Increasing Energy Efficiency in Buildings through Smart-Grid Enabled Residential Programs

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ABSTRACT

Utilities are investing billions of dollars in developing the smart grid, and millions of customers now have automated meters that enable two-way communication between the customer and the utility that could greatly enhance future residential energy efficiency program design.

With this opportunity in mind, two pilot programs in Vermont are exploring the role of automated metering infrastructure (AMI), in home displays (IHD), web presentment of energy savings information, energy efficiency coaching provided through Proactive Customer Service (PCS), and variable peak pricing on reducing energy use in residential buildings. One pilot is a Consumer Behavior Study (CBS) funded by the U.S. Department of Energy (DOE) through the federal Smart Grid Investment Grant (SGIG) program, which began in 2011 and is ongoing through 2014. A companion pilot also started in 2012 and completed in 2013 focused on residential low income customers with funding from a U.S. DOE Weatherization Innovation Pilot Program (WIPP) Grant.

This paper reports results thus far from the Consumer Behavior Studies, with a focus on explaining the use of hourly energy information, web presentment, "proactive" (rather than "reactive") marketing and customer service messages, and variable peak pricing to increase energy efficiency and conservation-based behavior in residential buildings. Key findings from the pilots are provided as well as lessons learned and implications for future residential energy efficiency programs are discussed.

Background

Substantial opportunity exists for using "smart grid" enabled technology and the real-time customer data available from Automated Metering Infrastructure to increase energy efficiency savings for residential utility customers. The potential to analyze customer specific data, gathered through smart-grid enabled technology, to identify energy savings opportunities and to proactively reach out to customers to provide energy efficiency coaching through existing Customer Support Call Centers to modify energy use behaviors and purchase decision is very compelling. As administrator of three Energy Efficiency Utilities (Efficiency Vermont, the District of Columbia Sustainable Energy Utility, and Efficiency Smart in the mid-West), Vermont Energy Investment Corporation (VEIC) sees great potential for continuing to modify and enhance our residential energy efficiency programs and services, informed by the new capabilities enabled by the smart grid, leveraging our best-in- class Customer Support Call Center.

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With this in mind, VEIC joined with Vermont utilities, the Vermont Department of Public Service, and the Vermont Office of Economic Stimulus and Recovery to develop a $66 Million grant request to the U.S. Department of Energy's (DOE) Smart Grid Infrastructure Grant (SGIG) program for federal stimulus funds for eEnergy Vermont, an initiative to deploy AMI, grid automation, and security technologies statewide. The grant was selected for funding by DOE, and is one of nine nationwide that also includes a Consumer Behavior Study (CBS) designed to better understand opportunities for reducing energy usage in the residential sector using smart grid technology and data. VEIC partnered with Vermont Electric Cooperative (VEC) to carry out the CBS pilot, which began in 2010 and will be completed in 2014.

Also in 2010, VEIC proposed a companion study focusing on residential low income customers in Vermont for the Weatherization Innovative Pilot Program (WIPP) managed by the DOE. VEIC is one of 16 weatherization pilots funded nationwide, with the pilot program launched in 2010 and completed in 2013.

When designing the studies, the study team set out to design multiple treatment groups consisting of specific technology and customer service interventions that would elicit energy savings behaviors and decisions. The underlying purpose for eliciting these behaviors is to explore the extent to which the combination of customer service and AMI-enabled technology could cost-effectively maximize energy and capacity savings. Electric Power Research Institute (EPRI) research protocols provided the basis for designing various treatment groups for each study (EPRI 2012).

Presented below is key information about the design and approach for both pilots, a discussion of key findings, and lessons learned from the studies thus far which help inform future residential energy efficiency programs.

