POWERCENTSDC™ PROGRAM: A CASE STUDY IN CUSTOMER-DRIVEN DEMAND RESPONSE

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Abstract

In the past several years, utilities have conducted numerous dynamic pricing pilot programs to assess consumer demand response to such prices. With few exceptions, such pilots have focused on a single type of pricing or technology treatment. Pepco and the District of Columbia, United States, collaborated on a residential pilot that combined pricing, control technology, and information feedback. It is called PowerCentsDC. The program went live in July 2008 and ran through October 2009. It included three pricing options: critical peak pricing, peak time rebate (critical peak rebate), and day-ahead hourly pricing. It included three feedback options: smart thermostats, monthly detailed energy usage reports, and online access to data via consumer engagement software. The thermostats provided prices currently in effect, month-to-date bill and usage, and notification of critical peak or high price events. The energy reports showed daily energy use by price period. Results for the period from July 2008 through February 2009 showed the greatest peak demand reductions in response to critical peak prices in combination with smart thermostats, with the lowest reductions coming from customers on day-ahead hourly prices. However, in all price groups, customers reduced peak demand on critical peak days. Summer 2009 results are currently under analysis.

Introduction

This report summarizes the design, operation and outcomes of the PowerCentsDC pilot program undertaken by the Smart Meter Pilot Program, Inc. (SMPPI) for the period from July 22, 2008 to February 28, 2009. PowerCentsDC tested the reactions and impacts on consumer behavior of three different smart prices:

- Critical Peak Prices (CPP)
- Critical Peak Rebates (CPR, sometimes called Peak-Time Rebate)
- Hourly Prices (HP)

The pilot was initiated in mid-2007 with customer recruitment of approximately 900 residential single and multi-family housing customers, plus selection of approximately 300 control customers. The treatment customers were placed on the smart prices starting on July 22, 2008. Nine critical peak events were called – six in summer and three in winter – between then and the end of the 2008-2009 winter on February 28, 2009.

Background

In the PJM Region, wholesale electricity prices vary each hour as electricity supply and demand conditions change. When temperatures are very high or very low, power use significantly increases as electricity consumption for cooling or electric heating increases. During these times,

power supplies may be limited, thereby increasing wholesale market electric prices. In addition, unexpected generation, transmission, and distribution equipment failure may constrain energy supply, thereby driving prices up during other periods.

PowerCentsDC provided consumers with electricity pricing options based on changing wholesale costs that enabled consumers to save money by altering their consumption of electricity. Conventional electric meters do not provide customers with all the information needed to effectively manage their consumption as they record only total consumption, much like a car's odometer records total miles and does not record the time at which electricity is used. Thus, the price of electricity to consumers does not reflect the variations in wholesale prices. If the electric rates paid by consumers tracked wholesale electricity market prices, then consumers could choose to reduce consumption during the highest cost hours and potentially lessen their electricity bills accordingly.

PowerCentsDC was an advanced or "smart" meter project through which selected District of Columbia residential customers in all eight wards had the opportunity to control their electric bills and potentially save money. It was sponsored by the Smart Meter Pilot Program, Inc. (SMPPI), a non-profit corporation created through a Pepco Merger Settlement Agreement and approved by the District of Columbia Public Service Commission (PSC) on May 1, 2002. The SMPPI Board is comprised of the Consumer Utility Board, IBEW, Office of People's Counsel, Pepco, and the PSC.

Project Summary

The PowerCentsDC project was the first program in the electric utility industry to test the response of residential customers to three different innovative pricing options under one program: Critical Peak Pricing, Critical Peak Rebate (Peak-Time Rebate) and Hourly Pricing. Through these pricing options, customers may save on their bills by reducing electricity use when their prices are high. These times are known as "critical peak hours" (under the project, 60 hours each year) and "critical peak days" (15 per year). Customer changes in electricity demand during these times are known as "demand response."

While customer participation was voluntary, the project design was carefully developed to ensure that the evaluated results are statistically representative. To facilitate a statistically valid analysis and for rate design purposes, participation was limited to customers receiving Standard Offer Service (SOS) from Pepco.

