

The Benefits of Load as a Strategic Resource in Wholesale Electricity Markets

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Outline of Talk

- In virtually all markets but electricity demand-side participation limits ability of suppliers to raise prices through their unilateral actions
- Regulatory barriers limit symmetric treatment of load and generation in US
 - Federal (wholesale) versus state (retail) regulatory oversight
 - History of shielding final consumers from hourly wholesale price
- Symmetric treatment of consumers and producers common to all markets besides electricity
 - Few markets where government provides “free option” to consumers
- Face consumers with real-time prices not time-of-use prices
- Limit load-profile billing to default customers only
- Necessity of hourly metering for active demand side participation
- Passive load participation and unilateral market power
 - UK Real-Time Pricing Contracts
- Strategic load participation and unilateral market power
 - Strategic use of price responsive load to limit unilateral market power of suppliers
- Limited benefits from restructuring in US without active demand

The Role of Demand

- Consumers reducing their consumption in response to higher prices limits ability of suppliers to raise prices through their unilateral actions
 - High airfares cause customers to avoid traveling on certain flights
- Similar mechanisms can operate in electricity
 - High-priced hours can cause customers to avoid consumption during these hours
- Customers with minimal demands in all hours can purchase expected consumption in advance
 - Buy 100 KWh for 24 hours a day, 7 days per week
 - Sell back excess during high-priced hours

Regulatory Structure in US

- Federal Energy Regulatory Commission (FERC)
 - Regulates wholesale electricity prices under mandate of Federal Power Act of 1930
 - Prices are required to be “just and reasonable”
 - Much higher standard for prices than US antitrust law requires
- State public utilities commissions (PUCs)
 - Regulate retail electricity prices
 - In vertically-integrated regime, utilities owned virtually all generation capacity necessary to serve demand or had long-term energy supply contracts for necessary energy
 - Conclusion--State PUCs controlled retail prices in vertically integrated regime
 - FERC had limited role in regulating wholesale prices

Regulatory Structure in US

- When significant fraction of wholesale energy is purchased from short-term wholesale market state PUC cannot control retail prices
 - Must pay wholesale price to receive energy
- Allowing final consumers to benefit from managing short-term wholesale price risk may be perceived by state PUCs as giving up regulatory authority
 - May explain why all state PUCs with wholesale markets are unwilling to treat load and generation symmetrically
- Significant cost associated with preventing final consumers from managing wholesale price risk
 - Consumers still have to pay high wholesale prices

Asymmetric Treatment of Load versus Generation

- Generation unit owners can fully benefit
 - From change in their output in response to hourly electricity prices
 - Produce more in higher-priced hours
 - From their ability to alter hourly price through their bidding or operating behavior
- With fixed retail price, consumers are prevented from realizing full benefits
 - From change in output in response to hourly price
 - In California, regardless of wholesale price during hour, consumer only saves \$0.13/KWh for each KWh not consumed
 - From their ability to alter hourly price
 - Strategic behavior of final demand (more on this later)

Asymmetric Treatment of Load versus Generation

- Default price loads pay for wholesale energy in all US states is constant over time and space
 - State regulator allows consumers to switch to and from this default price at any time
- “Free Option” to buy at default price at any time can be extremely valuable to consumers
 - Creates a enormous liability for load-serving entities that can arise with high probability during certain system conditions such as those in California from June 2000 to June 2001
- Default price generators receive in all of US markets is hourly wholesale spot price at their location
 - Generator must sign a hedging agreement to receive pre-specified fixed price for its output

Load as a Resource

- Symmetric treatment of producers and consumers of electricity
 - From perspective of grid reliability, a consumer is a supplier of “negawatts”
 - Let $D(p)$ equal consumer’s hourly demand as a function of hourly price p
 - Consumer’s supply curve for negawatts is $SN(p) = D(0) - D(p)$
- Default price for all consumers with hourly meters should be hourly wholesale price
 - Consumer is not required to pay this price for any of its consumption, just as generator is not required to sell any output at short-term price
 - To receive fixed price, consumer must sign a hedging arrangement with load-serving entity or electricity supplier
- There is nothing unusual about hedging spot price risk
 - Health, automobile and home insurance, cellular telephone

Involving Final Demand

- Real-time price should be default price for all large customers
 - Customers with sophistication to manage price risk
 - Required to have hourly metering technology
- Residential and small business customers that elect to exit default provider should face real-time price risk
 - Must have hourly meter to take service from competitive retailer
 - Once customer leaves default rate they cannot return
- Regulated retailer is spot price provider
 - Manages spot price risk on behalf of consumer
 - Default provider rate should be set to give customers incentive to take on real-time price risk
 - All retailers must offer fixed-price default provider rate, but they can also offer any other pricing plan
 - Regulated customers need not have hourly meters if retailer is providing short-term price risk management services

Real-Time Pricing not Time-of-Use Pricing

- Time-of-use (TOU) pricing
 - Prices that vary depending on time of day or day of day of the week
- TOU provides limited benefits to system reliability and market efficiency
 - Two fixed prices as opposed to one fixed price that does not vary with real-time system conditions
 - Same incentives as single fixed-price billing scheme
- Time-of-use pricing creates similar incentives to those from load-profile billing

Load-Profile Billing

- Measure total monthly consumption of electricity
- Representative load shape used to compute weighted-average energy price for month
 - $p(h,d)$ = price for hour h of day d ,
 - $w(h,d)$ = weigh for hour h of day d , $\sum_{h,d} w(h,d) = 1$
 - Monthly bill = (monthly consumption) \times (monthly weighted-average energy price). $\sum_{h,d} w(h,d) p(h,d) = p$
- Demand reduction when hourly energy price is \$0/MWh leads to same monthly savings as same demand reduction when hourly price is \$250/MWh.
- Want consumer to realize maximum benefit from reducing consumption when wholesale price is highest
 - Imagine difficulty in running competitive long-distance telephone company only measuring minutes of phone use per month

Need for Interval metering

- Analogy to long-distance competition
 - Can only measure total minutes of phone calls in month
 - Cannot measure duration, destination, time-of-day
 - Compute monthly bill on “calling profile” set by regulator
 - Would not think of doing “load-profile” billing in long-distance industry
 - Ratio of higher to lowest cost call can easily be 50:1
 - Consumers would have strong incentive to receive favorable “calling profiles” that impose huge costs on others
 - Receive local calling plan that assumes few long-distance calls of short duration and distance
 - Once receive plan make many long-distance calls of long duration and distance
 - Creates enormous across-customer subsidies

