MEASURED ENERGY SAVINGS FROM RETROFITS INSTALLED IN LOW-INCOME HOUSING IN A HOT AND HUMID CLIMATE

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ABSTRACT

The Florida Solar Energy Center (FSEC) is metering energy use in a Habitat for Humanity housing development. The objective is to understand the way in which energy is used in low income housing and how it can be effectively reduced.

The ten homes come from a conventional housing project built by in 1993 Habitat for Humanity in Homestead, Florida. The instrumentation was installed in thehomes in July of 1994 with over three years of 15-minute data collected on all sites. Data were obtained on seven electrical end-uses (air conditioning, heating, hot water, dryer, range, refrigerator, washer/freezer) as well as total. Weather conditions were also monitored as well as interior comfort conditions (temperature and humidity) and hot water consumption and window ventilation status. Baseline field data from a year of monitoring from the ten homes allowed unique insight into how energy is used in low income housing and suggested where consumption might be reduced.

In April of 1997, a series of detailed retrofits were applied to eight of the ten Habitat homes. These included solar water heaters installed in seven homes. In eight homes we retrofit light fixtures to compact fluorescent types, repaired and sealed duct air distribution systems, cleaned refrigerator coils and installed low-flow showerheads. Since each of he associated energy end-uses (including hot water consumption) is metered, we are able to assess the relative performance of each of the retrofits. We also measured of air conditioner performance and house tightness. These audits revealed numerous problems, but low-evaporator coil air flow was discovered in all homes. The paper describes the retrofit installation, audit data collected and the impact on measured energy consumption. Preliminary economics are explored.

INTRODUCTION

Verifying realized savings from weatherization programs is a continuing issue. Although there have been numerous evaluations, most have been of a programmatic type in which only the impact of collective measures can be determined (Hirst et al., 1989; Brown et al., 1994). In other cases, the influence of individual measures is estimated by statistical means from utility data and is necessarily inexact (e.g. Goldberg, 1986). A notable exception was an evaluation by Brown et al. (1989) which sub-metered the impact of water heating retrofit measures. Another was a study by Ternes and Levins (1992) which examined sub-metered impact of sealing and weatherization, air conditioner and radiant barrier retrofits in Oklahoma with some surprising results. However, no significant project of this type has been conducted in a hot and humid climate. The current study attempts to begin to remedy this gap in knowledge by examining the impact of a selected groups of retrofits applied to a group of ten intensively metered low-income homes.[1]

The homes are located in Florida City, just south of Homestead, Florida. Figure 1 shows one of the homes with a roof-top solar collector installed as part of the project. There are two similar building models in the project, both with simple rectangular floor plans. The houses with three bedrooms have a conditioned floor area of 1030 square feet; the four bedroom houses total 1190 ft^2. The construction is conventional for South Florida: concrete block on an uninsulated monolithic slab with an exterior light colored stucco finish. The homes generally face north or south with a small porch over the entrance. The roofs are of standard A-frame truss construction with ply-

[1] Originally, it had been anticipated that the homes would serve as a control group for a new Habitat development with very efficient construction. However, when this project did not come to fruition, we opted to install a series of energy saving retrofits in the homes already metered for a period of two years.

wood decking covered by asphalt shingles. The concrete block walls are insulated with R-3 $ft^2 \cdot hr \cdot °F/Btu$ insulation on the interior; the attic has R-19 fiberglass batts over the sheet rock ceiling. The windows are single glazed units with aluminum frames and are single-hung so that about 40% of their gross area can be opened for ventilation. Most of the homes' windows are located on north or south exposures.

Figure 1. A home with small roof-top solar collector installed.

The mechanical cooling system in the houses consists of 2.0-ton air conditioners in the three bedroom homes and 2.5-ton air conditioners in the four bedroom units. The split systems are conventional with an interior evaporator and air handler located in a small utility room. The air-cooled condenser is located outside with the R-22 refrigerant piping from the evaporator insulated to R-5 with foam insulation. The units have a rated seasonal energy efficiency ratio is 12.0 Btu/W. Heating is provided by 4.8 or 6.4 kW electric resistance elements located in the air handling unit.

