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Achieving Challenge Home in Affordable Housing in the Hot-Humid Climate

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and R. Allnutt
Building America Partnership for Improved Residential Construction

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Achieving Challenge Home in Affordable Housing in the Hot-Humid Climate

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Office of Energy Efficiency and Renewable Energy

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Definitions

ACH	Air changes per hour
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAB2010	Building America Benchmark, revised 2010
BA-PIRC	Building America Partnership for Improved Residential Construction
BEopt	Building Energy Optimization
CFL	Compact Fluorescent Lamp
CFM25	Cubic Feet per Minute at a Test Pressure of 25 Pascals
CH	Challenge Home
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ESC	Energy and Sustainability Consultants
FPL	Florida Power and Light
FSEC	Florida Solar Energy Center
HERS	Home Energy Rating System
HFH	Habitat for Humanity
HFHI	Habitat for Humanity International
HVAC	Heating, Ventilation, and Air Conditioning
ICF	Insulated Concrete Form
IECC	International Energy Conservation Code
LEED	Leadership in Energy & Environmental Design
MCHFH	Manatee County Habitat for Humanity
PV	Photovoltaic
RERH	Renewable Energy Ready Home
RESNET	Residential Energy Services Network
SEER	Seasonal Energy Efficiency Ratio
SEVHFH	Southeast Volusia County Habitat for Humanity
SHGC	Solar Heat Gain Coefficient
UA	Area Weighted Average U-Value

Acknowledgments

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Researchers are deeply grateful for the opportunity to conduct collaborative, applied research with Manatee County Habitat for Humanity (MCHFH) in Bradenton, Florida and Southeast Volusia County Habitat for Humanity (SEVHFH) in New Smyrna Beach, Florida. The leadership of both organizations sets a high bar for responsible stewardship in affordable housing construction. This research would not have been possible without the support of:

- Diana Shoemaker, Executive Director, MCHFH
- Rosemary Walker, Executive Director, SEVHFH

The innovative approach to constructing an interior duct system in the SEVHFH home is wholly attributable to the vision and leadership of Ray Allnutt, SEVHFH Construction Supervisor. He conceptualized an approach that solved failure points identified in previous research. Using the systems engineering approach of anticipating and solving problems before they happen, he and his team worked with Servair Heating and Air Conditioning to develop and implement a plan that delivered results beyond expectation.

Bruce Winter, Construction Director of MCHFH, was instrumental in the design and execution of MCHFH’s Challenge Home. Bruce led MCHFH’s effort to update the construction methods and building science employed to build its Challenge Home (CH). Bruce also provided detailed cost information comparing his construction to a basic frame house that is Florida code complaint, included as Appendix C.

The work contained in this report would not be possible without the work of the raters of record for both houses. MCHFH’s rater is Energy and Sustainability Consultants LLC of Sarasota, Florida, represented by Karl Handley-White, who graciously donates his efforts to the affiliate. SEVHFH’s rater is Patrick Gillis of Home Audit Technologies, located in Cocoa Beach, who provides Habitat for Humanity affiliates with deeply discounted services. Both of these raters stepped up and became CH certifiers to facilitate this work, which wouldn’t have been possible without their help.

Special thanks are due to Danielle Daniel for her excellent editorial assistance.

Executive Summary

The Building America Partnership for Improved Residential Construction (BA-PIRC) worked with two affordable housing builders who pursued and achieved CH certification. Both builders needed very few changes to reach CH; however, both were already certifying homes under the ENERGY STAR® for Homes Standard v.3.1. Habitat for Humanity affiliates' mortgage terms are 0% interest over a 30-year mortgage to qualified buyers.

To improve relevance of the study to the general homebuilding community, the cost-effectiveness calculations herein are based on a code-minimum reference rather than the builders' standard practice (ENERGY STAR), and projected first year cash flow is provided for both the builders' actual finance terms and for a market rate of 7% for the same mortgage period.

MCHFH pursued CH in duplex dwellings built with insulated concrete forms, an unvented attic, a ducted mini-split variable-capacity heat pump, a solar water heater, and a photovoltaic (PV) array. SEVHFH pursued CH in a frame home with a vented attic (regional convention), a seasonal energy efficiency ratio (SEER) 15 heat pump, and an innovative modified truss configuration that created an interior duct chase. The latter was featured in a Building America case study. The MCHFH and SEVHFH CHs scored 53 and 49, respectively, on the Home Energy Rating System (HERS) Index. With the addition of a 2.5-kW PV array, the HERS Index score dropped to 23 for the CH built by MCHFH.

Using the actual finance terms (0%, 30 years), cost analysis shows that MCHFH's CH costs $17,008 more than an identical geometry code-compliant home: $9,234 for solar hot water and PV and $7,774 for the rest of the improvement package. The projected first year cash flow associated with these two packages was $36 and $382, respectively, based on EnergyGauge USA calculations. This includes revenue generated from the sale of electricity back to the utility in the amount of $427 annually. MCHFH received renewable energy utility incentives available only to affordable housing providers that improved first year cash flow to $690.

Based on cost data provided by SEVHFH and data collected in previous studies, researchers estimate the cost of SEVHFH's CH with renewable-ready compliance (with a heat pump water heater) to be $4,636 compared to code-minimum specifications. This was reduced by a $600 in-kind donation available to all Habitat for Humanity affiliates from Dow Corporation. An additional $4,700 cost was incurred for a solar water heater, which was partially offset by the cost avoided for the heat pump water heater. Using the actual finance terms (0%, 30 years), the projected first year cash flow associated with these two packages was $214 and $238, respectively, based on EnergyGauge USA calculations. SEVHFH received a similar utility rebate for affordable housing for the full cost of the solar water heater that improved projected first year cash flow to $395.

Using market-rate finance terms (7%, 30 years), the projected first year cash flow is negative for both the renewable-ready and the solar-equipped scenarios for both houses. These calculations do not necessarily reflect the economics achievable by market-rate builders. The improvement packages were developed for a specific builder's resources which, in this case, included large utility incentives with limited availability. Market-rate builders may benefit from economies of scale or in-house labor capabilities that would implicate a different improvement package. A

preliminary analysis, conducted with a certified home energy rater, should be used to evaluate the projected energy savings and cost effectiveness of various improvements that suit a particular builder.

Several gaps and barriers to broader CH standard adoption were identified, including need for refinement of the innovative modified truss approach to interior duct systems developed by SEVHFH, research documenting the pros and cons associated with meeting the American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 62.2 ventilation rates, and a survey of stakeholders to develop a menu of ventilation strategies in use in the hot-humid climate region. The survey could help researchers identify which approaches are of greatest interest to stakeholders—those gaining market share, which are favored, and why.

1 Introduction and Background

Under the U.S. Department of Energy's (DOE) Building America program, DOE national laboratories and building science research teams conduct cost-shared research for and with stakeholders in the homebuilding industry. Researchers work closely with industry partners to develop innovative, real-world solutions that achieve significant energy and cost savings while safeguarding or improving occupant health and safety, indoor air quality, building durability, and comfort. After preliminary research in test houses, whole-house solutions are refined, and through research at community-scale, teams validate the reliability, cost effectiveness, and marketability of whole-house improvement packages and strategies for new and existing homes (Thomas-Rees et al. 2013; McIlvaine and Sutherland 2013; McIlvaine et al. 2013).

The DOE Challenge Home (CH) program provides a standardized platform for application of Building America innovations that, when combined, achieve significantly higher-than-code levels of whole-house energy efficiency while also improving durability, quality, affordability, and comfort. Some elements of the CH standard exceed construction methods and specifications of even very high performance homes such as zero energy homes built by other Building America Partnership for Improved Residential Construction (BA-PIRC) partners (Thomas-Rees et al. 2013).

BA-PIRC, one of the Building America research team leads, has partnered with two builders as they work through the CH certification process in one test home each. Both builders are located in central Florida in the Building America hot-humid climate and International Energy Conservation Code (IECC) climate zone 2 (Baechler et al. 2010).

This research serves to identify viable technical pathways to meeting the CH criteria for other builders in the region. A further objective of this research is to identify gaps and barriers in the marketplace related to product availability, labor force capability, code issues, cost effectiveness, and business case issues that hinder or prevent broader adoption on a production scale.

The following research questions were addressed:

- What are the major technical gaps and barriers associated with achieving CH in the hot-humid region?
- Do the partners favor the performance or prescriptive path for CH certification?
- What is motivating the partners' interest in high performance housing?
- What changes were needed to meet the mandatory requirements? For each, was the change minor, moderate, or major?
- What are the costs associated with meeting the mandatory requirements?

The builder partners participating in this cost-shared research are Southeast Volusia County Habitat for Humanity (SEVHFH) near Daytona, Florida and Manatee County Habitat for Humanity (MCHFH) near Tampa, Florida. Both are affiliates of Habitat for Humanity International (HFHI), a nonprofit affordable housing organization. Habitat affiliates produce and sell homes for 0% interest to qualified buyers who participate in the construction of homes with other volunteers. They sometimes receive donations or discounts on labor and materials. These factors influence economics and economic decision-making. Habitat's focus on long-term affordability increases interest in operating cost, building durability, and maintenance requirements.

1.1 Challenge Home Requirements

Conceptually, CH ties together key components of high performance housing including building science, best practices, efficient equipment, high performance envelope components, and indoor air quality control (Figure 1). CH also requires renewable-ready measures that make integrating renewable energy technologies such as photovoltaic (PV) and solar water heating easier for homeowners in the future. Combining renewable readiness with a Home Energy Rating System (HERS) Index requirement that exceeds ENERGY STAR®, CHs are zero net-energy ready, a key objective of the program.

Figure 1. CH requirements (top row) and recommended (bottom row) consolidate key concepts for high performance homes

(Rashkin undated)

1.1.1 Challenge Home Mandatory Requirements

CH builders must meet requirements in seven different categories (Figure 2) and must meet or exceed the projected energy performance of the Target Home specifications under the HERS Index.

Area of Improvement	Mandatory Requirements
1. **ENERGY STAR for Homes Baseline**	☐ Certified under ENERGY STAR Qualified Homes Version 3 [7, 8]
2. **Envelope**[9]	☐ Fenestration shall meet or exceed latest ENERGY STAR requirements [10, 11] ☐ Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels[12]
3. **Duct System**	☐ Ducts located within the home's thermal and air barrier boundary[13]
4. **Water Efficiency**	☐ Hot water delivery systems shall meet efficient design requirements[14]
5. **Lighting & Appliances**[15]	☐ All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. ☐ 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets ☐ All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified
6. **Indoor Air Quality**	☐ EPA Indoor airPLUS Verification Checklist and Construction Specifications [8,16]
7. **Renewable Ready**[17]	☐ EPA Renewable Energy Ready Home Solar Electric Checklist and Specifications[18] ☐ EPA Renewable Energy Ready Home Solar Thermal Checklist and Specifications[19]

Figure 2. CH Mandatory requirements for all homes

(DOE 2013a)

All seven categories of requirements, except number 3 (ducts located within the home's thermal and air barrier), are related to codes and standards external to the CH program. These include:

- Requirement 1: ENERGY STAR for New Homes (EPA 2009)
- Requirement 2: ENERGY STAR labeling standard for fenestration (IECC 2012)
- Requirement 4: Section 3.3 of the U.S. Environmental Protection Agency (EPA) WaterSense Single Family New Home Specifications (EPA WaterSense 2012)
- Requirements 5: ENERGY STAR labeling standards appliances, lighting, and ceiling, bathroom, and kitchen vent fans (EPA 2013a; EPA undated; EPA 2011a; EPA 2012)
- Requirement 6: EPA standards for Indoor airPLUS (EPA 2013b)
- Requirement 7: EPA Renewable Energy Ready Home (RERH) standards for solar electric and solar thermal technologies (EPA 2011b; EPA 2011c).

Readers should refer to the CH National Program Requirements (DOE 2013a) for complete details and references. The footnotes shown in Exhibit 1 above (Figure 2) and throughout the Program Requirements provide vital information necessary to consider in developing a CH.

There is no standard or single methodology to guide meeting the interior duct requirement. It has long been a recommendation by Building America and many in the home performance industry. Many factors influence the complexity of meeting this requirement in any given home, including building geometry and the builder's typical construction processes. Constructing a duct system fully inside the conditioned space may involve altering standard construction processes, which is more challenging than altering specifications. Readers can find examples and guidance in several Building America publications and the Solution Center:

- Requirement 3: Building America Measure Guidelines related to interior duct systems:
    - Measure Guideline: Summary of Interior Ducts in New Construction, Including an Efficient, Affordable Method to Install Fur-Down Interior Ducts (Beal et al. 2011)
    - Measure Guideline: Buried and/or Encapsulated Ducts (Shapiro et al. 2013)
    - Measure Guideline: Air Sealing Mechanical Closets in Slab-On-Grade Homes (Dickson 2012)
    - Measure Guideline: Implementing a Plenum Truss for a Compact Air Distribution System (Burdick 2013).

1.1.2 Challenge Home Prescriptive and Performance Paths

In addition to these mandatory requirements, CHs must meet or exceed the projected performance level of the Target Home specifications (Appendix A), which vary by climate. This can be pursued on a prescriptive path or a performance path. Under the prescriptive approach, builders adopt and implement all the Target Home specifications (or better) in their projects. The Target Home procedure is similar to, but more rigorous than, the ENERGY STAR 3.0 Target Home procedures. Note that performance tests for whole-house and duct airtightness are still required.

The performance path requires that a certified home energy rater model the house using approved software with the Target Home specifications to generate a Target HERS Index[1] score, a gauge of whole-house efficiency. Then the rater models the builder's proposed specifications. This approach allows builders to customize specifications as long as the combined effect is equivalent to or better than the Target HERS Index.

MCHFH and SEVHFH each worked with their HERS raters and BA-PIRC researchers to compare the builders' standard specifications against the requirements for CH and identify necessary changes. This included reviewing the detailed requirements for standards referenced in the mandatory requirements. Prior to undertaking the CH test house, each partner was already building high performance homes in compliance with Florida ENERGY STAR 3.1 and the DOE Builders Challenge, the predecessor program to DOE CH. Therefore, each already met many of the mandatory requirements (Table 1).

Table 1. Preliminary Assessment of CH Mandatory Requirements

Requirement	MCHFH	SEVCHFH
Meets Target HERS Index Without PV	Yes CH Target 60 MCHFH Actual 53	Yes CH Target 59 SEVHFH Actual 50
1. ENERGY STAR for Homes, Version 3.1[2]	Yes*	Yes
2. Envelope: **ENERGY STAR Fenestration** **2012 IECC Insulation Levels**	 No* Yes	 Yes Yes
3. Interior Duct System	Yes	No
4. Water Efficiency	Yes	Yes
5. Lighting and Appliances: **ENERGY STAR Refrigerators, Dishwashers, and Clothes Washers** **80% ENERGY STAR Fixtures/Bulbs** **ENERGY STAR Exhaust and Ceiling Fans**	 Yes (no dishwasher provided) Yes Yes	 Yes Yes Yes
6. EPA Indoor airPLUS	Yes (but not certified)	Yes (but not certified)
7. Renewable Ready for Solar Electric and Solar Thermal Systems	Not standard; a few homes included renewable energy	Not standard; a few homes included renewable energy

* "Yes" indicates that the criterion was met by the builder's standard construction practices. "No" indicates areas needing change to meet the mandatory CH criteria.

As evidenced in Table 1 above, the builders were already incorporating many of the energy efficiency and high performance strategies necessary for CH certification in their standard construction methods.

