Market Power Issues in Deregulated/Privatized Electric Power Markets

Inter-American Development Bank

Washington, DC

Presented by

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TCA: A Summary

Engineering and Management Consulting firm specializing in Energy and Manufacturing Systems

- Primary energy focus is electric and gas generation, transmission distribution and consumption
- Primary manufacturing focus is software development for production efficiency

TCA Provide Services in:

- Regulatory Policy at Federal and State Levels and International
- Project / Investment Evaluation
- Price Forecasting
- Software Development (both custom and marketable)
- Manufacturing Productivity
- Commercial and Industrial Energy Efficiency

25 Employees in Cambridge MA and Northern California

Presentation Outline

- Definition of Market Power
- How and why it is an issue?
- Competition or Regulation
- Concentration Measures
- Examples of Strategic Bidding
- Simulation Tools
  - GE-MAPS
  - COMPEL
  - META
- Mitigation Remedies
- Proposal for market Power Study for Central American Electric Power Markets

What is Market Power?

- **Definition: Ability of single firm or group of competing firms in a market to profitably raise prices above competitive levels and restrict output below competitive levels for a sustained period of time.**

Why Do We Care?

- **Mitigation of market power is essential for successful implementation of the de-regulation/privatization of the electric power industry.**
- **Important for**
  - **the consumers to realize the benefits of de-regulating the industry, and**
  - **for efficient operation of generation market.**

Vertical Market Power

- Same entity owns resources across production levels (generation, transmission, distribution).
- Structural solutions to vertical market power require vertical disintegration or functional unbundling (GenCo, TransCo, DistCo) while maintaining the transmission system regulated (Transmission Open Access).
- TransCos and/or ISOs are a major step in addressing vertical market power problems.

Horizontal Market Power

- **Same entity owns resources at the same production level (generation).**
- **Transmission open access with RTOs mitigates some of the institutional horizontal market power problems (eliminate pancaking, increases competing capacity).**
- **There is no general structural solution that fits all systems.**
- **Requires detailed analysis on a case by case basis using a standard approach focusing on profitability of strategic behaviour.**

Regulation vs. Market

- **Regulation at its best can reach the outcome of competitive markets.**
- **Willing to live with less than perfect competitive markets (workably competitive) if the social welfare loss is less than the cost of regulation**
  - **"Choice between imperfect and costly regulation versus market imperfections"**
- **It is preferable to have:**
  - **Market-based mitigation options, and**
  - **Minimal residual regulation when none of market-based mitigation options work.**

Structural Indices

- **Herfindahl-Hirschman Index (HHI).**
  - Sum of squares of market shares
  - Acceptable levels (1000-1800)
- **Time on Margin**
  - There is no formal criterion to determine market power using this measure, but sometime HHIs are calculated for on-peak, off peak and super peak hours.
- **Market shares**
  - one criterion would be less than X% (20 to 30%)
- **How good are these indices?**
  - do not take into account potential competition or market realities such as transmission constraints, and
  - cannot capture potential strategic behavior.

Behavioral Indices

- Lerner Index is a measure of the prices above competitive levels: LI = (P-C)/P
- The Price-Cost Margin Index: PCMI= (P-C)/C
- These indices can be averaged over any period of time, thus giving the ability to determine market conditions (load levels) when market power becomes apparent.

Behavioral Analysis

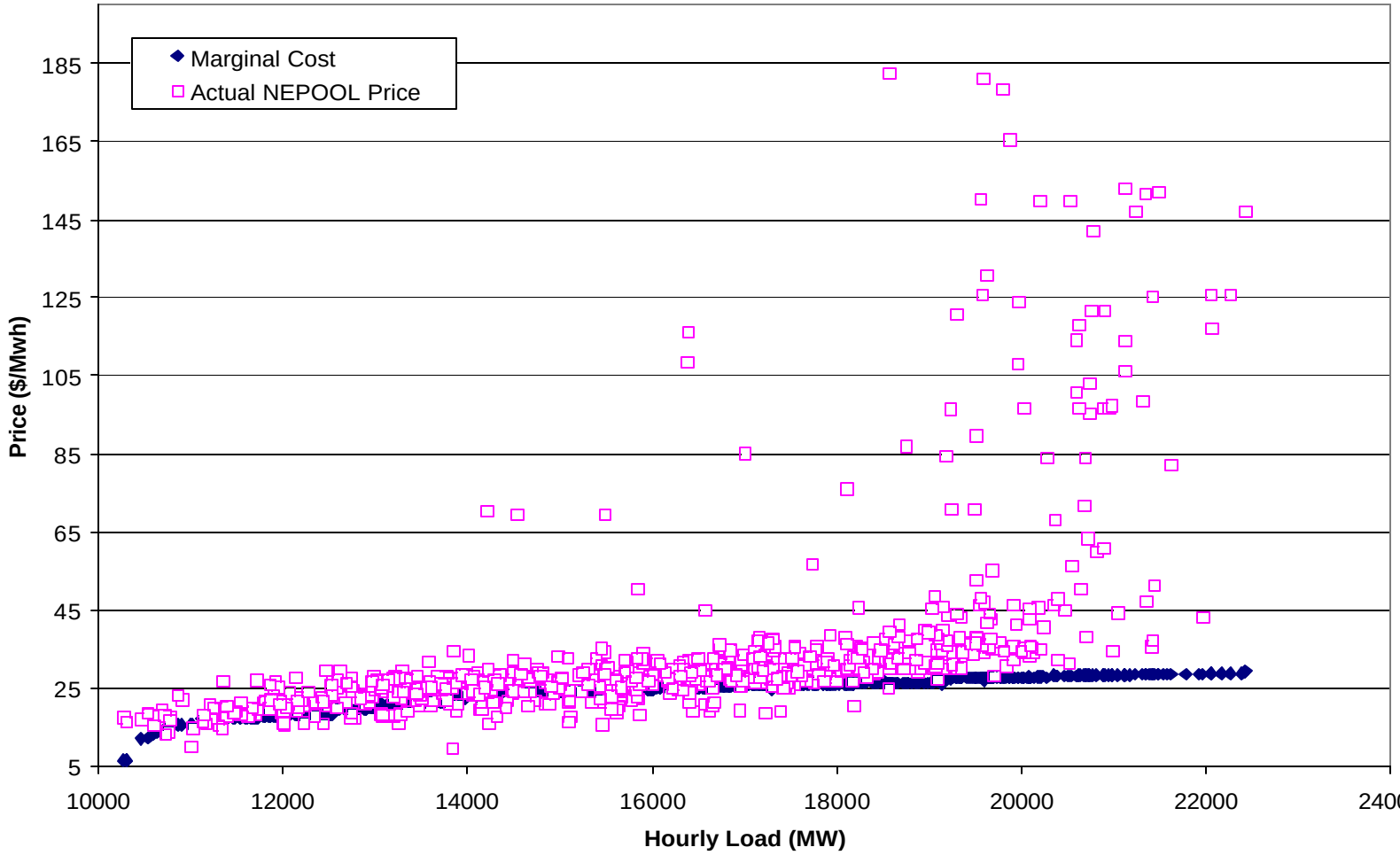
- **Behavioral analysis – direct analysis of market power;**
- **It is based on the simulation of strategies through which market participants could exercise market power. These strategies involve strategic bidding and capacity withholding (discussed later);**
- **It provides for direct measures of market power such as a price increase caused by the exercise of market power.**

What is Strategic Behavior?

- Choosing the level and price of generating capacity to offer at the deregulated market in order to maximize own profitability.
- It is often not in the generation owner's interest to sell (bid) all capacity it has, or sell it *at cost*, or both
- Strategic behavior may have a significant impact on the spot market price of electricity.
- Should capture
  - Short-term as well as medium-term and long-term dynamics
  - Barriers to entry (or lack of) and other market realities
  - Transmission constraints

Strategic Behavior is a Real Phenomenon

Market Clearing Prices vs. Marginal Costs. NEPOOL, July-1999
(15 hourly prices in excess of $200/MWh are not shown)



Strategic Bidding

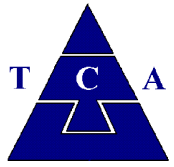
- Strategic bidding involves generating firms bidding prices above the variable production costs of their units, with the intent of forcing the market clearing price above competitive levels.
- Under this strategy, generating units are usually dispatched in the same merit order as under the production cost bidding.