Pilot 1: VEC Consumer Behavior Study

The primary objective of the VEC Consumer Behavior Study is to test the effectiveness of information, automation treatments, and dynamic pricing for residential customers on lowering peak and total electric loads. Specifically, the VEC study combines a web portal, an increased level of customer support, and a Variable Peak Price (VPP) in an attempt to reduce peak and total energy usage. If these customer systems can operate seamlessly within the AMI infrastructure, the hope is that they will "fundamentally change how customers manage their energy use."(eEnergy Vermont 2009)

The research design of the VEC Consumer Behavior Study is aimed at three primary questions of interest:

1. Are customer service-based information treatments (embodied in Proactive Customer Service) and technology-based treatments complements or substitutes in encouraging demand response and energy efficiency, as measured through monthly customer-level electricity usage and hourly electricity demand?
2. How does a Variable Peak Price (VPP) affect customer level electricity usage and hourly electricity in the presence of customer service-based information, technology-based information feedback, and automated response capabilities? How much does PCS enhance a transition to VPP?
3. How do customer service-based information and technology-based information affect customer attitudes (as measured by post-treatment surveys) towards energy management and the introduction of VPP tariffs?

As implemented, the study features the following major elements:

1. Proactive Customer Service
2. In-Home Display
3. Web Portal
4. A Variable Peak Pricing Rate
5. Hourly usage information collected using AMI

Year One of the study sought to distinguish the effect of technology in the form of an In-Home Display (IHD) and Web Portal from the effect of "energy efficiency coaching" in the form of outreaching "Proactive Customer Service (PCS)." The treatment groups summarized in Table 2 each received some combination of technology and/or efficiency coaching via telephone. The control group was divided into two, allowing one group to have access to the web portal and one group to not have access to the web portal.

Table 1. Year one treatment groups

Technology or Price	Treatment Group			Control	
	T1	T2	T3	C1	C2
Proactive Customer Service	X		X		
In-Home Display		X	X		
Flat Rate + Web Presentment	X	X	X	X	
Flat Rate + No Technology					X
Group Size	268	115	95	2500	2500

Year Two of the study (currently underway) introduces a Variable Peak Price (VPP) to measure the impact of price on consumption, particularly peak consumption. The treatment group shown in Table 3 receives a Variable Peak Price supported by an enhanced version web portal which includes a bill comparison calculator and price alerts via text message. The control group remains on the standard flat electric rate, and has access to a standard web portal that does not include a bill comparison calculator or price alerts in any form.

Table 2. Year two treatment groups

Technology or Price	Treatment Group	Control Group
Customer Service	X	
Flat Rate + Web Presentment		X
Variable Peak Price + Enhanced Web Presentment w/ Price Alerts	X	
Group Size	848	841

Pilot 2: WIPP Consumer Behavior Study

Completed in 2013, the purposes of the Weatherization Innovation Pilot Program project were to:

1. Provide low-income households the opportunity to benefit from smart grid technologies they are helping to pay for; and
2. Demonstrate the benefits of integration of the Weatherization Assistance Provider (WAP) network, energy efficiency program offerings, and distribution utility services that otherwise typically operate independently of each other when assisting low-income households.

Participants in this pilot received a combination of Proactive Customer Service in the form of telephone and/or on-site energy efficiency coaching, In-Home Displays, and Web Portal access. The study period covered 12 full months, with 6 months of pre-study outreach through mailings, telephone calls, and technology installation. Energy usage information was collected using Current Transformer (CT) clamps which communicated data wirelessly to a web portal.

The WIPP study varied from the VEC Consumer Behavior Study in two significant ways. First, study participants were required to have a total household income less than 185% of the federal poverty level. Second, the Proactive Customer Service treatment was divided into two groups. One group received energy efficiency coaching through one or more outgoing or incoming telephone calls with VEIC's existing Customer Support Call Center and the other group received energy efficiency coaching through one on-site visit to their home by a trained Weatherization Assistance Program provider. These approaches to Proactive Customers Service were intended to assess the effectiveness of telephone PCS versus using an existing network of trained outreach specialists, such as WAP staff, to provide more extensive energy efficiency coaching, exploring additional energy efficiency measures beyond the coaching and/or measures typically offered by agencies delivering WAP services.

