Technology's Role, Rates and Customers, 1985-2016

Wisconsin Public Utility Institute
Madison, Wisconsin

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THE Brattle GROUP

A brief history of time

For over a century, electric rates for commercial and industrial customers have been comprised of three elements

- a fixed service charge to cover the costs of billing, metering and customer care;
- a demand charge to cover the costs of the distribution grid and of transmission and generation capacity costs;
- and an energy charge to cover fuel costs; this often varied by time-of-day

The cost structure of electricity is passed on to customers, promoting efficient use of energy and capacity, and promoting fairness and equity between customers

Residential rates are a totally different story

Consisting mostly of a volumetric energy charge (expressed in pennies per kWh) and a small fixed charge

- Capacity costs are buried in the volumetric charge, using the load factor of the class
- The fixed charge does not fully recover the fixed costs of serving the customer

Once in a while the energy charge varies with time-of-day and sometimes it varies across the days

This rate structure creates subsidies between customers with low load factor and those with high load factor

Rates are often explicitly subsidized for low income customers

In 1938, the British writer D. J. Bolton summed up the plight of the tariff designer

EXTRACT FROM
PREFACE TO FIRST EDITION

THERE has never been any lack of interest in the subject of electricity tariffs. Like all charges upon the consumer, they are an unfailing source of annoyance to those who pay, and of argument in those who levy them. In fact, so great is the heat aroused whenever they are discussed at institutions or in the technical press, that it has been suggested there should be a " close season " for tariff discussions. Nor does this interest exaggerate their importance. There is general agreement that appropriate tariffs are essential to any rapid development of electricity supply, and there is complete disagreement as to what constitutes an appropriate tariff.

A book on such a subject can, therefore, hardly fail to be of service. So many papers and discussions have dealt (fully or in part) with electricity costs and charges, that a mere collection and codification of all this material would of itself be well worth while. The present aim, moreover, is a somewhat more ambitious one, namely to present a fundamental and critical review of the underlying principles of rate construction, together with a quantitative statement of the tariff situation in Great Britain.

. . . .

The present tariff position in this country is little short of chaos. Even the terminology has not been standardised, and the tariffs themselves appear to be the unbridled whim of the particular undertaking. To quote only one example—taking a single load group (industrial power) and a single type of tariff (the block rate), and considering only the larger undertakings (one quarter of the whole), there were found to be 102 different tariffs ! At this rate, the block-rate tariffs alone would muster about 400 different specimens. Kipling might well have said of electricity :—

There are nine-and-sixty ways in which the user pays
And every single one of them is right.

. . . .

The Arab-Israeli War of 1973 triggered energy legislation in the US

The Public Utility Regulatory Policies Act (PURPA) was passed by Congress and became the federal law of the land in 1978

It called for state commissions to test the cost-effectiveness of time-of-use (TOU) rates

Whether the rates would involve time-variation in energy charges or demand charges was not spelled out

TOU experiments were carried out by the US Federal Energy Administration (FEA)

In 1975-76, FEA initiated 16 projects involving pricing experiments to demonstrate the potential for load management

Fourteen of the sixteen involved some 6,700 residential customers who were placed on TOU rates

The objective was to evaluate customer acceptance and demand response to TOU rates

The experiments varied in geography, experimental design, the number of rates that were tested, duration, and the number of participating customers

The Results

On average, TOU rates result in lower peak demand and somewhat higher off-peak demand

TOU rates result in some conservation of overall energy consumption

High usage customers respond more than low usage customers

Responsiveness differs across customers who own different appliances

Response does not differ between the typical weekday and the day of the system peak

DSM was so much more exciting

Leave the rates alone

Bribe customers to buy efficient equipment that they would not otherwise have bought

Given precedence to energy conservation over efficient use of grid

Pricing designers sleepwalked their way through the 1980s and 1990s

A second oil shock came in 1979

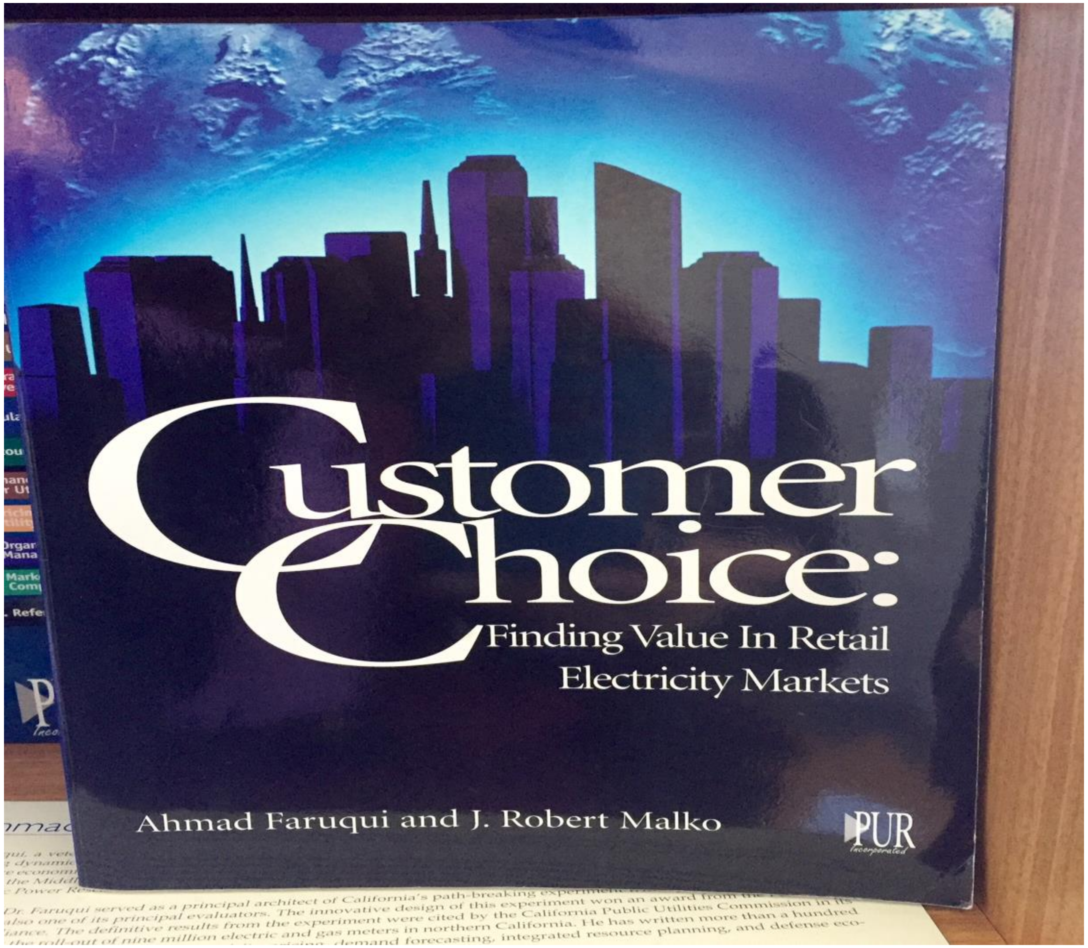
Concerns about rising bills brought about a “second wind” to DSM