The cooled air is distributed through a duct system in the attic to ceiling mounted supply registers. The air distribution system consists of approximately 50 ft of R-5 flex duct. Thermostat control is located in the interior hallway on an interior wall. The slide type thermostat has a set range from 50 - 90°F with two toggle switches for mode selection (heating/off/cooling). The fan mode selection has two modes: "on" where the fan runs constantly regardless of the compressor operation and "auto" in which the fan operates only when the heat strips or compressor are energized.

The major appliances in each home are: a 40 gallon electric resistance storage water heater, an 18 ft^3 refrigerator, an electric clothes dryer, range, and a washing machine. Several homeowners have added a chest freezer. Except for the refrigerator, all the appliances are located in a small conditioned utility room. Lighting in the homes is of the conventional incandescent type. Typical minor appliances include a living room ceiling fan, microwave oven, video cassette recorder, television, and stereo.

The occupant density is fairly high; whereas occupants number 2.4 in the average Florida household, the Habitat homes have an average of 4.6 members. The households vary from a maximum of eight occupants per home to a minimum of three and all have one or more children of varying ages. Although income information is not available, Habitat for Humanity's mission is to provide affordable housing for low-income families. Each household has been in residence for two years or more and although the homeowners have an interest free mortgage payment for their homes, they are responsible for payment of their monthly utility bills. We found the head of household at each house to be very aware of their monthly utility expenses. At least one family (House 4) has only very limited prior experience with air conditioning systems.

ENERGY MONITORING

In April, of 1994, the homeowners were interviewed after which multi-channel data loggers and associated metering equipment was installed. Site data collection system began in mid-July, 1994. Detailed performance data included energy use of all major appliances, meteorological conditions and interior house conditions such as temperatures, water use and window ventilation status. The measured electrical end-uses included total household demand, air conditioner, air handler and strip heat, water heater, refrigerator, freezer and clothes dryer and washer. Miscellaneous electricity use for lighting and other plug loads were obtained by differencing the total recorded site electrical use from the recorded energy use of the various sub-metered major appliances. Data are transferred from the data loggers via modems and dedicated phone lines to the project mainframe computer each evening.

The energy use data from the project in its baseline condition and details on energy related occupant behavior has already been summarized in detail in a previous publication (Parker et. al., 1996a). Electricity consumption averaged 43 kWh/day in the homes with air conditioning making up approximately 40% of total use.

At the end of the cooling season, in December, 1994, the person primarily responsible for controlling the cooling system, was interviewed at each home. The interview questions were designed to provide detailed information about how the cooling systems are controlled as well as the occupant's reasons for operating the systems as they do. The results of the interview and facets learned about AC usage patterns have been covered elsewhere (Parker et al., 1996b). One of the major findings of the baseline data analysis was that 80% of the house-to-house variation in air conditioning consumption was accounted for the interior temperature maintained. For each degree (F°) which the thermostat was lowered below 81°, annual cooling energy rose by 12%.

RETROFITS

Energy systems in eight of the homes were altered. The specific retrofits included addition of water heating systems, sealing of duct return plenums, addition of low-flow showerheads, cleaning of refrigerator coils and substitution of compact fluorescent lighting for incandescent bulbs. All of the above items were retrofit in each household except for the solar water heating systems which were installed in seven homes. Table 1 shows how the retrofits were allocated.

The retrofits were primarily installed during the three day period from April 7th - 9th, 1997. Each house was examined by the team of three individuals performing the retrofits. The protocol is described in detail below.

RETURN DUCT SEALING

A blower door test was performed on each home to determine relative envelope leakiness. Test results are reproduced in Table 2.