Need for Interval Metering

- Variation in hourly electricity prices over month
 - Regulation--ratio highest to lowest cost in month is ~5:1
 - Efficiency costs of monthly load profile-billing is limited
 - To the extent that hourly wholesale prices are very similar limited to benefits to interval metering
 - Wholesale market--ratio highest to lowest price in month, or even week or day, can be much greater than 1000:1
 - In Australia bid cap is currently \$10,000/MWh with plans to go higher
 - Would never have negative wholesale prices if consumers had ability to participate in market
 - How many consumers would be willing to be paid to consume more electricity?
 - Efficiency costs of monthly load-profile billing are potentially extremely large in a wholesale market

Universal Interval Metering

- Cost is not a barrier to ubiquitous interval metering
 - Puget Sound Energy serves ~400,000 customers
 - Recent study for 7 million meters in NY
 - Average monthly bill increase of \$2 for universal metering
 - Approximately equals savings in meter reader costs
- Price of metering technology falling rapidly
- Sophistication of metering technology rising rapidly
- Increasing number of households with Internet access
- Regulator can run competitive procurement process for provision of interval metering infrastructure to regulated distribution companies

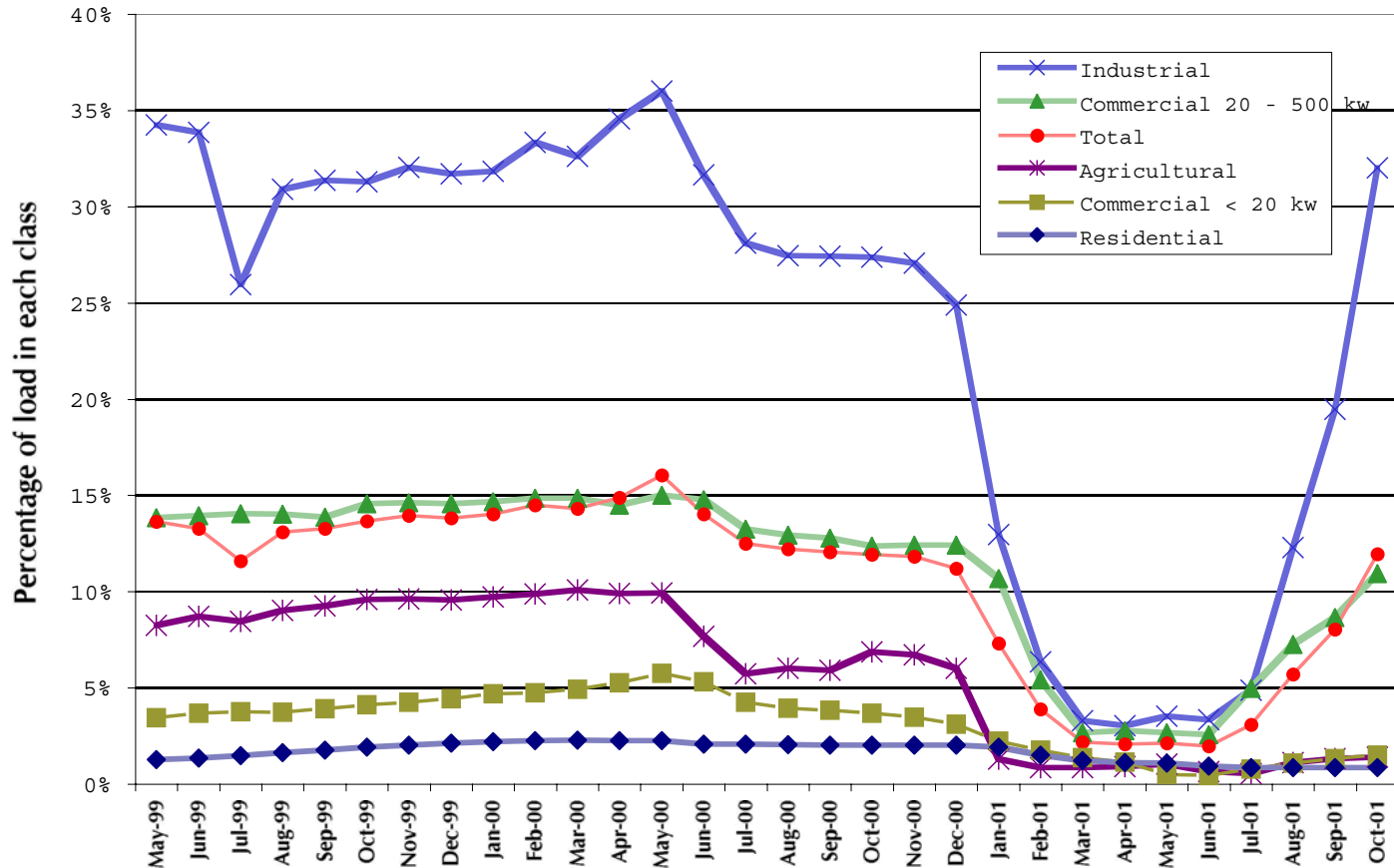
Can Active Demand Benefit Market?

