

# The Retail Electric Power Marketer's Problem

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# Outline

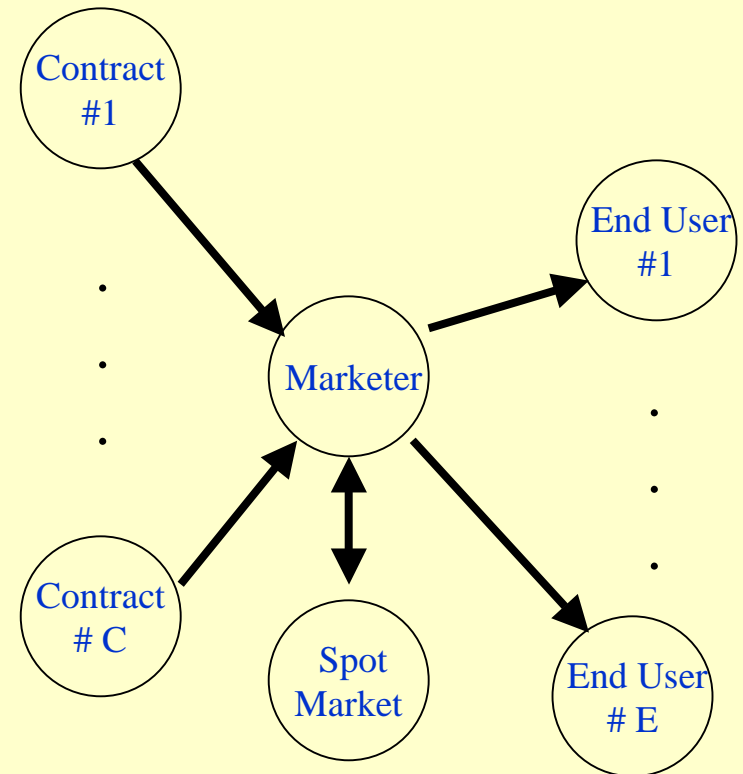
- ◆ Problem Overview
- ◆ Optimization Formulations
- ◆ Ongoing Work

# Problem Overview

- ◆ Due to restructuring and deregulation in the U.S., electric power retailers have become a force in the market
- ◆ These retailers or marketers typically set up contracts for electricity with wholesalers (e.g., generators) and sell to end-users such as
  - Commercial Business
  - Industries
  - Universities, Hospitals, etc.

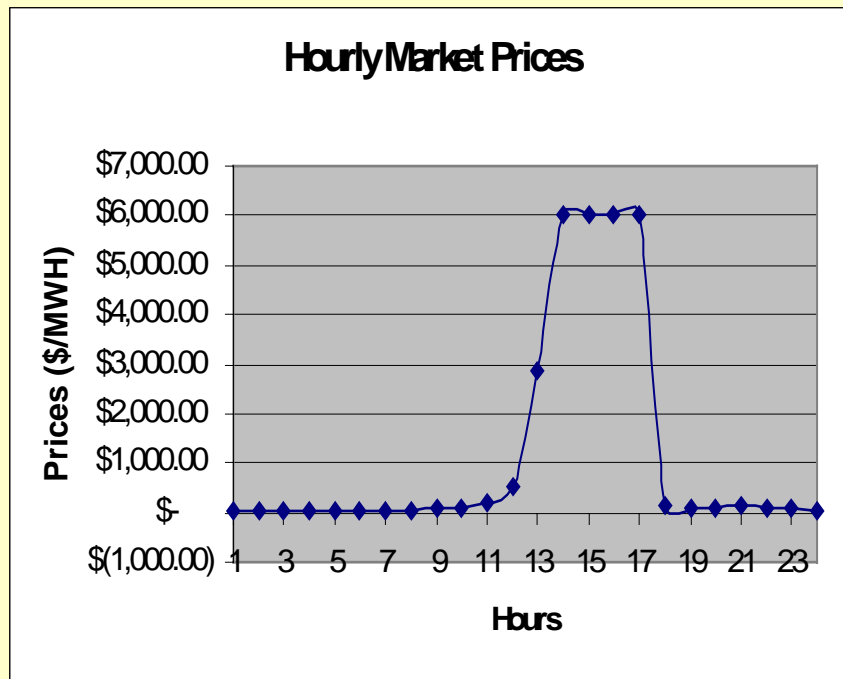
# Problem Overview

- ◆ Retailers typically make very small margins on the sale of electric commodity.
  - However, Retailers can gain profits but also lose huge amounts of money due large fluctuations in:
    - Spot market prices
    - End-user loads
- ◆ The spot market electricity is needed whenever there is
  - Over-supply of electricity relative to demand—sell surplus to the spot market
  - Under-supply of electricity relative to demand —buy deficit from the spot market