Study Findings to Date

Presented below are key findings to date from the Consumer Behavior Studies, with an emphasis on changes in consumer behavior and the resulting energy savings from the WIPP study (which has been completed) and on lessons learned from the study design and approach for the VEC study (which is ongoing and will be completed in 2014). The findings draw upon results of a survey sent to all treatment group participants of both studies midway through Year One with the goal of measuring the perception of the participants and their savings, and to evaluate how effective each technology or PCS treatment was at achieving savings. A 36% response rate was achieved for the survey.

Proactive Customer Service Yields Up To 5% Energy Savings

Two models were used to quantify energy savings from Proactive Customer Service provided for the WIPP study either by telephone or by on-site energy efficiency coaching

following a pre-established curriculum[2]. The methods included an Actual Savings model, and the "Difference of Differences" model. While the results in Table 4 were variable based on the method used to calculate change, some key findings are apparent. For the WIPP study, the treatment group receiving telephone based energy efficiency coaching offered multiple times using real-time information on energy use consistently achieved positive monthly energy savings of between 3.7% and 5.1%. The WIPP treatment group receiving on-site energy efficiency coaching following a pre-established curriculum not informed by real-time information on energy use consistently showed monthly kWh changes that were not significantly different from 0, meaning there was no measurable change in savings.

Table 3. Comparative statistical models showing monthly energy savings for WIPP participants

Result	Actual		Diff. of Diff.	
	On-Site	Phone	On-Site	Phone
Avg. Monthly kWh Savings	7	26	-2	36
% Savings	0.9%	3.7%	-0.2%	5.1%
p-value	0.18	<0.0001	0.45	0.007
Significant from 0?	No	Yes	No	Yes

A regression model (referred to as the Actual Savings model) that relates heating degree days (HDD) and cooling degree days (CDD) to energy use was developed for pre-project energy use patterns of each account, and then savings were estimated as the difference between actual post-project usage and the usage predicted by the pre-project regression model using the actual temperature data from the post-project period.

The Difference of Differences method does not rely on using a regression model to make predictions, and instead uses a control group to compare post project performance with treatment groups. To account for random differences in energy usage that may have existed prior to the project, differences between the control and treatment groups in the post project period were adjusted by differences in their pre-project use.

Evaluating savings results from two different models (with one assessing actual energy savings and the other measuring savings based on differences from the control group), was important given the sample size of the study, and the relatively short study period in order to evaluate the effectiveness of the treatments. Overall, the results from each model conclude that telephone efficiency coaching can be an effective approach to influencing occupant behavior and ultimately reducing energy use, while delivering on-site outreach may not provide as compelling results.

[2] A Typical Meteorological Year (TMY) 3 Predictor model was also used to calculate savings. The results from this model, which predicts what future savings would look like for study participants using "30 year normal" weather data, indicated savings slightly higher than the Actual and Difference of Differences models

The Number of Contacts and the Number of Days between Technology Installation and the First PCS Contact Correlate with Energy Savings

Energy savings among study participants appear to have a strong correlation with the number of days between when the In Home Display was installed and the first PCS telephone call or on-site visit. Telephone PCS is less time intensive than the on-site visits, which means that a homeowner can be contacted more times with less effort, less cost, and less disruption to their regular schedules. On-site PCS requires a pre-visit scheduling telephone call, and then the homeowner has to be home during the visit, which often times means they have to leave work. The WIPP study did not prove to be a high enough priority to the participants for them to consider taking time off from work to receive a home visit. Outgoing telephone calls are inherently easier to perform than on-site visits because they do not require a scheduled home visit or the homeowner to even be at home.

Figure 1 plots energy savings and number of days until PCS, and the results indicate that the more time that passes the less effective PCS becomes.

