Fifth Review of the Variable Resource Requirement Curve

MEETING #1: OVERVIEW AND REQUEST FOR STAKEHOLDER INPUT

PRESENTED BY

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PRESENTED TO

PJM Market Implementation Committee

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Brattle

Agenda

Scope of the Quadrennial Review

Approach to Assessing VRR Curve Shape

Preview: Approach to Assessing CONE and Net E&AS Offset

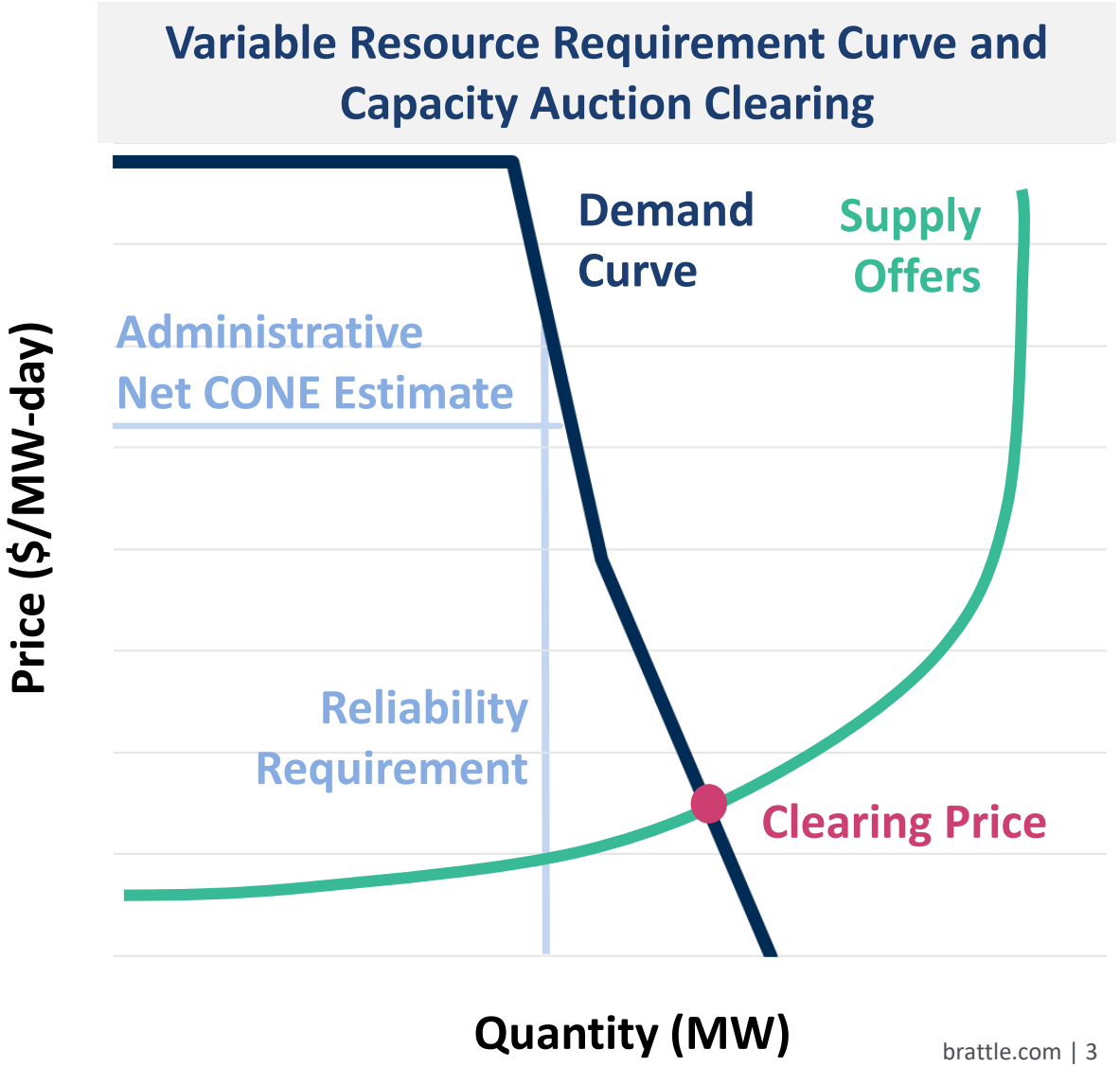
Next Steps

Scope of the Quadrennial Review

Recap: What is the VRR Curve?

