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Measured Results of Phased Shallow and Deep Retrofits in Existing Homes

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ABSTRACT

The U.S. Department of Energy (DOE) Building America program, in collaboration with Florida Power & Light (FPL), is pursuing a phased residential energy-efficiency retrofit program in Florida. This research is to establish annual energy and peak energy reductions from the technologies of two levels of retrofit – shallow and deep, with savings levels at the high end expected to reduce whole-house energy use by 40%. The Phased Deep Retrofit (PDR) project, has installed energy-efficiency retrofits in a sample of 60 existing, all electric homes.[1]Energy end-use savings and economic evaluation results from the phased measure packages and single measures are summarized along with lessons learned.

Background

Verified savings from residential energy retrofit programs are of considerable interest. An early large-scale evaluation and audit program in the 1980s achieved modest energy savings in the Hood River Conservation Project. There, Oregon homes received comprehensive retrofits of 15 improvements with a verified 12% savings and a 91% participation rate among several utilities' territories (Hirst and Trumble 1989).

During the 1990s in Florida, the Florida Solar Energy Center (FSEC) demonstrated a 14% energy savings in ten retrofitted Habitat for Humanity homes (Parker et al. 1998). In a more aggressive single project in an occupied home, FSEC demonstrated a measured reduction in measured energy use by 45% (Parker et al. 1997). Another occupied home has been progressively retrofit in recent years to obtain zero net energy (Parker 2012). However, no project has attempted such improvements in a larger sample of contemporary homes.

Phased Deep Retrofit Project

Detailed audit data has been obtained from all homes and includes house size and geometry, insulation levels, materials, finish, and equipment. A blower door test was completed on each home. Detailed photographs were also made of home exterior, appliances and equipment, and thermostat. Flow rate of shower heads was measured during the shallow retrofit, and duct testing was conducted as part of the deep retrofit.

The homes are located in Central and South Florida, with varied construction characteristics. Figure 1 shows the geographic distribution of study sites over the state. Built between 1942 and 2006, the homes averaged 1,777 square feet in living area (s.d.= 410 ft^2), with an average occupancy of 2.6 persons. Homes were audited and instrumented during the second half of 2012. Shallow retrofits came in spring 2013 with deep retrofits in summer and autumn.

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[1] Four homes dropped out of the project over the year; thus results from 56 homes are summarized here.

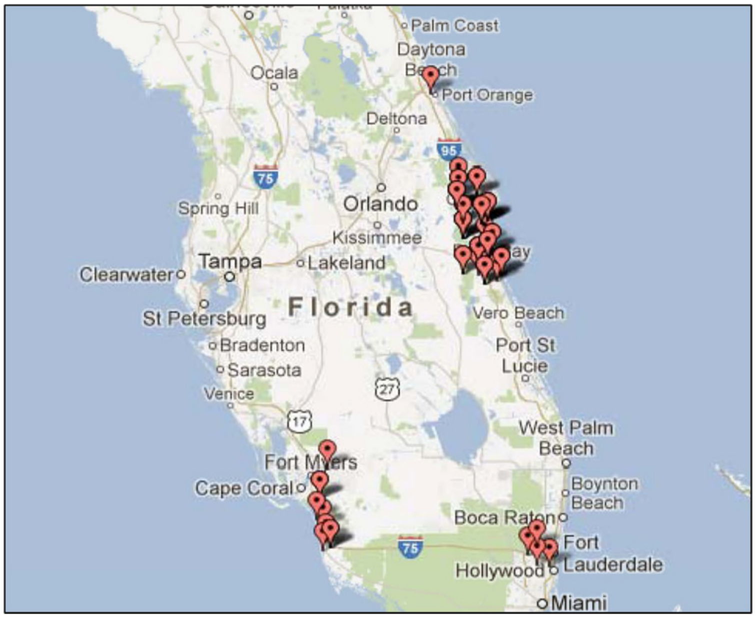


Figure 1. Geographic distribution of the PDR sites in the state of Florida.

End-use energy data were collected to evaluate energy reductions and the economics of each retrofit phase. Monitoring included whole house power and the various end uses, heat pump compressor, air handler and resistance heat, water heating, clothes dryer, range, refrigerator, freezers, swimming pool pumps and several spare circuits to pick up non-conventional end-uses (Parker, et.al, 2013). This was supplemented by portable loggers to take indoor temperature and humidity data as well as a portable power logger to record energy use of the home entertainment center, game systems, and home office/computer workstations. Hourly data was retrieved daily over the internet via broadband connection. Ambient temperature and relative humidity were obtained from nearby weather stations.

Monitored Data

A dedicated website hosts the monitored energy data from the project: http://www.infomonitors.com/pdr/. A graphical summary of each site's eleven energy end-uses is shown by the stacked bar presentation in Figure 2 for all of 2013. A second graphic, Figure 3, shows the average percentage end-use make up for the entire sample. A third graphic, Figure 4 shows the average daily time-of-day demand profile from each site and for each end-use when averaged over the year. A consistent color-coding by end-use is used in all of the charts.

Measured average annual consumption across sites was 42.8 kWh/day, although highly diverse end-uses suggest a complex challenge for efficiency programs. In the pie chart shown in Figure 3, no single end-use dominates. Heating, cooling and water heating only comprised 45% of measured consumption. Moreover, difficult-to-tackle loads such as clothes dryers and home entertainment centers, accounted for 10% of use and home office, game station, lighting, fans and other plug loads were fully 25% of consumption. Average pool pump energy reported in this synopsis is for all 56 sites in the overall sample. When confined to the eighteen pool sites, pump consumption averaged ~10 kWh/day.

