FLORIDA SOLAR ENERGY CENTER®

CONTRACT REPORT

Energy Efficient Renovations of Storm Damaged Residences - Florida Case Studies

FSEC-CR-1648-06
September 8, 2006

Submitted to:

U.S. Department of Energy
Cooperative Agreement No. DE-FC26-99GO10478

Submitted by:

Dave Chasar, P.E.
Neil Moyer
Eric Martin

1679 Clearlake Road, Cocoa, FL 32922-5703 • Phone: 321-638-1000 • Fax: 321-638-1010
www.fsec.ucf.edu

A Research Institute of the University of Central Florida

Abstract

This study documents the energy impact of retrofit options performed on four Central Florida homes suffering damage from hurricanes in the summer of 2004. Case studies are presented to show the costs and benefits of various retrofit strategies, including the potential to enhance comfort and durability. Results are based on pre- and post-retrofit home performance testing as well as analysis of simulated and actual energy savings. Whole house energy savings resulting from the retrofits is estimated to be between 1% and 27%, while cooling savings ranged between 3% and 45%.

Executive Summary

Storm-damaged homes offer the opportunity for repairs that reduce energy use, improve comfort and enhance resistance to future storms. Case studies of four Florida homes damaged in the summer of 2004 were documented to show the costs and benefits of various retrofit strategies. All four homes required roof replacement and each took advantage of roof cladding with higher reflectance than the original – a proven means of reducing cooling energy use. Two of the case studies included improvements to attic insulation, tightening of the envelope and/or duct system and improved efficiency equipment and lighting. Energy savings attributable to storm repairs were estimated through detailed computer simulation and in one case savings were directly measured in a before/after fashion.

Whole-home energy savings estimates derived by computer simulation ranged from a high 27%, in the home requiring the greatest amount of renovation, to a low of 1% in the home with a light-colored shingle roof replacement. Cooling energy savings was also analyzed as it typically makes up the largest single subset of whole-home energy use in Central Florida. Cooling savings derived from the computer model ranged from 3% to 45% and, as in the case of whole home energy, was directly impacted by the level of home repair. Measured data obtained from one home showed a 19% reduction in cooling energy use after the dark shingle roof was replaced with white metal. This fell roughly in line with computer estimated cooling savings of 16%.

Table of Contents

1.0 Introduction

The hurricane season of 2004 was one of the most active in recent history and hit the Central Florida region especially hard with three major storms out of the 14 named weather events. One storm, Frances, took a path rarely taken by previous hurricanes; making landfall in Melbourne area and heading west-northwest across the state, turning north on the western coast and moving northward through the Tallahassee region (Fig 1).

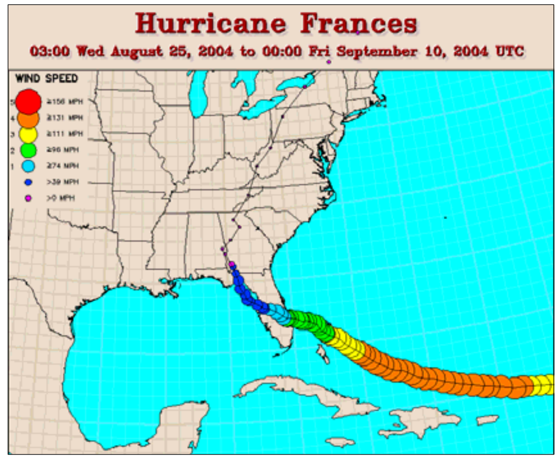


Figure 1 Path of Hurricane Frances 2004

Many homes in east central Florida suffered serious damage from three hurricanes in the summer of 2004. This study documents the energy impact of retrofit options performed on four homes damaged primarily by wind and wind-driven rain. Measured and predicted energy use data are presented as well as installed costs as reported by the homeowners. These homes offer a range of retrofit options providing data on costs and benefits of effective retrofit strategies for hot-humid climates.

Envelope and duct tightness tests were performed both before and after renovations to improve energy evaluations and show any impact the retrofits may have had on these important home performance measurements. Post-retrofit testing, and in some cases monitoring, helped determine the final performance level of each home. Test results, in conjunction with a home audit, provided the information needed for an energy analysis performed with hourly simulation software (Energy Gauge USA).

1.1 Home Performance Testing

Blower door and duct blaster tests were performed to establish airtightness levels. Where hurricane renovations were expected to impact leakage levels, testing was performed both before and after retrofits. Test results provided supportive inputs to the Energy Gauge USA energy analysis software for improved energy use and savings predictions.

Tests of the building envelope and duct system assist in the determination of air-transported moisture that can cause damage to building components, increase energy consumption and decrease occupant comfort. Three tests using a blower door and duct blaster were performed. The first test employs the blower door and establishes a leakage rate for the house at a specific pressure (air changes per hour at 50 pascals or ACH50). (250 Pascals is equal to 1 inch water column). The next two tests use the duct blaster and yield the leakage rate of the duct system in a similar manner (cubic feet per minute of air leakage at 25 pascals or CFM25). One test measures the total leakage from the duct system to the interior and exterior of the building (CFM25total) and the second test measures leakage to the exterior of the building only (CFM25out).

1.2 Simulated Energy Use and Savings Analysis

The U.S. Department of Energy (DOE) Residential Buildings Program developed the Building America Research Benchmark (Hendron, 2005) to track progress toward whole-house energy savings goals of 40-70% and onsite power production of up to 30%. The Benchmark is generally consistent with mid-1990s standard practice, as reflected in the Home Energy Rating System (HERS) Technical Guidelines (RESNET, 2002), with additional definitions for residential end-uses. A series of user profiles, intended to represent the behavior of a "standard" set of occupants, was created for use in conjunction with the Benchmark.

Energy Gauge USA software was used to determine performance of storm damaged homes relative to the Building America benchmark. In addition to whole-house energy, cooling energy was separately analyzed due to the high impact on this end-use afforded by the retrofit measures. Repairs on each case study home included roof cladding with cooler colors than were present before storm damage and in many cases improved attic insulation and/or sealing.

