VRR Curve Variations Testing Lower Price Caps

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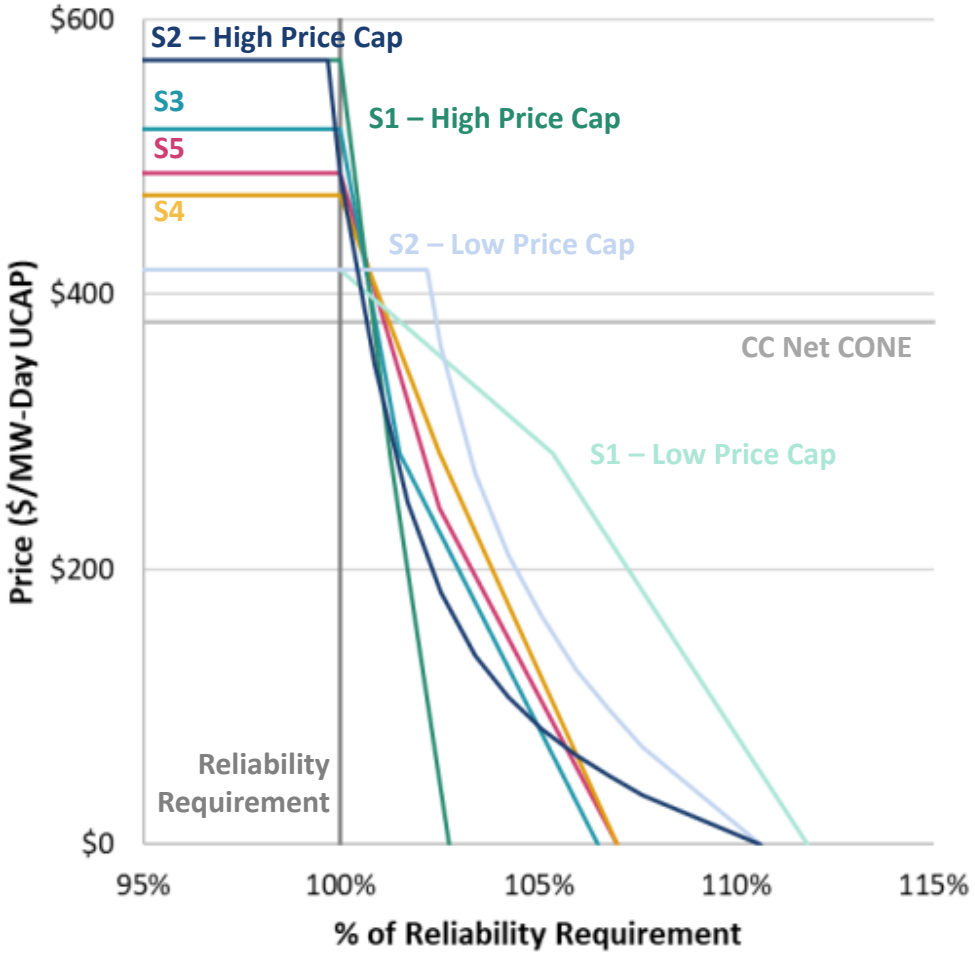
Overview: VRR Curve Simulations Testing Lower Price Caps

- For all model runs, the simulations examine options to minimize the VRR curve price cap formula while still being "tuned" to the 1-in-10 LOLE reliability standard
- We report a separate set of curves with a CC versus a CT reference technology (true Net CONE = administrative net CONE in all simulations)
  - **FLAG:** We reiterate Brattle's finding that the $350/MW-day Reference Price is our best estimate of long-run cost of new entry, much closer to the CC than the CT Net CONE
- Series 3, 4, and 5 test the use of the gross CONE based minimum parameter in the price cap formula (lowest price cap corresponds to 0.47-0.52 × CC CONE, or 0.81-0.91 × CT CONE)

Series	Description (All Curves Tuned to 1-in-10 LOLE Reliability)	Lowest Price Cap w/CC Net CONE	Lowest Price Cap as % of CC Net CONE
S1	Kinked curves with cap at the Reliability Requirement. Lower the cap by right-stretching the quantity points.	$418-$570/MW-Day UCAP	110%-150%
S2	Series of MRI-based curves tuned to the 1-in-10 reliability standard by adjusting the quantity at the price cap	$418-$570/MW-Day UCAP	110%-150%
S3	Steeper kinked curve with set quantity points, tuned to 1-in-10 reliability standard by adjusting the price cap	$521/MW-Day UCAP	137%
S4	Wider kinked curve with set quantity points, tuned to 1-in-10 reliability standard by adjusting the price cap	$472/MW-Day UCAP	124%
S5	Kinked curve meant to emulate the shape of the VRR Curve, tuned to reliability standard by adjusting the price cap	$488/MW-Day UCAP	129%

