Debunking IHD Misconceptions

Candice Churchwell, Nexant, Inc.
Ujavlla Gupta and Gregory Mandelman, Pacific Gas and Electric Co.

ABSTRACT

In-home displays (IHDs) were installed in 354 residential homes at a large west coast gas and electric utility. The IHDs' main function was to engage customers with real time electricity usage and the costs associated with that usage, and, as a result, help customers adopt more energy efficient behaviors. The device appeared to accomplish this goal: an estimated 5% daily electric usage savings was found in an evaluation that included billing analysis, surveys of participants about device usability and satisfaction, and separate focus groups with satisfied and dissatisfied participants. This study revealed that prominent display of the IHD in the home's common areas and specific IHD display design elements were important in engaging customers with the device. Public positioning helped stimulate conversations about energy conservation both inside and outside the household. This finding contradicts the commonly held industry belief that the optimal vehicle to communicate information about energy consumption is the personal electronic device (PED). Pilot participants preferred the stand-alone IHD over the PED because it was readily viewable by all members of the household and it displayed compelling usage information. Mobile devices on the other hand, are usually private and energy usage information would need to be pulled by the customer, rather than pushed by the utility. Specific displays of the IHD, such as the "speedometer" of current kW, were greatly preferred over other displays for conveying information about electric consumption. IHD design matters – we have only scratched the surface in terms of understanding how to attract and engage customers.

Introduction

The Pacific Gas and Electric Company (PG&E) IHD pilot was launched to help participating residential customers monitor their electricity usage in real time and better understand the monthly cost of their electric consumption. The IHD enables customers to see:

- The price of electricity ($/kWh) and how it changes throughout the month as the customers move from one pricing tier to another;
- The amount of electricity being used at the moment, month-to-date, and the dollars and cents cost of that usage; and
- The temperature outside (if the customer elected to connect the device to their home wireless network).

The pilot was designed to accommodate up to 500 participants. Installations began with employees on March 1, 2012 and with nonemployee customers on October 1, 2012. By October 27, 2012, the Control4 IHD was professionally installed, by appointment, in the homes of 69 PG&E employees and 354 customers.

The primary objectives of this evaluation are to estimate average daily changes in energy consumption attributable to the IHD's presence in the home and to assess the participants' experiences and satisfaction with the device.

The load impact estimation is accomplished by using hourly load data before and after introducing the IHD to their household. The load impact evaluation also uses interval data from a control group of customers who did not participate in the pilot. The process evaluation relied on four sources of information:

- Two surveys of pilot participants; one survey was conducted four to six weeks after the installation of the IHD and another survey was conducted six months after installation. These surveys inquired about IHD functionality and use, customer satisfaction with IHD installation, reported behavioral changes in response to IHD information, and overall satisfaction with the pilot; and
- Two focus groups with pilot participants at the conclusion of the pilot.

Energy Savings

IHDs provide real time information that shows customers: how much electricity they have used; the cost of that electricity since the start of a month or billing period; and the instantaneous usage and cost of that usage occurring at any point in time throughout the day. Such feedback makes it easier for consumers to understand how their behavioral decisions (both purchase and usage behaviors) impact electricity use and costs. Monthly bills are the result of numerous daily decisions over a 30-day billing period and the mix of appliances that exist in the home. As such, it is impossible for consumers to understand what impact behavior changes have on their bills except in a very general sense (e.g., "If I run my air conditioner less, my bill will probably be lower, but I wonder how much?"). With an IHD, customers can turn appliances on and off and observe the difference in the rate of electricity usage and cost. Equipped with better information, consumers should be able to make more knowledgeable decisions about energy use. Two research reviews in recent years on the effect of IHDs on energy consumption suggest that this can indeed occur (Neenan et al. 2009; Faruqui et al. 2010).

Analysis Approach

A robust approach for evaluating the energy impacts due to IHDs involves:

1. Randomly assigning customers to a treatment group that receives the IHD and a control group that does not. This research design is called a randomized controlled trial (RCT);
2. Measuring usage prior to, during, and after exposure to the treatment;
3. Using sample sizes large enough to ensure the required statistical precision; and
4. Relying on repeated measurements for both treatment and control group customers before and after the IHDs are deployed (which bolsters statistical power) to further enhance statistical precision.

