

Symmetric Treatment of Load and Generation: A Necessary Condition for Demand Response to Benefit Wholesale Market Efficiency and Manage Intermittency

Frank A. Wolak

Director, Program on Energy Sustainable Development

Professor, Department of Economics

Stanford University

wolak@stanford.edu

<http://www.stanford.edu/~wolak>

Chair, Market Surveillance Committee of California
Independent System Operator

Outline of Talk

- **Dynamic Pricing** versus **Time-of-Use Pricing**
- Symmetric treatment of load and generation
 - A necessary condition for realizing the benefits of dynamic pricing
 - Analogues in markets for other products
 - Problems with a legacy default fixed retail price
- Why dynamic pricing is inevitable
 - Managing intermittency
 - Managing unilateral market power
- Dynamic Pricing Plans
 - Hourly Pricing (HP)
 - Critical Peak Pricing (CPP)
 - Critical Peak Pricing with Rebate (CPP-R)
- Day-ahead versus real-time dynamic pricing programs
 - Technology-assisted demand reductions
 - The role of symmetric treatment of load and generation

Dynamic vs. Time-of-use pricing

- Dynamic pricing
 - Retail prices that vary with real-time system conditions
 - Supply of “negawatts” that depends on hourly wholesale price
 - Requires hourly meters to implement
 - Must measure consumption on hourly basis to charge hourly prices
- Time-of-use pricing (TOU)
 - Retail prices that vary with time of day, regardless of system conditions
 - Low price from midnight to 12 pm and 6 pm to midnight
 - High price from noon to 6 pm
 - Does not require hourly meter
 - Only meter that records monthly consumption in two time periods

Dynamic vs. Time-of-use pricing

- Dynamic pricing
 - Customers have incentive to reduce demand during periods with high wholesale prices and stressed system conditions
 - Reduces wholesale price volatility and increases system reliability
 - Limits ability of suppliers to exercise unilateral market power
 - Retailers with dynamically priced customers can even use them to exercise monopsony power (more on this if there is time)
 - Downward sloping hourly demand for electricity with respect to hourly wholesale price
- Time-of-use pricing
 - Customers have no incentive to reduce demand during periods with high wholesale prices and stressed system conditions
 - Similar incentive to single fixed price tariff
 - Two fixed prices all days as opposed to one fixed price all days
 - Produces perfectly inelastic hourly demand for electricity with respect to hourly wholesale price

Symmetric Treatment of Consumers and Producers

- In all markets, default price all consumers must pay and producers must receive is real-time price
 - Without symmetric treatment, maximum amount of active demand-side participation that benefits market efficiency is unlikely to develop
 - Neither consumers or producers are required to pay or receive this price, but in order to avoid it, market participant must sign a hedging arrangement
- Example from airline industry
 - Customers always have option to show up at airport and purchase ticket for flight they would like to travel on at real-time price
 - This default purchase strategy has significant price risk because flight can sell out
 - To hedge risk, consumer purchases ticket in advance (fixed-price forward contract)
 - Electricity consumers must face same default price as consumers of all other products for demand response to benefit market efficiency

Symmetric Treatment of Consumers and Producers

- Because of legacy of vertically integrated-monopoly market structure, in many jurisdictions customers have hedge against real-time price for unlimited quantity of electricity
 - In vertically-integrated monopoly regime, utility provided spot electricity price insurance to customer
 - Customer paid firm's average cost for each KWh consumed and utility ensured supply was always available
- In wholesale market regime it is very difficult to set a fixed retail price for unlimited quantity that is guaranteed to always cover wholesale energy costs
 - No secondary market activity in this kind of contract

