Communicating Thermostats for Residential Time-of-Use Rates: They Do Make a Difference

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ABSTRACT

Public Service Electric and Gas Company (PSE&G) recently completed a residential demand response pilot program to understand how customers react to price signals, and to test customer reaction to the opportunity to conserve when power is in peak demand. The pilot utilized two-way communications to transfer energy pricing and interval consumption data to and from the customer meter and allowed PSE&G to test and measure customer response to various pricing signals under various weather and price conditions. They provided communicating thermostats to one-half of the participants in their pilot to test the influence of technology enabled response. The pilot tested Time of Use (TOU) rates and Critical Peak Pricing (CPP) rates.

Customers with the enabling technology showed greater reductions in summer peak day demand, both in response to the daily TOU rates and the special CPP events. Technology enhanced customers reduced their average hourly demand during the 1:00 p.m. to 6:00 p.m. period by 21% (0.59 kW) in response to the TOU on-peak rate, and they reduced their demand by an additional 26% (0.74 kW) if a CPP event was called. This is a total reduction of 47% (1.33 kW). Compare this to impacts achieved by customers with central air-conditioning that were on the same rates but only received informational materials. They reduced their average hourly demand during the 1:00 p.m. to 6:00 p.m. period by 3% (0.07 kW) in response to the TOU on-peak rate, and then they reduced their demand by an additional 14% (0.36 kW) if a CPP event was called. This showed that the enabling technology helped customers double their CPP response and increase their daily on-peak TOU response seven-fold.

While the major finding of this study is that technology enabled customers are able to create substantially greater load reductions during peak hours for both TOU on-peak periods and CPP events, a look at energy savings throughout the year brings a secondary finding to light. Customers who only received information created greater year-round energy savings on a percentage basis. It is hypothesized that their need to change behavioral energy use patterns during the summer to benefit from the TOU and CPP rates raised their energy consciousness. That new energy consciousness became a habit that they continued throughout the year. Technology enabled customers did not create similar behavioral habits.

Introduction

Residential Time-of-Use (TOU) rates are gathering more attention as utilities look for productive ways to improve their operations. Some residential customers may be motivated to take full advantage of their TOU rates, but struggle with remembering to respond on a daily basis. When utilities add Critical Peak Pricing (CPP) components to their TOU rates, this problem is magnified as customers must become aware of CPP events and then take action during the CPP hours. Utilities are increasingly looking to technology to help with this dilemma, and some have turned to communicating thermostats. By providing their TOU/CPP customers with a “smart” thermostat that can be programmed to respond to TOU price points and can receive a signal to respond to a CPP event, the utilities provide their customers with a tool to manage their demand and energy use. Does it work? Do those on TOU/CPP rates with communicating thermostats produce more summer demand savings than those without? How do customers with such thermostats respond to winter TOU/CPP rates?

Public Service Electric and Gas Company (PSE&G) recently completed a pilot program over two years to answer those questions. PSE&G is the largest utility in New Jersey, serving three-quarters of the state’s electric and gas customers. They provided communicating thermostats to one-half of the participants in their TOU/CPP pilot. This paper will present the final results from that pilot, discussing differences between the two participant groups in terms of summer and winter demand and energy savings, customer satisfaction and bill savings.

Description of Pilot

The myPower Pricing Pilot tested two-way communication technologies to the customer’s meter to understand the potential to change the way customers think about energy delivery and consumption, to understand how customers react to price signals, and to test customer reaction to the opportunity to conserve when power is in peak demand. The pilot utilized two-way communications to transfer energy pricing and interval consumption data to and from the customer meter and allowed PSE&G to test and measure customer response to various pricing signals under various weather and price conditions.

The Pilot tested two approaches to encouraging customer responses to energy prices:

1) *Information Only (myPower Sense)* – These customers received program educational materials which included energy saving tips, pricing plan information and website information.
2) *Technology Enhanced* (*myPower Connection*) – These customers received program educational materials and a communicating, programmable thermostat.

The thermostats receive signals sent by PSE&G to indicate daily price period changes and critical peak events. The thermostats react to the signal and automatically implement specific temperature adjustments programmed by the customer in advance.