Participating customers received a free special "smart meter" installation for their home, which measured the customer's electricity use at hourly intervals and sent the data wirelessly to a third party billing vendor daily. The vendor used these data to calculate customers' bills based on the PowerCentsDC tariff and to provide participants with a report, mailed with their bill each month, depicting their electricity consumption during the month.

About a third of the project participants – those with central air conditioning that wanted one – received a free "smart thermostat" that reduced central air conditioner compressor use in response to receipt of a utility radio-controlled signal during high priced periods; provided

customer messages; and when programmed, automatically reduced electricity use of air conditioners or central heating systems during selected hours.

Relationship to Other Pilots

PowerCentsDC was one of several smart meter pilots conducted by utilities across the United States and worldwide. In November 2008, a research article summarized some of the more recent pilots as follows:

> …this article summarizes the results of several second-wave dynamic pricing experiments that have been carried out in the U.S., Canada, France, and Australia. Our review of these pilots reveals that dynamic electricity pricing programs are effective in reducing electricity usage for residential customers. In general, CPP programs supported with enabling technologies result in the largest reductions in load. However, CPP programs alone (without an enabling technology) also achieve significant reductions in load. TOU programs without enabling technologies reduce load somewhat; however, when TOU programs are supported with enabling technologies, the average load reduction is larger. Based on the pilot results, the combination of dynamic prices with enabling technologies appears to be the most effective program design for reducing electricity usage during high-priced periods.[1]

Importantly, however, none of the pilots conducted previously included the comparison of CPP, CPR, and HP in a single residential population; the effect of smart thermostats on these three rates; nor the reaction of low-income customers to these specific options.

The program's ambitious goals included assessing the response of different subgroups to three different types of dynamic prices (see Table 1), for both regular and all-electric customers, and analyzing the differential results for customers with smart thermostats.

Table 1: PowerCentsDC Prices Included Both Discounts and Premium Prices

Price Plan	Description	Example Prices per kWh	High Price/Rebate Event Hours
CPP	Slight discount during 8700 hours per year; much higher price during critical peaks (60 hours per year)	Critical peak: about 75¢; most times: 10.9¢	2 pm-6 pm summer weekdays (12 events per summer); 6 am-8 am and 6 pm-8 pm winter weekdays (3 events per winter)
CPR	Rebates earned for reduction below baseline during critical peaks	Rebate: about -75¢; most times: 11¢	Same as for CPP
HP	Prices change hourly following wholesale prices	Range from 1¢ to 37¢	High prices typically summer weekday afternoons and winter mornings/evenings

[1] - A. Faruqui and S. Sergici, "Household Response to Dynamic Pricing of Electricity. A Survey of Seventeen Pricing Experiments." November 2008.

Pilot Program Prices

The pilot included both control customers on standard prices and the treatment customers on dynamic prices.

Control customers received the Pepco Standard Offer Service prices. In the District of Columbia such prices have two or three tiers, depending on the individual customer. The lowest price is for monthly consumption under a tier threshold and a higher price for consumption over that threshold. The thresholds for residential consumers vary by season and customer rate schedule (e.g. R, AE, RAD, and RAD-AE). The rationale for tiered pricing is to provide a price signal to consumers to conserve until such time as smart meters are installed and smart pricing can be offered in the District. The table below summarizes the tiered prices. These prices include generation, transmission, and distribution charges.

Table 2: Standard Offer Service Prices Rounded to Nearest Tenth of a Cent, Summer 2008

Price Plan	Summary	Tier 1 Size (kWh)	Tier 1 Price per kWh	Tier 2 kWh	Tier 2 Price	Tier 3 kWh	Tier 3 Price
R	Applies to most residential customers	0-400	12.9¢	401+	14.7¢	–	–
AE	Residential customers with electric heating	0-400	12.8¢	401+	14.7¢	–	–
RAD	Limited income customers	0-400	5.4¢	401+	14.8¢	–	–
RAD-AE	Limited income with electric heating	0-400	5.4¢	401-700	12.3¢	701+	14.6¢

Critical Peak Prices

Under CPP, customers faced two prices: 1) critical peak prices, and 2) prices for all other hours. Critical peak prices were in effect for four hours on critical peak days, of which there were 15 each year. During the summer (June 1 to September 30), there were normally 12 critical peak days, and during the winter (November 1 to February 28) there were normally 3 critical peak days.

