Demand Curve Definitions

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Market Structures Working Group

DRAFT: For Discussion Purposes Only

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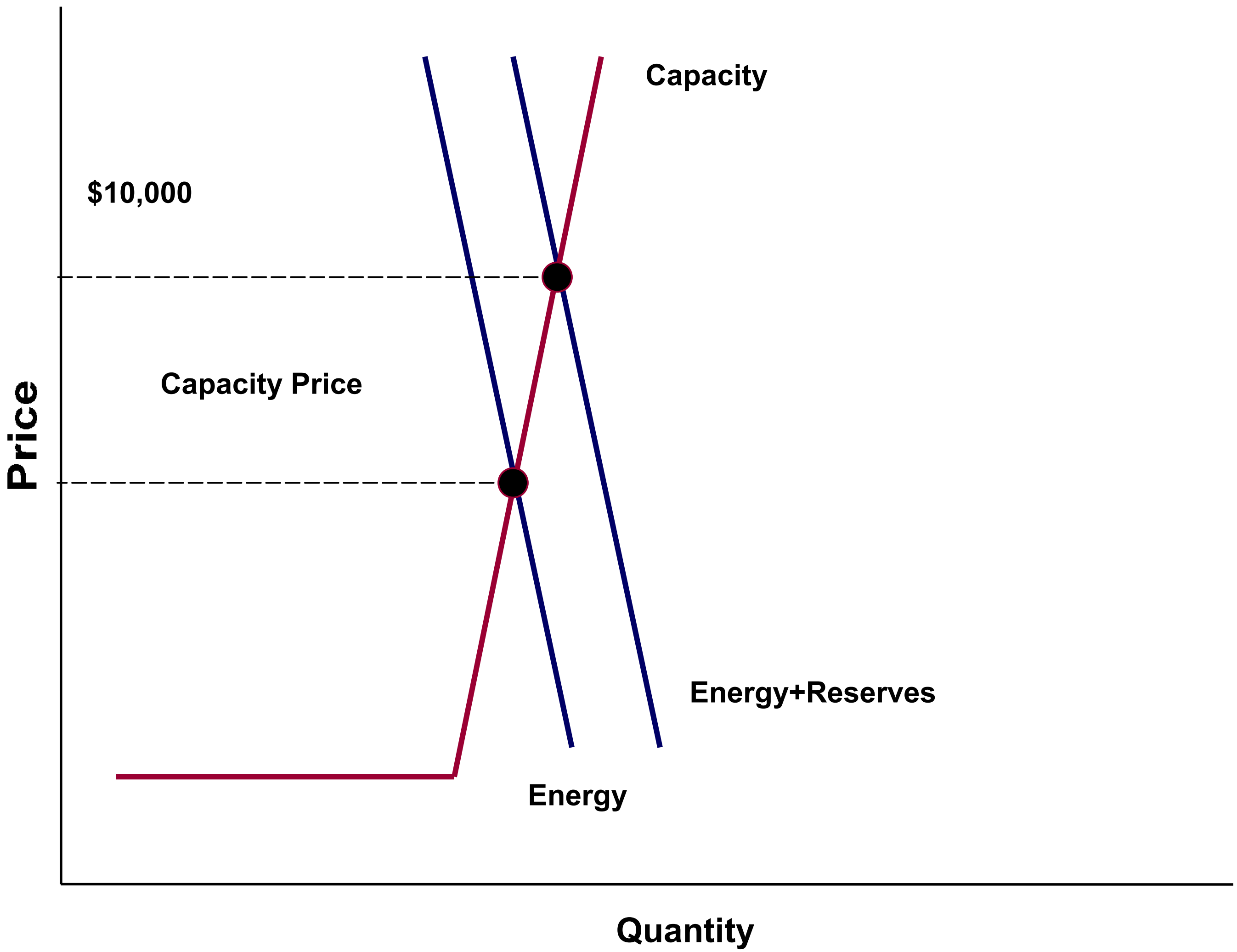
AGENDA

The agenda for today's presentation is:

- Quick recap of demand curve concepts
- Understanding reserve demand curves as applied to New York's markets:
  - Additive demand curves;
  - Comparative demand curves between products;
  - Questioning operations to determine appropriate demand curves between products and in aggregate;


Capacity
$10,000
Capacity Price
Price
Energy+Reserves
Energy
Quantity

Even very small reserve shortages can drive reserve prices to very high levels.