Both groups received interval electric meters and were put on the TOU rate with a CPP component. Table 1 presents the rate designs that were used during the pilot. The TOU rate provided different prices for electricity depending upon the time of day (essentially a base rate with a night discount and an on-peak adder). Rates changed based on the season and the market price of energy. The CPP aspect of the rate was a significant adder at 69 cents per kWh in 2006 and $1.37 per kWh in 2007. In the summer of 2007, the CPP rate was more than 15 times greater than the base electric rate.

Table 1. Rate Design for myPower Pricing Pilot

	Summer				Non Summer					
	Jun-Sept 2006		Jun-Sept 2007		Oct 2007		Nov '06-Mar '07		Apr-May 2007	
	M-F	SS	M-F	SS	M-F	SS	M-F	SS	M-F	SS
9AM-1PM										
1PM-5PM	On-Pk &	Base	On-Pk &	Base		Base		Base		Base
5PM-6PM	Critical		Critical		Critical		On-Pk &		Critical	
6PM-9PM							Critical			
9PM-10PM										
10PM-6AM	Night		Night		Night		Night		Night	
6AM-9AM					Base		Base		Base	

	Jun-Sept 2006	Jun-Sept 2007	Oct 2007	Nov '06-Mar '07	Apr-May 2007
Base Rate	9.2032¢	8.6775¢	8.667¢	8.667¢	8.667¢
Night	- 5¢	- 5¢	- 4¢	- 4¢	- 4¢
On-Peak	+ 8¢	+ 15¢		+ 3¢	
Crit-Peak	+ 69¢	+ $1.37	+ 23¢	+ 23¢	+ 23¢

At the end of the program, 379 customers were participating in the Information Only group and 319 in the Technology Enhanced group. Due to the nature of the enabling technology, all customers in the Technology Enhanced group had central air-conditioning. However, only sixty-one percent of the customers in the Information Only group had central air-conditioning. A matched Control Group was used to evaluate results and care was taken to split the Control Group into those with central air-conditioning and those without for comparison.

Table 2. myPower Pricing Program Participants and Control Group

Segment	Households
Information Only – myPower Sense	379
Technology Enhanced – myPower Connection	319
Control Group	450
Total	1,148

All results in the remainder of this report compare Technology Enhanced participants with Information Only participants that had central air-conditioning.

Summer Peak Day Impacts

Customers with the enabling technology showed greater reductions in summer peak day demand, both in response to the daily TOU rates and the special CPP events.

Both Technology Enhanced and Information Only customers consistently lowered their summer on-peak demand in response to price signals across both years of the study.[1] During the summer there were daily reductions in demand from 1:00 p.m. to 6:00 p.m. on weekdays due to the on-peak prices in the TOU rate. When critical peak days were called, both groups of

[1] There were two CPP events in the summer of 2006 and five CPP events in the summer of 2007. After estimating impacts for each year separately, it was determined that there was no significant difference in impacts between the two years and they could be combined to improve the reliability of the analysis.

customers reacted to the CPP rates and created even more demand reduction during the 1:00 p.m. to 6:00 p.m. period.

Table 3. TOU and CPP Demand Reduction on Summer Peak Days in 2006 and 2007

Segment	Baseline Avg On Peak kW	TOU On-Peak Period Reduction		Additional CPP Reduction		TOU Plus CPP Reduction	
		kW	%	kW	%	kW	%
Technology Enhanced with Central AC	2.85	0.59	21%	0.74	26%	1.33	47%
Information Only with Central AC	2.60	0.07	3%	0.36	14%	0.43	17%

Source: Summit Blue analysis of PSEG myPower data

While both groups of customers showed a response to the TOU and CPP rates on hot summer peak days, the response was substantially greater for those customers that had received programmable, communicating thermostats as part of the pilot (Technology Enhanced customers). Table 3 shows that Technology Enhanced customers reduced their average hourly demand during the 1:00 p.m. to 6:00 p.m. period by 21% (0.59 kW) in response to the TOU on-peak rate, and they reduced their demand by an additional 26% (0.74 kW) if a CPP event was called. This is a total reduction of 47% (1.33 kW).

