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

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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

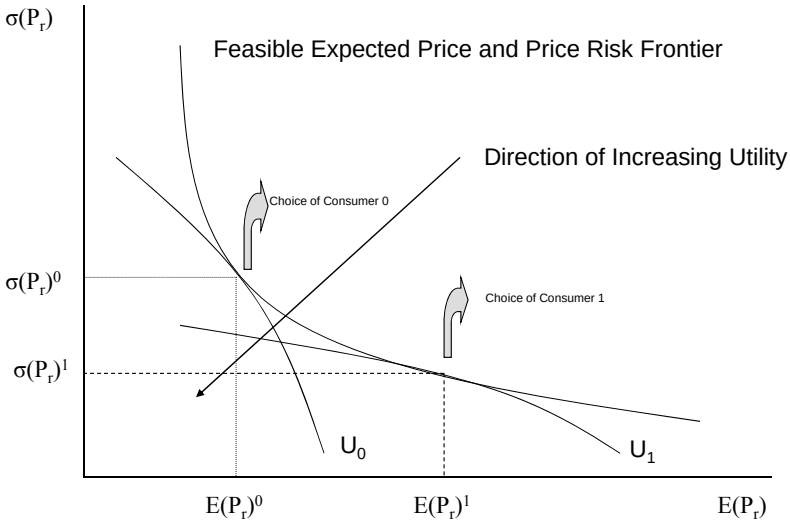
Setting Default Retail Price

- 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 by at three-week advance purchase price, why ever buy three weeks in advance?

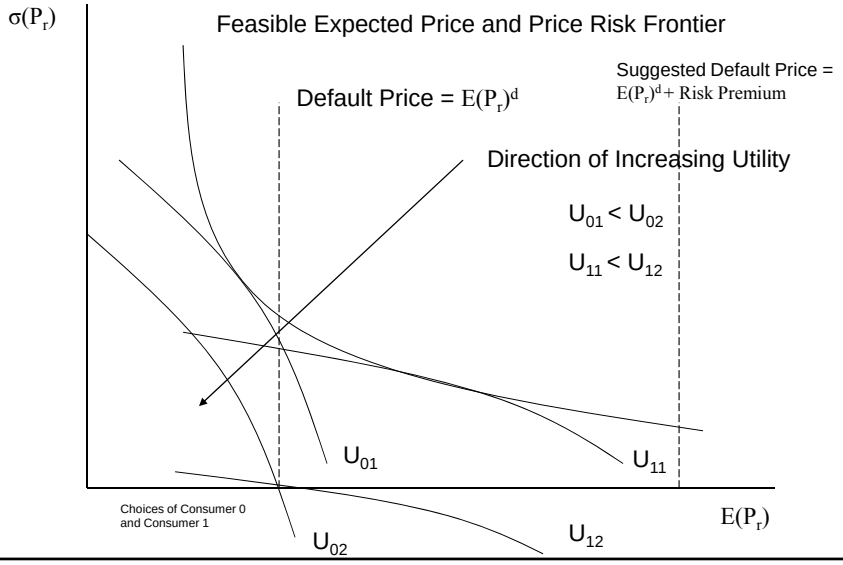
The Trouble with a Fixed Default Retail Price

- 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

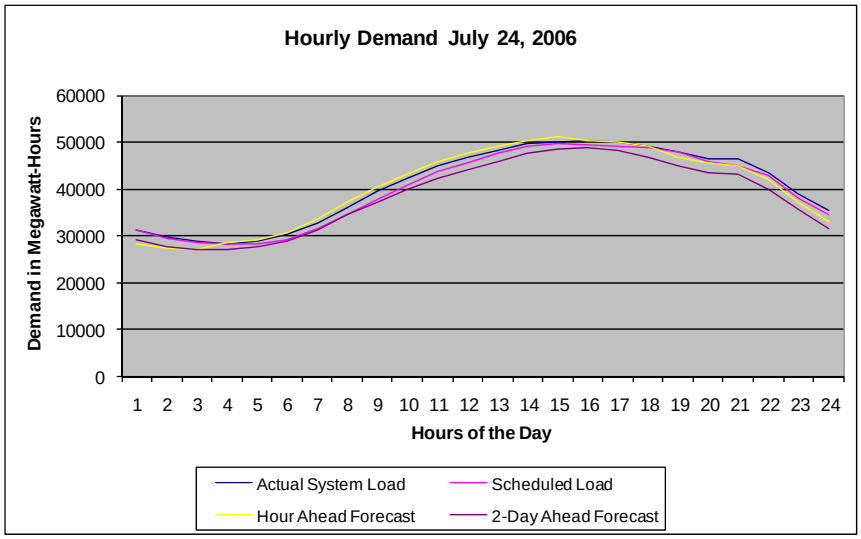
- Fixed-retail price does not imply customers do not pay real-time hourly wholesale prices in retail price
  - Retailers will go bankrupt if retail price does not satisfy equation given below on an annual basis
    - P(retail) ≥ P(wholesale) + P(transmission) + P(distribution)
- Conclusion—Cannot "protect 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?*

