Behavior-Based Electricity Savings: Results of a Home Energy Coaching Program

Martha Amram and Kate Latham, WattzOn

ABSTRACT

Miscellaneous end-uses (electronics, small appliances, lighting and small motors) comprise the majority of electricity growth in the U.S. residential sector. While its growing impact has been detailed, no savings paradigm has been introduced other than to set minimum performance standards for the manufacturers. In contrast, this paper describes an alternate approach to reducing miscellaneous loads, through home energy coaching. WattzOn has developed and implemented a home energy-coaching program for the city of Benicia, CA. During a 23-month period over 200 homes participated in the Benicia Home Efficiency Program and participants reduced their electricity use post-visit by 8% (year-to-year basis), including significant reductions in miscellaneous end uses. This paper examines the results of the home energy coaching program and the source of savings. The results show a highly cost-effective program that catalyzes substantial energy savings from behavior changes; a novel approach worthy of further study.

Introduction

Miscellaneous end-uses of electricity (electronics, small appliances, lighting and small motors) is growing rapidly, approximately 8% per year. Ironically, in highly-efficient homes – meaning efficient in heating, cooling, hot water and major appliances – miscellaneous end-uses of electricity can account for more than half of total energy consumption (Parker, Fairy & Hendron 2010; Roth et al. 2008). For policy and program planning these trends are dismaying. Years of home retrofit programs can be offset by the growth in electronics – after all a TV can use as much electricity as a fridge. And, while policies to create appliance standards and Energy Star models can help tip the market toward energy efficiency products, there has been little attention paid to effective programs that reduce miscellaneous electricity use from items already in the home.

This paper describes the Benicia Home Efficiency Program (BHEP), which uses a home visit to coach residents on how to save energy from behavior changes. As described below, these changes are almost exclusively electricity savings from miscellaneous end-uses. The program is novel in its delivery (light-touch home coaching visits), in its use of technology to support resident engagement and data collection (the WattzOn web platform), and in its ability to catalyze savings results from behavior changes. The program averages 7% electricity savings per month from all participants.

The results from nearly two years of program operation demonstrates that a cost-effective home coaching program can deliver substantial electricity savings to participants. The results also suggest that we are just at the beginning of a research agenda to understand the mechanisms of catalyzing electricity savings from behavior changes. This agenda is now relevant more because of increasing electricity use from miscellaneous end-uses, increased interest in energy savings from behavior changes, and programmatic interest in not offsetting home retrofit energy saving gains with increased purchase and use of home electronics.

The plan of this paper is as follows. The next section introduces the city of Benicia and the BHEP, and this is followed by a description of the data. The fourth section discusses the electricity use of the participants, and the fifth section details the savings results. The final section draws conclusions and discusses next steps on the research agenda.

About Benicia and the Benicia Home Efficiency Program

Benicia is a city of 27,000 residents in the northeast corner of the San Francisco Bay. It is a waterside community and covers an area of 15 square miles, three of which extend into the water. The city has a temperate climate – dry summers and mild winters and its summer temperatures are significantly lower than nearby communities due to its adjacency to the bay. Many residents of Benicia commute to jobs outside the city in San Francisco, Berkeley and Oakland.

Eighty-five percent of the nearly 11,000 homes in Benicia were built after 1960 and 70% of them are owner-occupied. Seventy-five percent of homes are single-family residences. The 2011 median household income was $87,000. The ethnic composition of the city residents is: 73% white; 12% Hispanic; 11% Asian; and 6% African-American (BoC 2012).

BHEP was launched in March 2010 and funded by a settlement between city residents and Valero, a local oil refinery. The goal of the program is to reduce the carbon footprint of residents and to involve Benicia High School students in the effort. A home energy coaching program has been developed and delivered by WattzOn. Students assist by performing an assessment and coaching session of indoor water use, under the supervision of WattzOn.[1] WattzOn has developed online tools to quickly record, analyze and report energy and water data, including the printing of personalized reports in the home.

