TOU Rates As If Prices Mattered: Reviving an Industry Standard for Today's Utility Environment

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ABSTRACT

Like many utilities that began offering a time-of-use (TOU) rate to residential customers in the 1980s, one prominent investor-owned utility in the southeast (referred to in this paper as "SPC") has seen enrollment decline significantly, and the company is no longer actively promoting the rate. However, interest in TOU rates resurfaced as SPC sought to defer new generating capacity and provide opportunities for customers to lower electric bills in the face of rising fuel costs. In response, the utility developed a new time-differentiated rate with a shorter "peak" period, greater peak/non-peak price differential, and a critical peak price.

In designing this new rate, it was essential to provide sufficient price incentive for customers to shift load away from the peak period while also allowing active customers to reduce their bills. In order to address these objectives, Summit Blue developed a customized TOU Price Optimization Model that "optimized" peak, mid-peak, and off-peak prices such that projected bill savings were maximized even while ensuring "bill neutrality" for typical customers. Bill savings were projected to be greater than 4% for the average customer and as much as 10% for large residential customers who shift a greater share of peak load. Reductions in system peak could exceed 100 MW with less than 10% customer participation.

Many utilities are experimenting with innovative rates to provide price signals that better reflect the true cost of electric supply. This paper will present 1) the methods SPC used to design its new rate, 2) the essential design parameters of this rate, and 3) findings from the load and bill impact analyses.

Introduction

Note: The investor-owned utility that is the subject of this paper is referred to as Southern Power Company, or SPC, because the company is currently considering whether and how to approach its regulatory commission regarding a pilot TOU rate, and the analysis discussed here has been deemed proprietary.

Like many utilities that began offering a time-of-use (TOU) rate to residential customers in the 1980s, Southern Power Company (SPC) has seen enrollment decline significantly, and the company is no longer actively promoting the rate. However, interest in TOU rates resurfaced as SPC sought to defer expensive investment in new generating capacity and to provide opportunities for customers to lower electric bills in the face of rising fuel costs.

Specific drivers behind the subsequent investigation into new residential rate alternatives included the following:

- Interest in developing an alternative, more economical means of reducing summer peak loads than is possible under the company's existing direct load control program.

- Providing customers with greater opportunity to control their electric bills than is afforded under SPC's current inverted price structure.
- SPC's existing TOU rate has not attracted high levels of participation due in part to its relatively long summer on-peak period and to its two-tier pricing structure with relatively little price differential (less than 5 ¢/kWh difference between peak and off-peak rates).
- An initial investigation of new TOU rates by SPC found that the "rebound" (increase in load) after the end of a TOU peak period may offset any peak load reductions.
- Recent utility experience with time-differentiated rates across the country suggested that peak load reductions and customer bill savings were possible with a properly designed rate structure.

Many utilities throughout the United States have recently piloted time-based rates that differ significantly from the common two- and three-tier time-of-use structures that utilities, including SPC, have been offering for several decades. These innovative rate structures commonly include features such as critical peak prices (*i.e.*, extremely high prices for several hours on a few select days) and hourly prices set a day in advance (E3, 2006). Some of these new rate structures have provided significant peak load reductions to the utilities as well as modest bill savings for participants. In light of these reports, SPC hoped to learn from other utilities' experiences and assess whether the company and its customers could benefit from a modification of the existing TOU tariff.

Rate Design Alternatives: Learning from Utility Experience with TOU Rates

The passage of the 2005 Energy Policy Act (EPAct) has encouraged a number of state commissions and utilities to initiate pricing pilots incorporating innovative attributes. These can provide a starting point for developing rate options that can be screened against SPC's specific situation to identify promising alternatives. Time-differentiated pricing has evolved from simple two-tier TOU rates to rate structures that offer customers more choice and are better aligned with utilities' costs of serving load. While the myriad program types can be categorized in many different ways, programs have been grouped into the following categories for the purpose of discussion of a potential new residential tariff:

- **Time-of-Use rates** characterized by a finite number of discrete pricing periods throughout each day, with fixed prices within each period;
- **Critical Peak Pricing**, a variation of TOU rates, but with an additional, higher-priced period in effect during select "events" as called by the utility for reliability or economic purposes;[1]
- **Day-Ahead Hourly rates**, a form of "real-time pricing" in which prices typically vary each hour and are established one day ahead of the time that the prices are in effect.

