RESULTS FROM RECENT REAL-TIME FEEDBACK STUDIES

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EXECUTIVE SUMMARY

This report summarizes the results of recent (2009-2011), large-scale, real-time feedback pilots and experiments in the U.S., U.K. and Ireland. It builds upon previous work done by ACEEE that found household electricity savings due to all types of feedback ranging from 4-12%, based on pilot studies with small sample sizes (Ehrhardt-Martinez et al. 2010). We undertook the current study to verify this range of savings in light of recent large-scale feedback pilots conducted in the U.S. and Europe. The nine pilot studies reviewed here tested various combinations of interventions, but we have limited our discussion to savings from interventions providing direct, real-time feedback on residential electricity consumption and prices through in-home displays, web interfaces, and prepayment meters.

Residential electricity (kWh) savings from real-time feedback in the nine pilots reviewed here ranged from 0-19.5%, with average savings across the pilots of 3.8%. This figure excludes results from the Northern Ireland study, which had the highest savings, because it differs in important ways from the others. Four pilots also considered the effect of various dynamic pricing mechanisms on peak demand, finding peak (kW) savings up to 11.3%.

The largest savings came from the replacement of pre-existing prepayment meters in Northern Irish homes with new prepayment meters having a real-time display. This study deserves special attention because it differs from the other pilots reviewed here in focusing on the impact of a combination of prepayment for electricity with real-time consumption feedback in households that tend to be low income. We include it in this review because it demonstrates the large impact that real-time feedback can have, albeit in one particular context.

The smallest savings were observed in two pilots, which found no aggregate effect of real-time feedback on overall electricity consumption. The lack of savings may partly be due to the business-as-usual or opt-out design of the trials, under which any savings among a small group of participants may have been masked by the lack of savings in the larger population. There were also issues with the adoption and installation of the feedback technologies, which may have limited the potential for savings.

One of the most promising results is that a small percentage of households in several of the pilots had large savings of up to 25%. We propose calling this group the *cybernetically sensitive*, because they seem to respond more readily to feedback, either as a predisposition or, we can speculate, as the result of some type of learning, new motivation, or habit formation that emerges from the process of getting feedback on their energy consumption.

Several pilots found incremental savings of approximately two to four percentage points from real-time feedback devices, over and above savings from other interventions, such as energy-saving advice and more frequent enhanced bills. This suggests that real-time feedback provided through an in-home display or website—or, in the future, on a smart phone—can work in combination with other types of interventions to increase savings.

The wide range of findings across pilots for similar technologies indicates that realizing savings from interventions involving real-time feedback is not one-size-fits-all, but appears to depend on a host of factors, including:

- a “sensitivity” towards real-time energy consumption feedback;
- the design of and content provided by feedback devices, and the degree to which these facilitate the tasks that consumers want to accomplish through feedback;
- the installation process and reliability of feedback devices;
- engagement with feedback, which is both confounded and encouraged by dynamics within the household; and
- the degree to which learning and habit formation take place.

While the cyber-sensitive group may already be predisposed to feedback, and lower income households appear to readily respond to the potent combination of prepayment and real-time feedback, the question remains of whether efforts to entice the “less sensitive” to save through feedback programs are a good utility investment. Based on the very limited data from the nine pilots reviewed here, the cost of providing real-time feedback remains high.

More and different kinds of research need to be done to better understand the actions and investments that households may be making to save energy in response to real-time feedback. We believe that ethnographic research methods, while producing data that is highly context-specific, provide insights that can have a large impact on the design of more effective programs, policies and technologies.

INTRODUCTION

One of the major questions researchers and program designers have regarding demand side management programs is how to better engage customers with their energy usage. There is uncertainty as to what methods work best to deliver information in order to enable behavior change, how long any effect might reasonably be expected to last, and how best to measure and evaluate any savings as part of a utility energy efficiency portfolio. In order to support efforts in this arena, ACEEE received funding from the Overbrook Foundation to produce a snapshot of recent real-time feedback pilot projects—which use either in-home displays, web interfaces, or a combination—to deliver energy use data to customers. Our aim was to be both comprehensive, and also to capture a specific point along a trajectory of extremely rapid technological development and deployment.

Background

ACEEE has long been involved in research and policy related to improving the efficiency of technologies: witness our current engagement in the realm of Intelligent Efficiency, which is the synergistic effect that emerges from the interaction between information and communication technology (ICT)-enabled devices. Technological innovation is an impressive driver of efficiency gains; over time, however, it has become clear that without some understanding of human factors, the full potential of energy efficiency will never be unlocked. With the continued rapid deployment of smart meters across the country, we can now examine the "cybernetic" effect of human/device interactions. We propose to use the term cybernetics in this context based on its definition as the "science of communication and control in animals and machines" (Oxford American Dictionary 1986, from the subtitle of Norbert Weiner's book defining the field).

At least two difficulties present themselves when attempting to understand the dynamics of cybernetic (feedback) systems: human variability and bounded rationality. Machines can be set and regulated—within certain parameters or tolerances—but the same cannot be said of human beings. The decisions that people make are influenced by the available information, their cognitive abilities, time, and other psychological and environmental factors. The impact of human decision-making upon the way cybernetic systems work cannot therefore be underestimated.

Unexpected push-back against smart meters is one aspect of this relationship; from the perspective of residential consumers, these new meters may appear to be delivering data unilaterally from household to utility. Real-time feedback displays provide a means of leveraging the capabilities of smart meters for the benefit of consumers by providing them with information that enables them to, ideally, have more control over household energy consumption.

With the proliferation of devices in our daily lives, it becomes ever more difficult for consumers to maintain an accurate awareness of what devices are operating and how much energy they may be consuming at any given time. The more devices we add, the murkier the picture becomes, and the harder it is to change energy use behaviors. Real-time feedback displays, which in the very near future will likely include 'push' style apps on smartphones, can help consumers recapture this necessary overview of household management and expenditure.

Consumers often do not have very good insight regarding which appliances use the most electricity. Smaller devices or shorter-term activities (like cooking Thanksgiving dinner or using Christmas lights) are often seen as the cause of unexpected spikes in energy consumption. Real-time, on-going data available to consumers in an engaging format can operate as a learning tool, in addition to simply enumerating usage levels.

Goals

The purpose of this report is to summarize the results of recent (2009-2011), high-quality real-time residential feedback pilots and experiments that are, with one exception, large-scale, long-term or both. It builds upon previous work done by ACEEE that found household electricity savings due to all types of feedback ranging from 4-12%, based on pilot studies with small sample sizes (Ehrhardt-Martinez et al. 2010). We undertook the current study to verify this range of savings in light of recent large-scale feedback pilots conducted in the U.S. and Europe.

The pilots reviewed here tested various combinations of interventions but we have limited our discussion to residential electricity savings from interventions providing direct, real-time feedback on energy consumption and prices through in-home displays, prepayment meters, and/or web interfaces. In most pilots discussed here, however, it is not always possible to isolate the impact of direct feedback by itself, as it was deployed in combination with other interventions. In some cases we have identified the incremental impact on electricity savings of adding an in-home display.

Previous reviews of real-time feedback and pricing pilots have reported a range of savings. As mentioned above, Ehrhardt-Martinez et al. (2010) found household electricity savings ranging from 4-12% (with average savings of 9.2%) for real-time premise level feedback pilots conducted from 1995–2010, but many of these had relatively small sample sizes and were conducted over short periods of times. A Brattle Group analysis of pilots employing different combinations of real-time feedback, prepayment, and time-varying rates found average electricity savings of 7% from in-home displays alone, 14% with the addition of a prepayment system, and peak demand savings of 1.8-30% (Faruqui et al. 2010).

Because we found relatively few recent, large-scale pilots in the United States that had publicly available data and had not been reviewed elsewhere, we widened our sample to include utility pilots and experimental studies from other English-speaking countries. Doing so gave us the large data sets we wanted for a robust analysis, without it becoming complicated by sharp differences. While the U.S., U.K. and Ireland may have differing structural and regulatory environments, they share important cultural and linguistic traits—and their respective pilots employed similar feedback technologies—leading us to believe that their comparison could be useful for characterizing the impact of real-time feedback on energy consumption. That said, we do not attempt to account for all differences in pilot structure, design, geography, or demographics.

Recent smart grid policy initiatives in the United States, the U.K., and Ireland have led to large-scale research programs investigating the use of real-time feedback technologies that leverage data provided by smart meters. In the United States, with the awarding of the Recovery Act's Smart Grid Investment Grant, several utilities have completed large-scale pilots. The governments of the U.K. and Ireland have also been active in testing a wide variety of informational and time-varying rate treatments. The results of these studies have become available in the last year, so we consider this a reasonable opportunity to review these programs.

KEY FINDINGS

In the studies reviewed here, the ability of humans to act in widely different ways with respect to real-time feedback was demonstrated in terms of the types of actions people took based on the information provided, how often people chose to refer to these systems, in some cases whether they were installed at all, and if their use fell off due to, for example, their being moved (e.g., from living room to office) during the pilot period. Despite the difficulty of predicting individual actions, human activity on large scales exhibits patterns, presumably built up from habits and lifestyles, and we can see some regularities emerging from the data.

