You Want Me to Do What? Smart Grid and Demand Response Pilots Test the Waters with Residential Customers

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ABSTRACT

Electric utilities throughout the United States are deploying Smart Grid meter technology with the expectation that it will provide new functionality through which the utility and individual consumers can manage electricity use, understand electricity pricing strategies, and see the results of conservation or curtailment efforts. Linking this technology to demand response programs is expected to provide the visibility and information needed to influence customer behavior. However, process evaluations of residential demand response programs tied to Smart Grid technology initiatives are rare - meaning that many facets of how customers experience enabling technology and respond to curtailment requests remain unknown.

In the fall of 2011, the authors conducted a process evaluation of a set of residential demand response and technology pilots launched by a California utility the previous summer. Each pilot contained different mixes of information, enabling technologies, and curtailment notification strategies, and each targeted a different set of residential customers.

This paper presents the results of the surveys, focus groups, and in-depth interviews completed in the winter of 2011-2012. We found that the information provided by in-home displays (IHD) is largely valued by those who request the devices; however, it is not clear that the information provided by IHDs is sufficient for demand response. We also found no demographic or attitudinal factors that predicted savings among those receiving curtailment requests via outbound phone calls direct from the utility, nor did we find that their savings reflected their reported level of effort. Finally, we found that there is substantial room for improvement in the user interfaces of these devices.

Introduction

This paper presents the results of process evaluation activities[1] conducted to understand the customer experience of participating in one of three demand response pilots running simultaneously in San Diego in the summer and fall of 2011. This paper also presents insights for using enabling technologies to facilitate conservation and demand response in future pilots. Two of the pilots, Residential Automated Control Technology pilot (RACT) and Low Income pilot, had extensive involvement with San Diego Gas & Electric's (SDG&E's) home area network (HAN) team. Members of the HAN team provided an important interface between program staff, smart meter integration efforts, and the utility's third-party technology vendor. HAN projects require information technology engagement, as deployment required setting up a gateway portal on customers' existing wireless routers.[2] Both HAN pilots included installing specific technology in customer homes.

[1] The evaluation activities included surveys, focus groups, and in-depth interviews with participants.
[2] Participants in the HAN pilots were required to have high speed internet access and a working router.

The third pilot, Peak Time Rebate (PTR), was larger in scale than either of the HAN pilots and did not involve installing any technology in customer homes. PTR sought to encourage short-term behavioral changes that would result in measurable reductions in household energy use by notifying each participant of a *"Reduce Your Use"* day and offering a bill credit for each measured reduction in household kilowatt hour (kWh) consumption.

The Pilots: Similarities and Differences

Each pilot was slightly different. The HAN pilots sought to expose residential customers to detailed information about their energy consumption patterns, but provided few incentives for saving energy. The HAN pilots facilitated automatic curtailment by providing communicating thermostats and plug load control devices. On the other hand, PTR provided little information to consumers on their energy use, but did provide bill credits to residential customers who reduced their electricity consumption when requested.

Table 1. Pilot Design Summary

		Home Area Network Pilots				**Peak Time Rebate**
		RACT		**Low Income**[3]		
Pilot		**TECH**	**IHD**	**IHD**	**PCT**	
Enrollment Method		Opt-in	Opt-in	Opt-in	Opt-in	Random
Enrollees		99	108	273	66	3,000
Technology	Website	✓	✓	✓	✓	
	IHD	✓	✓	✓		
	PCT	✓			✓	
	PLC	✓				
Number of Technologies		4	2	2	2	1
Event Day Notification		✓	✓		✓	✓
Method of Notification	Device	✓	✓	✓	✓	
	Email	✓	✓			Opt-in
	Text					Opt-in
	Phone Call					✓
Incentive for Curtailment						✓
Contest		✓	✓			

The Home Area Network Pilots

The RACT and the Low Income pilots were administered by SDG&E's Customer Programs and Assistance Group in the summer of 2011. Both pilots relied on SDG&E's HAN technologies and the services of a third-party vendor, Tendril, to test and evaluate customer response to several energy management devices. For these pilots, the HAN team, pilot staff, and representatives from Tendril worked together to leverage the benefits of near real-time energy use and price information by linking this to customer-facing communication devices.