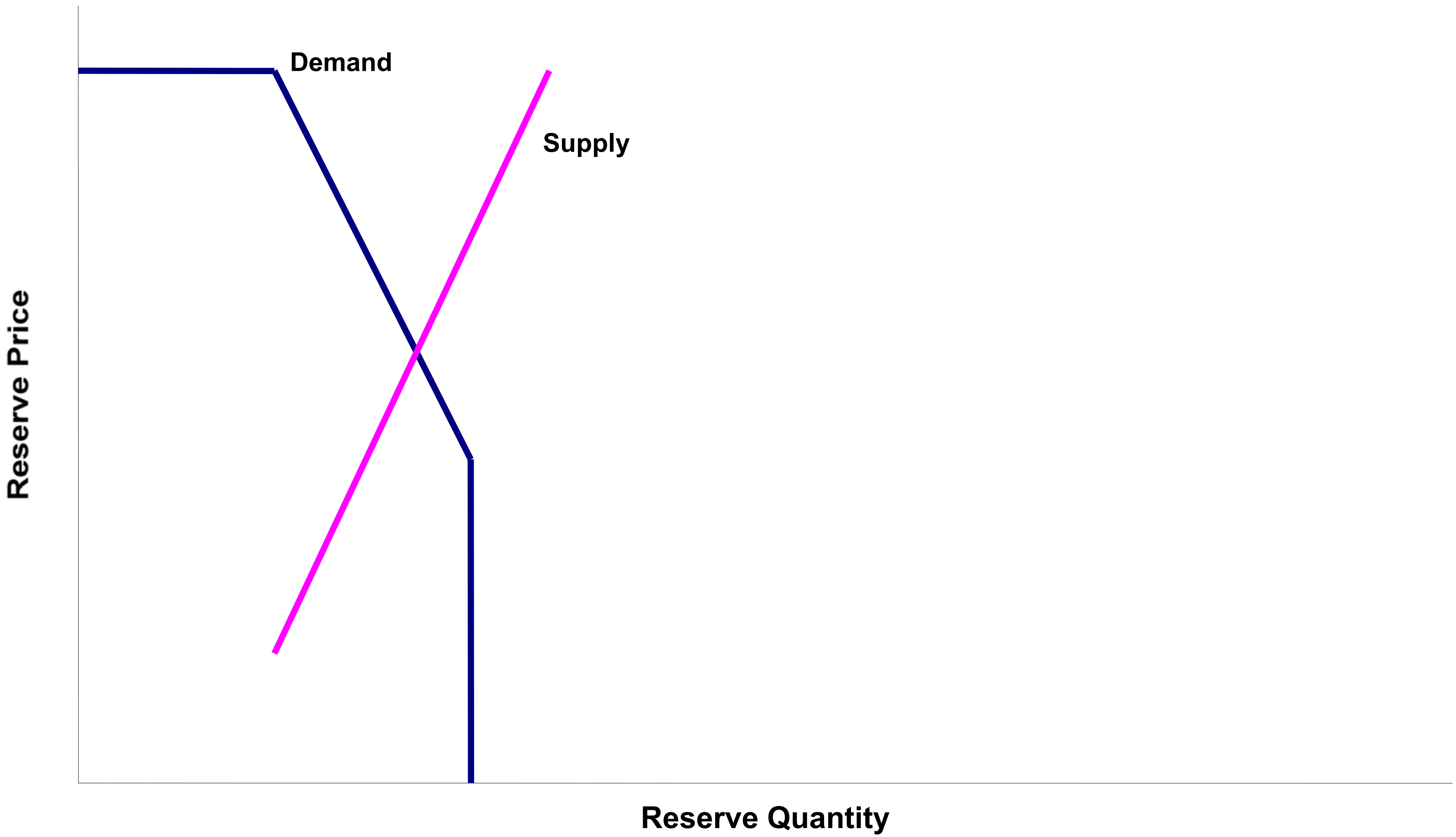
- Even in a co-optimized market for energy and reserves, such a fixed demand curve for reserves could require the ISO to purchase energy at unlimited prices in order to maintain targeted reserve levels.
- The fixed demand curve approach is, therefore, likely to produce economically irrational outcomes under high load conditions, even in a highly competitive market.
- The reality is the market software today has a demand curve, it is just set at very high prices.

The vertical demand curve model leads to irrational outcomes because it is inconsistent with the actual operation of the grid.

- The vertical demand curve for ancillary services implies that system operators would shed load whenever reserves fell below targets.

- In practice, system operators do not shed load to maintain desired reserve targets. This reality implies that the underlying demand curve for reserve is not vertical, and this should be recognized in the pricing system.