[1] Given that one objective of time-differentiated rates is reduction of peak loads, some utilities are creating pricing programs that are only in effect during critical-event days, either through higher prices during "critical" hours or through bill credits based on verified load reductions during the events. However, these types of programs are less common and have only recently been tested. As a result, there is limited information on the long term effects of an "event-based" critical peak pricing rate.

This paper is focused on TOU rates and critical peak pricing. Day-ahead hourly rates and other real time pricing approaches are not addressed further.

Time-of-Use (TOU) Rates

This category of pricing programs describes SPC's existing TOU rate and is characterized by a finite number of discrete pricing periods throughout each day, with fixed prices within each period. The highest price, set above standard rates, is assigned to the "peak" period, which corresponds to hours with a relatively high demand and cost of supply, while the off-peak period(s) is discounted from the standard rate. The periods often vary weekday versus weekend and summer versus winter season.

TOU rates have been offered by U.S. utilities since at least the 1970s and are themselves not a new, innovative rate. However, *TOU rates developed in recent years typically are different from those of the past in several important ways*:

- **Most new TOU rates contain three price tiers**, as opposed to the two-tier rates that are common in many long-standing TOU programs, including SPC's. This allows the utilities to set high prices during their highest peak periods and offer exceptionally low off-peak prices overnight when the cost of electricity supply is at its lowest and supply is plentiful relative to demand. The majority of hours are assigned a "mid-peak" price that is typically a small discount to the standard rate.
- **The duration of the peak period is typically shorter than in the past.** Whereas older TOU rates average about 10 hours on peak, most new TOU rates assign peak periods of approximately are five to seven hours in duration.[2] Figure 1 illustrates the start and end times of peak periods for residential TOU programs at 60 U.S. utilities. SPC's nine-hour peak period is about average, and its noon to 9 p.m. start and end times are somewhat later in the day than most utilities. Figure 2 presents this same information but for six residential TOU rates introduced in the past six years, plus SPC's current TOU rate.[3] By these more recent standards, SPC's nine-hour peak may be considered long, although the company's flat summer peak-day load shape may warrant a longer peak period than other utilities.

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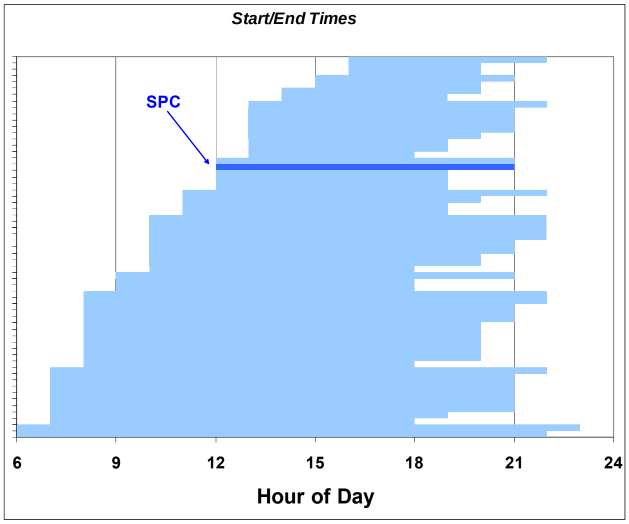
[2] Many new TOU rates structures are part of critical peak pricing programs, discussed below. But even Arizona Public Service Company, which has a participation rate of over 40% in its longstanding TOU program, introduced a new TOU rate option in 2006 that shortens the peak period from 12 hours to seven hours. APS' objective is to experiment with a more "aggressive" rate with shorter on-peak hours and a higher on-peak to off-peak price ratio. Source: Chuck Miessner, Rate and Regulatory Advisor, APS.