The critical peak hours occurred between 2 p.m. to 6 p.m. in the summer and between 6 a.m. to 8 a.m. and between 6 p.m. to 8 p.m. during the winter. Critical peak "events" were called by the project implementation contractor when forecast next day high temperatures are at or above (or below, in winter) a threshold level approved by the SMPPI Board of Directors. For summer 2008, the threshold was 90 degrees and for winter 2008-2009, the threshold was 18 degrees.

Customers were notified of these events the day before, by 5 p.m., via their choice(s) of an automated phone call, email, text page, or smart thermostat notification. Prices during the 60 critical peak hours each year were substantially higher than conventional SOS rates but were offset by lower prices during the remaining 8,700 hours of the year. The resulting prices are shown below.

Table 3: Critical Peak Prices Rounded to Nearest Tenth of a Cent, Summer 2008 and Winter 2008-9

Price Plan	Summer Tier 1	Summer Tier 2	Summer Tier 1 Critical Peak	Summer Tier 2 Critical Peak	Winter Tier 1	Winter Tier 2	Winter Tier 1 Critical Peak	Winter Tier 2 Critical Peak
R	12.3¢	14.1¢	77.1¢	78.9¢	11.7¢	12.6¢	72.2¢	73.1¢
AE	12.3¢	14.2¢	75.1¢	76.9¢	11.6¢	12.1¢	70.2¢	70.7¢

The CPP represents about a five-fold increase over the SOS price. Critical peak prices occur for four hours on critical peak days only.

Critical Peak Rebate

PowerCentsDC also tested the impacts of a Critical Peak Rebate (CPR) pricing structure (sometimes called Peak Time Rebate). In contrast to the CPP, the CPR provided a refund to participants for reductions below their "baseline" usage during the critical peak hours. The CPR electricity prices were the same as Standard Offer Service prices, so the initial bill amount was exactly the same as an SOS bill. Then, if the customer earned a rebate, that amount was subtracted. The concept is similar to programs that have been offered to large commercial and industrial customers for many years, known as "curtailable" rate programs.

The rebate was calculated by multiplying the reduced consumption, measured in kilowatt-hours, by the rebate amount per kilowatt-hour. Customer consumption reduction was calculated using the following method: consumption during the critical peak event was subtracted from the customer's baseline consumption; the difference was the consumption reduction.

Also, because the incentive during the critical peak hours was a rebate, there was no adjustment to the SOS price in effect throughout the year. On average, a participant making no change in response to the critical peak events would pay the same bill on SOS plus CPR as they would if they had paid only SOS prices. As for CPP above, Critical Peak rebates were in effect only when critical events were declared (15 per year, comprising 12 summer and 3 winter events).

The CPR rebate amounts are shown below, with minus signs reflecting that the amounts are rebates. Note that the winter rebate amounts were significantly lower than the summer amounts.

Table 4: Critical Peak Rebates Rounded to Nearest Tenth of a Cent, Summer 2008 and Winter 2008-9

Price Plan	Summer Critical Peak Rebate per kWh	Winter Critical Peak Rebate per kWh
R	-66¢	-36¢
AE	-67¢	-38¢
RAD	-83¢	-53¢
RAD-AE	-89¢	-63¢

Hourly Pricing

Under HP, electricity prices varied hourly. The prices were set the day ahead, based on the prices in the "day-ahead" wholesale market, which is the regional power market operated by the PJM Interconnection. Prices were posted on the project website, www.PowerCentsDC.org, for access by HP participants and were also available by calling a toll-free number. Prices were displayed in real-time on smart thermostats for those customers who elected to use them. Based on wholesale market trends at the beginning of the program, HP prices were expected to exceed Standard Offer Service prices only about one-third of the time within a year, with lower prices the remainder of the time.