The VRR curve sets the quantity of capacity that PJM will procure in each capacity auction as a function of price:

- **Quantities:** Tied to the reserve margin needed to meet 1-in-10 standard
- **Prices:** Tied to Net CONE, the estimated long-run marginal cost of capacity
- **Shape/Width:** Balance tradeoffs among reliability, price volatility, and cost



Recap: Definitions of Key Parameters

Parameter	Definition
VRR Curve VRR = Variable Resource Requirement	Administrative demand curve for capacity that establishes the maximum price that PJM would pay for a given quantity of capacity
Gross CONE CONE = Cost of New Entry	Annualized investment plus fixed operating and maintenance costs for building and maintaining a new capacity resource
E&AS Offset E&AS = Energy and Ancillary Services	Net revenues anticipated to be earned from participation in the energy and ancillary service markets
Net CONE Net CONE = Gross CONE – E&AS Offset	Net capacity payments needed to attract a new resource into the capacity market (i.e. long-run marginal cost of capacity supply)
Reference Resource	Technology used as the basis for developing estimated Net CONE

Tariff Requirements for the Quadrennial Review

Quadrennial review will evaluate the ability of the VRR curve to meet reliability needs, including:

- VRR Curve Shape
- Gross CONE
- E&AS Offset

Updated VRR Curve parameters will apply for planning years 2026/27 through 2029/30

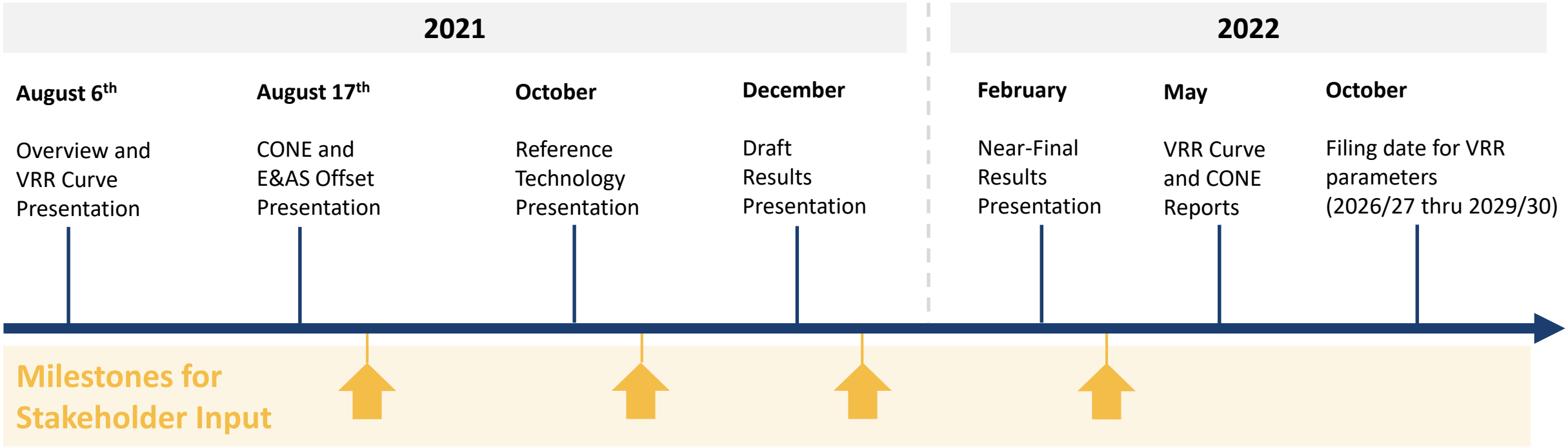
"Beginning with the Delivery Year that commences June 1, 2018, and continuing no later than for every fourth Delivery Year thereafter, the Office of the Interconnection shall perform a review of the shape of the Variable Resource Requirement Curve.

Such analysis shall be based on simulation of market conditions to quantify the ability of the market to invest in new Capacity Resources and to meet the applicable reliability requirements on a probabilistic basis. *Based on the results of such review, PJM shall prepare a recommendation to either modify or retain the existing Variable Resource Requirement Curve shape."*

-PJM Tariff, Attachment DD.5.10, Section (a)(iii), p. 4

Timeline for Quadrennial Review

Quadrennial review will require stakeholder input at several points.



Demand Curve Design Objectives

Stakeholder Input Requested: What design objectives and performance metrics should we use to assess VRR Curve performance?

