Management Plans" (updated 9/01/03) by Dr. Ren Anderson, National Renewable Laboratory.

Gate 1 System Evaluations

Gate 1A – Expected Whole House Energy Saving and Cost Targets
Gate 1A Research Objective
Within a whole building context and technology package, estimate system's contribution to BA energy performance and neutral cost targets using energy simulations and currently available performance data.

Gate 1A "Must Meet" Criteria
Source Energy Savings Target*
1. Expected source energy savings of a technology package including the advanced system must meet BA program performance goal.

Met: Proposed packages (2007) were intended to meet the then current BA Benchmark savings of 30%, determined using the Benchmarking software provided in EnergyGauge USA. As the project progressed and BA performance objectives became more stringent, minor adjustments were incorporated and adopted by the participants to maintain the BA 30% Benchmark goal throughout the project.

Neutral Cost Target
2. The incremental mature market cost of all energy improvements, when financed as part of a 30 year mortgage, should be less than or equal to the annual reduction in utility bill costs relative to the BA Benchmark house.

Met: Proposed packages were estimated to implement for approximately $2,000 in increased costs and yield a positive cash flow. Participant's willingness to proceed was based on an assumed positive cash flow. As the quest for program participants continued, the only volunteers that came forward were Habitat for Humanity Affiliates. Habitat's 20 year, 0% mortgage further leverages any potential positive cash flow.

*** Notes: Calculated based on the BA Performance Analysis Procedures. Specifications for target source energy savings based on Energy Gauge USA analysis.**

Gate 1A – "Should Meet" Criteria
Least Cost
Mature market incremental cost of technology package including advanced system should be less than or equal to currently available "least cost" alternatives based on sum of utility bills and energy-related increases in mortgage costs.

Met:

Marketability
2. System should contribute market value and performance benefits* relative to climate region best practices.

Not Applicable to Non-profits in Project: All participants in this program were non-profit providers of affordable housing. The main market value found for the participants was increased access to grant funding due to their enhanced building performance, as well as helping their clients live even more affordably. All participants were very “first cost’ oriented, and many participants adopted the proposed packages of improvements in all further homes due to their apparent cost effectiveness.

Gaps Analysis
3. Should include initial evaluation of major technical and market barriers to achieving the targeted system performance levels.

Standard building practices in the area needed to be addressed prior to trying to introduce the proposed improvements, as the area’s standard practice would undermine performance enhancements. Leaky duct systems and envelopes, poorly installed insulation, open air handler closets, floor insulation that did not touch the floor, grossly oversized space conditioning equipment and a myriad of other faulty building practices needed to be addressed prior to pushing for increased efficiency measures.

The project concentrated on the Gulf Coast region damaged by Hurricane Katrina in 2004. This region typically built houses with naturally vented combustion furnaces and water heaters. As a result, open-to-the-attic air handler closets were made to provide combustion make-up air to the furnaces. Due to the unique nature of Habitat building, this proved to be a bigger issue, as there is no drywall on-hand to seal the closet during drying-in. Consequently, closets were sealed with particle board or plywood.

There was also a noticeable distrust and dislike of heat pumps that some of the HVAC contractors expressed during the project, with claims of excessive freeze-up and defrost operation during heating due to the high ambient humidity. This bias was caused by the normal HVAC problems of over-sizing and poorly constructed duct systems.

*** Includes utility peak demand reduction benefits**

Gate 1B - System Evaluations and Specifications
Gate 1B Research Objective
Evaluate performance benefits and develop performance specifications for advanced systems using bench top tests, lab tests, tests in lab/research homes and energy simulations.

"Must Meet" Gate Criteria

Source Energy Savings and Whole Building Benefits
1. New whole house system solutions must provide demonstrated source energy and whole building performance benefits* relative to current system solutions based on BA test and analysis results.

Met: Using EnergyGauge USA software, the proposed Prototype 1 packages met or exceeded the 2008 BA 30% savings guideline. In project locals where energy codes existed, the packages vastly exceeded the code minimums.

Performance-Based Code Approval
2. Must meet performance-based safety, health, and building code requirements for use in new homes

Met: Packages exceeded all codes. The Gulf Coast area is somewhat lax about codes; during the project (2008) Louisiana adopted an energy code for the first time. Mississippi and Alabama had no mandatory energy codes. The proposed packages addressed ventilation and building durability and exceeded any local or regional code requirements.