During the actual program, however, rapidly falling wholesale prices caused average prices to fall for PowerCentsDC HP participants and increased their savings significantly. SMPPI adjusted the prices quarterly, so the falling prices were accounted for, but they continued to fall. From an economic perspective, by taking the risk of paying hourly pricing set in the wholesale markets, the HP participants enjoyed significant savings as wholesale prices dropped in response to falling oil prices and reduced overall demand for electricity caused by the recession that began in September 2008. Notably, for hourly priced customers, this meant that without changing consumption patterns, customers experienced bill savings.

HP participants were notified when prices were "high," as determined by a threshold approved by the SMPPI Board. The purpose was to enable participants to focus on those few hours when prices are significantly above average. The target was to have notifications for about 60 hours a year, to keep the notifications parallel to the critical peak events. The notifications were by voicemail, email, or text message, at the customer's option, and smart thermostats automatically reduced air conditioning load during high price events.

Participant Selection

The basic concept of the PowerCentsDC program was to have two groups of customers: participants and control customers. Invited voluntary participants were placed on a pre-assigned smart price, received a smart meter, and were offered a smart thermostat if they had central air conditioning. Control customers received a smart meter and are treated in the same way that Pepco customers generally are treated; these customers remain on their current SOS price and continue using electricity as they would normally. Candidate participants were randomly selected across the District of Columbia to allow participation by all demographic and income groups.

Each randomly selected customer received a single offer to one of the three price options: CPP, CPR, or HP. As in other pilot programs, CPP and HP participants were offered a "thank you" payment (in this case, $100) for participation. These participants received a $50 "up front" incentive and will receive a $50 "thank you" incentive at the conclusion of the pilot. Because a customer's bill could only remain the same or go down on CPR, no thank you payment was provided to CPR customers.

The recruitment results are shown below (RAD signifies limited income). The 95% confidence interval allows comparison of two different groups, for example R and RAD. To do so, we take the lower limit of the RAD interval (6.82%) and compare it to the upper limit of the R interval (6.55%). Because 6.82% is higher than 6.55%, we have 95% statistical confidence that in a large-scale recruitment, the RAD response will be higher than R, just as it was in this recruitment of only a small proportion of the total customers in the District. As seen in Table 5 limited income (RAD) customers volunteered at a rate higher than regular customers, and the difference is statistically valid.

Table 5: Recruitment Results by Customer Type

Customer Type	Recruitment Response	95% Confidence Interval	Population Weight	Regular (top) vs. Limited Income (bottom)
R	6.2%	+/- 0.35%	73.2%	6.4%
AE	7.2%	+/-0.64%	19.1%	
RAD	8.0%	+/-1.18%	5.7%	7.6%
RAD-AE	6.4%	+/-1.46%	1.9%	
Weighted Average	**6.6%**			

Table 6: Recruitment Results by Price Plan Offered

Customer Type	Recruitment Response	95% Confidence Interval
CPP	6.5%	+/- 0.52%
CPR	7.4%	+/-0.49%
HP	5.5%	+/-0.49%
Weighted Average	**6.6%**	

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Customer Education

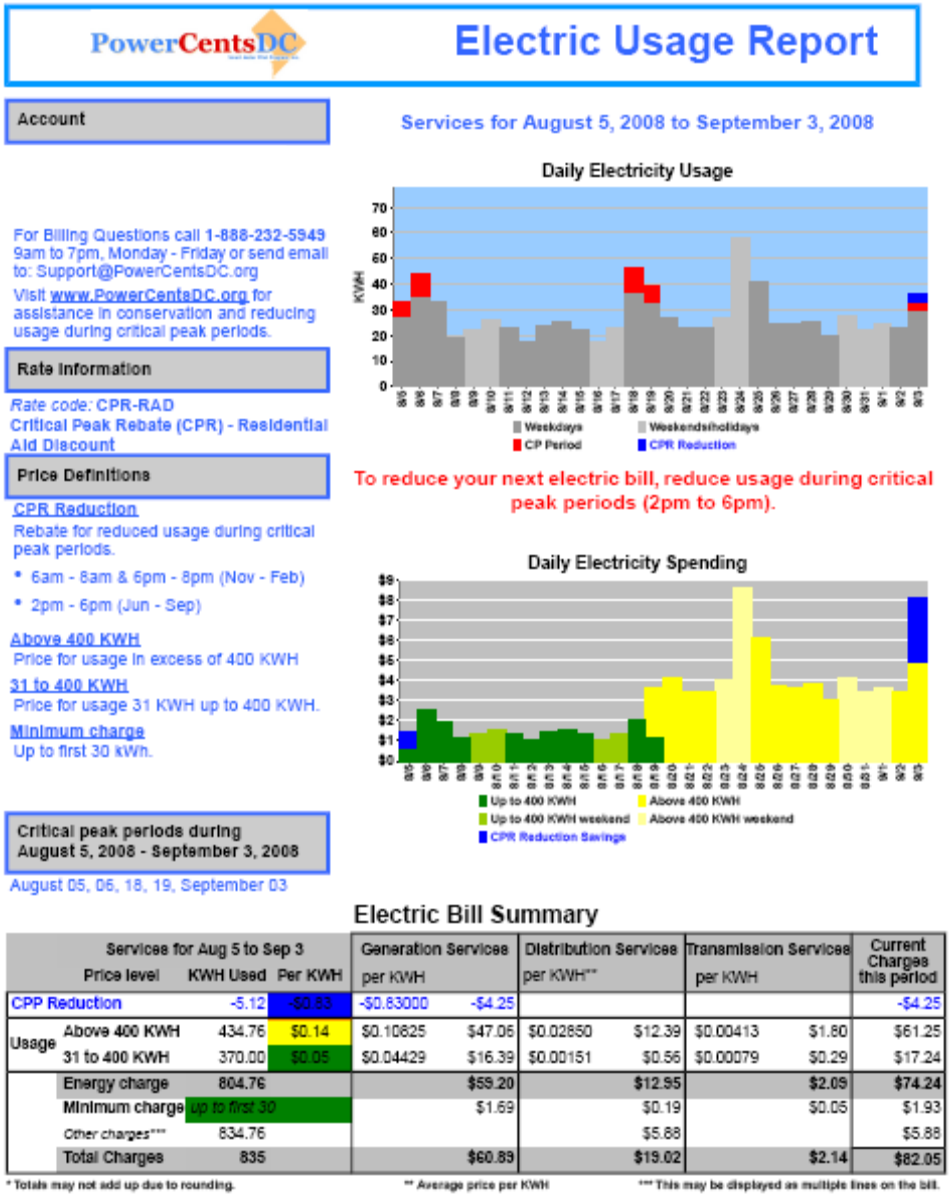
Initial participant education, beyond the material in the recruitment package, focused on a package mailed to each eligible participant approximately two weeks prior to "going live" on the PowerCentsDC smart prices. This confirmation mailing included the following:

- *Cover Letter*: Confirmed that the participant was enrolled under the assigned rate plan.
- *Refrigerator magnet:* Provided a reminder of the key program features, such as critical peak hours and how to get customer service.
- *Electricity conservation brochure*: This brochure provided a variety of conservation tips for electricity consumers that may be used during peak times or anytime.

Most importantly, each customer received a detailed customized energy usage report in his or her monthly bills called the "Electric Usage Report." The detailed report showed, day by day, how much electricity the customer used and how much the usage cost each day. The exhibit below shows a sample report for

an actual participant. This usage report was provided along with customers' bills beginning when billing under the new rates began.

Figure 1: Sample Electric Usage Report Provided with Monthly Bill



PowerCentsDC

Electric Usage Report

Account

Services for August 5, 2008 to September 3, 2008

Daily Electricity Usage

For Billing Questions call 1-888-232-5949 9am to 7pm, Monday - Friday or send email to: Support@PowerCentsDC.org

Visit www.PowerCentsDC.org for assistance in conservation and reducing usage during critical peak periods.

To reduce your next electric bill, reduce usage during critical peak periods (2pm to 6pm).

Rate Information

Rate code: CPR-RAD

Critical Peak Rebate (CPR) - Residential Aid Discount

Daily Electricity Spending

Price Definitions

CPR Reduction

Rebate for reduced usage during critical peak periods.

- 6am - 8am & 6pm - 8pm (Nov - Feb)
- 2pm - 6pm (Jun - Sep)

Above 400 KWH

Price for usage in excess of 400 KWH

31 to 400 KWH

Price for usage 31 KWH up to 400 KWH.

Minimum charge

Up to first 30 kWh.

Critical peak periods during August 5, 2008 - September 3, 2008

August 05, 06, 18, 19, September 03

Electric Bill Summary

Services for Aug 5 to Sep 3	Price level	KWH Used	Per KWH	Generation Services per KWH		Distribution Services per KWH**		Transmission Services per KWH		Current Charges this period
CPP Reduction		-5.12	-$0.83	-$0.83000	-$4.25					-$4.25
Usage	Above 400 KWH	434.76	$0.14	$0.10825	$47.06	$0.02850	$12.39	$0.00413	$1.80	$61.25
	31 to 400 KWH	370.00	$0.05	$0.04429	$16.39	$0.00151	$0.56	$0.00079	$0.29	$17.24
	Energy charge	804.76			$59.20		$12.95		$2.09	$74.24
	Minimum charge	up to first 30			$1.69		$0.19		$0.05	$1.93
	Other charges***	834.76					$5.88			$5.88
	Total Charges	835			$60.89		$19.02		$2.14	$82.05

* Totals may not add up due to rounding. ** Average price per KWH *** This may be displayed as multiple lines on the bill.

Critical Peak Events

During the 2008 summer period of the pilot, six critical peak events were called based on day-ahead forecasts that exceeded the thresholds. The first event was not called until August 5, 2008, because customers did not go onto the PowerCentsDC prices until July 22, 2008. Actual temperatures on the event days are provided below. Recall that the summer critical peak hours were 2 p.m. to 6 p.m.

Table 7: Dates and Maximum Temperatures of Summer 2008 Critical Peak Events

Critical Peak Day	Actual Max Temp (°F)	Time of High Temp
Tuesday, August 5	86	1:00 pm
Wednesday, August 6	94	4:00 pm
Monday, August 18	93	4:00 pm
Tuesday, August 19	94	4:00 pm
Wednesday, September 3	95	3:00 pm
Friday, September 4	95	4:00 pm

Since the summer temperatures were relatively moderate compared to previous summers (the previous five years were analyzed to establish the critical peak dispatch threshold), the events represented situations just slightly over the threshold values; in one case, the actual temperature was below the day-ahead forecast and the threshold. This is significant because other pilots have found that less load shifting occurs on moderate days in comparison to extreme temperature days.

Three critical peak events were called in winter based on a day-ahead forecast of below 18°F.

Table 8: Dates and Maximum Temperatures of Winter 2008-9 Critical Peak Events

Critical Peak Day	Actual Min Temp (°F)	Time of Low Temp	Mean Temp during Critical Peak (°F)
Thursday, January 15	17.1	12:00 am	22.9
Friday, January 16	10.9	12:00 am	12.5
Wednesday, February 4	23.0	12:00 am	28.0

Only January 16 was extremely cold during the critical peak hours.

Demand Response Results

The analysis of demand response was performed by Professor Frank Wolak of Stanford University. Peak demand reductions were determined by comparing the treatment group of participants with the control group of customers remaining on existing Standard Offer Service (SOS) prices. Dr. Wolak analyzed consumer response to the dynamic prices for each event day. Most, but not all, days had statistically valid results, defined as confidence levels of 90% or more. All days with confidence levels above 90% are included in the summary tables below.