	Demand Curve Objectives (Adapted from Prior VRR Curve Review)
Reliability	• Maintain 1-in-10 LOLE system-wide target on a long-term average basis; maintain 1-in-25 conditional LOLE in each locational deliverability area. Reliability as measured immediately prior to the delivery year • Rarely drop below a "minimum acceptable" level when PJM would intervene (at IRM minus 1%) • Maintain reliability across a range of potential market conditions, while mitigating the potential for over-procurement
Prices	• Prices high enough to attract entry when needed for reliability; prices low enough to enable efficient exit and retirements during surplus • Reduce price volatility due to small changes in supply and demand • Mitigate susceptibility to exercise of market power • Allow prices to move sufficiently to reflect changes in market conditions • Few outcomes at the administrative cap
Other	• Strike a balance among competing objectives • Aim for simplicity, stability, transparency, and consensus

Notes: VRR Curve design objectives as adopted in the Fourth Quadrennial VRR Curve Review.
LOLE = Loss of Load Events; IRM = Installed Reserve Margin; CONE = Cost of New Entry

Focus Areas for the VRR Curve Review

Stakeholder Input Requested: What are the most important questions or potential changes that we should evaluate in the Fifth VRR curve review?

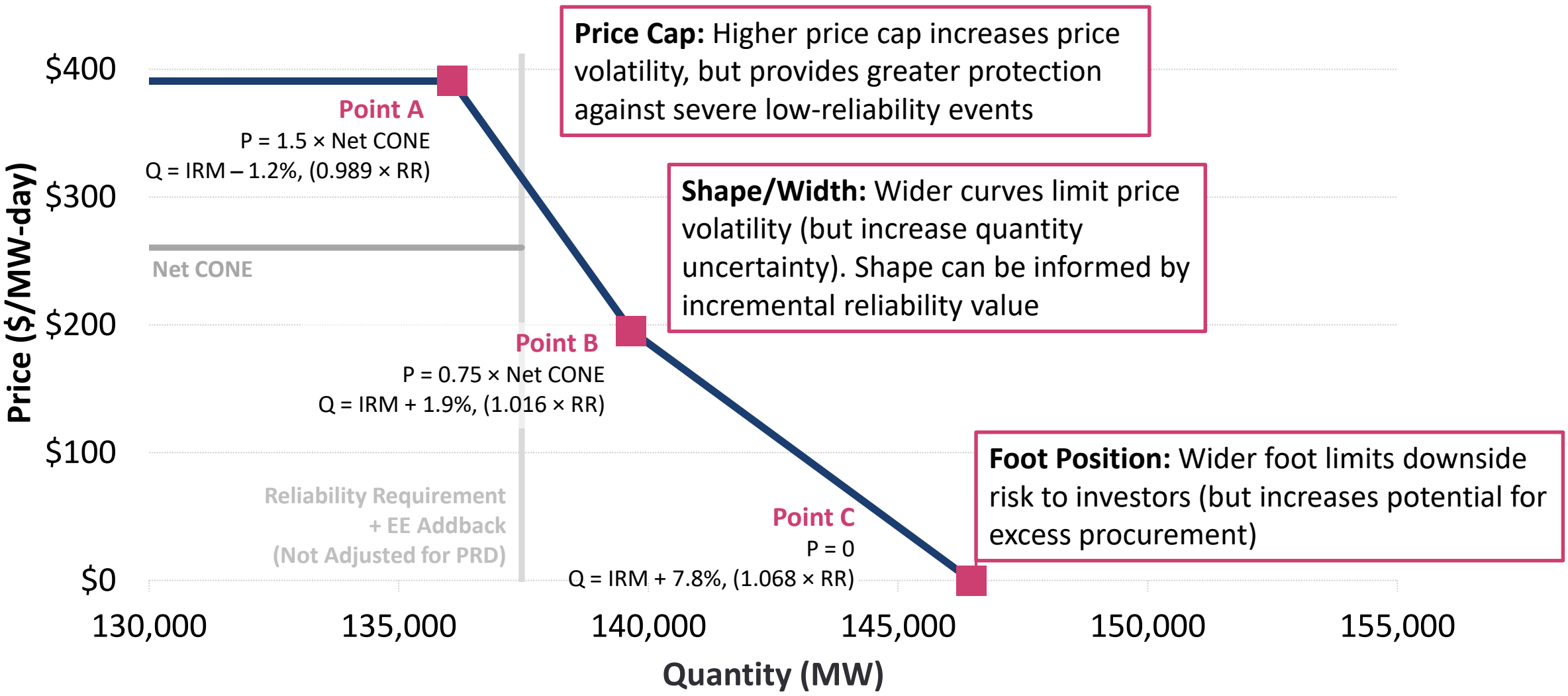
Focus areas will be informed by PJM Board guidance & stakeholder priorities:

- What is the most relevant reference technology: CT, CC, battery, other?
- What are the reasons for current excess supply conditions? How might the VRR curve be adjusted to mitigate oversupply?
- How should load forecast uncertainties be considered in establishing VRR curve parameters?
- Does the changing resource mix require a new approach to the cost recovery path for the reference technology?
- Others?