Table 1
Installation of Retrofits

House No.	Solar DHW	Compact Fluorescent Lighting	Refrigerator Coils Cleaned	Duct Repair	Low Flow Showerheads
H1	X	X	X	X	X
H2	X	X	X	X	X
H3	-	-	-	-	-
H4	X	X	X	X	X
H5	X	X	X	X	X
H6	X	X	X	X	X
H7	-	-	-	-	-
H8	X	X	X	X	X
H9	X	X	X	X	X
H10	-	X	X	X	X

Table 2
Blower Door Test Results

Site	House Volume	CFM_{50}	ACH_{50}	Pressure Pan Tests (Pa)
H1	9520	1684	10.6	All registers < 05
H2	8240	1220	8.9	All registers < 0.5
H4	9520	2257	14.2*	All registers < 0.5
H5	9520	1324	8.3	Kitchen = 1.0; Other < 0.5
H6	8240	1121	8.2	Bath = 1.0; Others < 0.5
H8	8240	1735	12.6	All registers < 0.5
H9	8240	1085	7.9	All registers < 0.5
H10	8240	1311	9.5	All registers < 0.5

* Broken window in west side of home; hole in bathroom ceiling.

The duct system supply registers were tested using the pressure pan technique. Although not uniform, most of the duct systems were well sealed on the supply side. The same was not true on the return side, however. The individual duct system plenums were physically examined; all were found to contain large leakage to the unconditioned attic from gaps around the supply duct as it passed from the plenum to the attic and from wall cavities from the return plenum to the attic. These leaks were then sealed with tape and mastic – a job which took approximately 3 hours for each site.

AIR CONDITIONER PERFORMANCE

After this was complete, the *in situ* air conditioner (AC) performance was assessed using an established protocol (see Parker et al., 1997). The procedure uses the resistance heat method to evaluate evaporator dry coil air flow. AC performance was determined by measuring its electrical demand while examining the before and after coil enthalpy difference against the mass flow rate. A check on the latent heat removal was performed by taking a condensate measurement. The computed system EER was indexed against the outside temperature conditions (Table 3). In several instances dirty air filters were cleaned and in other cases redundant system filters were removed prior to the testing.

One of the tested AC units, (H8) was not operational when tested due to faulty thermostat wiring. This was repaired and then evaluated. The air conditioner in H4 operated very poorly and the occupants reported seldom using the air conditioner although sometimes operating the air handler fan. The unit showed evidence of severe refrigerant undercharge. All of the tested air conditioners had a nominal SEER of 12.4; the EER at the ARI 95/80/67 condition was 11.1 and 11.6 Btu/W for the 2 and 2.5 ton units, respectively. The audited EER of the units at lower ambient temperatures (but varying indoor temperatures) varied considerably from only 4.4 Btu/W for the poorly operating AC in House 4 up to 12.1 Btu/W for the air conditioner in House 6. It is significant that the air flow across the evaporator at H6 was the only unit to within 10% of the rated flow for the evaporator (400 cfm/ton) – a large factor in the differing performance of the audited units. It is also noteworthy that these flow rates were measured after filters had been changed and are dry coil air flows. Wet coil air flow is certain to be less.

One further cooling-related measure was installed in each home. Given the great influence observed in the baseline analysis with regard to the interior temperature maintained, an easily visible digital thermometer was attached just above the thermostat to provide feedback to the household members with regards to the temperatures maintained inside.

WATER HEATING

The upper and lower tank temperature settings of the water heater storage tanks were examined. In homes with add-on solar water heating system, the lower tank thermostat set point was set to 90°F to reduce lower element activation during ordinary hot water draws. Upper elements were set to 125°F. All of the homes had the same shower fixtures; one of these was measured to determine the flow rate with an open tap. The showerhead then were replaced with a low-flow model and the flow re-evaluated. Our testing revealed that the flow rate of 3.1 gallons per minute (gpm) with the standard showerhead and 2.5 gpm with the low-flow model – a 19% reduction

