California ISO
Your Link to Power
10 Year Anniversary 1998–2008

Concepts of the CAISO Scarcity Pricing Design

Shucheng Liu, Ph.D.
Principal Market Developer
California Independent System Operator

HEPG Plenary Session

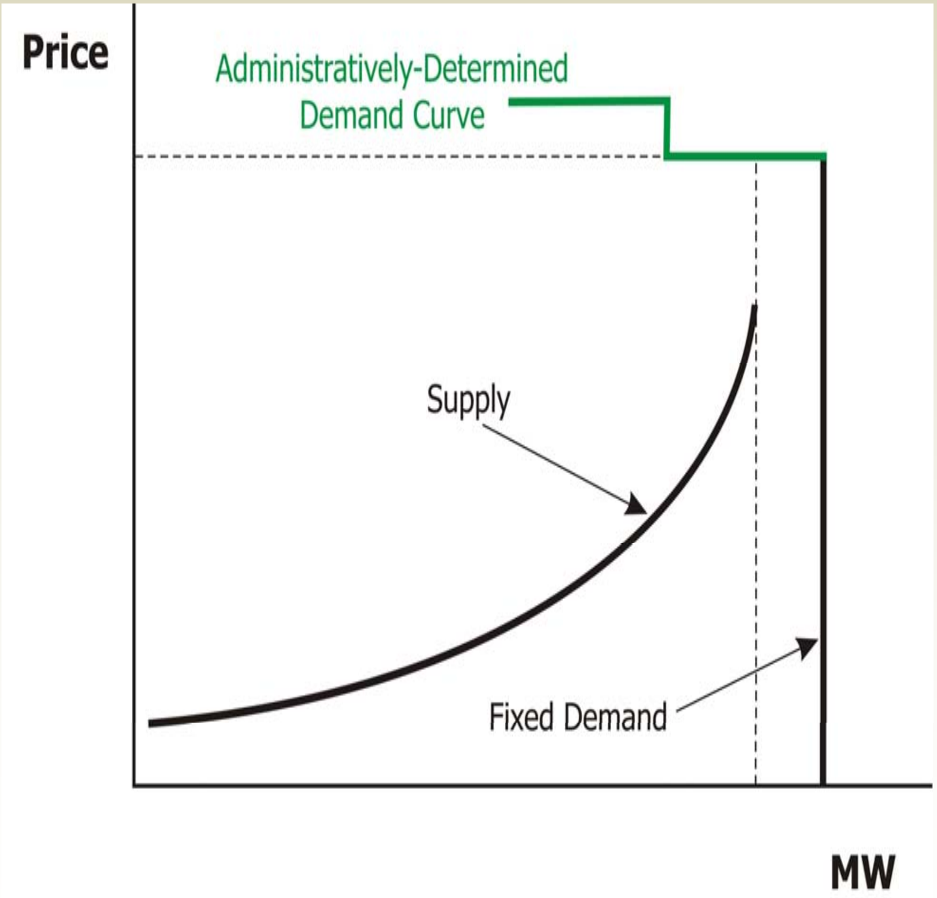
March 13, 2009
San Diego, California

FERC directs the CAISO to implement a reserve shortage Scarcity Pricing mechanism.

- Raising prices automatically during periods of genuine reserve shortage
- Applying administratively-determined graduated prices to various levels of reserve shortage
- Implementing the mechanism in both day-ahead (DAM) and real-time markets (RTM)

A demand curve approach Scarcity Pricing mechanism can improve market performance.

- Being transparent
- Clearing market with the demand curve in situation of reserve shortage
- Setting prices to reflect various levels of reserve shortage
- Encouraging cost based bidding

