

# ***Electric Power Market Simulations Using Individuals as Agents***

**GUENTER CONZELMANN**

Center for Energy, Environmental, and Economic  
Systems Analysis (CEEESA)

Argonne National Laboratory (ANL)  
9700 South Cass Avenue  
Argonne, Illinois 60439, USA

phone: 630-252-7173 fax: 630-252-6073  
email: [guenter@anl.gov](mailto:guenter@anl.gov)



# Market Simulations Allow Us to Explore Market Strategies and Agent Adaptive Behavior

- Practice strategies that we learned through our research of electric power markets
- Examine and discuss the emergent behavior of individual agents and their market strategies
- Compare the behavior of Argonne agents to the observed evolution of the California and New England markets
- Gain insights into the methods that can be used to emulate market strategies of individual agents in the EMCAS model

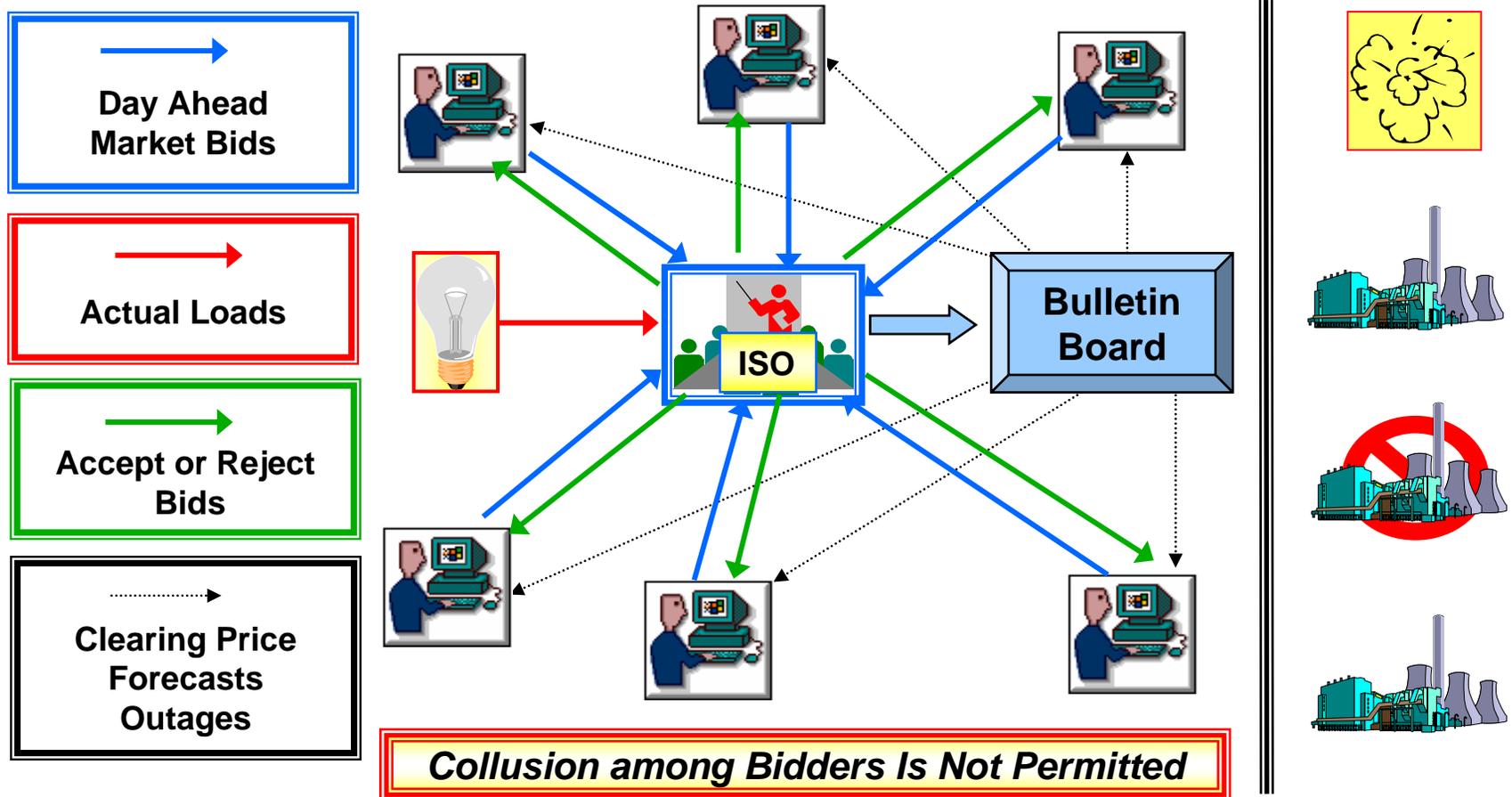


# Argonne Staff Act Out the Roles of Individual Agents in a Virtual Electric Power Market

- **Demand agent**
  - Consume electricity
  - Curtail demand when electricity becomes very expensive
- **Generation agents**
