Demand Curve Definitions

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LECG
ECONOMICS
FINANCE

Market Structures Working Group

DRAFT: For Discussion Purposes Only

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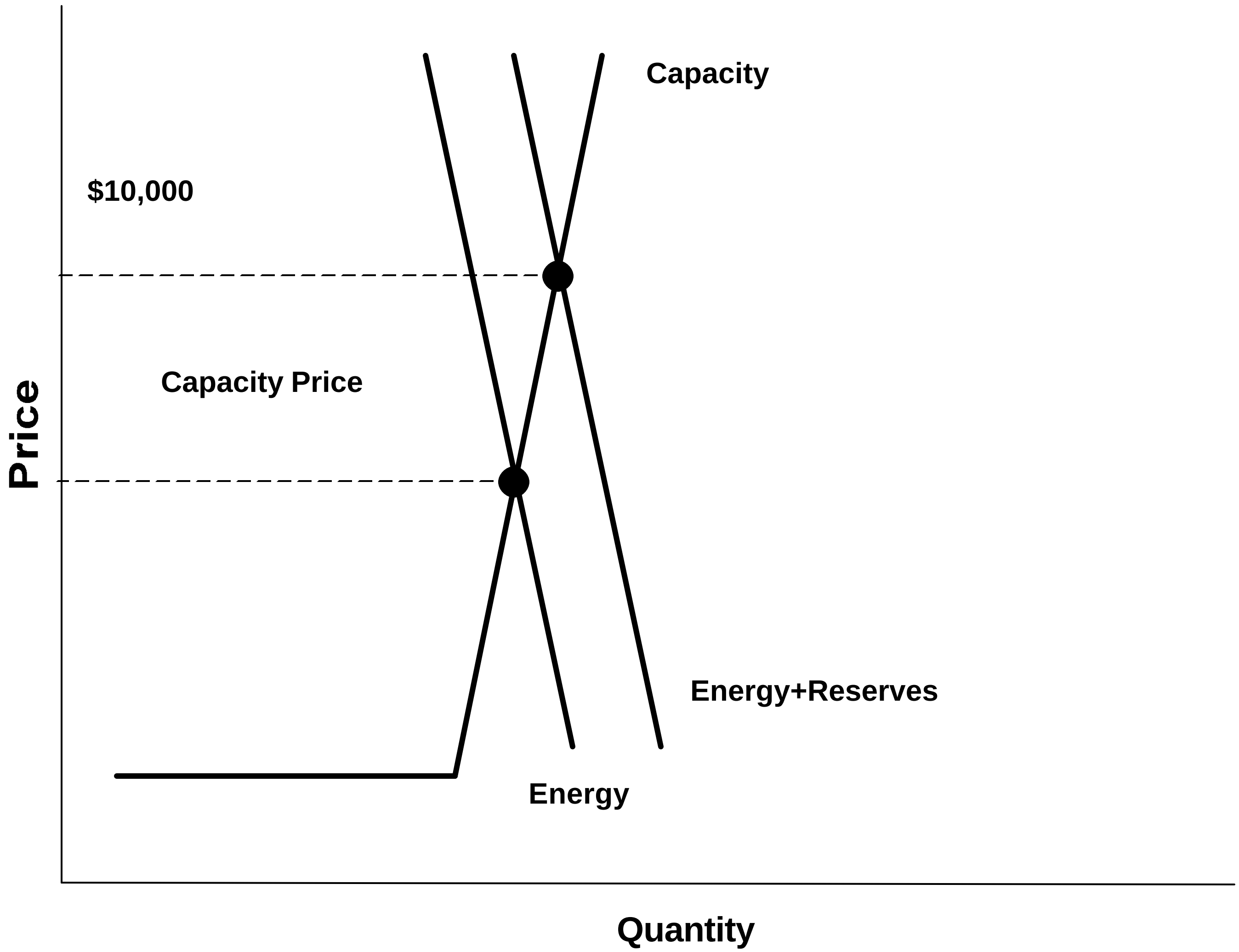

Capacity
$10,000
Capacity Price
Price
Energy+Reserves
Energy
Quantity

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.