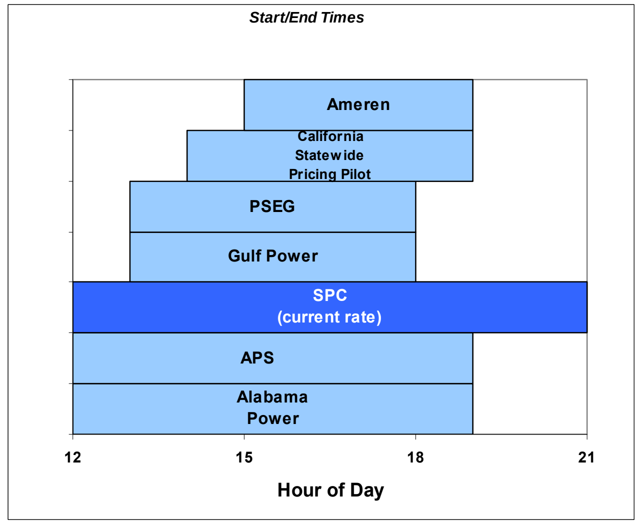
[3] These recently adopted TOU rates, some of which are/were pilot programs only, include a critical peak price (with the exception of APS' new TOU offering) that is higher than the standard peak price and that is in effect only when called by the utility and only for a limited number of hours each year. Critical peak pricing rates are discussed below.

Figure 1. Peak Periods in Utility TOU Rates



Source: TOU tariffs from 60 U.S. utilities

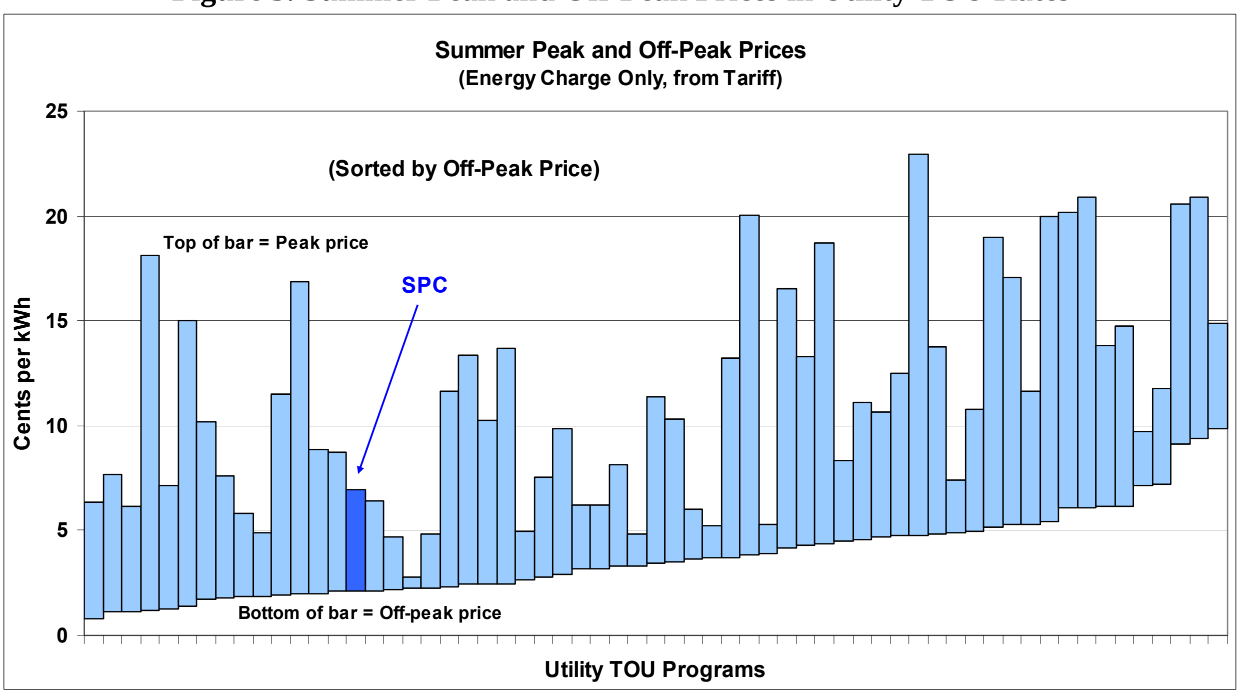
Figure 2. Peak Periods in New TOU Rates



Source: Utility tariffs and promotional materials

- **The price differentials between peak and off-peak prices tend to be greater than in the past** to encourage load shifting away from the peak period. For longstanding TOU rates (*i.e.*, TOU-only rates with no critical peak price) this differential averaged about 7.6 cents/kWh, whereas newer programs tend to have a differential of greater than 10 cents/kWh. SPC's 4.8 cents/kWh differential is somewhat low even by the standards of older rate structures (Figure 3), and most new rates are designed with peak prices at least 10 cents/kWh greater than off-peak prices (see Figure 4 in the discussion of critical peak pricing).

