Ten Myths About Competitive Electricity Markets: Lessons for Designing Congestion Management Protocols

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Competitive Electricity Market Requires a Paradigm Shift in System Operation

Last paragraph of introductory chapter of *Power Generation and Operation and Control (2nd edition)*, by Allen J. Wood and Bruce F. Wollenberg

"In the extreme cases mentioned above [industry re-structuring of the form implemented in the United Kingdom], many of the dispatch and scheduling methods we are going to discuss will need to be re-thought and perhaps drastically revised. Current practices in automatic generation control are based on the tacit assumptions that the electricity market is slow moving with only a few, more-or-less fixed, interchange contracts that are arranged between interconnected utilities. Current techniques for establishing optimal economic generation schedules are really based on the assumption of a single utility serving the electric energy needs of its own customers at minimum cost."

Market Operator not System Operator

- In a competitive market economic concerns drive engineering decision-making
  - Consumers want the small, powerful, low cost cell phones--engineers have financial incentive to meet these demands
  - Consumers want high performance, fuel efficient cars--engineers have financial incentive to meet these demands

Consumers want low-cost, reliable electricity supply

Do power systems engineers/operators have a financial incentive to meet these demands?

Ten Myths about Competitive Electricity Markets

- All myths arise from applying logic of engineering paradigm to competitive market
- All industry participants have fallen victim to some or all of these myths
- Some are much quicker to adapt to new paradigm than others because of incentives they face
  - Merchant producers quickest
  - Incumbent investor-owned utilities next
  - Large consumers
  - Regulators slowest to adapt

Myth #1--Verifiable Forced Outage

- Impossible for outside entity (e.g., regulatory body), no matter how expert, to determine if generating unit declared forced out was actually able to run
  - During summer of Autumn of 2000, California Public Utilities inspected plants throughout California
  - Federal Energy Regulatory Commission Staff prepared January 2001 report on plants outages
- Generating facilities are extremely complex pieces of machinery and have potential to create enormous environmental damage if operated improperly
  - Particularly for old units, on any day there are a large number of reasons why a plant may be unable to operate
  - Considerable amount of operator discretion goes into making decision as to whether plant can run
    - Operator knows plant best and should therefore make this decision

Myth #1--Verifiable Forced Outage

- Analogous problem in labor market--sick days
  - Employee calls in sick
  - Impossible for boss to tell whether or not employee is fact sick
  - Boss can send doctor to employee’s house to verify illness
  - Human bodies are extremely complex machines, so that employee can display symptoms of some previously unheard of disease
  - Boss recognizes this potential response by employee and therefore does not bother to send doctor to verify illness
- Solution to labor market problem
  - Boss allows sick day but requires employee to find another worker in firm to replace him during that day
  - This places risk of sick day on employee
  - Boss does not have to devote any resources to verifying sick days

Myth #1--Verifiable Forced Outage

- Solution to problem for competitive electricity market
  - Risk of all unplanned generation outages borne by generation unit owner
  - Every generation unit owner must have a bid into market for entire capacity of unit during every hour unit is not scheduled out
  - If unit is unable to run in hour, unit owner has three choices
    - Bid higher that expected price in that hour to avoid running
    - Purchase replacement power from other units not likely to win in market during this hour
    - Purchase replacement power for quantity unable to supply from energy market
- This problem has arisen in virtually every competitive electricity market. For an example from the UK, see
  - Wolak, Frank and Patrick, Robert "The Impact of Market Structure and Market Rules on the Price Determination Process in the England and Wales Electricity Market," available from web-site.

Myth #2--Unit Specific Dispatch Instructions

- In all multi-settlement markets generators and load schedule on a day-ahead and hour-ahead basis to supply or demand energy at a specific location in the transmission grid
  - Forward schedules represent firm financial commitments to supply energy or consume energy
- Example from California
    - Generation unit schedules 500 MWh in forward market
    - If unit produces 600 MWh in real-time, it is sells additional 100 MWh at real-time energy price
    - If unit produces 450 MWh in real-time, it is buys 50 MWh that it was scheduled to supply at real-time energy price
  - All generators buy or sell deviations from schedule at the real-time price
    - All units can produce more or less than their schedule in real time
    - When real-time price at a given location is increased, all unit owners in this location have the ability
      - To earn this price for sales beyond their final schedule
      - To pay this price for the amount their production is less than their final schedule