[1] Residential Energy Services Network (RESNET) Mortgage Industry National Home Energy Rating Standards govern the calculation method for the HERS Index. On the HERS Index, lower scores indicate lower net energy consumption.
[2] The ENERGY STAR for Homes program issued a Version 3.1 for Florida.

MCHFH was on target to meet all CH Mandatory Requirements except the ENERGY STAR fenestration (Requirement 2). SEVHFH also needed to incorporate the RERH (Requirement 7) measures as well as interior ducts (Requirement 3). The latter led to changes in design and construction processes.

Both builders' general approaches to CH and specific solutions are discussed in the following sections.

2 MCHFH Challenge Home Specifications and Key Solutions

The CH target HERS Index for MCHFH was 60. On the HERS Index, lower numbers are better; therefore, any HERS Index score below 60 complies with the CH requirement. (A HERS Index score of "0" indicates a zero net-energy home). The achieved HERS Index without solar PV was 53; with PV it was 23.

For more than 15 years, MCHFH built wood-framed homes using the most economical products available with the objective of producing very affordably priced housing. The start of a new development, Hope Landing, provided MCHFH with an opportunity to rethink how it was building homes, specifically with an additional objective of producing homes that are more affordable to live in on a monthly basis. Working with an architectural firm and a certified home energy rater, MCHFH chose to move away from conventional wood-framed, low-cost material construction to a highly energy-efficient, sustainable, and safer home. These decisions aligned with the organization's mission to build homes that are not only affordable to purchase, but also affordable to live in.

MCHFH reviewed programs such as ENERGY STAR for Homes, Leadership in Energy & Environmental Design (LEED) for Homes, and the DOE Builders Challenge, which subsequently became the CH program. MCHFH also reviewed new building methods and materials that could be handled by Habitat's volunteer labor force without sacrificing the cost effectiveness necessary to meet the organization's financial goals. In the end, MCHFH developed a new design (Figures 3 and 4), a duplex floor plan, and changed almost all of its construction methods and products, a bold move requiring careful management.

Figure 3. MCHFH duplex homes

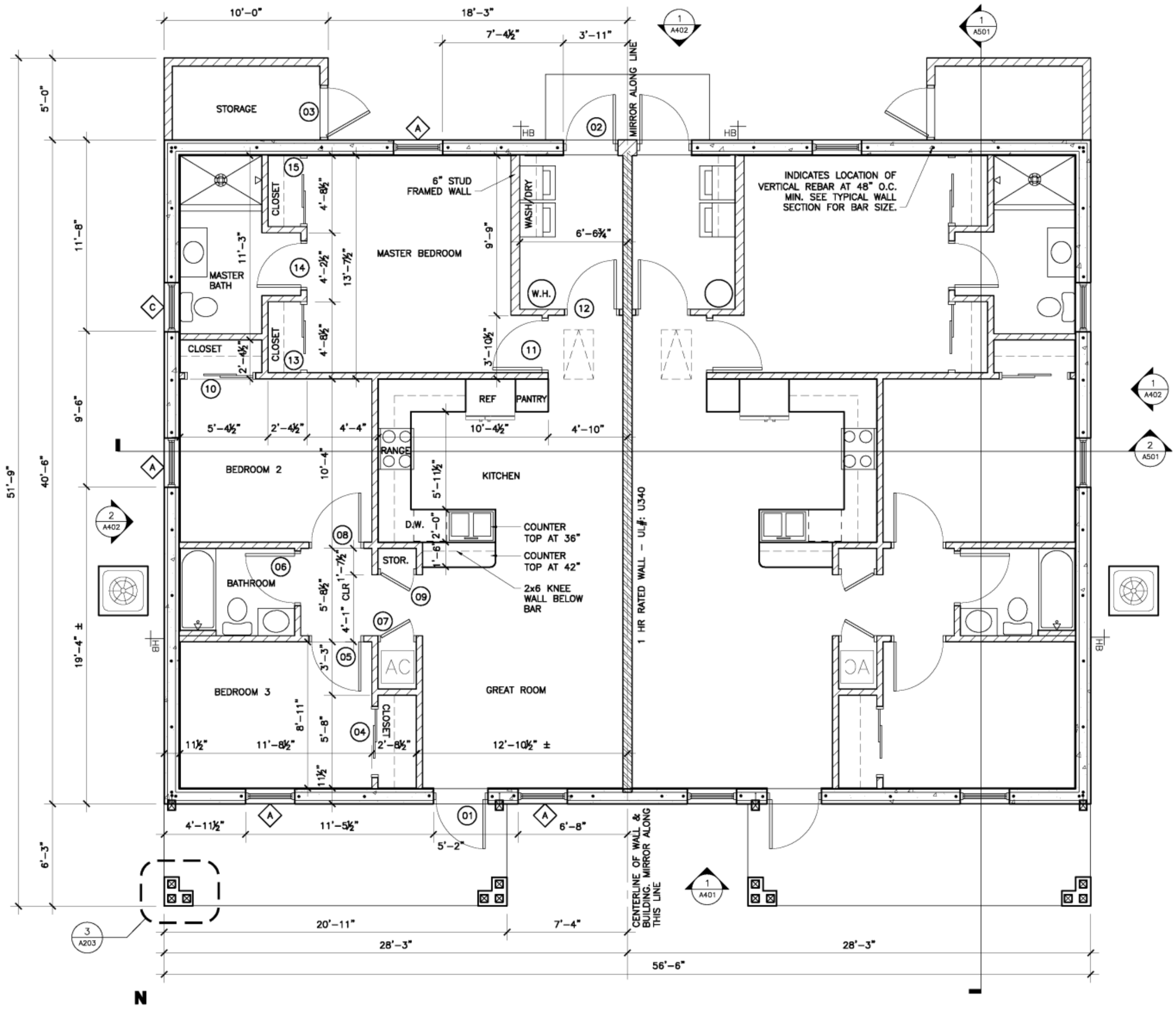

Figure 4. MCHFH Hope Landing floor plan

To validate the new design and construction methods, MCHFH initiated a plans review with a third-party testing and verification organization, Energy and Sustainability Consultants (ESC).

About a year before construction began, MCHFH construction staff held meetings with volunteer crew leaders to discuss the new construction methods. A Build Book was developed with selected crew leaders detailing more than 45 building steps in the new construction process. Quality check sheets were developed to verify that work met specifications before being turned over to the next crews to ensure repeatability and uniformity in construction regardless of crew and volunteer turnover. Ongoing training sessions and on-the-job training help new volunteers meet competency levels in the construction techniques. Excerpts from MCHFH's Build Book are included in Appendix B.

As construction at Hope Landing began, ESC conducted inspection visits. Any time a change or correction was required, it was reported to the architect and to the volunteer author of the Book Build section for update. ESC completed the final testing and certified early homes under the ENERGY STAR for Homes, Florida Green Home, and LEED for Homes programs.

MCHFH prepared a new homeowners and maintenance manual called "The What and Why of How We Build and How to Care for Your Home" to help buyers understand the features and operation of their new homes.

Although this activity was done before MCHFH decided to build a CH test house, it provides an excellent example of how to navigate the transition from building code-compliant homes to building high performance homes. The Build Book, in particular, informs the whole construction team. It provides construction objectives, detailed process guidance, and quality assurance check points. In a systems engineering exercise, the design and construction team develop solutions for anticipatable problems and confusion on paper. A document such as the Build Book, along with construction drawings of unfamiliar details and subcontractor scopes of work, can support problem solving at the job site.

2.1 MCHFH Meeting Challenge Home Mandatory Requirements

MCHFH's new construction method included R-23 insulated concrete form (ICF) walls and R-21 open-cell spray foam applied to the underside of the roof deck to create an unvented attic (Figures 5 and 6). The duct system installed in the unvented attic meets CH Mandatory Requirement 3, Interior Ducts. The combined effect of the wall and roof deck insulation effectively produces an envelope meeting CH Mandatory Requirement 2 (Envelope) for achieving 2012 IECC insulation levels. It does not meet the prescriptive envelope component U-value requirements for walls and attics; however, compliance is achieved using the "Total UA" alternative method (DOE 2013a). Also, the ICF block and foam roof decking provide excellent wind load characteristics, a plus in peninsular Florida where hurricanes present the main disaster resistance need.

Figure 5. ICF exterior wall under construction

Figure 6. Mechanical system in unvented attic formed by open-cell spray foam (not yet installed) under roof decking

The other CH mandatory envelope requirement is ENERGY STAR labeled fenestration (EPA 2009). MCHFH's standard window had a solar heat gain coefficient (SHGC) of 0.28, very narrowly missing the ENERGY STAR criterion for the hot-humid climate, which is 0.27. DOE granted MCHFH an exemption for this requirement on one of the completed houses. For future homes, MCHFH has changed specifications to regionally qualified ENERGY STAR windows.

To meet CH Mandatory Requirement 4, Water Efficiency, MCHFH changed the plumbing design by locating insulated pipes under the slab foundation (Figure 7) rather than in the interior walls and the attic. This allowed shorter, more direct runs, minimizing water wasted while waiting for hot water. The criterion specifies less than 0.5 gallons of water in the piping/manifold between the water heater and any fixture. Calculations were performed during design and the rater verified compliance at final testing.

Figure 7. Insulated pipes under the slab foundation

The EPA Indoor airPLUS program referred to in Requirement 6 calls for humidity control capability in climate zones 1, 2, and parts of 3. MCHFH achieves this requirement using a thermostat with built-in humidistat associated with the ducted mini-split mechanical system. The outside air ventilation system consists of a dampered fresh air duct to the return plenum (Figure 8).

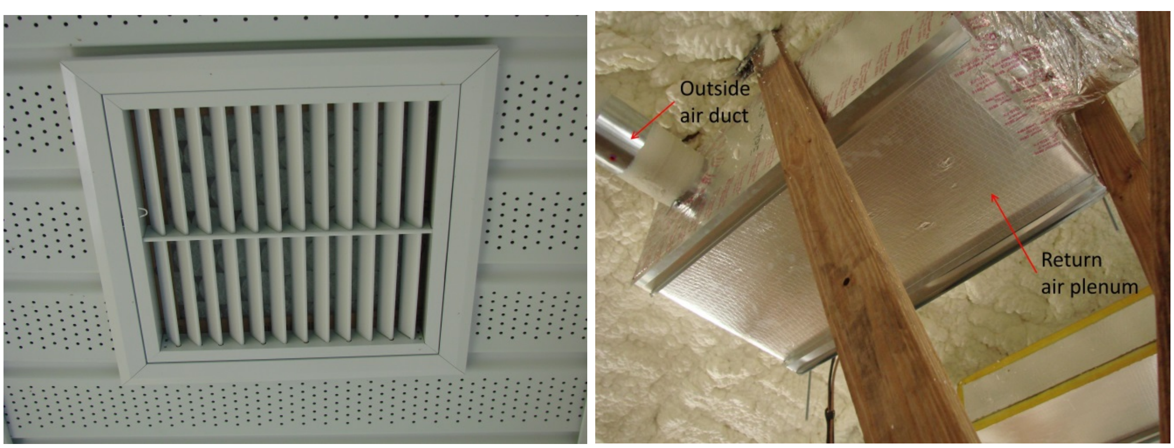

Figure 8. Outside air ventilation, filter-back intake grille (left) and duct terminating in return plenum (right)

This particular home was equipped with a 40-ft^2 direct circulation, drain-back solar water heater and a 2.5-kW PV array with micro-inverters (Figure 9). If a solar PV or solar hot water system is installed, compliance with any unmet criteria in the solar PV or solar hot water RERH checklist, respectively, is not required. Not all the homes in Hope Landing are equipped with solar technologies; however, this builder meets the renewable readiness standards for solar thermal and PV in all the other homes.

Figure 9. Solar thermal and solar PV panels

The builder does not include a dishwasher in standard construction. The refrigerator, clothes washer, lighting, exhaust fans, and ceiling fans are all ENERGY STAR-labeled products satisfying Mandatory Requirement 5.

MCHFH's home energy rater, ESC, completed certification of compliance with ENERGY STAR for Homes Version 3.1, CH Mandatory Requirement 1. The CH label is shown in Figure 10. A specifications summary for the MCHFH CH is provided in Table 2.

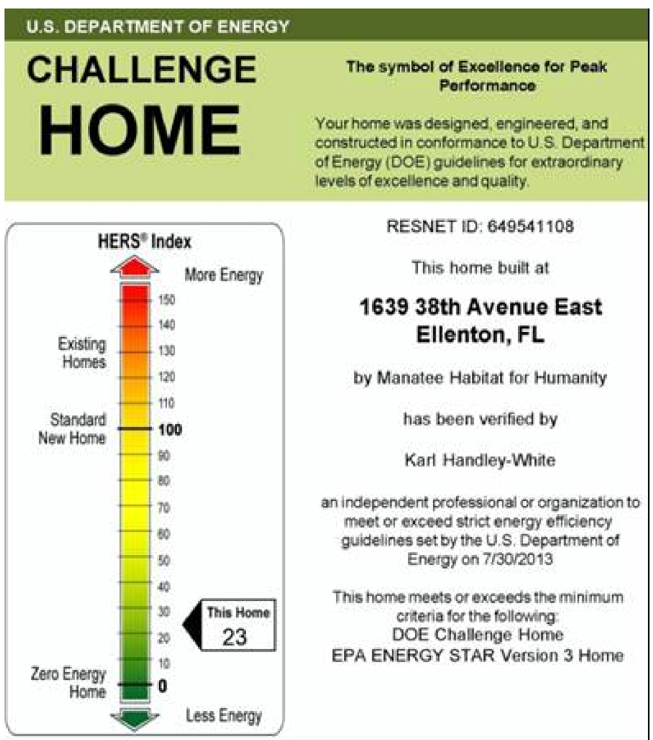

Figure 10. MCHFH's CH certificate

Table 2. MCHFH Key Energy Efficiency Measures

Components and Parameters	Description	Related Mandatory CH Requirements
HERS Index Score	CH target 60 (must be met without PV) Actual 53 without PV Actual 23 with PV	Satisfies CH target HERS Index requirement
Design	1148 ft^2, 3 bedroom, 2 bath duplex	No house size penalty
ENERGY STAR for Homes	Certification under the ENERGY STAR for Homes Standard by a RESNET-certified home energy rater	CH Requirement 1 and portions of Requirement 6, Indoor airPLUS
Envelope		
Windows	Double-pane, low-e, vinyl-frame windows U-value = 0.32, SHGC = 0.28*	CH Requirement 2, Fenestration; also improves HERS Index
Whole House Airtightness	Tightly sealed house ACH50 = 1.02	Improves HERS Index
Foundation	Slab-on-grade R-0	CH Requirement 2, Insulation
Wall Type and Insulation	R-23 ICF blocks; R-11 partition wall between duplex dwellings	
Attic Type and Insulation	Unvented attic with R-21 open cell, spray-foam insulation adhered to underside of roof deck	
Roof Finish	Galvalum metal roof	Improves HERS Index
Equipment, Appliances, and Lighting		
Mechanical Equipment	SEER 16 heating season performance factor 10 mini-split heat pump with central air handler unit and compact duct system	Improves HERS Index
Air Distribution System Materials	R-6 flex ducts sealed with water based mastic and fiberglass mesh	
Air Distribution System Airtightness	$CFM25_{,total}$ = 90 cfm ($Q_{n,\,total}$ = 0.08) $CFM25_{,out}$ = 13.5 cfm ($Q_{n,\,out}$ = 0.01)	ENERGY STAR requirement; improves HERS Index
Air Distribution System Location	Mini-split air handler and a compact duct system in unvented attic	CH Requirement 3, Interior Duct System
Lighting and Appliances	100% ENERGY STAR CFLs, ceiling fans, refrigerator, and clothes washer. Dishwasher not provided.	CH Requirement 5, Lights and Appliances; also improves HERS Index
Renewable Energy		
Water Heating	40-ft^2 collector, 10-gal drain back tank over an 80-gal electric water heater for storage and backup	CH Requirement 7, Renewable Ready
PV	2.5-kW PV system	CH Requirement 7, Renewable Ready

*CH Exemption granted by DOE for this CH
Note: ACH, air changes per hour; SEER, seasonal energy efficiency ratio; CFL, compact fluorescent lamp; CFM25, cubic feet per minute at 25 ACH

2.2 MCHFH Challenge Home Economics

Energy use and cost data are available from two modeling software programs, EnergyGauge USA (used to determine CH compliance), and Building Energy Optimization (BEopt) 2.1, a software used by the Building America program for optimization. Modeling results are shown in Table 3. Cost-effectiveness calculations are provided in Table 4.