VRR Curves with Lower Price Caps, Using CC Net CONE



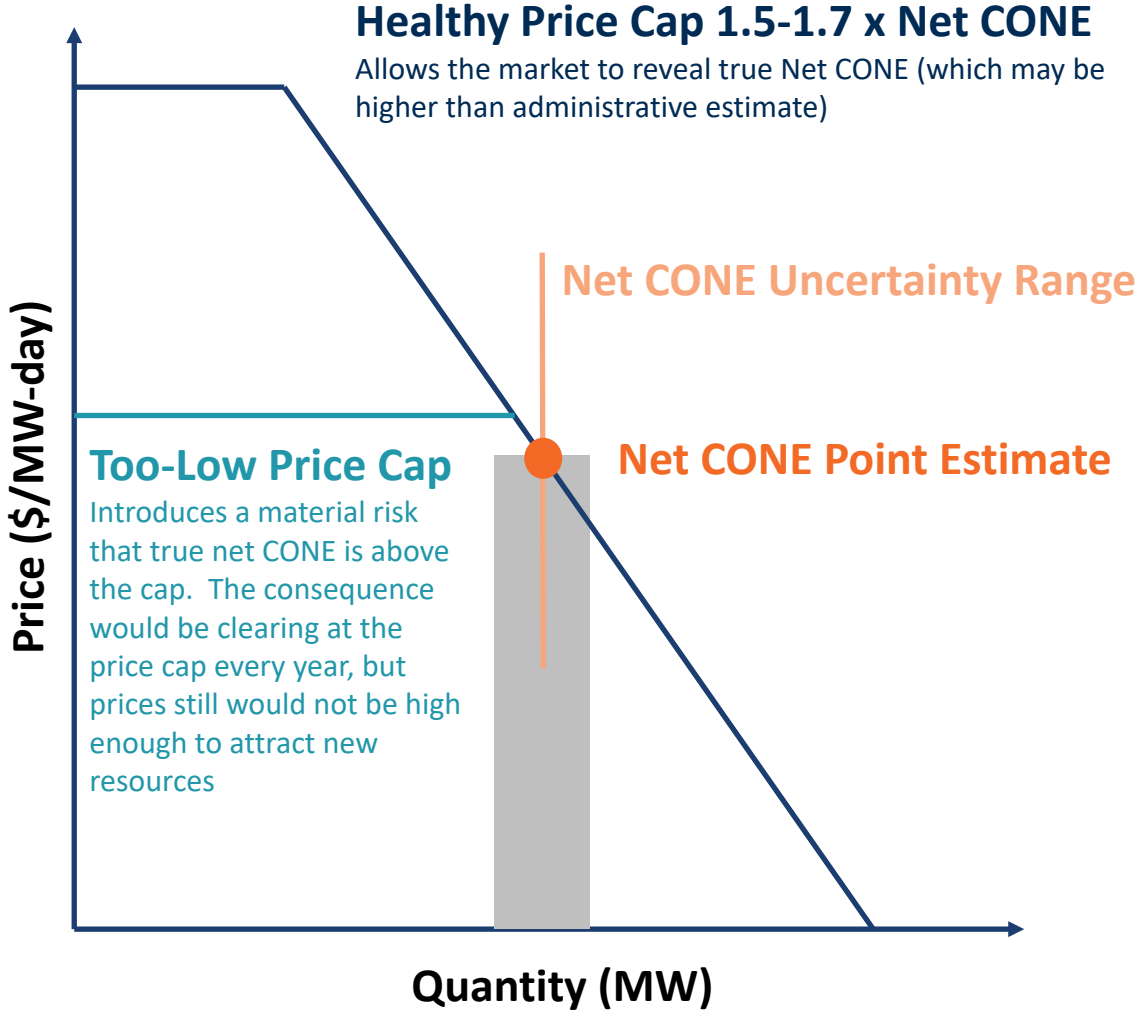
Sources and Notes: Curves shown are based on the administrative and true Net CONE of a combined cycle (CC) plant. See the VRR Curve Report for further explanation of the analysis. Spees, et al., Sixth Review of PJM's Variable Resource Requirement Curve, April 9, 2025.

