

COMMISSIONING HIGH PERFORMANCE RESIDENCES IN HOT, HUMID CLIMATES

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ABSTRACT

Since 2001, the authors have engaged several builders in the Gainesville, FL area to build over 500 high performance new energy efficient homes in multiple sub divisions. The builders keep building to increased levels of energy efficiency. Each home is individually designed, inspected, rated and commissioned for optimum performance. This paper summarizes the experiences to date with two production builders who have cost shared with the Building America program to deliver these outstanding results. Keys to success are commitment from the final decision maker; scopes of work for subcontractors with specific performance criteria; clear communication with the trades often accompanied by training and education activities; independent third party testing, commissioning and feedback to builder; ongoing training of sales staff and model center displays and finally extensive marketing that educates the consumers about the benefits of high performance homes.

INTRODUCTION

One of the major goals of the U.S. DOE Building America program (www.buildingamerica.gov) is to conduct cost shared research and development that leads to high performance energy efficient homes that are routinely built by production builders in community scale. These homes are significantly more energy efficient than Energy Star homes and feature improved indoor air quality (IAQ) and comfort. In this paper, we describe the process by which hundreds of high performance homes have been built and commissioned in the hot-humid climate of Gainesville, FL as part of the Building America (BA) program. The paper

concentrates on describing the process for two production builders of single family homes -- G.W. Robinson Builders (GWR) and Tommy Williams Homes (TWH) who build for different market segments, see Figures 1 and 2.



Figure 1 Typical GWR Home



Figure 2 Typical TWH Home

Commitment

The first step in the process is to get the unequivocal commitment of the final decision maker. Both GWR and TWH are privately held building companies building 50 to 100 homes a year in multiple communities in the greater Gainesville, FL market. The presidents of both companies understood that the BA process is fundamentally different from conventional building in that the whole house is systems engineered and commissioned to be significantly more energy efficient, comfortable, and with improved IAQ. They both committed to building 100% of their homes this way rather than offering a BA “option” package. It has generally

been the BA experience that companies who choose to systemically transform their processes reap a larger reward in the market place than those who choose to offer a BA option.

The motivation for the two builders were different. GWR builds for the move-up market and was most interested in leaving a legacy of high-quality high performance sustainable homes and joined the BA program in 2001. In the case of TWH, the desire was to improve the quality of the homes and reduce callback complaints. TWH joined the program in 2004. Both builders build homes constructed out of 2x4 on a slab on grade foundation with vented attics. Both builders were building code minimum homes at time of joining the program and committed to a process of incrementally improving the energy efficiency of *all* their homes over the years to Building America target levels.

SYSTEM ENGINEERING AND COMMISSIONING PROCESS

Engineering and Team Work

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

After the initial analysis to determine the specifications for the communities, the BA systems engineering approach includes an evaluation of each design (floor plan, elevations and specifications) to identify opportunities for improvements and ensure specifications were called out correctly. The floor plan is analyzed and adjusted to bring the air handler into conditioned space from its typical garage location and the mechanical ventilation intake is identified. Details of this are available in Fonorow et al. (2006). Next, a room-by-room ACCA Manual J load calculation is performed to determine the heating and cooling equipment size and a duct system design is developed based on ACCA Manual D calculations. Finally the duct system plan is drawn and specifications (including duct tightness) are provided to the

mechanical contractor. Important details are integrated into the construction drawings.

Next, Florida H.E.R.O. conducts a sub-contractor meeting after the framing of the model to discuss working together as a team. In attendance are the builder, all senior office staff, the project real estate agents and representatives or owners of all subcontractors. The builder's goals, objectives, and expectations are clearly articulated with the opportunity for the whole team to ask questions. This initial broad based meeting provides the opportunity to discuss what the adoption of high performance specifications means including the interrelationship of the different building components and trades. This is an important element of the quality assurance approach. Each subcontractor knows in advance what is expected by this developer/builder and how their work fits in with the whole project. They know that the builder will not accept a sub-contractor compromising the quality of their own work or creating an environment that compromises the work of others. For example, it would be unacceptable for the plumber to run lines in an area that has been designated for the duct system because, in these homes, the duct system is a precise design. To reduce the amount of coordination required among the mechanical, plumbing, and electrical sub-contractors, these three systems are installed in sequence on every job site. The least flexible of the three sub-systems, the duct system is installed first. Next the plumbing rough-in is installed followed by the electrical runs, the most flexible of the three major sub-systems.

