Title

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Cost-Effectiveness of Price Response in the Residential Sector: Preliminary Findings from the California Experience

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Abstract

Like many states and countries with restructured electricity industries, California is considering the use of price response to stabilize markets, improve reliability and reduce rates. An official investigation into the cost-effectiveness of advanced metering, demand response and dynamic pricing in the commercial, industrial and residential sectors is currently underway in California. Preliminary results show that some price response options are likely to be cost-effective for the residential sector. Ongoing research in California includes a statewide experiment to determine price elasticities in the residential sector, with results expected at the end of 2003. Future work will use these results in a detailed analysis of the cost-effectiveness of advanced metering and dynamic pricing in California.

Background

Traditionally, demand response programs have been reliability-driven, meaning that they are used when electricity systems are at or near emergency conditions. Over the past decade, however, restructuring of the electricity industry in California and around the world has shifted the focus of many in the field from *reliability-driven* demand response to *price-driven* demand response. Price-driven demand response, or "price response," is attained by passing the price volatility associated with wholesale electricity costs on to retail customers through dynamic rates. Price response can theoretically lower average retail rates by reducing purchases of high-priced electricity during peak demand periods and by reducing the need for payments to interruptible loads.

Residential dynamic pricing tariffs and programs are currently uncommon, but some existing examples include the GoodCents Select program in Florida and the Tempo rate in France. In California, policy-makers are currently investigating the cost-effectiveness of offering dynamic rates in all sectors, including the residential sector, where price elasticity is high relative to other sectors [1].

1. Electricity Demand, Rates and Research in California

On the West Coast of the United States, peaks in electricity demand are caused almost exclusively by air-conditioning during unusually hot weather events, which occur only a few times each summer. **Figure 1** shows daily peak loads and average maximum temperatures in the California ISO control area during the summer of 2000. As can be seen in the graph, the highest loads occur when the average temperature in the state is also high. Of the nearly 45 GW peak, 30% is due to air-conditioning load, half of which occurs in the residential sector.

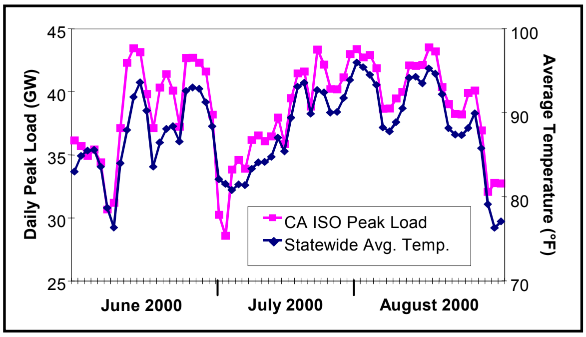

Fig. 1. Load vs. Temperature, California ISO Control Area, Summer 2000

Peak loads in California have been increasing recently with growing populations in the hot inland regions, which have high air-conditioning demand. One way to meet these peaks is to build generating units, which are relatively expensive when operated at low annual capacity factors. Peaking units may cost upwards of $500 per MWh (50¢/kWh) when operated only one or two hundred hours per year [2], a time period consistent with very high load in California. In addition, transmission and distribution systems must be sized to meet the highest possible peak loads. As a result, the marginal cost of meeting peak loads can be orders of magnitude higher than the cost of serving the average load.

For decades, load shifting and peak reductions have been accomplished in California by exposing larger customers to time of use (TOU) energy prices and on-peak demand charges, but very few residential customers face anything but flat rates. Today, 97% of Pacific Gas and Electric's residential accounts are on flat rates, while only 3% have selected TOU rates [3]. **Figure 2** illustrates hourly wholesale electricity prices in a restructured market compared to what retail customers pay under flat pricing. The lack of connection between wholesale market prices and retail rates is often cited as the major cause of the financial problems recently experienced by utilities in California [4].

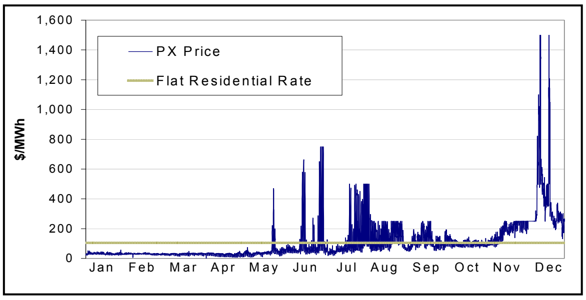

Fig. 2. 2000 California Power Exchange Prices vs. PG&E Residential Rate

Concerns over this mismatch of wholesale market prices and retail rates combined with severe electricity market problems prompted California energy agencies in 2002 to undertake an investigation into advanced metering, demand response and dynamic pricing for both large and small customers [5]. A major outcome of Phase 1 of this investigation is a decision to go forward with a statewide experiment to determine the elasticities of homes and small businesses under dynamic pricing tariffs in California [6]. Phase 2 will investigate whether and under what conditions price response is more cost effective than generation.