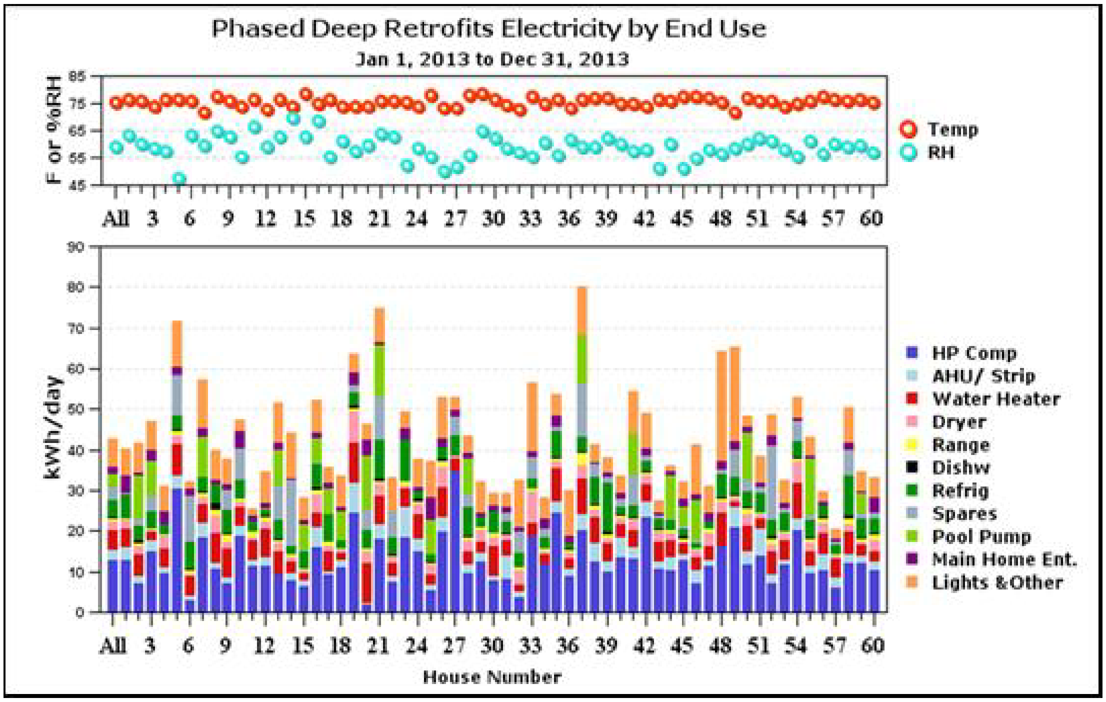


Figure 2. End use energy by site over 2013 in the total PDR sample[2].

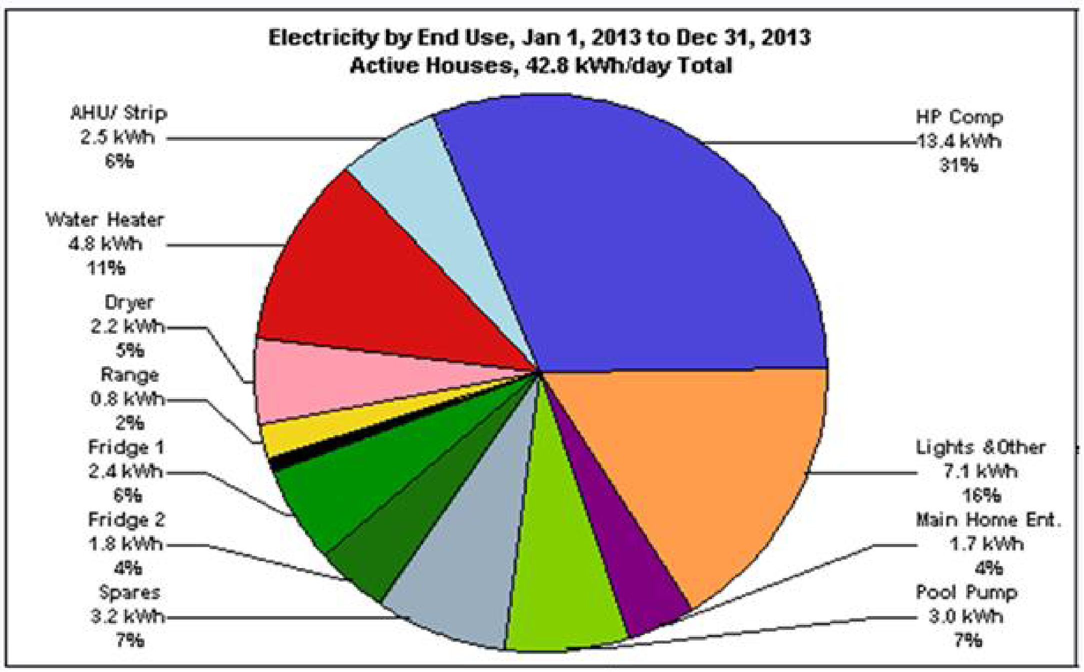


Figure 3. Average energy end-use in 2013 in the PDR sample.

[2] HP Comp is the heat pump or air conditioning compressor. AHU/Strip is air handler unit, strip electric resistance heating. Spares circuits 1-4 include potpourri of loads: additional televisions, computer work stations, gaming consoles, hot tubs, fountain pumps and room air conditioners.

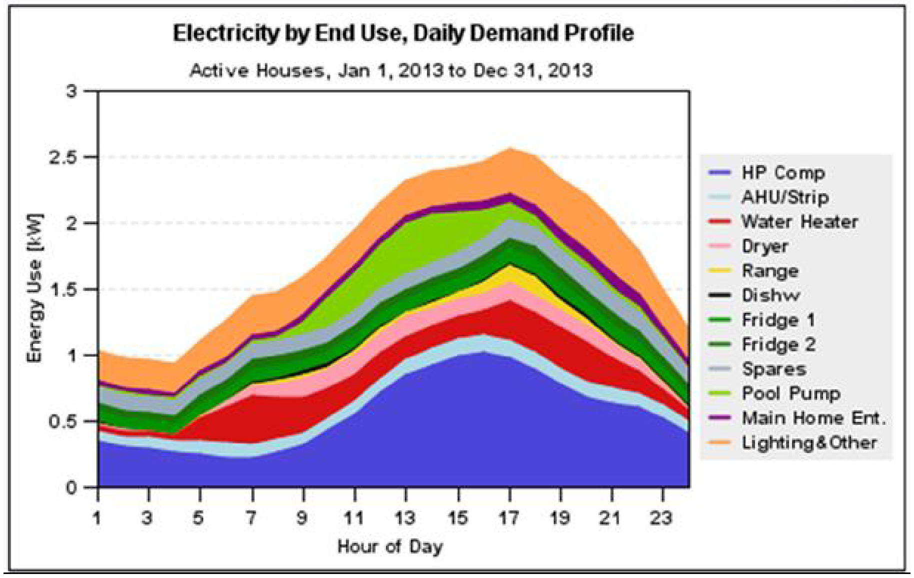


Figure 4. Average daily demand profile in the month of December 2012 in the PDR sample.

