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Approaches to 30% Energy Savings at the Community Scale in the Hot-Humid Climate

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Building America Partnership for Improved Residential Construction

March 2013

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Definitions

ACH_{50}	Air changes per hour at 50 Pascals
ASHP	Air source heat pump
BABM10	Building America Benchmark
BA-PIRC	Building America Partnership for Improved Residential Construction
BEopt	Building Energy Optimization
Btu	British thermal unit
CFL	Compact fluorescent lighting
cfm_{25}	Cubic feet per minute at 25 Pascals
COP	Coefficient of performance
EF	Energy factor
FDC	Fur-down chase
FSEC	Florida Solar Energy Center
ft^2	Square foot
ft^3	Cubic foot
gal	Gallon
HERS	Home Energy Rating System
HFH	Habitat for Humanity
HPWH	Heat pump water heater
HSPF	Heating seasonal performance factor
kBtu	Thousand Btu
kWh	Kilowatt-hour
LSH	LifeStyle Homes
MBtu	Million Btu
o.c.	On center
RESNET	Residential Energy Services Network
SHGC	Solar heat gain coefficient
SEER	Seasonal energy efficiency ratio
TWH	Tommy Williams Homes
UA	Unvented attic
WHES	Whole-house energy savings
WHSES	Whole-house source energy savings
ZEH	Zero energy home

Executive Summary

The Building America Partnership for Improved Residential Construction, formerly the Building America Industrialized Housing Partnership, has worked with several community-scale builders within the hot-humid climate zone to improve performance of production-, or community-scale, housing. Tommy Williams Homes (Gainesville, Florida), LifeStyle Homes (Melbourne, Florida), and Habitat for Humanity (various locations, Florida) have all been continuous partners of the Building America Program. The activities of these partners, described in this report, achieved the Building America goal of 30% whole-house source energy savings using packages adopted at the community scale. For new homes, the reference case is the B10 Benchmark, aligned with 2009 building codes.

This report describes how these goals were achieved in production-scale homes that were built cost effectively at the community scale and modeled to reduce whole-house energy use by 30% or more in the hot-humid climate region. Key aspects of this research include determining how to evolve existing energy efficiency packages to produce replicable target savings, identifying builders' technical assistance needs for implementation and working with them to create sustainable quality assurance mechanisms, and documenting commercial viability through neutral cost analysis and market acceptance. This report documents barriers that builders overcame and the approaches they implemented to accomplish Building America Program goals that have not already been described in previous reports.

Although the general approach to achieving 30% savings is similar among the builders, subtle variations in the comparable specifications show that trade-offs exist, allowing optimization of the efficiency package to fit regional fuel preferences, product availability/cost, subcontractor experience, house size, and each community's intended market. All packages use standard, off-the-shelf components with proven durability and reliability. Successful, community-scale energy efficiency improvements were not only the result of specified components and packages based on energy modeling software analysis, but were coupled with elements of design, quality control, and creative marketing.

The evaluation demonstrates that the overall benefits of the integrated energy efficient measures used in each of the 30% whole-house source energy savings packages are marketable and result in neutral or net positive cash flow for homeowners. The findings are primarily applicable to builders and subcontractors in the hot-humid climate looking to replicate the same success in building cost-effective, energy efficient, comfortable, and durable homes. The high performance home business model calls for sweeping yet systematic change to code minimum construction that, over time, pays dividends to both builder and homeowner.

1 Introduction

The Building America Partnership for Improved Residential Construction (BA-PIRC), formerly Building America Industrialized Housing Partnership, has worked with several community-scale builders within the hot-humid climate zone to improve performance of production-scale housing. Tommy Williams Homes (TWH; Gainesville, Florida), LifeStyle Homes (LSH; Melbourne, Florida), and Habitat for Humanity (HFH; various locations, Florida) have all been continuous partners of the BA program. The activities of these partners, described in this report, achieved 30% whole-house source energy savings (WHSES) using packages adopted at the community scale. Nine BA case studies have been written about these partners' previous BA work.[1] The key to this adoption at the community scale has been robust sales, and the key to robust sales has been the documentation and associated communication of the cost neutrality of the package to the buyer, along with the intangible benefits of comfort, health, and indoor air quality.

The three partners represent a cross section of builder classifications. TWH is a "move-up" (or second-time buyer), small production builder. LSH started out building entry- to mid-level production-scale homes and has segued into higher end production-scale home building for a portion of its market. These two for-profit partner builders continued to experience continual sales during the recession of 2008, which is attributable to the market differentiation resulting from the integrated and promoted systems engineering approach. The nonprofit HFH affiliates that construct affordable housing have embraced a similar approach, allowing first-cost considerations to take a back seat to minimizing total cost of ownership. This evaluation also explains how this success is a result of quality construction synchronized with the BA program, creative marketing strategies, and staffers that are well educated in energy efficiency.

1.1 Building America Goals

The goal of the U.S. Department of Energy (DOE) BA program is to conduct research to develop market-ready energy solutions that improve efficiency of new and existing homes by 30%–50%. For new homes, the reference case is the B10 Benchmark (BABM10), aligned with 2009 building codes (Hendron and Engebrecht 2010).[2] Along with energy savings, the program also focuses on solutions that lead to the following:

- Improved indoor air quality, which can benefit occupant health
- Higher comfort levels in all rooms throughout the home
- Durable and moisture-resistant building designs
- Increased builder profitability through reduced construction time.

Through targeted research, industry partnerships, and collaboration with related DOE residential initiatives, BA works to make cost-effective energy efficient homes a reality for all Americans.

This report describes how these goals were achieved in production-scale homes that were built cost effectively at the community scale, and modeled to reduce whole-house energy use by 30%

[1] See http://www.ba-pirc.org/casestud/index.htm for more information.
[2] The B10 Benchmark is consistent with the 2009 International Energy Conservation Code (IECC), with additional definitions that allow evaluation of all residential end uses consistent with typical homes built in 2010.

or more in the hot-humid climate region. Key aspects to the research at the community scale include determining how to evolve existing energy efficiency packages to produce replicable target savings, identifying builders' technical assistance needs for implementation and working with them to create sustainable quality assurance mechanisms, and documenting commercial viability through neutral cost analysis and market acceptance.