A control group provides information about how customers with IHDs would have used electricity had they not been exposed to the IHD. However, on its own, the use of a control group does not guarantee accurate results. Because customers self-selected into the IHD pilot, participants are, by definition, different from those who are offered participation but decline.

Random assignment helps ensure that the only systematic difference between the two groups is the fact that one group had IHDs while the other group did not. In other words, random assignment helps eliminate alternative explanations for changes in energy consumption. Pretreatment data allows for verification that the differences in energy consumption were caused by the introduction of IHDs and not by pre-existing differences. It significantly bolsters the precision of the estimates and the ability to distinguish the effect (the signal) from variation in electricity use (the noise). Large sample sizes reduce the likelihood that observed differences are due to random chance. Finally, repeated observations also reduce the likelihood that observed differences are anomalous.

This study relies on pre- and post-treatment data, uses reasonable if not relatively large sample sizes, and includes repeated measurements of each participant's hourly usage both before and after the IHDs were administered. However, we could not implement random assignment of IHDs to customers who self-selected into the pilot and instead relied on quasi-experimental methods to eliminate alternative explanations to the change in energy consumption besides the IHD. The study findings rely on a combination of propensity score matching using pre-treatment data and a difference-in-differences estimation.

Propensity score matching is an approach for developing control groups that addresses self-selection based on observable differences between IHD pilot participants and nonparticipants. It is used to identify statistical look-alikes based on observable characteristics from a large pool of control group candidates. Propensity score matching works best when there are many observable characteristics and many potential control group candidates. For example, if the control group is nearly identical across many characteristics such as climate, electric rate, and proportion on PG&E's Balanced Payment Plan (BPP), it decreases (but does not eliminate) the likelihood of bias. The main critique of propensity score matching is that it does not (and cannot) control for unobservable differences between the treatment and control groups. It cannot guarantee that a factor not included in the selection/matching model does not cause the differences in consumption between the IHD and control group customers. For example, while the location, size, rate, and other observable characteristics of participants may be the same, it is possible that another unobserved factor – i.e., the motivation or desire of the homeowner to reduce their energy use – causes the difference in consumption between the treated and control group. However, for such an unobserved factor to bias results, it would have to satisfy three conditions. It would need to:

- Be related to the variable of interest, monthly, or daily electricity use;
- Affect the pilot participants differently than the control group; and
- Be weakly related or not at all related to the factors included in the matching process.

The likelihood of inaccurate or invalid study results is reduced through careful use of pretreatment data. A control group was selected based on consumption patterns during periods when neither IHD participants nor control group customers had IHDs. In other words, the control group customers not only have the similar characteristics, but also used electricity in the same manner as IHD participants during periods preceding the study (pretreatment data period). Matching on electricity consumption patterns during pretreatment data periods substantially lowers the chance that an unobserved factor leads to bias in the results simply because unobserved factors must be correlated with energy use for them to bias results.

The robustness of the results is enhanced further by analyzing the data using a difference-in-differences method, a standard statistical technique used to account for pre-existing differences between treatment and control groups. This approach nets out differences between the control and IHD groups observed during the pretreatment data period. In other words, differences that could not be accounted for through developing a matched control group may be accounted for in the difference-in-differences estimation. This technique improves precision of results and improves the causal link regardless of whether control groups are developed through random assignment or by matching.

Pilot Recruitment

Offers to participate in the IHD pilot were mailed to 3,635 residential customers in the two Bay Area communities of Orinda and Moraga. These communities were chosen for recruitment in order to minimize installation costs and management of logistics. Orinda and Moraga are also in the same baseline allowance territory, and thus face the same tiered electricity prices. The recruitment list of customers was prescreened to only include dual-fuel customers taking the E1 electric rate. There were also screens to ensure that all potential recruits had advanced metering infrastructure (AMI) electric meters that met minimum firmware requirements and that recently reported excellent communication rates. Medical baseline, net metered, Direct Access, Community Choice Aggregation (CCA), BPP customers and customers taking a voluntary dynamic pricing rate were also excluded from the recruitment list. All 3,635 customers on the list also received a follow-up recruitment telephone call. During outbound or inbound recruitment calls, volunteers were further screened to verify that they were the individual in the household responsible for paying the PG&E bill, that they did not intend to move within the next 6 months and that they lived in a single family dwelling where the meter was within 75 feet of the home.