The process of the home energy coaching visit is as follows: the resident signs up for an appointment at the program website, answers some basic questions, and ideally provides a one-year history of utility bills. Often bills are not prepared in advance, and the home energy coach simply completes the task with the resident at the start of the visit. In general the home visit has four parts: kitchen table conversation about current bills, how they compare and how the rate tiers apply; diagnostic of energy use, including data from TED meter[2] installed to the circuit breaker panel; review of findings and savings opportunities with the resident; final recommendations printed and reviewed with resident. Up to $75 in light bulbs, smart power strips, timers and low-flow showerheads are also made available to residents. The light bulbs are installed if requested. The program is free to Benicia residents, but they are required to provide pre- and post-audit energy bill data. Feedback on the home coaching visits has been hugely positive.

There are two items to note about the home visit. First, the program provides for a single visit. There is no follow-up coaching at this time, although residents are invited to call WattzOn with any questions; all energy savings are catalyzed by the single contact. Second, the final recommendations recorded for the resident in a printed report, and analyzed below, are actually a

[1] Residents saved 10% on their annual water bills from the coaching sessions. Details can be found in the March 2012 program report.

[2] The phrase "TED meter" refers to The Energy Detective, a real-time home energy monitor. See www.thenergydetective.com.

subset of all savings opportunities. The recommendations reported are only those that have been selected by the resident, in conversation with the energy coach. For example, while unplugging the garage fridge will save energy, if the resident says they do not want to take that action the recommendation is not reported.

BHEP is a very cost-effective energy savings program. Table 1 compares its cost and performance to the benchmarks issued by EPA in 2009 for weatherization and direct installs programs (EPA 2009). BHEP provides first-year savings at less than one-fifth the cost of the EPA benchmarks. While it is important to understand the nature of the savings, which is the focus of the remainder of this paper, this cost advantage suggests further consideration of this novel approach is warranted.

Description of Data

Before detailing the energy use and energy savings results, it is useful to summarize the data set. Participants in the program were required to provide one year of utility bills at the time of the home visit and to provide energy bills twice during the following year. The WattzOn web technology provides automated utility bill downloads for over a hundred utilities, and was used to make this data collection effort easier for the participant who simply set up their account on WattzOn once. Pacific Gas & Electric (PG&E) is the natural gas and electric utility for Benicia, and has changed its online account display several times since BHEP was launched. Inevitably some residents failed to maintain their updated online PG&E accounts and their data was no longer available to WattzOn, despite phone calls and emails. The data available are summarized in Table 2.

We expect self-selection in program participants, but when BHEP participants were compared to demographic and housing data from the U.S. Census and to appliance saturation surveys in California, no discernable differences were found: program participants are very much similar to the larger population. Details can be found in WattzOn's review report to Benicia (Amram & Latham 2012).

We attempted to obtain monthly data on electricity use for the sample period from PG&E for the city of Benicia. This would be used as a control group in our savings analysis. This data has not yet been made available to us. We recognize that there could be significant self-selection bias in the results, as only residents already interested in saving energy are likely to sign up for BHEP. We will explore this issue further once the control data is made available.

Electricity savings are measured by resident via year-over-year comparisons, e.g., January 2011 minus January 2010 equals Change. PG&E publishes its meter reading/bill processing schedule, and Benicia homes are clustered into the groups billed at the end of the calendar month (Groups B, C and D).[3] Because of this coincidence, billing month is approximately calendar month.

Finally, we note that all homes have smart meters installed after March 2009, the first month in our data. Our experience is that program participants do not use the smart meter data available to them on their online accounts. This conclusion is based on how few residents had signed up for an online account, remembered their online password or knew that they could see their data.

Electricity Use by Program Participants

The home visit focused on electricity and water savings, with a small amount of time and effort spent on natural gas savings. For the remainder of this paper we will examine electricity

[3] The 2012 meter reading schedule is found here: http://www.pge.com/includes/docs/pdfs/shared/customerservice/meter/readingschedule/mtr_schedule.pdf. Our experience is that the meter reading schedule is also the billing schedule. We have noticed no change in the timing of bills after the installation of smart meters, which of course, can be read at any time.

savings only. The other savings are detailed in the program report (Amram & Latham 2012). Benicia's summer climate is much cooler than surrounding cities because of its bay location, and few residents use their air conditioner on a regular basis. Almost all winter heating is fueled by natural gas. Daily electricity use does not follow a seasonal pattern, instead remains fairly constant throughout the year.