1.2 Builder Profiles

The community-scale builders discussed in this report have been heavily influenced by the same BA program goals and have similar general energy efficiency improvement strategies they have embarked on since they were inducted as partners. Features that may be important to delineate, however, are the approaches that distinguish them from each other. These result from internal decisions, regionally-accepted practice, or target market. Their homes include differing structural strategies (block versus frame), insulation methods, exterior finishes, and roof coverings. All the builders discussed, though, are similar in home energy optimization results and Home Energy Rating System (HERS) Indices, ultimately reaching the same goal of cost-effectively improving WHSES without compromising occupant health, safety, or comfort.

Two of the builders have taken steps to maximize performance of select homes by incorporating renewable energy. Detailed discussion of energy and economic implications of zero energy homes (ZEHs) is outside the scope of this report because those implications go beyond the near-term BA goals of 30% energy savings. Note, however, that in some cases, achieving ZEH status on the small scale has served as a catalyst leading to achievement of more modest savings on a much larger scale. Continued pursuit of production-scale ZEHs by these builders also shows that the tipping point of cost-effective, low-energy-use, production-scale homes has not been reached. In addition, a growing consumer demand for ZEHs supports the BA program's continued research into ZEHs.

1.2.1 Tommy Williams Homes

TWH has been a BA partner since 2004 and has accelerated its standard construction practices to a high performance level consistent with BA program goals. TWH was one of the "Pioneering Builders" of the DOE Builders Challenge when the challenge was first offered in 2008. TWH has two communities under construction that will total 411 homes when built out. These communities have gradually integrated advanced measures of construction over time. All of the houses are single-family, slab-on-grade with brick and fiber cement siding. These two developments consist of one- and two-story houses between 1,450 and 3,100 ft^2 with three to five bedrooms.

In 2009, TWH confirmed its plans to build on its efficiency package and construct its first ZEH with a HERS Index of 0. The home was the first ZEH for this production builder and the first true ZEH for a production builder in Florida. During the design, the team factored in a safety net and a goal of a HERS Index of better than 0. The final inspection and testing of the home resulted in a HERS Index of –2, which means it is expected to produce more energy than it consumes.[3] TWH has completed and sold an additional five ZEHs, and is developing plans for a community consisting exclusively of ZEHs.

[3] See http://www.ba-pirc.org/casestud/pdf/BA_BuildersChallengeSpotlight_TWH-ZEH.pdf for more information.

The TWH focus on building high performance homes has led to the development of an aggressive marketing and incentive program with targeted social media outlets and blogs, among other features. Marketing is a key component to TWH's success in selling a premium product that demands a premium price even in a suppressed economy. As discussed in Section 4 of this report, in one community a non-BA builder also constructs an equal number of homes alongside TWH high performance homes. Property sales records show that TWH outsells this builder at a higher price per square foot in addition to selling homes faster. Marketing is a key component to TWH success in selling a premium product that demands a premium price even in the current economic recession.

1.2.2 LifeStyle Homes

The partnership between BA-PIRC and LSH began with the builder's desire to build more energy efficient homes in its home market of Melbourne, Florida. Following many of BA-PIRC's energy recommendations and options, LSH has taken notable steps in realizing and exceeding its energy efficiency goals. Construction on LSH's first BA Builders Challenge home was completed in April 2009 with a HERS Index of 60 (approximately 25% WHSES savings over BABM10), and LSH quickly committed to building all of its homes to this level. LSH completed its first ZEH in August 2010. Final inspection and testing of the home resulted in a HERS Index of –6. Subsequently, the builder has constructed 15 ZEHs as of the writing of this report. This milestone has led LSH to consider developing a community of ZEHs in the Brevard County, Florida area.

LSH's focus on building high performance homes has led to the development of its SunSmart package, which is a combination of better building techniques and high performance components that aim to deliver improved indoor air quality, comfort, durability, as well as lower energy cost. LSH CEO Jake Luhn confirms the relevance of BA goals: "Our ultimate goal has remained unchanged since our friends at FSEC [Florida Solar Energy Center] sold us on it. We will not rest until we can deliver truly affordable net ZEHs with sufficient energy production and/or storage capacity to recharge two electric automobiles overnight. Doing that will change everything."

As with TWH, BA-PIRC has worked with LSH on marketing the economic benefits of energy efficient homes. LSH asserts that three challenges, once addressed, resulted in its success: overcoming a mindset that it was impossible to build more energy efficient homes at reasonable costs; optimizing climatically-responsive energy saving features at cost neutrality; and—with BA-PIRC's assistance—educating and encouraging cooperation of trade partners and subcontractors in the field responsible for implementing LSH's SunSmart Program. LSH continues to evaluate improvements to the SunSmart package, providing that new measures considered will be cost effective to both builder and potential home buyers. Part of LSH's formula for selecting and implementing energy efficient mortgages is to show, via modeling, the costs and benefits of installed measures over a 30-year mortgage.

After experiencing the effects of the continued economic slowdown caused by the 2008 recession, LSH's priority is to align energy savings with the most cost-effective implementation strategies that meet neutral cost targets. As a result, LSH emerged from the downturn early with enhanced business and previously uncharted growth. Additionally, LSH continues to educate its potential buyers and sales staff on the value-added benefits of its product, which is paramount for customer buy-in. LSH is committed to working with BA to communicate the benefits of high performance construction to the industry as a whole.

1.2.3 Habitat for Humanity

The BA-HFH partnership, formed in 1995 at HFH's Environmental Initiative Kickoff, has brought BA-PIRC into the design, construction, and evaluation process of hundreds of HFH homes built by more than 50 HFH affiliates in more than 20 states. HFH homes are sold to qualified buyers who also contribute hundreds of hours of "sweat equity." In general, HFH affiliates finance the homes using a 0% interest mortgage for 15–30 years depending on the home buyer's ability to pay. Because of the volunteer process and the 0% loans, the actual costs to the HFH affiliates for executing some of the performance improvements can be lower than those achievable in standard for-profit construction.