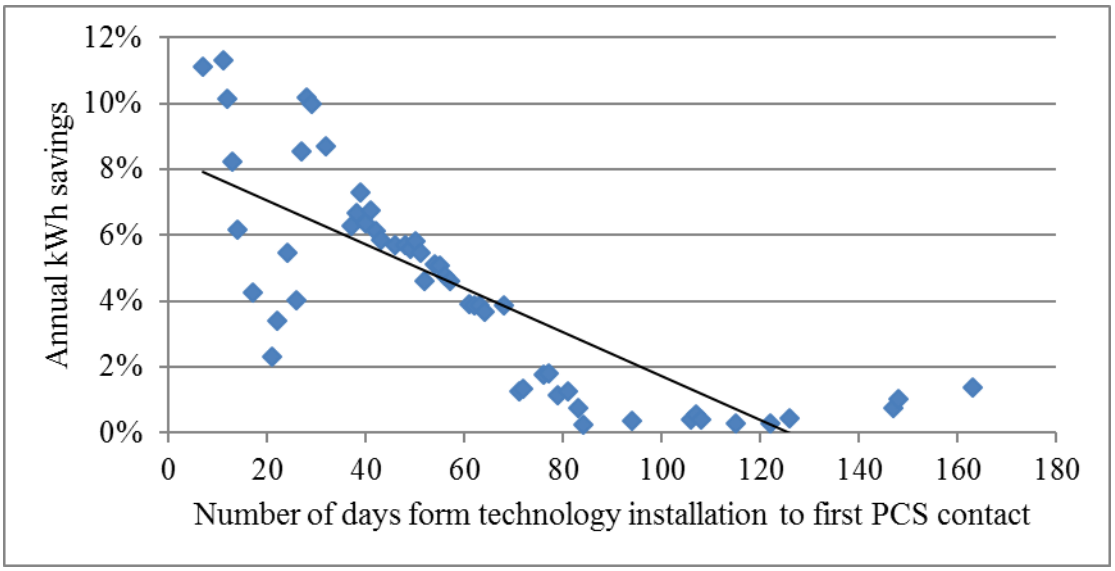

Figure 1: % of annual energy savings based the number of days between technology installation and first PCS contact.

Figure 2 uses a scatter plot to illustrate energy savings arranged by the number of PCS interactions, and a pattern emerges that indicates greater savings when more PCS contacts are made.

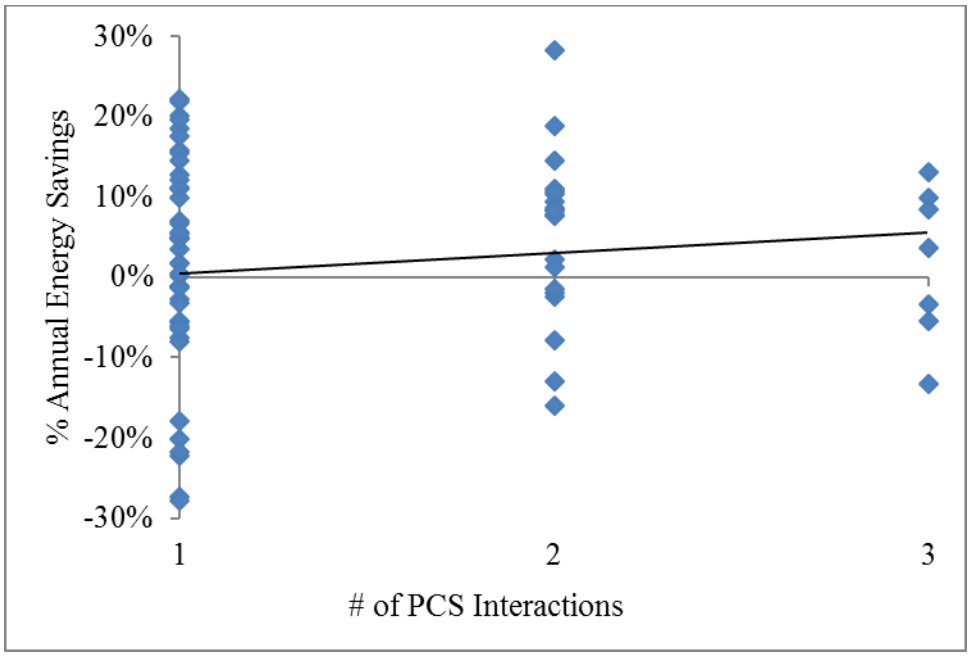

Figure 2: % of annual energy savings based the number PCS interactions.

