Fifth Review of the Variable Resource Requirement Curve

MEETING #2: STAKEHOLDER INPUT FOR CONE AND E&AS OFFSET

PRESENTED BY

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PRESENTED TO

PJM Market Implementation Committee

AUGUST 17, 2021

Brattle

Agenda

Introduction: What is Net CONE and how does its estimation relate to the VRR curve?

Selecting Reference Technology

Approach to Updating CONE

Review of Forward-Looking E&AS Approach

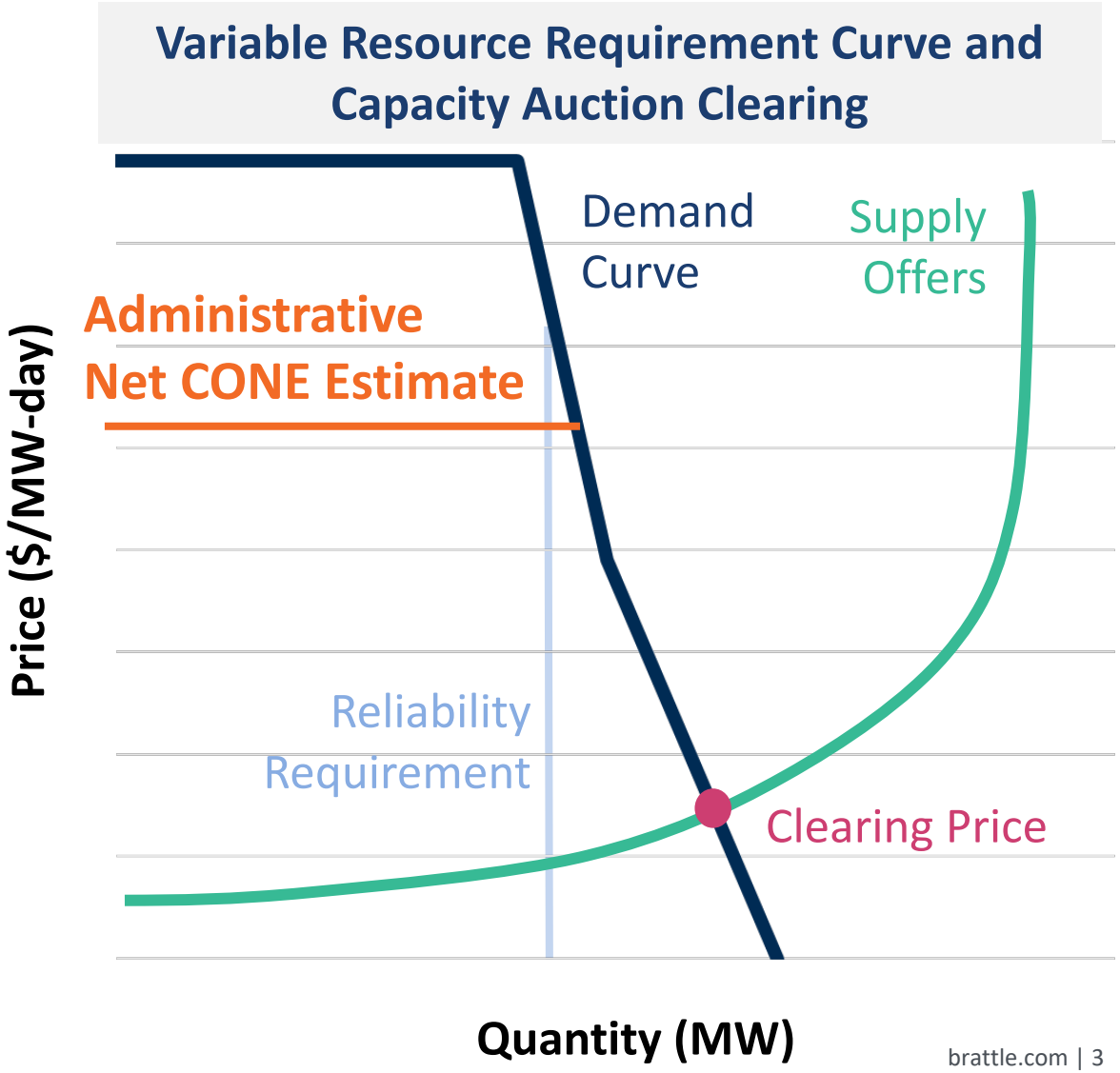
Next Steps

Introduction

Recap: What is Net CONE?

Role of Net CONE is to anchor the VRR curve

- As in any market, competitive suppliers should be willing to enter at a price equal to the long-run marginal cost of capacity (i.e., Net CONE).
- Setting the VRR curve quantity to approximately the target Reserve Margin (RM) at that price should therefore yield the target RM in the long run; the slope will allow for an even stronger signal when short.
- Accordingly, Net CONE is the capacity price at which a marginal technology should be willing to enter to just earn its return on/of capital, estimated as:
  - 1st-year annualized fixed costs (CONE)…
  - *minus* projected cost recovery from revenues in the energy and ancillary service (E&AS) markets



Which Factors Most Affect Net CONE?

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 Impact of Various Parameters on Net CONE Estimates

(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.