Capacity Withholding

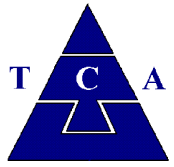
- Capacity withholding involves firms removing some of their capacity from the bidding process or from the market for a certain period of time, in an effort to cause more expensive units in the system to set the market clearing price.
- Unlike strategic bidding, capacity withholding changes the merit order in which units are dispatched.

Profitability & Market Equilibria

- **Behavioral analysis measures increase in profitability under different market equilibria.**
- **Nash: A player maximizing its own payoff given the strategies followed by all opposing players (General equilibrium)**
  - **Cournot: Set of outputs for which each firm maximizes profit given the *outputs* of the remaining firms**
  - **Bertrand: Set of outputs for which each firm maximizes profit given the *prices* of the remaining firms**
  - **Supply Function: Set of outputs for which each firm maximizes profit given the *supply curves* of the remaining firms**

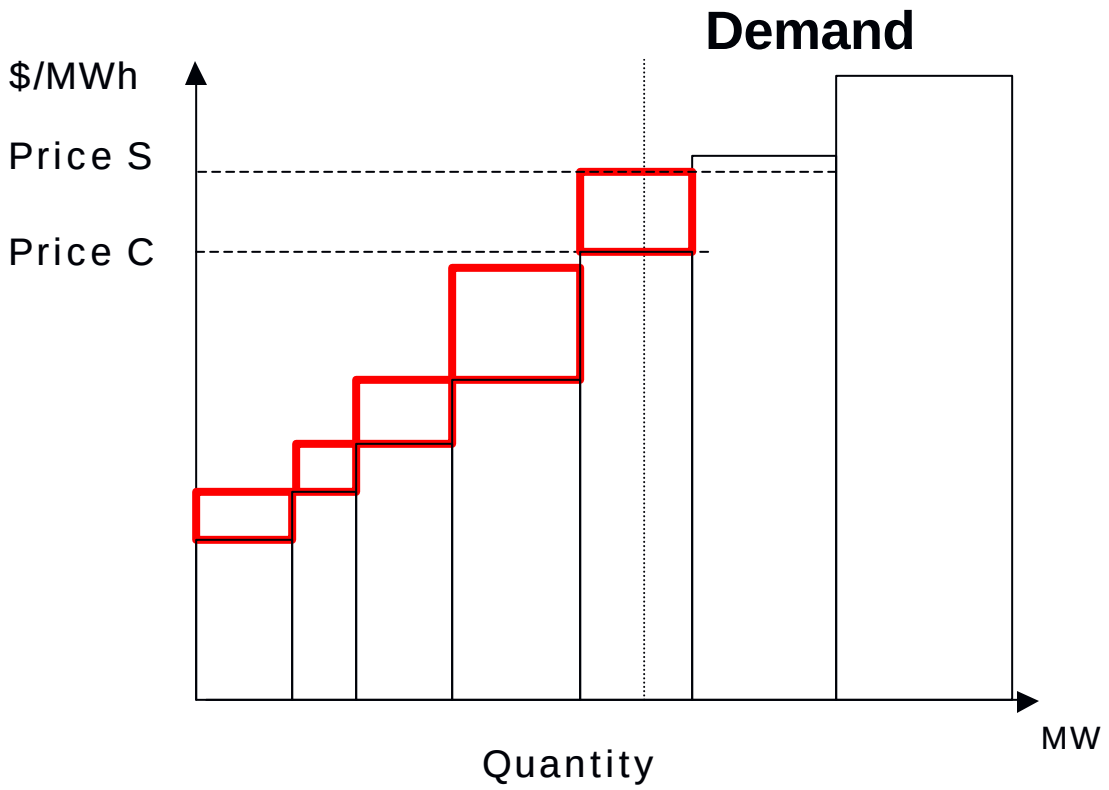


Examples of Strategic Bidding in Electric Power Markets



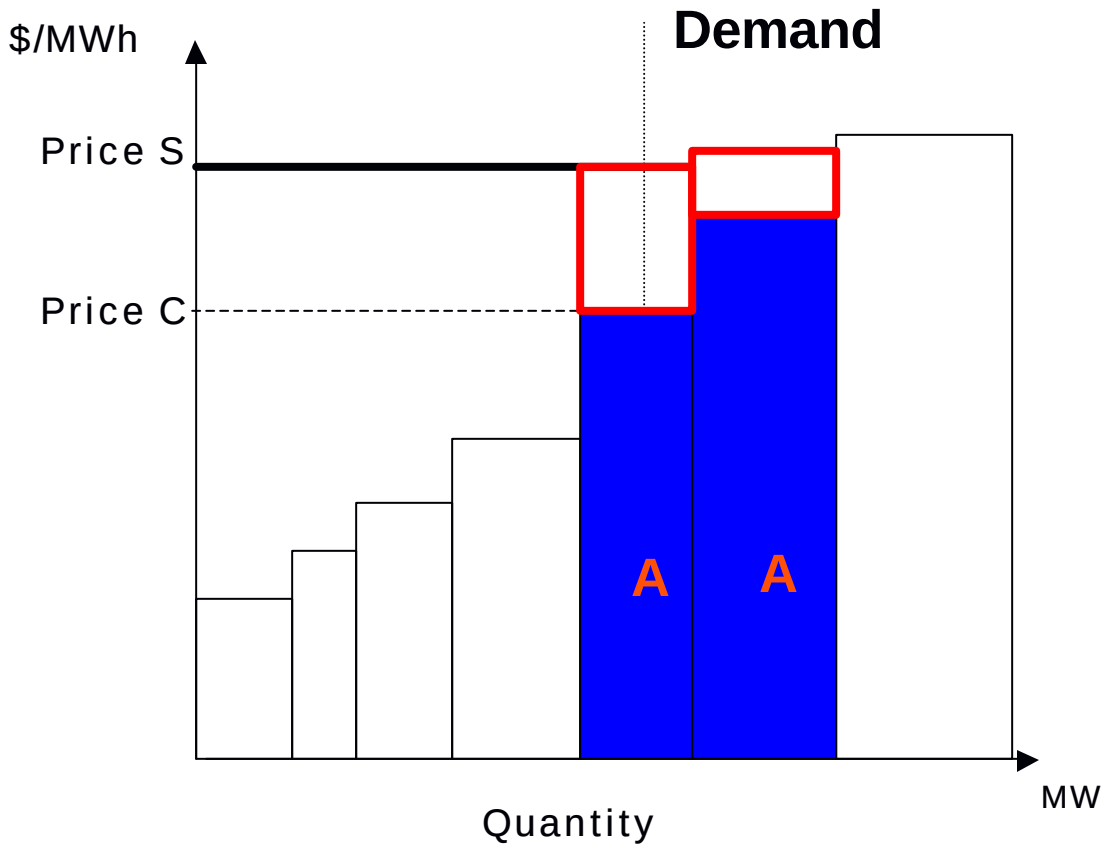
Strategic Bidding- Strategy One

- **Strategy One: Bid up to the next unit in the merit order.**
- **This strategy increase generators profits without risking losing revenues, since same unit merit order is maintained**