Table 1 Predicted Annual Total Energy Comparison

House	*BA Benchmark*	*Pre-retrofit*		*Post-retrofit*		
	kWh (*Therms*)*	kWh (*Therms*)*	Benchmark Savings	kWh (*Therms*)*	Benchmark Savings	Overall Savings
A	18,578	15,106	19%	13,234	29%	10%
B	20,223	17,414	14%	16,487	19%	5%
C	15,082 (*339*)	13,305 (*309*)	11%	13,171 (*312*)	12%	1%
D	13,681 (*267*)	13,940 (*368*)	-7%	14,040	20%	27%
*Homes C & D had gas heating and hot water prior to retrofit. House D converted to all electric at during remodeling.						

Table 2 Predicted Annual Cooling Energy Comparison

House	*Pre-retrofit (kWh)*	*Post-retrofit (kWh)*	*Cooling Savings*
A	4,294	3,372	21%
B	6,854	5,746	16%
C	5,005	4,870	3%
D	6,930	3,805	45%

2.0 Case Study Examination

Each home was evaluated to determine its relative performance in each of three areas: energy savings, comfort and indoor air quality. The four homes are presented here with a table describing the relevant pre-retrofit and post-retrofit construction details and homeowner-provided repair costs.

Up to three years of utility bills were collected for each home to provide additional documentation of energy use. These are presented as plots in Appendix A along with cooling degree day weather profiles. Multiple factors presented complications in using the utility data, thus no formal analysis was performed. Some of these factors included:

- All Homes experienced storm-related power outages during the months of August and September in 2004 with up to one third of the billing cycle being lost.

- Home A: while there was a noticeable energy reduction in 2005 over the previous two years this included the removal of an unknown amount of pool pumping energy (a potentially large energy end use).
- Home D: extensive damage in this home caused electric utility service to be shut down after the storm and not restored until June of 2006.

2.1 Home A

Predicted Annual Savings Against BA Benchmark	
Pre-retrofit	Post-retrofit
19%	29%

This home was constructed in 1963, and had concrete block walls enclosing approximately 1100 square feet of conditioned space. The roof over conditioned space was sloped at a 3:12 pitch and covered with shingles, while the garage had a flat roof covered with roll roofing. A previous owner added on to the home using wood frame construction to increase the conditioned space to 1740 square feet. Approximately 300 square feet of these additions were added with flat roofs. The current residents purchased the home in 2001, and did some minor remodeling including replacement of the home's air conditioning/heating system.

Most of the damage caused to the home during Hurricane Frances was due to failure of the roof covering subject to high winds, and subsequent rainwater intrusion. One flat roof section was stripped bare to the plywood decking, and there were a large amount of damaged and missing shingles. Extensive water stains were apparent on the ceiling drywall in every room when the homeowners regained access to the home after the storm. In two rooms, large holes eventually formed in the ceiling as the heavy, wet drywall failed under its own weight. A number of recessed can light fixtures and ceiling fans were also damaged due to the water. In addition, some of the water that leaked through the roof flowed down the trusses to where they meet the exterior concrete block walls, and flowed down behind the drywall where it pooled on the floor, ruining carpet and baseboards.

After an inspection by an insurance adjuster, the original plan was to replace the entire roof covering, any damaged roof decking, and to cut out and patch damaged areas of the ceiling and wall board. The long lead time encountered to get the roof replaced led to additional mold growth on the ceiling drywall. As a result, the owner decided to replace entire ceiling. Old blown in fiberglass and fiberglass batts were removed and the owner took advantage of this opportunity to converted the attic to an unvented type using BioBased foam. Rather than replace the roof covering with shingles that only have a life expectancy of 15-25 years, the owner decided to utilize white standing seam metal on pitched areas of the roof with a 50 year life expectancy. For the flat roof areas, rather than using a roll roofing, built up covering, or bituminous covering with a life expectancy of 5 years, the owner used a 10-year system that includes 1" of closed cell foam sprayed on the exterior of the flat roof decking which was then covered by reflective silver colored, spray applied, coating to protect the foam from UV deterioration.

In addition, 85% of the existing incandescent lighting was converted to fluorescent by removing all recessed can lights and installing Energy Star Gossamer Wind ceiling fans with light kits and other Energy Star fixtures and bulbs. Damaged carpet was replaced with laminate cork flooring.

The small, 4000 gallon swimming pool received some damage from the storm debris and, with the owners expecting a new baby and lack of previous use, decided to remove the pool. Therefore there was little to no energy used for pool pumping from 9/04 on.

Table 3 Home A Construction Details

	Pre-Retrofit	Post-Retrofit
Construction date	1963	
Construction type	Concrete block (and 2x4 frame)	
Floor type / Area (ft^2)	Slab-on-grade / 1,740	
Attic / Roof type	Vented / Grey shingle	Sealed / White metal / Silver foam
Window type	Single-pane / Clear / Aluminum	
Glass/Floor Area	33%	
Insulation attic/wall/floor	R16 / R4 (R11) / R0	R-20 / R-4 (R11) / R-0
Exterior wall cladding	stucco	
Air Conditioner	3-ton, 14 SEER, heat pump	
Thermostat	Programmable	
Ventilation type/amount	none	OA duct installed – not connected
Water heater	Electric, 50 gal, EF 0.88	
Other appliances	Refrigerator, Dishwasher, Clothes dryer, Clothes Washer	
Fluorescent lighting	5%	85%
Occupancy	2	3 (as of 9/05)
Infiltration (ACH50)	9.9	6.0
Duct leakage (CFM25, total/out)	164/124	80/58
Pool pumping	240 V	None

2.1.1 Post-retrofit Energy Savings

Primary improvements expected to result in energy savings include the choice of a more reflective, roof covering, creation of an unvented attic that brought the ductwork inside conditioned space, and use of primarily fluorescent rather than incandescent lighting. Removal of the swimming pool was also expected to result in some energy savings. These improvements are reflected in the utility bill history plot for Home A in the appendix when comparing the post-retrofit energy use in 2005 with the pre-retrofit numbers. A formal analysis of utility bill data was not performed due to the removal of unknown pool pumping energy (potentially large energy user).