Table 3 shows the average annual utility bill for program participants. Again, BHEP participants are fairly typical consumers; these expenditures are close the PG&E regional averages (Amram & Latham 2012).

Daily electricity use without the seasonal influence is comprised of a number of typical end-uses, such as refrigerators, other appliances, media and computer electronics, and other miscellaneous end-uses. The number or size of these items might increase with the size of the home or the number of occupants. Figures 1 and 2 present summary findings about the pattern of electricity use in this regard.

As the figures show graphically, and as the statistical results also indicate, there is only a weak relationship between electricity use and home size, and almost no relationship between electricity use and number of occupants. With the same number of occupants, daily electricity use can vary by a factor of ten. And similarly, for the same size of home, daily electricity use can vary by a factor of three.[4]

These findings have two implications. First, the largest energy users cannot be identified by the two obvious externally observed attributes; large users are best identified through their bills. This means outreach for a program such as BHEP cannot be targeted by these physical attributes, and thus a broad outreach program is needed. Second, the data speak to a large behavioral component in daily electricity use, providing scope for the savings of BHEP.

Electricity Savings

At the end of each home visit, a personalized report was prepared for the resident that summarized energy use and energy savings opportunities. As mentioned earlier, only the energy savings measures that were of interest to the resident were recorded. Table 4 shows that on average, these recommendations totaled 2–3 kWh per day, 10–14% of total electricity use.[5] The realized savings were about half that amount, 7% on average.

Panels A and B of Table 4 examine the savings data more closely for homes in the program. The homes are divided by their level of electricity use into four groups to better examine the nature of savings opportunities. The data show that savings opportunities are found at all levels of electricity use, and that savings were realized by all but the lowest group. The magnitude of the savings recommended and realized increases with the level of electricity use. These data support the concept that daily electricity use has a large behavioral component, and that savings can be catalyzed with a home coaching visit.

For the BHEP participant, the average realized savings is $102 per year, less than $10 per month. There are additional monetary savings from natural gas and water, but these are relatively small.

The program data provides an opportunity to separate savings from light bulb swaps from savings from other sources. The BHEP offers participating residents certain energy saving devices for free, including up to 15 light bulbs per home. The resident can purchase additional light bulbs at cost, but this

[4] The Adjusted R^2 s show that very little of the variation in electricity use is explained by either observable attribute; the estimated slope coefficient (which is statistically significant in both equations) shows that electricity use goes up by 5 kWh per day per 1000 square feet and by 1.8 kWh per day per additional occupant. In both cases the increase is small relative to the dispersion in the electricity use data.

[5] The table also shows the pre-visit electricity use, 21 kWh per day, which very close to the regional average of 22 kWh for PG&E.

option was never used. On average a 15-watt CFL replaced a 60-watt incandescent bulb. It is assumed that the average usage in the associated fixture is 2 hours per day. Using data by home on light bulbs installed, the amount of electricity saved by these bulb swaps can be estimated separately. The result is shown in Table 5.

As Table 5 shows, only a very small fraction of the savings in the recommendations is from light bulbs. The vast majority of recommendations for electricity savings are directed to other end uses. These behaviors can be reduced usage or to purchase a new energy efficient appliance. Because of this mix of usage and purchases, "behavior" is put in quotes to indicate its extended meaning.

The data of Table 5 is another puzzle piece that contributes to our understanding of the nature of electricity savings catalyzed by the home visit. Having ruled out seasonal variation and light bulbs, as well as heating and cooling end uses, Tables 6 and 7 examine the recommendations made in more detail.

Table 6 shows the recommendations made in the home visits, ranked by frequency. After light bulbs, the second most frequent recommendation was about the refrigerator. The remaining recommendations are from miscellaneous end-uses, and their presence is an indication of both the types of items in participants' homes and a bit about how they use them. A full 18% of the recommendations are to either eliminate an electronics device or reduce its hours of use. As most Americans are not willing to reduce their hours of television viewing, the recommendations recorded are the more acceptable "turn off computers at night" or "have only one TV on at a time." and so on.

Benicia homes, as seen by BHEP participants have more refrigerators than the California or national averages, as 46% of BHEP participants have two or more refrigerators or freezers. And nearly 3% of homes have four units.

