VRR Curve Parameter Review Process

- Section 5.10 of the PJM Tariff requires the periodic review of the three key parameters in the PJM Variable Resource Requirement (VRR) Curve: the Cost of New Entry, Energy & Ancillary Services Offset methodology and the VRR Curve shape.
- PJM retained The Brattle Group, via an RFP process, to perform a review of the these parameters.
- This document serves as Brattle's education for stakeholders on the scope of work, Brattle's *preliminary* recommendations for modifying or retaining existing parameters, and analytical support for its recommendations.
- At the May 9 CSTF, PJM will document stakeholder feedback on the review. Stakeholders should submit written feedback to Amanda Egan (amanda.egan@pjm.com) by noon on May 8.
- Recommendations made by Brattle will be considered by PJM staff, who will develop PJM recommendations and post them on May 15, per the PJM Tariff. Recommendations will be discussed through formal stakeholder process in the CSTF.
- Final stakeholder consensus on these recommendations will be due by August 31, 2014, with a FERC filing deadline of October 1, 2014.

Triennial Review of RPM

Draft Study Results

PRESENTED TO

PJM Interconnection, L.L.C. and Stakeholders

PRESENTED BY

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Sargent & Lundy

April 29, 2014

THE Brattle GROUP

Contents

Scope of Triennial Review

Three topics in our scope of work

A. **Review CONE** to ensure accurate estimation of the total net revenues (from both capacity and E&AS) a new generation resource needs to enter

B. **Review E&AS Methodology** to ensure accurate estimation of Net CONE, the capacity revenues a new generation resource needs to enter

C. **Review Shape of VRR Curve** to meet reliability objectives in all locations while avoiding excess price sensitivity to small changes in supply-demand

RPM topics <u>not</u> in the scope of our study

- Reliability standards (which are taken as given, as "objectives")
- Load forecasting
- Forward procurement period, incremental auctions, and 2.5% holdback
- Participation rules and penalties(e.g., for DR, imports, new generation)
- MOPR and other mitigation measures

Approach

A. Review CONE

- With Sargent & Lundy, conduct engineering cost study for CT and CC capital and fixed O&M costs, with locations and tech specs based on "revealed preference," environmental and fuel considerations, and tariff (e.g., GE 7FA for CT)
- Update ATWACC and calculate levelized CONE values

B. Review E&AS Methodology

- Compare calculated E&AS to actuals; compare historical data to futures
- Review locational considerations

C. Review Shape of VRR Curves

- Use Monte Carlo model to simulate curve performance
- Evaluate curve performance against objectives:
  - Average reliability across years at 1-in-10 LOLE for the system, and 1-in-25 conditional LOLE in LDAs (primary PJM design objective)
  - Rarely fall below 1-in-5 LOLE (~IRM – 1%);
  - Be robust to changes in market conditions, admin parameters, and uncertainties, but without relying on major over-procurement to eliminate all potential risks
  - Mitigate price volatility and susceptibility to the exercise of market power
- Evaluate alternative curves, highlighting tradeoffs among objectives

A. Draft CONE Recommendations

Recommendation	Reasons	Implications for Net CONE
Adopt Updated CONE Values	• Ensure accurate and updated values	• Compared to 2017/18 values escalated 3%, CT CONE is -11% to +6%; CC CONE is -6% to +11% • See table on next slide
Use average of CC and CT reference technologies instead of just CT (average their Net CONEs)	• Merchants are building CCs, not CTs • Averaging two technologies will help stabilize Net CONE values through fluctuating market conditions and estimation errors • Avoids a full switch to CCs as new reference technology	• Long-term, more stable Net CONE • Short-term, magnitude is unclear as CC Net CONE may no longer be below CT with updated CONE values and E&AS margins calibrated to actuals
Adopt level-real value for gross CONE	• Level-nominal likely understates future net revenues and overstate what developers need to enter	• Would decrease CONE by 15%; CT Net CONE by about $60/MW-day • Makes it important to calibrate overstated E&AS, particularly for CCs • Moves Net CONE closer to merchant entry pricing in recent RPM auctions
For annual CONE updates, replace Handy-Whitman "Other" index with wage, materials, and turbine indices from BLS	• Stabilize CONE updates by avoiding the anomalous patterns of the Handy-Whitman index currently used	• None for 2018/2019; better reflects market conditions thereafter

A. Draft CONE Recommendations (cont.)

		Simple Cycle					Combined Cycle				
		1 EMAAC	2 SWMAAC	3 RTO	4 WMAAC	5 Dominion	1 EMAAC	2 SWMAAC	3 RTO	4 WMAAC	5 Dominion
Net Summer ICAP	*(MW)*	396	393	385	383	391	668	664	651	649	660
Gross Costs											
Overnight	*($/kW)*	$1,015	$951	$903	$974	$934	$1,218	$1,108	$1,092	$1,146	$1,081
Installed	*($/kW)*	$1,063	$996	$947	$1,020	$979	$1,333	$1,213	$1,199	$1,253	$1,184
Levelized FOM	*($/MW-day)*	$41	$76	$52	$38	$54	$71	$117	$81	$64	$78
After-Tax WACC	*(%)*	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Levelized Gross CONE											
Level-Real	***($/MW-day)***	**$346**	**$346**	**$310**	**$331**	**$326**	**$472**	**$462**	**$422**	**$442**	**$423**
Level-Nominal	***($/MW-day)***	**$408**	**$408**	**$365**	**$390**	**$384**	**$556**	**$545**	**$497**	**$521**	**$498**
Prior CONE Estimates											
PJM 2017/18 Parameter *	*($/MW-day)*	$443	$413	$405	$425	$363	$548	$483	$528	$525	$466
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Increase (Decrease) Above Prior CONE Estimates											
PJM 2017/18 Parameter	*($/MW-day)*	($35)	($5)	($40)	($35)	$22	$9	$62	($31)	($4)	$32
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PJM 2017/18 Parameter	*(%)*	-9%	-1%	-11%	-9%	6%	2%	11%	-6%	-1%	6%
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Notes: All values are expressed in 2018 dollars, except "overnight" costs, which are in nominal dollars in the year in which they are incurred
* PJM 2017/18 Parameters are the MOPR prices for the 2017/2018 RPM Base Residual Auction, escalated to 2018.
** Brattle estimates from the 2011 CONE Study are escalated from 2015/16 to 2018.
Escalation rates are 3.1% and 3.0% per year for CCs and CTs, based on S&L analysis of trends in labor and other cost components.

We are still considering adding dual fuel to Rest of RTO; we plan to remove dual fuel from SWMAAC CC which we already assume has firm gas transportation. Dual fuel adds $18-20 million in present dollars, with about an $20/MW-day and $12/MW-day impact on CT and CC level-nominal Net CONE, respectively .

B. Draft E&AS Methodology Recommendations

Recommendation	Reasons	Implications for Net CONE
Make E&AS simulations more realistic, starting by investigating why they significantly exceed actuals for CCs in all areas and for CTs in SWMAAC	• Avoid overstating E&AS and understating Net CONE (and under-procuring), especially in LDAs	• Substantial increase in SWMAAC Net CONE • CC Net CONE would increase everywhere, bringing it closer to CT Net CONE • Mitigates impact of recommended shift from level-nominal to level-real
Develop a forward-looking E&AS calculation methodology (instead of purely historical)	• Stabilize Net CONE by normalizing out anomalous historical market conditions (esp. w/scarcity pricing) • Better align Net CONE with the future conditions considered by developers (instead of conditions 4-6 years earlier)	• CC E&AS would decrease (futures prices lower than historical prices), causing CC Net CONE to rise, e.g., up to $75/MW-day in EMAAC based on simplified calculation, but depends on methodology and what other recommendations are adopted • Smaller effect on CT Net CONE

B. Draft E&AS Methodology Recommendations (cont.)

Recommendation	Reasons	Implications for Net CONE
Align E&AS offset calculation more closely to modeled LDAs	• Improve the accuracy of Net CONE estimates in LDAs (using one E&AS location throughout a CONE Area does not recognize that margins differ in embedded LDAs)	• Would increase CT Net CONE in PSEG, PSEG North, Pepco, and MAAC; decrease it in ATSI, ATSI-C, and DPL-S; each by roughly $10-15/MW-day • Relates to recommended improvement of CONE Areas mappings (see Appendix)
Consider imposing parent-LDA Net CONE value as a minimum for sub-LDA Net CONE (or at least carefully investigate E&AS and CONE estimates if Net CONE values are lower in import-constrained LDAs, esp. SWMAAC)	• Reduce impact of Net CONE estimation errors, especially in small LDAs where errors are more likely • Import-constrained zones are constrained for a reason, so lower estimate of Net CONE may be an error and will blunt signal to build there • Substantial reliability consequences of understating LDA Net CONE (see simulation results)	• Could increase Net CONE in some constrained LDAs (e.g., about $30/MW-day in SWMAAC and PEPCO under 2017/18 parameters)

C. Draft VRR Curve Recommendations: System

Recommendation	Reasons	Other Implications
Right-shift point "a" (at the price cap) to a quantity at 1-in-5 LOLE (approx. IRM – 1%)	• Avoid shortcoming of Current VRR curve, which does not meet 1-in-10 reliability objective on average (assuming accurate load forecasts and Net CONE estimates) • Reduce likelihood of significant reliability target shortfalls • Particularly important if CONE based on lower level-real value	• Raises VRR curve at low reserve margins (see chart on next slide) • No change to expected long-term average prices
Stretch the VRR Curve into a convex shape (steeper at low RM, flatter at high RM)	• Consistent with more gradual decline of reliability value at higher RM • Reduce price volatility at higher RMs	• Raises VRR curve at high reserve margins (see chart on next slide) • No change to expected long-term average prices
PJM may consider right-shifting the curve 1-2% as insurance against stress scenarios	• Reduce risk of low reliability under stress conditions with Net CONE underestimation or higher supply-demand shocks	• Right-shifted curve does not raise long-term average prices but increases average quantity and thus average procurement costs by 1-2%

Executive Summary

C. Draft VRR Curve Recommendations: System

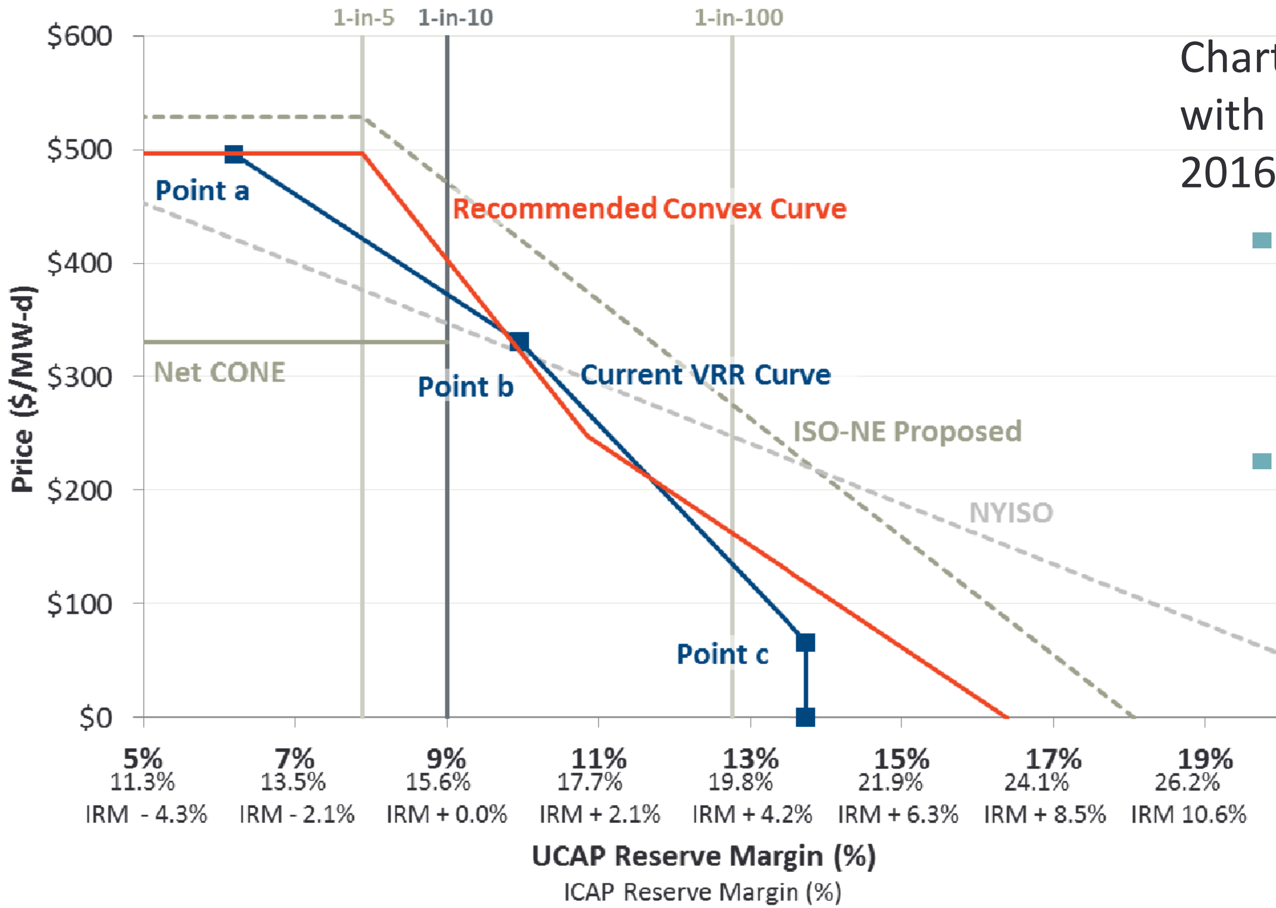


Chart shows all demand curves with Net CONE based on PJM 2016/17 Planning Parameters

- It does not show the effects of our recommendations from the CONE and E&AS methodology reviews
- Also note that ISO-NE and NYISO define their demand curves based on level-real CONE estimates and forward-looking E&AS

Notes:
All curves' prices are scaled to the same Net CONE, from the 2016/17 PJM Planning Parameters for RTO.
ISO-NE and NYISO quantity points are scaled based on quantity as a percentage of reliability requirement, with the ISO-NE proposed cap set at 1-in-5 LOLE and the bottom of the curve the same reserve margin percentage rightward as in ISO-NE's proposal.

C. Draft VRR Curve Recommendations: LDAs

Recommendations	Reasons	Other Implications
Adopt the same recommendations as for the system, plus increase the LDA price cap to 1.7x Net CONE	• Higher cap needed to meet reliability targets due to LDAs' small size relative to realistic shocks to supply, demand, and CETL	• No effect on expected long-term average prices, although higher curve could increase prices in short-term, depending on entry
Impose a minimum curve width equal to 25% of CETL (from point "a" to "c")	• CETL uncertainty is a major additional driver of VRR curve performance in LDAs • Smallest, most import-dependent LDAs show poor reliability outcomes and high price volatility in our simulations • Wider curve has less extreme volatility of prices and quantities	• VRR curves become wider in SWMAAC (by 2.5 %age points), PEPCO (8.1%), DPL-S (6.7%), PSEG (4.3%), PSEG-N (2.8%), ATSI (3.4%), and ATSI-C (12.9%) • No impact on long-term average prices, but very slight (<2%) increase in procurement costs due to higher quantity procured locally.

Approach

Brattle and Sargent & Lundy (S&L) collaborated on specifying the technologies, configurations and locations of the reference CC and CT plants, based primarily on predominant practice among recently developed projects

We developed comprehensive, bottom-up estimates of the costs of building and maintaining the specified plants

- Sargent & Lundy (S&L) estimated plant proper capital costs
- S&L and Brattle estimated owner's capital cost and annual fixed operations and maintenance (fixed O&M) costs

Brattle then estimated cost recovery needed in the first year, or "CONE," based on the capital and fixed O&M costs, an estimated cost of capital, and consideration of likely net revenues over the rest of an assumed economic life

Locational Screening Methodology

Step 1: Identify Candidate Locations Based on Revealed Preference

- Review actual projects (since 2002) and proposed projects
- Identify areas of primary development, putting more weight on current/recent merchant projects
- Note: the data for some CONE areas may be plentiful and somewhat focused (e.g., EMAAC); for others the signal may be scattered (e.g., RTO); in both cases, proceed to Step 2 to sharpen the definition about where development is likely going forward

Step 2: Refine Population of Locations Based on Feasibility and Economics

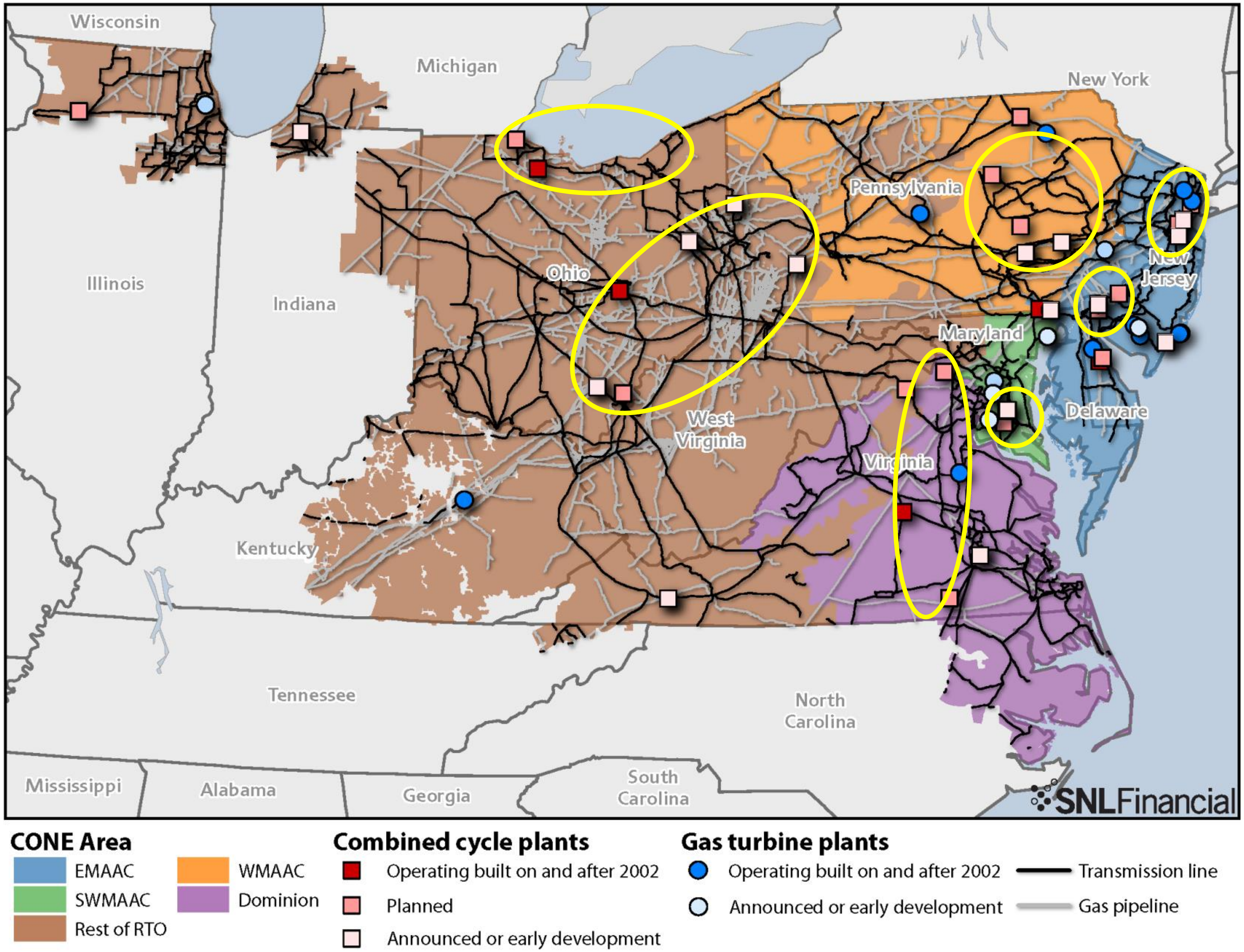
- For CONE Areas where revealed preference data is plentiful: filter out counties that would appear to be infeasible based on environmental or land constraints, or very economical (absent special offsetting factors we wouldn't know about) going forward
- For CONE areas where revealed preference data is weak or scattered: have to think like developers to identify promising locations based on feasibility (esp. proximity to gas and electric interconnections), and key economic factors (labor rates and EAS)

Step 3: Estimate Representative Costs Factors for the Population of Selected Locations

- For most variables such as labor rates, take an average of relevant labor pools, eliminating outliers, based on *Labor Rates for the Construction Industry, 2013*, using electrician rate as a proxy
- For E&AS, plan to identify a single energy zone that is representative of the population, based on 2010-2012 data

A. CONE Review

Location Screening within Each CONE Area



CT Technical Specifications

- **2x0 GE 7FA turbines**, per tariff
- Capacity and heat rate reflect **ambient summer conditions** in each CONE Area
- Assume **SCR and CO catalyst** required in each Area; recognize FERC ruling on frame turbine SCR feasibility; (Note: Dominion did not have SCR in previous CONE study)
  - SCR is now specified in Dominion, unlike 2011 CONE Study, due to additional consideration of the regulatory requirements of being located in the Ozone Transport Region
- Consistent with 2011 CONE Study, assume **dual fuel** in all Areas except Rest of RTO (but considering adding it there too)

Plant Characteristic	
Turbine Model	GE 7FA.05
Configuration	2 x 0
Cooling System	n/a
Power Augmentation	Evaporative Cooling; no inlet chillers
Net Plant Power Rating (MW)	396 / 393 / 385 / 383 / 391 *
Net Heat Rate (HHV in Btu/kWh)	10,309 / 10,322 / 10,297 / 10,296 / 10,317 *
Environmental Controls	
CO Catalyst	Yes
Selective Catalytic Reduction	Yes
Dual Fuel Capability	Dual / Dual / Single / Dual / Dual *
Firm Gas Contract	No
Special Structural Req.	No
Blackstart Capability	None
On-Site Gas Compression	None

***Notes**:*
* For EMAAC, SWMAAC, Rest of RTO, WMAAC, and Dominion CONE Areas, respectively

CC Technical Specifications

- **2x1 GE 7FA turbines**, reflecting the most common configuration in recently constructed plants
- Capacity and heat rate reflect **ambient summer conditions** in each CONE Area
- Assume **cooling tower** in all Areas; with reclaimed water, except in Rest of RTO where it is less available
- Assume **SCR and CO catalyst** are required in all Areas
- **Firm gas transportation** assumed in SWMAAC due to pipeline issues
- Assume **dual fuel** in all Areas except Rest of RTO (and considering adding it there too); still have to remove dual fuel from SWMAAC due to firm transportation

Plant Characteristic	
Turbine Model	GE 7FA.05
Configuration	2 x 1
Cooling System	Cooling Tower *
Power Augmentation	Evaporative Cooling; no inlet chillers
Net Plant Power Rating (MW)	
w/o Duct Firing	595 / 591 / 578 / 576 / 587 **
with Duct Firing	668 / 664 / 651 / 649 / 660 **
Net Heat Rate (HHV in Btu/kWh)	
w/o Duct Firing	6,800 / 6,811 / 6,791 / 6,792 / 6,808 **
with Duct Firing	7,028 / 7,041 / 7,026 / 7,027 / 7,039 **
Environmental Controls	
CO Catalyst	Yes
Selective Catalytic Reduction	Yes
Dual Fuel Capability	Dual / Dual / Singl / Dual / Dual **
Firm Gas Contract	No / Yes / No / No / No **
Special Structural Req.	No
Blackstart Capability	None
On-Site Gas Compression	None

Notes:
* CONE Area uses ground/surface water; all others use reclaimed water for cooling
** For EMAAC, SWMAAC, Rest of RTO, WMAAC, and Dominion CONE Areas, respectively

Certain Assumptions for Capital Costs

Labor: Labor costs increased particularly in Dominion and SWMAAC, with largely union labor, per S&L market intelligence on prevailing wage rates and productivity factors; our 2011 CONE Study assumed all non-union labor in those two regions

Contingency: Assumed EPC contingency at 10% of other EPC costs and owner's contingency at 9% of other owner's costs; total contingency is about 9.6% of (pre-contingency) overnight cost, an increase from 6.4% in 2011 CONE Study

Electric Interconnection: Updated analysis from previous study, with average costs calculated to be $32/kW (in 2014$)

Project development: 5% of total EPC plus OFE costs, an increase from about 2% in 2011 CONE Study

Dual Fuel: With plant modifications and storage, assumeing three days of fuel inventory, adds $17.5 million to CC and $20 million to CT plant costs (in 2014$).