The Control4 IHDs were installed in the home by a technician and by appointment. Installation appointments were made for 366 customers; of which 354 appointments resulted in successful IHD installations. The remainder of the 3,635 customers who did not get an IHD installation appointment did not respond to the mailing or follow-up telephone call. The in-home installation appointment included the following steps:

- Customer signs participation agreement;
- Customer selects location for the IHD;
- Installer powers up IHD and checks for connectivity with the electric meter, moving the IHD to a different location in the home if necessary;
- Installer connects IHD to the customer's wireless network if they wish to use the IHD's weather reporting functionality;
- Installer registers IHD with PG&E customer information system;
- Installer instructs customer on how to use the IHD; and finally,
- Installer leaves behind welcome kit.

The load impacts estimation described below utilized interval data from these 354 customers in addition to interval data from a matched control group. There are various methods that can be used to conduct the matching process. The method used here is described below.

Selecting a Matched Control Group

Propensity score matching was used to select a valid control group. This method is a standard approach for identifying statistical look-alikes from a pool of potential candidates. Propensity score matching explicitly addresses self-selection into the pilot based on observable differences between pilot participants and nonparticipants. The control group was selected from the pool of PG&E residential customers in Orinda and Moraga.[1] Taken together, the population of these two communities is small (i.e., about 12,000 customers in total); and the pool of customers who were included in the pilot recruitment comprised a substantial fraction of this population (i.e., about one-third). Removing the third of the population that had been exposed to the recruiting campaign would have significantly decreased the available population for propensity score matching. For this reason, the customers subject to recruitment were retained in the pool of customers used for control group selection. While it is not ideal to include those who may have explicitly declined the offer to participate in the matching process, most of these customers never were contacted during the telemarking phase of pilot recruitment due to out-of-date or missing telephone numbers. In the end, the risk of bias from including the customers who had received recruiting materials was judged to be lower than the risk introduced by narrowing the available population for propensity matching by one-third.

With propensity score matching, customer characteristics are weighted based on the degree to which they predict pilot participation and are used to produce a propensity score. For each participant, the control group candidate with the closest propensity score was selected. Weather conditions were not factored into the match because all customers in the pool of potential matches face the same weather conditions as the participants. Electric consumption and customer characteristics from the pretreatment period (September 2011 through September 2012) were used to calculate the propensity score:

- Average summer hourly usage during on-peak (12 to 6 PM) and off-peak periods (remaining hours);
- Average winter hourly usage during the on-peak and off-peak periods;
- BPP status during the pretreatment period; and
- Dynamic pricing status during the pretreatment period.[2]

Table 1 compares the customer characteristics of the matched control group and the pilot participants. For example, customers taking electric rates with a low-income discount represent 1% of all customers in both the treatment and matched control groups; the treatment and control groups are almost statistically identical for most customer characteristics tested. The t-statistic indicates how different the treatment and control group are with respect to a particular characteristic. A t-statistic of 0 indicates that the two groups are identical with respect to that variable, while a positive or negative t-statistic indicates that one group has for example, more or less customers participating in an air conditioning load control program than the other. The p-values indicate if the differences are statistically significant. The matched control group and treatment group are statistically different with respect to the proportion of customers

---

[1] Less than 1,000 customers with very high or very low usage were excluded from the control group pool.