Other than four recommendations to upgrade pool pumps and air conditioners, the purchase recommendations to save electricity are entirely about refrigerators. For convenience, these recommendations are consolidated in Table 7.

Eighty four out of the 91 recommendations in Table 7 are to purchase a more energy efficient fridge or freezer. Typically only one of these recommendations would be made per home, so roughly 84 out of 156 homes, or 54%, would benefit from an upgraded fridge or freezer, had the residents been interested in this information. We have not conducted a follow-up survey to ascertain if residents actually made these upgrades, but anecdotal evidence leads us to believe that most purchases have not been made yet. These data suggest a programmatic focus on refrigerators might lead to additional energy savings above what has been realized to date from BHEP.

Variation and Persistence of Electricity Savings

The final set of results we examine in this paper are the monthly electricity savings realized by program participants. There are nearly 100 homes with one year of post-visit electricity bills and Table 8 shows the monthly savings.

The top part of Table 8 shows the average electricity savings by month for all homes. A seemingly clear trend line emerges, with 9% savings in the first month after the visit decaying down to 1% savings 12 months later. This suggests that the savings do not persist over time; consistent with behavior changes as the source of the savings, not light bulbs or new refrigerators. The minimum and maximum electricity savings per month indicate large changes in household composition, vacations, remodels, and so on are also present in the data. Finally, the relatively large standard deviation indicates a wide dispersion of electricity bill changes in each month. Panels A and B of Table 8 explore this further.

Panel A breaks the monthly savings data into cohorts, defined by the month of the home visit. As the columns in Table 8 are the time relative to the home visit, there are different calendar months in the cells of any column. The yellow colored cells highlight the way to see a single calendar month in the table, as a diagonal line to the upper right.

Examining the data by cohorts shows that at the micro level, there is no clear trend line. There are large jumps in electricity use by month for each cohort. Looking at the diagonals, there is a bit of consistent variation due to the calendar month in the upper left, but not in the middle or below. The table shows that there is simply enormous movement in the monthly electricity data from month to month, indicating a complex pattern of behavior and other factors.

Figure 3 vividly illustrates the movement in the monthly electricity use. The nine cohorts are plotted separately and there is no common pattern of savings or of change.

Panel B of Table 8 reports that a solid majority of homes, approximately 60–75%, had savings in each month post-visit, indicating that the results are not driven by just a few participants. Further, when a home did save electricity, it achieved savings of 15–21%, an amount that will be noticeable and psychologically rewarding to the resident. Note that the majority of the monthly decay in the average savings over time comes from the decrease in the number of homes continuing to save. When residents continue to save, they generally maintain savings. This suggests that prompts and other means of continued engagement could be effective in reminding residents to save.

Table 8 highlights both program successes – strong average savings, and a solid majority of savers – and also how much is not known about the source of these savings. While we have previously eliminated seasonal factors, air conditioning, and refrigerator purchases, we have not identified the exact actions taken nor why they are not sustained each month.

Conclusions

The Benicia Home Efficiency Program is a novel and cost-effective approach to reducing residential electricity use. The program results show that the home coaching visits catalyze savings, and that these arise from behavior changes. The huge dispersion in changes in monthly electricity bills suggests that there is more to learn about how residents reduce electricity use.

In a recent report, Navigant Consulting found only one validated model of energy savings from behavior changes, the model of peer comparisons by OPower (Navigant 2011). Average savings from the OPower model are approximately 2% per year, but Navigant challenged the source of these savings, arguing that at least one study had found that 75% of the energy saved came from equipment changes (Dougherty 2011). OPower challenges this conclusion (Lyng 2012). In contrast, we find a large role for usage-based behavior changes, and the data here suggest little or no equipment changes underlie our program results.

Further, the many studies cited by Navigant in its review of OPower suggest that peer comparisons are activating savings in a small minority of residents who receive the information. The OPower program is highly cost-effective, but the vast majority of residents are not engaged. In contrast, the results from BHEP show broad engagement in savings after a home visit, as more than 60% of homes save, and a deep level of savings (15%+ on average). We conclude that the home visit coupled with the scalable technology provided by WattzOn, creates a platform to drive more savings throughout the community.