The trend lines in each of these figures provide an area that warrant further investigation. While the number of contacts and length of time between PCS contacts appear to be related, additional sample sets could potentially provide a more conclusive result.

In Home Displays Were Preferred Over Web Portals

A clear finding from the WIPP study shown in Figure 3 is that the participants found the web portal to be less useful than the In Home Displays. 70% of respondents reported checking their IHD at least on a weekly basis, while only 17% reported logging in to their web portal weekly.

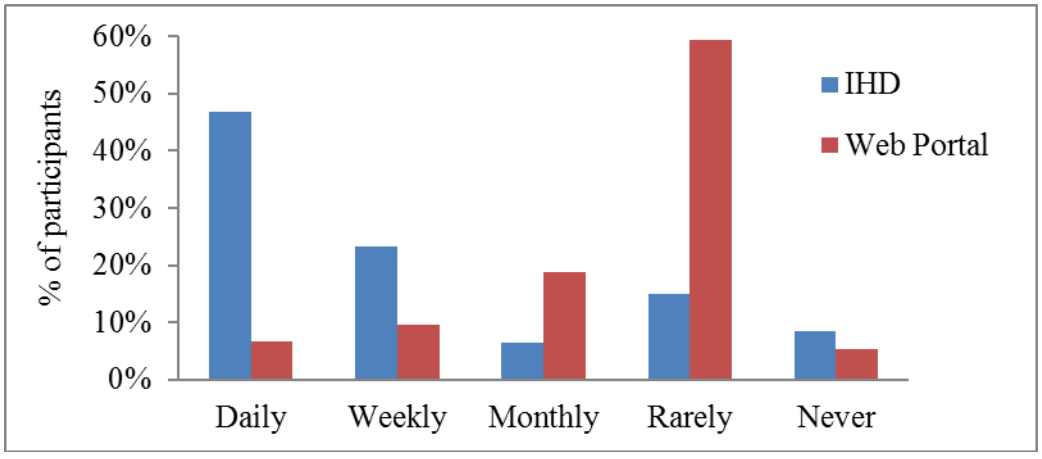

Figure 3. Frequency of checking in-home display and web portal.

This result could be due to two factors - ease of use and location of the IHD. The web portal requires the participant to actively login in to see their electric use, while the IHD only has

to be glanced at to see the same information. While the web portal provides more granularity of information about electric use as well as energy savings tips, it cannot be accessed as quickly as an IHD for the simple function of seeing real time and daily energy use.

Location of In-Home Display Directly Corresponds with Frequency of Use

The location of the IHD in a residence appears to have an impact on how often it is used. Over 60% of study participants responding to the survey chose to locate their IHD in the kitchen or living room, and of the respondents 40% reported checking their IHD on a regular basis.

