The Effects of Household Characteristics and Energy Use Consciousness on the Effectiveness of Real-Time Energy Use Feedback: A Pilot Study

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ABSTRACT

Much research has been done to date examining the effect of energy feedback information on occupant behavior. The newest type of feedback, "real-time" or continuous energy use monitoring, has become popular through its application in educational and professional settings. This paper investigates whether continuous feedback is effective in a residential setting, and explores the effects of socioeconomic status and household characteristics on conservation practices and energy use consciousness. Ten households were randomly invited from a 60-household survey to receive a digital electricity monitor called The Energy Detective. Drawing on surveys, utility bill records, and semi-structured interviews with these households, we discuss the effectiveness of the monitor in each household. We conclude that the monitors have a greater effect on energy consciousness than on conservation behavior in both high-income and low-income homes. Recommendations are made for a more extensive study involving monitors with downloadable data.

Introduction

This paper examines how well stand-alone, real-time feedback can teach residential users with different household characteristics about their electricity use. We begin by addressing the opportunities and challenges for continuous feedback, both as an augment to the monthly bill, and as an informative and educational tool. Recent studies have show that real-time feedback can be a powerful stimulant for behavioral change when coupled with competition (Petersen et al. 2005) and visual displays (Matsukawa 2004; Petersen et al. 2005; Ueno et al. 2006). Instead of investigating the impact of technologically innovative and graphically stimulating feedback, our pilot study investigates whether a simple, commercially available, whole-house electricity monitor can serve the same purpose as these more complex and expensive systems. In a regulatory environment where conservation can only be encouraged by voluntary actions, what is the minimum level of feedback sufficient to produce a change in either understanding or behavior of residential customers? Through a case study conducted in the town of Oberlin, OH, we investigate the impact of attitudes and household characteristics, particularly income, on the effectiveness of energy feedback in general, and on the potential success of real-time feedback in a residential setting. Ultimately, we consider the importance of introducing a least-cost planning model to utilize real-time feedback in residential settings.

Continuous Feedback: The Next Step In Residential Energy Conservation?

Most residential consumers only receive feedback on their energy use in the form of a monthly bill from their utility provider. Most utilities in the US give one monthly reading for electricity use, which does not encourage consumers to examine how their electricity use may have changed over the month. It is likewise difficult for consumers to identify the biggest sources of energy use in their homes, in order to take effective action to lower future energy bills. Since the 1970s, many researchers from various fields have studied how feedback on energy use impacts residential consumer understanding and behavior. Studies involving informative billing and periodic feedback have realized energy savings between 10 and 20%. It is assumed, based on theory and field research, that if residential consumers had more detailed and/or frequent information about their consumption, they would both better understand their energy use patterns and be able to change them effectively (Darby 2000; Van Raaij & Verhallen 1983).

In terms of specificity and frequency, there are unanswered questions in the literature to date. Is there a point at which specificity and frequency of energy feedback information ceases to lead to increased energy use awareness and/or behavioral change? Should feedback frequency be daily, hourly, or continuous? Should the information presented include only utility prices, or should non-price information be included as well? Would residents pay more attention to per unit or cumulative price? These are critical questions when one is considering the costs and benefits of feedback strategies. It may be that after a certain level of feedback frequency and specificity has been reached, consumers will no longer respond to additional feedback by changing their energy use behavior. It is even possible that continuous feedback might be *less* effective than monthly or periodic feedback, since consumers respond more strongly to large cumulative energy use numbers than smaller numbers representing short time increments, even though these numbers are more informative about specific energy-use behavior (Bittle, Valesano & Thaler 1979-80).

Continuous energy feedback was first tested by McClelland & Cook (1979). They found that homes with continuous electricity use feedback had, on average, a 12% lower electricity use than their neighbors without monitors. Hutton et al. (1986) installed the “Energy Cost Indicator” (ECI) in 25 households in three cities. Over 75% of subjects in each of the ECI treatments indicated that the feedback provided by the monitor was somewhat useful in helping them conserve energy. California, where residents had the lowest level of energy use understanding, showed the most support of the ECI, and was willing to pay more for the monitor.