Site Inspections

Site visits are conducted at key points in the construction process to verify that specs are being met. This includes conducting a "mid-point" duct leakage test after mechanical system rough-in to locate leaks that will be sealed before the drywall is installed (for easier access.) Any other deficiencies discovered during site visits are reported back to the builder and a meeting with the trades often occurs to correct deficiencies and conduct training. Site visit activity also includes completing the new Energy Star Thermal Bypass Inspection

Checklist (TBIC) which includes an inspection of the air barrier continuity, thermal barrier (insulation) integrity, and duct system layout. Figures 3 and 4 show some details that these builders have implemented to meet some of the TBIC criteria. The TBIC checklist and additional information on Energy Star homes are online at http://www.energystar.gov/index.cfm?c=bldrs_1enders_raters.homes_guidelns09



Figure 3 Solid blocking at tray ceiling framing (GWR).

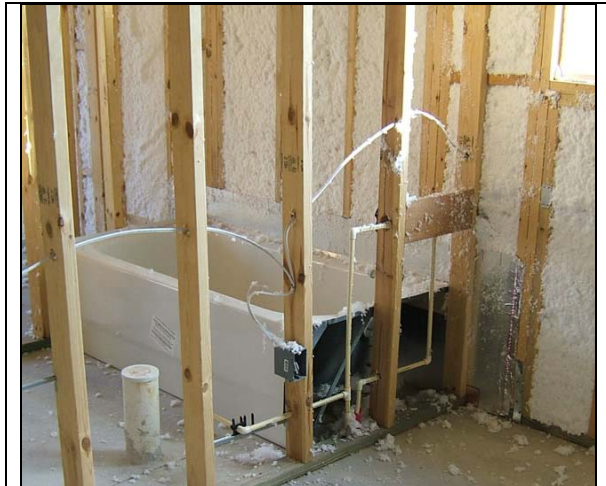


Figure 4 Draft stopping and Insulation behind tub (TWH)

Testing and Commissioning

Upon completion of the home, seven performance tests are conducted for commissioning and feedback to the builders:

1. *Whole House Air Tightness Testing:* A computerized multi-point whole-house air tightness depressurization test is performed using the Energy Conservatory Automated Performance Testing (APT) or the DG700 equipment. The pressure of the house with respect to the attic is performed concurrently. Figure 5 shows measured data from 77 GWR homes and 25 TWH homes (Total of 102 homes). Note that the average is lower than typical new homes in Florida which is 5.2 ACH50 (Swami, et al. 2006)

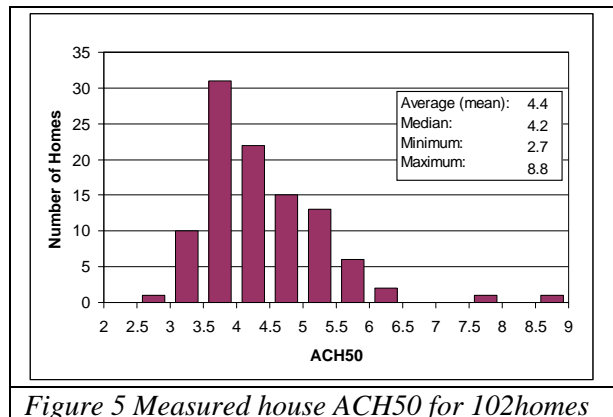


Figure 5 Measured house ACH50 for 102homes

2. *Duct System Air Tightness Testing:* A Duct Blaster® is used to perform a duct air tightness depressurization test and quantify duct leakage (cfm25 total and cfm25 to outside). Duct air tightness is part of the mechanical contractor's scope of work. The duct leakage is measured on every single home. The duct leakage test is conducted in accordance with standard building science practices at 25 pascals of negative pressure. Total system leakage (CMF25,total) as well as leakage to the outside (CFM25,out) are measured. Figure 6 shows measured duct leakage to outside (CFM@ 25 pascals expressed as a percentage of the floor area in square feet). Note that this is lower than typical duct leakage to outside of 5.7% measured in 40 central Florida homes (Swami, et al., 2006)

