Sixth Review of PJM's RPM VRR Curve Parameters

PRELIMINARY GROSS CONE AND E&AS METHODOLOGY

PREPARED BY

The Brattle Group

Sam Newell

Andrew W. Thompson

John Higham

Nathan Felmus

Sargent & Lundy

Joshua Jungé

Hyojin Lee

PRESENTED TO

PJM Market Implementation Committee

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Brattle

Agenda

Introduction: Motivation, Context, Scope, and Approach

Preliminary Gross CONE

- Overview
- Resource Specifications
- CapEx and O&M Costs
- Calculate CONE
- Annual CONE Updating Methodology

E&AS Methodology Review

- Review of the E&AS Purpose and Current Approach
- Construction of Hourly Forward Prices
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- Natural Gas Hub Mapping

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Next Steps

RPM and VRR Curve Design Objectives – Recap for Grounding

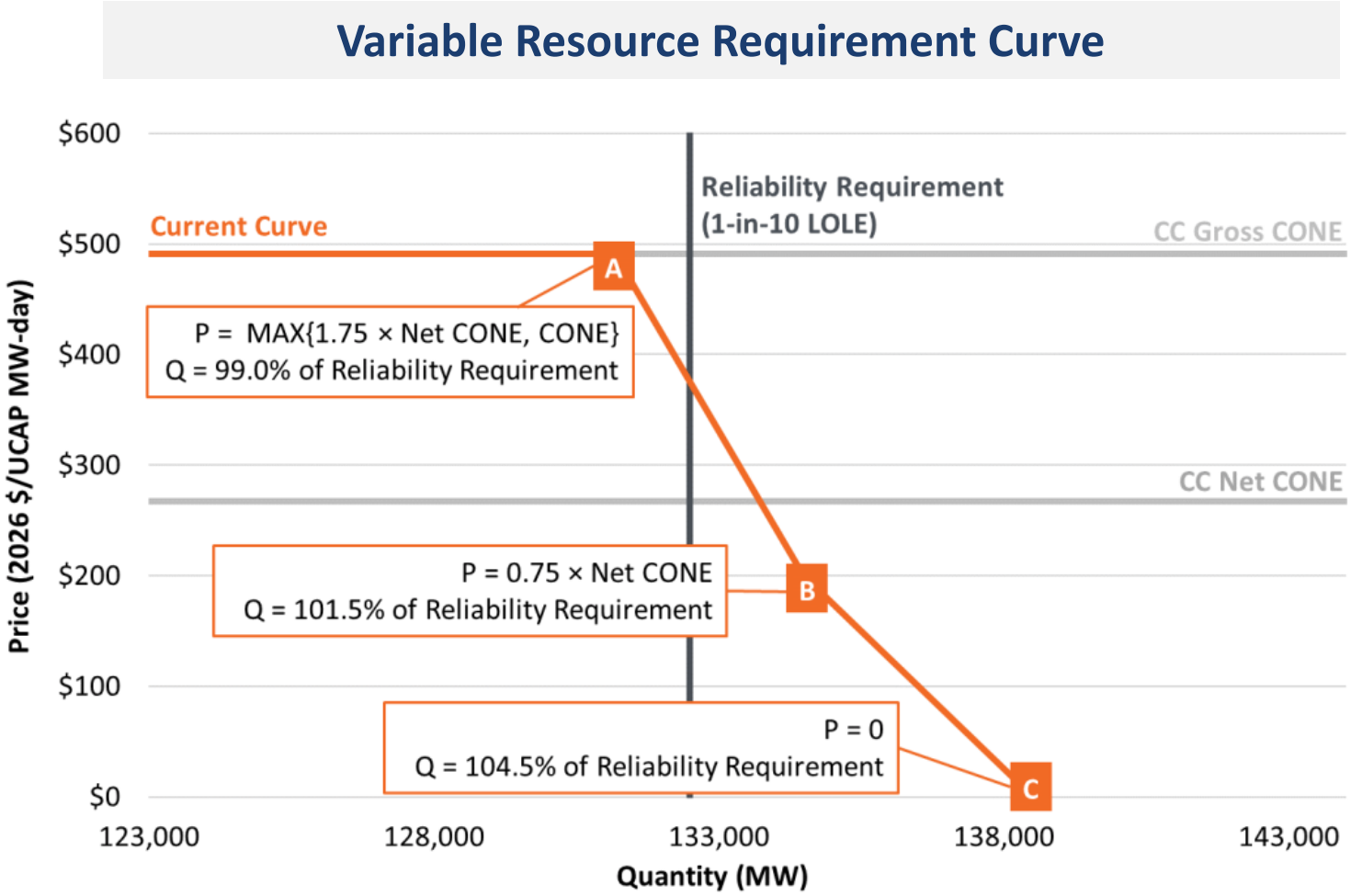
Demand Curve Objectives (Adapted from Prior VRR Curve Review)	
Reliability	• **Maintain 1-in-10 LOLE system-wide planning target on a long-term average basis**; maintain 1-in-25 conditional LOLE in each LDA. (Reliability as measured immediately prior to the delivery year) • **Assess curve performance with additional criteria** including, LOLE, LOLH, and EUE on avg and extremes • **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, but allow prices to move sufficiently to reflect changes in market conditions • **Mitigate susceptibility to exercise of market power** • **Few outcomes at the administrative cap**
Other	• Avoid outcomes that are economically disruptive and could threaten acceptance of RPM • Strike a balance among competing objectives • Aim for **simplicity, stability, and transparency**