[2] The control pool, like the treatment group, excluded customers who were on dynamic pricing before recruitment began. This variable that is being used for the match indicates those customers who enrolled in dynamic pricing after recruitment began but before the installation period.

participating in air conditioning load control and the proportion of customers taking all-electric service from PG&E. The differential of all-electric customers in the control group is four customers, or 1% of the treatment group. Since all-electric service status is closely related to electric consumption, matching on summer and winter average hourly usage should capture this difference between the treatment and matched control group. The differential between AC load control program participation is more interesting: this differential could be a result of a difference in the level of motivation to save energy between the two groups of customers, or it could be a result of a difference in general receptivity towards utility messaging and offers. If the former, then the fact that a difference in motivation to save energy existed prior to treatment, the presumed depression in energy usage that would follow from that would be accounted for in the match on electricity usage. If the latter, the matching process was unable to capture such a difference in customer attitudes. When the status of AC load control participation was included as a candidate factor in the matching process, the overall quality of the match with respect to electricity consumption was poorer.

Table 1. Comparison of customer characteristics of treatment and matched control group

Variable	IHD Treatment	Control Group	t-statistic	p-value
BPP Participation	0.00	0.00	–	–
Low-income Electric Rate Discount Participation	0.01	0.01	0.00	100%
AC Load Control Participation	0.12	0.07	1.93	5%
Dynamic Pricing Participation	0.04	0.04	0.00	100%
All-electric Service	0.00	0.01	-2.01	5%

Comparisons were also made between the treatment and matched control groups on the basis of average summer and winter load shape characteristics and on load for each hour of the day. The treatment and control groups have almost identical load shapes before the onset of the IHD treatment; no differences in hourly or peak load are statistically significant. A table presenting t-test statistics is included in the final report of this evaluation (Sullivan et al. 2013).

Figure 1 shows daily electricity usage for the treatment and control groups during the pretreatment period and the post-treatment periods, that is, before and after the IHD was installed. The pretreatment period under study begins in September 2011 and ends in September 2012. An installation period during the month of October that spans the period of time during which the IHDs were installed was excluded from analysis. The post-treatment period available for study was late October 2012 through late April 2013. Prior to the installation of IHDs, the daily usage patterns are nearly identical. In summer months, the difference between treatment and control daily electricity usage ranges from -5.3% to 6%. During winter months, the difference ranges between -2.4% and 6.9%. Importantly, the difference-in-differences modeling approach will compensate for these differences; these pre-existing differences will not be attributed to the presence of the IHD in the home. The bottom half of Figure 1 shows the difference between average daily usage as a percent of the control's usage.