Neither of the HAN pilots offered payment for measured curtailment, nor were there penalties for households that did not reduce their energy use during specified events. RACT

[3] One-half of each of the Low Income pilots (both IHD and PCT) also received advice emails.

participants were eligible to earn prizes by enrolling in the Biggest Energy Saver contest and then reducing their electricity use relative to the prior year.[4]

The RACT pilot targeted high use residential customers (those with average monthly use over 750 kWh), and operated with two sub-groups - a TECH group and an IHD group (Table 1). The RACT pilot provided more technology than the other pilots, and the mix of technologies varied by group assignment (IHD-only or TECH). Participants received a mixture of enabling technologies, contest rewards, event notification, and conservation messages; and were provided one or more of the following:

- An in-home display (IHD);
- A programmable communicating thermostat (PCT);
- A plug load controller (PLC);
- Access to an energy management website hosted by Tendril; and/or
- An invitation to participate in a Biggest Energy Saver contest that ranks participants by kWh energy savings relative to the previous year.

Those assigned to the TECH group received all of the devices listed above. The PCTs and the PLCs provided the "automated" load control part of RACT. Through the PCT, SDG&E could remotely increase the temperature of air conditioning settings by up to four degrees in participant homes. The PLCs allowed SDG&E to automatically turn off any devices plugged in to them for the duration of a demand response event. Participants in the RACT IHD group received only the IHD. Both groups had access to the energy management website. The program did not offer incentives for energy or demand savings that the participants achieved.

The Low Income pilot also had two groups - one that received only an IHD and another that received only a PCT. In addition, conservation-minded messages were emailed to one-half of each group.

Peak Time Rebate (PTR) Pilot

The PTR pilot program[5] offered a bill credit of 75¢ per kWh for customers who reduced their energy use when requested by SDG&E during specific event periods. PTR did not assess any penalties for households that did not achieve measurable reduction of electricity usage. To encourage customers to embrace automated enabling demand response technologies, the pilot paid a premium incentive of $1.25 per kWh reduced for customers enrolled in the Summer Saver air-conditioning (AC) cycling program. Bill credits for each unit of electricity reduced are calculated based on event day reduction in electricity usage below an established customer-specific reference level (CRL) for that day.[6]

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[4] Thirty-five of the 208 participants signed up for the contest.

[5] The PTR Program was adopted by the California Public Utility Commission (CPUC) in Decision 08-02-034.

[6] The CRL for a weekday event is defined as the total consumption for the PTR event period averaged over the three (3) highest days from within the five (5) similar non-holiday weekdays immediately preceding the event. The highest days are defined to be the days with the highest total consumption between 11:00 a.m. and 6:00 p.m. The similar days will exclude weekends, holidays, other PTR event days, and other demand response program event days for customers participating in multiple demand response programs. The CRL for a weekend or holiday event is defined as the total consumption during the PTR event period for the highest day from within the immediately preceding three (3) weekend days.

Although PTR participants were offered additional information about their energy use and event day performance through post-event emails and access to a website that presented more detailed energy use data, awareness of these opt-in services was very low.

Research Tasks

Process evaluation tasks touched all three pilots in the fall and winter of 2011/2012 and included mixtures of email surveys, phone surveys, focus groups, and follow-up in-depth interviews (Table 2). Because each of the pilots had different target populations and offered different mixes of devices, we customized the survey instruments and approaches for each pilot. SDG&E and the evaluation team knew less about the randomly enrolled PTR population and, therefore, assumed these participants would be less likely to respond to an email survey than the HAN pilot participants who volunteered themselves for the pilot.

Table 2. Research Methods

	Research Method			
Pilot	**Phone Survey**	**Focus Groups**	**Email Survey**	**In-Depth Interviews**
RACT			✓	✓
LI			✓	✓
PTR	✓	✓		

Pilot-Specific Findings

HAN Pilots

Participants in the HAN pilots reported high levels of agreement with several positive statements about the benefits of the technology(ies) provided to them (Table 3). Information on price may be particularly important to California homeowners, many of whom are subject to a somewhat complicated set of pricing tiers whereby the price per kWh increases substantially as monthly use increases.[7]