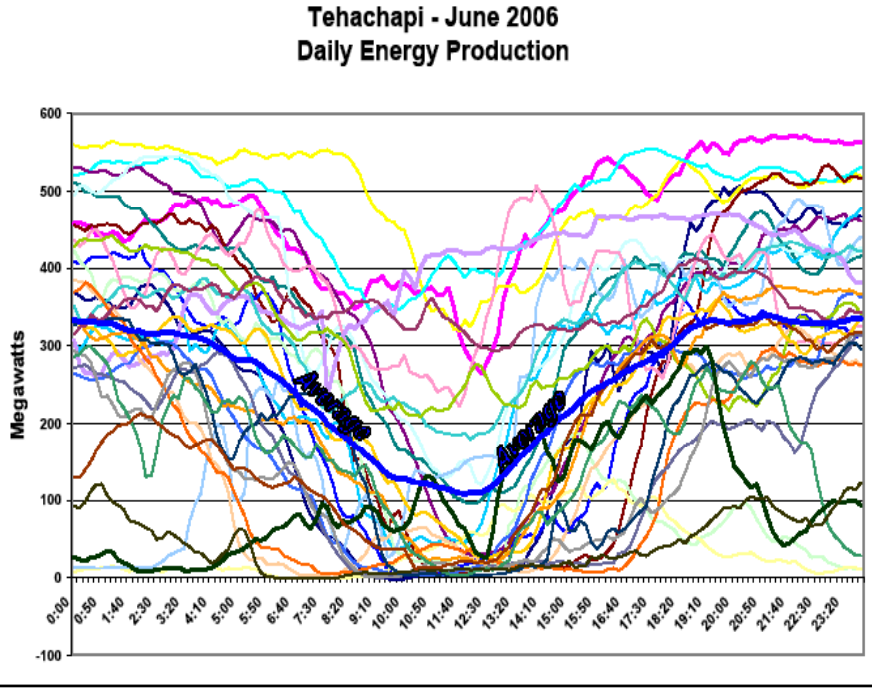
11

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 negawatts" to maintain system balance
    - Load-shifting or investments in energy storage technologies