- To the extent that regulatory process allows it
 - Reduction in demand in response to increase in fixed retail rates in early 2001
 - California's 20-20 program--Roughly 1/3 of California consumers qualified for rebates
- Extremely dull price incentives were surprisingly successful at improving wholesale market performance

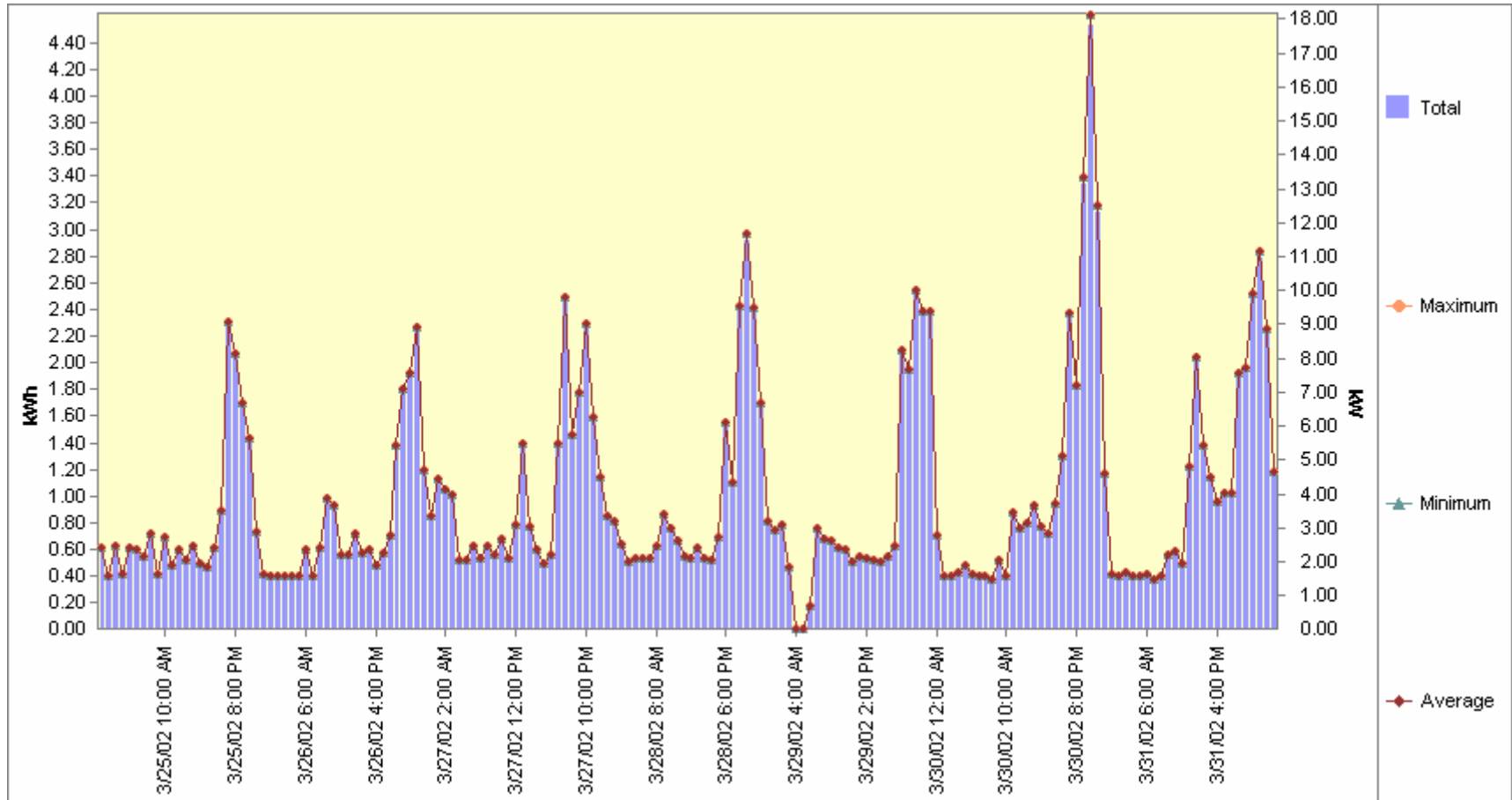
Consumers very sophisticated to the extent they are allowed