Table 3. MCHFH's CH Projected Costs and Savings Results From EnergyGauge USA and BEopt 2.1 Using $0.12/kWh

		CH Renewable Ready (No Solar)		CH With Solar (PV and Water Heater)	
		EnergyGauge USA	**BEopt 2.1**	**EnergyGauge USA**	**BEopt 2.1**
Annual Source Energy	HERS Index Score	66*		23	
	Energy use (MMBtu)	96.6	94.2	34.0	40.4
	Energy use savings over BAB2010 (%)	N/A	30.9%	N/A	70.4%
	Energy use savings over comparable Florida code minimum house (MMBtu)	28.2	22.8	90.8	76.6
	Percent source energy savings over Florida code	22.6%	19.5%	72.7%	65.5%
Annual Site Energy	Energy costs ($0.12/kWh)	$1010	$985	$356	$423
	Energy cost savings over comparable Florida code minimum house ($)	$295	$239	$522	$378
	Projected PV production annual revenue	NA	NA	$427	$423
	Combined annual cost savings over code	$295	$239	$949	$801

*The HERS Index score of 53 reported earlier in the report includes the solar water heater, which is allowed whereas PV is not, when assessing compliance with the CH Target HERS Index.
Note: BAB2010, Building America Benchmark, revised 2010, refers to a calculation procedure with standardized reference characteristics used to assess all Building America projects (Hendron and Engebrecht 2010).

Table 4. MCHFH's CH Projected First Year Cash Flow Calculations From EnergyGauge USA and BEopt 2.1 Using $0.12/kWh

		Compared to Florida Energy Code:					
		CH Renewable Ready		CH With Solar (PV + Hot Water) No Incentives		CH With Solar (PV + Hot Water) With Incentives	
Incremental First Cost Over Florida Code Minimum House		$7,774		$17,008		$17,008	
FPL Utility Renewable Energy Rebates		NA		NA		$9,234	
Adjusted First Cost Over Florida Code Minimum House		$7,774		$17,008		$7,774	
Modeling Software		EnergyGauge USA	BEopt 2.1	EnergyGauge USA	BEopt 2.1	EnergyGauge USA	BEopt 2.1
MCHFH Mortgage Terms (0% - 30 Years)	Incremental Annual Mortgage Cost	$259	$259	$567	$567	$259	$259
	Annual Energy Cost Savings	$295	$239	$949	$801	$949	$801
	Projected First Year Cash Flow	$36	–$20	$382	$234	$690	$542
Market Rate Mortgage Terms (7% 30 Years)	Incremental Annual Mortgage Cost	$626	$626	$1,371	$1,371	Utility incentive available for low income housing only	
	Annual Energy Cost Savings	$295	$239	$949	$801		
	Projected First Year Cash Flow	–$331	–$387	–$422	–$570		

Note: FPL, Florida Power and Light

MCHFH's CH is projected to save $949 ($801 in BEopt) in annual energy costs at $0.12/kWh, compared to the same home configured to meet Florida code. This includes a projected PV output of $427 ($423 in BEopt) per year. The solar hot water system and small PV array added $9,233 to the house's construction costs. MCHFH participated in an FPL rebate program (FPL undated) to install a solar water heating system. FPL reimbursed MCHFH for the full cost ($4,151). MCHFH also installed a 2.5-kW PV system, garnering a further FPL rebate of $2/installed Watt for a total of $5,082 through FPL's Residential Photovoltaic Program, which covered the total cost of the PV installation.

The non-solar upgrades beyond code were calculated to add $7,774. MCHFH reports this is about 8% of total cost per unit. When combined with the $9,234 renewable costs, this totals $17,008. These costs are outlined in detail in Appendix C.

2.3 MCHFH Challenge Home Awards, Recognition, and Advocacy

MCHFH's CH was entered in DOE's Housing Innovation Award, winning an award in the "Affordable Builders" category (Figure 11). The CH was entered in the 2013 Manatee-Sarasota Homebuilders Association Parade of Homes, providing a community outreach opportunity to visitors. MCHFH has received numerous awards for the Hope Landing development (Figure 12). It was named "Best in Category" in the Multi-Family, Four or Less Units category over many developments in higher end neighborhoods. Further accolades were garnered at the Southeast Building Conference where MCHFH won two prestigious Aurora Awards in 2012, one in the Environmental Design category for "Best Energy Efficient Home," and a second in the Affordable Housing Design category. The home was certified LEED Platinum. The press coverage provided another opportunity to spotlight the benefits of high performance construction for all housing—not just affordable housing.

Figure 11. Executive Director Diana Shoemaker and Construction Director Bruce Winter with their Housing Innovation Award

(Used with permission of Diana Shoemaker and Bruce Winter)

Figure 12. Additional awards won by MCHFH's CH

In addition to incorporating high performance, sustainable building practices in homes it builds, MCHFH advocates the concept to the community. MCHFH organized and issued an open invitation to a free community discussion on November 13, 2013 to promote construction of affordable and sustainable buildings. Discussion included programs such as CH that catalyze change in the homebuilding industry. The event featured a moderated panel discussion with a question and answer period after the discussion. The moderator was Scott Dennis from the local ABC TV News. Panel members were Janet McIlvaine of BA-PIRC; Dennis Stroer representing Calcs-Plus, a ratings service that provides Habitat for Humanity (HFH) with HERS Ratings on a volunteer basis; Carlos Ugarte of Ugarte and Associates, the architects for the CH; Bruce Winter, Construction Director of MCHFH; and Thomas Harriman of Harriman Inc., provider of solar hot water and PV systems for the CH (Figure 13). The event was well attended and sparked a lively discussion and many questions.

Figure 13. Free green building roundtable organized by MCHFH included discussion of programs such as CH as a catalyst for change in the homebuilding industry.

MCHFH construction staff worked with their design team to develop a 30-minute TV program for the local educational television station discussing sustainable building and the importance of involving local building specialists when considering building and remodeling. The MCHFH website details the sustainability strategy for the Hope Landing development (Figure 14).

Figure 14. MCHFH website features a "Green Build" section that describes key elements of the Hope Landing construction strategy.

3 Southeast Volusia County Habitat for Humanity

SEVHFH has a long-standing relationship with Building America. SEVHFH originally partnered with Building America as part of the Building America Industrialized Housing Partnership in 2009. Since then SEVHFH has consistently built houses that meet or exceed ENERGY STAR criteria, including the latest ENERGY STAR standard in Florida, Version 3.1. SEVHFH was also an early adopter of the Builders Challenge. With this history, it was a natural step for SEVHFH to build a CH.

In contrast to the MCHFH methods, SEVHFH's standard practice embraces typical central Florida building techniques, with an emphasis on volunteer friendliness and readily available products and labor. MCHFH's slab-on-grade, single-family homes (Figure 15) have wood-frame walls and a vented attic with blown-in insulation. SEVHFH's CH did not replace any of these "conventional" building materials. These simple yet efficient homes are sterling examples of affordable housing built affordably, while being affordable to live in.

Figure 15. SEVHFH's single-family detached, wood frame CH

3.1 SEVHFH Meeting Challenge Home Mandatory Requirements

SEVHFH achieves its ENERGY STAR and CH status by deploying a package of proven, cost-effective efficiency improvements developed and implemented over time. Table 5 summarizes the specifications for the SEVHFH CH.

Table 5. SEVHFH Key Energy Efficiency Measures

Components and Parameters	Description	Related Mandatory CH Requirements
HERS Index Score	49	Satisfies CH target HERS Index of 59
Design	1250-ft^2, 3-bedroom, 2-bath, single-family home	No house size penalty
ENERGY STAR for Homes	Certification under the ENERGY STAR for Homes Standard by a RESNET-certified home energy rater	CH Requirement 1 and portions of Requirement 6, Indoor airPLUS
	Envelope	
Windows	ENERGY STAR-labeled double-pane, low-e, vinyl-frame windows; U-value = 0.33, SHGC = 0.18	CH Requirement 2, Fenestration
Whole House Airtightness	Well sealed house; ACH50 = 4.00	Improves HERS Index
Foundation	Slab-on-grade R-0	CH Requirement 2, Insulation
Wall Type and Insulation	R-13 frame walls with R-3 exterior sheathing	
Attic Type and Insulation	Raised heel truss, vented attic with R-38 blown-in attic insulation	
Roof Finish and Deck	Light color shingle roof with radiant barrier backed roof deck	Improves HERS Index
	Equipment, Appliances, and Lighting	
Mechanical Equipment	SEER 15/heating season performance factor 8 heat pump	Improves HERS Index
Air Distribution System Materials	R-4.3 duct board sealed with water based mastic and fiberglass mesh	Improves HERS Index
Air Distribution System Airtightness	$CFM25_{,total}$ = 39 cfm ($Q_{n,total}$ = 0.03) $CFM25_{,out}$ = 0 cfm ($Q_{n,\ out}$ = 0.0)	Improves HERS Index
Air Distribution System Location	Ducts in a fur-up chase created with modified truss design; air hander closet in conditioned space	CH Requirement 3, Interior Duct System
Lighting and Appliances	100% ENERGY STAR CFLs, ceiling fans, refrigerator, dishwasher, and clothes washer	CH Requirement 5, Lights and Appliances
	Renewable Energy	
Water Heating	40 ft^2/80-gal open loop solar water heater	CH Requirement 7, Renewable Ready
PV	Renewable ready	CH Requirement 7, Renewable Ready

This CH provides an excellent model for any central Florida builder because the CH Target HERS Index is achieved by combining a package of envelope and equipment specifications that are moderately better than typical regional practices with the addition of a solar water heater that takes advantage of utility incentives. A similar path could be used by many central Florida builders to achieve the target CH HERS Index without major changes in structural systems, components, or equipment. Although house size and characteristics drive the target HERS Index, researchers have found that targets generally fall in the mid to low-50s working for a variety of home sizes and types. A typical code compliant home in Florida scores in the low 90s to upper 80s on the HERS Index. The gap of 30–40 in the HERS Index is diminished by many of the mandatory CH requirements (e.g., ENERGY STAR windows) so that after meeting those only a few additional improvements may be needed.

The Target HERS Index for the SEVHFH house was 59; the final achieved HERS Index was 49, far exceeding the requirement (Figure 16).

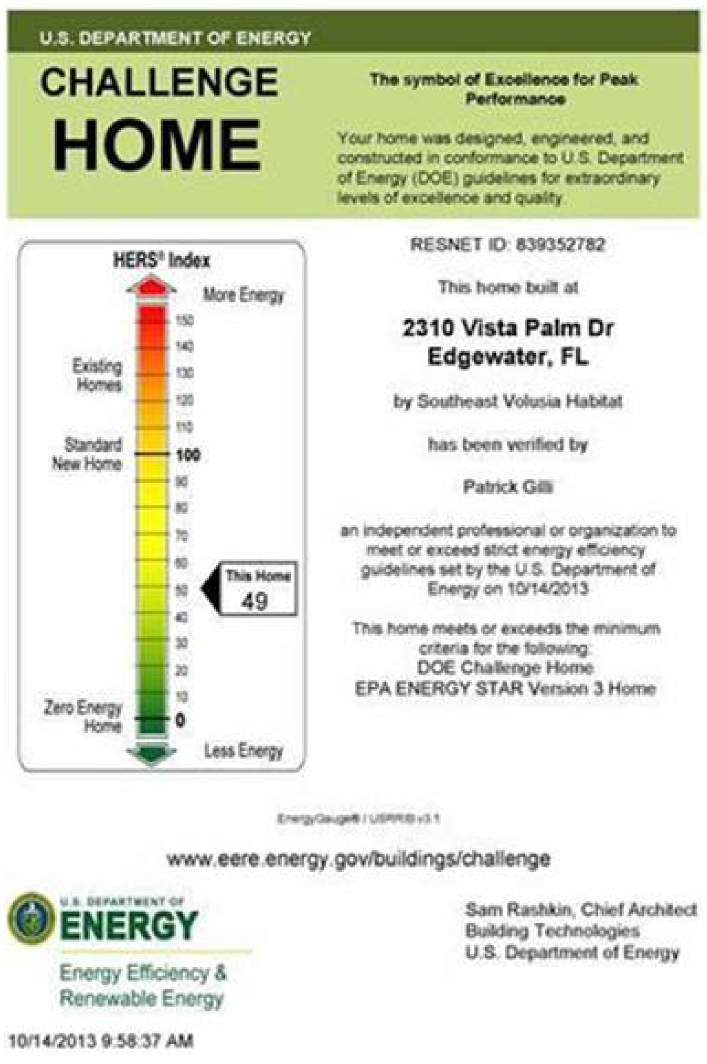

Figure 16. SEVHFH CH certificate

The conventional 2 × 4 walls have RESNET Grade 1 insulation (required by ENERGY STAR for Homes) with an added layer of R-3 rigid insulation over the exterior house wrap. The attic insulation of R-38 is becoming a regional standard. To meet the mandatory envelope insulation criterion (Requirement 2), SEVHFH used the U-factors in Table 402.1.3 of IECC 2012. The insulation levels of fenestration, ceilings, walls, floors, and slabs can be traded off using the UA approach under both the prescriptive and the performance paths of the CH program. The CH compliance software used by the rater and Building America researchers automatically evaluates whether or not a house meets IECC 2012 insulation levels, including using the UA alternative path. This, combined with ENERGY STAR fenestration, satisfies Requirement 2.

ENERGY STAR appliances (Figure 17), lighting, and fans throughout the house meet Requirement 5.

Figure 17. ENERGY STAR appliances, ceiling fans, and bath fans

SEVHFH standard construction included many of the Indoor airPLUS requirements that are not typical of regional builders. For example, Indoor airPLUS item 4.3 states "No air-handling equipment or duct work installed in garage AND continuous air barrier in adjacent assemblies." Compliance with the garage portion is easy because SEVHFH homes don't have garages. The assemblies adjacent to the air handler closet are sheet rocked and sealed thoroughly (Figure 18).

Figure 18. Construction of air handler closet

SEVHFH participates in FPL's Residential Solar Water Heating (Low Income New Construction) Program when it is available, which was the case for this CH. SEVHFH received an FPL rebate of $4,700 for the solar hot water system installed on its CH (Figure 19), which covered the cost for this item.

Figure 19. 40-ft^2 solar water heater installed on the south-facing roof (left) with an 80-gal tank in the utility room (right)

Inclusion of solar water heating exempts this home from any unmet criteria in the Solar Water Heating RERH standard. In other homes, when this incentive is not available, a hybrid heat pump water heater is installed. Occasionally, the affiliate builds in neighborhoods with natural gas and installs an instantaneous gas water heater. Both of these improved hot water systems would allow SEVHFH's homes to qualify for the CH program as long as they are ENERGY STAR models. For builders installing ENERGY STAR-labeled water heaters, the CH standard exempts builders from several specifications related to providing infrastructure for future solar water heating systems on the EPA Renewable Ready Solar Thermal Checklist.