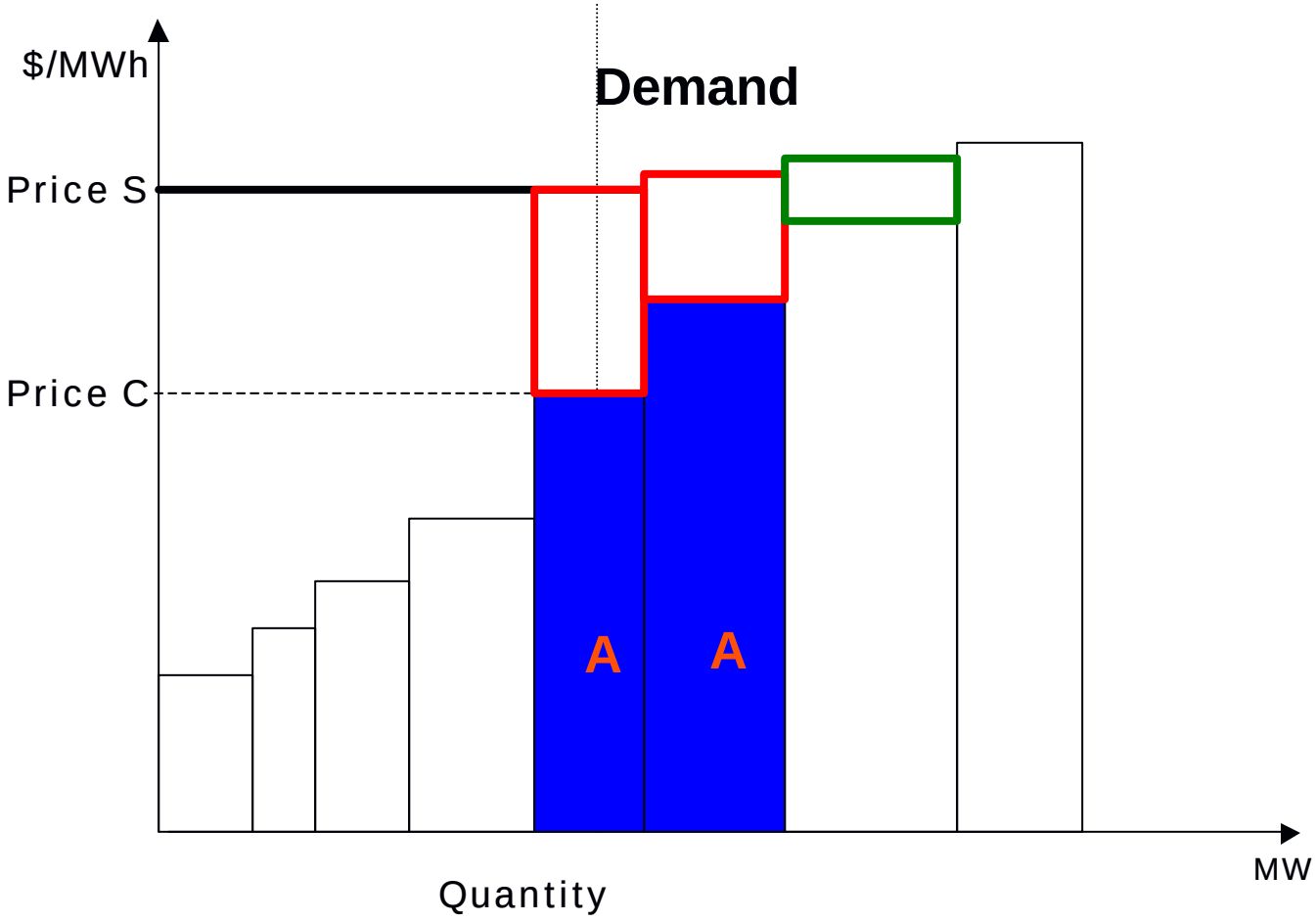
Strategic Bidding- Strategy Two

- Bid up to the next owner in the merit order.
- Generation companies can increase market clearing prices without risking losing any profits since they are maintain the same company merit order



Strategic Bidding- Strategy Three

- **Bid up anticipating that your competitors will follow a strategy (any of the above strategies).**



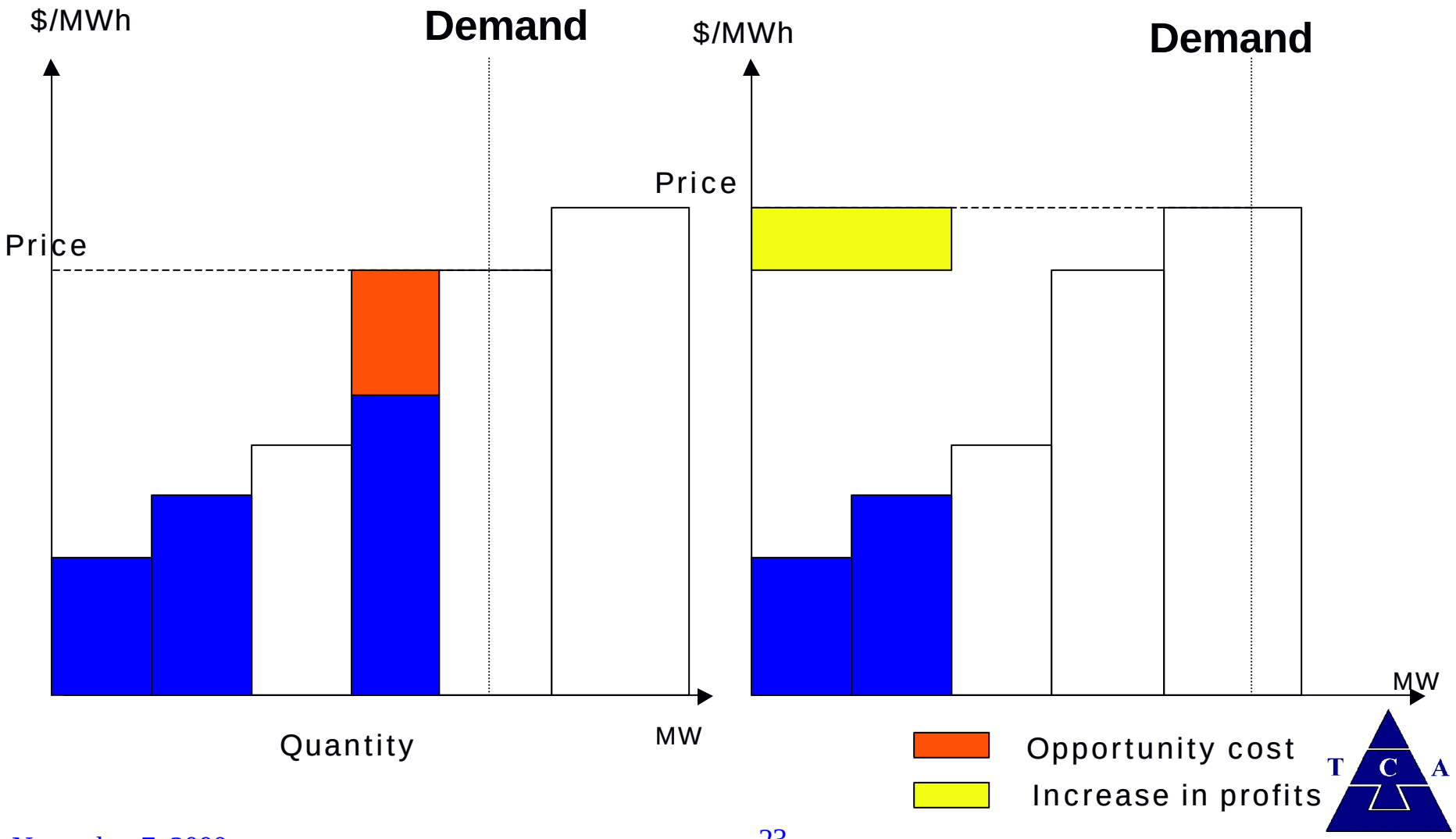
Equilibrium Strategies

- The SFE approach is a sophisticated form of strategy three where the units maintain the same unit merit order.
- Cournot equilibrium involves changing the merit order and effectively withdrawing capacity.
- Another strategy would be to use transmission constraints to maximize profits of a portfolio of generation assets or portfolio of generation and transmission assets.

Generation Capacity Withholding

- Generation companies have incentives to withhold capacity and increase market clearing prices only if they can increase their profits
- Generation company increase their profits by withholding units only if the increase in revenues is higher than the lost opportunity costs

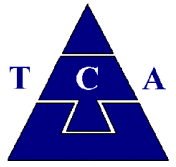
Profitability for BlueCo



Profitable Strategic Bidding

- **A generation company may profitably withhold capacity or strategically bid if any or all of the following is true:**
  - **it owns many generating units and has a relatively large market share**
  - **its units are strategically located on the supply curve (many base-load and marginal units)**
  - **it can implicitly collude with other generating companies to reach a market equilibrium**

Simulation Tools



Simulation Models

- **TCA uses a commercially available production cost simulation software such as MAPS developed by General Electric as well as software developed by TCA staff to model competitive electric power markets.**
- **GE-MAPS**
  - **Is a least-cost security-constrained dispatch model that is similar the to dispatch software used in control centers. It determines the least cost dispatch of generation units subject to security constraints and calculates the associated locational market clearing prices.**
- **COMPEL**
  - **Is a strategic behavior model that simulates the bidding behavior be generators in deregulated power markets. Instead of marginal cost based bids, it determines a set of bids that maximize the revenue for a portfolio of generation assets for each market participant.**