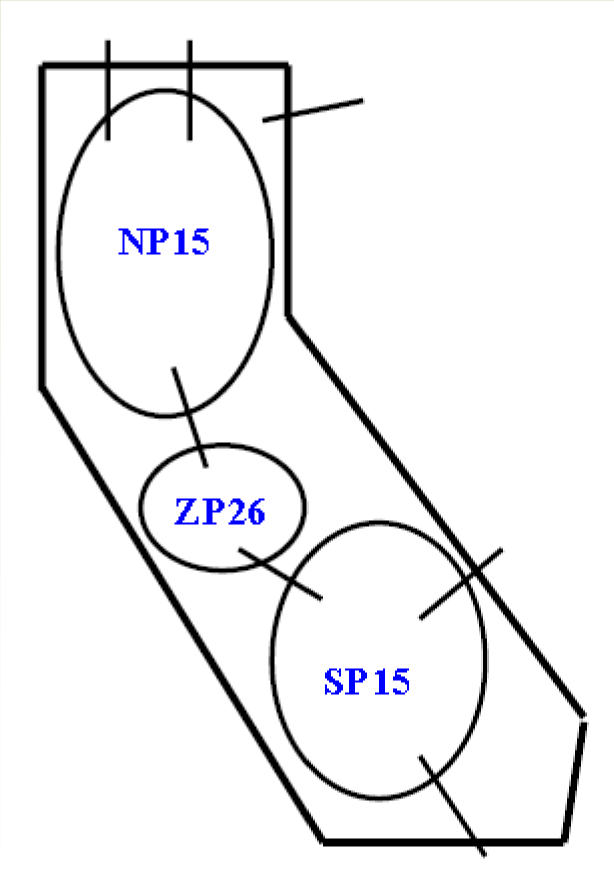


California ISO
Your Link to Power
10 Year Anniversary 1998–2008

The CAISO may procure higher quality reserve to meet the requirement for lower quality reserve.

- Reserves from high to low quality
  - Regulation Up, Spinning, Non-spinning
  - Regulation Down
- Reserve substitution
  - Higher quality can be procured to meet the requirement for lower quality reserve if it is economic to do so

The CAISO may also procure reserves by A/S sub-regions.



- NERC and WECC reliability criteria specify reserve requirements for the CAISO system (A/S region)
- CAISO sets reserve procurement targets for A/S sub-regions as needed
- Reserves procured in an A/S sub-region also meet the requirements of the A/S region

Market recognizes the value of high quality reserves and reserves needed in the sub-regions.

- Price of a higher quality reserve is always higher than or equal to the price of a lower quality reserve in the same location
- Price of a reserve in a sub-region is always higher than or equal to the price of the same reserve in the outer region
- This is also true in situation of reserve shortage

The proposed reserve demand curve may set reserve scarcity prices higher than energy bid cap.

	CAISO	Sub-region
Regulation Up	$200	$100
Spinning	$100	$100
Non-Spinning Shortage > 210 MW Shortage > 70 & ≤ 210 MW Shortage ≤ 70 MW	 $700 $600 $500	$250
Sum	**$1000**	**$450**
Regulation Down	$600	

- Reserve scarcity prices are additive
- Scarcity price can get as high as $1,000/MWh system-wide and $1,450/MWh in A/S sub-region

Scarcity Pricing interacts with other market components.

- With demand response
  - Scarcity Pricing can set price to trigger demand response
  - Demand response resources provide reserves
- With Resource Adequacy (RA) program
  - Scarcity Pricing complements the RA program and rewards capacity with high ramping capability

Market power mitigation is an important aspect of the Scarcity Pricing design.

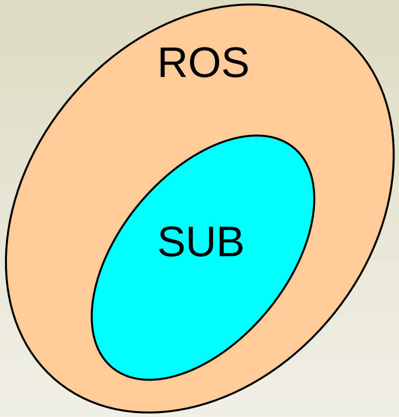
- The CAISO procures 100% A/S requirements in DAM
- RA capacity DAM must-offer requirement prevents capacity withholding
- Demand curve approach Scarcity Pricing mechanism caps reserve prices in situation of reserve shortage

California ISO
Your Link to Power
10 Year Anniversary 1998–2008

Appendix: Numerical Examples

All examples follow these common assumptions.

- SUB – a sub-region in the CAISO system
  ROS – the rest of the CAISO system
- Generator G1 in ROS and G2
  in SUB supplying energy and one type
  of reserve
- Minimum A/S procurement requirement
  for SUB and for the system
- Fixed energy demand for the system.



Example 1 – No shortage

- Input: supply, demand, and reserve demand curve values

Supply		Max Cap (MW)	Max A/S Cap (MW)	Energy Bid ($/MWh)	A/S Bid ($/MWh)
ROS	G1	3,500	195	37	6
SUB	G2	1,000	95	50	23

Demand (MW)	Energy	Min A/S		
System	4,050	235		
SUB		90		

Reserve Demand Curve Value ($/MWh)				
System	800			
SUB	400			

Example 1 – No shortage (cont.)