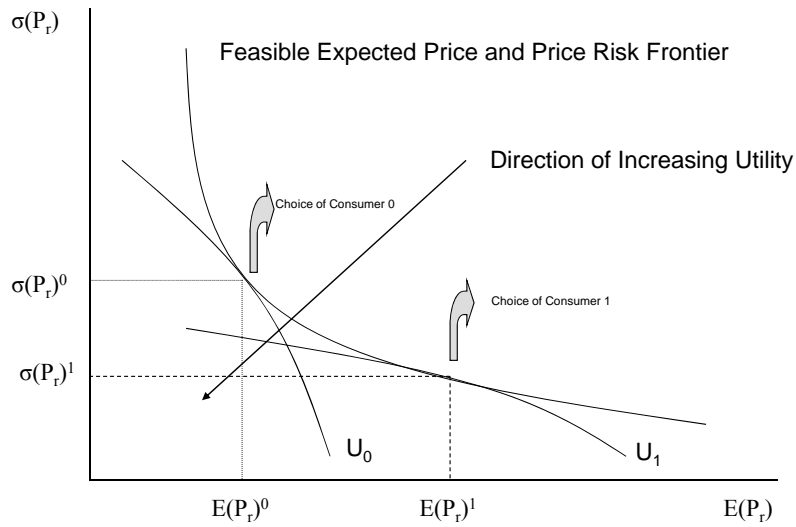
Setting Default Retail Price

- Pass through hourly real-time wholesale price in default retail rate (or set extremely high fixed default price)
 - For all customers with interval meters
- No customer needs to pay real-time price, but all customers need to face risk of real-time price just as generation unit owner does
 - Real time price risk exists and someone must manage it
 - Putting all risk on suppliers is unlikely to be least cost solution
- Customers can select pricing plans that take on desired level of real-time price risk, but they must pay appropriate price for level of risk they take on—Risk management is not costless
- Analogue to airline industry--If customer can always buy at three-week advance purchase price, why ever buy three weeks in advance?

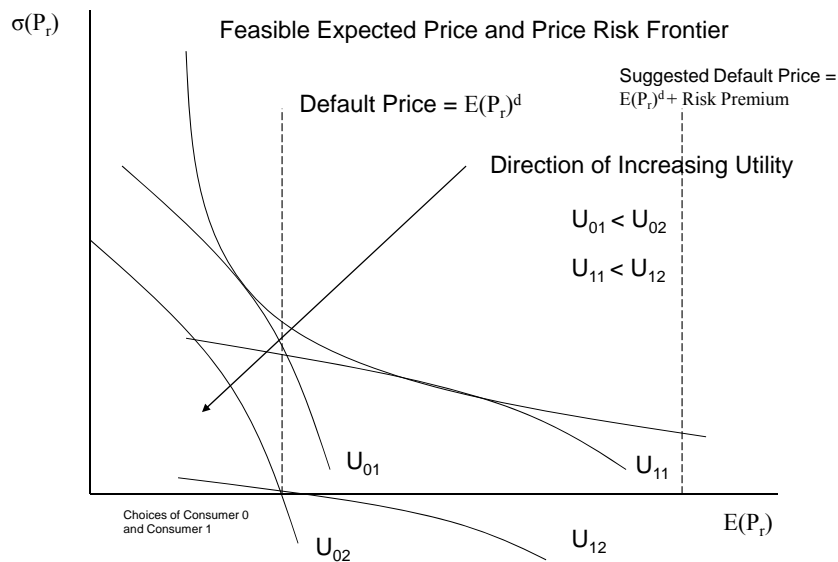
The Trouble with a Fixed Default Retail Price

- Simple example to illustrate problems created by regulator setting default fixed retail price for encouraging active participation of final demand
- Assume consumers have expected utility functions, $U(E(P), \sigma(P))$, that are decreasing in expected price, $E(P)$, and standard deviation of price, $\sigma(P)$, paid for retail electricity
 - Customer would prefer lower expected price, $E(P)$, and lower standard deviation of expected price, $\sigma(P)$
- Retailers can only offer lower expected price, $E(P)$, if customer is willing to take on more price risk, $\sigma(P)$
- If regulator offers default fixed retail price that is too low, few if any customers will voluntarily choose to a dynamic pricing tariff

Expected Retail Price ($E(P_r)$) and Standard Deviation of Retail Price ($\sigma(P_r)$) Frontier