Nodal Pricing - The Mathematical Model

The model can be mathematically described as follows:

Minimize Total Cost = $\sum_{i \in I} GenCost_i * Gen_i$

Subject to:

(1) $Gen_i \leq MaxCap_i \qquad \forall i \in I$

(2) $\sum_{i \in I} Gen_i = \sum_{a \in A} Load_a + Spin\,Reser_{Pool}$

(3) $PowerFlows_l \leq MaxFlows_l \qquad \forall l \in L$

(4) $PowerFlows_l \geq MinFlows_l \qquad \forall l \in L$

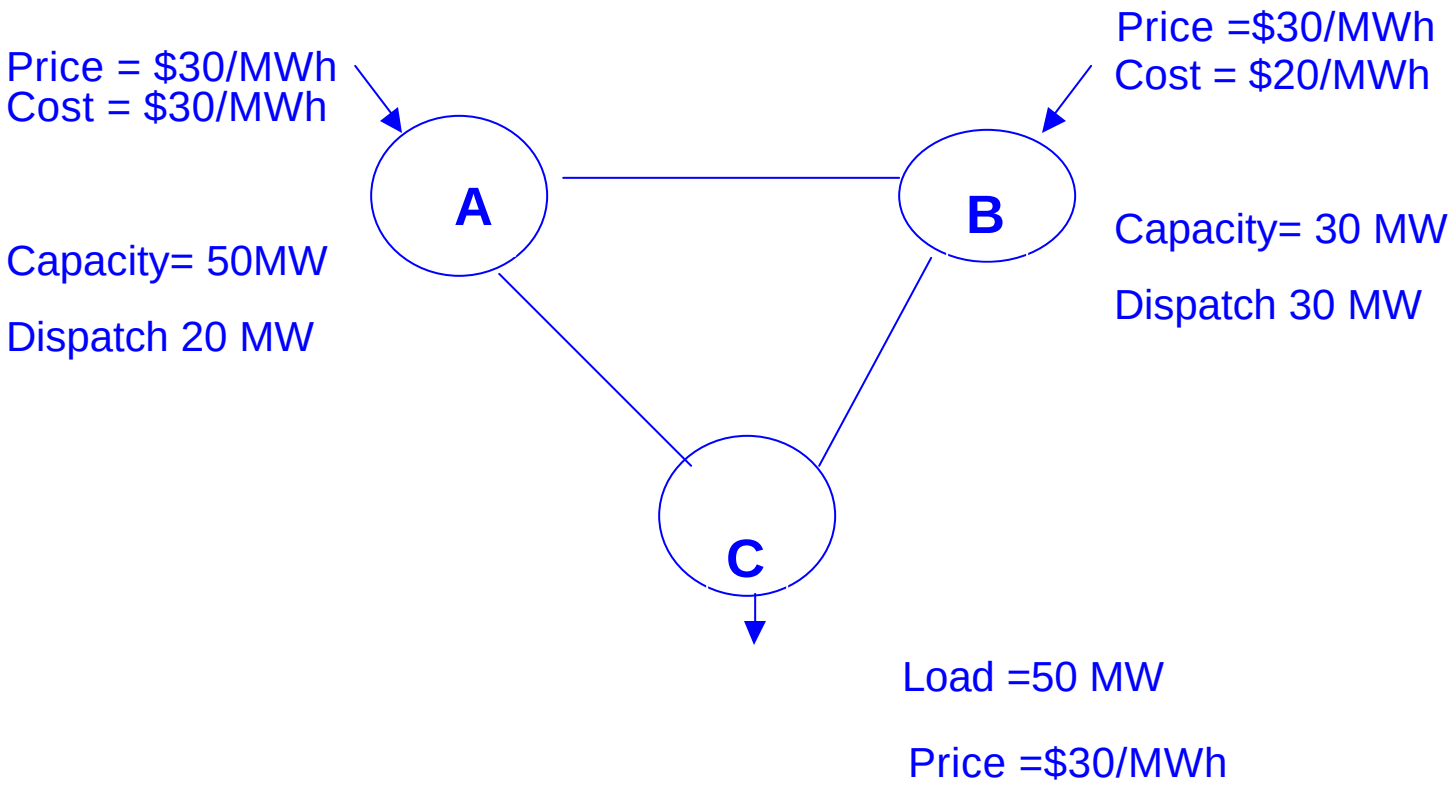
Nodal Marginal Pricing - Theory

Nodal prices are not necessarily capped by the marginal costs of marginal units - they can be higher than the most expensive unit, or negative.

- **Nodal prices can be higher than the marginal cost of the most expensive unit running.**
- **Nodal prices at constrained out areas can be negative.**

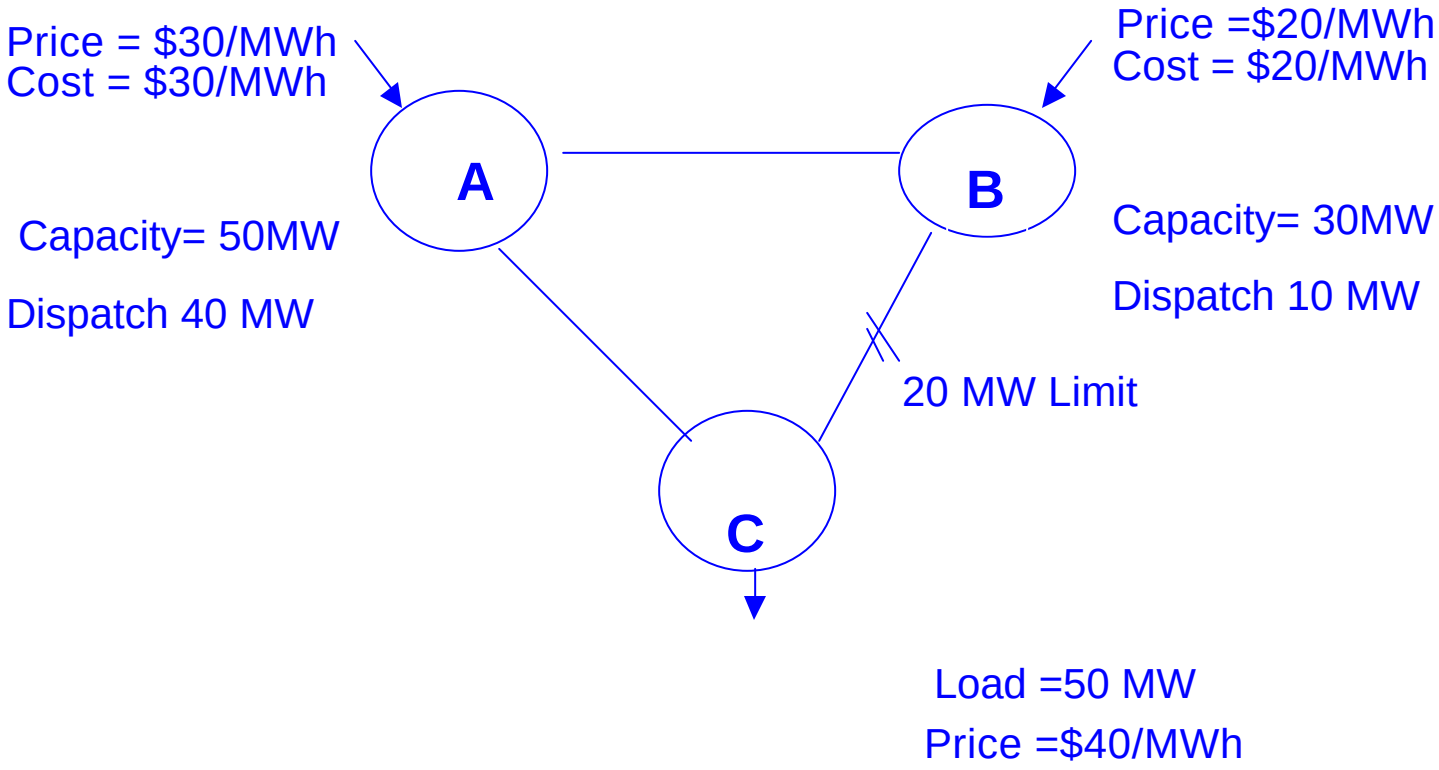
Nodal Marginal Pricing - Theory

Example of nodal prices without constraints.