2.1.2 Material Costs

The roof was supplied and installed by a roofing contractor. The standing seam metal panels were 16" wide galvalume coated with a Fluoroceram coating containing 70% Kynar 500 or Hylar 5000 PVDF resin. The coating has a 20 year warranty. The metal was installed over 1x2 battens and synthetic underlayment was used. A self-adhering underlayment was used on a portion of the deck. The flat roof covering consisted of 1" of polyurethane closed cell spray foam covered with a thin layer of an elastomeric acrylic coating for UV resistance.

Table 4 Home A Contractor Installed Roofing Costs

Remove existing roof; install underlayment, battens, drip edge, flashings, boots, vent & ridge cap; install metal roof on pitched areas	*Price not broken down*
Install foam roof system on flat areas	
Total	**$ 14,025**

The homeowner obtained several other roofing estimates from different contractors for a similar overall scope with varying materials.

Table 5 Home A Roofing Estimates

30 year dimensional shingles and mod-bit granulated for flat	$8,440
Aluminum standing seam metal and Bidimit for flat	$16,448
30 year dimensional shingles and mod-bit granulated for flat	$11,300
Standing seam metal and mod-bit granulated for flat	$16,500
5-vee metal and mod-bit granulated for flat	$15,300

A single vendor was used for installation of spray foam to create an unvented attic.

Table 6 Home A Contractor Installed Insulation Costs

5 ½ inches (R-22) BioBased foam under pitched roof ($1.65/sqft)	1,925
3 ½ inches (R-14) BioBased foam under flat roof ($1.40/sqft)	433
3 ½ inches (R-14) BioBased foam under flat roof ($1.40/sqft)	135
Total	**$ 2,493**
Some spray foam was also used to replace damaged insulation in wood frame exterior walls.	

The homeowners purchased their own ceiling fans and lights and utilized an electrician to re-wire for lighting location changes and install the fans and fixtures.

Table 7 Home A Lighting Costs

Electrical labor	$622
7 Gossamer Wind Ceiling fans with fluorescent light kits	$1183
Other fluorescent fixtures and bulbs	$150
Total	**$ 1,955**

2.1.3 Opportunities For Enhanced Comfort

The homeowners report a slight improvement in overall comfort after the retrofit and slightly better humidity control. It is expected that this is experienced as a result of the unvented attic providing more even temperature distribution throughout this older home, and reducing uncontrolled air infiltration, as demonstrated by pre and post envelope testing. The white metal roof and unvented attic also provide for lower indoor air temperatures during spring and fall, reducing reliance on air conditioning.

2.1.4 Assessment Of Indoor Air Quality

It is expected, although not quantified, that indoor air quality in this home post retrofit is better than pre-retrofit. The homeowners have reported less "dust" present in the home, presumably from the unvented attic reducing uncontrolled air flow. Although no duct sealing was conducted, the unvented attic brings the ductwork within the home's air and thermal boundaries and reduces the effect of existing duct leakage on space depressurization and subsequent uncontrolled air infiltration. In addition, the use of hard surface flooring in place of carpet is likely to reduce the presence of dust and dust mites. Lastly, the entire home needed to be repainted, the homeowners used paint classified as containing "low" and "zero" volatile organic compounds (VOC).

The use of the unvented attic which reduced the Air Changes Per Hour at 50 pascals (ACH50) from 10 down to 6 has caused the homeowner to consider adding mechanical ventilation for better perceived indoor air quality. The owner has also been considering the addition of supplemental dehumidification for enhanced comfort. Spot ventilation is present via bath fans, windows, and exterior vented kitchen range hood to remove intermittent sources of humidity, but it is rarely used. The owner has purchased equipment and installed necessary ductwork to implement the mechanical ventilation / supplemental dehumidification scheme shown in the following figure, but has not yet made the scheme operational.

Table 8 Home A Mechanical Ventilation / Supplemental Dehumidification Costs

50 pint per day dehumidifier	180
6" flex duct – 25 feet	41
10" x 10" ductboard box	12
10" x 10" filter back grill w/pleated filter	21
6" duct collar with manual damper	8
homeowner purchased **Total**	**$ 262**

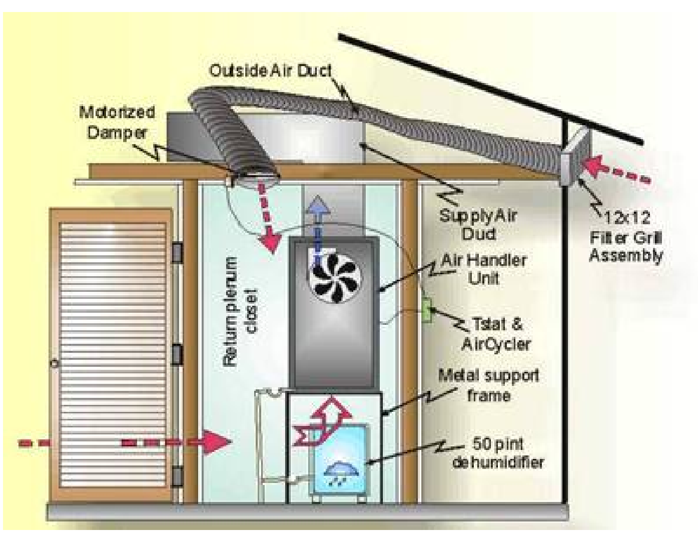


Figure 2 Dehumidified Return Plenum w/AirCycler Control

2.2 Home B


Predicted Annual Savings Against BA Benchmark	
Pre-retrofit	Post-retrofit
14%	19%

This 1,700 square foot home in Cocoa, Florida was damaged by hurricanes Frances and Jeanne. A white metal roof was chosen to replace the damaged shingles to reflect summer heat and thereby reduce cooling energy use. The shingles were not removed but left in place below the newly installed metal.