See Appendix for line-by-line cost details

Certain Assumptions on O&M Costs

LTSA: Only included the monthly fixed payment portion in Fixed O&M and considered the costs based on plant operations as Variable O&M

Property Tax: Conducted a broader survey of state and county tax regulations compared with analysis done in 2011 CONE Study; in SWMAAC, Rest of RTO and Dominion, we include tax on personal property, calculated based on local rates

Insurance: 0.6% of plant overnight capital cost

Firm Gas Contract: assume CC plant in SWMAAC will obtain a firm fuel contract due to gas delivery challenges on the Dominion Cove Pipeline (DCP)

See Appendix for line-by-line cost details

Cost of Capital Estimates

We recommend the after-tax weighted average cost of capital (ATWACC) for the CONE estimate to be 8.0%

- Equivalent to 13.8% ROE at 7% COD and 60% debt

We reviewed a broad range of sources to estimate the cost of capital for a pure-play merchant generator without PPAs

- Estimated the ATWACC for publicly traded companies (6.3% for Dynegy, 5.7% for NRG, 7.4% for Calpine)
- Considered additional data points based on (a) previous estimates, (b) fairness opinions for merchant generation divestitures, and (c) analyst estimates;
- 2011 and 2012 data points have been adjusted to Feb 2013 financial market conditions based on changes in the risk-free rate (2011 = -0.9%, 2012 = +0.7%)

As most of these companies have some level of long-term PPAs, a pure-play merchant generator without PPAs should be above our estimates for publicly traded generation companies

ATWACC Reference Points and Recommendation

Company	S&P Credit Rating [1]	Equity Beta [2]	Return on Equity [3]	Cost of Debt [4]	Debt/ Equity Ratio [5]	After Tax WACC [6]	July 2012 Financial Advisor Estimates for NRG-GenOn Merger [7]	Apr 2011 Brattle Estimates [8]	2011 Analyst Estimates [9]	2011 Fairness Opinions [10]
	Brattle Updated ATWACC Estimates						Prior Estimates Adjusted to Feb 2014 Risk-Free Rate			
Publicly Traded Companies										
Calpine	B	1.19	11.0%	8.5%	61/39	7.4%		6.7%	6.6%	
NRG	BB	0.98	9.7%	7.0%	73/27	5.7%	7.7 - 9.2%	6.3%	6.2%	
Dynegy	B	0.56	7.2%	8.5%	42/58	6.3%		7.4%	7.1 - 11.1%	
Acquired Companies (previously traded)										
GenOn Energy							9.2 - 10.2%	10.3%	7.6 - 9.6%	
Mirant								8.0%	7.6 - 8.6%	
Merchant Generation Divestitures										
FirstEnergy Merchant Generation										7.1 - 8.1%
Allgheny Merchant Generation										7.1 - 7.6%
Duke's Merchant Generation										7.3 - 8.3%
Recommendation			**13.8%**	**7.0%**	**60/40**			**8.0%**		

Comparison to 2015/16 Parameters

Compared to Brattle's 2011 CONE Study (adjusted to 2018 $s), CT CONE values are similar in EMAAC, Rest of RTO and WMAAC and higher by 10% in SWMAAC and Dominion; CC CONE estimates are 2 to 19% higher

CT CONE values are higher than before in SWMAAC and Dominion

- Per S&L market intelligence, prevailing wage rates and productivity factors there are higher than in the prior study, reflecting largely union labor
- We now consider property taxes on personal property, increasing annual FOM
- The addition of SCR in Dominion increases total capital cost

CC CONE values are higher than before in all CONE areas

- Drivers are higher estimated contingency, project development costs, and plant O&M costs
- Higher O&M estimates explain the majority of the increased difference cost premium for CCs over CTs
- SWMAAC and Dominion increased the most due to higher assumed labor costs, property taxes, and additional costs of firm gas in SWMAAC

A. CONE Review

CONE Calculation Summary

		Simple Cycle					Combined Cycle				
		1	2	3	4	5	1	2	3	4	5
		EMAAC	SWMAAC	RTO	WMAAC	Dominion	EMAAC	SWMAAC	RTO	WMAAC	Dominion
Gross Costs											
Overnight	*($m)*	$401	$374	$347	$373	$365	$813	$736	$712	$743	$713
Installed	*($m)*	$420	$392	$364	$391	$382	$890	$805	$781	$813	$781
First Year FOM	*($m/yr)*	$6	$11	$7	$5	$8	$17	$28	$19	$15	$19
Net Summer ICAP	*(MW)*	396	393	385	383	391	668	664	651	649	660
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Reference Technology as the Average of CC and CT

Arguments for Gas CT

- Existing reference technology (as prescribed by PJM tariff)
- Continuity of market design will minimize price changes due to changes in administrative parameters
- Frequent switching based on each year's lowest Net CONE would under-procure if relative economics of technologies are switching
- Lower absolute E&AS means its estimation error has lower impact
- Existing reference technology (as prescribed by PJM tariff)

... for Gas CC

- Predominant new build in PJM & US

  Current 7FA CT may look good on paper (and recently accepted by FERC as feasible w/ SCR in NYISO), but why is no one building them?

  Is there room for gas CTs going forward or do a combination of CCs and DR make them uneconomic?
- More standardize technology and better information on for estimating CONE
- Easier to calculate forward-looking CC E&AS offset from 5x16 futures
- E&AS not as widely varying among actual plants for idiosyncratic reasons

...for Average of CC and CT

- In the long run, all <u>economic</u> resource types should have the same Net CONE; makes sense to average if they are all economic for merchant entry
- Averaging results in a closer-to-equilibrium estimate, as any one technology likely will be out of the money for temporary periods
- Prevents problems from switching and reduces impact of administrative error of estimates
- Will help mitigate impacts of volatile or uncertain E&AS estimates
- Averaging for the next 4 years would provide continuity and time to observe whether predominance of CC builds is temporary or reflects a permanent change

Level-Real vs. Level-Nominal CONE Estimates

We recommend transitioning to level-real CONE estimates

- Average CT and CC costs have increased at or above inflation rates
  - For example, CT cost trends matched CPI inflation over 1960-2010 but exceeded inflation by 60-80 basis points over 1990-2010 and by 130-150 basis points over 2000-2010
  - Environmental requirements and overseas growth may keep CT cost trends above inflation
- As a result, capacity payments increase with technology cost inflation
- However, CT and CC cost trends offset by E&AS erosion for existing plants
  - Net revenues increase by less than technology cost because E&AS revenues earned by existing plants will decline over time relative to increasingly more-efficient new plants
  - Value of revenue erosion offset likely modest (e.g., approx. $5/kW-yr over 20 years for CT or 50 basis points less than CONE increases)
- Likely positive terminal value at end of 20-year levelization period may further reduce “true” CONE value

Level-real CONE likely a more accurate estimate of how resources are compensated over time

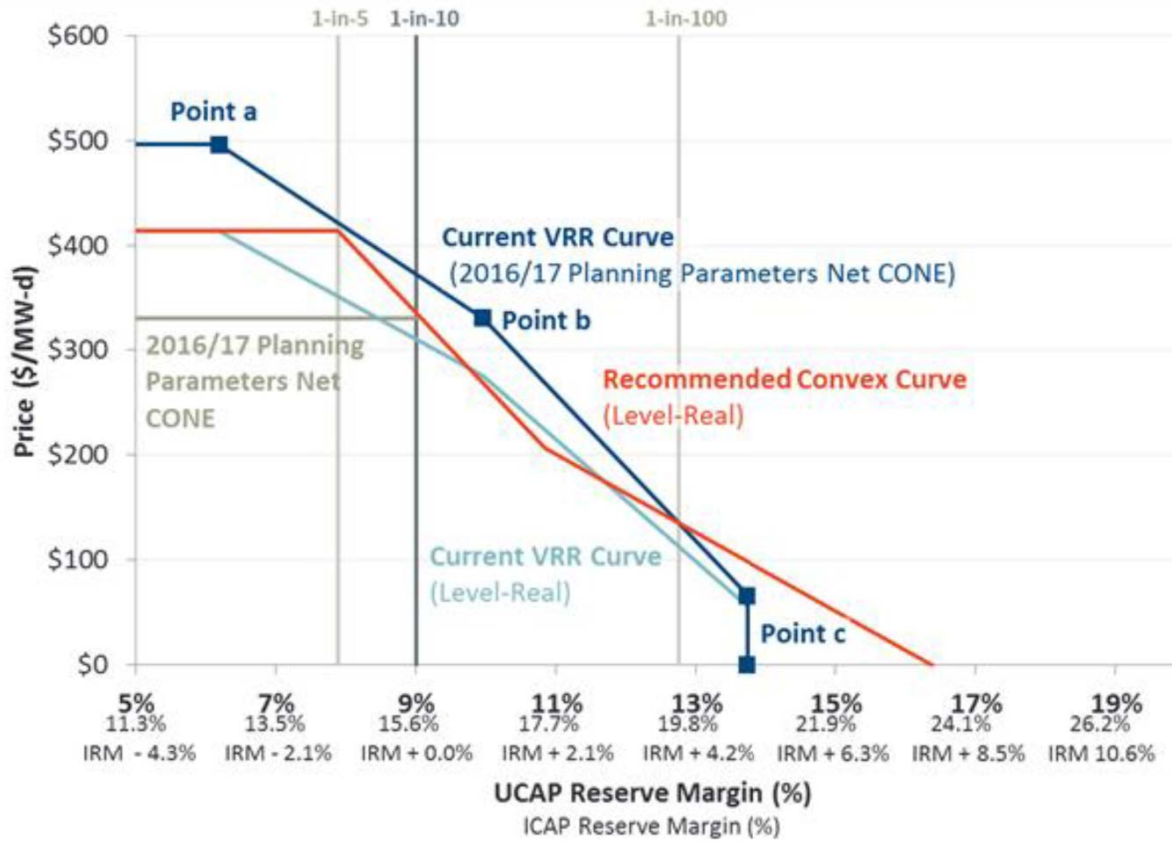
- Level-real estimates also used by NYISO and ISO-NE

A. CONE Review

Level-Real vs. Level-Nominal CONE Estimates

- Transitioning to level-real CONE would have significant implications on RPM performance unless combined with recommended revisions to VRR curve (as discussed in Section C below)
  - Dark blue line for existing VRR curve based on level nominal
  - Light blue and orange lines for VRR curves based on level real
- Downward shift in Net CONE due to transition to level-real CONE would likely be partly offset for CTs (fully offset for CCs) by calibration of currently overstated E&AS margins (see Section B below)

Implications of Shifting to Level-Real CONE Estimates on Current and Recommended VRR Curve

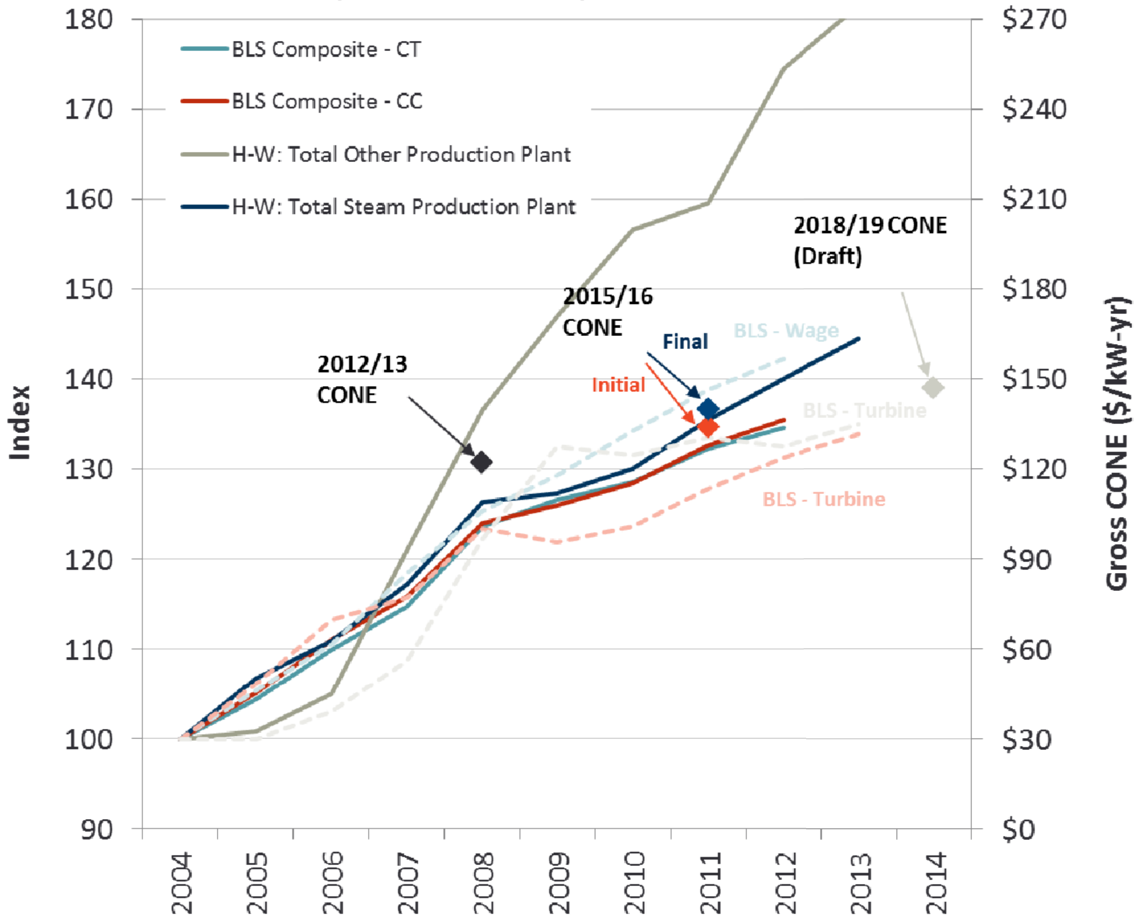


A. CONE Review

Index for Annual Updates

- Handy-Whitman "Other" index is substantially different from other estimates of cost trends for electricity generation plants
- Handy-Whitman escalates more quickly than escalation implied by the triennial update of CONE estimate
- We recommend switching to a weighted average BLS index
  - Use three BLS price indices: wage, materials, and turbines
  - Weight each index based on the relevant proportion of capital costs in a CC or CT

Handy-Whitman Indices Compared to Weighted-Average of BLS Indices



Executive Summary

Basis for Recommendations

A. CONE Review

B. **E&AS Methodology Review**

- Accuracy of Historical E&AS Estimate
- Forward-Looking E&AS Adjustments
- Locations for E&AS Calculations
- Minimum Net CONE at Parent LDA Value

C. VRR Curve Review

Appendix

Accuracy of Historical E&AS Estimate

Reviewed actual unit-specific E&AS margins from IMM and compared to PJM's historical simulation (see following slides)

- CT estimate appears accurate in most locations, although actual units' E&AS varies over an extremely wide range (may reflect poor data quality or uniquely-situated units)
- CC estimate too high in most locations

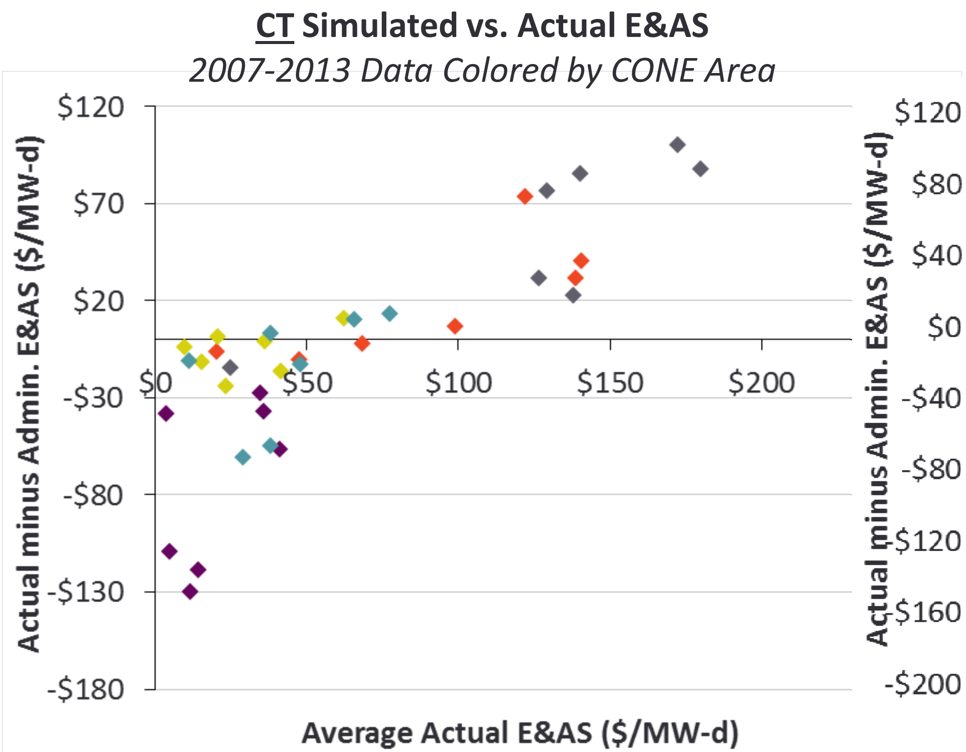
Concern in SWMAAC

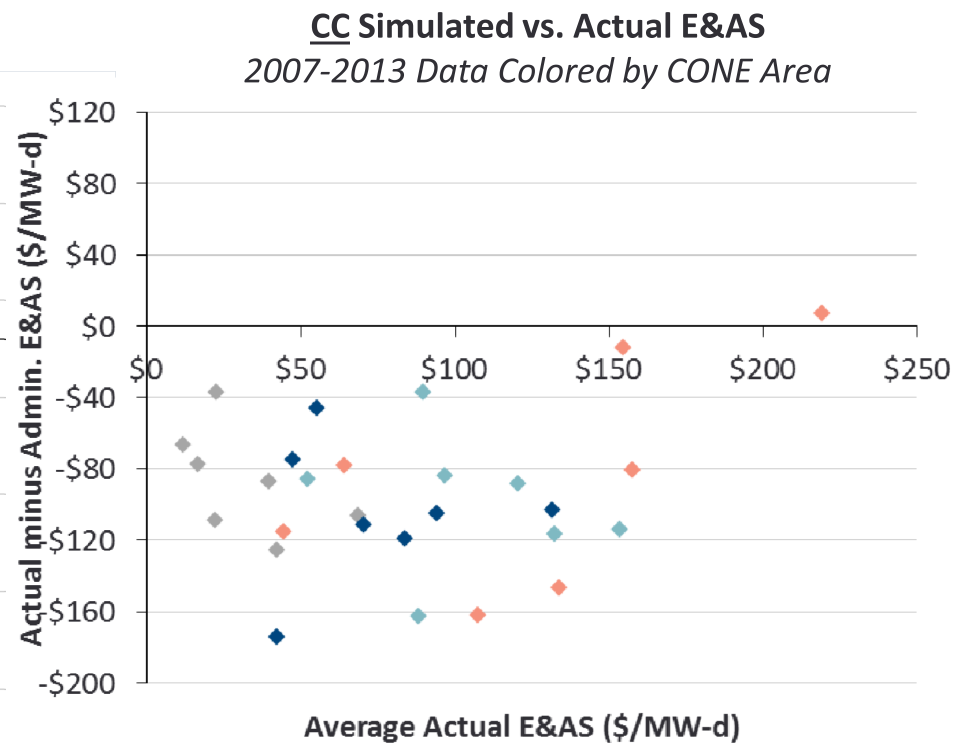
- Gas deliverability issues require more oil-based dispatch, causing higher costs and lost revenues
- Not accounting for this overstates E&AS margins (and underestimates Net CONE)