Notes: VRR Curve design objectives adopted from the Fifth Review of PJM's Variable Resource Requirement Curve for Planning Years Beginning 2026/27 and Discussions with PJM. LOLE = Loss of Load Events; IRM = Installed Reserve Margin; CONE = Cost of New Entry

Current VRR Curve Has Kink and Cap that Depend on Net CONE and CONE at Specific Quantity/Reliability Points

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 LOLE standard
- **Prices**: tied to Net CONE, the estimated LRMC of capacity, so market can be expected to achieve target.
- **Shape/Width**: Balance tradeoffs among reliability, price volatility, and cost. Shape has been informed by but never explicitly tied to relative reliability value.



Sources and Notes: VRR curve design as adopted from Spees et al., Fifth Review of PJM's Variable Resource Requirement Curve for Planning Years Beginning 2026/27, April 19, 2022.
CC = Combined Cycle Gas Turbine, CT: Combustion Gas Turbine

Scope of this Review

Evaluate the ability of the VRR curve to meet reliability needs and other RPM objectives, focusing on:

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

Discuss further reform areas

Updated VRR Curve parameters will apply for planning year 2028/29

Then 2029/30 through 2031/32 with updates

Approach to this Review

As part of the CONE, E&AS and VRR shape analysis approaches, we will pay special attention to **making the curve robust to future changes in market/regulatory/design conditions** as experienced for 2025/26 and 2026/27 (e.g., CIFP, short-forward, new regulations, rapidly changing costs and CoC, sudden increase in load growth, big changes in EAS).

Approach to Net CONE: overstating Net CONE result in a curve that would procure more than target in long-run; understating Net CONE can under-procure

- Aim to minimize uncertainty/error
- Recognize uncertainty drivers from Oct presentation, amid changing market and regulatory conditions
- Net CONE may be overestimated if more economic technologies exist, true costs are lower, investor optimism is greater, or EAS is higher; Net CONE may be understated if the Reference Resource is infeasible to build, or true costs are higher, or EAS or long-term outlook is poorer
- Consider supply-chain tightness effect on costs and lead times
- Reference resource may differ by area; would need new definition of "RTO Net CONE"

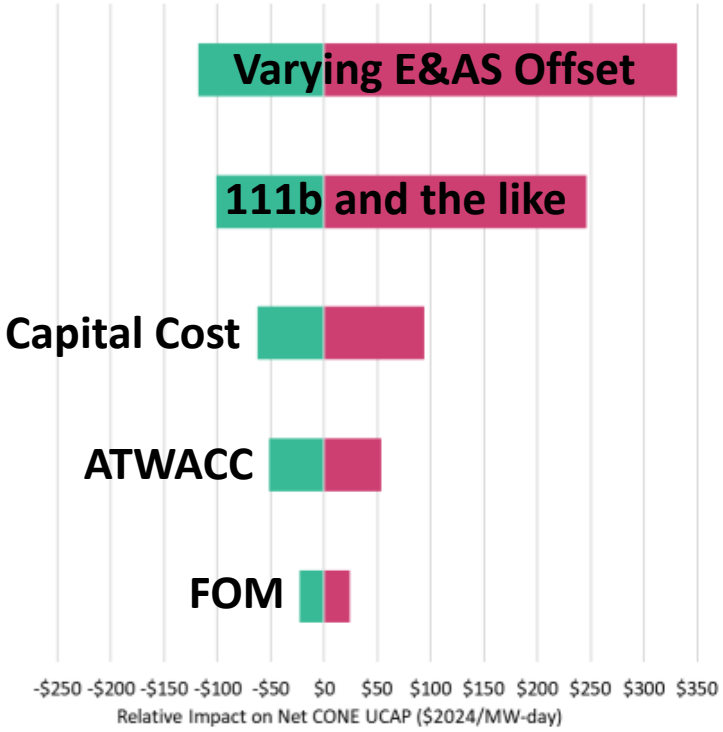
Approach to VRR Curve: design curve to meet reliability target even with Net CONE error, but without too much volatility; make robust to future market design reform

- Review definition of cap.
- Steeper slopes provide more quantity certainty in uncertain cost environment, but with greater price volatility.
- We will delve into MRI curves and address how adaptable to possible seasonal construct.