How low can the price cap be?

There is no specific theoretical minimum on the price cap, but pushing the cap "too close" to Net CONE erodes performance:

- Higher likelihood that true Net CONE is above the cap
  - No new entry will be attracted, because developers will not bother proposing projects that cannot pencil
  - Reliability will continuously erode over time
- Even if true Net CONE remains below the cap, performance will erode:
  - More price cap events will occur (and associated low-reliability events)
  - Curve must be right-shifted to offset reliability risks (introduces higher risk of over-procurement on average)
  - Sellers of all types will see less upside potential in the market, so fewer projects will be proposed (auction will be tighter and less competitive)
  - Some higher-cost, short-term resources will not participate and provide buffer for short-term needs (e.g. year-to-year capacity trade, some DR)

Illustrative Example of Price Cap Considerations



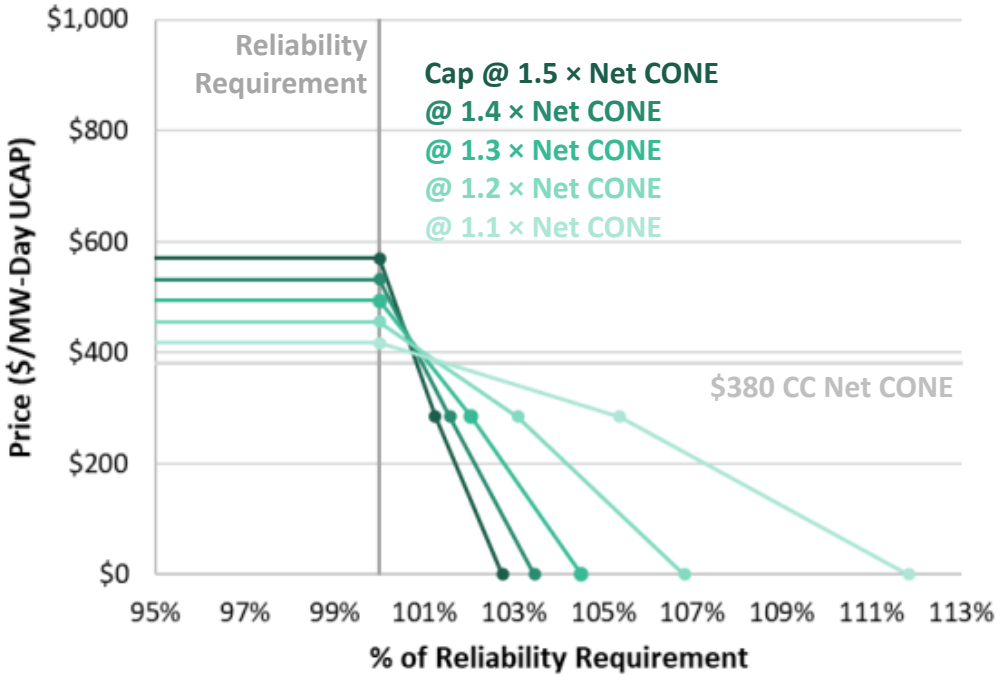
Series 1: Kinked Curves, Price Cap @ Reliability Requirement

Tuning Approach: Quantity at the cap is 100% of Reliability Requirement and declining price caps as multiple of Net CONE. Other quantity points are stretched so that curve meets the 1-in-10 LOLE standard.