The industry discovered restructuring: the market would solve the problem

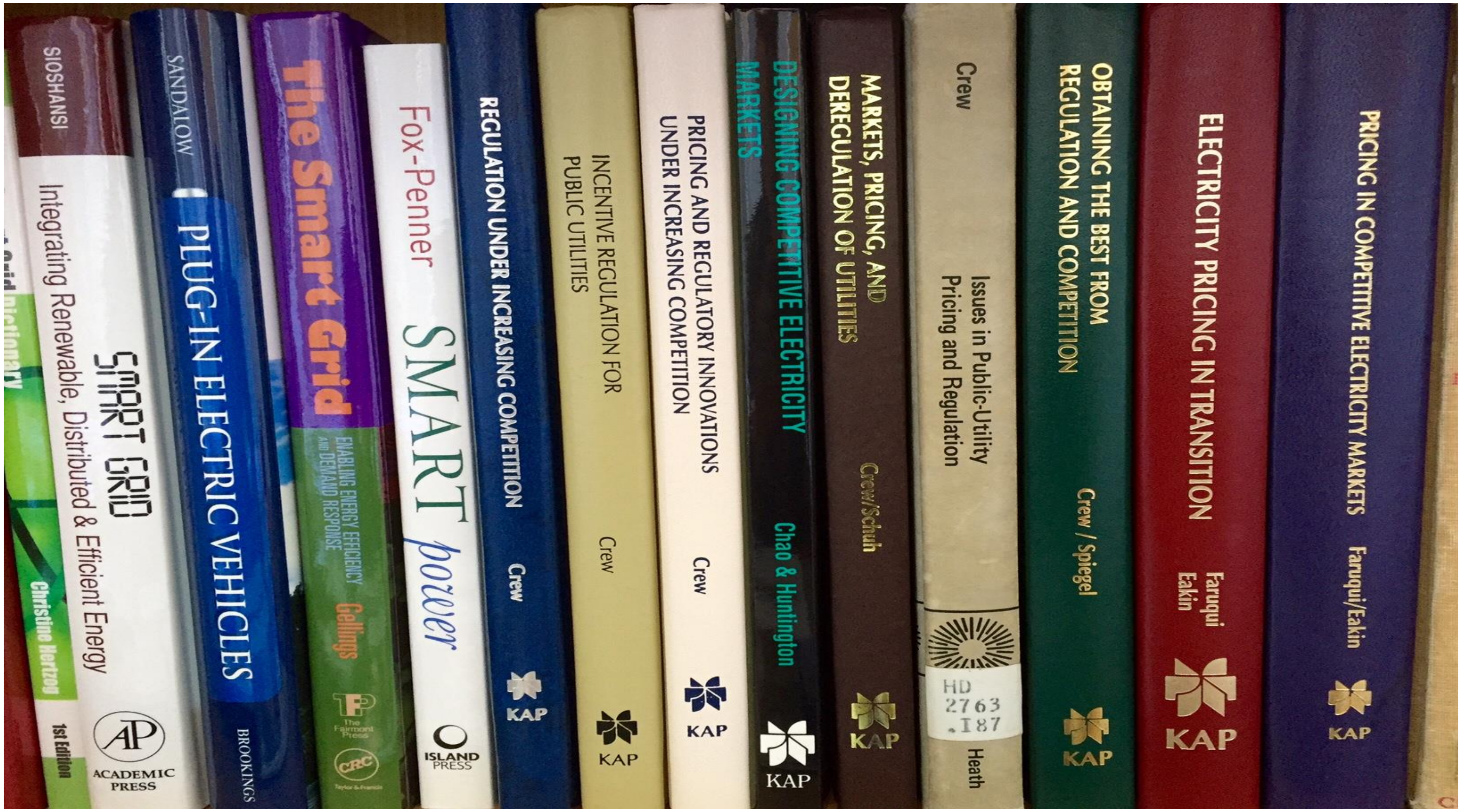
As utilities restructured, to lower costs, departments were disbanded, staff were let go

Customer choice was going to solve the problem

Bob Malko and I co-edited a collection of essays by the nation's leading authorities



More books began to appear as the years went by



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An energy crisis gripped California in 2000 and did not relent until a year later

At the turn of the century, Y2K came and went unnoticed

May 2000, temperatures at the Fisherman's Wharf in SF were in the 1990s

Something was going to happen

And it did

Commissioner Michael Peevey of the California PUC issued an Order Instituting Rulemaking (OIR) in 2002