Table 3
AC Audit Performance Test Results

Site	Air Flow Actual/(Rated)	Sens. Cap.	Lat. Cap.	Total Capacity Actual/(Rated)†	Total Watts	EER Btu/W	T_{amb} °F	$T_{int, db}$ °F	$T_{int, wb}$ °F
H1	848 (1000)	20148	6107	26255 (30,200)	2214	11.86	80.0	70.2	59.7
H2	568 (800)	12698	5756	18454 (22,600)	1998	9.24	85.5	72.6	60.9
H4*	757 (1000)	8502	1053	9555 (30,200)	2185	4.37	85.0	82.6	68.8
H5	777 (1000)	12335	5714	18049 (30,200)	2202	8.20	84.1	76.5	64.0
H6	776 (800)	16510	6486	22996 (22,600)	1903	12.08	81.5	71.8	61.8
H8	582 (800)	12194	6135	18329 (22,600)	1941	9.44	86.0	79.8	67.8
H9	638 (800)	11920	6178	18098 (22,600)	1657	10.92	75.1	78.4	65.2
H10	658 (800)	8812	5419	14231 (22,600)	1807	7.88	82.8	75.3	62.9

* Measured refrigerant temperatures and pressures indicated severe under-charge of unit.
† Standard ARJ conditions (95 ° ODDB, 80 IDDB, 67 IDWB)

at full pressure. This result agrees closely with other laboratory and field assessments (SBW Consulting, 1994). However, the way in which flow and shower water consumption would vary with actual use conditions was unknown.[2]

REFRIGERATORS

All of the houses contain an identical 18 cubic ft top freezer refrigerator with a DOE estimated annual energy consumption of 697 kWh/year or about 1.9 kWh/day. During the audit, the freezer and refrigerator interior temperatures being measured by temperature probes that were inserted for an hour before being read. After this time, the refrigerator condenser coils (on the underside the refrigerator in the model used in the homes) were cleaned using a specially designed brush. If the refrigerator temperatures were between 35 and 40°F, they were unchanged; however, the freezer temperature were adjusted upwards if they were found to be lower than 5°F. None of the refrigerator fresh food compartment settings were altered; most were found warmer than expected and one refrigerator was not working properly.

LIGHTING

The lighting in each home was inventoried. All fixtures contained incandescent lamps of various wattages. The occupants were interviewed to learn which fixtures were used most. Based on this information, between seven and ten compatible fixtures were altered to compact fluorescent lamps (CFLs). In most cases an attempt was made to match the lumens output of the replaced incandescent fixture, although circumstances varied.[3] Outdoor porch fixtures - which occupants reported using these frequently - were all replaced. In certain cases the wattage of individual fixtures were increased since burned out incandescent lamps were replaced with CFLs. In several instances, frequently used fixtures were encountered which could not be replaced (e.g., dining room chandeliers).

The change in connected lighting load gives a relative indication of the potential reduction in lighting energy, but is necessarily inexact since savings will be strongly influenced by fixture utilization.

RESULTS

For analysis purposes we used a period of April 10th, 1997 - January 15th, 1998 over which to establish the post retrofit performance of each improvement. We used the year previous to the retrofit covering the same dates to establish the performance under baseline conditions. The baseline for assessing the influence of the solar water heaters was different for the four homes which had the solar system installed at an earlier time. Weather conditions in the two comparison years was similar. The average temperature over the two nine month pre and post periods were 76.8° and 76.7°, respectively.

Average saving for the duct sealing measure was 12% or 2.40 (± 2.39) kWh/day. The absolute savings were large: an impact of 880 kWh/year. However, the percentages savings from one house to the next varied from +27% (an increase) to a reduction of 35%. Much of the reasons for the variance have to do with thermostat behavior. House 1 and 6, which did not see savings had significantly lower thermostat settings in the post period. In spite of supplying highly visible digital thermometers just above the thermostats, there was little evidence that this influenced interior temperature preferences from one year to the next. A possible influence on the lower post period temperature preference at H1 was a change in occupancy (an infant was born and a family member passed away). An example of the recorded impact on time of day electricity use is given in Figure 2, which shows the average nine-month air conditioner load profile at H2 before and after the duct sealing and evaporator coil air flow enhancement. Savings are highest during day time hours when the AC operates frequently.