Customers Choosing Non-Utility Service by percentage of class load

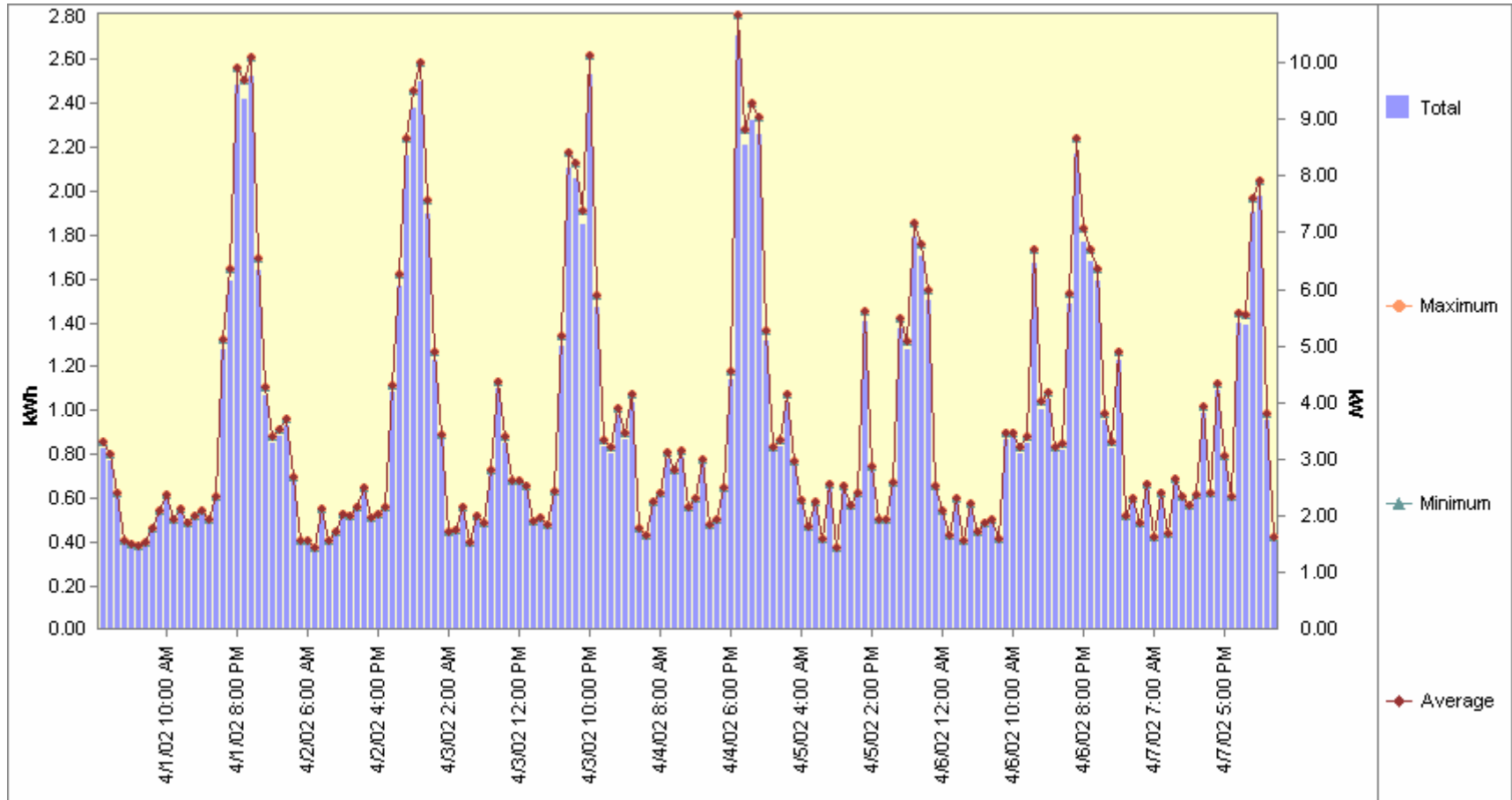


Even Residential Consumers Can Respond



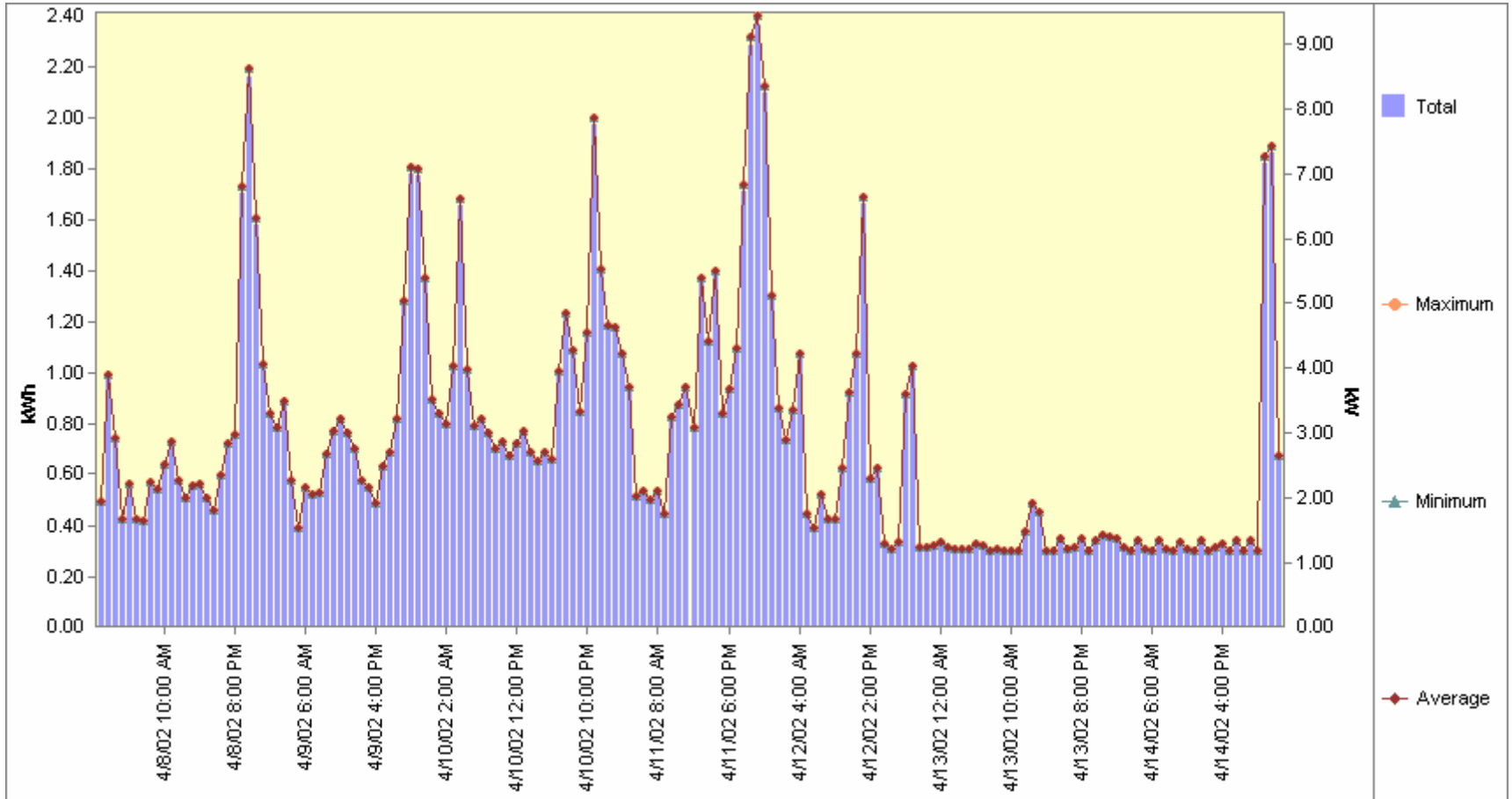
Weekly Consumption Monday to Sunday

Even Residential Consumers Can Respond



Weekly Consumption Monday to Sunday

Even Residential Consumers Can Respond



Weekly Consumption Monday to Sunday

Active Demand Participation

- Symmetric treatment of load and generation
 - Encourages demand flexibility across hours in the day
- Total energy consumption need not fall under RTP
- It could even result in more energy being consumed, but at a lower average price
- In California, total annual energy demand in 2004 divided by number of hours in year is ~28,000 MW
- Total in-state capacity is ~50,000 MW
 - Symmetric treatment of load and generation can reduce need for new capacity
- Encourages development of renewable and distributed generation technologies

UK 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
- Econometric model of 48 half-hourly demands for electricity throughout day for large industrial and commercial customers
 - “Estimating the Customer-Level Demand for Electricity Under Real-Time Market Prices” Patrick and Wolak (available from web-site)
 - Quantify degree of substitutability of consumption across 48 half-hours of the day

Real-Time Pricing Contracts

- Significant price response from all classes of industrial customers--water suppliers, industrial process plants, retail stores
 - Water utilities have very favorable average load shape and are very price responsive
- Paper shows that even with a small fraction of these customers passively bidding into demand side of UK pool market power can be significantly limited
- Passive demand-side bidding implies bidding $D(p)$ into short-term energy market
 - Price-taking behavior on demand-side of market
 - Note that price-taking supplier bids true willingness to supply--Marginal cost curve