Table 9 Home B Construction and Testing Details

	Pre-Retrofit	Post-Retrofit
Construction date	1991	
Construction type	Wood-frame	
Floor type / Area (ft^2)	Slab-on-grade / 1,710	
Attic / Roof type	Vented / Dark shingle	Vented / White metal
Window type	Single-pane / Clear / Aluminum	
Glass/Floor Area	16%	
Insulation attic/wall/floor	R19 / R11 / R0	
Exterior wall cladding	Natural cedar (med-dark)	
Air Conditioner	3-ton, 9 SEER, heat pump	
Thermostat	Standard	
Ventilation	None	
Water heater	Active Solar, electric backup	
Energy Star appliances	H-axis Clothes washer	
Other appliances	Refrigerator, Dishwasher, Clothes dryer	
Fluorescent lighting	30%	
Occupancy	6	
Infiltration (ACH50)	7.0	
Duct leakage (CFM25, total/out)	250/180	

2.2.1 Post-retrofit Energy Savings

A before/after energy comparison was made possible with monitored data collected at the home in 2004 and 2005. Indoor, outdoor and attic temperatures along with air conditioner energy use and runtime were analyzed to assess performance.

Table 10 Home B Measured 9-Week Performance Highlights (June 25 – August 31)

	Dark Shingle 2004	White Metal 2005	Reduction	% Savings
Cooling Energy (kWh)	2,170	1,749	420	
Cooling Cost (@ $0.10/kWh)	$217	$175	$42	19%
Avg. Peak Attic Temp (°F)	111°F	96°F	15°F	
Avg. Peak Ambient Temp (°F)	89.4°F	88.6°F	0.8°F	
Notes: Energy estimate based on linear fit accounting for ambient temperature difference				

A nine-week period in the summer of 2005 show the white metal roof providing a 19% savings in air conditioner energy over the same period in 2004 when shingles were in place. Similar savings were seen in a more rigorous 2002 study comparing side-by-side homes in Ft. Myers, Florida. (Parker, Sonne, and Sherwin 2002)

Figure 3 shows the effect on cooling energy use by plotting daily air conditioner energy against the difference in indoor and outdoor temperature. This approach helps account for the difference in average outdoor temperature between 2004 (79.5°F) and 2005 (82.5°F).

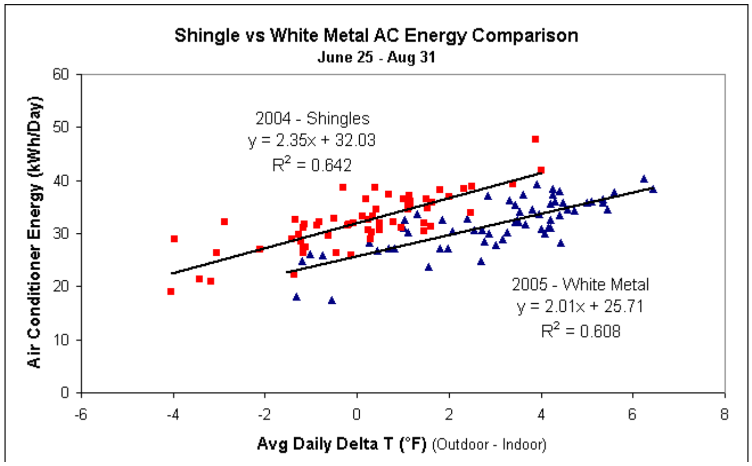


Figure 3 Shingle vs. White Metal

The average-day plot (figure 4) illustrates the effect of the white roof on attic temperature and cooling power. In this plot, average values of temperature and power for each hour over the 9-week data period result in an "average" 24 hour profile. The attic is noticeably cooler under the white metal roof (15°F at peak) during the day but is actually warmer at night, due to the warmer nighttime temperatures in 2005.

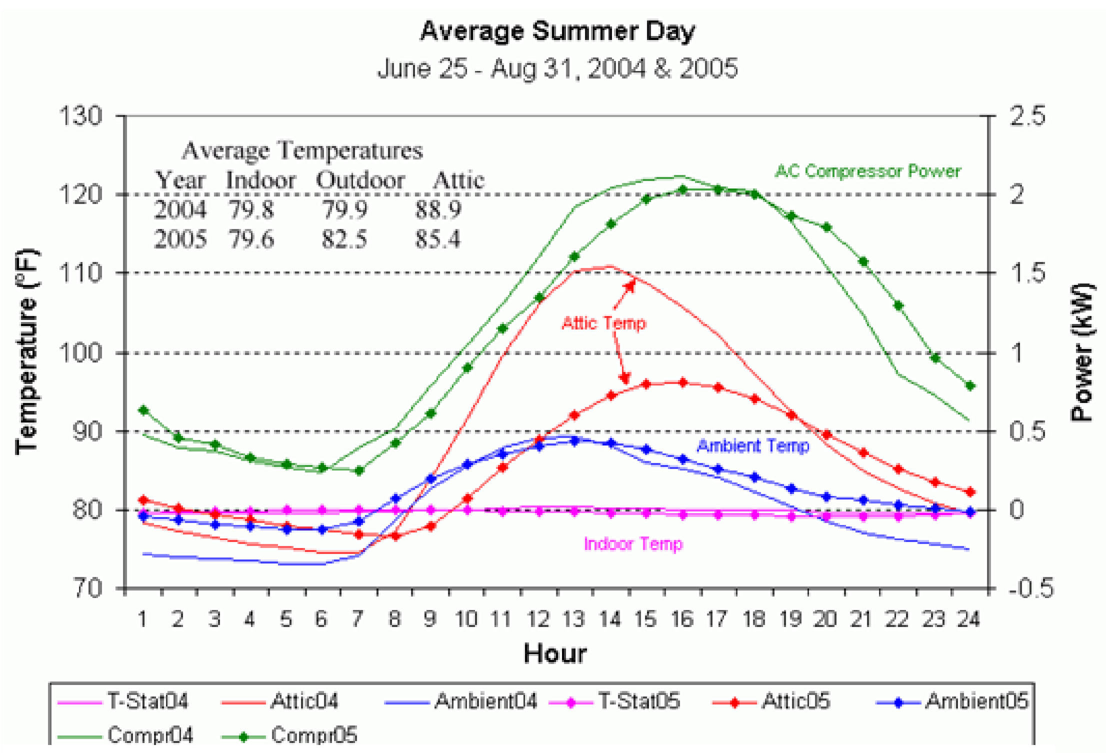


Figure 4 Average Summer Conditions

2.2.2 Material Costs

The new roof was purchased and installed by the homeowner. A three foot wide, exposed fastener, steel panel proved the most economical choice that included galvalume substrate and Kynar paint finish. Galvalume is an aluminum-zinc alloy that has shown improved performance over galvanized roofing in tests conducted by BIEC International. Kynar is a fluoropolymer paint available through many manufacturers and reputed to outlast siliconized polyester based paints. Warranties were found to be generally longer on Galvalume and Kynar products than with typical galvanized metal panels. The product purchased for this project came with a 40-year warranty on the finish.