  - Own and operate virtual power plants
  - Submit power bids to the independent system operator (ISO)
  - Generate electricity to meet loads
  - Strive to maximize profits
- **Independent system operator agent**
  - Accept and reject generation agents' bids
  - Dispatch operational units according to market rules
  - Post next-day weather and load forecasts
  - Compute and post market clearing prices
  - Post unit outages



# Information Flow among the Agents Is a Critical Feature of the Simulation Process



# Simulation Bulletin Postings Are Very Similar to the Information Found on the California ISO Web Page



Current System Load: **34096**  
 Today's Peak Demand: **34096**  
 Today's Forecast Peak: **35987**  
 Tomorrow's Forecast Peak: **36513**  
 Load is reported in MegaWatt

FOR: 23-May-2001 at 11:45 AM -- California Generation Curtailments

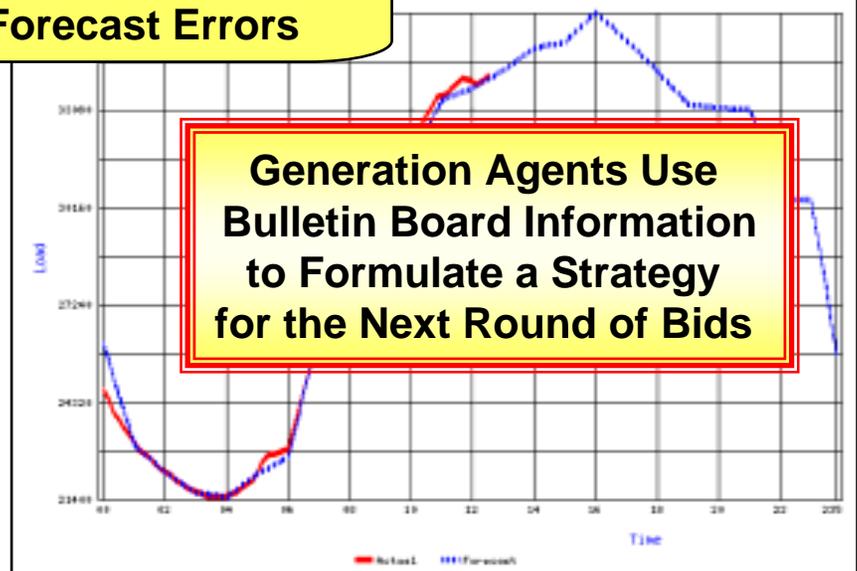
Res Name	Type	Unit	Maximum	Owner	Location	MW Curtailed
AES PLACERITA INC.					SP15	128.17
AGRICO					NP15	25
ALAMITOS UNIT 1					SP15	175
ALAMITOS UNIT 2	U1	176.6		AES	SP15	176.6
ALAMITOS UNIT 5	U1	482		AES	SP15	2
ALAMITOS UNIT 6					SP15	1