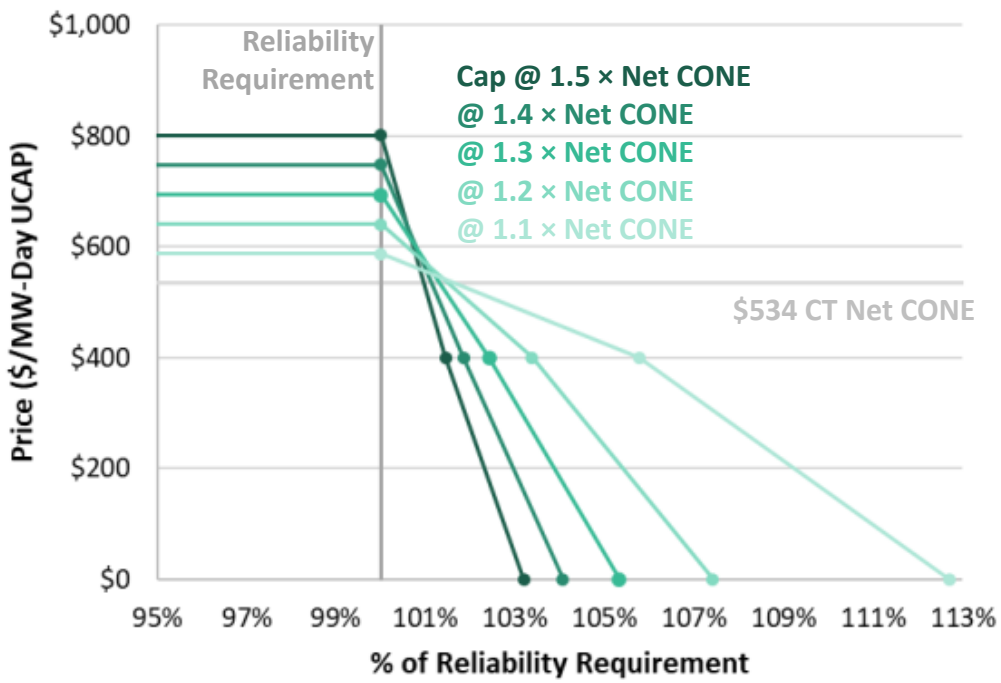
Takeaways

- Lower price cap requires right-stretching curves
- Once cap gets below 1.3 x Net CONE, a disproportionately wider curve is required to maintain 1-in-10

Curves Tuned to CC Net CONE



Curves Tuned to CT Net CONE



Series 1: Kinked Curves, Price Cap @ Reliability Requirement

	Price			Reliability						Cost
	Average Clearing Price	Standard Deviation	Frequency at Cap	Average LOLE	Average Excess (Deficit) Above Reliability Requirement	Average Excess (Deficit) Above Target Reserve Margin	Normalized Portfolio EUE (% of Target)	Frequency Below Reliability Requirement	Frequency Below 99% of Reliability Requirement	Average Procurement Cost
	($/MW-d)	*($/MW-d)*	*(%)*	*(events/yr)*	*(MW)*	*(UCAP RR + X %)*	*(%)*	*(%)*	*(%)*	*($ mln/yr)*
CC Net CONE										
Price Cap at 1.5 x Net CONE	$380	$147	24.9%	0.100	542	0.41%	109.7%	24.9%	15.4%	$18,678
Price Cap at 1.4 x Net CONE	$380	$128	26.6%	0.100	649	0.49%	111.2%	26.6%	16.4%	$18,674
Price Cap at 1.3 x Net CONE	$380	$105	27.8%	0.100	778	0.58%	112.2%	27.8%	17.6%	$18,675
Price Cap at 1.2 x Net CONE	$380	$76	29.6%	0.100	1,021	0.76%	114.0%	29.6%	18.7%	$18,688
Price Cap at 1.1 x Net CONE	$380	$42	31.3%	0.100	1,261	0.94%	115.3%	31.3%	19.6%	$18,709
CT Net CONE										
Price Cap at 1.5 x Net CONE	$534	$218	26.6%	0.100	673	0.50%	112.4%	26.6%	16.6%	$26,253
Price Cap at 1.4 x Net CONE	$534	$187	28.6%	0.100	816	0.61%	113.5%	28.6%	18.0%	$26,254
Price Cap at 1.3 x Net CONE	$534	$151	30.0%	0.100	978	0.73%	114.5%	30.0%	18.6%	$26,262
Price Cap at 1.2 x Net CONE	$534	$110	31.0%	0.100	1,157	0.86%	115.2%	31.0%	19.7%	$26,277
Price Cap at 1.1 x Net CONE	$534	$60	31.8%	0.100	1,441	1.07%	115.4%	31.8%	20.4%	$26,320

Price Volatility & Exposure to Cap Events: Much lower with lower price cap.

Over-procurement Risk: Modestly higher w/ lower caps. But single-scenario analysis understates the potential for large over-procurements with widest curves (foot extends to 113% of Requirement)

Reliability: Frequency and reliability impact of price-cap events increases only modestly with low price caps, but likely understated in single scenario (since possibility of understated Net CONE is not accounted for).