Shallow Retrofits

Shallow retrofits were conducted in all project homes from March to June 2013. The energy reduction measures were chosen based on ease of installation. These targeted lighting (CFLs and LED lamps), domestic hot water (wraps and showerheads), refrigeration (cleaning of condenser coils), pool pump (reduction of operating hours), and the home entertainment center ("smart plugs"). Measures were implemented to various degrees and not all measures were conducted in all homes.

Thirty-four percent of the homes in the dataset had swimming pools. Of these 19 pool homes, nine homeowners already had their pool pump timer set at or below the measure threshold of five hours/day. Ten homes had their pool pump timers reduced to ≤ six hours/day. On average, pump time was reduced by two hours/day.

Most houses already had some energy efficient lighting (defined to be CFL or LED types). Indeed, one home already had 100% LED lighting, whereas six others had mostly CFLs and needed fewer than 20% of bulbs changed. Owners sometimes objected to lighting retrofits for some lamps which were not changed. A total of 55 homes were affected by the lighting retrofit. On average, 54% of bulbs were replaced with CFLs or LEDs, ranging from 5% to 96% of the home's total lighting.

We made an effort to reduce domestic hot water energy through two means: (a) reducing use through low-flow showerheads and (b) reducing storage thermal losses by insulating tanks and hot or warm pipes. Understandably, many homeowners were particular about their showerhead and rejected this measure. Space limitations generally restricted the application of R-10 thermal blankets, so most homes received a smaller R-3.5 wrap. Exceptions to tank wrapping include one tank already insulated, one heat pump water heater, and three homes where the tank was partially inaccessible. All accessible hot or warm water pipes were insulated. A total of 53 homes had domestic hot water reduction measures installed: 26 homes had at least one showerhead replaced with a low-flow head and 51 homes had a hot water tank insulated with R-3 insulation around all accessible hot and warm pipes. Fifty homes had fouled refrigerator coils cleaned. The refrigerators at five sites were either very new or had recently been cleaned.

Figure 5 shows observed daily power for affected end-uses at site #54 during this sixty-one day analysis period. The vertical, dashed, purple line indicates the shallow retrofit date.

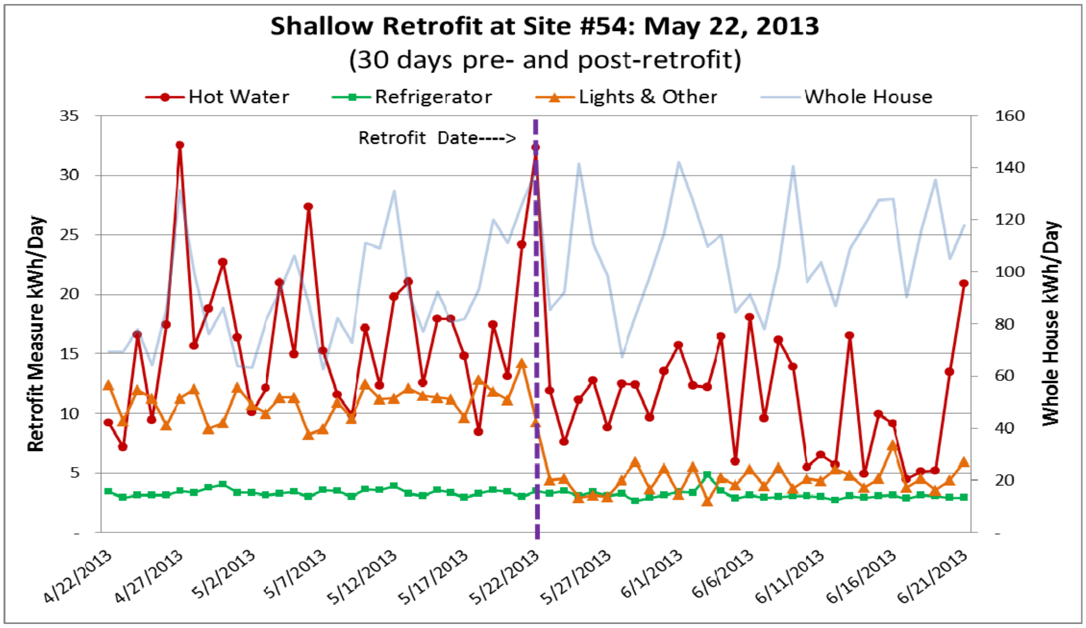


Figure 5. Illustration of evaluation method showing impact of shallow retrofit at PDR site #54 spanning one-month period before and after installed retrofit measures.

The plot shows how lighting and domestic hot water heating retrofit measures produced immediate reductions to energy use (approximately 50% and 31% savings, respectively). Though not visually obvious, refrigerator coil cleaning also generated modest savings (6%).

The shallow retrofit savings were evaluated in two ways; a weather-adjusted 30-day, pre- and post-retrofit end-use comparison for all 56 sites and a 30-day, same calendar month of different years with similar weather conditions, pre- and post-retrofit end-use comparison for 17 sites. Estimated whole house savings were similar between the two approaches, at 9% and 8% savings, respectively. Table 1 summarizes whole house and end-use savings results evaluations.

Table 1. Shallow retrofit savings: two evaluation method results

Shallow Retrofit Average Daily Savings	Hot Water (kWh)	Refrigerator (kWh)	Pool Pump (kWh)	Lights & Other (kWh)	Whole House (kWh)	% Whole House Savings
30 Days Pre-Retrofit	5.6	2.4	10.7	7.7	40.5	
Weather-Adjusted, 30 Days Post-Retrofit	5.2	2.3	8.0	6.4	36.3	
Weather-Adjusted, 30 Day Pre- vs. Post-Retrofit	0.4	0.1	2.7	1.2	4.2	9.2%
October 2012	4.2	3.2	7.4	8.6	45.3	
October 2013	3.6	2.3	7.2	6.1	41.7	
October 2012 vs. October 2013	0.6	0.9	0.2	2.5	3.6	7.9%

Overall, the measures generating greatest initial savings were pool pumps followed by the lighting retrofit and then water heating. This relationship of total and relative end-use impact for the 30 days pre and post evaluation method is graphically displayed in Figure 6.