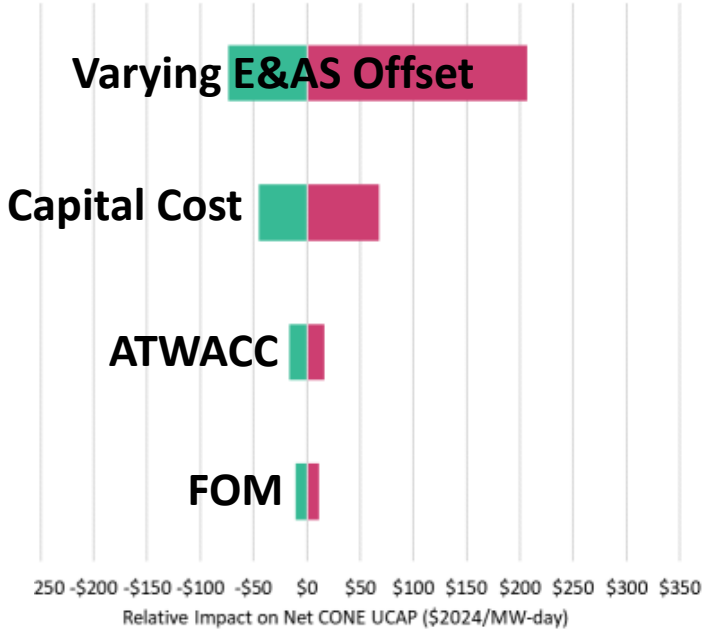
Will also evaluate the concept of moving to a more stable value-based curve, such an MRI curve with "VOLL" scaling factor that is more stable than ever-changing Net CONE, and accept less strict adherence to 1-in-10-as-modeled target.