Real-Time Pricing Contracts

- All real-time pricing customers face same half-hourly pattern of prices over course of the year
- Those that benefit most from real-time pricing are the ones that consume more of their electricity during lowest price periods, to realize the lowest quantity-weighted average price $P(\text{avg})$

$$P(\text{avg}) = \frac{\sum_{h=1}^H P_h Q_h}{\sum_{h=1}^H Q_h}$$

P_h equals wholesale price in half-hour h

Q_h equals wholesale energy purchased by customer in half-hour h

H = total number of half-hours in the year

Average Prices for FY 1991 Across RTP Retail Customers

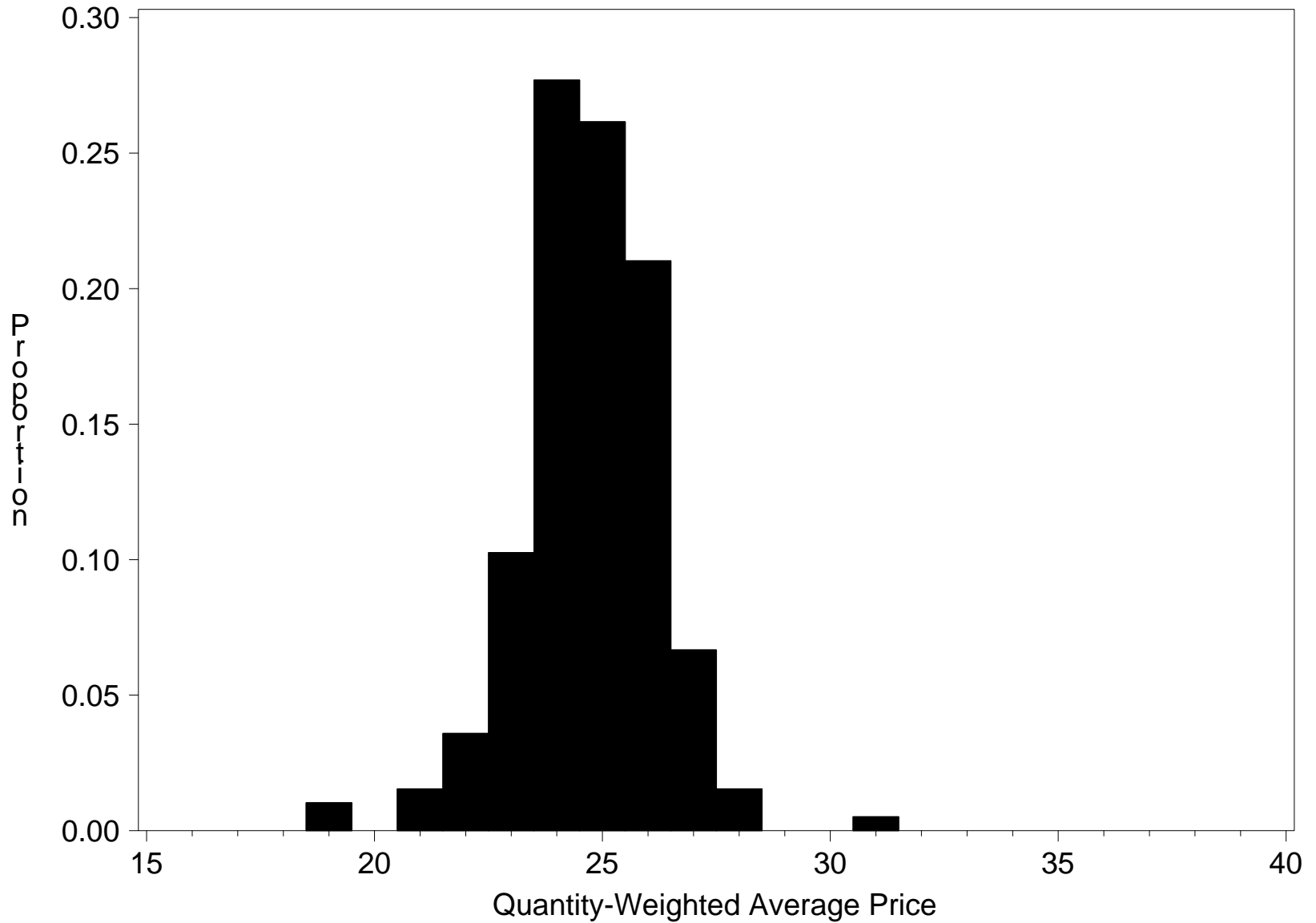
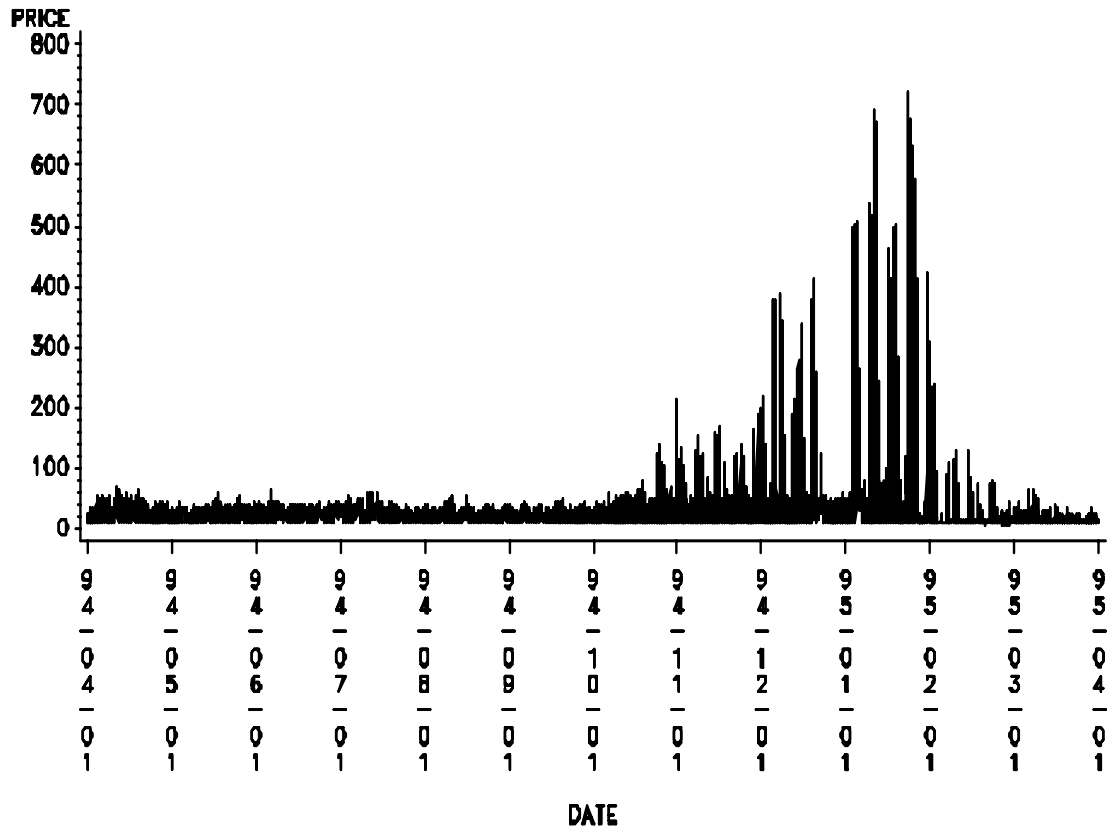