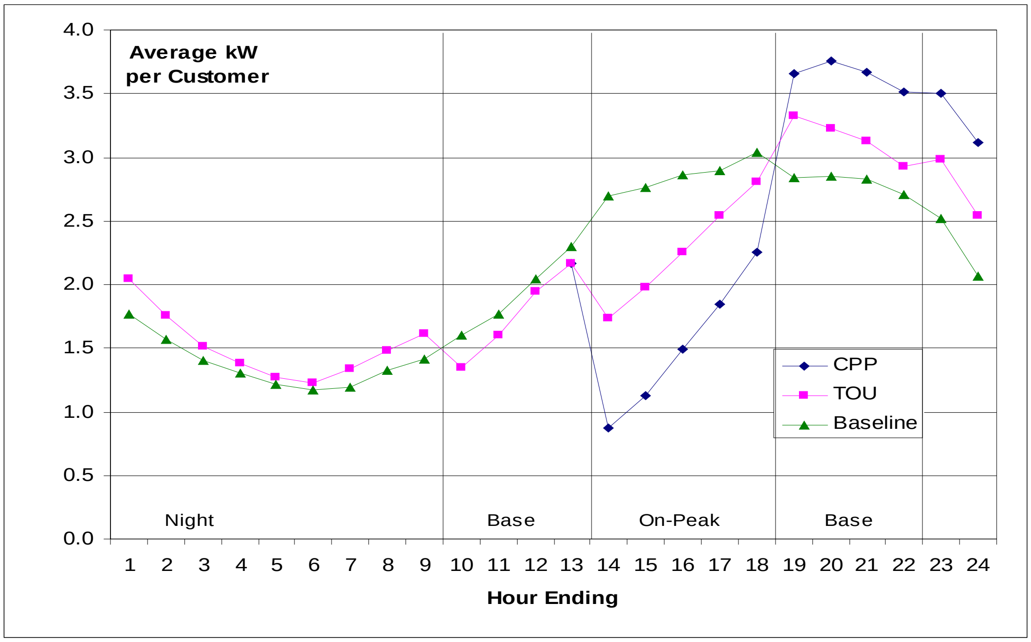
Compare this to impacts achieved by Information Only customers with central air-conditioning. They reduced their average hourly demand during the 1:00 p.m. to 6:00 p.m. period by 3% (0.07 kW) in response to the TOU on-peak rate, and then they reduced their demand by an additional 14% (0.36 kW) if a CPP event was called.[2] The enabling technology helped customers double their CPP response and increase their daily on-peak TOU response seven-fold. Figure 1 and Figure 2 illustrate these reductions for the hottest days of the summer.

A similar recent pilot of technology-enabled response to TOU and real-time pricing rates in the Pacific Northwest also showed that automation was particularly helpful for obtaining consistent responses from demand resources (Hammerstrom, et al, 2008).

It is of interest to note that while the CPP rate increased dramatically from 2006 to 2007, the load impact remained essentially the same in both years. This indicates that 69 cents per kWh was sufficiently high to get customers to take whatever actions they were willing to take to reduce their on-peak energy use. Their ability to respond was tied closely to their air-conditioning use and there were no additional significant loads to shed when the price increased to $1.37 per kWh.