Consumer Choices with Default Rate Set at Average Wholesale Price



Important Point

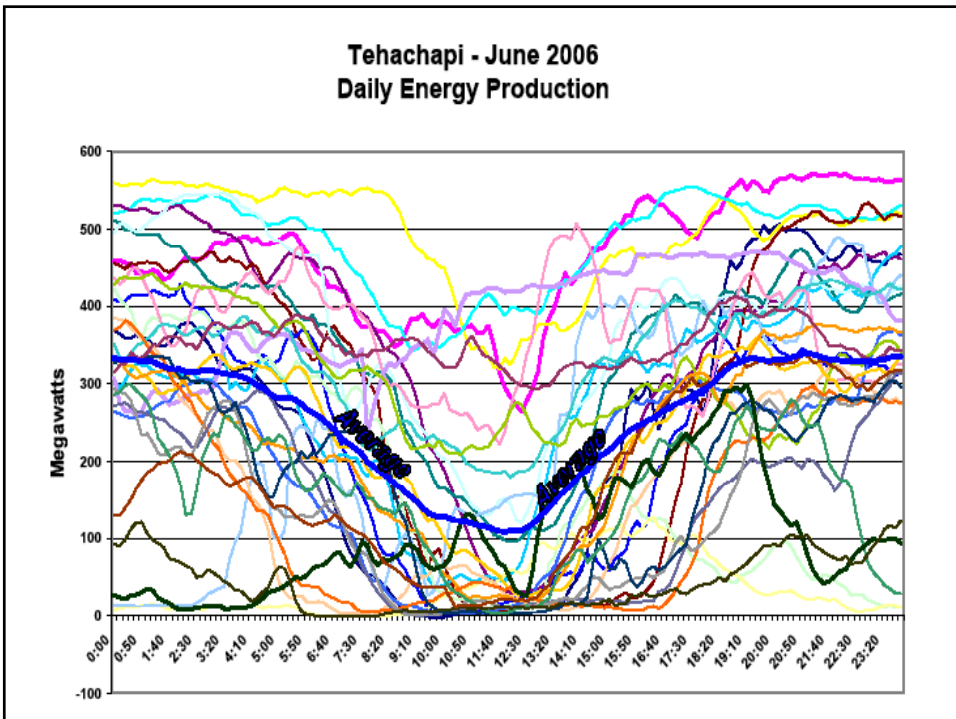
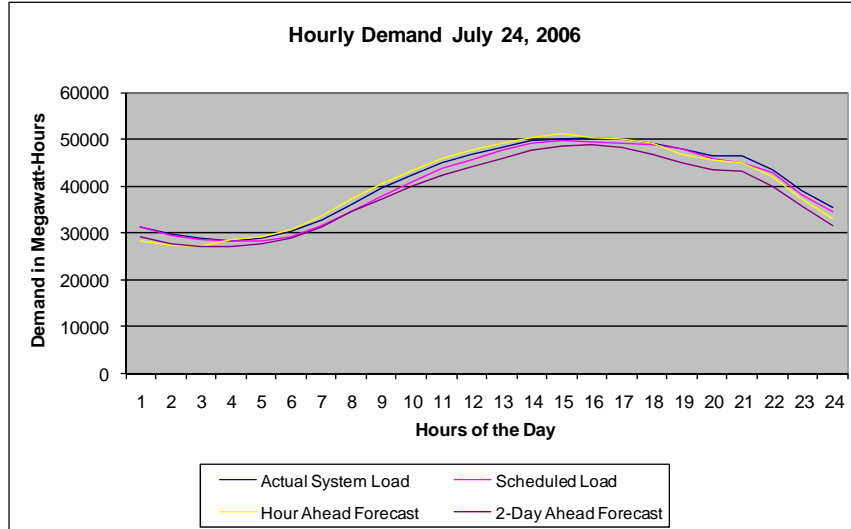
- Fixed-retail price does not imply customers do not pay real-time hourly wholesale prices in retail price
 - Retailers will go bankrupt if retail price does not satisfy equation given below on an annual basis
 - $P(\text{retail}) \geq P(\text{wholesale}) + P(\text{transmission}) + P(\text{distribution})$
- Conclusion—Cannot “protect customers from volatile wholesale prices”
 - Can only prevent them from taking actions to limit wholesale price volatility and reduce their monthly bill
 - *Investments in energy storage and demand flexibility can only be profitable with symmetric treatment of load and generation*
 - *If pay 10 cents/KWh for all KWH, how you do make storage and load-shifting investments pay?*

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Why Dynamic Pricing is Inevitable

- Many states have ambitious renewable energy goals
 - California has 33 percent renewable share goal by 2020
- Renewables are often unavailable during peak periods
 - During July 2006 heat storm, July 24 demand in California ISO control area hit a 1 in 50 year peak of 50,200 MW
 - Less than 5 percent of installed wind capacity was operating at the time
 - Wind energy comes primarily during night and solar energy can only come during the day
 - Cloud cover can significantly reduce solar PV output
- Major factor driving need for dynamic pricing—High wholesale prices do not cause more wind or solar energy to be produced
 - As share of renewable energy grows final consumers must supply more “dispatchable megawatts” to maintain system balance
 - Load-shifting or investments in energy storage technologies