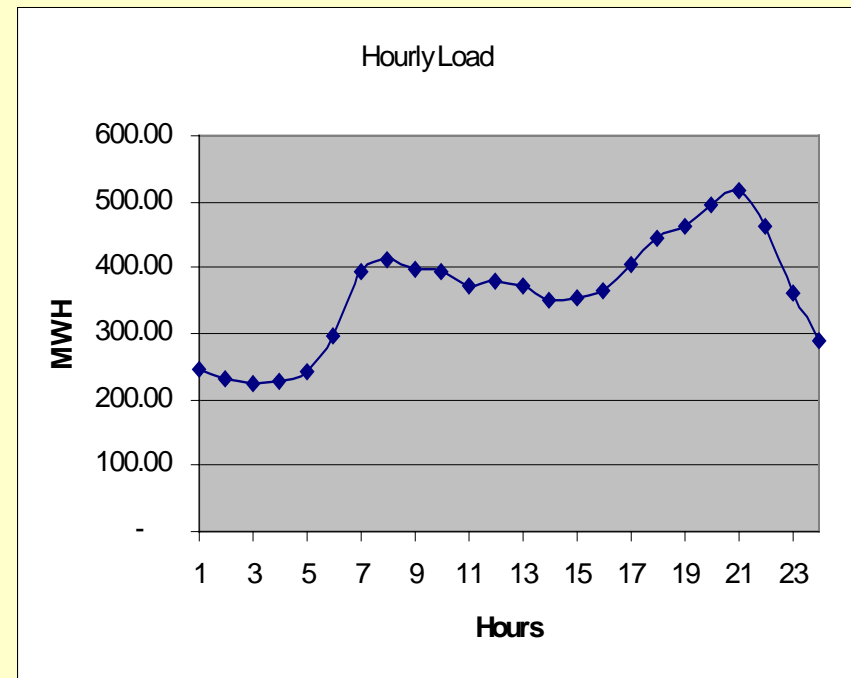


# Problem Overview

- ◆ Example: May 8, 2000 in the New England Market



### Loads for one of the retailers



# Problem Overview

- ◆ One can consider the following “states of the world”
  - SMP = spot market price
  - RP = retail price to end-users
  - WP = wholesale price

# Problem Overview

- We can't have  $WP > RP$

$\leq$ less \$			more \$ $\Rightarrow$
SMP	WP	RP	
WP	SMP	RP	<i>will ignore</i>
WP	RP	SMP	
<i>RP</i>	<i>SMP</i>	<i>WP</i>	<i>(no)</i>
<i>RP</i>	<i>WP</i>	<i>SMP</i>	<i>(no)</i>
<i>SMP</i>	<i>RP</i>	<i>WP</i>	<i>(no)</i>

# Problem Overview

**SMP > RP > WP**

**SMP < WP < RP**

## State 1

Marketer loses money  
(buy needed power at SMP but can only sell it at the RP)

## State 2

Marketer makes money  
(buy needed power at SMP and sell it at RP)

**Under-forecast:**

**Actual Load >  
Forecasted Load**

## State 3

Marketer makes money  
(sell surplus power at SMP it cost WP)

## State 4

Marketer loses money  
(sell surplus power at SMP but it cost WP)

**Over-forecast:**

**Actual Load <=  
Forecasted Load**



# Problem Overview

## General Comments

- ◆ The main problem is to determine the supply contracts to set up, the price to end-users, and the load forecasts (by hour) to the suppliers
- ◆ The retailer needs to provide accurate load forecasts to the supplier as part of “bandwidth” constraints in the contracts (penalty/reward)
- ◆ Not obvious that you always want to match forecasts to expected load
- ◆ The particular types of contracts with suppliers and end-users can vary by jurisdiction
- ◆ We assume that the retailer does not consider the day-ahead or hour-ahead markets

# Problem Overview

## Bandwidth Constraints

$$\text{Want } \frac{\left| \text{LOAD}_{c,e,h}^A - \text{LOAD}_{c,e,h}^F \right|}{\text{LOAD}_{c,e,h}^F} \leq \text{BW}_{c,e,h}$$

where

c = contract #

e = end - user class #

h = hour #

$\text{LOAD}_{c,e,h}^A$  = actual load

$\text{LOAD}_{c,e,h}^F$  = forecasted load

$\text{BW}_{c,e,h}$  = bandwidth % (typically  $\approx 8\%$ )

if within bandwidth, retailer & supplier split settlement

if not, retailer gets the full amount (good or bad)