Takeaways from the Last Presentation on Uncertainty Drivers

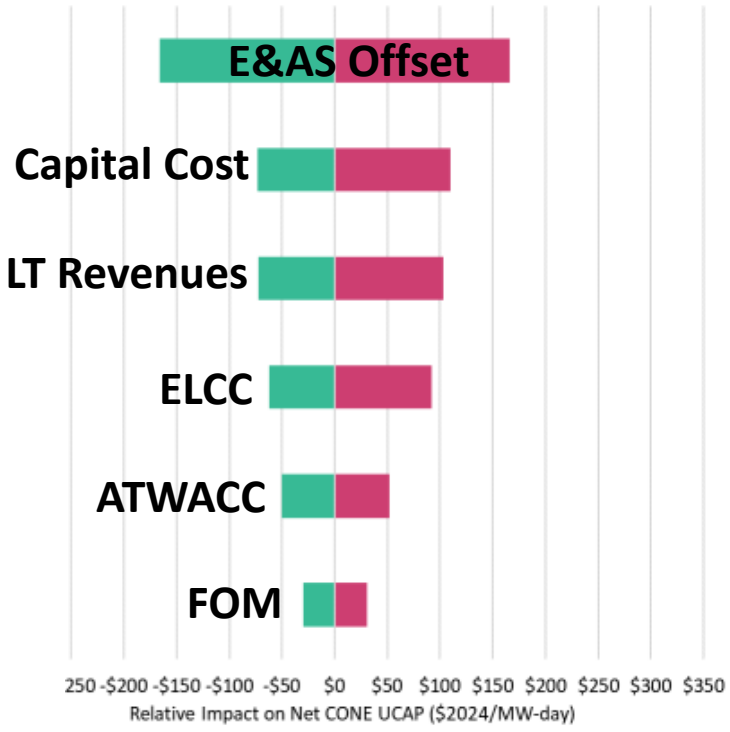
Gas CC Net CONE



Gas CT Net CONE



4hr BESS Net CONE



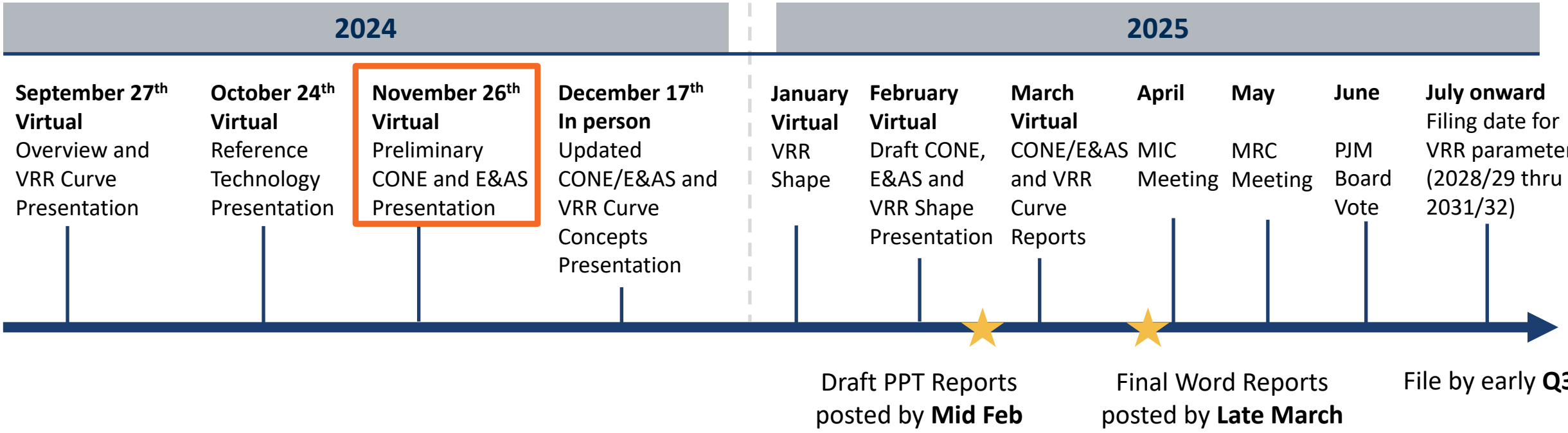
Some states may have additional downsides for fossil-fired generation. See October 24 meeting materials for assumptions.

Initial Screening Analysis from Last Presentation

Low  High

Tech	Feasible to Build for Delivery Year	Economic Source of Capacity	Accuracy of Net CONE Estimates	Complies w/Local Regulations	Stable ELCC 29/30 – 32/33
Gas CC	Some development for '28; equipment backlogs?	Recent entry and queue but doubts with 111(b) rules	**CONE:** increased policy risks **EAS:** good forward indicators even if varies over time	Varies by state	
Gas CT	Little development for 2028/29	No merchant entry in queue, but some anecdotal interest and favorable indicative Net CONE	**CONE:** less policy risk **EAS:** almost as good as CCs	Varies by state	
BESS 4 hr	Much development; short construction	Much development, indicative Net CONE worth pursuing further	**CONE:** uncertain future LRMC **EAS:** sensitive to AS, dispatch		

Where we are in this Review



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Overview of CONE approach

1. Choose Candidate Reference Resources

Presented at October 24th, 2024 MIC meeting

"Revealed Preference" method paired with estimates of Indicative Net CONE led to selection of:

Short-Listed Candidate Reference Resources for Full Evaluation

- Gas-fired CC
- Gas-fired CT
- 4hr BESS

2. Identify resource specifications and conduct bottom-up cost analysis

Draft presented in this meeting

Resource Specifications

Starting point: same as from 2022 Quad Review

Updates: Change Gas CT to dual-fuel, change to 20-year economic life for BESS, and additional location for new ComEd CONE zone

Cost Estimates

Bottom-up estimates of Capital and O&M costs as of November 2024, then costs escalated to the mid-point construction period

3. Calculate Cost of New Entry (CONE)

Draft presented in this meeting

CONE represents the first-year recovery of capital and fixed costs a resource would need to earn to enter, given its costs, its projected future net revenue trajectory, and its cost of capital

CONE Calculation

- Determine levelization "shape" (e.g., level-nominal) and lifetime
- Develop ATWACC
- Calculate first-year revenue requirement for NPV=0 in **CONE spreadsheet model** (accounts for taxes w/depreciation, etc.)
- Provide annual updating method

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Gas-fired CT and CC Specifications

- Biggest difference from prior Quad Review is switching Gas CT from firm gas to dual fuel, due to much higher ELCC and no indication that dual fuel couldn't be built
- Other specifications consistent with 2022 CONE study, including locations within each previous CONE Area (following slide on new ComEd CONE zone)

