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Pilot Evaluation of Energy Savings and Persistence from Residential Energy Demand Feedback Devices in a Hot Climate

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Pilot Evaluation of Energy Savings and Persistence from Residential Energy Demand Feedback Devices in a Hot Climate

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ABSTRACT

According to past studies, providing instantaneous feedback on household electrical demand has shown the promise to typically reduce energy consumption by 5-10%. This paper briefly reviews past research and describes a two year pilot evaluation of a low cost residential energy feedback system installed in twenty case study homes in Florida. Although not a statistical sample (the participants were self-selected and interested in reducing energy use), the study showed an average 7% reduction in energy use from feedback homes in the second year of monitoring after controlling for weather-related influences. However, a follow-up evaluation done three years later found little persistence of effect. Not surprisingly, we discovered that user motivation appears to play a large role in achieved reductions with important implications for future research as well as larger scale utility deployment.

Introduction

It has long been known that occupant behavior can have very large impacts on residential energy use (e.g., Socolow and Sonderegger, 1976). Indeed, some evaluations suggest that these influences can be as large as the impact of intrinsic differences in building materials and energy consuming appliances. For instance, Schipper et al. (1989) indicates approximately 50% of energy use in homes comes from the intrinsic building shell, equipment, lighting and electronics, but the remainder comes from the occupant interactions with the above systems. However, other evidence suggests that while the range of behavior related variation may be large, the potential of actually changing behavior may be much lower. For instance, Laitner, Ehrhardt-Martinez and McKinney (2009) estimated the potential for changes in behavior at approximately 22%. Also, a novel evaluation by Swanson et al. (2005) examined 2,600 single family homes in the Phoenix area, split the households into groups of movers and stayers and showed a 10% average occupancy related effect. However, the differences on the tails were much larger due to occupancy – 23% at a 90% level and 122% at the maximum. This means that while different occupants in the same home can result in more than a 100% change in the household energy use, this is not often seen and the average occupancy related effect is much smaller—about 10%.

Evidence of the magnitude of occupancy related effects can be found by examining nearly identical housing. Here, we highlight two examples. First is a study done by FSEC in the mid 1990s measuring the energy use in ten identical Habitat for Humanity all-electric homes built the year before monitoring in Homestead, Florida (Parker et al., 1996). Even though all homes had two or more occupants, with identical appliances and equipment, as shown in Figure 1, energy use varied by 2.6 to 1 from the highest to lowest consumer and the standard deviation was nearly 13 kWh/day – 32% of the mean. Detailed measurement of the end-uses in the homes revealed that while the electrical consumption of appliances like refrigerators were remarkably

similar, other uses such as air conditioning varied by 5:1 from the highest to lowest. Evaluation of interior temperature showed large differences due to differing thermostat behavior.

A second study is of eleven very similar solar homes built in Sacramento, California under SMUD's solar homes program (SWA, 2005). This study evaluated the utility bills of the more efficient homes with solar features against other non-solar homes in the same community. As seen in Figure 2, the variation in annual energy use in the solar homes was tremendous. The most frugal home had negative utility cost (produced more solar electricity than it used), while the highest consuming solar home used near twice as much electricity as the average energy use of non-solar homes.

Figure 1. Variation in Annual Energy Use in Ten Otherwise Identical Habitat for Humanity Homes in Homestead, FL (1994-1995)