# Optimization Formulations

- ◆ Two approaches:
  - Imperfect foresight model
    - Non-convex optimization formulation
    - Considers one hour at a time given the cumulative results
    - Selection of supply contracts are fixed
    - Prices to end-users are fixed
    - Main variables are:
      - load forecasts
      - binary variables related to bandwidth restrictions
      - penalties for not meeting cumulative revenue targets

# Optimization Formulations

- ◆ Two approaches:
  - Perfect foresight model
    - Leads to a non-convex optimization formulation
    - Considers all hours together
    - Main variables are:
      - load forecasts
      - prices to end-users
      - penalties for not meeting cumulative revenue targets
      - binary variables related to selection of supply contracts
      - binary variables related to bandwidth restrictions

# Optimization Formulation: Perfect Foresight Model

Maximize

- [expected revenue from sales to end-users]
- + [expected revenues from spot market settlements]
- [supplier costs]
- [contract fixed costs]
- [penalties for cumulative revenue targets for key hours]

s.t.

Bandwidth constraints (uses “either or” constraints”)

Cumulative revenue constraints (for key hours)

Contract selection constraints

Bounds on variables

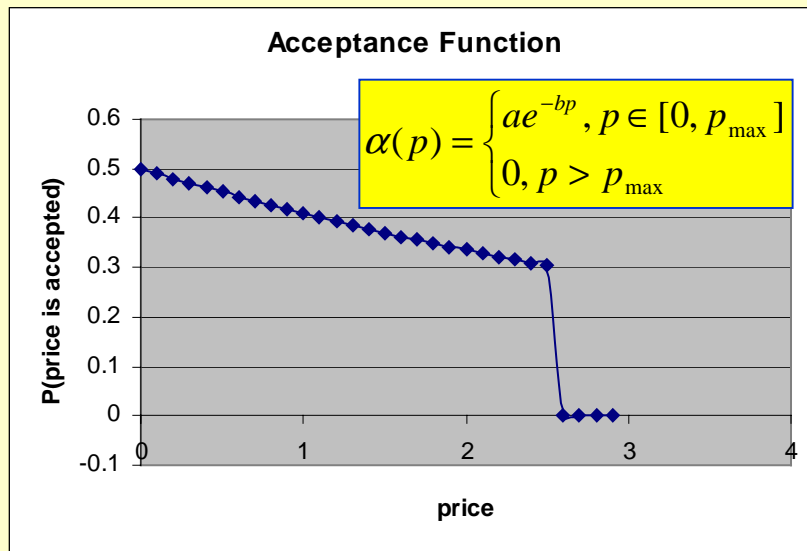
# Optimization Formulation: Perfect Foresight Model Objective Function

[expected revenue from sales to end-users]      # of end-users in class e (D)

$$\sum_{\omega_L \in \Omega_L} \sum_{c: h \in [START_c, END_c]} \sum_{e \in E} \sum_{h \in H} (PRICE_{e,h}^{EU}) \alpha(PRICE_{e,h}^{EU}) N_e LOAD_{c,e,h}^A(\omega_L) \lambda_{c,e,h}(\omega_L)$$

price to end-user (DV)

(D)



actual load/end-user  
(RV)

pmf for loads,  $\omega_L$

is a particular realization in  $\Omega_L$   
(D)

# Optimization Formulation: Perfect Foresight Model Objective Function

[expected revenue from spot market settlements]

$$\sum_{\omega_L \in \Omega_L} \sum_{\omega_P \in \Omega_P} \sum_{c: h \in [START_c, END_c]} \sum_{e \in E} \sum_{h \in H} \gamma_{c,e,h}(\omega_L) (PRICE_h^{SM}(\omega_P)) (TS_{c,e,h} - TD_{c,e,h}(\omega_L)) \pi_h(\omega_P) \lambda_{c,e,h}(\omega_L)$$

settlement % to retailer, toggles  
with bandwidth constraints (DV)

Total supply-total  
demand (DV)

spot market price (RV)

$\omega_P$  is a particular realization in  
 $\Omega_P$  (D)

pmf for spot market prices  
(D)

pmf for loads  
(D)

# Optimization Formulation: Perfect Foresight Model Objective Function

[supplier costs]

$$\sum_{c:h \in [START_c, END_c]} \sum_{e \in E} \sum_{h \in H} PRICE_{c,h}^{SU} \alpha(PRICE_{c,e,h}^{EU}) N_e LOAD_{c,e,h}^F$$

price from supplier (D)

acceptance function (D)

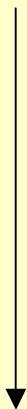
# of end-users in class e (D)

forecasted load/end-user (DV)