Daily Load Shape in California



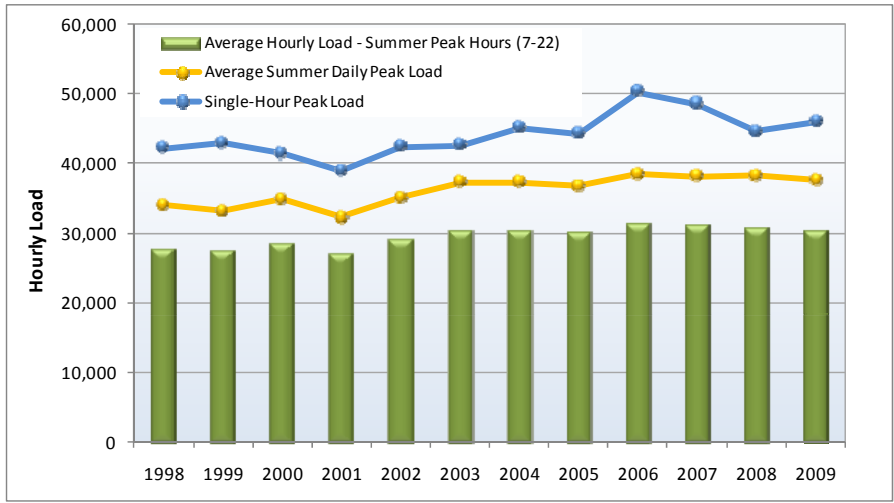
Price Implications of Intermittency

- Intermittency and price for GHG emissions enhances electricity price volatility
 - With a significant renewable share wholesale prices are likely to be very low when these units are operate
 - With a price of GHG emissions and high fossil fuel prices, when fossil-fuel units operate wholesale prices are very high
- Creates incentive for investments in storage only if final consumers face hourly price as default
 - Value of storage technology is ability to turn low-priced electricity into high-price electricity
- Conclusion--Symmetric treatment of load and generation provides strongest possible incentive for active participation of final consumers in wholesale market

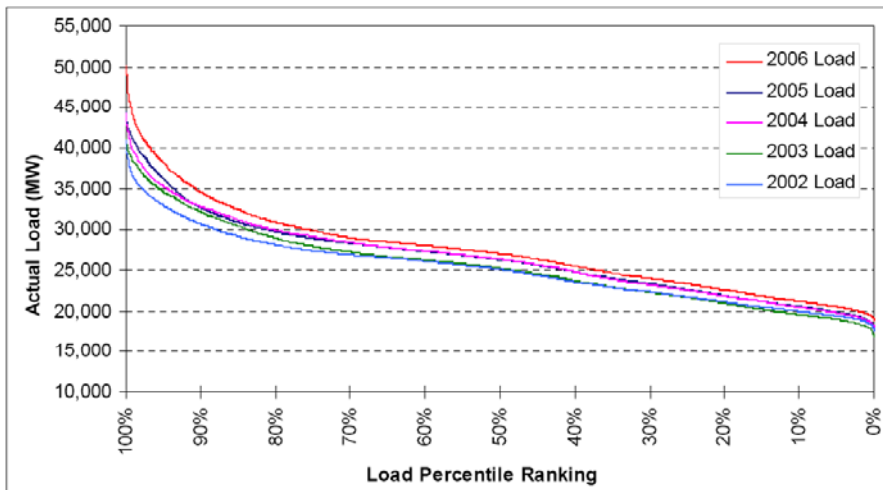
Economics of Energy Efficiency

- Variation in electricity demand throughout day and year
 - On 7/24/06 demand ranged from 28,300 MW to 50,200 MW
- Average MW consumption per hour during 2006
 - Approximately 27,000 MW
 - Peak demand for 2006 is 50,200 MW
- Reducing peak demand through dynamic pricing
 - Eliminate need to construct new generation capacity
 - Can retire old inefficient units located close to large cities
- Significant fraction of generation capacity used very infrequently
 - In California approximately 5,000 MW (10 percent of peak demand) used less than 2 percent of hours of the year
 - With climate change larger fraction is likely to be used even less frequently

Summer Load Conditions: 1998 to 2009 (Demand Peaks are More Variable than Total Demand)



California ISO Control Area
Figure E.5 Hourly Load Duration Curves



Barriers to Dynamic Pricing

- Substantial state-level regulatory barriers to dynamic pricing
 - “Consumers must be protected from short-term price risk”
 - “Electricity is a right, not a commodity”
 - Wolak, Frank (2007) “Managing Demand-Side Economic and Political Constraints on Electricity Industry Restructuring Processes,” on web-site.
- Existing stakeholders in regulatory process realize few, if any, benefits from dynamic pricing
 - Regulatory staff, Generation unit owners, Distribution utilities
 - Only consumers realize benefits, and that typically requires them to make some effort—load shifting actions, storage investments

