FLORIDA SOLAR ENERGY CENTER
Creating Energy Independence

CASE STUDY
COLLABORATIVE RESEARCH WITH PACIFIC NORTHWEST NATIONAL LABORATORY
2012

Habitat for Humanity Palm Beach County, Florida: Existing Home Retrofit

This unoccupied, foreclosed, single-family detached home in Lake Worth, Florida (Figure 1) was initiated in 2011 by Habitat for Humanity Palm Beach County, Inc. (www.habitatpbc.org), a non-profit, affordable housing organization. Table 1 summarizes the projected annual energy use and cost savings for this deep energy retrofit project.

Figure 1. Pre-retrofit with hurricane shutters in place (exterior unchanged during retrofit).

Table 1. Annual Energy Use and Cost Simulation

Parameter	As Found	Actual Retrofit
HERS Index	97	75
Annual Simulation kWh (BABM08)	12,773	9,421
Annual MBtu Usage (BABM08)	43.6	32.2
Annual Energy Cost (BABM08)	$1,656	$1,225
Project Status: Completed 5/26/11		

Notes: HERS, Home Energy Rating System; kWh, kilowatt hour; BABM, Building America Benchmark; MBtu, million British thermal units

Built in 2003, this three bedroom, two bath, frame construction home has 1,373 square feet of conditioned space. In February 2011, a test-in audit was conducted to document the home's pre-retrofit characteristics, which served as the retrofit base case model. The eight-year-old home had many energy efficient elements incorporated into its original construction. The existing home characteristics were a light-colored exterior, a white shingle roof, R-19 attic insulation, above bedroom door transfer grilles, and extensive shading of the large, east-facing window. Windows were single-pane, metal frame, with clear glazing. Appliances and lighting in place included an ENERGY STAR® labeled refrigerator, a few compact fluorescent light bulbs (CFLs), a minimally efficient electric water heater, and a central, forced air heating and cooling system. The mechanical system, a Seasonal Energy Efficiency Ratio (SEER) 12 air conditioner with a heat pump, exceeded the minimal efficiency available at the time.

The whole house was tight (air changes per hour at 50 pascal's (Pa) of pressure (ACH50) = 5.9) and duct leakage was low (Qn,out = 0.047)[1]. Pressure pan diagnostics were performed to highlight potential areas of concern within the supply duct system, and none were found. Findings are presented in Table 2.

Table 2. Pre-Retrofit Pressure Pan Diagnostics

Register Location	Pressure (Pa)
Kitchen 1	0.3
Kitchen 2	0.8
Kitchen 3	0.1
Living Room	0.5
Bedroom 1	0.4
Bedroom 2	0.2
Bedroom 3	0.3

Our partner decided the mechanical system, only eight years old, had enough useful life to be retained. The partner was willing, however, to incorporate a passive outside air ventilation system. The package of improvements included replacing the domestic hot water heater (Energy Factor (EF) = 0.88) with a hybrid heat pump water heater (coefficient of performance (COP) = 2.35), insulating the attic to R-38, insulating one wall found to be without insulation to R-13, replacing the outdated ENERGY STAR® refrigerator with a currently qualified model, and an extensive use of CFLs.

This retrofit, completed May 26, 2011, was comprised of a package of measures (Table 3) that resulted in an estimated $431 in annual energy cost savings. Based on the partner provided renovation costs of $3,246, these savings outweigh the added mortgage cost by an average of $14 per month. In addition, researchers analyzed the incremental first costs for the higher efficiency options. The monthly cash flow increased to $21 with a 5-year simple payback.