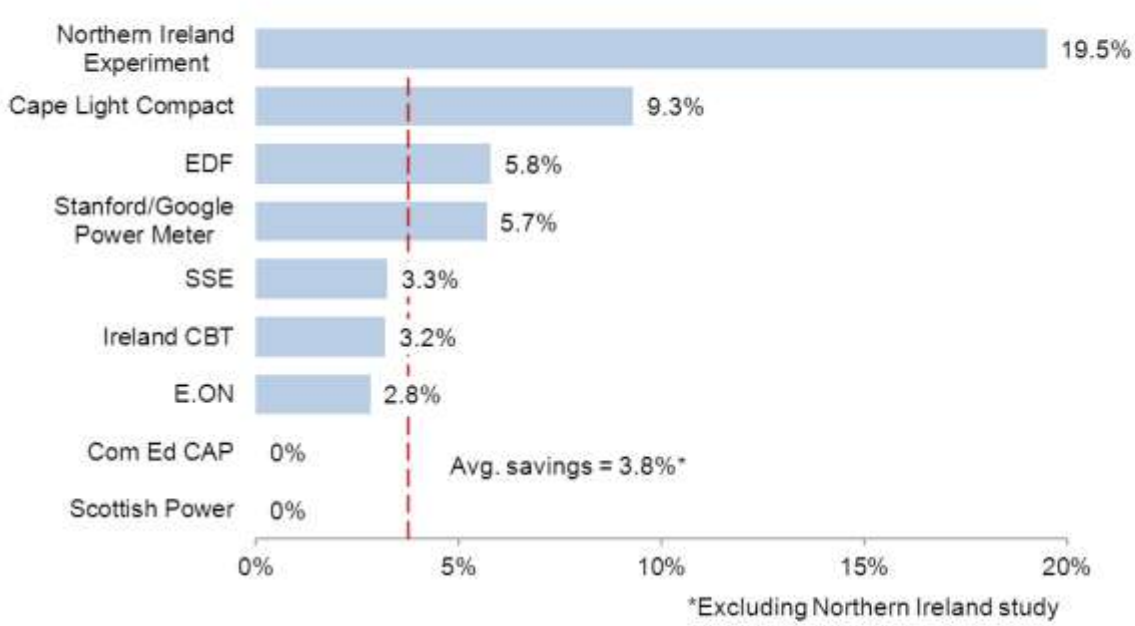
Electricity Savings

Figure 1 shows residential electricity (kWh) savings[1] from real-time feedback in the nine pilots reviewed here ranging from 0-19.5%, with average savings across the pilots of 3.8%. This figure excludes results

[1] The five pilots discussed in AECOM (2011) and CER (2011a) also tested the effects of feedback on gas consumption. For ease of comparison across pilots, we report only electricity savings in our findings.

from the Northern Ireland study, for reasons discussed below. Four pilots also considered the effect of various dynamic pricing mechanisms on peak demand,[2] finding peak (kW) savings up to 11.3%. The summary table on page 6 provides further details of the pilots.

Figure 1: Average Savings[3] from Real-Time Feedback



Source: see summary table on page 6

As shown in Figure 1, the largest savings came from the replacement of pre-existing prepayment meters in Northern Irish homes with new prepayment meters having a real-time display. This study deserves special attention because it differs from the other pilots reviewed here in focusing on the impact of a combination of prepayment for electricity with real-time consumption feedback. Several factors about Northern Ireland may have affected the results. First, its residential retail electricity rates are among the highest in the U.K. and Europe, and the Northern Ireland Government estimates suggest that one-third of households are fuel poor. Second, customers had no choice of electricity supplier; third, prepayment customers may already have been actively monitoring their electricity consumption to avoid having the power cut off. All three factors suggest that prepayment households in this study were highly motivated to make behavioral changes affecting consumption, and that the provision of real-time feedback further enabled this pre-existing motivation or set of habits around the prepayment meter. We include it in this review because it demonstrates the large impact that real-time feedback can have, albeit in one particular context.

The smallest savings were observed in two pilots, which found no aggregate effect of real-time feedback on overall electricity consumption. The lack of savings may partly be due to the business-as-usual or opt-out design of the trials, under which any savings among a small group of participants may have been masked by the lack of savings in the larger population. There were also issues with the adoption and installation of the feedback technologies, which may have limited the potential for savings.

[2] Peak demand, measured in kilowatts (kW) or megawatts (MW), refers to the highest level of electricity demand over a given time period in a particular utility service area. Utilities must have enough spare generating capacity to meet peak demand, or they risk unplanned outages. Therefore, reductions in peak demand, whether absolute or due to shifts in the time when demand takes place, benefit the power system.

[3] EDF, E.ON, & SSE figures reflect midpoint of savings ranges given in their respective summaries.

One of the most promising results is that a small percentage of households in several of the pilots had large savings of up to 25%. We propose calling this group the *cybernetically sensitive* (or *cyber-sensitives* below), because they seem to respond more readily to feedback, either as a predisposition or, we can speculate, as the result of some type of learning, new motivation or habit formation that emerges from the process of getting feedback on their energy consumption.

Several pilots found incremental savings of approximately two to four percentage points from real-time feedback devices, over and above savings from other interventions, such as energy-saving advice, and more frequent enhanced bills. This suggests that real-time feedback provided through an in-home display or website—or, in the future, on a smart phone—can work in combination with other types of interventions to increase savings.

Factors Impacting Savings

While the choice of opt-in, opt-out, and business-as-usual in designing the pilot appears to affect its cost effectiveness and scale, there is no clear evidence from the studies reviewed here that this aspect of pilot design, by itself, affects the level of savings. It is important to note that the actual adoption, installation, and use of feedback devices themselves are effectively something households must always *choose* to do; i.e., this aspect of the pilots is always opt-in. In several of the pilots reviewed here, a large portion of households offered in-home displays refused them, even if they were not required to pay for them. Even among those households that accepted the devices, installation rates varied widely. Finally, actual rates of use of the installed devices also varied among households that had installed them. Therefore, there are at least three points along the human-technology spectrum that pilots must address: technology adoption, effective installation, and continued use. At the very least, requiring professional installation of feedback devices and providing some training on use of the device during installation are two potentially easy ways to avoid large attrition in use of the devices, and so maximize potential for savings.

Dynamics among household members were reported in several pilots as a source of what we have called “inertia” on the potential for reducing energy consumption. That said, other pilots reported the presence of a child under the age of 15 as a factor in higher energy savings. These complex dynamics deserves more attention to understand their effect on the potential for changes in energy consumption.

Those who had relatively higher savings tended not to be more aware, after the fact, of the actions or investments that they took to realize those savings, compared to participants who had lower savings. Furthermore, participants’ perception of their level of effort to save energy is not necessarily correlated with actual savings. That said, there is some evidence that greater engagement with in-home displays—whether in terms of the frequency of interaction or amount of time per interaction—has some impact on savings levels. All of this suggests that any savings achieved may have been because of habits acquired through the course of the pilots.

The types of information provided by real-time displays was not equally valued or considered relevant by pilot participants. The cost of electricity was recalled most easily and seen as most relevant, followed by electricity consumption and, in some cases, the “traffic light” feature providing an environmental cue of usage. In addition, in several pilots participants reported higher engagement with advanced displays compared to more basic displays. In-home displays (IHD) were also rated more highly than other interventions in helping customers become aware of and control their energy consumption; therefore, the installation of an IHD may provide a perceived benefit to customers as part of a larger smart grid rollout.

Overall, consumers’ perception of the usefulness of feedback devices—and the types of information and features that they use—may depend on the tasks they are trying to accomplish. Some tasks that were mentioned include cost savings, control over energy consumption, reassurance that previous actions or investments “worked,” and help in motivating other household members to reduce energy consumption.

Learning and Persistence

Several pilots revealed that electricity savings due to feedback—and perhaps the use of real-time feedback devices themselves—appears to ramp up over time, perhaps following a typical S-shaped adoption, or learning, curve. Darby (2006) ascribes this pattern to the contribution that feedback makes to the building up of a person's (or household's) concrete know-how about energy consumption. The question of savings persistence comes from the recognition that learning—and increasing savings—may cease after some period of time.

Ehrhardt-Martinez et al. (2010) found that the continued provision of feedback generally results in continued savings, and the pilots reviewed here confirm this. Not all pilots reviewed here tested for persistence, but of those that did, all but one found that savings persisted over the course of the pilot (up to 21 months). The one exception found that savings returned to zero only four weeks after the start of the pilot.

Several other pilots also revealed that, while savings did not drop to zero compared to the benchmark period, high initial savings from an in-home display did fall over time. This may have been the result of loss of interest in the device or even the result of learning—i.e., household members interact less with devices as they learn about their "normal" energy consumption. Understanding if it is possible to maintain (and even increase) engagement with real-time feedback devices is a critical area for future research.

None of the pilots, however, tested for persistence of savings after the end of the pilot period, an issue that we take up in the discussion section below.

Costs

The limited data available on the costs of pilots suggests an upper bound for scaling up to the program level. The pilots reviewed here indicated per-household costs to the utility of $100-870 for software, hardware, and installation, with the most common cost being approximately $500. In two cases this is known not to include utility staff time or evaluation costs, but in the other cases it is unclear. These can therefore be considered baseline estimates of one-time technology and installation costs, not operational costs.

Based on the very limited amount of information from the studies reviewed here, the cost of energy saved from real-time feedback pilots is currently high compared to efficiency options. We can think of today's cost per household to the utility as an investment that generates returns over the course of some period of time. Assuming that advanced metering technologies share a cost structure with computers, we can amortize the utility's $500 per-household cost over 5 years at 5%, which yields a cost of saved energy of nearly 30¢/kWh.[4]

Of course, economies of scale and economies of scope would drive these costs down significantly. Cost declines due to learning in the production of demand-side energy technologies are well-documented (see Laitner & Sanstad 2004). To offer a simple example, according to Producer Price Index data published by the Bureau of Labor Statistics, the cost of computers and computer equipment declined by 88% from 1991 to 2010 (BLS 2012), suggesting an average annual decline of approximately 10%. Assuming that the technologies employed in real-time feedback programs are comparable to computer equipment, we might reasonably expect the cost of these technologies to decline at a similar rate. This suggests that the per-household cost to the utility of real-time feedback programs could drop by more than half by the end of the current decade,[5] but that would still be fairly expensive compared to other efficiency options. This does not take into account any additional cost declines due to learning on the part of program staff or contractors conducting the installation.

[4] This is based on average annual U.S. household electricity consumption of 10,300 kWh (EIA 2011b & Census 2011) and average program savings of 3.8% (excluding the Northern Ireland study).

[5] $500*(1-0.9)^8 = ~$215, or ~43% of the current cost.