**Future Forced Outages Are Unknown**

**There Are Weather Forecast Errors**

**Demand Forecasts Are Imperfect**

PG&E	Fri 05/25			Date
	Max	Min	Sky	
Stockton	96	59	Stazy	2001/05/23 15:10
Santa Rosa	77	49	Stazy	2001/05/23 15:10
San Francisco	68	53	Stazy	2001/05/23 15:10
Concord	87	55	Fair	2001/05/23 15:10
San Jose	83	57	Stazy	2001/05/23 15:10
Fresno	100	69	Fair	2001/05/23 15:10
Bakersfield	101	71	Fair	2001/05/23 15:10



**Generation Agents Use Bulletin Board Information to Formulate a Strategy for the Next Round of Bids**

Source: <http://www.caiso.com/>

# Argonne Agents Submit Bid Forms to the ISO

**Bid Prices & Quantities**

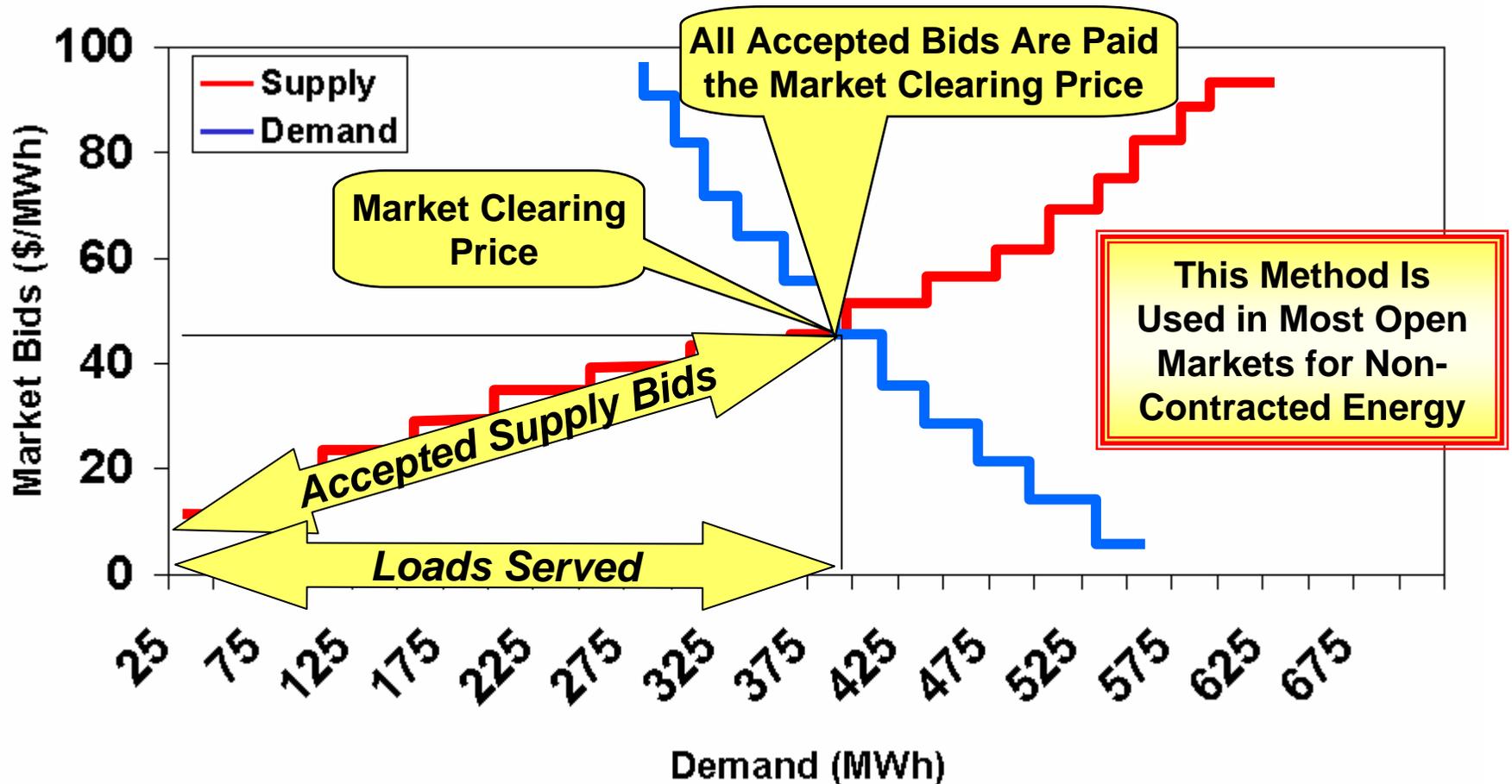
**In EMCAS, Simulated Generation Company Agents Submit Bids**