Finally, we note that monthly electricity savings data presented here is quite "jumpy"; while the average savings has a smooth profile of decay over time, the individual data show quite a varied pattern. Ceniceros (2009) discusses these same phenomena, and concludes with the need for a better understanding of the savings mechanism. Our study reinforces that conclusion.

In sum, the BHEP program produces excellent savings from miscellaneous end-uses at a reasonable cost through behavior changes and is worthy of additional study.

Table 1. Comparison of Electricity Savings and Costs to EPA Benchmarks

	EPA	BHEP
kWh saved per home	260	489
Cost per home	$1,200	$362
Cost per kWh saved	$4.62	$0.74
kWh saved per program $	0.22	1.35

Source: EPA 2009 and authors' calculations

Table 2. Composition of Program Data

Total Home Visits, Mar 2010 - Nov 2011	198
Homes that did not provide utility bills	23
Total Homes with Utility Bill Data	**175**
GROUP A	
Homes with audits before Dec 1, 2010	120
Homes without post-visit utility bills	15
Residents who moved (incomplete data)	5
Installed PV post-visit (incomplete data)	2
Homes with 1-year Post-Visit Data	**98**
GROUP B	
Home Visits, Dec 2010 - Oct 2011	74
Homes without post-visit utility bills	16
Homes with 2-months Post-Visit Data	**58**
GROUP C = GROUP A + GROUP B	**156**

Table 3. Average Annual Utility Bills for Program Participants (Before Home Energy Saving Visit)

	Fuel	Percent
Electricity	$1,256	70%
Natural Gas	$539	30%
TOTAL	**$1,795**	**100%**

Source: Based on 12-months utility bill history provided by program participants. Group C sample.

Table 4. Energy Use, Recommendations and Realized Savings

	Average kWh per Day			Percent of Pre-Visit		
Homes	**Before Home Visit**	**Savings Reported***	**Savings Realized**	**Reported***	**Realized**	**No. in Group**
TOTAL (GRP A)	21	3	1.5	14%	7%	98
TOTAL (GRP B)**	19	2	1.3	10%	7%	58
Panel A -- Group A (one year of post-visit data)						
Level of Use						
Ultra-high	35	7	1.0	21%	13%	16
High	24	4	0.2	15%	6%	32
Medium	15	2	0.1	12%	5%	44
Low	9	1	0.0	10%	0.3%	6
Panel B -- Group B (two months of post-visit data)						
Level of Use						
Ultra-high	36	4	0.6	12%	15%	6
High	25	2	0.1	8%	7%	16
Medium	15	2	0.1	12%	4%	32
Low	8	1	-0.1	11%	-6%	4

* Savings Reported are the subset of savings measures identified that are of interest to the resident.
Ultra-high homes use 30 or more kWh/day; High use 20–29 kWh/day; Medium use 10–19 kWh/day; Low use less than 10 kWh/day.

Table 5. Decomposition of Savings Recommendations*

Level of Electricity Use	**Electricity Savings**	**Savings from Light Bulbs***	**Savings from Other "Behaviors"**
Ultra-high	13.4%	1.4%	12%
High	6.0%	1.4%	4.6%
Medium	5.1%	1.7%	3.4%
Low	0.3%	-	-

*Data are for Group C, all homes participating in the program.

Table 6. Frequency Count of Electricity Saving Recommendations

Recommendations	Count	Percent of Total
Change to CFLs	592	67%
Eliminate electronic device	91	10%
Reduce hours of use for electronics	71	8.1%
Upgrade kitchen fridge to new Energy Star	42	4.8%
Upgrade garage fridge to new Energy Star	20	2.3%
Upgrade garage freezer to new Energy Star	19	2.2%
Replace electronic device to more efficient	11	1.3%
Reduce hours of use (pool pump)	10	1.1%
Eliminate/unplug small fridge	6	0.7%
Reduce hours of use (recirculation pump)	6	0.7%
Upgrade small fridge to Energy Star	3	0.3%
Upgrade to multi-speed pool pump	2	0.2%
Turn down water temp setting in hot tub	2	0.2%
Upgrade AC to Energy Star	2	0.2%
Turn off hot tub	1	0.1%
Eliminate garage freezer	1	0.1%
TOTAL NUMBER OF RECOMMENDATIONS	**879**	
Average number of recommendations per home*	6	

* Data from Group C, 156 homes.