Discussion:
Study Scope and Focus Areas

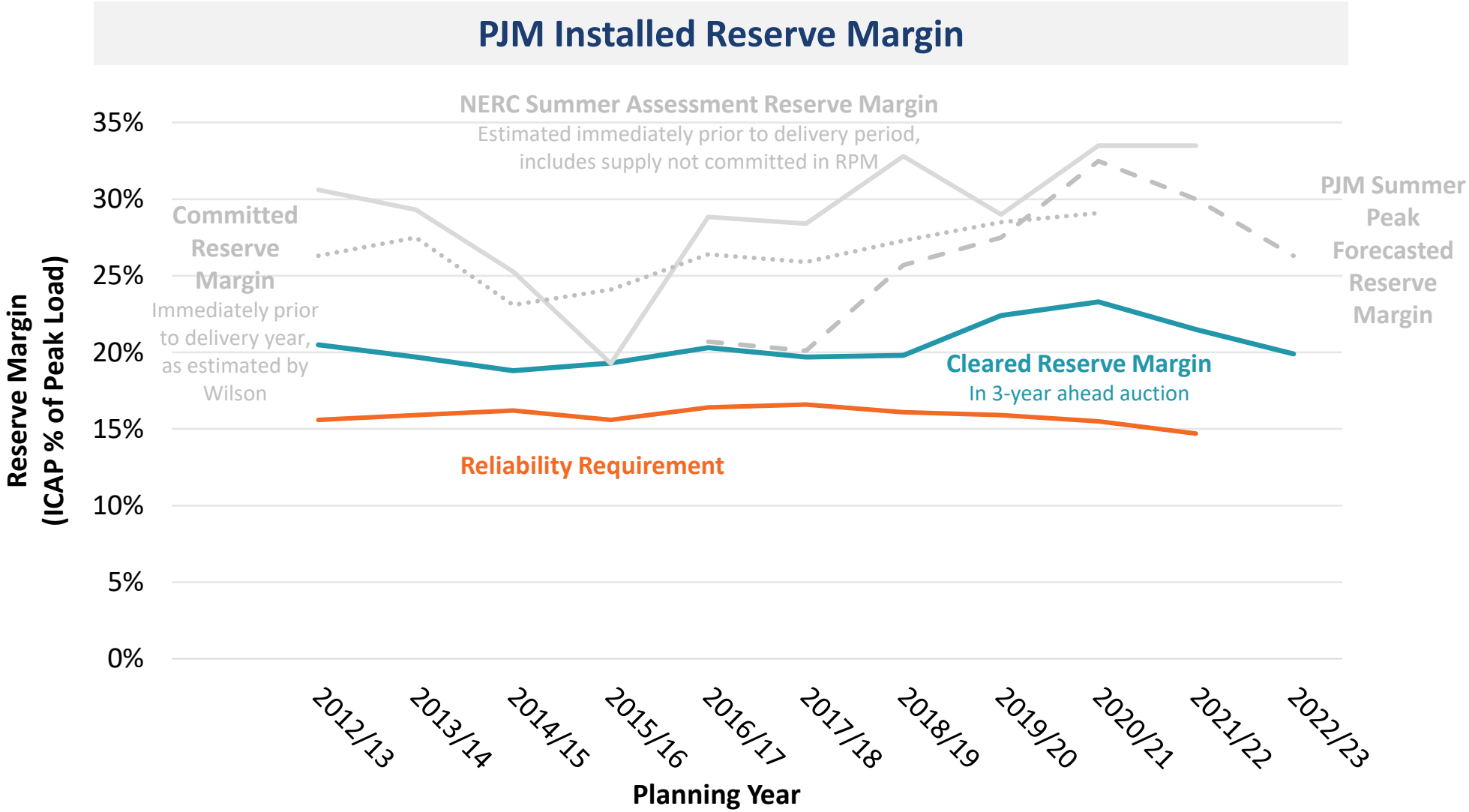
Stakeholder Input Needed: Approach to Assessing Demand Curve Shape

Conceptual Basis for VRR Curve Parameters



Source: 2022/23 RPM Base Residual Auction Planning Parameters

New: Diagnosis of Reasons for Capacity Over-Procurement



Input Requested:
What might contribute to over-procurement?