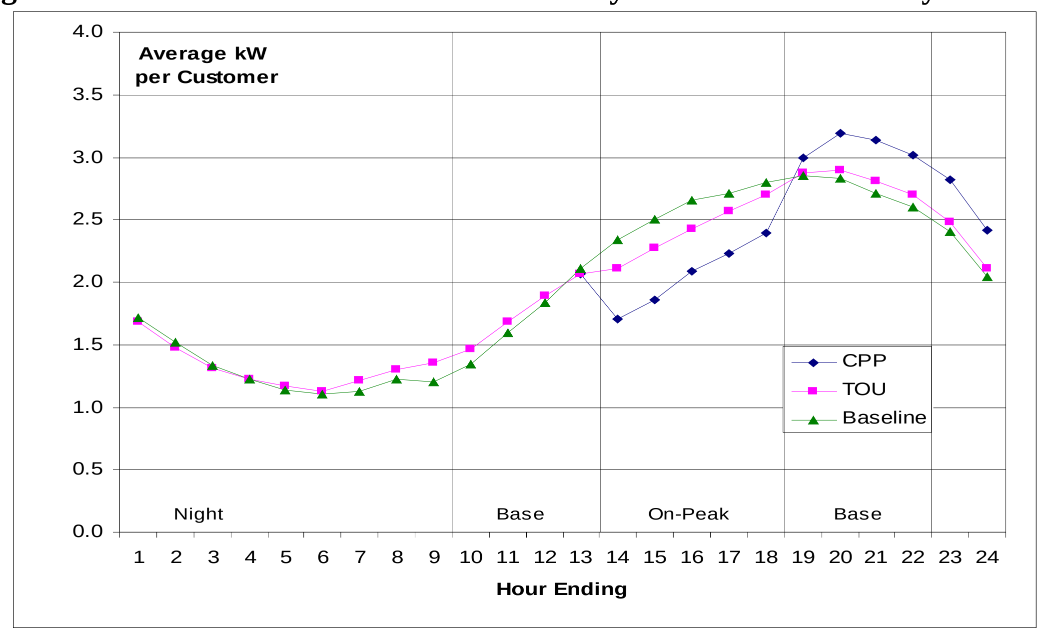
[2] All summer load impacts were estimated using a time-series cross-sectional regression model. The impacts were statistically significant at the 99% confidence level using a standard t-test.

Figure 1. Load Curves on Hottest Summer Days for Technology Enhanced Customers



Source: Summit Blue analysis of PSEG myPower data

Figure 2. Load Curves on Hottest Summer Days for Information Only Customers



Source: Summit Blue analysis of PSEG myPower data

Winter Peak Day Impacts

The TOU rate was in effect for the whole year and CPP events were called in winter months as well as summer months. Did enabling technology help customers save in winter as well as summer? Since the programmable thermostat controls both heating and cooling load, large electric load reductions are expected in summer because air-conditioning is an electric end-use. However, few customers have electric space heat so the thermostat is not expected to have a large effect on winter loads.

Table 4 summarizes the average winter impacts estimated for both the TOU and the CPP rates for each program segment over the on-peak period. These can be compared to the summer impacts shown in Table 3. Before making this comparison, it is important to recognize how winter peak periods differ from summer peak periods. While summer peak periods occur from 1:00 p.m. to 6:00 p.m., winter peak periods are shorter and occur later in the day, from 5:00 p.m. to 9:00 p.m. Also, total loads are much lower in winter than they are in summer, and the rate differentials are much lower.

Keeping this in mind, Table 4 shows that Technology Enhanced customers perform as expected. They show much less demand reduction during winter. Their enabling technology is no longer helping them to reduce demand as much as in the summer. However, Information Only customers maintain roughly the same percentage load reduction in both seasons (17% in summer and 21% in winter for Information Only customers with central AC).

Table 4. TOU and CPP Demand Reduction on Winter Days 2006/2007 Season

Segment	Baseline Avg On Peak kW	TOU On-Peak Period Reduction		Additional CPP Reduction		TOU Plus CPP Reduction	
		kW	%	kW	%	kW	%
Technology Enhanced	1.39	0.04	3%	0.37	27%	0.41	30%
Information Only with Central AC	1.59	0.11	7%	0.22	14%	0.33	21%
Note: On Peak hours are 1:00p.m. to 6:00 p.m. in summer, and 5:00 p.m. to 9:00 p.m. in winter.							

Source: Summit Blue analysis of PSEG myPower data

Customers in the Technology Enhanced group that rely on technology support during the summer show that they are willing to take behavioral actions to cut their energy use by an additional 27% during CPP events. However, they are less willing than Information Only customers to take those behavioral actions on a regular, everyday basis in response to the TOU rates, showing only a 3% reduction in use during the on peak period compared to a 7% reduction for Information Only.[3] Figure 3 and Figure 4 present the average load curves for cold winter days for the two groups of customers. Figure 3 shows there is little TOU response for Technology Enabled customers.