Recommended Next Steps

- We recommend that PJM investigate the historical data and reasons for the significant differences between actual and idealized virtual dispatch net revenues
- This will make it possible to find the most appropriate way to capture more realism in E&AS estimates, whether PJM continued to rely on historical estimates or transitions to forward-looking estimates (see next slides)

CT and CC Simulated vs. Actual E&AS



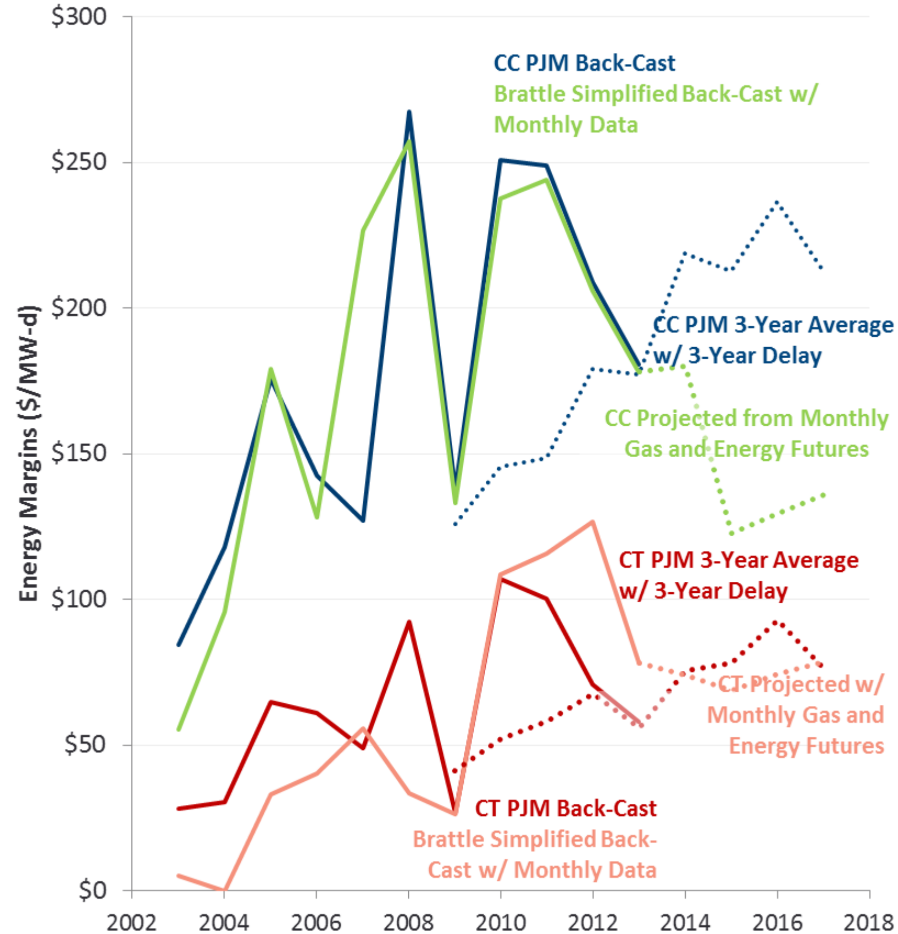


Notes:
CT chart reflects CTs > 140 MW and online since 2000.
CC chart reflects CCs > 500MW, online since 2000, not cogen.
Different dot colors represent different CONE areas.
No CC Actual data available for SWMAAC.

Historical vs. Forward-Looking E&AS

- Historical 3-year average has disadvantages:
  - 4- to 6-year delay between historical year and future delivery year; likely very different market conditions
  - New scarcity pricing mechanisms may result in unusually high E&AS in years with extreme weather or gas price events, which could artificially depress administrative Net CONE for three years
  - These effects risk Net CONE estimation errors; our simulations show asymmetric reliability consequences, with potential overstated E&AS (understated Net CONE) leading to under-procurement and steeply rising LOLE
- Transitioning to a forward-looking E&AS offset would:
  - Better reflect the data points suppliers are using to make investment decisions
  - Normalize unusual years(e.g. extreme weather)
- Illustrative example (see right) shows significant difference between historical and futures
  - Simplified historical and futures calculation use monthly data for gas and electric prices to calculate net revenues for a plant dispatched across an entire month of on- or off-peak hours when doing so is yields positive margins

Illustrative Example of Differences in Energy Margins Based on Historical vs. Forward Prices in EMAAC



Notes: Gas prices are at Transco Z6 NNY; electric prices are an average of all energy zones in EMAAC based on energy futures at W. Hub plus differential from long-term FTR auctions.

Toward Developing a Forward-Looking E&AS Approach

We have not been asked by PJM to develop a complete forward-looking E&AS methodology, but we recently worked with ISO-NE and stakeholders to develop an approach for its proposed demand curve (filed with FERC in April). This approach, approved by ISO-NE stakeholders:

- Starts with actual 3-year average E&AS margins for like units
- Adjusts prices for the 3-year forward delivery year by multiplying historical actuals by the ratio of 5x16 futures prices (from ICE) to historical 5x16 prices
- Note: We recognize that the volume of trading behind futures prices is thin, and that a 5x16 futures approach is easier and more accurate for a CC than for a CT, but the forward adjustment is much better than none

We recommend that PJM develop a similar forward-looking approach

- Consider simple adjustments to account for the different fuel mix / pricing dynamics (e.g., use both gas and electricity futures)
- Incorporate realism about actual operating conditions, costs, and revenues (see prior discussion about investigating the causes of historical inaccuracies between estimates and actuals)

B. E&AS Methodology Review

Locations for E&AS Calculations

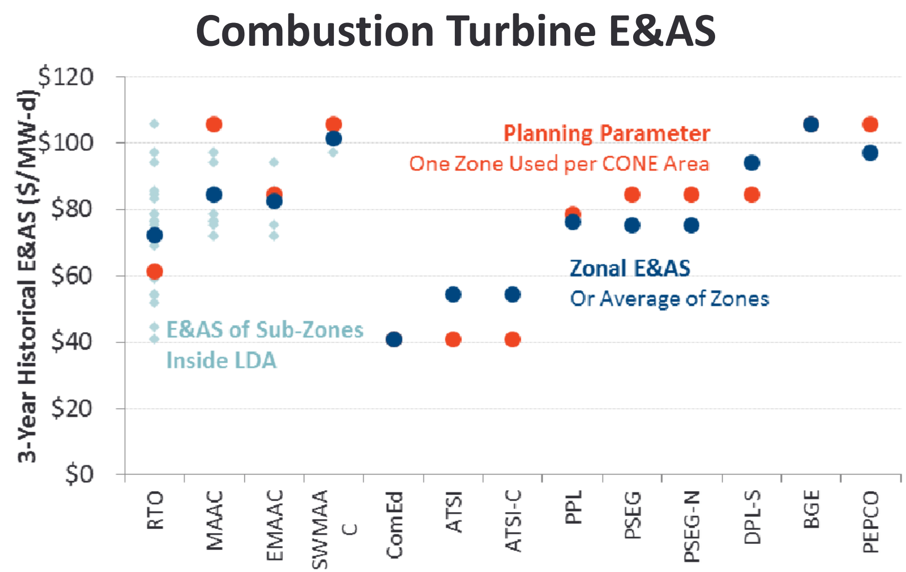
Concern

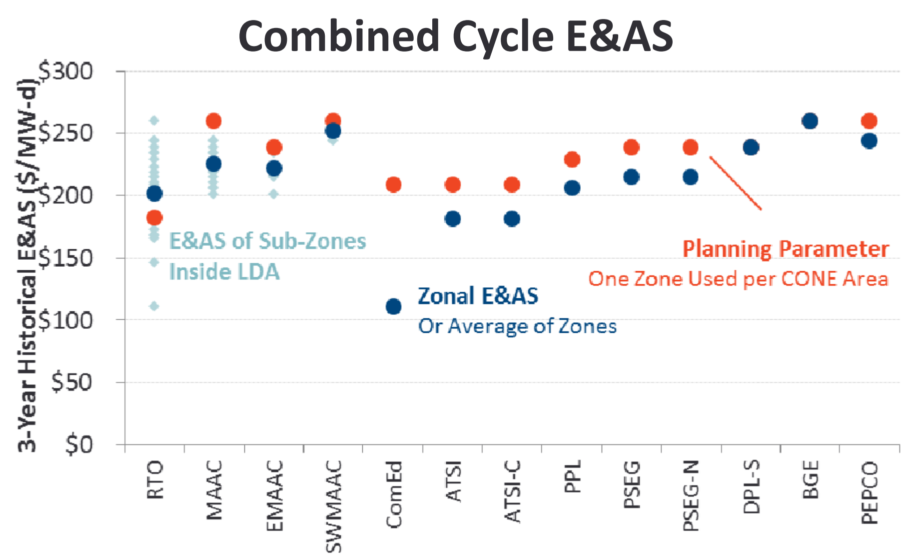
- Current tariff approach is to calculate E&AS consistent with the location of the original reference unit in the CONE Area
- LDAs are more granular than these broader CONE Areas

Recommendations

- Revise E&AS calculations to reflect conditions in each LDA using an LDA-wide generation bus average, or the mean/median of sub-zones' estimates
- Revise mapping to the actual location in question to avoid inconsistencies
  - Currently, CT E&AS offset is too low in ATSI , ATSI-Cleveland, and DPL South
  - It is too high in PSEG, PSEG-N, Pepco, & MAAC

(Also relates to CONE Areas mappings; see supplemental recommendations in Appendix)





E&AS and Net CONE in LDAs

To reduce Net CONE estimation errors and associated reliability impacts, match CONE and E&AS estimates to each modeled LDA

Do not allow Net CONE in sub-LDAs to fall below parent LDAs (or at least investigate carefully if it appears to be lower)

- If Net CONE appears lower, that may reflect estimation error
  - Especially in small LDAs, where Net CONE is not as fully calibrated
  - The fact that the area is an importer suggests barriers or net cost premiums
  - Investment lumpiness could eliminate the E&AS premium that makes Net CONE appear low
- If true Net CONE is higher, it would degrade reliability
- If true Net CONE is as low, entry could be possible, but…
  - Setting the low Net CONE offsets the incentive provided by the LDA's higher LMPs
  - With substantial entry, the LDA will stop being an importer, and the constraint won't bind or won't be modeled even if the parent Net CONE is applied as a minimum, hence no long-term harm in applying the minimum

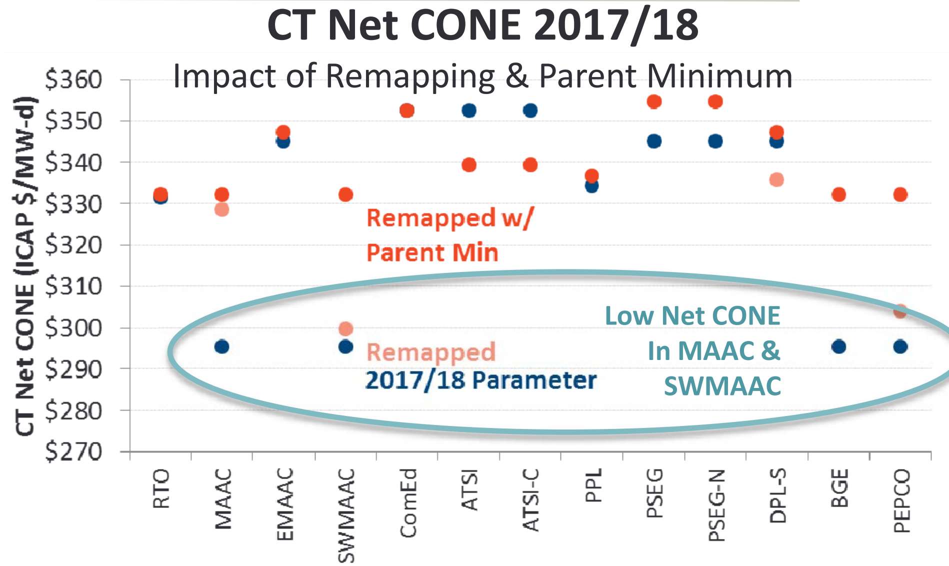
Minimum Net CONE at Parent LDA Value

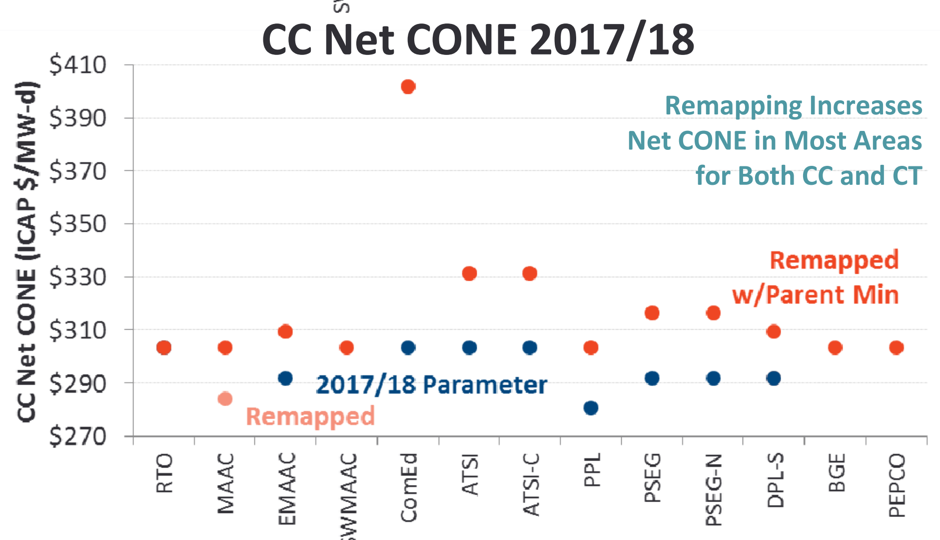
Example: Small LDAs with Net CONE set below parent Net CONE (esp. SWMAAC)

- Deviates from expectation that LDAs would not be import-constrained unless local Net CONE is higher
- Suggests that administrative local Net CONE may be inaccurately low, esp. in SWMAAC due to CONE and E&AS calculations overlooking gas availability constraints
- Even if accurate, blunts the LMP signal to locate in constrained areas
- SWMAAC problem cascades up to MAAC (whose Net CONE is set at minimum of sub-LDAs)
- SWMAAC problem may occur elsewhere if import-constrained LDAs have high energy prices but siting or fuel challenges are not reflected in CONE and E&AS
- Concerns increase as surplus capacity erodes

Recommendations

- Consider imposing the parent LDA Net CONE value as the minimum Net CONE value for sub-LDAs
- Consider eliminating current approach of setting MAAC Net CONE equal to the minimum of sub-LDAs (see Appendix)





Executive Summary

Basis for Recommendations

A. CONE Review

B. E&AS Methodology Review

C. **VRR Curve Review**

- **System VRR Curve**
  - **Approach** to Evaluating VRR Curve Performance
  - **Performance Concerns** with Existing VRR Curve
  - **Recommended Changes** to VRR Curve to Improve Performance
  - **Options for Further Safeguarding Reliability** in Stress Scenarios
- Local VRR Curves

Appendix

Design Objectives

Reliability

- Average reliability across years at 1-in-10 (primary PJM design objective)
- Limit the number of outcomes with reliability below 1-in-5 (about IRM – 1%)
- Curve should meet reliability objectives under a range of future conditions, but recognize that insuring against all eventualities comes at a cost

Prices

- Mitigate price volatility (but allow for prices that are still reflective of year-to-year changes in market conditions)
- Mitigate susceptibility to exercise of market power
- Include price cap (i.e., the top of the VRR curve) as safeguard, but price cap should rarely bind

Other

- Meet reliability and price objectives, while achieving balance between objectives where tradeoffs are necessary
- Stability in market rules and administrative estimates
- Simplicity in rules and parameter updates

Probabilistic Modeling Approach

Premise

- Simulate auction outcomes a VRR curve will provide, given a realistic supply curve and realistic annual shocks to supply, demand, and transmission (see Appendix);
- Start with long-term equilibrium where the average price across all outcomes equals Net CONE (not representing the current surplus or near-term conditions)

Approach

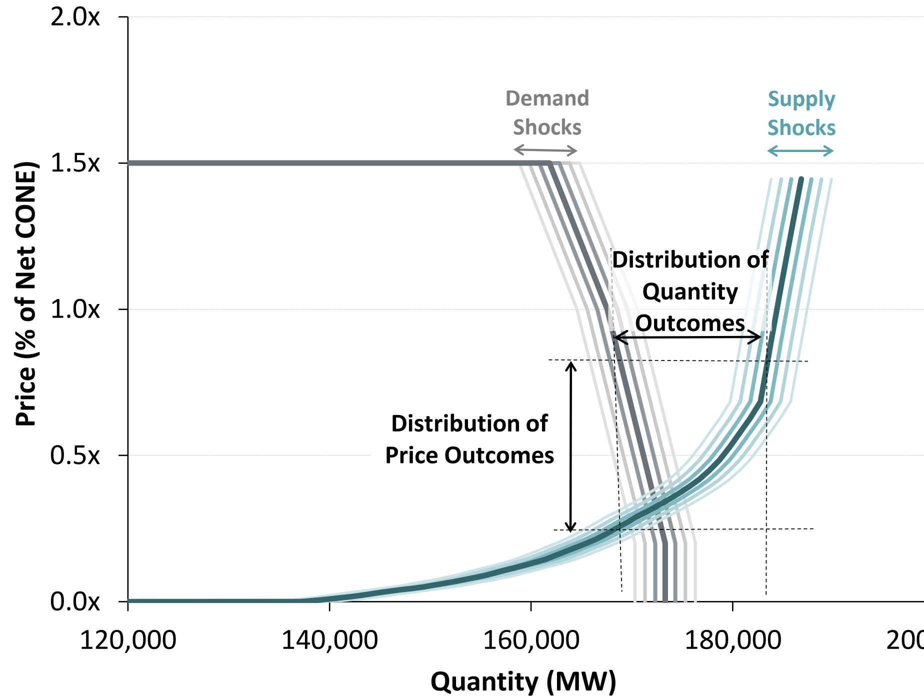
- Locational supply curves, demand curves, and transmission parameters
- Locational clearing model to calculate prices and quantities
- Monte Carlo analysis of realistic "shocks" to supply, demand, and transmission to simulate a distribution of outcomes
- Supply curve shifted such that average (long-term) price over all draws is calibrated to Net CONE

Primary Results

- Average, range, and distribution of capacity market outcomes for Price, quantity, and reliability (both system-wide and in each location)
- Results for different demand curve shapes under Base modeling assumptions and sensitivity analyses

Supply and Demand Shocks

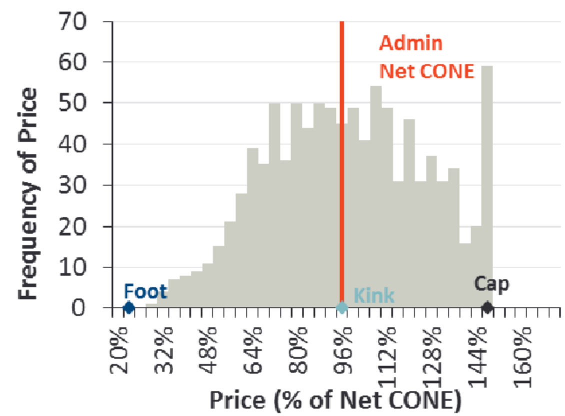
(Illustrative)



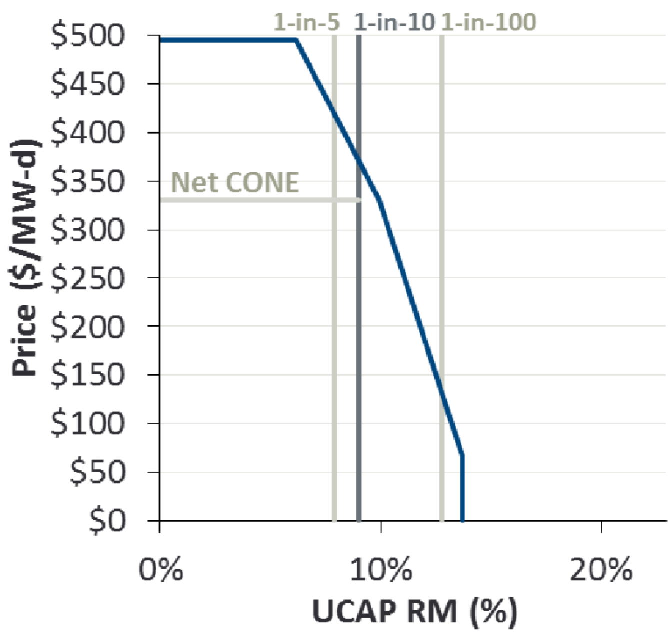
Performance of the Existing System VRR Curve

- Simulations show a high frequency of price cap events for current VRR curve
  - Assumes load forecast and Net CONE estimates accurate on average over all draws
- The quantity distribution weighted to the right of RR but with frequent low reliability events
- The following slides show stats then demonstrate even greater vulnerability under stress conditions

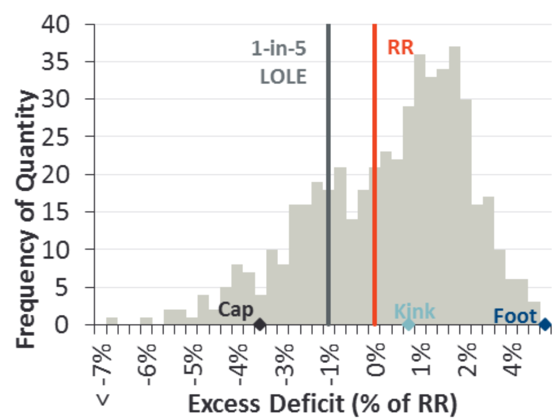
Simulated Distribution of Price Outcomes



Current VRR Curve



Simulated Distribution of Quantity Outcomes



Draft Study

Performance of the Existing System VRR Curve (cont.)