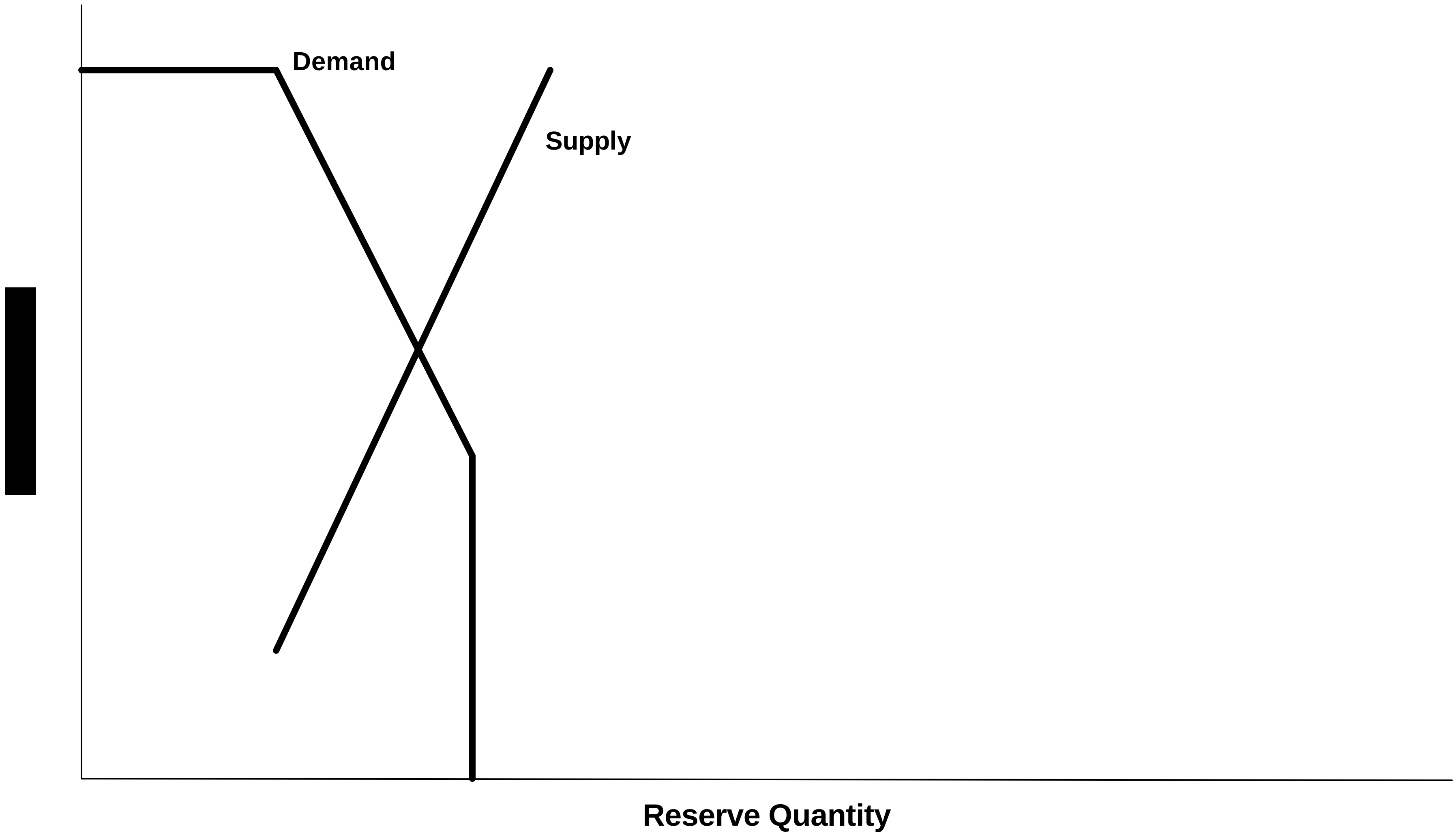
WHY A DEMAND CURVE? Fixed Demand

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

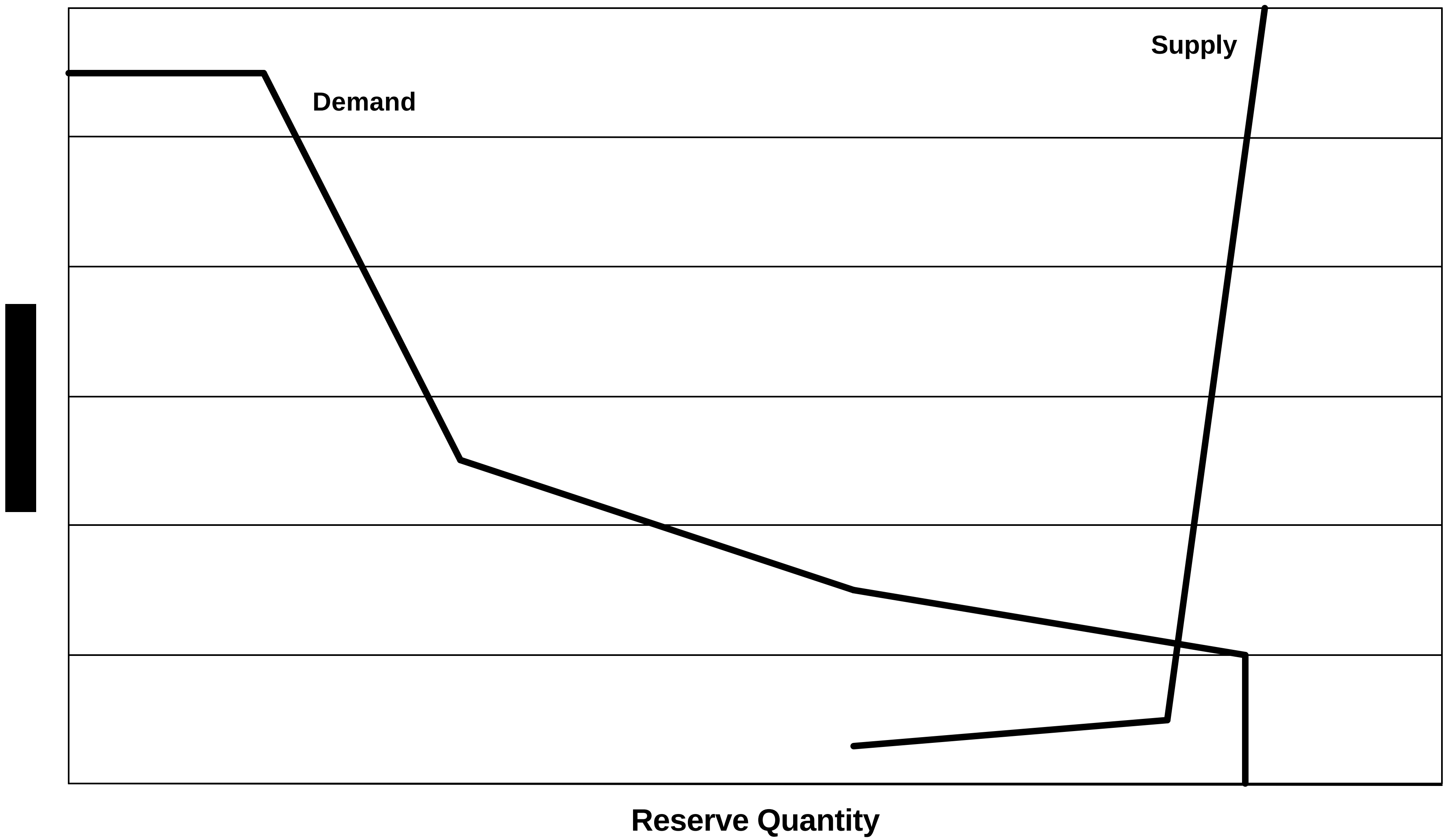


The demand curve approach to ancillary services pricing would replace a fixed vertical demand for reserves with a demand curve in which the quantity of reserves scheduled would depend both on transmission grid and generator characteristics and as-bid reserve costs.

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.

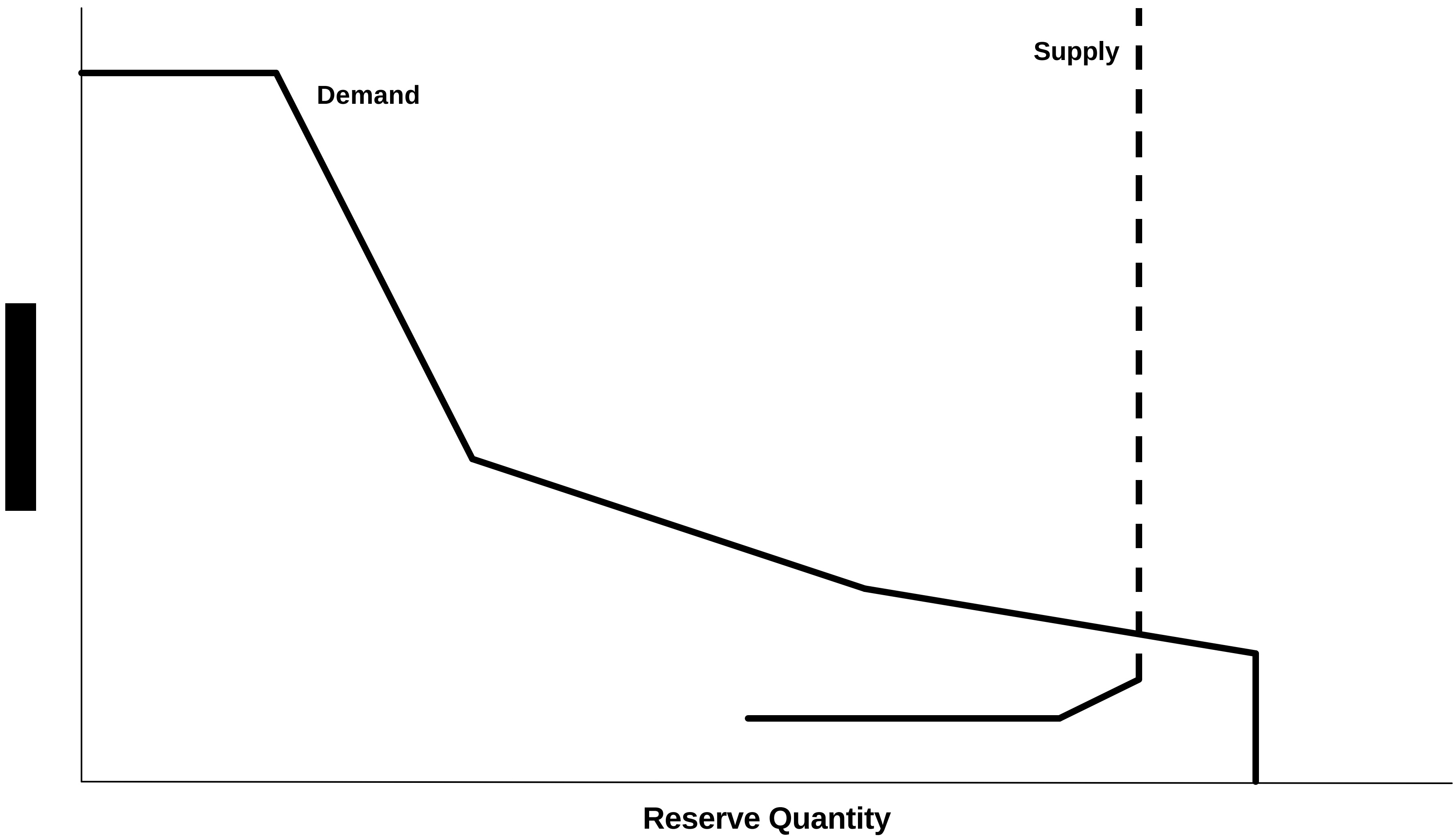
Demand Curve for Reserves



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: NYCA, 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.

EXAMPLE ONLY

	NYCA	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

RESERVE DEMAND CURVES Are Additive

The matrix of $1,000/MWh demand curves above may appear to provide for $1,000/MWh energy and reserve prices in all circumstances in which a reserve constraint is violated.

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

First, when the system is capacity constrained a reserve shortage involves an additive relationship between the incremental cost of the next MW of energy and the $1,000/MWh shortage cost of reserves.

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

EXAMPLE ONLY

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 to generate energy or to provide reserves. If Unit 1 is dispatched up 1 MW to meet 1 MW of additional load this would increase the shortage of 30-minute total reserves by an additional 1 MW.

The incremental cost of the additional 1 MW of energy would be $1,100/MW:

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

EXAMPLE ONLY

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

Note: 30-min reserve totals are inclusive of 10-min reserve MWs

Unit 1 is capacity constrained. All of its capacity is either scheduled to generate energy or to provide reserves. If Unit 1 is dispatched up 1 MW to meet 1 MW of additional load this would increase the shortage of both 10-minute total reserves and 30-minute total reserves by an additional 1 MW.

The incremental cost of the additional 1 MW of energy would be $2,100:

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

When the system is capacity constrained the relationship between the shortage costs established for each product can determine the order in which reserve constraints are violated.

Consider the NYCA 10-minute spinning reserve constraint and the NYCA 10-minute total reserve constraint. If the shortage cost determined for spinning reserve demand curve is set too low relative to the 10-minute total reserves 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 EXAMPLE ONLY

	NYCA	Eastern	LI
10-Minute Spinning Reserve	$ 100		
10-Minute Total Reserve	$ 300		
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	300
	Total	400

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

Note: In this example, the optimization would choose Option 3, which is an undesirable outcome and demonstrates consequences that must be taken into consideration in setting the curve values.

As the software is making its scheduling decisions to meet the 1200 MW 10-minute total reserve requirement for the NYCA and the 600 MW spinning reserve requirement for the NYCA 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 $400;
- 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 EXAMPLE ONLY

	NYCA	Eastern	LI
10-Minute Spinning Reserve	$ 300		
10-Minute Total Reserve	$ 100		
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	300
10-Minute Total Shortage Cost	1	100
	Total	400

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

Note: In this example, the optimization would choose Option 2 and demonstrates a desired outcome from the interrelationship of the shortage costs established for each product .

Option 3	Quantity	Incremental Cost
Schedule 1 MW of 10-Minute Reserve	1	150
Spin Shortage Cost	1	300
10-Minute Total Shortage Cost	0	0
	Total	450

If the demand curves are reversed for the two reserve requirements the options are:

- Schedule nothing at a combined shortage cost of $400;
- 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 $450.

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 the additive nature of the shortage costs is recognized 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.

EXAMPLE ONLY

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

Although the sum of the shortage costs in the entire matrix sum to $2,700, potentially leading to $3,700 prices in an unconstrained system, in practice, it is difficult for 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.

The scheduling and pricing functions in SCUC and BME have always included reserve demand curves. The reserve demand curves are analogous to the penalty function costs included in the objective function that allow constraints to be violated in order to obtain feasible solutions when not enough of a particular reserve is available.