Demand Curve for Reserves



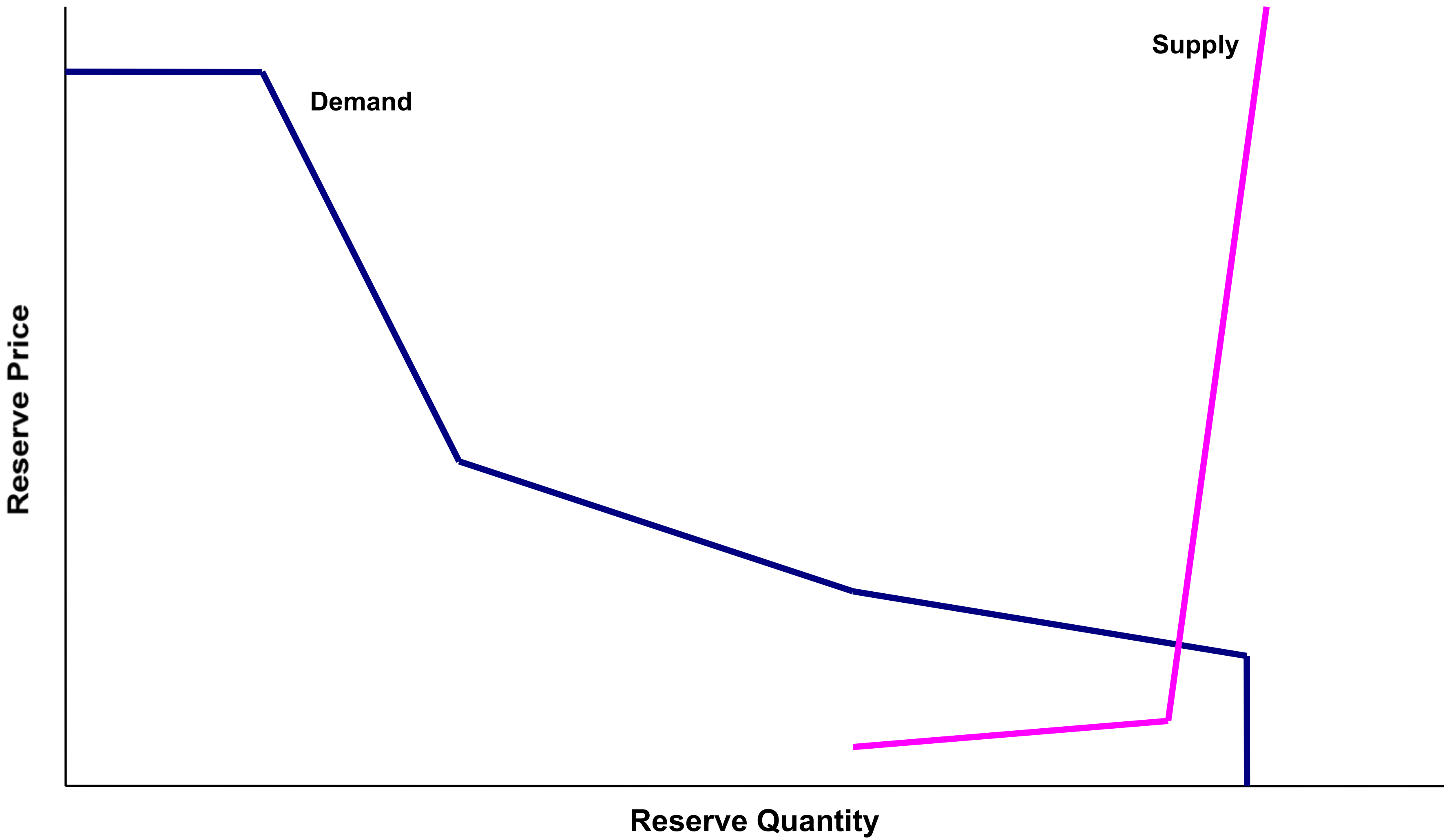
WHY A DEMAND CURVE?

The demand curve approach to ancillary services pricing would replace a fixed vertical demand for reserves with a demand curve in which the quantity of reserves scheduled would depend both on transmission grid and generator characteristics and as-bid reserve costs.

The demand curve would be defined to be consistent with the ISO's actual operating policies. If the ISO would not shed load to maintain a given level of spinning reserves, then the ISO would not be willing to pay more than the value of lost load to maintain that level of reserves.

More importantly, the ISO is not willing to pay more than the perceived value of that MW reserves.