Net CONE Uncertainty

We will estimate Net CONE as accurately as possible but recognize and address uncertainties

Uncertainty Drivers

- **Reference Technology**: Which technologies are economic?
- **Levelization**: How much total revenue investors would need (in year 1) to enter, *consistent with their long-term view of a market that is changing rapidly*?
- **Other Drivers**: Some other Net CONE uncertainty with cost of capital, bottom-up cost estimates, and EAS offsets, depending on the technology

Consequences of Uncertainty

- **Under-stating Net CONE**
  Risks under-procuring and threatening reliability
- **Over-stating Net CONE**
  Risks over-procuring, at a cost to customers
- The VRR curve analysis will explore these risks

Strategies to Reduce Uncertainty and Mitigate Risks

Reduce Uncertainty

- Conduct a rigorous study, based on a reference tech whose Net CONE can be assessed accurately (and that we're confident is economic and can be built for the delivery year)
- Consider using "empirical Net CONE" to validate "administrative Net CONE"

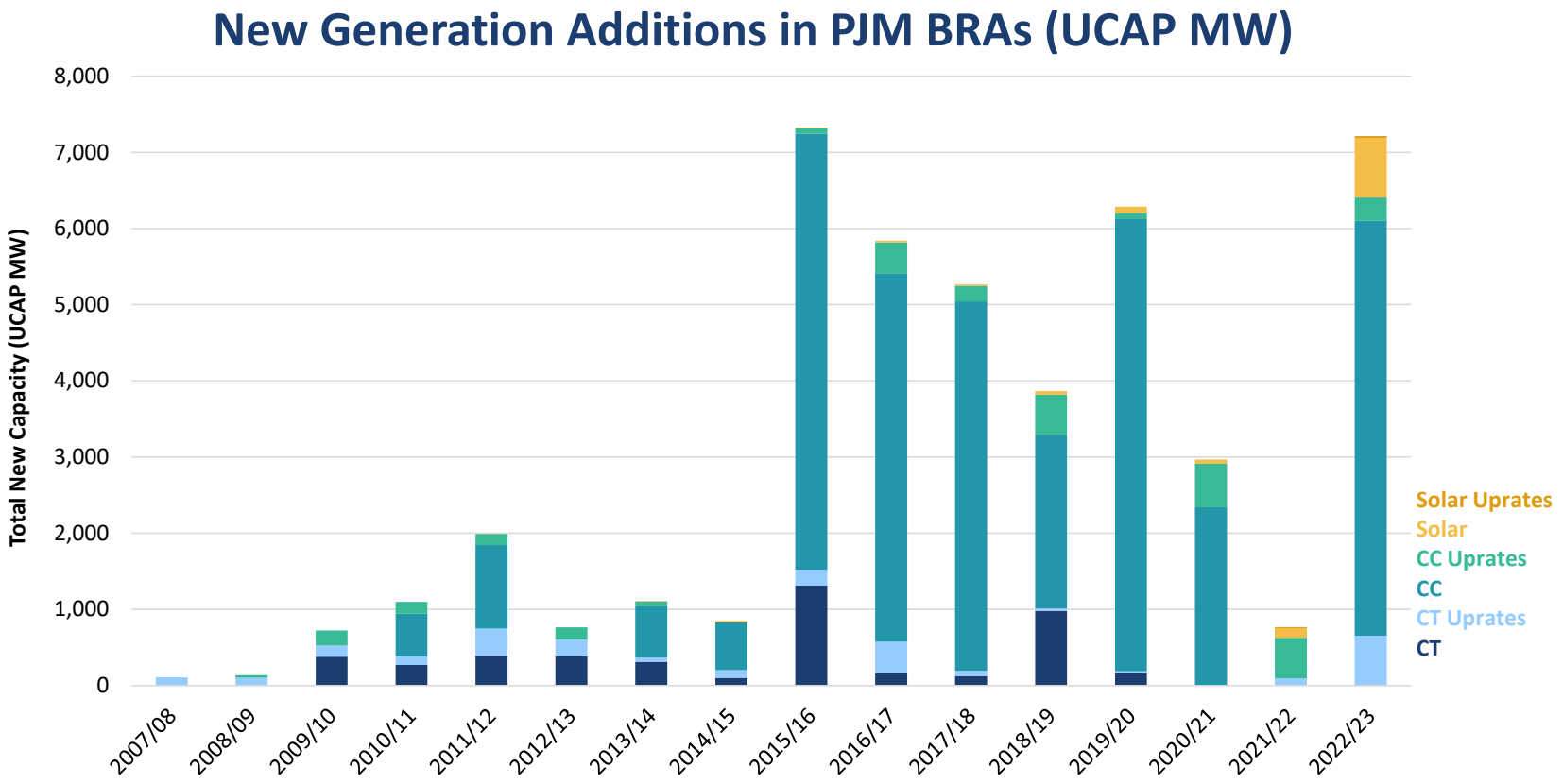
Mitigate risks, e.g., through possible VRR adjustments, such as:

- Steepening the VRR curve
- Shifting the VRR curve
- Defining conditions under which Net CONE would be adjusted