Figure 3. Summer Peak and Off-Peak Prices in Utility TOU Rates



Source: TOU tariffs from 61 U.S. utilities

Critical Peak Pricing (CPP)

The most common CPP rates are a variation of TOU rates, but with an additional, higher-priced period that is in effect during select "events" as called by the utility for reliability or economic purposes. A CPP rate can also be added on top of virtually any other rate structure (including day-ahead hourly pricing or even a flat rate) in order to create a price signal during a system emergency that was not forecast the previous day.

The benefit of a CPP rate over a standard TOU rate is that an extreme price signal can be sent to customers for a limited number of events when SPC requires load curtailments to complement its existing load control programs. Demand reductions during these events are typically greater than during a TOU peak period of the same duration, as demonstrated in several programs and pilots across the country (Table 1).

Table 1. Load Reductions During CPP Events and TOU Peak Periods

	% Reduction in Demand[a]		
Utility/Program	**CPP Events**	**TOU Peak Periods**	**Source**
Gulf Power	41%	22%	Borenstein *et al.*, 2002
California Statewide Pricing Pilot (SPP)	13% - 27%	5% - 16%	CRA 2005; CEC 2006
California SPP (ADRS) [b]	51%	32%	RMI 2006
Ameren	13% - 24%	2% - 3%	Voytas 2006
PSEG	>30%	12% - 18%	Summit Blue 2006
Puget Sound Energy (PSE)	n/a	5%	IEA 2005

[a] The percent reduction in demand is the average reduction over the duration of the CPP event or TOU peak period, calculated as the total kWh reduced over the period divided by the number of hours in the period. Gulf Power and PSE results are for winter peaks.

[b] ADRS is the Automated Demand Response System. This was a follow-on to the original California Statewide Pricing Pilot that tested the impact of automated controls (e.g., smart thermostats and load control switches) on high-consumption residential customers ability to reduce loads during CPP events and peak price periods.

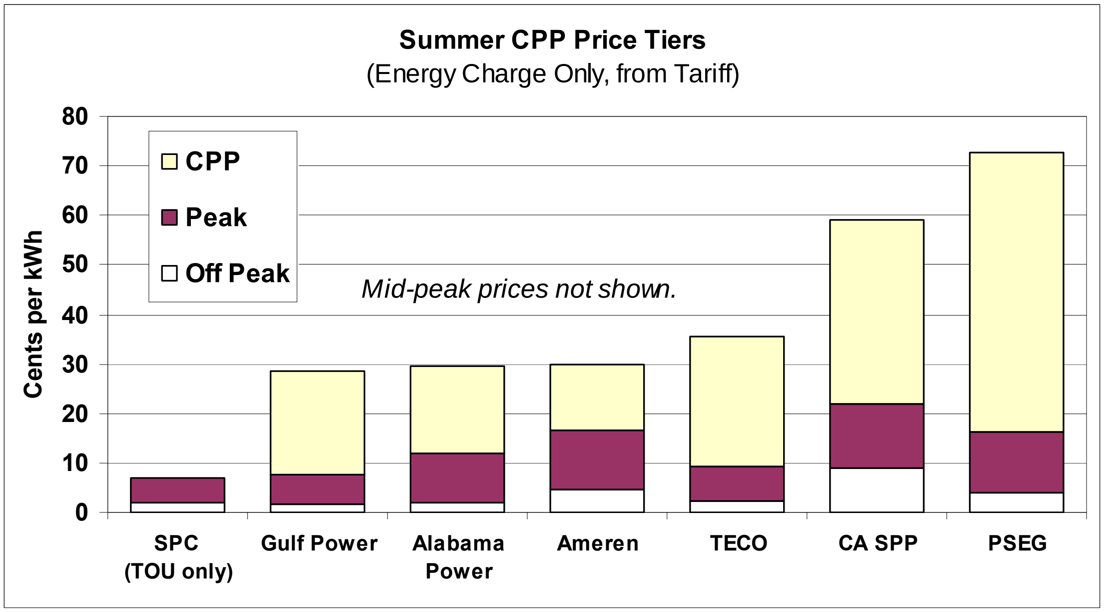
Several factors explain the increase in demand reduction from CPP:

1. Customers under CPP rates are often equipped with automated controls (*e.g.*, radio frequency switches and communicating thermostats) that are triggered in a manner similar to SPC's load management program.
2. The higher CPP rate serves as an incentive for customers to shift load away from the CPP event period.
3. The relative rarity of CPP events may encourage short-term behavioral changes resulting in reduced consumption during the events.