Summary of Pilot Results Related to Real-Time Feedback[6]

Pilot Name	*Source*	*Location*	*Years*	*Design*	*Sample Size*	*Interventions*	*Avg. Electricity Savings*	*Avg. Peak Demand Reduction*	*Cost to Utility per HH*
Com Ed CAP	EPRI 2011	US	2009-2010	opt-out	5,550	basic and advanced IHD, programmable thermostat, TOU rates	0%	None in aggregate; 5.6 - 21.8% of subset	-
Stanford/Google Power Meter	Houde et al. 2011	US	2010	opt-in	1,065	clip-on real-time display, web interface	5.7%	Not tested	$500+
Cape Light Compact	PA Consulting 2010	US	2009-2010	opt-in	100	clip-on real-time display, web interface	9.3%	Not tested	$870
Ireland CBT	CER 2011a, 2011b	Ireland	2010	opt-in	938	advanced IHD, TOU rates	3.2%	11.3%	-
EDF	AECOM 2011	England	2007-2010	BAU/opt-in	740	advanced IHD, heating controller, TOU rates	5.8%	4-8%	$500
E.ON	AECOM 2011	England	2007-2010	opt-in	4,781	advanced IHD, clip-on real-time display	2.8%	Not tested	$500
Scottish Power	AECOM 2011	Scotland	2007-2010	BAU/opt-in	1,120	advanced IHD, clip-on real-time display	0%	Not tested	$500
SSE	AECOM 2011	England, Scotland, Wales	2007-2010	BAU/opt-in	1,406	advanced IHD, clip-on real-time display, TOU rates	3.3%	0.3 - 0.5%	$500
Northern Ireland Experiment	Gans et al. 2011	Northern Ireland	1990-2009	BAU	45,149	pre-payment meter with real-time "keypad" display	19.5%	Not tested	$99-113

[6] Most of the pilots reviewed here tested a variety of interventions with multiple treatment groups. Here we report savings, sample sizes, and interventions used only for treatment groups receiving some type of real-time feedback (though often in combination with other interventions). Further details of each pilot are available in the following summary section.

PILOTS

Commonwealth Edison (Com Ed) Customer Application Program (CAP)[7]

Summary

The Customer Application Program was a large-scale pilot of smart meter-enabled dynamic pricing and real-time feedback technologies in households in the Chicago area. It utilized an opt-out design, in which households were randomly assigned to a treatment or control group, and remained enrolled unless they took explicit action to leave the trial. In the aggregate, there were no statistically significant impacts on energy consumption from either in-home displays or demand-response pricing treatments. A subset of participants (estimated to be ~5-10%), however, did respond to event-day price signals enough to get significant reductions in load of approximately 5.6-21.8%, corresponding to a total load reduction of approximately 0.3-2.2%. The strongest demand response was found for a subset of participants in the critical peak pricing treatment group, the group we are referring to as the *cybernetically sensitive*. Based on the data collected by the project designers, no demographic differences could be identified marking those who responded to events from those who did not.

Description

Part of Commonwealth Edison's Smart Grid Demonstration Project, the purpose of the Customer Application Program was to determine the impact of advanced metering infrastructure (AMI)-enabled dynamic pricing, technologies and educational strategies on customer electricity usage over the course of one year (June 2010-May 2011).

Participants were randomly selected from the 130,000 homes with AMI ("smart") meters already installed in two footprints: the I-290 region of Chicago and within the City of Chicago. The overall sample size of all treatments was 8,000, with 5,550 households assigned to receive some type of real-time feedback (although actual adoption of the devices was low).

The pilot employed an "opt-out" design, meaning that customers randomly chosen to participate were automatically assigned to a treatment group and informed of their rate and, as appropriate, the type of enabling technology they would receive. Participants remained part of the trial unless they took explicit action to opt out. This type of recruitment design was chosen primarily because opt-in designs have been the norm, and because an opt-out design was thought to offer a more cost-effective and quicker way of achieving the participation levels needed for robust analysis.

Pilot participants were randomly assigned to treatment groups that involved different combinations of a dynamic rate and an enabling technology, such as an in-home display or programmable thermostat. The five rate treatments consisted of: 1) day ahead real-time pricing (DA-RTP); 2) critical peak pricing (CPP) of $1.74/kWh; 3) peak-time rebate (PTR) of $1.74/kWh; 4) time-of-use (TOU); and inclining block rate (IBR).[8] Customers in all control groups remained on the standard (flat) rate appropriate to their dwelling type, and one of the control groups received an AMI meter.

All participants could also voluntarily enroll in an online service providing detailed information about their billing data. Some of the treatments above were combined, on a limited basis, with differing levels of education regarding the technologies, an up-front guarantee that bills would not increase under the pilot, and a requirement for partial payment for some of the enabling technologies.

Treatment groups were compared to their control groups in terms of total electricity consumed during the pilot, the extent of peak electricity reduction and load shifting from peak to off-peak periods, and other measures of usage, such as average daily consumption and average hourly peak-period consumption.

[7] Unless otherwise noted, information about the pilot is based on EPRI (2011).

[8] Under the time-of-use (TOU) rate schedule, prices differed between peak and off-peak demand periods on weekdays. Under the inclining block rate (IBR) schedule, prices increased in a stepwise fashion as consumption increased. The three remaining schedules were based on changing hourly prices given to customers one day ahead of time (DA-RTP), with significant additional charges for peak hours on demand event days (CPP) or significant rebates for reductions during peak hours on those days (PTR).

Data, regulatory, and technology issues led to high-usage customers being overrepresented in some of the samples. Specifically, high-usage customers were overrepresented in the external control group, the inclining block rate group, and groups receiving in-home displays. Consequently, the pilot results could not directly compare the impacts of these treatments with those of other treatments.

Impacts

EPRI's experimental design addressed a large number of hypotheses, not all of which deal with the energy efficiency effects of real-time feedback. Here we are most interested in the impact on overall electricity consumption (the "conservation effect") of treatments involving real-time feedback through a basic or advanced in-home display.

Analysis of treatment effects was split into summer (June-September) and non-summer (October-April) months. Across the entire sample during both summer and non-summer months, there is little evidence that any of the treatments had a statistically significant[9] impact on average electricity consumption. More specifically, across all hours of the summer, none of the treatments led to statistically significant reductions in overall electricity consumption compared to the control group, including real-time feedback given through the basic and advanced in-home displays. Likewise, across the non-summer months, none of the treatments had an impact on overall electricity consumption, including real-time feedback. The one exception to this was that education about and notification of demand response events was associated with lower electricity consumption during summer event hours only. This however, was not related to the real-time feedback technology treatments.

The authors of the CAP evaluation note that while the lack of savings associated with dynamic pricing and feedback technologies is at odds with the literature, that finding may be due to the opt-out design of the CAP pilot, which enrolled participants in the pilot without their explicit consent. Based on a review of the literature, the authors found that 10% or less of the total residential population appears to be predisposed to respond to dynamic pricing and real-time feedback treatments (EPRI 2011, p53). Because the CAP pilot employed a randomized opt-out design, it captured both this segment and the wider population that may not be predisposed to respond to these treatments. Therefore, the authors hypothesized that any savings from the predisposed segment would have been overwhelmed by the lack of savings from the wider population. As we will see below, however, other pilots employing an opt-out design did result in statistically significant electricity savings, so other factors that were not accounted for may have affected the result.

Another possible reason for the lack of savings from real-time feedback, in particular, may be the low adoption of in-home displays and programmable controllable thermostats, making it difficult to detect any influence from these treatments at the aggregate level. Reasons for low adoption were not reported in the evaluation.

In an attempt to identify subsets of participants who did respond to event-day prices or notifications, but whose responses were masked by the non-action of the majority of pilot participants, the researchers constructed customer-specific regression models. In this case, it was found that a subset of participants (6.8-11.6%, depending on treatment group) responded to event day price changes or notifications. Households on the critical peak pricing rate exhibited the strongest and most consistent peak load response, with 11.6% of them reducing load by an average of 21.8% during events.

It appears that event-responders (those who reduced electricity usage during peak hours on event days) typically had lower usage than non-responders, lending credence to the idea that there is a small group of people inclined to respond to price and consumption feedback

Implied reductions in the total CAP load associated with these event-responders ranged from 0.3% to 2.2%, with critical peak pricing showing the largest load reduction response. Some portion of these load reductions appears to be shifts in load, as customers tended to increase electricity consumption again after the end of the event.

[9] Results are considered statistically significant if they are unlikely to have occurred by chance. An alpha (α) level or p-value specifies the amount of evidence needed to make that claim, with 0.1, 0.05 and 0.01 being typical significance levels.

In summary, none of the treatments resulted in a statistically significant difference in usage in the aggregate, when comparing average use across all treatments. However, the analysis did find a statistically significant response by some of the customers under each of the rate types, but these responding customers constitute only about 10% of all CAP participants enrolled in a dynamic rate. In addition, because the installation rates for in-home displays were low, any effects that actually are present (estimated to be 1-2% in other pilots) would have been overwhelmed by the large percentage of participants not receiving the treatment.

Survey Results

Com Ed conducted a post-pilot survey that addressed customer satisfaction, understanding of the rate treatment under CAP, and the degree to which behavioral changes differed between those who responded to events and those who did not. It did not ask questions about what actions participants took to reduce energy use or shift that use during events periods. The survey received 2,423 responses and had an overall response rate of 34%, with only slight variation in response across the different treatment groups.

On a scale of 0-10 (with 10 being "extremely satisfied"), respondents were asked to rate their satisfaction with both their rate plan and Com Ed. The average score for the rate plans was 5.6, with no statistically significant differences between the other rates. Interestingly, the standard flat rate was rated lower than the others (receiving a 5.1 on average), implying that simpler rate structures do not necessarily lead to higher customer satisfaction. In their attitudes towards Com Ed, respondents expressed a higher overall satisfaction than with the rate plans, giving their satisfaction with Com Ed a score of 6.3. Respondents who had received the day ahead real-time rate were significantly more satisfied with Com Ed than flat-rate customers, with satisfaction ratings of 6.5 and 6.1, respectively.

Further questions about participants' understanding of their rates generally indicated that the responses were in the right direction, meaning that customers on a particular rate plan were generally more likely to respond correctly to a feature that was specific to their plan. There was, however, an indication that there was sometimes a low level of understanding of rates, which is perhaps not unexpected given the spotty record of large-scale education campaigns.

In terms of behavioral and attitudinal differences between event-responders and non-responders, the survey found that event-responders tended to agree more often than non-responders that the in-home device helped to reduce electricity usage, and more than 60% of event-responders on the critical peak pricing rate also reported using appliances in off-peak hours. Overall, the survey found that event-responders and non-responders do not differ from each other demographically, but in other ways that are unobservable, at least in this study. Therefore, it may be difficult to identify and enroll non-responders in an opt-in program design, meaning that only those who are already inclined to reduce their electricity usage will volunteer to take part in the program. This obviously presents issues for scaling up pilots, as well as for cost-effectiveness.