While limited income customers were specifically recruited, their dynamic nature ultimately resulted in sample sizes too small to be statistically valid (less than 30 customers). The program oversampled these customers, because they are a small proportion of the population. During the program, however, numerous customers changed premises, and others lost or gained RAD

qualification in the annual requalification process. The economic downturn exacerbated this effect. In the end, due to these physical and economic changes, only 55 percent of the original CPR-RAD treatment group and 61 percent of the CPR-RAD-AE treatment group remained. Due to high interest, Dr. Wolak continues to analyze the data, and any statistically valid results for limited income customers will be published when available.

Finally, the winter data for customers with smart thermostats was excluded. This is because the thermostats "cycled" heat pumps, with the unexpected result that back-up resistance heaters turned on – which, in turn, increased consumption. In future programs, smart thermostats should not be cycled in winter but should use a temperature adjustment instead.

The results show that consumers reduce peak summer electricity demand consistently when given a price signal. The statistically valid peak reductions by price plan and customer type are shown below. One reason the CPR peak reduction in winter is not statistically valid may be that the rebate amounts in winter were much lower than in summer (about half). The lower reductions for HP may be explained by two factors: the high prices were not as high as for CPP or as the rebate for CPR, and the HP customers saw declining average prices (see below).

Table 9: Average Peak Reductions During Critical Peak Events, Population Weighted Average

Price Plan	Peak Reduction – Summer	Peak Reduction – Winter
CPP	25%	10%
CPR	11%	(n/s)
HP	4%	4%

Results not statistically valid at the 90% level are denoted by "n/s"; most results are valid at the 99% level.

PowerCentsDC participants with smart thermostats had the benefit of automatic responses to summer critical peak events, provided their air conditioner was operating at the time of the critical peak event. This automated response significantly increased summer demand reductions. The peak demand reductions varied by price plan and customer type.

Table 10: Average Peak Reductions During Critical Peak Events, Without and With Smart Thermostats

	No Smart Thermostat			With Smart Thermostat		
Customer Type	CPP	CPR	HP	CPP	CPR	HP
Regular (R)	22%	9%	3%	34%	(n/s)	-8%
All Electric (AE)	29%	15%	8%	50%	26%	-7%

Customer Bill Impacts

PowerCentsDC smart prices were designed to be revenue neutral; therefore, on average, customers that did not change their behavior would pay the same amount as under SOS, and any

bill savings would be the result of load shifting. For the Hourly Price option, however, wholesale prices fell faster than quarterly adjustments for revenue neutrality, causing average prices to fall for HP participants and increasing their savings. By taking the risk of paying hourly pricing set in the wholesale markets, the HP participants enjoyed significant savings as wholesale prices dropped in response to falling oil prices and lower overall demand for electricity caused by the recession that began in September 2008.

On average, participants saved 7.8% monthly on their electric bills between July 2008 and February 2009, or $8.26 per month compared to Standard Offer Service. Savings were greater in summer. Over 92% of participants paid less on the smart prices, with 75% having bills between 10% less and 10% more on PowerCentsDC prices.

Table 11: Customer Bill Savings

Price Group	Average Bill SOS	Average Bill PowerCentsDC	Dollar Savings	Percent Savings
CPP	$106.70	$105.34	$1.36	1.3%
CPR	$101.39	$99.04	$2.35	2.3%
HP	$113.01	$87.68	$25.33	22.4%
Total/Average	**$105.99**	**$97.73**	**$8.26**	**7.8%**

Focus Group Results

Prior to recruitment of participants, focus groups were conducted to assess consumer preferences. Most focus group attendees liked the smart price concepts, strongly preferring the critical peak rebate price option for its simplicity and no-risk aspects. They liked that they could earn rebates by reducing peak demand but pay no more if they chose not to respond. They also liked having the program approved by the Public Service Commission.

Conclusions

The results of the first year of PowerCentsDC suggest the following:

- Consistent with other pilot programs, PowerCentsDC showed that consumers reduced summer peak demand in response to dynamic prices,
- The greatest peak demand reductions were under CPP prices,
- Both the R and AE customer groups reduced peak demand on hot days,
- Summer peak reductions were greater than winter, implying more discretionary load,
- Automated response via smart thermostats increased the reduction, and
- The vast majority of participants saved money, even with revenue neutral prices, including limited income customers.