Myth #2--Unit Specific Dispatch Instructions

- Implication--No such thing as a unit-specific dispatch instruction
    - All unit owners are free to change their output in response to a price change caused by the system operator accepting bid in the real-time energy market
    - The fact that only the unit whose bid was accepted received a dispatch instruction is irrelevant
    - All units see the real-time price and are free to respond to it and be compensated or make payments for their actions as described above
- Solution--Set prices at location
    - Increase prices at a given location if system state indicates demand increase
    - Decrease prices at a given location is system state indicates demand reduction
    - Unnecessary to have unit owners submit bids
        - System operator posts rate at which it will increase or reduce prices as a function of projected system imbalance during given 5-minute interval
        - Unit owners manage imbalance in real-time throughout grid according this price adjustment scheme

Myth #3--Grid Reliability Problems

- Reliability in monopoly versus competitive regime
    - In monopoly regime, grid reliability is percent of time that consumers actually receive power
    - In market regime, grid reliability is the percent of time that consumers willing to pay any price can receive power
    - Having to pay hourly price of energy in competitive regime may cause dramatic reduction in amount demanded
- This logic suggests revising usual protocols for determining level of generation reserves necessary for reliable grid operation
    - Potential source of efficiency gains from re-structuring

Myth #3--Grid Reliability Problems

- For some hours certain plants are constrained on
  - Given current transmission grid configuration
  - Geographic location of demand
- Generation resource is must-run
  - Only it can satisfy local grid reliability need
  - Regardless of hourly spot price of electricity
- This is not a reliability problem, it is a local market power problem
  - If pay generator what it wants, loads would obtain power
  - This price may violate FERC's "just and reasonable rates" standard

Myth #3--Grid Reliability Problems

Persistent Reliability Problems Arise Because of Inappropriate Market Incentives Provided to Generators and Loads

- Market participants take actions that harm or benefit system reliability because it is in their financial interest to do so given the market rules for compensating them for their actions
- If an system operator would like market participants to take actions which maintain system reliability, it must design market rules that provide financial incentives for these actions
- Persistent reliability problems do not exist separate from economic incentive or market power problems
- California ISO, much more so than East Coast ISOs, must rely on economic incentives, because generators self-schedule their units and market requires a substantial amount of imports

Myth #4-Good and Bad Imbalances

- Supply for electricity must equal demand at all points in transmission grid in real time
  - All imbalances, regardless of source, increase probability of outages
- System operators issue “unit specific dispatch instructions” (see Myth #2--unit specific dispatch instruction) in real-time to maintain system balance
  - Good imbalances--deviations from schedule that help system operator correct imbalances
  - Bad imbalances--deviations from schedule that system operator must correct by making requests for “good imbalances” from certain units

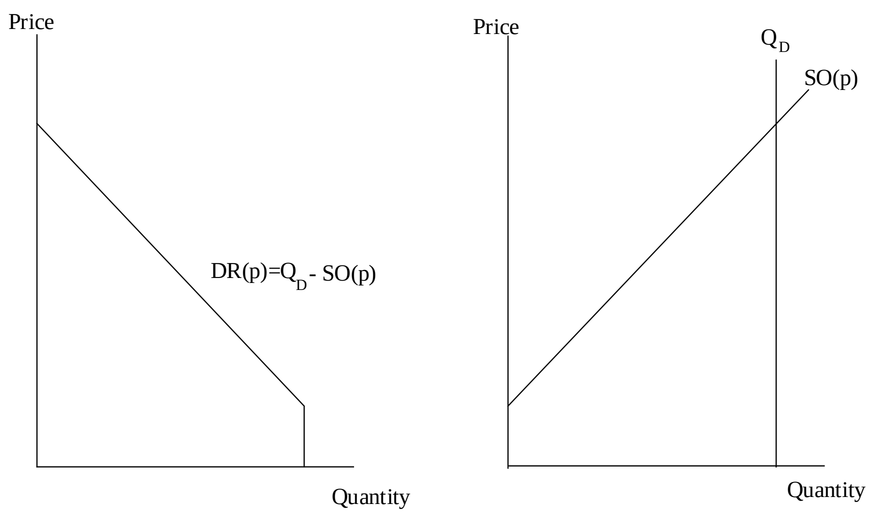
Myth #4-Good and Bad Imbalances

- Recall Myth #5--Grid reliability problems exist because of poorly designed incentives for generators
- California ISO pays “good imbalances” higher price than “bad imbalances”
  - Implication--two units with exactly the same schedule and same real-time production are be paid different amounts
  - Creates incentives for generators to turn all imbalances into “good imbalances”
- Firms owning a portfolio of generation units can create system conditions that increase the demand for “good imbalances” from some of their units