For-profit builders that work with BA are often motivated to adopt practices that will give them a market edge. On the other hand, many affordable housing providers are locked into a first-cost dominated planning and purchasing system, as well as mired in outdated information. Each HFH affiliate operates independently but builds homes in accordance with basic design criteria set by HFH. Because of these criteria, there is much similarity in the size and design of the homes.

The HFH information in this report specifically builds on previous BA work with HFH affiliates' housing in the Gulf Coast region (Alabama, Louisiana, and Mississippi). This work led to a hot-humid climate efficiency package specific to small houses (McIlvaine and Beal 2010). This improvement package was based on small (1,080 ft^2), three-bedroom, one- or two-bath houses built in the Gulf Coast, a region devastated by Hurricane Katrina. Efficiency measures that are not affected by house size, such as refrigeration, hot water usage, and—to a lesser extent—lighting, became a higher priority than more traditional efficiency measures that address envelope and HVAC improvements. This report focuses on an "enhanced" Gulf Coast package that has been adopted by most of the Florida-based HFH partners that BA assists, which, unlike the standard Gulf Coast package, specifically addresses water heating.

2 Implementation of the 30% Packages

2.1 Introduction

The builders described in this report all have slight variations in their construction specifications including individual components employed. This is the result of regional practices, varied business models, cost considerations, or a combination. Some builders have migrated toward different technologies as they have emerged, often because of the cost competitiveness of product offerings, like that of spray foam insulation. Some have increased energy and resource efficiency by increasing wall R-value, as did TWH, which advanced from 2 × 4 frame construction to 2 × 6 frame, purely for market competitiveness. In the case of HFH, the size of the house has an impact on the importance of the individual components (e.g., equipment, envelope, and fixtures/appliances) toward achieving the 30% WHSES reductions.

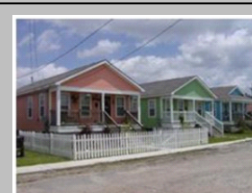
2.2 Packages and Energy Savings Analysis

The hot-humid builders profiled have adopted the BA systems approach and established packages that not only ensure a minimum of 30% WHSES, but are reported to enhance comfort and nearly eliminate callbacks. Table 1 provides the details of the packages that enabled these builders to achieve energy savings. A summary of the components with the largest contributions to package savings follows:

- **Minimization of conductive/convective/radiative heat gain from roof/attics.** Each builder employs minimum R-30 ceiling insulation (versus code minimum R-19) without gaps, voids, or compression, in a vented attic with a radiant barrier. TWH further enhances this through ducts within the conditioned space.
- **Efficient windows.** All builders use double pane windows with low emissivity glazing. Solar heat gain coefficient (SHGC) values range from 0.20 to 0.29.
- **Efficient cooling equipment.** Cooling equipment efficiencies range from seasonal energy efficiency ratio (SEER) 14 to 16.
- **Efficient water heating equipment.** Each builder employs an ENERGY STAR water heating technology.
- **Tight duct systems with air handlers inside conditioned space.** All builders limit duct leakage to less than 3 cfm_{25} per 100 ft^2 of floor area. All locate the air-handling components within the thermal envelope.
- **Mechanical ventilation.** All builders incorporate central fan integrated supply ventilation systems. All builders vent the kitchen exhaust to the outside.
- **Hardwired compact fluorescent (CFL) lighting.** All builders use hardwired CFL fixtures.
- **ENERGY STAR appliances.** All builders use ENERGY STAR appliances.

Although the general approach to achieving 30% savings is similar among the builders, subtle variations in the comparable specifications in Table 1 demonstrate that trade-offs exist. These trade-offs allow optimization of the efficiency package to fit regional fuel preferences, product availability/cost, subcontractor experience, tax credits and incentives, and each community's intended market. Packages all use standard, off-the-shelf components with proven durability and reliability. Packages were designed to free homeowners from additional maintenance burdens.

Table 1. Comparison of Hot-Humid Community-Scale Builders Specifications

Feature	Tommy Williams	Lifestyle SunSmart	HFH Standard
Building Envelope			
Roof Finish/Attic	Medium roof finish; radiant barrier; vented attic	Medium roof finish; radiant barrier; vented atttic	Light roof finish; radiant barrier; vented attic
Roof/Ceiling Insulation	R-30 blown in insulation; 10" heel truss/ R-19 knee wall	R-38 blown in insulation	R-38 blown in insulation
Wall Type	2x6 16" o.c. frame with ladder T and 2 stud corners when feasible	Light color masonry block with exterior insulation	2x4 16" o.c. frame
Wall Insulation	R-21 formaldehyde-free blown fiberglass	Reflective foil R-7 interior wall insulation	R-13 fiberglass batt
Windows	Double pane low-E (U = 0.34 SHGC = 0.25)	Double pane low-E (U = 0.35, SHGC = 0.29)	Double pane low-E (U = 0.40, SHGC = 0.20)
Floors	Slab; 70% tile, 30% carpet	Slab; 30% tile, 70% carpet	Slab; 100% tile
Envelope Leakage ACH_{50}	ACH_{50} = 2.9	ACH_{50} = 3.5	ACH_{50} = 4.5
Air Sealing	Expanding foam at all exterior openings and foam gasket at ceiling/wall joints	Expanding foam at all exterior openings	Expanding foam at all exterior openings
HVAC System			
Heating/Cooling system	ASHP - SEER 16/ HSPF 9.5; programmable thermostat	ASHP - SEER 15/ HSPF 8.5; programmable thermostat	ASHP - SEER 14/ HSPF 8.2; standard thermostat
Air Handler Location	Interior closet	Interior closet	Interior closet
Fresh Air Ventilation	Runtime vent system, kitchen exhaust to out	Runtime vent system, kitchen exhaust to out	Runtime vent system, kitchen exhaust to out
Duct R, Location	R-6, in conditioned space	R-6, attic	R-6, attic
Duct Leakage	0 leakage to out	2% leakage to out	2% leakage to out
Bathroom Exhaust Fans / Controls	Timer switch	Timer switch	Manual
Water Heating			
Water Heater	Tankless gas EF = 0.82	Solar flat plate (40 ft^2) open loop, 80 gallon storage	Standard electric EF = 0.92 or HPWH COP = 2.35
Lighting	100% fluorescent	100% fluorescent	100% fluorescent
Appliances ENERGY STAR	Yes	Yes	Yes
Photo Representative of Builder			