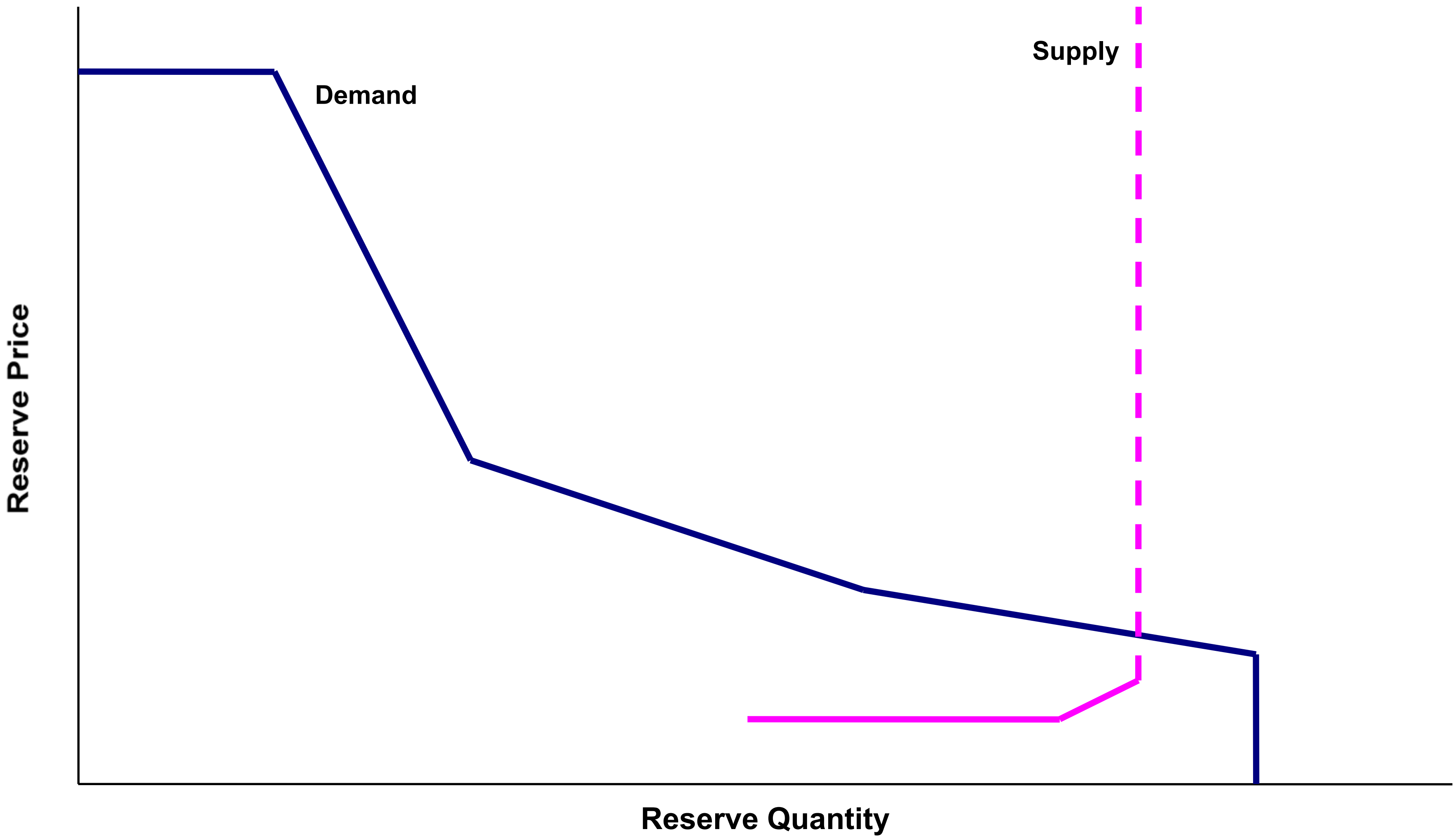
Demand Curve for Reserves



With the ISO's reserve scheduling governed by such a demand curve, the scheduling of incremental reserves to satisfy small reserve deficits (relative to reserve targets) would not result in irrational market clearing prices.

- Reserves that cost more to provide than their value to the market would not be scheduled.
- The price of reserves in shortage situations would reflect their value.
- Only MWs that are scheduled as reserves are paid

Demand Curve for Reserves



Under this approach, the price of reserves would be defined even if not enough reserves were available at any price to meet the ISO's reserve target.

- In shortage situations, the price of reserves would be set by the demand curve.
- Because demand curves for ancillary services cause ancillary service markets to clear, they will sometimes result in higher prices than would prevail under other pricing systems.
- The demand curve limits the level of price increases caused by market power to price/quantity pairs defined by the demand curve and creates a risk to the bidder that their bid will be to the right of the demand curve and thus not be designated as reserves or paid the reserve clearing price.