The Role of Interval Meters

- Lack of hourly metering of final demand makes it impossible to set hourly retail prices that pass-through hourly wholesale price
 - Customer reduces monthly bill by same amount by reducing consumption by 1 KWh during hour when wholesale price is \$5000/MWh as he does when price is \$0/MWh
- Economics of hourly meters is rapidly changing because of technological change
 - Major cost of monthly reading for conventional meters is labor cost
 - Modern hourly meters are read remotely by wireless or wireline technology
 - Interval metering investment can be largely justified based on metering reading labor cost saving and increased outage monitoring quality
- All California investor-owned utilities should have interval meters in place for all customers by end of 2011
 - Need retail prices that maximize benefits to consumers of these meters

Politically Acceptable Dynamic Pricing

- Major complaints with implementing dynamic pricing is that customers cannot respond to hourly wholesale prices
 - Difficult to determine best time to take action
- If taking action is costly and price increase is one hour in duration, a very large price spike is needed to cause customers to respond
 - For residential customer with 2.5 KW demand, a large price spike is needed to overcome \$5 cost of taking action to reduce demand by 20 percent
 - \$10,000/MWh for a 0.5 KWh demand reduction for 1 hour
 - AU \$10,000/MWh is offer cap on Australian market
 - Longer duration of high prices requires smaller increase in prices
 - \$5,000/MWh average price for 0.5 KWh demand reduction for 2 hours

Politically Acceptable Dynamic Pricing

- Critical Peak Pricing—Customer consumes according to usual fixed-price tariff or increasing block fixed-price tariff during all hours of each day
- Customers face risk of Critical Peak Pricing (CPP) day
 - Retailer commits to no more than pre-specified number of CPP days in given time interval
 - For example 12 CPP days during summer months
 - During peak-period of a CPP day, customer pays a much higher price for electricity
 - Peak period is typically 4 to 6 hours during day to address “cost of taking action problem”
- Regardless of wholesale price, retailer still profits from CPP event because customers are charged high retail price during CPP event
 - Creates moral hazard problem for retailer

Politically Acceptable Dynamic Pricing

- CPP with rebate mechanism (CPR-R) is even more popular with consumers
 - Consumption during peak hours of CPP days receives a rebate relative to household's reference consumption, if its actual consumption is less than reference consumption
 - Rebate implies that customers *guaranteed not to pay more* than they would have under baseline tariff
 - “You can't lose from rebate mechanism”
 - Reward customers with rebate for reductions during stressed system conditions
 - Politically palatable form of real-time pricing
 - Retailer faces risk that total rebates paid will be more than wholesale energy procurement cost savings
 - If CPP day wholesale price is \$300/MWh and wholesale price is below \$300/MWh, by calling a CPP day, the retailer loses money
 - Addresses moral hazard problem associated with CPP tariff

Designing Dynamic Pricing Plans

- Real-time pricing--Pass through hourly wholesale price in default retail rate
 - Puts all risk on final consumer
 - High cost of taking action could limit demand response
- Critical peak pricing
 - Addresses cost of taking action by committing to sustained period of high prices with advance warning
 - Moral hazard problem with retailer declaring CPP days
- Critical peak pricing with rebate
 - Addresses cost of taking action and moral hazard problem
 - Has option to give up problem
- Information provision and demand response
 - Smart thermostats

DCPowerCents Research Questions

- Do customers respond to high real-time prices and CPP events?
 - Treatment effects (price elasticities will come later)
- How do these price responses differ across customer classes?
 - Regular versus all electric customers
 - Low-income versus regular customers
 - Summer versus winter time
- Does cost of taking action limit demand response of RTP customers versus CPP customers?
- Does option to give up result in CPP response greater than CPP-R response?
- Do Smart thermostats boost demand response?

PowerCentsDC Program Overview

- Residential pricing pilot
 - Smart meters
 - Real-time pricing
 - Critical Peak Pricing (CPP)
 - Critical Peak Pricing with Rebate (CPR)
 - Governed by “Smart Meter Pricing Pilot, Inc.” (SMPPPI)
 - Public Service Commission, DC
 - DC Office of People’s Counsel
 - Consumer Utility Board
 - IBEW
 - International Brotherhood of Electrical Workers
 - Pepco (contributed \$2 million from shareholder funds)
- SMPPPI is a non-profit organization created through a Merger Settlement agreement and approved by the Commission on May 1, 2002.