Most of the recently adopted TOU rates discussed above include a critical peak component and are typically referred to as "critical peak pricing programs" or "CPP rates." The underlying peak periods from these relatively new CPP rates were presented above in Figure 2 and tend to be shorter than typical TOU rates designed in the 1970s and 1980s. The underlying on- and off-peak prices for the newly introduced CPP rates are presented in Figure 4, along with prices for SPC's current TOU rate.

With CPP, the effective peak price on a select number of "event" days is much higher than the standard peak price and is often at or above 30 cents/kWh. The inclusion of the CPP price tier clearly illustrates that the on- and off-peak price differential in SPC's TOU rate structure is quite small compared to that of other utilities.

Figure 4. Summer Prices from New CPP Rates



Source: Utility tariffs, promotional materials, and public reports

The review of utility programs employing TOU and CPP rates provided an indication of the range of prices that might be appropriate to encourage load shifting and result in lower customer bills. But it was necessary to customize prices in accordance with SPC's standard rates and with SPC customers' unique load shape characteristics. Each of these factors influences customer bill savings, and they must be incorporated into the determination of TOU/CPP prices in order that a new rate deliver the desired load reductions and bill savings.

The next section discusses the TOU price optimization model developed for this assignment and how it was used to determine TOU prices that are expected to allow for maximum customer bill savings[4] while ensuring "bill neutrality" for customers on the new rate who do not change consumption patterns.

[4] The importance of ensuring that a TOU rate enables customer bill savings is underscored by the experience of Puget Sound Energy (PSE). PSE began a TOU pilot in 2001 with over 200,000 customers moving from flat rates to TOU rates where the peak prices were just 1 cent/kWh greater than the mid-day prices. Despite peak load reductions of approximately 5% in the first year, 90% of customers saved less than the $1 per month metering surcharge, and the pilot was terminated the following year (FERC, 2006).

Price Optimization Model

Short of offering a new tariff to all customers, the best method of determining the impact of TOU rates on customer bills is to conduct a pilot program. However, bill impacts can be modeled to produce reasonable estimates for customers of different sizes who shift load according to assumed patterns based on the recent experience of U.S. utilities.

The TOU price optimization model developed for this assignment generates an optimal set of TOU prices for each of the TOU periods established for purposes of this analysis. The "optimal" set of prices refers to prices for peak, mid-peak, and off-peak periods that are expected to maximize participant bill savings based on a variety of inputs and subject to a variety of constraints, described below. The model itself is based on a Microsoft Excel spreadsheet containing SPC residential tariff charges and hourly load data for SPC customers. The model was designed to accept inputs for TOU periods, prices (including a critical peak price), customer size, load shifting, and other parameters in order to calculate annual kilowatt-hour consumption and electric bills under both standard residential rates and the designated TOU rate.

Data used in the model that is specific to SPC include the following:

- Residential tariff charges including the customer charge, energy and fuel, other miscellaneous charges, and the gross receipts tax.
- Hourly customer load data from 2005 for both the average residential customer and the "high consumption" load profile as defined by SPC.

Variable inputs to the model that are used in calculating changes in consumption and electric bills are described below, along with a discussion of the values used in the analysis.

TOU periods. These include starting and ending hours for peak and mid-peak periods (all other hours are considered off-peak unless a CPP event is called) for up to two unique weekday periods and one weekend period. Seasonal inputs include starting and ending months for the summer period and a unique set of peak and mid-peak hours for the winter period. The summer peak period was established to be from 2 p.m. to 7 p.m., and mid-peak and off-peak periods during the summer (the focus of the analysis) were established as presented in Figure 5.