Myth #5--Generators Bid Their Marginal Costs

- In all markets firms exercise market power
  - Equivalent to serving fiduciary responsibility to shareholders
  - Equivalent to maximizing profits
- Firms in all markets attempt to influence regulatory process and exploit regulator-imposed rules to maximize their profits
  - Example--airline industry safety regulation
  - Regulator must anticipate this use of regulatory process
- Profit-maximizing behavior by generators implies an optimal bid price above marginal cost except in very rare circumstances

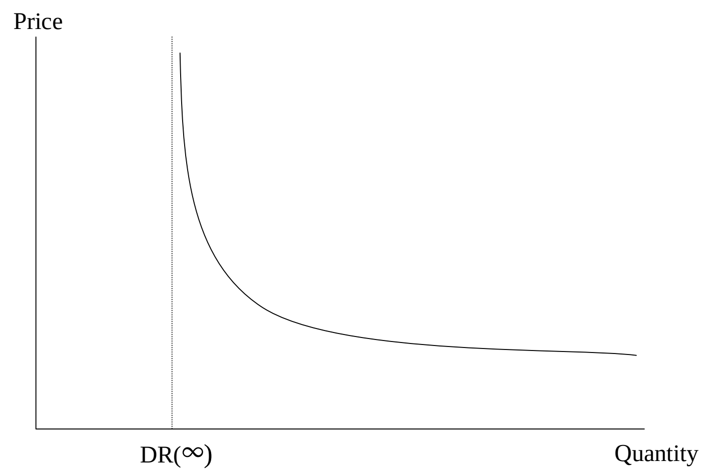
Residual Demand Function



Extreme Case--Pivotal Bidder

- Residual demand faced by Firm A is positive for all prices
  - In this case, Firm A is called a pivotal bidder
  - Mathematically, DR(∞) > 0
- Given bids of other firms, at least DR(∞) from Firm A is required to satisfy market demand
- Extreme case of market power
  - No matter how high a price Firm A bids for DR(∞), it will set market-clearing price