Notes: o.c., on center; SHGC, solar heat gain coefficient; ACH_{50}, air changes per hour at 50 Pascals; ASHP, air source heat pump; EF, energy factor; HPWH, heat pump water heater; COP, coefficient of performance

The simulation software Building Energy Optimization (BEopt) E+ V 1.3 calculates energy savings with respect to the BABM10 (Hendron and 2010).[4] Table 2 shows the results relative to the BABM10.

[4] A size adjustment factor is included in determination of the "adjusted" savings percentage. This numerical multiplier allows for comparison against the national average size home, rather than a home of the exact same size. The effect is that smaller homes are tabulated to be more efficient than larger homes.

Table 2. BEopt Analysis Results

Feature	Tommy Williams	Lifestyle SunSmart	HFH Standard	HFH HPWH
Conditioned Space (ft^2)	1700	2313	1080	1080
Number of Bedrooms	3	4	3	3
Source Energy Use Mbtu/yr	107	129	112	95
% Savings Over Adjusted BABM10	**31%**	**30%**	**27%**	**39%**

2.2.1 Tommy Williams Homes Implementation

Since partnering with BA, TWH has improved its efficiency package incrementally over time through component enhancements. The bulk of the current TWH 30% package has been standard practice for the builder for quite some time and has been documented previously (Fonorow et al. 2006). In terms of enhancements to standard practice to surpass the 30% savings mark, the greatest impact and the most regionally-atypical strategy has come from implementing ducts within the conditioned space via a fur-down chase (FDC), as seen in Figures 1 and 2 (Fonorow et al. 2010).

Figure 1. FDC after rough framing

Photo by Doug Thompson

Figure 2. FDC finish creates architectural elements

Even though the innovative strategy of implementing interior ductwork was initially challenging, lessons learned enabled more efficient and effective integration into TWH's standard practice across all floor plans offered. For instance, by keeping the top plate of the nonload-bearing interior walls ¾ in. from the bottom cord of the roof trusses, the drywall can be slipped through this space (Figure 3). By offsetting the drywall beyond the interior wall/chase, it is much easier to "tape and mud" the marriage line between the pieces (Figure 4). This method eliminates the dead wood required in small spaces to accept the drywall and the waste of drywall that results from having to cut small pieces of the material. It also reduces construction time, and hence labor costs. A BA measure guideline issued after continued improvement to the TWH practice of installing ducts within the conditioned space contained expanded detail about critical design, planning, construction, inspection, and verification steps taken in this process (Beal et al. 2011).

Figure 3. Drywall slipped through ¾-in. space between the top plate of the nonload-bearing interior wall

Figure 4. Drywall is also offset beyond the wall/chase to allow for marrying adjacent drywall

Continual communication and brainstorming sessions between builder, subcontractors, and local officials is critical to maintaining quality assurance as the interior duct approach is applied to new floor plans. Figure 5 shows one home with the duct chase located on an exterior wall, and local code officials required fire blocking (see arrows) to be installed below the chase. Installing ductwork before insulation resulted in restricted access to the portion of the exterior wall cavity above the fire blocking. This portion of the exterior wall is essentially part of the ductwork chase, and fully air sealing and insulating this area is important. Discovering and correcting this detail resulted in a slight change to construction sequencing for homes with duct chases along exterior walls.

Figure 5. Arrows point to code-required fire blocking under chase, preventing insulation from being easily installed behind duct. Correction involves re-sequencing so insulation can be installed in this area prior to duct.

Interior ducts, combined with upgraded envelope features such as 2 × 6 framing and a continual improvement in window SHGC, have enabled TWH's standard practice to exceed 30% savings. Interestingly, TWH did not begin to make these component changes specifically to achieve 30% savings—instead, the changes were motivated by the builder's desire to build ZEHs, and to make them as cost effective and marketable as possible. TWH's ongoing relationship with BA and upper management's top down oversight of trades and subcontractors during construction, along with continuous third-party inspections, regular sales staff education and training seminars, and an incentive strategy that pays the home buyers' energy bills for 1 year, are all critical facets to sustained achievement of 30% WHSES and robust sales.

2.2.2 LifeStyle Homes Implementation

Similar to TWH, after partnering with BA, the LSH SunSmart efficiency package has improved incrementally over time through component enhancements. The bulk of the current LSH 30% package has been standard practice for the builder for quite some time, and has been documented previously (DOE 2010). Recently, LSH has effectively implemented solutions to one common stumbling block, air sealing and insulating attic knee walls. This area of air sealing and insulating has long been a failure point on ENERGY STAR's thermal enclosure system checklist for program participants. The prevalent attic insulation in the hot-humid region is blown-in insulation. This type of insulation does not remain installed at the knee walls. Further failures resulted from a lack of sealing on six sides, as required by ENERGY STAR. LifeStyle Homes adopted two methods, one employing standard batt insulation and six-sided sealing, and another relying on spray foam to both air seal and insulate (Figures 6–10).

Figure 6. Backside of a foamed knee wall, showing blocker board used to serve as backing for the foam

Figure 7. Foam applied to knee wall in attic where ceiling heights transition from 8 to 10 ft

Figure 8. Backer board for foam, shown from inside garage

Figure 9. Radiant barrier backer board for standard batt insulation at knee wall installation

Figure 10. Batt insulation installed to backer board from Figure 9; six-sided sealing of cavity is provided by backer, facing drywall (yet to be installed), and framing members

2.2.3 Habitat for Humanity Implementation

As previously mentioned, the HFH efficiency package builds on previous BA work in the Gulf Coast region (McIlvaine and Beal 2010). The work led to a hot-humid climate package specific to small housing, with efficiency measures that are not affected by house size. Examples are refrigeration, hot water usage, and—to a lesser extent—lighting. These became a higher priority than more traditional efficiency measures that address envelope and HVAC improvements.