Objective Function $\min(37 \cdot E_1 + 50 \cdot E_2 + 6 \cdot AS_1 + 23 \cdot AS_2 + 800 \cdot SLK_{Sys} + 400 \cdot SLK_{SUB})$

St:

Energy Balance	$E_1 + E_2 = 4050$	λ_E
SUB A/S Requirement	$AS_2 + SLK_{SUB} \geq 90$	$\lambda_{AS,SUB}$
System A/S Requirement	$AS_1 + AS_2 + SLK_{Sys} \geq 235$	$\lambda_{AS,SYS}$
G1 A/S Capacity	$AS_1 \leq 195$	
G2 A/S Capacity	$AS_2 \leq 95$	
G1 Total Capacity	$E_1 + AS_1 \leq 3500$	
G2 Total Capacity	$E_2 + AS_2 \leq 1000$	
Non-negative	$SLK_{Sys} \geq 0,\ SLK_{SUB} \geq 0,\ E_i \geq 0,\ AS_i \geq 0\ \ (i = 1, 2)$	

Where: E_i, AS_i = energy and A/S schedule for generator *i* (*i* = 1, 2)

SLK_{SUB}, SLK_{Sys} = A/S requirement constrain slack variables

λ_E, $\lambda_{AS,SUB}$, $\lambda_{AS,SYS}$ = shadow prices of energy and A/S requirement constraints

Example 1 – No shortage (cont.)

- Co-optimization results

Optimal Energy Schedules and A/S Awards (MW)						
	E_1	E_2	AS_1	AS_2	SLK_{Sys}	SLK_{SUB}
	3,355	695	145	90	0	0
Shadow Prices ($/MWh)						
	λ_E	$\lambda_{AS,SYS}$	$\lambda_{AS,SUB}$			
	50	19	4			
Market Clearing Prices ($/MWh)						
	Energy		A/S			
Rest of the System	50 (λ_E)		19 ($\lambda_{AS,SYS}$)			
Sub-region	50 (λ_E)		23 ($\lambda_{AS,SYS} + \lambda_{AS,SUB}$)			

California ISO Your Link to Power 10 Year Anniversary 1998–2008

Example 2 – Ramping capacity shortage in the sub-region

- Reduced maximum A/S capacity of G2

Supply		Max Cap (MW)	Max A/S Cap (MW)	Energy Bid ($/MWh)	A/S Bid ($/MWh)
ROS	G1	3,500	195	37	6
SUB	G2	1,000	85	50	23

- Co-optimization results

Optimal Energy Schedules and A/S Awards (MW)						
	E_1	E_2	AS_1	AS_2	SLK_{Sys}	SLK_{SUB}
	3,350	700	150	85	0	5
Shadow Prices ($/MWh)						
	λ_E	$\lambda_{AS,SYS}$	$\lambda_{AS,SUB}$			
	50	19	400			
Market Clearing Prices ($/MWh)						
		Energy	A/S			
Rest of the System		50	19			
Sub-region		50	419			

California ISO
Your Link to Power
10 Year Anniversary 1998–2008

Example 3 – Ramping capacity shortage in the sub-region and rest of the system

- Reduced maximum A/S capacity of G1 and G2

Supply		Max Cap (MW)	Max A/S Cap (MW)	Energy Bid ($/MWh)	A/S Bid ($/MWh)
ROS	G1	3,500	138	37	6
SUB	G2	1,000	85	50	23

- Co-optimization results

Optimal Energy Schedules and A/S Awards (MW)						
	E_1	E_2	AS_1	AS_2	SLK_{Sys}	SLK_{SUB}
	3,362	688	138	85	12	5
Shadow Prices ($/MWh)						
	λ_E	$\lambda_{AS,SYS}$	$\lambda_{AS,SUB}$			
	50	800	400			
Market Clearing Prices ($/MWh)						
		Energy	A/S			
Rest of the System		50	800			
Sub-region		50	1,200			

Example 4 – Total capacity shortage

- Reduced maximum capacity of G2

Supply		Max Cap (MW)	Max A/S Cap (MW)	Energy Bid ($/MWh)	A/S Bid ($/MWh)
ROS	G1	3,500	195	37	6
SUB	G2	780	95	50	23

- Co-optimization results

Optimal Energy Schedules and A/S Awards (MW)						
	E_1	E_2	AS_1	AS_2	SLK_{Sys}	SLK_{SUB}
	3,360	690	140	90	5	0
Shadow Prices ($/MWh)						
	λ_E	$\lambda_{AS,SYS}$	$\lambda_{AS,SUB}$			
	831	800	4			
Market Clearing Prices ($/MWh)						
		Energy	A/S			
Rest of the System		831	800			
Sub-region		831	804			