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Electric Power Market Simulations Using Individuals as Agents

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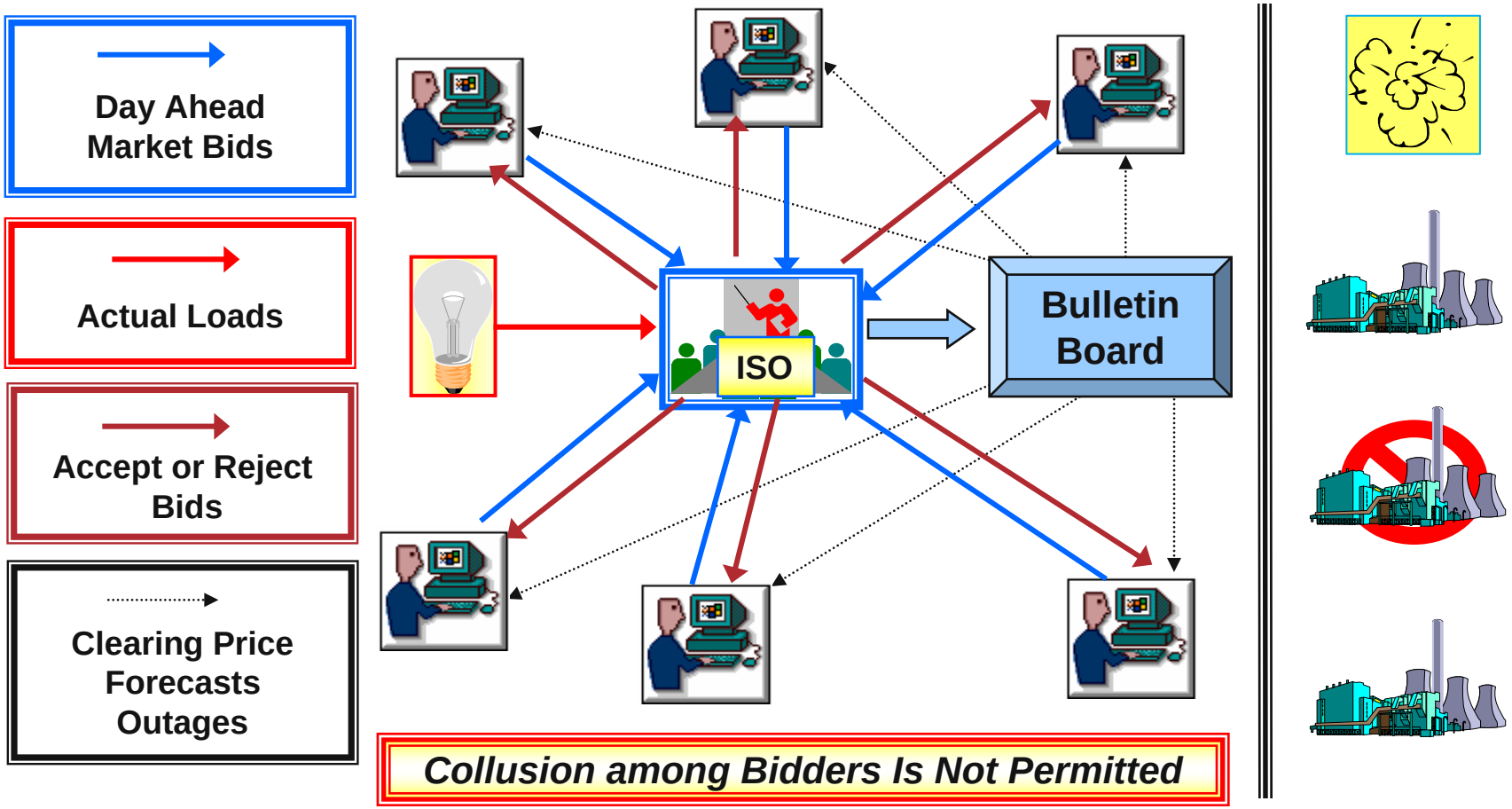
Market Simulations Allow Us to Explore Market Strategies and Agent Adaptive Behavior

