

**OG&E Smart Study TOGETHER:**  
**Technology-Enabled Dynamic Pricing Impact Evaluation**  
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## **Abstract**

OG&E continues on its Smart Study TOGETHER to assess the impact of multiple levels of enabling technology combined with different dynamic pricing rates on a customer's energy consumption. The ultimate goal is to determine if the demand reductions achieved through a combination of price response programs, in-home technology, and energy awareness will allow OG&E to delay capital investments in incremental generation resources. Can OG&E avoid building a new 165 MW peaking unit in 2015 and a second 165 MW unit in 2016? The first two summers (2010 and 2011) of the study are complete, with data collected and analyzed for a randomized sample of over 5,000 residential customers and over 700 small business customers in participant and control groups. Exciting results include demand reductions on weekdays ranging from 6% to 58% for some hours, and from 8% to 30% for the system peak hour. Notably, customers with response enabled by a programmable communicating thermostat (PCT) reduced load more than those with only web portal or in-home display information. With the PCTs, the customers chose how they responded to different prices – there was no direct utility control. The analysis included both a difference of differences approach and a regression approach to estimate savings. In this presentation, we describe the design of the study to enable impact evaluation, present and compare results from both summers, including the how the two methods compare, and share lessons learned.

## **Background and Study Description**

The primary goal of OG&E's Smart Study TOGETHER is to assess the demand response achieved through various technologies and dynamic rate plans. The ultimate goal is to determine if the demand reductions achieved through this program will allow OG&E to delay capital investments in incremental generation resources. With a demand response of 1.3 kW per customer, and 20% residential and small commercial participation, OG&E hopes to gain roughly 210 MW of virtual generation that will contribute to this avoided generation.

The experiment is to determine the load reduction enabled by smart grid resulting from various combinations of dynamic rates and enabling technologies. OG&E is testing two rates, a time-of-use (TOU-CP) and a variable peak price (VPP-CP), both with a critical peak component for both residential and small commercial. The four technology options include a web portal, in-home display (IHD), programmable communicating thermostat (PCT), and a combination of all three. For the summer of 2011, all customers received access to the web portal, so the IHD and PCT groups have become IHD-Portal and PCT-Portal for the 2011 analysis. While estimating the average on-peak period load reduction is the most important goal of the study, we also estimate how much load has shifted to the off-peak period, and if there is an overall reduction in energy consumption.

The following guiding principals were followed throughout the planning, design, implementation, and evaluation of Smart Study TOGETHER.

- Demand Response (DR) results will be obtained through customer empowerment.
- OG&E will not utilize any direct control of customer equipment or appliances.
- Customers will be provided time differentiated pricing and be allowed to choose their balance between cost and comfort.
- Pricing (rates) will reflect true costs minimizing any subsidies within or across customer rate classes.

- It is anticipated that all future customer participation will be voluntary, thus participation in this research will also be voluntary.
- Enabling technology will be provided to customers at no cost.
- Customers will be encouraged to remain on the program for the entire length of the study and incentives may be required.
- A control group will be utilized to eliminate the impact of weather, economic conditions, fuel prices, and other non-controllable variables.
- The number of customers participating in both the study and the control group must be large enough to provide statistically significant results which can be applied to OG&E's entire customer base.
- The sample will include a cross-section of customers that correspond to the demographic makeup of OG&E's customer population, though not proportionally represented.

### Rate and Technology Options

Residential customers were offered two rates as part of Smart Study TOGETHER. Based on their random assignment, participants were offered either a Time-of-Use rate with a Critical Price option (TOU-CP) or a Variable Peak Pricing rate with a Critical Price option (VPP-CP). Customers in the control group were left on their existing standard rates.

Each rate plan tested in this experiment includes a Critical Price component, or Price Overall Provision. With a minimum of two hours notice, a critical price event can be issued to raise the price level to the critical price. A price overcall may occur at any time during the year for a period lasting not less than two hours and not more than eight hours. The maximum number of hours during any calendar year that can be designated by the Company as critical peak period hours is 120.

**TOU-CP Rate.** The TOU-CP uses the existing Residential and General Service TOU rate structure and includes the critical price component explained above. During summer 2011, all the critical price events occurred on weekdays. Table 1 below lists the TOU-CP prices.