Stakeholder Input Needed: Selecting Reference Technology

Gas CCs have been the dominant new generation resource…

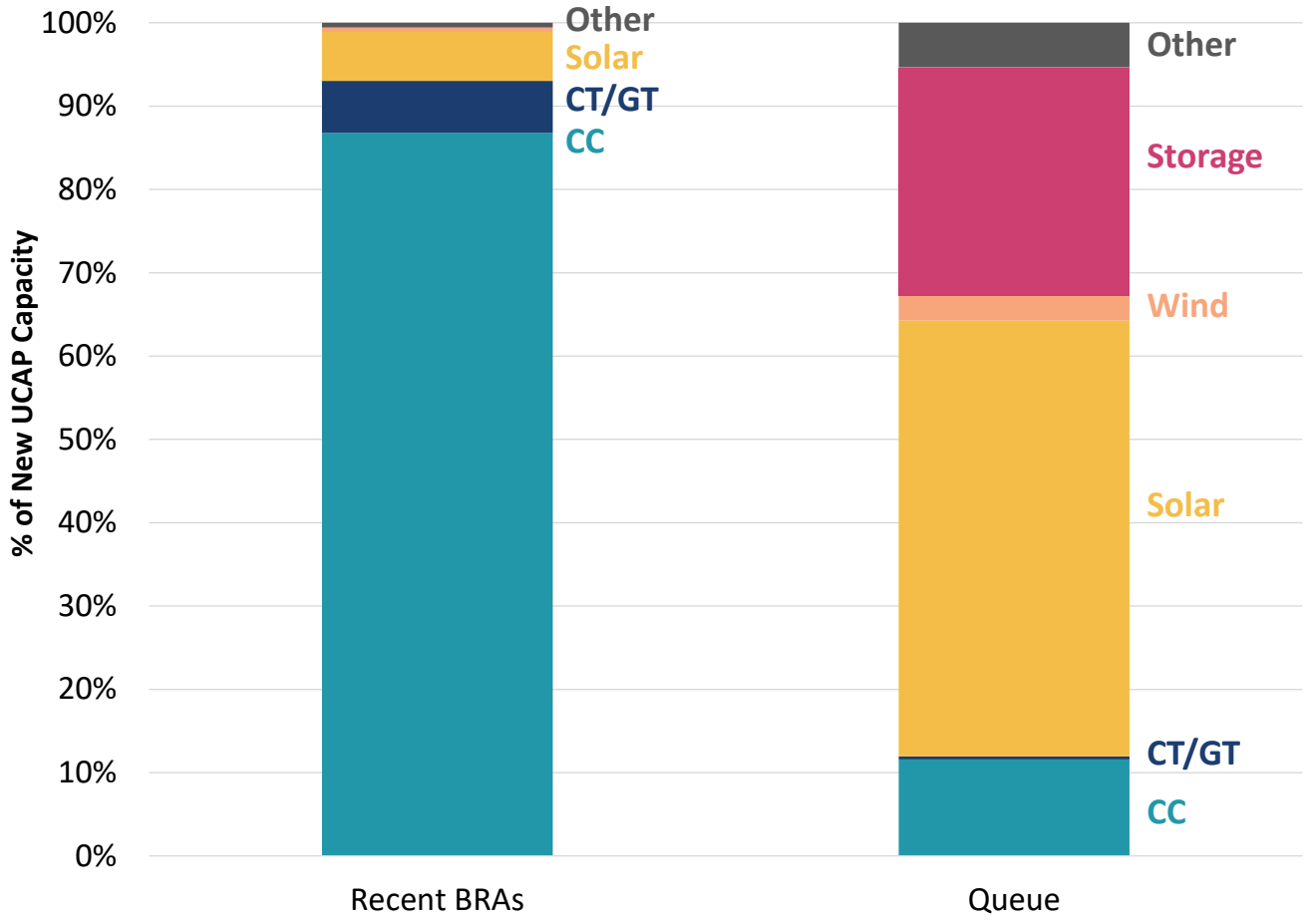
Over the past five auctions, 16,000 MW of new Gas CCs cleared compared to 1,150 MW of new Gas CTs and 1,080 MW of new solar (mostly in 2022/23)



Source: PJM Base Residual Auction Results for 2022/23, published on June 2, 2021

…although Solar and Storage Now Dominate the Queue

New Capacity Cleared in Recent BRAs (2018/19 - 22/23) vs. the More Forward-Looking Queue



Sources and Notes : PJM Base Residual Auction Results for 2022/23, published on June 2, 2021 and PJM New Service Interconnection Queue (submitted since 2018), accessed August 1, 2021.
Assumptions for translating solar and storage ICAP to UCAP: solar tracking 4-Hour battery storage.

Proposed Criteria for Selecting Reference Technology

Feasible to build for the delivery year, given local laws/regulations and technical factors

Economic source of incremental capacity

- Demonstrated by recent merchant entry, not in anomalous situations
- Not having a Net CONE much higher than other candidates
- Likely to remain economic through the end of the review period (2029/30)

Costs, net E&AS revenues, and RA contribution per MW can be assessed accurately

- Evidence of capital and operating costs exists from commercial experience
- Costs are uniform when scaled, rather than increasing steeply as best sites are exhausted
- Has stable UCAP/ICAP ratio or ELCC, rather than changing steeply with penetration or fleet composition
- Has high UCAP/ICAP ratio or ELCC, else uncertainties are amplified per kW UCAP
- Not largely dependent on revenues that are difficult to forecast (AS, energy volatility, RECs)

Input Requested: What criteria should PJM use to select the Reference Technology?