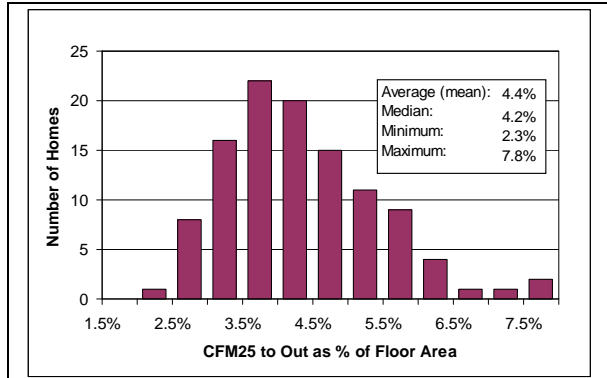


Figure 6 Measured Duct leakage to Out (CFM25/Floor area) for 102 homes

3. *Pressure Mapping:* The home is pressure mapped using a digital manometer. All rooms with doors that can isolate them from the main return pressures with reference to the house are measured with the air handler operational, and the pressure that the home operates under with reference to the outside is measured. In hot humid climates, the mechanical ventilation system should positively pressurize the house and Figure 7 shows that it has been achieved in these homes. The one house with a -1.1Pa entry is an anomaly and probably a data entry or operator error. Nevertheless, we have included it in the chart. The three other homes with a slight negative pressure were probably measured in a windy day. Note that most houses without mechanical ventilation experience a negative pressure. Data from 40 central Florida homes, built by different builders, show that the average house to outside pressure in homes without a mechanical ventilation system averages -0.18 Pascals (Swami et al., 2006).

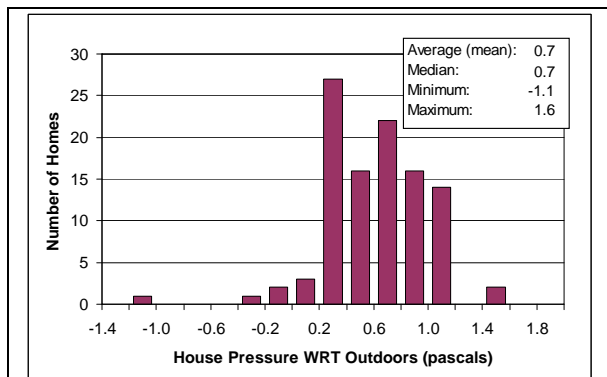


Figure 7 Measured House to Out pressurization for 102 homes

4. *Outside Air Flow Measurement:* The flow of the outside air intake is measured using the Energy Conservatory Exhaust Fan Flow Meter. Figure 8 shows the measured fresh air ventilation rate. The average ventilation rate when the air handler operates averages about 30 CFM and analysis shows that it is about 50% of the rate required by the ASHRAE 62.2 standard (ASHRAE, 2007). See Figure 8 below.

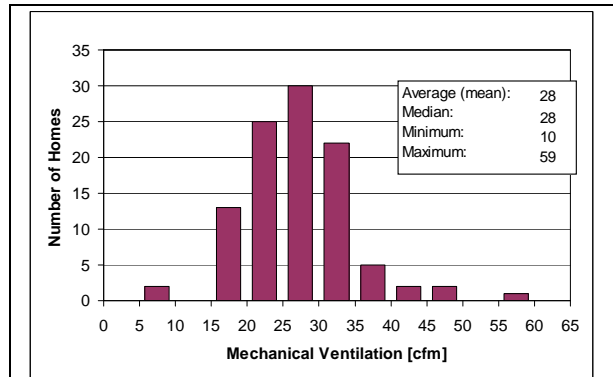


Figure 8 Measured whole house ventilation rate for 102 homes

The outside air ventilation system consists of a filtered OA intake from the front or rear porch or soffit connected with a 4" flex duct to the return air plenum downstream of the return air filter. A manual damper can be closed in the event of forest fire etc. This simple system provides ventilation air only when the air handler is running and homeowners are educated to set the fan on "auto" rather than "On". This system was developed about 10 years ago to solve odor and high wintertime humidity complaints from some unventilated homes. In over 500 homes we have not received odor or humidity related complaints from homeowners that have this ventilation system. The authors plan to systematically measure the temperature and relative humidity in some of these homes and obtain survey data on occupant satisfaction in 2008 and 2009.

5. *Static Pressure:* A digital manometer and static pressure probes are used to measure the pressure that the air handler is operating under and expressed as inches of water column (IWC). The average for the 102 homes was 0.54 IWC.