Table 3. HAN Participants – Value of Technology

RACT Pilot	**Portion Agreeing**
My in-home display is easy to use. (n=77)	79%
The in-home display helps me save money. (n=79)	80%
Low Income IHD Pilot	**Portion Agreeing**
My in-home display is easy to use. (n=52)	88%
The in-home display helps me save money. (n=52)	81%

IHDs provide feedback on household energy use in near real-time. The level of detailed information provided by the IHD allowed households participating in the pilots to pinpoint when

[7]Tiers start at 14¢ per kWh, and then ratchet steadily up to 31¢ per kWh at 200% of baseline. Baseline consumption varies by climate zone, residential rate class, billing period length, type of space heating, and time of year. Typical summer baseline usage for a household with both electric and gas service in a coastal climate zone is 288kWh/month, and 492kWh/month for a household with both electric and gas service in a desert climate zone. The middle tiers decrease by 2¢ per kWh in winter.

they moved into the higher cost/higher tier power. For many customers, this provided a first opportunity to access information sufficient to “see” their energy use, rather than wait up to 45 days for a bill. The information contained in typical utility bills provides insufficient feedback to energy consumers and leads to widespread “blindness” as to how one’s household is actually consuming energy (Ehrhardt-Martinez et al. 2010). Tying IHDs to the near real-time consumption data available through interval meters and interactive websites offers immediate feedback on household energy consumption for those who want it.

We wanted to understand how the participating households were using their IHDs and what specific features they found useful. Figures 1 and 2 present the portion of these households that found each of the features of their IHD useful.

Figure 1. RACT Participants - Usefulness of IHD Information (n=82)

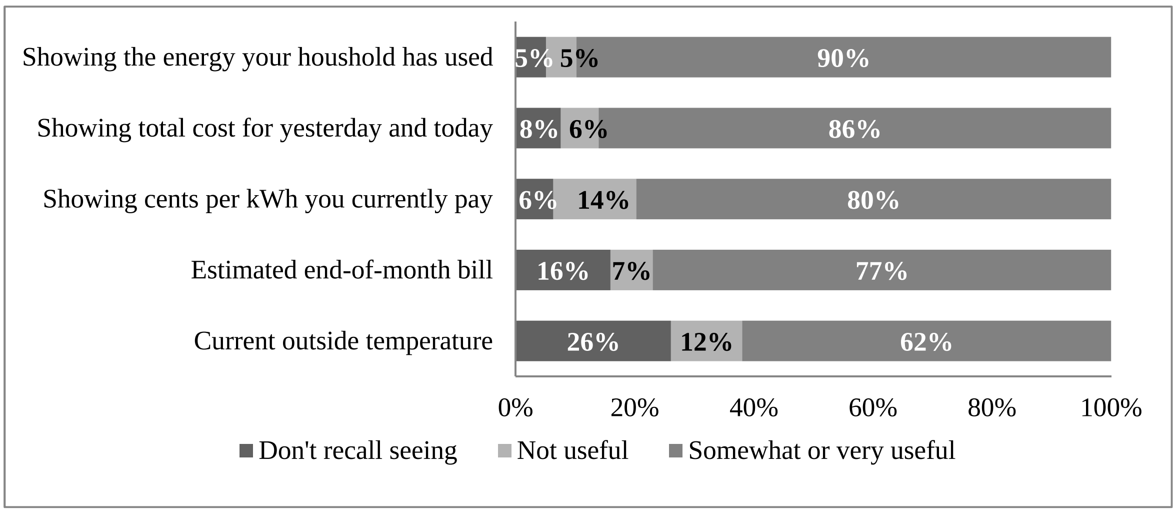
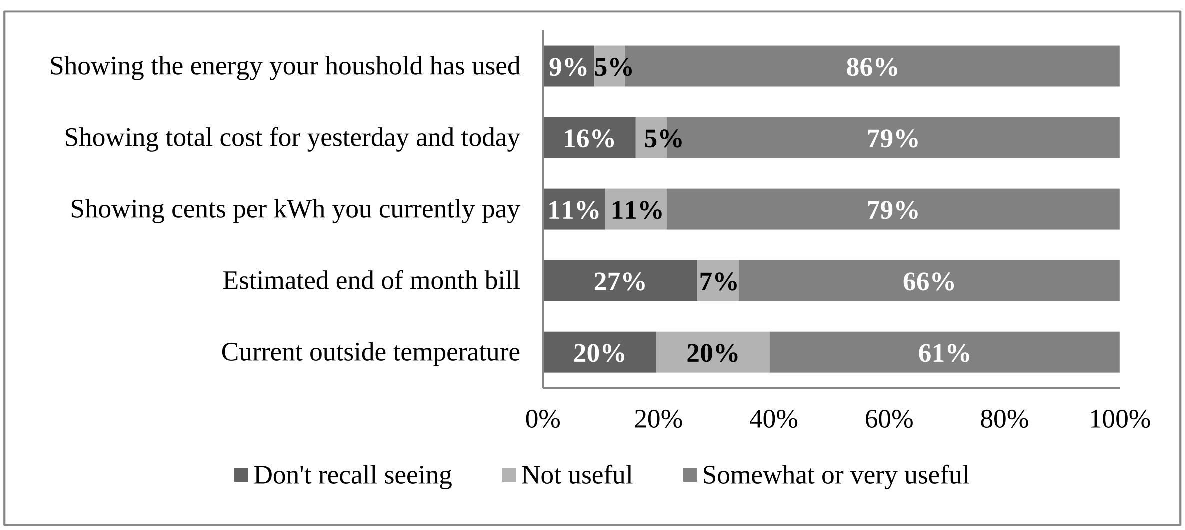