Table 11 Home B Metal Roofing Costs – Material Only

26 ga, 3 ft, exposed fastener, Galvalume panel w/ Kynar paint (includes flashing, gutters and screws)	4,100 sqft	$ 6,300
Synthetic Underlayment (5 - 1,000 sqft rolls)	5,000 sqft	$ 750
Skylight Flashing	2	$ 150
Caulk & Pipe Boots		$ 200
homeowner purchased	**Total**	**$ 7,400**

The shingle replacement estimate provided by the insurance adjuster included all material and labor costs with a 29% profit margin and special increases associated with post-disaster market conditions.

Table 12 Home B Estimated Shingle Replacement Cost – Material + Labor

(includes “special market conditions” increase)		
Dimensional Shingle	3,900 sqft	$ 6,500
30lb Felt Underlayment		$ 550
Miscellaneous flashing/boots		$ 700
Labor (including shingle removal)		$ 4,200
	Total	**$11,950**

The cost comparison shown here is an isolated example in a local market impacted by conditions following unusual hurricane activity. Material and labor price instability are expected under such circumstances and will certainly vary from one situation to another but are presented here for comparison purposes.

2.2.3 Economic and Other Benefits

While metal and shingle roofing costs vary with choice of material and difficulty of installation, metal roofing is generally more expensive than shingles. The energy savings shown here would take many years to offset the increased cost of metal but other benefits to consider include:

- Lasts about 3 time longer (50 yrs vs. 17 yrs)
- Resists harsh weather, wind and fire
- Possible insurance discounts to homeowners (none in this case)
- Minimum 25% recycled content (as high as 50%)
- 100% recyclable at end of useful life

Sources: http://www.metalroofing.com/ (Metal Roofing Alliance)
http://www.wbdg.org (National Institute of Building Science)

2.2.4 Installation

Codes in many jurisdictions allow for at least two layers of roofing material before removal of existing cladding is required. The determining factor for removal is the weight of material and metal roofing meets the requirements with less difficulty as it is far lighter than shingles on a per square foot basis. Shingle removal is labor intensive and the material must be hauled away. The existing shingles, in this case, were left in place since damage was limited to individual shingle tabs and there was no major exposure of underlayment or roof decking.

Two options were considered for installing metal over shingles: (1) install 1x4 purlins or battens over the shingles prior to affixing the metal, and (2) install new underlayment over the shingles and then affix the metal panels directly to the shingles. In either case, manufacturer's recommendations should be followed as some products are designed for installation over solid decking while others can be installed on open framing. For this project, 5-foot wide synthetic underlayment was nailed to the shingles followed by fastening of the metal panels. The major drawback of this approach was a marked increase in "oil-canning", a common imperfection in metal roofing related to wrinkling of the panels upon installation. While some amount of oil-canning can be expected in any installation its presence does not generally influence performance.

2.2.5 Opportunities for Enhanced Comfort

An average peak attic temperature 15°F lower than before the retrofit is expected to provide cooler peak interior temperatures during future power outages when air conditioning is unavailable.

2.2.6 Assessment of Indoor Air Quality

The retrofit is expected to have little or no impact on indoor air quality.

2.3 Home C

Predicted Annual Savings Against BA Benchmark	
Pre-retrofit	Post-retrofit
11%	12%

This 1, 960 square foot home in Rockledge, Florida was the least damaged of the four houses chosen in this evaluation. There were loss of shingles, but only a small amount of water actually came through to the ceiling. The damage to the ceiling was slight and when allowed to dry, only needed to be repainted. The fiberglass insulation in the attic was not affected either. The replacement roof for this home was purchased and installed by the homeowner. The original dark, 3-tab asphalt shingles were removed and replaced with white ones.

Table 13 Home C Construction Details

	Pre-Retrofit	Post-Retrofit
Construction date	1987	
Construction type	Wood-frame	
Floor type / Area (ft^2)	Slab-on-grade / 1,960	
Attic / Roof type	Vented / Dark shingle	Vented / White shingles
Window type	Single-pane / Clear / Aluminum	
Glass/Floor Area	10%	
Insulation attic/wall/floor	R19 / R4 / R0	
Exterior wall cladding	Stucco	
Air Conditioner	4-ton, 10SEER, straight cool	
Heating	0.67 AFUE Natural gas furnace	
Thermostat	Standard	
Ventilation	None	
Water heater	34KBtu Natural gas 40 gallon (tank)	
Other appliances	Refrigerator, Dishwasher	
Fluorescent lighting	10%	
Occupancy	2 to 3	
Infiltration (ACH50)	6.0	
Duct leakage (CFM25, total/out)	233 /199	

2.3.1 Post-retrofit Energy Savings

A small amount of energy savings are expected as a direct result of replacing the dark asphalt shingles with lighter colored ones. Payback on such a measure is immediate however, as this is considered a no-cost upgrade. An estimated 3% of annual cooling costs will be saved with this retrofit measure. Similar savings were seen in a more rigorous 2002 study comparing side-by-side homes in Ft. Myers, Florida. (Parker, Sonne, and Sherwin 2002)

2.3.2 Material Costs

The following cost breakdown was provided by the homeowner who purchased and installed the new roof.

Table 14 Home C Shingle Roofing Costs – Material Only

3-tab Asphalt Shingles (White)	3,000 sqft	$ 1,410
15# Felt Underlayment	3,000 sqft	$ 255
Delivery & Taxes		$ 350
Other Material		$ 1,350
Day Labor		$ 1,170
homeowner purchased	**Total**	**$ 4,535**

2.3.3 Opportunities For Enhanced Comfort

Slightly lower attic temperatures are expected with the white shingle roof installed. The average maximum attic temperature was 6.6°F lower than the dark shingle base case in the Ft. Myers study mentioned above. During future power outages this may translate into cooler interior peak temperatures while air conditioning is unavailable.