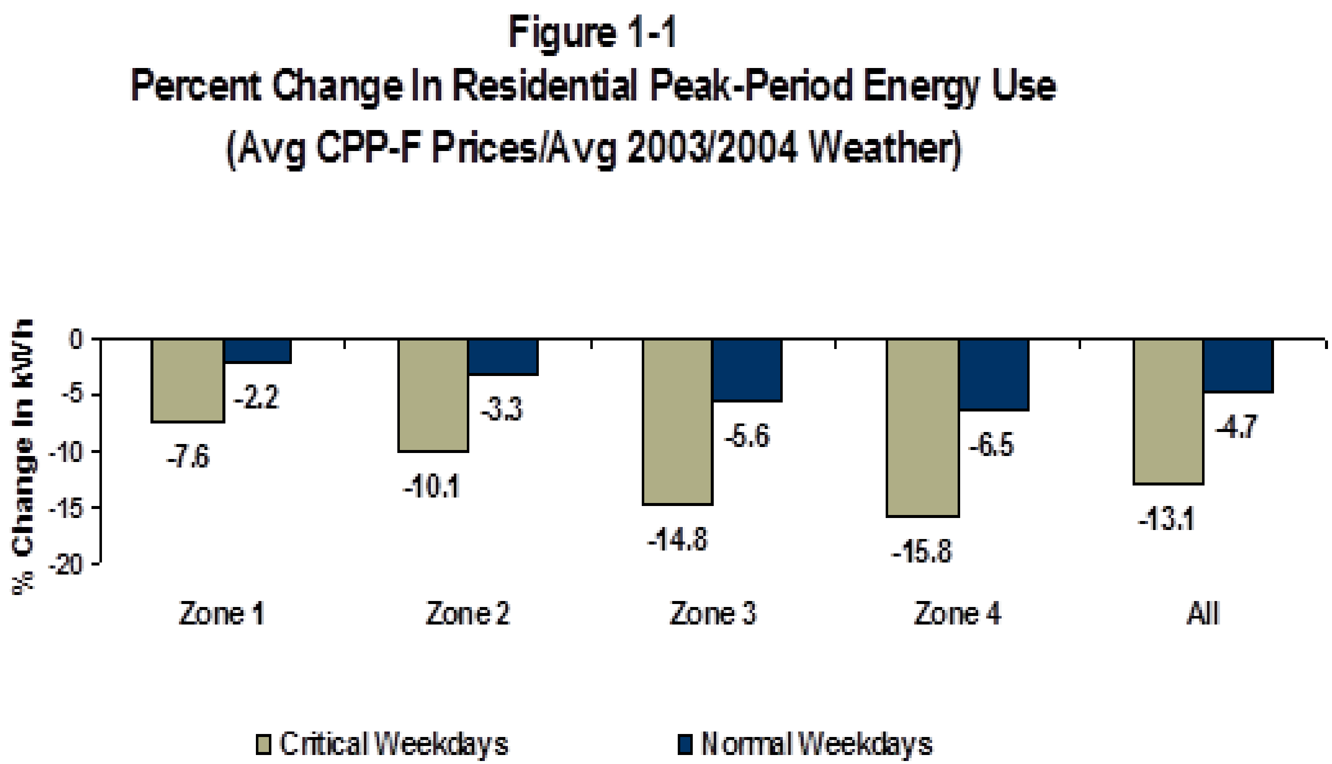
The intent was to study advanced metering, dynamic pricing and demand response through two working groups

The small customer working group decided to conduct an experiment to test customer response to a variety of pricing options

Called the Statewide Pricing Pilot (SPP), it was jointly carried out by the three investor-owned utilities

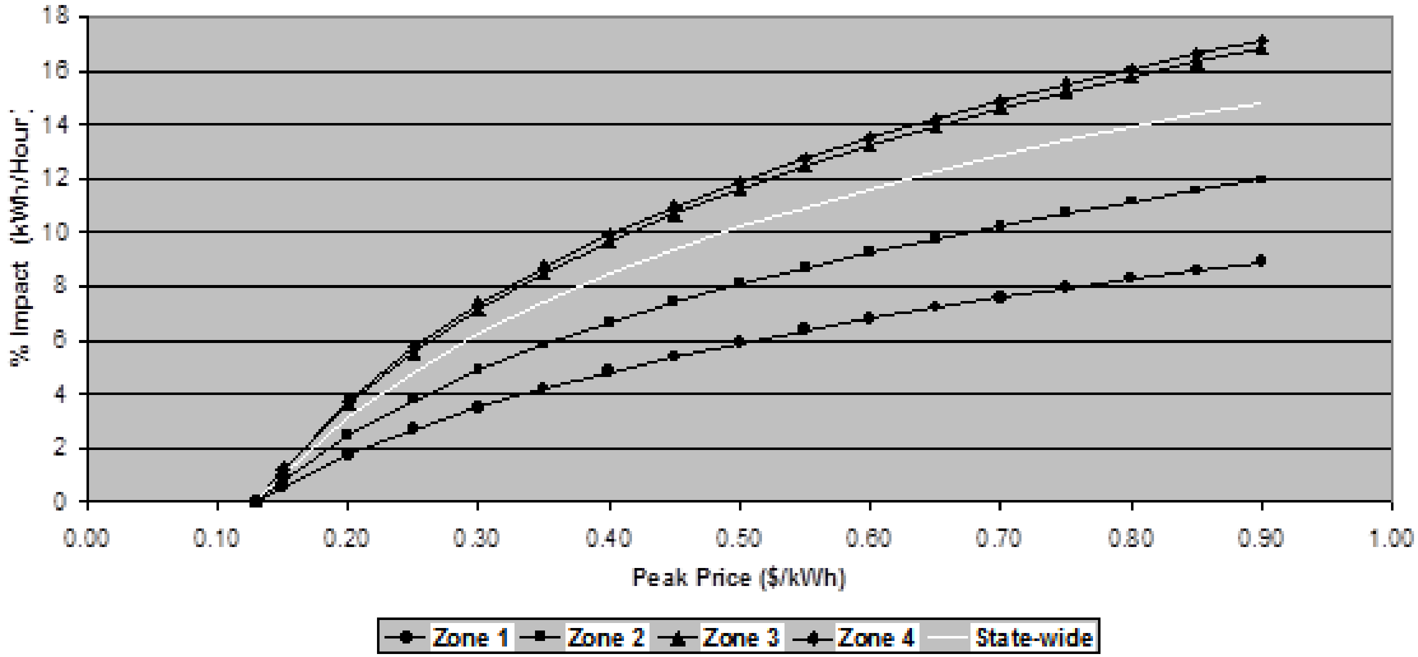
It ran for two years and included several rate options and some 2,500 customers