Figure 2. Low Income Participants – Usefulness of IHD Information (n=56)



A majority of HAN pilot participants said that the best part of the program was the increased understanding and awareness of their energy use that they gained through access to detailed information from the IHD and Tendril website, as well as through experimentation with enabling devices. Customers used their IHDs to monitor both short- and long-term energy use and costs, and liked the features and accessibility of the website. Findings indicate that participants in both pilots used their devices to experiment with energy use by monitoring it on the IHD or website while an appliance cycled on or off. RACT TECH group participants, in particular, appreciated the ability to use their PLCs as watt-meters to isolate the energy use of specific appliances; and this increased visibility may have facilitated greater program involvement (including higher device monitoring, website use, and involvement in the Biggest Energy Saver Contest). A majority of participants reported taking new day-to-day efforts to reduce their energy use after receiving the enabling technology.

Participants in the RACT pilot and the PCT group of the Low Income pilot reported generally high awareness of demand response events (over 90%), and two-thirds reported a "moderate" or greater level of effort to curtail during these events. The most commonly reported actions were turning off lights, shifting laundry times, and raising AC temperatures. Less than half of those with auto-curtailing devices reported noticing their equipment shut down. Generally, though, participants in the HAN pilots were unsure of the best actions to take on demand response days, and many seemed to have difficulty in distinguishing demand response messages from conservation and efficiency messages.

Peak Time Rebate Pilot

With no enabling or communicating devices, the PTR pilot relied on direct requests for behavior change on specific days. For the pilot, these requests occurred via direct calls from the utility to the phone numbers associated with enrolled households. Survey results found that those enrolled in PTR accepted the event day requests to reduce their energy use, with a large majority (91%) wanting to stay in the program. We also found that participant willingness to accommodate event days was linked to an understanding that event days are called based on need. Enrollees reported that a sense of civic responsibility was the primary motivation for participation in events; cost savings (both through bill credits and, indirectly, through reducing the need for new generation capacity) was a secondary motivation. Ninety-three percent of respondents agreed that "it is important to do our part to save energy in times of high demand," while 63% agreed that "participating in this program helps me save money."

PTR participants reported four main barriers to participating in event days: 1) lack of awareness of effective curtailment actions (not knowing what to do); 2) difficulty reducing electricity use above existing conservation efforts; 3) inability to take action when not at home during the day; and 4) the perception that feasible actions were limited by the need to maintain lifestyle and/or avoid unreasonable discomfort.

Unprompted PTR participants stated an interest in receiving some of the same types of information that was available to HAN pilot participants through the display devices. In addition to desiring more specific information about how to participate in event days, PTR participants wanted more feedback about their performance, particularly:

- Feedback on their event day performance and advice on how to improve;
- Information on the energy use of household devices and opportunities to curtail these devices on event days; and/or
- Information about how actions contribute to larger conservation efforts.