- 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

CALIFORNIA ISO

Current System Load:	34096
Today's Peak Demand:	34096
Today's Forecast Peak:	35987
Tomorrow's Forecast Peak:	36513

Load is reported in MegaW

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

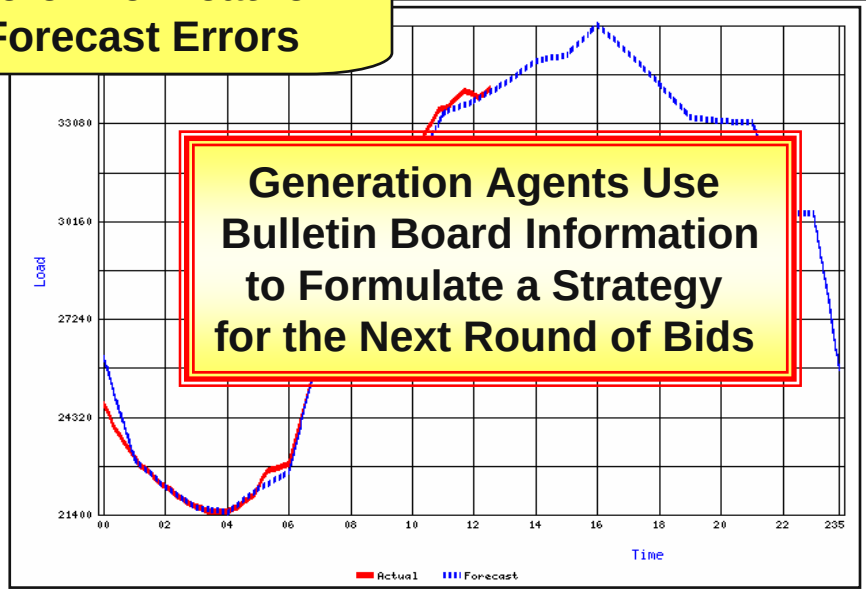
Res Name	Type	Unit Maximum	Owner	Location	MW Curtailed
AES PLACERITA INC.				SP15	128.17
AGRICO				NP15	25
ALAMITOS UNIT 1				SP15	175
ALAMITOS UNIT 2	U,P	176.6	AES	SP15	176.6
ALAMITOS UNIT 5	U	482	AES	SP15	2
ALAMITOS UNIT 6				SP15	1

Future Forced Outages Are Unknown

There Are Weather Forecast Errors

Demand Forecasts Are Imperfect

PG&E				Fri 05/25			Date
				Max	Min	Sky	
				89 [15]	50 [04]	Partly Cloudy	2001/05/23 15:18
				95 [17]	62 [05]	Partly Cloudy	2001/05/23 15:18
Sacramento	92 [17]	58 [06]	Sunny	88 [17]	58 [05]	Partly Cloudy	2001/05/23 15:18
Stockton	96 [17]	59 [06]	Sunny	92 [17]	57 [05]	Partly Cloudy	2001/05/23 15:18
Santa Rosa	77 [15]	49 [06]	Sunny	75 [15]	51 [04]	Mostly Cloudy	2001/05/23 15:18
San Francisco	68 [15]	53 [05]	Sunny	68 [15]	53 [04]	Mostly Cloudy	2001/05/23 15:18
Concord	87 [16]	55 [06]	Fair	84 [16]	54 [05]	Mostly Cloudy	2001/05/23 15:18
San Jose	83 [16]	57 [06]	Sunny	80 [16]	56 [04]	Mostly Cloudy	2001/05/23 15:18
Fresno	100 [17]	69 [06]	Fair	98 [17]	66 [05]	Partly Cloudy	2001/05/23 15:18
Bakersfield	101 [17]	71 [06]	Fair	99 [17]	70 [05]	Partly Cloudy	2001/05/23 15:18
SCE	Thu 05/24			Fri 05/25			Date