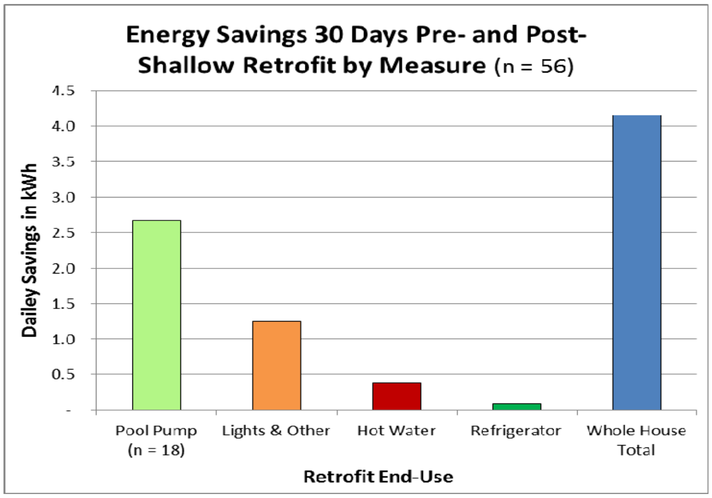
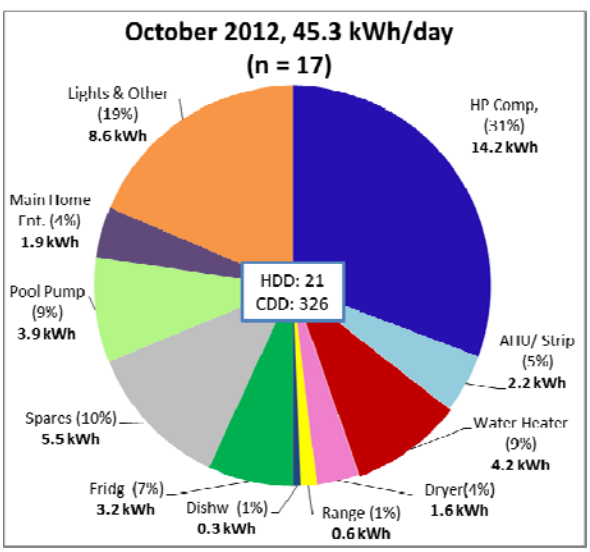


Figure 6. Average energy savings by measure: 30 days pre- and 30 days post-retrofit for all shallow retrofits.

Year-to-Year Evaluation

While more time is required before we can estimate year-long shallow retrofit savings evaluation, we gain insight even using a short period of time. This allows us to examine savings persistence and also to gauge the savings a homeowner would see comparing their bills.

Figures 7 shows the average load profiles for all end-uses on a 17 PDR home sample for October 2012 vs. October 2013. The sample size was limited to homes fully monitored by October 1, 2012 and excludes deep retrofit sites. October was selected among the few months with many homes monitored by October 1, 2012 and for its comparable weather behavior. Average end-use savings between the two years vary from our normalized 30 day pre- and post-retrofit methodology above; savings for this period were slightly lower: 3.6 kWh/day, or 7.9%.



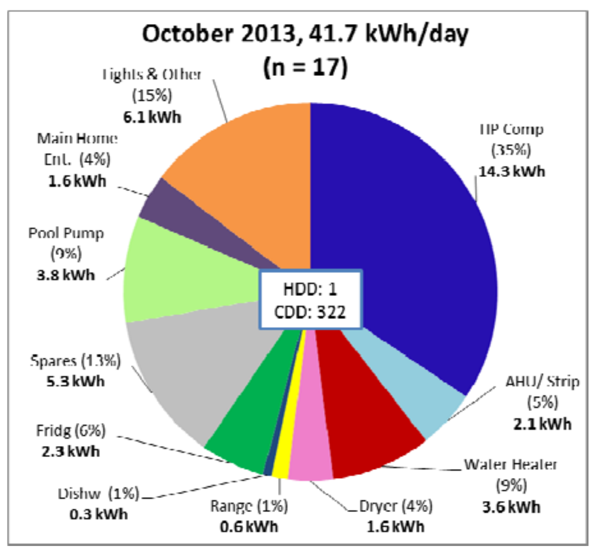


Figure 7. Average end-use load profile in shallow retrofit sample, October 2012 versus October 2013.

The lighting retrofit produced significant savings. Note the large difference in lighting and plug-load energy in the sample between years, 2.5 kWh/day, or 29.1% savings; more than twice the 1.2 kWh/day savings than found in our normalized 30 day pre- and post-retrofit methodology above. This may be due to the smaller sample size, but also to the greater use of indoor illumination in autumn. Refrigeration and water heating savings, 0.9 kWh/day for 28.1% and 0.6 kWh/day for 14.3% savings, respectively, are also larger than in our 30 day pre- and post-retrofit evaluation above. Based on anecdotal reports, we believe that the thermostats in a number of refrigerators were re-set to avoid frozen milk. Daily savings for water heating is similar in both analyses.

Meanwhile, pool pump savings comparing October 2012 to October 2013 was substantially lower, with only 0.1 kWh/day, or 2.6%. This is quite different from the preliminary analysis showing 2.7 kWh/day savings, or 15.9%. This lack of savings persistence appears due to adjustments to pool pump timers. Along with seasonal adjustments, many pump timers were likely been moved back to pre-retrofit settings. Professional pushback was reported on the timer adjustment from some homeowners responding to the pool maintenance industry.

The cost-effectiveness of the shallow retrofits appears promising. We estimate that the averaged per site energy savings from the shallow retrofits was 1,310 – 1,530 kWh/year. The average total cost of the shallow retrofits was estimated to be $372 of which $250 was hard costs and the remainder was labor. Administrative costs would be in addition. A simple payback is reached for each end-use in five years or less and in two years with all measures taken together.

Deep Retrofits

Deep retrofits were conducted on 10 of the project homes beginning in August 2013 and were completed in early 2014. Measures associated with this second phase of the project included major modifications to the heating and cooling system (HVAC), including replacement of air source heat pumps, duct repair and addition of learning thermostats. To reduce water heating energy, heat pump water heaters were installed. Appliances were replaced when old and inefficient; pool pumps were replaced with variable speed units, and ceiling insulation was augmented where deficient. A series of more extensive retrofits will take place in summer 2014 (window and wall insulation in a subset of homes).