Initial Screening Analysis of Technologies

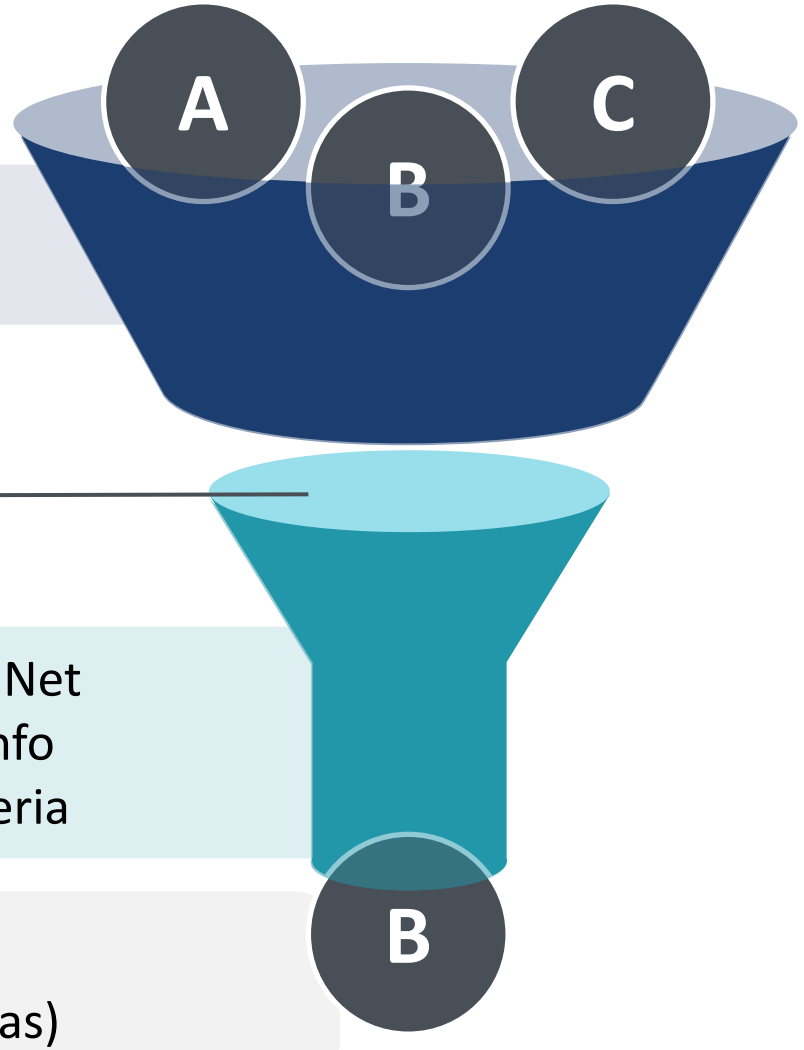
Technology	Feasible to Build for DY	Evidence of Economic Source of Capacity	Accuracy of Net CONE Estimates
Gas CC	Yes	Yes	High
Gas CT	Yes	Unclear (few built, higher Net CONE)	High
Battery Storage	Yes	Unclear (no standalone cleared in RPM)	Medium (falling costs; AS-dependence; ELCC stability?)
Hybrid PV-BESS	Yes	Unclear (is any entering as merchant?)	Medium (REC-dependence; ELCC stability?)
Utility-Scale PV	Yes	Unclear (is any entering as merchant?)	Medium (REC-dependence; med ELCC, stability)
Wind	Yes	Unclear (is any entering as merchant?)	Low (REC-dependence; low ELCC, stability)
Energy Efficiency/DR	Yes	Yes	Low (varies by site)
Uprates/Conversions	Yes	Yes	Low (varies by site)
Emerging Technologies	No	None	Low

Input Requested:

- Should other resources be considered?
- Are new Gas CCs and CTs feasible to build in all LDAs?
- Are CTs economic to build?
- Will entry of CCs continue to be economic in a decarbonizing future?
- Are storage and solar currently being developed on a merchant basis?
- Should the reference technology differ across zones, as well as between BRA and Incremental Auctions?

Process for Selecting

Screening Analysis: Apply criteria to all candidate technologies

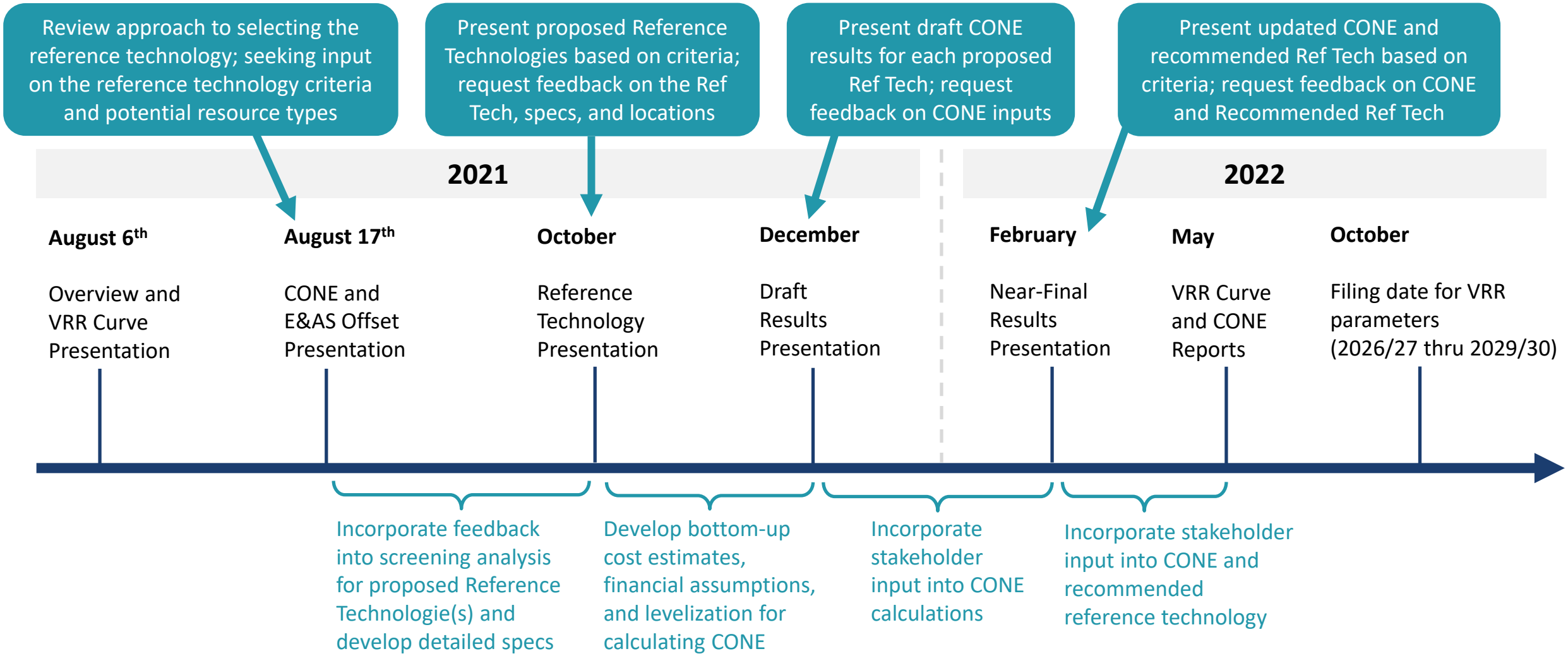


SHORT LIST OF 2 PROPOSED TECHNOLOGIES (TO PRESENT IN OCT)