***Whole building performance benefits include labor and material cost tradeoffs, comfort, durability, reliability, health, …**

Gate 1B – Systems "Should Meet" Criteria
Prescriptive-Based Code Approval
1. Should meet prescriptive safety, health and building code requirements for use in new homes.

Met: Packages exceeded local code where there was local code. Packages were designed to enhance indoor air quality by controlling ventilation and reducing infiltration. Packages addressed building durability issues by specifying a cementitious siding in lieu of vinyl and planned wall drainage planes and site drainage.

Cost Advantage
2. Should provide strong potential for cost benefits relative to current systems within a whole building context

Met: Packages were designed to be buildable for a cost increase of $2,000 with a WHSES savings of 30% compared to the BA Benchmark house. The result was an estimated savings of over $200/yr.

Reliability Advantage
3. Should meet reliability, durability, ease of operation, and net added value requirements for use in new homes

Met: Packages used **all** standard, off the shelf, components with proven durability and reliability and were designed to add no additional maintenance burdens to the homeowner.

Manufacturer/Supplier/Builder Commitment
4. Should have sufficient logistical support (warranty, supply, installation, maintenance support) to be used in prototype homes

Met: Packages used **all** standard, off the shelf, components.

Gaps Analysis
5. Should include system's gaps analysis, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level.

The Gulf Coast region was somewhat behind the curve in building energy efficient buildings. Many of the regions had no energy code (Alabama and Mississippi still do not) and no resources or services necessary to foster better building energy performance.

Often, the proposed packages could not be implemented due to regional building practices that needed to be changed first. For instance, a prevalent number of air handler closets were completely open to the attic to provide make-up air for gas furnaces. This problem needed much reinforcement with the site foremen to ensure that the detail was carried out correctly.

There was a common dislike of heat pumps with typical complaints from HVAC contractors who said that it was "too humid" in the area, therefore causing the units to freeze up in the winter. This problem was overcome by finding contractors who were comfortable with heat pumps. There was a very entrenched "this is the way we always did it" work ethic in the area; however most participants had at least some knowledge of advanced building techniques, allowing our packages to be acceptable at least as a path that could be followed.

Gate 2 - Prototype House Evaluations

Gate 2 Research Objective
Evaluate ability to integrate advanced systems with production building practices in prototype homes using results from field tests and energy simulations

"Must Meet" Gate Criteria
Source Energy Savings – Goal 30% Whole House Source Energy Savings
1. Prototype homes must provide targeted whole house source energy savings based on a performance analysis procedures and energy performance measurements.

Met: Researchers calculated the HERS Index and WHSES Benchmark, shown in Table G-1 and Figures G-1 and G-2, for nine demonstration houses completed in 2008 and 2009. The 30% WHSES goal was met in all of the demonstration houses. One house had higher than specified whole house infiltration and duct leakage but still qualified for ENERGY STAR. Three of the houses exceeded WHSES of 40%, two by improving the hot water heater, and one by incorporating an improved insulation package and all ENERGY STAR equipment and appliances.

Table G-1: Demonstration House HERS Indices and Benchmark Whole House Source Energy Savings (WHSES)

		Total Annual Whole House Site Energy Use				Total Annual Whole House Source Energy Use			
House #	**HERS Index**	**Benchmark (Mbtu)**	**Prototype (Mbtu)**	**Savings (Mbtu)**	**Savings (%)**	**Benchmark (Mbtu)**	**Prototype (Mbtu)**	**Savings (Mbtu)**	**Savings (%)**
Mobile House 1	69	54.01	35.94	18.07	33.5%	181.73	120.92	60.81	33.5%
Mobile House 2	60	46.94	26.57	20.37	43.4%	157.95	89.41	68.54	43.4%
MSGC House 1	69	57.26	36.37	20.89	36.5%	192.68	122.38	70.3	36.5%
MSGC House 2	71	58.14	38.87	19.27	33.1%	195.64	130.81	64.83	33.1%
Slidell House 1	71	55.80	37.61	18.19	32.6%	187.78	126.56	61.22	32.6%
Slidell House 2	73	55.80	38.89	16.91	30.3%	187.78	130.85	56.93	30.3%
Foley House 1	68	63.41	41.53	21.88	34.5%	213.37	139.75	73.62	34.55
Foley House 2	60	55.11	31.90	23.21	42.1%	185.45	107.33	78.12	42.1%
Abitta House 1	64	69.92	41.94	27.98	40.0%	235.27	141.11	94.16	40.0%