BME on numerous occasions has calculated energy prices and reserve shadow prices well in excess of $1,000 because of reserve constraint violations. However, these BME prices have never been used to settle the energy or reserves scheduled in BME.

SCD does not solve these reserve constraints, but rather receives the reserve schedules from BME and calculates LMPs that do not include the full shortage or scarcity value of the reserves.

The fundamental goal of the demand curves in the RTS/SMD2 software is to implement a more robust and tightly integrated method of pricing reserves and energy during scarcity conditions relative to the current interim approach in today's legacy system.

The demand curves need to meet the objective of reflecting appropriate scarcity values while maintaining consistency with operational practice and reserve scheduling requirements (i.e., maintain scheduling objectives such that it has a negligible effect on the number of times or the magnitude by which reserve requirements might be violated without impacting system reliability).

The analysis and demand curve definitions that follow attempt to create a set of rational demand curves based on observed market results.

There are two distinct types of reserve constraints modeled in today's SCUC and BME.

- There are those that are based off reserve requirements that correspond to specific reliability rules, e.g., NYCA spinning reserve, NYCA 10-minute total reserve, NYCA 30-minute total reserve, Eastern 10-minute total reserve and the Long Island 30-minute total reserve.
- There are other reserve constraints in SCUC and BME that are based on guidelines that the NYISO is not required to maintain, e.g., Long Island spinning reserve, Long Island 10-minute total reserve, Eastern spinning reserve, Eastern 30-minute total reserve.

SCUC and BME currently do not distinguish between these two types of reserve constraints and all of these constraints are modeled using the same violation costs.

The implementation of the reserve demand curves will allow the reserve guidelines (as opposed to requirements) to be treated in a manner more consistent with the manner in which real-time operation would treat these reserve constraints.

Min		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-		$ -
Max		$7,102.41	$ -	$ -	$ 143.23	$3,986.74	$ 831.72	$ 552.51	$ 100.00	$4,019.54	$ 8,008.80	6.00		$ 4,022.86
Ave		$ 2.04	$ -	$ -	$ 0.40	$ 5.54	$ 5.04	$ 0.45	$ 0.36	$ 7.32	$ 21.14	1.91		$ 15.27
StdDev		$ 82.60	$ -	$ -	$ 5.32	$ 58.69	$ 17.67	$ 8.01	$ 4.15	$ 46.82	$ 133.53	1.50		$ 50.73

Date	Hour	EAST 10	EAST 30	EAST SPIN	LI 10	LI 30	LI SPIN	NYPP 10	NYPP 30	NYPP SPIN	SUM	Non-zero SPs	NYPP REGUL
9/3/02	20	$ 1	$ -	$ -	$ -	$ 3,987	$ -	$ -	$ 1	$ 4,020	$ 8,009	5	4023
7/23/02	18	$ 7,102	$ -	$ -	$ -	$ -	$ -	$ 553	$ -	$ -	$ 7,655	3	1090
3/10/03	14	$ 3	$ -	$ -	$ -	$ 3,017	$ -	$ -	$ -	$ -	$ 3,019	3	0
6/26/02	15	$ 2,336	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,336	2	0
8/2/02	15	$ 21	$ -	$ -	$ -	$ 889	$ -	$ -	$ 50	$ -	$ 961	4	50
8/2/02	16	$ 48	$ -	$ -	$ -	$ -	$ 832	$ 2	$ 56	$ -	$ 937	5	56
7/3/02	16	$ 571	$ -	$ -	$ 3	$ -	$ -	$ 49	$ -	$ -	$ 623	4	49
2/17/03	21	$ 563	$ -	$ -	$ -	$ 33	$ -	$ -	$ 23	$ -	$ 619	4	67
2/18/03	16	$ 1	$ -	$ -	$ -	$ 325	$ -	$ -	$ 1	$ 266	$ 594	5	341
1/2/03	18	$ 1	$ -	$ -	$ -	$ 511	$ -	$ -	$ 1	$ 7	$ 520	5	15
2/17/03	15	$ -	$ -	$ -	$ -	$ 253	$ -	$ -	$ 50	$ 211	$ 514	4	229
2/17/03	11	$ 82	$ -	$ -	$ -	$ 203	$ -	$ 137	$ 89	$ -	$ 510	5	226
2/17/03	10	$ 81	$ -	$ -	$ -	$ 207	$ -	$ 155	$ 3	$ -	$ 446	5	158
2/17/03	7	$ -	$ -	$ -	$ -	$ 1	$ -	$ -	$ 3	$ 382	$ 386	4	393
2/17/03	16	$ -	$ -	$ -	$ -	$ 156	$ -	$ -	$ 50	$ 127	$ 333	4	214
2/17/03	9	$ -	$ -	$ -	$ -	$ 156	$ -	$ -	$ 3	$ 174	$ 332	4	195
2/17/03	17	$ -	$ -	$ -	$ -	$ 143	$ -	$ 122	$ 50	$ -	$ 316	4	177
2/17/03	12	$ -	$ -	$ -	$ -	$ 168	$ -	$ -	$ 3	$ 133	$ 304	4	117
2/17/03	14	$ -	$ -	$ -	$ -	$ 166	$ -	$ -	$ 3	$ 123	$ 292	4	107
1/27/03	18	$ 29	$ -	$ -	$ -	$ 151	$ -	$ 96	$ 1	$ -	$ 278	5	131
2/18/03	17	$ -	$ -	$ -	$ -	$ 162	$ -	$ -	$ 3	$ 112	$ 277	4	47
2/17/03	18	$ 23	$ -	$ -	$ -	$ 134	$ -	$ 78	$ 33	$ -	$ 267	5	147
7/30/02	8	$ 244	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 244	2	8
6/26/02	16	$ 243	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 243	2	0
4/17/03	11	$ 23	$ -	$ -	$ -	$ 1	$ -	$ 206	$ 3	$ -	$ 233	5	209
9/20/02	13	$ -	$ -	$ -	$ -	$ 1	$ -	$ -	$ 3	$ 228	$ 231	4	185
2/17/03	8	$ -	$ -	$ -	$ -	$ 97	$ -	$ -	$ 3	$ 121	$ 221	4	155
4/8/03	10	$ 0	$ -	$ -	$ -	$ 116	$ -	$ -	$ 2	$ 92	$ 211	5	3
8/12/02	17	$ -	$ -	$ -	$ -	$ 48	$ -	$ -	$ 100	$ 62	$ 210	4	177
2/18/03	20	$ -	$ -	$ -	$ -	$ 123	$ -	$ -	$ -	$ 86	$ 209	3	165
1/28/03	18	$ -	$ -	$ -	$ -	$ 159	$ -	$ -	$ 3	$ 47	$ 209	4	61
2/17/03	19	$ -	$ -	$ -	$ -	$ 129	$ -	$ 76	$ 3	$ -	$ 208	4	114
8/13/02	17	$ 53	$ -	$ -	$ -	$ 53	$ -	$ -	$ 100	$ -	$ 207	4	153
8/1/02	17	$ 80	$ -	$ -	$ -	$ -	$ 1	$ 26	$ 100	$ -	$ 206	5	206
8/14/02	15	$ 24	$ -	$ -	$ -	$ 79	$ -	$ -	$ 100	$ -	$ 203	4	100

The table above shows the highest levels of aggregate operating reserve shadow prices since Exports as Reserves were implemented within BME. The period covered includes June 16th 2002 through May 31st 2003 (8344 hours of data).

There are only 4 observations during this period for which the aggregate shadow price exceeded $1,000/MWh. All of these were cases in which a reserve constraint, other than the NYCA total 30-minute reserve requirement which is impacted by exports as reserves, was solved at very high costs.

If $300/MWh was used as the penalty function defining the reserve demand curve for each of the reserve requirements that were solved by BME at very high prices, in none of the hours in which reserve shadow prices exceeded $1,000/MWh in aggregate would shadow prices have exceeded $1,000/MWh when capped by the $300/MWh demand curve.

In June of 2002 "Exports as Reserves" was implemented in SCUC and BME.

The Exports as Reserves mechanism allows SCUC and BME to count up to 600 MW of recallable export transactions as 30-minute operating reserves capable of meeting the NYCA 30-minute total operating reserve requirement of 1800 MW.

- This is consistent with actual operation of the system in real time, as the NYISO operators can count curtailable exports as 30-minute operating reserves without initiating any emergency procedures.

The first 200 MW of exports is included in reserves at a cost of $50. The second 200 MW is included at a cost of $100. The third 200 MW is included at a cost of $200.