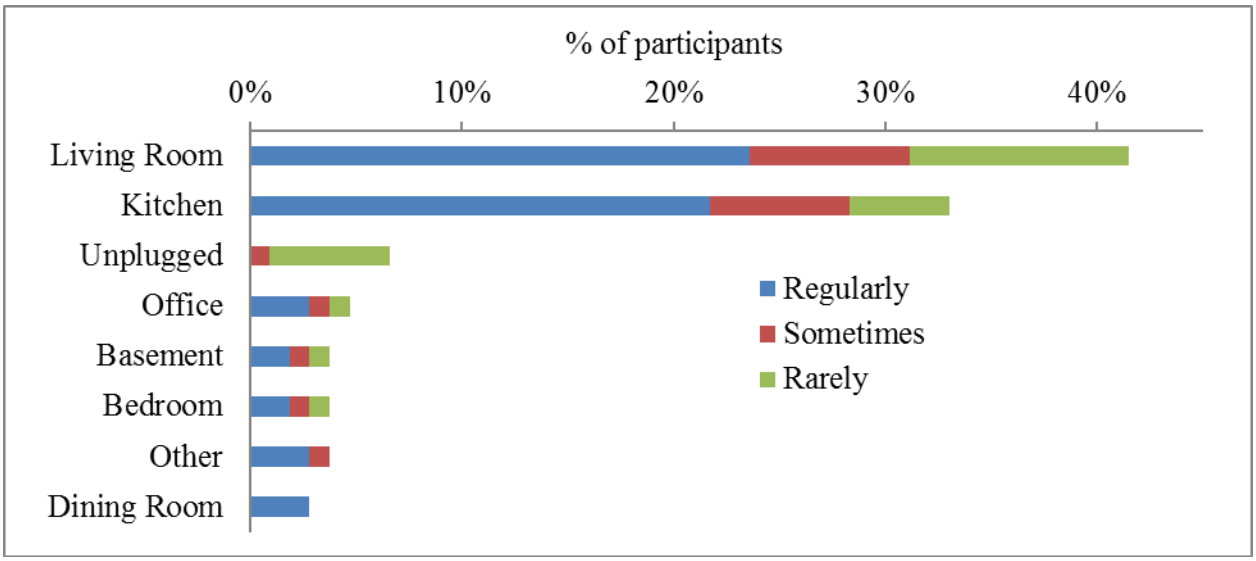

Figure 4. IHD location and frequency of use.

Efficiency Coaches Motivate Participants to Make Energy Saving Behavior Changes

Participants overwhelming reported a positive response to the Proactive Customer Service. When asked if their efficiency coach motivated them to make behavior changes that would save them electricity, 70% responded that they either agreed, or strongly agreed. Even more, when asked if they implemented any recommendations of their efficiency coach, 70% answered yes. When comparing the results of these two questions together in Figure 5, it is clear that most participants that were motivated to change actually made a change.

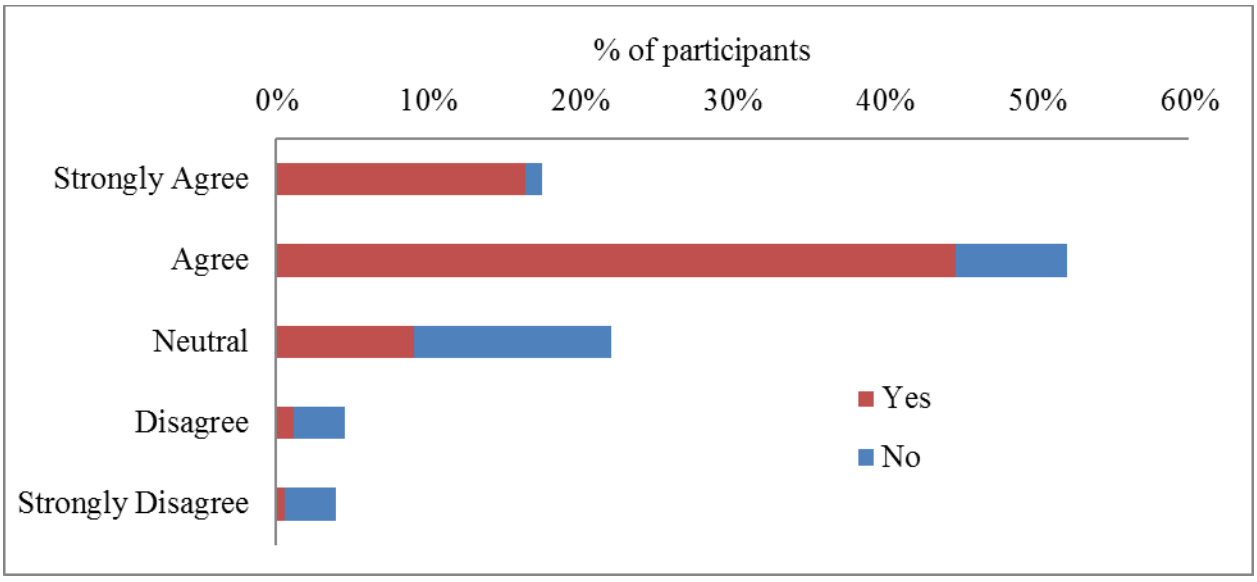

Figure 5. Participant motivation and behavior implementation.