- Temporary market conditions
- Load forecast error
- Accounting differences (UCAP/ICAP, NERC/RPM)
- Demand curve clearing beyond requirement, including intent to procure modest (not excess) oversupply when prices are low
- Reference technology selection
- Net CONE error
- Supply that is available but uncommitted in RPM

Sources: NERC Summer Reliability Assessments, 2013-2021 ; PJM 2022/2023 RPM Base Residual Auction Results, Table 1; Wilson, J., "Over-Procurement of Generating Capacity in PJM: Causes and Consequences", February 2020; PJM Forecasted Reserve Margin Graphs

Prior Approach: Probabilistic Assessment of Equilibrium Market Conditions

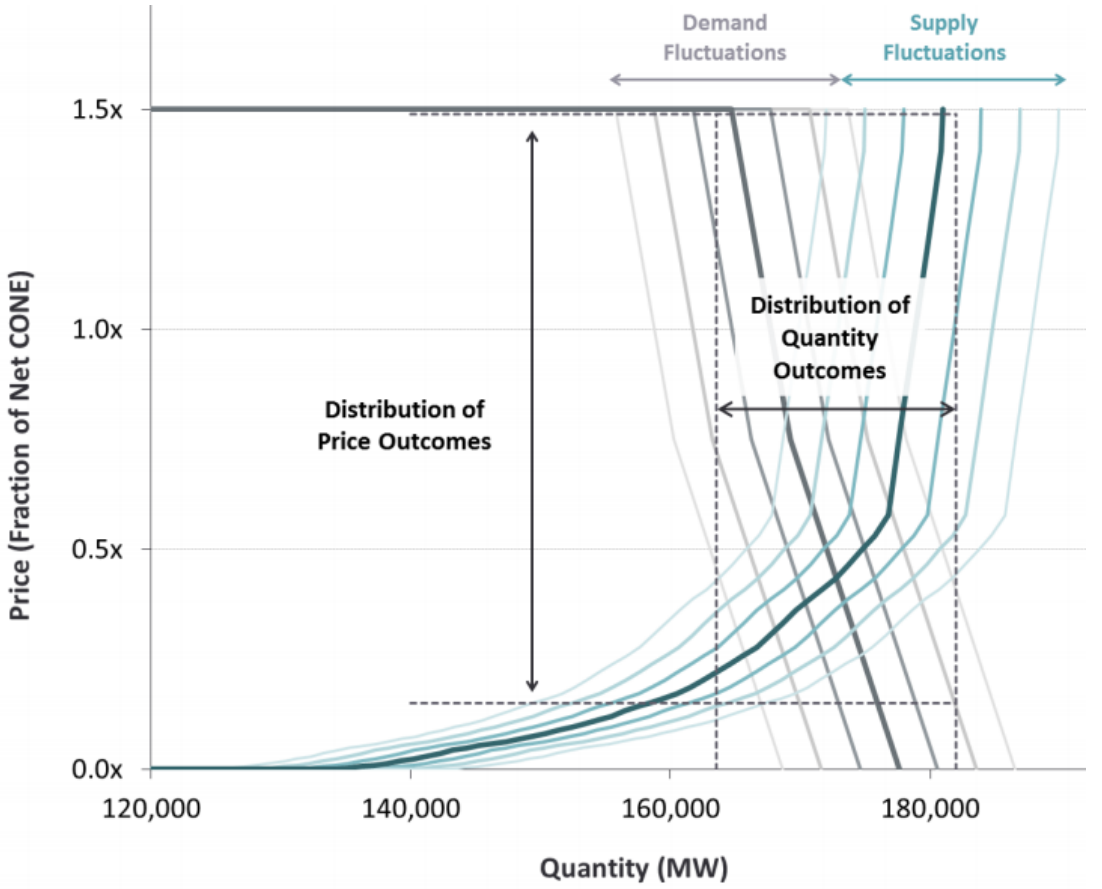
PRIOR MODELING APPROACH

- Monte Carlo model of 3-year forward capacity market clearing price and quantity outcomes
- Accounted for variability in supply curve shapes, supply quantity, demand quantity, and transmission (not time-sequential)
- All model inputs derived from historical market data
- Assessed long-run equilibrium conditions with prices equal to Net CONE (accounting for the possibility that "true" Net CONE may not always equal the administrative Net CONE estimate)
- Produced an expected distribution of price, quantity, and reliability outcomes that were compared to design objectives

Input Requested:

- How should the probabilistic modeling assessment be updated?
- For any proposed updates, how can we inform modeling parameters with historical data?