2.3.4 Assessment Of Indoor Air Quality

The retrofit is expected to have little or no impact on indoor air quality.

2.4 Home D

Predicted Annual Savings Against BA Benchmark	
Pre-retrofit	Post-retrofit
-7.5%	20%

This home was the most severely damaged of the four buildings in the analysis. A section of the rear portion of the roof was destroyed allowing water to enter into the dwelling which resulted in severe damage to the interior. As a result, the interior had to be completely demolished and rebuilt per recommendations. This retrofit included light roof color, unvented or sealed attic, sealed air distribution system, higher efficient heating and cooling system and double pane low-e windows. In addition, the gas water heater that was located within the conditioned space was replaced by an electric unit (there were 2 primary reasons for the replacement -1) age of the unit and 2) the electric unit did not require combustion/dilution air).

Table 15 Home D Construction Details

	Pre-Retrofit	**Post-Retrofit**
Construction date	1966	
Construction type	Concrete block	
Floor type / Area (ft^2)	Slab-on-grade / 1,440	Slab-on-grade / 1590
Attic / Roof type	Vented / Dark fiberglass composite panel	Sealed / Light fiberglass composite panel
Window type	Single / Clear / Aluminum	Dbl-pane / Clear / Aluminum
Glass/Floor Area	12%	
Insulation attic/wall/floor	R11 / R0 / R0	R20 / R0 / R0
Exterior wall cladding	Painted block	
Air Conditioner	2.5-ton, 8SEER, straight-cool	3-ton, 13SEER, heat pump
Thermostat	Standard	programmable
Ventilation	None	
Water heater	40 gal Natural gas	40 gal Electric
Other appliances	Refrigerator, Dishwasher, Clothes dryer	
Fluorescent lighting	10%	
Occupancy	2	
Infiltration (ACH50)	7.5 *estimated*	5.0
Duct leakage (CFM25, total/out)	220/175 *estimated*	32/0

The homeowner opted to slightly increase the conditioned floor space by incorporating the small storage area (part of the original attached garage) in the front of house as part of the living area. This was an increase of approximately 150 square feet (1500 cubic feet of volume).

2.4.1 Post-retrofit Energy Savings

As a result of considering opportunities for energy efficiency during the retrofit process, the owners expected to experience lower utility bills as a result of their repair decisions. Primary improvements that were expected to result in energy savings include the choice of a more reflective, energy efficient roof covering, creation of an unvented attic that brought the ductwork inside conditioned space, and increased heating and air conditioned equipment efficiency.

Table 16 Home D Contractor Installed Roofing Costs

Remove existing roof	*Price not broken down*
Apply synthetic underlayment	
Apply batten system	
Install drip edge, flashings, boots, kitchen vent and ridge cap	
Install light fiberglass composite panel roof	
Total (approximate)	**$ 15,000**

Figure 5 Finished light colored composite roof panels installed

Table 17 Home D Contractor Installed Insulation Costs

5 ½ inches (R-22) Icynene™ foam under pitched roof (~$2/sqft)	$3180
Total	**$ NC**
Material and labor costs were donated by Icynene to research post retrofit energy consumption	

Figure 6 Sealed attic with spray foam insulation (Icynene™). Note the duct work is below the insulation, which places it within the air & thermal boundaries.

Table 18 Home D Contractor Installed HVAC Costs

Remove existing system	*Price not broken down*
New sealed air distribution system	
New heat pump	
Total (approximate)	**$ 6000**

Table 19 Home D Contractor Installed Envelope and Other Improvement Costs

New electric water heater	500
Interior renovation (walls, floors and cabinets)	6000
New windows (dbl pane clear)	3,500
Total (approximate)	**$ 9,500**

2.4.2 Opportunities For Enhanced Comfort

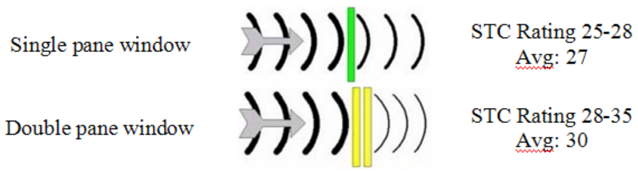


Figure 7 www.soundproofwindows.com/comparison.html

This home is in the final stages of remodeling. The homeowners have had a long uphill battle with insurance issues, finances and contractors. It is hoped that by late summer or early fall of 2006, the home will finally be finished (at the time of this report, the drywall has been hung and taped). Comfort enhancements will include some sound control with the installation of the double pane windows (figure 7) and a slight increase in the thermal losses, especially in the winter months.

The new heat pump and tight duct work should provide more uniform temperature and humidity control throughout the house. The new system is now totally within the thermal and air boundaries of the building. The coolest air no longer needs to pass through the hottest portion of the house (attic) as it is delivered to the rooms. In addition, there appeared to be a fairly large return side leak to the air handler in the old system. The air associated with that leak was pulled directly from the attic space. (The system was not tested because of water damage to the structure.)

Slightly lower attic temperatures are expected with the white shingle roof installed. The average maximum attic temperature was 6.6°F lower than the dark shingle base case in the Ft. Myers study mentioned above. During future power outages this may translate into cooler interior peak temperatures while air conditioning is unavailable.

2.4.3 Assessment Of Indoor Air Quality

The removal of the gas appliances from within the conditioned space and converting the vented attic space to an unvented attic eliminates the sources of potential pollutants (combustion gases, moisture, insulation particles, and various dust particles. Also, there should be enhanced humidity control since the new unit is not able to pull hot humid attic air into the return air stream.

3.0 Conclusions

Home repairs necessitated by storm damage offer an excellent opportunity to reduce energy use, improve comfort and enhance resistance to future storms. An excellent example is reroofing, a repair required by each of the case study homes. This is a common post-hurricane repair that, with the right material choice, can reduce summertime cooling costs as well as improve indoor conditions during future power outages. A decade of research at the Florida Solar Energy Center clearly shows that a white reflective tile or metal roof can reduce space-cooling loads by 20% or more. Each case study home took advantage of roof cladding with a higher reflectance than the original.