The next logical step to improve the efficiency of the HFH package was to address water heating equipment efficiency. Various affiliates have experimented with tankless gas and solar water heaters. The recent advent of ENERGY STAR-rated hybrid water heaters or HPWHs has provided all-electric houses with an additional method to reduce water heating energy use in addition to heating water with solar power. Several of BA's affordable housing partners have adopted hybrid HPWHs as part of their improvement packages. HPWHs have advertised COPs of greater than 2. This, coupled with better aesthetics and a significantly lower first cost than a solar water heating system, makes HPWHs attractive. Similar commercially-available units that had been on the market in the past, however, suffered from poor reliability and difficulty meeting demand. ENERGY STAR-certified HPWHs come with a minimum 6-year warranty on the sealed, heat pump portion of the system. The units have a back-up electric resistance element that comes on automatically to meet heavy demand. Various control strategies are available to suit the homeowners' lifestyle. FSEC research and monitored data show savings in the range of 40% of traditional electric resistance tank type water heaters (Colon 2012).

Limited space was a challenge in many HFH homes when implementing the HPWH. HPWH manufacturers recommend a space of not less than 100 ft^2, to avoid possible overcooling of the area that could potentially affect performance. Ambient noise created by the heat pump is a perceived concern with an interior installation, and garages are often the installation location of choice in a warm climate. Because HFH homes are typically small, however, it is not uncommon for the floor plans to be without a garage. To address this, two BA-PIRC partner HFH affiliates adopted HPWHs in their specifications by installing them in alternative locations. One installed the units in an exterior unconditioned closet specifically designed and constructed for this purpose. Although the exact configuration differed slightly from plan to plan, the closet typically had to be smaller than the HPWH manufacturer's recommendation of 100-ft^2 minimum. A unique feature was included to overcome this limitation— connecting the air volume of the closet to the air volume of the attic via air vents (Figures 11 and 12).

Figure 11. Completed exterior HPWH closet

Figure 12. Closet under construction. Grille on back wall connects attic space of closet to vented attic of house through gable end. Rough framing can be seen for grille in closet ceiling that will complete connection between closet and attic.

Another HFH affiliate partner allowed BA-PIRC to install a simple monitoring system to track the efficiency of an HPWH that was installed in a utility room smaller than 100 ft^2 within a home. Instrumentation consisted of a Campbell Scientific data logger monitoring the inlet and outlet temperature of the water, water flow, energy use of the tank, and temperature and relative humidity of the utility room. Results from 80 days of data (April 9, 2012–June 27, 2012) yielded an average daily consumption of 37.5 gal of hot water used, delivering 34.42 kBtu using 4.16 kWh/day. This produced an average daily COP of 2.42, slightly better than the manufacturer's advertised COP of 2.35, showing that the performance was not severely affected by this particular restricted space installation.

2.3 Quality Control/Quality Assurance

The builders' careful attention to quality control and quality assurance differentiates them from much of their competition. In addition, it is considered a critical requirement for achieving cost and energy savings associated with the high performance, systems engineered packages. Buy-in at the top executive level within a builder's organization is critical for all components of high performance housing, but top-down attention to quality control and quality assurance is especially important. When many builders are cutting costs, TWH executive management insists on continual site supervision and third-party inspections, which Todd Louis states "gives us an edge above and beyond the competition." This creates a niche market for TWH against others who are claiming but not validating high performance. LSH CEO Jake Luhn attributes "effective quality control mechanisms performed by our RESNET [Residential Energy Services Network] affiliated professionals provide the final proof of quality for each SunSmart home we deliver." This provides a performance guarantee to LSH customers.

It is critical that each home is individually designed, inspected, rated, and commissioned for optimum performance, comfort, and cost effectiveness. Keys to success include the following:

- Scopes of work for subcontractors that include specific performance criteria
- Clear communication with the trades, often including training and education activities
- Independent third-party testing and commissioning with feedback to the builder and trades.

These builders use proper documentation of energy, comfort, and durability features on job-site-ready checklists extensively as part of their high performance formula (Baechler and Love 2004). One of the best ways to foster program compliance is to provide detailed, specific plans enumerating all energy efficiency and durability items. Distributing trade-specific job-site checklists is also extremely helpful in ensuring program compliance. Affordable housing providers such as HFH often have brisk turnover rates, exacerbating the effects of poor or missing documentation. Such documentation is necessary if their products are to consistently and continually meet high performance expectations. Although this is true for almost all the builder/partners featured in this report, perhaps the small home size and speed of construction in HFH disallows time needed for corrections after the fact.

Commissioning activities conducted in every home have evolved over time, coincident with requirements of key labeling programs including EPA ENERGY STAR and DOE Builders Challenge. To some degree, such programs have provided the impetus toward more rigorous and systematic quality control. Although marketing benefits often result from program participation, builders place greater value on the contribution toward ensuring comfort, efficiency, and cost effectiveness. This includes staff and subcontractor education on the front end as well as careful oversight throughout design, construction, and commissioning. The commissioning activities require builders and third-party raters to engage in regimented inspection and performance testing of enclosure, air flow, and HVAC system performance elements (Fonorow et al. 2007). With the recent evolution of ENERGY STAR to version 3, and the change from DOE Builders Challenge to Challenge Home, builders, subcontractors, and third-party raters are currently exploring ways to carefully transition so the new program requirements become cost-effectively integrated into their success models.

3 Cost Effectiveness of the 30% Packages

The builders in this report continuously exercise performance improvement cost analysis, and often subject new individual measures under consideration to cost-effectiveness criteria in addition to packages of measures. For example, committed to constantly improving the energy performance and indoor environment and comfort of its homes, TWH first implemented ducts within the conditioned space on a prototype zero energy home and has since made this feature standard. Various methods to achieve the objective were originally compared: spray foam technique at the roof deck creating an unvented attic (UA), and installing the ducts below the insulated ceiling within the conditioned space via FDCs. Table 3 breaks down costs for each method (Fonorow et al. 2010).