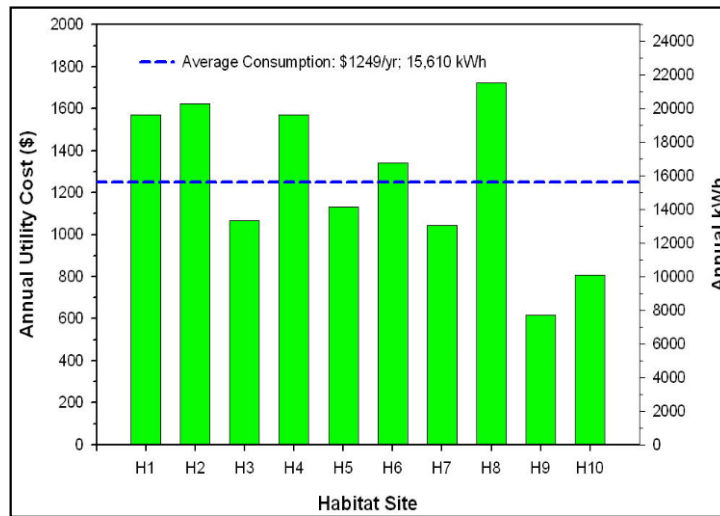
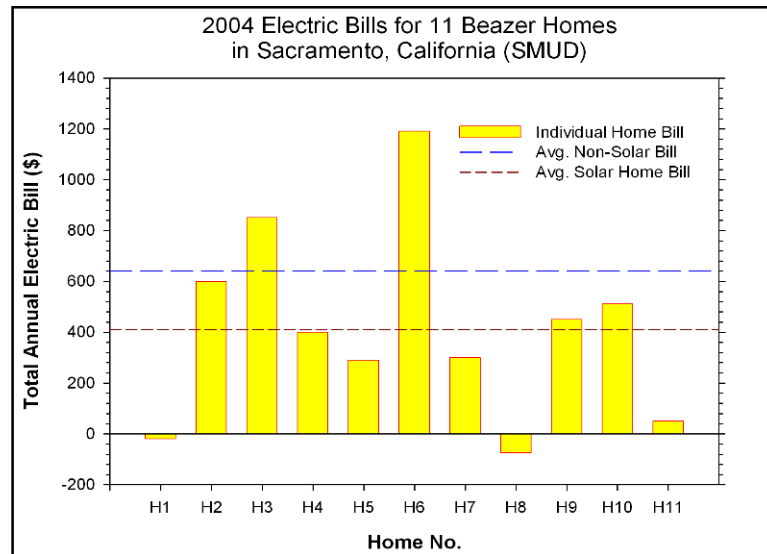


Figure 2. Variation in Annual Energy Use in Eleven Similar SMUD Solar Homes in Sacramento, CA (2004)



Both studies in very different part of the U.S. would suggest that motivating changes to occupant behavior could be a powerful potential to achieve energy reductions. This may be particularly true in more efficient homes with renewable energy features. Not only are these reductions potentially large as they comprise *all* end-uses, they may provide unique opportunities to realize goals for high-efficiency buildings. Reducing and shifting electrical demand is particularly important in Zero Energy Homes (ZEH), where it would be desirable to match solar electric PV output with household loads. Unfortunately, most homes currently have no means to judge household energy use other than their monthly utility bill. However, this does not readily provide insight as to how, or where the energy is being used, given the long time delay between action and feedback.

Technology Summary

Due to advances in microelectronics and computing, energy feedback devices for home use are now commercially available and low in price. Models typically provide a small wall or desk mounted display that communicates the second-by-second electric power demand of the household. Most accumulate the data to show expected monthly utility costs or time related energy cost data. Some are now available for as little as \$140. More detailed (and expensive) systems can report on disaggregated end uses. However, the question remains as to whether the additional information is a benefit or liability (“valuable insight” vs. “too much information”). Commercially available models vary in terms of capability as summarized in our previous report. The two most popular devices currently, is the *PowerCost Monitor* (Mountain, 2006) and *The Energy Detective* (TED) Both systems simplify installation by avoiding costly hard-wiring. The TED sends the energy demand signal over household wiring, whereas the *PowerCost Monitor* using a radio signal from the sending unit. However, the TED device does have two important advantages: 1) it has a resolution of 10W vs. 100W for the *PowerCost Monitor* which is quite important for evaluating energy use of small appliances, lighting and standby power and 2) real-time updates are also more frequent – every second for TED versus every 30 seconds for the *PowerCost Monitor*.

With the surge of interest in smart meters, a very large number of feedback and combination feedback and control devices have recently become available. While this market is changing very rapidly, a recent survey summarizes some of the most notable systems (Parker, Fairey and Hendron, 2010).