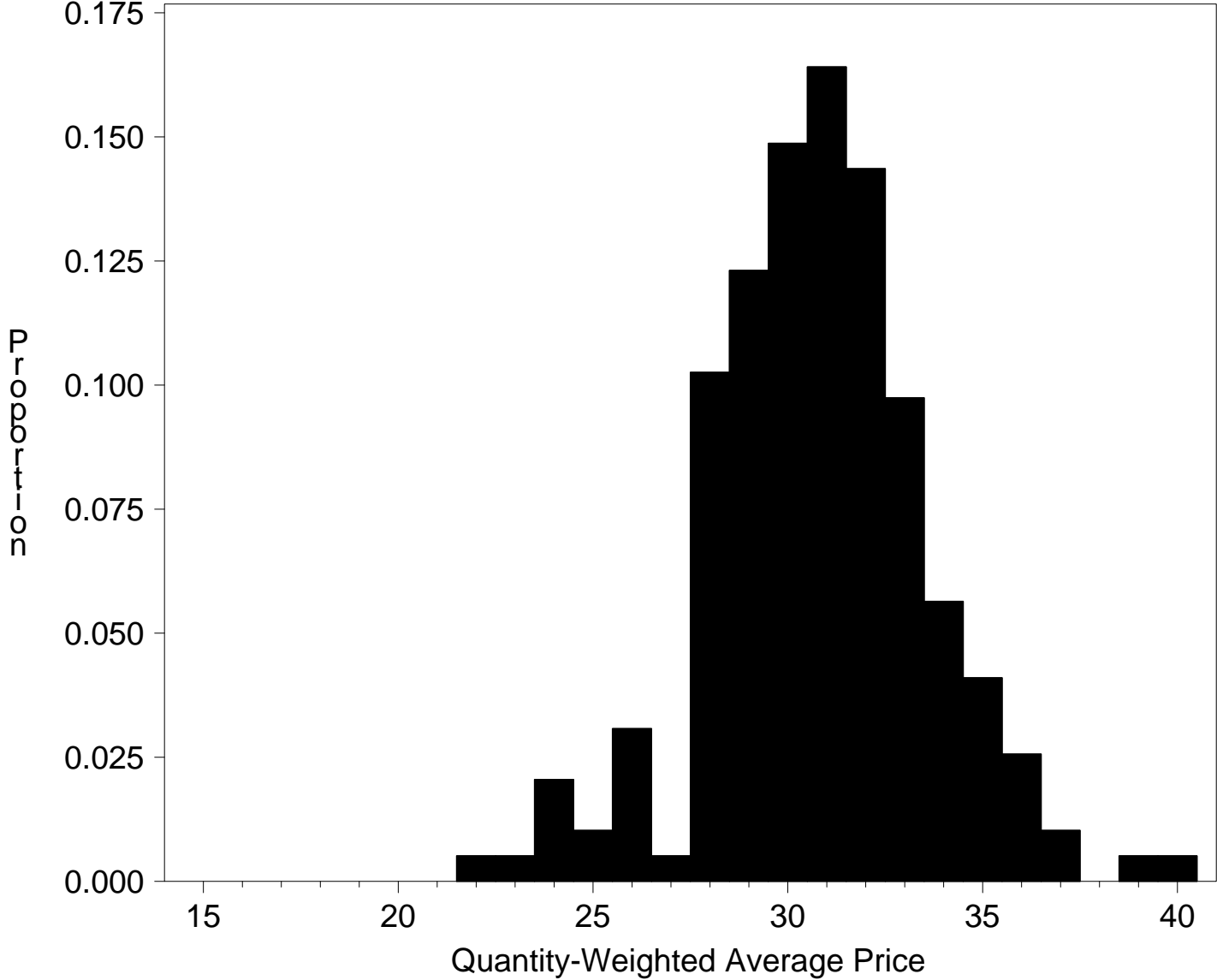
Figure 2 (d)

Price 94-95



PRICE

Average Prices for FY 1994 Across RTP Retail Customers



Using Real-Time Pricing to Exercise Buyer Power

A retailer that serves real-time pricing and fixed-price customers can exercise unilateral monopsony power

$P(\text{RTP},t)$ = price paid by RTP consumers in half-hour t

$P(W,t)$ = wholesale purchase price in half-hour t

$Q(t)$ = energy purchased by RTP customers in hour t

Retailer makes commitment that following constraint holds on monthly basis

$$\rightarrow P(\text{RTP},t)Q(t) = \rightarrow P(W,t)Q(t)$$

RTP customers also receive a share of saving to retailer in serving its fixed price customers from RTP customer's active demand-side participation

Using Real-Time Pricing to Exercise Buyer Power

Retailer uses real-time pricing customers to reduce its demand in hours when aggregate supply is steep