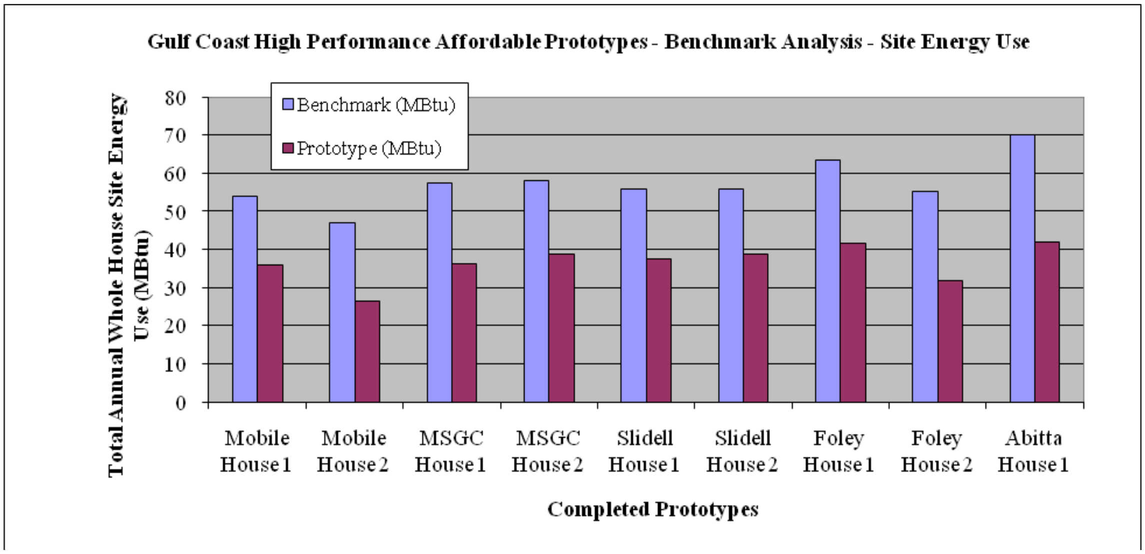

Figure G-1: Comparison of demonstration houses site energy use to 2008 BA Benchmark.

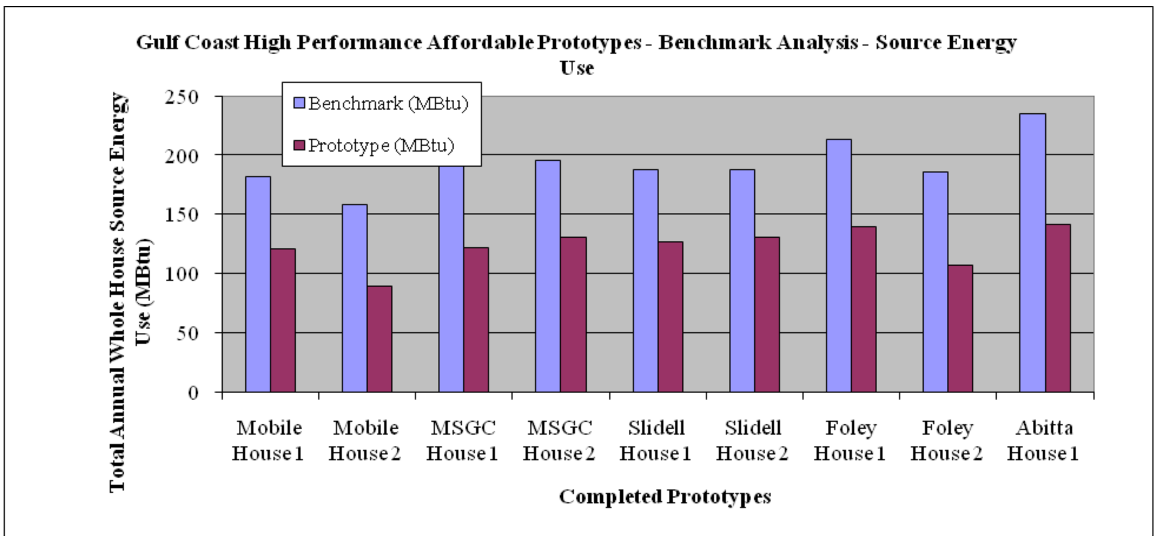

Figure G-2: Comparison of demonstration houses source energy use to 2008 BA Benchmark.