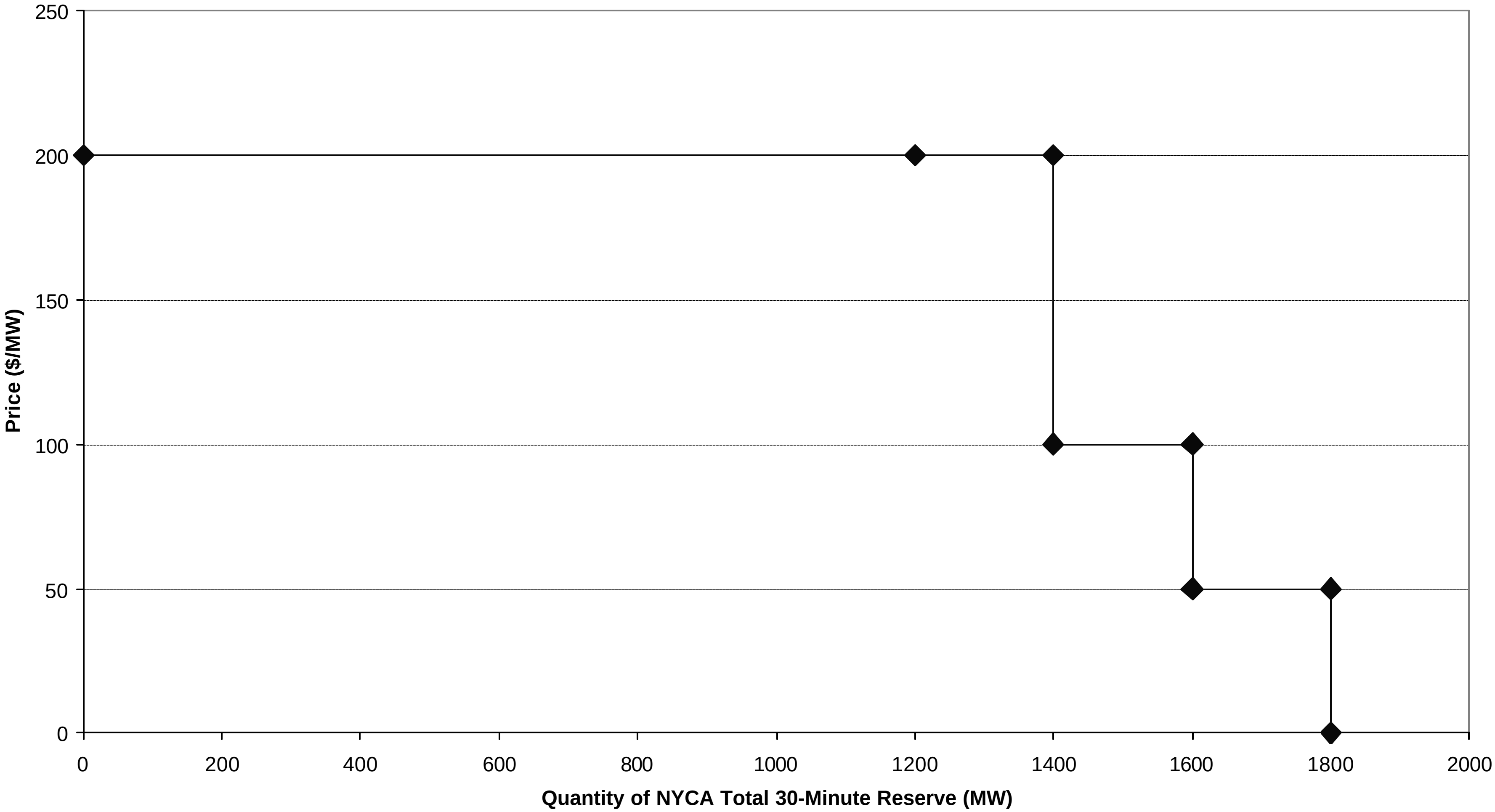
In reviewing the actual operation of the SCUC and BME models there were 7 hours in SCUC (spread over 2 days) and 22 hours in BME (spread over 8 days) during which exports were counted by the relevant model towards meeting the NYCA 30-minute total operating reserve requirement.

In every one of SCUC and BME hours during which exports were counted as reserves, the total quantity of export transactions scheduled significantly exceeded the quantity of exports counted as reserves. In the 22 BME hours the total exports exceeded the quantity scheduled as reserves by an average of over 1,100 MW.

Had the exports as reserves mechanism instead been implemented as a reserve demand curve with the same cost function (200 MW @ $50, 200 MW @ $100 and 200 MW @ $200), the outcome would have been identical for all instances in which the exports were included in 30-minute reserves in BME or SCUC.

In other words, the exports as reserves mechanism has functioned exactly like a reserve demand curve for the NYCA 30-minute total operating reserve requirement.

NYCA Total 30-Minute Reserve Demand Curve



We propose that the first 600 MW of the NYCA 30-minute total reserve demand curve (between 1800 MW and 1200 MW) match the curve that has previously been used for the Exports as Reserves mechanism.

$200 will be used between 1200 MW and 0 MW for the NYCA 30-minute demand curve. There are no observations where the shadow price reached $200 and if the total quantity of reserves were to fall to less than 1200 MW a demand curve for another locational requirement or reserve category would also bind.

While the exports as reserves implementation gives us direct experience of a demand curve applied to the 30-minute total reserve requirement constraint, there is no way to get the same level of direct comparison for the other reserve requirements.

Instead, we must rely upon the reserve shadow prices observed during the period that exports as reserves were modeled in the market to provide us with guidance in choosing reasonable levels for setting demand curves associated with the remaining reserve requirement constraints.

Count of Hours where Shadow Prices Higher than	EAST 10-Minute Total	EAST 30-Minute Total	EAST Spinning Reserve	LI 10-Minute Total	LI 30-Minute Total	LI Spinning Reserve	NYCA 10-Minute Total	NYCA 30-Minute Total	NYPP Spinning Reserve	NYPP Regulation
$500	4	0	0	0	4	1	1	0	1	2
$300	4	0	0	0	5	1	1	0	2	5
$200	6	0	0	0	8	1	2	0	5	12
$150	7	0	0	0	18	5	3	0	8	33
$100	12	0	0	6	96	34	5	8	39	91
$50	37	0	0	29	289	252	24	22	241	504
$25	68	0	0	49	450	644	32	31	650	1577

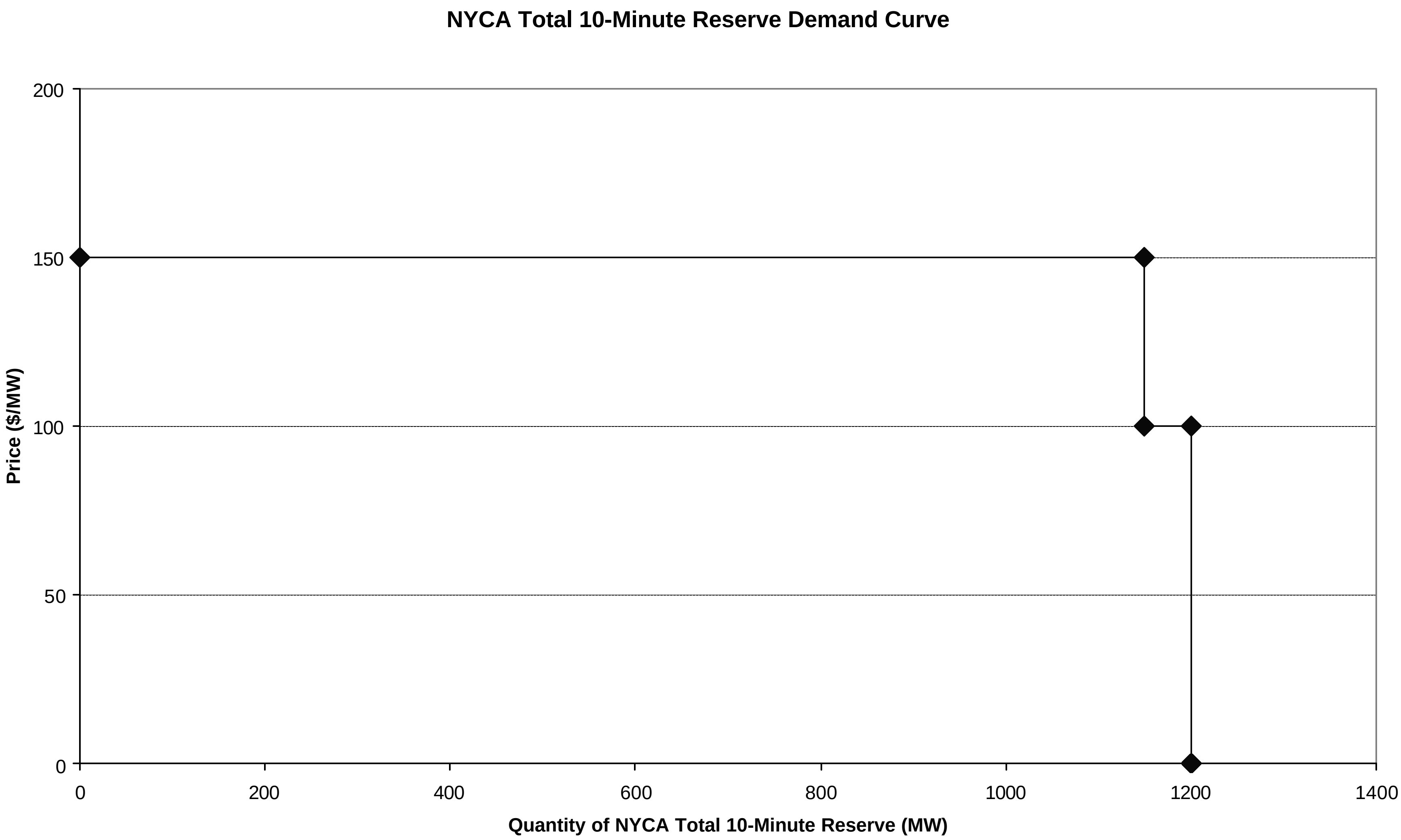
Count of Hours where Shadow Prices Higher than	EAST 10-Minute Total	EAST 30-Minute Total	EAST Spinning Reserve	LI 10-Minute Total	LI 30-Minute Total	LI Spinning Reserve	NYCA 10-Minute Total	NYCA 30-Minute Total	NYPP Spinning Reserve	NYPP REGULATION
$500	0.048%	0.000%	0.000%	0.000%	0.048%	0.012%	0.012%	0.000%	0.012%	0.024%
$300	0.048%	0.000%	0.000%	0.000%	0.060%	0.012%	0.012%	0.000%	0.024%	0.060%
$200	0.072%	0.000%	0.000%	0.000%	0.096%	0.012%	0.024%	0.000%	0.060%	0.144%
$150	0.084%	0.000%	0.000%	0.000%	0.216%	0.060%	0.036%	0.000%	0.096%	0.395%
$100	0.144%	0.000%	0.000%	0.072%	1.151%	0.407%	0.060%	0.096%	0.467%	1.091%
$50	0.443%	0.000%	0.000%	0.348%	3.464%	3.020%	0.288%	0.264%	2.888%	6.040%
$25	0.815%	0.000%	0.000%	0.587%	5.393%	7.718%	0.384%	0.372%	7.790%	18.900%

The tables above show the number of hours, as a count, and percentage, of the total number of BME hours evaluated, for which the shadow price of a particular reserve requirement constraint exceeded various price levels.