Smart Thermostat


- Offered to customers with central A/C and who controlled their thermostat
- Approximately 25% of customers opted for the smart thermostat.
- LED lights up during CPP or High Price event (depending on pricing plan)

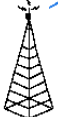

PowerCentsDC

PowerCentsDC™ Smart Thermostat

Features

- Automatic energy-saving remote control via radio waves
- Reduces air conditioning and heating energy use automatically when power prices are highest
- Shows important electricity information:
 - Power consumed since last bill
 - Estimated power cost since last bill
 - Price of power right now
- Programmable for automatic operation:
 - Daytime
 - Nighttime
 - Weekdays
 - Saturdays
 - Sundays
- Comes pre-programmed for ease of set-up
- U.S. Department of Energy certified



Benefits

- FREE thermostat, including free installation
- Reduces energy costs automatically
- Manual override capability keeps the consumer in charge
- "Set-and-forget" convenience
- Flexible to meet personal lifestyle needs
- Works with most central air conditioning and heating systems, including heat pumps

PowerCentsDC Pricing Options

- **Critical peak pricing (CPP)**
 - A maximum of 12 CPP days during summer and 3 during winter
 - Between 2 pm and 6 pm during summer (4 hours)
 - Between 6 am to 8 am and 6 pm to 8 pm during winter (4 hours)
 - Customers pay according to an increasing block schedule during all other hours
 - Customer charged 70 cents/KWh for energy during CPP period
 - Transmission and distribution charges same as non-CPP period
- **Critical peak rebate (CPR)**
 - Customer earns rebates during critical peak hours by reducing usage below reference level set by SMPPI
 - Customers pay according to an increasing block schedule during all other hours
 - Customer receives rebate approximately equal to 63 cents/KWh and 8 cents/KWh is average energy price from standard pricing schedule
 - Customer faces approximately same marginal price as CPP customer during CPP period

PowerCentsDC Pricing Options

- Hourly pricing plan
 - Hourly energy prices based day-ahead PJM prices
 - Hourly pricing curve made more extreme
 - High price periods upweighted slightly
- Treatment received by customers
 - All types of customers notified day before via automated phone call, email, or text page
 - CPP and CPR customers notified day before CPP event occurs
 - CPP event days during summer called when forecast of high temperature for day is above 90 degrees
 - CPP event days during winter called when forecast of low temperature for day is below 18 degrees
 - Hourly pricing customers receive notification of high price (HP) warning hour
 - Hours when day-ahead price for energy is above 23 cents/KWh (> \$230/MWh) during summer months
 - Hours when day-ahead price for energy is above 15 cents/KWh (> \$150/MWh) during winter months

Preliminary Answers to Research Questions

- Price responsiveness
 - Both R and AE customers reduce their consumption in response to CPP and HP hours
 - CPP effects are largest, in the 15% to 25% range
 - HP events smaller percentage (3% to 8%) range
 - Effect (% reduction in consumption from CPP or HP event) larger for AE customers relative to R customers in both summer and winter
 - For R customers effect primarily confined to summer periods
- RAD customers
 - RAD-R customers reduce their consumption in response to CPP hour
 - RAD-AE customers show little evidence of treatment effect
 - Small sample problem for RAD-AE customers
- Difficult to see evidence of cost-of-taking action effect of hourly pricing
 - Hourly pricing effect is between 1/3 to 1/4 of size of CPP effect consistent with HP warning being for energy prices that are 1/3 to 1/4 the size of CPP energy price
 - For AE customers very large HP warning effect

Preliminary Answers to Research Questions

- Strong evidence in favor of option-to-quit effect
 - For both R and AE customers CPR effects it ½ to 1/3 of CPP effect
 - For RAD customers not possible to examine this hypothesis because only CPR treatment was given to them
 - Sizeable treatment effect for CPR for RAD-R customers relative to R and AE customers
- Smart thermostat significantly enhances treatment effect
 - Almost doubles effect for CPP treatment for AE customers
 - Also increase treatment effects for for R customers
 - Does not impact RAD-R or RAD-AE customers