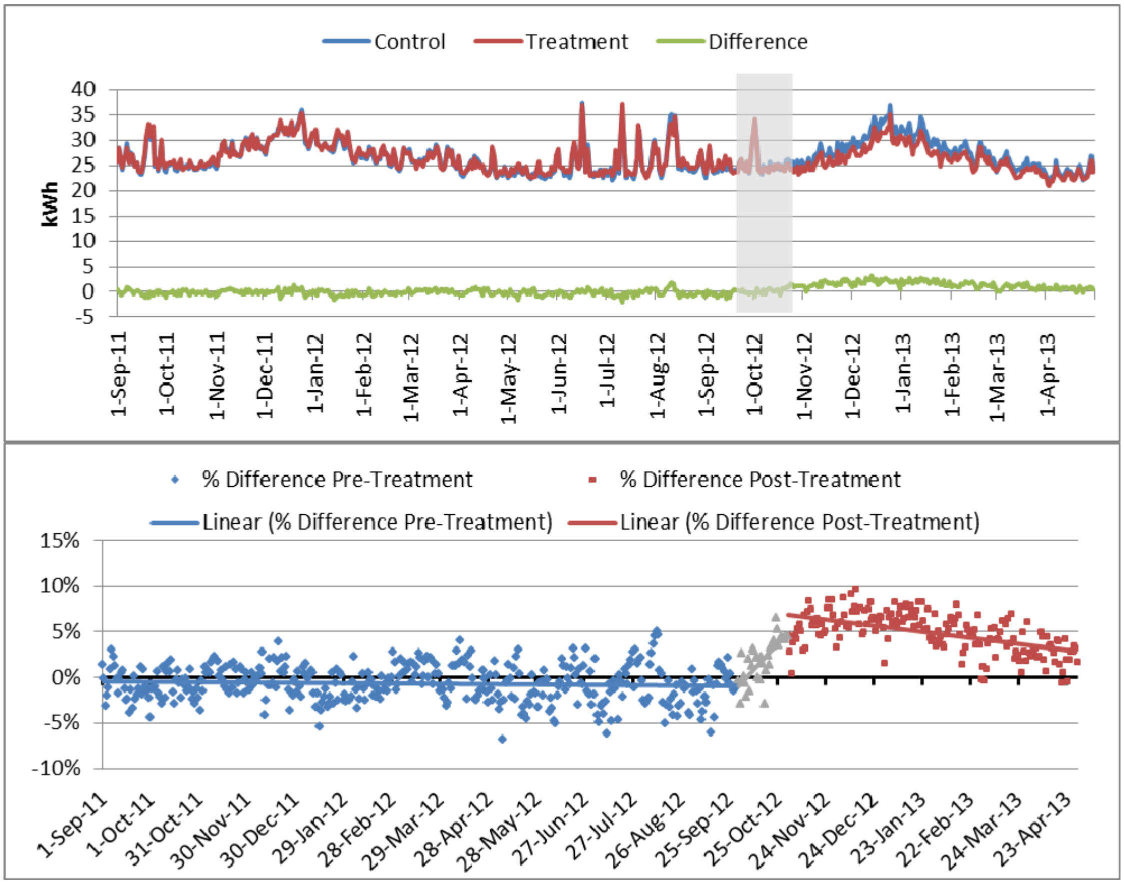

Figure 1. Control and treatment group daily usage comparison – pre and post-treatment (treatment period in grey).

Regression Results

A panel regression was estimated to quantify the difference in usage and the uncertainty of that estimate between the pre and post-treatment periods of the two groups. This difference-in-differences model used daily kWh usage as the dependent variable with daily and customer dummy variables (known as time and fixed effects) and a treatment period indicator as the independent variables. Standard errors calculated using the panel model rely on clustered standard errors and are conservative – that is, the level of precision of the estimate would be higher if we explicitly modeled the auto-regressive processes assumed to be present in daily electric consumption data.[3] The panel regression results (with errors clustered at the customer level) are summarized in Table 2, indicating statistically significant savings from the IHD customers of 5.6% on average per day. The 5.6% decrease represents an average reduction of about 1.55 kWh per day. The regression specification is presented in Equation 1. These regressions were estimated excluding the installation period of October 2012.

While the load impact over the study period is estimated to be statistically significant at the 95% confidence level, Figure 1 indicates that energy savings declines over the post-treatment period. Whether the IHD effect on energy consumption would level off with the passage of more time, or whether it would continue to decay to zero, or whether it would rebound at the

[3] Cluster-robust standard errors do not control well for serial correlation when the dataset under analysis has many customers but many time periods. See "Microeconomics using Stata. Cameron, A. Colin and Trivedi, Pravin K.

conclusion of the spring "shoulder months" and at the beginning of the cooling season is unknown. Future IHD studies would be most valuable if time and funding are available for assessing the persistence of IHD effects over time, or at a minimum, permitting analysis across a full year so that effects can be estimated during heating, cooling, and shoulder months.

Table 2. Panel regression results – average daily impact on electricity usage

Measure	Average Daily Impact	Standard Error	95% CI	
			Lower	Upper
kWh	-1.55	0.34	-0.88	-2.22
Percent	-5.6%	1.2%	-3.2%	-8.0%

Equation 1. Panel Regression Specification – Average Daily Electricity Usage

$$DailyLoad_{i,t} = a + b \cdot treatment_i \cdot period_t + \sum_{t=1}^{N} d_t \cdot date_t + \sum_{i=1}^{M} e_i + \varepsilon_{i,t}$$

Table 3. Panel regression variable descriptions

Variable	Description
$DailyLoad_{i,t}$	Total Daily kWh per customer
a	Estimated constant
b, c_t	Estimated parameter coefficients
$treatment_i$	Dummy variable indicating treatment group individuals
$period_t$	Dummy variable indicating the post-treatment period
$date_t$	Dummy variable for each date
N	Number of days analyzed (9/1/2011-4/30/2013)
d_t	Fixed effects for each customer
M	Number of customers analyzed (347 Control, 347 treatment)
$\varepsilon_{i,t}$	Error term, assumed to be mean zero and uncorrelated with any of the independent variables