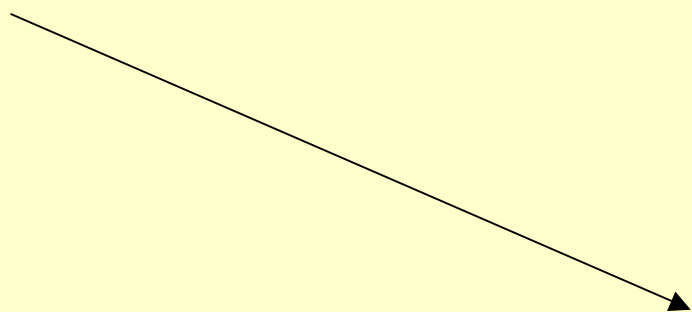
# Optimization Formulation: Perfect Foresight Model Objective Function

[fixed costs]

$$\sum_{c \in C} FC_c x_c$$



fixed set-up costs for contract c (D)



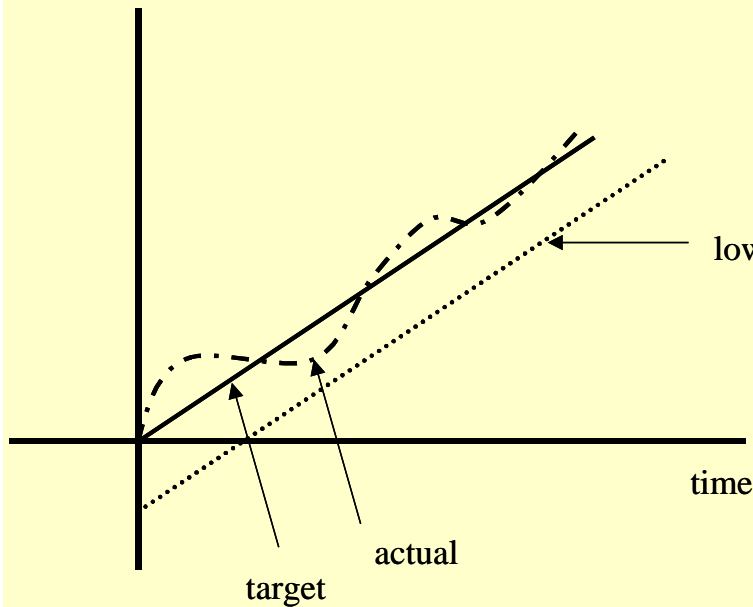
binary contract variable (DV)

# Optimization Formulation: Perfect Foresight Model Objective Function

[penalties for cumulative revenue targets at key hours]

$$\sum_{\tilde{h} \in \tilde{H}} \rho(\text{penalty}_{\tilde{h}})$$

cumulative net profit



$$\text{penalty}_{\tilde{h}} \geq \eta_{\tilde{h}}^{\min} - \left[ \sum_{\omega_L \in \Omega_L} \sum_{c: h \in [START_c, END_c]} \sum_{e \in E} \sum_{h=1}^{\tilde{h}} PRICE_{e,h}^{EU} \alpha(PRICE_{e,h}^{EU}) N_e LOAD_{c,e,h}^A(\omega_L) \lambda_{c,e,h}(\omega_L) \right. \\ \left. + \sum_{\omega_L \in \Omega_L} \sum_{\omega_p \in \Omega_p} \sum_{c \in C} \sum_{h \in H} \sum_{e \in E} \gamma_{c,e,h}(\omega_L) PRICE_h^{SM}(\omega_p) (TS_{c,e,h} - TD_{c,e,h}(\omega_L)) \pi_h(\omega_p) \lambda_{c,e,h}(\omega_L) \right. \\ \left. - \sum_{c: h \in [START_c, END_c]} \sum_{e \in E} \sum_{h=1}^{\tilde{h}} PRICE_{c,h}^{SU} \alpha(PRICE_{c,h}^{EU}) N_e LOAD_{c,e,h}^F \right], \forall e \in E, c \in C, \tilde{h} \in \tilde{H}$$

$$\text{penalty}_{\tilde{h}} \geq 0, \forall \tilde{h} \in \tilde{H}$$

expected cumulative revenue up to key hour

$$\tilde{h} \in \tilde{H}$$

# Ongoing Work

- ◆ Determine best approximation to pmfs for loads and spot market prices using:
  - Several years of PJM data
  - Conditional distributions given peak/offpeak and seasonal conditions for previous hour
  - Stochastic price processes
- ◆ Simulating best strategies for retailer
- ◆ Solving optimal strategies for retailer