Sexton, Johnson & Konankayama (1987) installed a real-time monitor in 68 homes after these households had spent one year adjusting to time-of-use electricity pricing. This monitor had to be turned on by the user; the screen displayed price and electricity use over the hour, day and month, and had a blinking light feature if the budgeted bill was exceeded. Monitoring in this study did not stimulate overall conservation, but residents did switch from peak to off-peak use. Interestingly, for all households except those with a 9:1 peak : off-peak rate, monitoring actually increased total consumption, especially of air conditioning.

Van Raaij & Van Houwelingen (1989) conducted a study with a similar monitor for one year, absent time-of-use pricing; they found that the average reduction in electricity use for households with the monitor was twice as much as those given other types of feedback. The monitor was used mainly as a permanent check on the effects of energy conservation efforts; the majority of participants felt that they needed the monitor present to help them conserve. Indeed, after the experiment was over, consumption in the monitor group rose again to be equal to that of the other feedback and control groups.

In a more recent study, Matsukawa (2004) gave a computer monitor to 113 Japanese households for three months. These consumers could see graphs and tables of their energy use on an hourly basis, as well as a graphic comparison to their historical performance. Matsukawa was able to monitor the frequency with which households interacted with the monitor. The elasticity of electricity demand with respect to monitor use was significant, but quite small (-.015). Price elasticity for households who used the monitor frequently (more than three times per month) was only .04 higher than that for households who used the monitor once a month. Matsukawa postulates that the modest impact of the monitor-provided information on electricity use may imply that monitor-provided information in the experiment was not as helpful as the households may have expected, and that there was a time cost to users in terms of information processing, even when the monitor was free to them (Matsukawa 2004, 16).

Ueno et al. (2005) conducted a micro-level study of nine Japanese households. Residents had access to a graphical display of their energy use, broken into different end-uses. The computer display also included energy prices and historic energy use and past bills. Installation of the monitoring system led to a 9% reduction in power consumption. An increased knowledge about energy-saving behaviors caused decreased consumption of both appliances displayed on the monitor and other appliances in the houses. Residents were far more interested in the daily load curve than the summarized ten-day curves; this is a surprising result, given the preference for less frequent information found by Van Raaij & Verhallen (1989) and Matsukawa (2004).

Two main conclusions can be drawn from this broad group of studies. First, real-time feedback has not been shown to stimulate more energy conservation than monthly or weekly feedback. Indeed, Sexton, Johnson & Konankayama (1987) saw an increase in energy use. What *is* new is the discussion of increased "awareness" as a major result of feedback. It seems that awareness, not behavioral change or financial savings, is the major impact of maximizing feedback frequency. The second point is that an increase in sophistication of real-time feedback technology has not corresponded with an increase in measured energy savings. In fact, Ueno's end-use study yielded less energy conservation than McClelland & Cook's basic electricity monitor, 30 years before! It seems that it is the presence of the information itself - not its presentation in a more salient, graphical format - that is causing the behavior change.

As a consequence of the unclear economic advantage of real-time usage feedback over other forms of energy feedback information, the main applications of real-time feedback have been in either commercial settings for facilities managers, or in schools and universities as an educational tool and technological experiment. Electric monitoring companies like Heliotronics (www.heliotronics.com) and Fat Spaniel (www.fatspaniel.com) advertise to schools, companies and homeowners interested in learning about the *quantity* of energy they use (or produce, in the case of photovoltaic systems) and its environmental effects. There is no price information displayed in either of these systems; energy costs are calculated in environmental terms. These products are clearly being developed by and marketed to people who are already deeply interested in the environmental performance of buildings. Both company systems are rife with colorful graphics, but they are oriented toward homeowners with residential photovoltaic systems, rather than toward the general energy consumer market.

Petersen et al. (2005) conducted a study testing whether quantity-based, educational real-time feedback stimulated energy conservation in dorm residents. It was found that in the context of a "dorm energy competition," the dorms with real time feedback did conserve more energy than other dorms on campus. However, more research must be done to determine whether residents will respond similarly to non-price signals absent the competitive context.