Summary of Cooling Energy Savings in Deep Retrofits

Table 2 shows the measured heat pump retrofit savings by site. In all but one case, the existing air conditioner or heat pump was replaced with a 3 or 4 ton two speed SEER 16-17 Carrier 25HCB6 heat pump (this unit was chosen to be compatible with the learning thermostat). Ducts were also tested and sealed at each site and a NEST learning thermostat was installed except at Site #10. At Site #10 a 3 ton multi-speed SEER 18 Carrier Infinity Model - 25HNB936A310 heat pump with a variable speed van coil (FE4ANF003) was installed.

Figure 8 graphically displays an example of HVAC retrofit savings analysis at Site #19. Post-retrofit savings at this site averaged 47% (19 kWh/day).

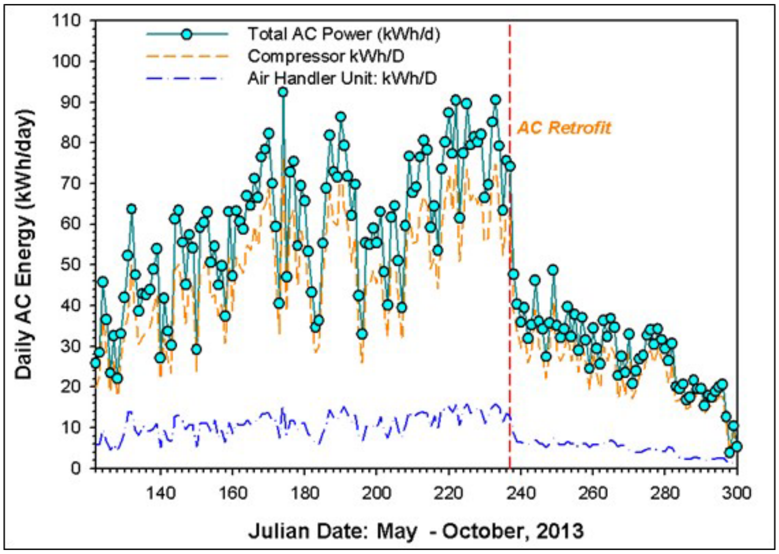


Figure 8. Site 19 air conditioning energy: pre and post retrofit, May – October 2013.

There is a large apparent reduction in cooling energy use from week before to week after (76.8 kWh to 37.9 kWh/day). However, the post period weather was cooler. Figure 9 shows that some of the changes seen in the weeks after the retrofit on August 26, 2013 are associated with a lower average outdoor temperature. Also, the occupants with the NEST learning thermostat maintained a very slightly higher temperature than before the retrofit.

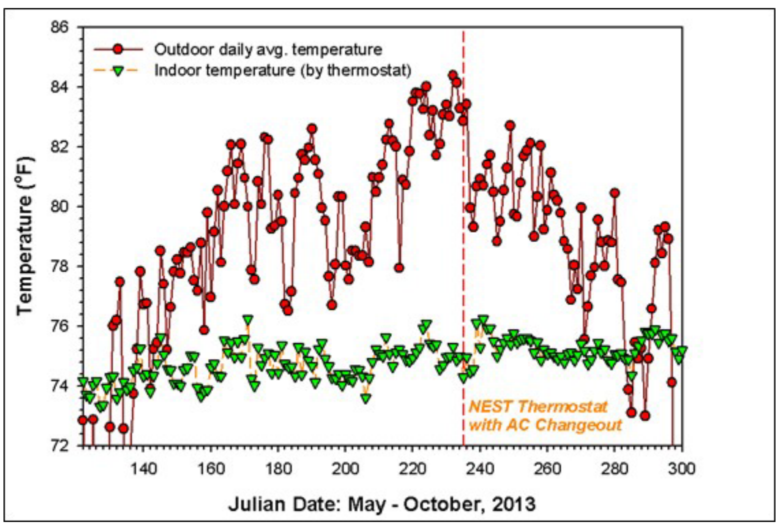


Figure 9. Site 19 average indoor and outdoor temperature May – October, 2013.

To evaluate weather influences, we used the pre and post daily air conditioning data and then regressed daily cooling kWh against the average daily air temperature (Figure 10).

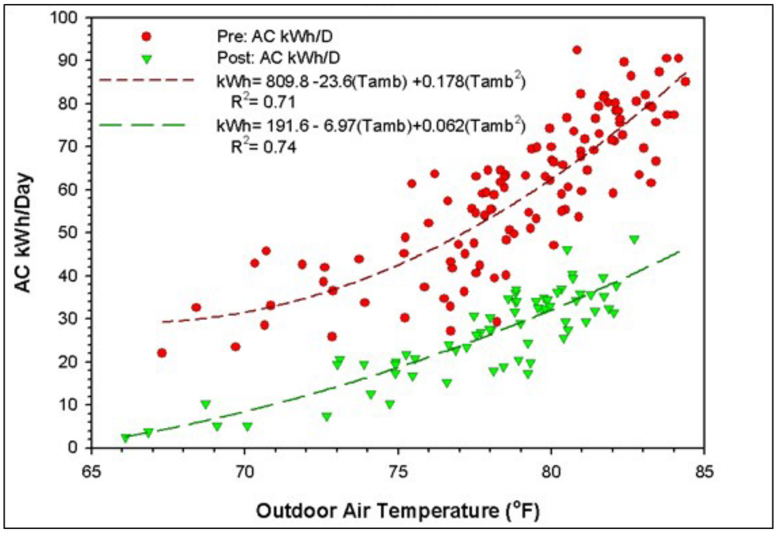


Figure 10. Site 19 average air conditioning vs. outdoor temperature May – October, 2013.

We used quadratic regressions to estimate the daily pre and post air conditioning and how it varied with outdoor temperature. At 80°F, the regressions indicated 61.0 kWh pre-retrofit and 30.8 kWh after – 30.2 kWh/day savings or a 47% reduction. This represents the HVAC retrofit overall savings includes all elements: AC change out, duct sealing and NEST learning thermostat. However, through examination of pre and post interior temperatures we attempted to separate out the savings attributable to the learning thermostat. In the month before the retrofit, the occupants maintained an average temperature 75.1°F; in the month after the retrofit, the interior temperature rose to an average of 75.4°F.