**Five Blocks**

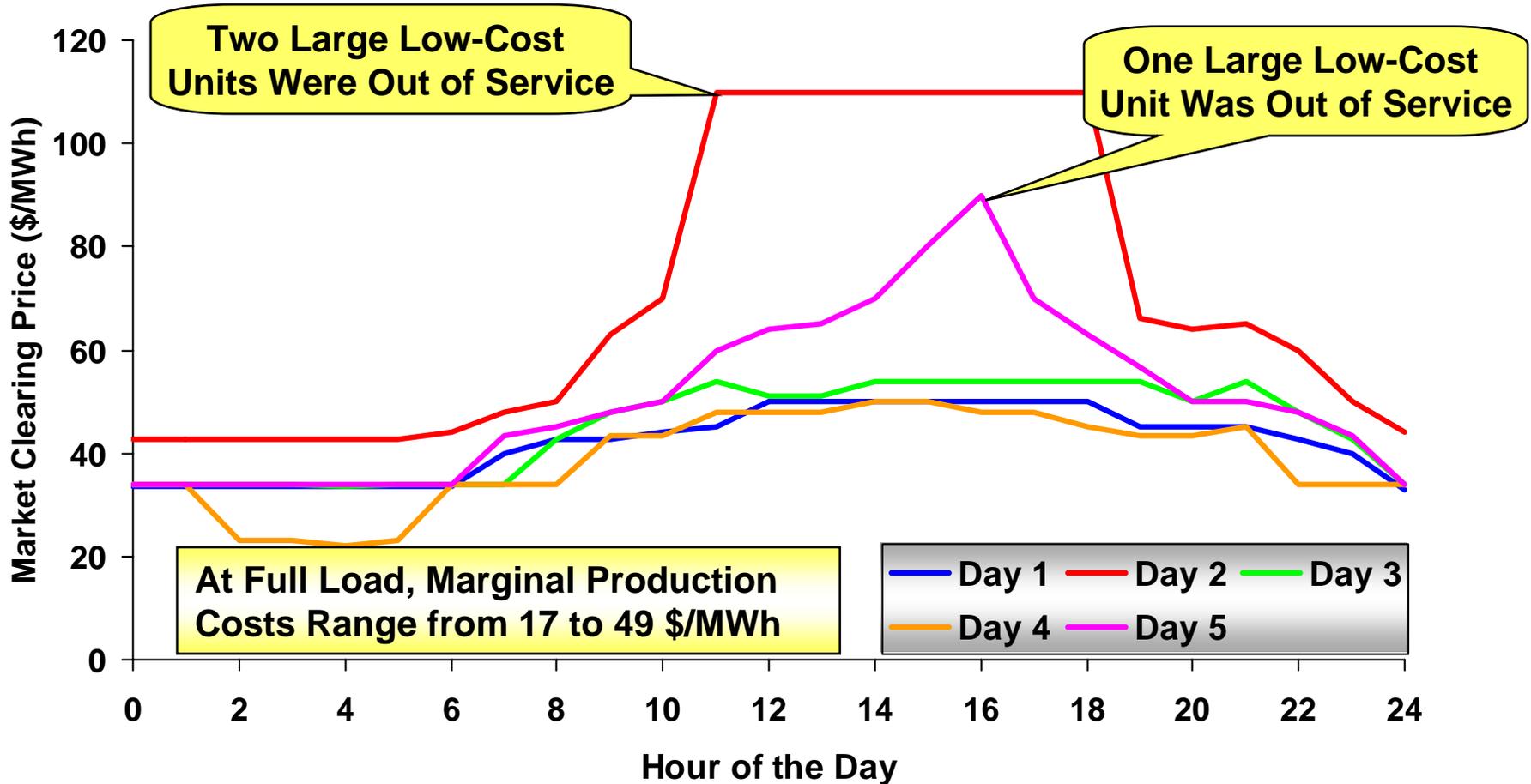
Unit ID Number	Supply Source	Energy Sales Block ID	Bid Price (\$/MWh)	Incremental Quantity (MWh)	Total Quantity (MWh)	Quantity Remaining (MWh)	Heat Rate (BTU/kWh)	Incremental Heat Rate (BTU/kWh)	Incremental Production Costs (\$/MWh)
1	Baseload Coal	1	20	25	25	475	19,077	19,077	33.3
1	Baseload Coal	2	21	225	250	250	10,885	9,975	18.8
1	Baseload Coal	3	22	125	375	125	10,127	8,611	16.6
1	Baseload Coal	4	23	125	500	0	9,758	8,651	16.6
1	Baseload Coal	5	90	0	500	0	9,758	0	0.0
2	NGCC	1	63	75	75	175	11,030	11,030	62.2
2	NGCC	2	64	100	175	75	7,986	5,704	32.6
2	NGCC	3	65	50	225	25	7,681	6,612	37.6
2	NGCC	4	66	25	250	0	7,514	6,012	34.3
2	NGCC	5	40	0	250	0	7,514	0	0.0
3	Gas-Turbine	1	70	35	35	40	11,003	11,003	67.0
3	Gas-Turbine	2	85	20	55	20	9,631	7,230	46.0
3	Gas-Turbine	3	100	20	75	0	9,150	7,827	49.3
3	Gas-Turbine	4	30	0	75	0	9,150	0	0.0
3	Gas-Turbine	5	30	0	75	0	9,150	0	0.0