The remainder of the presentation deals more specifically with the challenges and intuition behind creating a demand curve for New York's reserve markets which have three nested locations: Pool, East of Central East and Long Island; and three nested qualities of service: 10-minute spinning reserve, 10-minute total reserve and 30-minute total reserve.

As we develop the demand curves it is important that we understand the relationship between energy, regulation and each quality and location of reserves scheduled by the co-optimized software solution proposed in RTS.

	Pool	Eastern	LI
10-Minute Spinning Reserve	$ 1,000	$ 1,000	$ 1,000
10-Minute Total Reserve	$ 1,000	$ 1,000	$ 1,000
30-Minute Total Reserve	$ 1,000	$ 1,000	$ 1,000

Seemingly, the matrix of $1,000/MWh demand curves above provides for $1,000/MWh energy and reserve prices in all circumstances when a reserve constraint is violated.

However, there are two reasons why the previous statement is incorrect.

Firstly, the shortage of reserves involves an additive relationship between the incremental cost of the next MW of energy that would be dispatched and the $1,000/MWh shortage cost of reserves.

Secondly, the additive nature of multiple reserve constraints means that should two reserve constraints be violated the price in parts of the state can increase to $2,000/MWh plus the incremental cost of the next MW of energy.

Initial Dispatch				
	Capacity (MW)	Energy (MW)	Energy Offer Price ($/MWh)	30 Minute Total Reserve (MW)
Unit 1	200	180	$ 100	20
Unit 2	200	150	$ 200	50
Rest	28000	26300	$ 250	1700
30-Minute Reserve Shortage				30
Totals	28400	26630		1800

Incremental Dispatch of 1 MW				
	Capacity (MW)	Energy (MW)	Energy Offer Price ($/MWh)	30 Minute Total Reserve (MW)
Unit 1	200	181	$ 100	19
Unit 2	200	150	$ 200	50
Rest	28000	26300	$ 250	1700
30-Minute Reserve Shortage				31
Totals	28400	26631		1800

LBMP Determination			
	Change in Dispatch (MW)	Cost ($/MWh)	Total Change in Cost ($)
Unit 1	1	$ 100	$ 100
30-Minute Reserve Shortage	1	$ 1,000	$ 1,000
			$ 1,100

Unit 1 is capacity constrained. All of its capacity is either scheduled for energy or for reserves. To obtain an additional MW of energy Unit 1 must be dispatched up 1 MW. To do so increases the amount that the system is short of 30-minute total reserves by an additional MW.

The incremental cost of the additional MW of energy is $1,100:

- $100 from the incremental cost of the energy dispatched on Unit 1;
- $1,000 from the incremental cost of violating the 30-minute total reserve constraint by an additional MW.

Initial Dispatch					
	Capacity (MW)	Energy (MW)	Energy Offer Price ($/MWh)	10-Minute Total Reserve (MW)	30-Minute Total Reserve (MW)
Unit 1	200	180	$ 100	20	20
Unit 2	200	150	$ 200	50	50
Rest	28000	26890	$ 250	1110	1110
10-Minute Reserve Shortage				20	
30-Minute Reserve Shortage					620
Totals	28400	27220		1200	1800

Incremental Dispatch of 1 MW					
	Capacity (MW)	Energy (MW)	Energy Offer Price ($/MWh)	10-Minute Total Reserve (MW)	30-Minute Total Reserve (MW)
Unit 1	200	181	$ 100	19	19
Unit 2	200	150	$ 200	50	50
Rest	28000	26890	$ 250	1110	1110
10-Minute Reserve Shortage				21	
30-Minute Reserve Shortage					621
Totals	28400	27221		1200	1800

LBMP Determination			
	Change in Dispatch (MW)	Cost ($/MWh)	Total Change in Cost ($)
Unit 1	1	$ 100	$ 100
10-Minute Reserve Shortage	1	$ 1,000	$ 1,000
30-Minute Reserve Shortage	1	$ 1,000	$ 1,000
			$ 2,100

Unit 1 is capacity constrained. All of its capacity is either scheduled for energy or for reserves. To obtain an additional MW of energy Unit 1 must be dispatched up 1 MW. To do so increases the amount that the system is short of both 10-minute total reserves and 30-minute total reserves by an additional MW.

The incremental cost of the additional MW of energy is $2,100:

- $100 from the incremental cost of the energy dispatched on Unit 1;
- $1,000 from the incremental cost of violating the 10-minute total reserve constraint by an additional MW.
- $1,000 from the incremental cost of violating the 30-minute total reserve constraint by an additional MW.