**Table 1.** TOU-CP Prices

Price Level	Residential TOU-CP Price	Commercial TOU-CP Price	Number of days in summer 2011 at each price level
Off-peak (includes all day on weekends)	4.2¢ per kWh	4.7¢ per kWh	36
On-peak (weekdays 2:00 pm to 7:00 pm)	23¢ per kWh	30¢ per kWh	86
Critical Events	46.0¢ per kWh	60.0¢ per kWh	7 (also included in the 86 weekdays)

**VPP-CP Rate.** The VPP-CP was designed using the existing Residential TOU rate structure. The peak period price in the TOU rate is replaced with one of four variable prices explained in Table 2 below. A single price will apply to the entire five-hour on peak window each weekday. There are four defined price levels – low, standard, high, and critical – to simplify communications of price level. The prices assigned to each price level are based on the underlying Standard and TOU tariffs. Low prices, at 4.5¢ per kWh, are similar to off-peak energy prices, standard prices equate to the standard tariff summer season tail-block price, and high and critical prices reflect the peak period energy prices. The VPP-CP also includes the critical price component explained above.

The day-ahead on-peak prices for VPP-CP are communicated to the customer by 5:00 PM on the previous day via email, text message and/or voicemail. On-peak hours are from June 1 through September 30, beginning each day at 2:00 PM and ending at 7:00 PM, local time, excluding Saturdays, Sundays, Independence Day (as observed) and Labor Day. Off-peak hours are defined as all hours that are not On-peak hours. Table 2 shows the prices for the VPP-CP rate. Because the

critical events fell on different day types, the event days are also included in the count of the number of days at the various price levels.

**Table 2.** VPP-CP Prices

Price Level	Residential VPP-CP Price	Commercial VPP-CP Price	Number of days in summer 2011 at each price level
Off-peak (includes all day on weekends)	4.5¢ per kWh	5.0¢ per kWh	36
Low	4.5¢ per kWh	5.0¢ per kWh	27
Standard	11.3¢ per kWh	10.0¢ per kWh	25
High	23.0¢ per kWh	30.0¢ per kWh	28
Critical	46.0¢ per kWh	60.0¢ per kWh	6
Critical Events	46.0¢ per kWh	60.0¢ per kWh	7 (also included in the above)

**Technology Options.** OG&E is testing four technology options:

- Web portal- an energy information website providing customers with 15 minute interval data updated every 15 minutes, neighborhood comparisons, bill estimates, environmental impacts, as well as tips and tools to manage energy consumption.
- In-home display (IHD) - a countertop display providing customers with near real-time demand, estimated monthly cost and current price.
- Programmable communicating thermostat (PCT) - a customer controlled device with current pricing information which allows automation of comfort settings based on current energy prices.
- Combination of All 3- a combination of all three treatments: web portal, IHD and/or PCT

Customers that choose to participate in Smart Study TOGETHER were randomly assigned to one of the above technology configurations or to the control group.

### Experimental Design

The study used a randomized treatment/control design, with all customers randomly assigned to the eight participant groups or the control group before recruiting began. Customers were preassigned to rate/technology groups because the intent for the eventual roll-out was to offer only one combination of rate and technology, so we did not want to offer customers a choice. This allowed us to compare each rate/technology group separately with the control group, and use those results to predict what would happen if that combination of rate and technology were offered to the entire OG&E population.

For the first year recruits (those recruited before the summer of 2010), this randomization happened before smart meters were installed, so there was no pre-treatment data for either participant or control group customers. As a result, the impact for these customers was calculated using a direct load shape comparison, referred to as a first difference. For each day type, the savings was estimated as the difference between the average control group load shape for that day type and the average participant load shape for each rate/technology group.

For the second year recruits (those recruited after the end of the summer of 2010, but before the summer of 2011), the customer pool included only those with Smart meters installed by June 30, 2010, so these customers had pre-treatment data available. Because of this, a difference of differences analysis could be done, allowing for the savings during the treatment period (summer of 2011) to be adjusted based on the pre-existing differences between the participant and control groups.

A single control group was used for analysis for all eight rate/technology combinations, with a subset of that group used for the PCT groups. All PCT customers had central air conditioning, so the control group used for the PCT groups included only those customers with central AC. All PCT

group load shapes, savings shapes, consumption, and savings were estimated using this control group.

### Sample Sizes

The study was designed to recruit 240 residential customers for each rate/technology combination and 480 residential control group customers, for each of the two recruiting years. As designed, this would result in 2,400 customers for each year, for a total of 4,800 residential customers. The target for the commercial customers in the second recruiting year was 66 customers for each rate/technology group, and 132 control group customers, for a total of 660 customers. There were more customers recruited in total than targeted, but as is always the case, some had to be excluded because of data problems or other difficulties. The actual sample sizes used in the analysis are shown in Table 3, Table 4, and Table 5.