- Under base modeling assumptions, the existing VRR curve does not meet 1-in-10 objective on average
- Also shows a high portion of events below 1-in-5 (20%)
- Model is calibrated so prices equal Net CONE on average
- Price volatility of current curve is moderate

	Price			Reliability					Procurement Costs		
	Average	Standard Deviation	Freq. at Cap	Average LOLE	Average Excess (Deficit)	Reserve Margin St. Dev.	Freq. Below Rel. Req.	Freq. Below 1-in-5	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(Ev/Yr)*	*(IRM + X%)*	*(% ICAP)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
Base Modeling Assumptions											
Current VRR Curve	$330	$95	6%	0.121	0.4%	2.0%	35%	20%	$20,162	$12,669	$28,087

Performance Sensitivity to Modeling Uncertainty

- We change shocks sizes to test the robustness of base modeling assumption results
- Decreasing/eliminating shocks improves reliability and reduced price volatility
- Increasing shocks causes worse reliability outcomes and more price volatility

	Price			**Reliability**					**Procurement Costs**		
	Average	Standard Deviation	Freq. at Cap	Average LOLE	Average Excess (Deficit)	Reserve Margin St. Dev.	Freq. Below Rel. Req.	Freq. Below 1-in-5	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(Ev/Yr)*	*(IRM + X%)*	*(% ICAP)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
Current VRR Curve											
Current VRR Curve	$330	$95	6%	0.121	0.4%	2.0%	35%	20%	$20,162	$12,669	$28,087
Zero Out Supply Shocks	$330	$50	0%	0.074	0.8%	1.0%	22%	4%	$20,269	$16,352	$24,807
Zero Out Demand Shocks	$331	$91	4%	0.115	0.5%	1.9%	35%	19%	$20,172	$12,832	$27,620
Zero Out Net CONE Shocks	$331	$93	5%	0.120	0.5%	2.0%	35%	20%	$20,173	$12,605	$27,754
All Shocks 33% Higher	$330	$115	12%	0.186	0.2%	2.7%	39%	26%	$20,075	$10,917	$29,619
All Shocks 33% Lower	$330	$70	1%	0.089	0.7%	1.4%	29%	11%	$20,221	$14,821	$26,218

C. System VRR Curve Review – Performance Concerns

Performance with Higher/Lower Net CONE

- Tested curves performance under different Net CONE conditions
  - 20% higher, 20% lower, and 50% lower net CONE values
  - Still assumes administrative Net CONE equals true Net CONE
- Lower Net CONE improves reliability due to higher supply elasticity in that range of supply curve

	Price			Reliability					Procurement Costs		
	Average *($/MW-d)*	Standard Deviation *($/MW-d)*	Freq. at Cap *(%)*	Average LOLE *(Ev/Yr)*	Average Excess (Deficit) *(IRM + X%)*	Reserve Margin St. Dev. *(% ICAP)*	Freq. Below Rel. Req. *(%)*	Freq. Below 1-in-5 *(%)*	Average *($mil)*	Average of Bottom 20% *($mil)*	Average of Top 20% *($mil)*
<u>With</u> Price Cap Minimum at Gross CONE											
20% Higher Net CONE	$396	$120	7%	0.130	0.4%	2.2%	37%	22%	$24,156	$14,816	$34,153
Base Case	$330	$95	6%	0.121	0.4%	2.0%	35%	20%	$20,162	$12,669	$28,087
20% Lower Net CONE	$264	$73	5%	0.114	0.5%	2.0%	33%	17%	$16,141	$10,283	$22,185
50% Lower Net CONE	$166	$57	0%	0.076	1.0%	1.6%	25%	7%	$10,157	$5,897	$15,323
<u>Without</u> Price Cap Minimum at Gross CONE											
50% Lower Net CONE	$166	$50	7%	0.150	0.1%	2.5%	39%	22%	$10,089	$6,214	$14,631

Sensitivity to Errors in Admin Net CONE

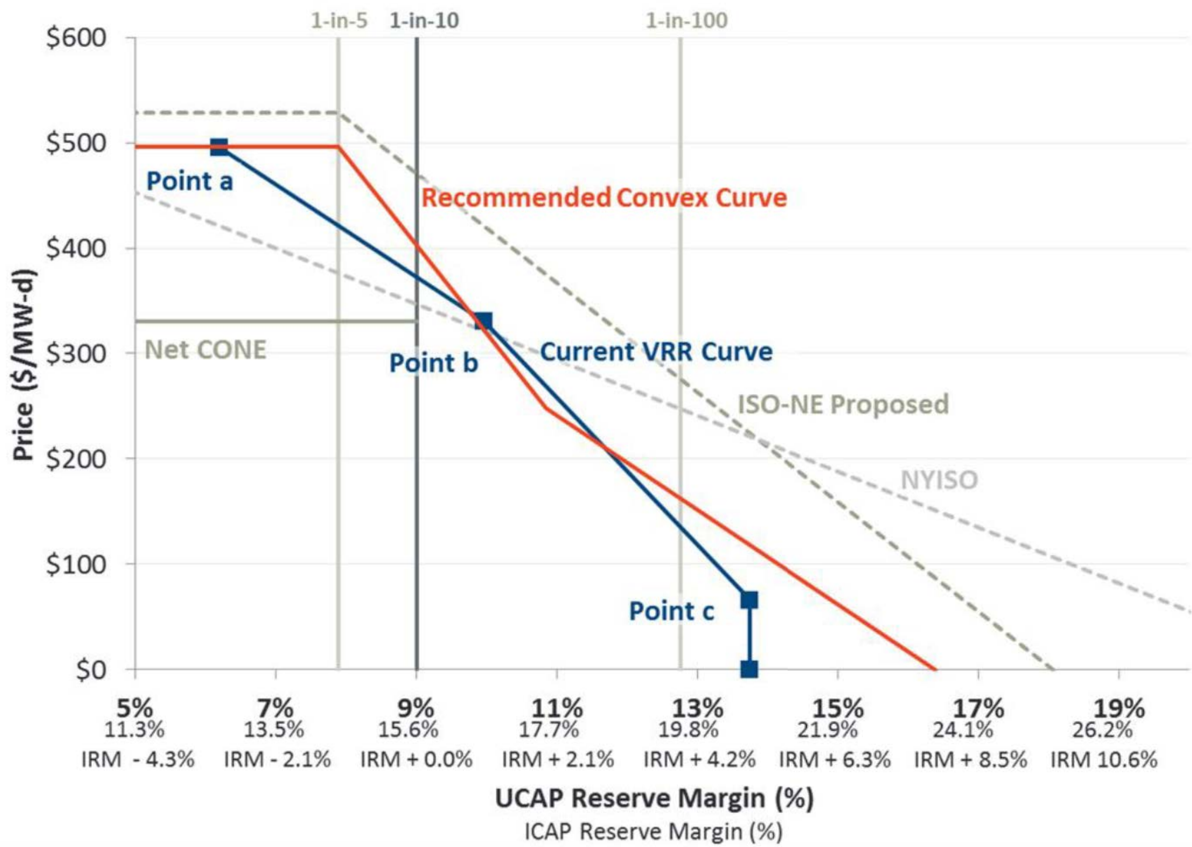
- Also tested results when administrative Net CONE does not equal True Net CONE
  - Demand curve is based on administrative Net CONE, but model is calibrated so that average price across all draws equals true Net CONE
- Administrative Net CONE errors have a substantial impact on reliability outcomes
  - Especially true for under-estimating Net CONE, which has high frequencies of low-reliability events

	Price			Reliability					Procurement Costs		
	Average	Standard Deviation	Freq. at Cap	Average LOLE	Average Excess (Deficit)	Reserve Margin St. Dev.	Freq. Below Rel. Req.	Freq. Below 1-in-5	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(Ev/Yr)*	*(IRM + X%)*	*(% ICAP)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
Base Case											
20% Over-Estimate	$330	$114	1%	0.064	1.5%	1.8%	18%	8%	$20,323	$11,551	$30,536
Accurate Net CONE	$330	$95	6%	0.121	0.4%	2.0%	35%	20%	$20,162	$12,669	$28,087
20% Under-Estimate	$330	$64	26%	0.370	-1.7%	2.5%	69%	50%	$19,770	$14,722	$24,484
True Net CONE 50% Lower (No Minimum on Cap)											
20% Over-Estimate	$165	$56	2%	0.069	1.4%	1.9%	19%	8%	$10,174	$5,922	$15,310
Accurate Net CONE	$166	$50	7%	0.150	0.1%	2.5%	39%	22%	$10,089	$6,214	$14,631
20% Under-Estimate	$165	$43	29%	0.713	-2.3%	3.4%	72%	55%	$9,857	$6,617	$13,582
True Net CONE 50% Lower (Cap at Gross CONE Min.)											
20% Over-Estimate	$165	$60	0%	0.048	1.7%	1.5%	10%	2%	$10,221	$5,732	$15,942
Accurate Net CONE	$166	$57	0%	0.076	1.0%	1.6%	25%	7%	$10,157	$5,897	$15,323
20% Under-Estimate	$165	$50	4%	0.143	-0.1%	1.8%	49%	25%	$10,040	$6,144	$14,312

Recommended Convex System VRR Curve

We recommend changing the VRR curve in two steps to better meet reliability objectives:

- Right-shift point "a" to 1-in-5 LOLE (to approx. IRM – 1%), which substantially improves reliability
  - Allows prices to rise faster when needed to avoid very low reserve margins
  - Helps the auction to procure all available resources before PJM's trigger point for backstop procurement at IRM-1
- Change the curve shape to convex by stretching the lower half of the curve
  - Consistent with more gradual decline in reliability value at higher RM



***Notes**:*
All curves are scaled to the 2016/17 PJM Planning Parameters Net CONE.
ISO-NE and NYISO quantity points are scaled based on quantity as a percentage of reliability requirement, with the ISO-NE Proposed curve cap fixed at 1-in-5 LOLE.

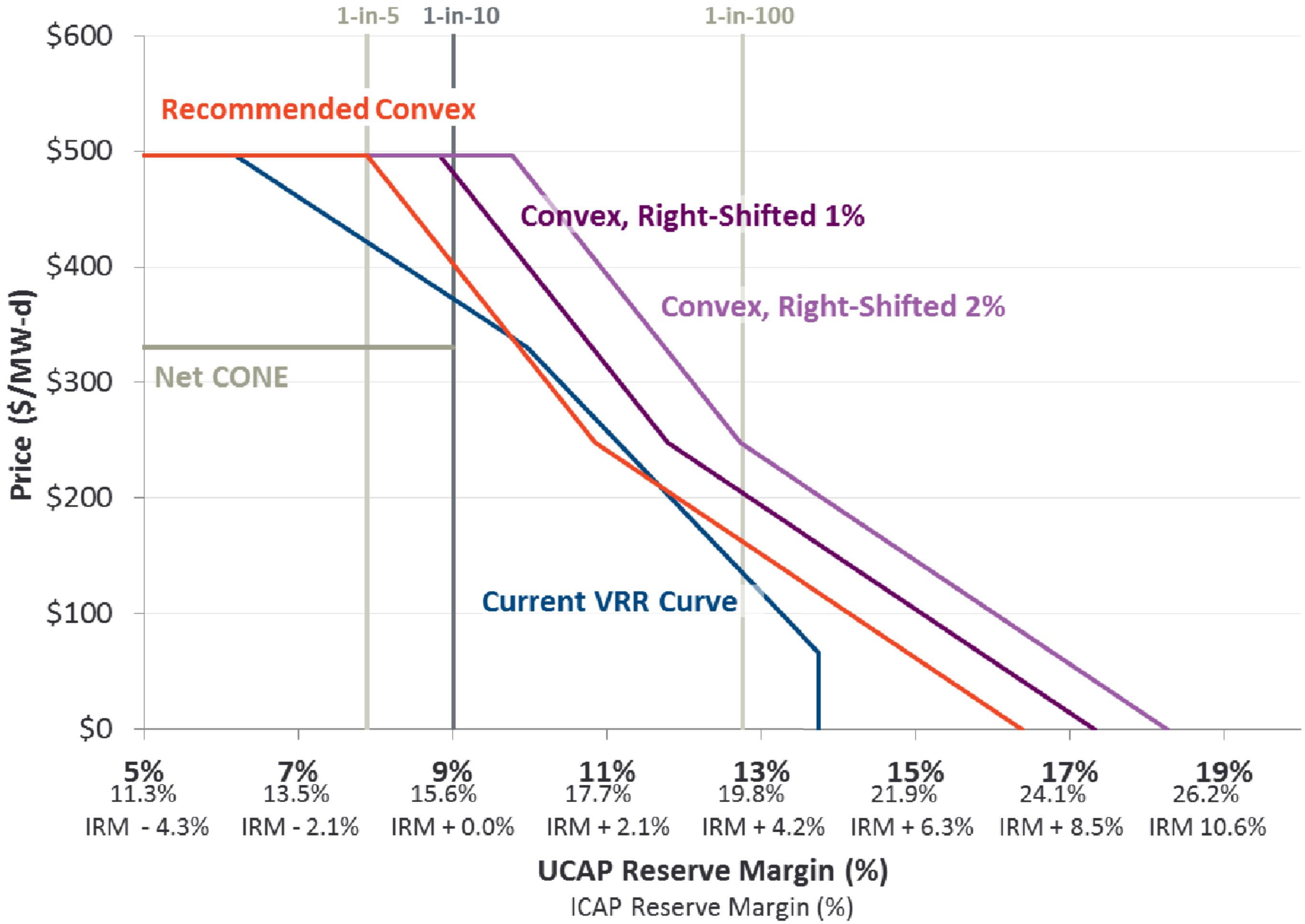
Convex VRR Curves Improve Reliability

- Our recommended convex curve is tuned to 1-in-10 LOLE and has fewer low-reliability events than the existing VRR curve
- Although the convex curve is steeper at low reserve margins, it is less steep at high reserve margins and avoids the cliff at point "c," which helps reduce price volatility when in that range
- The convex curve also performs better under stress scenarios (under-estimate Net CONE or higher supply/demand shocks)

	Price			Reliability					Procurement Costs		
	Average	Standard Deviation	Freq. at Cap	Average LOLE	Average Excess (Deficit)	Reserve Margin St. Dev.	Freq. Below Rel. Req.	Freq. Below 1-in-5	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(Ev/Yr)*	*(IRM + X%)*	*(% ICAP)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
Base Modeling Assumptions											
Current VRR Curve	$330	$95	6%	0.121	0.4%	2.0%	35%	20%	$20,162	$12,669	$28,087
Recommended Convex	$329	$107	13%	0.100	0.7%	1.9%	29%	13%	$20,146	$12,340	$29,538
20% Under-Estimate in Net CONE											
Current VRR Curve	$330	$64	26%	0.370	-1.7%	2.5%	69%	50%	$19,770	$14,722	$24,484
Recommended Convex	$330	$73	39%	0.282	-1.1%	2.4%	59%	39%	$19,859	$13,591	$25,199
33% Higher Shocks											
Current VRR Curve	$330	$115	12%	0.186	0.2%	2.7%	39%	26%	$20,075	$10,917	$29,619
Recommended Convex	$330	$124	21%	0.156	0.5%	2.7%	34%	21%	$20,112	$10,916	$30,850

Right-Shifting the Curve as Insurance?

- Recognizing that our recommended curve still does not perform well under stress scenarios with higher supply-demand shocks or Net CONE underestimation, PJM may consider options that further safeguard reliability by right-shifting the curve



Notes:
All curves are scaled to the 2016/17 PJM Planning Parameters Net CONE.
The Convex, Right-Shifted 1% curve shifts all three curve points by 1% in IRM terms, e.g., the cap moves from 14.4 % (IRM - 1.2%) to 15.4% (IRM – 0.2%).

Sensitivity to Shock Sizes

- Under base scenario, right-shifted curves have fewer low-reliability events (only 7% and 3% below 1-in-5)
  - However, procurement costs are higher (1% and 2% above the recommended convex curve)
- The main benefit is that the right-shifted curves have better reliability under stress scenarios where Net CONE is underestimated or shocks to supply/demand are higher

	Price			Reliability					Procurement Costs		
	Average *($/MW-d)*	Standard Deviation *($/MW-d)*	Freq. at Cap *(%)*	Average LOLE *(Ev/Yr)*	Average Excess (Deficit) *(IRM + X%)*	Reserve Margin St. Dev. *(% ICAP)*	Freq. Below Rel. Req. *(%)*	Freq. Below 1-in-5 *(%)*	Average *($mil)*	Average of Bottom 20% *($mil)*	Average of Top 20% *($mil)*
Base Modeling Assumptions											
Current VRR Curve	$330	$95	6%	0.121	0.4%	2.0%	35%	20%	$20,162	$12,669	$28,087
Recommended Convex	$329	$107	13%	0.100	0.7%	1.9%	29%	13%	$20,146	$12,340	$29,538
Convex, Right-Shifted 1%	$330	$107	13%	0.060	1.7%	1.9%	16%	7%	$20,333	$12,431	$29,785
Convex, Right-Shifted 2%	$330	$107	14%	0.036	2.7%	1.9%	8%	3%	$20,516	$12,541	$30,057
20% Under-Estimate in Net CONE											
Current VRR Curve	$330	$64	26%	0.370	-1.7%	2.5%	69%	50%	$19,770	$14,722	$24,484
Recommended Convex	$330	$73	39%	0.282	-1.1%	2.4%	59%	39%	$19,859	$13,591	$25,199
Convex, Right-Shifted 1%	$330	$74	39%	0.182	-0.1%	2.4%	42%	28%	$20,037	$13,708	$25,426
Convex, Right-Shifted 2%	$330	$73	39%	0.116	0.9%	2.4%	29%	19%	$20,219	$13,848	$25,636
33% Higher Shocks											
Current VRR Curve	$330	$115	12%	0.186	0.2%	2.7%	39%	26%	$20,075	$10,917	$29,619
Recommended Convex	$330	$124	21%	0.156	0.5%	2.7%	34%	21%	$20,112	$10,916	$30,850
Convex, Right-Shifted 1%	$330	$124	21%	0.099	1.5%	2.7%	23%	14%	$20,284	$10,998	$31,123
Convex, Right-Shifted 2%	$330	$125	21%	0.062	2.5%	2.7%	16%	9%	$20,461	$11,029	$31,399

Executive Summary

Basis for Recommendations

A. CONE Review

B. E&AS Methodology Review

C. **VRR Curve Review**

- System VRR Curve
- **Local VRR Curves**
  - **Overview** of Local Challenges and Recommendations
  - **Simulations Showing Performance Concerns** with Existing Curves
  - Simulations Showing How **Recommendations Improve Performance**

Appendix

Local VRR Curve Challenges

- LDAs are similar to the system, but also depend on CETL, which tends to fluctuate and introduce additional volatility in prices and quantities
  - We estimate 12% standard deviation in CETL values, based on historical data (see Appendix).
- Most importantly, LDAs are small relative to realistic fluctuations in supply, demand, and CETL.
  - In the smallest LDA (DPL-S), a 700 MW plant is more than 3x the width of the VRR curve (from pt “a” to “c”).
  - Highly import-dependent LDAs are sensitive to CETL shocks
  - In PEPCO, CETL would represent 60% of the reliability requirement whenever the LDA is import-constrained; a drop in CETL by 12% would correspond to a 625 MW drop in total supply , or more than 100% of the width of the entire VRR curve
- The large size of shocks relative to the curve width causes greater volatility in prices
  - One generating unit or CETL shock can move from the top to the bottom of the curve, eliminating any premium from the parent area
  - Historically, prices have been most volatile in the LDAs, driven especially by CETL changes
- The large relative size of shocks also makes LDAs vulnerable to low reliability outcomes
  - Wide distribution of LDA reserve margins (high percentage deviations from local reliability requirements)
  - Low local reserve margin outcomes translate to reliability below the LDA objective of 0.04 conditional LOLE
- Further threatening reliability, the likelihood of Net CONE estimation error is higher in small LDAs, and the reliability impacts are greater than at the system level
  - Estimation error is more likely due to idiosyncratic siting and environmental factors, which may not be discovered in CONE studies due to sparse data on actual projects’ costs (and if the LDA is not its own CONE area), and because E&AS margins are harder to calibrate if there are few comparable plants
  - Developers may avoid building efficient-scale plants to prevent collapsing the price premium for many years
  - Simulations show that underestimation degrades reliability, particularly in LDAs