Past Studies

Past studies show that providing household energy feedback promises to reduce consumption, although evaluation of the impact of real-time energy information are spotty (Katzev and Johnson, 1986; Farhar and Fitzpatrick, 1989). An early study in Twin Rivers, NJ in the 1970's showed the promise of real-time energy displays to reduce energy use by 10-15% (Seligman and Darley, 1977; 1978). Other early studies showed similar savings (Palmer et al., 1977, Bittle et al., 1979, McClelland and Cook, 1979). In one study conducted by *Ontario Hydro* in Canada, Dobson and Griffin (1992) found that displays in 25 Canadian homes produced overall electricity savings of 13%, which persisted for two-months after the devices were

removed. A few studies did not show any savings from energy-use feedback. For instance, in experiments in Canada and California, Hutton et al. (1986) showed uneven results with electricity savings of 5% in 92 Quebec homes compared with a control group, but minimal impact in the California sample. Another small evaluation showed no savings on ten mostly low-income homes by researchers at Oberlin College (Allen and Janda, 2006) using *The Energy Detective* (TED). While occupants reported increased energy use awareness, the results showed no statistically significant energy reductions.

Another small-scale evaluation of instantaneous electric demand feedback was conducted in Japan using displays, intensive two-way communication and emails. This showed up to a 12% measured average total energy reduction from feedback in ten highly instrumented test homes (Ueno et al., 2005). The apparent savings in electricity were even greater at 18% against those for natural gas (9%). However, these savings were about half this magnitude after controlling for pre/post changes to weather as seen in pre/post reductions to the control group. Often cited, however, is a large and recent statistical study of 382 sites compared with 42 control homes conducted in Canada using the *PowerCost Monitor*. This project showed a 6.5% savings from providing feedback to consumers (Mountain, 2006) although with some statistical shortcomings.¹

In summary, an earlier compilation of available data on numerous real-time feedback studies (Darby, 2000) suggests an average 5-15% energy savings. However, our recent review of studies would posit a lower and more variable range of 0-13% energy savings.

Energy Feedback Monitor

Our project was a two year pilot evaluation of a residential energy feedback system installed in twenty-two case study homes in Florida. The study consisted of an opportunity sample of households with participant self-selected based on interest. Although the monitor sells for \$140, there was no cost for the monitor or installation for the study participants.

However, several problems were encountered in analyzing the study results. One home could not obtain utility bill data for the period prior to the installation of the device. Another home experienced interference from home electronics which prevented the device from working (a problem that has largely been eliminated by the manufacturer). Two other homes did not yet have 12 months of post data when the analysis was complete. Finally, one further home was the author's own which was eliminated from the evaluation to reduce potential bias. This left a total of 17 households in the final analysis group which had a full year of pre and post data and matching data periods within the large utility sample which comprised the control.

The participants in the study had *The Energy Detective* (TED) installed. This is a small 3.5 x 5" display unit which plugs into the wall and receives power line carrier signals from a sending unit installed in the central breaker panel (Figure 3).

¹ The control group in the study was small (~=42). Savings in baseload electric for homes without electric DHW was 5.2% ± 5.4% -- not statistically significant.

Figure 3. Free Standing Display of *The Energy Detective (TED)* Feedback Device



Some characteristics of *TED*:

- Computes true power every second (kW) with a resolution 10 Watts. Energy use of the system itself was measured at 0.8 Watts.
- Sends signals on instantaneous electric power over house wiring by power line carrier so that the display device can be installed in any room.
- Shows both instantaneous and cumulative electric power for the month. Also records daily and monthly peak electrical demand.

One objective of our earlier investigation was to develop a protocol and educational element to help homeowners or auditors for Zero Energy homes use the feedback information to effectively inventory all electrical end uses (Parker, 2006). This was accomplished in each of the study homes. The developed method, which evaluates all loads on a given circuit breaker, was completely described in our previous report.

Based on our experience, we found such a protocol could potentially be a powerful means to reduce household energy use. Although the protocol was performed on each home in the study, occupants were not advised as to what energy-saving measures they might undertake.