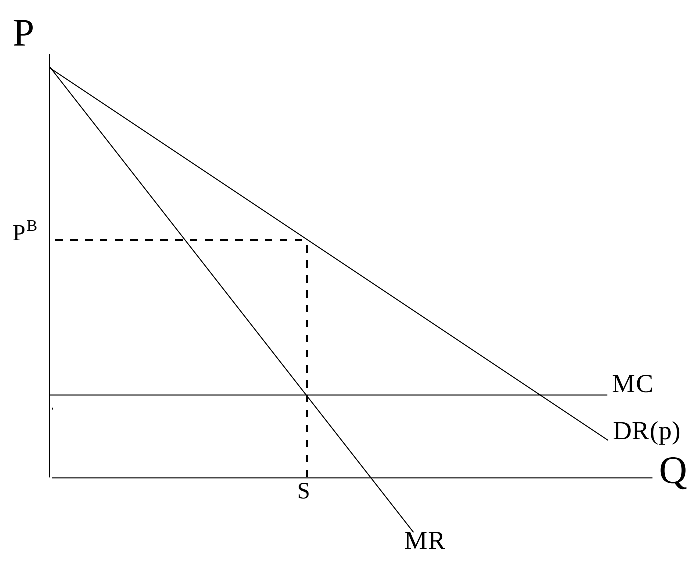
Pivotal Bidder



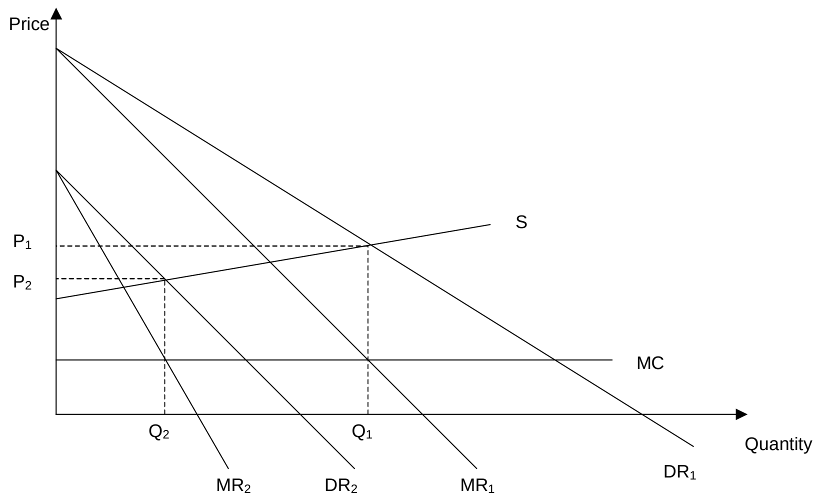
Elasticity of Residual Demand

- Elasticity of Residual Demand Determines extent to which Firm A's bids can set p > MC
  - Less price-elastic residual demand function allows p to be set further in excess of MC
    - Steep residual demand function, smaller loss of sales from higher prices
  - More price-elastic residual demand function forces p to be set closer to MC
    - Flat residual demand function, greater loss of sales from higher prices
- Firm's A optimal market price depends on the price elasticity of its residual demand

Bid to Maximize Profits Subject to Residual Demand



Bid to Maximize Expected Profits



Myth #6--High Electricity Prices Now Encourages New Investment

- One justification given for not correcting current market design flaws
  - High prices now are necessary to provide incentives for new investment
- Electricity generating facilities take at least two years to construct, longer if include siting process
  - Plant cannot earn revenues from market until it is actually able to produce electricity
  - High prices now provide no signal for new investment if they provide no information about value of price more than two years from now
    - Very likely if current high prices are due to market design flaws

Myth #6--High Electricity Prices Now Encourages New Investment

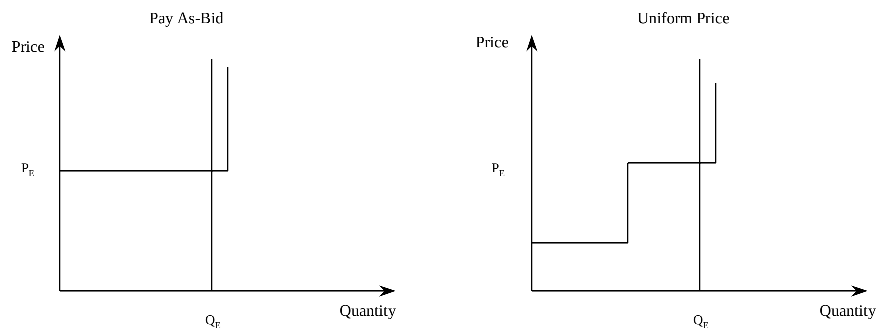
- Consider following thought experiment
  - Suppose all prospective entrants know with certainty that
    - Price for next two years will be very high
    - Prices will be very low after two years
  - No new entry will take place
    - Current high prices do not provide signals for new investment
- What signals do current high prices provide?

- Current high prices provide very strong economic signals for loads to reduce their current demand
  - Loads must face hourly price and can benefit from reducing their demand in high-priced hours
  - Hourly meters and real-time pricing of loads--No load profiling

Myth #7: Pay-As-Bid Auctions Superior to Uniform Price Auctions

- Many observers argue that high prices in spot electricity markets are due to uniform price auction mechanism
  - All bidders paid highest bid price necessary to meet demand
- Actual bid curves submitted in uniform price auctions have long segments at zero or negative prices
  - These bidders being paid more than their as-bid willingness to supply to market
- This logic ignores fact that rational profit-maximizing bidders would change how they bid in response to being paid-as bid versus uniform price auction
- All bidders would at least raise their bids to an estimate of the bid of highest bidder necessary to serve market demand

Myth #7: Pay-As-Bid Auctions Superior to Uniform Price Auctions



Myth #7: Pay-As-Bid Auctions Superior to Uniform Price Auctions

- With active forward markets little distinction between two auction formats
- Consider airline industry
  - Everyday airline operates uniform price auction for seats on flight
  - Every prospective traveler receives the same quote for the price of ticket with same characteristics
    - Date and time of travel and return, origin and destination, class of service
  - Each day airline runs a different uniform price auction for air travel with these characteristics
  - On date of flight virtually every person on flight in same class of service pays a different price for their ticket
    - Huge variability in actual price paid for each seat on flight
- Apparent pay-as-bid market outcome due to active forward market for airline tickets

Myth #8: Optimal Power Flow Models Yield Optimal Outcomes

- Many markets around the world use "optimal power flow" models from vertically integrated regime to schedule and dispatch generation units in a competitive market
- Optimality properties of dispatch obtained requires that bids submitted by market participants are in fact their actual marginal costs
- Recall Myth #5--Profit-maximizing generators do not bid their marginal costs into competitive markets
  - Dispatch obtained from optimal power flow model applied to bids submitted by profit-maximizing firms is not least cost
  - Unit owners must be provided with financial incentive to reveal their production costs through their bids
    - Owner knows unit's minimum operating costs and physical capabilities, system operator does not