To comply with the RERH checklists SEVHFH installed a conduit running from the power distribution panel to a box mounted on the south wall to facilitate running wire from exterior inverters to the panel. The panel has several blank spaces to accommodate a future circuit breaker for the PV input.

Two of the main things that distinguish the SEVHFH house from market rate production homes are the small footprint and lack of garage. Because of the small, compact floor plan (Figure 20), no changes were needed to pass the hot water distribution test, which limits standby hot losses at the fixture farthest from the water heater to 0.6 gallons. Because there is no garage, several items on the Indoor airPLUS checklist do not apply.

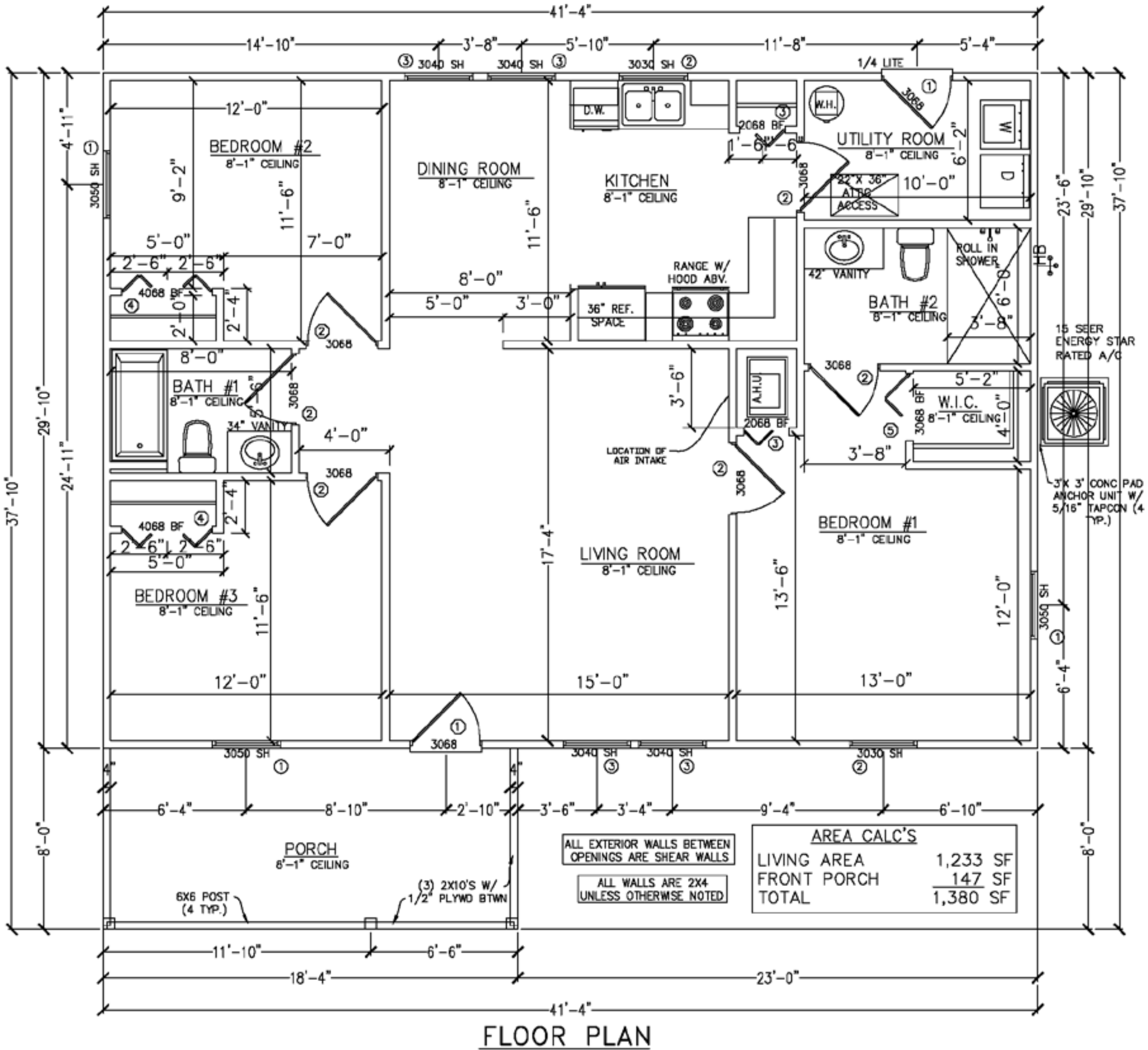

Figure 20. SEVHFH CH floor plan

The main change needed for CH compliance by SEVHFH was CH Mandatory Requirement 3, Interior Ducts. A foamed sealed attic was rejected because of the higher first cost involved. SEVHFH also rejected the idea of a fur-down approach, which creates a duct chase below the ceiling plane, because of code-mandated ceiling height requirements.

Code requires minimum ceiling height of 7 ft, 0 in., leaving slightly less than 1 ft, 0 in. to house the duct system once the dimensions for an air barrier and structural members are subtracted. Although this had been achieved on a production basis, it is extremely challenging to ensure that the finished ceiling height does not drop below 7 ft, 0 in. (McIlvaine et al. revised 2002; McIlvaine and Beal 2002).

Instead, SEVHFH's CH used an innovative interior duct system design to comply with CH Requirement 3. SEVHFH Construction Director, Ray Allnutt, worked very closely with the mechanical contractor, Servair Heating and Air Conditioning (Edgewater, Florida), to envision, design, and execute a creative fur-up or raised ceiling interior duct system strategy. This innovative approach included a modified truss design to accommodate a fur-up duct chase above the ceiling plane (Figure 21). More information about interior duct system design in general is available in the Building America Measure Guideline for interior ducts (Beal et al. 2011). The approach, developed by Allnutt, represents a significant improvement in technical execution.

Figure 21. SEVHFH duct chase created using a modified truss design, seen here from the attic side

The technical challenges of building a duct chase, whether fur-down or fur-up, are:

- Establishing a continuous, sealed air barrier between the chase and the surrounding unconditioned spaces, including building cavities
- Adequately insulating the chase.

Conventionally, drywall or other sheet goods are used to create the air barrier. Air sealing details must address all joints, edges, and penetrations in the air barrier. Where the chase extends into rooms through interior walls, the air sealing must isolate the chase from the wall cavities to remain truly in conditioned space.

Regarding insulation, the tops of fur-down chases are aligned with the ceiling plane; hence, attic insulation forms the thermal barrier for fur-down chases. Alternatively, fur-up chases rise above the ceiling plane, requiring a different insulation strategy. Insulating the top and vertical sides of the chase is similar to insulating tray ceilings and knee walls. Typically these are all built with 2 × 4s. With only a 3.5-in.cavity depth to work with, it is very challenging to achieve insulation levels on the sides and top of a fur-up duct chase that are similar to the rest of the attic.

Figure 22 shows the duct system layout. In this home, the framing for the chase is formed by truss members (2 × 4s) in a modified truss design that creates the structure for a chase running through the center of the house (Figure 23). The truss modification is offset from the central king post to reduce the structural impact of the modification. Accurate sizing of the chase and the ducts using exact dimensions is critical to avoiding issues with fitting the ducts into the chase.

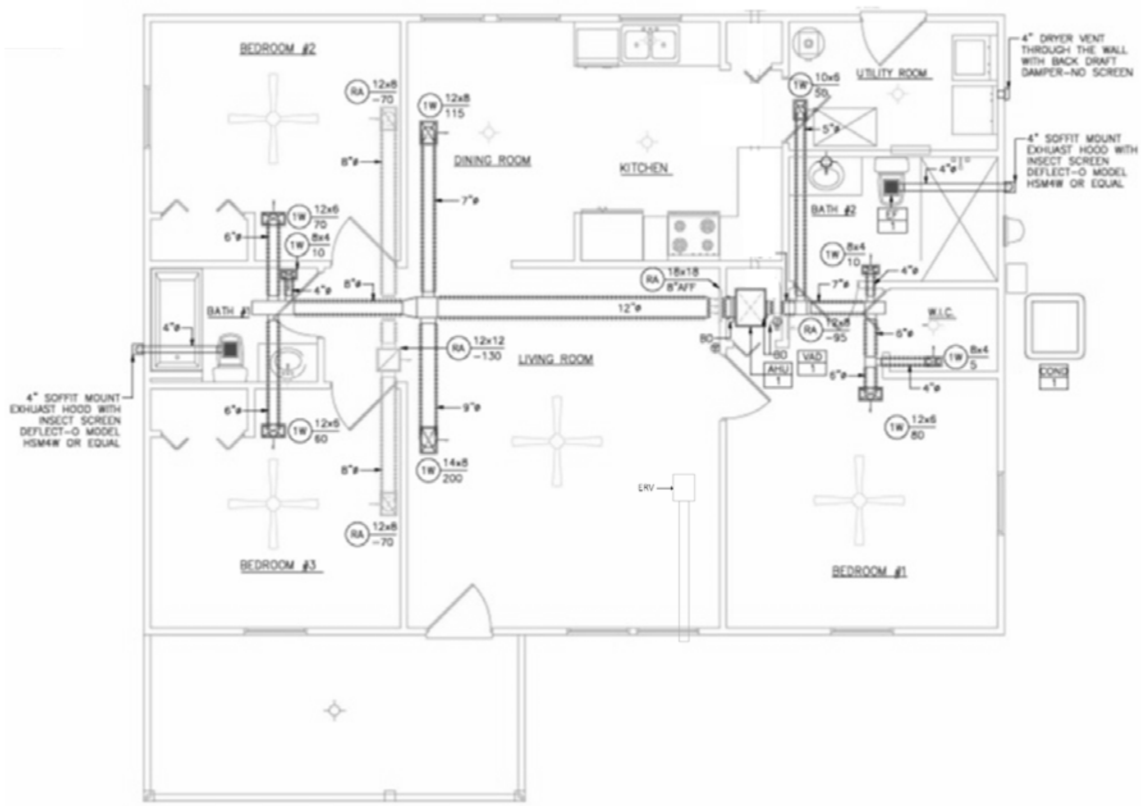

Figure 22. SEVHFH layout for interior duct system

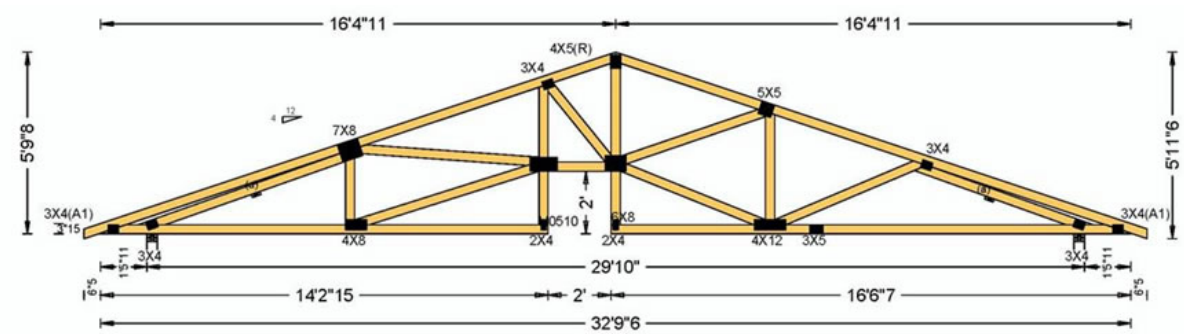

Figure 23. Truss modification design to create interior duct chase

SEVHFH's decision to build a fur-up chase was influenced by the availability of free materials through HFHI's "Gifts in Kind" Program, which partners with Dow Corning and others. Dow donates Dow Styrofoam, a rigid foam insulation product commonly referred to as *blue board*, to any Habitat affiliate that requests it. The availability of this product for free significantly reduced the cost for the affiliate's interior duct system while simultaneously tackling the insulation challenge. The economics of this approach would obviously be different for typical market costs; however, compared to constructing an unvented attic, the cost may be favorable.

Prior to using the product to form an interior duct chase, SEVHFH was already taking advantage of this partnership by using ½-in. Dow blue board on the exteriors of its houses. SEVHFH installs it over the house wrap and under the fiber cement siding (Figure 24) to meet Requirement 4.4.1 (Reduced Thermal Bridging) on the ENERGY STAR Thermal Enclosure System Rater Checklist. The blue board serves as the primary drainage plane, but the underlying house wrap forms a redundant drainage plane and an exterior air barrier.

Figure 24. SEVHFH exterior wall primary drainage plane formed by donated Dow Styrofoam rigid insulation

To meet CH Requirement 2, Envelope Insulation, SEVHFH needed to achieve at least R-30 insulation with all chase surfaces. Blue board provides insulation of R-5 per inch. SEVHFH requested 2-in. thick Styrofoam, Square Edge Insulation from Dow to form the air barrier for its fur-up chase. SEVHFH achieved an R-33 insulation level on the sides and the top of its fur-up duct chase by using a double layer of this R-10 product (Figure 25, left), resulting in R-20 of Styrofoam, to form the duct chase air barrier. Then the top and sides of the chase were wrapped in R-13 fiberglass batts (Figure 25, right), which fit into the bays formed by the modified truss. With this strategy, one of the major failure paths for fur-up chases, poor insulation, was avoided. The chase construction strategy is outlined in Figure 26.

Figure 25. SEVHFH fur-up duct chase with a double layer of 2-in. blue board insulation (R-20 total) (left) and R-13 attic-side fiberglass batt insulation (right)

Figure 26. Chase construction overview

The first layer of blue board is installed to the inside of the structural cavity formed by the modified truss cavity, and a ledger board installed to the inside of that will provide structure for the bottom of the chase (top, left). Next, All blue board joints are sealed with a product specifically for foam (top, right). Then the second foam layer is installed (bottom, left). Joints are staggered to further reduce air transport through the chase (bottom, right).

The first layer of blue board was installed to the inside of the chase structural cavity formed by modifying the truss. The edges and seams of the first layer of blue board were sealed with a construction adhesive specifically designed for foam. The seams in the second layer of blue board were staggered (with respect to the first layer, Figure 27) to further impede air exchange between the chase and the surrounding attic space and sealed in a similar manner. Through this careful attention to detail, the major challenge of creating a continuous sealed air barrier was conquered. A ledger board to provide an attachment surface for the bottom of the chase was installed to the inside of the first foam layer. Locating it to the inside of the air barrier was an important detail that eliminated leakage paths around the structural element. Run out chases to serve rooms throughout the house branched off the main chase. Dead wood installed between trusses provided attachment surfaces for the foam top and sides (Figure 28).

Figure 27. Joints of the first and second layers of blue board were staggered to further impede air flow.

Figure 28. Runout chases seen from underneath (left) and the attic (right). Note dead wood framing between trusses that provides attachment surfaces for the foam air barrier.

Careful detailing proved effective as evidenced in the duct leakage test, which showed no leakage to the surrounding attic. This interior duct chase was featured in a Building America case study (DOE 2013b) and was used to generate Building America Solution Center content.

3.2 SEVHFH Challenge Home Economics

The cost for the interior duct system was approximately $1,887; however, this includes the cost of the Dow "Gifts in Kind" of $612 for 2-in. blue board to construct the chase. The donation reduced the realized incremental cost (above the builders typical duct system cost) to $1275, including $400 for the modified truss package (engineering and materials), $575 for alternative duct system construction (duct board instead of mainly flex duct), and $300 additional labor to build the chase.