Supply and Demand Variability
(Illustrative)



Note: For a more comprehensive description of modeling approach, see the Fourth VRR Curve Review.

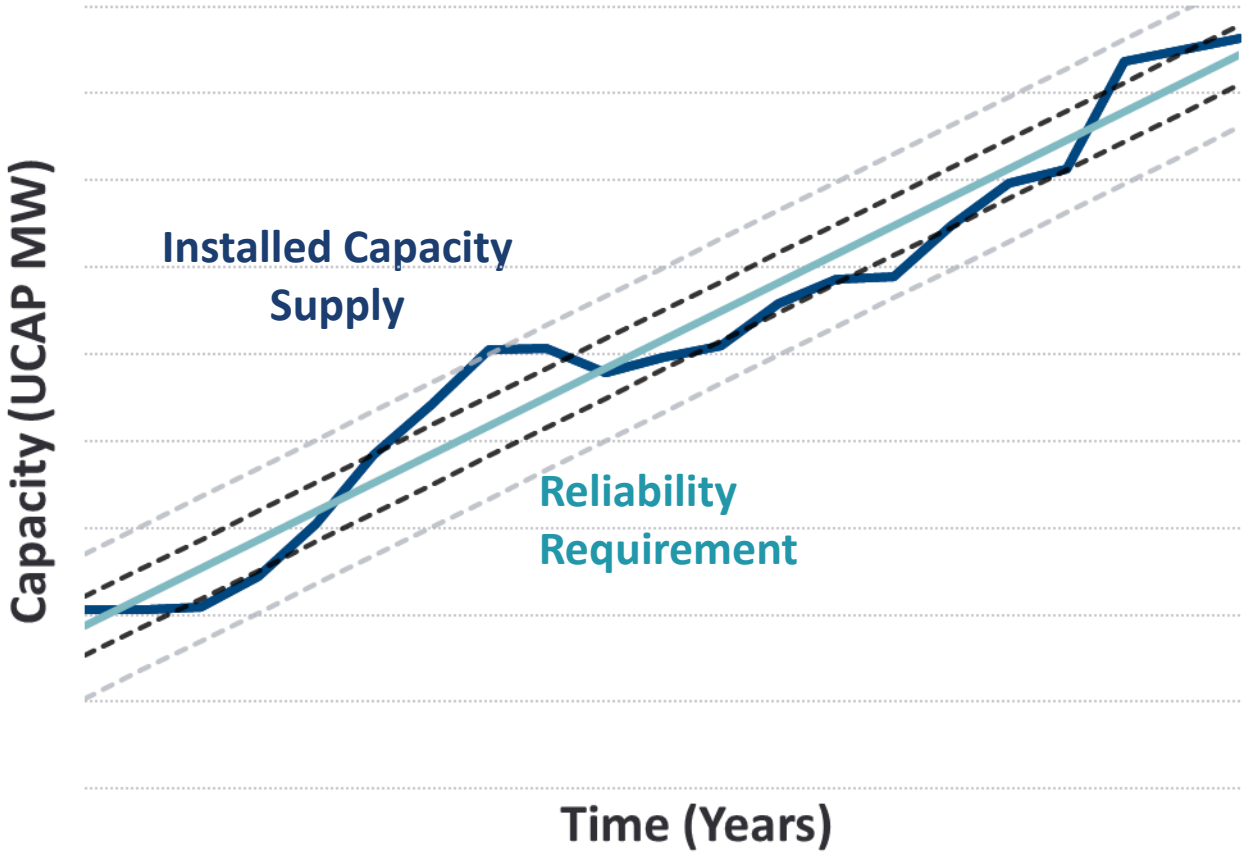
Potential New Analysis: Time-Sequential Modeling of Disequilibrium Conditions

One consideration in VRR curve shape relates to how the curve may tend to mitigate (or exacerbate) the duration of long or short supply conditions

Input Requested:

- Should the VRR Curve review consider a time-sequential analysis? What can this approach tell us that the prior methodology cannot?
- How would the analysis inform the most appropriate VRR Curve shape?
- How can we use historical data to inform market participants' response to recent/anticipated market conditions? (We hope to avoid "guessing" on any modeling parameters that may drive reliability outcomes.)

Supply Over the Investment Cycle
(Illustrative)



Note: Illustrative example of supply over the investment cycle, not intended to reflect PJM.