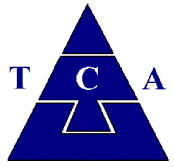
Nodal Marginal Pricing - Theory

Example of nodal prices *with* constraints. Note that prices can exceed the highest marginal cost unit.



Price Forecasting Models

- **There are three possible approaches to price forecasting:**
  - **Production Cost Models: Build a Market Model with specified assumptions**
    - » **Can be complicated**
    - » **Results accuracy depends on accuracy of input assumptions**
  - **Stochastic Models: Run a large number of Monte Carlo simulations**
    - » **Require large number of simulations**
    - » **Require knowledge of the distribution of the input variables**
  - **Knowledge-Based Systems: Try to learn the market by observing prices and relating these to events**
    - » **Need to learn all possible events**
    - » **Price accuracy depends on the training**

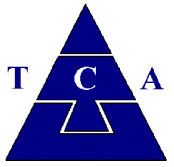


Market Model

The market model can be either one of the following:

- **Competitive: Generators bid incremental costs**
- **Duopolistically Competitive:**
  - **Most realistic, but difficult to model**
  - **Many possible equilibria**
- **Monopolistic: Generators maximizes revenues**

We use GE MAPS to model both perfectly competitive market where generators bid incremental costs and oligopolistic markets where generators reach a Nash-type equilibrium (Supply Function Equilibrium). We use another model, COMPEL, to determine the strategic bids.



MAPS Model Inputs

Thermal Characteristics

- Units Summer and Winter capacities
- Units heat rates, fuel types & outages
- Units variable operation and maintenance cost by unit type and size

Hydro Unit Characteristics

- Hydro and pump storage generation levels

Fuel Prices

- Fuel prices for each geographic area

Transmission System Representation

- Transmission constraints

External Supply Curves

- Imports and exports from outside the Northeast system

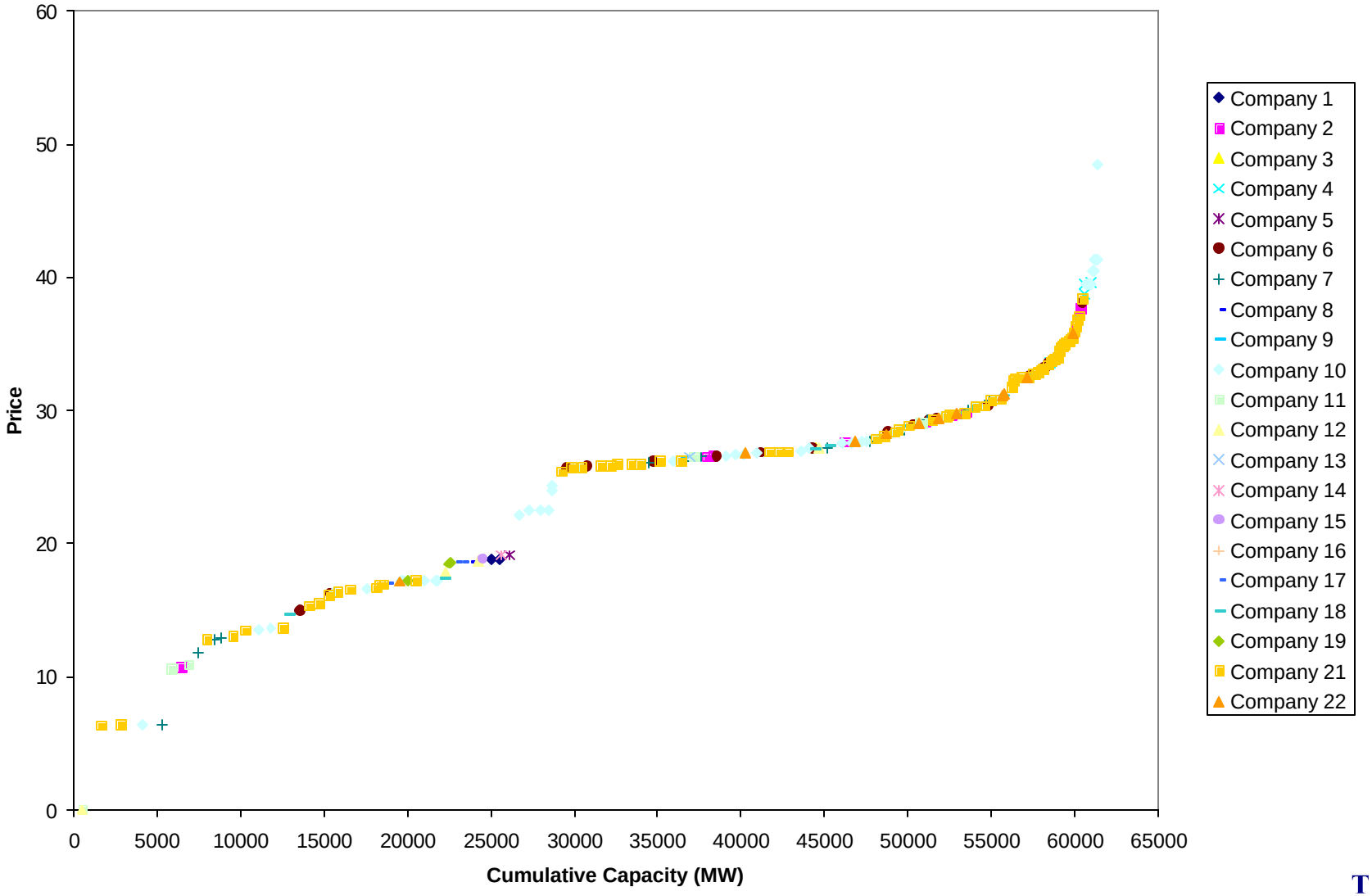
Load Requirements

- Forecasted peak load and hourly shape, and dispatchable demand
- Reserves requirements