6. *Temperature Drop:* The temperature difference (delta T) across the coil is measured using digital thermometers. The average for all 102 houses was 17.5 °F.

7. *Exhaust Fan Air Flow Measurement:* The flow of all bath exhaust fans is measured. It is consistently found to be approximately half the manufacturer rating.

These test measurements in addition to house characteristics such as make and model of the air handler and condenser section, water heater size, energy efficiency of appliances, and lighting types are noted and reported to the builder using a form entitled "Home Energy Rating Report" which also notes areas of deficiency that need to be addressed and re-evaluated.

Finally each home is rated and its HERS Index calculated using the Energy Gauge® software (www.energygauge.com). All homes significantly exceed the Energy Star level of

performance (HERS Index <85 for hot, humid climates). See Figure 9.

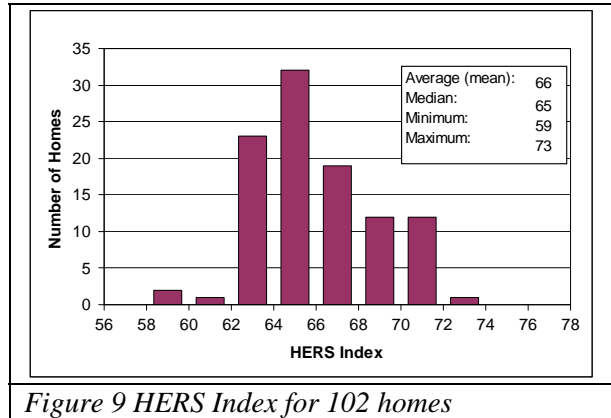


Figure 9 HERS Index for 102 homes

COMPARISON OF FEATURES

Table 1 below lists the 2006-2007 features for both builders and compares to the typical regional practice for the area. The average values for GWR is for 77 of their homes and the average values for TWH result from 25 of their homes.

Table 1 Features of GWR and TWH Homes compared to Typical Regional Practice

	GWR	TWH	Typical
Av. Floor Area, sq.ft.	2,755	1,729	Comparable
Av. Window/floor area	17.5%	13.3%	Comparable
Envelope			
Wall Framing	2X4 w/ladder T	2X4 w/ladder T and 2 stud corners when feasible	Standard 2 X 4
Wall insulation	R-13 cellulose	R-15 blown fiberglass	R-11 batt
Attic Radiant Barrier	Yes	No	No
Ceiling Insulation	R-30	R-30	R-30
TBIC Compliance	Yes	Yes	No
Windows	2 pane vinyl low-e; U=0.35, SHGC=0.28	2 pane vinyl low-e, U=0.33, SHGC=0.30	2 pane Aluminum clear, U=0.66, SHGC=0.66
HVAC System			
Heating System	93% Gas Furnace	HSPF 9 Heat Pump	80% Gas Furnace
Cooling System	SEER14	SEER15	SEER 13
System Sizing	Per Manual J	Per Manual J	?
AHU Location	Inside thermal envelope	Inside thermal envelope	Garage
Duct Location	Vented Attic	Vented Attic	Vented Attic
Duct Sizing	Per manual D	Per manual D	Unknown
Duct Leakage to Out	4.2% on Average	4.8% on Average	5.7% on Average
Mechanical Vent.	Run time Vent	Run time Vent	None
Water Heating			
Type	83% tank less gas	60% gas	60% gas

Pipe Insulation	½" foam	None	None
Lighting	50% CFL	75% CFL	10% Fluorescent
HERS Index, Av.	65	70.5	93
Est. Energy Savings	~30%	~20%	Base case

The estimated energy savings were calculated by taking a GWR and TWH floor plan and changing the envelope and equipment values to typical values. The savings for the TWH are lower on a % basis, mostly because TWH homes do not have savings in the water heater energy usage category. In addition the TWH homes have a lower glass to floor area ratio (13.3%) compared to the HERS reference house, where it is assumed to be 18% (See table 303.4.1 of the standards, online at [http://www.resnet.us/standards/mortgage/RESNET Mortgage Industry National HERS Standards 2006.pdf](http://www.resnet.us/standards/mortgage/RESNET_Mortgage_Industry_National_HERS_Standards_2006.pdf)). This results in TWH homes

getting a comparatively better HERS Index than GWR which have close to 18% window to floor area.