The regression differences between Figure 9 and 10 allow evaluation of how the learning thermostat influenced savings. At an average daily summer outdoor temperature of 80°F, the average outdoor to indoor temperature difference for the regression in Figure 11 was 5.34°F (Pre) and 4.66°F (Post). The predicted consumption is 32.1 kWh/day for a savings of 47%.

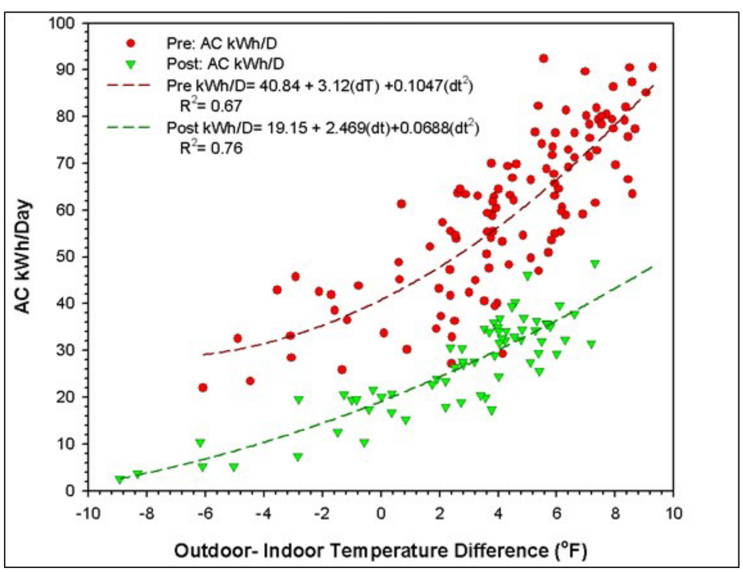


Figure 11. Site 19 average air conditioning vs. temperature difference May – October, 2013.

If we evaluate both pre and post consumption at the post NEST temperature difference, the predicted pre consumption falls to 58.4 kWh per day. This shows that when controlling for changes to indoor to outdoor temperature the AC retrofit and duct repair reduced consumption by 26.3 kWh per day (58.4 -32.1 kWh) or 45%. The remainder of the savings (2.1 kWh/day) comes from the learning thermostat with an implied cooling energy savings of approximately 4%.

Table 2 below summarizes the measured impact of the HVAC retrofits on cooling for the deep retrofit sites, all using an identical analysis method to that illustrated above. Results showed the heat pump replacement and duct repair saved an average of 40% of pre-retrofit consumption, but that lower interior temperatures were generally chosen (by an average of ~1°F) even with the learning thermostat.[3] Final cooling savings were about 15.4 kWh/day in summer or 37%.

Table 2. PDR cooling energy savings analysis (May – October, 2013)

Site	Pre kWh	Post kWh	Savings kWh	Percent Savings (%)	HVAC Saved (%)	Thermostat (°F)		Temperature-Related	
						Pre-Retrofit	Post-Retrofit	Savings (%)	Learning Thermostat Savings
7	38.3	33.8	4.5	12%	18%	72.10	71.10	-6%	-6%
8	35.4	14.7	20.7	58%	54%	77.90	78.50	4%	4%
10	57.7	25.9	31.8	55%	63%	77.80	73.80	-13%	*
19	61.0	30.8	30.2	50%	47%	75.10	75.40	3%	3%
26	41.2	21.8	19.4	47%	48%	75.10	73.60	-1%	-1%
30	19.3	16.5	2.8	15%	23%	77.80	76.90	-8%	-8%
37	40.0	33.6	6.4	16%	28%	78.30	75.80	-12%	**
39	23.2	15.0	8.2	35%	31%	78.30	79.10	4%	4%
40	32.4	20.6	11.8	36%	35%	75.40	75.70	1%	1%
51	39.7	21.5	18.2	46%	48%	80.50	79.20	-2%	-2%
Avg.	38.8	23.4	15.4	37.0	39.5	76.80	75.90	-1.9%	-0.6%

* No learning thermostat installed
** Received improper instruction relative to learning thermostat operation

Measured average savings for a typical summer day in Central Florida with an average temperature of 80°F were 15.4 kWh/Day or 37% of pre-retrofit consumption from the combination AC replacement/duct repair and learning thermostat installation. Using regression techniques with the outdoor weather and temperature maintained indoors we were able to separate out the influences of the AC retrofit and duct repair from the learning thermostat installation. We saw that the AC and duct repair saved an average of 40% of pre-retrofit consumption, but that lower temperatures were generally chosen, even with a learning thermostat so that the average final savings were about 37%.

In the single site without a learning thermostat, the interior temperature maintained post retrofit was 4°F cooler. With the learning thermostat, it was still about 0.7°F cooler post retrofit. There were four of the nine NEST sites where there were post retrofit savings from the learning thermostat of 1 – 4%. However, these were marred by others with negative savings.

We do not know why sites chose lower temperatures post retrofit—although with Site #37 this arose from improper instruction on learning thermostat operation (this site was eliminated from the computed averages). It is possible that the households chose a lower

[3] Temperature-related 'take-back" maybe worse without such thermostats. In the single site without the NEST learning thermostat, the post-retrofit interior temperature was 4°F cooler.

temperature to compensate for the learning thermostat attempts to raise the interior temperature. It is also known from occupant feedback, that Site #7 defeated the "auto-away" feature to prevent the thermostat from increasing the interior temperature while they were not home.

It is important to understand the limitations of this study relative to learning thermostats. A key caveat is that we cannot evaluate what learning thermostats will do to systems where the AC system is not being changed. AC retrofit may very well alter occupant expectations. Thus, the large degree of temperature take-back seen at Site #10 may be typical. A previous study replacing five air conditioners with high efficiency units in 2001 showed an average temperature related take-back of 1.0ºF (Masiello et al. 2004). This cannot known without further research – which we anticipate being able to attempt by a series of NEST-only retrofits to some of the shallow retrofit group in the summer of 2014.

