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Residential implementation of critical-peak pricing of electricity

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Abstract

This paper investigates how critical-peak pricing (CPP) affects households with different usage and income levels, with the goal of informing policy makers who are considering the implementation of CPP tariffs in the residential sector. Using a subset of data from the California Statewide Pricing Pilot of 2003–04, average load change during summer events, annual percent bill change, and post-experiment satisfaction ratings are calculated across six customer segments, categorized by historical usage and income levels. Findings show that high-use customers respond significantly more in kW reduction than do low-use customers, while low-use customers save significantly more in percentage reduction of annual electricity bills than do high-use customers—results that challenge the strategy of targeting only high-use customers for CPP tariffs. Across income levels, average load and bill changes were statistically indistinguishable, as were satisfaction rates—results that are compatible with a strategy of full-scale implementation of CPP rates in the residential sector. Finally, the high-use customers earning less than $50,000 annually were the most likely of the groups to see bill increases—about 5% saw bill increases of 10% or more—suggesting that any residential CPP implementation might consider targeting this customer group for increased energy efficiency efforts.

Keywords: Electricity rates; Residential electricity; Demand response

1. Introduction

Between May 2000 and June 2001, peak wholesale prices on the California spot electricity market sustained record highs, and capacity shortages were frequent. While factors leading up to the onset of the California electricity crisis are complex, there is reasonable consensus that the lack of real-time response by retail demand was a major contributor to its severity and duration (Borenstein, 2002; Jurewitz, 2002; Woo, 2001; Woo et al., 2003). Since that time, increasing real-time demand response to electricity price changes by strengthening the real-time price link between wholesale and retail markets has become an explicit policy goal at both state and national levels. In California, policy makers have set a goal for 2007 of meeting 5% of peak demand with a price-responsive load (California Energy Commission, 2004). At the national level, the Energy Policy Act of 2005 states that it is now "the policy of the United States that time-based pricing and other forms of demand response…shall be encouraged, the deployment of such technology and devices that enable electricity customers to participate in such pricing and demand response systems shall be facilitated, and unnecessary barriers to demand response participation in energy, capacity and ancillary service markets shall be eliminated".

Historically, utilities have used two strategies to reduce residential peak load: direct load-control (DLC) programs and time-of-use (TOU) tariffs. DLC programs, which have existed in California since the early 1980s, offer households recurring monthly bill credits in exchange for utility control of large electrical end uses, most commonly central air conditioning. One reason for the popularity of DLC programs is that, unlike price-based demand response programs, DLC programs are feasible with the existing metering infrastructure.

While effective in providing load relief when warranted by capacity shortage, DLC programs may be seen as inequitable for three reasons. First, DLC programs are

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voluntary, offering fixed financial incentives for unmeasured load reductions. This encourages adverse selection that results in "free riders"—participants who provide little to no load relief during load-control events, but still benefit as much as do those providing significant load reductions. Second, although customers without central air conditioning do not cause system peak demand surges on hot days, they are not eligible for program benefits. Third, when payments to participants exceed system benefits, these same customers must suffer higher electricity rates to pay for the bill savings enjoyed by the program participants.

The other common residential peak reduction strategy in use today is voluntary TOU pricing. TOU tariffs typically have high peak prices on weekday afternoons and lower off-peak prices for the remaining hours of the week. Experimentation with TOU rates in the residential sector indicates that TOU prices flatten load shapes by decreasing usage in the high-price periods and increasing usage in the low-price periods (Atkinson, 1979; Caves and Christensen, 1980; Caves et al., 1984; Herriges et al., 1984). The shortcoming of TOU tariffs is that they do not provide additional incentives to reduce demand further on days when the system is most stressed, because they reflect only long-term average expectations of daily peak marginal costs (Crew et al., 1995).

The potential shortcomings of DLC programs and TOU tariffs, combined with the decreasing cost and increasing functionality of electricity meters, have prompted growing interest in encouraging peak reductions through dynamic rates. By more closely linking short-term wholesale and retail electricity prices, tariffs based on dynamic rates provide the reliability benefits of peak load reductions, while improving the allocation of electricity procurement costs among residential customers with diverse demands (Borenstein, 2002; Braithwait and Faruqui, 2001; Hirst, 2002; Kueck et al., 2001).

More than any other retail electricity rate structure, real-time pricing (RTP) closely tracks time-dependent marginal wholesale costs. Hourly RTP tariffs have been implemented successfully for large industrial and commercial firms (Taylor et al., 2005). Notwithstanding the long-run efficiency benefits of RTP (Borenstein, 2005), policy makers generally consider hourly RTP too complex for small electricity users and are thus reluctant to allow residential customers to face the inherently volatile wholesale market. An exception to this generalization can be found in Illinois, where state legislation has recently prompted the first RTP option for residential customers (Illinois Public Utilities Act, 2006).

Where dynamic rates are being considered, but RTP is deemed infeasible for residential customers, a reasonable alternative is critical-peak pricing (CPP). CPP tariffs augment a time-invariant or TOU rate structure with a dispatchable high or "critical" price during periods of system stress. The critical price can occur for a limited number of discretionary days per year, or when system or market conditions meet pre-defined criteria. Participating customers receive notification of the dispatchable high price, typically a day in advance, and in some cases are provided with automated control technologies to support efficient load drop. Because all of the prices in a CPP rate are preset, CPP is not as economically efficient as RTP; this same characteristic, however, also makes CPP politically more appealing, because it diminishes the potentially large price risk associated with RTP.

Empirical evidence supports the view that CPP can achieve significant load reductions during critical periods. In California, households supplied with sophisticated end-use controls dropped an average of 41% of baseline load (i.e., load that would have occurred absent the CPP price signal) over 2-h hot-weather CPP events. In the absence of end-use controls, households dropped an average of 13% of baseline load over 5-h hot-weather CPP events (Herter et al., 2006).

While the effectiveness of residential CPP in California to deliver load reduction appears certain, there is an ongoing debate as to whether to implement CPP, because how to do so remains controversial. The objective of this paper is to provide empirical evidence that aids in the decision about which, if any, CPP implementation schemes might be considered for the residential sector.

The analysis described here uses data from 457 residences, determined to be representative of California households (see Appendix A), that participated in the California Statewide Pricing Pilot (SPP) of 2003 and 2004. Average load changes during summer events, annual bill changes, and post-experiment satisfaction values are calculated across six customer segments, categorized by historical usage and income level.

The analysis shows that high-use customers respond significantly more, in kW reduction, than do low-use customers, while low-use customers save significantly more, in percentage reduction of annual electricity bills, than do high-use customers. For equity reasons, these results challenge the strategy of targeting only high-use customers for CPP tariffs.

Across income levels, average load and bill changes were statistically indistinguishable, as were satisfaction rates—results that are compatible with a strategy of full-scale implementation of CPP rates in the residential sector. Finally, the high-use customers earning less than $50,000 annually were the most likely of the groups to see bill increases—about 5% saw bill increases of 10% or more—suggesting that any residential CPP implementation might consider targeting this customer group for increased energy efficiency efforts.

2. The CPP implementation problem

The three primary criteria for designing sound rate structures are capital attraction, consumer rationing, and fairness to ratepayers (Bonbright et al., 1988). Capital attraction, or meeting revenue requirements, can be accomplished through proper design of nearly any tariff