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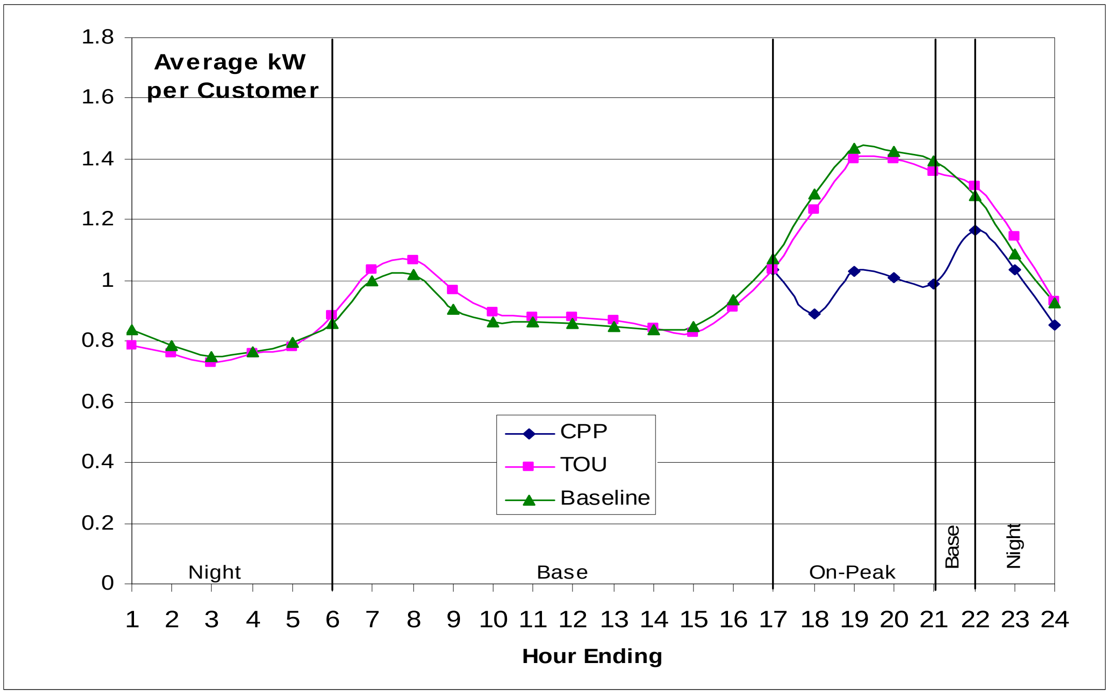
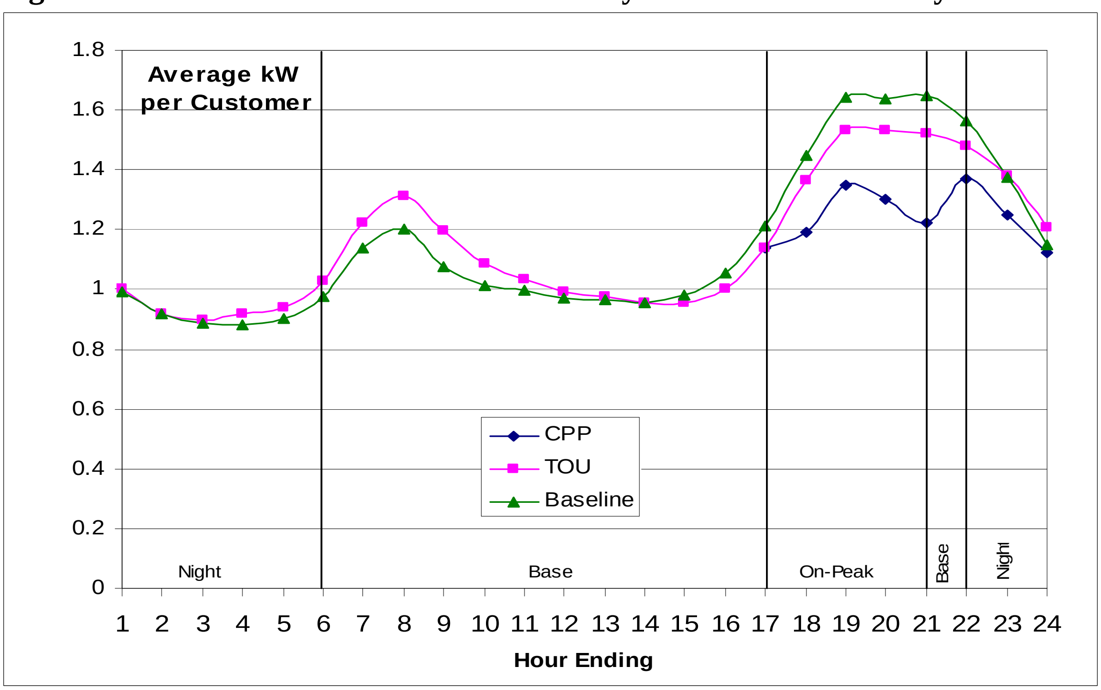
[3] The CPP impact estimates are statistically significant at the 99% confidence level. The reported 7% TOU impact is statistically significant at the 88% confidence level. The 3% TOU savings estimate is not statistically significant at that confidence level and may actually be zero. All testing was done using the standard t-test.