Participant Surveys and Focus Groups

There are very few published accounts describing the impacts of IHDs on consumer behavior. In fact, the Electric Power Research Institute (EPRI) has identified premise-level real-time information display as an area of electric utility customer behavioral research where key behavioral effects still need to be quantified (Neenan et al. 2012). Nevertheless, there has been no lack of speculation about how these devices may or may not be affecting consumer behavior over the past few years. This speculation represents what might best be characterized as folk wisdom – produced by a combination of ambiguous research evidence and self-serving marketing chatter. Key findings from this study challenge what, in our view, are misconceptions of the way consumers react to IHDs:

- *Feedback presented through IHDs does not significantly change energy consumption* – this study presents good evidence that energy consumption was lowered by 5%;
- *They do not change energy use-related behavior* – consumers report changing a number of energy use-related behaviors including routine actions and appliance purchase decisions;
- *Consumers ignore IHDs after a short period of time* – only 14% of consumers with this device reported that their device is no longer in service after a year and nearly 80% reported that they look at it twice a week or more after six months; and
- *Consumers would rather have a portable hand-held device* – most consumers in this study said they preferred the IHD to any sort of portable device for reasons that are obvious in retrospect (i.e., the IHD is public where your mobile phone is private, the IHD is always on whereas your mobile phone has to be interrogated).

Participant Surveys

To assess customer experiences with the IHD devices and other program components, two online surveys were administered to pilot participants – one shortly after the pilot commenced, in November 2012 – and another shortly before the pilot ended, in April 2013. A total of 214 out of 354 participants (60%) completed the first survey. While 282 participants (67%) completed the second survey, a comparison of the initial and exit surveys found that participants looked at the IHD less frequently at the time of the exit survey than they did at the time of the initial survey. On the other hand, exit survey respondents reported taking more energy-saving actions than the initial survey respondents. Responses to other questions remained consistent across the two surveys. The IHD's "likeability" had staying power between surveys, with 65% of initial and 61% of exit survey respondents giving the device high scores. Participants were also asked to report how much they are willing to pay for the device in a retail setting if they were told that it takes 10 minutes to set up at home. On average, respondents said that they would pay $22 for the device. While 17% reported that they would not be willing to buy the device at any price, 52% of respondents said they would pay between $10 and $25. No respondent stated that they would be willing to pay the retail price of the IHD at the time of the pilot, which was $225. Respondents were consistent across the study period in reporting whether or not there were occasions when the device appeared to not be working – 30% of respondents said that there had been times when the device did not appear to work. Very few respondents of both surveys reported contacting PG&E for IHD support, and when they did, about half of these customers reported being satisfied with the support provided by customer service representatives.

A little more than half (54%) of exit survey respondents reported that they believe their household reduced its energy consumption as a result of receiving the IHD. Testing whether customers' perception of energy savings reflects actual energy savings would be an interesting investigation. Testing customer perceptions should be incorporated into a large scale IHD pilot where it is possible to segment participants by their stated belief that they have saved energy due to the IHD.

Survey data is of limited use for understanding exactly how consumers were using the IHDs because the answers obtained from surveys are by necessity somewhat superficial. For example, the majority of customers said they were looking at the IHD on at least a daily basis after six months of using the device. This begs several questions such as:

- What information on the IHD exactly are they looking at;

- What do they find interesting about it; and
- Are they doing anything as a result of looking at it?

Participant Focus Groups

These questions and other follow-on questions are essentially impossible to anticipate and incorporate into a short survey that can be administered by mail, telephone, or internet. To fully understand how customers were using and responding to the IHD in more depth and to assess the likely response of customers to PG&E's forward going plan for supporting IHDs, two focus groups were organized – one with customers who said they were highly satisfied with their experience with the IHD and another group that expressed dissatisfaction.