Prescriptive-Based Code Approval

2. Must meet prescriptive or performance safety, health and building code requirements for new homes

Met: When BAIHP began working with these partners, Louisiana had not adopted the energy code that went into effect in July of 2007. The code is the 2006 International Energy Conservation Code with one exception. Return and supply duct insulation is only required to be R-6 instead of R-8. Alabama and Mississippi do not have a mandatory energy code.

During the project, only one code issue arose that was related to the fresh air inlet directed into the return of the air handler. Code requires a specific access dimension to allow the installation and removal of the air handler, which was being blocked by the fresh air inlet due to the small size of the air handler closets. This issue was resolved by moving the location of the fresh air duct in the closet. The same official also required that the portion of the fresh air duct that was exposed in the return be a non-flammable material, not PVC as found. This obstacle was overcome by truncating the duct flush with the return platform, preventing any exposed duct.

The demonstration homes met all other applicable building codes. The researchers met with the chief mechanical inspector in Slidell at the inspector's request and in the City of Mobile after a presentation to the Mobile Area ACCA Chapter.

Quality Control Requirements

3. Must define critical design details, construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors

Met: Researchers found that the builder partners and other builders who participated in the workshops were not accustomed to thinking about establishing a whole house air barrier, a sealed duct system including the return plenum, neutral or slightly positive house air pressures, and a continuous drainage plane behind vented or water absorbing exterior wall cladding.

Training on these core concepts was essential to ensuring successful implementation. Training was conducted through classroom and site instruction. The most effective training exercises were those that included a demonstration of house air flows including blower door and duct tightness testing, pressure mapping, and the use of a table top air flow model. Setting an intermediate goal of achieving ENERGY STAR was a good way of establishing acceptable practice and measurable expectations for the house air barrier, insulation quality, and duct leakage. Though some builders in Louisiana were familiar with the idea of measuring duct leakage and infiltration because of a now defunct state grant program that gave incentives for achieving ENERGY STAR under the 1999 standards, the majority of builders we encountered had never seen the testing procedures.

One of the key strategies for meeting the high performance goals was to locate the air handler unit (AHU) inside the conditioned space and to ensure that it was separated from the attic by the whole house air barrier. This approach generated the most change for some of our partners.

The partner who had been putting the AHU in the attic found that the change required revision of the floor plan; mechanical, electrical, plumbing, and truss designs/drawings; and the door schedule and procurement package. An extra site visit with each contractor was required to identify exactly how the wiring, plumbing, trusses, and ducts would be installed. The first attempt by this builder was unsuccessful because they failed to change the truss layout to accommodate the supply plenum rising from the closet to enter the attic. At project end they were still working on their second attempt.

Three of the partners were building an air handler closet that was well isolated from the attic. One partner placed their air handler in the attic. Three others were putting their AHUs in an interior closet space; however, they were not enclosing the top of the closet. Typically, the walls of the closet were not finished in these homes. Looking into the closet and the central return plenum below the platform, one would see the attic above and wall framing members from the top plate all the way down to the bottom plate. In some cases, there was an effort to separate the return plenum from the space above the platform. By talking to mechanical inspectors, researchers learned that the practice of leaving the closet open to the attic was conventional practice to ensure that atmospheric combustion gas furnaces would have adequate combustion air. These are very common in the region. (*see more discussion at "Gaps Analysis" below.*) The two partners that were already building a well isolated closet installed and finished sheet rock in the whole closet, including the ceiling, before building the AHU platform. This process requires the builder to have a few sheets of drywall on site before it would normally be delivered. It also requires the mechanical contractor to cut a hole in the ceiling for the return plenum and work in restricted quarters.

Researchers tested and then repaired a leaky closet and return plenum and found that it was a factor in very high duct leakage and whole house infiltration. This detail is fundamental to gaining the control over house air flow needed to reach high performance goals for energy efficiency, indoor air quality, and durability.

Compliance with the Thermal Bypass Checklist was problematic with raised floor houses with batt floor insulation. As the project was carried out in areas hurt by Katrina, there were code mandated flood requirements that required at least vented crawlspaces, and in many cases, post and pier construction. This requirement led to the need to insulate the floors of the houses, which was rarely carried out with the ability to meet the Thermal Bypass Checklist criteria of the air barrier and the thermal barrier being aligned. This problem was so chronic that one participant dropped out of the program due to their inability to install floor insulation correctly. In houses with crawlspaces, two solutions were employed, inset stapling the kraft paper on the insulation (paper side facing the crawlspace) so that the insulation stayed in contact with the floor of the house, and using foam insulation. In homes with post and pier construction, the inset stapling idea was not applicable due to fire concerns and the exposed kraft paper; however, several participants in the program used spray foam under all their raised houses. The use of fiberglass clips used to support the insulation in between floor joists was an unheard of detail, making adoption of the technique difficult.