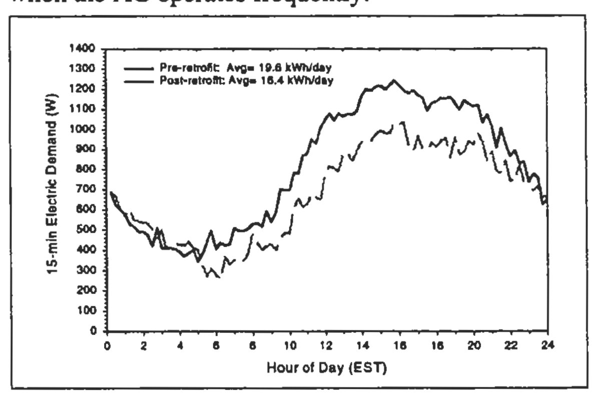

Figure 2. Measured impact of return duct sealing and evaporator air flow enhancement on AC load profile at House #2 from 1996 to 1998.

[2] Some have theorized showers with less flow may feel cooler resulting in more hot water use. Perhaps more importantly, we knew the altered hot water tank thermostat settings might tend to increase hot water use to achieved the desired mix temperature.

[3] Examining the light output of the CFLs, several occupants requested lower wattage CFLs for locations where they had previously placed 100 W bulbs because that was all they had available when re-lamping.

Table 4
Hot Water Retrofit Actions*

Number of Occupants	Site ID	Solar System Code	Collector (sqft)	Top Set (°F)	Bottom Set (°F)	Altered to ...
8	H1	SS-200-24	26	125	125	125° top, 90° bottom
4	H2	O-26-R	26	135	110	125° top; 90° bottom
7	H4	O-32-R	32	New Tank		125° top; 90° bottom
3	H5	SS-200-24	26	125	125	125° top; 110° bottom
5	H6	OPV-24/32	32	125	125	120° top; 110° bottom
3	H8	0-26-R	26	New Tank		125° top; 90° bottom
3	H9	SS-200-24	26	125	110	125° top; 90 °bottom
3	H10	None	None	120	120	120° top; 110° bottom

* All eight audited homes had low flow showerheads installed

Table 5
Refrigerator Audit Results

Site	Refrigerator Temperatures	Freezer Temperatures	Action
H1	41.4°	4.9°	Clean coils; no change
H2	43.0°	4.5°	Clean coils; no change
H4	43.5°	7.0°	Clean coils; no change*
H5	36.5°	-19.5°	Clean coils; set freezer up
H6	40.3°	0.7°	Clean coils, set freezer up slightly
H8	53.8°	14.2°	Clean coils; set lowest; no change**
H9	40.8°	4.2°	Clean coils; no change
H10	37.6°	-13.4°	Clean coils; set freezer up

* Refrigerator was over-filled-- particularly freezer; was already set lowest; coils completed faced over.

** Refrigerator was operating poorly, after cleaning coils the freezer temperature dropped in one hour to 3.8 °F and the refrigerator interior to 50.2°, although still deficient.

Table 6
Lighting Retrofit Audit

Site	Number Lamps*	Total Watts*	CFLs Installed	Change in Connected Load
H1	22	975	7	-300 W
H2	21	785	10	-615 W
H4	6	415	8	-59 W **
H5	11	815	9	-508 W
H6	36	1925	7	-395 W
H8	21	1230	10	-417 W
H9	11	640	8	-385 W
H10	11	555	7	-303 W

* This the number of operating lamps encountered along with their nominal wattage. In most cases there were some burned out lamps.

** A number of lamps in critical areas such as the kitchen were not working which were replaced with CFLs. This significantly reduced potential savings.

Table 7
Retrofit Results (kWh/Day)