Daily Load Shape in California





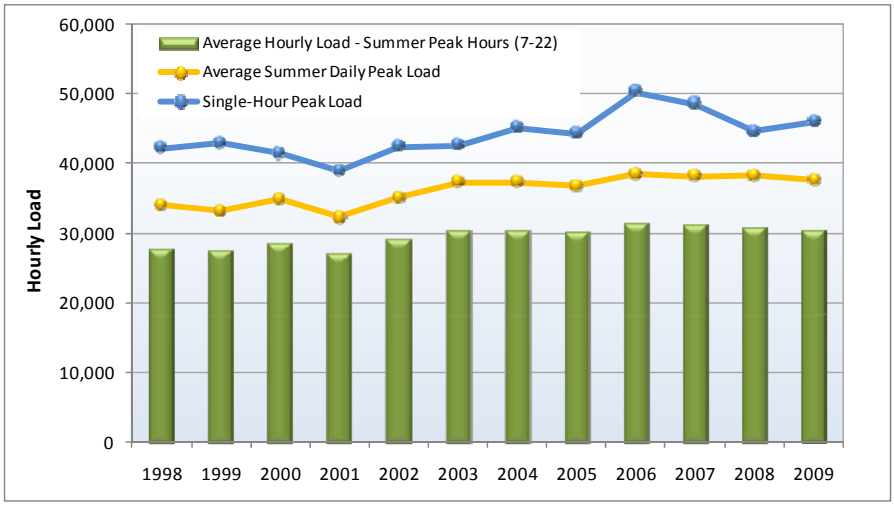
Price Implications of Intermittency

- 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

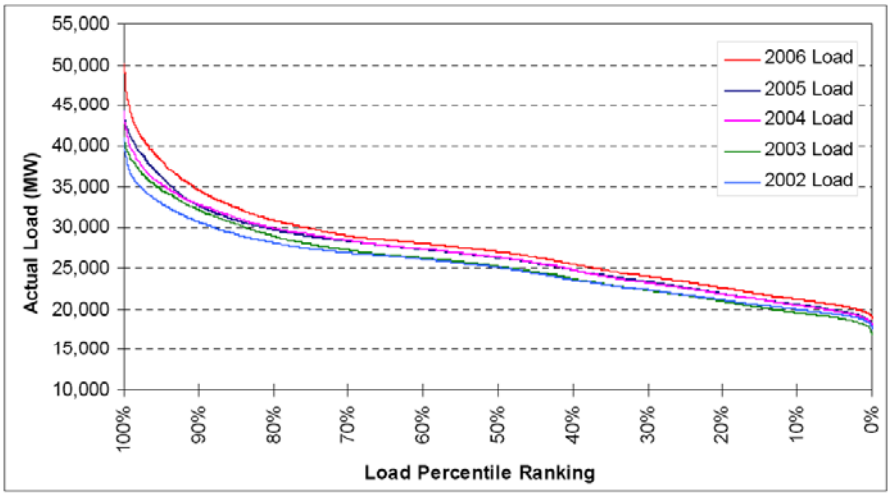
- Variation in electricity demand throughout day and year
  - On 7/24/06 demand ranged from 28,300 MW to 50,200 MW
- Average MW consumption per hour during 2006
  - Approximately 27,000 MW
  - Peak demand for 2006 is 50,200 MW
- Reducing peak demand through dynamic pricing
  - Eliminate need to construct 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 Re-structuring 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?

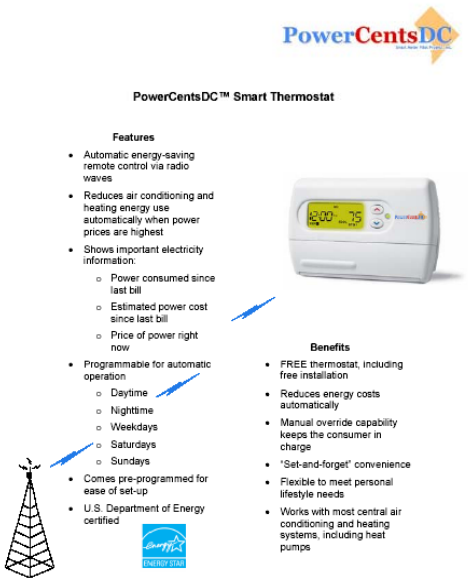
PowerCentsDC Program Overview

- 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." (SMPPI)
  - 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)

SMPPI 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 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 ¼ of size of CPP effect consistent with HP warning being for energy prices that are 1/3 to ¼ 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

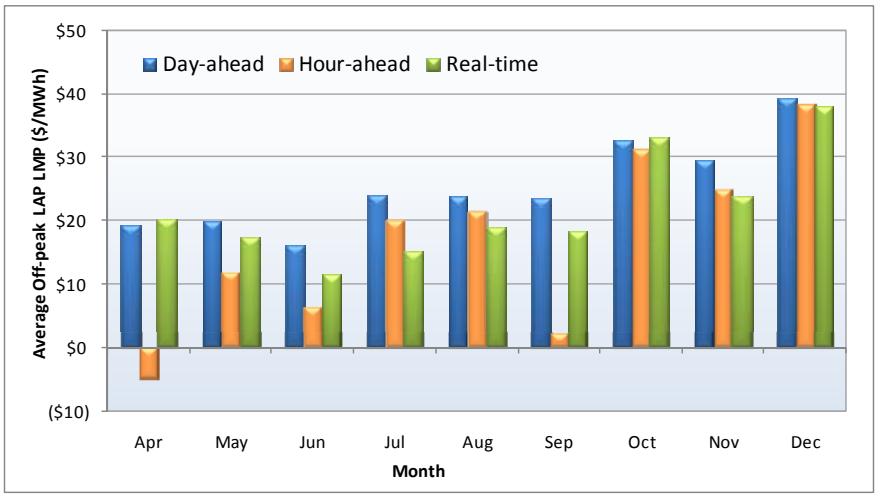
Day-Ahead versus Real-Time Dynamic Pricing