**Table 3.** First Year Recruits, Residential Sample as Used in Analysis

	Control	TOU-CP	VPP-CP	Total
Control	488			488
Web Portal		255	261	516
IHD		217	210	427
PCT		191	200	391
All 3		218	218	436
<b>Total</b>	<b>488</b>	<b>881</b>	<b>889</b>	<b>2,258</b>

**Table 4.** Second Year Recruits, Residential Sample as Used in Analysis

	Control	TOU-CP	VPP-CP	Total
Control	511			511
Web Portal		273	298	571
IHD		223	232	455
PCT		221	227	448
All 3		212	215	427
<b>Total</b>	<b>511</b>	<b>929</b>	<b>972</b>	<b>2,412</b>

**Table 5.** Second Year Recruits, Commercial Sample as Used in Analysis

	Control	TOU-CP	VPP-CP	Total
Control	239			239
Web Portal		98	101	199
IHD		48	46	94
PCT		46	36	82
All 3		51	47	98
<b>Total</b>	<b>239</b>	<b>243</b>	<b>230</b>	<b>712</b>

### Events

In 2011, there were 7 event days called, with varying lengths and varying advance notice times. Four were called on days that had already been set as VPP high price days and one each on VPP critical, standard, and low price days. Five of the seven event days had high temperatures over 100°F with only one mild day, which had a high temperature of only 86°F.

## Results

After reviewing the results across two years of recruiting, two rates, and four technology options, OG&E is implementing a larger program using the VPP-CP rate enabled with a PCT. This combination provided the ability to use pricing to reduce load on multiple days as needed, and to lower the system peak when used with appropriately-timed event calling.

We include highlights of the savings estimates and the load shape graphs here, with the focus on the results for the residential second year recruits, which had pre-treatment interval data available. The full report includes all the results, and is listed in the References section. Table 6 shows the kWh consumption change for the TOU-CP customers on the average non-event weekday, and for the VPP-CP customers on the average high-priced and critical-priced non-event weekdays, based on the difference of differences analysis. As discussed above, the PCT group included only customers with Central AC, and so the control group for that technology includes only customers with Central AC, which results in a different baseline.

**Table 6.** Change in Consumption by Time Period, Residential Second Year Recruits

	On-Peak Consumption (kWh)			Off-Peak Consumption (kWh)		
	Baseline	Change	% Change	Baseline	Change	% Change
TOU-CP Weekday Non-Event						
Web Portal	15.63	-1.41	-9.04%	38.04	-0.52	-1.37%
IHD&Portal	15.62	-1.09	-7.00%	38.74	-0.29	-0.76%
PCT&Portal	16.25	-4.18	-25.73%	39.36	0.89	2.27%
All 3	16.43	-3.54	-21.52%	40.93	0.78	1.92%
VPP-CP High Weekday Non-Event						
Web Portal	18.82	-1.39	-7.38%	47.27	-0.22	-0.46%
IHD&Portal	18.17	-1.19	-6.54%	44.99	0.08	0.17%
PCT&Portal	19.27	-4.73	-24.53%	47.49	2.37	4.98%
All 3	18.65	-4.02	-21.57%	46.09	1.41	3.05%
VPP-CP Critical Weekday Non-Event						
Web Portal	20.92	-1.22	-5.83%	54.74	-0.36	-0.65%
IHD&Portal	20.23	-1.24	-6.12%	51.63	1.11	2.14%
PCT&Portal	21.14	-5.78	-27.33%	53.43	4.30	8.05%
All 3	20.54	-5.51	-26.82%	52.55	2.53	4.81%

Note that in all these cases (and in all cases where price was anything but the lowest price), the PCT and All 3 groups (both with automated price response in the PCT) reduce on-peak consumption by much more than the IHD and Web Portal groups (who receive only information without automated control). Also, the VPP-CP customers with PCTs save more than the TOU-CP customers with PCTs, but it is important to note that the TOU-CP averages represent all weekdays, but the VPP-CP averages represent only a subset of days, and in the case of the high and critical price days, the hottest days.