Figure 3. Load Curves on Coldest Winter Days for Technology Enhanced Customers



Source: Summit Blue analysis of PSEG myPower data

Figure 4. Load Curves on Coldest Winter Days for Information Only Customers



Source: Summit Blue analysis of PSEG myPower data

Energy Savings

The main emphasis of TOU and CPP rates is to reduce energy use during particular time periods, and it has been demonstrated that programmable thermostats were very effective at helping customers reduce their air-conditioning use for short periods of time on hot days. Were they also effective at helping customers reduce total energy use over the whole summer?

Customers in all three groups – Technology Enabled, Information Only, and the Control Group – actually increased their summer consumption during the program years compared to the preceding year, even after weather-normalization. However, the increase was noticeably smaller for the participant groups. Table 5 shows that comparing the differences between the participant groups and the matching Control Group, the best estimates of summer energy savings from the myPower Pricing program are 3.3% for Technology Enhanced customers and 3.7% for Information Only customers with central air- conditioning.[4]

Table 5. TOU Summer Energy Savings Estimates for 2006 and 2007

	Control Group Change in Use [beyond baseline]		Participant Group Change in Use		Summer Energy Savings from TOU (Percent) [over controls]		Total Summer Energy Savings from TOU (kWh per Cust)
Technology Enhanced	5.2%	-	1.9%	=	3.3%		139
Information Only with Central AC	5.2%	-	1.5%	=	3.7%		144

Source: Summit Blue analysis of PSEG myPower data

These results show that the enabling technology did not have a large effect on the overall energy savings for the summer. How can a large effect during on-peak periods on the hottest days be reconciled with little effect over the entire summer? Figure 1 and Figure 2 show that the decreased use during the on-peak periods was offset by increased use during the base and night periods for all customers, but particularly those with programmable thermostats. These shifts in usage created bill savings, but small overall changes in the total level of energy use.

There is another possible explanation for why enabling technology did not help create greater overall energy savings. Customers with the enabling technology did not have to think about their energy use on a day-to-day basis to benefit from their rates. Once the thermostat was programmed at the beginning of the summer and the CPP response levels were chosen, the customers with enabling technology could be assured of savings without having to take any additional actions. On the other hand, Information Only customers had to take regular behavioral actions to benefit from the TOU and CPP rates. This constant attention to their energy consumption may have encouraged them to reduce their overall energy use in end-uses beyond air-conditioning.

A similar energy savings analysis was conducted for the winter months. Neither the Control Group nor the Technology Enabled group showed any change in their winter energy

[4] All summer energy savings were estimated using a time-series cross-sectional regression model. The standard errors of the coefficients were used to construct probability ranges for the estimates at the 90% confidence level using a standard t-test. There was no overlap in the ranges for the 1.9% estimate and the 1.5% estimate, so they can be considered to be statistically different at the 90% confidence level.

usage compared to the year before participation in the program. However, the Information Only group showed a 1.7% decrease in their energy use.[5] It appears that their conscious attention to energy demand and load shifting during the summer may have become habit and carried over into the winter months.

Is Energy Consciousness Habit-Forming?

While the major finding of this study is that Technology Enabled customers are able to create substantially greater load reductions during peak hours for both TOU on-peak periods and CPP events, a look across all of the impact estimates brings a secondary finding to light. Information Only customers create greater year-round energy savings on a percentage basis.