Problems occurred with poorly installed ducts that were too leaky. In one instance, they were too leaky to qualify for ENERGY STAR, and in another case the leakage caused the house to fall short of the Qn $< 4\%$ goal. Both of these partners attempted to go behind their HVAC contractor and seal the duct system themselves, with the reported bad results. Both partners were in Louisiana where the as-found duct systems were extremely leaky.

Additional quality control issues linked to the outside air ventilation strategy are related under "Should Meet" Criteria #2.

"Should Meet" Criteria
Neutral Cost Target
The incremental annual cost* of energy improvements, when financed as part of a 30 year mortgage, should be less than or equal to the annual reduction in utility bill costs relative to the BA Benchmark. *<u>Met:</u>* (Table G-2)

Table G-2:Cost and Cash Flow Summary

House	Incremental Cost Information			
	Reported Cost	Added Estimated Cost	Total Cost	Annual Cash Flow
Mobile House 1	$1,462	$886.50	$2,348.50	$179.63
Mobile House 2	$3,176	$1,016.50	$4,192.50	$186.93
MSGC House 1	$1,491	$843	$2,334	$238.46
MSGC House 2	N/A	N/A	N/A	N/A
Slidell House 1	$2,408.80	$0	$2,408.80	$206.67
Slidell House 2	$2,408.80	$0	$2,408.80	$161.84
Foley House 1	$1,670	$1,109.50	$2,779.50	$231.83
Foley House 2	$5,000	$1,308.63	$6,308.63	$55.82
Abitta House 1	$3,096.34	$191.50	$3,287.84	$339.67

Quality Control Integration
2. Health, Safety, Durability, Comfort, and Energy related QA, QC, training, and commissioning requirements should be integrated within construction documents, contracts and BA team scopes of work.

Partial Success: The primary quality assurance measure required to meet the 30% WHSES was a scope of work and commissioning of the mechanical system. All of the demonstration homes needed at least minor changes in their original configuration. The outside air ventilation system was unfamiliar to all of the mechanical contractors. The improvements related to changes in the construction process also required some staff training to ensure that opportunities were not missed. Specifically, the house wrap details, air sealing details, and window and door flashing details needed to be covered in depth with the staff involved in those tasks. With a for-profit builder, this would probably take the form of working through these details with the insulation contractor in the same manner that was needed with the mechanical contractor.

Gaps Analysis
3. Should include prototype house gaps analysis, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level.

Though none of the partners were building demonstration homes with gas heating, the recommendation would be to enclose the air handler closet , provide a 90%+ efficient gas furnace which have safety features to prevent exhaust spillage, back drafting and flame rollout. This recommendation was not well received among the partners or the builders we met in workshops because of the high first cost. Indeed, it would significantly impact the cash flow economics because the heating season is short. This issue will have to be addressed before making a blanket recommendation to the builders of the region to tighten up infiltration and duct leakage, particularly because the conventional construction of the central return plenum is an unducted framed platform that the AHU rests on. These are often connected to the space around the AHU by penetrations in the platform which could significantly depressurize the combustion zone.

This market needs an inexpensive gas fired alternative to atmospheric combustion furnaces that will ensure combustion safety in the manner that the 90%+ gas furnaces do. Many consumers prefer gas heat to heat pumps, but the heating load is not sufficient enough to justify the incremental cost of the high efficiency gas models.

* *Incremental first cost evaluated relative to builder standard practice, using estimated mature market cost*

Gate 2 - Prototype House Evaluations
Gate 2 Research Objective
Evaluate ability to integrate advanced systems with production building practices in prototype homes using results from field tests and energy simulations

"Must Meet" Gate Criteria
Source Energy Savings
1. Prototype homes must provide targeted whole house source energy savings based on BA performance analysis procedures and energy performance measurements.

Met: The project required a minimum of eight houses built to meet the project requirements. The final count of houses meeting the requirements was nine. Unfortunately, four houses did not meet the criteria. These failures will be addressed in the gaps analysis.