Two-Million Home Control Group

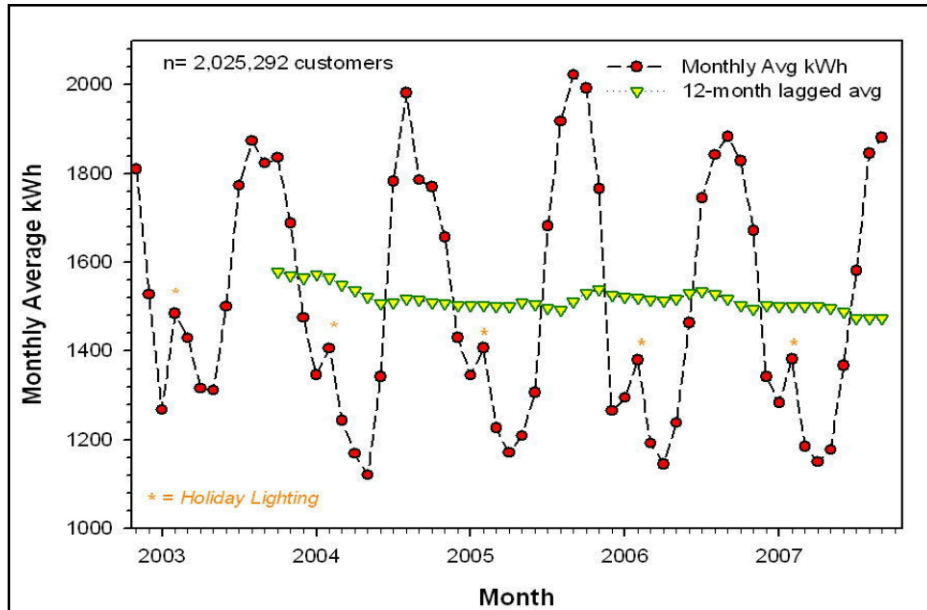
We wished to establish a control group with which to compare our limited opportunity sample of 17 volunteer households, so we approached the largest Florida utility, *Florida Power and Light Company (FPL)* and asked if it might be possible to obtain long term billing histories for all single-family customers who are not seasonal residents.

The utility agreed to help, providing five year average data on average energy use in the over 2 million single family homes in their service territory. These homes represent roughly 2% of the entire U.S. residential building stock and a third of all residential dwelling units of all types in the State of Florida.

The advantage of using this data was that it would allow a control group for both the pre and post periods for each participant that would intrinsically adjust for natural changes due to

appliance saturation and behavior as well as responses to monthly weather conditions. Figure 4 shows the average electricity use in the two million customers over a five year period stretching from September 2002 to August of 2007. One can see superimposed on the data a moving 12-month average of electrical consumption which takes out the seasonal variation in energy use. This arithmetic mean, shown as yellow triangles, shows that electricity use in year round occupied single family residences slowly declined over the measurement period.

Figure 4. Measured Average Five Year Monthly Electricity Consumption in all Florida and Light Company Single-Family Non-Seasonal Homes



Annual consumption averaged 18,948 kWh in the first year, slowly declining to 17,688 kWh in the last year. Analysis of the data when compared to weather data from West Palm Beach (perhaps the geographic account-weighted center of the FPL service territory) revealed that most of the decline in consumption is coming from slowly dropping heating degree days (HDD) during Florida’s mild winter over the five year period. Interestingly, holiday lighting (holiday), is very evident both in the graphical presentation of the data and the statistical model, being estimated at approximately 160 kWh for the month of December.

The advantage of using this very large data source was that if its energy use characteristics matched, we could then have it serve as the control group for comparison of how the non-experiment population’s consumption varied over the specific pre and post period for each individual site. Generally, most sites saw a natural, weather-related reduction from the pre and post period (the variation was -4.0% to + 2.5%) with an average drop of 1.9% for the overall group of 17. This was computed for each individual site.

Evaluation Results

Table 1 shows the overall results from the year pre and post in the 17 homes, both with and without the control group weather correction. Although there was no guarantee that our

participant group was similar to the aggregate utility group the data indicated a very good match based on energy consumption. Note that pre-installation consumption averaged 18,396 kWh/year—virtually identical to the 18,201 kWh seen in FPL’s two million home control group from May 2005 - April 2006.