Table 3. Key Energy Efficiency Measures

Component	Pre- and Post-Retrofit Characteristics
Ceiling Insulation	From R-19 to R-38, blown-in fiberglass
Exterior Walls	Insulated one non-insulated wall with R-13 fiberglass batts
Whole House Infiltration	From ACH50=5.9 to ACH50 = 6.26, installation of passive runtime outside air ventilation system
Water Heating System	From 50 gal, electric, EF = 0.88 to 50 gal, electric heat pump hybrid water heater, COP = 2.35
Refrigerator	From default to Energy Guide label of 378 kWh/yr
Lighting	From 10% CFLs to 80% CFLs

[1] Duct air tightness is expressed in terms of airflow required to achieve a standard test pressure (25 Pa) in the duct system, measured in cubic feet per minute or CFM25. The test procedure measures leakage involving air outside the conditioned space (CFM25,out) or leakage inside and outside (CFM25,total). For comparison among different size house, CFM25,out, (or CFM25,total) results are normalized by condition floor area of the house, yielding Qn,out (or Qn,total).

The estimated annual energy savings, added mortgage costs, and anticipated positive cash flow associated with the whole package of improvements are presented in Table 4.

Table 4. Annual Energy Savings Analysis

	Full Cost & Full Savings	Incremental Cost & Incremental Savings
HERS Index Improvement (%)	23%	23%
Annual Energy Cost Savings ($)	$431	$431
Annual Energy Cost Savings (%)	26%	26%
Improvement Costs	$3,246*	$2,246*
Monthly Mortgage	$22	$15
Monthly Energy Cost Savings	$36	$36
Monthly Cash Flow	$14	$21
Simple Payback (years)	8	5
*Retrofit choices compared to minimum efficiency choices considering only the incremental increases in cost and savings		

The slight increase in the whole house infiltration can likely be attributed to the installation of the passive runtime ventilation system into the return plenum, as there were no other penetrations into the envelope during the renovation. This passive run-time ventilation strategy also produces a slight positive pressure in the house with respect to the outside while the air handler is running, a building durability feature to ensure that infiltration of hot humid outdoor air will not occur under normal operating conditions and that any house depressurization will be neutralized with air from a known, clean path rather than through envelope infiltration points. Although auditors attempted to block the fresh air intake for the air tightness tests, duct mask did not adhere well to the boot or surrounding plywood.

The duct leakage-to-out was essentially unchanged between test-in and test-out; however, there was a worsening of the total duct leakage. The air handler and single, central return system were interior, with supply distribution running through the attic. With the house depressurized to -50 Pa, the attic registered at +47 Pa with reference to the main body of the house. This result indicated good separation between the conditioned space and the attic. Neither the mechanical system nor its duct work was replaced as part of this retrofit. Predictably, duct leakage to the outside (Qn,out = 0.05) was essentially unchanged at test-out; however Qn,total increased from 0.09 to 0.12. Again, researchers attribute this finding to the outside air ventilation installation. Duct leakage test results are presented in Table 5.

Table 5. Pre-Retrofit vs. Post-Retrofit Duct Leakage

Duct Testing	Pre-Retrofit	Post-Retrofit
Cubic feet per minute (CFM) 25, total:		
Return	118	153
Supply	129	174
Qn,total	0.09	0.12
CFM 25,out:		
Return	56	55
Supply	72	81
Qn,out	0.047	0.05

During the post-retrofit audit, pressure mapping was performed to assess whole house system pressure boundaries. Auditors induced a “worst case” scenario by running the air handler and exhaust fans and shutting all bedroom doors. Operating in “worst case” the home was only slightly depressurized (-0.5 Pa), and there was not excessive pressure built up in any of the bedrooms. Therefore, the existing above door transfer grilles are doing an adequate job of balancing mechanically induced house pressures. See Table 6 for a summary of the post-retrofit pressure mapping results. Figure 2 is a picture of above door transfer grilles.

Table 6. Post-Retrofit Pressure Mapping

Location	Pressure (Pa)
House WRT Out	-0.5
Master WRT House	0.7
Bedroom 2 WRT House	0.4
Bedroom 3 WRT House	0.7

Note: WRT, with respect to

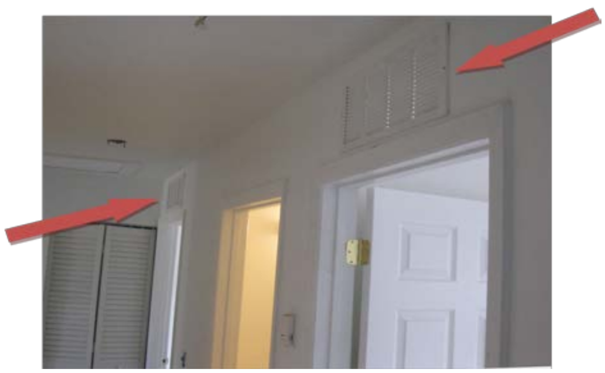

Figure 2. Above door transfer grilles.