Stanford—Google PowerMeter Field Experiment[10]

Summary

Real-time feedback was provided through the The Energy Detective (TED) device and Google PowerMeter web interface to households of Google employees, resulting in an average 5.7% reduction in electricity consumption. Savings were initially seen across all hours of the day, but savings tended to clump into the morning and evening peak hours as the pilot progressed. Savings were not significant after the fourth week of the pilot, suggesting a rapid reversion to old habits or disengagement with the TED device or web interface. Differences in demographics, household characteristics, and self-reported attitudes and values were not associated with differences in response to real-time feedback.

Description

The purpose of the pilot study was to test the effects of Google PowerMeter,[11] a web application that displays real-time premise-level consumption information, on residential energy consumption under

[10] Unless otherwise noted, information about the pilot in the section is from Houde et al. (2011).

[11] The Google PowerMeter is defunct as of September 16, 2011 (Google 2011).

experimental conditions. The pilot used The Energy Detective (TED) 5000[12] in-home monitoring device to gather energy data in 1743 households recruited from among Google's U.S. employees. For the purposes of this pilot, Google disabled the TED's native web-based application, sending the consumption data to the Google Power Meter web interface.

Participation in the pilot was voluntary (opt-in), with recruitment initially confined to employees in Google's California headquarters, and then expanded to all Google offices in the continental United States. Like other opt-in pilots, volunteers had to meet certain eligibility requirements to participate. Households in the Google pilot were given the TED device for free, but were responsible for installation of both the device and Google's PowerMeter web interface. Participants were reimbursed for installation costs (estimated at approximately $500). Considering that the sample consisted primarily of engineers, this self-installation requirement was probably not unreasonable in the pilot, but would likely to lead to very high attrition in programs designed for the general population.

Of the initial 1743 households volunteering for the program, 1628 met eligibility criteria, completed the pre-program survey and agreed to take part in the trial. Of these, 67% (1089) successfully installed the device in the first three months of the experiment, and 24 additional households were excluded due to significant problems with the technology. Thus, 1065 households served as the experimental sample.

Google's PowerMeter was used because it was thought to provide better data realization and to have features not available on TED's native web interface. Feedback was provided in the form of a graph of real-time and historical electricity consumption. Other features included an annual budget tracker and electricity bill forecast, total daily kWh, an estimate of normal "baseload" consumption, projection of electricity consumption during different times of day, day-level comparisons to historical consumption, links to a web page with efficiency tips, and an email reminder. The PowerMeter appeared on a participants' iGoogle homepage, providing a regular visual display of electricity consumption.

Volunteers were randomly assigned to either the treatment or control groups, stratified by U.S. region. The treatment group was given access to the Power Meter interface for 3 months (March–May 2010), after which time the control group was also given access. This allowed the effect of real-time feedback to be measured twice over the course of the study. The study concluded in October 2010, a pilot period of eight months.

Impacts

Real-time feedback on electricity usage led to average savings across all participants of 5.7% ($p<0.01$) over the eight months of the experiment, with the largest savings during the morning and evening peak periods. These savings were estimated using an econometric modeling that controlled for household and day fixed effects, as well as for weather. Baseline data was unavailable, but the use of a fixed effects model allowed the study authors to estimate the average savings in two ways: for the first three months, the savings reflect a comparison of the treatment group to the control group; thereafter, the savings reflect a comparison of the control group to itself before and after receiving access to the PowerMeter interface.

During the first three months of the pilot, when only the treatment group had access to feedback, electricity use in the treatment group was less than that of the control group. Interestingly, once the control group gained access to the Power Meter, its average electricity consumption fell below that of the original treatment group. After another three months, the electricity consumption of both groups began to converge. This suggests that feedback initially had a large impact, no matter the group, but that the impact declined quickly.

The study authors found that treatment and control groups were demographically similar, except for the fact that more participants in the treatment group had incomes below $100,000 compared to the control

[12] The TED device installs in the home's breaker panel and sends information over the existing power lines to a gateway in the home that then connects to an internet router. Energy consumption information is viewed online through TED's proprietary software. The gateway also has the capability to send information wirelessly to an optional in-home display, although these were not used in this pilot (TED 2011).

group. They found no relationship between demographics and observed variances in electricity consumption.

Several other findings are of interest. First, savings initially occurred equally across all hours of the day, but then began to clump together during the morning and evening hours. The difference between these and other times of day became more pronounced over the course of the pilot, which suggests that changes in electricity use were associated with daily habits or with investments in appliances used mostly at those times.

Second, average savings were found not to persist beyond the fourth week of the pilot, which the authors ascribe to participants' reversion to old habits, signaled by this shift in consumption across the hours of the day. Savings during the morning and evening peak periods did persist, but were not large enough to make a difference in average daily savings.

Third, there was no evidence that self-reported demographic, housing and attitudinal differences among participants explained any of the differences in response to feedback from the PowerMeter interface. However, some differences in self-reported energy-saving actions are worth mentioning: households in the treatment group were much more likely to perform an energy audit and turn off power strips when not in use than the control group.

Finally, the study also found evidence that households with higher baseline consumption (i.e., prior to the beginning of the treatment), have larger absolute reductions in kWh consumption, although percentage reductions were the same across quartile groups.

Cape Light Compact Residential Smart Energy Monitoring Pilot[13]

Summary

Real-time feedback provided through the installation of a clip-on display and web interface in 100 households led to average savings of 9.3%. Savings were not spread evenly over the participants: a small percentage of households had savings greater than 11%—our cyber-sensitives. Participant engagement with the web interface was high, with 80% logging in at least once a week, six months after the start of the pilot. The frequency of interaction with the feedback technologies appears to be a key factor in realizing savings. The provision of feedback reportedly led to changes in non-energy using habits, but some survey respondents said that the presence of other people in the household complicated the process of taking actions to save energy.

Description

Over the source of a year starting in the spring of 2009, Cape Light Compact (CLC), a small distribution utility on Cape Cod and Martha's Vineyard, conducted its Residential Smart Energy Monitoring Pilot to evaluate energy savings from a home energy monitoring system and to investigate behavioral aspects of energy use. Using an opt-in design, CLC recruited one hundred qualifying households into the pilot, stratified according to the distribution of customers in its service territory. Participants were provided, free of charge, with home energy monitoring technologies, with training on those technologies, and with access to an online dashboard for the duration of the pilot. The hardware and online dashboard were provided by Grounded Power (now Tendril), and included a clip-on monitor attached to the home's electrical panel, a wireless base station to receive data from the monitor and send it to Grounded Power through the home's router, and a web interface providing energy-use information down to the minute. The web interface provided near real-time access to electricity usage and demand;' energy savings in kWh, dollars and CO_2 emissions; comparisons with like cohorts; and energy-saving actions, among other features.

The pilot included two control groups that were similar to the treatment group both demographically and in their energy use characteristics. One control group consisted of households which initially expressed interest in participating but were not selected (Interested group), while the other consisted of a random sample of like households that also did not participate in the pilot (Blind group). Total cost to the utility for

[13] Unless otherwise noted, information in this section is taken from PA Consulting (2010).

the hardware and software came to $86,672, not including staff time or the evaluation (Kane 2011); this amounts to $870 per household.

Impacts

Overall average electricity savings for the participant group were 9.3% after accounting for spillover savings from programs running concurrently, a daily absolute savings of 2.9 kWh. As can be expected, the distribution of energy savings was wide, with approximately 5% of participants reducing consumption by 13-25%. At the other end of the spectrum, not all program participants saved energy: 23% of participants actually increased their energy use from 2008 to 2009. Savings were highest from August to October, ranging from 11.5-15.7%, or 3.6-4.9 kWh per day.

Survey Interview Results—Participants

During the course of the pilot, telephone interviews were conducted with both participants and members of the control groups to ask about their level of satisfaction with the pilot and their use of the clip-on display systems. Control groups were surveyed in October 2009, while participants were surveyed in February 2010, five to eight months after the installation of the devices. The participant group had a response rate of 72% (n=66), the interested group a 46% response rate (n=96) and the blind group had a 25% response rate (n=100).

Overall, the vast majority of participants were somewhat or very satisfied with most aspects of the pilot, particularly the home installation process, experience using the online dashboard, and assistance from the utility. Interestingly, the breadth and level of detail of information available on the online dashboard had the highest levels of dissatisfaction (12.5% somewhat or very dissatisfied). This suggests that a small portion of participants are very interested in receiving as much information about their energy use as possible.

The survey also gauged use of the online dashboard, finding that, approximately six months after installation of the system, 80% of participants reported logging in at least once per week. When they did log in, participants reported spending only a short amount of time on the site; 65% reported using the dashboard for less than five minutes per log in. A small percentage of participants indicated they typically spent 11-30 minutes logged in.

When asked to rate the effectiveness of features of the online dashboard on a scale of 0 to 10, participants rated the visibility of real-time energy use the highest at an average of 8.17; they also rated understanding energy use and cost savings highly. Understanding of household CO_2 savings was ranked lowest at 4.86.

The survey helped to identify specific actions taken by participants, including installing new lighting fixtures, reducing bulb wattage, increasing refrigerator temperature and using power strips. Those with the highest savings tended to install new indoor light fixtures more often than others with lower savings. In one case, understanding of energy use patterns led participants to purchase a new, smaller TV to be used in place of a 60 inch plasma screen. Because the smaller TV was placed in the kitchen, the family started eating dinner in the kitchen rather than in their previous spot, a fact which underlines the importance of considering non-energy spillover effects from providing this kind of energy-use information.

It is also worth noting that about one-third of participants reported that their savings under the pilot did not match their expectations, and one common reason given was that while they could control their own energy use, the presence of others in the household complicated the process of taking actions that would save energy. This suggests that, at least in these cases, there is one person who is more engaged in managing energy use in the household, and that negotiations within the household introduce some “inertia” into the system, reducing the scope of feasible efficiency potential.

The majority of participants expressed an interested in keeping the energy monitoring system after the conclusion of the pilot, and of those, the average monthly willingness to pay was $7.57, although 38% of participants reported they would not be willing to pay a monthly fee. Therefore, there was some appetite among participants to pay for this type of service—which they had initially received for free—at least after they had experienced it.

Survey Results—All Groups
There were few significant differences either within the participant group or between the participant and control groups in terms of the number or frequency of energy-saving habits (that frequently recur) and tasks (that recur once every 6 months) they reported engaging in. Interestingly, savings levels were not correlated with reported energy-saving actions, i.e., pilot participants did not report higher levels of engagement with energy-savings activities than non-participants, and pilot participants who saved a lot did not report more engagement than participants who saved a little or than participants who increased their use.