Table 1
Energy Use Pre and Post Installation of Feedback Monitors

Site	Install Date	Before Installation	After Installation	Reduction (%)	Weather Change* (%)	Raw Savings (kWh)	Normalized Savings (kWh)	Normalized Savings (%)
C1	May-06	49.9 kWh	52.1 kWh	-4.4%	1.36%	-2.2 kWh	-2.9 kWh	-5.9%
C2	Feb-06	41.3 kWh	41.3 kWh	-0.2%	1.20%	-0.1 kWh	-0.6 kWh	-1.4%
C3	May-06	39.9 kWh	38.1 kWh	4.4%	1.36%	1.8 kWh	1.2 kWh	3.1%
F1	May-06	51.4 kWh	50.0 kWh	2.6%	1.36%	1.3 kWh	0.6 kWh	1.2%
F2	May-06	113.3 kWh	92.2 kWh	18.6%	1.36%	21.1 kWh	19.5 kWh	17.5%
H1	Apr-06	39.7 kWh	37.9 kWh	-0.2%	0.88%	-0.1 kWh	-0.4 kWh	-1.1%
H2	May-06	30.2 kWh	27.1 kWh	10.3%	1.36%	3.1 kWh	2.7 kWh	9.1%
H3	Feb-06	40.8 kWh	36.7 kWh	10.0%	1.20%	4.1 kWh	3.6 kWh	8.9%
H4	Dec-06	76.0 kWh	66.4 kWh	12.6%	1.87%	9.6 kWh	8.2 kWh	10.9%
K1	Jul-06	43.8 kWh	44.3 kWh	-1.2%	3.95%	-0.5 kWh	-2.3 kWh	-5.4%
M1	May-06	18.3 kWh	19.1 kWh	-4.5%	1.36%	-0.8 kWh	-1.1 kWh	-5.9%
M2	Jun-06	32.8 kWh	31.2 kWh	5.0%	2.73%	1.7 kWh	0.8 kWh	2.4%
M3	May-06	45.6 kWh	38.3 kWh	16.1%	1.36%	7.4 kWh	6.7 kWh	15.0%
P1**	Jul-05	18.5 kWh	13.7 kWh	26.1%	-2.51%	4.8 kWh	5.3 kWh	27.9%
S1	Aug-06	26.0 kWh	27.4 kWh	-5.6%	3.56%	-1.4 kWh	-2.4 kWh	-9.5%
S2	May-06	31.8 kWh	28.9 kWh	8.9%	1.36%	2.8 kWh	2.4 kWh	7.7%
T1	Aug-06	138.4 kWh	114.1 kWh	17.5%	3.56%	24.3 kWh	19.3 kWh	14.5%
V1	May-06	38.8 kWh	32.7 kWh	15.7%	1.36%	6.1 kWh	5.6 kWh	14.5%
Overall		50.4 kWh	45.8 kWh	9.1%	1.80%	4.6 kWh	3.7 kWh	7.4%

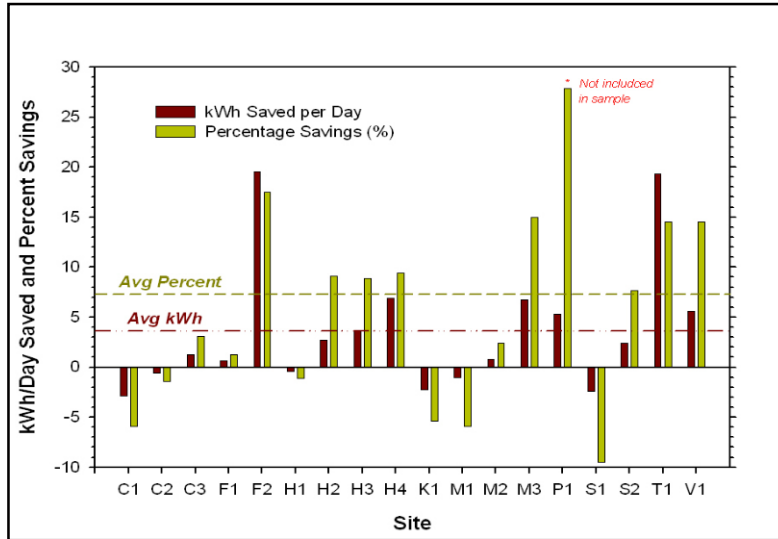
* Average % energy use reduction for FPL customers in the same time period as each participant in the study, according to their TED

** Author’s home; not included in overall averages

Our analysis showed that average electricity use in the overall group declined in the year after the installation of the energy monitor. However, as expected, the specific change varied substantially from one site to another. The average raw reduction was 9.1% or 4.6 kWh/day.