Detailed Analysis: Conduct detailed analysis of Net CONE for proposed technologies; incorporate info from 2023/24 BRA; then re-apply selection criteria

Recommend Reference Technology
(or technologies if appropriate for different areas)

Stakeholder Input Schedule for Reference Technology Selection



Discussion:

Selecting Reference Technology

Stakeholder Input Needed: Estimating Reference Technology CONE

Reference Technology Detailed Specifications

Key market changes since 2018 CONE Study:

- Few 7HAs developed as standalone CTs
- Continued CC development
- Commodity pricing and availability

Input Requested:

- Do any of these specs have to be modified? Provide supporting evidence to justify the modification.
- If other resources should be included in our detailed analysis, please provide specifications at a similar level of detail.

2018 Study Reference Technology Detailed Specifications

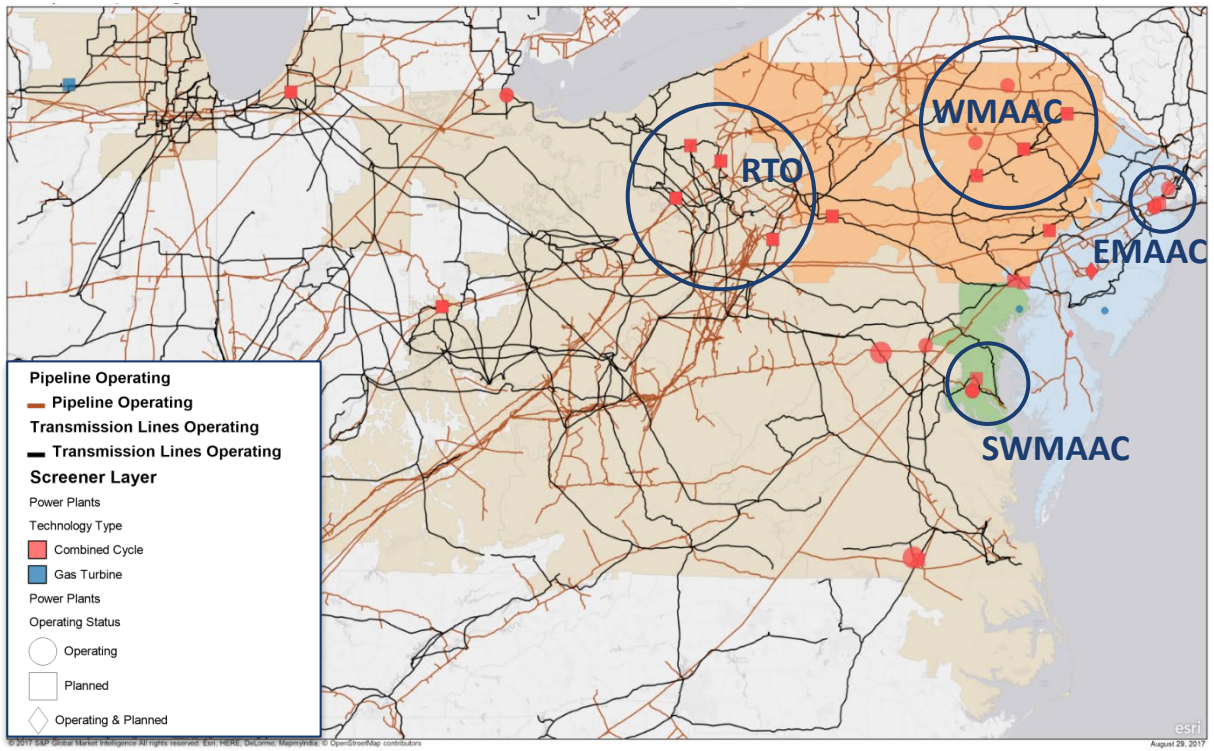
Plant Characteristic	Combustion Turbine	Combined Cycle
Turbine Model	7HA.02	7HA.02
Configuration	1x0	2x1
Power Augmentation	Evaporative Cooling, no inlet chillers	Evaporative Cooling, no inlet chillers
CC Supplemental Firing	---	+125 MW (+13%)
CC Cooling System	---	Cooling Towers
Fuel Supply	Dual Fuel	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.

CONE Area Locations

We identify locations primarily based on most recent areas of development for estimating labor costs, property taxes, land costs, and resource performance

2018 Study CONE Area Locations



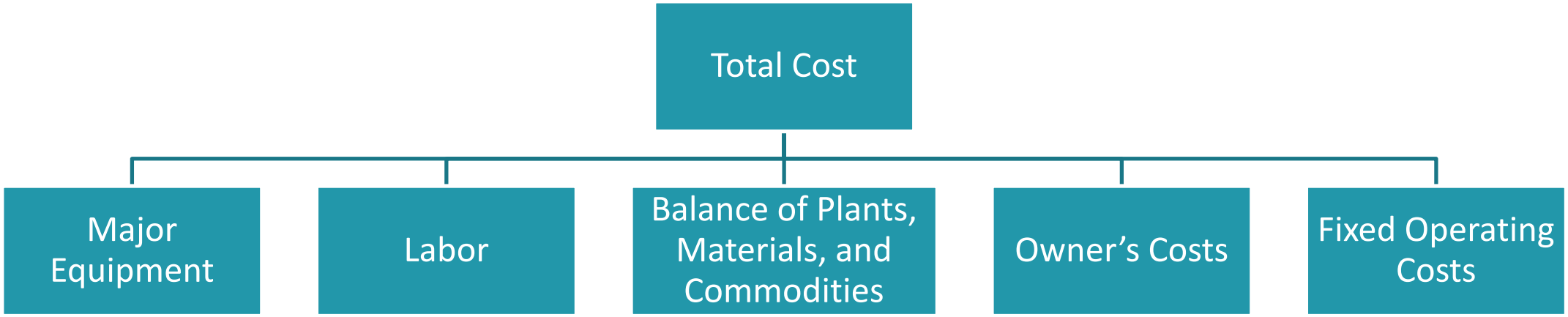
Source: SNL Financial, from Brattle 2018 CONE Study