Environmental Attitudes and Income in Relation to Feedback Effectiveness

The previous discussion treats feedback as something that can be universally maximized, as long as feedback information is supplied with the right specificity and frequency. It is easy to lose track of the reality that energy consumers are imperfect, and thus will not perform optimally under "optimal" feedback conditions. We are not machines, so we cannot function with perfect rationality; we have thoughts, emotions, and opinions. We each have a unique worldview and set of attitudes. And we are each subject to individual socioeconomic circumstances. In short, consumers are heterogeneous. When thinking about energy feedback, it is important to consider that certain characteristic differences between consumers may cause some to be generally more receptive to feedback than others. In this study, we consider income and attitudinal differences as factors in feedback effectiveness.

Much work has been done relating both socioeconomic variables and attitudes to energy use. Income is consistently found to be a significant determinant of baseline energy use, but not of energy conservation behavior in reaction to feedback (Brandon & Lewis 1999; Heslop, Moran & Cousineau 1981; Matsukawa 2004). This may be due to the fact that low-income consumers are unable to further reduce their energy use, and high-income consumers prefer to make one-time efficiency improvements rather than change their energy use habits (Cunningham & Joseph 1978). Higher income consumers tend to be more environmentally conscious, but this general concern for the environment may not translate into personal energy use consciousness (Heslop, Moran & Cousineau 1981).

Matsukawa (2004) has treated household characteristics as endogenous to energy use behavior in his study on real-time feedback. In his study, factors found to significantly increase the use of the monitor included number of children, age of head of household, and whether the family had a personal computer. Factors significantly decreasing use of the monitor included household size, number of TV sets, and whether there was a dish-washer.

In terms of environmental attitudes, studies have found that attitudes toward energy consumption are correlated only with conservation knowledge and reported activities, not actual conservation (Heslop, Moran, & Cousineau 1981; Neuman 1986). However, Mayer & Frantz (2005) have found that their 'Connectedness to Nature Scale' correctly predicts "ecological behavior," although this scale has not yet been applied to residential energy use. It may be that personal variables like environmental attitudes affect one-time conservation actions like installing insulation, while contextual variables like income have more influence on frequent conservation actions like setting thermostat temperature (Black, Stern & Elworth 1985; Macey & Brown 1983). This makes sense, given that high-income consumers are both less likely to engage in frequent behavioral conservation, and more likely to be environmentally conscious. Recently, Naesje, Andersen & Saele (2005) have taken another look at the relationship between user attitudes and their energy use behavior, in the context of feedback effectiveness; they conclude that some incentives may be necessary to activate energy saving attitudes, but some incentives are clearly wasted on people with non-energy saving attitudes.

What is needed is a marrying of Matsukawa and Naesje-type studies; consumers should be surveyed both on environmental and energy-use attitudes and behaviors, and on income and other demographic factors simultaneously. The pilot study below follows Matsukawa's lead in relating household characteristics to energy use, but also considers the effect of attitudinal differences on household energy use behavior.

Pilot Study of Real Time Feedback in Oberlin Homes

The authors conducted a pilot study to investigate real-time energy feedback responsiveness across households in Oberlin, Ohio. This study had two goals: first, to further explore the effect of real-time feedback in a residential setting; and second, to investigate the influence of both income and energy and environmental attitudes on response to this type of feedback.

Selection

During January 2006, a door-to-door energy use survey was administered to 60 Oberlin households. Oberlin neighborhoods are strongly divided by income, so two neighborhoods were surveyed in order to capture socioeconomic diversity. Thirty surveyed households were located in the lowest-income section of Oberlin (household income $23,147-$30,568), and the other thirty households were located in the highest-income section ($52,830-$60,250) (http://factfinder.census.gov). From these initial sixty households, a subsample of five households from each of the low-income and higher income neighborhoods were invited, on a first-come, first-serve basis, to be part of a pilot study involving real-time electricity monitors. Other than this deliberate neighborhood selection, choice of household was decided only by which households were home and agreed to participate.[1] Due to a last-minute cancellation by one of our low-income households, and a simultaneous extra request by a higher income household, our subsample contains four households from the low-income neighborhood, and six households from the higher income neighborhood.