When corrected to the control group (which often had weather related reductions in the post period) we saw the average savings from the energy feedback monitors of 3.7 (±3.5) kWh/day or 7.4%. However, as shown in Figure 6, this varied considerably from one home to another, ranging from an energy *increase* of 9.5% to a savings of 27.9%. Eleven homes showed savings while six homes showed energy use increases. The absolute value of the weather-adjusted savings varied from -2.9 to 19.5 kWh/day.

Figure 6. Measured Daily Electricity Savings in kWh and Percent by Site



Generally, the homes with the largest consumption also experienced the largest savings – a fact seen repeatedly in evaluations of energy savings for various measures in existing homes (e.g. Blasnik, 2008). Notably, the two homes with the largest pre-monitor installation use also achieved the largest savings in the post period and without these homes the conclusions would be significantly altered.² One household installed CFLs everywhere and installed a programmable thermostat; another reduced their pool pump hours after seeing the magnitude of consumption and also replaced an air conditioner that ran continuously.

Survey Findings

A short one page survey was sent to the homeowners at the end of the study. Of the 17 with complete utility data, 14 filled out and returned the survey. We found that the monitor was most commonly placed in the kitchen, although the degree with which the household paid attention to the device varied considerably. Several respondents indicated looking at the display several times a day, but others reported disinterest and one considered the device an eyesore. Most respondents indicated that their primary interest in using the device was in saving money; the second most common response was interest to help the environment.

In terms of how the device was used, responses again varied from “very interested and useful” to “total apathy.” Interestingly, those most interested in the device also uniformly reported making considerable changes to their energy using equipment or their schedules. Not surprisingly, we found responses correlated strongly to observed energy savings.

Although no effort was made to influence homeowner decisions, based on exit interviews two household paid close attention to the monitors and used what they learned to make overt changes in household appliances as well as scheduling for some equipment. This included large changes to household lighting, reduction of pool-pump hours and replacement of an aging AC

² We note that without the two large consumption homes engaging in retrofits, the conclusions would be significantly altered – savings of $1.5 \pm 1.9\%$ -- without statistical significance.

system in one. This may mean that energy feedback monitors would have special value for utilities in homes with high bill complaints. It also suggests that the economics of feedback will be most persuasive for interested high energy consumers. For instance, of the five respondents who reported both considerable interest in the device as well as considerable changes made in equipment or schedules, savings averaged 9.2 kWh/day or 13.3% versus a savings 1.0 kWh/Day and 2.6% reduction in the other less interested and less motivated respondents. It may be noteworthy that the two highest users were among those users who were most motivated.

Although a very limited sample, this study seems to indicate that interest and motivation were large factors in whether having the feedback device made a difference in energy use. Thus, consumers worried about high bills or otherwise interested in really lowering their energy use could be the best candidates for using the technology. What is not clear from the evaluation is how the timing of the savings would impact utility peak demand or the motivational factors that generate interest in the first place. One clue, however, is that the major motivation mentioned by participants was saving money, coupled with the fact that generally those saving most had the highest utility bills.

Examination of Savings Persistence

In 2009, we revisited all of the sites that could be reached from the original feedback study. Of the 16 sites (not including the author), two had moved and one homeowner could not be reached. We then compared the annual electricity use for each site in 2009 against that used in 2006 after installation of the energy feedback device. Although many households reported changes (added room, changes to occupants, new HVAC or water heating systems), the electricity use showed remarkable consistency over three years.

The average electricity consumption in the thirteen tracked households increased by 3.5% over the period (range was +17% to -13%), but was still 3.5% (1.6 kWh/day) lower than it had been in the pre-feedback period. However, after controlling for weather, they were only about 1% less (0.5 kWh/day) than they had been before the monitors were installed.