Awareness of event days among PTR participants was moderate, with two-thirds of interviewed participants recalling receiving at least one event day notification (out of five total events). Of those who recalled receiving notifications, over half (61%) reported they curtailed their use, most popularly by shifting laundry times, turning off lights, shifting dishwasher times, shifting cooking times, and increasing their AC temperature.

Participants' responses were inconsistently related to their curtailment performance during events. Using the performance data for the three events in August and October, we attempted to identify demographic, attitudinal, and behavioral factors affecting participants' kWh reductions during event days. Using a series of regression models, we looked for factors that predicted overall electricity use reduction, as well as reduction on each of the three event days (represented as "savings metrics" in Table 4). One important result is that no participant characteristics or responses consistently predicted event performance -- only the number of days participants successfully curtailed was consistently predictive of savings achieved on individual event days. Other predictors not included here, including education and income, were never predictive of performance.

Table 4. Significance of Demographic, Behavioral, and Attitudinal Predictors of Event Day Performance

Predictors		**Savings Metric**					**Number of Metrics Predicted**
		8/28 Savings	**10/12 Savings**	**10/13 Savings**	**Sum of Savings**	**Weighted Sum of Savings**	
Demographics	Number of occupants	ns	ns	ns	ns	ns	0
	Home size	ns	ns	ns	ns	ns	0
	Home ownership	ns	ns	ns	ns	ns	0
	Monthly kWh use	**	ns	ns	ns	ns	1
Self-Reported Event Day Behavior	At home or away	ns	ns	ns	ns	ns	0
	Made additional effort	ns	ns	ns	ns	ns	0
	Number of actions	**	ns	**	ns	ns	2
Attitudes	Participating saves $	ns	ns	ns	ns	ns	0
	Participating helps environment	ns	ns	ns	ns	ns	0
	Important to do our part to save energy	ns	ns	**	ns	ns	1
Performance Consistency	Number of performing days	**	**	**	**	**	5

** Significant predictor at $p<0.05$.
ns = not significant

A third of all surveyed participants (37%) reported performing new day-to-day activities to save energy because of their experience receiving a *Reduce Your Use* (RYU) notification (Reduce Your Use is how the event days were branded). Among these participants, reported activities were mostly conservation actions, such as turning off lights and reducing appliance use. A third of these respondents noted that they had started regularly shifting activities to off-peak hours, and about 7% reported efficiency investments, such as purchasing new appliances or CFLs.

Overarching Findings

Experience with Pilot Technologies

Program participants reported using their devices in different ways, and exhibited different informational needs. Three of the ten Low Income PCT participants contacted for in-depth interviews expressed a desire for information about basic steps to convert the information on the energy management website into actionable suggestions for making changes in their households. Others had taken first steps and wanted more tailored recommendations about the best ways to reduce energy use in their household.

From the accounts of how the RACT TECH group used the PLCs, it seems that participants would have found more information about how to use these devices useful, especially tips for placement and experimentation. Participants' descriptions reflect a "trial and error" approach to deciding what equipment to connect. It was not uncommon for participants to report using the PLCs as informational tools (like watt-meter devices) rather than auto-curtailment tools.

Over half (54%) of the RACT TECH interviewees had complaints about their PCT, most commonly that simple functions required multiple steps and that it was difficult to understand the information on the display. Some of these issues could be overcome with more, or more targeted, technical support focused on how to maximize the information value of these devices, or by providing devices with simpler user interfaces.

We also found that the level and type of information required will vary by end-user. An ongoing challenge for feedback programs is providing a way for customers to access the level of information appropriate for them and then providing additional detail as requested or desired to keep them engaged. Other studies have found that the average household electricity savings from feedback programs ranges from ~3%-12%, depending on the level of detail provided and the extent to which the information is real-time (Ehrhardt-Martinez et al. 2010).

Curtailment Requests and Energy Use Tracking

Overall, the evaluations did not find overwhelming evidence that pilot participants held strong attitudes about willingness to curtail certain types of equipment over others (either manually or automatically).