The observations highlighted in yellow indicate the areas around which the demand curves for each requirement have been constructed.

The demand curves were structured with the following general guidelines:

- Is the constraint a requirement or a guideline?
- Create demand curves with some slope where appropriate;
- Center the demand curves around an activation target that allows for the shadow prices of 0.05% of hours from the historical period to exceed the demand curve so that reserve requirements are violated very infrequently;
- Create demand curves such that the additive aggregate value of violating multiple constraints does not result in prices at multiples of $1,000/MW, i.e., try to stay at or below $300/MW for any individual reserve demand curve;
- Reflect the increasing importance of higher quality products, particularly spinning reserve and regulation.

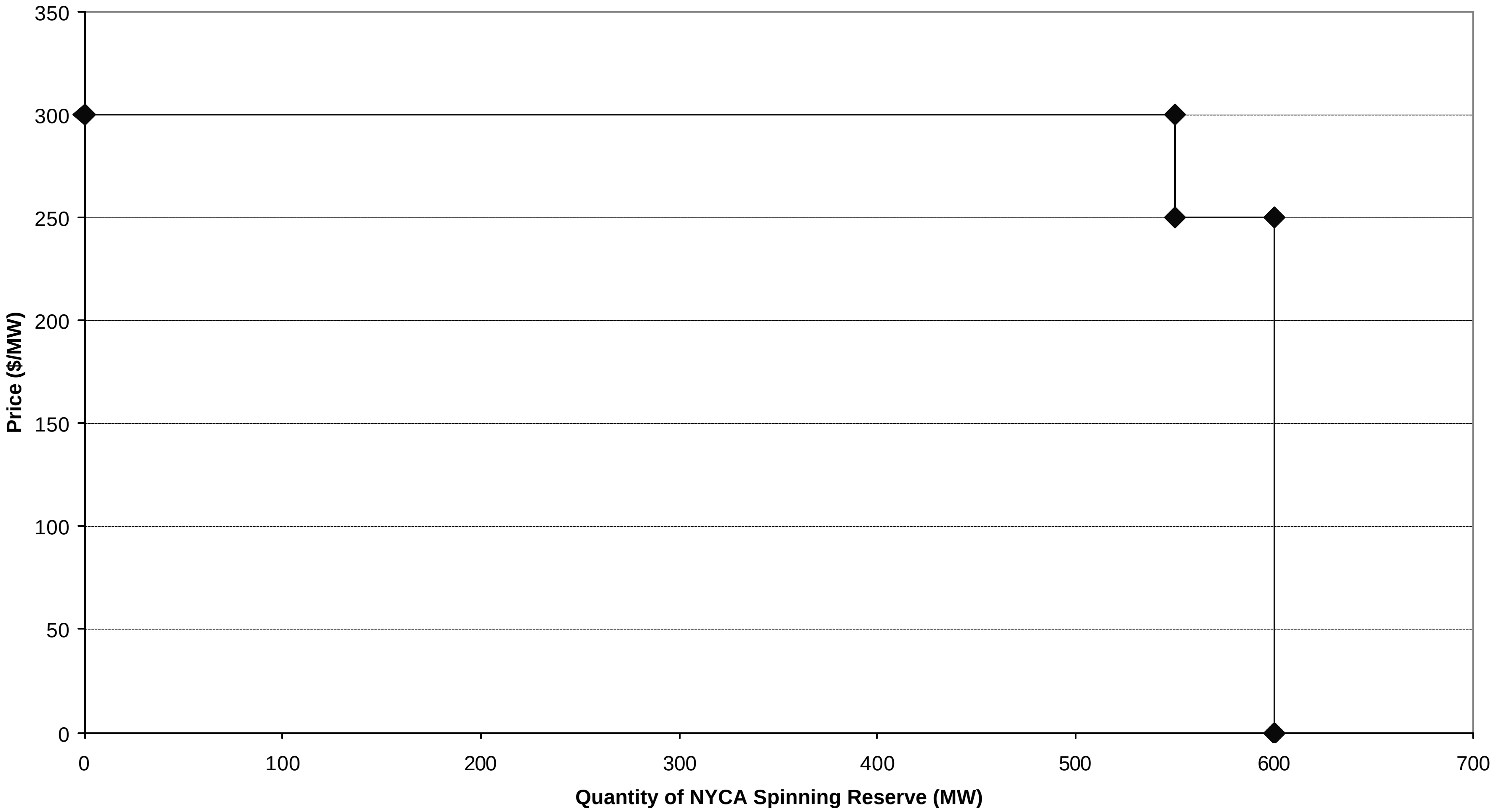


NYCA Total 10-Minute Reserve Demand Curve
Price ($/MW)
200
150
100
50
0
0
200
400
600
800
1000
1200
1400
Quantity of NYCA Total 10-Minute Reserve (MW)

The NYCA 10-minute total reserve demand curve was set with the following considerations:

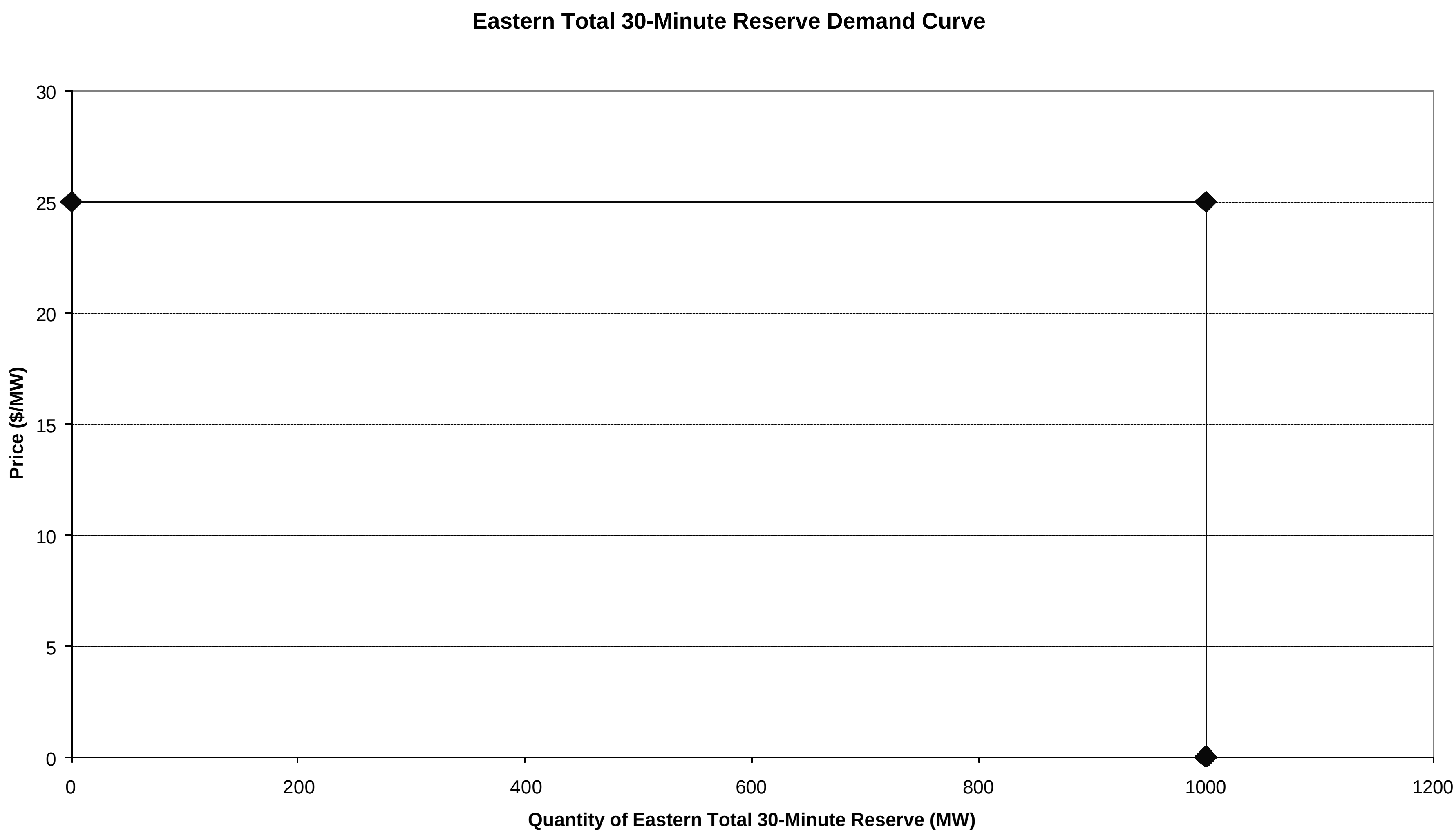
- This reserve constraint is a requirement and a shadow price somewhere between \$100/MW and \$150/MW meets the 0.05% hour standard during the historical period.
- The first 50 MW of the curve between 1150 and 1200 MW are priced at \$100/MW.
- The remainder of the 10-minute curve between 0 and 1150 MW is priced at \$150/MW.