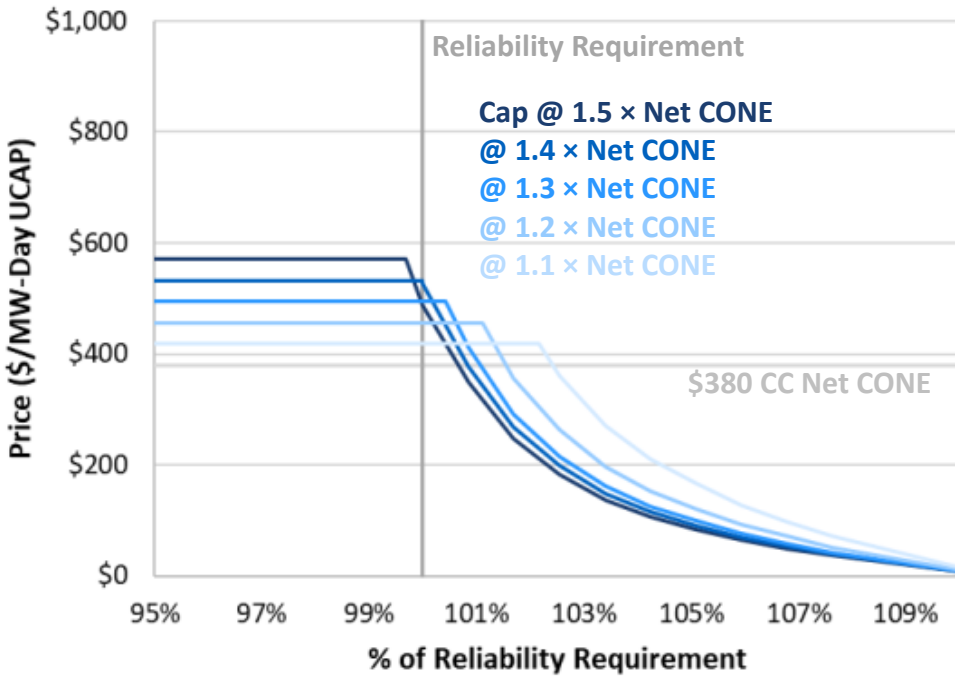
Series 2: MRI-Based Curves

Tuning Approach: All curves constructed using an anchor point at the price cap and have the shape of MRI. Lower price cap requires right-shifting the quantity at the cap (including above the reliability requirement).

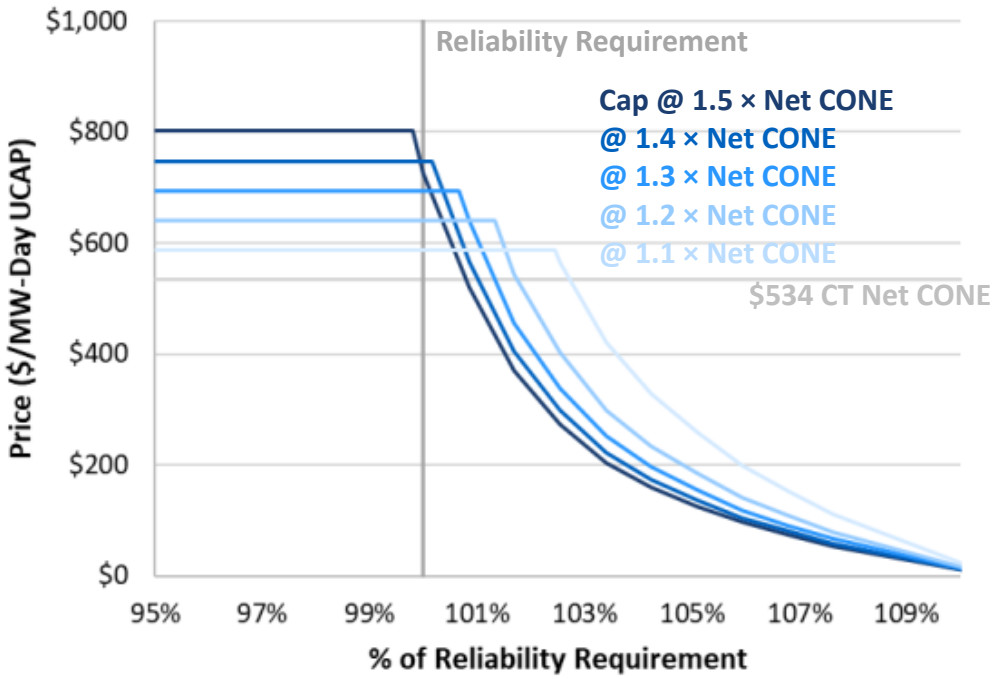
Takeaways

- Lower price cap requires right-shifting the quantity at the cap (up to ~103% of Requirement for a cap at 1.1 × Net CONE)
- Convex MRI shape produces less exposure to over-procurement at foot compared to concave shape in Series 1