Input Requested:

- Should the CONE Areas be revised to account for the changing resource mix?
- Are these locations representative and supportive of developing accurate cost estimates?
- If not, which locations are better and why?
- Should we consider any other locational factors?

Detailed Cost Estimation Approach

Based on the final detailed technology specifications and locations, we develop bottom-up cost estimates



Input Requested:

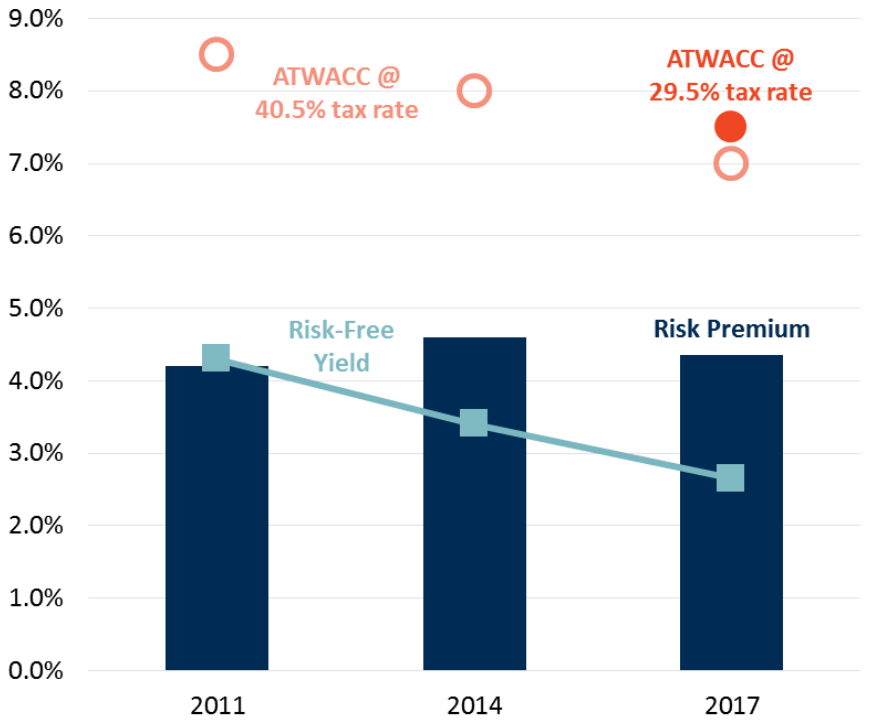
- Should we consider other sources to develop bottom-up cost estimates?
- Are there recent plant costs data we can use to benchmark our estimates?

Merchant Cost of Capital

Approach to Estimating the Cost of Capital

- Identify sample public companies and other reference points
- Consider relative risk of sample versus pure merchant
- Estimate overall cost of capital, then derive ROE, COD, Debt Rate based on market rates that together give the estimated ATWACC
- Develop an initial estimate in Fall 2021 and a final in Spring 2022

Comparison of Brattle Cost of Capital Recommendations for PJM



Source: Brattle 2018 CONE Study

Input Requested:

- What additional reference points inform the merchant Cost of Capital?
- Are there additional considerations we should include?
- Should we modify our existing scenario parameters or are there any other scenarios we should consider?

Levelization: Cost Recovery Path and Economic Life

In 2018, we recommended “level-nominal” cost recovery path based on the outlook for long-term cost escalation of new gas resources and performance improvements and assuming future gas-fired resources continue to be economic to develop

- Market will change considerably over the assumed 20-year economic life:
  - Growth in renewable resources
  - Decline in storage costs
- The assumption that gas-fired resources will remain marginal new capacity resources over the economic life of new resources needs to be re-assessed
- Note limited gas-fired development currently in the pipeline

Input Requested:

- How are developers thinking about long-term cost recovery for different resource types?
- How should we account for the mix of state energy policies across PJM?

Discussion:

Estimating Reference Technology CONE

Stakeholder Input Needed: E&AS Offset Review

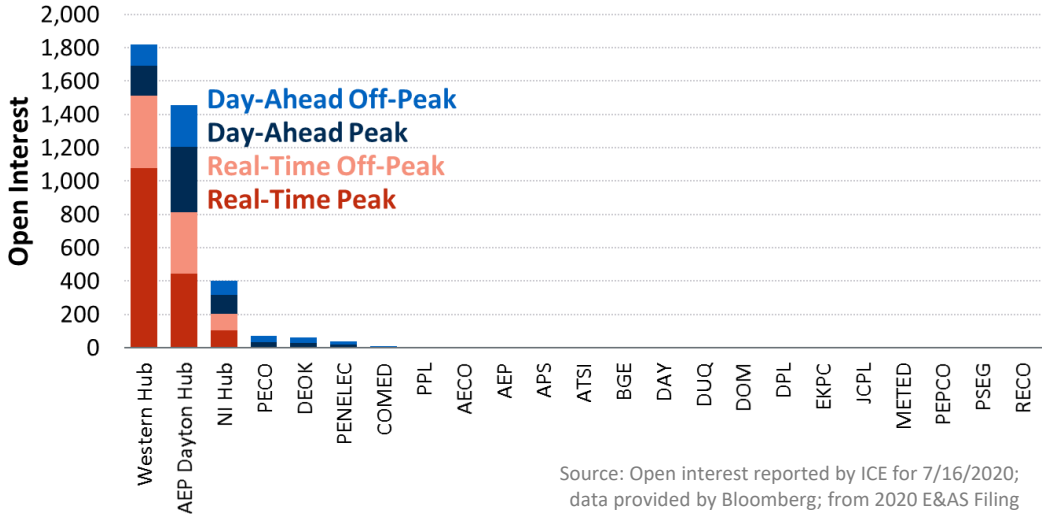
Forward-Looking Energy Prices

A key input to the development of forward-looking energy prices is the identification of liquid electricity futures trading hubs within PJM and how the energy prices at those hubs correlate to prices in each PJM zone

Electricity Futures Hub Liquidity: 2020 E&AS filing identified hubs with sufficient liquidity based on the total Open Interest on RT and DA products for the future period

Zonal Energy Price Correlation to Hubs: Hubs mapped to zones based on the historical correlation of prices between the zone and the identified hubs

Monthly Average Open Interest for PJM Futures Products (2024)



Source: Open interest reported by ICE for 7/16/2020; data provided by Bloomberg; from 2020 E&AS Filing

Hub-to-Zone LMP Correlation Analysis

Mapped Hub	Zone	Correlation
N. Illinois	COMED	1.00
AEP-Dayton	AEP	0.99
	ATSI	0.99
	DAY	0.99
	DEOK	0.96
	DUQ	0.99
	EKPC	0.99

Mapped Hub	Zone	Correlation
Western Hub	APS	1.00
	DOM	0.98
	PEPCO	0.99
	BGE	0.98
	DPL	0.92
	PENELEC	0.98
	PPL	0.94
	METED	0.93
	PECO	0.93
	AECO	0.93
	PSEG	0.93
	JCPL	0.93
	RECO	0.94

Source: 2020 E&AS Filing

Input Requested: Should PJM use a different approach to identifying liquidity, including futures sources, metrics, or hubs?

Input Requested: Is there an alternative approach to mapping hubs to zones that PJM should consider?

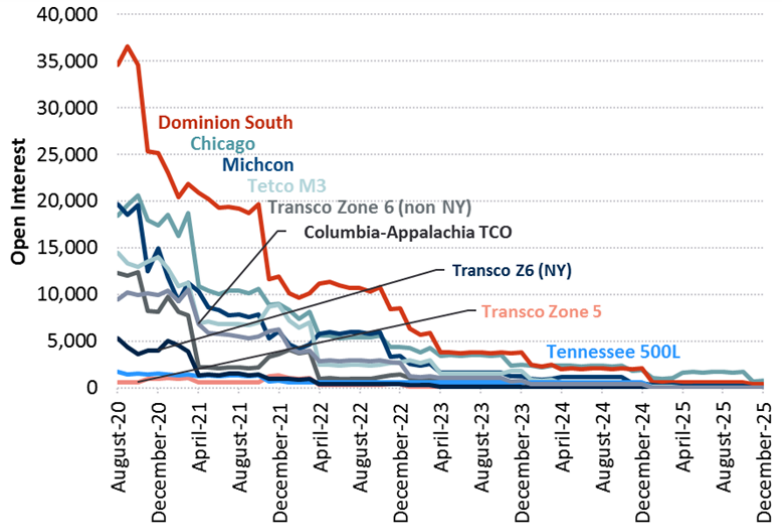
Forward-Looking Natural Gas Prices

For natural gas prices, PJM maps each zone to one of nine gas trading hubs, determines whether there is sufficient liquidity at each hub, and for illiquid hubs finds a liquid trading hub with the highest historical correlation

Natural Gas Hub Futures Liquidity: 6 liquid hubs and 3 illiquid hubs identified based on future Open Interest

Hub Correlation: 3 illiquid hubs mapped to the liquid hub with the highest historical correlation

Open Interest at PJM Gas Hubs Through 2025



Source: Open interest reported by ICE for 7/15/2020; data provided by Bloomberg; from 2020 E&AS Filing

Mapping between Illiquid Gas Hubs and Liquid Gas Hubs

Gas Hub	Mapped Gas Hub	2017-2019 Correlation
Transco Zone 5	Transco Zone 6 (non NY)	0.996
Tennessee 500L	Columbia-Appalachia TCO	0.976
Transco Z6 (NY)	Transco Zone 6 (non NY)	0.995

Source: 2020 E&AS Filing

Input Requested: Should PJM use a different approach to identifying liquidity, including futures sources, metrics, or hubs?

Input Requested: Is there an alternative approach to mapping illiquid gas hubs to liquid gas hubs?

Forward-Looking Ancillary Service Prices

Unlike energy and natural gas prices, there are no observable forward markets for ancillary services in PJM

Due to the Reserve Pricing Reforms implemented in 2018 (that will be put into effect in 2022), the E&AS offset estimates relied on the following approaches for estimating forward-looking ancillary service prices:

- *Reserve Prices*: use historical hourly reserve prices
- *Regulation Prices*: scale historical regulation prices by changes in energy prices as the planned reserve pricing reforms do not directly impact regulation pricing

Input Requested: Is there a better approach to developing forward-looking AS prices?