Table 3. TWH Cost Analysis of Ducts Within Conditioned Spaces

Parameter	TWH UA Case	TWH FDC Case
Floor Area (ft^2)	2,250	2,250
House Volume (ft^3)	25,500	22,500
Roof Pitch	7/12	7/12
Heat Transfer Area (ft^2)	2,520	2,250
R-Value	21	38
Insulation Cost ($/$ft^2$ of floor area)	$5,625 ($2.50)	$1,688 ($0.75)
Duct Within Conditioned Space Cost ($/$ft^2$ of floor area)	N/A N/A	$875 ($0.39)
Radiant Barrier Cost ($)	$0	$500
Total Cost ($/$ft^2$ of floor area)	$5,625 ($2.50)	$3,063 ($1.36)

The FDC method is more cost effective, and although no direct performance comparison of the methods has been documented in the hot-humid climate, most agree that the FDC method is at least as effective, if not superior to, the UA method in terms of energy savings. Energy modeling also confirms this effect. Analysis such as this and experience with the method gave TWH the necessary feedback to proceed with constructing the ducts within the conditioned space as standard practice. Many builders in hot-humid climates, however, are reluctant to consider this over the method of spray foaming at the roof deck (UA) because of the design work required on the front end to implement FDC in an aesthetically pleasing manner. Once this reluctance is overcome, though, builders such as TWH report that customers appreciate the enhanced aesthetic appeal created.

Not included in this analysis is additional value accruing from enclosing the air handler in a conditioned closet as opposed to regional practice of installing the air handler in an unconditioned attached garage. This effectively adds approximately 15 ft^2 of conditioned space, with a sales value of nearly $2,000. The first cost of the detail adds about $500 to the total cost of the project, resulting in a net gain of $1,000.

Conducting performance improvement cost analysis in affordable housing has revealed unique challenges faced by this sector. By its nature, affordable housing is often small; for example, a typical HFH three-bedroom house is 1,100 ft^2 or smaller. There are fixed costs associated with high-efficiency HVAC equipment (i.e., advanced or multiple motors) that do not scale with house size. These fixed costs serve to effectively increase the cost of small (1.5–2 ton) high-efficiency HVAC units disproportionately more than large (3–4) ton HVAC units. Further challenges are encountered when improving envelope efficiencies. The small area of windows, attics, floors, and walls decreases their thermal impact on the overall load of the building compared to more size-independent loads, such as lighting, water use, and, to an extent, internal loads. WHSES packages that make financial sense for larger housing stock do not always translate accurately to smaller housing. This highlights the need for investigation and information dissemination across a range of housing types.

BEopt software was used to determine site energy savings for packages discussed in this report and combined with cost data collected from builders for application of those packages. Table 4 presents the results from this analysis. As the table shows, when the added costs of the efficiency package are included in a 30-year mortgage at 5% interest, positive cash flow results from the energy savings of those packages over the BABM10.

Table 4. Builders Specifications, Improvement Costs, and Energy Savings Analysis

Feature	BABM10	Tommy Williams	Inc. Cost	Lifestyle SunSmart	Inc. Cost	HFH Standard	Inc. Cost	HFH HP H2O	Inc. Cost
Building Envelope									
Roof Finish/Attic	Medium roof finish; no radiant barrier; vented atttic	Medium roof finish; radiant barrier; vented attic		Medium roof finish; radiant barrier; vented atttic		Light roof finish; radiant barrier; vented attic		Light roof finish; radiant barrier; vented attic	
Roof/Ceiling Insulation	R-30 blown in insulation @ ceiling	R-30 blown in insulation @ceiling 10" heel truss		R-38 blown in insulation @ roof	$675	R-38 blown in insulation @ ceiling	$350	R-38 blown in insulation @ ceiling	$350
Wall Type	Frame 2x4	2x6 16" o.c. frame w/ladder T and 2 stud corners when feasible		Light color masonry block		2x4 16" o.c. frame		2x4 16" o.c. frame	
Wall Insulation	R-13 fiberglass batt	R-21 formaldehyde-free blown fiberglass	$700	Reflective Foil R-7 interior wall insulation	$150	R-13 fiberglass batt		R-13 fiberglass batt	
Windows	U = 0.40 SHGC = 0.30	Double pane low-E (U = 0.34 SHGC = 0.25)		Double pane low-E (U = 0.35, SHGC = 0.29)	$385	Double pane low-E (U = 0.40, SHGC = 0.20)*	-$10	Double pane low-E (U = 0.40, SHGC = 0.20)*	-$10
Floors	20% tile	70% tile, 30% carpet		30% tile, 70% carpet		100% tile	$800	100% tile	$800
Envelope Leakage ACH_{50}	ACH_{50} = 5	ACH_{50} = 2.9		ACH_{50} = 3.5		ACH_{50} = 4.5		ACH_{50} = 4.5	
Air Sealing	None	Expanding foam at all exterior openings & foam gasket at ceiling/wall joints	$100	Expanding foam at all exterior openings	$500	Expanding foam at all exterior openings	$200	Expanding foam at all exterior openings	$200
HVAC System									
Heating/Cooling system	ASHP - SEER 13 / HSPF 7.7; standard thermostat	ASHP - SEER 16 / HSPF 9.5; programmable thermostat	$800	ASHP - SEER 15/HSPF 8.5; programmable thermostat	$800	ASHP - SEER 14 / HSPF 8.2; standard thermostat	$200	ASHP - SEER 14 / HSPF 8.2; standard thermostat	$200
Air Handler Location	Garage	Interior closet		Interior closet		Interior closet		Interior closet	
Fresh Air Ventilation	ASHRAE 62.2-2007b	Runtime vent system, kitchen exhaust to out	$200	Runtime vent system, kitchen exhaust to out		Runtime vent system, kitchen exhaust to out		Runtime vent system, kitchen exhaust to out	
Duct Insulation, Location	R-6, attic	R-6, in conditioned space	$663	R-6, attic		R-6, attic		R-6, attic	
Duct Leakage	5% leakage to out	0 leakage to out		2% leakage to out	$100	2% leakage to out	$50	2% leakage to out	$50
Bathroom Exhaust Fans / Controls	Manual	Timer switch		Timer switch		Manual		Manual	
Water Heating									
Water Heater	Electric EF = 0.97	Tankless gas EF = 0.82	$450	Solar flat plate (40 ft^2) open loop, 80 gallon storage	$3,600	Electric EF = 0.92		Heat pump COP = 2.35	$600
Lighting	33% fluorescent	100% fluorescent	$125	100% fluorescent	$100	100% fluorescent	$45	100% fluorescent	$45
Appliances ENERGY STAR	No	Yes	$100	Yes	$300	Yes	$100	Yes	$100
Total Cost of Improvements			$3,138		$6,610		$1,735		$2,335
Annual Mortgage Cost (5%,			$204		$430		$113		$152
Annual Energy Savings (elec.@ $0.13/kWh - gas. @ $1.25 therm)		$430		$591		$257		$447	
Annual Cash Flow		**$226**		**$161**		**$145**		**$295**	

