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
  - 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

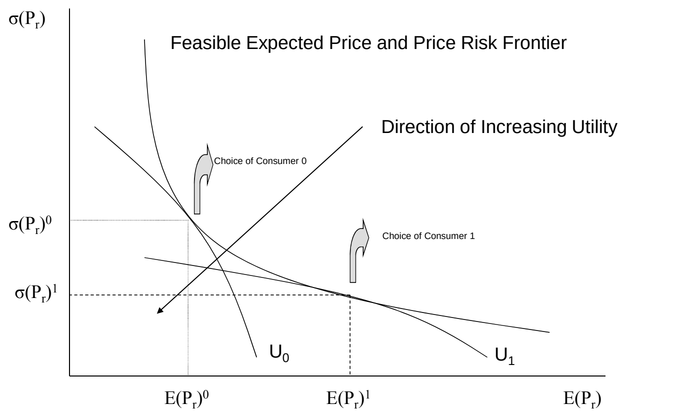
Setting Default Retail Price

- 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?

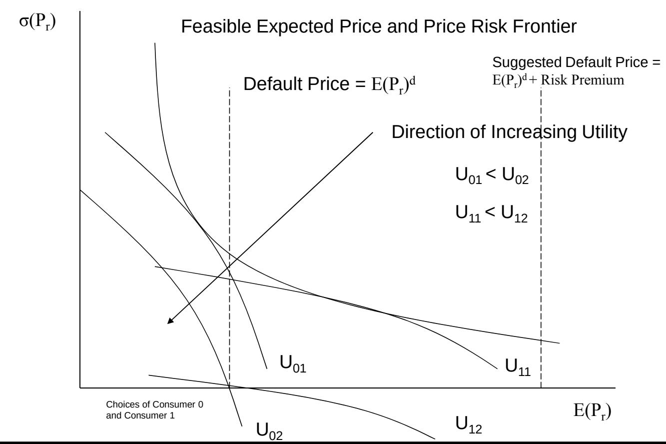
The Trouble with a Fixed Default Retail Price

- 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),σ(P)), that are decreasing in expected price, E(P), and standard deviation of price, σ(P), paid for retail electricity
  - Customer would prefer lower expected price, E(P), and lower standard deviation of expected price, σ(P)
- Retailers can only offer lower expected price, E(P), if customer is willing to take on more price risk, σ(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 price in retail prices
  - Retailers will go bankrupt if retail price does not satisfy equation given below on an annual basis
    - P(retail) $\geq$ 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?*