Prescriptive-Based Code Approval
2. Must meet prescriptive or performance safety, health and building code requirements for new homes

Met: During the project, only one code issue arose that related to the fresh air inlet directed into the return of the air handler. Code requires a specific access dimension to allow the installation and removal of the air handler, which was being blocked by the fresh air inlet due to the small size of the air handler closet. This issue was resolved by moving the location of the fresh air duct in the closet. The same official also required that the portion of the fresh air duct that was exposed in the return be a non-flammable material, not PVC as found. This obstacle was overcome by truncating the duct flush with the return platform, preventing any exposed duct.

Quality Control Requirements
3. Must define critical design details, construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors.

Met: See Gate 1, same results

"Should Meet" Criteria
Neutral Cost Target
The incremental annual cost* of energy improvements, when financed as part of a 30 year mortgage, should be less than or equal to the annual reduction in utility bill costs relative to the BA Benchmark.

Met: See Gate 1, same results

Quality Control Integration
2. Health, Safety, Durability, Comfort, and Energy related QA, QC, training, and commissioning requirements should be integrated within construction documents, contracts and BA team scopes of work.

Partial Success: See Gate 1, same results

Gaps Analysis
3. Should include prototype house gaps analysis, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level.

Problems occurred with poorly installed ducts that were too leaky. In one instance, they were too leaky to qualify for ENERGY STAR, and in another case the leakage caused the house to fall short of the Demonstration's leakage goal.

A major stumbling point for this project was lack of conformance to the Thermal Bypass Checklist. This was encountered with floor insulation. As the project was carried out in areas hurt by Katrina, there were code mandated flood requirements that required at least vented crawlspaces, and in many cases post and pier construction. This requirement led to the need to insulate the floors of the houses, which was rarely carried out with the ability to meet the Thermal Bypass Checklist criteria of the air barrier and the thermal barrier being aligned. This problem was so chronic that one participant dropped out of the program due to their inability to install floor insulation correctly. In houses with crawlspaces, two solutions were employed, inset stapling the kraft paper on the insulation (paper side facing the crawlspace) so that the insulation stayed in contact with the floor of the house, and using foam insulation. In homes with post and pier construction, the inset stapling idea was not applicable due to fire concerns and the exposed kraft paper; however, several participants in the program used spray foam under all their raised houses. The use of fiberglass clips used to support the insulation in between floor joists was an unheard of detail, making adoption of the technique difficult.

Building a sealed interior air handler closet was a foreign concept to many of the participants of the project, as most were used to building a closet that housed a gas furnace. The practice of leaving the top of the closet open to the attic was baffling to researchers at first, until it was explained as the way the region provided make-up air to gas furnaces.

Implementation Checklist for Moving AHU from Attic To Interior Closet

- ☐ Develop closet design with mechanical contractor
  - Revise Manual J and Manual D calculations
  - Size return opening per Manual D calculations
  - Anticipate minimum of 3 foot by 3 foot interior dimension
  - 6" Recommended clearance on all sides of air handler to improve accessibility
  - Condenser location may need to be moved
- ☐ Integrate closet design with floor plan

  - Reflect changes on mechanical, electrical, and plumbing plans
  - Truss design and layout must accommodate supply plenum
  - Provide closet elevations as needed
    - Show return grill rough opening dimensions
    - Indicate filter location
    - Locate thermostat, condensate drain line path
    - Locate outside air ventilation duct and damper
  - Provide section of closet to explain construction
    - Show drywall (green board ok) lining for entire closet including ceiling
    - Show framing details for AHU platform – constructed inside drywall lining
    - Show blocking for return air grill
    - Indicate air sealing points
      - Seal all edges and seams in drywall lining with code approved sealant – recommended materials include drywall mud, mastic, fire rated caulk, and fire rated foam
      - Seal around supply plenum
      - Seal between all framing members in rough opening for return grill
      - Seal all wiring and plumbing penetrations through the drywall and AHU platform
- ☐ Develop quality assurance checklist for interior AHU closet
- ☐ Call sub-contractor attention to new details
  - All changes should be reflected in construction documents, specifications, and emphasized in a cover letter
  - With slab on grade floors, plumber must install condensate drain line before slab is poured
- ☐ Provide materials (drywall and sealant) for roughing out and finishing closet prior to mechanical rough-in
- ☐ Complete quality assurance checklist for interior AHU closet prior to mechanical rough-in