Consumption savings are important to understand, but for a demand response program, the demand reduction during the course of the event, and particularly at the time of the peak, is the real goal. Table 7 shows both the average demand reduction across the on-peak period and the maximum demand reduction. This is the highest reduction achieved during the five on-peak hours, regardless of when it occurs. The baseline demands differ between technologies both because of the different control groups for the PCT groups, and because the hour in which the maximum demand reduction occurs differs in some cases. Note that by convention, these numbers are demand reductions, not

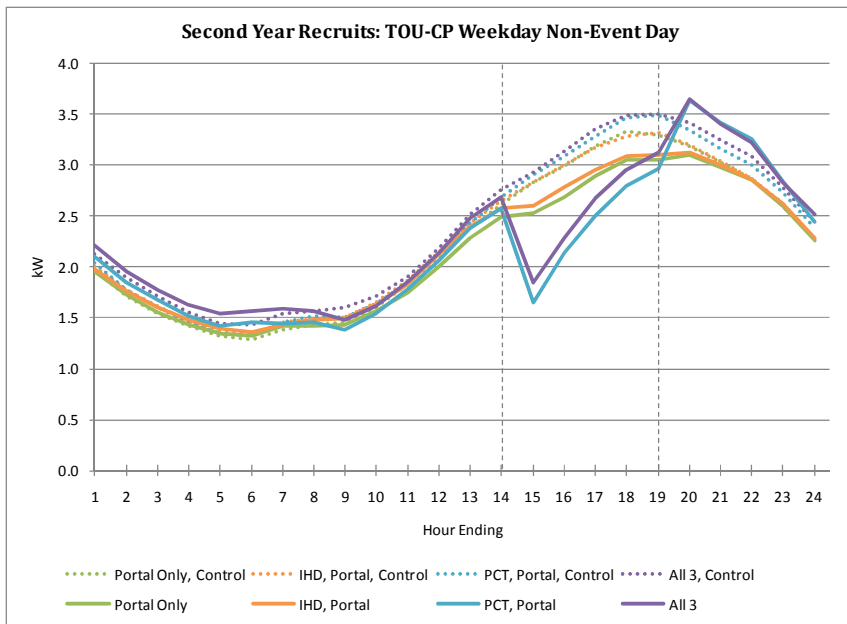
changes as are reflect in the consumption estimates in Table 6 above. A positive number here denotes a lower demand.

**Table 7.** Average Demand Reduction and Maximum Demand Reduction, Residential Second Year Recruits

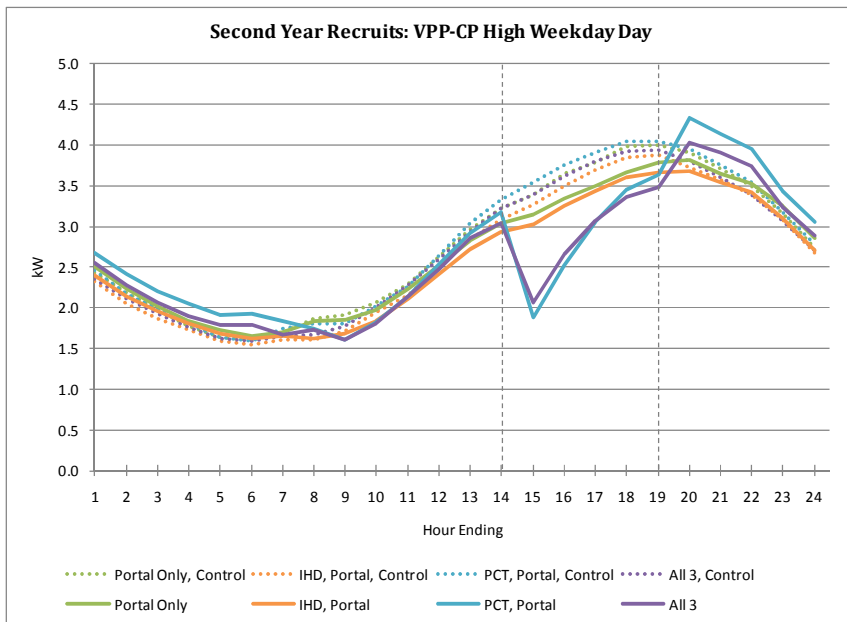
	Average On-Peak Demand			Demand at Maximum Reduction		
	Baseline	Change	% Change	Baseline	Change	% Change
TOU-CP Weekday Non-Event						
Web Portal	3.13	0.28	9.04%	2.83	0.30	10.70%
IHD&Portal	3.12	0.22	7.00%	2.83	0.23	8.12%
PCT&Portal	3.25	0.84	25.73%	2.91	1.25	42.98%
All 3	3.29	0.71	21.52%	2.93	1.09	37.00%
VPP-CP High Weekday Non-Event						
Web Portal	3.76	0.28	7.38%	3.99	0.32	7.96%
IHD&Portal	3.63	0.24	6.54%	3.70	0.26	6.90%
PCT&Portal	3.85	0.95	24.53%	3.53	1.65	46.55%
All 3	3.73	0.80	21.57%	3.38	1.32	39.01%
VPP-CP Critical Weekday Non-Event						
Web Portal	4.18	0.24	5.83%	4.32	0.29	6.83%
IHD&Portal	4.05	0.25	6.12%	3.84	0.27	7.09%
PCT&Portal	4.23	1.16	27.33%	4.02	1.97	49.09%
All 3	4.11	1.10	26.82%	3.91	1.77	45.17%