While RACT participants' use of PLCs provides some indication of the appliances they are willing to auto-curtail; generally, interview findings suggest that most participants had not settled on particular appliances. RACT-TECH participants most often reported connecting entertainment equipment, lamps, and computer equipment to their PLCs. However, in interviews, participants also expressed concerns about curtailing each of these device types. Contacts noted that home theater settings needed to be reprogrammed after an event, that laptop batteries would not last for the duration of an event, and that curtailing lighting provided little savings. Rather than leaving them connected to an individual device, some participants reported experimenting with their PLCs to better understand and monitor their energy use. Some of these reported using their PLCs as watt-meters rather than as auto-curtailment devices, and left the PLCs unplugged after initial experimentation.

Interest in, and Understanding of, Their Energy Use Patterns

The level of engagement and desire for specific information appear to vary by household. Interviews and surveys revealed that, while approximately 10% of participants did not find the information provided by the devices useful,[8] most contacts sought more detailed information than the devices could provide. For instance, all of the PTR focus group participants, who lacked the information available from an IHD, sought greater clarity on how their behaviors affect bills.

Among both RACT and Low Income-IHD participants, more than three-fourths of survey and interview contacts appreciated the ability to monitor their energy use and costs with the IHD. Several households reported using their devices to investigate specific loads using the rapid feedback of the IHD. Others reported using the device to track their expected electricity bills. RACT-TECH participants liked the appliance-level and plug-level granularity of the PLC-website combination. In fact, some RACT-IHD group participants and Low Income participants requested additional functionality/visibility, similar to that provided to the RACT-TECH participants. RACT-TECH group participants also liked the website functionality, and used it more often than participants who did not have the PCT and PLC devices.

These findings are consistent with a recent American Council for an Energy-Efficient Economy (ACEEE) report reviewing nine real-time feedback pilots in the United States, the United Kingdom, and Ireland (Foster and Mazur- Stommen 2012). In this report, the authors note that, while the cost of electricity "was recalled most easily and seen as most relevant," households with higher savings did not report more awareness of actions or a higher level of effort. They also found:

- Participants reported higher engagement with advanced displays compared to more basic displays; and
- IHDs were rated more highly than other interventions in helping customers become aware of and control their energy consumption.

There is evidence that linking the information provided by feedback devices to other motivational and behavioral approaches may be required to maximize the potential energy savings from the feedback device. Ehrhardt-Martinez et al. (2010) suggest using commitments, goals setting, social comparisons, normative messaging, and strategies that engage participants in small actionable steps. Small sample sizes and short-term pilot horizons limit the transferability of findings associated with many of the pilots reviewed by Ehrhardt-Martinez et al., and that is also the case with SDG&E's HAN pilots. Nevertheless, some important insights were obtained.

Conclusions

Research with participants in the three pilots did not reveal any clear demographic or attitudinal predictors of the customers and/or households who are most willing to curtail during demand response events. Both randomly selected (PTR) participants and opt-in (RACT and Low Income) participants agreed that a sense of civic responsibility motivated them to participate.

Among PTR participants, willingness to curtail was eclipsed by limited awareness of event days and a sense that there is little opportunity to reduce energy use when a participant is

[8] This includes 2.5%-7% of LI-IHD participants who disagreed that the various pieces of information displayed on the devices were useful, and 4 of 30 RACT interviewees (13%) who said the IHD had limited usefulness.

away from home during peak times. No systematic attitudinal or demographic differences predicted curtailment performance across PTR enrollees.

There also is evidence that participants who feel most strongly about the need to reduce their energy use are *not* necessarily the ones who feel a strong obligation to curtail during demand response events. In open-ended responses, two surveyed RACT participants felt that by asking them to curtail in addition to what they already do to save energy, SDG&E was failing to recognize that these customers already “do their part” to conserve energy. End-users who perceive that they already are doing their part to conserve energy may be either unable or unwilling to do *more* during demand response events.

Insights for Future Programs

Clarify messages around conservation and demand response. While we heard eloquent descriptions of peak load constraints from some participants, many did not distinguish between requests to reduce their energy use during specific events and requests to reduce energy use *in general*. Initial impact estimates indicate that PTR, with the addition of extraordinary outbound dialing from the utility to participants, was able to achieve greater demand impacts than the HAN pilots. These results are consistent with previous findings that feedback programs focused on demand reduction at peak periods are less effective than those that communicate the need to save energy all the time (Ehrhardt-Martinez et al. 2010). By linking to existing smart meter technology and household wireless networks, IHDs offer the opportunity to engage residents more fully overall household conservation, as these devices now have the capacity to provide near real-time feedback and visibility into household energy consumption, and do so continuously.