Methods

The ten households who agreed to participate in the subsample study had already filled out a three-page survey concerning their energy use behaviors and attitudes, as well as general environmental attitudes and household characteristics. General environmental attitudes were measured using Frantz and Mayer's Connectedness to Nature Scale (CNS). Additionally, households had agreed to give us access to their electricity records. Electricity records and survey results for the 50 other participating households constituted our control group.

Energy Detectives were installed in all ten households between January 30 and February 18, 2006.[2] A researcher and electrician spent about half an hour at each residence. Upon installation, we programmed the monitor in the presence of the homeowners, and then demonstrated how to switch between different screens. Homeowners were welcome to ask questions, and were left with a product manual and savings chart. In terms of using the monitors to achieve energy savings, homeowners were not given any specific advice or goals. They were only told to use the monitors as they liked, and that we would return a month later to talk with them about their experience. Minimal help was given because we were interested in observing to what extent residents would be motivated to teach themselves energy savings using the monitor.

[1] The door-to-door query was carried out on weekend afternoons and weekday evenings, in an attempt to avoid targeting only homeowners who are home the majority of the time. Researchers moved from north to south in both neighborhoods, and knocked on each door only once.

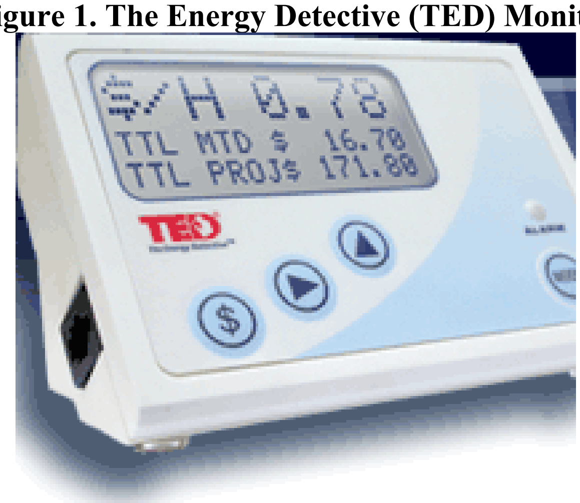
[2] Monitors were installed in households A-I within the first week; due to scheduling problems, installation for household J was delayed two weeks.

Semi-structured interviews were conducted at the residences one and two months after installation. Open-ended questions were used to loosely guide the interviews; residents were encouraged to talk about what had been most interesting to them about owning the monitor. Questions asked about two general areas: first, in what ways the monitor had been useful to the household; and second, what specific features of the monitor were used or not used, and why. One-month check-in interviews lasted from 15 to 50 minutes; two-month check-in interviews were a simple follow up, and lasted about 10 minutes for each household. Interviews were recorded using a hand-held voice recorder. The interviews were conducted in order to find out how each household used the monitor, and to identify any special problems.

The Energy Detective

The Energy Detective (TED) is a monitor that measures whole-house electricity use. The monitor, displayed in Figure 1, is a six-inch countertop display unit that may be plugged into any house outlet. Once the monitor has been plugged in and electricity rates have been programmed, the monitor immediately displays current kilowatt use and dollars spent per hour on electricity. When the TED is working correctly, a green LED flashes once per second. Using two buttons, users can display six different attributes of their use in either dollars or kilowatt-hours, and access several other features. Additionally, users may program an alarm into their monitor, edit electricity rate information, or check their historical use by pressing buttons in combination.

Figure 1. The Energy Detective (TED) Monitor



Source: http://www.theenergydetective.com

The Energy Detective was chosen for this study because it is a cheap ($140), commercially available monitor that has been successful on the market. This monitor has a similarly simple screen to those monitors tested by McClelland & Cook (1979), Sexton, Johnson and Konankayama (1987) and Van Raaij & Verhallen (1987), but there are more available functions. Unlike Sexton's monitor, the TED is always on; however, in order to see different information, users must invest the time to learn how to operate the various buttons. Unlike Matsukawa's and Ueno's monitors, users do not need a personal computer to have the monitor installed in their home; this opens the potential reach of the product to families who choose not to, or cannot afford to purchase a computer. There are no graphical displays or colorful, flashy features, except for the consistently blinking green LED. In essence, this monitor contains improved informational features over monitors of the past, without the added graphical and manipulative capabilities available in computer energy monitors. Our study investigates whether this simpler real-time feedback was effective in helping residents understand and change their energy use, and how this effect was related to household characteristics and attitudes.