New: Implications of Load Forecast Error

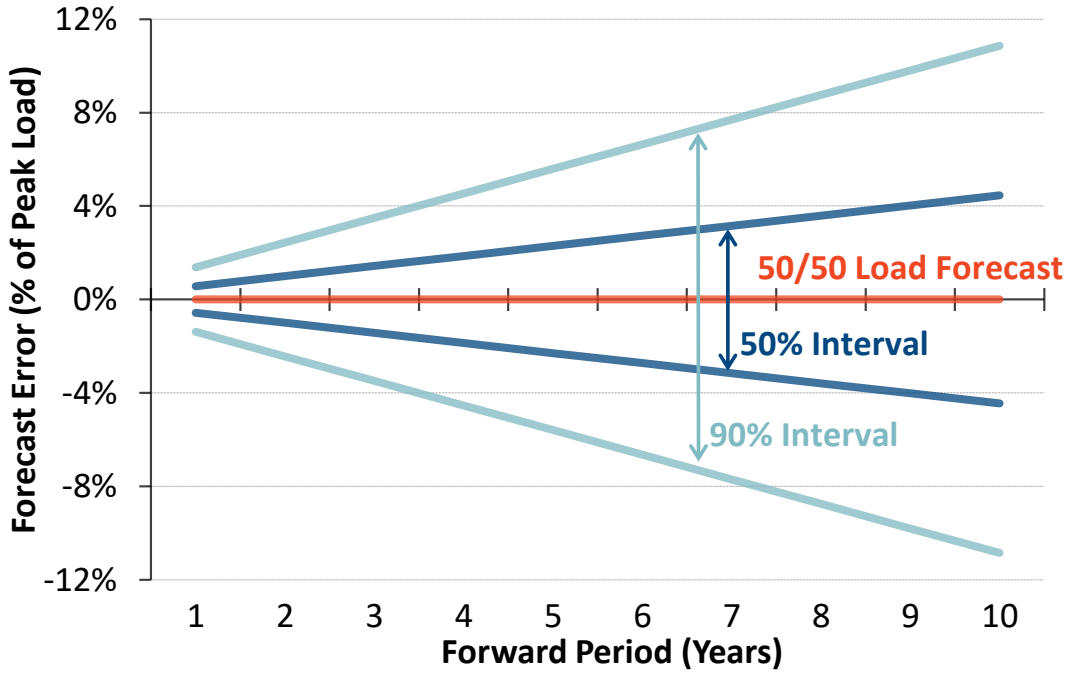
Three-year forward load forecast error can cause oversupply (in over-forecast) or reliability challenges (in under-forecast)

Input Requested:

- Should the VRR curve shape be affected by estimated load forecast error? How?
- What analysis of forecast error should inform the VRR curve shape?
- In case of under-forecast in the 3-year forward auction, how much supply would be available to purchase on a short-term 0-2 years forward Incremental Auctions?
- What historical experience can inform assumptions regarding availability of short-term supply (in the Incremental Auctions) to meet unanticipated reliability needs (given that PJM has not historically experienced such a shortage)?

Non-Weather Forecast Error

Illustrative



Note: Illustrative example of load forecast error as a function of forward period (not intended to reflect PJM).

Other Anticipated Components of the VRR Curve Review

In addition to the focus areas discussed above, the VRR Curve review will incorporate an assessment of the following

- **Historical Performance:** as informed by reliability, price volatility, and cost outcomes
- **Details of Demand Curve Formula:** Determination of CONE and Net CONE, adjustments for EE and PRD
- **Locational Curves:** Probabilistic and conceptual assessment of locational demand curve shapes
- **Marginal Reliability Value:** Extent to which system or locational reliability value can be used to inform demand curve shape
- **System & Local Net CONE:** Differences in Net CONE estimates, and mapping of Net CONE estimates to local demand curves

Input Requested: Anything else that should be considered?

Discussion:
VRR Curve Assessment Approach

August 17th Stakeholder Meeting Preview: Stakeholder Input Needed on CONE and Net E&AS Offset

Gross CONE and Reference Technology

We will be seeking stakeholder feedback on the CONE and reference technology, especially in the following areas:

- Criteria for selecting the reference technology
- Resource types that should be considered as the reference technology based on those criteria
- Detailed specifications for the candidate reference technologies
- Representative locations for developing bottom-up cost estimates
- Public companies to include in the sample for estimating the Return on Equity
- Recent transactions that provide additional reference points for cost of capital

We will also be seeking stakeholder feedback on ways to further improve the recently approved forward-looking E&AS offset

Impact of CONE & Reference Technology on VRR Curve

We aim to focus stakeholder input on developing a robust evidentiary basis for the assumptions that have the most material impact on the Net CONE estimate.