The SPP yielded some powerful results that varied across climate zones



The SPP also yielded a model, PRISM, that could be used for predictions

Figure 1-2
Percent Reduction in Peak-Period Energy Use on Critical Days
Average Summer, 2003/04



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Other experiments followed

Connecticut

District of Columbia

Florida

Illinois

Maryland

The US Department of Energy entered the fray with the passage of the ARRI Act

A hundred SGIG awards were made and a dozen featured customer behavior studies including:

Detroit Edison

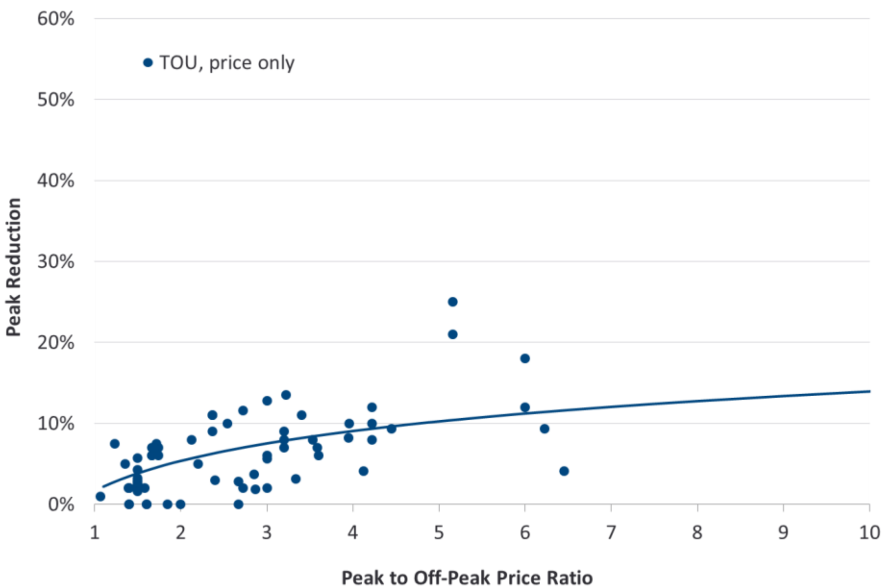
First Energy

OG&E

SMUD

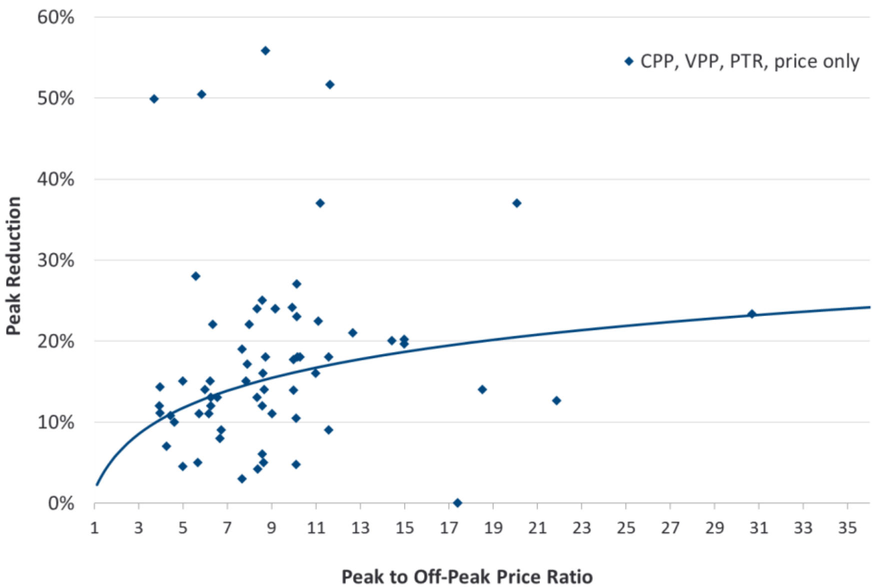
Compiling the results from multiple experiments, we obtain the Arc of Price Responsiveness

TOU Impacts (price only)



Source: Faruqui, Ahmad. "Arcturus." The Brattle Group.
Notes: Chart includes 67 data points from TOU pricing treatments without enabling technology.
The Arc was specified considering all 235 time-varying pricing treatments including CPP, VPP, PTR, and TOU.

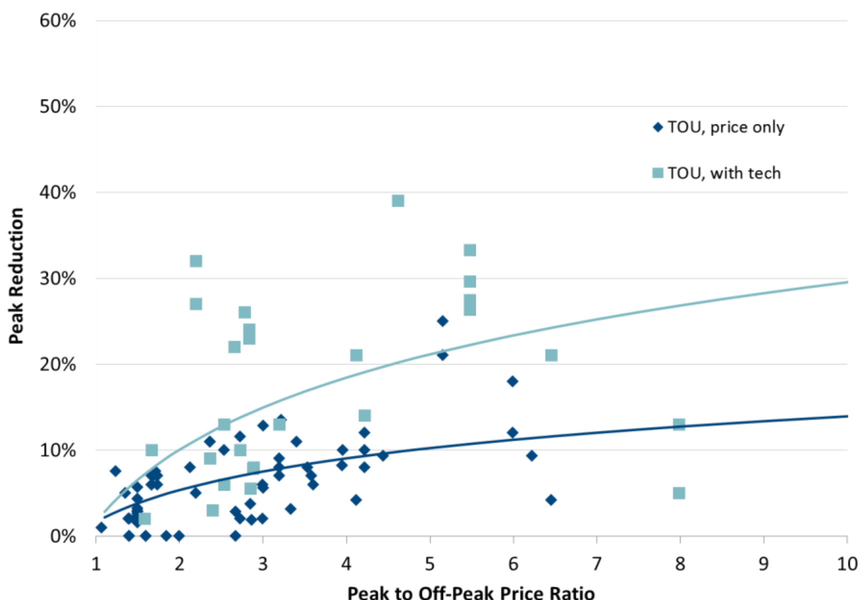
Dynamic Pricing Impacts (price only)



Source: Faruqui, Ahmad. "Arcturus." The Brattle Group.
Notes: Chart includes 68 data points from dynamic pricing treatments without enabling technology.
The Arc was specified considering all 235 time-varying pricing treatments including CPP, VPP, PTR, and TOU.