This suggests that, although one-third of participants reported that the energy monitoring system made them more aware of their energy consumption, it did not make them more aware of the specific actions they took as a result of that information, at least to the point where they could recall and report those actions. This suggests, further, that the actions that led to savings may have become unconscious habits acquired over the course of the pilot.

Program engagement was estimated by log-in activity, the time series of which provides some interesting insights. After installation was completed, there was an initial spike in the number of log-ins, suggesting a period of experimentation and perhaps habit formation. The number of log-ins averaged approximately 400 per month through the end of 2009, about 6 months after the start of the pilot, and then showed a slight downward trend, perhaps indicating a fall-off in engagement with the website.

While reported actions did not correlate with energy savings levels, for pilot participants, differences in use of the online portal between those who saved a lot of energy ("high savers") and those who saved little or even increased their use ("low saver/negative") provide some evidence that engagement with the online portal was involved in producing savings. On average, high savers spent more time logged into the home energy monitor site than low or negative savers, and they were more likely than the other two groups to report "always" or "often" looking at the graph of household energy use, energy-saving action suggestions and summary of energy savings. In addition, while not a statistically significant difference, high savers tended to log in to the online portal more frequently than low or negative savers. Therefore, frequency and type of interaction with the home energy monitoring system appears to be a key to getting energy savings.

Ireland's Smart Metering Project—Customer Behavior Trial (CBT)[14]

Summary
A nation-wide pilot of time-of-use rates and informational interventions found overall reductions in electricity consumption of 2.5% and in peak consumption of 8.8. The one trial group receiving an in-home display and bi-monthly enhanced bill achieved the highest electricity savings of 3.2% and peak savings of 11.3%. Unlike other pilots reported here, the distribution of savings was not equal across demographic groups: households with higher initial consumption, more formal education, higher incomes or more children under 15 had higher savings.

Description
As a preliminary step in Ireland's proposed national rollout of smart meters, the Commission for Energy Regulation (CER) conducted a trial in 2010 to test both time-of-use (TOU) rates and the effect of the informational interventions on the demand for energy. This Customer Behavior Trial (CBT) was conducted on both electricity and gas service in the residential and commercial sectors; here we report only on the design and results of the residential electricity trial.

The residential electricity trial was conducted over the course of 18 months from July 2009 to December 2010. The first six months consisted of the collection of energy consumption benchmark data, with the actual trial beginning on January 1, 2010 and lasting through the end of December 2010. Smart meters were professionally installed in participating households prior to the benchmark period.

Participants in the trial were randomly assigned to either a control or treatment group. Treatment groups were assigned to one of four TOU rates and one of four combinations of informational interventions. The

[14] Unless other noted, information in this section is taken from CER (2011a, 2011b).

TOU rates were designed to be cost-neutral (i.e., having no financial impact on those who didn't shift consumption), and each had differential pricing during the night, weekdays, and peak weekday hours. There was also a weekend rate. The information treatments included a bi-monthly enhanced electricity bill (the typical frequency), a more frequent monthly enhanced bill, an in-home display (IHD), and a financial incentive for reducing use 10% below actual historical consumption. The control group continued on the typical flat rate and did not experience any changes to their bills or billing frequency.

The IHD used was designed specifically for the trial, and provided near real-time information on electricity consumption and costs, a budgeting feature with both default and self-entry options, and historical consumption information. The enhanced bill included a first page that was very similar to the traditional bill, except for the inclusion of information about the new rates. The second page of the bill—the enhanced "energy usage statement"—provided information on the estimated costs of running select appliances, energy saving tips, weekly average costs of electricity, an explanation of changes in consumption, and a list of online resources for further information.

For the purposes of this report, the particular treatment groups of interest received a bi-monthly enhanced bill and an in-home display, and were assigned to one of four TOU rates. Out of a total sample size of 5028 for the residential electricity trial, these four groups consisted of a total of 938 households. Participation in the trial was voluntary (opt-in), and participants received a small financial incentive (bill credit) for taking part.

Participants were recruited into the trial by invitation letters sent in five phases. Those opting into the trial during each phase were compared with Ireland Electric's customer population (equal to the national population, at the time) to minimize self-selection bias.[15] At the end of the recruitment process, the final sample was compared again to the national population and found to be broadly representative, although smaller households and those with lower average consumption were slightly under-represented.

As a further check against bias, the final sample was also compared to the group of people who did not respond to the recruitment invitation, and found the two groups to be similar in most respects. The one area of difference was in the two groups' attitudes towards energy and engagement with energy reduction, but this was not found to affect a household's likelihood to participate in the trial. The most common reason given for not participating, reported by 45% of non-participants, was the perception that there was no benefit. This was followed by concern about the inconvenience of having a new meter installed, which was reported by 40% of those not participating in the trial.

It should be noted that the majority of Irish homes do not use electricity for heating and do not have air conditioning, so reductions in electricity use are mainly possible through behavioral changes or technology investments related to lighting, appliances such as washing machines and dishwashers, and water heating.

Impacts

Results of the trial were analyzed to evaluate the impact of time-of-use and information interventions on overall and peak electricity usage. Specifically, the analysis estimated the change in energy consumption in the trial groups between the trial and benchmark periods, and compared that to the same change in the consumption of the control group. This type of analysis strips out fluctuations in energy consumption not due to the rate or information interventions.

The trial resulted in an average reduction in overall electricity consumption of 2.5% and a reduction in peak consumption of 8.8%, across all the TOU rates and information interventions. There was a noticeable shift in electricity consumption away from peak and daytime periods (when the price of electricity was relatively higher) and to the immediate post-peak evening period and night period (when the price was relatively lower); this may account for some of the reduction in peak consumption.

The trial groups of interest—which was on a TOU rate and which received the bi-monthly enhanced bill and in-home display—reduced average electricity consumption by 3.2% ($p<0.01$) and peak consumption by 11.3% ($p<0.01$) across the four rate treatments. Among the informational interventions, this

[15] Self-selection bias in this case refers to the tendency for participants in smart metering trials to be more highly educated and/or affluent than the population as a whole, and so to have non-representative energy consumption profiles (CER 2011b).

combination of treatments was the most effective in reducing overall and peak electricity consumption. When compared to the other treatment groups receiving only a bi-monthly enhanced bill, the addition of the IHD resulted in incremental savings of 2.1 percentage points and peak savings of 4.4 percentage points.

Unlike in other pilots reviewed here, changes in electricity consumption for the CBT trial overall were not evenly distributed along demographic lines. Households with a higher annualized benchmark consumption, more formal education or higher incomes tended to make the largest reductions in both overall and peak consumption, perhaps because of more discretionary energy use rather than "cybernetic sensitivity." Specifically, households with the highest consumption had overall electricity savings of almost 10%. Interestingly, there was also a clear relationship between the presence of teenage children in the household and greater reductions in overall and peak electricity consumption. This mirrors findings from other pilots that energy consumption is impacted by intra-household dynamics. Fuel poor households also saw a reduction in bills due to the introduction of TOU rates and a move away from peak time use, balanced by slightly higher overall consumption.

Analysis of changes in consumption over the course of the trial due to the information interventions shows a general trend towards larger reductions in overall and peak consumption from the first to the second half of the trial. The one exception was the trial group receiving the bi-monthly enhanced bill and in-home display, which showed a 1.6 percentage point decline in its impact on overall electricity reductions and a 0.8 percentage decline in impact on its peak electricity reductions from the first to second half of the trial. However, the impact of this group on electricity consumption greatly exceeded that of the other informational interventions for the first five months of the trial, after which point the impact fell in line with the other treatment groups. Thus, the combination of bi-monthly enhanced bill and IHD—while the most effective of the informational interventions initially and overall—did not maintain its impact as well as the other interventions over the course of the trial.

This finding is consistent with the analysis of savings persistence in other pilots reviewed here, although the period of persistence of relatively high savings (five months) from the IHD group is longer than in other studies. Below we look at potential reasons for the fall off in impact of the IHD.

Survey Results

Both pre- and post-trial surveys were conducted, with the post-trial survey capturing any changes in attitude, appliance use or electricity consumption since the initial survey. The pre-trial survey took place in Q4 2009 and the post-trial survey in Q1 2011. Participation in the surveys was a requirement for trial participation, so response rates were high (81%).

Fifty-four percent of survey respondents reported that the trial made them more aware of their energy usage, while 18% reported no effect from the trial. While the majority of participants reported *that* they were more aware of energy consumption as a result of the trial, only 22% reported knowing *how* to reduce consumption after the trial, and only 24% reported being more interested in doing so. Furthermore, the trial resulted in little shift in participants' attitudes towards energy use.

Participants' satisfaction with the IHD was particularly high, with 84% saying it helped to reduce their electricity consumption and 84% saying it helped them to shift their peak consumption. Ninety percent perceived the IHD as an important support to achieving overall reductions in electricity consumption, and 91% perceived it as an important support for peak reduction.

Seventy-one percent of participants reported that they were still regularly or occasionally using the IHD at the end of the trial. Of the 29% who reported not using the IHD, 24% said that they did not understand the information or find it appropriate, and another 39% attributed it to failure of the IHD, although device failure was not independently confirmed.

Finally, 74% of survey respondents also reported believing that they had made "minor" changes to the way they used electricity, while 38% believed they had made "major" changes. However, when these responses were matched with actual savings, there was no discernible difference in the responses between those who achieved large and small savings. In addition, while some trial participants did report investing in energy-efficient appliances or other energy saving home improvements during the course of the trial, similar or higher proportions of the control group also made such investments, indicating that the trial had little influence on efficiency investments decisions.

Taken together, these survey results suggest that while participants became more aware of electricity consumption and realized actual electricity savings as a result of the trial, it remains unclear how they achieved these savings. Furthermore, participants' perception of their level of effort to reduce electricity consumption does not correlate with the level of savings.

Great Britain's Energy Demand Research Project (EDRP)[16]

Overall Description

The Energy Demand Research Project was a large-scale effort undertaken in Great Britain in 2007-2010 to test consumer response to information and feedback about energy use. The project involved pilots conducted by four of the major energy suppliers in Great Britain: EDF, E.ON, Scottish Power, and SSE. The total cost of the pilots came to £19.5 million ($30 million), half of which came from the individual utilities, the other half being matched by the British government. This implies an average cost per household to the utilities, across all four pilots, of $500.