Figure 5. Summer Time-of-Use Periods

SUMMER									2pm to 7pm															
Hour Ending ►	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6
Weekday	Mid-Peak								On-Peak					Mid-Peak				Off-Peak						
Weekend	Mid-Peak																	Off-Peak						

TOU prices. Prices can be set for off-peak, mid-peak, peak, and critical peak periods. One set of prices applies to both summer and winter, although the hours during which the prices are applicable will depend on how the periods are defined. Prices can be manually entered, but the bill savings analysis conducted for SPC determined prices using Excel's built-in Solver optimization algorithm, which established prices that maximized customer bill savings subject to the constraints identified in Table 2.[5]

Table 2. Constraints Used in Optimization of TOU Prices

Constraint Category	Constraint Value	Rationale
Off-peak price	4.0 ¢/kWh minimum	Approximates off-peak avoided costs.
Mid-peak price	9.0 ¢/kWh maximum	Ensures mid-peak discount from standard rate.
Peak price	19.6 ¢/kWh maximum	Limits maximum rate to promote customer acceptance; consistent with other utility programs.
Peak to mid-peak price ratio	2.0 minimum	Ensures reasonable differential between peak and mid-peak prices.
Difference between mid-peak price and off-peak price	+0.5 ¢/kWh	Ensures that off-peak prices are less than mid-peak prices (by at least 0.5 ¢/kWh).
Critical peak price	35.0 ¢/kWh	High price promotes peak load reductions; consistent with other utility programs.
Annual change in customer bill without change in consumption	$0.00	Ensures “bill neutrality”.

Note: Price values reflect all variable charges, including clauses.

Common sense, as well as the experience of utilities offering TOU rates, suggests a reasonable range of prices that is acceptable to customers and that could reasonably be expected to elicit the load shifting assumed in the model and described below. The values used to constrain TOU prices reflect these considerations.[6] The optimization resulted in a peak price of 19.6 ¢/kWh, which is the maximum value allowed by the constraints. This result reflects the fact that the model is intended to maximize bill savings by customers who shift load away from peak, and there is a greater opportunity for bill savings when the peak price is high, all other things equal. The relatively low off-peak price of 4.7 ¢/kWh similarly allows for greater bill savings from load shifting. This off-peak price is greater than the minimum constraint, however, since more revenues to SPC were required for the model to ensure bill neutrality. The full set of optimized prices, including all charges, is presented in Table 3.

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[5] The Microsoft Excel Solver tool is the same tool used by SPC in its non-linear programming (NLP) model for optimizing dispatch of load management resources. Solver uses the Generalized Reduced Gradient (GRG2) nonlinear optimization code developed by Leon Lasdon, University of Texas at Austin, and Allan Waren, Cleveland State University. Linear and integer problems use the simplex method with bounds on the variables, and the branch-and-bound method, implemented by John Watson and Dan Fylstra, Frontline Systems, Inc. Source: Microsoft ® Office Excel 2003.

[6] In practice, the relationship between TOU prices and customer load shifting is dynamic in that the greater the differential between peak and non-peak hours, the greater the load shifting is likely to be—all other factors held constant. High and low load shift scenarios were run to account for the uncertainty in actual load shifting, as described later in this section. A pilot program would be necessary to provide a more definitive indication of how much load shifting would occur under various pricing scenarios.

Table 3. Optimal TOU/CPP Prices for Bill Savings Analysis

TOU Period	Electricity Price *cents/kWh*
Off-peak	4.7
Mid-peak	9.0
On-peak	19.6
CPP	35.0

Note: Includes customer charge and variable charges.

Customer size. The model can be specified to perform calculations based on the hourly load data of either an average SPC customer or a customer characterized as having a high winter/ high summer load profile. The price optimization was conducted for the average customer, but bill savings were calculated for both customer groups.

Load shift characteristics. The model uses assumptions about the increase or decrease in load during each hour of the four TOU periods (including CPP events) to calculate consumption in each period. The user can specify a unique load shift percentage for each of the four periods during both weekdays and weekends over both the summer and the winter. The bill savings analysis used several load shift scenarios, which are described later in this section.

CPP events. The number of events for the bill savings analysis was designated at six per year, with an average event duration of four hours, based on SPC's expectations of calling CPP events.

Monthly customer charge. A monthly customer charge that is different from the standard tariff can be set to reflect any additional customer charge that SPC may wish to levy to pay for incremental metering or other costs. For purposes of this analysis, the charge was set at the standard tariff level.