Recommendations to Address Challenges

- The <u>same changes we recommended for the system</u> (move point "a" right to approx. IRM-1%, and stretch the curve into a convex shape) will also help in the LDAs
  - Without moving point "a," LDA prices would not reach the cap until reliability falls substantially below target
- However, <u>these changes are not enough for LDAs</u> to meet reliability targets given the greater challenges described on the prior slide
- It makes sense to <u>raise the LDA price caps</u> to protect against low reliability outcomes, particularly in the event of Net CONE underestimation
  - Raising LDA price caps from 1.5 Net CONE to 1.7 Net CONE would help reliability substantially, but still not to target levels in all LDAs under a reasonable range of LDA Net CONE premia (without even assuming estimation error), and it slightly increases already-high price volatility
- It also makes sense to <u>stretch the curve rightward in the smaller, more import-dependent zones</u>, so that the curve is wider and less sensitive to fluctuations in supply, demand, and CETL
  - We tested many approaches and found that the most targeted and effective way to improve performance is by applying a minimum curve width (from points "a" to "c") of 25% of CETL
  - By imposing a minimum width at a percentage of CETL we tie the level of right-stretching more closely with both LDA size (which approximately scales with CETL) as well as the level of import dependence
- We recommend all of the above changes

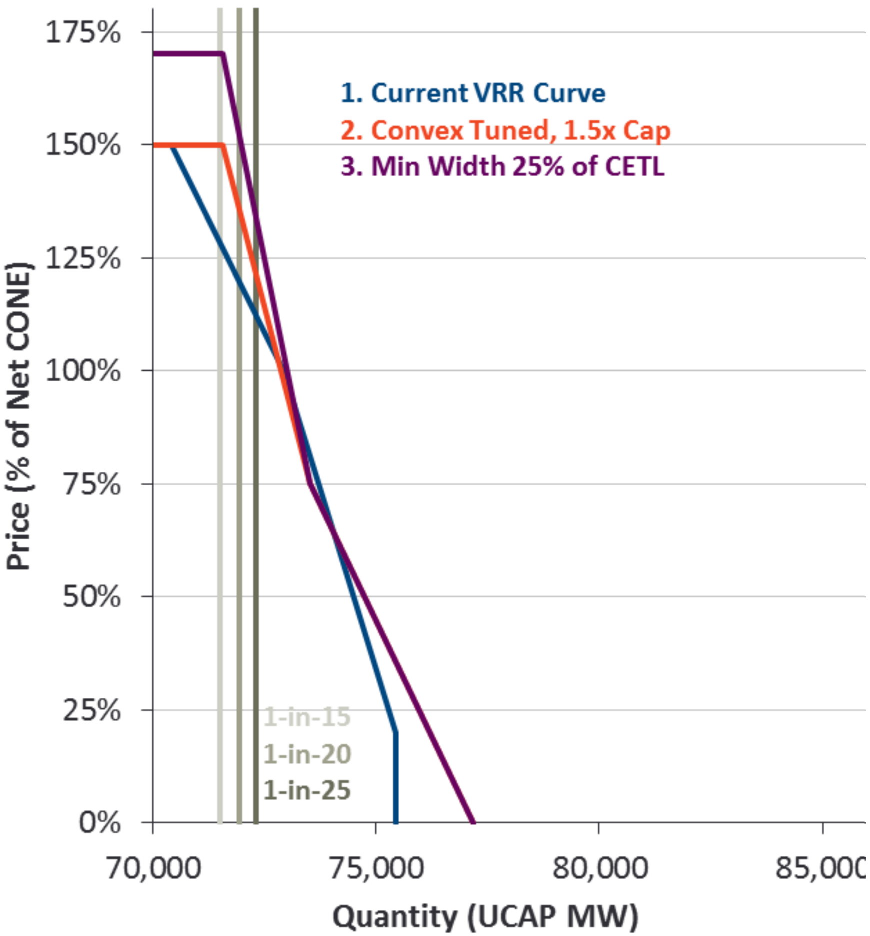
The combined effects on the Local VRR curves are shown on the next two slides

Subsequent slides will describe the simulation analysis supporting this recommendation

Illustration of Recommended Revisions to Local Curves

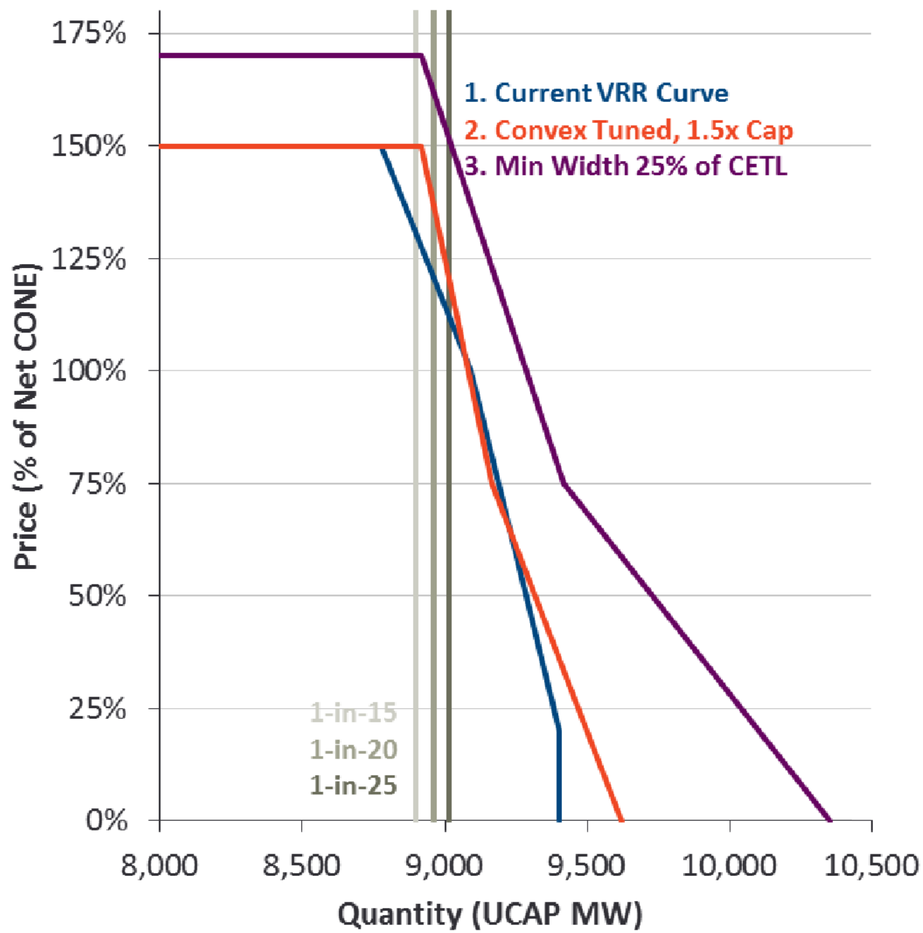
MAAC

Minimum-width constraint not binding, similar in EMAAC



PEPCO

Minimum-width constraint binding, as in other LDAs (by different amounts)



Recommended Right-Stretch Varies by LDA

Curve Width (distance from point "a" at the cap to "c" at the bottom of the curve)

Expressed in in UCAP terms and as a percentage of reliability requirement

LDA	Absolute Curve Width: Current VRR (MW)	Absolute Curve Width: Convex Tuned (MW)	Absolute Curve Width: Min Width 25% of CETL (MW)	Curve Width (% of RR): Current VRR (%)	Curve Width (% of RR): Convex Tuned (%)	Curve Width (% of RR): Min Width 25% of CETL (%)
MAAC	5,003	5,639	5,639	6.9%	7.8%	7.8%
EMAAC	2,747	3,096	3,096	6.9%	7.8%	7.8%
SWMAAC	1,198	1,351	1,785	6.9%	7.8%	10.3%
ATSI	1,125	1,268	1,814	6.9%	7.8%	11.2%
PSEG	891	1,004	1,560	6.9%	7.8%	12.1%
PEPCO	624	703	1,433	6.9%	7.8%	15.9%
PSEG-N	446	502	683	6.9%	7.8%	10.6%
ATSI-Cleveland	427	481	1,273	6.9%	7.8%	20.7%
DPL-S	219	246	459	6.9%	7.8%	14.5%

Framework for Analysis of Current vs. Recommended Local VRR Curves

- LDA challenges would be avoided if true Net CONE in sub-LDAs were lower than in parent LDAs
  - Developers would build, the LDA would not be import-constrained, and reliability and prices would converge to the parent LDA levels
  - Our simulations confirmed this intuitive result
- Challenges persist if Net CONE in sub-LDAs are higher than in parent LDAs
  - Higher Net CONE discourages construction unless price separation is frequent enough to provide the needed premium, but price separation occurs only when reserve margins are relatively low
  - As discussed in the E&AS Methodology section, we believe import-constrained LDAs should have Net CONE values at least as high as parent LDAs (else they would not be import-constrained)
  - VRR curve shapes should provide acceptable performance under this likely scenario for Net CONE values
- To evaluate this challenge, we analyzed VRR curves under 2 cases with higher Net CONE in LDAs (assuming administrative Net CONE = true Net CONE):
  - LDA Net CONE 5% higher than each successive parent area (e.g., PS-N 20% above RTO)
  - Same as above, but 20% higher in smallest LDAs: PS-N, DPL-S, PEPCO, and ATSI-C (e.g., PS-N 35% above RTO)
- We also test a stress case with Net CONE underestimated by 20% in each LDA
- Results show that neither the current local VRR curves nor the recommended system-level convex curve meets LDA reliability targets
  - Some LDAs fail to meet targets under the 2 Net CONE cases
  - Most LDAs fail to meet targets under the stress case
- However, recommended local VRR curves (1.7x cap plus stretched to 25% CETL) meet target performance under the 2 simulated Net CONE cases (and substantially improve stress case results)

C. Local VRR Curve Review – Performance Concerns

Current VRR and Convex Curves' Performance

- When Net CONE in each sub-LDAs is 5% higher than in parent LDA:
  - Current VRR curve falls short of 0.04 conditional LOLE in four LDAs
  - Convex curve with 1.5x cap (corresponding to the recommended system curve) shows modest improvement but falls short of 0.04 in 3 LDAs
- In the scenario where Net CONE is 5% higher than parent areas and 20% higher in the smallest LDAs, even the convex curve falls short in 5 LDAs

	Price				Reliability								Procurement Costs		
	Average	St. Dev	Freq. at Cap	Freq. of Price Separation	Conditional Average LOLE	Conditional Average LOLE (Additive)	Average Excess (Deficit) Above Rel. Req.	St. Dev.	Average Quantity as % of Rel. Req.	St. Dev. as % of Rel. Req.	Freq. Below Rel. Req.	Freq. Below 1-in-15	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(%)*	*(Ev/Yr)*	*(Ev/Yr)*	*(MW)*	*(MW)*	*(%)*	*(%)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
Current VRR Curve, Net CONE 5% Higher than Parent															
MAAC	$277	$89	12%	33%	0.053	0.160	1389	2356	102%	3%	27%	17%	$7,218	$4,199	$10,669
EMAAC	$291	$98	8%	25%	0.033	0.193	1349	1706	103%	4%	22%	15%	$4,058	$2,274	$6,049
SWMAAC	$291	$96	6%	17%	0.042	0.202	1215	1163	107%	7%	14%	8%	$1,689	$969	$2,504
ATSI	$277	$87	11%	18%	0.035	0.143	1152	1121	107%	7%	14%	11%	$1,476	$904	$2,120
PSEG	$305	$105	5%	15%	0.022	0.215	1036	886	108%	7%	13%	9%	$1,351	$730	$2,003
PEPCO	$305	$104	25%	14%	0.064	0.266	1099	923	112%	10%	11%	10%	$856	$471	$1,292
PS-N	$321	$116	31%	15%	0.023	0.238	503	442	108%	7%	12%	8%	$687	$361	$1,047
ATSI-C	$291	$95	10%	12%	0.059	0.202	906	694	115%	11%	9%	8%	$533	$316	$796
DPL-S	$305	$105	13%	15%	0.027	0.220	309	259	110%	8%	12%	7%	$308	$167	$464
Convex Curve w/1.5x Cap; Assume LDA Net CONEs are 5% Higher than Each Successive Parent															
MAAC	$277	$97	14%	31%	0.043	0.131	1615	2315	102%	3%	23%	14%	$7,234	$4,047	$11,069
EMAAC	$291	$107	12%	23%	0.027	0.158	1536	1694	104%	4%	18%	11%	$4,066	$2,194	$6,294
SWMAAC	$291	$104	8%	16%	0.034	0.165	1311	1159	108%	7%	12%	7%	$1,692	$934	$2,604
ATSI	$277	$95	9%	17%	0.030	0.117	1232	1118	108%	7%	12%	9%	$1,479	$879	$2,209
PSEG	$305	$114	8%	14%	0.019	0.177	1106	885	109%	7%	11%	7%	$1,354	$699	$2,075
PEPCO	$305	$111	9%	14%	0.055	0.219	1138	922	113%	10%	10%	8%	$858	$454	$1,337
PS-N	$321	$123	8%	14%	0.019	0.196	537	443	108%	7%	10%	6%	$688	$342	$1,077
ATSI-C	$291	$102	7%	11%	0.048	0.166	943	695	115%	11%	9%	7%	$534	$303	$821
DPL-S	$305	$113	7%	15%	0.023	0.182	323	259	110%	8%	10%	6%	$309	$160	$480
Convex Curve w/1.5x Cap; Assume LDA Net CONEs are 5% higher than each successive parent but 20% higher in PS-N, DPL-S, PEPCO, and ATSI-C															
MAAC	$277	$98	14%	31%	0.044	0.132	1604	2319	102%	3%	23%	14%	$7,358	$4,148	$11,152
EMAAC	$291	$107	13%	24%	0.028	0.160	1523	1697	104%	4%	19%	12%	$4,149	$2,228	$6,343
SWMAAC	$291	$104	8%	16%	0.034	0.166	1317	1162	108%	7%	12%	7%	$1,732	$968	$2,629
ATSI	$277	$95	9%	17%	0.030	0.118	1232	1119	108%	7%	12%	9%	$1,498	$893	$2,213
PSEG	$305	$114	9%	14%	0.019	0.178	1108	885	109%	7%	11%	8%	$1,415	$719	$2,139
PEPCO	$349	$137	23%	35%	0.423	0.589	540	899	106%	10%	26%	22%	$914	$488	$1,381
PS-N	$367	$149	22%	39%	0.067	0.245	237	429	104%	7%	28%	19%	$758	$356	$1,155
ATSI-C	$332	$127	21%	31%	0.630	0.748	461	686	108%	11%	23%	21%	$566	$316	$849
DPL-S	$349	$139	21%	35%	0.107	0.267	164	253	105%	8%	26%	20%	$336	$166	$510

Sensitivity to Administrative Net CONE Error

- The risk of Net CONE estimation error is even greater at the LDA level than the system level because (1) estimation error is more likely, esp. for the smallest LDAs with no location-specific Gross CONE or calibrated E&AS estimate; and (2) a given percentage error has a larger impact at the LDA level
- If Net CONE is 20% under-estimated in LDAs, both the current VRR curve and the convex (1.5x capped) system-level curve show reliability shortfalls in <u>all</u> LDAs
- Net CONE under-estimation leads to greater degradation of reliability in LDAs than at system level

	Price				Reliability								Procurement Costs		
	Average ($/MW-d)	St. Dev ($/MW-d)	Freq. at Cap (%)	Freq. of Price Separation (%)	Conditional Average LOLE (Ev/Yr)	Conditional Average LOLE (Additive) (Ev/Yr)	Average Excess (Deficit) Above Rel. Req. (MW)	St. Dev. (MW)	Average Quantity as % of Rel. Req. (%)	St. Dev. as % of Rel. Req. (%)	Freq. Below Rel. Req. (%)	Freq. Below 1-in-15 (%)	Average ($mil)	Average of Bottom 20% ($mil)	Average of Top 20% ($mil)
Current VRR, Assuming Net CONE is Underestimated by 20% in each LDA															
MAAC	$277	$63	24%	52%	0.219	0.518	-365	2570	100%	4%	54%	41%	$7,183	$4,868	$9,343
EMAAC	$291	$70	25%	40%	0.103	0.621	151	1790	100%	5%	46%	34%	$4,035	$2,646	$5,305
SWMAAC	$291	$67	22%	29%	0.180	0.699	593	1182	103%	7%	32%	24%	$1,685	$1,117	$2,194
ATSI	$277	$61	22%	31%	0.128	0.427	528	1137	103%	7%	33%	27%	$1,466	$1,024	$1,884
PSEG	$306	$73	22%	26%	0.085	0.706	512	897	104%	7%	28%	22%	$1,341	$867	$1,747
PEPCO	$305	$71	22%	24%	0.404	1.103	639	934	107%	10%	25%	21%	$857	$554	$1,133
PS-N	$321	$78	21%	27%	0.076	0.782	233	446	104%	7%	30%	21%	$683	$426	$902
ATSI-C	$291	$65	20%	20%	0.445	0.873	543	694	109%	11%	20%	18%	$533	$357	$705
DPL-S	$306	$73	21%	24%	0.106	0.727	175	259	106%	8%	26%	20%	$308	$194	$409
Convex Curve w/1.5x Cap, Assuming Net CONE is Underestimated by 20% in each LDA															
MAAC	$277	$70	33%	49%	0.161	0.382	36	2516	100%	3%	45%	33%	$7,211	$4,495	$9,565
EMAAC	$291	$76	30%	41%	0.084	0.466	384	1771	101%	4%	39%	29%	$4,054	$2,465	$5,408
SWMAAC	$291	$73	22%	28%	0.139	0.521	714	1178	104%	7%	27%	20%	$1,692	$1,041	$2,242
ATSI	$277	$68	23%	31%	0.104	0.326	630	1129	104%	7%	29%	23%	$1,476	$949	$1,945
PSEG	$305	$79	21%	25%	0.070	0.536	593	895	105%	7%	25%	20%	$1,348	$802	$1,791
PEPCO	$305	$77	19%	24%	0.318	0.840	703	932	108%	10%	22%	18%	$861	$518	$1,156
PS-N	$321	$84	21%	27%	0.064	0.600	274	445	104%	7%	26%	19%	$687	$401	$917
ATSI-C	$291	$71	15%	19%	0.334	0.659	596	694	110%	11%	18%	15%	$537	$333	$724
DPL-S	$305	$79	18%	24%	0.083	0.549	201	259	106%	8%	23%	17%	$309	$180	$417

Note: All LDA *true* Net CONEs assumed 5% higher than each successive parent.