Similarly, participants may not fully understand that PCTs are unlikely to result in energy and bill savings -especially for households with an existing programmable thermostat. Programs will want to avoid overpromising benefits from PCTs. Unless the auto-curtailment features are employed frequently, a PCT without the interactive features of the IHD provides limited benefits to participants.

Explore ways to identify those primed for feedback. Process evaluation interviews and preliminary impact data indicate that not all households respond equally to the detailed information provided by IHDs. It is important to note that both of the HAN pilots operated with an opt-in recruitment strategy, rather than enrollment and opt-out. Consistent with decision architecture literature (Thaler & Sunstein 2008), creating opt-out opportunities makes the default choice to stay in the program. Participation rates tend to be higher for opt-out feedback programs (Ehrhardt et al. 2010).

However, increasing participation rates alone may not increase the odds that a program has identified the customers most able and willing to absorb the information and act on it. Foster and Mazur-Stommen use the term “cybernetically-sensitive” to describe the small portion of households in feedback pilots that demonstrate large savings of up to 25% (Foster & Mazur-Stommen 2012). These households demonstrate an extraordinary level of sensitivity to the information provided by the feedback device. Because of the cost of providing these devices to individual households, utility and evaluation staff should continue efforts to identify factors that align with cyber-sensitivity.

RACT program staff reported that approximately 14,000 households received marketing materials, and 4% of these households responded to the outreach. While pilot enrollment was limited to only 200, the 4% response rate provides some estimate of existing interest. A similar response rate (~5%) was achieved for the Low Income pilot, but only after multiple touches (prospective PCT participants received up to seven letters.) These are slightly higher than response rates for time-of-use pilots, historically below 2% (Peters et al. 2009), and it is not unusual for IHD and demand response programs to require substantial efforts to recruit participants.[9] While program recruitment for opt-in feedback programs produces low response rates, those enrolled are more likely to be actively seeking feedback.

Ensure that feedback and curtailment devices meet standards for user interface. While participants generally valued the information obtained from the technology they received through the pilots, a notable minority of participants (13% of IHD and 20% of PCT users) found the devices difficult to use. Contacts suggested that the devices' user interfaces were not intuitive and that the PCTs in particular required multiple steps to carry out simple functions. These findings are consistent with a recent paper about two Black Hills Energy pilots in which the authors describe customer difficulty understanding and operating the thermostats installed (Mantei et al. 2012).

Devices that are difficult to use are less likely to be used, particularly given the high expectations today's consumers have for the usability and engagement of electronic devices. According to the Usability Professionals' Association, *usability* refers to the quality of a product and incorporates the extent to which a product is efficient, effective, and satisfying for those who use it. Usability testing is standard practice in other fields that rely on electronic communication devices, and should be an important component of utility procurement decisions.

Third-party vendors and equipment manufacturers should be aware of the need for their devices to be easy to use and engaging. While much of the development of communication and feedback devices has been focused on the internal capacity of the hardware to interact with the specific metering infrastructure in a given utility territory, it is time to prioritize the usability aspects as well.

Given the rapid evolution and increasing technological capacity of Smart Grid communication devices, utilities and other large-scale purchasers should consider asking vendors to report usability results.[10] A functional, intuitive, and attractive user interface has become a central selling point for many devices, e.g., Apple and Android smartphones and tablets. Program technologies compete with these intuitive devices for users' attention.

[9] In a paper delivered at the 2012 AESP National Conference, contacts from Black Hills Energy described "valiant efforts," in recruiting including direct mailings to 5,000 households that failed to enroll the goal of 400 participants in a smart thermostat pilot.

[10] The National Institute of Standards and Technology supports the Industry Usability Reporting Project provides links to the Common Industry Format (CIF) and provides information on ISO standards for usability. There are two international standards that define usability and human-centered (or user-centered) design: ISO 924-11 and ISO 13407. See the Usability Professionals' Association website http://www.upassoc.org.

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