Findings from Surveys and Utility Bill Records

Since residents self-selected for this pilot monitor study, there was a possibility that they might be different in some way from the 50 other households in our survey group, the average of which was our baseline electricity use for each neighborhood.[3] In order to test for bias in the monitor users, we compared average survey results and electricity bill data for these households to that of the control group. We found no difference between our subsample and control groups in terms of environmental consciousness (CNS score) and motivation to conserve energy. We did find that subsample households tended to think about their energy bill less, and discuss energy use with their household less than control households. This indicates that households who requested the monitor were less energy conscious than the control households. Monitored households have engaged in more one-time efficiency improvements than control households, on average, and slightly less behavior curtailment actions. Also, the monitor subsample was less likely to sacrifice comfort for energy savings. Given that monitored households tend to think about their energy use less than control households, these results make sense; efficiency actions are one-time installations, and do not require day-to-day consciousness. Not surprisingly, monitor households are more likely to want more precise and/or frequent feedback about their energy use than the control households,

Households within the subsample were assigned code letters A-J to ensure anonymity. A-D were from the low-income neighborhood, and E-J were from the higher income neighborhood. Table 1 displays selected survey results for these ten households. There does not appear to be a connection between income and environmental attitudes within this subsample. B, D, and E stand out as highly energy conscious households. Households E and H should be especially interested in conserving, since they express the lowest level of satisfaction with their level of energy use. In terms of energy conservation practices, Households B, D, and J seem to have taken the most steps to reduce their use. Interestingly, both households A and G have only practiced behavior curtailment strategies, which the other households have practiced curtailment and efficiency improvement strategies more evenly.

Households are split in their motivation to conserve; however, all except E mention money as at least one of their primary motivations. This may mean, based on what we know about the weak connection between environmental values and conservation, that E will be less affected by the monitor feedback than the other households. Households B, D, G, and J are unwilling to sacrifice comfort to reduce their energy use. This may or may not mean that they will be less willing to change their behavior in response to the monitor; it depends, of course, on whether they perceive behavior changes as sacrificial to comfort. Households C, D, E, and H

[3] Control group residents also self-selected, although their participation was limited to a 5-minute survey. However, it is notable that, in the door-to-door query, 272 and 132 households were approached before obtaining 30 participants in the low and high-income neighborhoods, respectively. This suggests that study results for the low-income households may be less easily generalized than those for the high-income households.

could not remember the dollar amount of their last bill. Assumedly, continuous feedback will be especially helpful to these households in raising energy awareness and understanding.

Certain household factors besides income may affect monitor usage, as was found in Matsukawa's study. Households vary greatly in the number of years at their current address; A and I are newcomers, while B, D, F, and H have been there for quite some time. Households A, G, and H are home less than the others, which may lower their electricity use somewhat; also, they may have less time at home to devote to the monitor. A, B, E, G, H and I have children, which may mean they have less time to devote to monitoring their usage; on the other hand, they may be motivated to use the monitor to teach their children about energy conservation.

Table 1. Oberlin Residential Energy Consumption Survey: Summary of Results

Household	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Frequency of thinking about energy bill*	3	5	3	5	4	2	3	4	5	3
Frequency of energy use as household topic	2	5	2	4	5	3	3	4	4	2
How actively household is conserving	4	5	3	4	5	3	3	4	3	3
Satisfaction level with household energy use	3	4	3	3	2	3	3	2	3	3
#1 motivation to conserve**	$	$eh	$	$e	e	$	$	$	$	$eh
Energy use mangagement:										
Behavior curtailment (out of 6)	2	6	4	2	5	5	4	3	4	5
Efficiency improvements (out of 13)	0	7	4	9	4	3	0	9	3	8
Sacrifice comfort to lower energy use?	Y	N	Y	N	Y	Y	N	Y	Y	N
Remember dollar amount of last bill?	Y	Y	N	N	N	Y	Y	N	Y	Y
Remember kwh used last month?	N	N	N	N	N	N	N	Y	N	N
Know how much OMLPS charges/kwh?	Y	N	N	N	N	N	N	Y	N	N
Does the bill give adequate information?	N	N	N	N	Y	N	Y	Y	Y	N
Want more precise/frequent feedback?	Y	Y	Y	Y	Y	?	Y	N	Y	Y
Connectedness to Nature Scale score (of 70)	38	42	43	62	44	55	54	46	57	52
Household Characteristics:										
years at current address	3	40	10	30	7	25	8	19	4	7
relative house size (s, m, l)	s	m	s	s	m	m	L	l	L	m
hours/day house is occupied	15	24	20	20	24	20	18	20	22	14
number of people in household	3	3	2	2	4	2	4	4	4	2
number of children	2	1	0	0	2	0	2	2	2	0
relative income: high (h) or low (l)	l	l	l	l	h	h	h	h	H	h