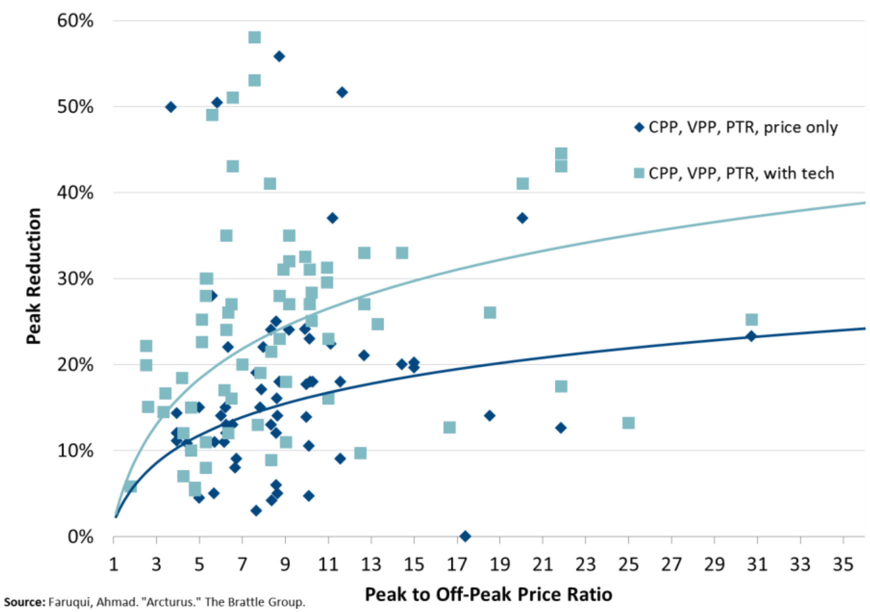
Higher responsiveness is observed when prices are combined with enabling technology

TOU Impacts



Source: Faruqui, Ahmad. "Arcturus." The Brattle Group.
Notes: Chart includes 67 data points from TOU pricing treatments without enabling technology and 30 data points with enabling technology.

Dynamic Pricing Impacts



Source: Faruqui, Ahmad. "Arcturus." The Brattle Group.
Notes: Chart includes 68 data points from dynamic pricing treatments without enabling technology and 70 data points with enabling technology.

Residential rate design is ripe for rethinking

Flat rate pricing is ubiquitous today and it has persisted over the past century because of two reasons

- Lack of advanced metering
- A perception that residential customers are not ready for a change, which has become a self-fulfilling prophecy
- A long time ago, Professor Bonbright warned us of guarding against the “tyranny of the status quo”

For many utilities, their residential rates and costs are grossly misaligned

Cost categories	Utility's Costs	Customer's Bill

Variable ($/kWh)
- Fuel
- Operations & maintenance

Fixed ($/customer)
- Metering & billing
- Overhead

Size-related (demand) ($/kW)
- Transmission capacity
- Distribution capacity
- Generation capacity

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This is not just a problem for the utility's shareholders

The oversized volumetric rate can be avoided through investment in high-efficiency appliances and distributed generation

Customers who don't (or can't) make these investments, particularly low income customers, subsidize those who do

The cross-subsidy has significant implications with regard to equity and fairness – two important ratemaking criteria (more later)

Residential technology is changing and demand flexibility will soon be the norm

Digital technology is becoming ubiquitous (the Internet of Things)

- Smart thermostats, smart appliances, smart light bulbs and smart plug loads
- Home energy management systems
- These allow households to manage their loads dynamically in real time

If prices fall in the middle of the day, e.g., as renewable energy resources kick in, customer loads will rise automatically; as prices rise later in the evening, loads will fall automatically

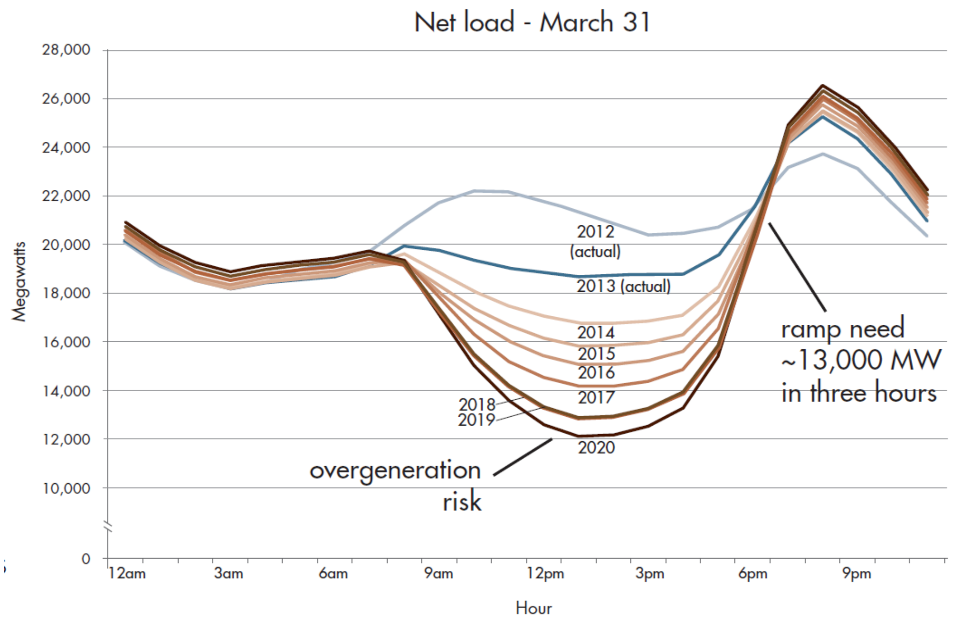
MIT's Fred Schweppe called this "homeostatic control" in 1981

However, if customers adopt uneconomic levels of DG, this will raise energy costs for all customers

Increases in customer generation may have two effects:

- Reduce capacity costs
  - Depends on the degree generation is coincident with system peak
  - Depends on the degree of customer generation reliability
- Increase other costs
  - Intermittency may result in
    - Increased generation ramping requirements [the duck! (now a goose)]
    - Increased level of operating reserves (idling generation)
    - Reduced efficiency of unit commitment
  - There may also be additional costs associated with maintaining power quality
  - And distribution-level capacity upgrades may be needed