As discussed above, the model uses the SPC-specific data and the variable inputs to calculate annual kilowatt-hour consumption and electric bills under both the current tiered residential rate and the designated TOU/CPP rate. Results are presented in a comparison table similar to Table 4, which shows results from an analysis of an average SPC customer using the inputs discussed above (and with a "base case" load shift scenario, described below).

Table 4. Bill Comparison from the Price Optimization Model

	SPC's Current Tiered Rate	Proposed TOU/CPP Rate	Difference *TOU minus Flat Rate*	
			Nominal	%
Annual Bill	$1,507	$1,443	-$64	-4.3%
Annual kWh	14,199	14,016	-184	-1.3%
Average rate: *¢/kWh*	10.6	10.3	-0.3	-3%

Note: Results are for an average SPC customer under "base case" assumptions. Bills and average rates include all customer charge and all variable charges, including the gross receipts tax.

SPC Customer Bill Savings

The price optimization model was used to determine TOU price points and assess the change in customer bills under a variety of scenarios. Prices were fixed at the "optimal" values described above, and the following parameters were changed:

Customer size. First, the load shape for the average SPC customer was used (this is the same load shape used in the initial price optimization). Next, the "high consumption load profile" was substituted, with prices and all other inputs held constant. The high-consumption customers have peak loads of more than double those of average customers (roughly 6 kW versus 2.5 kW).

Load shift characteristics. Three unique load-shift scenarios were modeled, reflecting the range of load shifting that has been observed in residential rate programs at other utilities.[7] Using a "Base Case" as the starting point, the other scenarios tested the following (Table 5):

- Fewer peak load reductions than in the Base Case and no overall conservation effect as measured in kWh consumption.
- Greater peak load reductions and greater conservation effect.

Table 5. Load-Shift Scenarios Modeled for Customer Bill Impact

Load Shift Scenario	Hourly Peak Load Reduction[a]	Hourly Load Reduction During CPP Events[a]	Net Conservation[b]
Low Shifting	10%	15%	0.0%
Base Case	**15%**	**20%**	**1.3%**
High Shifting	20%	30%	2.4%

[a] Load reductions are the percent decrease in kW load *in each hour* during peak period or CPP events.

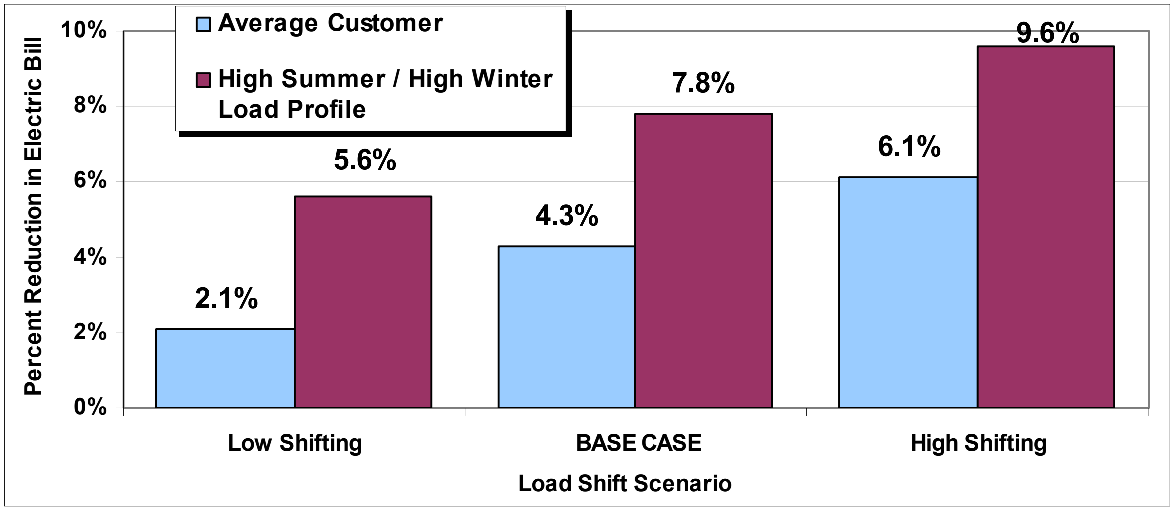
[b] Net Conservation is the reduction in kWh consumption for "average" SPC customers based on assumptions of fixed-percent changes in peak, mid-peak, and off-peak loads.