The California dynamic pricing experiment currently underway involves over 2000 participants spread across the three major utility service areas. The existing experimental design will test two types of dynamic rates. Both rates are based on a TOU rate that allows a high "critical" price to be dispatched for five continuous hours, up to 12 days per year. The simpler of the two allows the critical price to be dispatched only during peak hours, from 2 p.m. to 7 p.m. For this rate, customers are notified a day in advance via telephone or email. The other is a TOU rate that allows a dispatchable high price at any time of day, not just during the peak. For this second rate only, customers will have the opportunity to use responsive thermostats to automatically respond when a high-price signal is sent.

2. Dynamic Rate Design

Most rates in use today are non-dynamic or "fixed," meaning that prices have been decided for all hours, and can only be changed by changing the tariff sheets - a process that can take months or years. Such pricing structures are not capable of reflecting hourly or daily price spikes, resulting in inefficient purchasing behavior and higher overall rates. Dynamic rates, in contrast, allow short-term retail price changes on short notice. Such changes may be called in response to temporary system conditions or wholesale price spikes. Typically, customers on dynamic tariffs are given advance notice of price changes that will be in effect for one or more hours that day or the following day.

The daily price curves shown in **Figure 3** illustrate the difference between dynamic and fixed rates, and show the range of possible rate structures in each category. Note that TOU pricing is a *fixed* pricing structure, and that rates are not limited to two or three price tiers – a TOU rate with hourly or sub-hourly prices could easily be constructed. Only when discretionary price changes or "dispatchable prices" are included in the tariff can a rate be considered dynamic.

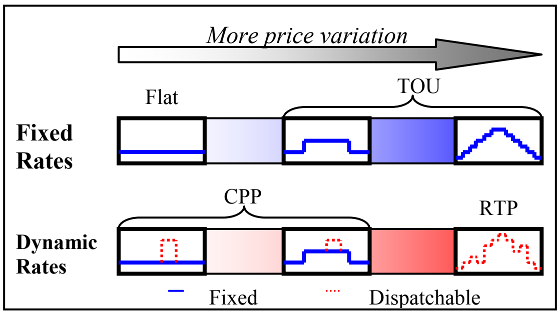

Fig. 3. Fixed vs. Dynamic Rates, Daily Price Curves

The simplest dynamic rate structure is one that allows a single predetermined but dispatchable high or "critical" price to occasionally override the default fixed rate structure – for perhaps 10-15 days annually to address wholesale price spikes or low reserve margins. More complex rate structures might allow the dispatch of one of several possible critical prices, depending on the amount of the wholesale price or severity of the system problem. Such dynamic pricing structures are often referred to as c*ritical peak pricing*, or CPP. In exchange for the exposure to high prices during critical periods, customers are offered offsetting lower prices in other periods, so customers that shift or reduce load during critical periods can benefit. CPP tariffs designed around a baseline number of critical hours also offer customers the chance to benefit when mild wholesale market prices and system conditions warrant fewer than the baseline number of critical hours.

CPP tariffs provide a better connection between wholesale and retail markets than do flat or TOU tariffs, and *real time pricing* (RTP) tariffs allow an even more direct link than do CPP tariffs. Unlike CPP prices, which are predetermined and documented in the tariff sheets, RTP prices are determined on the fly, to reflect market conditions in near real-time. “One-part” RTP tariffs charge customers the marginal cost of generation for 100% of their load. “Two-part” RTP tariffs involve a take-or-pay contract for a baseline amount, with any consumption over or under the baseline bought or sold at the marginal price. Two-part tariffs not only link wholesale and retail markets, but also satisfy utility revenue requirements by simultaneously covering long-term costs and shorter-term market purchases.

Although some load might be able to buy and sell in wholesale markets with hourly or 15-minute price changes, the cost and complexity of such participation is currently beyond the capabilities of many or most electricity customers, especially in the residential sector. However, only a fraction of load need be exposed to dynamic prices, since a large portion of expected power need is bought forward through contracts, utility generation, or futures. We know of no study that has attempted to quantify an optimal price-responsive fraction. In California, the current goal is 2500 MW or about 5% of peak load.

3. Price Response Technologies

An electricity system that allows all residential customers a dynamic tariff option requires at a minimum a system of interval meters with a sufficient number of intervals to store energy use for each measured time period. For example, a system designed to collect hourly energy use values once a month would require at least 744 data storage bins – one for each hour of the month. However, with a system-wide replacement of residential meters comes the opportunity to install a variety of additional features that would make the full metering system even more cost-effective. For example, remote meter reading is often included in new metering systems to reduce or eliminate manual meter reading costs, among other things. In fact, some studies have found that the aggregated benefits of such advanced metering systems outweigh costs – with or without the added benefits of price response – through improved operational efficiency and customer service [7][8]. Phase 2 of the California investigation of advanced metering, demand response and dynamic pricing will examine this issue.