Reducing Susceptibility to Low-Reliability Events

- As the prior slides show, the LDAs are susceptible to low reliability under both the current VRR curve and convex curves (corresponding to the recommended curve at the system level), particularly LDAs that are highly import-dependent or may have Net CONE substantially above the parent Net CONE
- Our recommended enhancements for reducing the incidence of low reliability outcomes in the LDAs (as already discussed in slides 50-52):
  - Start with the convex curve recommended at the system level
  - Increase the LDA Cap to 1.7x Net CONE
  - Stretch the curve such that the minimum width (from points a to c) is 25% of CETL
- The following two slides show how these enhancements improve performance

  Slide 57:
  - If LDA Net CONEs are 5% above parents, the recommended curves enable all LDAs to meet reliability targets
  - If the smallest LDAs have Net CONEs 20% above immediate parents, 3 LDAs do not meet reliability objectives, but reliability events are substantially mitigated, with LOLEs dropping 70% compared to the current VRR curve

  Slide 58:
  - If Net CONE is systematically under-estimated by 20%, 6 LDAs would not meet reliability objectives
  - However, the recommended curves mitigate reliability impacts, with 80% lower LOLE in the most-affected LDAs
  - Hence, the recommended curves help but do not solve this stress scenario; this highlights the importance of estimating Net CONE carefully (see recommendations in Sections A and B)

C. Local VRR Curve Review – Recommendations to Improve Performance

Performance with Recommended Adjustments

	Price				Reliability								Procurement Costs		
	Average	St. Dev	Freq. at Cap	Freq. of Price Separation	Conditional Average LOLE	Conditional Average LOLE (Additive)	Average Excess (Deficit) Above Rel. Req.	St. Dev.	Average Quantity as % of Rel. Req.	St. Dev. as % of Rel. Req.	Freq. Below Rel. Req.	Freq. Below 1-in-15	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(%)*	*(Ev/Yr)*	*(Ev/Yr)*	*(MW)*	*(MW)*	*(%)*	*(%)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
Recommended LDA Curves; Assume LDA Net CONEs are 5% Higher than Each Successive Parent															
MAAC	$277	$103	9%	24%	0.030	0.116	2113	2301	103%	3%	17%	9%	$7,218	$4,001	$11,601
EMAAC	$291	$115	9%	19%	0.020	0.137	1829	1691	105%	4%	14%	8%	$4,058	$2,170	$6,590
SWMAAC	$291	$112	6%	15%	0.020	0.136	1531	1154	109%	7%	7%	5%	$1,691	$922	$2,721
ATSI	$277	$98	6%	15%	0.018	0.104	1486	1120	109%	7%	8%	6%	$1,482	$880	$2,226
PSEG	$306	$122	4%	13%	0.010	0.147	1317	883	110%	7%	6%	4%	$1,356	$698	$2,186
PEPCO	$305	$119	5%	12%	0.017	0.154	1422	919	116%	10%	6%	4%	$859	$451	$1,393
PS-N	$321	$133	5%	13%	0.012	0.159	637	442	110%	7%	7%	4%	$690	$340	$1,149
ATSI-C	$291	$105	4%	12%	0.014	0.118	1169	694	119%	11%	4%	4%	$539	$304	$834
DPL-S	$305	$122	4%	14%	0.012	0.148	391	258	112%	8%	5%	3%	$309	$159	$505
Recommended LDA Curves; Assume LDA Net CONEs are 5% higher than each successive parent but 20% higher in PS-N, DPL-S, PEPCO, and ATSI-C															
MAAC	$277	$104	9%	24%	0.030	0.117	2115	2308	103%	3%	17%	9%	$7,346	$4,115	$11,684
EMAAC	$291	$116	9%	19%	0.020	0.137	1841	1695	105%	4%	14%	8%	$4,141	$2,216	$6,662
SWMAAC	$291	$112	6%	15%	0.021	0.138	1529	1158	109%	7%	8%	5%	$1,736	$955	$2,751
ATSI	$277	$98	6%	15%	0.018	0.104	1488	1120	109%	7%	8%	6%	$1,506	$900	$2,242
PSEG	$305	$123	4%	13%	0.011	0.148	1318	884	110%	7%	6%	4%	$1,418	$714	$2,255
PEPCO	$349	$150	14%	32%	0.132	0.270	857	897	110%	10%	16%	14%	$925	$485	$1,476
PS-N	$367	$167	15%	34%	0.039	0.186	363	429	106%	7%	19%	11%	$762	$356	$1,262
ATSI-C	$332	$133	12%	32%	0.143	0.248	730	684	112%	11%	13%	12%	$580	$327	$880
DPL-S	$349	$152	13%	33%	0.047	0.185	247	253	108%	8%	16%	12%	$339	$168	$553

Performance of Recommended Curves with Administrative Net CONE Estimation Error

	Price				Reliability								Procurement Costs		
	Average ($/MW-d)	St. Dev ($/MW-d)	Freq. at Cap (%)	Freq. of Price Separation (%)	Conditional Average LOLE (Ev/Yr)	Conditional Average LOLE (Additive) (Ev/Yr)	Average Excess (Deficit) Above Rel. Req. (MW)	St. Dev. (MW)	Average Quantity as % of Rel. Req. (%)	St. Dev. as % of Rel. Req. (%)	Freq. Below Rel. Req. (%)	Freq. Below 1-in-15 (%)	Average ($mil)	Average of Bottom 20% ($mil)	Average of Top 20% ($mil)
Recommended LDA Curves without Systematic Net CONE Error															
MAAC	$277	$103	9%	24%	0.030	0.116	2113	2301	103%	3%	17%	9%	$7,218	$4,001	$11,601
EMAAC	$291	$115	9%	19%	0.020	0.137	1829	1691	105%	4%	14%	8%	$4,058	$2,170	$6,590
SWMAAC	$291	$112	6%	15%	0.020	0.136	1531	1154	109%	7%	7%	5%	$1,691	$922	$2,721
ATSI	$277	$98	6%	15%	0.018	0.104	1486	1120	109%	7%	8%	6%	$1,482	$880	$2,226
PSEG	$306	$122	4%	13%	0.010	0.147	1317	883	110%	7%	6%	4%	$1,356	$698	$2,186
PEPCO	$305	$119	5%	12%	0.017	0.154	1422	919	116%	10%	6%	4%	$859	$451	$1,393
PS-N	$321	$133	5%	13%	0.012	0.159	637	442	110%	7%	7%	4%	$690	$340	$1,149
ATSI-C	$291	$105	4%	12%	0.014	0.118	1169	694	119%	11%	4%	4%	$539	$304	$834
DPL-S	$305	$122	4%	14%	0.012	0.148	391	258	112%	8%	5%	3%	$309	$159	$505
Recommended LDA Curves with Net CONE systematically under-estimated by 20%															
MAAC	$277	$78	20%	31%	0.069	0.279	1177	2460	102%	3%	30%	20%	$7,160	$4,374	$10,198
EMAAC	$291	$88	20%	30%	0.049	0.328	983	1745	102%	4%	29%	19%	$4,029	$2,375	$5,853
SWMAAC	$291	$85	14%	22%	0.066	0.345	1055	1175	106%	7%	19%	12%	$1,682	$1,006	$2,407
ATSI	$277	$73	13%	22%	0.047	0.257	1023	1126	106%	7%	17%	13%	$1,469	$947	$1,972
PSEG	$305	$93	12%	19%	0.028	0.356	962	893	108%	7%	15%	11%	$1,345	$770	$1,936
PEPCO	$305	$89	10%	19%	0.089	0.434	1033	927	112%	10%	13%	10%	$858	$504	$1,252
PS-N	$320	$101	12%	20%	0.032	0.388	430	445	107%	7%	16%	10%	$686	$378	$1,001
ATSI-C	$291	$78	9%	17%	0.076	0.333	871	693	114%	11%	10%	9%	$536	$334	$761
DPL-S	$305	$93	9%	18%	0.030	0.358	299	258	110%	8%	12%	8%	$308	$173	$453

Draft Study Results

Note: All LDA *true* Net CONEs assumed 5% higher than each successive parent.

Executive Summary

Basis for Recommendations

Appendix

- CONE Review Details on Capital and FOM Costs
- VRR Curve Modeling Assumptions
- More Simulation Tests for Local VRR Curves
- Related Recommendations

Appendix – CONE Study

CT Capital Costs

	CONE Area				
	1	2	3	4	5
Capital Costs (in $millions)	**EMAAC**	**SWMAAC**	**Rest of RTO**	**WMAAC**	**Dominion**
Owner Furnished Equipment					
Gas Turbines	$98.8	$98.4	$94.0	$98.7	$98.6
HRSG / SCR	$18.9	$18.7	$17.9	$18.8	$18.8
Sales Tax	$8.2	$7.0	$6.4	$7.1	$7.3
Total Owner Furnished Equipment	$125.9	$124.1	$118.3	$124.6	$124.8
EPC Costs					
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0
Condenser	$0.0	$0.0	$0.0	$0.0	$0.0
Steam Turbines	$0.0	$0.0	$0.0	$0.0	$0.0
Other Equipment	$30.9	$30.5	$25.5	$30.8	$30.7
Construction Labor	$71.7	$55.4	$55.3	$54.5	$48.2
Other Labor	$21.2	$19.6	$18.6	$19.6	$19.0
Materials	$9.7	$9.0	$8.6	$9.6	$9.4
Sales Tax	$2.8	$2.4	$2.0	$2.4	$2.5
EPC Contractor Fee	$26.2	$24.1	$22.8	$24.1	$23.5
EPC Contingency	$28.8	$26.5	$25.1	$26.6	$25.8
Total EPC Costs	$191.4	$167.4	$157.9	$167.6	$159.2
Non-EPC Costs					
Project Development	$15.9	$14.6	$13.8	$14.6	$14.2
Mobilization and Start-Up	$3.2	$2.9	$2.8	$2.9	$2.8
Net Start-Up Fuel Costs	$4.2	$5.0	$2.9	$4.8	$4.9
Electrical Interconnection	$13.8	$13.7	$13.4	$13.3	$13.6
Gas Interconnection	$22.6	$22.6	$22.6	$22.6	$22.6
Land	$2.0	$2.2	$1.1	$1.2	$1.6
Fuel Inventories	$5.3	$5.3	$0.0	$5.1	$5.2
Non-Fuel Inventories	$1.6	$1.5	$1.4	$1.5	$1.4
Owner's Contingency	$6.2	$6.1	$5.2	$5.9	$6.0
Financing Fees	$9.4	$8.8	$8.1	$8.7	$8.6
Total Non-EPC Costs	$84.0	$82.5	$71.2	$80.7	$80.9
Total Capital Costs	$401.3	$373.9	$347.5	$372.9	$364.9
Overnight Capital Costs ($million)	**$401**	**$374**	**$347**	**$373**	**$365**
Plant Capacity (MW)	**396**	**393**	**385**	**383**	**391**
Overnight Capital Costs ($/kW)	**$1,015**	**$951**	**$903**	**$974**	**$934**
Installed Cost ($/kW)	**$1,063**	**$996**	**$947**	**$1,020**	**$979**

Notes: overnight costs and components thereof are expressed in nominal dollars at the time when the cost is incurred; installed costs are expressed in 2018 $s and include the cost of capital during construction

Appendix – CONE Study

CC Capital Costs

	CONE Area				
	1	2	3	4	5
Capital Costs (in $millions)	**EMAAC**	**SWMAAC**	**Rest of RTO**	**WMAAC**	**Dominion**
Owner Furnished Equipment					
Gas Turbines	$97.3	$97.2	$92.6	$97.2	$97.2
HRSG / SCR	$43.5	$43.5	$43.5	$43.5	$43.5
Sales Tax	$9.9	$8.4	$7.8	$8.4	$8.8
Total Owner Furnished Equipment	$150.7	$149.1	$143.9	$149.1	$149.5
EPC Costs					
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0
Condenser	$4.2	$4.2	$4.2	$4.2	$4.2
Steam Turbines	$35.5	$35.5	$35.5	$35.5	$35.5
Other Equipment	$60.6	$60.4	$56.4	$60.4	$60.3
Construction Labor	$213.8	$162.1	$164.5	$168.2	$146.9
Other Labor	$45.1	$40.4	$39.9	$41.0	$39.1
Materials	$37.8	$37.8	$37.8	$37.8	$37.8
Sales Tax	$9.7	$8.3	$7.7	$8.3	$8.6
EPC Contractor Fee	$66.9	$59.7	$58.8	$60.6	$57.8
EPC Contingency	$62.4	$55.8	$54.9	$56.5	$54.0
Total EPC Costs	$536.1	$464.2	$459.6	$472.5	$444.3
Non-EPC Costs					
Project Development	$34.3	$30.7	$30.2	$31.1	$29.7
Mobilization and Start-Up	$6.9	$6.1	$6.0	$6.2	$5.9
Net Start-Up Fuel Costs	-$0.4	$1.8	-$2.1	$2.5	$2.0
Electrical Interconnection	$23.2	$23.1	$22.7	$22.6	$23.0
Gas Interconnection	$22.6	$22.6	$22.6	$22.6	$22.6
Land	$2.7	$3.0	$1.5	$1.7	$2.2
Fuel Inventories	$6.1	$6.1	$0.0	$5.9	$6.0
Non-Fuel Inventories	$3.4	$3.1	$3.0	$3.1	$3.0
Owner's Contingency	$8.9	$8.7	$7.5	$8.6	$8.5
Financing Fees	$19.1	$17.2	$16.7	$17.4	$16.7
Total Non-EPC Costs	$126.6	$122.3	$108.1	$121.7	$119.5
Total Capital Costs	$813.4	$735.6	$711.7	$743.3	$713.2
Overnight Capital Costs ($million)	**$813**	**$736**	**$712**	**$743**	**$713**
Plant Capacity (MW)	**668**	**664**	**651**	**649**	**660**
Overnight Capital Costs ($/kW)	**$1,218**	**$1,108**	**$1,092**	**$1,146**	**$1,081**
Installed Cost ($/kW)	**$1,333**	**$1,213**	**$1,199**	**$1,253**	**$1,184**

***Notes**:* overnight costs and components thereof are expressed in nominal dollars at the time when the cost is incurred; installed costs are expressed in 2018 $s and include the cost of capital during construction

Appendix – CONE Study

CT O&M Costs

	CONE Area				
	1	2	3	4	5
O&M Costs	**EMAAC**	**SWMAAC**	**Rest of RTO**	**WMAAC**	**Dominion**
Fixed O&M (in 2018$ million)					
LTSA	$0.3	$0.3	$0.3	$0.3	$0.2
Labor	$1.5	$1.1	$1.2	$1.1	$1.0
Consumables	$0.2	$0.2	$0.2	$0.2	$0.2
Maintenance and Minor Repairs	$0.4	$0.4	$0.4	$0.4	$0.4
Administrative and General	$0.2	$0.2	$0.2	$0.2	$0.2
Asset Management	$0.4	$0.4	$0.4	$0.4	$0.4
Property Taxes	$0.4	$6.1	$2.5	$0.4	$3.1
Insurance	$2.4	$2.2	$2.1	$2.2	$2.2
Firm Gas Contract	$0.0	$0.0	$0.0	$0.0	$0.0
Woring Capital	$0.0	$0.0	$0.0	$0.0	$0.0
Total Fixed O&M (2018$)	**$5.9**	**$10.9**	**$7.2**	**$5.3**	**$7.7**
Plant Capacity (MW)	**396**	**393**	**385**	**383**	**391**
Levelized Fixed O&M (2018$/MW-day)	**$41**	**$76**	**$52**	**$38**	**$54**
Variable O&M (2018$/MWh)					
Major Maintenance - Hours Based	2.40	2.39	2.39	2.39	2.36
Consumables, Waste Disposal, Other VOM	1.89	1.89	1.89	1.89	1.89
Total Variable O&M (2018$/MWh)	**4.29**	**4.27**	**4.27**	**4.27**	**4.25**

Appendix – CONE Study

CC O&M Costs

O&M Costs	CONE Area 1 EMAAC	2 SWMAAC	3 Rest of RTO	4 WMAAC	5 Dominion
Fixed O&M (in 2018$ million)					
LTSA	$0.3	$0.3	$0.3	$0.3	$0.2
Labor	$4.6	$3.3	$3.6	$3.5	$3.0
Consumables	$0.3	$0.3	$0.3	$0.3	$0.3
Maintenance and Minor Repairs	$4.7	$4.1	$4.3	$4.2	$4.0
Administrative and General	$0.4	$0.3	$0.3	$0.3	$0.3
Asset Management	$0.7	$0.6	$0.7	$0.6	$0.6
Property Taxes	$1.4	$11.9	$5.5	$1.5	$6.0
Insurance	$4.9	$4.4	$4.3	$4.5	$4.3
Firm Gas Contract	$0.0	$3.1	$0.0	$0.0	$0.0
Woring Capital	$0.1	$0.1	$0.0	$0.1	$0.0
Total Fixed O&M (2018$)	**$17.4**	**$28.4**	**$19.2**	**$15.2**	**$18.8**
Plant Capacity (MW)	**668**	**664**	**651**	**649**	**660**
Levelized Fixed O&M (2018$/MW-day)	**$71**	**$117**	**$81**	**$64**	**$78**
Variable O&M (2018$/MWh)					
Major Maintenance - Hours Based	1.49	1.45	1.47	1.47	1.45
Consumables, Waste Disposal, Other VOM	1.14	1.14	1.14	1.14	1.14
Total Variable O&M (2018$/MWh)	**2.63**	**2.60**	**2.61**	**2.61**	**2.60**

Executive Summary

Basis for Recommendations

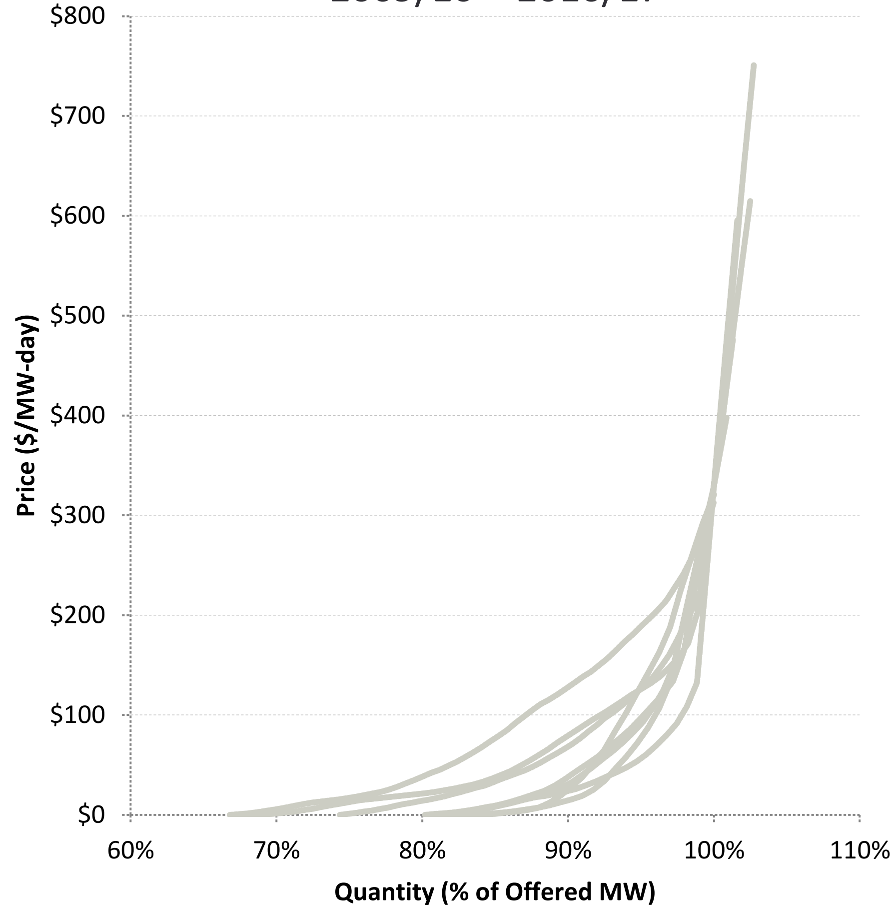
Appendix

- CONE Review Details on Capital and FOM Costs
- VRR Curve Modeling Assumptions
- More Simulation Tests for Local VRR Curves
- Related Recommendations

Appendix – VRR Modeling Assumptions
Supply Curves

- Model relies on smoothed supply curve shapes, consistent with 2009/10-16/17, excluding transition period before full three-year forward auctions
- Cycle through each of the eight shapes
- "Lumpiness" reflected in local curves:
  - Use resources size and location from 2016/17 offer curve
  - Randomly shuffle the order of the offer blocks to create 1,000 different curves
  - Re-state prices consistent with the smoothed supply curve shape
- Effect is a relatively elastic supply curve at the system level, but small LDAs are more greatly affected by the impact of lumpy investments

Smoothed Supply Curves
2009/10 – 2016/17



Draft Study Results

Appendix – VRR Modeling Assumptions

Parameters and Shocks

- Parameters consistent with year 2016/17 parameters
- Per discussion with PJM, we will adopt the 2016/17 parameter estimates for Net CONE as base case assumption (note: model results will not converge to Net CONE in LDAs with Net CONE below parent Net CONE, so local quantities will be subject to an arbitrary maximum in those cases)
- Shocks to supply, demand, CETL, and administrative Net CONE create volatility that depends on LDA size and level of import-dependence

Model Inputs in Base Case

Parameter	RTO	ATSI	ATSI-C	MAAC	EMAAC	SWMAAC	PSEG	DPL-S	PS-N	PEPCO
Average Parameter Value										
Administrative Net CONE ($/MW-d)	$331	$363	$363	$277	$330	$277	$330	$330	$330	$277
True Net CONE ($/MW-d)	$331	$363	$363	$277	$330	$277	$330	$330	$330	$277
CETL (MW)		7,881	5,245	6,495	8,916	8,786	6,581	1,901	2,936	6,846
Reliability Requirement (MW)	166,128	16,255	6,164	72,299	39,694	17,316	12,870	3,160	6,440	9,012
Standard Deviation of Simulated Shocks										
Administrative Net CONE ($/MW-d)	$26	$23	$23	$37	$34	$37	$34	$34	$34	$37
Reliability Requirement (MW)	1,499	259	164	794	492	279	215	76	131	220
Reliability Requirement (% of RR)	0.9%	1.6%	2.7%	1.1%	1.2%	1.6%	1.7%	2.4%	2.0%	2.4%
CETL (MW)		965	662	771	1,055	1,008	793	230	364	844
Supply Excluding Sub-LDAs (MW)	624	507	157	532	1,132	315	136	97	226	328
Supply Including Sub-LDAs (MW)	4,054	663	157	2,767	1,591	644	363	97	226	328

Appendix – VRR Modeling Assumptions

Supply Shocks

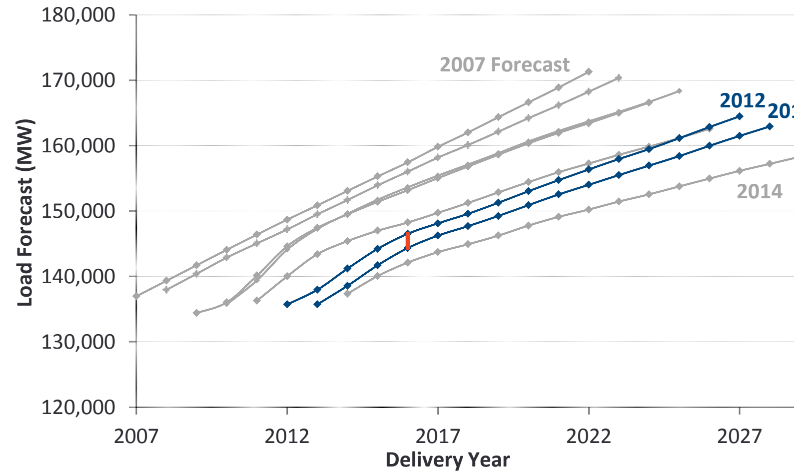
- Supply shocks based on range of actual total supply offers observed in historical BRAs
- Shocks used in simulation model are based on formula using historic deviations in supply offer from time trend, and LDA size