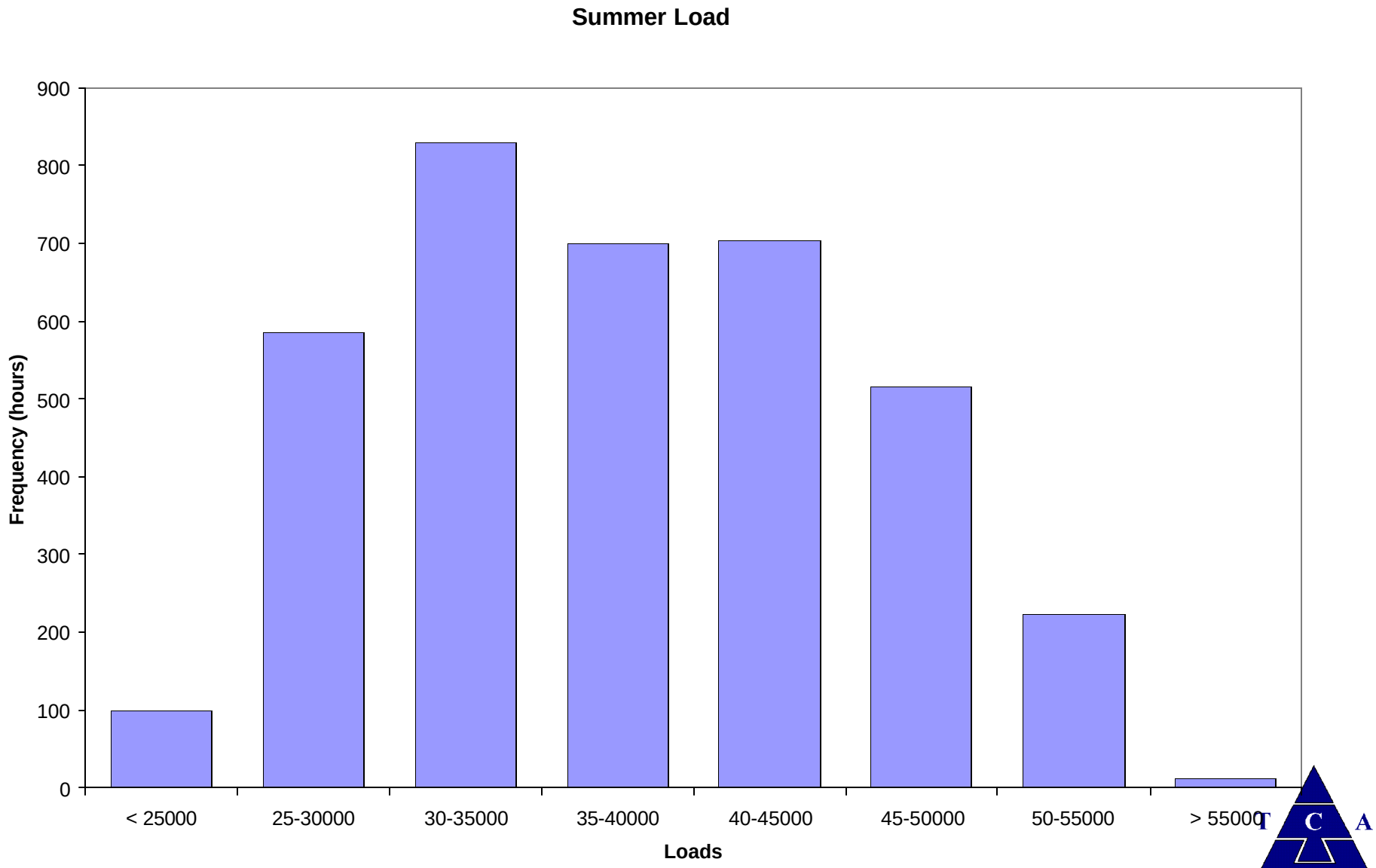
Economic Entry and Retirements

Example of Market Analysis using GE-MAPS

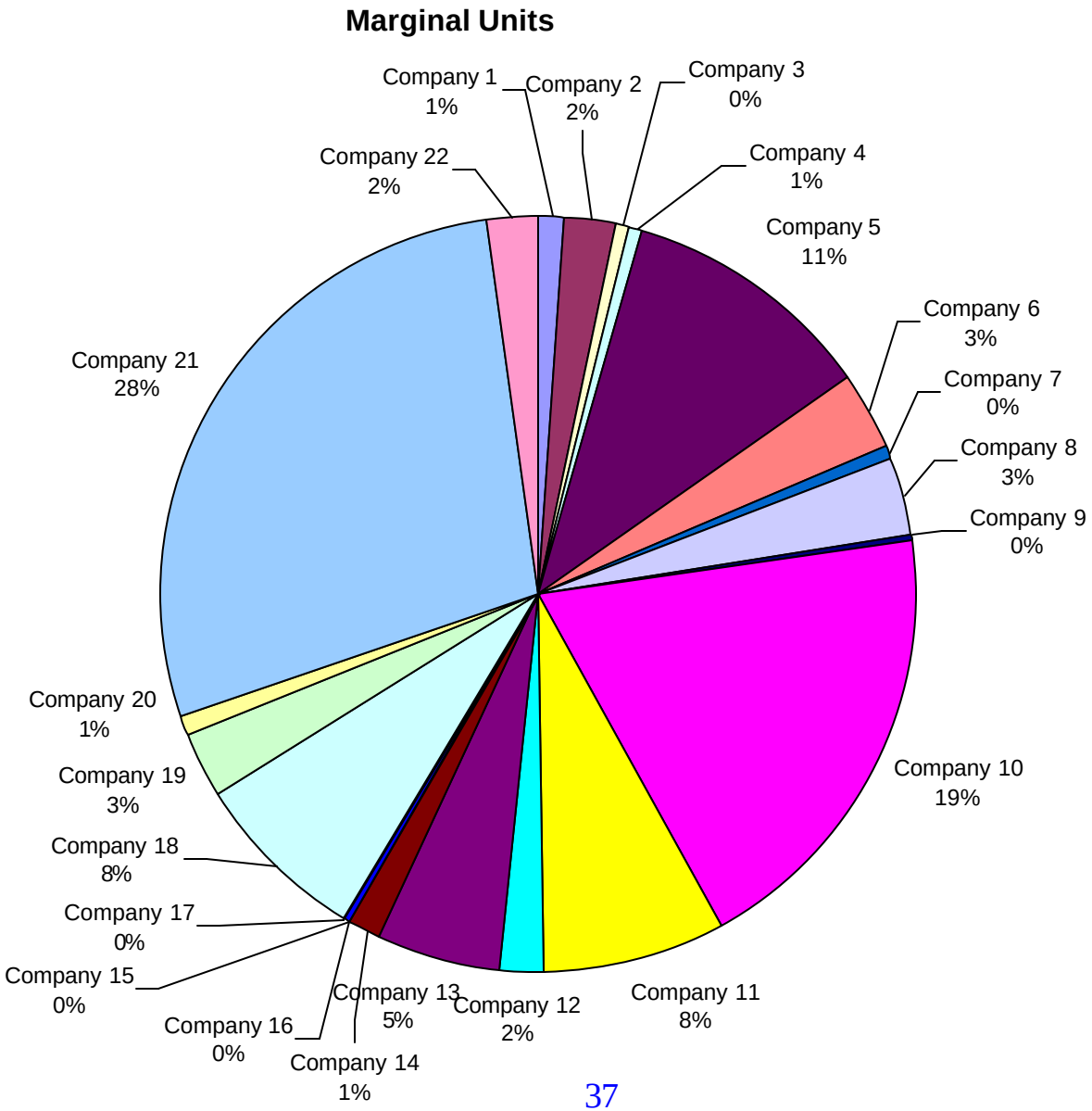
Supply Curve & Ownership of Generation Units for a Typical Electricity Market in the US



Load Histogram

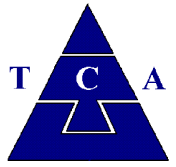


Ownership of Marginal Units



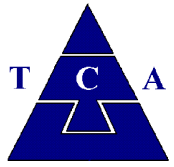
COMPEL: TCA Model for Simulating Strategic Behavior

- COMPEL is a software model developed by TCA under the Small Business Innovation Research grant from the National Science Foundation.
- COMPEL's major feature is the ability to directly model strategic behavior of generating companies in deregulated power markets.
- COMPEL is powered with unique computational algorithms whose distinctive feature is the use of the innovative game-theoretical approach based on the Supply Function Equilibrium (SFE) technique.