Modeling software estimates energy savings from moving SEVHFH's typical, well-sealed duct system from the attic to the interior chase are $11 annually (at $0.12/kWh, results from

EnergyGauge USA). This small savings is the result of SEVHFH's standard construction, which typically includes a very tight duct system (data from previous projects show typical $Q_{n, out}$ = 0.017), with only the R-6 supply ductwork in the attic. The air handler and central return plenum are housed in an interior closet. Furthermore, meeting the ENERGY STAR for Homes and CH requirements diminish heating, ventilation, and air conditioning (HVAC) loads. With shorter runtimes, the heat exchange and leakage of the duct system become less important than in code-minimum homes. The very compact nature of small affordable housing additionally reduces duct losses compared to larger homes, which may see larger benefits.

Energy use and energy cost data are available from two modeling software programs: EnergyGauge USA (used to determine CH compliance) and BEopt (a software program used by Building America program). SEVHFH's CH is projected to save $509 ($365 in BEopt) in annual energy costs at $0.12/kWh, compared to the same home configured to meet Florida code (Table 6). This includes $161 ($162 in BEopt) of annual energy savings generated by the solar water heater. The solar water heater costs $4,700; however, SEVHFH participates in FPL's Residential Solar Water Heating (Low Income New Construction) Program, which will rebate the entire cost of an approved solar water heater for affordable housing providers.

Based on cost data provided by SEVHFH and data collected in previous studies, researchers estimate the cost of SEVHFH's CH with renewable ready compliance (with a heat pump water heater) to be $4,636 compared to code-minimum specifications (Table 7). This was reduced by a $600 in-kind donation available to all HFH affiliates from Dow Corporation. The estimated annual energy cost savings of $348 produces a first year positive cash flow of $214 (BEopt results were $203 and $69, respectively) (Table 7).

Table 6. SEVHFH's CH Projected Costs and Savings Results From EnergyGauge USA and BEopt Using $0.12/kWh

		CH Renewable Ready		CH With Solar (Hot Water Only)	
		EnergyGauge USA	**BEopt 2.1**	**EnergyGauge USA**	**BEopt 2.1**
	HERS Index score	55	N/A	49	N/A
Annual Source Energy	Energy use (MMBtu)	89.61	112.4	74.23	96.90
	Energy use savings over BAB2010 (%)	N/A	17.3%	N/A	28.7%
	Energy use savings over comparable Florida code minimum house (MMBtu)	33.21	19.4	48.58	34.9
	Percent source energy savings over Florida code	27%	14.7%	39.6%	26.5%
Annual Site Energy	Energy costs ($0.12/kWh)	$937	$1176	$776	$1014
	Energy cost savings over comparable Florida code-minimum house ($)	$348	$203	$509	$365
	Portion of savings from solar water heating	N/A	N/A	$161	$162

Table 7. SEVHFH's CH Projected First Year Cash Flow Calculations From EnergyGauge USA and BEopt 2.1 Using $0.12/kWh

		Compared to Florida Energy Code:					
		CH Renewable Ready (With Heat Pump Water Heater)		CH With Solar (Hot Water Only) No Incentives		CH With Solar (Hot Water Only) With Incentives	
Incremental First Cost		$4636		$8736		$8736	
FPL Utility Renewable Energy Rebates		NA		NA		$4,700	
In-Kind Donation		$612		$612		$612	
Adjusted First Cost		$4024		$8124		$3424	
Modeling Software		EnergyGauge USA	BEopt 2.1	EnergyGauge USA	BEopt 2.1	EnergyGauge USA	BEopt 2.1
0% Interest, 30 Years MCHFH Mortgage	Incremental annual mortgage cost	$134	$134	$271	$271	$114	$114
	Annual energy cost savings	$348	$203	$509	$365	$509	$365
	Projected first year cash flow	$214	$69	$238	$94	$395	$251
7% Interest, 30 Years Market Rate Mortgage	Incremental annual mortgage cost	$374	$374	$704	$704	Utility incentive available for low-income housing only	
	Annual energy cost savings	$348	$203	$509	$365		
	Projected first year cash flow	–$26	–$171	–$195	–$339		

An additional $4,700 cost was incurred for a solar water heater, which was partially offset by the cost avoided for the heat pump water heater. Adding the solar water heater increases annual mortgage burden to $271, but also increases annual savings to $509. This produces a slightly higher projected first year cash flow of $238 ($94 in BEopt). SEVHFH also received a utility incentive (as did MCHFH) for the full cost of the solar water heater. No solar PV incentives were available. The utility incentive improved projected first year cash flow about 65% to $395 ($251 in BEopt).

The in-kind donation was removed from the incremental cost for the market rate mortgage (terms of 7% over 30 years) calculations, which resulted in projected first year cash flow that is negative for both the renewable ready and the solar water heating scenarios. The utility involved offers these solar incentives to affordable housing builders only.

The results shown for market rate mortgage terms are provided for reference. They do not necessarily reflect the economics a market-rate builder could achieve, because the improvement packages were developed for a specific builder’s resources. In this case, it included free materials and utility incentives that are not available to market-rate builders. However, those builders may benefit from economies of scale or in-house labor capabilities that would implicate a different improvement package. A preliminary analysis, conducted with a certified home energy rater, should be used to evaluate the projected energy savings and cost effectiveness of various improvements that suit a particular builder.

4 Research Questions and Answers

For each builder partner, researchers pursued the following research questions:

4.1 What Are the Major Technical Gaps and Barriers Associated With Achieving Challenge Homes in the Hot-Humid Region?

Based on the CH efforts reported here as well as discussions with other BA-PIRC high performance builders, researchers found two main barriers:

- Balancing ventilation and indoor air quality metrics such as relative humidity
- Interior duct system construction.

4.1.1 Ventilation Barriers

ENERGY STAR for New Homes (CH Requirement 1) requires mechanical ventilation levels per calculation methods in the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.2. For the homes in this study, that corresponds to approximately 50 cfm of constant outside air exchange. The standard does not specify how the exchange is to be achieved. Builders expressed concern that the higher ventilation rates will create unanticipated problems that are potentially difficult to resolve and may lead to warranty claims. One installed an energy recovery ventilator for a balanced ventilation approach, which meets the required ventilation rate, but these are known to have poor latent heat removal capacity in the swing seasons when the HVAC equipment provides little dehumidification but outdoor relative humidity can still be high. The other is using a fan cycler in the air handler with an outside air duct into the return plenum. The thermostat also has a relative humidity setting capability. This supply-only approach is preferred for the hot-humid climate. Although fairly simple to install, commissioning this type of system to ensure outside air flow meets design intent requires more accurate airflow measurement devices than HVAC contractors typically have on hand.

Other BA-PIRC existing partners have been very resistant to implementing ASHRAE Standard 62.2 ventilation rates, feeling that the required amount of outdoor air may threaten the building durability because of the excessive moisture content of outside air. Supplemental dehumidification is viewed by these partners as the only practical solution to ensure there are no problems. However, it is viewed as an additional expense, a noise nuisance that may lead to the occupants disabling it, a maintenance burden, and an additional electricity load. Based on feedback from a limited sample of approximately one dozen moderate- to high performance builders, it appears that there is a lack of confidence in ventilation and dehumidification equipment currently available for single-family housing in the hot-humid climate.

Many stakeholders in the home building industry are considering these challenges. The research community has not generated, or perhaps not delivered to builders, a body of proven indoor air quality benefits from ASHRAE Standard 62.2 ventilation rates in the hot-humid climate. Research documenting the benefits and drawbacks of 62.2 levels of ventilation as well as guidance on climate-appropriate system design appear crucial to increasing uptake of the CH program (and ENERGY STAR) in Florida. With climate specific research proving the benefits of higher ventilation rates, builders will be in a position to integrate that into their high performance marketing strategy. The Florida Solar Energy Center (FSEC) collaborated with researchers of the Building Science Corporation and IBACOS on a white paper that discusses these issues more thoroughly (Martin 2014). BA-PIRC has a relevant, monitored field study in progress. Publication of preliminary results is expected in 2014.

The silver bullet for this challenge would be off-the-shelf equipment or a standardized system that is easily designed, installed, and commissioned to provide outside air that does not create adverse pressure imbalances and simultaneously ensures indoor higher humidity levels are maintained within comfort boundaries.

A potential code issue in Florida also arose. Florida building code expressly forbids outdoor air ventilation levels that exceed ASHRAE Standard 62.2, meaning any implementation that complies with ASHRAE 62.2 is very close to violating code, and may actually do so given accuracy of test equipment and fluctuations in actual flow.

4.1.2 Interior Duct Systems

Several Building America teams and other stakeholders are working toward developing inexpensive and effective ways to incorporate the CH program's interior duct requirement.

The simplest way to accomplish an interior duct system in a typical Florida slab-on-grade home is a sealed attic. SEVHFH and other BA-PIRC partners in central Florida find the lower R-value (limited by material properties) and significantly increased costs of the available foam systems unappealing. Foam costs are typically more than double per square foot per R-value. Additionally, the increased area requiring insulation when the thermal barrier is moved from the attic floor to the roof deck further increases the costs of the foamed attic approach.

On the other hand, BA-PIRC partners further south in the state, including MCHFH, have experienced condensation problems in attics with radiant barriers and R-6 flex-duct supply air systems in attics. This is related to extremely high summertime dew point temperatures. This has led to more widespread adoption of the sealed attic construction by builders in that area as well as creating some competition among applicators, lowering price.

Because slab-on-grade foundations are the norm in Florida new construction and across much of the hot-humid climate region, unvented crawlspaces are not an option for interior ducts.

The alternative to an unvented attic is to construct a duct chase separated from unconditioned spaces by an air barrier and a thermal barrier. BA-PIRC has documented solutions to the sealing details of both fur-up and fur-down methods of chase construction (McIlvaine et al. revised 2002; McIlvaine and Beal 2002), but builder resistance is still high. The reality is that either method requires forethought, insight, and careful design and execution.

Incorporating a fur-up or raised ceiling chase by using a modified truss approach can be a very complex task in typical Florida new construction, which features multiple roof lines. The inherent difficulty in creating a continuous air barrier with a fur-up duct chase generates a demand for new quality assurance procedures. The approach developed by SEVHFH bears further investigation. It has promising technical merit, but the cost effectiveness must be further evaluated before widespread application in market-rate housing.

The more conventional approach to interior ducts involves building a chase below the ceiling plane. The aesthetic pros and cons have been debated for many years. BA-PIRC partners in the Gainesville, Florida area developed an innovative approach to construction of fur-down chases that significantly reduces the labor and complexity of establishing the continuous air barrier.

4.2 Do the Partners Favor the Performance or Prescriptive Path for Challenge Home Certification?

Both partners selected the performance path of compliance with the CH program. The small size of HFH homes and the high standard practices of both builders allowed the homes to meet the target HERS Index score without resorting to the significantly increased equipment efficiencies found in the prescriptive path (e.g., SEER 18 heat pump).

BA-PIRC developed packages for several market-rate builders during the recruiting effort for this study. All homes reviewed followed the performance path because all the candidates had one or more specifications that significantly exceeded that found in the prescriptive path (e.g., ICF walls, solar water heating) and did not meet others. By pursuing the performance path, costs to meet the lacking prescriptive specifications were avoided while still meeting the HERS Index requirements of the CH program.

4.3 What Is Motivating the Partners' Interest in High Performance Housing?

The partners covered in this report are both local affiliates of HFHI, an international nonprofit affordable housing provider that sells homes at 0% interest to qualified buyers. The organization's mission is simply stated as "building decent affordable housing." To fulfill that goal, these affiliates have realized that the least expensive home to build is not the least expensive home to live in.

Additionally, there are several organizational mechanisms in place that make building to a higher performance standard a no-brainer for many HFH affiliates. First, HFH's 0% interest rate means that its buyers pay a lower annual mortgage premium than do market-rate mortgage holders for the efficiency improvements. Next, Habitat has many partners that donate energy and building science-related products to affiliates. These partnerships are found at the national and local levels. Through HFHI's national "Gifts in Kind" program, Whirlpool donates ENERGY STAR refrigerators and other appliances, and Dow donates a wide product line. At the local level, both affiliates in this study received their HERS ratings for free or at a significantly reduced cost. Many of the affiliates receive discounts or donations of subcontractor time and materials. Last, but not least, some grant programs available to affordable housing entities require either ENERGY STAR or similar construction to receive funds or provide funds to install solar on qualifying homes. Both of our partner affiliates participated in both types of grant programs, receiving monies to cover the entire costs of solar water heaters (and PV in Manatee County) and more funding to build ENERGY STAR homes through the U.S. Department of Housing and Urban Development Self-help Homeownership Opportunity Program.

4.4 What Changes Were Needed To Meet the Mandatory Requirements? For Each, Was the Change Minor, Moderate, or Major?

Both of the partners profiled in this document were building homes that exceeded the target HERS Index for ENERGY STAR 3.1, as well as meeting all mandatory ENERGY STAR requirements. Additionally, CH HERS targets were being met or exceeded. There were only a few mandatory CH requirements that were not being complied with prior to the affiliates building CHs.

MCHFH was meeting ALL CH requirements except ENERGY STAR-labeled windows. This was a minor change, involving a change to the specifications and material ordering. This level of compliance is the result of years of work by the affiliate to refine and improve its house to be not only affordable to buy, but, more importantly, affordable to live in. Perhaps the least obvious changes needed are the preparation, planning, prototyping, etc. MCHFH exemplified the process by undertaking a review of what the organization was previously doing (code minimum) and what its real goals were. This is an important step. Transitioning from code-minimum construction to very high performance levels involves major changes from design through permitting and purchasing through final inspections and occupancy. In past research similar to this CH effort, the builders, whether affordable housing or market rate, that align what they are building with their organizational missions, have a much better chance of hitting and maintaining performance targets. During this evaluation, input should be gathered from everyone who influences construction with the objective of solving problems before they happen (Thomas-Rees et al. 2013; Baechler et al. 2011).

SEVHFH was meeting all the CH requirements except the mandatory interior ducts and the solar-ready provisions. For the CH, SEVHFH took advantage of a local utility rebate initiative, FPL's Residential Solar Water Heating (Low Income New Construction) Program, which reimburses low-income, nonprofit builders for the entire costs of an approved solar hot water system. This represented a moderate change; however, the affiliate had participated in the program with several houses prior to the construction of the CH. The mandatory solar-ready PV requirement was easily met by the installation of strategically placed pieces of electrical conduit. SEVHFH's solution to the interior duct requirement was a very well thought out and implemented fur-up or raised ceiling chase system detailed in Section 3.1, above, and a case study (DOE 2013b).

Getting started with CH will be much more challenging for code-minimum builders. The Target HERS Index requirement is a good place to start. Although there is no direct correlation between HERS Index and state energy codes, typical code-compliant new homes in Florida score in the mid-80s. Much Building America research has been conducted on how to cost-effectively reach a HERS Index score in the upper 60s (Thomas-Rees et al. 2013). Likewise, working with a certified home energy rater will help any builder identify a path to satisfy CH Requirement 1, ENERGY STAR for New Homes. In addition to meeting the Target HERS Index score, ENERGY STAR certification experience is a fundamental starting point for any CH effort.

4.5 What Are the Costs Associated With Meeting the Mandatory Requirements?

Although the two builders in the study were building to specifications significantly better than code requirements when they began their CH efforts, cost-effectiveness calculations are based on a code-minimum reference to improve relevance of the study to the general homebuilding community. Both builders sell their homes to qualified buyers at 0% interest over a 30-year mortgage. Again to improve relevance, researchers calculated projected first year cash flow based on market rates of 7% for the same mortgage period.