NYCA Spinning Reserve Demand Curve



The NYCA spinning reserve demand curve was set with the following considerations:

- This reserve constraint is a requirement and a shadow price somewhere between $200/MW and $300/MW meets the 0.05% hour standard during the historical period.
- The first 50 MW of the curve between 550 and 600 MW are priced at $250/MW.
- The remainder of the spinning reserve demand curve between 0 and 550 MW is priced at $300.
- In practice, Operations would place a higher priority on addressing a MW shortage of spinning reserve over a shortage of regulation so the spinning reserve demand curve should be no lower than the regulation demand curve. The value created for spin by the 10-minute and 30-minute reserve shadow prices if they are greater than 0 will ensure scheduling of spin.

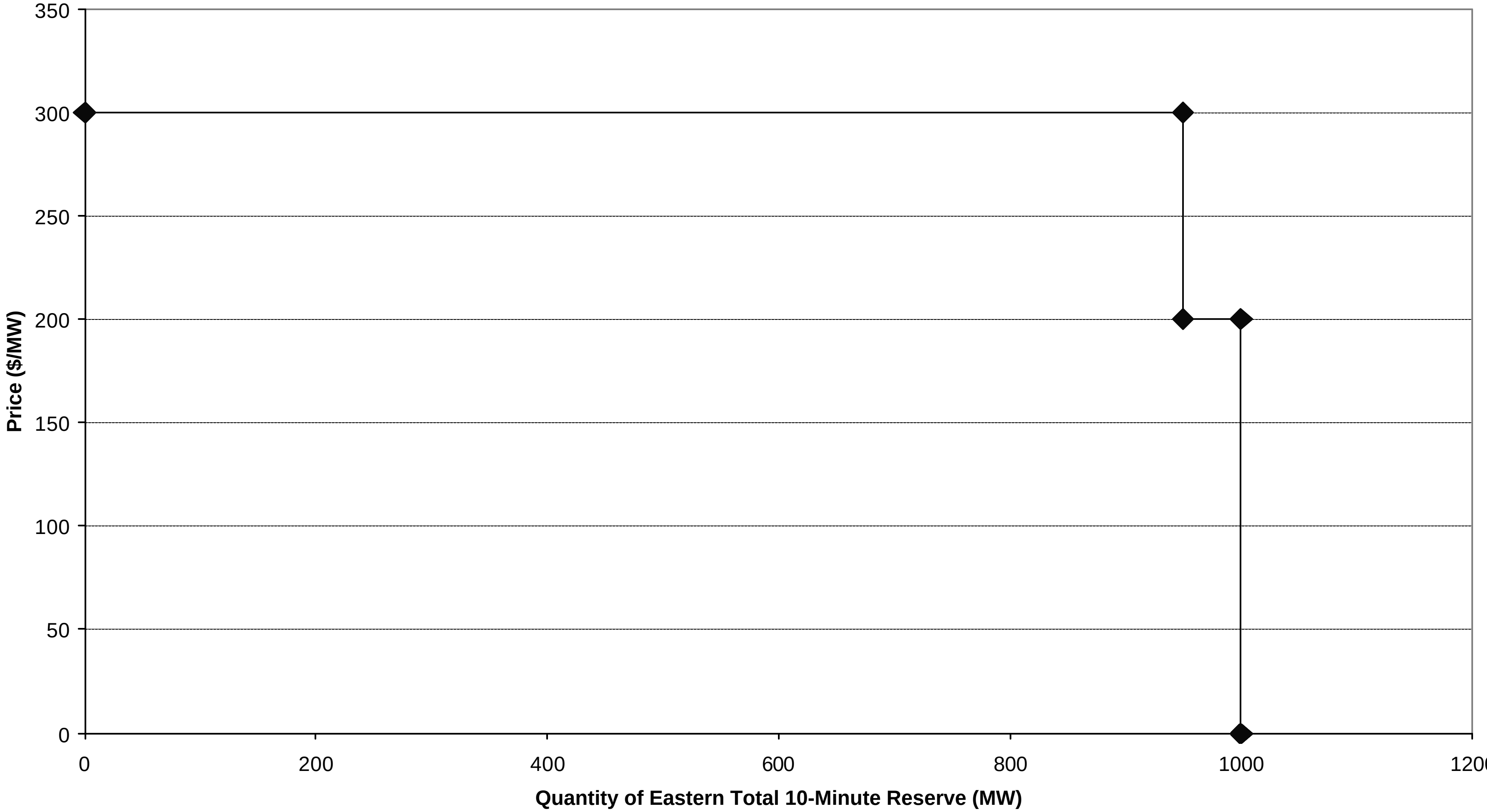

Eastern Total 30-Minute Reserve Demand Curve
Price ($/MW)
30
25
20
15
10
5
0
0
200
400
600
800
1000
1200
Quantity of Eastern Total 30-Minute Reserve (MW)

RESERVE DEMAND CURVES Eastern 30-Minute

The Eastern 30-minute total reserve demand curve was set with the following considerations:

- This reserve constraint is a guideline not a requirement and all observed shadow prices during the historical period were all \$0/MW;
- This constraint was never violated over the historical period as the 30-minute Eastern and 10-minute Eastern reserve requirements are at the same level (1,000 MW) and the 10-minute reserve requirement was always met;
- A minimum value of \$25/MW for the 30-minute Eastern reserve demand curve has been used to value some incremental reliability benefit to having dispersed reserves.
- A value of \$0/MW would allow the 30-minute Eastern reserve requirement to be violated at no cost to the algorithm.

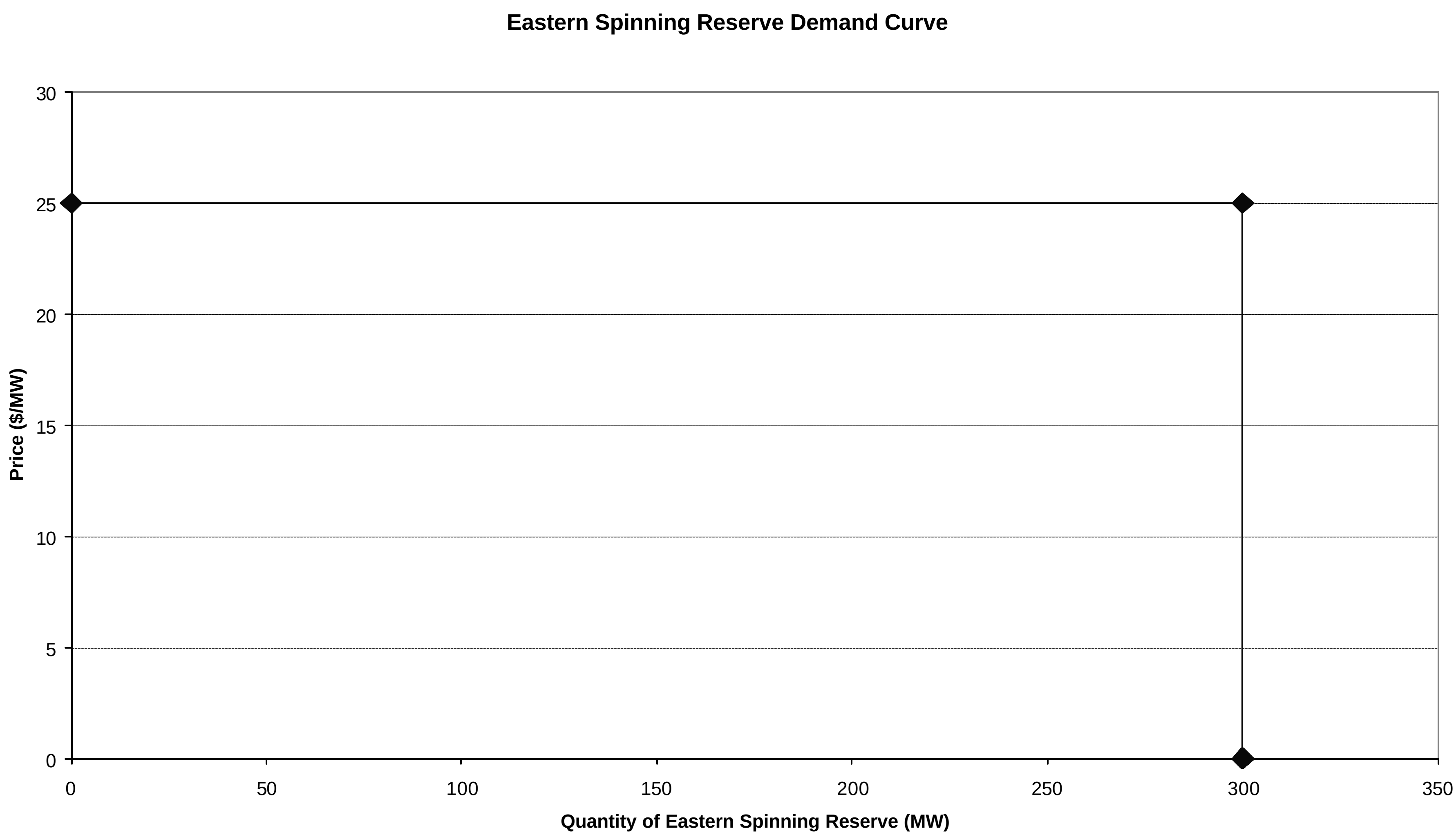
Eastern Total 10-Minute Reserve Demand Curve