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

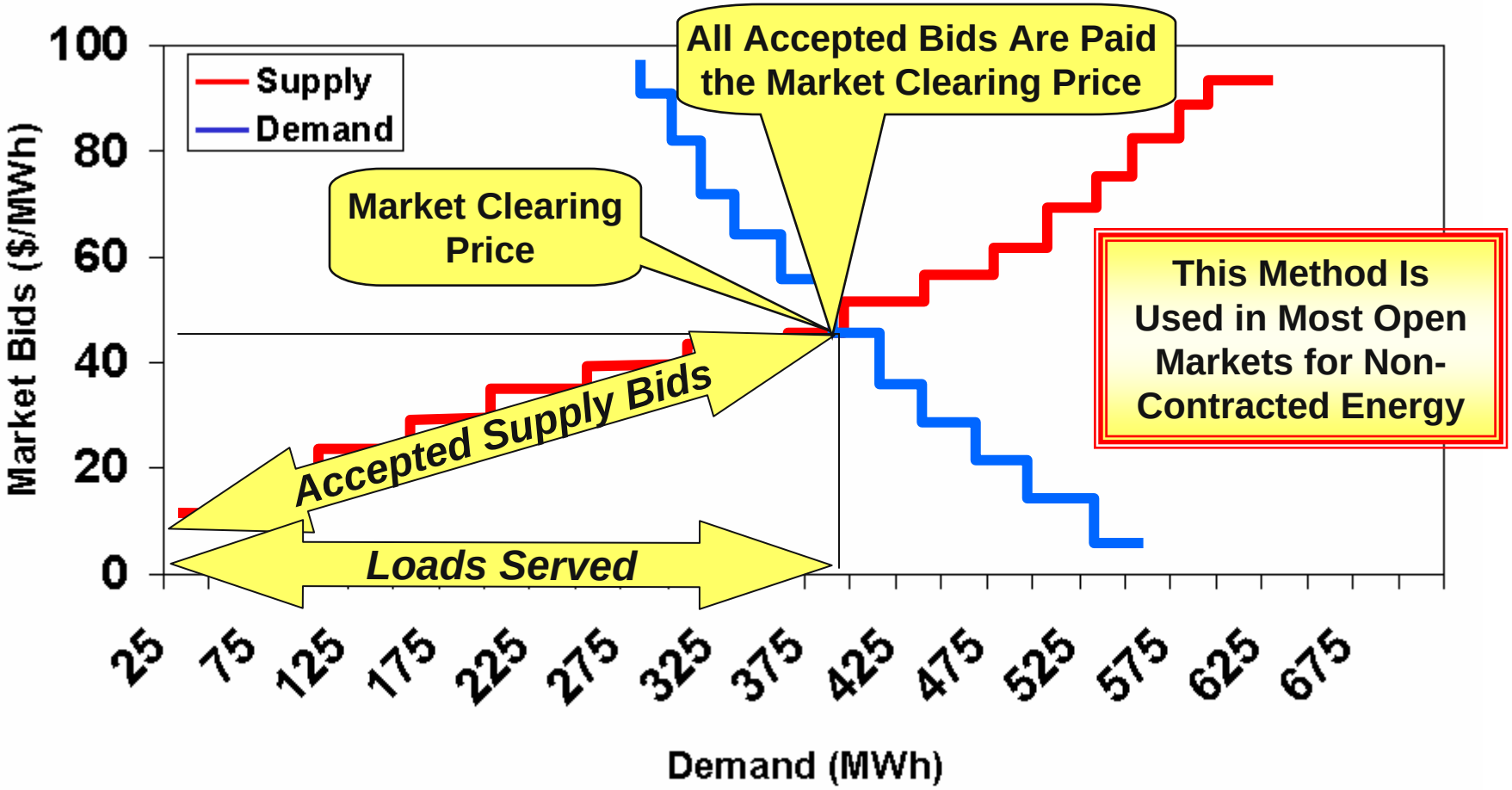
Bid Prices & Quantities

In EMCAS, Simulated Generation Company Agents Submit Bids

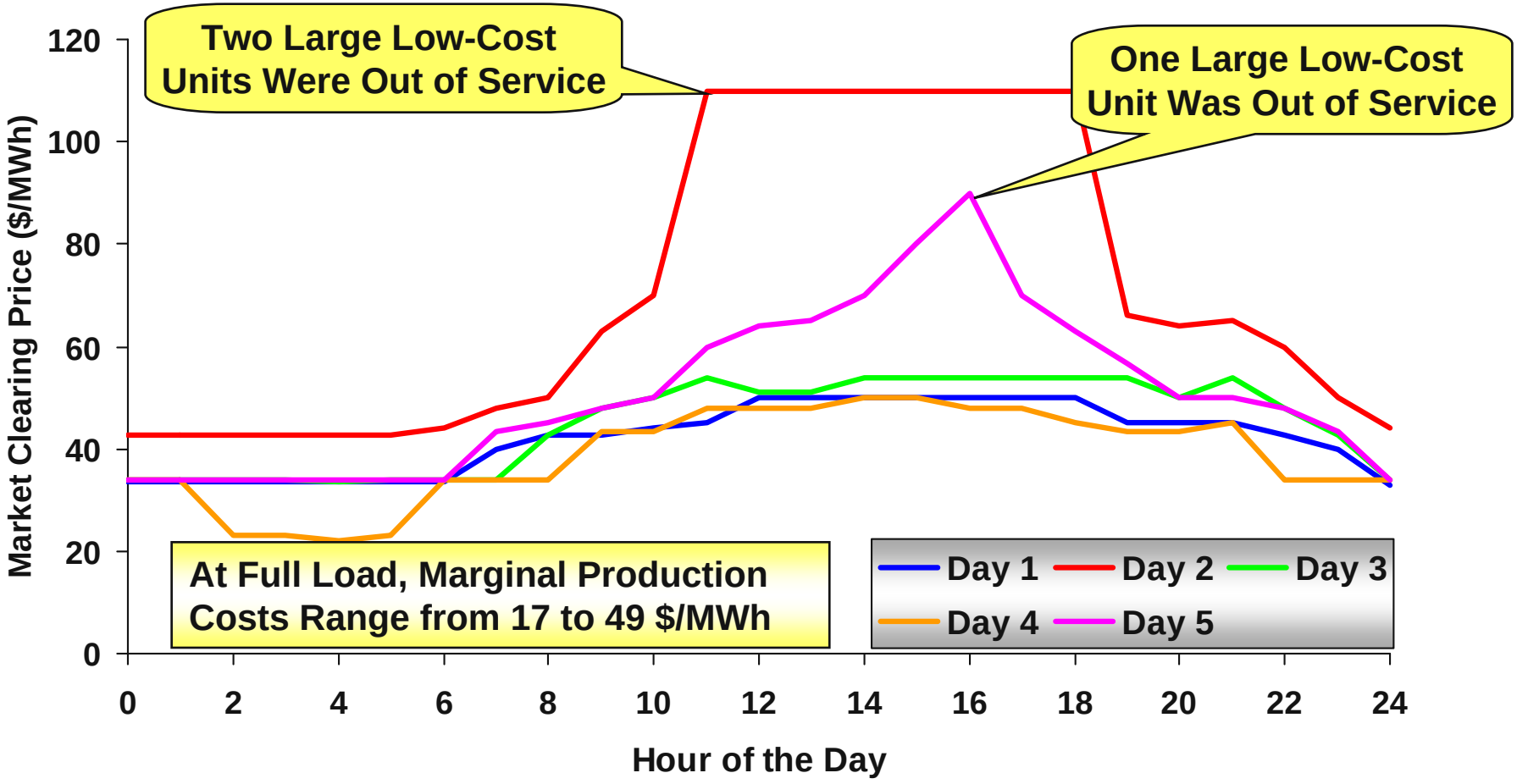
Five Blocks

Unit ID Number	Supply Source	Energy Sales Block ID	Bid Price ($/MWh)	Incremental Quantity (MWh)	Total Quatity (MWh)	Quantity Remaining (MWh)	Heat Rate (BTU/kWh)	Incremental Heat Rate (BTU/kWh)	Incremental Production Costs ($/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