Myth #8: Optimal Power Flow Models Yield Optimal Outcomes

- How generation unit owners are compensated for their actions should lead them to reveal to their minimum costs to system operator
- Atomistic competition is one way to guarantee truthful reporting is optimal
  - Many small firms competing in large market
  - All face horizontal residual demand curve
    - Optimal for all firms to bid marginal cost
  - Usually not possible given starting point of restructuring and technology of generation
- This is fundamental challenge of electricity market design

Myth #8: Optimal Power Flow Models Yield Optimal Outcomes

- Market Design Problem
  - Set number and size of market participants
  - Set rules for determining revenues each firm receives
  - So that combined actions of each participant acting in its own best interest
  - Yields market outcomes as close as possible to regulator’s desired outcome
- Political constraints often imposed on process
  - Difficult to break-up incumbent monopolist

Myth #9: FERC Treats All Market the Same

- The Federal Energy Regulatory Commission approves market rules for all US ISOs
  - Internal consistency in policies with respect to all ISOs appears to be a useful goal to pursue
  - If one ISO granted some market rules, others should have right to request similar rules, or told why rules cannot be applied in their market
- Example--Cost based bid caps on generation resources
  - California ISO has made several requests to FERC to impose cost-based bid caps on market participants when they have local market power

Myth #9: FERC Treats All Market the Same

- In PJM ISO, FERC allows cost-based bid caps on all units whose construction commenced before July 9, 1996
- If, on a day ahead basis, a generating unit must be dispatched out of merit order based on its bids because of transmission constraints
  - There are three ways energy bids will be capped for those hours or entire day at ISO’s discretion
    - Price bids replaced by 1.1*cost curve
    - Average prices at node when unit was dispatched in merit order
    - Mutually agreed upon price between ISO and participant
- Dispatch and pricing algorithm re-run with this mitigation measure in place
- Mitigated generator can set or receive price at node

Myth #10: Loads Require Different Treatment from Generation

- Many observers argue that loads can only be passive participants in competitive electricity markets
- The basis for this logic is that electricity is an essential commodity
  - Consumers will purchase their desired demand regardless of the price
  - High prices will only impose economic harm on consumers with no reduction in demand
- Large loads cannot respond to real-time dispatch instructions like generating facilities
  - This logic fails to recognize the existence of a wide variety of co-generation and short-term energy storage technologies
  - Pumped storage facilities are profitable if highest price of electricity in the day is more than twice the lowest price in the day

Need for Price-Responsive End-Users

- End-user that faces an hourly price for actual hourly consumption
  - Can be commercial, industrial or residential
- Time lag of price-response less important than purchasing hourly quantity at an hourly price
  - Forward financial contract holdings reduce generator incentives to exercise market power in spot market
- Ability to shift load across hours in the day due to high prices more important than reducing total daily consumption because of high prices
  - Hourly prices can be used to smooth demand across hours in the day

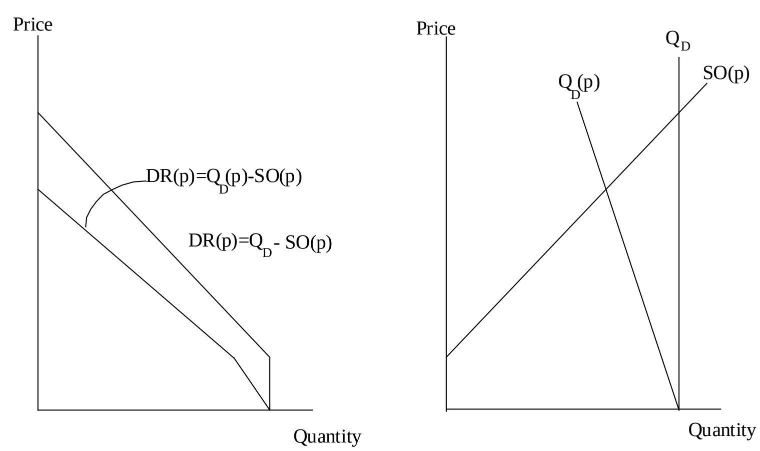
Load-profile billing does not yield price-responsive end-users

- Can only measure total monthly consumption of electricity
- Representative load shape used to compute weighted-average energy price for month
- Monthly bill = (monthly consumption) x (monthly weighted-average energy price)
- Demand reduction when hourly energy price is $0/MWh leads to same monthly savings as same demand reduction when hourly price is $250/MWh.