The relationship between the shortage costs defined for each product reflect the relative substitutability of reserves for each other.

Consider the pool 10-minute spinning reserve constraint and the pool 10 minute total reserve constraint. If the shortage cost for spinning reserve is set too low then a difference in the cost of providing the two types of reserve may cause the optimization to intentionally short itself of spin while meeting the 10 minute total reserve constraint with 10 minute non-synchronized reserves.

Demand Curve

	Pool	Eastern	LI
10-Minute Spinning Reserve	$ 100		
10-Minute Total Reserve	$ 500		
30-Minute Total Reserve			

Scenario

	Quantity	Incremental Cost of Next MW
10-Minute Spinning Reserve	599	$ 200
10-Minute Total Reserve	1,199	$ 50

Option 1	Quantity	Incremental Cost
Spin Shortage Cost	1	100
10-Minute Total Shortage Cost	1	500
	Total	600

Option 2	Quantity	Incremental Cost
Schedule 1 MW of Spin	1	200
Spin Shortage Cost	0	0
10-Minute Total Shortage Cost	0	0
	Total	200

Option 3	Quantity	Incremental Cost
Schedule 1 MW of 10-Minute Reserve	1	50
Spin Shortage Cost	1	100
10-Minute Total Shortage Cost	0	0
	Total	150

As the software is making its scheduling decisions it may come across the scenario described in the tables above.

If spin costs $200/MWh, 10-minute total reserve costs $50/MWh and the shortage costs for spin and 10-minute total reserves are $100/MW and $500/MW respectively the software has three options.

- Schedule nothing at a combined shortage cost of $600;
- Schedule a MW of spinning reserve resulting in no shortages at a cost of $200
- Schedule a MW of 10-minute total reserve at a cost of $50 for a total cost including shortages of $150.

The software will choose the third option at a cost of $150 resulting in a 1 MW shortage of spinning reserve.

Demand Curve

	Pool	Eastern	LI
10-Minute Spinning Reserve	$ 100		
10-Minute Total Reserve	$ 500		
30-Minute Total Reserve			

Scenario

	Quantity	Incremental Cost of Next MW
10-Minute Spinning Reserve	599	$ 200
10-Minute Total Reserve	1,199	$ 150

Option 1	Quantity	Incremental Cost
Spin Shortage Cost	1	100
10-Minute Total Shortage Cost	1	500
	Total	600

Option 2	Quantity	Incremental Cost
Schedule 1 MW of Spin	1	200
Spin Shortage Cost	0	0
10-Minute Total Shortage Cost	0	0
	Total	200

Option 3	Quantity	Incremental Cost
Schedule 1 MW of 10-Minute Reserve	1	150
Spin Shortage Cost	1	100
10-Minute Total Shortage Cost	0	0
	Total	250

If the cost of 10-minute total reserve is actually $150/MWh rather than $50 the options are:

- Schedule nothing at a combined shortage cost of $600;
- Schedule a MW of spinning reserve resulting in no shortages at a cost of $200
- Schedule a MW of 10-minute total reserve at a cost of $150 for a total cost including shortages of $250.

The software will choose the second option at a cost of $200 resulting in no shortage of reserves.

Note that if the software had chosen the first option the shortage cost, while included in the objective function, is not charged back to loads.

The previous examples indicate that each shortage cost needs to be of a magnitude that reflects the potential for substitution of lower quality reserves. Low individual values allow substitutions of lower quality reserves to occur more readily.

While we have recognized the additive nature of the shortage costs through the matrix of reserve constraints it may be necessary for the sum of the nine shortage costs to exceed $1,000, potentially by a significant amount to ensure that reserve substitutions that are not desired are unable to occur.

To assuage fears that having a sum of demand curves that exceeds $1,000 may result in dramatically high prices we have analyzed the pattern of reserve constraints and reserve shortages to determine what combinations are likely and unlikely to occur based on historical observations.

	Pool	Eastern	LI
10-Minute Spinning Reserve	$ 300	$ 300	$ 300
10-Minute Total Reserve	$ 300	$ 300	$ 300
30-Minute Total Reserve	$ 300	$ 300	$ 300

Even though the sum of the shortage costs of the entire matrix sum to $2,700 leading to the potential for $3700 prices the reality is that it is very difficult to imagine realistic scenarios that allow the total shortage cost to reach $2,700.

We analyzed the shadow prices from SCUC and BME to show that even this seemingly extreme set of demand curves is not that impractical when evaluated against actual observed data.