Energy savings from storm repairs on four homes were estimated through detailed computer simulation and in one case measured directly in a before/after fashion. Computer-derived Whole-home energy savings ranged from a high of 27%, in the most extensively renovated home, to a low of 1% in the home with a light-colored shingle roof replacement. Cooling energy was also analyzed as it typically makes up the largest single end use of whole-home energy consumption in Central Florida. Cooling savings derived from the computer model ranged from 3% to 45% and, as in the case of whole home energy, was directly impacted by the level of home repair. Measured data obtained from one home showed a 19% reduction in cooling energy use after the dark shingle roof was replaced with white metal. This fell roughly in line with computer estimated cooling savings of 16%.

Up to three years of utility bills were collected for each home to provide additional documentation of energy use. These are presented as plots in Appendix A along with cooling degree day weather profiles. Multiple factors presented complications in using the utility data, thus no formal analysis was performed.

4.0 References/Resources

Parker, D., Sonne, J., Sherwin, J., "Comparative Evaluation of the Impact of Roofing Systems on Residential Cooling Energy Demand in Florida," Proceedings of ACEEE 2002 Summer Study, American Council for an Energy Efficient Economy, Washington, DC, August 2002. (http://www.fsec.ucf.edu/bldg/pubs/coolroof/)

http://www.eere.energy.gov/buildings/disaster_recovery/dr_consumers.html

http://www.homeenergy.org/katrina.html

Operation Fresh Start is a project of the National Center for Appropriate Technology (NCAT). It began in 1997 with support from the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) in response to 1997 flooding in Red River, North Dakota. http://freshstart.ncat.org/rebuild.htm

Hendron, R. (2005). Building America Research Benchmark Definition, Version 3.1, Updated July 14, 2004. 40 pp.; NREL/TP-550-36429.

Residential Energy Services Network (RESNET). 2002. “Mortgage Industry National Home Energy Rating Systems Accreditation Standards.” Chapter 3, pp. 29-54. San Diego, CA: RESNET.

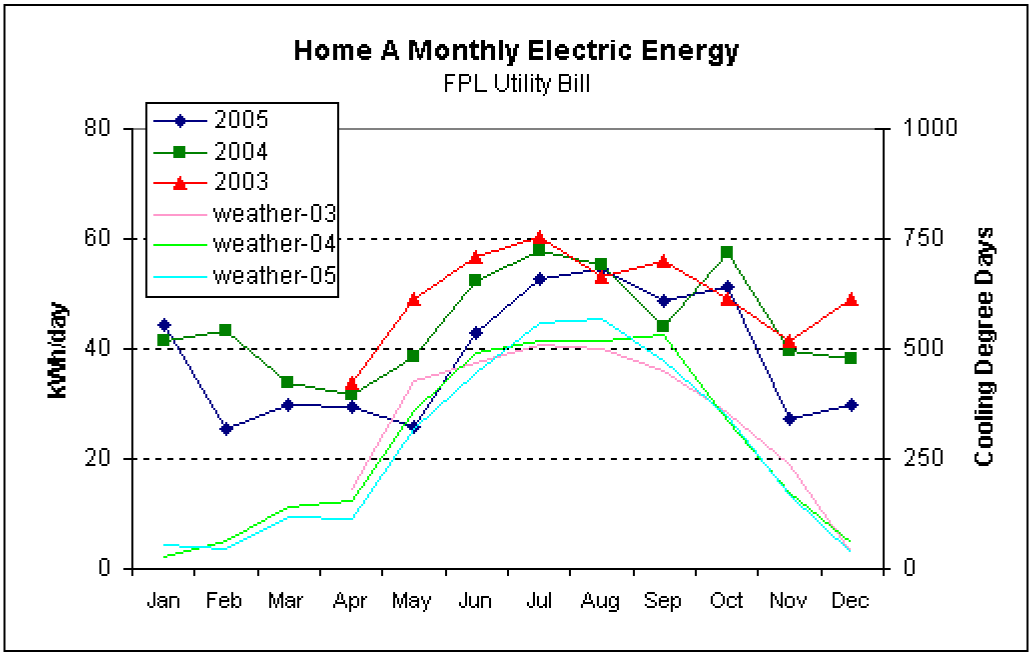
5.0 Acknowledgement

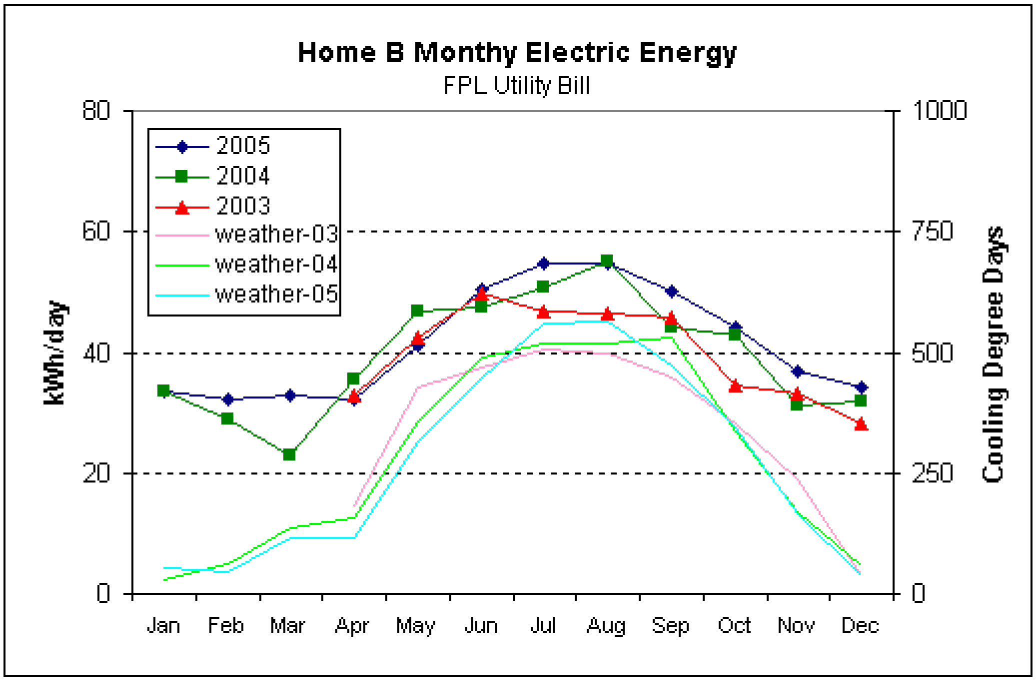
This work is sponsored, in large part, by the US Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, Buildings Technologies Program under cooperative agreement number DE-FC26-99GO10478. This support does not constitute an endorsement by DOE of the views expressed in this report.