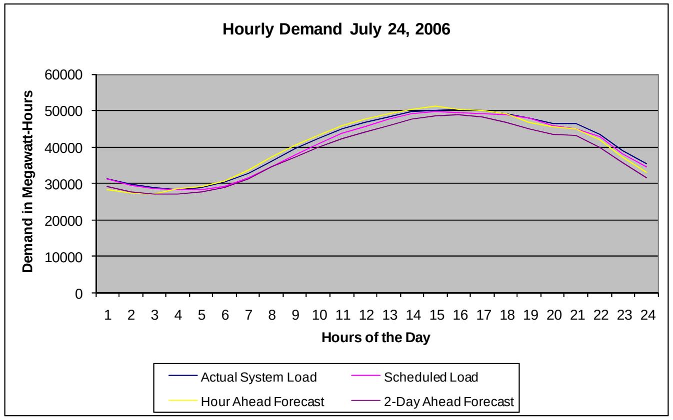
Why Dynamic Pricing is Inevitable

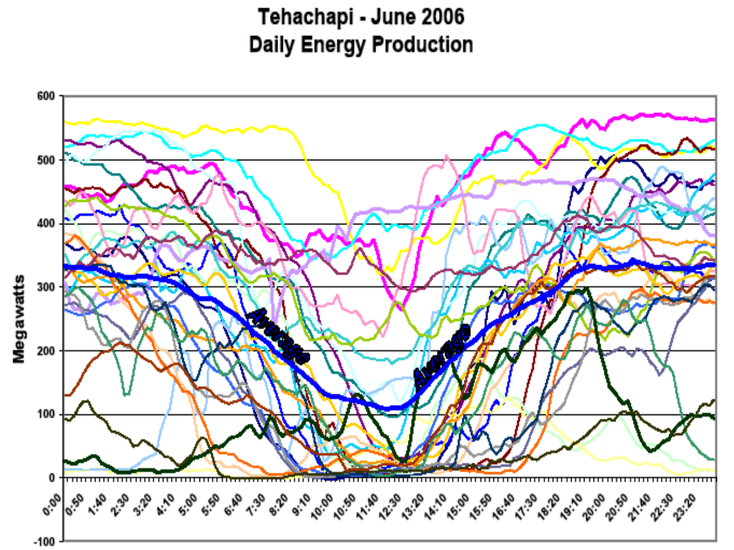
- Many states have ambitious renewable energy goals
  - California has 33 percent renewable share goal by 2020
- Significant system operation challenges associated with large renewable energy share
  - With 33 percent renewable share, significant fraction of energy can disappear with little warning
  - Operators need to hold more operating reserves
    - Fossil fuel units running with unloaded capacity
    - Quick start combustion turbine generation units
  - Energy storage technologies required
    - Transfer off-peak power to peak
    - Price differences across hours of day make storage economic

Managing Intermittency

- Wind and other renewables often unavailable during peak periods
  - 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
  - Solar photovoltaic panels less efficient during very hot portion of day

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 technologies
  - Value of storage technology is ability to turn low-priced electricity into high-price electricity
- Symmetric treatment of load and generation creates the strongest possible incentive for final demand to participate actively 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
  - 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

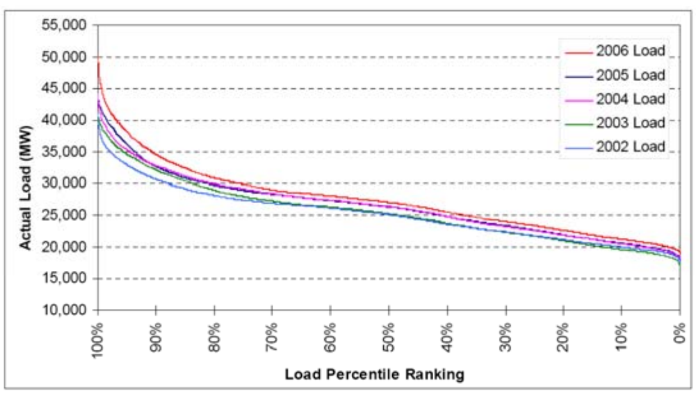
Table E.1 Load Statistics for 2003 – 2007*

Year	Avg. Load (MW)	% Chg.	Annual Total Energy (GWh)	Annual Peak Load (MW)	% Chg.
2003 Actual	26,345		230,857	42,581	
2004 Actual	27,309	3.5%	239,312	45,597	7.1%
2005 Actual	26,990	-1.2%	236,483	45,562	-0.1%
2006 Actual	27,427	1.6%	240,344	50,270	10.3%
2007 Actual	27,646	0.8%	242,265	48,615	-3.3%
2003 Adjusted	25,471		223,206	41,063	
2004 Adjusted	26,436	3.7%	231,660	44,209	7.1%
2005 Adjusted	26,477	0.2%	231,994	44,260	0.1%
2006 Adjusted	27,427	3.5%	240,344	50,198	11.8%
2007 Adjusted	27,646	0.8%	242,265	48,615	-3.3%

* Adjusted figures are normalized to account for day of week, changes in the CAISO Control Area footprint, and the 2004 leap year.