MCHFH did a thorough cost analysis of its house versus a code-complaint frame house of the same size and orientation. The cost analysis concluded that the MCHFH's CH cost $17,008 more than an identical code-compliant home. This included $9,234 for solar hot water and PV, or the non-solar improvements beyond code resulted in a $7,774 cost increase for the CH. This cost analysis is included in Appendix C. The projected first year cash flow associated with these two packages was $36 and $382, respectively, based on EnergyGauge USA calculations. This includes revenue generated from sale of electricity back to the utility in the amount of $427 annually. MCHFH received utility incentives to cover the full cost of the solar equipment; this improved first year cash flow to $690. Under market-rate mortgage terms, projected first year cash flow is negative for both the renewable-ready and the solar-equipped scenarios. The utility incentives applied to MCHFH's CH were available for low-income housing providers only.

Based on cost data provided by SEVHFH and data collected in previous studies, researchers estimate the cost of SEVHFH's CH with renewable-ready compliance (with a heat pump water heater) to be $4,636 compared to code-minimum specifications. This was reduced by a $600 in-kind donation available to all HFH affiliates from Dow Corporation. An additional $4,700 cost was incurred for a solar water heater, which was partially offset by the cost avoided for the heat pump water heater. The projected first year cash flow associated with these two packages was $214 and $238, respectively, based on EnergyGauge USA calculations. SEVHFH also received a utility incentive for the full cost of the solar water heater. No solar PV incentives were available. The utility incentive improved projected first year cash flow to $395. The in-kind donation was removed from the incremental cost for the market rate mortgage calculations, which resulted in a projected first year cash flow that was negative for both the renewable-ready and the solar water heating scenarios. The utility incentive applied to SEVHFH's CH was available for low-income housing providers only.

5 BEopt Analysis

The CH program includes a HERS Index score requirement. Calculations related to the HERS Index were made with EnergyGauge USA because BEopt does not include a HERS Index calculation option. The HERS Index requirement necessarily drives decision-making for builders striving to achieve CH certification.

The CH program has a very specific whole-house efficiency in the form of a Target HERS Index. Although the houses are entered into BEopt 2.1, partners' decisions on what and how to build the CHs were made independently of output from BEopt. BEopt does not produce a HERS Index calculation and therefore did not aid the partners in determining if their homes were meeting the efficiency requirements of the CH program. CH requires that an approved HERS rating software be used. In this case, the partner's HERS raters and Building America researchers evaluated the partners' proposed improvement packages using EnergyGauge USA, a HERS rating software, to determine if the homes would meet the target CH HERS Index. Furthermore, some of the characteristics of the homes could not be modeled in BEopt. FSEC communicates regularly with the BEopt development team when such issues arise.

The homes' general layouts and the features that could be modeled in BEopt are entered into the Building America Field Data Repository. Costs that were known were modified for the BEopt runs. These include the costs of both partners' solar hot water systems, ceiling fans, mini-split heat pumps, duct systems, and PV systems. The BEopt output tables and graphs are included below (Tables 8–12 and Figures 29–32).

Table 8. BEopt Source Energy Use Comparison for MCHFH CH Scenarios

	MCHFH Source Energy Use (All Electric)			
	BAB2010 (MMBtu/yr)	MCHFH CH (MMBtu/yr)	CH With Code Minimum Characteristics (MMBtu/yr)	CH Renewable Ready (No Solar) (MMBtu/yr)
Miscellaneous	34.56	36.24	40.02	36.06
Vent Fan	1.5	1.5	0.25	1.5
Large Appliances	25.98	10.06	11.28	10.06
Lights	12.9	8.36	14.23	8.36
HVAC Fan/Pump	7.9	0.23	6.75	0.2
Cooling	24.6	17.17	21.08	14.81
Heating	0.81	0.19	0.42	0.29
Hot Water	28.06	6.1	22.93	22.94
Total	136.3	79.9	117	94.2
PV	0	39.4	0	0
Net (Total - PV)	136.3	40.4	117	94.2
Source Energy Savings Over BAB2010	–	95.9	19.3	42.1
Source Energy Savings % Over BAB2010	–	70.4%	14.2%	30.9%
Source Energy Savings Over Code Minimum	–	76.6	–	22.8
Source Energy Savings % Over Code Minimum	–	65.5%	–	19.5%

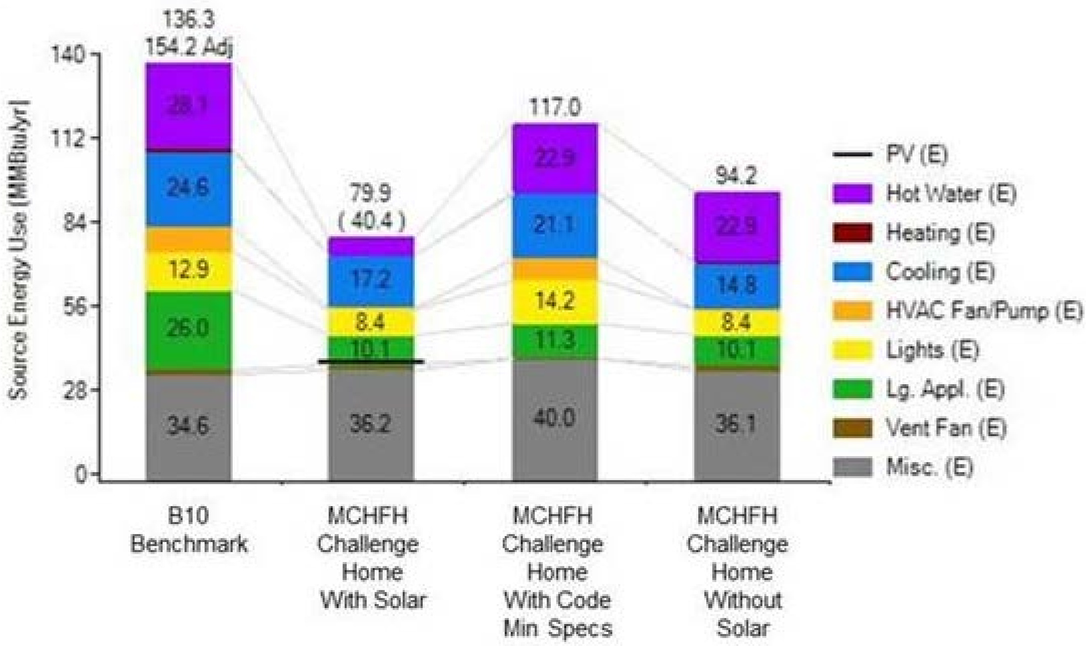

Figure 29. Source energy use by end use for MCHFH CH scenarios

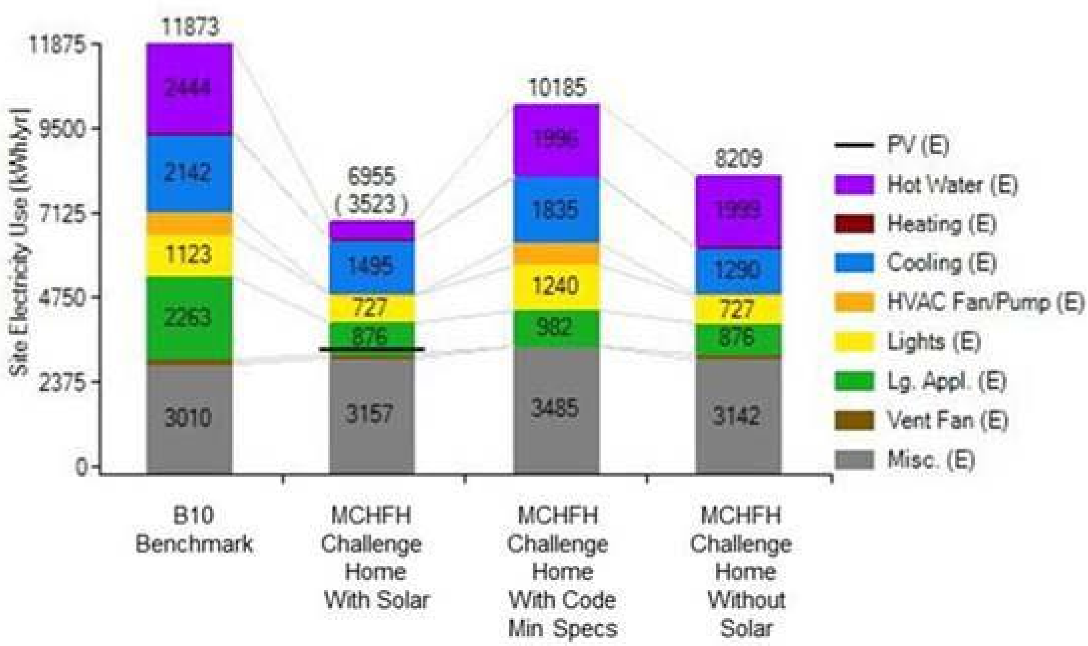

Figure 30. Site energy use by end use for MCHFH CH scenarios

Table 9. MCHFH BEopt Percent Source Energy Savings by End Use

	Source Energy Use (All Electric)		Source Energy Savings	
	BAB2010 (MMBtu/yr)	MCHFH CH (MMBtu/yr)	% of End Use (MMBtu/yr)	% of Total (MMBtu/yr)
Miscellaneous	34.56	36.24	–4.9%	–1.2%
Vent Fan	1.5	1.5	0.0%	0.0%
Large Appliances	25.98	10.06	61.3%	11.7%
Lights	12.9	8.36	35.2%	3.3%
HVAC Fan/Pump	7.9	0.23	97.1%	5.6%
Cooling	24.6	17.17	30.2%	5.5%
Heating	0.81	0.19	76.5%	0.5%
Hot Water	28.06	6.1	78.3%	16.1%
Total	136.3	79.9	41.4%	41.4%
PV	0	39.4		
Net (Total – PV)	136.3	40.4	70.4%	70.4%

Table 10. BEopt Source Energy Use Comparison for SEVHFH CH Scenarios

	SEVHFH BEopt Source Energy Use (All Electric)			
	BAB2010 (MMBtu/yr)	SEVHFH CH (MMBtu/yr)	CH With Code-Minimum Characteristics (MMBtu/yr)	CH Renewable Ready (No Solar) (MMBtu/yr)
Miscellaneous	34.98	36.28	39.55	36.1
Vent Fan	1.53	4.51	0.25	4.51
Large Appliances	25.98	20.16	24.82	20.16
Lights	13.54	9.94	14.94	9.94
HVAC Fan/Pump	7.1	5.03	5.92	4.31
Cooling	21.47	13.75	18.17	11.74
Heating	2	0.3	0.91	0.44
Hot Water	29.31	6.91	27.21	25.2
Total	135.9	96.9	131.8	112.4
Source Energy Savings Over B10 Benchmark	–	39.0	4.1	23.5
Source Energy Savings % Over B10 Benchmark	–	28.7%	3.0%	17.3%
Source Energy Savings Over Code Minimum	–	34.9	–	19.4
Source Energy Savings % Over Code Minimum	–	26.5%	–	14.7%

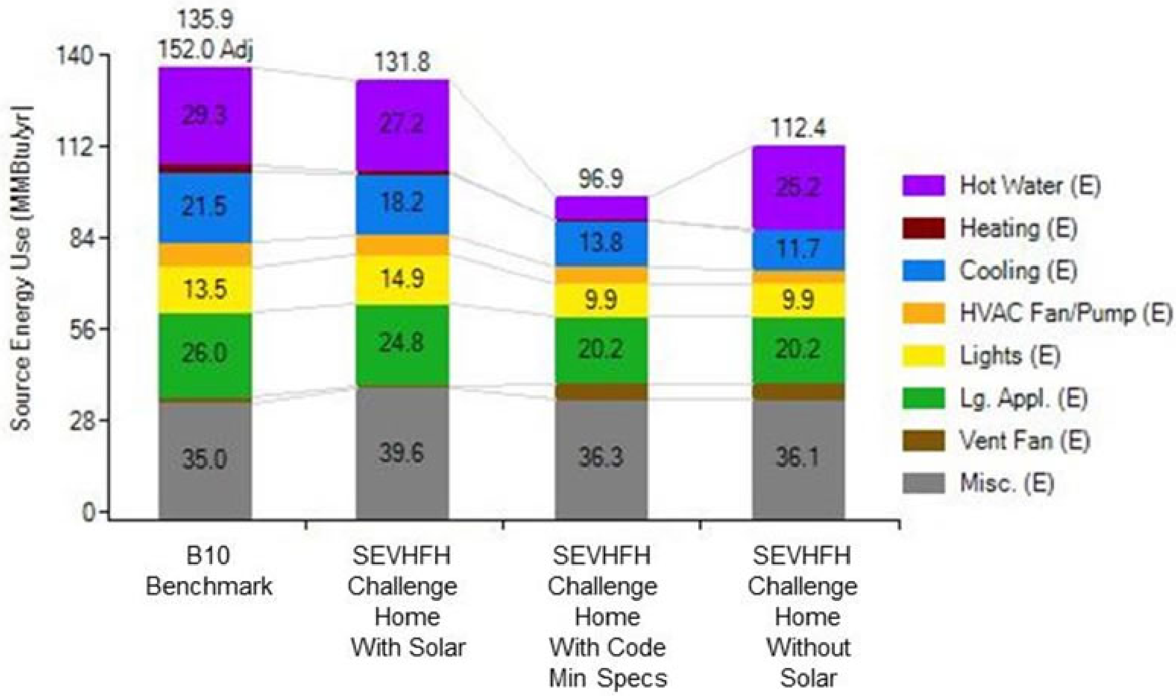

Figure 31. Source energy use by end use for SEVHFH CH scenarios

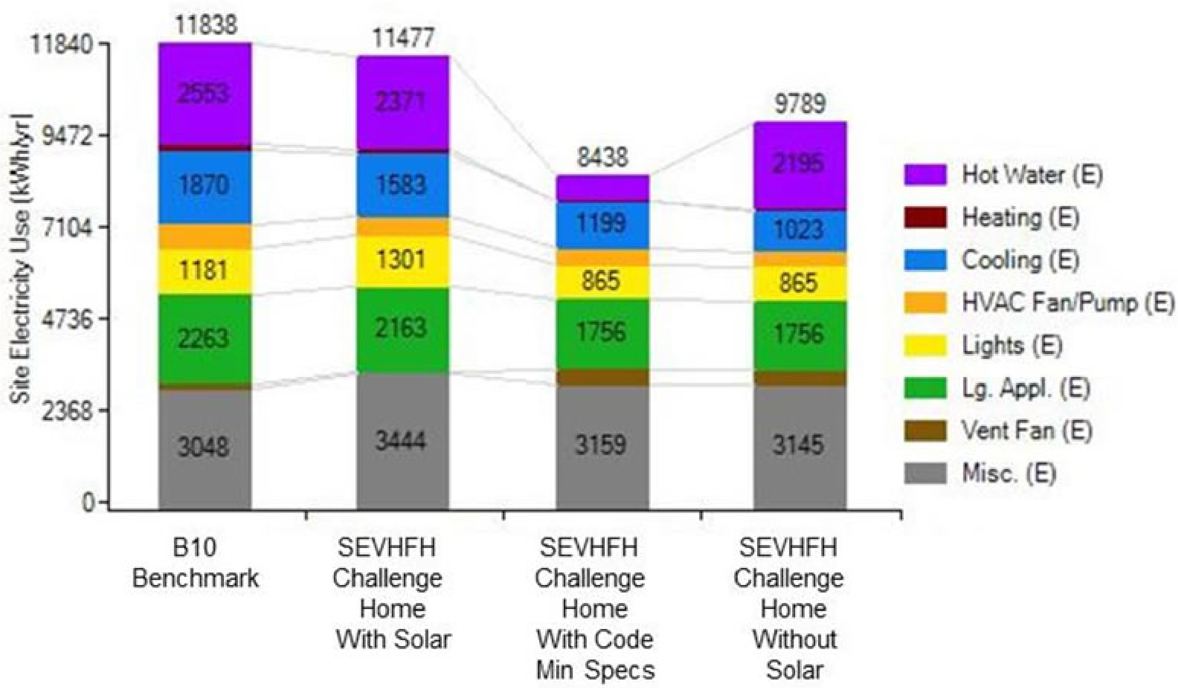

Figure 32. Site energy use by end use for SEVHFH CH scenarios

Table 11. SEVHFH BEopt Percent Source Energy Savings by End Use

	Source Energy Use (All Electric)		Source Energy Savings	
	BAB2010 (MMBtu/yr)	SEVHFH CH (MMBtu/yr)	% of End Use (MMBtu/yr)	% of Total (MMBtu/yr)
Miscellaneous	34.98	36.28	–3.7%	–1.0%
Vent Fan	1.53	4.51	–194.8%*	–2.2%
Large Appliances	25.98	20.16	22.4%	4.3%
Lights	13.54	9.94	26.6%	2.6%
HVAC Fan/Pump	7.1	5.03	29.2%	1.5%
Cooling	21.47	13.75	36.0%	5.7%
Heating	2	0.3	85.0%	1.3%
Hot Water	29.31	6.91	76.4%	16.5%
Total	135.9	96.9	28.7%	28.7%
PV	NA	NA	NA	NA
Net (Total – PV)	NA	NA	NA	NA

This is the impact of the energy recovery ventilator running continuously.