COST EFFECTIVENESS

The cost effectiveness of the technical features are calculated based on the energy savings by comparing with typical regional practice (slightly better than code minimum) homes and using the 2007 local utility rates of 12 cents/kwh and \$1.48/therm for natural gas. Table 2 below shows the estimated added costs and savings and simple paybacks and monthly cash flows.

Table 2 Estimated Added Costs and Benefits of Energy Efficiency Measures for Typical Homes

Measure	GWR[77 Homes]	TWH[25 Homes]	Notes
Engineering and Testing – Manual J, D, testing and rating	\$400	\$400	
Wall Insulation	\$494	\$370	
Attic Radiant Barrier	\$806	None	
TBIC Compliance	\$300	\$250	TBIC compliance for 2 story home with bonus room can be \$1,500
House Air Sealing	\$200	\$200	
Windows	(\$128)	(\$71)	Vinyl double pane low –e cheaper!
Heating System	\$400 - furnace	\$0	
Cooling System	\$350 – SEER 14	\$1,000 - SEER 15	
Credit for Tonnage Reduction	(\$1,500) for 1.5 tons	(\$500) for 0.5 tons	Typical home has bigger a/c
Vent System	\$300	\$300	
Duct Air Tightening	\$165	\$165	
Air Handler Inside Thermal Envelope	\$500	\$500	
Hot Water Pipe Insulation	\$100	None	
Water Heater	\$900	\$0	
Lighting	\$50	\$50	TWH has less fixtures
Cost to Builder	\$3,337	\$2,664	
Credit for Increased appraisal for 15 sq. ft of air handler inside	(\$1,500)	(\$1,500)	

conditioned space			
Net cost to Builder	\$1,837	\$1,164	
Net cost to buyer	\$2,021	\$1,280	Assuming 10% profit
Annual Savings in Utility Bills	\$863/yr or 30.1% compared to typical	\$402/yr or 21.4% compared to typical	Based on typical home
Simple Payback, yrs	2.3 years	3.2 years	
Monthly Cash Flow	\$58/mo	\$25/mo	Utility bill savings – monthly payments at 7% , 30yr mortgage

Note that the economics are very attractive for both builders. Because of systems engineering, significant credits and values result from bringing in the air handler inside the conditioned space (from the garage). The 3ft x 5ft space can now be counted as conditioned floor area.

MARKET ACCEPTANCE

Both builders have incrementally improved their home specs over the years and continue to build *all* their homes to BA specs. GWR builds move up homes, primarily in three communities and TWH builds starter homes primarily in two communities. Table 3 provides some market statistics for both builders for 2006.

- The first step in this process requires a clear and consistent commitment of the final developer. The support of this “champion is necessary to maintain improvement and quality assurance efforts.
- A scope of work including specific *performance* criteria gives sub-contractors a clear idea of what is expected from them and provides a mechanism for linking payment to work quality. An example would be to include in the contract language, a provision requiring that the mechanical system will have no greater than 10% total leakage and 5% to out when using the standard cfm25 duct test.

Table 3 Market Statistics for GWR and TWH

	GWR	TWH
Range of Home Size	2,022-4,768 sq. ft.	1,450-2,416 sq. ft.
2006 Av. selling price	\$165 / sq. ft.	\$147 / sq. ft.
Number of homes sold in 2006	101	54

In addition both builders expend significant dollars in advertisement and training of the sales force so that potential homebuyers are well educated in the benefits of BA homes – energy savings, greater comfort, better indoor air quality, less noise, greater durability, reduced water usage and less overall impact on the environment.

CONCLUSIONS

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

- Effective communication of performance expectations to the person(s) responsible for implementation in the field must be performed, often in conjunction with education and demonstration activities
- Ongoing quality assurance field inspections by either the project manager or an independent third party must be conducted to ensure consistency over time.
- Final commissioning of each home, including performance testing is an integral component of a systems approach, as it provides a timely feedback loop to the builder. It also puts the trades on advance notice that their work will be tested.

- In order for the builder to achieve sales goals, the sales representatives must be knowledgeable about the features and benefits that have been built into the home. Thorough and repeated sales training and advertisement is critical to success.

If the above process is followed the results appears to be increased sales and profits for the home builders, satisfied homeowners and significant energy savings with its attendant economic and environmental benefits for all. During 2008 and 2009 FSEC plans to conduct utility bill surveys, indoor environmental monitoring and homeowner interviews in a statistically valid sample of BA and typical homes to obtain additional data quantifying the value of BA homes.

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