The California ISO "Duck Curve"



Several new flavors are being considered

- Demand Charges
- Buy-Sell Arrangement (FIT/VOS)
- Fixed Monthly Charge
- Time-Varying Rates
- Capacity Charge
- Installed Capacity Fee (Grid Access Charge)
- DG Output Fee
- Interconnection Fee
- Minimum Bill
- Standby Rates

Time-varying prices should be the foundation for all energy rates

Economic efficiency

- The costs of supplying and delivering electricity vary by day, and some economists have argued that the electricity used in each hour is a separate commodity
- Unless consumers see this time variation in prices, they will have no incentive to modify their pattern of energy usage
- Excess capacity will have to be built and kept on reserve to meet peak loads during a few hundred hours of the year

Equity

- Under flat energy rates, customers who consume relatively less power during peak periods subsidize those who consumer relatively more power during peak periods

TVP will lower energy costs and reduce cross-subsidies

There are almost 60 million households with smart meters today but less than 2 million of them are on TVP

That prevents us from harnessing the benefits of universal dynamic pricing

- $7 billion per year in lower energy costs
- $3 billion per year in reduced cross-subsidies between customers

But the story does not end with TVP, it just begins with it

A few utilities have begun moving to a three part rate, i.e., a monthly service charge, a demand charge and time-variant pricing (TVP), and many others are expected to follow

- Such rates have a long history for commercial and industrial (C&I) customers, backed up by a long series of papers dating back to Hopkinson and Wright (see Appendix A and C)
- TVP of energy does not eliminate the need for demand charges; Georgia Power has 2,200 C&I customers on real time pricing but these customers still face a demand charge for their use of the grid. https://www.georgiapower.com/docs/rates-schedules/marginally-priced/6.20_RTP-DA.pdf
- Facility-based demand charges will persist in California even when CPP is rolled out for C&I customers

Three part rates convey a cost-based price signal

Utilities that supply energy would use a five-part rate

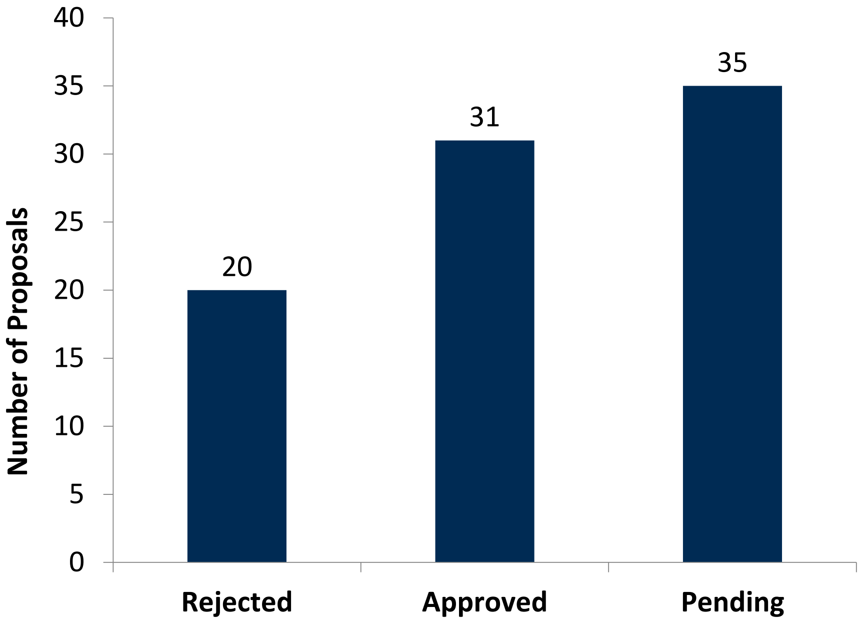
- Monthly service charge
- Charge for connected load (or maximum customer demand)
- Maximum demand charge (coincident with the distribution peak)
- Charge for generation capacity
- Time-varying energy charge

Distribution-only utilities would use a three-part rate

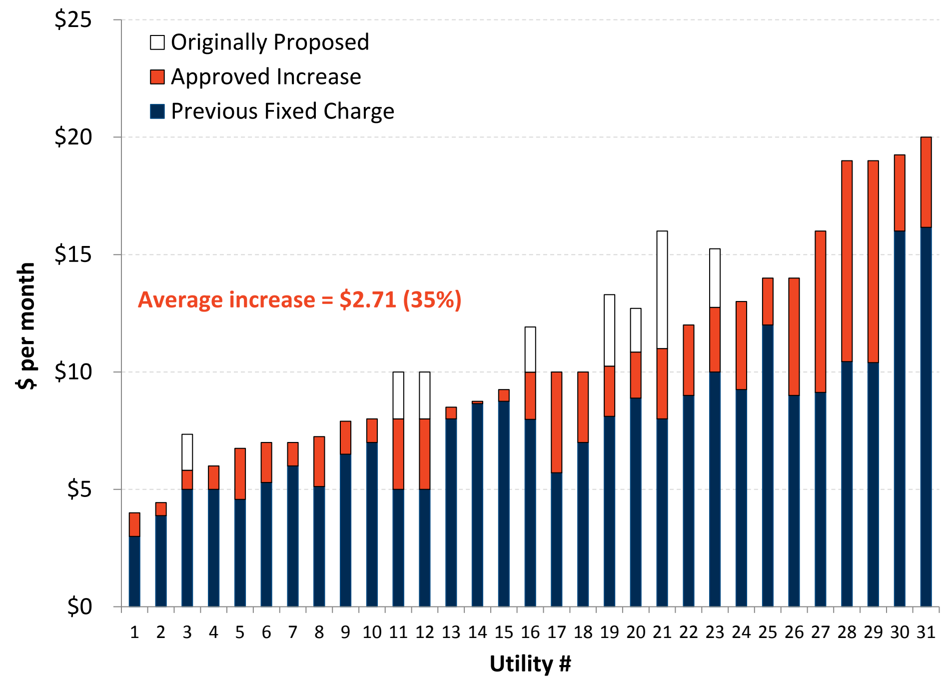
- Monthly service charge
- Charge for connected load (or maximum customer demand)
- Maximum demand charge (coincident with the distribution peak)

Many utilities have proposed to increase the fixed charge and stick with a two-part rate

Recent Proposals to Increase Fixed Charge



Amount of Approved Increase



Data sources: NC Clean Energy, “The 50 States of Solar,” Q2 2015. Supplemented with review of additional utility rate filings.