A longer-term analysis will likely reveal larger savings because the full effect from the HVAC load-reduction measures are not realized, since most of the cooling season was missed and some retrofit measures were incomplete. Also weather in the post-retrofit period was biased with both greater post-retrofit heating and cooling (CDD and HDD).

Heat Pump Water Heaters

Eight existing electric resistance water heaters in the deep segment were replaced with new heat pump water heaters in eight Central Florida homes in September and October of 2013. Measured average savings was calculated at 64% (3.62 kWh) by comparing thirty days of pre and post-retrofit energy. Savings were slightly higher (66%, 3.77 kWh) after adjusting for the influence of weather as inlet water temperatures declined over the autumn period. These results are consistent with past research at different locations around the U.S. For instance, savings of 40 systems monitored in the Pacific Northwest showed an average savings of 51% (Fluid Market Strategies 2013). Table 3 lists measured savings results from eight sites in order of installation date. A group of 47 homes where resistance water heaters were unchanged served as a control for normalizing to seasonal changes in water heating energy. Average energy use in the control group increased 4.4% when comparing the same thirty day period before and after the retrofit.

Table 3. Heat pump water heater retrofit savings at 8 sites (30 days pre and post)

Site	Install Date	kWh/day Savings	Raw Savings	Control Group kWh/day Change	Control Group Change N = 47	Normalized Savings	Pre-retrofit Equipment Capacity	HPWH Equipment Capacity
Site 51	09/04/13	1.39	68.1%	0.03	0.9%	68.4%	40 gal	60gal
Site 10	09/05/13	2.67	60.2%	0.07	1.9%	61.0%	50 gal	60gal
Site 30	09/09/13	4.41	68.7%	0.13	3.6%	69.8%	40 gal	80gal
Site 26	09/12/13	5.53	70.7%	0.16	4.7%	72.1%	55 gal	80gal
Site 40	09/13/13	1.94	59.8%	0.19	5.3%	61.9%	40 gal	60gal
Site 19	09/19/13	5.76	64.8%	0.22	6.5%	67.1%	50 gal	80gal
Site 07	09/24/13	2.30	52.0%	0.17	4.9%	54.4%	40 gal	60gal
Site 08	10/16/13	4.96	66.8%	0.26	7.0%	69.1%	50 gal	80gal
60gal	average	2.08	61.4	0.12	3.3%	61.4%		
80gal	average	5.16	69.5	0.19	5.4%	69.5%		
Overall	average	3.62	63.9%	0.15	4.4%	65.5%		

A heat pump water heater with either a 60 or 80 gallon capacity was chosen for each retrofit according to occupancy. Four homes received an 80 gallon HPWH and the other four, 60 gallon units. All were installed in the garage. As might be expected, savings were generally higher with the 80 gallon units in the homes with greater occupancy averaging 70% with energy use reduced by 5.16 kWh/day. The 60 gallon units installed in homes with relatively lower hot water loads averaged 61% savings and 2.08 kWh/day of reduced energy use.

Figures 12 and 13 show the impact on daily electric energy use 30 days before and after the retrofit. In most cases all data was included for analysis but extremely low energy use observed during pre-retrofit periods in three homes signaling a clear period of vacancy lasting from three to four days. These days were removed and substituted with an equivalent number of days taken just prior to the 30 day span before retrofit. It should be noted that all electric resistance water heaters in this analysis had a tank wrap and piping insulation installed as part of the shallow retrofit measures in the spring of 2013 such that savings are slightly conservative. This includes the eight pre-retrofit units replaced with HPWHs as well as the entire group of 47 control homes that also had tank wraps installed.

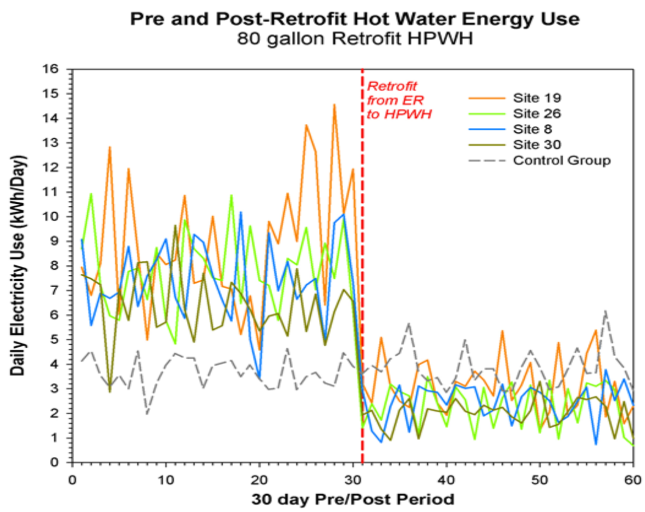


Figure 12. Pre and post-retrofit hot water energy use for homes receiving 80 gallon HPWHs.

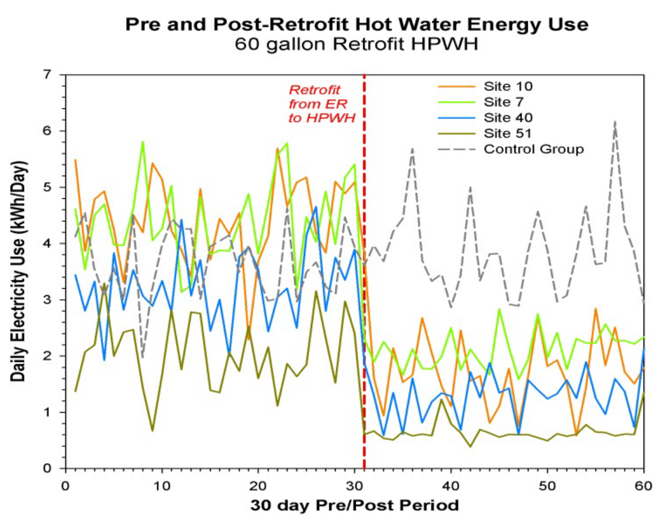


Figure 13. Pre and post-retrofit hot water energy use for homes receiving 60 gallon HPWHs.

Appliance Replacement

The deep segment of the project made high energy use refrigerators eligible for replacement as well as dishwashers and washers and dryers. Refrigerator replacement in three deep homes had average savings of 42% (1.3 kWh/day). Post-retrofit energy savings for the single dishwasher change-out to an Energy Star unit was 32% (0.5 kWh/day).