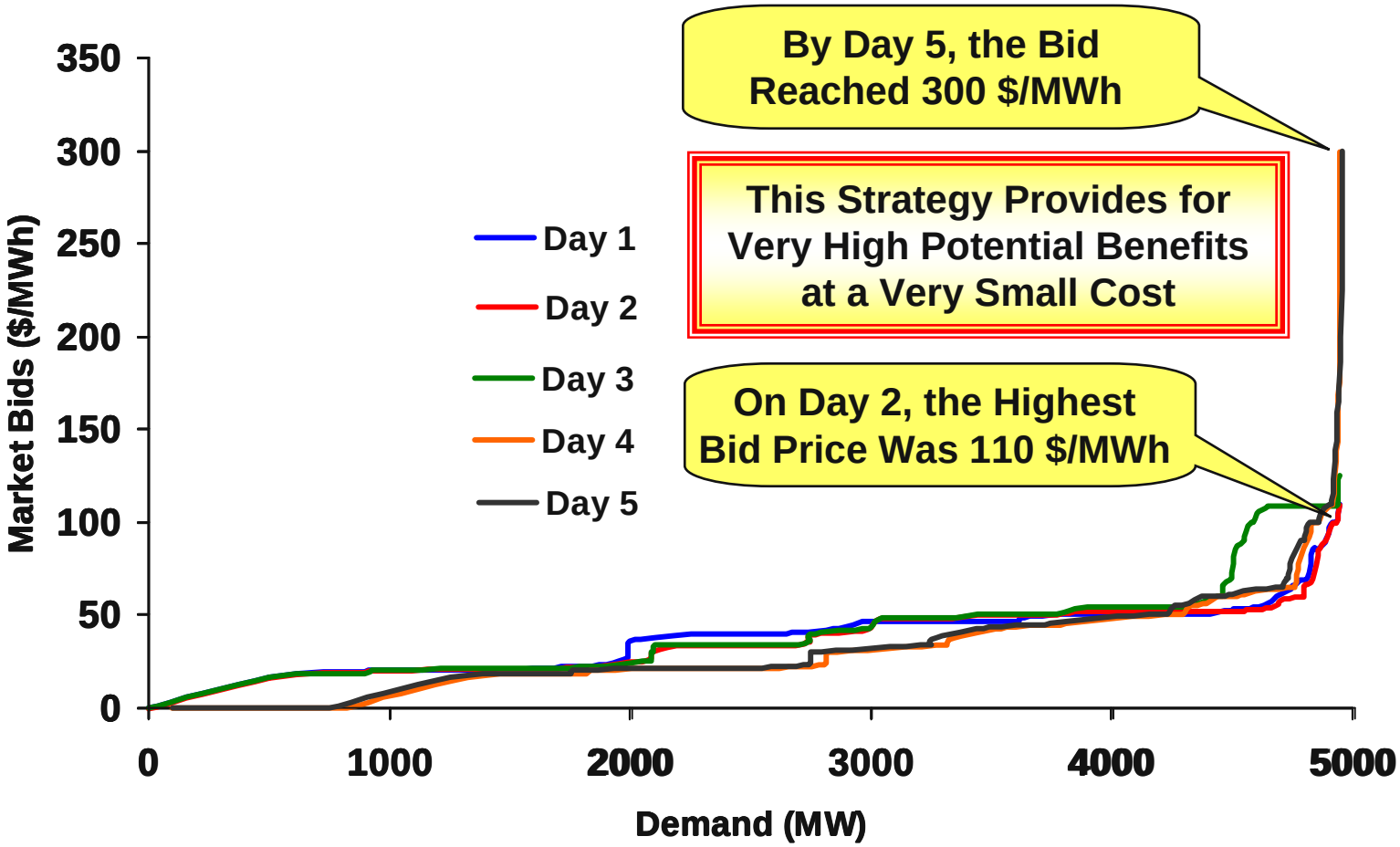
Based on Agent Bids, the ISO Determines Market Clearing Prices