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

Price-Responsive Demand

- 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 2011
  - Need retail prices that maximize benefits to consumers of these meters

Politically Acceptable Real-Time Pricing

- Major complaints with implementing hourly pricing is that customers cannot respond to hourly wholesale prices
  - Difficult to determine when is best time to take action
- If 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) flat load shape, 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 Real-Time 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 Real-Time 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 then if wholesale price is below $300/MWh, by calling a CPP days the retailer loses money
    - Addresses moral hazard problem associated with CPP tariff

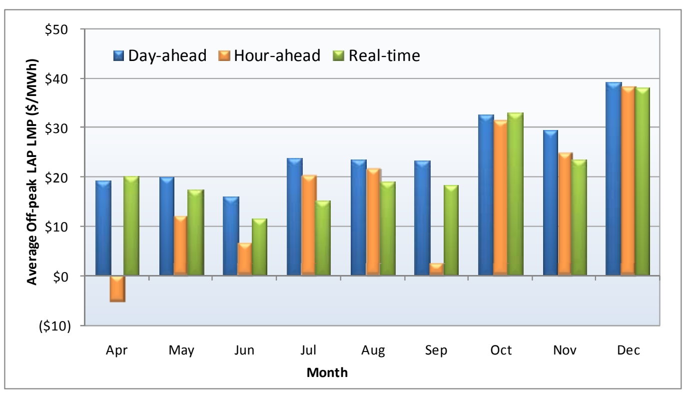
Day-Ahead versus Real-Time Dynamic Pricing

- 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

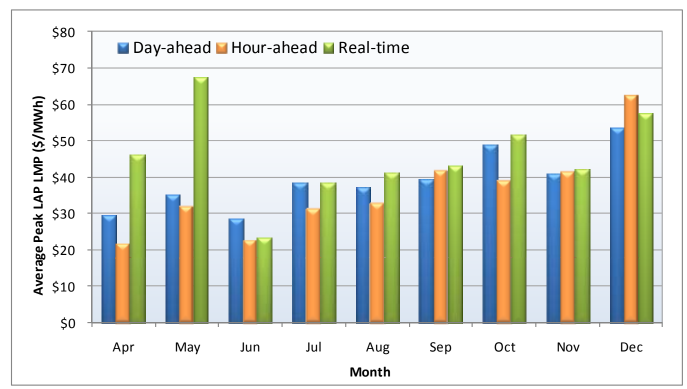
Day-Ahead versus Real-Time Dynamic Pricing

- 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

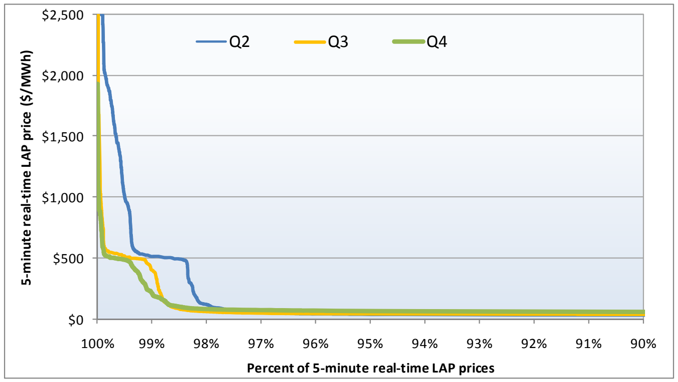
Monthly Average Off-Peak Period Prices for 2009 (SCE LAP)



Monthly Average Peak Period Prices for 2009 (SCE LAP)



Quarterly Real-Time Price Duration Curves for 2009 SCE LAP



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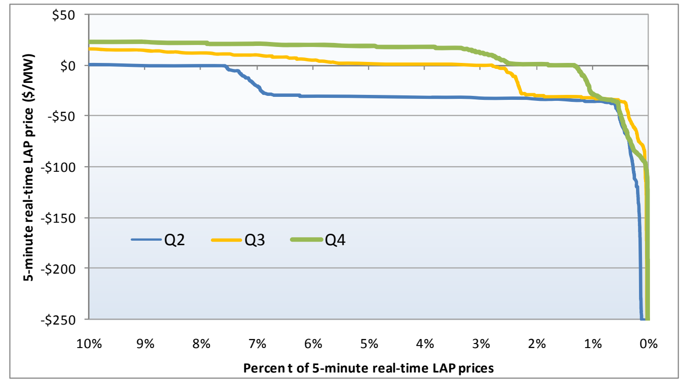

Day-Ahead versus Real-Time Dynamic Pricing

- 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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