Conclusions from DCPowerCents Study

- Default real-time pricing may not be that difficult for consumers to respond to
 - High price periods tend to cluster together, similar to CPP periods
 - Cost of taking action does not seem substantial
 - Further work required to provide more definitive conclusion
- California is considering default CPR for all customers
 - Loss in price-responsiveness could be large
 - Option-to-quit is produces substantially smaller treatment effect
 - Further argument for default pass-through of real-time price or CPP default
- Smart thermostats and significantly enhance price responsiveness of regular customers
 - Air-conditioning intensive areas of California may benefit most
- Low-income consumers can achieve significant price responsiveness
 - Larger percentage reduction for CPR than for R and AE customers

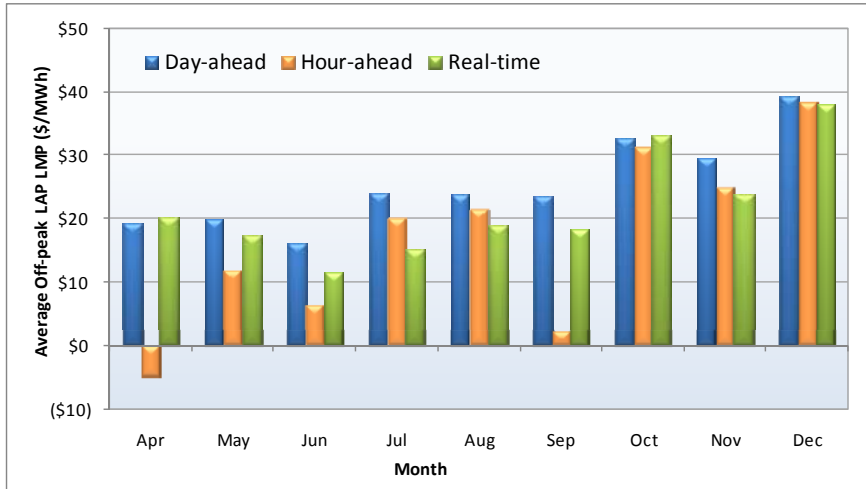
Day-Ahead versus Real-Time Dynamic Pricing

- All US wholesale markets are multi-settlement markets
 - Day-ahead forward market
 - Buy and sell energy for delivery and withdrawal during each hour of following day at fixed hourly price
 - Real-time imbalance market
 - Buy or sell imbalances relative to day-ahead schedules during each hour of day at hourly price
- All dynamic pricing plans currently based on day-ahead prices
 - Day-ahead prices are substantially less volatile than real-time prices

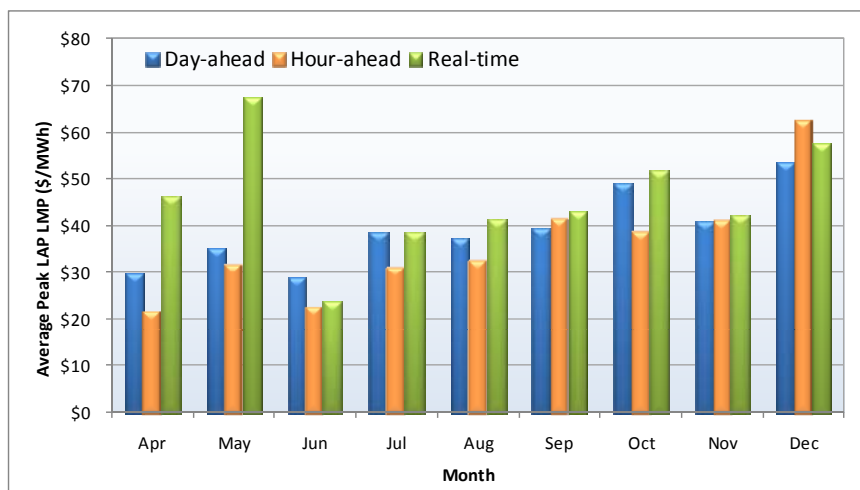
Day-Ahead versus Real-Time Dynamic Pricing

- Symmetric treatment of load and generation revisited
 - Default price that supplier receives is real-time price
 - Only if supplier sells in day-ahead forward market can it be paid the day-ahead price, but only for quantity sold in day-ahead market and not for actual production
- *If default price that all consumers pay is real-time price, this will open a floodgate of innovation and investment in automated and human intervention-based demand response*
- Automated demand-side participation in wholesale market can help overcome regulatory barriers to symmetric treatment of load and generation