A follow-up survey of homeowners participating in the study gave reason to believe that some of the impacts may have been short lived. Evaluation of the response revealed that about half of the monitors were no longer used, with several having failed. Of the respondents, 13 (81%) indicated that the monitors were used more when first installed. Relative to how they had affected household energy use patterns, while four respondents (25%) indicated long term changes in behavior or even retrofits, most indicated that while the monitors had increased awareness regarding energy use, they had not led to long term changes. As seen earlier, user motivation appeared to be a primary driver of differences and those claiming to have made long term changes or undertake retrofits did show savings that persisted three years later.

It must be re-emphasized that while the savings from this small study initially averaged 7%, that the sample size was far too small to achieve statistical significance. Also the sample was intentionally self-selected, which likely led to more motivated households actively using the feedback information than would be seen in a sample representative of general population. Thus, there is the possibility of the “Hawthorne effect” in the results where those being experimentally studied are more likely to show short-term increases in performance whether from attention or feedback (Parsons, 1974). Finally, the limited data available on persistence in the study would

indicate that the long-term impact of such devices could be a critical issue without continuing incentives or motivation. The indicated savings after three years was only 1%— indistinguishable from zero. Although results from the study may indicate that motivated groups may benefit from having such feedback, larger utility samples are needed to address such questions.

Update on Recent Large Scale Studies

Since the original publication of our research, several larger studies of residential energy feedback have become available. In 2008, a pilot project using the Power Cost Monitor (PCM) by *Dominion Virginia Power* reported a 2% electricity savings without electric water heater and 15% with after controlling for weather in 180 evaluated installs (Mountain, 2010). A very recent, as yet unpublished study in Wisconsin shows similar numbers for savings, also finding that those with electric clothes drying had larger savings.³ A smaller study of three feedback systems by *Seattle City Light* showed a 2-3% savings from 33 tracked installations against a larger control group (Henrikson, 2009). On the other hand, a larger recent study of 350 households using the Power Cost Monitor in Oregon in 2009 found some indications of reductions, but no findings of statistical significance (Sipe and Castor, 2009). Of particular surprise in that study was that the “early adopters” did not show any savings in the most statistically robust fixed effects model. The group receiving the monitor within a home energy audit showed indications of a 0.63 kWh/day reduction, or 2.0% savings, but again without statistical significance. However, the study did find diminishing impact after install.

Another recent study comes from Massachusetts where 3,500 PCMs were installed and billing analysis was used on a subset of 243 homes to examine the difference between pre-use and post-use electricity usage for customers (Siems, 2009). After correcting for weather related effects, the study found that the users of the PCMs resulted in a 0.87 kWh/day reduction in household energy use. This represented a 2.9% reduction in household energy use and was statistically significant. Similarly, the Massachusetts evaluation found only 35% of the devices in use after twelve months for a variety of reasons. (All of the evaluations of the PCM reported a number of failures as well as frequent disuse due to exhausted batteries). However, the study found behavioral changes manifested past the length of the study.

A related topic is the interaction between critical utility pricing with real-time energy data (Mitchell-Jackson, 2005, Wood et. al., 2004; Neenan & Robinson, 2009). A recent study by *Baltimore Gas and Electric* with 625 monitors (Energy Orb) in a dynamic-pricing pilot installed showed a 5-6% reduction to peak demand from February 2008 to March 2009 (Faruqui and Sergici, 2009). Further, a study of 1,251 residential customers by Connecticut Light and Power in 2009 showed that while the *Energy Orb* and the *Power Cost Monitor* did not statistically lower energy consumption (CL & P, 2010) although smart thermostats did achieve a 7% peak energy reduction.

In summary, the more recent, larger utility studies have shown indicated savings from residential energy feedback of 0-7% with a high degree of variability. With a standard deviation

³ A working hypothesis is that the PCM can only show larger loads (>100 Watts). Thus, the electric water heater and clothes dryer shows that costs of operation are exceeding \$0.50 per hour with these appliances which tends to get homeowner’s attention. There were anecdotal reports of homeowners deciding to use clothes lines once they saw the magnitude of the dryer energy use.