Table 7. Detail on Refrigerator and Freezer Recommendations

Recommendations	Count
Upgrade kitchen fridge to new Energy Star	42
Upgrade garage fridge to new Energy Star	20
Upgrade garage freezer to new Energy Star	19
Eliminate/unplug small fridge	6
Upgrade small fridge to Energy Star	3
Eliminate garage freezer	1
TOTAL	**91**

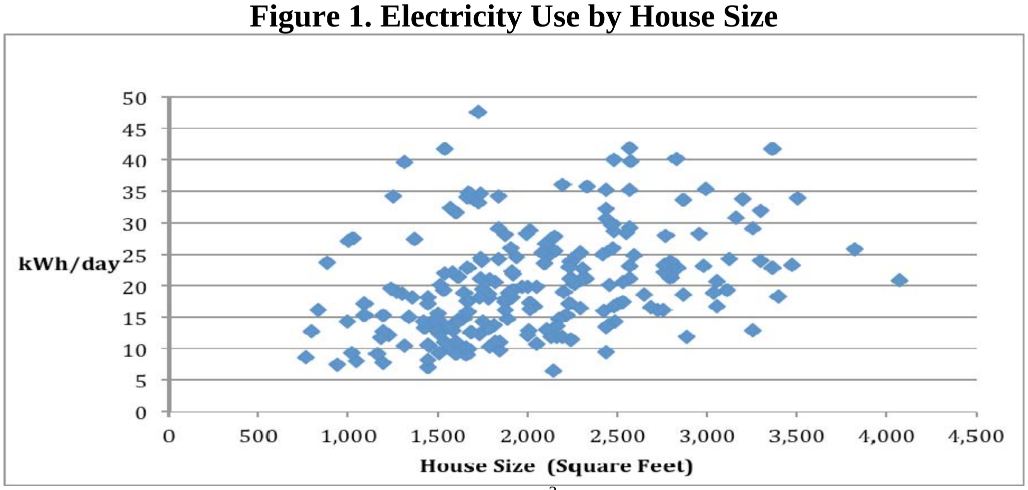
Source: Authors' calculations. Recommendations made for Group C

Table 8. Detail on Electricity Savings by Month

Month of Home Visit (in 2010)	No. of Homes	Month Post-Visit											
		1	2	3	4	5	6	7	8	9	10	11	12
Average		-9%	-7%	-3%	-6%	-4%	-6%	-5%	-3%	-4%	-2%	-2%	-1%
Min		-62%	-41%	-60%	-79%	-78%	-82%	-86%	-66%	-73%	-59%	-63%	-57%
Max		79%	55%	76%	527%	131%	48%	56%	155%	180%	89%	252%	96%
Std. Dev.		20%	19%	22%	59%	23%	19%	20%	27%	31%	23%	34%	21%
Panel A: Electricity Savings by Cohort													
March	15	-21%	-12%	16%	-21%	-7%	-7%	-4%	0%	-7%	-17%	-4%	-2%
April	14	-7%	9%	-20%	-15%	-7%	-14%	2%	-12%	-22%	2%	14%	8%
May	15	7%	-19%	-12%	-11%	-17%	-5%	-13%	-21%	-3%	-3%	1%	-4%
June	12	-15%	-3%	-1%	-11%	6%	1%	-12%	4%	-9%	-1%	-4%	0%
July	9	-8%	-4%	-14%	-7%	-7%	-18%	-6%	8%	12%	10%	-3%	8%
August	10	-1%	-15%	11%	41%	2%	-1%	-11%	9%	8%	7%	5%	-2%
Sept.	8	-9%	2%	-5%	-18%	4%	3%	4%	3%	7%	4%	-8%	1%
October	6	-22%	-18%	-14%	-4%	-13%	-4%	5%	-1%	2%	-9%	-14%	-15%
Nov.	8	-13%	-10%	7%	8%	4%	-8%	3%	-6%	-12%	-7%	-11%	-9%
Panel B: Homes with Electricity Savings													
Number of Homes		73	71	59	68	59	65	58	58	62	62	58	55
Percent of Homes		74%	72%	61%	72%	61%	66%	59%	60%	64%	64%	61%	58%
Average Savings		-18%	-17%	-16%	-21%	-17%	-17%	-17%	-17%	-20%	-15%	-16%	-15%