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



Agents Adapted Their Strategies Over Time

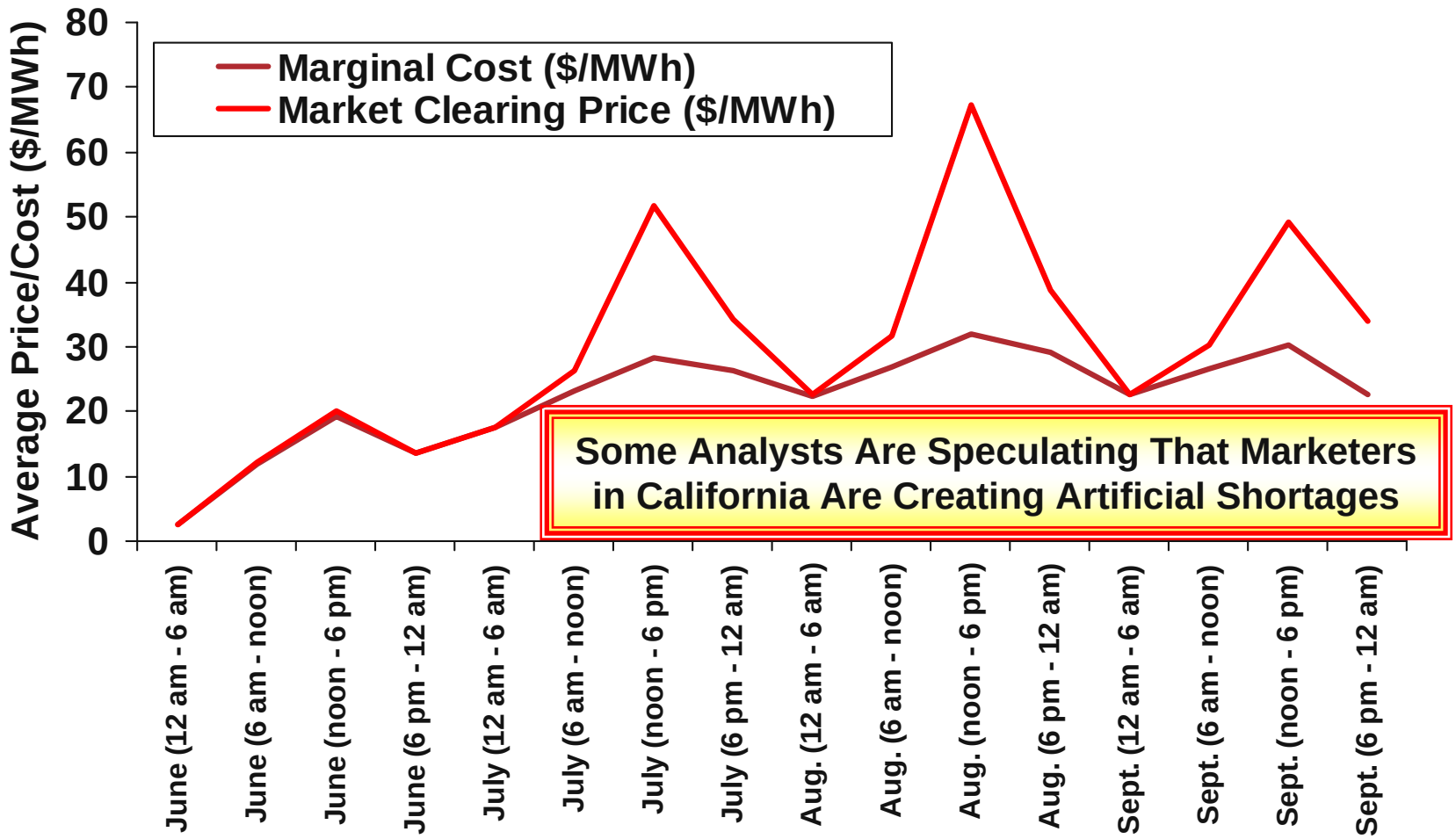


This Type of Gaming by Marketers Is Reportedly a Reality in California[1]

- 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

[1]**Source: *Sacramento Bee* May 6, 2001**

As Reserve Margins in California Shrink, On-peak Prices Rise above Marginal Costs[1]



[1]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