Curves Tuned to CC Net CONE



Curves Tuned to CT Net CONE



Series 2: MRI-Based Curves

	Price			Reliability						Cost
	Average Clearing Price	Standard Deviation	Frequency at Cap	Average LOLE	Average Excess (Deficit) Above Reliability Requirement	Average Excess (Deficit) Above Target Reserve Margin	Normalized Portfolio EUE (% of Target)	Frequency Below Reliability Requirement	Frequency Below 99% of Reliability Requirement	Average Procurement Cost
	($/MW-d)	*($/MW-d)*	*(%)*	*(events/yr)*	*(MW)*	*(UCAP RR + X %)*	*(%)*	*(%)*	*(%)*	*($ mln/yr)*
CC Net CONE										
Price Cap at 1.5 x Net CONE	$380	$135	21.3%	0.100	627	0.47%	110.2%	27.7%	15.7%	$18,670
Price Cap at 1.4 x Net CONE	$380	$123	26.5%	0.100	701	0.53%	111.0%	26.5%	16.4%	$18,673
Price Cap at 1.3 x Net CONE	$380	$108	32.3%	0.100	758	0.57%	112.4%	27.8%	17.6%	$18,673
Price Cap at 1.2 x Net CONE	$380	$89	44.2%	0.100	921	0.69%	114.7%	29.7%	18.7%	$18,683
Price Cap at 1.1 x Net CONE	$380	$63	62.0%	0.100	1,163	0.86%	115.5%	31.5%	19.6%	$18,705
CT Net CONE										
Price Cap at 1.5 x Net CONE	$534	$203	24.3%	0.100	778	0.58%	112.3%	28.7%	16.9%	$26,249
Price Cap at 1.4 x Net CONE	$534	$184	30.3%	0.100	854	0.64%	113.3%	28.5%	18.0%	$26,254
Price Cap at 1.3 x Net CONE	$534	$161	37.1%	0.100	952	0.71%	114.3%	29.9%	18.5%	$26,262
Price Cap at 1.2 x Net CONE	$534	$131	46.9%	0.100	1,069	0.79%	115.3%	31.0%	19.7%	$26,275
Price Cap at 1.1 x Net CONE	$534	$93	65.1%	0.100	1,303	0.96%	116.8%	31.9%	21.0%	$26,305

Price Cap Events: Very likely to occur with convex MRI shape and low price cap (but still only 19-20% chance of falling below 99% of reliability requirement, since price cap is right shifted)

Over-procurement: Less prone to over-procurement compared to kinked curves (especially in other scenarios where true Net CONE is below estimated Net CONE).

Series 3, 4, and 5: Kinked Curves with Varying Shapes

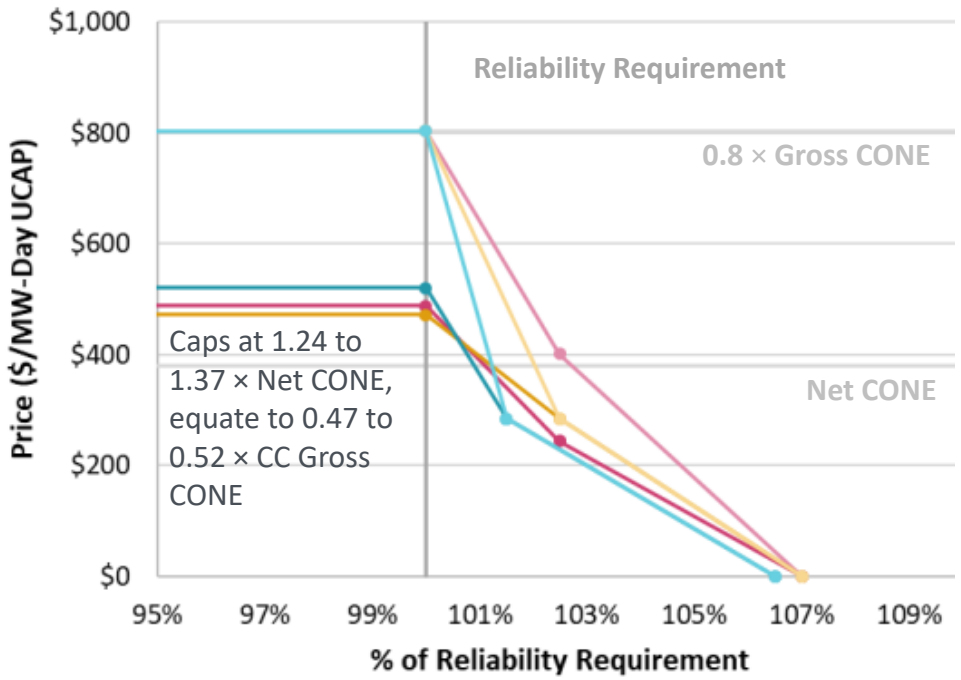
Series 3 (Steeper Kinked Curve): Point A (100% of RR, *1.37 x Net CONE*); Point B (101.5% of RR, 0.75 x Net CONE); Point C (106.5% of RR, $0/MW-Day)
Series 4 (Wider Kinked Curve): Point A (100% of RR, *1.24 x Net CONE*); Point B (102.5% of RR, 0.75 x Net CONE); Point C (107% of RR, $0/MW-Day)
Series 5 (Kinked Curve Based on MRI Curve Shape): Point A (100% of RR, *1.29 x Net CONE*); Point B (102.5% of RR, 0.5 x Price Cap); Point C (107% of RR, $0/MW-Day)

Tuning Approach: Changing the price cap while keeping the quantity points on each curve constant

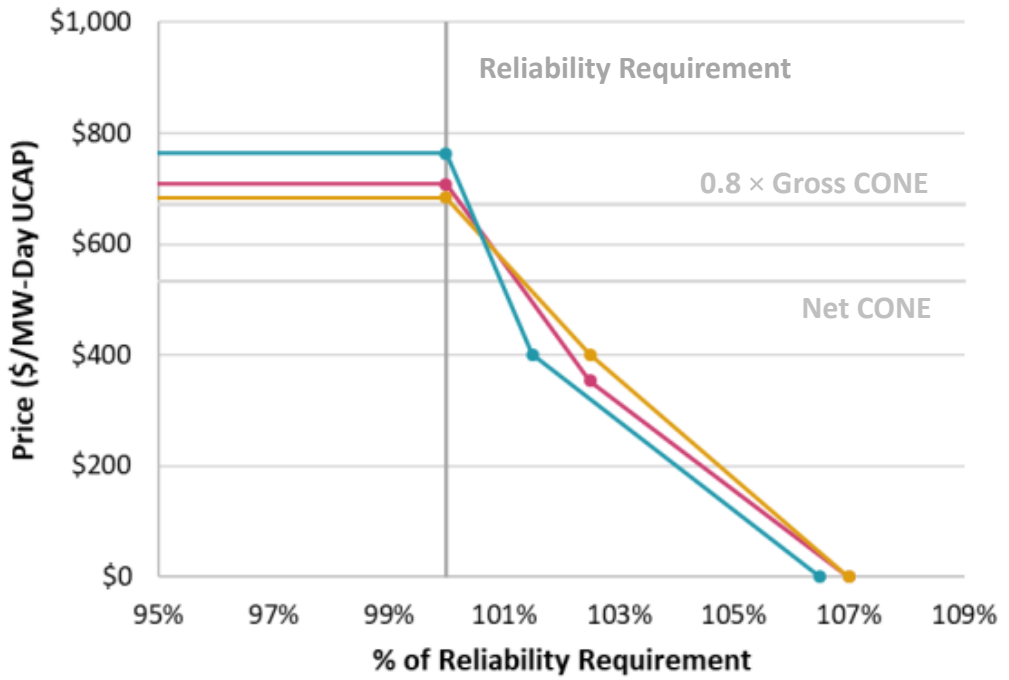
Takeaways

- Gross CONE based minimum parameter for the price cap is only binding for the CC-based curves
- Wider curves can achieve the 1-in-10 reliability standard with a lower price cap
- Maintaining CONE-based minimum not needed if CPI-based Net CONE update is adopted