Site No.	AC* Pre/Post	T° Interior Pre/Post	Hot Water† Pre/Post	DHW Pre/Post	Refrig. Pre/Post	Lighting Pre/Post	Total Pre/Post
H1	23.7/24.0	75.0/74.3	73/70	11.2/3.0	2.4/2.2	12.8/13.2	6.6/48.5
H2	19.6/16.4	77.9/78.2	95/123	14.2/8.7	3.0/3.2	11.3/9.3	57.7/46.9
H4	21.9/ 0.1	78.6/84.9	150/134	16.9/6.8	3.5/1.9	10.4/15.8	72.8/42.9
H5	17.4/13.4	77.4/77.8	47/41	4.3/1.3	2.3/2.4	3.8/3.3	31.6/26.8
H6	25.7/24.0	74.7/73.9	75/67	9.4/5.7	2.3/1.9	5.6/5.1	42.6/41.4
H8	35.9/23.3	75.2/75.0	46/38	8.9/0.8	3.2/2.2	7.9/3.3	48.8/33.9
H9	8.9 /11.3	79.1/79.2	16/16	2.6/0.4	2.0/2.1	4.8/5.2	18.1/19.9
H10	19.2/18.4	77.3/77.4	54/39	2.2/2.1	6.5/6.3	4.3/3.1	30.8/28.9
Average**	21.5/18/7	76.7/76.5	69/66	9.6/4.1	2.6/2.3	7.2/6.1	40.9/35.2

* Includes AH (fan and electric resistance elements) on the circuit ; both heating and cooling are summed.

** Averages for AC and total does not include H4 which did not use their air conditioner in the post period. Similarly, H4 is not included in the total for lighting since the change out of fixtures did not appreciably reduce the connected lighting load.

† Gallons per day.

Changing to low flow showerheads along with storage tank temperature adjustment reduced average hot water consumption by an average of 5% (4.3 gal/day) from the pre to post period, but with large variation and no statistical significance. The data suggest this measure was strongly affected by lowering of the tank temperature setting (e.g., H2) which could serve to elevate hot water consumption in spite of the installation of low flow showerheads. The sole house which only had low flow showerheads installed showed a reduction in hot water energy use of about 3%. The small sample does not allow separate determination of the impact of hot water tank set temperature.

The combination retrofit of solar water heating systems along with low flow showerheads and tank temperature re-set realized the largest per measure savings of any measure installed: an average reduction of 2,040 (±854) kWh/year. The average measured reduction in hot water electricity consumption was 60%. Although all households evidenced reduced hot water energy use, the percentage savings varied from a 39% to a 91% reduction. The data suggest that the low flow showerheads may have been responsible for about 4% of the realized reduction. Figure 3 shows an example of the impact of installing a solar water heating system by comparing the daily water heating loads at House 4 before and after the installation.

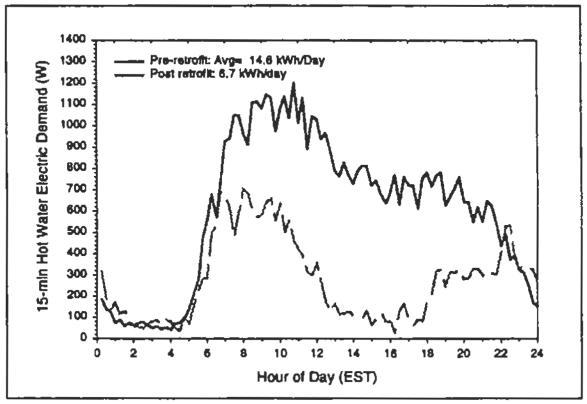

Figure 3. Impact of installation of solar water heating system on the daily load profile at Houst #4 from 1996 - 1998.

Cleaning refrigerator coils along with reset of the freezer temperatures showed small, but demonstrable savings. The average savings in refrigerator electricity use was 12% (+5% to a 45% reduction), although the absolute reduction was only about 130 kWh/year. The results mirror another study showing little savings from cleaning refrigerator coils (Litt et al., 1993). Our findings may be specific to the refrigerator involved and is also affected by the change in freezer set temperatures in two of the households. Even after coil cleaning and temperature reset, we found the average refrigerator to use about 20% more electricity than suggested by the DOE-2 test procedure – a likely consequence of the warmer household temperatures seen in a cooling dominated climate.