Illustrative Adjustments to Net CONE Values

(based on 2022/23 COMED values)

Assumption	2018 CONE Study Assumption	Illustrative Sensitivity	Net CONE ($/MW UCAP-Day)	Impact ($/MW UCAP-Day)	Impact (%)
CT 2022/23 MOPR	---	---	$256/MW-day	---	---
Reference Technology	Gas CT	Gas CC	$135/MW-day	-$121/MW-day	-47%
Cost Recovery Path (or "Levelization")	Level-Nominal	Level-Real	$211/MW-day	-$45/MW-day	-18%
Detailed Specification	Selective Catalytic Reduction (SCR)	No SCR	$221/MW-day	-$35/MW-day	-14%
Return on Equity	13%	14%	$266/MW-day	+$9/MW-day	+4%

Selection of Reference Technology is likely the most important study assumption.

2018 CONE Study Reference Technology Detailed Specifications

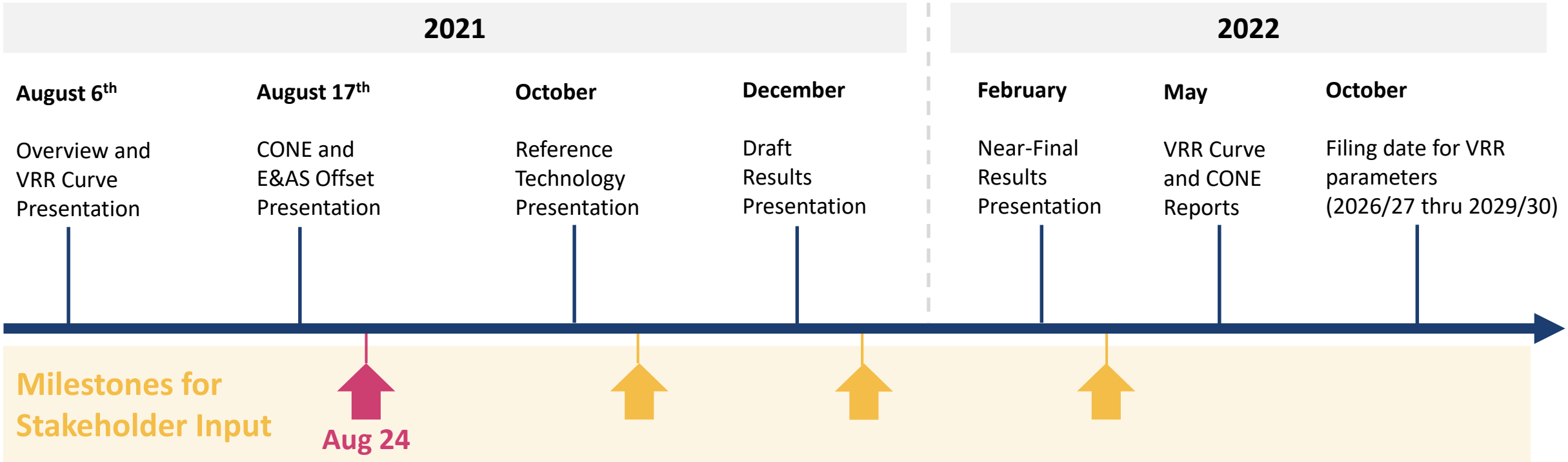
Plant Characteristic	Combustion Turbine	Combined Cycle
Turbine Model	7HA.02	7HA.02
Configuration	1x0	2x1
Power Augmentation	Evaporative Cooling, no inlet chillers	Evaporative Cooling, no inlet chillers
CC Supplemental Firing	---	+125 MW (+13%)
CC Cooling System	---	Cooling Towers
Fuel Supply	Dual Fuel	Dual Fuel, except SWMAAC (firm gas)
Environmental Controls	SCR and CO Catalyst	SCR and CO Catalyst
Net Summer ICAP	321 – 355 MW	1,126 – 1,160 MW
Net Heat Rate (HHV)	9,221 – 9,274 Btu/kWh	6,295 – 6,312 Btu/kWh

Note: Net Summer ICAP and Net Heat Rate estimated based on average summer ambient conditions in each CONE Area. For the CC, ICAP is with duct firing and net heat rate is without duct firing (adds about 240 Btu/kWh). See 2018 CONE Study for additional information.

Next Steps

Stakeholder Input to Inform the Quadrennial Review

Provide initial input on study scope and approach by **August 24** to **Melissa.Pilong@pjm.com** or **Gary.Helm@pjm.com**



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