Date	Hour	EAST-10	EAST-30	LI-10	LI-30	LI-SPIN	NYPP-10	NYPP-30	NYPP-SPIN	Total	Count of Non-Zero Shadow Prices
	Min	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	0
	Max	$ 1,000	$ 1,000	$ 352	$ 1,000	$ 352	$ 1,000	$ 1,000	$ 1,000	$ 3,022	5
	Average	$ 5	$ 2	$ 0	$ 15	$ 5	$ 1	$ 10	$ 5	$ 45	1.503446
	Standard Deviation	$ 67	$ 48	$ 8	$ 74	$ 19	$ 30	$ 91	$ 38	$ 208	1.107722
2001-AUG-10	15	$ -	$ 1,000	$ -	$ 1,000	$ -	$ 22	$ 1,000	$ -	$ 3,022	4
2001-AUG-08	11	$ -	$ 1,000	$ -	$ -	$ -	$ 1,000	$ 1,000	$ -	$ 3,000	3
2001-AUG-08	16	$ 1,000	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 3,000	3
2001-AUG-08	17	$ 1,000	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 3,000	3
2001-AUG-08	19	$ 1,000	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 3,000	3
2001-AUG-08	20	$ -	$ 1,000	$ -	$ -	$ -	$ 1,000	$ 1,000	$ -	$ 3,000	3
2001-AUG-08	21	$ -	$ 1,000	$ -	$ -	$ -	$ 1,000	$ 1,000	$ -	$ 3,000	3
2001-AUG-09	9	$ -	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000	$ 1,000	$ 3,000	3
2001-AUG-09	16	$ -	$ 1,000	$ -	$ -	$ -	$ 1,000	$ 1,000	$ -	$ 3,000	3
2001-AUG-10	13	$ 1,000	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 3,000	3
2001-JUL-25	13	$ 1,000	$ -	$ -	$ 1,000	$ -	$ -	$ 1,000	$ -	$ 3,000	3
2001-JUL-25	19	$ 1,000	$ -	$ -	$ 1,000	$ -	$ -	$ 1,000	$ -	$ 3,000	3
2001-JUL-25	18	$ 1,000	$ -	$ -	$ 1,000	$ -	$ -	$ 588	$ -	$ 2,588	3
2001-AUG-10	12	$ 1,000	$ 869	$ -	$ -	$ -	$ -	$ 655	$ -	$ 2,524	3
2001-AUG-09	19	$ 1,000	$ 135	$ -	$ 5	$ -	$ -	$ 924	$ -	$ 2,065	4
2001-AUG-07	18	$ 1,000	$ 51	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,051	3
2001-AUG-20	16	$ -	$ 1,000	$ -	$ -	$ -	$ 1,000	$ 48	$ -	$ 2,048	3
2001-JUL-25	17	$ 13	$ -	$ -	$ 1,000	$ -	$ -	$ 1,000	$ -	$ 2,013	3
2001-AUG-07	17	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-08	12	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-08	13	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-08	14	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-08	15	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-08	18	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-09	12	$ -	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-09	13	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ 2,000	2
2001-AUG-09	14	$ -	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-09	15	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-09	18	$ -	$ 1,000	$ -	$ -	$ -	$ 1,000	$ -	$ -	$ 2,000	2
2001-AUG-31	16	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-JUL-25	14	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-JUL-25	15	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-JUL-25	16	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-MAY-04	17	$ -	$ -	$ -	$ 1,000	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-MAY-12	20	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ 1,000	$ 2,000	2
2001-SEP-10	16	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ -	$ 2,000	2
2001-AUG-09	20	$ 1,000	$ 130	$ -	$ -	$ -	$ -	$ 850	$ -	$ 1,980	3
2001-SEP-10	10	$ -	$ -	$ -	$ 776	$ -	$ -	$ 1,000	$ 156	$ 1,932	3
2001-AUG-09	21	$ 1,000	$ 109	$ -	$ 9	$ -	$ -	$ 760	$ -	$ 1,878	4
2001-AUG-09	22	$ 5	$ 80	$ -	$ 1,000	$ -	$ -	$ 670	$ -	$ 1,754	4

The table above shows the BME data for 2001. In 2001 there were no exports as reserves so when he model could not solve it set prices a extremely high levels. These have been modified to $1,000 for the purpose of display.

Of the 75 observations where the aggregate shadow price exceeded $1,000/MWh, 73 contained unsolved reserve constraints at extremely high values.