The Control4 device is capable of displaying electricity consumption information in a wide variety of visually attractive formats that include: the real time display of electricity consumption; historical displays of energy consumption; electricity consumption by end use; and weather. In all, the device can display 13 different screens. Consumers in the study reported that they concentrated almost all of their attention on the Home screen as shown in Figure 4. Within the Home screen they concentrated their attention on the My Home Now (the speedometer) and the My Cost per Hour quantity. It should be noted that the popular "speedometer" visualization is one among a number of in-home device display options that, until now, have not been subject to piloting and evaluation. Participants said they spent about 95% of their time looking at the Home screen when viewing the device.

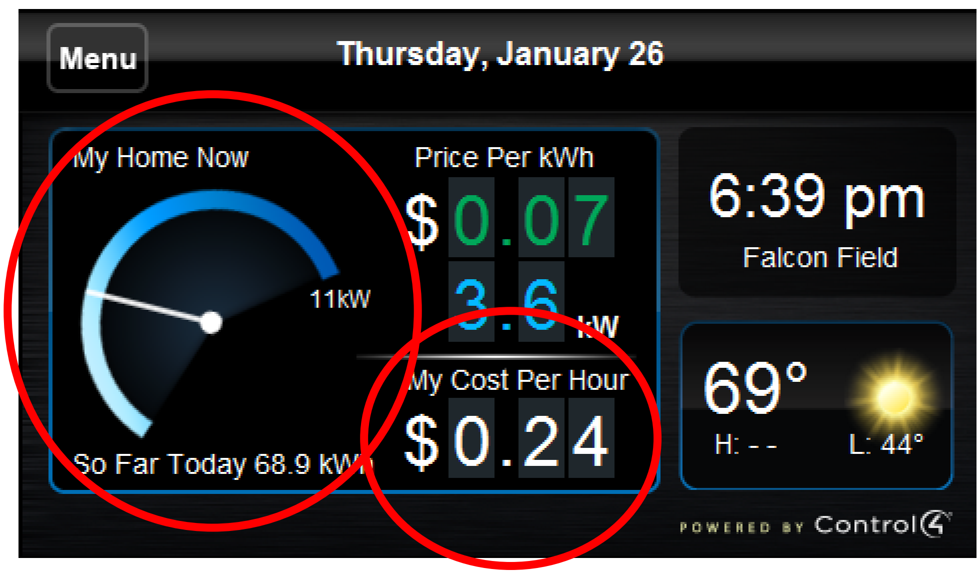

Figure 2. Control home screen.

Most of the respondents (satisfied and dissatisfied) described experiments they did in their homes using the device to discover how much electricity particular appliances were using. However, dissatisfied customers said they thought the device should be able to display end-use loads without having to experiment with them. Several customers reported that they attempted to systematically identify their baseline energy use (i.e., by observing usage when all major loads were off) and then observed how much incremental load the various appliances in their home produced when they turned them on. Those who did this were able to accurately describe the loads of their appliances and say how those loads differed by time of day and day of week. They also identified the presence of baseline loads like refrigeration and vampire loads and to at least think about eliminating the latter. Most customers used the device to discover and learn how the things in their home used energy.

Most of the people in the highly satisfied group reported making changes to the ways they used electricity in their homes as a result of what they learned from their IHDs. They reported turning off unnecessary loads like lighting or appliances not in use and installing more energy efficient lighting where possible. Some parties reported using the device's real time display to identify when their usage was higher than they thought it should be for a given time of day (e.g., bedtime) and going around and shutting down loads until they reached their desired baseline. In addition, several of the customers in this group identified appliances they thought were using large amounts of electricity and discontinued their use. For example, two customers in the group reported that they stopped using their clothes dryer and instead dried their clothes on racks. Two others indicated that they discontinued using radiant electric floor heaters. This topic was not dealt with in any depth in the dissatisfied group, so it is difficult to say with confidence how these customers used the information they obtained from the IHDs.