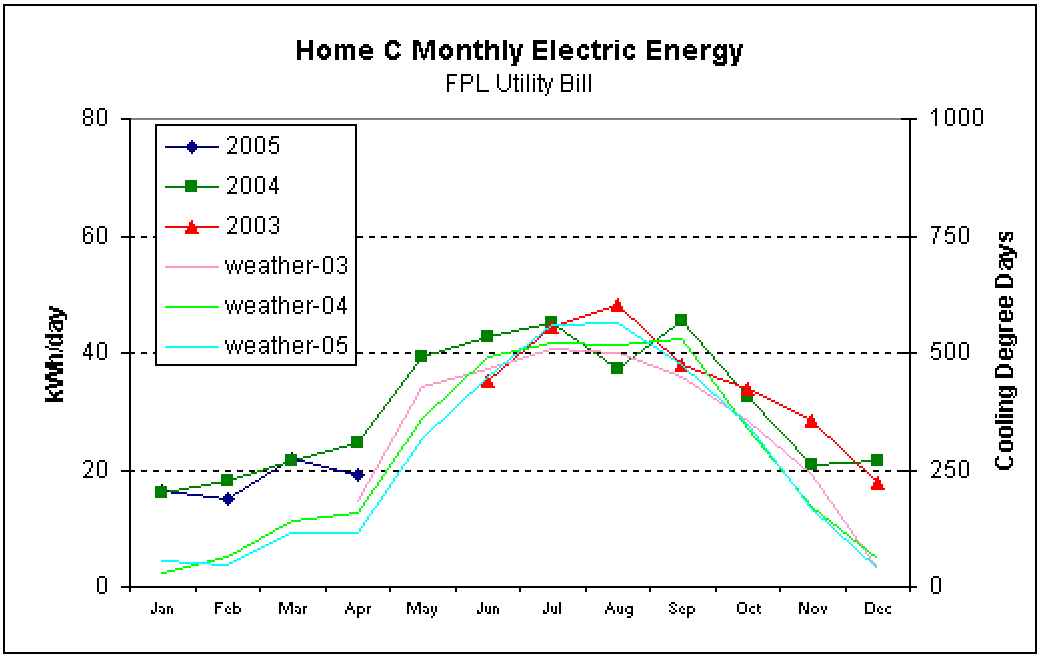
The authors appreciate the encouragement and support from the homeowners who provided their homes and Mr.Terry Logee, Mr. George James, Mr. Ed Pollock, and Mr. William Haslebacher of the US Dept of Energy.

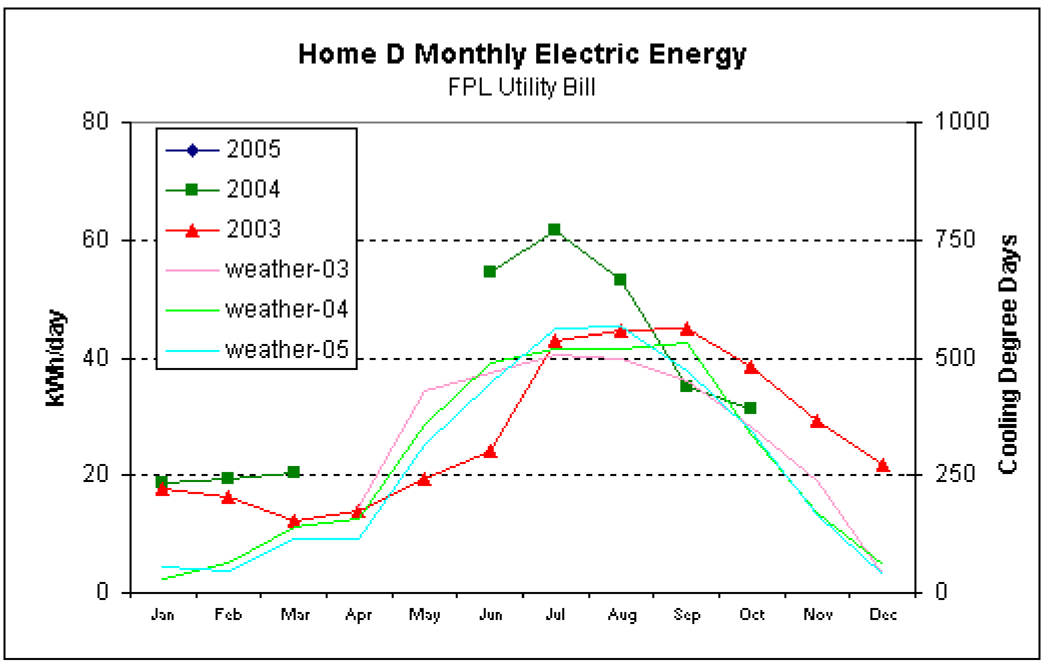
6.0 Disclaimer

Appendix A: Utility Bill Comparison






Home C Monthly Electric Energy
FPL Utility Bill
kWh/day
Cooling Degree Days
80
60
40
20
0
1000
750
500
250
0
2005
2004
2003
weather-03
weather-04
weather-05
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Home D Monthly Electric Energy
FPL Utility Bill
kWh/day
Cooling Degree Days
80
60
40
20
0
1000
750
500
250
0
2005
2004
2003
weather-03
weather-04
weather-05
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec