HOUSEHOLD RESPONSE TO DYNAMIC PRICING OF ELECTRICITY

A SURVEY OF SEVENTEEN PRICING EXPERIMENTS

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Since the energy crisis disrupted markets in California and several other western states in 2000-2001, much attention has been given to boosting demand response in electricity markets. One of the best ways to let that happen is to let customers see the dynamic variation in wholesale energy costs. This can be accomplished by letting retail prices vary dynamically, but that can only be done by changing the metering infrastructure, which is expensive. While a good portion of this investment can be covered by savings in power distribution costs, a significant portion still has to be covered by reductions in power costs that is brought about through demand response. Thus, many states are investigating whether customers will respond to the higher prices by lowering demand and if so, by how much.

To help them in this assessment, we survey the evidence from the 17 most recent experiments with dynamic pricing of electricity. We find that, on average, households (residential customers) respond to higher prices by lowering usage. The magnitude of price response depends on several factors, such as the magnitude of the price increase, the presence of central air conditioning and the availability of enabling technologies such as two-way programmable communicating thermostats and gateway systems that allow multiple end-uses to be controlled remotely. Across the range of experiments studied, time-of-use rates induce a drop in peak demand that ranges between three to six percent and critical-peak pricing tariffs lead to a drop in peak demand of 13 to 20 percent. When accompanied with enabling technologies, the latter set of tariffs lead to a drop in peak demand in the 27 to 44 percent range.

INTRODUCTION

There is substantial evidence on the value of demand response[2]. A recent study showed that just a five percent reduction in U.S. peak electric demand would provide a benefit of $35

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[1] The authors are economists with The Brattle Group based respectively in the firm's San Francisco, CA and Cambridge, MA offices. We have benefited enormously from comments on earlier drafts of this paper by individuals who have had primary involvement with the experiments surveyed in this paper and from others with an interest in analysis of experimental data and with dynamic pricing more broadly. Any errors that remain are our responsibility. Comments can be directed to ahmad.faruqui@brattle.com.

[2] U.S. Department of Energy (DOE) defines demand response as "changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized." (February 2006 DOE EPAct Report)

billion for the US as a whole.[3] Over the past several years, several demand response programs have been included in utility plans as alternatives for developing more generating stations and directed at large commercial and industrial customers. In most restructured states, customers who draw more than 500 kW demand from the grid are placed on a default real-time pricing rate. Others have the option of volunteering onto incentive-based demand response programs of various kinds. In certain other states, mostly located in the Southeastern U.S., large customers can volunteer onto real-time pricing rates on a day-ahead or hour-ahead basis. However, for residential customers, the only demand response program that has been widely deployed in recent years is some form of direct load control of end-uses such as central air conditioning or electric water heating.

Time-based pricing programs could substantially expand the benefits of demand response to customers, utilities, and society as a whole. However, such programs are still in their infancy, largely because of concerns that customers won't effectively respond to time-varying rates. Are these concerns valid or are they misplaced? Pricing pilots and experimentation are undertaken to shed light on this question that sits at the heart of the debates over the effectiveness of full-scale pricing programs. This is a fair question since the deployment of advanced metering infrastructure (AMI) to measure demand response is costly and financing parties need to be assured that expenses will be justified by potential benefits of the demand response. The only way to assess this cost-benefit trade-off without deploying a full-scale program is to conduct an experiment or a pricing pilot. A well-designed pilot tests the parameters of a time-based pricing program and provides an estimate of how much demand response is likely to realize after controlling for all other factors that have the potential to confound estimations.

In this paper, we seek an answer to this question by drawing upon the evidence from 17 recent residential pricing experiments that examine customer response to time-varying prices. We find that the time-of-use (TOU) rates are likely to induce three to six percent drop in peak usage while critical-peak pricing (CPP) tariffs induce a drop in the range of 13 to 20 percent, for the average customer. Our review reveals that the availability of enabling technologies amplifies customer response to time-varying prices. Customers with enabling technologies are likely to reduce their peak demand in the 27 to 44 percent range.

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[3] Faruqui, A., R. Hledik, S. Newell, and J. Pfeifenberger, "The Power of Five Percent," *The Electricity Journal* Vol. 20 (2007), Issue 8:68-77.

It is important to note that the pricing pilots reviewed in this study are largely heterogeneous in terms of their study designs. Some of them are true scientific experiments with random treatment and control groups with proper accounting of before and after treatment effects. Others have random control groups but the treatment groups suffer from self-selection bias. Some experimental designs involve several rates allowing for the estimation of price elasticities while others feature only a single rate. Some experiments last for several years and some others last only for a couple of months. In this paper, we don't attempt to control for differences in the design of the experiments. However, we describe each experiment in sufficient detail so that readers can place each experiment in perspective.

OVERVIEW

In the late 1970s and early 1980s, the first wave of electricity pricing experiments was carried out under the auspices of the U.S. Department of Energy and its predecessor agency, the Federal Energy Administration. Those experiments were focused on measuring customer response to simple (static) time-of-day and seasonal rates.[4] The top five experiments were analyzed collectively in a project carried out by the Electric Power Research Institute.[5] The results were quite conclusive: customers responded to higher prices during the peak period by reducing peak period usage and/or shifting it to less expensive off-peak periods. The results were consistent around the country once weather conditions and appliance holdings were held constant. Customer response was higher in warmer climates and within a given climate; it was higher for customers with central air conditioning systems.

However, despite the conclusive findings, time-varying rates were not widely accepted across the country. In part this was due to the high cost of time-of-use metering. In part it was because the peak periods that were offered in these rate designs were much too broad for customers to cope with. This lack of acceptance was also because the cost of peaking capacity did not vary sufficiently from the cost of off-peak capacity to bother offering time-of-use rates.

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[4] Faruqui, A. and J. R. Malko. 1983. "The Residential Demand for Electricity by Time-of-Use: A Survey of Twelve Experiments with Peak Load Pricing." *Energy* Vol. 8: 781-795.

[5] Caves, D. W., L. R. Christensen, and J. A. Herriges. 1984. "Consistency of Residential Customer Response in Time-of Use Electricity Pricing Experiments." *Journal of Econometrics* 26:179-203.

The California energy crisis of 2000-2001 rekindled interest in time-varying rates. A variety of academics, researchers and consultants called for the institution of rates that would be dynamically dispatchable during critical-price periods. These occur typically during the top one percent of the hours of the year where somewhere between nine and 17 percent of the annual peak demand is concentrated. It is very expensive to serve power during these critical peak periods and even a modest reduction in demand during such periods can be very cost-effective. In addition, the introduction of digital technology in meters has brought with it the availability of advanced metering infrastructure, AMI, making dynamic pricing a cost-effective option in most situations.

As stated before, this article summarizes the results of several second-wave dynamic pricing experiments[6] 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. Summaries of the characteristics and impacts associated with the experiments reviewed in this article are shown in Table 1 and Figure 1.

Comparative results are presented for the following experiments:

- **California-** Anaheim Peak Time Rebate Pricing Experiment
- **California-** Automated Demand Response System Experiment (ADRS), which was conducted as an adjunct to the statewide pricing pilot

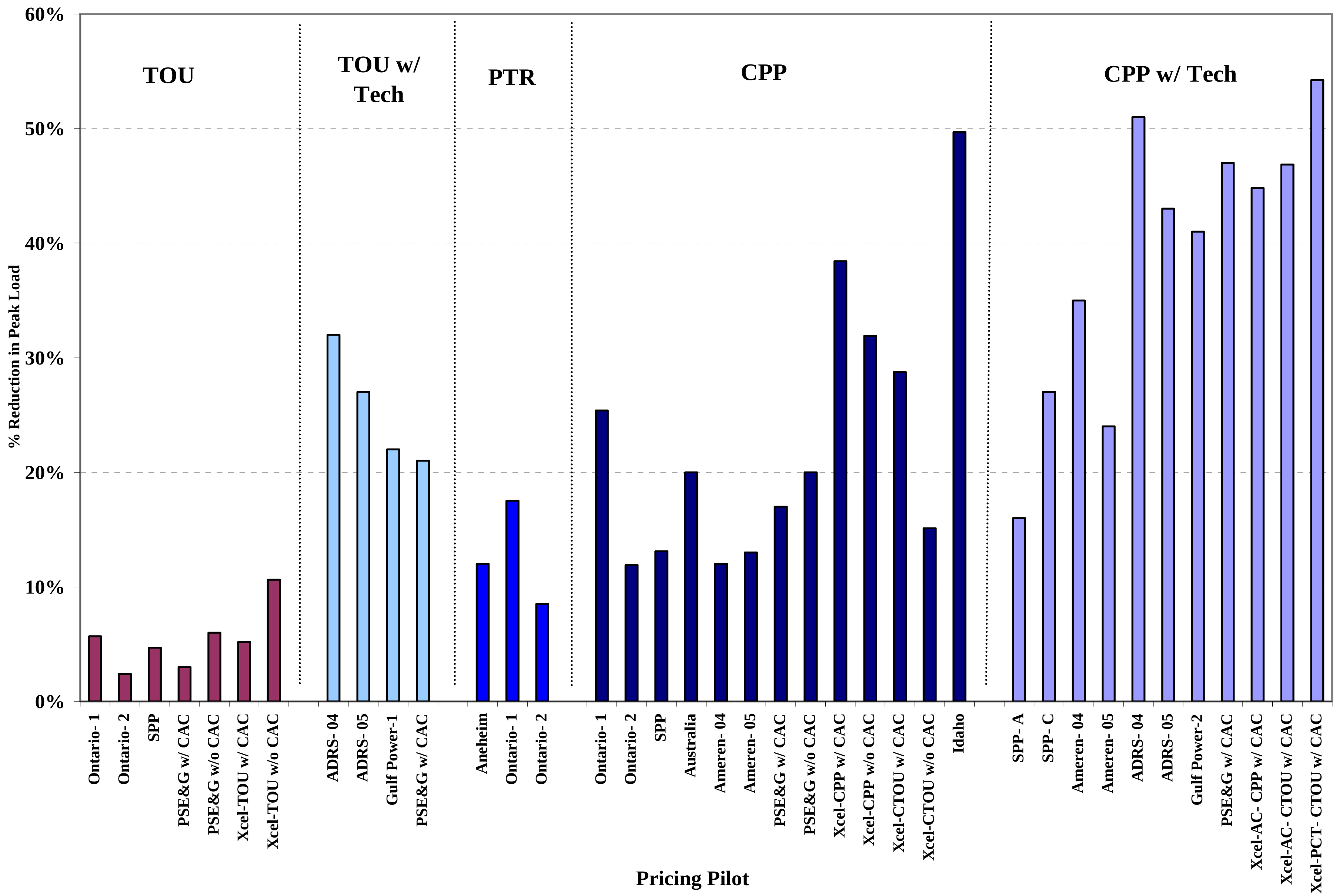
[6] We use the term "dynamic pricing" to refer to pricing signals that are triggered based on actual wholesale market prices and not set in advance. Thus, a time of use (TOU) rate is not a dynamic price, since the peak period is known in advance as its timing whereas under critical peak pricing (CPP), although the rate may be set in advance, the critical days are called based on wholesale market conditions.

- **California-** Statewide Pricing Pilot (SPP)
- **Colorado**- Xcel Experimental Residential Price Response Pilot Program
- **Florida-** The Gulf Power Select Program
- **France-** Electricite de France (EDF) Tempo Program
- **Idaho-** Idaho Residential Pilot Program
- **Illinois**- The Community Energy Cooperative's Energy-Smart Pricing Plan (ESPP)
- **Illinois**- Ameren Illinois Utilities Power Smart Pricing Program
- **Illinois-** ComEd Residential Real Time Program
- **Missouri-** AmerenUE Residential TOU Pilot Study
- **New Jersey**- GPU Pilot
- **New Jersey-** Public Service Electric and Gas (PSE&G) Residential Pilot Program
- **New South Wales/ Australia-** Energy Australia's Network Tariff Reform
- **Ontario/ Canada-** Ontario Energy Board Smart Price Pilot
- **Washington (Seattle Suburbs)-** Puget Sound Energy (PSE)'s TOU Program
- **Washington** - Olympic Peninsula Project

Table 1- Overview of the Experiments

Pilot	State	Utility	Year	Number of Customers	Number of Rates Tested in the Pilot
Anaheim Critical Peak Pricing Experiment	California	Anaheim Public Utilities (APU)	2005	52 control, 71 treatment	1
California Automated Demand Response System Pilot (ADRS)	California	Pacific Gas & Electric (PG&E), Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E)	2004-2005	In 2004: 104 control, 122 treatment In 2005: 101 control, 98 treatment	1
California Statewide Pricing Pilot (SPP)	California	Pacific Gas & Electric (PG&E), Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E)	2003-2004	2,500 customers	3
The Gulf Power Select Program	Florida	Gulf Power	2000-2001	2300 customers participating in the RSVP program	2
Electricite de France (EDF) Tempo Program	France	Electricite de France	Since 1996	400,000 customers	1
Idaho Residential Pilot Program	Idaho	Idaho Power Company	2005-2006	TOD Program- 420 control, 85 treatment EW Program- 355 control, 68 treatment	2
The Community Energy Cooperative's Energy-Smart Pricing Plan (ESPP)	Illinois	Community Energy Cooperative	2003-2005	1,500 customers	2
AmerenUE Residential TOU Pilot Study	Missouri	AmerenUE	2004-2005	TOU - 89 control, 88 treatment TOU/CPP- 89 control , 85 treatment TOU/CPP w/ Technology- 117 control, 77 treatment	2
GPU Pilot	New Jersey	GPU	1997	Not Available	2
Public Service Electric and Gas (PSE&G) Residential Pilot Program	New Jersey	Public Service Electric and Gas Company (PSE&G)	2006-2007	450 control, 836 treatment	1
Energy Australia’s Network Tariff Reform	New South Wales	Energy Australia	2005	TOU program: 50,000 customers SPS: 1300 treatment	Tested several dynamic tariffs.
Ontario Energy Board Smart Price Pilot	Ontario/Canada	Hydro Ottawa	2006-2007	125 control, 373 treatment	3
Puget Sound Energy (PSE)’s TOU Program	Washington	Puget Sound Energy	2001-2002	300,000 customers	1
Olympic Peninsula Project	Washington and Oregon	Bonneville Power Administration, Clallam County PUD, The City of Port Angeles, Portland General Electric, and PacifiCorp	2005	28 control, 84 treatment	3
Xcel Experimental Residential Price Response Pilot Program	Denver- Colorado	Xcel Energy	2006-2007	1350 control, 2349 treatment	3

Figure 1- Estimated Demand Response Impact by Experiment



Notes:

*Percentage reduction in load is defined relative to different bases in different pilots. The following notes are intended to clarify these different definitions.

1. TOU with Technology (TOU w/ Tech) and CPP with Technology (CPP w/ Tech) refer to the pricing programs that had some form of enabling technologies.
2. TOU program impacts are defined relative to the usage during peak hours unless otherwise noted.
3. CPP program impacts are defined relative to the usage during peak hours on CPP days unless otherwise noted.
4. Ontario- 1 refer to the percentage impacts during the critical hours that represent only 3-4 hours of the entire peak period on a CPP day. Ontario- 2 refer to the percentage impacts of the programs during the entire peak period on a CPP day.
5. TOU impact from the SPP is based on the CPP-F treatment effect for normal weekdays on which critical prices were not offered.
6. ADRS- 04 and ADRS- 05 refer respectively to the 2004 and 2005 impacts. ADRS impacts on non-event days are represented in the TOU with Technology section.
7. CPP impact for Idaho is derived from the information provided in the reviewed study. Average of kW consumption per hour during the CPP hours (for all 10 event days) is approximately 2.5 kW for a control group customer while this value is 1.2 kW for a treatment group customer. Percentage impact from the CPP treatment is calculated as 50%.
8. Gulf Power-1 refers to the impact during peak hours on non-CPP days and therefore shown in the TOU with Technology section while Gulf Power- 2 refers to the impact during CPP hours on CPP days.
9. Ameren- 04 and Ameren- 05 refer to the impacts respectively from the summers of 2004 and 2005.
10. SPP- A refers to the impacts from the CPP-V program on Track A customers. Two thirds of Track A customers had some form of enabling technologies.
11. SPP- C refers to the impacts from the CPP-V program on Track C customers. All Track C customers had smart thermostats.
12. Xcel-CPP program only differentiates between CPP and non-CPP hours while Xcel-CTOU program differentiates between CPP, on-peak, and off-peak hours.

PRICING EXPERIMENTS

CALIFORNIA- ANAHEIM CRITICAL PEAK PRICING EXPERIMENT

The City of Anaheim Public Utilities (APU) conducted a residential Critical Peak Pricing Experiment between June 2005 and October 2005.[7] A total of 123 customers participated in the experiment: 52 in the control group and 71 in the treatment group. The CPP rate rewarded participants with a rebate of $0.35 for each kWh reduction below the reference level peak-period consumption on non-CPP days (i.e., the baseline consumption). The rate design is presented in Table 2.

Table 2- Anaheim CPP Program Rate Design

Group	Charge	Applicable Period
Control	Standard increasing-block residential tariff: $0.0675/kWh if consumption <=240kWh per month $0.1102/kWh if consumption >240kWh per month	All hours
Treatment	Standard increasing-block residential tariff	All hours except except peak hours (12 a.m. - 6 p.m.) on CPP days
Treatment	$0.35 rebate for each kWh reduction relative to their typical peak consumption on non-CPP days.	Peak hours (12 a.m. - 6 p.m.) on CPP days

Wolak compared 15-minute average daily load profiles of the treatment and control groups in the pre-program period to assess whether there were any biases in the selection of these two groups of customers. Statistical comparisons reveal that the load differences between treatment and control group customers are not statistically significant and the selection of treatment and control customers was random.

Impact analysis from the experiment shows the treatment group used 12 percent less electricity on average during the peak hours of the CPP days than the control group did. Demand response by treatment customers was greater on higher temperature CPP days than on lower temperature CPP days.

7 Wolak, Frank A., "Residential Customer Response to Real-Time Pricing: Anaheim Critical Peak Pricing Experiment," UCEI and Department of Economics, Stanford and NBER, 2007.

CALIFORNIA- AUTOMATED DEMAND RESPONSE SYSTEM PILOT[8]

California's Advanced Demand Response System (ADRS) pilot program by Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E) companies was initiated in 2004 and extended through the end of 2005. ADRS operated under a critical peak pricing tariff which was supported with a residential-scale, automated demand response technology. Participants of the pilot installed the GoodWatts system, an advanced home climate control system that allowed users to web-program their preferences for the control of home appliances. Under the CPP tariff, prices were higher during the peak period (2 p.m. to 7 p.m. on weekdays). All other hours, weekends, and holidays were subject to the base rate. When the "super peak events" were called, the peak price was three times higher than the regular peak price.

Results show that program participants achieved substantial load reductions in both 2004 and 2005 compared to the control group. Load reductions on super peak event days were consistently about twice the load reductions during the peak periods on non-event days. Peak reductions were as high as 51 percent on event days and 32 percent on non-event days. Enabling technology emerged as the main driver of the load reductions especially on super peak event days and for the high consumption customers. Overall, load reductions of the ADRS participants were consistently larger than those of the other demand response program participants without the technology.

Table 3 presents the impact estimates from the ADRS for high consumption customers on CPP event days and non-event days.

Table 3- Peak Period Load Reductions for High Consumption Customers

	Event Days		Non-Event Days	
Program Year	**Average Reduction (kW)**	**% Reduction**	**Average Reduction (kW)**	**% Reduction**
2004	1.84	51%	0.86	32%
2005	1.42	43%	0.73	27%

8 Rocky Mountain Institute, "Automated Demand Response System Pilot," 2006.

California- Statewide Pricing Pilot[9]

California's three investor-owned utilities, Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E), together with the two regulatory commissions conducted the Statewide Pricing Pilot (SPP) that ran from July 2003 to December 2004 to test the impact of several time-varying rates. The SPP included about 2,500 participants including residential and small-to-medium commercial and industrial (C&I) customers. SPP tested several rate structures:

- TOU-only rate where the peak price was twice the value of the off-peak price.
- CPP rate where the peak price during the critical days was roughly five times greater than the off-peak price; on non-critical days, a TOU rate applied. The SPP tested two variations of the CPP rates.
  - The CPP-F rate had a fixed period of critical peak and day-ahead notification. CPP-F customers did not have an enabling technology.
  - The CPP-V rate had a variable-length of peak duration during critical days and day-of notification. CPP-V customers had the choice of adopting an enabling technology.

The SPP utilized "standard demand models" derived from microeconomic theory to identify the impact of different rate and information structures on energy use. In addition to the estimation of impacts associated with the average prices used in SPP, these demand models allowed estimation of the impacts from other potential prices. A demand system of two equations was estimated for each different rate structure. One of these equations models daily energy use while the other equation models the ratio of peak to off-peak usage.

In this review, we cover only the residential customer impacts for three rate structures: CPP-F, TOU, and CPP-V.

CPP-F Impacts

The average price for customers on the standard rate was about $0.13 per kWh. Under the CPP-F rate, the average peak-period price on critical days was roughly $0.59 per kWh, the peak price

[9] Charles River Associates, "Impact Evaluation of the California Statewide Pricing Pilot." Oakland, California, 2005.

on non-critical days was $0.22 per kWh, and the average off-peak price was $0.09 per kWh. CPP-F rate impacts are as follows:

- On critical days, statewide average reduction in peak-period energy use was estimated to be 13.1 percent. Impacts varied across climate zones from a low of 7.6 percent to a high of 15.8 percent.
- The average peak-period impact on critical days during the inner summer months (July-September) was estimated to be 14.4 percent while the same impact was 8.1 percent during the outer summer months (May, June, and October).
- On normal weekdays, the average impact was 4.7 percent, with a range across climate zones from 2.2 percent to 6.5 percent.
- No change in total energy use across the entire year was found based on the average SPP prices.
- The impact of different customer characteristics on energy use by rate period was also examined. Central AC ownership and college education are the two customer characteristics that were associated with the largest reduction in energy use on critical days.

Table 4- Residential CPP-F Rate Impacts on Critical Days for Inner Summer Months (July, August, September) for All Customers

Year			Start Value (kWh/hr)	Impact (kWh/hr)	Estimate	T-stat	Impact (%)
2003	Rate Period	Peak	1.28	-0.163	-	-20.94	-12.71
		Off-peak	0.8	0.021	-	7.8	2.57
		Daily	0.9	-0.018	-	-6.88	-1.95
	Elasticity	Substitution	-	-	-0.086	-20.51	-
		Daily	-	-	-0.032	-6.8	-
2004	Rate Period	Peak	1.28	-0.178	-	-18.49	-13.93
		Off-peak	0.8	0.01	-	2.95	1.25
		Daily	0.9	-0.029	-	-8.7	-3.24
	Elasticity	Substitution	-	-	-0.087	-16.84	-
		Daily	-	-	-0.054	-8.55	-

Notes:

[1] Estimations are based on average customer approach. The average customer approach involves using the input values (e.g., weather, AC saturations and starting energy use values by rate period) for the average customer across all climate zones.
[2] All the numbers are based on average critical day weather in 2003/2004.

TOU Impacts

The average price for customers on the standard rate was about $0.13 per kWh. Under the TOU rate, the average peak-period price was roughly $0.22 per kWh and the average off-peak price was $ 0.09 per kWh.

- The reduction in peak period energy use during the inner summer months of 2003 was estimated to be 5.9 percent. However, this impact completely disappeared in 2004.
- Due to small sample problems in the estimation of TOU impacts, normal weekday elasticities from the CPP-F treatment may serve as better predictors of the impact of TOU rates on energy demand than the TOU price elasticity estimates.

CPP-V Impacts

The average price for customers on the standard rate was about $0.14 per kWh. Under the CPP-V rate, the average peak-period price on critical days was roughly $0.65 per kWh and the average off-peak price was $0.10 per kWh. This rate schedule was tested on two different treatment groups. Track A customers were drawn from a population with energy use greater than 600kWh per month. In this group, average income and central AC saturation was much higher than the general population. Track A customers were given a choice of installing an enabling technology and about two thirds of them opted for the enabling technology. The Track C group was formed from customers who previously volunteered for a smart thermostat pilot. All Track C customers had central AC and smart thermostats. Hence, two-thirds of Track A customers and all Track C customers had enabling technologies.

- As shown in Table 5, Track A customers reduced their peak-period energy use on critical days by about 16 percent (about 25 percent higher than the CPP-F rate impact).
- Track C customers reduced their peak-period use on critical days by about 27 percent.

Comparing the CPP-F and the CPP-V results suggest that usage impacts are significantly larger with an enabling technology than without it.

Table 5- Residential CPP-V Rate Impacts for Summer for All Customers

			Start Value (kWh/hr)	Impact (kWh/hr)	Estimate	T-stat	Impact (%)
Track A	Rate Period	Peak	2.14	-0.3374	-	-10.89	-15.76
		Off-peak	1.33	0.0445	-	4.26	3.34
		Daily	1.46	-0.0187	-	-1.71	-1.28
		Weekend Daily	1.3	0.0173	-	2.72	1.33
	Elasticity	Substitution	-	-	-0.111	-11.76	-
		Daily	-	-	-0.027	-1.7	-
		Weekend Daily	-	-	-0.043	-2.74	-
Track C	Rate Period	Peak	2.33	-0.635	-	-35.03	-27.23
		Off-peak	1.26	0.044	-	3.19	3.52
		Daily	1.43	-0.059	-	-9.85	-4.17
		Weekend Daily	1.34	0.016	-	4.1	1.2
	Elasticity	Substitution	-	-	-0.077	-10.61	-
		Tech. Impact-Substitution	-	-	-0.214	-24.04	-
		Daily	-	-	-0.044	-3.49	-
		Tech. Impact-Daily	-	-	-0.019	-3.49	-
		Weekend Daily	-	-	-0.041	-4.12	-

Notes:

[1] Estimations are based on average customer approach.
[2] Track A analysis was conducted for summer 2004.
[3] Track C analysis pools summers 2003 and 2004 and estimates a single model.

COLORADO- XCEL ENERGY TOU PILOT[10]

In the summer of 2006, Xcel Energy initiated a pilot program that tested the impact of TOU and CPP rates, as well as enabling technologies, on demand in the Denver metropolitan area. The effective treatment period lasted about a year, from July 15, 2006 through July 15, 2007. Approximately 3,700 residential customers initially volunteered into the pilot program; approximately 26 percent of those customers left the pilot by the end, leaving a final sample of about 2,900 participants.[11] The program made use of Advanced Meter Reading (AMR) infrastructure. All customers had interval meters installed, prior to the pilot program, which could wirelessly transmit consumption to mobile vehicles collecting the household data. Some

[10] Based on the following two reports: "Xcel Energy TOU Pilot Final Impact Report," Energy Insights, Inc, March 2008; and, "Experimental Residential Price Response Pilot Program, March 2008 Update to the 2007 Final Report," Xcel Energy, March 2008.

[11] The report notes that, because customers who want to participate are included in the pilot, there is an inherent self selection bias involved.

customers were offered enabling technologies—AC cycling switches and Programmable Communicating Thermostats (PCT)—in addition to the tested rate structures. Customers were subject to one of the three rate options:

- Time-of-use (RTOU)
  - Higher price during on-peak periods and a lower price during off-peak periods
- Critical peak (RCPP)
  - Critical peak prices up to 10 summer days; lower off-peak prices at all other times
  - Notification of the peak days by 4 pm the day before.
- Time-of-use+ critical peak (RCTOU)
  - Higher on-peak price (lower than the RTOU on-peak prices), lower off-peak prices, and critical peak prices up to 10 summer days

Table 6 illustrates the demand response impacts from the treatment groups during critical peak, on-peak, and off-peak hours in the summer months of pilot period.[12] All results presented below were determined to be statistically significant. Participants subject to critical peak pricing reduced demand during peak hours substantially more so than customers not subject to CPP. Nevertheless, all groups experienced some reduction in demand. Important to note again, however, is that self-selection may have played a role in the observed demand response impacts.

Table 6- Demand Response Impacts

Rate	Enabling Technology	Central AC	Critical Peak	On Peak	Off Peak
TOU	None	No	-	-10.63%	-2.95%
TOU	None	Yes	-	-5.19%	-0.27%
CPP	None	No	-31.91%	-	-0.08%
CPP	None	Yes	-38.42%	-	0.59%
CPP	AC Cycling Switch	Yes	-44.81%	-	1.34%
CTOU	None	No	-15.12%	-2.51%	8.69%
CTOU	None	Yes	-28.75%	-8.21%	3.56%
CTOU	AC Cycling Switch	Yes	-46.86%	-10.63%	4.00%
CTOU	PCT	Yes	-54.22%	-10.29%	2.96%

[12] As defined above, the summer months of the pilot included June, July, August, and September. As the pilot started in July of 2006 and ended in July of 2007, impacts were not measured for the months of June of 2006, and August and September of 2007.

Xcel Energy notes in the conclusion to its report that the pilot was conducted as a proof of concept rather than a technology test.[13] While the demand reduction was significant, the meters implemented in the pilot were too expensive to make the offerings cost-effective.

FLORIDA- THE GULF POWER SELECT PROGRAM[14]

In 2000, Gulf Power started a unique demand response program that provides customers with three different service options as described below.

- The standard residential service (RS) pricing option which involved a standard flat rate with no time varying rates.
- A conventional TOU pricing option (RST) which is a two-period TOU tariff.
- The Residential Service Variable Price (RSVP) pricing option which is a three-period CPP tariff.

Under the RSVP option, the energy company provides the price signals and customers modify their usage patterns through a combination of the price signals and advanced metering and appliance control. Gulf Power markets the RSVP option under the GoodCents Select program and charges the participants a monthly participation fee. By the end of 2001, approximately 2,300 homes were served by the RSVP.

Table 7 shows the rates under the Gulf Power demand response program.

Table 7- Residential Tariffs for Summer Months

Program	Period	Charge	Applicable
RS	Base	$0.057/kWh	All hours
RST	Off-peak	$0.027/kWh	12 a.m.-12 p.m. and 9 p.m.-12 a.m.
RST	Peak	$0.104/kWh	12 p.m.- 9 p.m.
RSVP	Off-peak	$0.035/kWh	12 a.m.-6 a.m. and 11 p.m.-12 a.m.
RSVP	Mid-peak	$0.046 /kWh	6 a.m.-11 a.m. and 8 p.m.-11 p.m.
RSVP	Peak	$0.093/kWh	11 a.m.-8 p.m.
RSVP	CPP	$0.29/kWh	When called

[13] "Experimental Residential Price Response Pilot Program, March 2008 Update to the 2007 Final Report," Xcel Energy, March 2008.

[14] Borenstein, S., M. Jaske, and A. Rosenfeld, "Dynamic Pricing, Advanced Metering and Demand Response in Electricity Markets", UCEI 2002.

Gulf Power reports the base coincident peak demand as 6.1 KW per household (hh). RSVP program performance results presented in Table 8 show that RSVP program participants reduce their demand by 2.75 KW per household during the critical peak period corresponding to a 41 percent reduction in energy usage during the critical peak period.

Table 8- RSVP Program Performance by Period

Impact Type	Period	Impact
Average Demand Reduction	Peak Critical Peak	2.1 kW/hh 2.75 kW/hh
Average Energy Reduction	Peak Critical Peak	22% 41%

FRANCE- ÉLECTRICITÉ DE FRANCE (EDF) TEMPO PROGRAM[15]

Électricité de France (EDF) initiated the Tempo program in 1996. Rate design entails two price-tiers, peak and off-peak. A distinctive feature of the Tempo program is day-of-the-year pricing which groups the 365 days in a year into three day-types:

- *Blue days* are the least expensive 300 days.
- *White days* are moderately priced 43 days.
- *Red days* are the most expensive 22 days.

Customers learn which day would be in effect the next day through the use of several resources including web-resources, call-centers, subscription to e-mail alerts and plugging in an electrical device into their electrical sockets.

EDF implemented a pilot program before launching the Tempo on a full-scale. The pilot program set prices that were much higher than the Tempo prices. The own-price elasticity for peak demand was estimated at -0.79, much higher than any of the estimates for U.S. pilots. Own-price elasticity for off-peak usage was estimated to be -0.18.

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15 Faruqui, A., S. S. George. 2002. "The Value of Dynamic Pricing in Mass Markets." *Electricity Journal* Vol.15.6: 45-55.

IDAHO- IDAHO RESIDENTIAL PILOT PROGRAM[16]

Idaho Power Company initiated two residential pilot programs in the Emmett area of Idaho in the summer of 2005 and the summer of 2006: Time-of-day (TOD) and Energy Watch (EW).

Time-of-Day Pilot

The TOD pilot was designed as a conventional TOU program where the participants were charged different rates by time of the day as shown in Table 9. The TOD pilot included 85 treatment and 420 control group customers as of August 2006.

Table 9- Rate Design for the Time-of-Day Pilot

Period	Charge	Applicable
On-Peak	$0.083/kWh	Weekdays from 1pm to 9pm
Mid-Peak	$0.061/kWh	Weekdays from 7am to 1pm
Off-Peak	$0.045/kWh	Weekdays from 9pm to 7am and all hours on weekends and holidays

As shown in Table 10, the results from the TOD pilot for the summer of 2006 show that, on average, the peak period percentage of total summer usage was the same for the treatment and control groups – about 22 percent. In fact, the percentage of usage during the mid-peak and off-peak periods was also the same between the two groups. This indicates that the TOD rates had no effect on shifting usage. However, in light of the very low ratio of on-peak to off-peak rates (about 1.84), this result is not so surprising. It suggests that a higher ratio of peak to off-peak rates is needed to induce customers to shift usage from peak to off peak periods.

16 Idaho Power Company, "2006 Analysis of the Residential Time-of-Day and Energy Watch Pilot Programs: Final Report," 2006.

Table 10- Summer 2006 (June-August) Usage under the TOD Pilot

	Average Use (kWh)		% of Total Summer Use		Program Impact	
Period	Treatment	Control	Treatment	Control	Difference (Control- Treatment)	T-stat
On-Peak	800	763	22%	22%	-36.46	0.66
Mid-Peak	591	568	16%	16%	-22.43	0.52
Off-Peak	2307	2162	62%	62%	-145.78	0.99
Summer 06 Usage	3698	3493	100%	100%	-204.67	0.87

Energy Watch Pilot

The Idaho Power Company Energy Watch (EW) pilot was designed as a CPP pilot where the participants were notified of the CPP event on a day-ahead basis. A total of 10 EW days were called during the summer of 2006. EW was designed as follows:

- CPP hours from 5 p.m. to 9 p.m.
- Day-ahead notification
- CPP energy price of $0.20/kWh
- Non-CPP energy price of $0.054/kWh

The EW pilot included 68 treatment and 355 control group customers as of August 2006.

Table 11 shows the reduction in load (kW) on CPP days for each of the event days. Average hourly demand reduction ranged from 0.64 kW (on June 29) to 1.70 kW (on July 27). Average hourly load reduction for all ten event days was 1.26 kW. The average total load reduction for a 4-hour event was 5.03 kW.

Table 11- Energy Watch Day: Load Reductions (kW) On Each of the Ten Event Days

Hour Beginning	Hour Ending	29-Jun	11-Jul	14-Jul	18-Jul	19-Jul	25-Jul	27-Jul	3-Aug	9-Aug	15-Aug	Average
5pm	6pm	0.64	1.31	1.09	1.39	1.2	1.33	1.58	1.14	0.83	1.02	1.17
6pm	7pm	0.69	1.5	1.17	1.43	1.32	1.45	1.62	1.27	1.14	1.15	1.29
7pm	8pm	0.77	1.58	1.16	1.57	1.41	1.55	1.7	1.24	1.02	0.96	1.33
8pm	9pm	0.8	1.48	1.11	1.47	1.27	1.4	1.6	1.13	0.95	0.89	1.25
4-Hour Total		2.89	5.87	4.53	5.85	5.2	5.74	6.5	4.77	3.94	4.02	5.03
Average Hourly		0.72	1.47	1.13	1.46	1.3	1.43	1.62	1.19	0.99	1.01	1.26
Min Temp		68	65	65	61	62	75	68	59	62	67	65
Max Temp		85	100	98	94	98	99	104	92	85	92	95
Avg Temp		75	84	83	79	80	87	87	76	73	80	80

ILLINOIS- ENERGY SMART PRICING PLAN

Community Energy Cooperative's ("CEC") Energy-Smart Pricing Plan (ESPP) was the first large-scale residential real-time pricing (RTP) program in the US. It took place in Illinois, and ran between 2003 and 2006. ESPP initially included 750 participants and expanded to nearly 1,500 customers in 2005. The same number of participants was maintained for the 2006 program year. ESPP focused on low cost technology and tested the hypothesis that major benefits may result from RTP without the adoption of expensive technology.

The ESPP design included:

- Day-ahead announcement of the hourly electricity prices for the next day (on the day of the event, customers were charged the hourly prices that had been posted the day before).
- High-price day notification via phone or email when the price of electricity climbed over $0.10 per kWh (in 2006, the notification threshold was set to above $0.13 per kWh).
- A price cap of $0.50 per kWh for participants meaning that the maximum hourly price is set at $0.50 per kWh during their participation in the program.
- In 2005 (continued in 2006), cycling switches for central air conditioners were installed at participants homes, which effectively reduced energy consumption by AC units during high price periods.
- In 2006, the Energy PriceLight, a glass orb similar in design to the Energy Orb of PG&E, was distributed. The Energy PriceLight is a glass orb that receives wireless price information and relays this information, i.e. high or low electricity prices, by glowing in different colors.

- Energy usage education for participants.

Pilot Program Results for 2005[17]

The main goals of the pilot were to determine the price elasticity of demand and the overall impact on energy conservation. A regression based analysis was conducted to estimate the price elasticity of demand for the summer months. Overall, the price elasticity during the summer of 2005 was estimated to be -0.047.

With enabling technology, i.e. automatic cycling of the central-air conditioners during high-price periods, the overall price elasticity increased to -0.069. The largest response occurred on high-price notification days. For instance, on the day with the highest prices during the summer of 2005, participants reduced their peak hour consumption by 15 percent compared to what they would have consumed under the flat ComEd residential rate. Price responsiveness varied over the course of a day. Own price elasticities by time of day are presented in Table 12.

Table 12- Elasticity Estimates from ESPP

Time of the Day	Elasticity Estimate
Daytime (8 a.m. to 4 p.m.)	-0.02
Late afternoon/evening hours (4 p.m. to midnight)	-0.03
Daytime+ High-Price Notification	-0.02
Late Daytime/Evening+High-Price Notification	-0.05

The impact analysis indicated that ESPP participants consumed 35.2 kWh less per month during the summer months compared to what they would have consumed without the ESPP. These savings represented roughly three to four percent of summer electricity usage. Statistically significant savings were not found for winter usage which is not surprising since most high price days occur in the summer months in this area. Overall, ESPP resulted in a net decrease in monthly energy consumption.

Pilot Program Results for 2006[18]

Results from the analysis of the ESPP in 2006 supported the findings of program's previous years. The price elasticity during the summer of 2006, for hours when the price of electricity

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17 Summit Blue Consulting, "Evaluation of the 2005 Energy-Smart Pricing Plan-Final Report," 2006.
18 Summit Blue Consulting, "Evaluation of the 2006 Energy-Smart Pricing Plan-Final Report," 2007.

was equal to or below $0.13 per kWh, was estimated to be -0.047.[19] The price elasticity for the same period, but for hours when the price of electricity was above $0.13 per kWh, was estimated to be -0.082.[20] The Energy PriceLight improved customer responsiveness resulting in an elasticity of -0.067 across all hours. For customers with A/C cycling, the price elasticity for high price periods was quite high, estimated at -0.098.

Results of the energy impact analysis indicated that ESPP participants consumed 16.7 kWh less per month, year round, relative to individuals not on the ESPP rate. During the summer months, participants consumed an additional 10.0 kWh less per month, or equivalently 26.7 kWh less per month total. This translates to approximately three percent of summer electricity usage, similar to the savings results of the 2005 program year. Again, on the whole, ESPP resulted in a decrease in monthly energy consumption.

ILLINOIS- POWER SMART PRICING PROGRAM[21]

Ameren Illinois Utilities ("AIU") started AIU residential real-time pricing program, branded as the Power Smart Pricing program in 2007. The program was to be administered in the service areas of the three Ameren Illinois Utilities: AmerenCIPS, AmerenCILCO, and AmerenIP. As of the end of 2007, 484 customers had enrolled.

The program is similar in design to the ESPP pilot that was conducted in Illinois. Residential customers pay rates that vary from hour to hour and day to day. In turn, customers are expected to reduce consumption during periods of high electricity prices. Customers receive electricity price information through the following means: 1) customers are alerted of high electricity prices (above 13 cents per kWh) a day in advance by via email or a telephone call 2) customers can access price information via the internet or by calling a price hotline 3) select customers received the "PriceLight," a device similar to the Energy Orb distributed by PG&E, which relays qualitative price signals.

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[19] In other words, a 100 percent increase in price would lead to a 4.7 percent reduction in demand. However, this elasticity is estimated for all hours and does not distinguish between the hours where the price of electricity was above and below $0.13 per kWh as was done in 2006 analysis of ESPP.

[20] In other words, a 100 percent increase in price would lead to a 8.2 percent reduction in demand.

[21] CNT Energy, "Power Smart Pricing, 2007 Annual Report," 2008.

The PriceLight is a glass orb that receives wireless prices signals from the utility and subsequently changes colors. Cooler colors (green and blue) correspond to lower prices while warmer colors (orange and red) correspond to higher electricity prices. In 2007, only seven PriceLights were distributed; although another 118 PriceLights are to be distributed in 2008.

Power Smart Pricing program was not actively marketed until the fall of 2007. As such, only a small number of participants were enrolled during the summer of 2007, and consequently, a full load impact analysis was not conducted. Rather, a bill impact analysis was conducted, and it demonstrated, for bills issued through the end of January 2008, participants saved on average 16.2 percent relative to what their bill would have been on the standard rate. A more thorough analysis, including load impacts, is expected to be available at the end of the 2008 program year.

ILLINOIS- COMED RESIDENTIAL REAL-TIME PROGRAM[22]

Commonwealth Edison ("ComEd") of Illinois currently offers its customers the Residential Real-Time Pricing Program, an outgrowth of the Energy Smart Pricing Program ("ESPP") which was administered between 2003 and 2006 and is also reviewed in this paper. The program officially began on January 2, 2007; however, operations did not begin until April 1, 2007. As of the end of 2007, 3,994 residential customers were enrolled in the Real-Time Pricing Program, and of these, 3,334 actively participated at year's end.

The program's rates are based on hour-ending PJM wholesale prices. With respect to technology, the program participants are equipped with meters that are capable of charging real-time rates. Additionally, program participants are given the option to enroll in the "Load Guard" program, which equips participants' central air conditioning ("CAC") units with a "Digital Control Unit" ("DCU") that curtails CAC load during periods of high prices at a specified price threshold.

Other features of the Residential Real-Time Program include:

[22] Comverge Inc., "ComEd Residential Real-Time Program- 2007 Annual Report," 2008.

- A web portal which provides outreach, education, enrollment, online bill comparison, and other energy-used management tools.
- Online and phone-based price information, providing access to next day hourly price schedules, access to hour-ending prices and five minute real-time price intervals, predicted day-ahead price notifications via email, text messages, and/or automated phone calls, and real-time day-of price alerts via email or text messages.
- High-price notification via phone or email when the day-ahead hour-ending price of electricity clears at or climbs over $0.13 per kWh (the option to set the threshold at $0.10 per kWh or $0.14 per kWh is also available).
- Energy usage education for participants.

While the published results of the program did not detail demand response effects, energy conservation effects, or price elasticities associated with real-time pricing; the pilot did investigate participant bill savings. Key results from participant data collected over 2007 indicated that participants were benefiting from the program. Results revealed that 95 percent of participants saved money relative to what they would have spent on the same level of consumption on a flat rate. More specifically, participants who had been in the program for a full 12 month period saved seven to 12 percent on their electricity bills on average. Overall, bill savings of the participants reached $164,000 in 2007.

MISSOURI- AMERENUE CRITICAL PEAK PRICING PILOT

First Year of the Pilot Program (2004)[23]

AmerenUE in collaboration with Missouri Collaborative formed by Office of Public Counsel (OPC), the Missouri Public Service Commission (MPSC), the Department of Natural Resources (DNR) and two industrial intervener groups initiated a residential TOU pilot study in Missouri during the spring of 2004. Program impacts associated with three different TOU programs were evaluated:

- TOU with peak, mid-peak, and off-peak rates

[23] RLW Analytics, "AmerenUE Residential TOU Pilot Study Load Research Analysis: First Look Results," 2004.

- TOU with a CPP component
- TOU with a CPP component and an enabling technology (smart thermostat)

Table 13 shows the rates evaluated in the pilot.

Table 13- Residential TOU Experiment Summer Rate Design

Program	Time	Charge	Applicable
TOU	Off Peak	$0.048/kWh	Weekday 10pm–10am, weekends, holidays
TOU	Mid Peak	$0.075/kWh	Weekdays 10am– 3pm and 7pm-10pm
TOU	Peak	$0.183/kWh	Weekdays 3pm – 7pm
TOU-CPP	Off Peak	$0.048/kWh	Weekdays 10pm–10am, weekends, holidays
TOU-CPP	Mid Peak	$0.075/kWh	Weekdays 10am– 3pm and 7pm-10pm
TOU-CPP	Peak	$0.168/kWh	Weekdays 3pm – 7pm
TOU-CPP	CPP	$0.30/kWh	Weekdays 3pm – 7pm, 10 times per summer

Table 14 shows the number of participants in the treatment and control groups by type of rate.

Table 14- Experiment Sample Allocation

Treatment	Treatment Sample Size	Control Sample Size
TOU	88	89
TOU-CPP	85	89
TOU-CPP-Tech	77	117
Total	250	295

The following results are based on the data compiled from the pilot between June 1, 2004 and September 30, 2004. Average usage and demand by participants during the pilot is provided in Tables 15 and 16:

- Results from Table 15 show that the participants in the TOU and TOU-CPP groups did not shift a statistically significant amount of load from the on-peak to off-peak or mid-peak periods. Off-peak consumption increased and peak consumption decreased only slightly for the treatment groups compared to the control groups for both TOU and TOU-CPP programs. However, none of these differences in consumption between the treatment and control groups are statistically significant.
- Results from Table 16 show that the TOU-CPP-Tech group reduced their average CPP period demand by 35 percent compared to the control group on the event days. TOU-CPP

group reduced their demand by 12 percent during the same period. Both impacts are statistically significant at the five percent level.

Table 15- Average Participant Use by Program and Time Period- 2004

Program	June 1-September 30 Period	Control Group (kWh)	Treatment Group (kWh)	Difference (Control-Treatment)	T-test	Pr> |t|	Statistical Significance of the Difference
TOU	Off Peak	33.63	34.87	-1.24	-0.71	0.479	Not Significant.
TOU	Mid Peak	23.59	22.78	0.81	0.71	0.476	Not Significant.
TOU	On Peak	13.81	13.36	0.45	0.67	0.505	Not Significant.
TOU	Seasonal	60.00	60.34	-0.34	-0.12	0.905	Not Significant.
TOU-CPP	Off Peak	35.84	38.36	-2.52	-1.19	0.235	Not Significant.
TOU-CPP	Mid Peak	24.11	24.54	-0.43	-0.34	0.733	Not Significant.
TOU-CPP	On Peak	13.82	13.29	0.53	0.73	0.466	Not Significant.
TOU-CPP	CPP	19.8	18.85	0.95	0.86	0.390	Not Significant.
TOU-CPP	Daily	62.87	65.3	-2.43	-0.72	0.473	Not Significant.
TOU-CPP-Tech	Off Peak	37.61	33.31	4.3	2.44	0.002	Significant.
TOU-CPP-Tech	Mid Peak	25.86	22.47	3.39	3	0.003	Significant.
TOU-CPP-Tech	On Peak	14.86	12.77	2.09	3.09	0.002	Significant.
TOU-CPP-Tech	CPP	21.39	15.48	5.91	6.5	0.000	Significant.
TOU-CPP-Tech	Daily	66.63	58.28	8.35	2.88	0.000	Significant.

Table 16- Average CPP Period Demand on the 6 Event Days in Summer 2004

Program	Control Group (kW)	Treatment Group (kW)	Difference (Control-Treatment)	% Difference	T-test	Pr> |t|	Statistical Significance of the Difference
TOU-CPP	4.98	4.37	0.61	12%	2.09	0.038	Significant.
TOU-CPP-Tech	5.36	3.49	1.87	35%	8.09	0.000	Significant.

Second Year of the Pilot Program (2005)[24]

During the second year of AmerenUE Critical Peak Pricing Pilot, the first year rate design described earlier remained in effect (see Table 13). Table 17 provides average participant usage by time period and program while Table 18 summarizes the average demand on peak periods of eight CPP days in the summer of 2005.

- In 2005, the TOU-CPP and TOU-CPP-Tech customers reduced their usage during CPP periods by statistically significant amounts. However, seasonal usage reductions are not statistically significant at five percent level.

[24] Voytas, R., “AmerenUE Critical Peak Pricing Pilot,” presented at Demand Response Research Center Conference, Berkeley, California, 2006.

- Average CPP period demand reduction during eight event days is 13 percent for TOU-CPP customers and 24 percent for TOU-CPP-Tech customers. Both impacts are statistically significant at five percent.

Table 17- Average Participant Use by Program and Time Period – 2005

Program	Jun 1- Aug 31 Period	Control Group (kWh)	Treatment Group (kWh)	Difference (Control-Treatment)	T-test	Pr> |t|	Statistical Significance of the Difference
TOU-CPP	Off Peak	4495	4450	45	0.28	0.78	Not Significant.
TOU-CPP	Mid Peak	2054	2019	35	0.54	0.59	Not Significant.
TOU-CPP	On Peak	927	896	31	0.96	0.34	Not Significant.
TOU-CPP	CPP	252	219	33	3.92	0.00	Significant.
TOU-CPP	Seasonal	7,729	7,584	145	0.58	0.56	Not Significant.
TOU-CPP-Tech	Off Peak	4147	4017	130	0.91	0.37	Not Significant.
TOU-CPP-Tech	Mid Peak	1934	1901	33	0.46	0.65	Not Significant.
TOU-CPP-Tech	On Peak	884	863	21	0.64	0.52	Not Significant.
TOU-CPP-Tech	CPP	240	182	58	5.99	0.00	Significant.
TOU-CPP-Tech	Seasonal	7,205	6,963	242	0.98	0.33	Not Significant.

Table 18- Average CPP Period Demand on Eight Event Days in Summer 2005

Program	Control Group (kW)	Treatment Group (kW)	Difference (Control-Treatment)	% Difference	T-test	Pr> |t|	Statistical Significance of the Difference
TOU-CPP	5.56	4.84	0.72	13%	3.9	0.0001	Significant.
TOU-CPP-Tech	5.29	4.05	1.14	24%	6.05	0.0001	Significant.

NEW JERSEY- GPU PILOT[25]

GPU offered a residential TOU pilot program with a critical peak price and enabling technology component in the summer of 1997. The rate design involved three price tiers (peak, shoulder, and off-peak) and a critical peak price that is only effective for a limited number of high-cost summer hours. Moreover, the pilot program tested the impacts from two sets of alternative rates by allocating treatment customers to two groups and subjecting each group to one of the two sets. Table 19 shows the control and treatment group rate designs.

25 Braithwait, S. 2000, "Residential TOU Price Response in the Presence of Interactive Communication Equipment," In *Pricing in Competitive Electricity Markets*, edited by Kelly Eakin and Ahmad Faruqui: Springer.

Table 19- Experiment Rate Design

Group	Charge	Applicable
Control	Standard increasing-block residential tariff: $0.12/kWh if consumption <=600kWh per month $0.153/kWh if consumption >600kWh per month	All hours
Treatment Group 1 (High shoulder/peak design)	Off-peak: $0.065/kWh	1a.m.-8a.m. and 9p.m.-12p.m. weekdays; All day on weekends and holidays.
	Shoulder:$0.175/kWh	9a.m.-2p.m. and 7p.m.-8p.m. weekdays.
	Peak:$0.30/kWh	3p.m.-6p.m. weekdays
	Critical:$0.50/kWh	When called during peak period
Treatment Group 2 (Low shoulder/peak design)	Off-peak:$0.09/kWh	1a.m.-8a.m. and 9p.m.-12p.m. weekdays; All day on weekends and holidays.
	Shoulder:$0.125/kWh	9a.m.-2p.m. and 7p.m.-8p.m. weekdays.
	Peak:$0.25/kWh	3p.m.-6p.m. weekdays
	Critical:$0.50/kWh	When called during peak period

One important feature of this pilot is that the treatment customers were installed communication equipment that allowed them to preset their usage patterns in response to the time-varying rates and receive price signals from the utility during the critical hours.

Analysis of the hourly load data for each of the treatment and control group customers collected for the period of June through September 1997 revealed the following results:

- On non-critical weekdays, the largest usage reductions in the average hourly load were observed during the peak period and averaged to 0.53 KW or 26 percent relative to the control group. Load reductions were also observed during the late-morning shoulder period, but these reductions were limited compared to those during the peak period. The treatment group with the high rate design reduced usage by roughly 50 percent more during each of peak and shoulder periods than the treatment group with the low-rate design.
- On CPP days, the results were similar to those on the non-CPP weekdays; though larger in magnitude, especially during the peak period. In the first hour of the peak period, average load reduction was 1.24 KW or a 50 percent reduction compared to the control group. During the next two peak hours, the reduction was around 1 KW, later falling to 0.59 KW on the last peak hour. Also, the treatment group usage was substantially larger than the control group during the shoulder and off-peak periods following the critical peak hours.

- On weekends, average usage was similar for the control and treatment customers, with slightly lower (though not statistically significant) levels for the treatment customers.
- Average usage over all days by the treatment group decreased compared to the control group, but the result was not statistically significant. A large portion of these reductions can be attributed to the changes in the weekday usage. Average daily usage on weekend, weekdays, and all days are presented in Table 20.

Table 20- Average Daily Usage for Summer 1997 (kWh)

	Control	Treatment	Usage Difference	% Difference
Weekdays	30.4	28.3	-2.1	-6.9%
Weekends	34.1	33.7	-0.4	-1.2%
All days	32.5	30.9	-1.6	-4.9%

Pilot results were also utilized for the estimation of the substitution elasticities. Elasticity estimates were based on two alternative demand models; the constant elasticity of substitution (CES) model and the generalized Leontief (GL) model.

- Substitution elasticity from the CES model is estimated to be -0.30. This estimate is larger than -0.17, the average of previous estimates from several other studies. Larger substitution elasticities from this pilot can be attributed to the presence of interactive communication equipments through which the customers preset their usage patterns of air conditioning (AC) and some other appliance.
- GL model allows substitution elasticity estimates to vary by the time-period. Substitution elasticity between peak and off-peak periods was estimated as -0.40 from the GL model. Substitution elasticities between other time-periods can be seen in Table 21.

Table 21- Substitution Elasticities

Month	Time Period	CES	GL	
			High Rate Tariff	Low Rate Tariff
1	Overall	-0.306	-	-
	Peak-shoulder	-	-0.155	-0.166
	Peak-off-peak	-	-0.395	-0.356
	Shoulder-off-peak	-	-0.191	-0.187
2	Overall	-0.295	-	-
	Peak-shoulder	-	-0.055	-0.06
	Peak-off-peak	-	-0.407	-0.366
	Shoulder-off-peak	-	-0.178	-0.176

NEW JERSEY- PSE&G RESIDENTIAL PILOT PROGRAM [26]

Public Service Electric and Gas Company (PSE&G) offered a residential TOU/CPP pilot pricing program in New Jersey during 2006 and 2007. The PSE&G pilot had two sub-programs. Under the first sub-program, *myPower Sense*, participants were educated about the TOU/CPP tariff and were notified of the CPP event on a day-ahead basis and the program assessed the reduction in energy use when a CPP event was called. Under the second sub-program, *myPower Connection*, also designed to assess the reduction in energy use when a CPP event was called, participants were given a free thermostat that received price signals from PSE&G and adjusted their air conditioning settings (CAC) based on previously programmed set points. A total of 1,148 customers participated in the pilot program; 450 in the control group, 379 in myPower Sense, and 319 in myPower Connection. PSE&G recruited the participants separately for each group through direct mail with follow-up telemarketing[27]. Customers didn't have the opportunity to choose the treatment they would be receiving. *myPower Sense* customers received a $25 incentive upon enrollment and another $75 to be paid upon the conclusion of the program. *myPower Connection* participants were provided free programmable thermostats and received $75 at the end of the program.

The TOU/CPP tariff included a night discount, a base rate, an on-peak adder, and a critical peak adder for the summer months as shown in Table 22.

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26 PSE&G and Summit Blue Consulting, "Final Report for the myPower Pricing Segments Evaluation" December 2007.

27 PSE&G recruited pilot participants from Cherry Hill and Hamilton towns as they had high percentages of residents on standard rates and high predicted penetrations of CAC.

Table 22- TOU/CPP Rate Design: Summer Months (June to September 2006 and 2007)

Period	Charge (June to September 2006)	Charge (June to September 2007)	Applicable
Base Price	$0.09/kWh	$0.087/kWh	All hours
Night Discount	-$0.05/kWh	-$0.05/kWh	10 p.m.-9 a.m. daily
On Peak Adder	$0.08/kWh	$0.15/kWh	1 p.m.-6 p.m. weekdays
Critical Peak Adder	$0.69/kWh	$1.37/kWh	1 p.m.-6 p.m. weekdays when called (Added to the base price when called)

PSE&G called two CPP events in Summer 2006 and five CPP events in Summer 2007. Table 23 summarizes the peak demand impacts on these 7 CPP event days. Results show that:

- *myPower Connection customers* reduced their peak demand by 21 percent due to TOU-only pricing. These customers reduced their peak load by an additional 26 percent on CPP event days.
- *myPower Sense* customers with CAC ownership reduced their peak demand by three percent on TOU-only days. On CPP event days, their peak load reductions reached to 17 percent. Interestingly, *myPower Sense* customers without CAC ownership achieved six percent peak reductions on TOU-only days while the reductions reached 20 percent on CPP event days.
- *myPower Connection* customers reduced their peak-demand consistently more than *myPower Sense* customers. The larger reductions for *myPower Connection* customers were not surprising since these customers had an enabling technology (i.e., the programmable thermostat) whereas the myPower Sense customers did not.

Table 23- Estimated Peak Demand Impacts on 2006 and 2007 Summer CPP Event Days (Average kW per Hour)

Impact Estimate	Base Average Peak Consumption (kW)	TOU Impact		CPP Impact		Total Impact	
		kW	%	kW	%	kW	%
myPower Connection	2.85	-0.59	-21%	-0.74	-26%	-1.33	-47%
myPower Sense with CAC	2.6	-0.07	-3%	-0.36	-14%	-0.43	-17%
myPower Sense without CAC	1.61	-0.09	-6%	-0.23	-14%	-0.32	-20%

Source: Summit Blue analysis of PSE&G myPower data

Study also estimates summer substitution elasticities for *myPower Connection and myPower Sense* customers. Table 24 presents the elasticity estimates and the associated lower and upper bounds for 90 percent confidence level.

As expected, *myPower Connection* customers have the largest elasticity of substitution, followed respectively by *myPower Sense* customers with and without CAC ownership.

Table 24- Estimated Substitution Elasticity for Summers 2006 and 2007

Impact Estimate	Substitution Elasticity	90% Confidence Interval
myPower Connection	-0.125	-0.12 to -0.131
myPower Sense with CAC	-0.069	-0.063 to -0.075
myPower Sense without CAC	-0.063	-0.055 to -0.072

NEW SOUTH WALES/AUSTRALIA- ENERGY AUSTRALIA'S NETWORK TARIFF REFORM [28]

The TOU pricing program is the largest demand management project by Energy Australia. Recent price elasticity estimates from the TOU tariffs are presented in Table 25.

Table 25- TOU Price Elasticity Estimates

Type	Season	Peak Own Price Elasticity	Peak to Shoulder Cross Price Elasticity	Peak to Off-Peak Cross Price Elasticity
Residential	Summer 2006 Winter 2006	-0.30 to -0.38 -0.47	-0.07 -0.12	-0.04 -
Business (less than 40 MWh)	Summer 2006 Winter 2006	-0.16 to -0.18 (ns) -0.2 (ns)	-0.03 -	- -
Business (40 MWh to 160 MWh)	Summer 2006 Winter 2006	-0.03 to -0.13 (ns) -0.02 to -0.09 (ns)	- -	- -

Note: ns refers to "not statistically significant"

The TOU results show that:

28 Harry Colebourn, "Network Price Reform," presented at BCSE Energy Infrastructure and Sustainability Conference, December 2006.

- Slight energy conservation effects resulted from residential consumption under TOU rates compared to residential consumption under the flat tariffs.
- Conservation effects were larger in winter than in summer for the residential customers.
- Business customer price elasticities are not statistically significant. Therefore, they should be interpreted with caution.

Energy Australia started the Strategic Pricing Study in 2005 which included 1,300 voluntary customers (50 percent business, 50 percent residential customers). The study tested seasonal, dynamic, and information only tariffs and involved the use of in-house displays and online access to data. Study participants received dynamic peak price signals through Short Message Service (SMS), telephone, email, or the display unit.

Preliminary results that are available from three dynamic peak pricing (DPP) events show that:

- Residential customers reduced their dynamic peak consumption by roughly 24 percent for DPP high rates (A$2+/kWh) and roughly 20 percent for DPP medium rates (A$1+/kWh).
- Response to the 2nd DPP event was greater than that to the 1st DPP event. This may be attributed to the day-ahead notification under the 2nd DPP event (versus day-of notification under the 1st DPP event) and/or temperature differences.
- Response to the 2nd event was also greater than to the 3rd DPP event. This may be explained by lower temperatures on the 3rd DPP event which may have led to less discretionary appliances to turn off.

ONTARIO/CANADA- ONTARIO ENERGY BOARD SMART PRICE PILOT[29]

The Ontario Energy Board operated the residential Ontario Smart Price Pilot (OSPP) between August 2006 and March 2007. The OSPP used a sample of Hydro Ottawa residential customers and tested the impacts from three different price structures:

- The existing Regulated Price Plan (RPP) TOU: The RPP TOU rates are shown in Table 26.
- RPP TOU rates with a CPP component (TOU CPP). The CPP was set at C$0.30 per kWh based on the average of the 93 highest hourly Ontario electricity prices in the previous

[29] Ontario Energy Board, "Ontario Energy Board Smart Price Pilot Final Report," 2007.

year. The RPP TOU off-peak price was decreased to C$0.031 (from C$0.035) per kWh to offset the increase in the critical peak price. The maximum number of critical day events was set at nine days, however only seven CPP days were called during the pilot.

- RPP TOU rates with a critical peak rebate (TOU CPR): The CPR provided participants with a C$0.30 per kWh rebate for each kWh of reduction from estimated baseline consumption. The CPR baseline consumption was defined as the average usage during the same hours over the participants' last five non-event weekdays, increased by 25 percent.

Table 26- Regulated Price Plan (RPP) TOU Rate Design

Season	Time	Charge	Applicable
Summer (Aug 1- Oct 31)	Off-peak	C$0.035/kWh	10 p.m.- 7 a.m. weekdays; all day on weekends and holidays
Summer (Aug 1- Oct 31)	Mid-peak	C$0.075/kWh	7 a.m.- 11 a.m. and 5 p.m.- 10 p.m. weekdays
Summer (Aug 1- Oct 31)	On-peak	C$0.105/kWh	11 a.m.- 5 p.m. weekdays

A total of 373 customers participated in the pilot: 124 in TOU-only, 124 in TOU-CPP, and 125 in TOU-CPR. The control group included 125 participants who had smart meters installed but continued to pay non-TOU rates.

The OSPP results show that:

- The load shift during the critical hours of the four summer CPP events ranged between 5.7 percent and 25.4 percent. [30]
- The load shift during the entire peak period of the four summer CPP events ranged between 2.4 percent and 11.9 percent.

Table 27 shows the shift in load during the summer CPP events as a percentage of the load in critical peak hours and of the entire peak period. It is important to note that the percentage reductions for the TOU-only customers are not significant at the 90 percent confidence level.

[30] Under the OSPP, 3 to 4 hours of the peak period were defined as critical on a CPP day.

Table 27- Percentage Shift in Load during the Four Summer CPP Events

Period	TOU- only	TOU- CPP	TOU- CPR
Shift as % of critical peak hours	5.7%	25.4%	17.5%
Shift as % of all peak hours	2.4%	11.9%	8.5%

This study also analyzed the total conservation impact during the full pilot period. The total reduction in electricity consumption due to program impacts is reported in Table 28. The average conservation impact across all customers was estimated to be six percent.

Table 28- Total Conservation Effect for the Full Pilot Duration

Program	% Reduction in Total Electricity Usage
TOU-only	6.0%
TOU- CPP	4.7% (ns)
TOU- CPR	7.4%
Average Impact	6.0%

SEATTLE SUBURBS- PUGET SOUND ENERGY (PSE)'S TOU PROGRAM[31]

PSE initiated a TOU program for its residential and small commercial customers in 2001. The rate design involved four price periods. Prices were most expensive during the morning and evening periods with mid-day and economy periods following these most expensive periods. Some 300,000 PSE customers were placed in the program and given the option to go back to the standard rates if they were not satisfied with the program. The peak price was roughly 15 percent higher than the average price that prevailed before the program and the off-peak price was 15 percent lower. In 2002, the second year of the program, customers were charged a monthly fee of $1 per month for meter-reading costs. The results of PSE's quarterly report revealed that the 94 percent of the customers paid an extra $0.80 (the total of $0.20 power savings and $1 meter reading costs) by participating in the pilot. This was in contrast with the first year results where customers were not charged meter reading costs and around 55 percent of them experienced bill savings. As a result of customer dissatisfaction and negative media coverage, PSE ceased its TOU program. Following are several lessons that were derived from this experience:

[31] Faruqui, A., S. S. George. 2003. "Demise of PSE's TOU Program Imparts Lessons." Electric Light & Power Vol. 81.01:14-15.

- Modest price differentials between peak and off-peak may induce customers to shift their load if they are accompanied with unusual circumstances such as the energy crisis of 2000-2001 in the West. An independent analysis of the program found that the customers lowered peak usage by five percent per month over a 15 month period, with reductions being slightly higher in the winter months and slightly lower in the summer months.
- It is important to provide the customers with accurate expectations about their bill savings.
- It is essential to offer a pilot program before implementing a full-scale program.

WASHINGTON- THE OLYMPIC PENINSULA PROJECT[32]

The Olympic Peninsula Project was a component of the Pacific Northwest GridWise Testbed Demonstration that took place in Washington and was led by the Pacific Northwest National Laboratory (PNNL). The Peninsula Project tested whether automated two-way communication systems between grid and passive resources (i.e., end use loads and idle distributed generation) and the use of price signals as instruments would be effective in reducing the stress on the system. Our review focuses on the residential response and does not cover the impacts associated with the distributed generation resources.

By the end of 2005, the project recruited participants with the assistance of the local utility companies. The project received a mailing list from the utilities of the potential participants who had high-speed internet, electric HVAC systems, electric water heater, and electric dryer. Letters were mailed to these customers to recruit potential participants. At the end of the recruiting process, 112 homes were installed with the two-way communication equipments that allowed utilities to send the market price signals to the consumers and allowed consumers to pre-program their demand response preferences. These residential participants were then evenly divided into three treatment groups and a control group. Equipment was also installed in the control group homes but they were given no additional information.

Each treatment group was assigned to one of the three electricity contracts:

- Fixed-prices: prices remained constant at all times.

[32] Pacific Northwest National Laboratory. “Pacific Northwest GridWise Testbed Demonstration Projects Part 1: Olympic Peninsula Project”, 2007.

- Time-of-use/critical peak prices (TOU/CPP): prices differed between peak and off-peak time periods. Peak price were much higher during critical peak days.
- Real time prices: prices under this contract were unpredictable and varied every five minutes. Participants in this contract responded to real time prices by pre-setting their appliance controls for their preferences through the web but they still had the option to override their preferences at any time.

Table 29 shows the prices that prevailed under fixed price and TOU/CPP contracts.

Table 29- Experimental Rate Design

Contract	Season	Period	Charge	Applicable
Time-of-Use/ CPP	Spring (1 Apr-24 Jul) and Fall/Winter (1 Oct-31 Mar)	Off-peak	$0.04119/kWh	9 am-6pm and 9pm-6am
		On-peak	$0.1215/kWh	6am-9am and 6pm-9pm
		Critical	$0.35/kWh	Not called
	Summer (25 Jul- 30 Sep)	Off-peak	$0.05/kWh	9am-3pm
		On-peak	$0.135/kWh	3pm-9pm
		Critical	$0.35/kWh	When called
Fixed-Price	All seasons	All day	$0.081/kWh	All hours

Results from the pilot are as follows:

- The fixed-price group saved two percent on their average monthly bill compared to the control group; the time-of-use pricing group saved 30 percent and the real time pricing group saved 27 percent.
- Differences in average energy consumption between the contract groups were small but statistically significant. The time-of-use group consumed 21 percent less energy and achieved conservation benefits from time-of-use pricing. The real time group consumed as much as the control group. The fixed-price group used four percent more energy than the control group. The usage comparison across the contract groups is presented in Table 30.

Table 30- Average Daily Energy Consumption per Home (April 06- December 06)

Contract Type	Average Daily Energy Consumption (kWh)	Standard Deviation(kWh)	Percentage Difference (compared to the control)
Control	47	24	0%
Fixed	49	22	4%
Time-of-Use	39	29	-21%
Real-Time	47	26	0%

- Examination of the residential load shapes by contract and season revealed that the time-of-use/CPP contract was the most effective design at reducing the peak-demand.
- On average, the real-time contract did not bring the lowest average peak demand. This is explained by the fact that the real-time pricing induces the response when it is most needed, during a relatively small portion of all hours. Nevertheless, real-time prices were effective at reducing congestion peaks.

Variation of the Demand Response Impacts

Our review of the 17 pricing experiments reveals that the demand response impacts from different pilot programs vary widely due to the difference in the rate designs tested, use of enabling technologies, ownership of central air conditioning and more generally, due to the variations in sample design. To summarize the information, we have constructed a dataset of 28 observations where the impacts are grouped with respect to the rate designs and the existence of an enabling technology. Table 31 provides the mean impact estimates and the 95% confidence intervals associated with the mean values from this dataset.

Table 31- Summary Statistics for Impact Estimates

Rate Design	Number of Observations	Mean	95% Lower Bound	95% Upper Bound	Min	Max
TOU	5	0.04	0.03	0.06	0.02	0.06
TOU w/ Technology	4	0.26	0.21	0.30	0.21	0.32
PTR	3	0.13	0.08	0.18	0.09	0.18
CPP	8	0.17	0.13	0.20	0.12	0.25
CPP w/ Technology	8	0.36	0.27	0.44	0.16	0.51

Notes:

1- Confidence intervals are calculated assuming normal distribution of the impact estimates.

2- Xcel Energy pilot results are excluded from the summary statistics due to the role of self-selection bias, as reported in the study, in driving the large demand impacts.

3- CPP impact for Idaho is also excluded from the summary statistics since it is an outlier.

On average, TOU programs are associated with four percent reduction in peak usage, with a 95 percent confidence interval of three to six percent. CPP programs reduce peak usage by 17 percent on average with a 95 confidence interval of 13 to 20 percent. In the same fashion, CPP programs supported with enabling technologies reduce peak usage by 36 percent on average with a 95 confidence interval of 27 to 44 percent. Average peak reduction impacts associated with PTR and TOU supported with enabling technology programs are also provided in Table 31, however these numbers should be interpreted with caution due to small number of observations underlying the distributions. Nine out of twelve impact estimates with enabling technologies are tested on the customers with CAC ownership, so these impacts also capture impacts due to CAC ownership to some extent.

Our survey finds that in addition to a wide variation among the impact estimates across different rate designs, the impacts also vary widely among the experiments using the same time varying rate concepts. Differences in the rate designs tested and heterogeneity of the experimental designs emerge as the main drivers of this wide variation. It is also important to note that these impacts are induced by the price elasticities of the customers. In simple terms, demand impacts are obtained by the multiplication of the price elasticity of demand and the percent price change relative to the existing rate. Therefore, the variation in the price elasticities of the customers in different regions together with the differences in relative prices help explain this spread in the impact estimates from different programs. Substitution elasticities from the pilots reviewed in this paper ranges from -0.07 to -0.40 while the own price elasticities range from -0.02 to -0.10. Availability of the enabling technologies, ownership of central air conditioning and the type of the days examined (weekend vs. weekday) are some of the factors that lead to variations in the demand elasticities.

Another interesting question is how the impact estimates vary for different critical peak prices. To address this question, we have simulated the demand response to increasing levels of critical prices using the California SPP experiment data and the PRISM (Price Impact Simulation Model).

The PRISM[33] model predicts the changes in electricity usage that are induced by time-varying rates by utilizing the parameter estimates of a constant elasticity of substitution (CES) demand system[34]. This demand system consists of two equations. The substitution equation predicts the ratio of peak to off-peak quantities as a function of the ratio of peak to off-peak prices and other factors. The daily energy usage equation predicts the daily electricity usage as a function of daily price and other factors. Once the demand system is estimated, the resulting equations are solved to determine the changes in electricity usage associated with a time-varying rate. PRISM has the capability to predict these changes for peak and off-peak hours for both critical and non-critical peak days. Moreover, PRISM allows predictions to vary by other exogenous factor such as the saturation of central air conditioning and variations in climate. The model can be set to demonstrate these impacts on different customer types.

Since we would like to determine how the usage impacts vary as the critical prices are increased gradually, we have run the PRISM model using the data points provided in Table 32. To clarify how PRISM models the relationship between the prices and the percentage impact on load in a non-linear fashion, consider the following example. For the average customer, peak period energy usage decreases by 4% when the peak-price increases from $0.13 per kWh to $0.23 per kWh. However, peak period energy usage decreases by only 8% when the peak price is increased from $0.13 per kWh to $0.43 per kWh. This example demonstrates that the load impact increases by one-fold (rather than two-fold) when the price increases by two-fold. We can also observe the differences between customer types in their price-responsiveness from these response curves. For a given price increase, Non-CAC customers (without CAC ownership) are the least responsive group while CAC customers (with CAC Ownership) are the most responsive.

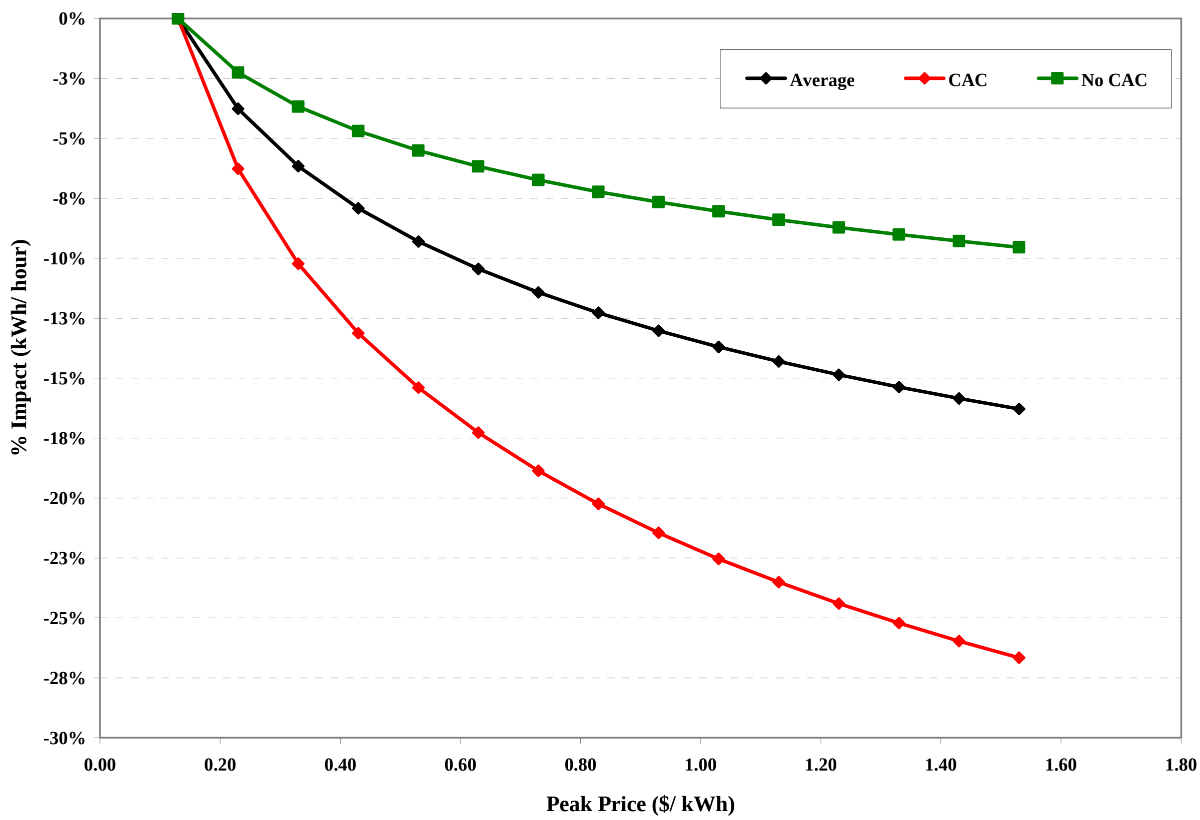
Table 32- PRISM Impact Simulation

[33] PRISM emerged from the data collected during the 2003-2005 California Statewide Pricing Pilot (SPP).

34 For the description of the CES model, see Charles River Associates, “Impact Evaluation of the California Statewide Pricing Pilot,” March 2005.

	% Reduction in Quantity		
Critical Price (cents/kWh)	**Average Customer**	**Customer w/ CAC**	**Customer w/o CAC**
0.13	0.0%	0.0%	0.0%
0.23	-3.8%	-6.3%	-2.3%
0.33	-6.2%	-10.2%	-3.7%
0.43	-7.9%	-13.1%	-4.7%
0.53	-9.3%	-15.4%	-5.5%
0.63	-10.4%	-17.3%	-6.2%
0.73	-11.4%	-18.9%	-6.7%
0.83	-12.3%	-20.2%	-7.2%
0.93	-13.0%	-21.5%	-7.7%
1.03	-13.7%	-22.5%	-8.0%
1.13	-14.3%	-23.5%	-8.4%
1.23	-14.9%	-24.4%	-8.7%
1.33	-15.4%	-25.2%	-9.0%
1.43	-15.8%	-26.0%	-9.3%
1.53	-16.3%	-26.7%	-9.5%

Figure 2- Residential Customer Peak Response Curves on Critical Days



The response curves in Figure 2 demonstrate how the percent impact on peak period energy usage varies with the peak-period price on critical days. These curves show that the percentage impact on the peak period energy usage increases as prices increase, but at a decreasing rate. This non-linear relation between usage impacts and prices is reflected in the concave shape of the response curves.

CONCLUSIONS

This article reviews the most recent evidence on the effectiveness of residential demand response dynamic pricing programs in the United States and elsewhere. We find that demand responses vary from modest to substantial, largely depending on the time-varying rates used in the experiments and the availability of enabling technologies integrated into the experiment designs. Across the range of experiments studied, time-of-use rates induce a drop in peak demand that ranges between three to six percent and critical-peak pricing tariffs lead to a drop in peak demand of 13 to 20 percent. When accompanied with enabling technologies, the latter set of tariffs lead to a drop in peak demand in the 27 to 44 percent range. In summary, residential dynamic pricing designs can be effective demand side resources in reducing peak demand.

These results have important implications for the reliability and least cost operation of an electric power system facing ever increasing demand for power and surging capacity costs. Demand response programs that blend together customer education initiatives, enabling technology investments, and carefully designed time-varying rates can achieve demand impacts that can alleviate the pressure on the power system. Uncertainties involving the fuel prices and the form of a carbon pricing regime that is in the horizon emphasize the importance of the demand-side resources. Dynamic pricing regimes also incorporate some uncertainties such as the responsiveness of customers, cost of implementation and revenue impacts. However, these uncertainties can be addressed to a large extent by implementing pilot programs that produce invaluable insights for a full-scale deployment of the dynamic rates.

Table 31- Summary of the Experimental Tariffs from the Studies Reviewed

Study	Control Group Tariff	Applicable Period	Treatment Group Tariff	Applicable Period
California- Anaheim Peak Time Rebate Pricing Experiment	$0.0675/kWh $0.1102/kWh	Usage<=240kWh per month Usage>240kWh per month	**PTR/** Control group tariff **PTR/** $0.35/kWh rebate for each kWh reduction from baseline	All hours except 12a.m.- 6p.m. on CPP days 12a.m.- 6p.m. on CPP days
California- Statewide Pricing Pilot	$0.13/kWh	All hours	**TOU/** Off-peak: $0.09/kWh **TOU/** Peak: $0.22/kWh **CPP-F/** Off-peak: $0.09/kWh **CPP-F/** Peak: $0.22/kWh **CPP-F/** CPP: $0.59/kWh **CPP-V/** Off-peak: $0.10/kWh **CPP-V/** Peak: $0.22/kWh **CPP-V/** CPP: $0.65 /kWh	12a.m.- 2 p.m. and from 7 p.m. until 12a.m. weekdays, all day on weekends 2 p.m. to 7 p.m. weekdays 12a.m.- 2 p.m. and from 7 p.m. until 12a.m. weekdays, all day on weekends 2 p.m. to 7 p.m. weekdays 2 p.m. to 7 p.m. weekdays when called 12a.m.- 2 p.m. and from 7 p.m. until 12a.m. weekdays, all day on weekends 2 p.m. to 7 p.m. weekdays 2 or 5 hours during 2 p.m. to 7 p.m., weekdays when called
Florida- The Gulf Power Select Program	$0.057/kWh	All hours	**RST/** Off-peak: $0.027/kWh **RST/** Peak: $0.104/kWh **RSVP/** Off-peak: $0.035/kWh **RSVP/** Mid-peak: $0.046 /kWh **RSVP/** Peak: $0.093/kWh **RSVP/** CPP: $0.29/kWh	12 a.m.-12p.m. and 9p.m.-12a.m. 12p.m.- 9p.m. 12a.m.-6a.m. and 11p.m.-12a.m. 6a.m.-11a.m. and 8p.m.-11p.m. 11a.m.-8p.m. Assigned hours on CPP days
Idaho- Idaho Residential Pilot Program	$0.054/kWh $0.061/kWh	Usage<= 300 kWh per month Usage>300 kWh per month	**TOU/** Off-peak: $0.045/kWh **TOU/** Mid-peak: $0.061 /kWh **TOU/** On-peak: $ 0.083/kWh **CPP/** Non-CPP hours: $0.054/kWh **CPP/** CPP: $0.20/kWh	9p.m. to 7a.m. weekdays, all day on weekends 7a.m. to 1p.m. weekdays 1p.m. to 9p.m. weekdays All hours except CPP hours 5 p.m. to 9 p.m. on CPP days
Missouri- AmerenUE Residential TOU Pilot Study	-	-	**TOU/** Off-peak: $0.048/kWh **TOU/** Mid-peak: $0.075/kWh **TOU/** On-peak: $0.1831/kWh **CPP/** same as TOU except that there is a CPP component set at $0.30/kWh and peak price is decreased to $0.1675 /kWh	10p.m.–10a.m. weekdays, all day on weekends 10a.m.– 3p.m. and 7p.m.-10p.m. weekdays 3p.m. – 7p.m. weekdays CPP days when called, otherwise same as TOU

Table 31- (Cont'd) Summary of the Experimental Tariffs from the Studies Reviewed

Study	Control Group Tariff	Applicable Period	Treatment Group Tariff	Applicable Period
New Jersey- GPU Pilot	$0.12/kWh $0.153/kWh	Usage<=600kWh Usage>600kWh	**High-rate Design** **CPP/** Off-peak: $0.065/kWh **CPP/** Shoulder:$0.175/kWh **CPP/** Peak:$0.30/kWh **CPP/** Critical:$0.50/kWh **Low-rate Design** **CPP/** Off-peak:$0.09/kWh **CPP/** Shoulder:$0.125/kWh **CPP/** Peak:$0.25/kWh **CPP/** Critical:$0.50/kWh	 1a.m.-8a.m. and 9p.m.-12p.m. weekdays, all day on weekends and holidays 9a.m.-2p.m. and 7p.m.-8p.m. weekdays 3p.m.-6p.m. weekdays When called during peak period 1a.m.-8a.m. and 9p.m.-12p.m. weekdays, all day on weekends and holidays 9a.m.-2p.m. and 7p.m.-8p.m. weekdays 3p.m.-6p.m. weekdays When called during peak period
New Jersey- PSE&G Residential Pilot Program	$0.087/kWh	All hours	**CPP/** Night: $0.037/kWh **CPP/** Peak: $0.24/kWh **CPP/** CPP: $1.46/kWh	10 p.m.-9a.m. daily 1p.m.-6p.m. weekdays 1p.m.-6p.m. weekdays when called
Ontario/ Canada- Ontario Energy Board Smart Price Pilot	$0.058/kWh $0.067/kWh	Usage<= 600 kWh per month Usage>600 kWh per month	**TOU/** Off-peak: $0.035/kWh **TOU/** Mid-peak: $0.075/kWh **TOU/** On-peak: $0.105/kWh **CPP/** same as TOU except that there is a CPP component set at $0.30/kWh and off-peak price is decreased to $0.031/kWh **PTR/** same as TOU with PTR at $0.30/kWh for each kWh reduction from the baseline	10 p.m.- 7 a.m. weekdays, all day on weekends and holidays 7 a.m.- 11 a.m. and 5 p.m.- 10 p.m. weekdays 11 a.m.- 5 p.m. weekdays CPP days when called, otherwise same as TOU CPP days when called, otherwise same as TOU
Washington - Olympic Peninsula Project	-	-	**Summer** **CPP/** Off-peak:$0.05/kWh **CPP/** On-peak:$0.135/kWh **CPP/** Critical:$0.35/kWh **Fall/ Spring/ Winter** **CPP/** Off-peak:$0.04119/kWh **CPP/** On-peak:$0.1215/kWh **CPP/** Critical:$0.35/kWh **Fixed Price/** All hours:$0.081/kWh	 9 am-6pm and 9pm-6am 6am-9am and 6pm-9pm When called 9am-3pm 3pm-9pm When called All hours

Table 32- Summary of the Experimental Elasticities from the Studies Reviewed

Pilot	Program	Substitution Elasticity	Own Price Elasticity	Cross Price Elasticity
California- Statewide Pricing Pilot	CPP-F	-0.087	-0.054 (daily)	-
	CPP-V/ Track A	-0.111	-0.027 (daily)	-
	CPP-V/ Track A	-	-0.043 (weekend daily)	-
	CPP-V/ Track C	-0.154 (*)	-0.044 (daily)	-
	CPP-V/ Track C	-	-0.041 (weekend daily)	-
Illinois- The Community Energy Cooperative's Energy-Smart Pricing Plan	RTP	-	-0.047 (Overall)	-
	RTP	-	-0.069 (Overall with AC cycling)	-
	RTP	-	-0.015 (Daytime)	-
	RTP	-	-0.026 (Late daytime/evening)	-
	RTP	-	-0.02 (Daytime+high price notification)	-
	RTP	-	-0.048 (Late daytime/evening+high price notification)	-
New Jersey- PSE&G Residential Pilot Program	CPP w/ CAC	-0.069	-	-
	CPP w/o CAC	-0.063	-	-
	CPP w/ Tech.	-0.125	-	-
New Jersey- GPU Pilot		**1st Month**		
	CPP w/ Tech.	-0.306 (Overall)	-	-
	CPP w/ Tech.	-0.155, -0.166 (Peak-shoulder)	-	-
	CPP w/ Tech.	-0.395, -0.356 (Peak-off-peak)	-	-
	CPP w/ Tech.	-0.191, -0.187 (Shoulder-off-peak)	-	-
		2nd Month		
	CPP w/ Tech.	-0.295 (Overall)	-	-
	CPP w/ Tech.	-0.055, -0.06 (Peak-shoulder)	-	-
	CPP w/ Tech.	-0.407, -0.366 (Peak-off-peak)	-	-
	CPP w/ Tech.	-0.178, -0.176 (Shoulder-off-peak)	-	-
New South Wales/ Australia- Energy Australia's Network Tariff Reform	TOU	-	-0.30 to -0.38	-0.07 (Peak to shoulder)
	TOU	-	-	-0.04 (Peak to off-peak)

(*) Elasticity of substitution for CPP-Track C customers is estimated to be -0.077 and excludes the impact of technology (-0.214).
We calculated substitution elasticity including the impact of technology as -0.154 through simulation.

BIBLIOGRAPHY

Borenstein, S., M. Jaske, and A. Rosenfeld. 2002. "Dynamic Pricing, Advanced Metering and Demand Response in Electricity Markets." UCEI, Berkeley, California.

Braithwait, S. D. 2000. Residential TOU Price Response in the Presence of Interactive Communication Equipment. In *Pricing in Competitive Electricity Markets*, edited by K. Eakin and Ahmad Faruqui: Springer.

Caves, D. W., L. R. Christensen, and J. A. Herriges. 1984. "Consistency of Residential Customer Response in Time-of-Use Electricity Pricing Experiments." *Journal of Econometrics* 26:179-203.

CNT Energy. 2008. "Power Smart Pricing, 2007 Annual Report." 2008.

CRA International. 2005. "Impact Evaluation of the California Statewide Pricing Pilot." March 16, 2005.

Colebourn H. 2006. "Network Price Reform." presented at BCSE Energy Infrastructure& Sustainability Conference. December, 2006.

Comverge Inc. 2008. "ComEd Residential Real-Time Program- 2007 Annual Report." 2008.

Energy Insights Inc. 2008. "Xcel Energy TOU Pilot Final Impact Report." March, 2008.

Energy Insights Inc. 2008. "Experimental Residential Price Response Pilot Program March 2008 Update to the 2007 Final Report." March, 2008.

Faruqui, A. and J. R. Malko. 1983. "The Residential Demand for Electricity by Time-of-Use: A Survey of Twelve Experiments with Peak Load Pricing." *Energy* Vol. 8: 781-795.

Faruqui, A. and S. S. George. 2002. "The Value of Dynamic Pricing in Mass Markets." *The Electricity Journal* Vol.15.6: 45-55.

Faruqui, A. and S. S. George. 2003. "Demise of PSE's TOU Program Imparts Lessons." *Electric Light & Power* Vol. 81.01:14-15.

Faruqui, A., R. Hledik, S. Newell, and J. Pfeifenberger. 2007. "The Power of Five Percent." *The Electricity Journal* Vol. 20, Issue 8:68-77.

Idaho Power Company. 2006. "Analysis of the Residential Time-of-Day and Energy Watch Pilot Programs: Final Report." December, 2006.

Ontario Energy Board. 2007. "Ontario Energy Board Smart Price Pilot Final Report." July, 2007.

Pacific Northwest National Laboratory. 2007. "Pacific Northwest GridWise Testbed Demonstration Projects Part 1: Olympic Peninsula Project." October, 2007.

PSE&G and Summit Blue Consulting. 2007. "Final Report for the Mypower Pricing Segments Evaluation." December, 2007.

RLW Analytics. 2004. "AmerenUE Residential TOU Pilot Study Load Research Analysis: First Look Results." February, 2004.

Rocky Mountain Institute. 2006. "Automated Demand Response System Pilot, Final Report." March, 2006.

Summit Blue Consulting, LLC. 2006. "Evaluation of the 2005 Energy-Smart Pricing Plan-Final Report." August, 2006.

Summit Blue Consulting, LLC. 2006. "Evaluation of the 2006 Energy-Smart Pricing Plan-Final Report." 2007.

U.S. Department of Energy (DOE). 2006. "Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them: A Report to the United States Congress Pursuant to Section 1252 of the Energy Policy Act of 2005." February, 2006.

Voytas. R. 2006. "AmerenUE Critical Peak Pricing Pilot." presented at Demand Response Resource Center Conference, June 2006.

Wolak, F. A. 2007. "Residential Customer Response to Real-Time Pricing: Anaheim Critical Peak Pricing Experiment." UCEI and Department of Economics, Stanford and NBER.