Energy Star Clothes Dryer

A highly efficient washer and Energy Star clothes dryer was demonstrated in the project. This is important since electric resistance clothes drying accounted for 5% or 790 kWh/yr of annual energy consumption in the PDR sample. The Samsung DV457A1 clothes dryer modulates fan speed and drying time to provide savings estimated in the laboratory to be approximately 25-30% (Ecova, 2013). In our field tests, the *Energy Star* clothes dryer showed savings of 18% (0.6 kWh/day) for the eight homes where installed when evaluated over a 90-day period pre and post. Savings were highly variable; the home with largest use showed a 26% reduction, while some sites had negative savings. We received homeowner reports of dissatisfaction with the longer drying times of the most energy efficient "Eco-normal" cycle—likely a reason for the variability. All but one of the sites elected not to use the "Eco-normal" cycle because of this issue and one homeowner was displeased with the unit's operation.

Swimming Pool Pumps

Measured pool pump energy was high in homes with pools, averaging about 3,400 kWh/yr in the 18 project homes prior to intervention. Savings from variable speed pumps installed at three pool sites within the deep retrofits were very large with reductions: 80 – 90% (8.8 to 16.8 kWh/day). However, we found only about half the potential savings were achieved unless the variable speed units were properly programmed. Thus, commissioning becomes a critical issue for this measure. Figure 14 shows representative savings for Site 7. On September 24, 2013, the variable speed pump and new filter were installed resulting in a 90% reduction in measured energy use through December 15, 2013 (82 days). The 3 horsepower variable speed pump runs for 12 hours/day at 0.16 kW with average energy use of 1.9 kWh per day.

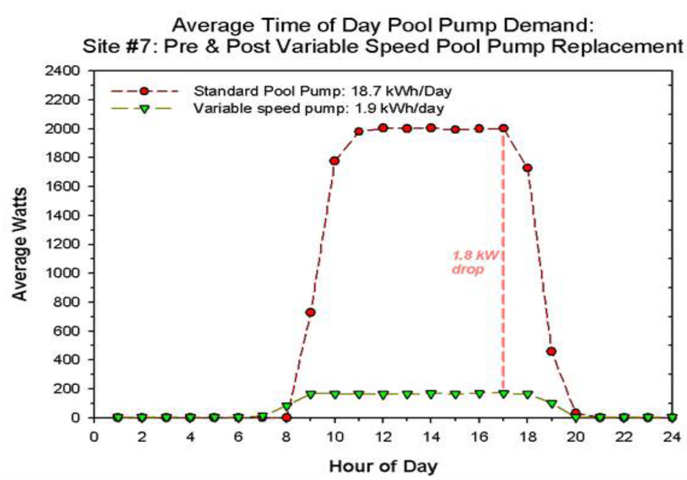


Figure 14. Time of day pool pump demand at site #7; pre (red) and post (green).

With some two-million residential pools in the state of Florida, the potential savings of this measure are enormous. The average pool in the state uses approximately 4,000 kWh/year for circulation, with demand that is often coincident with the summer peak (Parker, 2002).

Preliminary Overall Savings for Deep Retrofits

For the deep retrofits, more time is required before a comprehensive pre- to post-retrofit savings can be estimated. However, we conducted a preliminary assessment using the first few months of data on the six sites with consistent pre and post monitoring. Figure 15 shows the average load profiles for all end-uses on a deep retrofit sample for pre- and post-retrofit periods.

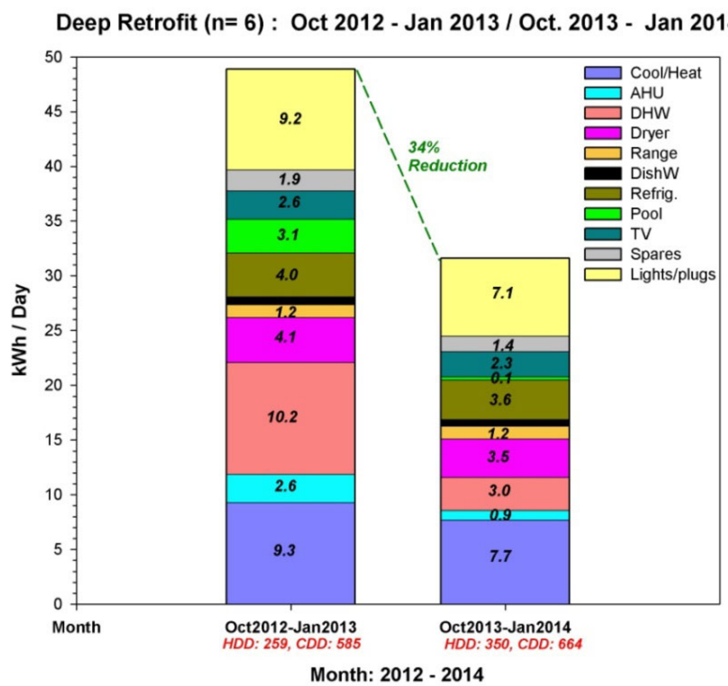


Figure 15. Avg end-uses in deep retrofit sample, October 2012 – Jan. 2013 versus Oct. 2013- January 2014.

Comparing the four-month period of October 2012 - January 2013 to October 2013 – January 2014, total savings for the post-retrofit period averaged 16.5 kWh/day, or 34%. Final savings estimates are almost certain to be higher as the monitoring period did not include the energy-intensive summer period. Also, weather was more extreme in the post monitoring period in the two years post and not all the deep retrofit measures (such as added ceiling insulation) were complete at the time of evaluation.

Conclusion and Next Steps

A Phase Retrofit Project in 56 homes in Florida found an average savings of 9% or about 4 kWh/day for shallow retrofits with very favorable economics. Early results for the deeper (but incomplete) retrofits in ten additional homes found savings of 17 kWh/day or 34%. Full annualized savings are expected to be larger. Savings of HVAC replacement, heat pump water heaters and variable speed pool pumps all showed large and reliable energy reductions. Future reporting will revise estimates with long-term data, and include a deep retrofit economic analysis. Planning is also underway to implement shallow-plus and deep-plus retrofits for a number of the heavily instrumented sites in the coming year.

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