Greatly reduces wholesale price for all purchases

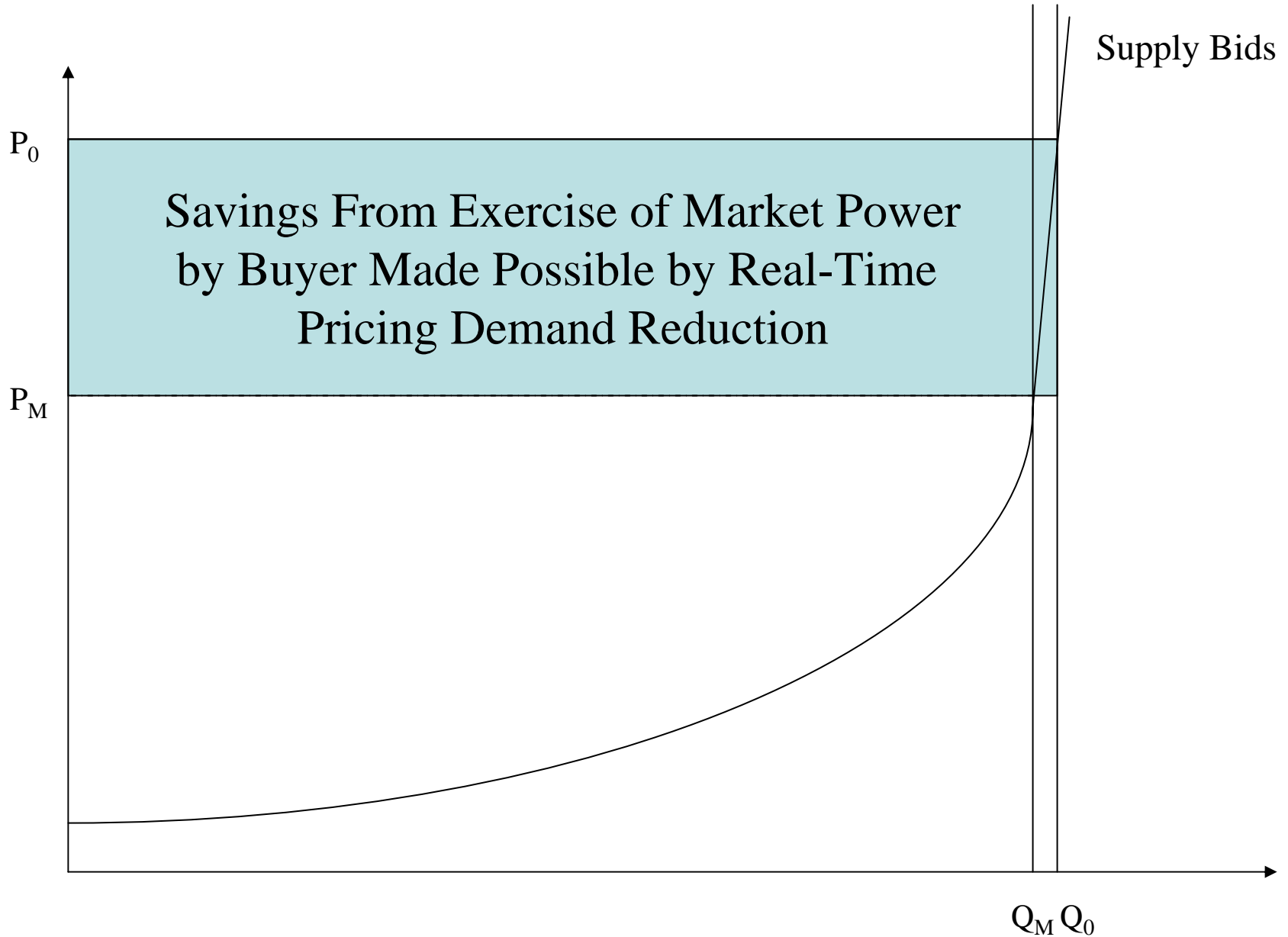
Retailer compensates by using real-time pricing customers to increase demand in hours when aggregate supply is flat

Slightly increases wholesale price for all purchases

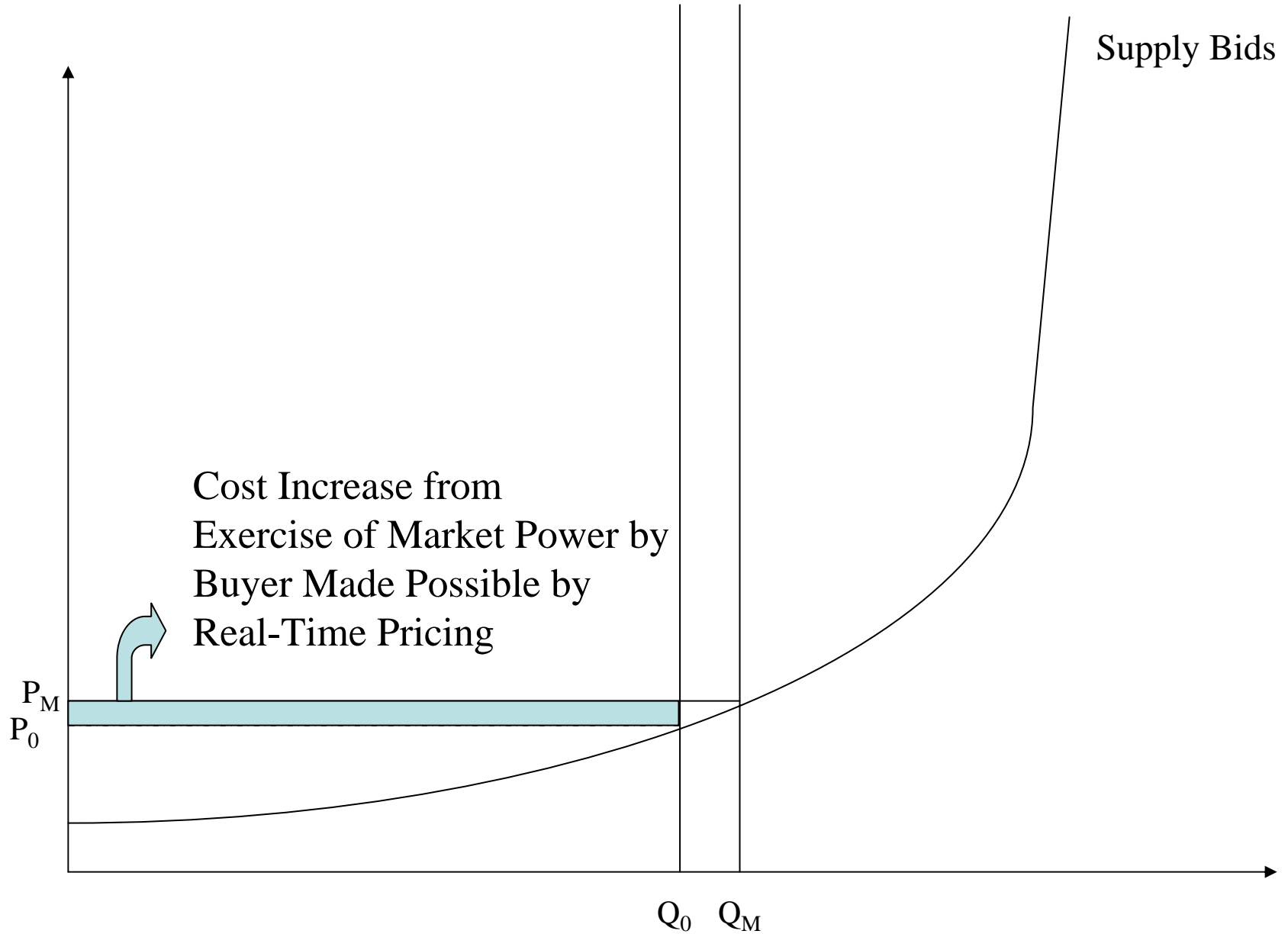
During steep supply hours $P(\text{RTP},t) > P(W,t)$