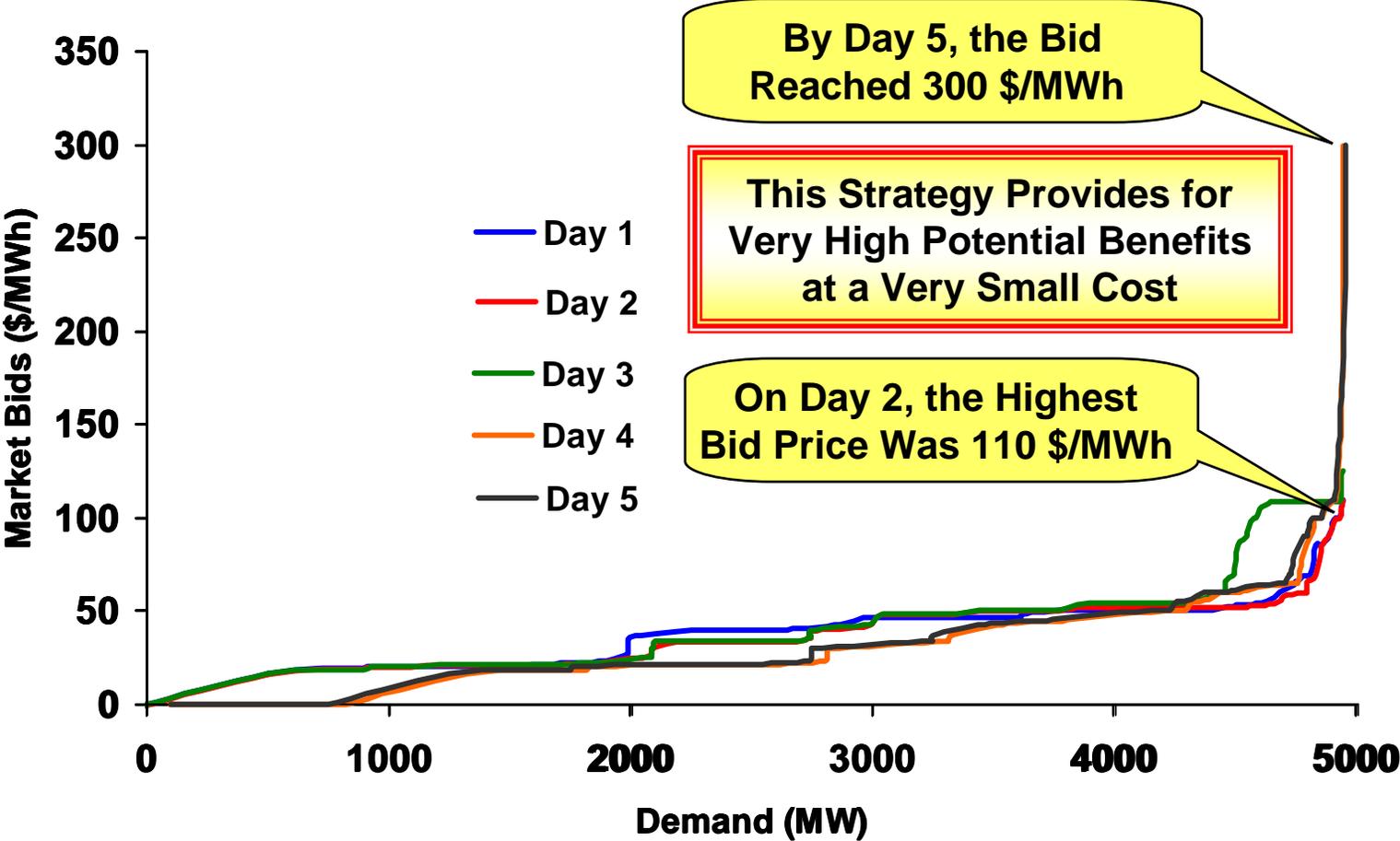
# Based on Agent Bids, the ISO Determines Market Clearing Prices