Table 12. Comparison of MCHFH and SEVHFH

	Compared to the B10 Benchmark		Compared to Typical Code Minimum	
	CH With Renewables	CH Renewable Ready	CH With Renewables	CH Renewable Ready
MCHFH	70.4%	30.9%	65.5%	19.5%
SEVHFH	28.7%	17.3%	26.5%	14.7%

6 Conclusions

All but the third of the seven CH requirements are related to codes and standards external to the CH program. There are multiple Building America Measure Guidelines to support fulfillment of Requirement 3, interior duct systems. Even so, the complexity of implementing the strategies in the measure guideline presents challenges to standard construction practices that require forethought, careful execution, and a solid quality assurance process. This and builder concerns about outside air ventilation impacts were identified as barriers to broader adoption of the CH program.

BA-PIRC worked with two affordable housing builders who pursued and achieved CH certification. Both builders were already certifying homes under the ENERGY STAR for Homes Standard v.3.1. To improve relevance of the study to the general homebuilding community, the cost-effectiveness calculations herein compare the CHs to a code-minimum baseline rather to the builders' standard practices, which already significantly exceeded code requirements. Additionally, both are affordable housing builders that sell their homes to qualified buyers at 0% interest over a 30-year mortgage. Projected first year cash flow calculations are shown for those terms, but also for a market rate of 7% for the same mortgage period.

MCHFH pursued CH in duplex dwellings built with ICFs, an unvented attic, a ducted mini-split variable-capacity heat pump, solar water heater, and a PV array. SEVHFH pursued CH in a frame home with a vented attic (regional convention), SEER 15 heat pump, and an innovative modified truss configuration that created an interior duct chase. The MCHFH and SEVHFH CHs scored 53 and 49, respectively, on the HERS Index. With the addition of a 2.5-kW PV array, the HERS Index score dropped to 23 for the CH built by MCHFH.

MCHFH did a thorough cost analysis of its house versus a code-complaint frame house (regional convention) of the same size and orientation (Appendix C). The cost analysis concluded that the MCHFH's CH cost $17,008 more than an identical code-compliant home. This included $9,234 for solar hot water and PV. Subtracting the solar costs, the improvement beyond code resulted in a $7,774 cost increase. The projected first year cash flow associated with these two packages was $36 and $382, respectively, based on EnergyGauge USA calculations. This includes revenue generated from sale of electricity back to the utility in the amount of $427 annually. MCHFH received utility incentives to cover the full cost of the solar equipment; this improved first year cash flow to $690. Under market-rate mortgage terms, projected first year cash flow is negative for both the renewable-ready and the solar-equipped scenarios. The utility incentives applied to MCHFH's CH were available for low-income housing providers only.

Based on cost data provided by SEVHFH and data collected in previous studies, researchers estimate the cost of SEVHFH's CH with renewable-ready compliance (with a heat pump water heater) to be $4,636 compared to code-minimum specifications. This was reduced by a $600 in-kind donation from Dow Corporation available to all HFH affiliates. An additional $4,700 cost was incurred for a solar water heater, which was partially offset by the cost avoided for the heat pump water heater. The projected first year cash flow associated with these two packages was $214 and $238, respectively, based on EnergyGauge USA calculations. SEVHFH also received a utility incentive for the full cost of the solar water heater. No solar PV incentives were available. The utility incentive improved projected first year cash flow to $395. The in-kind donation was removed from the incremental cost for the market-rate mortgage calculations, which resulted in a projected first year cash flow that was negative for both the renewable ready and the solar water heating scenarios. The utility incentive applied to SEVHFH's CH was available for low-income housing providers only.

The results shown for market-rate mortgage terms are provided for reference. They do not necessarily reflect the economics a market-rate builder could achieve, since the improvement packages were developed for a specific builder's resources. In this case, they included free materials and utility incentives that are not available to market-rate builders. However, those builders may benefit from economies of scale or in-house labor capabilities that would implicate a different improvement package. A preliminary simulation study, conducted with a certified home energy rater, should be used to evaluate the projected energy savings and cost effectiveness of various improvements that suit a particular builder. This should be undertaken as part of an integrated design process that takes into consideration the capabilities and insights of the builder's team and other stakeholders outside the company such as code officials and real estate agents (Baechler et al. 2011).

Gaps identified included:

- With the test results proving the technical merit of SEVHFH's innovative modified truss approach to interior duct systems, research is needed to identify less expensive ways to achieve the same results.
- A clear desire among high performance builder partners for research that clearly delineates the pros and cons associated with meeting ASHRAE Standard 62.2 ventilation rates with the methods and equipment available on the market today.
- A survey of stakeholders would be useful to develop a menu of ventilation strategies already in use in the region. This could help researchers identify which approaches are of most interest to stakeholders—which ones are gaining market share, which ones are favored, and why.

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Appendix A: Challenge Home Target Specifications

A target HERS Index for certifying a home under the Challenge Home standard is determined by applying the specifications laid out in Exhibit 2 of the Challenge Home National Program Requirements to the house in an approved software simulation tool. Exhibit 2 is provided here for reference. The homes in this report were governed by Revision 3 of the Challenge Home Standard (DOE 2013a).

Exhibit 2: DOE Challenge Home Target Home 5[20]

HVAC Equipment[21]			
	Hot Climates (2012 IECC Zones 1,2)[22]	**Mixed Climates** (2012 IECC Zones 3, 4 except Marine)	**Cold Climates** (2012 IECC Zones 4 Marine 5,6,7,8)
AFUE	80%	90%	94%
SEER	18	15	13
HSPF	8.2	9	10[23]
Geothermal Heat Pump	ENERGY STAR EER and COP Criteria		
ASHRAE 62.2 Whole-House Mechanical Ventilation System	1.4 cfm/W; no heat exchange	1.4 cfm/W; no heat exchange	1.2 cfm/W; heat exchange with 60% SRE
Insulation and Infiltration			
• Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standards. • Infiltration[24] (ACH50): 3 in CZ's 1-2 | 2.5 in CZ's 3-4 | 2 in CZ's 5-7 | 1.5 in CZ 8			
Windows[25, 26, 27]			
	Hot Climates (2012 IECC Zones 1,2,)	**Mixed Climates** (2012 IECC Zones 3, 4 except Marine)	**Cold Climates** (2012 IECC Zones 4 Marine 5,6,7,8)
SHGC	0.25	0.27	any
U-Value	0.4	0.3	0.27
Homes qualifying through the Prescriptive Path with a total window-to-floor area greater than 15% shall have adjusted U-values or SHGCs.[28]			

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Figure 33. Exhibit 2: DOE CH Target Home 5

Appendix B: Manatee County Habitat for Humanity Build Book Excerpts

Excerpts from Manatee County Habitat for Humanity Build Book delineating details for insulating wall in their duplex homes in Hope Landing.

Manatee County Habitat For Humanity Training Manual
For: <u>*No. P121 -- Insulate, Foam, and Seal*</u>

Building Task: To insulate the party and interior walls, and spray foam the doors, windows, and interior wall pertrusions, as the local code and GREEN build dictates.

Task Goal: To fully insulate the party wall, laundry room (non-conditioned room), and bathroom walls that could have noise to the other rooms. To spray foam insulate around all the windows, doors, and holes in the interior walls for pipes, wires, or any other openings.

When Work Is Performed: Windows and doors are foamed as they are being put in, to complete the task. The batten insulation and additional spray foam has to be done before the drywall is hung, and after all the skilled trades have completed and final inspected.

Personnel Needs For This Task: Crew Leaders: **1** Volunteers: **4-6**

Material Needs: Non-faced roll insulation
Foam insulation - cans
Self leveling sealing caulk

Tool Needs: 25' tape measure
Razor knife W/blades
Straight blade papering knife
Stapler W/ 1/4" staples
16" long straight edge to cut insulation
Caulking gun for tube caulking

Safety Equipment Needs: Gloves, safety glasses, dust mask, baby powder, and no open type shoes

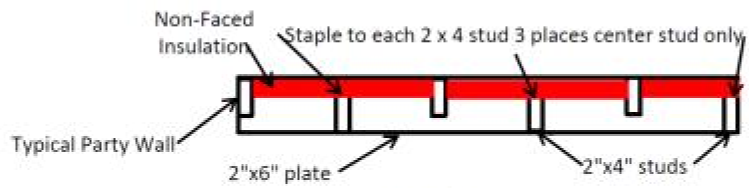
Procedure: <u>Non-Faced roll insulation = Spray form insulation = Pipe floor pertrusion</u>

<u>Non-Faced (roll) Insulation</u>

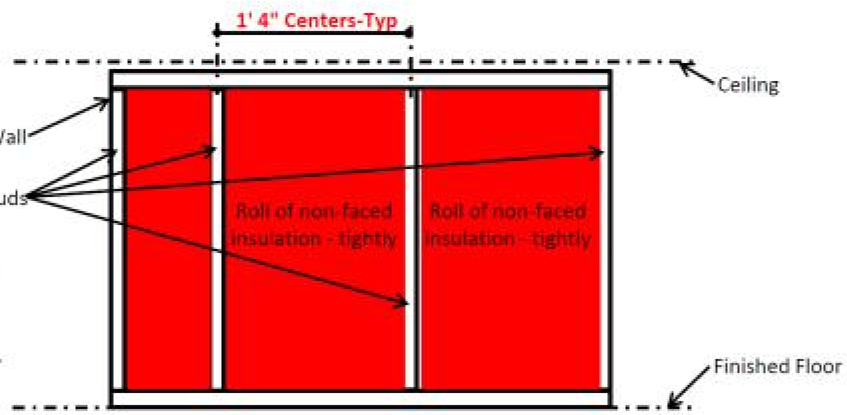
1. Non-faced roll insulation will be used on the party wall (see drawing #1 below), 3 interior walls (water wall of main bathroom and both walls of the laundry room.
2. This insulation must be used the entire length and height of the wall from foundation to under the roof completely sealing it off.
3. Stud must be a "Maximum" of 16" centers, if less then cut to suit making sure the cuts are snug enough to help hold the insulation up between the studs. If stud centers are more than 16" then you must cut to length and width to fit the difference, and remember to cut wide enough to hold up (suggest 1/2" to 1" wider).

1 of 4 **As Of: 1/26/2011**

Drawing No. 1



Top View



NOTE: This wall must be solidly insulated and drywalled with no openings at all.

Front View

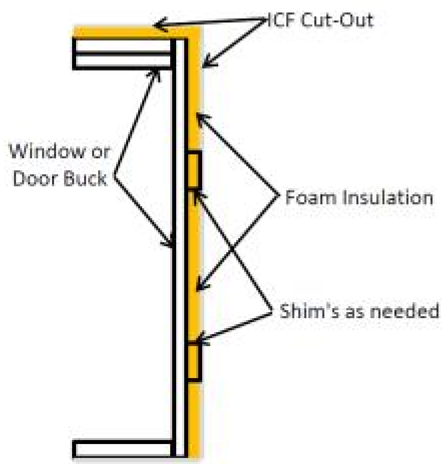
4. Interior wall will done the same way except use only the "Front View" for reference. There will not be any off setting studs like shown in the top view.

Spray Foam Insulation

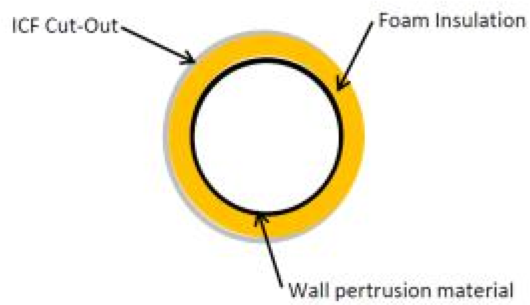
5. Spray foam insulation will be used to seal up any opeinings on the outside (ICF) walls to include windows, doors, back wall, and any holes needed for piping, ventilation, or electrical.

6. See drawings # 2 and #3 below for a typical example. Remember this is only done on the outside walls only

Drawing No. 2



Drawing No. 3

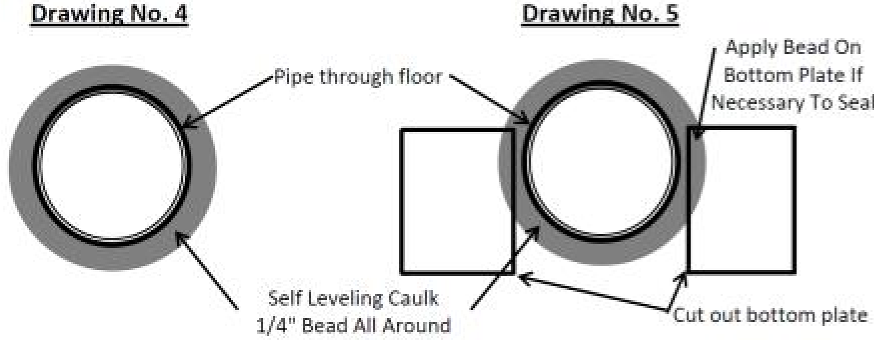


Floor Pipe Pertrusions

7. Floor pipe pertrusions is nothing more than sealing any and all pipes that come thru the concrete floor with a self-leveling caulk that seals the opening. The only exception is the tub or shower drain that is covered with the fixture.