RESERVE DEMAND CURVES Eastern 10-Minute

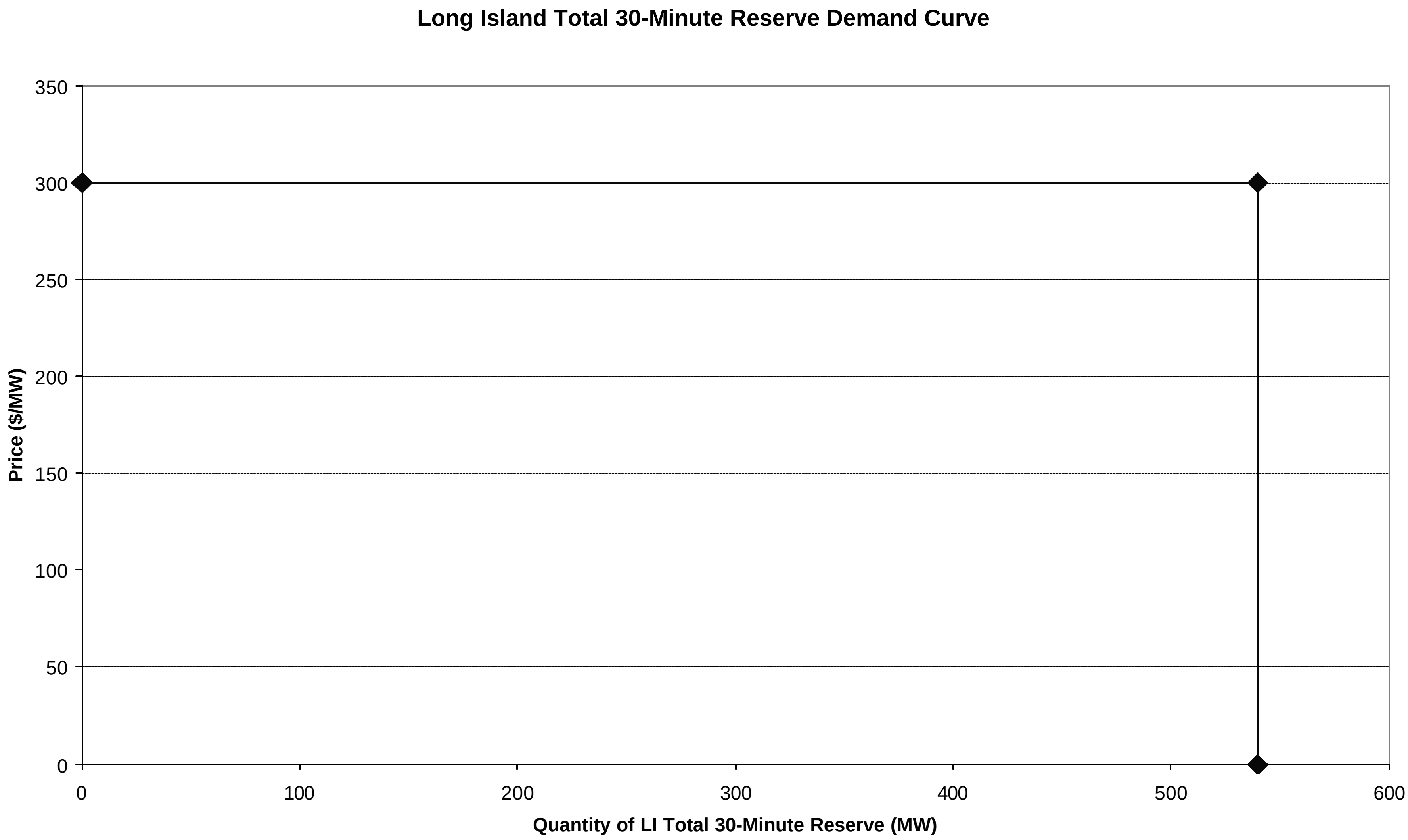
The Eastern 10-minute total reserve demand curve was set with the following considerations:

- This reserve constraint is a requirement and a shadow price somewhere between \$200/MW and \$300/MW meets the 0.05% hour standard during the historical period.
- The first 50 MW of the 10-minute Eastern reserve demand curve between 950 and 1000 MW are priced at \$200/MW.
- The remainder of the 10-minute Eastern reserve demand curve between 0 and 950 MW is priced at \$300/MW.


Eastern Spinning Reserve Demand Curve
30
25
20
15
10
5
0
Price ($/MW)
0
50
100
150
200
250
300
350
Quantity of Eastern Spinning Reserve (MW)

The Eastern spinning reserve demand curve was set with the following considerations:

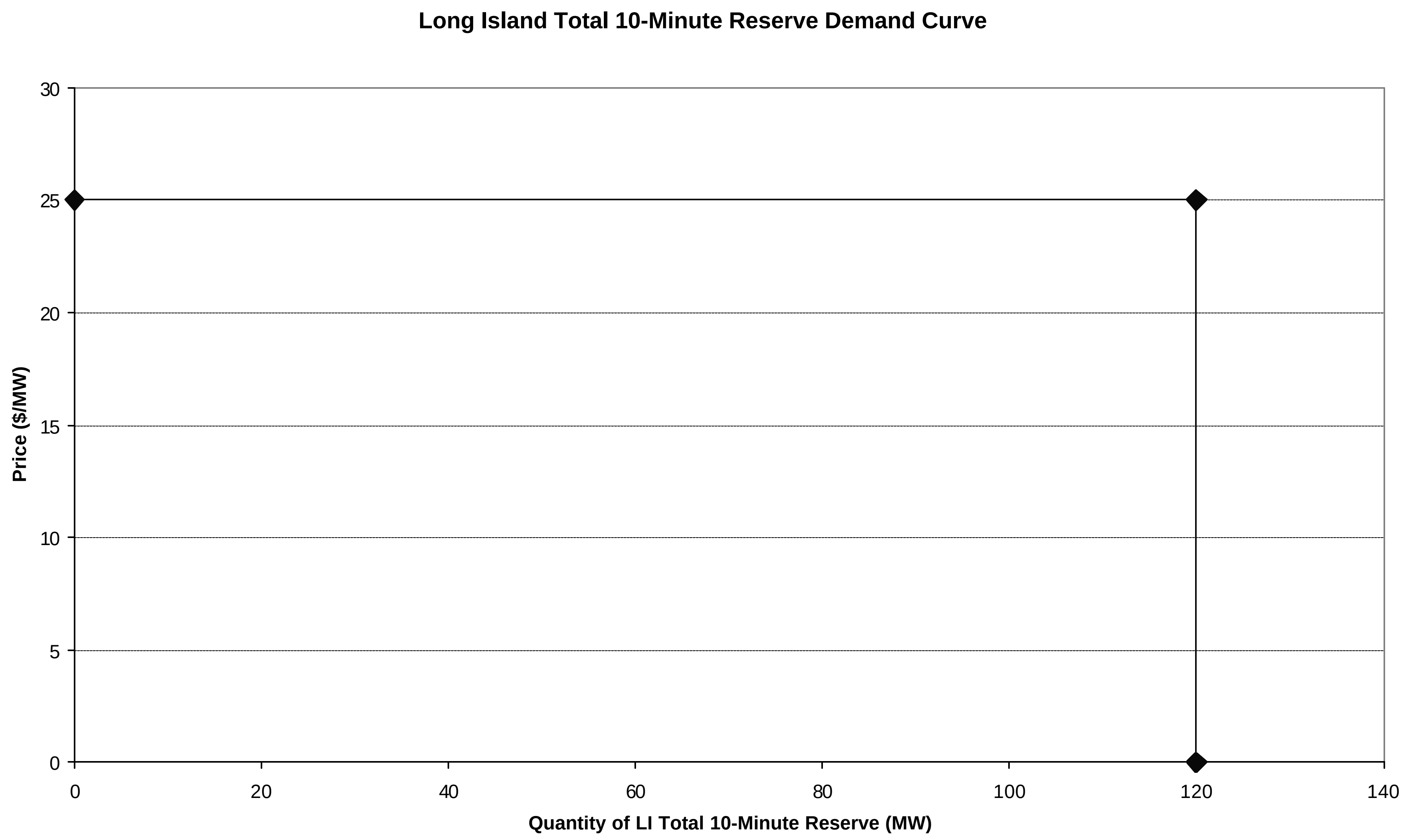
- This reserve constraint is a guideline not a requirement and the observed shadow prices during the historical period were all $0/MW;
- This constraint was never violated as there is always to be enough spinning reserve available in the East at $0/MW to satisfy the Eastern spinning reserve requirement or enough spinning reserve available at low prices that additional Eastern spinning reserve is scheduled either to meet the NYCA spinning reserve requirement or the Eastern 10-minute total reserve requirement;
- A minimum value of $25/MW for the demand curve has been used to value some incremental reliability benefit to having dispersed reserves.



Long Island Total 30-Minute Reserve Demand Curve
Price ($/MW)
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
Quantity of LI Total 30-Minute Reserve (MW)

The Long Island 30-minute total reserve demand curve was set with the following considerations:

- This reserve constraint is a requirement and a shadow price somewhere between $300/MW and $500/MW meets the 0.05% hour standard during the historical period;
- The entire demand curve is priced at $300/MW;
- The Long Island 30-minute total reserve requirement varies between 270 and 540 MW across the day. The price of this curve is always $300/MW regardless of the level of the requirement;
- The chart above shows the demand curve for an hour with a 540 MW requirement.