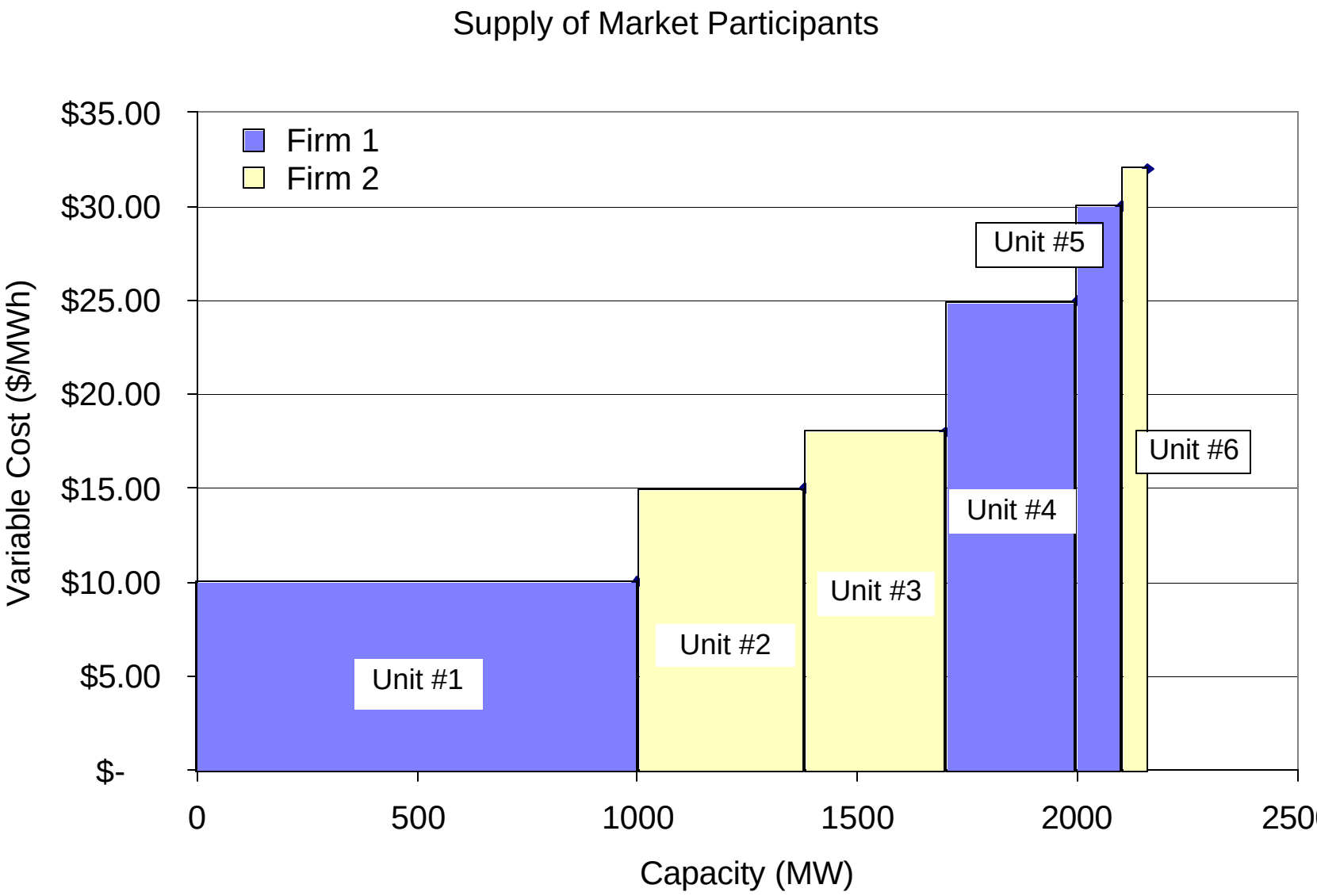
COMPEL Algorithms

- Generate equilibrium unit capacity withholding strategies.
- Generate equilibrium bidding strategies.
- Solve a two-stage game-theoretical problem in which capacity withholding decisions and bidding strategies are inter-dependent.
- Compute a system dispatch subject to generated capacity withholding decisions and bidding strategies.
- COMPEL can simulate the unilateral strategic behavior of one firm as well as tacit collusion of any sub-group of firms.