8. See drawing # 4 and # 5 below for more information.

Drawing No. 4 **Drawing No. 5**



Straight Through **Pipe Into Wall W/ Cut Out Plate**

Manatee County Habitat For Humanity Training Manual
For: ***No. P121 -- Insulate, Foam, and Seal***

This process is complete

Revision Information:

No.	By	Description	Date
00		This is the original procedure	
01			
02			
03			
04			

Training and Quality Check Off Sheet For:
No. P121 -- Insulate and Foam

Initial	No.	Step to Complete	Comments
	1	Is all equipment needed, available for this project?	
	2	Is all Material needed, available for this project?	
	3	Has job scope / safety been explained to all volunteers?	
		For non-faced roll insulation	
	4	Have all openings to be insulated, been checked for any misses and corrected as needed?	
	5	Has all excess material been picked up and disposed of in the correct disposal location?	
		For spray foam insulation	
	6	Have all outside openings been sealed off with spray foam and no daylight can be seen anywhere?	
	7	Has all excess material been scraped off of the inside or outside surface making it level?	
	8	Has all excess material been picked up and disposed of in the correct disposal location?	
		For pipe pertrusion caulking	
	9	Have all pipe pertrusion areas been properly swept completely clean so caulk will properly stick?	
	10	Have all pipe pertrusions been sealed up to include any bottom plates to ensure a total seal all around?	
	11	Has all excess material been picked up and disposed of in the correct disposal location?	
	12	Has this form been completed and given back to the construction manager?	
	13	Has the quality person or construction manager reviewed this form and recorded any findings?	
	14	Has any of the findings or retraining needed been discussed or retrained and documented as needed?	

As Of: 1/26/2011

Training and Quality Check Off Sheet For:
No. P121 -- Insulate and Foam

Crew Ldr Quality Ldr	Name and any Comments	Date Completed
Crew Ldr.		
Crew Ldr.		
Crew Ldr.		
Quality Ldr.		
Quality Ldr.		

Comments or Retraining Needed:			
Const. Supervisor Name:		Date:	

Revision Information

No.	By	Description	Date
00		This is the original Training / Quality Document	
01			

2 of 2   As Of: 1/26/2011

Figure 34. Excerpts from MCHFH training manual

Appendix C: Manatee County Habitat for Humanity Cost Data

Provided by Bruce Winter, Construction Manager
Manatee County Habitat for Humanity (MCHFH)
September 25, 2013

Table 13. Florida Building Code Compliant Home Versus Hope Landing Home Energy Efficiency and Sustainability Cost Comparison

Categories		Energy Efficiency	Sustainability
Foundation	Only two issues here in Florida over code: one is larger 5- to 10-ft overlap of plastic (no real cost difference) and the second is self-leveling crack filler around all slap penetration (air quality). Two tubes × $7.20 = $14.40		
	Additional for Hope Landing Home:	**$14.40**	**$0.00**
Exterior Wall	**Wood Framed Home:** Foam seal Rolls 50’ 2 × 4.47 = $8.94 Bottom Plates PT 2 × 4 ×10-2 × 4.56 = $9.12 Bottom Plates PT 2 × 4 ×16 – 5 × 7.94 = $37.70 Double Top Plate 2 × 4 ×10 4 × 4.38 = $17.52 Double Top Plate 2 × 4 ×16 – 10 × 7.58 = $75.80 Wall Studs 2 × 4 × 92 5/8 – 100 × 2.92 = $292.00 16d HDG Nails by the box – 1 × 52.93 = $52.93 Simpson Titan screws (Box 20) – 5 × 66.99 = $334.95 Simpson SP1 - 73 × 1.76 = $128.48 Simpson H-10 - 48 × 2.28 = $109.44 Simpson Corners - 2 × 2.25 = $4.50 Simpson nails - 1 × 99.95 = $99.95 Simpson hold-downs - 2 × 39.95 = $79.90 ½-in. plywood 24 sheets × 18.65 = $447.60 8d HDG nails 1 box × 81.59 = $81.59 House wrap (150 ft 1 × 160.00 = $160.00 Plastic cap nails 1 box × 25.98 = $25.98 R-13 wall batt insulation 7 bags × 46.03 = $322.21 Staples 1 box × 8.49 = $8.49 **Total $2,297.02**		

Categories		Energy Efficiency	Sustainability
	ICF Block Home: U-channel (100 ft aluminum bent flat stock) $14.00 Shot/fasteners $16.20 ICF Blocks (160 S. and 12 C. and freight) $1,876.09 Rebar (2/3 bundle) $467.95 Plastic Ties $12.50 Window/door buck lumber $290.65 Lag screws ½ in. × 6-64 in. × 1.18 = $75.52 Concrete (14 yds.) $1,185.75 Concrete labor and pumper truck $387.50 Simpson MGT 2 × 39.99 = $79.98 Bolts ½ in. × 6 in. 2 × 2.11 = $4.22 Simpson HETA20 (Need 96/Box 100) $88.22 PVC ¾ in. ×1¼ in. × 2 in. × 3 in. × 4 in. (wall penetrations) $24.00 Spray foam adhesive 4 × 6.02 = $24.08 **Total $4,546.66**		
	Additional for Hope Landing Home:	**$2,249.64**	**$0.00**
Exterior Finish	The soffit, fascia, corners and trim could be the same using the construction practices we have built with in the past for both types of house. The big difference would be in the siding panels.		
	Florida Building Code Home Vinyl siding is the same material nationwide. It has a lifetime warranty that is prorated. Vinyl siding has about a 12-year life in the Florida sun until it becomes brittle and faded. From experience the warranty reimbursement is every little by this time. 1 box roofing nails × 33.92 = $33.92 8 sq × $78.0/sq = $624.00 **Total $657.32**		

Categories		Energy Efficiency	Sustainability
	Hope Landing Home HardiePlank fiber cement lap siding is enhanced to address the climate trends for our Florida conditions. It has a 30-year non-prorated warranty that is transferable. 1 box self-sinker weather resistant screws × 129.00 = $129.00 130 planks × $6.32 = $818.44 **Total $947.44**		
	Additional for Hope Landing Home:	**$0.00**	**$290.12**
Windows	**Florida Building Code Home**Aluminum, single-hung, duel-glazed, non-impact glass, non-ENERGY STAR, with U-factor of 0.54 and SHGC of 0.31 4 – 4 × SH-25 and 1 × SH22 **Bid: $583.00**		
	Hope Landing Home Vinyl, single-hung, duel-glazed, non-impact glass, low-E, argon gas filled, ENERGY STAR Southern with U-factor of 0.30 and SHGC of 0.22 – 4 × BLVFSH-25 and 1 × BLVFSH22 **Bid: $1,066.53**		
	Additional for Hope Landing Home:	**$483.53**	**$0.00**
Exterior Doors	**Florida Building Code Home** Basic Econo-Steel, insulated, 6-panel, double-bore, pre-hung outswing door in wood jamb with standard 1½-in. raise metal threshold 2 × 116.00 = **The two doors are $232.00**		
	Hope Landing Home Premium fiberglass, insulated ENERGY STAR, 6-panel, double-bore, pre-hung outswing door in fiberglass jambs (no riot). Front door with bottom swipe has ADA threshold (less than ¾ in. raise) and rear door has 1-in. raise metal threshold. **Custom Built bid price $341.84**		
	Additional for Hope Landing Home:	**$0.00**	**$109.84**

Categories		Energy Efficiency	Sustainability
Roofing	**Florida Building Code Home Roof** 5/8" plywood - 65 sheets × $22.50 = $1,462.50 5/8" plywood clips - 1 box × 49.95 = $49.95 10d ring-shank nails - 1 box × 50.00 = $50.00 15w roof felt - 9 rolls × 34.91 = $314.19 Plastic cap nails - 1 box × 25.98 = $25.98 **Sheathing Sub-Total $1,902.62** Asphalt 3-tap shingles – 54 bundles × 22.74 = 1,227.96 (3-tap – $22.74 Vs. architectural – $32.50 per bundle) Roofing nails - 1 box × 33.92 = $33.92 **Total roof $3,164.50**		
	Hope Landing Home ⅝-in. Zip panels and tape Bid Price 1,456.09 10d ring-shank nails 1 box × 50.00 = $50.00 Sheathing Sub-Total $1,506.09 5V Galvalume panels, trim gaskets and fasteners Bid Price = $2,405.00 **Total roof $3,911.09**		
	Additional for Hope Landing Home:	**$0.00**	**$746.59**
Insulation - Attic	**Florida Building Code Home** **R-19** Owens Corning Atticat loose fill blown-in insulation. (R-19 is $426.48 and R-30 is $534.24) **By bid price: $426.48**		
	Hope Landing Home **R-21** Certaspray open-cell foam insulation at 5½ in. provides insulation value and air-sealing in a single step. **By bid price: $1,552.00** (Manufacturers say you get increased insulation value when on the underside of the roof and you get a conditioned space in the attic. R-30 spray foam would add another $835.00 to the cost of insulation.)		
	Additional for Hope Landing Home:	**$1,125.52**	**$0.00**

Categories		Energy Efficiency	Sustainability
Interior Walls	There are no real cost differentials between wooden interior wall construction methods we would use in either home. We use our scrap materials and advance framing techniques to provide: Ladder cross blocking for corners tie-ins Two stud corners "California" headers over all interior doors Cabinet, shelving and bath hardware blocking Door knob wall bracing (prevents dry wall damage) We add batt insulation into the utility room to master bedroom wall and the hall bathroom side walls adjacent to both front bedrooms for sound deadening. **1 ½ Bags × 46.03 = $69.05**	**$0.00**	**$0.00**
	Additional for Hope Landing Home:	**$0.00**	**$69.05**
HVAC	**Florida Building Code Home** 1 ½-ton 13 SEER non-ENERGY STAR conventional system with same duct work, no outside make-up/ventilation air, and non-ENERGY STAR bath fans. Meets FL Building Codes Standards. **Bid Price: $5,109.50**		
	Hope Landing Home Mitsubishi Electric Mr. Slim .3 to 1.2 Ton, 16 to 23 SEER, ENERGY STAR, mini-split system with invertor technology, variable speed fan and variable speed compressor. Air distribution through pancake fan/condenser feeding distribution to R-6 duct work all in conditioned space. Make-up fresh air through 6-in. filtered duct in the soffit and controlled by manual/motorized dampener. Both bathroom fans are ENERGY STAR ducted to the outside under the soffit. Kitchen vent fan is ducted through roof. **Bid Price: $5,067.50**		
	Amount less for Hope Landing Home:	**($42.00)**	**$0.00**
Plumbing Systems	Require all piping is to be insulated.	**$0.00**	**$0.00**
	Shortened pipe runs for hot water to <0.5 gal changed from overhead to in slab reducing material usage.	**$0.00**	**$0.00**

Categories		Energy Efficiency	Sustainability
	We use all low-flow fixtures that were donated by Kohler that meets Water Sense standards. We would have used them in either type of home constructed.	**$0.00**	**$0.00**
	Florida Building Code Home 12-year 50-gal standard electric water heater installed **Bid Price $709.00**		
	Hope Landing Home Solar water heating system - 80 gal. drainback system installed **Bid Price $4,860.00**		
	FPL reimburses us 100%. The cost differential has been included even though it would be at no cost to us.		
	Additional for Hope Landing Home:	**$4,151.00 (No cost for MCHFH)**	**$0.00**
Electrical Systems	Base cost of electrical system cost would be unchanged if not slightly lower because of lower rated electrical devices being used. PV ready home – conduit run from CB panel into attic (no charge added by contractor)	**$0.00**	**$0.00**
	Florida Building Code Home Contractor grade fans w/lights 3 × 41.95 = $125.85		
	Hope Landing Home ENERGY STAR fans w/lights 3 × 99.95 = $299.95		
	Additional for Hope Landing Home Fans:	**$174.10**	**$0.00**
	All CFLs (estimate of difference)	**$66.00**	**$0.00**
	All appliances are ENERGY STAR and they are donated through a gift-in-kind program from Whirlpool. However, ENERGY STAR appliances can be purchased for about the same price as regular ones through hard shopping and discounts.	**$0.00**	**$0.00**
Drywall	All wall and ceil penetrations are to be sealed – tubes of caulk – 4 tubes × $2.28 = $9.12	**$9.12**	**$0.00**

Categories		Energy Efficiency	Sustainability
	Top of drywall to top plates are sealed - tubes of caulk – 8 tubes × $2.28 = $18.24	**$18.24**	**$0.00**
Cabinetry and Counter	We have purchased cabinets from a local wholesale manufacturer for more than four years. They meet material standards under the CH requirements. No cost differential between construction methods would be realized.	**$0.00**	**$0.00**
Floor Covering	We are using all hard surface flooring in our houses now. This is a change from the carpet and roll vinyl we used in the past that we paid to be installed. Our volunteers now do the work saving us the installation costs but we would do this for either method of construction.	**$0.00**	**$0.00**
Interior Trim	All trim moldings are solid wood and doors meet material standards. Closet shelving is metal. Bathroom hardware, Medicine cabinets, mirrors, and door hardware are all solid wood, metal or plastic. No cost differential between construction methods would be realized.	**$0.00**	**$0.00**
Interior Finish	All low or NO VOC products were used. Habitat receives <50 g/L VOC paints from Valspar through our Gift-in-Kind program. All caulks and adhesives used in the construction of the houses are low VOC. However, it is possible to find the low VOC products at the same cost of ordinary one. No cost differential between construction methods would be realized.	**$0.00**	**$0.00**
Lot Improvements	This is driveways, sidewalks, sod and landscape. We use South Coast Florida native plants without irrigation. Some houses have rain barrels (we offer for $50.00) with soaker hoses to water plantings. We use Bahia glass for drought tolerance and poor soil growth ability. No cost differential between construction methods.	**$0.00**	**$0.00**

Categories		Energy Efficiency	Sustainability
Jobsite Facilities	We use a four dumpster recycling system (general waste, cardboard, metal, plastic) to sort waste into. We were able to cut our waste by more than 25% through designing the house so it uses the size of the ICF so no cuts are required to layout the house and preparing material lists that order specific size material for every task. We now pay for only the general waste removal weight and the recycle materials pays for the dumpsters to be on site and their waste removal. This has caused a reduction in waste removal costs for previous methods of all waste in one dumpster. Hard to put a cost of what the saving are but it has been no extra cost to recycle.	**$0.00**	**$0.00**
Project Fees	No change - we actually have received $140.00 from FPL and on some $4,000.00 from HD-HFHI Sustainability Program in the past for certifying energy-efficient construction.	**$140.00**	**$0.00**
Consumables	These are items and materials that are used and disposed of that may or may not be outside of one of the other categories. .No cost differential between two types of house construction methods	**$0.00**	**$0.00**
Contingencies	Certification fees vary greatly by what which and how many certifications you chose to achieve. Fees also vary between raters for their work and the testing they do. The cost to Habitat to certify a LEED or Challenge Home with other certifications costs about –	**$2,600.00**	**$0.00**
	We received a FPL reservation for a 10-kW system at the allowance of $2.00/kW. We split that system over two houses for a 2.5-kW system with a rebate from FPL of $5,082.43 for each house. The two systems were installed on houses already closed and no planning for addition of a PV system so the cost was $5,898.98 for each install. However, with doing the install at time of construction or even after the house is sold as long as the conduit is run to allow access to the CB panel, you should be able to install the PV system for close to the $2/W of the system.	**$5,082.43 (no cost for MCHFH)**	**$0.00**
Grand Totals	Addition Cost for Hope Landing Challenge Home Versus Florida Building Code Home	**$15,791.98**	**$1,215.60**

Categories		Energy Efficiency	Sustainability
	Less reimbursements from FPL (Solar Water Heater $4,151.00 & PV System $5,082.43)	$9,233.43	
	Habitats extra cost for efficient Hope Landing Homes	**$6,558.55**	
	Cost of Hope Landing Home more than Florida Building Code Home (Energy Efficiency $6,558.55 + Sustainability $1,215.60)		**$7,773.55**

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