Substitution of CFL lamps for incandescent bulbs revealed a 16% reduction in measured miscellaneous electricity consumption – equivalent to a 420 (±460) kWh/year reduction in lighting energy use. Savings varied from +4% (lighting use increased) to a 59% reduction. We believe the mean estimate is valid with the level of significance influenced by the small sample. House 4 was not included in the sample since CFLs were added for many burned fixtures such that the connected lighting load was not appreciably reduced. Lighting savings were obtained indirectly by examining changes to "other" electricity use after subtracting all recorded major energy end uses from total. This approach has been verified in two previous studies (Parker and Schrum, 1996) and (Parker et al., 1997b). It results in conservative estimates since any increases in appliances (such as the added television at House 1) or non-lighting end-uses will reduce the estimated savings estimate. The change in occupancy is likely responsible for the lack of savings at H1; a similar circumstance may have influenced results at H9. An example of the measured impact of substituting CFLs is shown in Figure 4 for House #10. The plot shows the expected behavior: most savings are concentrated in the early morning or evening hours.

The total project savings averaged 14% per household (not counting the change in air conditioning or lighting use at House 4) and varied from 10% to 31%. The absolute energy reduction was approximately 5.7 (±4.2) kWh per day or about 2100 kWh/year.

PRELIMINARY ECONOMICS

With the significant proviso that our study represents a very small sample, we examined the preliminary economics of the measures installed. Since we performed the retrofits, we were able to accurately estimate the time involved for each measure's installation (we assumed a cost of approximately $20 per hour for the work by a weatherization agency). We also knew the cost of the hardware utilized. Savings were estimated by taking the averages from the results for each measure evaluated at a typical electricity rate of $0.08. We made a separate estimate for the incremental cost of each measure for both existing and new construction since several measures would be less expensive done at the time of construction (duct sealing in particular).

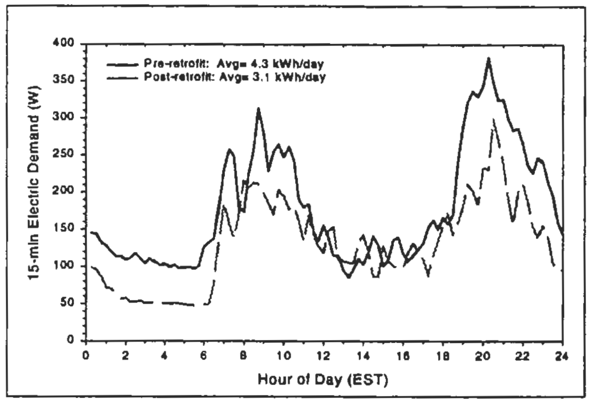

Figure 4. Measured impact of substitution of energy efficient lighting fixtures on "other" electricity use load profile at House #10 from 1996. To 1998.

The measure economics show that duct sealing and correction to evaporator air flow in homes with central air conditioning systems can produce large impacts at low cost. Solar water heating systems produced the largest annual savings, although at a larger capital expense. One measure seldom considered in weatherization programs, compact fluorescent lighting, showed very attractive economics.

CONCLUSIONS

A series of retrofits were installed in eight monitored low-income homes in South Florida. Measures included return duct sealing, solar water heating

Table 8
Measure Economics

Measure Description	Annual kWh	Savings ($)	Cost $ Existing	Cost $ New	Simple Payback Existing	Simple Payback New
Return Duct Sealing	880	$ 70	$ 250	$ 50	3.6	0.7
Solar Water Heater*	1960	$157	$1,600	$1,500	10.2	9.6
Low Flow Shower	80	$ 6	$ 20	$ 10	3.3	1.7
Clean Frig. Coils**	130	$ 10	$ 10	—	1.0	—
CFL Lighting	420	$ 34	$ 125	$ 70	3.7	2.1

* 80 kWh subtracted to account for impact of low flow showerheads
** Refrigerator coil cleaning is a retrofit measure only and likely has only a short term impact.

systems, low flow showerheads, refrigerator coil cleaning and compact fluorescent lighting. Matching nine month pre and post periods were used for the analysis. The retrofits produced an average 14% reduction (2100 kWh) in annual energy use in the retrofit homes. Retrofit of solar water heating systems produced the largest and most consistent savings. Duct system sealing and evaporator coil enhancement also produced large savings a fairly low retrofit cost. One measure seldom considered by weatherization programs, compact fluorescent lighting, showed very beneficial economics. Refrigerator coil cleaning and low flow shower heads produced small, but cost effective reductions to annual energy consumption.

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