Lessons Learned and Implications for Future Programs

Proactive Customer Service Can Increase Energy Efficiency Savings

Results from the WIPP study indicate that energy efficiency coaching provided through Proactive Customer Service can result in 5% savings, especially when the PCS is delivered soon after installation of an In Home Display or other energy saving measure. Key implications to consider for future programs include, among others:

- Proactive Customer Service requires different skills to successfully initiate and complete outgoing calls, than the skills typically needed for Call Centers that serve only incoming calls initiated by the customer. Additional training may be needed to transition call center team members to be able to handle both incoming and outgoing calls successfully.
- Outgoing PCS calls take time to successfully complete. The average outgoing call time for the Consumer Behavior Studies thus far is 17 minutes, which is longer that VEIC's average incoming call time.
- The scheduling of outgoing Proactive Customer Service calls may also differ from typical Call Center hours for energy efficiency program administrators, with outgoing calls being scheduled more during the evening than during the workday. This can have scheduling implications for program administrators and may add cost.

Smart Grid Enabled Technology is Continually Evolving, Full Scale Programs Should Use Fully-Commercialized Proven Technology

Smart grid enabled technology, data platforms, and applications are developing and changing rapidly right now. Although they were selected through a rigorous and competitive RFP and vendor screening process completed as recently as 2011, the In Home Displays used for the VEC and WIPP studies are already outdated. Firmware updates are no longer available, the technology installation was not as seamless as envisioned, and deployment in rural Vermont was

expensive and took much longer than anticipated by the vendor. This is partially due to the fact that a pre-commercial technology was selected for the pilots, based on the aspirations of the vendor to integrate their device with the type of innovative and creative energy efficiency coaching envisioned for the Proactive Customer Service to be provided. Key implications to consider for future programs include, among others:

- While pre-commercial technology can be an acceptable choice for a pilot program, such technology is not recommended for full scale program roll-outs since technology problems and troubleshooting to fix problems can slow program rollout, diminish confidence with customers, and increase costs.
- For technology that is to be fully deployed, ensure it is plug-and-play and does not require special installation by an electrician or an on-site installer, and work with a vendor with a proven track record.
- While telephone applications could be the future, not all demographics will necessarily benefit from phone apps the same way (such as the elderly and low income), so that is a consideration.
- Although Web Portals were checked less often than In Home Displays in the Consumer Behavior Studies, Web Portals provide more complete information, greater functionality (savings tips, historical bills that can be compared to current bills, etc.), and can be checked from anywhere there is access to the web. The rapid growth of companies, such as Opower, providing web-based energy efficiency services indicates the future use of In Home Displays may be very limited, despite their promise just three or four years ago!

Addressing Customer Data Sharing Issues Could Provide New Opportunities for Targeting Residential Energy Efficiency Programs Where Most Needed

The WIPP pilot required fairly extensive efforts to develop the recruitment list for participants because of the need to work from separate customer files from the Weatherization Assistance Program, LIHEAP, and the utilities serving the customers. The experience of having to work across three separate customer data systems reinforced the unrealized opportunity that smart grid technology provides for linking utility customer databases and/or energy efficiency program databases to further enabled the identification of those consumers most in need of energy efficiency improvements and for targeting offerings to those end users. However, concern about consumer data privacy due to smart grid capabilities combined with the long-term practice of utilities not sharing customer information with other parties limit the potential for such targeting of services.

Policy makers and / or utility regulators might consider how to encourage data sharing for purposes of coordinating and integrating the delivery of energy efficiency services between utilities and federal programs such as LIHEAP and WAP. For the VEC and WIPP Consumer Behavior Studies, permission was obtained from customers upfront to share data as part of the study participation agreement executed with each customer.

Next Steps

The VEC Consumer Behavior Study will conclude in the summer of 2014. Data collection and analysis will be done to understand how Variable Peak Pricing affects energy use, and how consumers can benefit from access to a web portal that provides real-time energy use

information. Additionally, these results will be compared side by side with results of the WIPP study, ideally providing a distinction between how certain segments of the population react differently to varying types of technology treatments and Proactive Customer Service to reduce energy use.

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