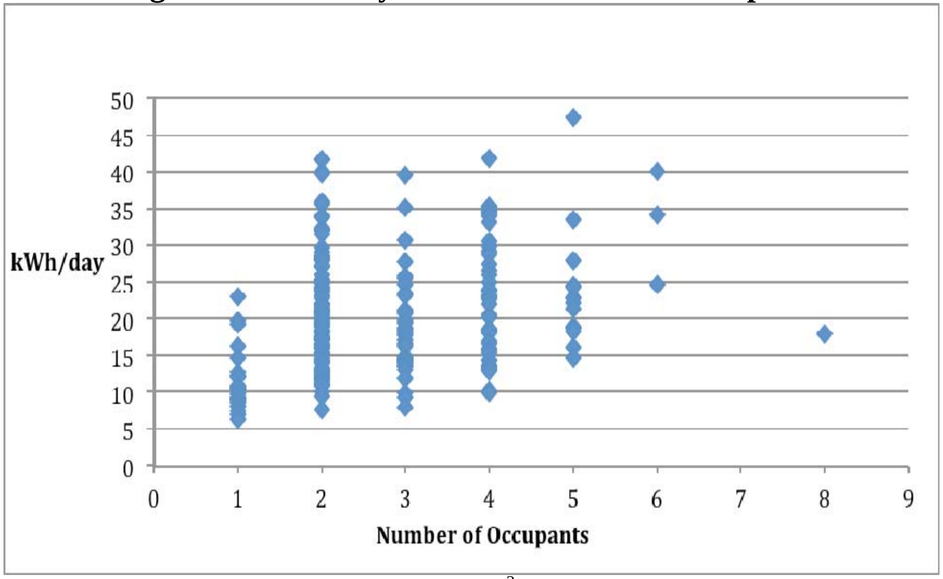
Note: Homes are in Group A, with one year of post-visit data.

Figure 1. Electricity Use by House Size



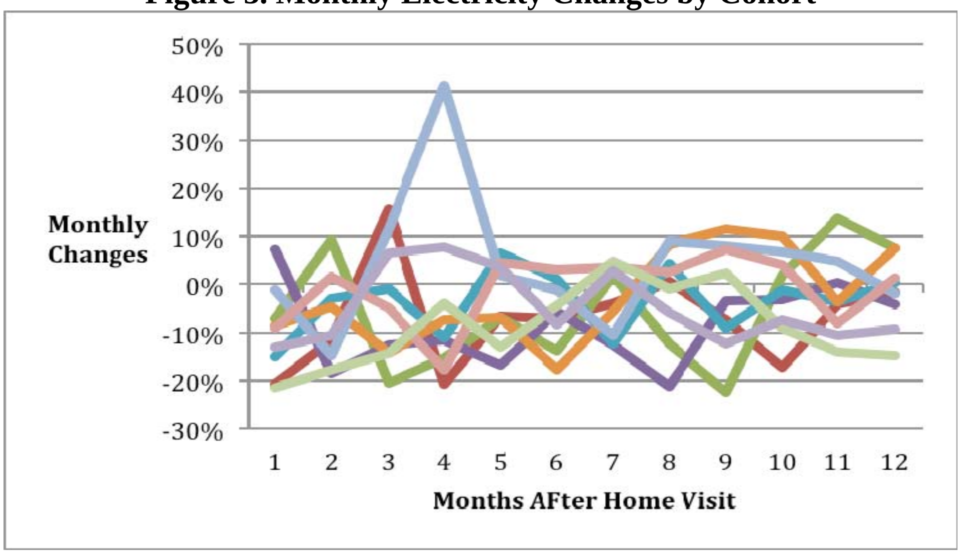
Regression Results (fitted line): Adjusted $R^2 = 0.137$; Slope = 0.005; t-stat = 5.88

Figure 2. Electricity Use and Number of Occupants



Regression Results (fitted line): Adjusted $R^2 = 0.072$; Slope = 1.80; t-stat = 4.186

Figure 3. Monthly Electricity Changes by Cohort



Note: Savings are negative changes. Data is from Panel A of Table 7

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