EE Wholesale Energy Savings

Annual wholesale energy savings estimated based on the publicly-available data for BG&E, ComEd, and PPL EE programs

- These utilities reported detailed program-level data
- Represent the largest utility programs in their states
- Excluded 14 programs that do not qualify for offering capacity or would participate in the capacity market as demand response, not EE

Energy savings estimated based on forward-looking zonal hourly prices and program data on annual energy savings and peak demand reduction

Input Requested: Are there other utility EE programs that should be included in our analysis?

Customer Class	Program Name	Included/ Excluded	Annual Energy Savings *MWh*	Peak Demand Savings *MW*
BGE				
Residential	Residential Lighting	Included	140,707	19.5
Residential	Appliance Rebates	Included	3,251	0.7
Residential	Home Performance with ENERGY STAR	Included	3,933	1.1
Residential	HVAC Rebates	Included	10,860	3.2
Residential	ENERGY STAR for New Homes	Included	6,377	2.5
C&I	Small Business Energy Solutions	Included	26,000	5.5
C&I	Prescriptive	Included	62,000	3.5
C&I	Custom	Included	21,000	5.5
C&I	Building Tune-up	Included	4,000	1.0
C&I	Instant Savings	Included	28,000	10.0
Residential	Appliance Recycling	Excluded	8,639	1.5
Residential	Quick Home Energy Check-up	Excluded	11,421	0.1
Residential	Smart Thermostats	Excluded	7,412	1.0
Residential	Smart Energy Manager	Excluded	46,102	10.4
Residential	Smart Energy Rewards	Excluded	1,573	115.2
C&I	Combined Heat and Power	Excluded	24,000	3.6
ComEd				
Residential	Appliance Rebates	Included	5,580	0.9
Residential	Elementary Energy Education	Included	1,734	0.2
Residential	Home Energy Assessments	Included	8,875	0.9
Residential	HVAC and Weatherization	Included	18,770	4.8
Residential	Multifamily - Tenant Area	Included	3,268	0.3
Residential	Res Fridge and Freezer	Included	26,185	2.6
Residential	Residential New Construction	Included	547	0.3
C&I	AirCare Plus	Included	2,786	0.3
C&I	Business Instant Lighting Discount	Included	282,451	51.1
C&I	Business New Construction	Included	43,303	8.6
C&I	Business Custom	Included	26,725	3.6
C&I	Data Centers	Included	19,153	1.8
C&I	Industrial Systems	Included	39,434	4.9
C&I	Retro- Commissioning	Included	25,215	0.5
C&I	Business Standard	Included	230,289	25.8
Residential	Meter Genius Pilot	Excluded	n/a	n/a
Residential	Res ES Lighting (Carryover)	Excluded	87,810	9.9
C&I	Business Instant Lighting Discount (Carryover)	Excluded	31,002	6.3
C&I	Energy Analyzer	Excluded	59,217	n/a
C&I	Strategic Energy Management Pilot	Excluded	7,160	n/a
PPL				
Residential	Efficient Lighting	Included	128,036	17.4
Residential	EE Kits & Education	Included	11,829	1.1
Residential	EE Home	Included	18,802	3.6
Residential	SEEE	Included	6,024	0.6
C&I	All Programs	Included	162,377	22.7
Residential	Appliance Recycling	Excluded	10,731	1.6
Residential	Home Energy Education	Excluded	30,311	5.3
Residential	LI WRAP	Excluded	14,412	1.6

Source: 2020 ACR/EE Net CONE Study

Discussion:

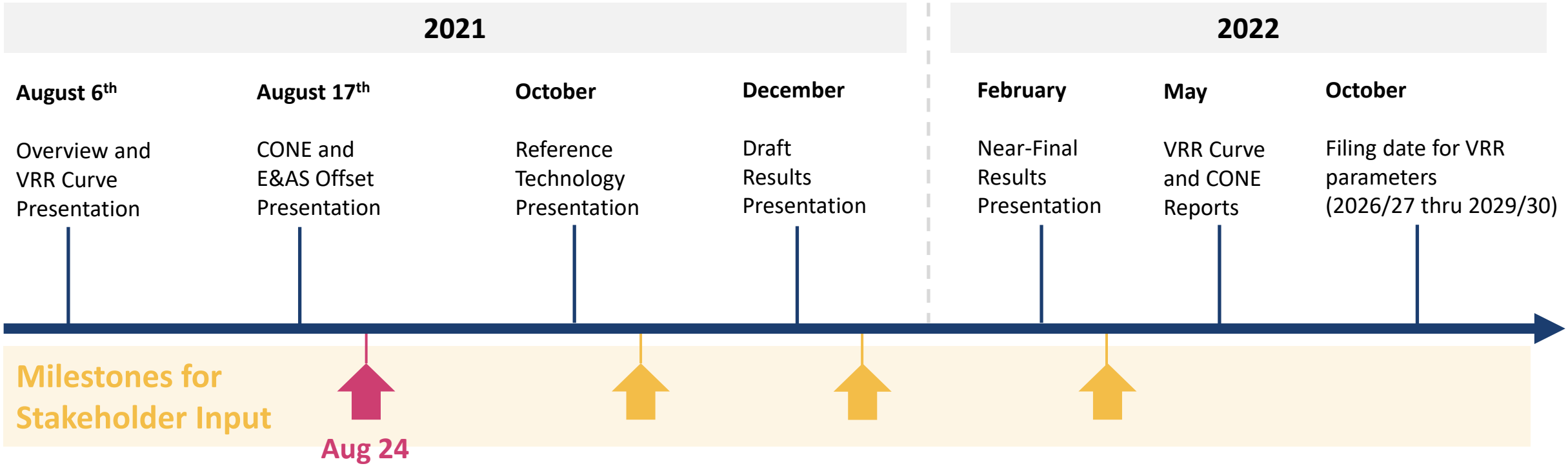
Reviewing E&AS Offset Approach

Next Steps

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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