Table 6 compares the demand and energy reductions that have been presented previously in this report. The customer group that achieved the greatest percentage reduction during each study period is highlighted. Though the total level of energy savings is modest, it still becomes clear that the Information Only customers save energy consistently during times that the programmable thermostat is not able to provide automatic savings.

Customers in the Information Only group have to develop an energy consciousness in their everyday actions in order to benefit from the TOU and CPP rates during the summer. It appears that they carry those habits into the winter months. On the other hand, Technology Enabled customers do not have to take regular behavioral actions to benefit from TOU and CPP rates during the summer because their technology will take care of it for them. Their habit is to not think about energy use, and they continue that habit throughout the winter months.

Table 6. Comparison of Electric Demand and Energy Reductions Across Seasons

	Summer Peak Day			Winter Peak Day			Summer Energy	Winter Energy
	TOU OnPk Hrs	CPP Hrs	TOU Plus CPP (kW)	TOU OnPk Hrs	CPP Hrs	TOU Plus CPP (kW)		
Technology Enhanced	21%	26%	1.33	3%	27%	0.41	3.3%	0.0%
Information Only	3%	14%	0.43	7%	14%	0.33	3.7%	1.7%

Shaded cells indicate the customer group with greater savings during the time period.

Other research (Nevius and Pigg, 2000) has shown that the regular behavioral actions of customers without programmable thermostats can create savings equal to what is seen with the use of programmable thermostats. While that study was focused on winter heating savings, it still reinforces the hypothesis that customers who are energy-conscious can develop habits that create energy savings without the help of automated technology.

[5] All winter energy savings were estimated using a time-series cross-sectional regression model. The coefficient estimate of a 1.7% reduction in energy use was statistically significant at the 90% confidence level using a standard t-test.

Customer Satisfaction

Overall satisfaction with the myPower program varied somewhat between the two segments, but remained relatively consistent throughout the pilot whenever measured. Satisfaction with the Technology Enhanced program overall at the end of the program (7.4 on a 10-point scale where 10 was "extremely satisfied") was essentially the same as the level achieved in 2006 (7.5), rebounding after a slight decline following both CPP events (7.1 in the January 2007 CPP Survey and 7.0 in the August 2007 CPP Survey).

Information Only participants' satisfaction improved at the end of the program (7.7) compared to 2006 (7.4) and the January CPP Event (7.3), and was similar to the August CPP Event (7.8).

The most frequently mentioned reasons why both Technology Enhanced and Information Only participants were satisfied with the program (customers providing an answer of 8 through 10 on a scale of 1 to 10, 10 being extremely satisfied) were the bill savings, the ease of participation, and the education they received about the best time to use appliances.

While bill savings was the most frequently cited reason for program satisfaction, it was also the main reason cited for dissatisfaction (a rating of 1 through 6 on a 10 point scale). On average all participants reported that they had saved money with myPower, although a number of participants did not achieve the electricity bill savings they expected. Technology Enhanced participants reported saving an average of $188 on the program vs. an expected average savings of $222; Information Only participants reported saving an average of $105 on the program vs. an expected average savings of $132.[6]

About 15% of Technology Enhanced participants reported that they had difficulty programming the thermostat and about 15% were uncomfortable during the high price and CPP events. Fewer Technology Enhanced participants said that their home was comfortable during high price hours outside of critical events (71% vs. 78% in 2006). Aligning with these reasons, 'simplifying the thermostat' (24%) and 'improve customer training' (13%) were cited as the main suggestions for program improvement.

The enabling technology created a slightly higher enthusiasm for the program, although the overwhelming majority of both Technology Enhanced and Information Only customers supported it. There were 91% of Technology Enhanced participants and 85% of Information Only participants who agreed that PSE&G should offer more programs similar to myPower to customers. Roughly eight out of ten Technology Enhanced (77%) and Information Only (81%) participants would recommend myPower to a friend or relative. The majority of Technology Enhanced (84%) and Information Only (83%) participants believe that programs such as myPower benefit the environment. And, 71% of both Technology Enhanced and Information Only participants believe they saved money.