Under the proposed pricing structure, the annual electric bill of an "average" residential SPC customer participating in the program is expected to be roughly 4% less than for the same customer under SPC's standard rate. High consumption customers can expect nearly 8% savings, up to nearly 10% under the high-load-shift scenario. Bill savings for both customer types under each of the three scenarios is presented in Figure 6.

It should be noted that larger SPC customers who opt for the TOU rate are expected to see reduced bills even if they do not alter their consumption. This is a result of the fact that under the standard inverted rate, large customers are paying the higher tiered rate for a majority of their usage. However, under a TOU program, these customers would pay the peak charge for only five hours per day. The TOU rate would in effect provide a discount for what is probably higher-than-average morning and evening usage. Furthermore, their relatively high baseload consumption during the overnight hours would be charged at the lowest rate.

[7] Load shifting during TOU peak periods and CPP events was based on hourly event data from the California Statewide Pricing Pilot, as provided by the California Energy Commission, and on reported results from six programs from across the country.

Figure 6. Estimated Annual SPC Customer Bill Savings under TOU/CPP Rates



The fact that larger customers can benefit more than average customers can be viewed as an incentive for participation for this important customer segment. These customers tend to have extremely high afternoon loads, but they have little economic incentive to reduce consumption during this time. For a TOU program to successfully encourage load shifting away from peak periods, it must be attractive to those customers who arguably have the greatest opportunities to contribute to reductions in system peaks—and who certainly provide the greatest benefit for the fixed marginal costs of recruiting new participants.

It should also be noted that many participants will save more than the values that are estimated here. The assumptions used in the model are based on "average" results from other programs. By definition, perhaps half of the participants did even greater load shifting and would therefore have even greater savings. Furthermore, bill savings in the summer—when a relatively higher share of consumption is charged at the more expensive inverted tier rate under the standard tariff—will likely be much higher than the monthly average over the course of a year.

One method to allow for greater bill savings is to set rates such that even participants who do not shift load will see a reduction in their electric bills. A side benefit of this approach is that the bills of most individual "no-shift" customers are less likely to increase, which could easily happen since no customer exactly matches the average profile used in the analysis. This highlights the importance of using individual customer data, not just average data, to ensure bill neutrality for a large majority of customers. Despite the fact that ensuring bill neutrality could create free riders, the favorable rates can be viewed as a necessary incentive to participate. This approach can still be a worthwhile tradeoff if it helps make the program successful and if the benefits still exceed the costs even with the higher overall bill savings that reduce SPC revenue.

Conclusions

In SPC's quest to design a new, more effective TOU rate for residential customers, it was essential to provide sufficient price incentive for customers to shift load away from the peak period while also allowing active customers to reduce their bills. These objectives led the company to develop a customized TOU Price Optimization Model that "optimized" peak, mid-peak, and off-peak prices such that projected bill savings were maximized even while ensuring "bill neutrality" for typical customers. The peak period and rate constraints used in the model were based on findings from an investigation tariff structures used at more than 60 U.S. utilities.

The result was a candidate rate structure with a shorter "peak" period, greater peak/non-peak price differential, and a critical peak price. Bill savings were projected to be greater than 4% for the average customer and as much as 10% for large residential customers who shift a greater share of peak load. Meanwhile, typical customers who do not shift any load were projected to see no changes in their monthly bills. Furthermore, reductions in system peak during CPP events were projected to exceed 100 MW with less than 10% customer participation. These system peak savings reduce SPC system costs and can be used to finance a new tariff (*i.e.*, pay for administrative costs and the lost revenues resulting from lower electric bills).

This case study demonstrates that TOU rates with a CPP component can yield both a reduction in system peak demand and a reduction in customer bills. However, the rate must be designed to balance the need for price incentives with protections for customers who may have limited ability or willingness to shift load away from peak. This is particularly important if a new tariff is proposed for all customers, as opposed to only those who choose to adopt the new rate.

The Price Optimization Model provides a tool for any utility to assess the likely bill impacts of various TOU/CPP rates on different segments of the residential customer population. The key to customizing the analysis is utilization of customer load shapes that are unique to the utility conducting the analysis. By applying findings of the modeling analysis to screen candidate rates structures, a utility can better design new rates or pilot programs and increase the likelihood of a successful outcome that benefits the utility, participating customers, and ratepayers.

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