Fixed charges can help to address the "cost shift" problem

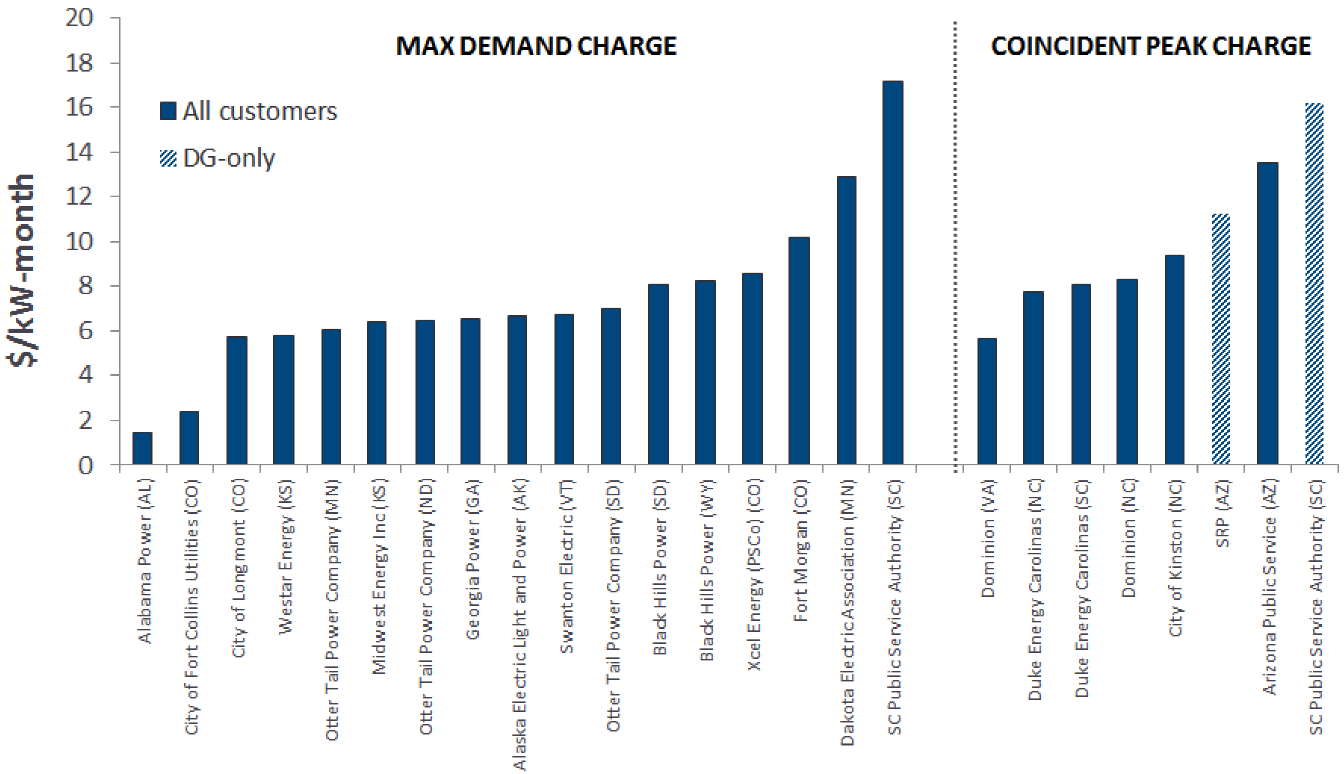
In the absence of advanced metering infrastructure (AMI), rate design options for addressing the cost-shift issues associated with DG adoption and volumetric rates are somewhat limited

Fixed charges are one option for addressing the cost-shift issue and do not require metering upgrades

Some costs, such as metering, billing, and general overhead are clearly fixed and vary with the number of customers, not with the amount of electricity consumed

Many utilities are considering demand charges, which are already being offered by some others

Summer Demand Charges in Existing Rates



Notes:
1) All rates are drawn from their respective utility tariff sheets, valid as of July 2015.
2) The SRP rate is tiered and varies by season and amount of demand; we show the average summer demand charge for a 10 kW customer for illustrative purposes.
3) The SC Public Service Authority DG rate includes a peak rate of $11.34/kW-mo and an off-peak rate of $4.85/kW-mo. We present the sum for simplicity.

Comments

- 19 utilities offer residential demand charges, 10 of which are IOUs
- They have been proposed in Arizona, Kansas, Illinois, Nevada, and Oklahoma

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Can residential customers understand demand charges?

Anyone who has purchased a light bulb has encountered watts; ditto for anyone who has purchased a hair dryer or an electric iron

Customers often introduced to kWh's by way of kWs; e.g., if you leave on a 100 watt bulb for 10 hours, it will use 1,000 watt-hours, or one kWh

Similarly, if you run your hair dryer at the same time that someone else is ironing their clothes and lights are on in both bathrooms, the circuit breaker may trip on you since you have exceeded its capacity, expressed in kVA's or kW's

Customers don't need to be electricity experts to understand a demand charge

Responding to a demand charge does <u>not</u> require that the customers know exactly when their maximum demand will occur

If customers know to avoid the simultaneous use of electricity-intensive appliances, they could easily reduce their maximum demand without ever knowing when it occurs

This simple message should be stressed in customer marketing and outreach initiatives associated with the demand rate

Examples from utility websites

- APS: "Limit the number of appliances you use at once during on-peak hours"
- Georgia Power: "Avoid simultaneous use of major appliances. If you can avoid running appliances at the same time, then your peak demand would be lower. This translates to less demand on Georgia Power Company, and savings for you!