Residential price response technologies range from simple customer notification with manual end-use control, to utility controlled switches on customer end-uses, to user-programmable control systems such as thermostats and gateways. Residential end-uses typically targeted for price response include air-conditioning, water heaters, and pool pumps. The authors' view is that customers should choose which, if any, technologies are appropriate for their homes. The utilities' role should not be to choose and provide hardware, but instead to offer technical advice and rebates where appropriate. Such a policy would parallel policies on energy efficiency technologies and encourage market innovation [9].

4. Cost Effectiveness

The barrier to comparing cost-effectiveness across resources often lies in the complexity of quantifying the various related factors. A detailed cost-benefit analysis of price response should include control technology market factors, end-use power needs, consumer behavior, electricity prices, and regional environmental and reliability issues, among many others. The analysis presented below derives very rough dollar per kilowatt-year ($/kW-yr) cost estimates from expected load response values and control technology costs. A more thorough analysis of this type will be completed in Phase 2 of the California Public Utilities Commission investigation [5].

As of the writing of this paper, summer 2003 price response data from the California pricing experiment was just being distributed among parties to the rulemaking. This data had not been properly analyzed or made publicly available. For illustrative purposes, then, we will use what appear to be similar results of Gulf Power's GoodCents Select program. All GoodCents Select participants are provided with systems to control heating, ventilation and air-conditioning (HVAC), electric water heaters and pool pumps. **Figure 4** shows that between 3 and 5 p.m., a tripling of price reduced the average residential program participant's electricity use by about 1.6 kW. Based on this value, we estimate average load drop values for major end-uses and associated control technologies as

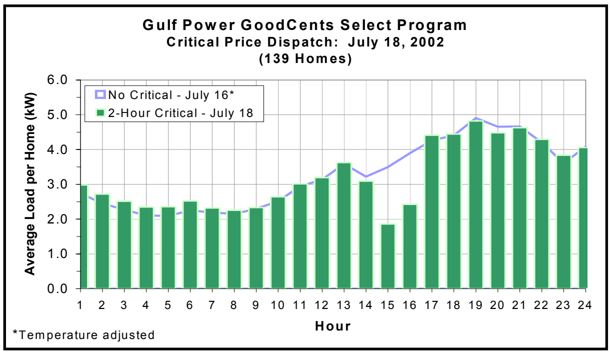

Fig. 4. Residential Load Response to Price Tripling in Gulf Power's GoodCents Select Program [10]

shown in **Table 1.** Also shown are cost estimates for each control technology, annual cost estimates and $/kW-yr values.

Table 1. Approximate Costs of Control Technologies that Facilitate Dynamic Pricing

End-use and Control Technology	Capital Cost ($)	Ongoing Costs ($/yr)	Annual Cost* ($/yr)	Expected Response (kWh/h)	Capacity Cost** ($/kW-yr)
Pool pump (switch)	$ 100	$ 24	$ 42	0.2	$ 200
Water heater (switch)	$ 100	$ 24	$ 42	0.2	$ 200
Air-Conditioner (switch)	$ 100	$ 24	$ 42	1.4	$ 30
HVAC (thermostat)	$ 200	$ 24	$ 60	1.4	$ 40
HVAC/Water Htr/Pool (gateway)	$ 800	$ 24	$ 167	1.6	$ 100

* Assumes discount rate 6% real, service life 10 years, capital recovery rate 13%
** Rounded to one significant digit

Several factors make these $/kW-yr values inappropriate for direct comparison to competing peak resources. First, assuming the customer is at home during high-priced hours, the duration of residential load response is limited by the setpoint temperature the customer is willing to endure. Simulations show that air-conditioning response to a 4-degree setpoint increase is limited to about two hours [11]. This alone may double the cost of price response, since peak generation is commonly needed for about four hours on peak days. Moreover, a properly sized residential air-conditioning unit may not be able to drop any load on very hot days.

Table 1 also fails to incorporate several potential costs and benefits. The inclusion of metering, data and billing system costs would allow consideration of a variety of utility efficiency benefits. The balance of this addition may be positive or negative, depending on the service territory and analysis methods. Inclusion of environmental factors would undoubtedly favor price response, as would customer-side operational benefits. These issues are beyond the scope of this paper, but will be considered in the California investigation.

Table 2. Costs of Competing Peak Resources

Peak Resource	$/kW-yr
Residential price response	See Table 1
New combustion turbine	$60-$90
Interruptible contracts	$70

Table 2 shows the costs of competing peak resources. To be competitive on a standard economic measure, price response options must cost under $60/kW-yr. According to Table 1, air-conditioning switches and responsive thermostats may already be competitive. Both thermostats and gateways are likely to become more competitive as the technologies mature. It remains to be seen whether inclusion of the additional costs and benefits mentioned previously will favor or be detrimental to the cost-effectiveness of price-response in the residential sector. These and other results are expected from the California investigation in late 2003.

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