Long Island Total 10-Minute Reserve Demand Curve
Price ($/MW)
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
Quantity of LI Total 10-Minute Reserve (MW)

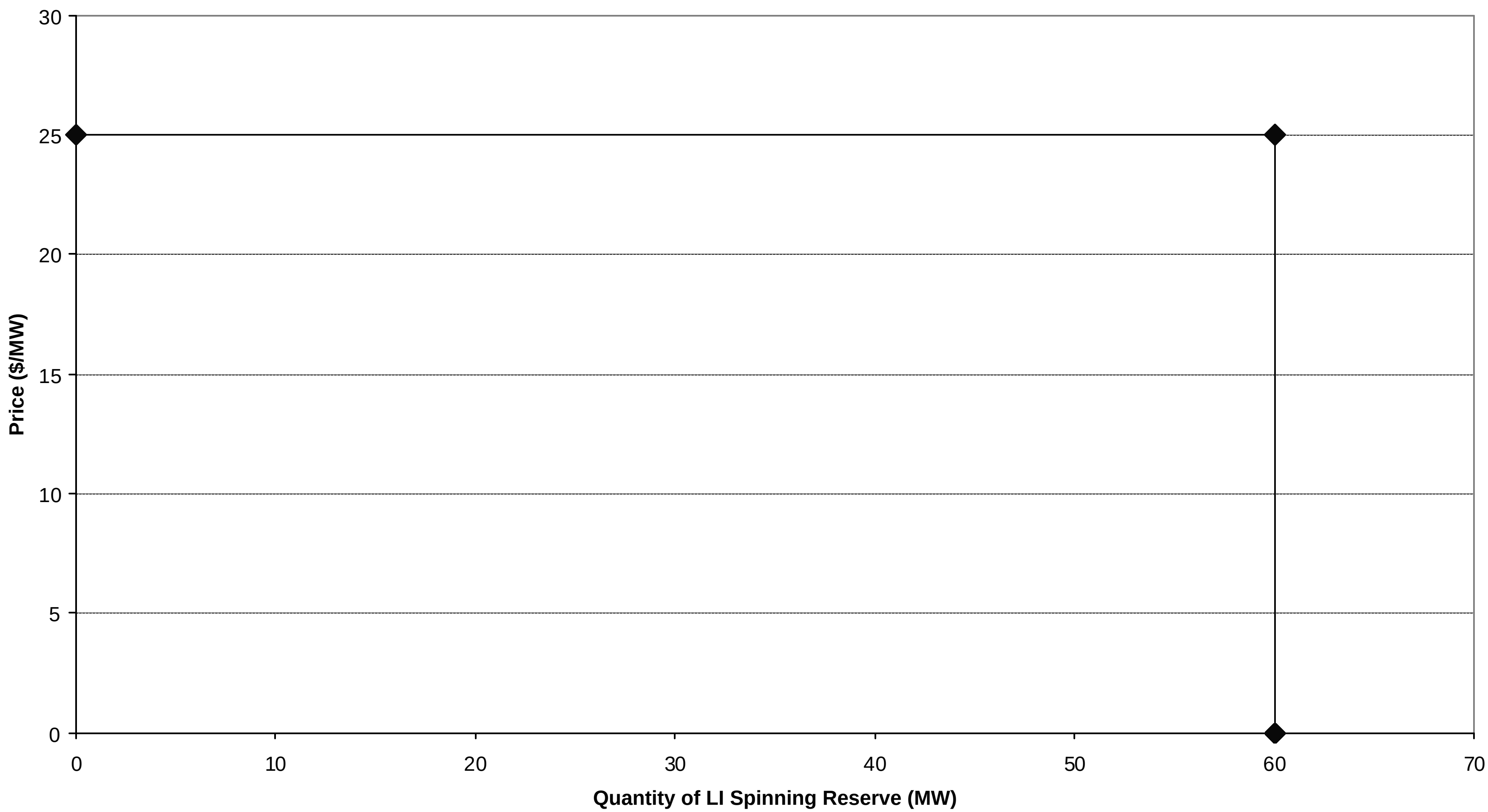
RESERVE DEMAND CURVES LI 10-Minute

The Long Island 10-minute total reserve demand curve was set with the following considerations:

- This reserve constraint is a guideline not a requirement and a shadow price somewhere between $100/MW and $150/MW meets the 0.05% hour standard during the historical period

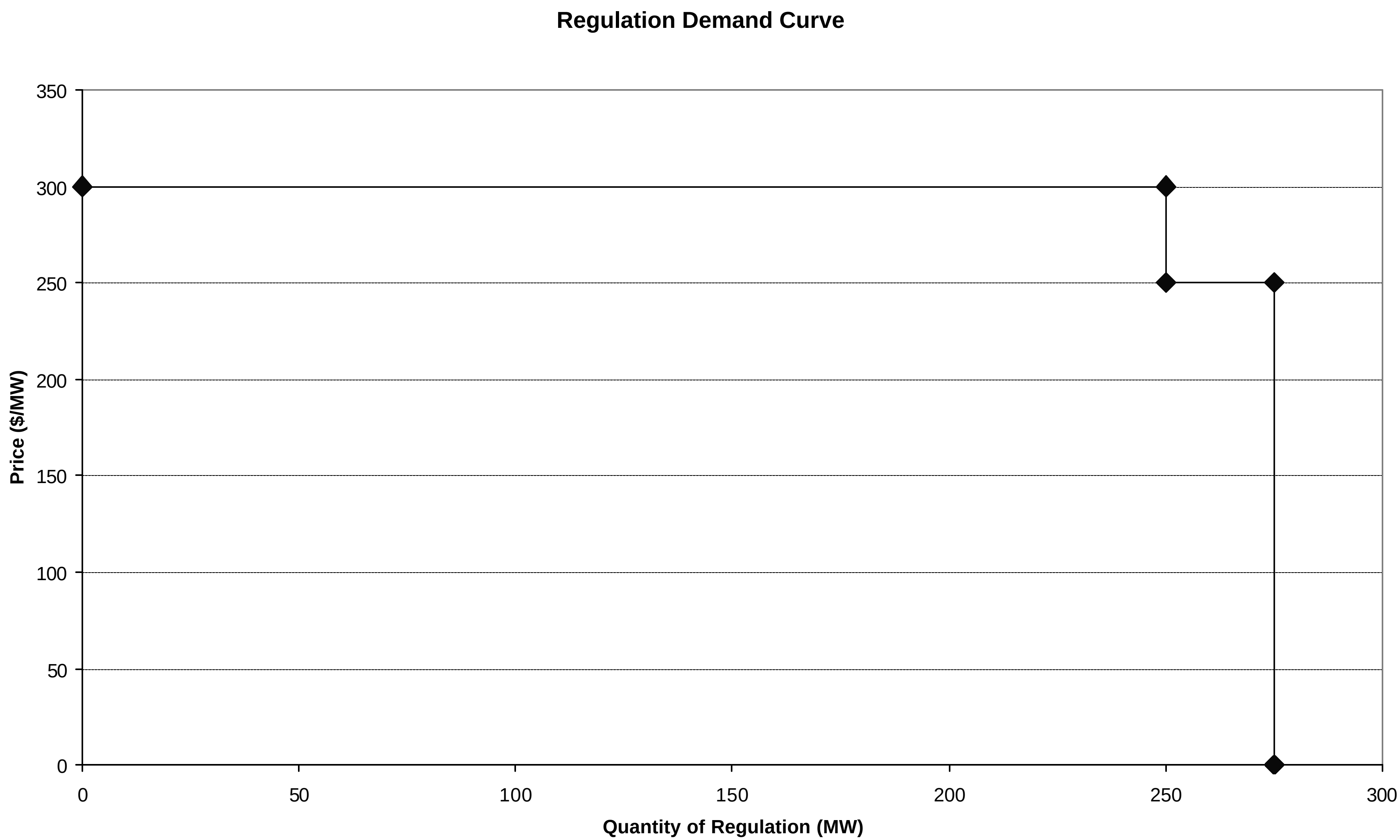
- A minimum value of $25/MW for the demand curve has been used to value some incremental reliability benefit to having dispersed reserves.

Long Island Spinning Reserve Demand Curve



The Long Island spinning reserve demand curve was set with the following considerations:

- This reserve constraint is a guideline not a requirement and a shadow price somewhere between $150/MW and $200/MW meets the 0.05% hour standard during the historical period
- A minimum value of $25/MW for the demand curve has been used to value some incremental reliability benefit to having dispersed reserves.



Regulation Demand Curve
350
300
250
200
150
100
50
0
Price ($/MW)
0
50
100
150
200
250
300
Quantity of Regulation (MW)

The regulation demand curve was set with the following considerations:

- A shadow price somewhere between \$300/MW and \$500/MW meets the 0.05% hour standard during the historical period;
- The regulation requirement varies across the day and is either 275 MW or 200 MW.
- The first 25 MW of the curve between 250 and 275 MW are priced at \$250/MW (between 175 MW and 200 when the requirement is 200 MW).
- The remainder of the 275 MW curve between 0 and 250 MW is priced at \$300/MW (between 0 and 175 when the requirement is 200 MW).

The table below summarizes the regulation demand curve and the nine operating reserve demand curves that have been proposed.

	NYCA	East	LI
Spin	$250 to $300	$25	$25
10-Total	$100 to $150	$200 to $300	$25
30-Total	$50, $100 and $200	$25	$300
Regulation	$250 to $300		