If $300/MWh is used as the reserve demand curve for each of the reserve requirements that could not be solved by BME none of the 75 observations that exceeded $1,000/MWh in aggregate would have exceeded $1,000/MWh when capped by the $300/MWh demand curve.

Date	Hour	EAST-10	EAST-30	EAST-SPIN	LI-10	LI-30	LI-SPIN	NYPP-10	NYPP-30	NYPP-SPIN	Total	Count of Non-Zero Shadow Prices
Min		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	0
Max		$ 7,102	$ -	$ -	$ 143	$ 163	$ 152	$ 553	$ 100	$ 109	$ 7,673	4
Average		$ 9	$ -	$ -	$ 2	$ 2	$ 8	$ 1	$ 0	$ 1	$ 36	1.017882
Standard Deviation		$ 197	$ -	$ -	$ 12	$ 14	$ 19	$ 16	$ 3	$ 5	$ 213	0.992586
2002-Jul-23	18	7102.41	0	0	0	0	0	552.51	0	0	7672.92	2
2002-Jun-26	15	2336.13	0	0	0	0	0	0	0	0	2351.13	1
2002-Jul-03	16	570.99	0	0	3.18	0	0	48.77	0	0	638.94	3
2002-Jun-26	16	242.52	0	0	0	0	0	0	0	0	258.52	1
2002-Jul-30	8	243.68	0	0	0	0	0	0	0	0	251.68	1
2002-Jul-30	13	76.53	0	0	0	0	0	0	100	0	189.53	2
2002-Jul-31	22	0.64	0	0	0	162.69	0	0	0	0	185.33	2
2002-Jul-29	18	73.87	0	0	0	0	0	93.36	0	0	185.23	2
2002-Jul-31	21	23.08	0	0	0	139.61	0	0	0	0	183.69	2
2002-Jul-31	20	2.52	0	0	0	159.12	0	0	0	0	181.64	2
2002-Jul-19	18	123.99	0	0	39.45	0	0	0	0	0	181.44	2
2002-Jul-29	15	85.64	0	0	0	0	0	79.5	0	0	180.14	2
2002-Jul-29	17	74.48	0	0	0	0	0	88.54	0	0	180.02	2
2002-Jul-31	19	2.51	0	0	0	158.35	0	0	0	0	179.86	2
2002-Jul-31	17	48.68	0	0	60.43	0	0	0	50	0	176.11	3
2002-Jul-29	14	73.82	0	0	0	0	7.47	80.16	0	0	175.45	3
2002-Jul-31	15	46.18	0	0	0	114.17	0	0	0	0	175.35	2
2002-Jul-31	16	47.55	0	0	0	111.08	0	0	0	0	174.63	2
2002-Jul-31	14	32.97	0	0	0	125.16	0	0	0	0	172.13	2
2002-Jul-29	13	81.54	0	0	0	0	0	77.06	0	0	171.6	2
2002-Jul-31	13	10.07	0	0	0	147.23	0	0	0	0	170.3	2
2002-Jul-30	22	0	0	0	0	148.13	0	0	0	0	170.13	1

The table above shows the BME data for 2002.

There are only 2 observations during June and July of 2000 where the aggregate shadow price exceeded $1,000/MWh and both of these involved cases where a reserve constraint unaffected by exports as reserve was unable to be solved.

If $300/MWh is used as the reserve demand curve for each of the reserve requirements that could not be solved by BME neither of the observations that exceeded $1,000/MWh in aggregate would have exceeded $1,000/MWh when capped by the $300/MWh demand curve.

We are working with NYISO operations staff to understand their perspectives on the relative substitutability of various qualities and locations of reserves and the actions that they would take to adjust for shortages of reserves of each type and location.

This effort is ongoing and we will report our findings at the next discussion of reserve demand curves.

We had previously discussed that the reserve demand curves might be suspended or gradually re-introduced during and after reserve pickups and other system shocks.

After reviewing how the reserve demand curves function and the need for prices during system shocks and reserve pickups to be consistent with prices before and after those events it is clear that the reserve demand curves continue to apply in their normal form.

Any suspension or reduction of the demand curves would result in prices during severe system events that would not reflect the scarcity conditions or real costs faced by the system. We do not want to reproduce the pricing inconsistencies that exist in the treatment of today's reserve pickup pricing in SCD.

Between today's meeting and the next time we meet to discuss reserve demand curves we will have:

- Completed a sequence of meetings with operations staff and will be able to report back on their perspectives related to reserve shortages and the actions they take to protect against them;
- Developed a series of potential demand curve definitions to present to the group
- Expand analysis of BME shadow prices to include more of 2002.