Bill Savings

An analysis was also performed to understand the bill impacts experienced by customers participating in the Pricing Segments of the pilot. On each monthly bill, customers were shown a

[6] These savings occurred over the pilot period which lasted for 15 months from June 2006 through September 2007. It covered two summer seasons and one winter season.

comparison of their actual bill under the myPower program and what their bill would have been had they used the same amount of electricity under the otherwise applicable Residential Service (RS) rate schedule. The bill also provided a similar comparison of program-to-date impacts.

The CPP rate was designed to be revenue neutral for the average residential customer. First, PSE&G constructed an average hourly load shape for the RS rate class. Then, the CPPs were established such that over each summer and non-summer period, a customer using electricity according to this average load shape would experience no gain or loss if billed on the CPP rate without taking any action to modify his energy use pattern.

Needless to say, it is highly likely that no customer, including the customers participating in the pilot, used electricity exactly according to the average load shape. If all of the participating customers had done nothing to change their energy use, one would expect about half of the participants to experience a bill increase and about half to experience a bill decrease. Even this conclusion assumes that the electricity usage of participating customers was reflective of the average RS customer, a conclusion that is likely not true. Participating customers in general used more electricity than average use customers, especially the Technology Enhanced customers, who all had central air-conditioners

Table 7 presents the summary of bill savings. It shows that participants with enabling technology were more likely to achieve bill savings, and that their bill savings were larger than customers without the technology.

Table 7. myPower Pilot Bill Impacts for June 2006 – Sept 2007

Participant Group	Higher Bills				Lower Bills			
	%	Average	Greatest Increase	Smallest Increase	%	Average	Greatest Reduction	Smallest Reduction
Technology Enhanced	14%	$44.41	$201.82	$0.67	86%	($156.91)	($639.20)	($2.17)
myPower Sense	29%	$44.36	$238.25	$0.53	71%	($95.88)	($601.82)	($0.62)

Source: PSEG analysis of myPower billing data

Conclusion

Residential central air-conditioning customers with communicating thermostats were able to contribute greater summer load reductions in response to both Time of Use (TOU) and Critical Peak Pricing (CPP) rates than customers without the enabling technology. On hot summer days they were able to reduce their load during the TOU on-peak period by over 21%, or 0.59 kW per customer, while customers on the same rates but without the enabling technology reduced their load by 3%, or 0.07 kW per customer. During CPP events, they were able to create additional load reductions which were twice as great as customers without the enabling technology. Customers with enabling technology contributed a total of 1.33 kW of load reduction during CPP events compared to 0.43 kW for central air-conditioning customers on the same rate but without the communicating thermostats.

This greater electric load reduction from customers with communicating thermostats was tied to central air-conditioning load and, as expected, it did not hold during the winter season. During winter CPP and TOU on-peak events, customers with enabling technology contributed load reductions similar to those demonstrated by customers without the enabling technology.

While the major finding of this study is that Technology Enabled customers are able to create substantially greater load reductions during peak hours for both TOU on-peak periods and

CPP events, there is a secondary finding that Information Only customers create greater year-round energy savings on a percentage basis.

Customers with the enabling technology did not have to think about their energy use on a day-to-day basis to benefit from their rates. Once the thermostat was programmed at the beginning of the summer and the CPP response levels were chosen, the customers with enabling technology could be assured of savings without having to take any additional actions. On the other hand, Information Only customers had to take regular behavioral actions to benefit from the TOU and CPP rates. This constant attention to their energy consumption may have encouraged them to reduce their overall energy use in end-uses beyond air-conditioning. This energy-consciousness appears to have become a habit creating winter savings as well as summer savings.

Customers with enabling technology had a slightly higher enthusiasm for the program, although it was also well received by customers who didn't receive thermostats. Comfort levels were slightly less for customers with the thermostats. This was probably a reflection of their regular increases in indoor temperature settings in response to on-peak TOU rates every weekday throughout the summer.

Customers with enabling technology were more likely to achieve bill savings, and higher levels of bill savings, than those without.

The results of this study provide the impact data that a utility would need to determine the load-shifting benefits of technology enabled demand response rates. It raises further questions, though, about how year-round energy consciousness can be integrated with a technology enabled demand response solution.

References

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