Overall, more than 60,000 households participated in the pilots, which primarily tested interventions to reduce residential energy consumption (both gas and electricity), with a smaller focus on peak load shifting. At the time of the pilots, 18,000 households had smart meters installed. Pilots done in connection with installed smart meters included interventions using real-time in-home displays, some with the ability to control space and water heating. Other interventions not requiring smart meters included the installation of clip-on real-time displays, provision of energy efficiency advice, historic and peer-group consumption comparisons, commitment devices, financial incentives, and the use of other digital media such as the web and TVs for providing feedback information.

The recent evaluation report from AECOM (2011) provides results both overall and from the individual pilots, and was prepared in anticipation of the proposed national roll-out of smart meters. Overall results for the four pilots will be discussed here, leaving the details of each pilot below.

Overall Impacts

In households without installed smart meters, with two exceptions, there were no statistically significant energy savings. Savings of 1% were found in treatments involving clip-on displays and benchmarking against similar households (peer comparison).

Interventions including installed smart meters were more frequently successful and produced larger savings: approximately 3%, with some variation depending on fuel, customer group and period. Results suggest that in-home displays are more successful in realizing electricity than gas savings. For electricity, providing an in-home display increased savings by 2-4 percentage points over other interventions with only an installed smart meter (there was a range of 0-11% depending on customer group). For gas customers, the smart meter itself, or some aspect of the experience of getting the smart meter, resulted in savings of approximately 3%; therefore real-time feedback may be more effective in achieving electricity rather than gas savings. One pilot of the four found that savings persisted for 15 months, and there is some indication that continued real-time feedback, in combination with other interventions such as energy-saving advice or additional billing information, could help sustain savings.

The trials found that neither financial incentives nor general pledges (without targets or rewards) made by households had any reliable or persistent effect on consumption. The latter is in line with evidence showing that only specific, public commitments have a reliable effect on savings.

Some differences in the design of the devices led to reported differences in use. In-home displays that were connected directly to the smart meter, as opposed to clipping onto the traditional electromechanical meter, tended to have more features and to be installed, retained, used and rated positively. One pilot tested displays that included environmental cues, with differing results. A display with an audible alarm of high consumption had no effect on energy consumption and received only negative comments in the

[16] Unless otherwise noted, information in this section is taken from AECOM (2011).

customer survey, while another display providing visual cues of consumption through the use of a "traffic signal" was rated positively.

The use of web interfaces to provide advice, billing information and feedback (delayed by one day, not real-time) were found to have no effect on consumption, likely due to their failure to engage consumers on a large scale. Those who did engage, however, did reduce their energy consumption.

Data from an EDF survey found that customers could have benefited from more instruction and guidance during the installation of the in-home display, and frustration with this process may have impacted use of the device and consequent savings. The survey also indicated that customers reported using cost information more than kWh information, and valued it more. They reported positive impressions of temperature, but did not notice or value information about carbon emissions. Portability of the in-home display was also perceived as a benefit by participants.

Persistence was measured in several of the pilots: electricity savings from a combination of in-home displays and installed smart meter were generally persistent in trials that were long enough to test for this; in contrast, savings from treatments using financial incentives did not persist once the incentive was removed.

Results on load shifting were limited to two of the four trials, finding a response up to 10%, with a stronger effect in smaller households (two or fewer people).

Some differences in response to feedback were found among demographic groups. The "fuel-poor" demographic—customers estimated to spend more than 10% of their take-home salary on fuel bills—were generally more responsive to interventions. Prepayment customers tend to have lower consumption, and—as mentioned in the Northern Ireland example—may already have more experience monitoring energy consumption and costs. Consumption reductions for prepayment customers in the SSE pilot point to the fact that savings are possible, if not always realized, as was the case with Scottish Power's treatment of prepayment customers.

EDRP Pilot: EDF

Description

EDF conducted its trial over the course of two years from 2008 to 2010, employing a large number of treatments involving advanced metering infrastructure (smart meters, in-home displays and time-of-use rates), enhanced billing, energy-saving advice, self-reading of meters and others. Here we are concerned with results from the "Wall Panel" groups, which received an advanced in-home display showing near real-time electricity and/or gas consumption, monthly and hourly cost, CO_2 emissions, historical data, and advice on savings energy.

The trial employed an opt-in design, recruiting participants by phone from EDF's service territory, which includes London and the southeast of England. The sample size for all treatments was 1979, stratified by estimated annual consumption, prepayment customers, fuel poor customers, customers on a green tariff, and age. A smaller number of households (740) had in-home displays installed. Customers were initially required to have 12 months of prior usage history (4 actual meter readings), but this was relaxed to two readings early in the recruitment process because of few households met this requirement.

Impacts

The pilot resulted in electricity savings for all groups with an in-home display ("Wall Panel") compared to their respective control groups, and these savings increased over the course of the pilot. For electricity-only customers with an in-home display, median electricity savings were 7.2% ($p<0.01$) during the first year of the trial and 11.0% ($p<0.01$) by the end of the second trial year. Savings for all customers with in-home displays (both electricity only and dual-fuel) were slightly lower: 4% ($p<0.05$) at the end of the first trial year, and 5.8% ($p<0.1$) at the end of the second trial year. None of the treatment groups had statistically different consumption prior to the start of the pilot, meaning that the difference in observed changes in consumption was not due to differing baselines. There were no statistically significant electricity savings seen in groups on time-of-use rates.

Higher average savings for electricity-only customers than for dual-fuel and gas customers in the Wall Panel group may indicate that real-time feedback on electricity consumption has more of an impact than feedback on gas consumption. This may be due to the larger number of opportunities for residential electricity savings than for gas. Electricity savings associated with groups having in-home displays were persistent (and increasing) throughout the two-year trial period, perhaps due to some learning process involving the IHD or energy use practices in the home.

To understand the additional effect of time-of-use (TOU) rates on peak electricity consumption, the pilot compared TOU rate treatment groups with the Wall Display groups. In addition to the new rate structure, the TOU rate group received a basic in-home display with only a one-line readout. Compared to customers receiving feedback through the advanced in-home display, customers on TOU rates had an 8% reduction in peak electricity consumption, although these savings occurred primarily on weekends, and only for smaller households (two or fewer people). Smaller savings of 4% were found on weekdays, compared to the in-home display groups, which suggests that people may not be as engaged with the feedback technologies during the weekdays.

Survey Results

The post-pilot survey found that self-reported awareness of the existence of the advanced in-home display did not necessarily lead to savings, although savings seen from these treatment groups may be due to the frequency with which those who were aware of the device interacted with it. Participants in the time-of-use group receiving only a basic in-home display reported low engagement with the device; higher savings might have been realized with a more advanced in-home display.

In questions about the actions taken to achieve savings, the survey revealed no statistically significant differences between groups in self-reported actions, although there was non-significant evidence associating the installation of insulation and weatherproofing, and the possession of fewer appliances, with the three treatment groups that had savings.

Participant response to the in-home displays was positive for those groups that received them: 69.1% of electricity-only customers and 86.2% of dual-fuel customers reported finding the displays useful or very useful. In addition, households receiving an in-home display tended to more strongly agree that smart meter technology had enabled them to plan or budget for home energy use, signaling that the installation of an IHD provides a perceived benefit to customers as part of a larger utility smart grid rollout.

Other survey results suggest that positive attitudes towards energy savings did not necessarily translate into lower consumption. In addition, customers seem to be inclined to uptake smart meter-related technologies for several reasons: cost savings (enabled by TOU rates) and more control over energy consumption (enabled by more immediate feedback from IHDs).

EDRP Pilot: E.ON

Description

E.ON conducted its trial in stages, from 2007 to 2010. It employed large number of treatments involving both advanced metering infrastructure (smart meters, advanced in-home displays with a “traffic light” linked to consumption), enhanced and more frequent (monthly) billing, energy-saving advice, and clip-on real-time displays in homes without smart meters.

Although E.ON’s trial was designed primarily as a business-as-usual (BAU) replacement of existing meters, installation of clip-on and advanced in-home displays required customers consent. Participants were recruited by mail and phone from the E.ON service territory in the Midlands area of central England. The sample size for all treatments was 28,450, with 4781 receiving real-time feedback. Of these 2257 households had a clip-on display installed (without a smart meter) and received additional bill data and energy-saving advice; another 2524 received an advanced in-home display, a smart meter, a more frequent (monthly) enhanced bill, and energy-saving advice.

Installation of clip-on displays (i.e., real-time displays not requiring a smart meter) was treated as business as usual, with households being told they would receive the displays, but not being told they were taking part in a trial. As a result, uptake of the clip-on displays was high, though not 100%, because access by the installer was not always possible or granted by the homeowner. In contrast, households assigned to have an in-home display installed were required to actively opt-in to receive the device, although they were not made aware that they would be participating in a trial.

After being randomly assigned to a treatment group, households were stratified based on whether they had high baseline usage,[17] were fuel poor,[18] or had Economy 7 meters.[19]

Impacts

Overall, only those treatment groups with an IHD (plus monthly enhanced billing and advice) realized significant savings. Reductions in median electricity consumption ranged from 1.7-3.9% over the course of the pilot, with savings differing by demographic stratum: fuel poor households had savings of 1.7% ($p<0.05$), households with an Economy 7 meter had savings of 2.9% ($p<0.01$), and the high baseline usage stratum had savings of 3.9% ($p<0.01$). The authors of the evaluation caution that savings in the high baseline group may be due to differences in baseline consumption compared to the control group, not to the intervention itself. This is supported by the fact that the high usage groups reduced their consumption in all interventions, both with and without an in-home display installed.

Importantly, this pilot also tested the incremental savings from the in-home display of 2.8-4.2 percentage points ($p<0.01$), compared to other trial groups that did not have an in-home display. Most of these savings came from the fuel-poor strata, meaning that the addition of an in-home display benefitted fuel-poor households more than other households. This suggests that the fuel-poor may be more sensitive to real-time feedback than other groups. Savings associated with an in-home display persisted over the course of the pilot, particularly for some demographic strata. High baseline users had persistent savings for seven quarters, while savings for fuel poor households actually increased over that time.

Gas savings were significant in all treatments involving a smart meter. Households with a smart meter and in-home display had median savings ranging from 2.2-4.9%, with savings ranging up to 7.2% for some groups even *without* an in-home display. Gas savings showed less persistence than electricity savings, typically lasting 5 or 6 quarters.