The same trends that held for the consumption reduction show up with the reduction at the maximum demand reduction, but the differences are more extreme. Participants with PCTs show significantly larger savings than the other technology groups because the maximum demand reduction for those customers with PCTs occurs at the beginning of the on-peak period, with a sharp drop in demand when the thermostats are reset based on the higher price. Then, throughout the on-peak period the savings diminish as the home warms up to the new set point and the AC units turn back on.

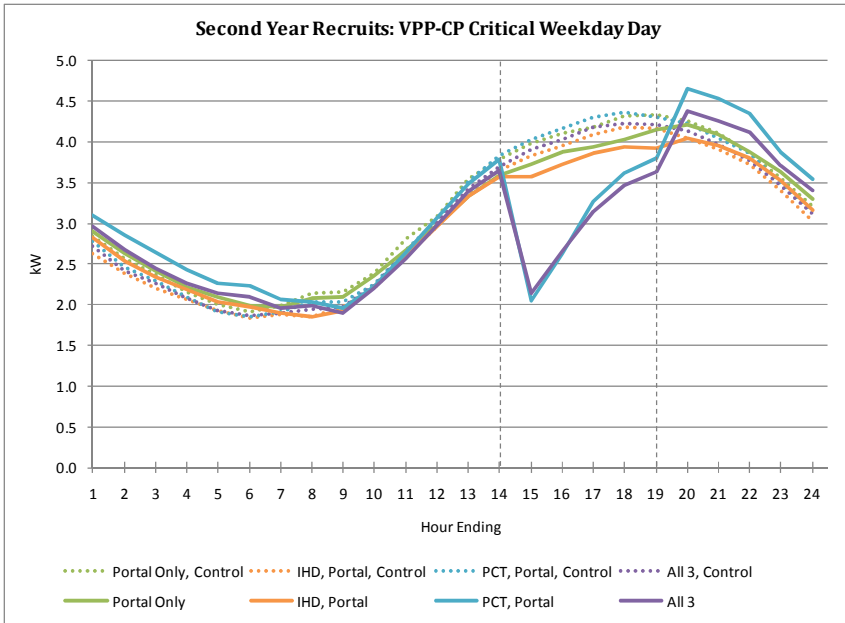
Figure 1 shows the load shapes for the adjusted control group and the participants for the four technology groups for the TOU-CP group on the average non-event weekday. The hourly savings are the difference between each participant group's average load shape and the corresponding control group's average load shape. Figure 2 shows the average load shapes for the adjusted control group and the participants for the four technology groups for the VPP-CP group on the average non-event high-priced weekday, and Figure 4 is the same graph for the average critical-priced weekday.



**Figure 1.** TOU-CP Weekday Non-Event Day



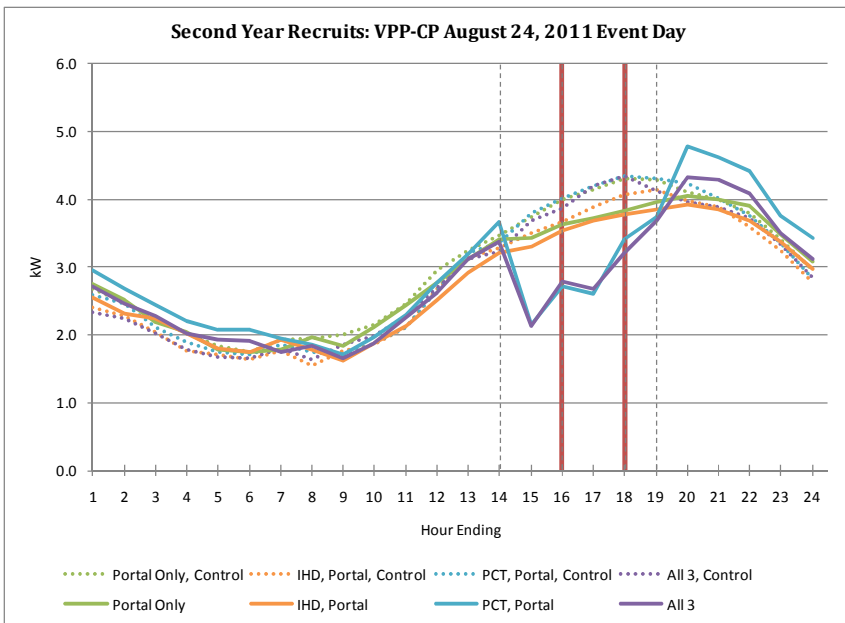
**Figure 2.** VPP-CP Weekday Non-Event Day, High Price