		Total Supply Offered by Delivery Year								Standard Deviation of Historical "Shocks"						
		2009	2010	2011	2012	2013	2014	2015	2016	Total Offers	Annual Change in Offer	Diff. from Trend	Total Offers	Annual Change in Offer	Diff. from Trend	Simulation Shock St. Dev
		(MW)	*(MW)*	*(MW)*	*(MW)*	*(MW)*	*(MW)*	*(MW)*	*(MW)*	*(MW)* [1]	*(MW)* [2]	*(MW)* [3]	*(%)* [4]	*(%)* [5]	*(%)* [6]	*(MW)* [7]
RTO Including Subzones																
Total Offered (No Adjustments)		133,551	133,093	137,720	145,373	160,898	160,486	178,588	184,380	20,040	7,229	4,816	13%	5%	3%	4,129
Adjust for Expansions Only	[A]	133,551	133,093	137,057	144,333	146,479	146,646	163,802	165,729	12,594	6,105	3,983	9%	4%	3%	
Adjust for FRR Only	[B]	133,551	133,093	137,720	145,373	160,898	160,486	163,231	169,023	14,604	5,518	3,878	10%	4%	3%	
Adjust for Expansions and FRR	[C]	133,551	133,093	137,057	144,333	146,479	146,646	158,769	160,696	10,537	4,452	2,697	7%	3%	2%	
Parent LDAs Including Sub-LDAs																
MAAC		63,443	63,919	65,582	68,283	68,338	70,885	74,261	71,608	3,842	2,069	1,229	6%	3%	2%	2,818
EMAAC		31,684	31,218	32,034	32,983	33,007	34,520	37,226	34,140	1,939	1,829	1,102	6%	5%	3%	1,620
SWMAAC		10,312	10,928	11,651	12,396	11,768	12,458	12,722	12,386	843	562	409	7%	5%	3%	655
ATSI		n/a	n/a	n/a	n/a	13,335	12,679	11,777	12,791	646	1,043	557	5%	8%	4%	676
PSEG		6,957	7,220	7,403	7,431	8,033	8,184	8,964	6,784	725	987	657	10%	13%	9%	369
Average LDA Shock										**1,599**	**1,298**	**791**	**7%**	**7%**	**4%**	
Smallest LDAs																
PEPCO		5,064	5,498	5,670	5,382	5,289	5,875	6,235	6,126	412	325	234	7%	6%	4%	334
PS-North		3,767	3,871	4,010	3,420	4,173	4,170	4,931	4,182	436	586	338	11%	14%	8%	231
ATSI-Cleveland		n/a	n/a	n/a	n/a	2,232	2,341	1,657	2,874	499	956	473	22%	42%	21%	160
DPL-South		1,587	1,546	1,486	1,499	1,612	1,600	1,768	1,764	108	84	70	7%	5%	4%	98
Average LDA Shock										**364**	**488**	**279**	**12%**	**17%**	**9%**	

Appendix – VRR Modeling Assumptions
RTO Load Forecast Error (LFE) Shock

- Calculate historical "shocks" to RTO load forecast as delta between four- and three-year ahead forecast for the same delivery year, since that's the change market participants see just before each auction
- Observe 0.8% standard deviation for RTO
- LDA-level load forecast shocks consider correlations with RTO and parent LDAs:
  - Generate shocks for smallest LDAs as RTO shock plus another independent shock that depends on LDA size
  - Bigger LDAs aggregate small LDA shocks and an appropriately sized "rest of" LDA shock

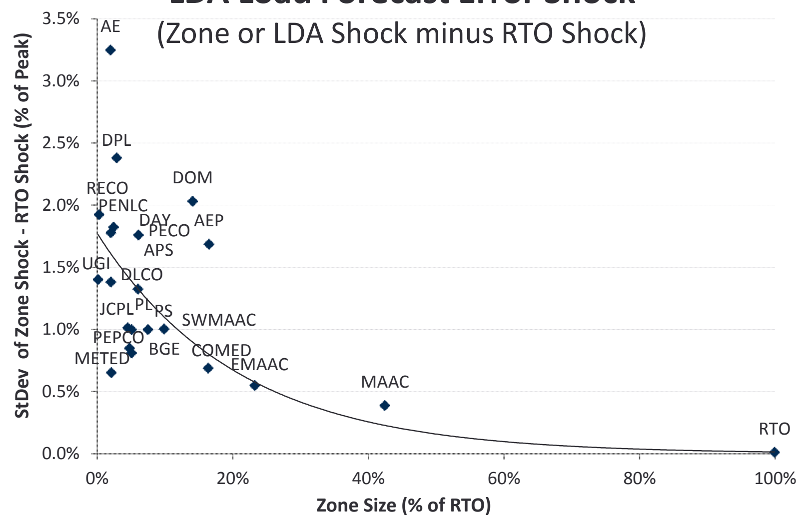
RTO Load Forecast



Aggregate RTO and LDA Shocks

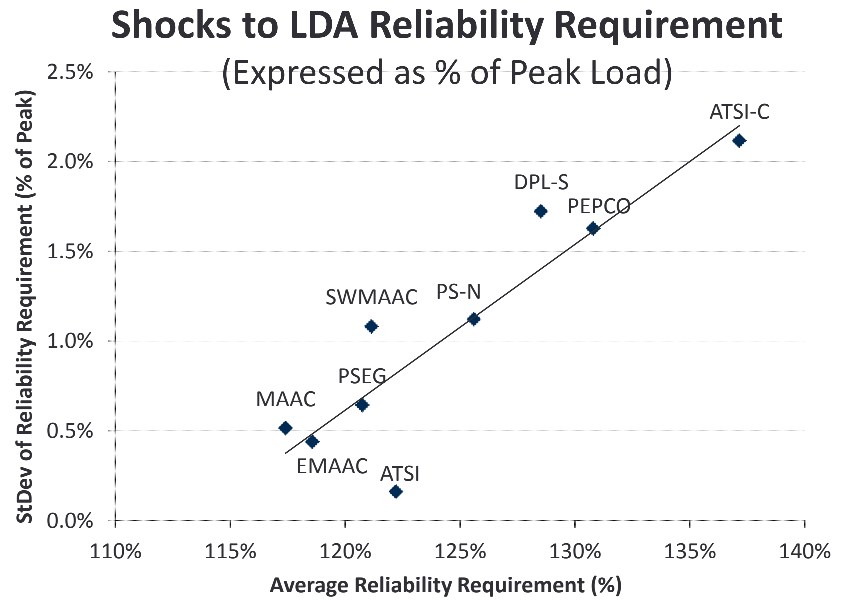
Location	Base Assumptions 2016/17 Peak Load (MW)	Base Assumptions 2016/17 Total Shocks (MW)	Simulated Shock Standard Deviation RTO-Correlated Shock (%)	Simulated Shock Standard Deviation Shock on Top of RTO (%)	Simulated Shock Standard Deviation Total Shock (%)	Historical Load Forecast Shocks (%)
RTO	152,383	1,237	0.8%	0.0%	0.8%	0.8%
MAAC	61,080	604	0.8%	0.6%	1.0%	1.0%
EMAAC	33,299	373	0.8%	0.8%	1.1%	1.3%
SWMAAC	14,088	187	0.8%	1.1%	1.3%	1.2%
ATSI	13,295	183	0.8%	1.1%	1.4%	1.3%
PSEG	10,600	158	0.8%	1.3%	1.5%	1.3%
PEPCO	6,800	114	0.8%	1.5%	1.7%	1.0%
PS-N	5,141	87	0.8%	1.5%	1.7%	n/a
ATSI-C	4,562	77	0.8%	1.5%	1.7%	n/a
DPL-S	2,439	46	0.8%	1.7%	1.9%	n/a

LDA Load Forecast Error Shock
(Zone or LDA Shock minus RTO Shock)



Shocks to Reliability Requirements

- Total Reliability Requirement shock is load forecast shock plus an independent shock to the Reliability Requirement itself (expressed as a % of Peak load)
- **RTO:** the RR% has a standard deviation of 0.4%, calculated based on variation among historical reliability requirements (this is in addition to the 0.8% load forecast error)
- **LDAs:** standard deviation of Reliability Requirements increases for LDAs where it is a greater % of peak load

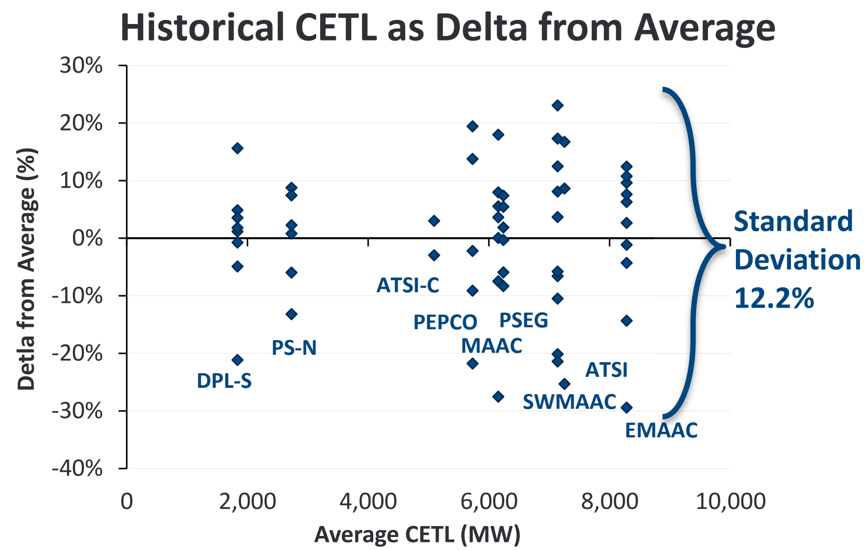


Shocks to Reliability Requirements

Location	2016/17 Reliability Requirement (MW)	2016/17 Reliability Requirement (% of Peak)	Simulation Shock Standard Deviations: Reliability Requirement (% of Peak)	Simulation Shock Standard Deviations: Load Forecast (MW)	Simulation Shock Standard Deviations: Total Load Forecast + RR (MW)	Historical Reliability Requirement StDev (% of Peak)
RTO	166,128	109%	0.4%	1,237	1,499	0.4%
MAAC	72,299	118%	0.4%	604	794	0.5%
EMAAC	39,694	119%	0.5%	373	492	0.4%
SWMAAC	17,316	123%	0.7%	187	279	1.1%
ATSI	16,255	122%	0.8%	183	259	0.2%
PS	12,870	121%	0.7%	158	215	0.6%
PEPCO	9,012	133%	1.6%	114	220	1.6%
PS NORTH	6,440	125%	1.1%	87	131	1.1%
ATSI-Cleveland	6,164	135%	2.2%	77	164	2.1%
DPL SOUTH	3,160	130%	1.4%	46	76	1.7%

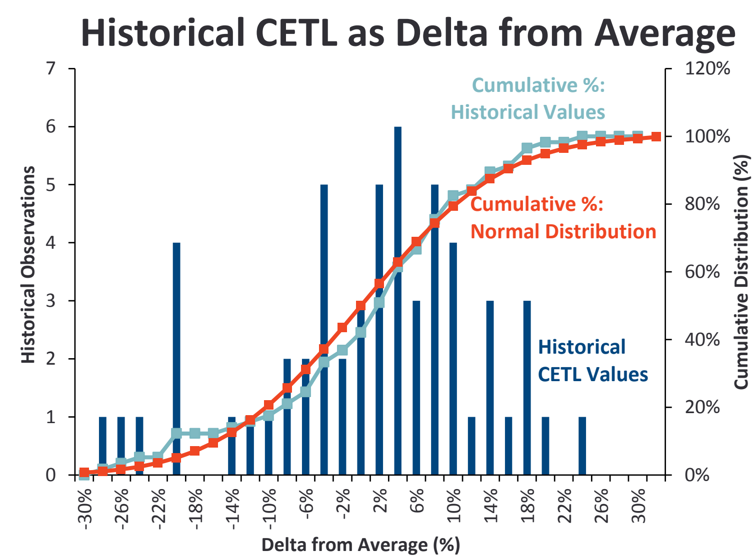
CETL Shocks

- We implement CETL shocks using a normal distribution with a standard deviation of 12.2% around the 2016/17 parameter value
- We find that shocks are proportional to absolute CETL size (but relatively constant as a % of CETL)



Historical and Simulation CETL Shocks

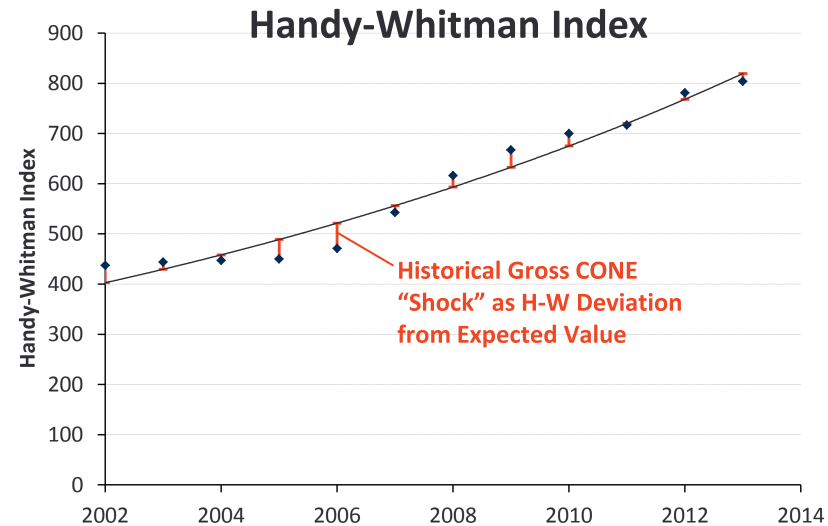
LDA	Historical CETL Values				Simulation CETL Values		
	Average *(MW)*	Standard Deviation *(MW)*	Standard Deviation *(%)*	Count	2016/17 Value *(MW)*	Standard Deviation *(MW)*	Standard Deviation *(%)*
EMAAC	8,286	1,091	13%	10	8,916	1,090	12%
SWMAAC	7,140	1,095	15%	10	8,786	1,074	12%
ATSI	7,256	1,619	22%	3	7,881	963	12%
PEPCO	5,733	964	17%	5	6,846	837	12%
PSEG	6,241	387	6%	6	6,581	804	12%
MAAC	6,155	886	14%	7	6,495	794	12%
ATSI-C	5,093	216	4%	2	5,245	641	12%
PS-North	2,733	191	10%	8	2,936	359	12%
DPL-South	1,836	228	8%	6	1,901	232	12%

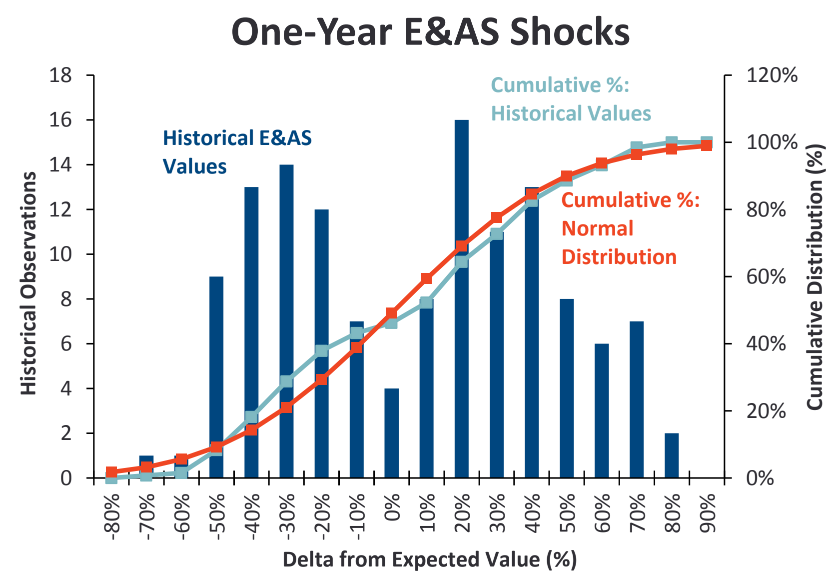


Draft Study Results

Net CONE Shocks

- Net CONE shocks are developed as the sum of shocks to gross CONE and a 3-year average E&AS shock, but assuming no systematic bias
- Gross CONE shocks of 5.4% based on deviations in Handy-Whitman Index away from long-term trend
- E&AS Shocks:
  - One-year historical E&AS estimated with standard deviation of 38% around expected value, based on deviation of administrative estimates in each year from a fitted trend over 2003-13
  - Administrative E&AS shock of 22%, based on rolling 3-year average E&AS
- Results in standard deviation of 8% in administrative Net CONE for RTO (deviations from true Net CONE)





Net CONE Shocks

LDA	Base Assumptions from 2016/2017				Standard Deviation of Shock Components				Historical
	Expected Gross CONE *($/MW-d)*	Expected E&AS *($/MW-d)*	Expected Net CONE *($/MW-d)*	Shocks to Net CONE *($/MW-d)*	Gross CONE *(%)*	One-Year E&AS *(%)*	Three-Year E&AS *(%)*	Net CONE *(%)*	Shocks to Net CONE *(%)*
RTO	$405	$74	$331	$26	5.4%	38.4%	22.1%	8.0%	5.5%
ATSI	$405	$43	$363	$23	5.4%	38.4%	22.1%	6.4%	1.1%
ATSI-C	$405	$43	$363	$23	5.4%	38.4%	22.1%	6.4%	1.1%
MAAC	$413	$136	$277	$36	5.4%	38.4%	22.1%	13.1%	18.8%
EMAAC	$443	$113	$330	$33	5.4%	38.4%	22.1%	10.1%	9.8%
SWMAAC	$413	$136	$277	$36	5.4%	38.4%	22.1%	13.1%	12.8%
PSEG	$443	$113	$330	$33	5.4%	38.4%	22.1%	10.1%	3.0%
DPL-S	$443	$113	$330	$33	5.4%	38.4%	22.1%	10.1%	5.2%
PS-N	$443	$113	$330	$33	5.4%	38.4%	22.1%	10.1%	3.0%
PEPCO	$413	$136	$277	$36	5.4%	38.4%	22.1%	13.1%	4.6%

Notes:
Expected Gross CONE, E&AS, and Net CONE consistent with 2016/17 Planning Parameters.
Historical "Shocks" expressed as average of deviations from "trend" in Net CONE (i.e. point "b"), note that most LDAs have few data points.

Net System Supply minus Demand Shocks

- Calculated historical net shocks to supply minus demand in two ways:
  - Standard deviation of absolute MW values of net supply
  - Standard deviation of differences from time trend
- Compare historic net shocks to simulated net shocks
  - Simulation shocks are in between two historic shock series

LDA	Standard Deviation (MW) Supply (MW)	CETL (MW)	Reliability Requirement (MW)	Net Supply (MW)	Standard Deviation as % of 2016/17 LDA Size Supply	CETL	Reliability Requirement	Net Supply (%)
Historical Absolute Value								
RTO	20,040	n/a	14,783	5,894	12.1%	n/a	8.9%	3.5%
MAAC	3,549	811	931	3,480	4.9%	1.1%	1.3%	4.8%
EMAAC	1,900	721	645	2,451	4.8%	1.8%	1.6%	6.2%
SWMAAC	907	910	335	1,652	5.2%	5.3%	1.9%	9.5%
PS	820	352	288	832	6.4%	2.7%	2.2%	6.5%
PS NORTH	534	252	101	585	8.3%	3.9%	1.6%	9.1%
DPL SOUTH	112	206	57	282	3.5%	6.5%	1.8%	8.9%
PEPCO	423	1,060	233	1,673	4.7%	11.8%	2.6%	18.6%
ATSI	717	1,742	38	2,421	4.4%	10.7%	0.2%	14.9%
ATSI-Cleveland	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Historical Deviation from Trend								
RTO	4,816	n/a	4,850	2,147	2.9%	n/a	2.9%	1.3%
MAAC	1,229	808	792	2,208	1.7%	1.1%	1.1%	3.1%
EMAAC	1,102	717	578	2,091	2.8%	1.8%	1.5%	5.3%
SWMAAC	409	378	283	792	2.4%	2.2%	1.6%	4.6%
PS	657	329	96	759	5.1%	2.6%	0.7%	5.9%
PS NORTH	338	222	84	401	5.3%	3.4%	1.3%	6.2%
DPL SOUTH	70	172	48	193	2.2%	5.4%	1.5%	6.1%
PEPCO	234	236	166	585	2.6%	2.6%	1.8%	6.5%
ATSI	557	n/a	n/a	n/a	3.4%	n/a	n/a	n/a
ATSI-Cleveland	473	n/a	n/a	n/a	7.7%	n/a	n/a	n/a
Simulation Shocks								
RTO	4,054	n/a	1,499	4,277	2.4%	n/a	0.9%	2.6%
MAAC	2,767	771	794	2,984	3.8%	1.1%	1.1%	4.1%
EMAAC	1,591	1,055	492	1,954	4.0%	2.7%	1.2%	4.9%
SWMAAC	644	1,008	279	1,214	3.7%	5.8%	1.6%	7.0%
PS	363	793	215	908	2.8%	6.2%	1.7%	7.1%
PS NORTH	226	364	131	446	3.5%	5.7%	2.0%	6.9%
DPL SOUTH	97	230	76	259	3.1%	7.3%	2.4%	8.2%
PEPCO	328	844	220	935	3.6%	9.4%	2.4%	10.4%
ATSI	663	965	259	1,186	4.1%	5.9%	1.6%	7.3%
ATSI-Cleveland	157	662	164	699	2.5%	10.7%	2.7%	11.3%

Sensitivity of Current Local VRR Curves' Performance to Assumed Shock Sizes

- Price volatility increases and reliability decreases with higher shocks; the reverse with lower shocks
- For 33% lower shocks, current VRR curve achieves reliability objectives in all LDAs
- For 33% higher shocks, only two of nine LDAs meet the reliability target
- Assuming no CETL shocks largely improves reliability in the most import-dependent zones but has minimal impacts in the larger and less import-dependent LDAs
- These cases assume local Net CONE is always 5% Higher than parent, with no systematic estimation error