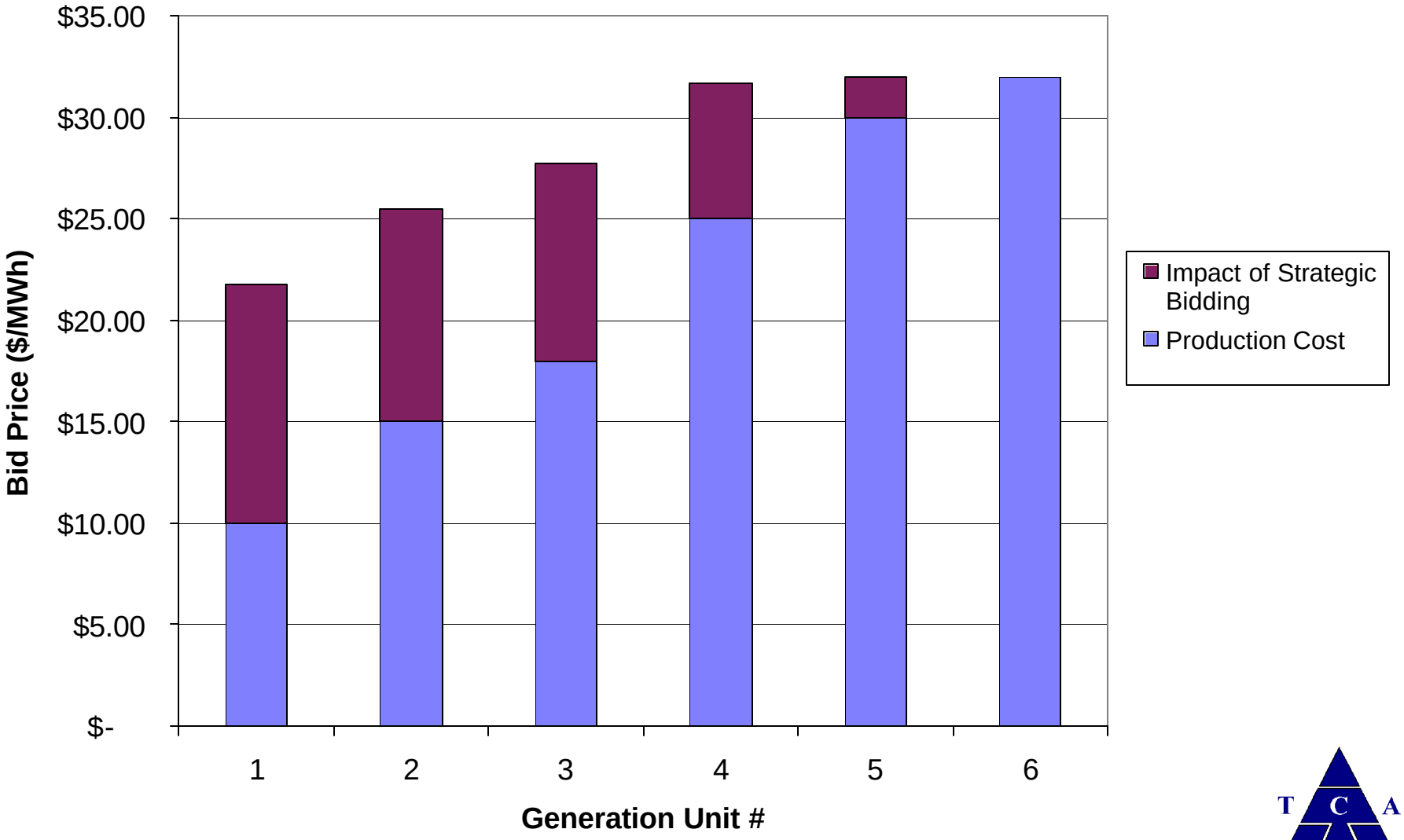


Example of Strategic Bidding In COMPEL

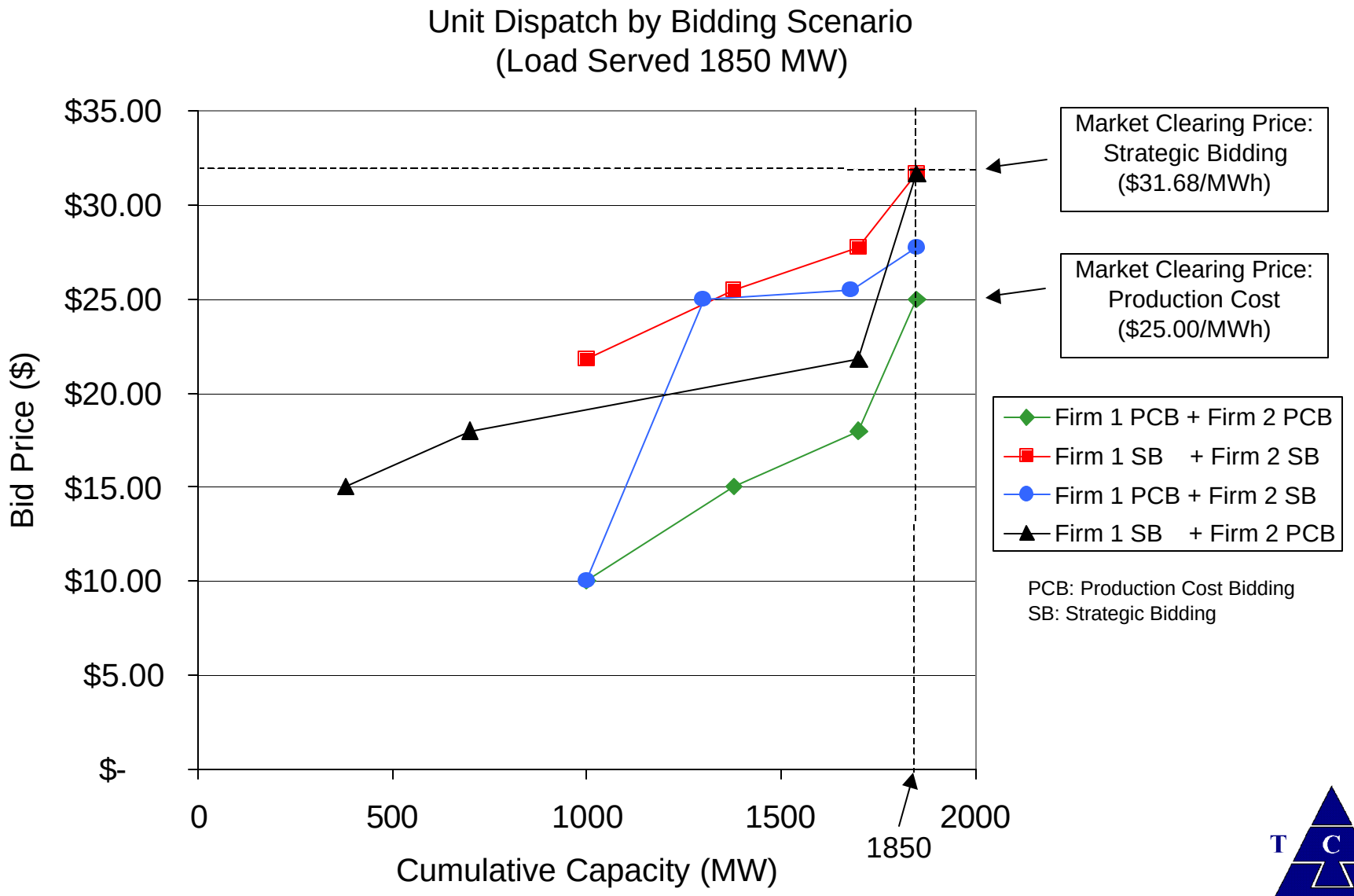
Supply of Market Players



Impact of Strategic Bidding on Production Cost Bid

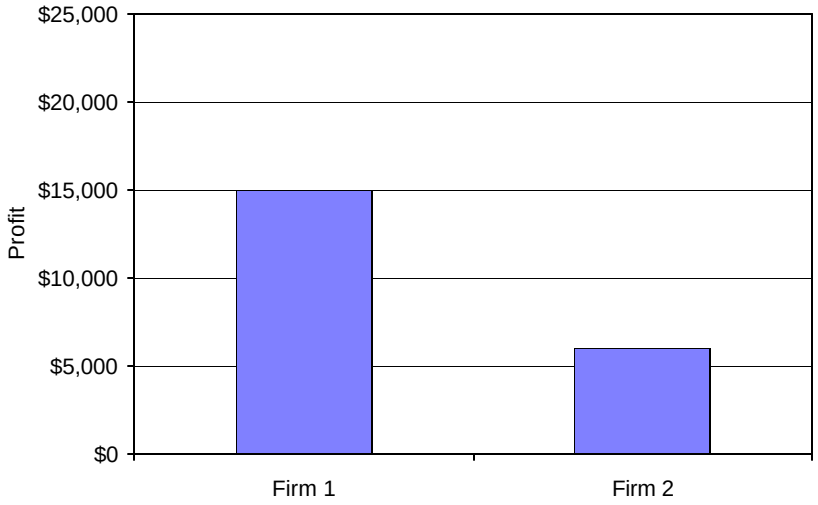


Unit Dispatch by Bidding Scenario

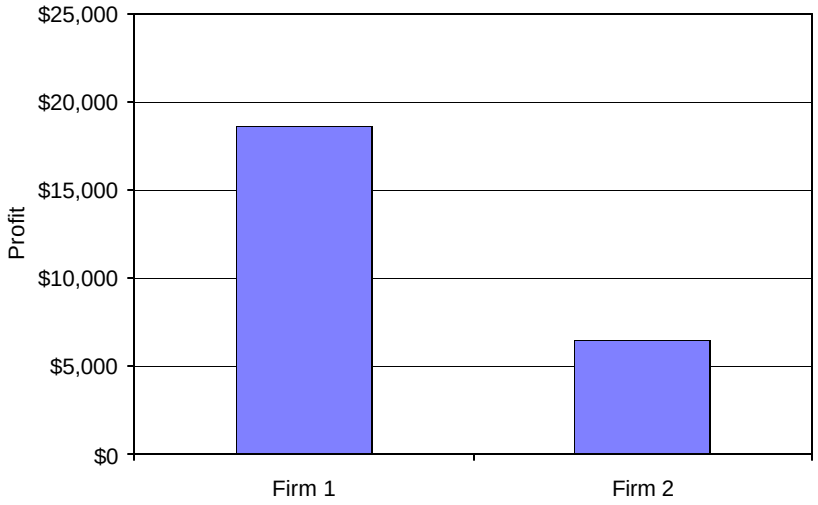


Profit

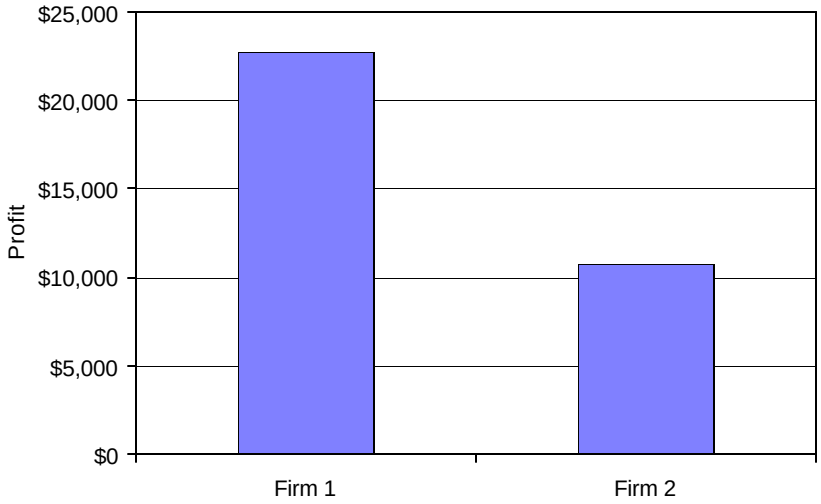
Profit with Both Firms Bidding Production Cost



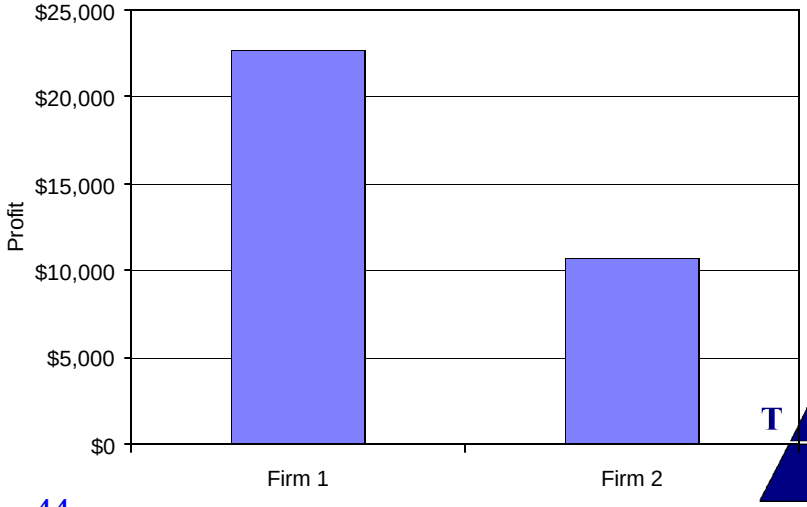
Profit with Firm 1 Bidding Production Cost, Firm 2 Bidding Strategically



Profit with Firm 1 Bidding Strategically, Firm 2 Bidding Production Cost



Profit with Both Firms Bidding Strategically



Mitigation Remedies

For markets with high industry concentrations regulation could be minimal and gaming reduced by implementing certain policies:

- **Price or revenue caps**
- **Divestiture of generation assets**
- **Must-run cost-based bids**
- **Control delegation (long-term operation control or blind trust)**
- **Contract for differences**
- **Transmission reinforcements**
- **Assign transmission rights to the load in case of transmission congestion**

MAPS and COMPEL

- We use GE MAPS to solve for market clearing prices and companies profits under both marginal cost bidding and strategic bidding subject to transmission and operating constraints.
- Also, we use GE MAPS and COMPEL to determine the impact and effectiveness of proposed mitigation measures in reducing the potential for exercising market power.

Are Electric Generation Markets Contestable?

- Contestability: Little entry and exit costs
- Long term equilibrium: contestable markets are equivalent to Bertrand equilibrium where prices are capped at the cost of new entry or long-run average cost
- How much contestable?
- Are there barriers to entry ?
- What about new generation technologies ? Distributed generation ?

Where is the Cutoff?

- **Where do you draw the line between economic rent and market power rent?**
- **If the market is competitive with no significant barriers to entry would not the average price be naturally capped by the long-run cost of energy production ? If it is higher, it is an invitation for new entry.**