**Figure 3.** VPP-CP Weekday Non-Event Day, Critical Price

Note that in all cases, the two groups with PCTs (PCT with Portal and All 3) have a large drop in load at the beginning of the on-peak period, and the savings diminishes throughout the remainder of the period. The technologies that provide only information (IHD with Portal, and Portal Only) have savings that are fairly consistent throughout the on-peak period.

This creates a problem for OG&E, which has a system peak that usually occurs in the hour ending 4:00 pm or the hour ending 5:00 pm. By that time, the savings from the PCTs have decayed and there is not nearly as much load reduction available during the time of the peak, when it is really needed. . We can find a solution to this problem by looking at one of the events that was called on August 24, 2011. This was originally a high-priced day, and an event was called starting at 4:00 pm and going until 6:00 pm. The load shapes for the VPP-CP customers are shown in Figure 4.



**Figure 4.** VPP-CP August 24, 2011 Event Day, Critical Price



On this day, the customers saw the price rise from low to high at 2:00 pm, and then rise again from high to critical at 4:00 pm. This provides the solution to the decay in savings for customers with PCTs – the savings drops and then rises again when the second price increase occurs. This creates a flatter savings shape throughout the on-peak period, and particularly during the usual hours of the system peak. Looking more closely at the results, Table 8 shows the average demand reduction and the maximum demand reduction for the VPP-CP group on the August 24 event day. Note that the average and the maximum are much closer to each other, since the demand reduction is more consistent across the entire on-peak period.

**Table 7.** Average Demand Reduction and Maximum Demand Reduction, August 24 Event.

	Average On-Peak Demand			Demand at Maximum Reduction		
	Baseline	Change	% Change	Baseline	Change	% Change
VPP-CP August 24 Event, with High Price in the Peak Period						
Web Portal	4.06	0.42	10.28%	4.30	0.47	10.84%
IHD&Portal	3.99	0.33	8.37%	4.07	0.30	7.33%
PCT&Portal	4.23	1.39	32.75%	4.19	1.59	37.98%
All 3	4.37	1.12	25.67%	4.19	1.50	35.87%

## Conclusions and Recommendations

The most effective rate/technology combination going forward for residential customers is the VPP-CP with PCT. The VPP rate provided the highest load reduction on the hottest days, and also provides the full range of prices for OG&E to work with. On days when capacity is plentiful, there is no need for customers to reduce on-peak energy, so the low rate can be set. When capacity is short, a high or critical price can be set, and the Load reductions will be greater. The VPP-CP allows OG&E to tailor the price to the capacity. Combining the PCT with the rate automates the load reduction, giving the customer the ability to choose between the relative importance of cost and comfort, and to vary that choice across the different prices. All customers now have access to the Web Portal as well, allowing them to better understand their energy use to make further changes to save money.

With the current rates in place, in order to maximize the load reduction on the system peak day, or on any day when capacity is constrained, OG&E should set the VPP price as high, and then call a Critical Price event starting at 4:00. This will provide more continuous load reduction across the entire on-peak period, particularly at the time of the usual system peak.

In the long term, OG&E should investigate adding a “super-peak” period, probably from 4:00 pm to 6:00 pm, with a higher price than the on-peak period. This would allow the automated response of the PCTs to spread the savings more evenly over the entire on-peak period without having to call events as described above.

As a result of this Pilot, OG&E is going forward with the implementation of the program using a VPP-CP rate and the PCT enabling technology, with plans to call events as described during 2012 to maximize the demand reduction at the time of the system peak. OG&E plans to recruit 37,500 customers, targeting a demand reduction of 72 MW.

## Smart Grid Program

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## **References**

Williamson, Craig 2012. "OG&E Smart Study TOGETHER Impact Results: Auxiliary Final Report – Summer 2011." Copyright OGE Energy Corp.