* Due to small home sizes and reduced window sizes, the savings almost equaled incremental cost of high performance windows

4 Marketability of the Homes

Energy efficient measures alone do not attract new home buyers in an economy where retrofits and renovations are now booming. Nor do energy efficient homes propagate first-cost affordability. Although a high performance home's monthly cost of ownership is less than that of a code minimum home, and consumers are learning that not only do they cost less to operate but provide a better indoor environment, this "educated consumer" is a high performance home builder's ideal customer. Together with a vigorous advertising campaign; an educated, well-trained sales staff; and innovative strategies directed by senior executives, whole-house, high performance solutions result in home sales, not just home builds.

Community-scale builders' success stories of marketing the homes with the 30% package are explained in this section. A key component to this success can be attributed to the builders making the package standard. "It wasn't an option for the customer to cherry-pick [from] our SunSmart energy efficiency package the items they wanted in their home," said LSH CEO Luhn. LSH representatives acknowledged that at first they thought this standardization would require them to communicate all the particulars involved in their SunSmart package for every sale, but they quickly realized that was unnecessary. LSH's management reminds the sales staff that "when the sale is made, stop selling." For example, when customers ask about SunSmart, in a manner consistent with "I'm getting that SunSmart thing included in my price, right?" it is no longer necessary to elaborate on technical details. It is the communication of the overall benefits of the package that sells the homes, not a description of the individual components.

Builders have also found that merely claiming energy use reduction is not enough. The successful builders have implemented strategies that can be outlined in three steps: (1) inform the customer that the features have benefits; (2) use show-and-tell type illustrations or mockups to create a hands on bonding experience with the customer; and (3) develop/enlist incentives, promotions, programs, and third-party certifications that are offered to the customer. Recorded home sale statistics with respect to specifications of both BA builders and non-BA builders demonstrate the importance of not only building high performance homes but putting forth the effort and resources to market them. Without advertising, marketing, or expending adequate resources to accompany value-added features, success is not realized (Thomas-Rees, Fonorow, Chandra 2010).

TWH aggressively markets its high performance homes with dedicated resources for advertising, realtor education seminars, and groundbreaking[5] and open house dedications. In 2007, Todd Louis, vice president of TWH, organized an event during the construction of one of TWH's high performance homes, whereby Alachua County proclaimed April 25, "Building America Day." [6]

Some of the most successful advertising is created by TWH and talks to the first point of showing that the feature has a benefit (Figure 13). Customer savings can save money, but the benefits of saving money in energy costs allow for establishing college funds, upgrading kitchen countertops, or even paying for a vacation.

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[5] See, for example, http://www.tommywilliamshomes.com/about/files/march2009a.pdf.
[6] See http://www.ba-pirc.org/casestud/baday/Alachua-proclamation.pdf for more information.

Illustration from Tommy Williams Homes

Figure 13. Example of TWH marketing showing the feature has a benefit

A Gainesville realtor has been blogging about TWH and his search for the best energy efficient home in the area. He has publicized HERS Indices and ZEHs and is not affiliated with TWH.[7]

LSH purports the second key point to successfully marketing high performance homes in that they also provide open house and demonstrate their features in their models with show-and-tell opportunities (Figure 14).

Figure 14. LSH uses show-and-tell type illustrations and mockups to create a hands on bonding experience with the customer.

[7] See http://activerain.com/blogs/davegibbs/tags/zero%20energy%20home for more information.

Incentives, promotions, and tangible third-party certifications and or seals of approval, or both are other key components to successfully marketing high performance homes. LSH and TWH promote the HERS Index on their websites, communicate the advantages of high performance homes, and promote available incentives. TWH pays the first year's electric bills on all its new home sales.

Packages adopted by partners had to provide real cost effectiveness and reasonable payback periods. To quote LSH CEO Jake Luhn, "Our original impetus was to differentiate the new homes we wanted to build from homes we built before the recession that were coming back on the market at heavily discounted prices. 'It may look like the same home, Mrs. Smith, but it is not the same home by a long shot. Let me show you why it is to your advantage to purchase a brand new SunSmart home rather than that short sale down the street.' The fact that bringing a genuinely superior product to the market would be doing the right thing for our customers was the deciding factor in initiating our energy efficiency program. Our goal is always to achieve business success for LSH by delivering superior value to our customers. Making a significant contribution to family health and environmental preservation is a happy by-product of our value-driven, energy efficiency marketing strategy. Our customers told us emphatically that what they wanted were solid—from day one—cost savings that would grow in value over time as energy prices rise. If those cost savings could deliver appreciable family health benefits and make a significant contribution to environmental preservation, so much the better. It's too early to tell about repeat customers, but our customer referral rate has risen significantly." LSH never uses the word "green" in marketing materials or sales presentations. They think their customers view green as expensive and perceive that the original homeowner's incremental investment might never be recouped. Customers want solid, documented cost savings. LSH's obligation as business professionals is to offer customers what they want to buy. If they can do this and "raise awareness of family health and environmental preservation issues in the process, so much the better," says Luhn.