Survey Results

As in the EDF trial, awareness of the in-home displays was not particularly high (48%) among households that had them installed, but of households that were aware of the displays, approximately half looked at them every day. Slightly more than half of participants getting real-time feedback from displays found them useful, with the “traffic light” feature rated most useful, followed by electricity consumption across time and real-time electricity use in monetary terms. The usage alarm and carbon emission features were not widely used nor highly rated.

One interesting finding from the survey is that the percentage of people reporting they had taken actions to reduce energy consumption during or after the pilot was consistently higher in groups receiving advice, with or without an in-home display. This suggests that providing people with information about specific actions they can take to save energy, at the very least, allows them to recall the actions that they took or continue to take. Whether providing advice led to actions that saved energy is unclear from the trial.

EDRP Pilot: Scottish Power

Description

Scottish Power implemented its pilot in three phases from 2007–2010, and, like the other EDRP pilots, included treatments with and without installed smart meters. Phase 1 lasted twelve months, Phase 2 lasted seven months, and Phase 3 lasted fifteen months. Non-smart meter treatments were begun during the first phase of the trial, and included additional historical consumption information on the bill, energy-saving advice, and the installation of clip-on real-time displays that provided data on consumption, cost and carbon emissions. The second phase involved the installation of smart meters and replacement of clip-on displays with advanced in-home displays for credit customers, a reconfiguration of prepayment

[17] High baseline usage was defined as annual consumption of 7000 kWh or more.

[18] Fuel poverty refers to households that spend more than 10% of annual income on energy.

[19] Economy 7 meters provide differential peak/off-peak pricing, with off-peak referring to the seven overnight hours.

meters to provide real-time feedback to prepayment customers, additional historical consumption data sent separately to bills, and energy-saving advice. The third phase introduced financial incentives and commitment devices designed to encourage reductions in energy consumption.

Customers were sampled from Scottish Power's service territory in the Greater Glasgow and Lanarkshire areas in the Central Belt of Scotland. The trial was designed to take a business as usual approach; customers were not aware that they were involved in a trial, and were not given the opportunity to either opt in or out of the program. Installation of in-home displays was treated as part of the normal meter upgrade process, although the installation of clip-on displays in Phase 1 required customer consent.[20]

Credit (standard payment) and prepayment customers were randomly assigned to separate treatment groups, and each customer type had a control group. Despite the business as usual approach, there were problems with retention in several of the treatment groups due to the utility's not being able to contact the household, or customer refusal to upgrade to the smart meter technology package. This required that additional customers be recruited after Phase 1 to maintain a valid sample. In total 2403 households were part of the trial at the start of Phase 1, with 1120 of these receiving either a clip-on display or advanced IHD. By Phase 3, total participation had fallen to 1946 households, with 774 receiving real-time feedback.

Impacts

In measuring impacts, treatment groups were compared both with their respective control groups and with each other, which enabled an analysis of the incremental impact of in-home displays.

None of the treatments in Phase 1 in households without an installed smart meter had an effect on electricity consumption, including the clip-on real-time display, either for credit or prepayment customers. This may be due partly to technology issues. Only 42% of clip-on displays in credit households were still working when advanced IHDs were installed in Phase 2. Fifty-eight percent of prepayment households reported that their clip-on displays were still installed and working at the end of the trial. This fact obviously limits the potential for savings from this type of real-time feedback device.

The installation of smart meters and advanced in-home displays in Phase 2 likewise led to no statistically significant electricity or gas savings. This result should be interpreted with caution, however, as only 3 months of data was used—a period potentially too short to allow for learning or habit formation around the devices. In-home displays were found to be more reliable than clip-on displays, with 77% of survey respondents reporting that they were still installed and functioning at the end of the trial.

The introduction of financial incentives in Phase 3 led to statistically significant, but temporary, reductions in gas consumption by the three credit treatment groups. There were no incremental gas savings in groups with an in-home display.

Survey Results

No differences were found between the percentage of trial groups reporting that they had taken new actions to save energy over the course of the trial, a finding which supports the lack of significant savings. The percentage of participants reporting that they checked their energy use either frequently or occasionally was higher for groups that received an in-home display or that were prepayment customers, compared to other trial and control groups. This suggests the display enabled and/or motivated engagement with energy consumption information among these households, although it did not lead to savings.

The most frequently recalled pieces of information from the IHD, across all phases of the pilot, were electricity consumption and cost. This was followed by high recall in Phase 1 of the temperature/humidity function, but this fell off over the course of the trial, perhaps because this information was more salient initially as people considered changes to thermostat settings but then became less salient. Electricity cost and consumption information was also considered more relevant than other types of information, although the "traffic light" indicator of consumption was also found to be highly relevant. There was a

[20] In those groups that were offered the clip-on display, 22-30% refused to have it installed. The reasons for refusal were not given in the evaluation report (AECOM 2011).

"ramp up" period in which the percentage of people checking how much energy they consumed increased, suggesting that the development of habits around the device takes time.

Although there was interest in the information provided by in-home display, issues with reliability (as noted above) and design of the devices may have reduced their potential for savings. While households receiving an IHD were generally positive about using the device, 32% reported finding it difficult or very difficult to change settings.

EDRP Pilot: SSE

Description

Like the other EDRP trials, the SSE pilot tested treatments both with and without installed smart meters over the course of three years, from 2007-2010. Non-smart meter treatments included clip-on real-time displays, peer comparisons, additional bill information and energy-savings advice. Treatments in households with installed smart meters included advanced in-home displays (with "traffic light"), a time-of-use tariff, increased frequency of billing, additional information on the bill, energy-saving advice provided by mail, and consumption history available through a web interface. Although unclear from the evaluation report, it appears that households were required to install the clip-on displays themselves. The pilot also tested an "incentive to reduce" for electricity, a credit equivalent to 5% for a 10% year-on-year reduction in consumption.

All trial participants were recruited from SSE's U.K.-wide service territory, with 1.4 million customers selected as potential trial candidates. Of this, 27,887 households were enrolled in the trial, with 1406 receiving some type of real-time feedback on electricity consumption.

Participant households were stratified demographically to ensure that treatment and control groups were similar. Households were also stratified within the groups according to whether they were aware of the trial and committed to reducing energy consumption. Households in the Unaware stratum were not aware that they were participating in a trial, and were enrolled in treatment groups (including the IHD and clip-on display group) without their consent; installation of smart meters and displays was treated as a business-as-usual meter replacement. The Aware stratum was actively recruited into the trial and randomly assigned into a treatment group. The Committed stratum was also actively recruited into the trial, and submitted signed statements to SSE indicating their commitment to reduce energy. The recruitment rate for the latter two groups was initially less than 10%, due to the complexity of the initial questionnaire. In addition, a "very large number" of customers in these groups said they were simply not interested in participating in the trial. Subsequent changes to the recruitment process—including phone follow-ups to the recruitment letters and allowing Committed customers to pledge over the phone—led to better recruitment results.

Impacts

The results of the trial were evaluated through a factor analysis, a type of multivariate analysis which disaggregates the impact of each of the components of the combined interventions on electricity (and gas) consumption. Compared to all other groups, households that had an in-home display installed (and received energy-saving advice and enhanced bills) had average electricity savings of 3.6%. The incremental savings from an in-home display above and beyond the provision of energy-saving advice and enhanced bill information was estimated to be 1.8 percentage points. The combination of a prepayment smart meter and in-home display led to slightly lower electricity savings of 2.9%. There was also a small reduction in electricity consumption of 1% ($p<0.05$) in households receiving a clip-on real-time display.

Credit households with an IHD had average gas savings of 3.2%, but there were no statistically significant gas savings for prepayment households with a smart prepayment meter and real-time display.

The original analysis of the trial by SSE (rather than AECOM) also found a significant effect of awareness about the trial on electricity savings, with the Aware group realizing savings of 6.4% relative to its respective baseline, the Committed group 6.1%, and the Unaware group 4.0%. A household's postal code and demographic classification also had an effect on consumption. However, the *effect of the different treatments* did not vary with awareness, location or other demographic variables; in other words, the observed difference in savings from the various treatments was not due to these variables. This provides more evidence for the unobserved category that we are calling the cyber-sensitives.

Peak demand reductions from time-of-use rates were small, approximately 0.3 percentage points on weekdays, and 0.5 percentage points on weekends.

Survey Results

Two years after their initial recruitment into the trial, participating households that had received a smart meter or a smart meter and in-home display were asked to take part in a survey. The most common reason given for joining the trial was to save money, followed by helping the environment. Those with an in-home display installed were more likely than those without to say they were motivated to join the trial to obtain detailed information about energy consumption (12% vs. 5%) and to identify excessive energy use (6% vs. 3%). These results should be interpreted with caution, however, not only because of the length of time that had passed since the decision to join the trial, but also because participants already had experience with the devices, which may have limited their answers.

As in the Scottish Power case, installation problems with the clip-on real-time displays may have limited their savings potential. Of households sent a clip-on display, 83% reported receiving it, only 46% reported having installed it, and only 31% reported that they were still using it. This suggests that professional installation of these technologies is important to enable savings.

The survey found that displays were most often kept in the kitchen by credit households (52% for those with IHD, 29% for clip-on) and by prepayment households (49%), followed by the "lounge" (13%), the hall (11%) and in a drawer or cupboard (8%). As we will see below, the choice of where to locate the display has implications for energy use, and is often the result of intra-household dynamics.

As was found in some other pilots, cost information on the in-home display was rated more highly by survey respondents than was consumption information. The "traffic light"—an environmental cue—was rated as the most useful feature, which has interesting implications for design. These two findings together suggest that consumers do not necessarily want information in energy units, but may prefer visual or other environmental cues of energy use, combined with cost information, which is comparable across areas of a household's budget.

These responses also provide some clues to the tasks that customers want to accomplish through in-home displays: to be provided a sense of "reassurance" that efforts to reduce energy consumption are working; to take more "control" over consumption; to have "more influence" over bills; and to get help in "encouraging" other household members to save energy.

The survey revealed no reliable pattern of actions that participants took to save energy, and no pattern of difference between treatment groups that could help explain differences in savings due to the trial.

Finally, the survey addressed the issue of continued use of the in-home display, which has implications for savings persistence. Of participants with an in-home displays installed who were no longer using it, 32% reported never having looked at the device, 24% reported using it for a few months and then stopping, and 43% reported using it for shorter periods before stopping. The most common reason given for the fall-off in using the displays was the quality of information provided.