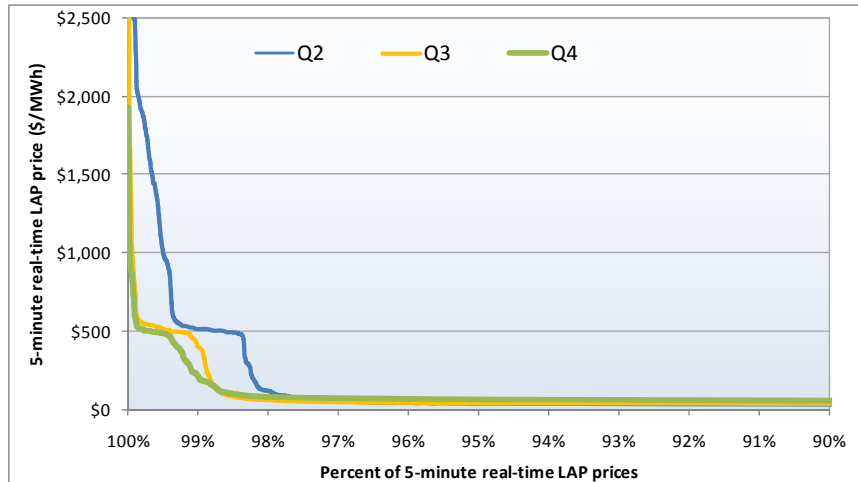
Monthly Average Off-Peak Period Prices for 2009 (SCE LAP)



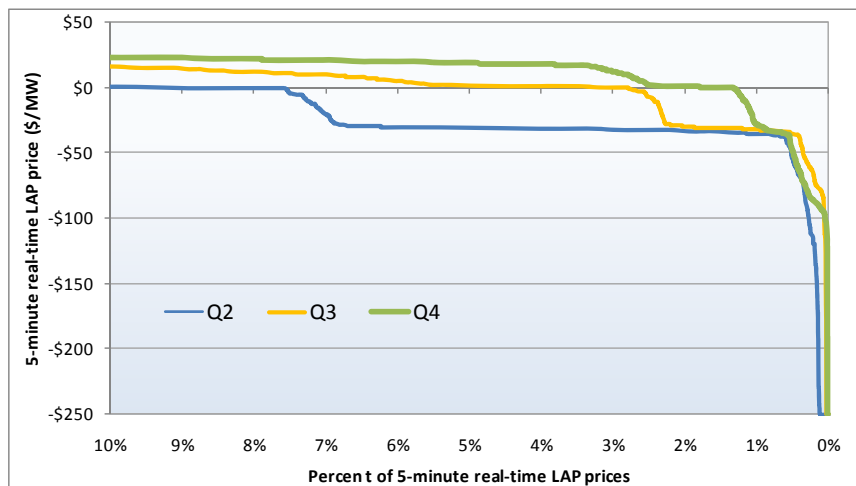
Monthly Average Peak Period Prices for 2009 (SCE LAP)



Quarterly Real-Time Price Duration Curves for 2009 SCE LAP



Quarterly Real-Time Price Duration Curves for 2009 (SCE LAP)



Day-Ahead versus Real-Time Dynamic Pricing

- Even during a year with a depressed economy and mild weather, there were a number of periods with very high real-time prices
 - With symmetric treatment of load and generation and automated response technology, shifting demand away from certain periods can yield significant cost savings
 - Buy energy at \$50/MWh in day-ahead market and sell it back at \$2,000/MWh in real-time market
- Most volatile prices are near major load centers
 - California retailers are currently able to buy at Load Aggregation Point (LAP) prices averaged over large geographic areas covered by three investor-owned utilities
 - This is likely to end in the near future

Conclusions

- Default real-time pricing maximizes consumer benefits from dynamic pricing
 - Makes day-ahead dynamic pricing, storage and automated load shifting technologies financially viable
 - No customer needs to pay this price for any consumption, only face it as a default price, just like in all other markets
- Default fixed price increases average prices to consumers or increases risk of retailer bankruptcy
 - Does not protect consumers from paying volatile wholesale prices
- Regulator must only allow consumers to purchase fixed load shapes at a fixed price, not all they want at a fixed price
 - Consumers buy and sell deviations from fixed load shapes in day-ahead and real-time markets
 - Similar to cell phone model
 - Purchase total monthly minutes at fixed price in advance
 - Real-time price per minute for consumption above total monthly minutes
 - Rollover of unused minutes similar to selling unconsumed contract quantity in day-ahead or real-time market

Questions/Comments
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