*Scale is 1-5; 1 is low, 5 is high. **$=money; e= environmental concern; h= setting household example.

Sub-sample households can also be grouped according to their baseline per capita electricity use. We obtained 2.5 years of electricity bills for all ten monitored households, and compared this usage to average control group usage over the same time period.[4] Households C,

[4] We chose to compare 2.5 years of electricity use data because household A had only lived at their address for 3 years; also, the number of households in the control group drops off after 2.5 years, making the control group comparison shaky before this time.

F, H and I are relatively high consumers.[5] Households A, B, E and G are relatively low consumers,[6] and households G and J both appear to be average relative electricity consumers.

Monitor Usage: Electricity Reduction and Findings from Semi-Structured Interviews

A Mann-Whitney test reveals that per capita percentage electricity use reduction did not differ significantly between subsample and total control groups from January to March. Median values are 23.9 and 24 for subsample and total control groups, respectively, with a two-tailed p-value of .996. Within the subsample, Household I achieved the largest percentage savings between January and March (45.3%); although this savings was not quite significant, it is more than twice their drop in consumption during this time two years before (18.59%), when electricity use patterns were much the same as they have been this year.[7] It seems that for this household, energy use was high enough to begin with that the effect of the real-time display was significant. Semi-structured interviews revealed that the majority of households did not use the monitor as frequently or as intensely as they could have and/or had planned to, with the exception of households D and H. For all residents except A and D, use of the monitor decreased over the first couple of weeks after installation, and then settled at a steady usage rate.

Residents generally talked about three levels of feedback from the monitor: the presence of the monitor itself, enhanced by the blinking LED; the kilowatt and money per hour (real-time) home screens; and the other screens and special features of the monitor accessed by pressing the buttons. All but B and C reported feeling an effect from the simple presence of the monitor. Most households looked at the home screen on a regular basis, and all except B reported being affected by the monitor in some way. However, few households investigated different screens or special features like the alarm mode, history, timer, or even month-to-date usage. It seems that, like in the Matsukawa study, there was a prohibitive cost of users' perceived learning time. However, it is notable that the real-time "home screen" was easy to understand, at least in terms of relative use with different appliances.

The degree to which households used the monitor was somewhat correlated with relative baseline per capita electricity use. B and G, the two households who did not use the monitor at all, had low baseline consumption. A, who was affected by monitor presence only, was a low baseline user as well. The other low user in the study, household E, yields surprising results. This household is similar to G in energy use and household characteristics, but E's electricity use actually *increased* by a significant amount after the monitor was installed. Use of the monitor may be correlated with income, although the small size of this pilot study precludes definite conclusions; of the low-income households, A, B, and C showed little interest in the monitor, but D was the most dedicated user. Monitor use does not seem to follow other household characteristics or level of energy consciousness.

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[5] Household D also appears to be a high user during the summer, but this is because the household expands from two to four during most of that time.

[6] Household G experienced a problem with their electricity meter reading during the study, and it was discovered that meter readings had been flawed since April 2005. However, consumption patterns for the year prior to the problem are consistent with households A, B, and E, and it is assumed that consumption patterns would not have changed significantly since that time. This assumption was confirmed after the meter was fixed, and the household was charged a lump sum for the past year; averaged, G's consumption was only slightly higher than consumption in the previous year. The average consumption is delineated by a straight line from April 2005 to April 2006.

[7] Electricity rates in Oberlin have barely changed in the past two years.