Curves Tuned to CC Net CONE



Curves Tuned to CT Net CONE



Sources and Notes: Darker lines represented curves without the 0.8 x Gross CONE minimum parameter for the price cap, while the lighted curves include the Gross CONE based minimum parameter. Gross CONE based minimum parameter not binding when using CT Net CONE and CT Gross CONE in the construction of the curves

Detailed Tuned Curve Parameters

Curves	CC Net CONE					CT Net CONE				
	Net CONE	Price Cap	Price Cap as a Percentage of Net CONE	Price Cap Adder Above Net CONE	Maximum Cost Exposure	Net CONE	Price Cap	Price Cap as a Percentage of Net CONE	Price Cap Adder Above Net CONE	Maximum Cost Exposure
	$/MW-Day	*$/MW-Day*	*%*	*$/MW-Day*	*$ million*	*$/MW-Day*	*$/MW-Day*	*%*	*$/MW-Day*	*$ million*
Series 1: Kinked Curves with Varying Price Cap										
Price Cap at 1.5 x Net CONE	$380	$570	150%	$190	$27,788	$534	$801	150%	$267	$39,049
Price Cap at 1.4 x Net CONE	$380	$532	140%	$152	$25,935	$534	$748	140%	$214	$36,446
Price Cap at 1.3 x Net CONE	$380	$494	130%	$114	$24,083	$534	$694	130%	$160	$33,843
Price Cap at 1.2 x Net CONE	$380	$456	120%	$76	$22,230	$534	$641	120%	$107	$31,239
Price Cap at 1.1 x Net CONE	$380	$418	110%	$38	$20,378	$534	$587	110%	$53	$28,636
Series 2: MRI-Based Curves with Varying Price Cap										
Price Cap at 1.5 x Net CONE	$380	$570	150%	$190	$27,696	$534	$801	150%	$267	$38,971
Price Cap at 1.4 x Net CONE	$380	$532	140%	$152	$25,930	$534	$748	140%	$214	$36,508
Price Cap at 1.3 x Net CONE	$380	$494	130%	$114	$24,184	$534	$694	130%	$160	$34,069
Price Cap at 1.2 x Net CONE	$380	$456	120%	$76	$22,479	$534	$641	120%	$107	$31,652
Price Cap at 1.1 x Net CONE	$380	$418	110%	$38	$20,820	$534	$587	110%	$53	$29,338
Series 3, 4, and 5: Kinked Curve with Varying Quantity Parameters										
Series 3 - No Gross CONE based Price Cap Parameter	$380	$521	137%	$141	$25,380	$534	$764	143%	$230	$37,227
Series 4 - No Gross CONE based Price Cap Parameter	$380	$472	124%	$92	$23,018	$534	$684	128%	$150	$33,322
Series 5 - No Gross CONE based Price Cap Parameter	$380	$488	129%	$108	$23,805	$534	$708	133%	$174	$34,494
Series 3 - With Gross CONE based Price Cap Parameter	$380	$803	211%	$423	$39,145	$534	$764	143%	$230	$37,227
Series 4 - With Gross CONE based Price Cap Parameter	$380	$803	211%	$423	$39,145	$534	$684	128%	$150	$33,322
Series 5 - With Gross CONE based Price Cap Parameter	$380	$803	211%	$423	$39,145	$534	$708	133%	$174	$34,494

Lowest Cap with moderate performance erosion: price cap in the range of 1.25-1.3 × CC Net CONE. Would need to build in other protections such as expedited price cap increases or backstop if insufficient developer interest is identified

Observations

- **Reference Technology:** Belief regarding “true” Net CONE and reference technology has by far the greatest impact on reasonable price cap. Brattle continues to recommend using $350/MW-day estimated reference price (rather than higher CT-based Net CONE), barring additional evidence
- **Lowest Cap:** Curves indicate that price cap in the range of 1.25-1.3 × CC Net CONE (~$475-$500/MW-day) show modest performance erosion, as long as Net CONE is accurate. With a lower price cap, additional protections should be considered to enable expedited price cap increases or other reliability protections in case sufficient developer interest is not attracted
- **CONE-based Minimum:** Not needed if transitioning to CPI-based updates (not susceptible to price collapse).
- **Shape:** Wider and less convex curves can support reliability with a lower price cap relative to steeper curves (but flatter and more concave curves are also more susceptible to over-procurement if Net CONE is over-estimated, a higher risk if selecting CT-based curves). MRI-based convex curve requires a right-shifted cap to maintain reliability as price cap decreases