# Market Clearing Prices Varied Significantly among the Hours and Days of the Week



# Agents Adapted Their Strategies Over Time



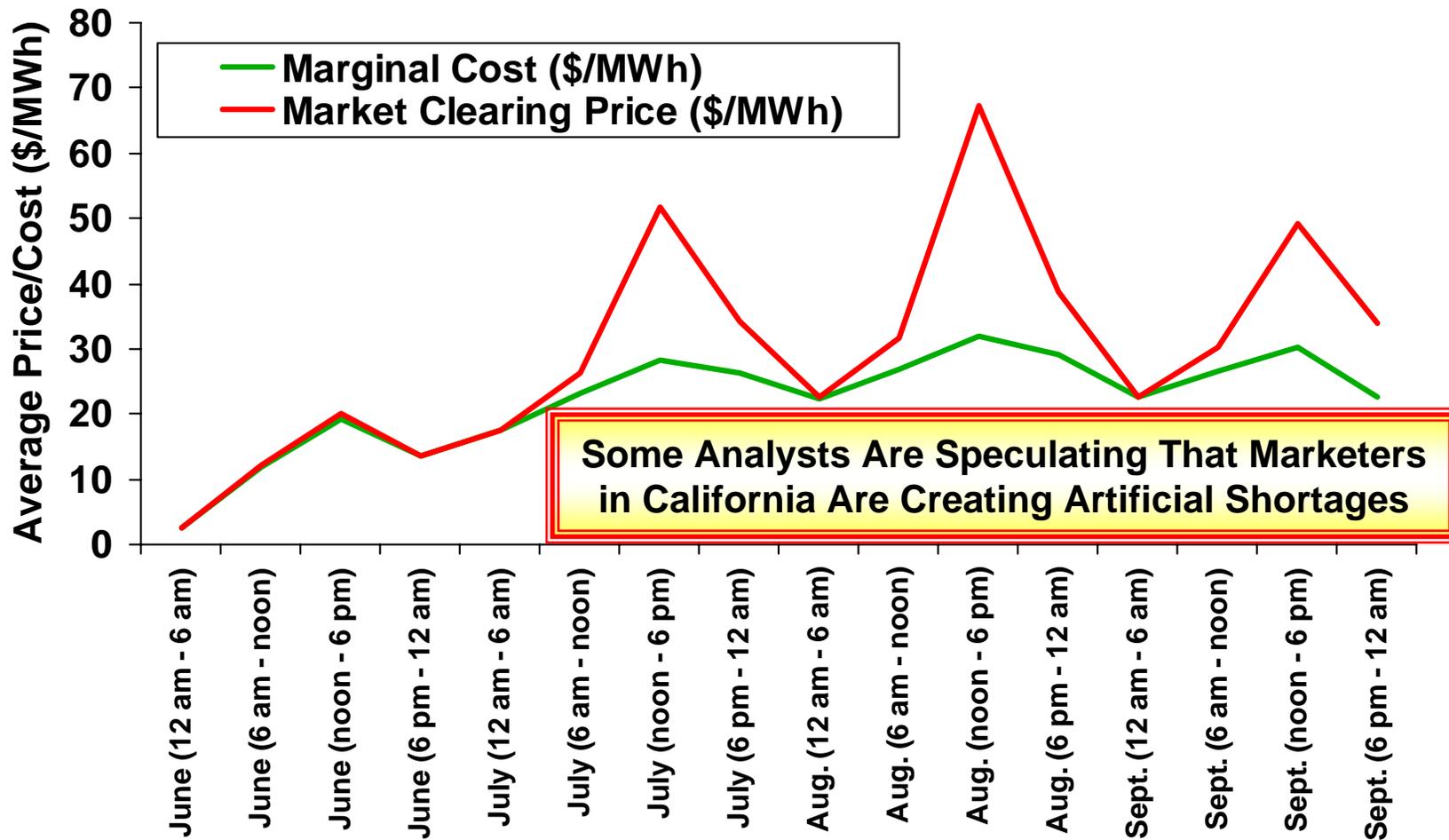
# **This Type of Gaming by Marketers Is Reportedly a Reality in California<sup>1</sup>**

- **On July 9, 1998, a bid price of reserve power needed by the ISO was reported to be 1 \$/MWh**
- **Suddenly, the \$1 bid price shot up to \$2500**
- **The bid price reportedly spiked suddenly to \$5000 where it stayed for 3 hours before dropping back to \$1**
- **Four days later a bid price rose to \$9999 and it stayed at that level for 4 hours before it dropped to \$0.01 in the next hour**
- **“All of us saw those numbers and realized ... there was nothing to stop someone from bidding infinity,” said Jeffrey Tranen (former ISO staff member)**
- **It was evident from the first year of the market operation that players (agents) were probing for weak spots**

<sup>1</sup>Source: *Sacramento Bee* May 6, 2001



# As Reserve Margins in California Shrink, On-peak Prices Rise above Marginal Costs<sup>1</sup>



<sup>1</sup>Source: *California's dysfunctional electricity market: policy lessons on market restructuring*, Energy Policy, January 2001

# Simulations That Use Individuals as Agents Can Provide Insights into How a Market Will Operate

- Agents learn about the behavior of the virtual market, and some will adapt their strategies to take advantage of the market rules and structure
- Agents can probe the virtual market for flaws
- In the future, market rules must be developed more carefully
- Market structures and rules should be tested through model simulations to help uncover flaws
- The California market might look different today if market designers had been able to perform rigorous market simulations in a virtual world before implementing rules in the real one