During flat supply hours $P(\text{RTP},t) < P(W,t)$

Peak Period Buyer Market Power



Off-Peak Period Buyer Market Power



Real-Time Pricing Allows Retailers to Obtain Lower Forward Contract Prices

Generators will recognize that effects shown on previous slides will operate to reduce spot prices and demand, particularly during high load periods

This implies that spot market prices will be lower in future than they would be in the absence of significant real-time pricing

The lower future spot prices that will result from a significant commitment to real-time pricing will create a lower opportunity cost to a generator signing a forward contract

Consequently, generators will be more likely to sign forward contracts at lower prices than they would in the absence of a large commitment to real-time pricing

Immediate benefits to consumers to reducing market power in spot and forward markets from real-time pricing

Only losers from real-time pricing are generators

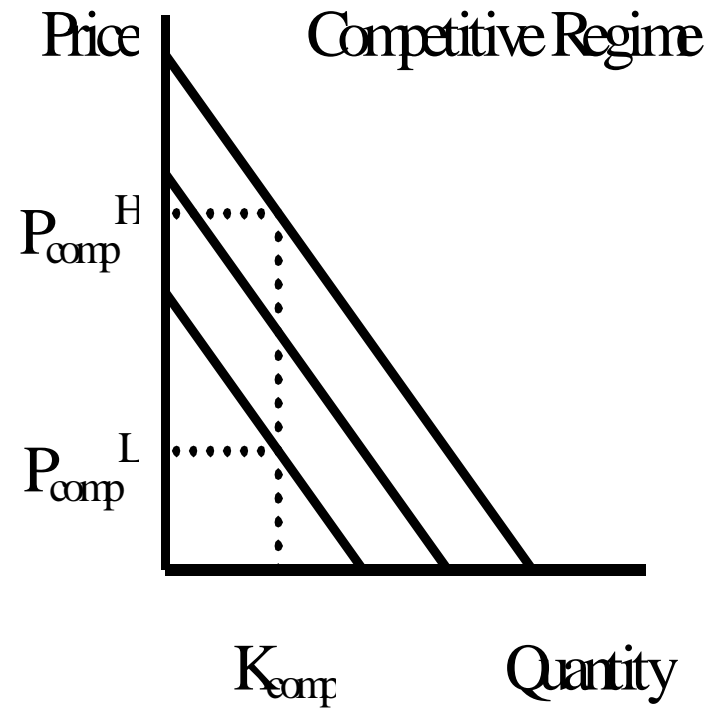
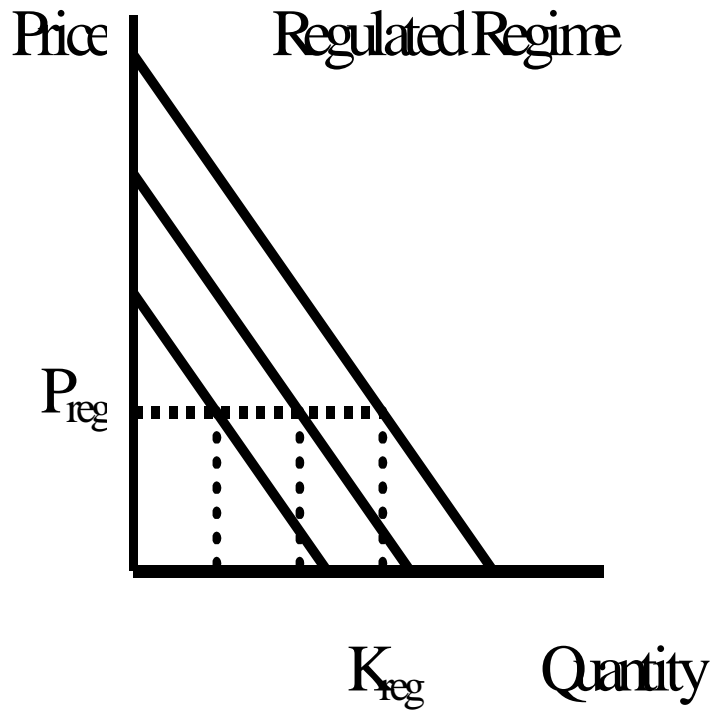
Limited Benefits from Restructuring in US Without Involving Demand

- 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



$$K_{reg} \gg K_{comp}$$

Example--US Airline Industry

- Load Factors = $(\text{Seats Filled}) / (\text{Seats Total})$,
 - In regulated regime highest load factors approximately 55% in 1976
 - Currently Load Factors are close to 75%
- 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.