	Price				Reliability								Procurement Costs		
	Average ($/MW-d)	St. Dev ($/MW-d)	Freq. at Cap (%)	Freq. of Price Separation (%)	Conditional Average LOLE (Ev/Yr)	Conditional Average LOLE (Additive) (Ev/Yr)	Average Excess (Deficit) Above Rel. Req. (MW)	St. Dev. (MW)	Average Quantity as % of Rel. Req. (%)	St. Dev. as % of Rel. Req. (%)	Freq. Below Rel. Req. (%)	Freq. Below 1-in-15 (%)	Average ($mil)	Average of Bottom 20% ($mil)	Average of Top 20% ($mil)
Base Shocks															
MAAC	$277	$89	12%	33%	0.053	0.160	1389	2356	102%	3%	27%	17%	$7,218	$4,199	$10,669
EMAAC	$291	$98	8%	25%	0.033	0.193	1349	1706	103%	4%	22%	15%	$4,058	$2,274	$6,049
SWMAAC	$291	$96	6%	17%	0.042	0.202	1215	1163	107%	7%	14%	8%	$1,689	$969	$2,504
ATSI	$277	$87	11%	18%	0.035	0.143	1,152	1,121	107%	7%	14%	11%	$1,476	$904	$2,120
PSEG	$305	$105	5%	15%	0.022	0.215	1036	886	108%	7%	13%	9%	$1,351	$730	$2,003
PEPCO	$305	$104	25%	14%	0.064	0.266	1099	923	112%	10%	11%	10%	$856	$471	$1,292
PS-N	$321	$116	31%	15%	0.023	0.238	503	442	108%	7%	12%	8%	$687	$361	$1,047
ATSI-C	$291	$95	10%	12%	0.059	0.202	906	694	115%	11%	9%	8%	$533	$316	$796
DPL-S	$305	$105	13%	15%	0.027	0.220	309	259	110%	8%	12%	7%	$308	$167	$464
Zero CETL Shocks															
MAAC	$277	$90	9%	35%	0.051	0.160	1163	2202	102%	3%	29%	19%	$7,206	$4,065	$10,917
EMAAC	$291	$101	11%	40%	0.044	0.204	650	1374	102%	3%	32%	20%	$4,061	$2,244	$6,205
SWMAAC	$291	$99	10%	36%	0.048	0.207	334	623	102%	4%	28%	17%	$1,706	$945	$2,602
ATSI	$277	$92	10%	29%	0.036	0.145	430	620	103%	4%	24%	17%	$1,490	$847	$2,227
PSEG	$305	$107	7%	31%	0.034	0.238	226	388	102%	3%	27%	14%	$1,361	$734	$2,077
PEPCO	$305	$105	8%	28%	0.035	0.243	270	378	103%	4%	24%	15%	$881	$469	$1,371
PS-N	$320	$115	9%	31%	0.036	0.274	144	255	102%	4%	29%	13%	$698	$357	$1,080
ATSI-C	$291	$99	6%	25%	0.030	0.175	171	217	103%	4%	22%	15%	$552	$298	$875
DPL-S	$306	$107	7%	27%	0.032	0.236	87	119	103%	4%	21%	12%	$313	$165	$486
33% Higher Shocks															
MAAC	$277	$106	13%	32%	0.115	0.267	1612	3139	102%	4%	29%	21%	$7,207	$3,620	$11,179
EMAAC	$291	$115	11%	24%	0.047	0.314	1743	2269	104%	6%	22%	17%	$4,048	$1,971	$6,364
SWMAAC	$291	$113	7%	16%	0.082	0.349	1648	1539	110%	9%	13%	10%	$1,686	$842	$2,623
ATSI	$277	$103	9%	17%	0.068	0.220	1,524	1,491	109%	9%	15%	12%	$1,473	$791	$2,234
PSEG	$306	$122	7%	14%	0.032	0.346	1402	1178	111%	9%	13%	10%	$1,347	$628	$2,099
PEPCO	$305	$120	8%	13%	0.162	0.511	1509	1223	117%	14%	11%	9%	$851	$405	$1,344
PS-N	$320	$133	7%	13%	0.029	0.376	686	584	111%	9%	11%	8%	$683	$304	$1,086
ATSI-C	$291	$110	6%	11%	0.172	0.392	1233	925	120%	15%	9%	8%	$531	$275	$826
DPL-S	$305	$122	6%	14%	0.049	0.364	413	343	113%	11%	11%	8%	$307	$142	$483
33% Lower Shocks															
MAAC	$277	$67	3%	39%	0.033	0.116	1100	1600	102%	2%	25%	11%	$7,267	$4,922	$10,018
EMAAC	$291	$77	4%	27%	0.027	0.143	952	1158	102%	3%	21%	11%	$4,091	$2,681	$5,682
SWMAAC	$291	$75	4%	20%	0.025	0.140	793	784	105%	5%	15%	7%	$1,704	$1,137	$2,360
ATSI	$277	$67	4%	20%	0.023	0.107	782	756	105%	5%	15%	9%	$1,483	$1,039	$1,988
PSEG	$306	$83	3%	16%	0.018	0.161	686	596	105%	5%	14%	7%	$1,363	$868	$1,891
PEPCO	$306	$84	6%	16%	0.028	0.169	722	624	108%	7%	12%	9%	$866	$556	$1,225
PS-N	$321	$92	4%	18%	0.020	0.181	329	302	105%	5%	13%	6%	$694	$425	$985
ATSI-C	$291	$76	5%	14%	0.026	0.133	585	466	110%	8%	11%	8%	$539	$360	$755
DPL-S	$306	$84	4%	17%	0.019	0.161	205	175	107%	6%	12%	7%	$311	$197	$438

Notes: All cases assume LDA Net CONEs are 5% higher than each successive parent area; no systematic Net CONE estimation error

Draft Study Results

Impacts of Right-Stretching the Local VRR Curves in Different Ways

- The widest-stretched curves provide the greatest reliability and price volatility benefits
- These benefits come at the expense of increasing the average quantity of supply, and therefore average customer costs by a proportional amount
- Increasing the width of the curves in proportion to CETL appears to be the best option, as it provides the most reliability benefit where it is needed
- Increasing the width to 50% of CETL would be necessary to fully meet the 0.04 LOLE standard in all LDAs with Net CONE 20% higher than parent, but this is a big change in design for a smaller incremental improvement than the 25% stretch

	Price				Reliability								Procurement Costs		
	Average	St. Dev	Freq. at Cap	Freq. of Price Separation	Conditional Average LOLE	Conditional Average LOLE (Additive)	Average Excess (Deficit) Above Rel. Req.	St. Dev.	Average Quantity as % of Rel. Req.	St. Dev. as % of Rel. Req.	Freq. Below Rel. Req.	Freq. Below 1-in-15	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(%)*	*(Ev/Yr)*	*(Ev/Yr)*	*(MW)*	*(MW)*	*(%)*	*(%)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
LDA Cap at 1.7x Net CONE															
PEPCO	$348	$156	17%	29%	0.218	0.360	716	899	108%	10%	20%	16%	$910	$472	$1,466
PS-N	$366	$171	17%	32%	0.045	0.196	326	429	105%	7%	22%	14%	$756	$347	$1,262
ATSI-C	$332	$142	16%	26%	0.342	0.449	566	685	109%	11%	18%	16%	$564	$313	$869
DPL-S	$349	$158	16%	30%	0.070	0.206	205	253	107%	8%	20%	16%	$335	$162	$552
LDA Cap at 1.7x Net CONE, Double Width of Curves															
PEPCO	$349	$147	14%	32%	0.135	0.252	853	899	110%	10%	16%	14%	$932	$510	$1,450
PS-N	$367	$156	11%	38%	0.029	0.154	426	430	107%	7%	15%	9%	$775	$391	$1,237
ATSI-C	$332	$135	13%	30%	0.206	0.307	662	685	111%	11%	15%	13%	$576	$320	$870
DPL-S	$349	$146	12%	35%	0.044	0.160	254	253	108%	8%	15%	11%	$343	$179	$542
LDA Cap at 1.7x Net CONE, 1,500MW Min Width of Curves															
PEPCO	$349	$150	14%	33%	0.125	0.266	871	897	110%	10%	16%	13%	$926	$484	$1,480
PS-N	$367	$150	8%	44%	0.018	0.166	539	430	108%	7%	9%	6%	$783	$396	$1,242
ATSI-C	$332	$131	11%	33%	0.109	0.215	781	684	113%	11%	13%	11%	$584	$329	$885
DPL-S	$349	$118	2%	55%	0.004	0.142	486	254	115%	8%	3%	2%	$368	$225	$548
LDA Cap at 1.7x Net CONE, Min Width of Curves at 25% of CETL															
PEPCO	$349	$150	14%	32%	0.132	0.270	857	897	110%	10%	16%	14%	$925	$485	$1,476
PS-N	$367	$167	15%	34%	0.039	0.186	363	429	106%	7%	19%	11%	$762	$356	$1,262
ATSI-C	$332	$133	12%	32%	0.143	0.248	730	684	112%	11%	13%	12%	$580	$327	$880
DPL-S	$349	$152	13%	33%	0.047	0.185	247	253	108%	8%	16%	12%	$339	$168	$553
LDA Cap at 1.7x Net CONE, Min Width of Curves at 50% of CETL															
PEPCO	$349	$137	8%	41%	0.046	0.174	1150	897	113%	10%	10%	8%	$962	$522	$1,486
PS-N	$367	$150	9%	43%	0.021	0.161	503	430	108%	7%	11%	7%	$784	$403	$1,232
ATSI-C	$332	$118	6%	41%	0.033	0.129	1008	684	116%	11%	8%	6%	$611	$359	$897
DPL-S	$349	$136	6%	45%	0.018	0.153	347	253	111%	8%	8%	5%	$352	$191	$552

Notes:
Assume LDA Net CONEs are 5% higher than each successive parent area but 20% higher in PS-N, DPL-S, PEPCO, and ATSI-C.
Results are reported only for the smallest LDAs in which we have assumed a 20% higher Net CONE than immediate parent.

Performance with Recommended Adjustments Applied Successively

- In the scenario where Net CONE is 20% higher than parent in the smallest LDAs, just raising the LDA price cap improves on the 1.5x convex curve, but still 4 LDAs do not meet the reliability target
- Incorporating both of our LDA recommendations (raise the cap and impose minimum width) improves performance substantially, although still not quite meeting targets in all LDAs in this scenario

	Price				Reliability								Procurement Costs		
	Average	St. Dev	Freq. at Cap	Freq. of Price Separation	Conditional Average LOLE	Conditional Average LOLE (Additive)	Average Excess (Deficit) Above Rel. Req.	St. Dev.	Average Quantity as % of Rel. Req.	St. Dev. as % of Rel. Req.	Freq. Below Rel. Req.	Freq. Below 1-in-15	Average	Average of Bottom 20%	Average of Top 20%
	($/MW-d)	*($/MW-d)*	*(%)*	*(%)*	*(Ev/Yr)*	*(Ev/Yr)*	*(MW)*	*(MW)*	*(%)*	*(%)*	*(%)*	*(%)*	*($mil)*	*($mil)*	*($mil)*
Modify Convex System-Like Curve Only by Raising LDA Price Cap to 1.7x															
MAAC	$277	$103	9%	23%	0.030	0.116	2123	2303	103%	3%	16%	9%	$7,327	$4,088	$11,669
EMAAC	$291	$115	9%	19%	0.020	0.136	1844	1694	105%	4%	14%	8%	$4,131	$2,193	$6,645
SWMAAC	$290	$113	6%	14%	0.025	0.141	1442	1157	108%	7%	9%	6%	$1,727	$941	$2,754
ATSI	$277	$99	7%	14%	0.021	0.107	1403	1119	109%	7%	10%	7%	$1,498	$885	$2,244
PSEG	$305	$124	6%	12%	0.014	0.151	1206	884	109%	7%	9%	5%	$1,411	$707	$2,264
PEPCO	$348	$156	17%	29%	0.218	0.360	716	899	108%	10%	20%	16%	$910	$472	$1,466
PS-N	$366	$171	17%	32%	0.045	0.196	326	429	105%	7%	22%	14%	$756	$347	$1,262
ATSI-C	$332	$142	16%	26%	0.342	0.449	566	685	109%	11%	18%	16%	$564	$313	$869
DPL-S	$349	$158	16%	30%	0.070	0.206	205	253	107%	8%	20%	16%	$335	$162	$552
Recommended LDA Curves (LDA Price Cap at 1.7x and Min Width at 25% of CETL)															
MAAC	$277	$104	9%	24%	0.030	0.117	2115	2308	103%	3%	17%	9%	$7,346	$4,115	$11,684
EMAAC	$291	$116	9%	19%	0.020	0.137	1841	1695	105%	4%	14%	8%	$4,141	$2,216	$6,662
SWMAAC	$291	$112	6%	15%	0.021	0.138	1529	1158	109%	7%	8%	5%	$1,736	$955	$2,751
ATSI	$277	$98	6%	15%	0.018	0.104	1488	1120	109%	7%	8%	6%	$1,506	$900	$2,242
PSEG	$305	$123	4%	13%	0.011	0.148	1318	884	110%	7%	6%	4%	$1,418	$714	$2,255
PEPCO	$349	$150	14%	32%	0.132	0.270	857	897	110%	10%	16%	14%	$925	$485	$1,476
PS-N	$367	$167	15%	34%	0.039	0.186	363	429	106%	7%	19%	11%	$762	$356	$1,262
ATSI-C	$332	$133	12%	32%	0.143	0.248	730	684	112%	11%	13%	12%	$580	$327	$880
DPL-S	$349	$152	13%	33%	0.047	0.185	247	253	108%	8%	16%	12%	$339	$168	$553

Notes: LDA Net CONEs assumed 5% higher than each successive parent but 20% higher in PS-N, DPL-S, PEPCO, and ATSI-C. Assume no systematic Net CONE estimation error.

Executive Summary

Basis for Recommendations

Appendix

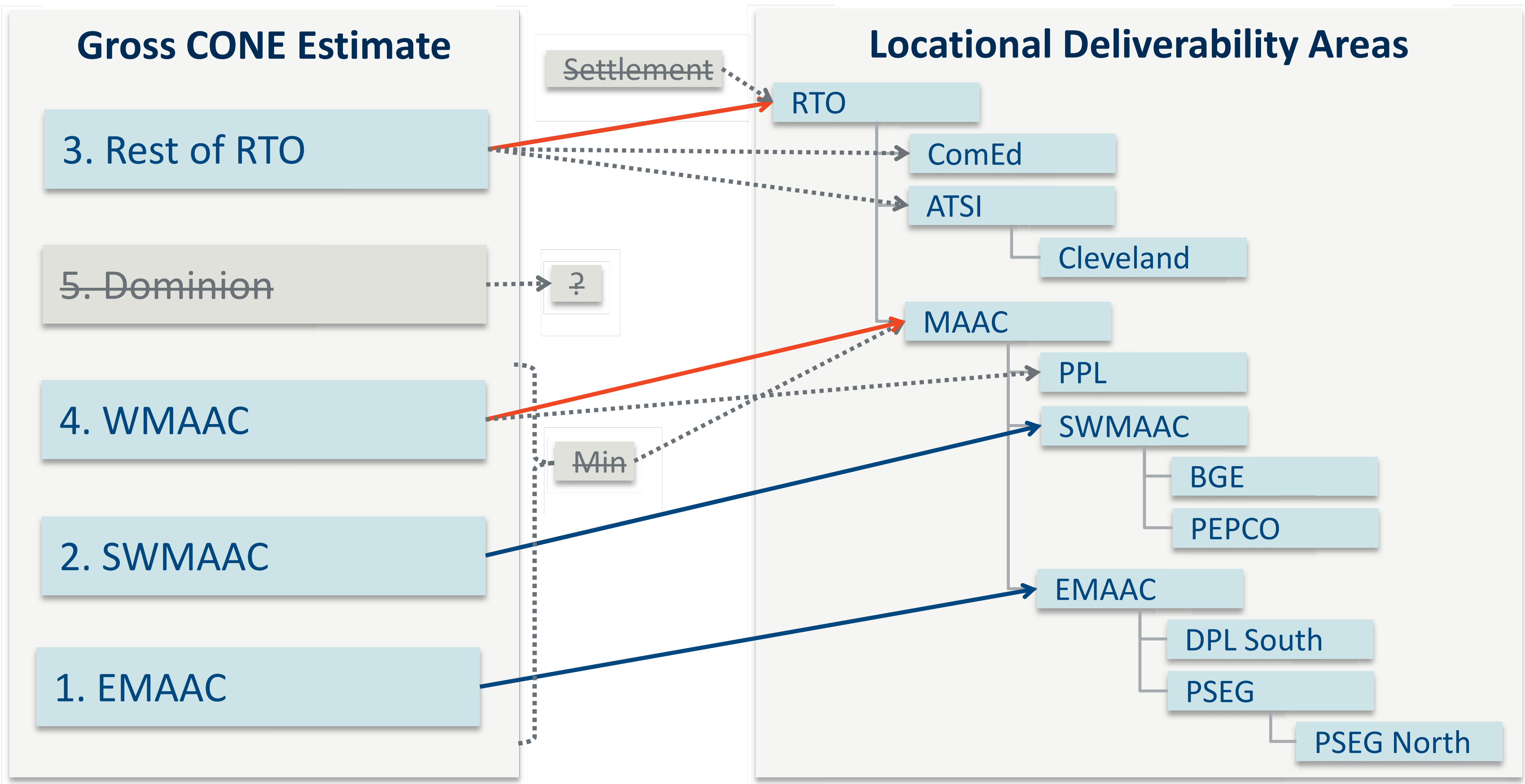
- CONE Review Details on Capital and FOM Costs
- VRR Curve Modeling Assumptions
- More Simulation Tests for Local VRR Curves
- Related Recommendations

CONE Mapping

Recommendation	Reasons
Better align CONE location assumptions with RTO-LDA structure, using Rest-of-RTO CONE for the system and WMAAC CONE for MAAC (rather than min of sub-areas)	• Produce more accurate/relevant CONE estimates in conjunction with revised E&AS mapping • This is consistent with the theory that the import-constrained areas should have higher CONE and exporting areas should have lower
Introduce a test for when to estimate a separate CONE in small LDAs	• Avoid under-procuring in an LDA if true costs are higher there (current CONE Areas don't recognize that)

Appendix – Related Recommendations

Location Designations for Calculating CONE



Note: Crossouts represent existing elements we recommend eliminating

Appendix – Related Recommendations

Recommended Changes to Gross CONE Mapping

Recommendation	Rationale
Use RTO CONE Estimate for RTO VRR Curve *(Rather than Fixed Number)*	• Legacy of most recent settlement agreement that currently the RTO gross CONE number is not based on the triennial CONE estimates but rather set at a fixed value agreed in settlement (updated with Handy-Whitman) • Revert to a standard approach consistent with other areas' gross CONE updates
Use WMAAC CONE Estimate for MAAC VRR Curve *(Rather than Min of Sub-Areas)*	• Currently, Tariff states that LDAs spanning multiple CONE Areas will use the minimum CONE of sub-LDAs, historically EMAAC initially, SWMAAC effective 2012/2013 • Revised approach is more consistent with underlying theory that the most import-constrained areas should have the highest Gross CONE and Net CONE
Eliminate CONE Area 5: Dominion	• Not used in setting VRR curves as Dominion has never been a modeled LDA
Add Test to Trigger a Separate Gross CONE Estimate for Small LDAs	• Current approach always estimates Gross CONE for the permanent, large LDAs (RTO, MAAC, SWMAAC, & EMAAC) • In some LDAs, it is possible that the reference technology is much more expensive or infeasible to build; if so, setting Net CONE based on the larger CONE Area's CONE might substantially under-procure • The test might consider whether the LDA is persistently import-constrained, shows little evidence of new entry, and shows evidence of structurally higher entry costs (e.g., if the reference technology cannot be built there)

LDA Modeling Issues

Recommendation	Reason
Define local reliability objectives in terms of normalized expected unserved energy (EUE)	LOLE target of 1 "event" in 10 years does not consider the expected depth and duration of an event; nor does it recognize that shedding X MWh of load in a single large area is not as bad as shedding the same amount in each of multiple sub-areas
Consider more flexible alternatives to the "nested" LDA structure	The nested LDA structure assumes a certain direction of capacity flows, i.e., into sub-areas
Consider revising the RPM auction clearing mechanics based on delivered reliability value	The current hard import constraint is artificially sudden—it does not recognize that capacity outside an area has less local value than internal capacity even before hitting the limit, but still has non-zero value afterward; as such, hard limits can introduce inefficiencies and artificially high price volatility

Find Ways to Reduce Shocks to Supply and Demand

- We recommend that PJM review its options for increasing the predictability and stability of net supply and demand in the footprint, to the extent feasible without distorting prices away from underlying fundamentals
- We find that primary drivers of volatility in the net supply-demand footprint in the region include not only market fundamentals, but also some drivers related to administrative parameters and rule changes
- The administrative factors most responsible for shocks to the supply-demand balance at the system level include:
  - Load forecast changes
  - Net supply shocks associated with FRR entry and exit, and RTO expansion
  - Rule changes that result in large quantities of resources entering or exiting the market simultaneously
- While some of variability and uncertainty in administrative parameters is unavoidable, we recommend that PJM seek incremental improvements

Evaluate Options for Increasing the Stability of Capacity Emergency Transfer Limits (CETL)

- We recommend that PJM continue to review its options for increasing the predictability and stability of its CETL estimates
- Based on our simulation results, we find that eliminating CETL uncertainty could significantly reduce capacity price volatility in LDAs
- Physical changes to the transmission system would continue to be reflected as changes in CETL, but reducing uncertainty would provide substantial benefits in reducing price volatility
- We provided reiterate our detailed suggestions on options for mitigating volatility in CETL from our 2011 RPM review