It is worth noting that there were unintended consequences of presenting the pricing information on the IHDs. Several respondents stated that they learned that the price of electricity did not vary by time of day by observing the price changes on their IHDs. While customers on the whole valued the information they received about the price and cost of electricity greatly, discovering that prices did not vary by time of day produced two unintended results. First, it caused some customers to be confused and frustrated by the actual tiered pricing structure. They could not understand how to schedule their electricity consumption in relation to pricing tiers so as to save money and were thus irritated by the information they received. One customer even concluded that they should be using most of their electricity early in the month because that is when it is less expensive. Another unintended consequence of presenting the prices of electricity is that parties who reported that they previously did laundry and other discretionary actions off peak to save money stated that they stopped worrying about the time of day during which they used electricity. Several recent surveys have identified the popular misconception that electricity prices vary by time of day. It seems that providing accurate information about the price of electricity on the IHDs corrected this misconception for several of the customers in the focus groups and probably had the unintended consequence of increasing their on-peak usage. It is probable that any action that corrects this misconception will lead to some growth in on-peak electricity consumption.

The industry is moving away from standalone IHD devices and is heading in the direction of information supplied through devices on smart phone devices. A surprise finding from the exit survey was that customers stated that they preferred the standalone IHD to a smart phone app. Customers were asked during the focus group discussions whether they preferred something that displayed information on their computer, a smart phone app, or on their TV, and if they preferred the stand-alone IHD, why. With few exceptions, customers in the focus groups said they preferred the stand-alone IHD. They offered several reasons. First, they said the IHD is public for everyone in the household to see and discuss. This facilitates problem definition and problem solving. Next, they said that they like to use the IHD as a surveillance mechanism and that it becomes inconvenient if they have to start an app to see the information. Finally, the IHD is a conversation piece that home occupants and visitors find interesting. Several of the participants indicated they liked that the device was open and visible to household members and neighbors because it stimulated interesting conversations about energy use.

Conclusion

This study estimates the electricity energy savings attributable to IHDs in addition to learning about customer experiences with and perceptions of the IHD using surveys and focus groups. Electricity use feedback, especially real-time premise-level information feedback, is an area of customer research that remains ripe for further investigation, most especially using studies that employ rigorous experimental design. Until substantial credible research evidence is accumulated, assumptions about IHDs' effectiveness in encouraging conservation-minded behavior and investment decisions may continue to be made on the basis of untested marketing claims and ambiguous research results. This study is a step in the right direction despite its limitations which included a geographically restricted test population, a quasi-experimental research method and a short period of time post-treatment available for assessing the effect of the IHD. This study's finding of 5% energy savings during the five months following the installation of the IHD is remarkable, however it is also credible given the extensive survey and focus group research that attended the energy analysis. The customer research revealed how compelling the tested IHD was, even among participants who otherwise reported relatively low pilot participation satisfaction. The speedometer and cost per hour in particular was reported to be the favorite display screens. Nearly 80% of survey respondents reported looking at the device more than twice a week, even six months after first receiving the device. These findings challenge the notion that IHDs are not a promising communication channel between the utility and the customer and are destined for the kitchen junk drawer. The ability of participants to identify specific display features that they used coupled with the evidence that customers preferred the idea of a standalone IHD rather than having the same content on their mobile phone or other personal electronic device points to two primary conclusions. First, that IHD design matters when it comes to generating meaningful energy savings. Second, the question of whether to require the customer to pull energy consumption from the utility rather than allowing the utility to push the information to the customer while facilitating household information sharing could very well be a keystone decision point for successful IHD programs in the future.

References

Faruqui, A., S. Sergici, and A. Sharif. 2010. "The Impact of Informational Feedback on Energy Consumption – A Survey of the Experimental Evidence." *Energy*. 35(4): 1598-1608.

Neenan, B., J. Robinson, and R.N. Boisvert. 2009. *Residential Energy Use Feedback: A Research Synthesis and Economic Framework*. Palo Alto, CA: Electric Power Research Institute.

Neenan, B., J. Robinson, T. Flaim, and R.N. Boisvert. 2012. *Understanding Electric Utility Customers – Summary Report*. Palo Alto, CA: Electric Power Research Institute.

Sullivan, M., C. Churchwell, C. Hartmann, and J. Oh. 2013. *Pacific Gas and Electric Company's Home Area Network (HAN) Pilot – Final Report*. San Francisco, CA: Freeman, Sullivan and Company.