For all homeowners, visual features of the monitor stood out as usability barriers. First, from the home screen, there were no clues as to what one was supposed to do next. This was enough to stop *half* of the households (A, B, D, H, I) from touching the monitor, even though all households had initially expressed interest in using it. When homeowners did explore different screens, there was considerable confusion as to what the numbers actually meant.[8] None of the households attempted to use the special alarm or history features of the Energy Detective. This is likely because these features are only accessible by pressing buttons in combination, and it is nearly impossible to figure out which buttons to press unless one reads the manual. Homeowners had clear ideas of how the monitor could be improved. Two households would have preferred graphical displays that synthesized the numerical information on the screen in a way that allowed them to analyze their energy use over time with a single glance. Also, five households felt that the monitor would have been more helpful if they had been able to limit the functions available to them. Homeowners agreed that there were too many screen options, and the high ratio of monitor functions to buttons made navigation confusing.

Although significant energy savings were not realized, five out of ten households opted to keep the monitor. The monitor became an interesting presence and information source for these households, and they did not want to lose the increased energy use awareness they gained from keeping the monitor in their homes. When asked whether they felt they would be able to retain their newfound awareness if we removed the monitors, all homeowners predicted that they would lose awareness over time. So, a simple monitor such as TED is clearly valued as an educational tool, but does not seem that it will pay for its costs via energy savings.

Conclusions and Recommendations for Future Research

It has been found, in empirical studies, that individualized energy use information in the form of better bills, periodic feedback, and continuous feedback, can lead to reductions in energy use. It is *not* clear, from research to date, whether feedback needs to be more frequent to be effective; it is also not clear that sophisticated real-time monitors are more effective than simpler versions.

We conducted a pilot study testing the effect of real-time feedback in ten Oberlin homes for three months. Residents overwhelmingly reported an increased awareness of their energy use patterns, but minimal changes in behavior, and no significant energy savings were realized over the fist three months of monitor installation. Some homeowners did not change their habits at all during the study. This indicates that if these monitors were installed in a for-profit, commercial project, they would not pay for themselves. Residents reported usability problems and thought that a more sophisticated, more easily navigable device might have helped them to better understand what the monitor was telling them. However, it remains an open question whether the presumed additional understanding would translate into enough behavioral change to justify the cost of a more technically advanced system. More research into the cost-effectiveness of the high-tech and lower-tech systems should be initiated to answer this question.

It is possible that, if given more time, some households might become more accustomed to using the monitor, and would thus use it more and realize more energy savings over time. This is probably not the case, though, given the general downtrend in attention to the monitor

[8] During their one-month check-in interviews, six homeowners requested a lesson in how to use the monitor. A, D, E and F had not taken the time to read the manual, but were willing to spend some time learning the monitor's functions when the researcher led them through it. Other usability problems with the monitor concerned predictions of total monthly usage, which were often distrusted for various reasons.

over time found in this study. Committed conservers like D might be able to reduce energy more over time, but none of the other households lends itself to this trend.

This pilot study also investigated household characteristics and environmental attitudes as influencing household response to real-time feedback. Environmental attitudes do not seem to have an effect on monitor usage; income may have an effect, and more research should be done to determine whether low income consumers are less likely to embrace real-time feedback.

Recommendations for Future Research

This is a pilot study analyzing only one type of electricity monitor. In a subsequent study, researchers should compare non-graphical to graphical real-time feedback in a larger sample. Energy Inc., the company that manufactures The Energy Detective, is soon to release a new version of their product, the Energy Detective 5000. In this version, the monitor's data will be downloadable, and customers will be able to view historical data in a graphical format. This monitor should be tested in a random sample of homes where the homeowners are either given access to the graphical computer data or not. One potential problem with this experiment would be that the sub-sample of homeowners allowed to access a graphical representation of their energy use would be limited to households with personal computers.

Additionally, much more can be done to analyze the data obtained in this pilot study. In our sample, we primarily examined income as a factor, and then made comparisons between income groups in terms of attitudinal factors and monitor use. It would be interesting to use level of average electricity use, or level of energy and environmental consciousness, as primary variables, and examine comparisons between these groups in terms of income and other factors.

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