in annual electricity consumption approaching half the mean (as seen in various utility data sets), the required sample size to reach 95% confidence interval can be large if pooled groups are used rather than pre and post analysis methods.⁴ However, large scale studies such as these are underway or recently completed. The Canadian utility, Hydro One, has initially reported on a 30,000 installation deployment of the PCM showing a 5.2% energy savings reduction even after accounting for considerable equipment-related problems (Rossini, 2009). Further, in the Chicago area, Commonwealth Edison is currently running a 129,000 site evaluation of a multi-treatment pilot using feedback, dynamic pricing and enabling technologies (ComEd, 2009). In the end, it may turn out that providing the information to a portion of homeowners will lead to savings. A distinction between the likely outcomes may have to do with whether the devices will be provided to those interested in using them. Still we hasten to point out that if the savings were only 2% when deployed with motivated customers, the aggregate energy savings could still be very large, even with questions on persistence of savings. In Florida, such a result would provide a reduction in household electricity use of 350 kWh for a device costing less than \$400.

Future Research

Energy feedback and our understanding of its impact on energy use is evolving. Not only are behavioral influences of feedback largely under-researched, but information is also lacking on the impact on time-of-day demand. Also, occupant interest in energy feedback will likely be influenced by the relative price of energy (see Hayes and Cone, 1977; Battalio et al., 1979; Winett et al., 1979) – another area where available research information is limited. Little, too, is known about the degree to which feedback display design itself determines the magnitude of reduction, although the available information would suggest that bold, vivid displays are best (Winett and Kagel, 1984). Also, the use of feedback systems as a tool for building diagnostics, audit and occupant education, such as suggested by Harrigan and Kempton (1995), has not been effectively evaluated. The author's own evaluation of this type of use suggests this technique could be a helpful strategy to locate household energy waste (Parker et al., 2006).

Finally, the potential impact of feedback on energy consumption could be even greater for low energy buildings with solar photovoltaics (PV). For instance in an early California ZEH, the occupants who were previously not interested in their low energy house, found that the energy feedback meter provided with the PV system became a powerful motivator to lower their energy use to better match the output of the solar electric system. Current research in Great Britain underscores the potential of feedback in grid-connected PV homes (Keirstead, 2005).

Conclusions

Earlier research dating from the 1970s have shown that providing effective feedback from appliance use decisions can be a useful means to impact energy use. Until recently, however, few methods have existed for households to gauge influences on household electricity use. Fortunately, a series of low cost energy monitors are now available that allow consumers to

⁴ For instance, a sample of 163 sub-metered homes in Florida showed mean consumption of 17,503 kWh with a standard deviation of 7,275.

obtain such information. Recent evaluations in the U.S., Canada and Japan suggest a typical range of energy savings from providing feedback of 2-10%.

We performed a pilot evaluation of a low cost monitoring system in 22 case study homes, of which 17 homes had one year of pre and post utility data. Although not a statistically significant sample (the participants were self-selected, with a number who were potentially motivated), the study showed an average 7.4% reduction in energy use (3.7 ± 3.5 kWh/day) from feedback in homes in the second year of monitoring after controlling for weather-related influences. We did see very large differences in the success of feedback from one household to the next. However, we also found that a large identified advantage of the technology is that it provides better guidance on profitable areas to reduce household electrical demand— many of which may be unanticipated. Savings from owning the device appeared roughly correlated with pre-installation consumption levels.

Moreover, exit survey results clearly showed that those expressing large interest in the monitor and those saying they were motivated to cut energy use were much more successful at achieving energy reductions than the remainder of the group. This would suggest that application of such devices with motivated users can be expected to result in the largest savings and should be the focal point of initial utility smart metering efforts. Conversely, widespread deployment to disinterested users could lead to disappointing results.

A follow-up of the study participants after a period of three years revealed that consumption had risen since 2007, but remained about 1% lower (0.5 kWh/day) than it was in the pre-installation period when corrected for weather. Based on a follow up survey, a number of monitor failures were seen as well as attrition due to long-term occupant apathy. Thus, this case study suggests that savings persistence could be a critical issue. However, countervailing influences could include interactions of the technology with time of day electric rates, critical peak pricing and homes with solar electric power production. As this project represents only a pilot evaluation of self-selected users, a more statistically representative impact evaluation must await results from larger scale monitoring projects around the U.S. Still, the authors point out if the savings were only 2% when deployed, the electricity savings from energy feedback devices would still be very large and highly desirable outcome.

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