- 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

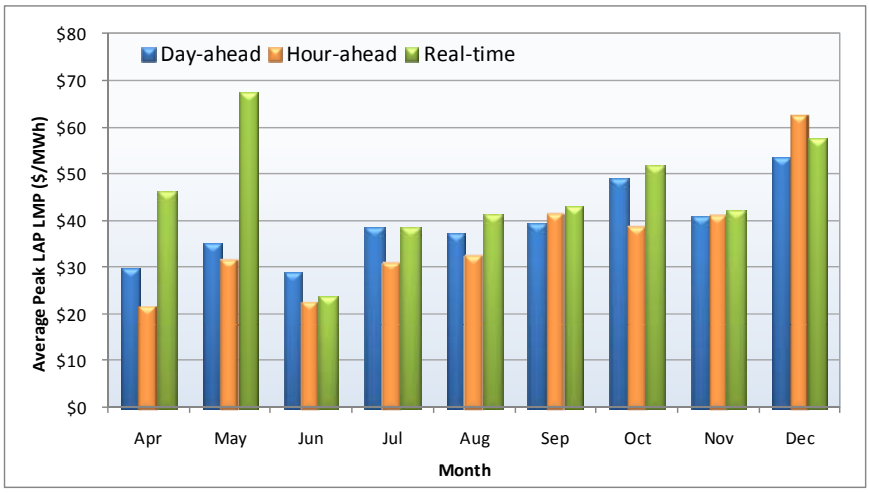
Day-Ahead versus Real-Time Dynamic Pricing

- 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

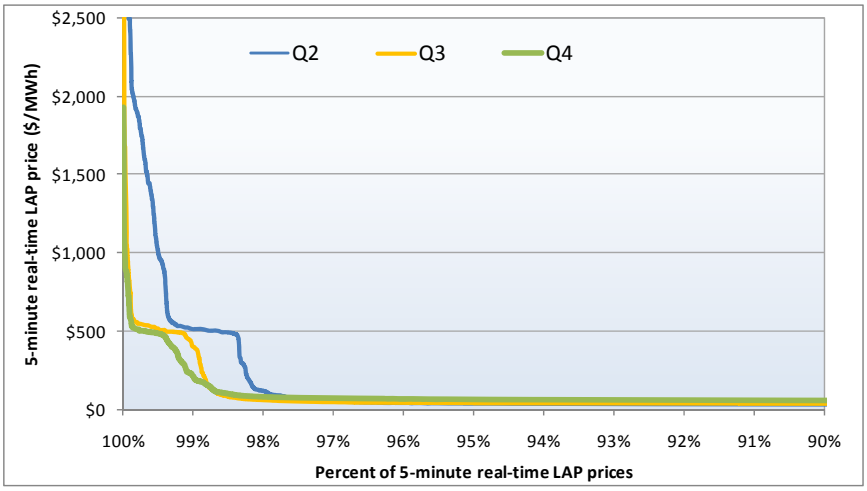
Monthly Average Off-Peak Period Prices for 2009 (SCE LAP)



Monthly Average Peak Period Prices for 2009 (SCE LAP)



Quarterly Real-Time Price Duration Curves for 2009 SCE LAP



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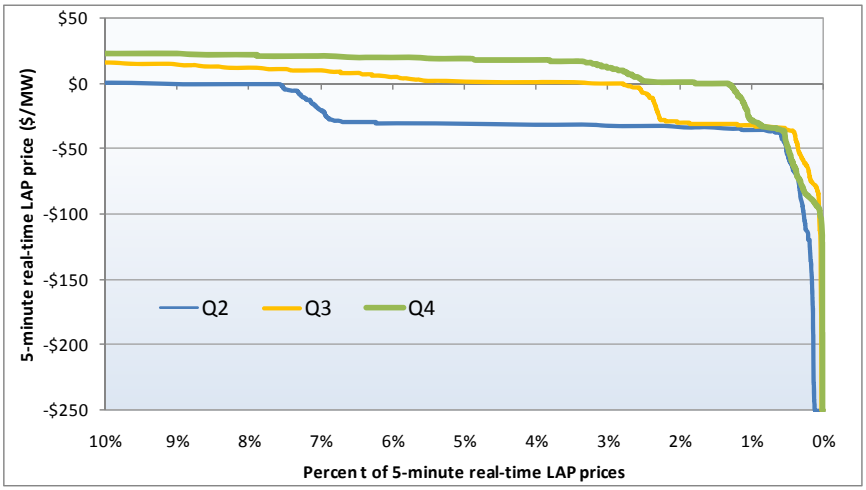

Day-Ahead versus Real-Time Dynamic Pricing

- 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

For more information:

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