Staggering the use of a few key appliances could lead to significant demand reductions

Avg. Demand Over 15 min

Appliance	Avg. Demand (kW)	
Clothes Dryer	4.0	Flexible Load (18.5 kW)
Oven	2.0	
Stove	1.0	
Hand iron	0.5	
Central air conditioner	5.0	
Spa heater and filter	6.0	
Misc. plug loads	0.2	Inflexible Load (1 kW)
Lighting	0.3	
Refrigerator	0.5	
Total	19.5	

Comments

- Use of some of the appliances is inflexible (1 kW)
- Use of other appliances could be easily staggered to reduce demand
- Simply delaying use of the clothes dryer, oven, stove, and hand iron would reduce the customer's maximum demand by 7.5 kW
- This would bring the customer's maximum demand down to 12 kW, **a roughly 38% reduction in demand**

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Bonbright Reloaded for the 21st century

The ideal rate design should promote economic efficiency, enhance customer equity, ensure the financial health of the utility, be transparent to customers, and empower customer choice.

Stakeholder concerns can be addressed through some new initiatives - I

Codify and learn from the experience of utilities that have deployed new rates in the US and in Europe

Quantify bill impacts, particularly for low- and moderate income customers

Assess customer understanding of the new rates through market research (interviews, focus groups and surveys) and identify the best way to communicate the concept and to design the rates

Stakeholder concerns can be addressed through some new initiatives - II

Assess customer response to new rates through a new generation of experiments whose design builds on insights gleaned from prior work on time-of-use pricing experiments

Study ways in which to mitigate financial impact on vulnerable customers, maybe by excluding them initially from the new rates, or by phasing in the rates, or by providing them financial assistance for installing energy efficiency measures

Conclusions

We are standing at the cusp of a revolution in rate design, driven by the arrival of the Internet of Things, the deployment of smart meters and the greening of consumers

Over the next three to five years, residential rates will begin evolving into three-part rates, featuring fixed charges, demand charges and time-varying energy charges

When energy-smart customers face cost-based prices, a win-win outcome that emphasizes economic efficiency and restores equity among customers will become increasingly likely

Presenter Information

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Ahmad Faruqui is an economist whose consulting practice is focused on the efficient use of energy. His areas of expertise include rate design, demand response, energy efficiency, distributed energy resources, advanced metering infrastructure, plug-in electric vehicles, energy storage, inter-fuel substitution, combined heat and power, microgrids, and demand forecasting. He has worked for more than a hundred clients on five continents. These include electric and gas utilities, state and federal commissions, independent system operators, government agencies, trade associations, research institutes, and manufacturing companies. Ahmad has testified or appeared before commissions in Alberta (Canada), Arizona, Arkansas, California, Colorado, Connecticut, Delaware, the District of Columbia, FERC, Illinois, Indiana, Kansas, Maryland, Minnesota, Nevada, Ohio, Oklahoma, Ontario (Canada), Pennsylvania, ECRA (Saudi Arabia), and Texas. He has presented to governments in Australia, Egypt, Ireland, the Philippines, Thailand and the United Kingdom and spoken at energy seminars on all six continents. His research on the energy behavior of consumers has been cited in Business Week, The Economist, Forbes, National Geographic, The New York Times, the San Francisco Chronicle, the San Jose Mercury News, the Wall Street Journal and USA Today. He has appeared on Fox Business News, National Public Radio and Voice of America. He is the author, co-author or editor of four books and more than 150 articles, papers and reports on energy matters. His work has appeared in peer-reviewed journals such as Energy Economics, Energy Journal, Energy Efficiency, and the Journal of Regulatory Economics and trade journals such as The Electricity Journal and the Public Utilities Fortnightly. He holds bachelors and masters degrees from the University of Karachi and a doctorate in economics from The University of California at Davis.

Appendix A:
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https://www.youtube.com/watch?v=0p6ZHaXszRQ

NYU School of Law. A day-long a conference on time-variation pricing as part of the REV Proceedings. New York, NY.

http://www.sallan.org/Sallan_In-the-Media/2015/04/rev_agenda_time_variant_p.php

Northwestern University's Kellogg Alumni Club. A two hour debate on the merits of dynamic pricing. San Francisco, CA.
https://vimeo.com/20206833

Appendix C:
Back to the future of rate design

Back to the future of rate design

Year	Author	Contribution
1882	Thomas Edison	• Electric light was priced to match the competitive price from gas light and not based on the cost of generating electricity
1892	John Hopkinson	• Suggested a two–part tariff with the first part based on usage and the second part based on connected demand
1894	Arthur Wright	• Modified Hopkinson's proposal so that the second part would be based on actual maximum demand
1897	Williams S. Barstow	• Proposed time-of-day pricing at the 1898 meeting of the AEIC, where his ideas were rejected in favor of the Wright system
1946	Ronald Coase	• Proposed a two-part tariff, where the first part was designed to recover fixed costs and the second part was designed to recover fuel and other costs that vary with the amount of kWh sold
1951	Hendrik S. Houthakker	• Argued that implementing a two-period TOU rate is better than a maximum demand tariff because the latter ignores the demand that is coincident with system peak
1961	James C. Bonbright	• Laid out his famous Principles of Public Utility Rates

Back to the future (concluded)

Year	Author	Contribution
1971	William Vickrey	• Fathered the concept of real-time-pricing (RTP) in *Responsive Pricing of Public Utility Services*
1976	California Legislature	• Added a baseline law to the Public Utilities Code in the *Warren-Miller Energy Lifeline Act*
1978	U.S. Congress	• Passed the *Public Utility Regulatory Act (PURPA),* which called on all states to assess the cost-effectiveness of TOU rates
1981	Fred Schweppe	• Described a technology-enabled RTP future in *Homeostatic Control*
2001	California Legislature	• Introduced *AB 1X,* which created the five-tier inclining block rate where the heights of the tiers bore no relationship to costs. By freezing the first two tiers, it ensured that the upper tiers would spiral out of control
2001	California PUC	• Began rapid deployment of California Alternative Rates for Energy (CARE) to assist low-income customers during the energy crisis
2005	U.S. Congress	• Passed the *Energy Policy Act of 2005*, which requires all electric utilities to offer net metering upon request

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