Nonprofit providers of affordable housing are often even more vested in helping their clients live affordably, and also more conscious of first costs. Yet nonprofit builders such as HFH affiliates have also adopted 30% packages as standard because they are cost effective. Approaches to and value of marketing and product differentiation, however, tend to differ from those of for-profit builders. Examples of market value found for nonprofits constructing high performance housing include increased access to grant funding resulting from enhanced building performance, often quantified through voluntary program compliance.

4.1 Sales Data/Statistics

TWH and LSH have been leaders in showing that marketing plays a key role in selling high performance homes. Although the story to be told to potential buyers includes a value proposition that yields large returns on extra investment, performance measures alone are not justification enough for success in terms of home sales, especially in a depressed economy. The story must be effectively communicated. Both TWH and LSH credit their success in this area to experienced sales staff and creative marketing. Marketing, and marketing to a targeted audience, is vital to the success of high performance builders. In TWH Longleaf Community located in Gainesville, Florida, a community with a cost-competitive builder constructing similar floor plans and same size homes, TWH has proven that premium construction returns premium price by selling homes faster and for more per square foot (Table 5).

Table 5. Longleaf Sales Data

	TW	Competitor
12/06–05/08 Sales Price	$\$161/ft^2$	$\$148/ft^2$
12/06–05/08 Sales	44 homes	22 homes
01/09–06/12 Sales Price	$\$130/ft^2$	$\$120/ft^2$
2009	Data n/a	Data n/a
2010	32–36	Data n/a
2011	19	15
2012 (May)	17	6

5 Conclusions

This report demonstrates achievement of BA 30% WHSES goals in the hot-humid climate by documenting successful approaches taken by both for-profit and nonprofit community-scale builders. The builders have all been continuously involved with the BA program since originally becoming partners and their specifications and resulting efficiency levels have evolved over that time. These builders were specifically chosen as subjects in this research to show that the evolving goals of the BA program marry well with evolving capabilities and interests of builders and their subcontractors, and the resulting homes meet the evolving needs and sophistication of the market.

In the Implementation section of this report, and through key references to past work, technical components of hot-humid 30% packages are described. Multiple packages containing subtle differences show that it is possible to achieve this savings level while tailoring specifications to meet a builder's unique needs and regional preferences. The need for quality assurance mechanisms is touched on to reiterate that when deployed at the community scale, systems engineered 30% packages can fall apart because of an imperfect match with a unique floor plan or oversight by a particular trade. In the Cost Effectiveness section of this report, it is shown that these packages do not increase the cost of home ownership, and in fact they generate positive cash flow to homeowners on the order of $200 per year. Although robust sales of these homes are reported here, the Marketability section makes it clear that the inherent value must be communicated, not in terms of the details of individual features, but in terms of the overall benefits of the package.

This report is expected to be of prime use to hot-humid climate builders interested in applying similar methodologies toward creating and selling energy efficient homes, resulting in both economic and environmental benefits. As described, the builders discussed are already progressing toward community-scale ZEHs, showing that the tipping point of cost-effective, low-energy-use, production-scale homes has not been reached.

References

Baechler. M.C.; Love, P.M. (2004). Building America Best Practices Series: Volume 1. Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Hot and Humid Climate. NREL/TP-550-36960. Golden, CO: National Renewable Energy Laboratory. Accessed February 2013: http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/36960.pdf.

Beal, D.; McIlvaine, J.; Fonorow, K.; Martin, E. (2011). Measure Guideline: Summary of Interior Ducts in New Construction, Including an Efficient, Affordable Method to Install Fur-Down Interior Ducts. FSEC-RR-385-11. Cocoa, FL: FSEC. Accessed September 2012: http://www.fsec.ucf.edu/en/publications/pdf/FSEC-RR-385-11.pdf.

Colon, C. (2012). Side-by-Side Testing of Water Heating Systems: Results from the 2010-2011 Evaluation. FSEC-RR-386-12. Cocoa, FL: FSEC. Accessed September 2012: http://fsec.ucf.edu/en/publications/pdf/FSEC-RR-386-12.pdf.

DOE Building Technologies Program, Office of Energy Efficiency and Renewable Energy (2010). “Builders Challenge: High Performance Builder Spotlight: LifeStyle Homes.” Building America Partnership for Improved Residential Construction. Accessed September 2012: http://www.ba-pirc.org/casestud/pdf/_BuildersChallenge_LifeStyle-Homes.pdf.

Fonorow, K.; Chandra, S.; Martin, E.; McIlvaine, J. (2006). “Energy and Resources Efficient Communities through Systems Engineering: Building America Case Studies in Gainesville, FL.” Proceedings of the 2006 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Asilomar, California, August.

Fonorow, K.; Chandra, S.; McIlvaine, J.; Colon, C. (2007). “Commissioning High Performance Residences in Hot, Humid Climates.” 7th International Conference for Enhanced Building Operations, San Francisco, California, November 1–2; pp. 4–6.

Fonorow, K.; Jenkins, D.; Thomas-Rees, S.; Chandra, S. (2010). “Low Cost Interior Duct Systems for High Performance Homes in Hot Climates.” ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, California, August 15–20.

Hendron, R.; Engebrecht, C. (2010). Building America House Simulation Protocols. NREL/TP-550-49426. Golden, CO: National Renewable Energy Laboratory.

McIlvaine, J.; Beal, D. (2010). Gulf Coast High Performance Affordable Housing Demonstration Project. FSEC-CR-1791-09. Cocoa, FL: FSEC. Accessed September 2012: http://www.ba-pirc.org/pubs/pdf/Gulf%20Coast%20Final%20Report.pdf.

Thomas-Rees, S.; Fonorow, K; Chandra, S. (2010). “Transforming the New Home Market Through High Performance Construction.” ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, California, August 15–20.

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