Northern Ireland's "Natural Experiment"[21]

Summary

Taking advantage of conditions in Northern Ireland to conduct a natural experiment, Gans et al. (2011), found average quarterly electricity savings of 19.5% for customers enrolled in a prepayment program that included real-time feedback through a "keypad" attached to the prepayment meter located inside the home. The high level of average savings in this case may be due, in part, to the fact that prepayment households were likely already monitoring their consumption and may have a strong motivation to keep costs down because of a high level of fuel poverty and high retail electricity rates.

[21] Unless otherwise noted, information in this section is taken from Gans et al. (2011).

Description

While not a pilot in the true sense, conditions in Northern Ireland's residential utility sector offered a setting for what social scientists call a "natural experiment," in which a hypothesis can be tested using "treatment" and "control" groups that are the result of exogenous forces. Though by definition not as replicable as a traditional experiment, such natural experiments have built-in advantages, key among them being their grounding in every-day, real-world, user-generated environments, activities, and experiences. Data collected in this way is truly empirical, and serves as a useful guide in developing expectations for larger-scale rollouts of new technologies across a wider sample size of the same population grouping.

Three conditions serve to set up this experiment. First, residential electricity rates in Northern Ireland are among the highest in the U.K. and Europe, with government estimates indicating that approximately one-third of households are fuel poor, i.e., that they spend 10% or more of household income on fuel use. In addition, Northern Ireland Electricity (NIE) was a monopoly distribution utility during the period of the study, so consumers may have been encouraged to make changes in their behavior when given the opportunity. Second, the plethora of pricing plans, including prepayment, allowed for the testing of pricing and changes in other plan features. Third, all customers on the prepayment plan had their old prepayment meters replaced, free of charge, with new meters that provided immediate consumption feedback through a "keypad."

Keypad prepayment meters have a basic display that provides information on the amount of credit left, electricity usage in pounds sterling over the previous day, week or month, and current electricity consumption in kilowatt-hours. Credits are added to the meter using a prepaid debit card. When credits run out an alarm sounds on the device and the customer is automatically given a small emergency credit to allow time to add more money to the meter before power to the household is switched off. Credits can be added to the prepaid card online, by phone, at the post office, and at local NIE outlets (NIE 2012).

As opposed to the United States, where monthly payment is most common (Foster & Alschuler 2011), default payment schedules under regular rate plans (i.e., not prepayment) in Northern Ireland are quarterly, so for customers on these plans, the connection between usage and price is arguably less salient than in the United States. Customers in Northern Ireland who elected a direct debit or level pay plan received a discount of 1.5-4% off the price of electricity, capped annually at different levels depending on plan type. In 2002, NIE began offering an uncapped discount of 2.5% to those who elected the prepayment plan. According to NIE's website, keypad prepayment meters are now quite common in Northern Ireland: one in four homes in the country was using this type of meter as of 2008 (NIE 2012).

A multi-year cross-sectional dataset of more than 45,000 observations was drawn from 18 consecutive waves of the Continuous Household Survey of Northern Ireland, a representative survey of the country's dwellings (including household characteristics and energy use), spanning the years 1990-2009. This data was combined with price and rate plan information from NIE, at the time the electric monopoly for the residential sector in Northern Ireland.

The treatment group consisted of customers on the prepayment plan—who began getting real-time consumption feedback and who were presumably already monitoring their energy usage under this plan—while the control group consisted of customers on other rate plans without this type of feedback. The change in electricity consumption due to feedback from the keypad was estimated based on data from before and after the new meter was installed, compared to any such change in the control group. An econometric analysis took into account the assumed bias of selection into pricing plans, changes in rates over time of the various plans, weather, household characteristics, income and other factors.

The study authors estimate the per-household cost to the utility of the prepayment meters and installation at £62-73 ($99-113).

Impacts

Keypad customers in Northern Ireland tend to live in smaller, terraced (non-detached) homes, to have lower household income, to be renters, and to use electric heat. Controlling for these characteristics through a multiple regression analysis, Gans et al. (2011) found that the introduction of the keypad reduced quarterly energy consumption by 19.5% ($p<0.001$) on average.

The outsized savings in this study raises the question of how these savings were achieved. Considering that prepayment customers tend to have lower incomes, they may have had fewer options than wealthier households for making energy-saving investments, and so may have depended more on lifestyle changes. Unfortunately, customers who participated in the prepayment plan were not surveyed after the installation of the new keypad meters in 2002, so there is no obvious way to answer these questions. There are also no results to report on customer satisfaction or persistence of savings over time, although the long study period suggests robust persistence. It also provides us with no information about the frequency with which customers on the prepayment program interacted with the keypad.

CONCLUSIONS

The nine studies reviewed here showed a range of savings of 0-19.5%, with average savings of 3.8%, excluding the Northern Ireland study. The wide range of findings across pilots for similar technologies indicates that realizing savings from interventions involving real-time feedback is not one-size-fits-all, but appears to depend on a host of factors, including:

- a "sensitivity" towards real-time energy consumption feedback;
- the design of and content provided by feedback devices, and the degree to which these facilitate the tasks that consumers want to accomplish through feedback;
- the installation process and reliability of feedback devices;
- engagement with feedback, which is both confounded and encouraged by dynamics within the household; and
- the degree to which learning and habit formation take place.

All of the pilots we discuss have taken some care to control for differences in demographics, housing characteristics, and even attitudes in order to attempt to explain differences in savings among groups. Several studies found that differences in demographics affect baseline energy consumption, but it was not these same demographic differences that explained the response to feedback. Instead, in several instances, there appears to be a group of people who are predisposed to respond to, or are more sensitive to, feedback about energy consumption, and so had energy savings that were higher than the average.

Because the cyber-sensitives cut across demographic lines, other methods of identifying this group are necessary. One potential method is "attitudinal segmentation," which the Smart Grid Consumer Collaborative describes as possibly more effective than demographic segmentation, given that, "'cost consciousness, comfort, green altruism, tech enthusiasm, indifference, and resistance…persist across cultures, income levels, and education levels'" (SGCC 2011, p.23). While attitudinal segmentation has not been widely used in the utility industry, it has apparently been effective in other industries in improving program performance and outreach by enabling a wider set of messages than simply "saving money." Of course, it is possible that what we are calling the cyber-sensitive category is not necessarily defined by conscious attitudes, but by an intuitive or emotional response to feedback. This would require another type of segmentation altogether.

While the cyber-sensitive group currently evades demographic pinpointing, one study (Northern Ireland) found convincing evidence that some observable factors can explain the response to real-time feedback in specific cases. In Northern Ireland, the response of households with keypad prepayment meters to feedback resulted in very high average savings of 19.5% over the course of almost two decades. For this demographic, which in Northern Ireland tends to have lower income, the combination of prepayment and real-time feedback was particularly potent.

Differences in historical feedback in the U.S. and U.K. may point to different solutions. In the U.K., feedback has tended to be quarterly, and, if NIE's experience with prepayment in Northern Ireland is a good guide, it is becoming more prevalent. In the U.S., feedback comes most often monthly in the form of the utility bill, and prepayment appears to be not as prevalent, although there are examples of large prepayment programs. One such program is the Salt River Project's M-Power program, which reports significant savings of 12.8% (Faruqui et al. 2010). If prepayment programs become more popular in the United States, looking to Northern Ireland, in particular, for an example of ways to reduce consumption with this type of program may be wise.

Another issue is the cost of behavior-based programs, particularly real-time feedback programs. Publicly available data on pilot costs is somewhat scarce, but is crucial for gauging the resources necessary to scale up to larger programs. We can speculate that there may be several reasons for this scarcity, including proprietary data, public relations concerns, or fears that a premature discussion of pilot costs will stifle investment or innovation. While these concerns are valid, the uncertainty created by a lack of data has its own stifling effects.

While the cyber-sensitive group may already be predisposed to feedback, and lower income households respond to the potent combination of prepayment and real-time feedback, the question remains of whether efforts to entice the “less sensitive” to save through feedback programs are a good utility investment. Based on the very limited data from the nine pilots reviewed here, the cost of providing real-time feedback remains high.

Finally, there is the question of what types of actions and investments households are taking in an attempt to save energy. To answer this question, pilots rely most often on self-reported data gathered through surveys, which are widely considered unreliable. While there is little reason to discontinue the use of surveys as standard evaluation practice, combining data from surveys with more observational data gathered through, for example, ethnographic interviewing could uncover important insights about the dynamics within the home that affect energy consumption, an area that was touched on in several of the pilots reviewed here. In other words, while many pilots have found that savings are taking place, the question of *how* people use real-time feedback devices remains largely unanswered. Providing insight into the second question could have an impact on the design of both future programs and feedback approaches, especially as that design affects persistence of savings.

For example, a series of in-depth interviews were conducted with a subset of participants from a real-time feedback pilot in eastern England from 2008-2010. The first round of interviews took place in late 2009, with follow-up interviews exactly 12 months later, in late 2010. Hargreaves et al. (2011) reports on the results of the follow-up interviews, the goal of which was to understand how the use of in-home displays changed over the course of the pilot.

Interviewees reported that their use of the devices fell off after a certain period of time, but, interestingly, not due to their being forgotten or discarded. Rather, use fell off only after pilot participants had gained a sense of their “normal” energy use, which many were apparently unmotivated to change significantly. Social dynamics and the placement of the displays were crucial to this learning process as well as to the fall off in use. Initially, the devices were kept in prominent communal areas such as the kitchen, but many interviewees reported moving the devices to private areas as time went on due to some household members’ finding them “annoying and ‘in your face’” (Hargreaves et al. 2011, p9).

Evidence from surveys conducted during the ERDP pilots in the U.K. echoes some of these findings. In these pilots, portability of the feedback display was seen as a desirable attribute, initially helping people to move around the home and understand the impact of different appliances, but then becoming less important as people learn their typical use (AECOM 2011).

We believe that this kind of ethnographic data, while highly context-specific, can have a large impact on the design of more effective programs, policies, and technologies. This type of research methodology may even be able to provide clues to addressing the critical issue of savings persistence. For example, in their study of the persistence of savings from in-home displays over the medium term in the Netherlands, van Dam et al. (2010) identify the encouragement of habit formation around the device, such as checking the monitor before bedtime, as a potential path towards increased persistence. More data of this kind is needed to understand what is really happening within the “black box” of the household.

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