The retrofit components responsible for the bulk of the projected energy cost savings are the hybrid heat pump water heater, added ceiling insulation and extensive use of CFLs. These measures, in addition to the installation of the mechanical runtime ventilation system, are highlighted in the following discussion.

As noted earlier, the existing mechanical system was determined to have several years of useful life and was not slated for replacement. The partner agreed to work with researchers, however, to bring fresh air into the home via the mechanical system. Our recommended passive, runtime ventilation strategy involves connecting duct work from the outside into the return plenum near the air handler where it is mixed with house air when the system is running. The outside air is drawn through an inlet mounted in the soffit. In this design, the outside air is being filtered at the entry to the air handler rather than at the soffit. We have found partners, in general, are reluctant to install filter back grilles in the soffit for the outside air. The filter-back component requires depth at the soffit to accommodate a manufactured or fabricated boot. For low pitch, there is not adequate vertical space to accommodate this component. Additionally, partners are skeptical that residents will replace an outside filter. The reasoning seems to be concern over general awareness of the filter in the long term as well as lack of availability of correct size filters from the retail outlets. Since the outside air must be filtered prior to crossing the cooling coil, the configuration implemented in this house has been accepted. An insect screen however was provided at the intake. Figures 3-5 show images of this installation.

Figures 3-5. Pre-retrofit return plenum (left), outside air ducted into the post-retrofit return plenum (middle), soffit retrofit for the air intake (right).

The attached, unconditioned storage room measuring 7’x 8’x 9’, was large enough to house a heat pump water heater. The installation of the hybrid water heater with heat pump (Figures 6-7) in this location has the added benefit of dehumidifying and cooling this storage area and the attic, which the room is open to.

Figures 6-7. Pre-retrofit electric tank water heater, EF = 0.88 (left), hybrid heat pump water heater, COP = 2.35 (right).

The existing ceiling insulation was comprised of R-19 fiberglass batts laid on top of the ceiling drywall. Blown-in fiberglass insulation was added to the existing batt, yielding R-38 total. Figures 8-9 illustrate the pre- and post-retrofit ceiling insulation.

Figures 8-9. Pre-retrofit (left) and post-retrofit (right) ceiling insulation.

The final significant retrofit measure was the installation of approximately 80% compact fluorescent light bulbs.

Several low-cost, energy saving recommendations not incorporated into the retrofit may have enabled this home to reach the 30% energy cost savings threshold. Our suggestions were to install a programmable thermostat, apply window film to the east and west facing windows, select ENERGY STAR® qualified ceiling fans, and insulate the hot water system pipes.

In summary, had the mechanical system been at or near the end of its life and replaced, or if some of the lower cost suggestions above had been incorporated into the renovation, this project would have easily achieved or exceeded the 30% energy cost savings goal. As noted in Tables 1 and 4, this retrofit attained a 26% projected energy cost savings with a projected annual energy cost of $1,225 and a projected annual cost savings of $431. This includes the slight energy use increase from the passive ventilation system. Using costs provided by our partner to address the cost-effectiveness of this retrofit, we see a monthly cash flow of $14 and a simple payback of 8 years. Considering incremental first costs only, the monthly cash flow is increased to $21 with a 5-year simple payback. Although this retrofit fell short of our savings goal it is an impressive example of energy efficiency gains that can be cost-effectively achieved in a newer home.

***This case study is an excerpt of the following master report and has been modified to stand alone:**

McIlvaine, J., Chasar, D., Beal, D., Sutherland, K., Parker, D., Abbott, K. (2012). *Partnership for High Performance Housing Draft Final Report*. FSEC-CR-1911-12. Florida Solar Energy Center: Cocoa, FL.