How Price-Responsive End-Users Enhance Market Efficiency

- Increase elasticity of residual demand each firm faces for its output
  - Less market power for the firm to exploit for a given industry structure
- Causes generators to bid more aggressively
  - Flatter supply bid curves
  - Lower prices for same bid quantity
- Forward price responsiveness--financial contracting--increases aggressiveness of generator bids
- Reduce market price volatility relative to case of no price-responsive end-users

Benefits of a Price Responsive Demand



Maximum benefits from restructuring requires price responsive end-users

- A competitive market requires final demand to become more sophisticated than it was under monopoly regime
- Potential for high prices is necessary to give demanders the incentive to invest in price-response technologies
  - Real-time metering for end-user customers
  - Interruptible purchase agreements for end-user customers
  - Within day load-shifting capital equipment for end-user customers
- Positive externalities to all other demanders from more price-responsive end-users
  - Rationale for subsidizing installation real-time metering technology
    - Provides demand with technology to become more sophisticated

The Role of High Prices

- Involving demand in the market requires long-lived, irreversible investments
- Without constant threat of high prices demanders will not make necessary investments
  - May be cheaper to work to continue price caps
- Carrot and stick approach
  - Carrot--subsidies to early adopters of demand response technologies
  - Stick--promise of removal or lifting of safety nets in future

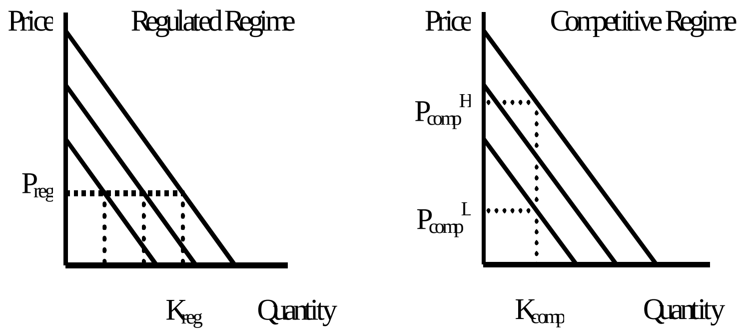
Limited Benefits of Restructuring Without Involving Demand

- US has privately-owned, profit-maximizing firms facing cost-of-service price regulation or incentive regulation plan
  - Detailed prudence review of investment
  - Hard to argue there are large deviations from minimum cost production
  - Vertically integrated ownership and centralized dispatch should be able to improve on bid-based dispatch on true production cost basis

Markets use prices to allocate scarce resources

- Competitive market should be able to get by with lower level of capacity and serve same customers
  - This implies lower capacity costs for market at large
  - If dispatch costs are close to the same, then average price in competitive market should be less than average price in regulated market
- A necessary condition for this to occur is a sufficient number of price-responsive consumers

Optimal Capacity Choice Under Regulation versus Competition



$K_{reg} >> K_{comp}$

Example--US Airline Industry

- Load Factors = (Seats Filled)/(Seats Total),
  - In regulated regime highest load factors approximately 55% in 1976
  - Currently Load Factors are close to 73%
- This increased capacity utilization rate allows real average fare per passenger-mile to be significantly less than under regulated regime
- Regime works because of large number of sophisticated price-responsive consumers.

Real-time pricing contracts

- All England and Wales retail customers have option to purchase hourly consumption according to hourly pool price plus transmission charge
- Many large industrial customers purchase according to this pool price contract
- "Estimating the Customer-Level Demand for Electricity Under Real-Time Market Prices" available from http://www.stanford.edu/~wolak.
  - Estimate half-hourly price responsiveness of a sample of large industrial and commercial customers in England and Wales
  - Significant price response from all classes of industrial customers--water suppliers, industrial process plants, retail stores
  - Even with a small fraction of these customers bidding into demand side of pool, market power can be mitigated.

Concluding Comment

Goal of Re-structuring (AB 1890, Section 1(a))

"It is the intent of the Legislature to ensure that California's transition to a more competitive electricity market structure ***allows its citizens and businesses to achieve the economic benefits of industry restructuring at the earliest possible date, creates a new market structure that provides competitive, low cost and reliable electric service, provides assurances that electricity customers in the new market will have sufficient information and protection***, and preserves California's commitment to developing diverse, environmentally sensitive electricity resources."

A properly designed competitive electricity market **can** achieve these goals.