Characteristic	Combustion Turbine	Combined Cycle
Site Type	Greenfield	Greenfield
Turbine Model	GE 7HA.02 60HZ	GE 7HA.02 (CT), STF-A650 (ST)
Configuration	1 x 0	2 Trains of 1 x 1 Single Shaft
CC Cooling System	n/a	Dry Air-Cooled Condenser
Power Augmentation	Evaporative Cooling; no inlet chillers	Evaporative Cooling; no inlet chillers
Net Summer ICAP (MW)	363 / 365 / 355 / 352 / 362*	Without Duct Firing: 1046 / 1050 / 1023 / 1014 / 1044* **With Duct Firing: 1174 / 1177 / 1147 / 1136 / 1172***
Net Heat Rate (HHV in Btu/kWh)	9257 / 9254 / 9241 / 9248 / 9236*	Without Duct Firing: 6348 / 6366 / 6342 / 6351 / 6339* **With Duct Firing: 6585 / 6602 / 6576 / 6584 / 6571***
Environmental Controls	Dry Low NOx burners, SCR and CO Catalyst	Dry Low NOx burners, SCR and CO Catalyst
Fuel Supply	**Dual Fuel**	Firm Gas

Sources and Notes: *For EMAAC, SWMAAC, Rest of RTO, WMAAC, and ComEd respectively.
See also Newell et al., PJM CONE 2026/2027 Report, April 21, 2022.

Gas CT and CC: ComEd Location = Will County

Will County in ComEd LDA contained most of the recent new build and uprates for CC/CTs

Technology:	Gas CC						Gas CT									
Build Type:	New Build			Uprate			New Build		Uprate							
County:	Will	Grundy	Lee	Will	Grundy	Lee	Lake	Lee	Kane	Will	Lake	Cook	Winnebago	Grundy	Lee	Du Page
Delivery Year																
2012-2013							495			54						
2013-2014									16	40		27				
2014-2015										56				13		
2015-2016			600													
2016-2017					20					20						
2017-2018					80											
2018-2019																
2019-2020															48	
2020-2021																
2021-2022										135	90					66
2022-2023	1,116												87			
2023-2024						24		314								30
2024-2025		1,150		120	93					46						
2025-2026										5						
Total 2012-2026	1,116	1,150	600	120	193	24	495	314	16	356	90	27	87	13	48	96

Sources and Notes: All numbers represent MWs of summer net Capacity Interconnection Rights (CIRs) received (for past years) or requested (for future years). Brattle analysis of PJM data from: PJM, Serial Service Request Status, October 2024.

4-hr BESS Specifications

- Most significant difference from prior Quad Review is moving from a 15-year to a 20-year economic life, based on S&L's experience with recent PPA terms and developers' financial models; add additional augmentation
- Other specifications consistent with 2022 CONE Study, including locations in each previous CONE Area (following slide on new ComEd CONE zone)

Characteristic	BESS
Battery Technology	Lithium-ion
Installation Configuration	Containerized
Rated Output Power (at POI)	200 MW-ac
Duration	4 hours
Installed Energy Capacity	1,023 MWh-dc
Annual Capacity Degradation	4% in Year 1, then 2% per year
Augmentation Period	Every 5 years
Use Case	Daily Cycling
Round Trip Efficiency	85%
Economic Life	20 Years

Sources and Notes: See also Newell et al., PJM CONE 2026/2027 Report, April 21, 2022.

4-hr BESS: ComEd Location = Will County

- Will County in ComEd LDA also had the most development for BESS either active in the PJM queue or in-service
- Using same ComEd location for all three Candidate Reference Resources simplifies back-end analysis and research on local cost considerations (e.g., interconnection, wage rates, local ordinances, etc.)

BESS in Service or Active in Queue (ComEd LDA)

County	MW Energy	MW Capacity
Will	1,361	1,266
McHenry	1,222	1,161
Lake	1,012	912
Cook	908	776
Livingston	750	750
Lee	410	670
McLean	650	590
Winnebago	250	384
Grundy	380	380
Stephenson	368	368
Kendall	214	264
Stark	0	252
Kane	210	170
Whiteside	154	153
Ogle	0	150
DeKalb	100	134
Adams	100	95
Lasalle	155	60
Logan	60	60
Woodford	50	50
Rock Island	80	32
Christian	30	12
Total ComEd	**8,814**	**9,040**

Sources and Notes: Capacity quantities represent MWs of summer net Capacity Interconnection Rights (CIRs) requested or received; Energy quantities represent the winter net energy submitted in interconnection request. Brattle analysis of data from PJM, Serial Service Request Status, October 2024.

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Approach to Bottom-Up Cost Analysis

Objective: Develop complete plant design given technical specifications from previous section

CAPEX: S&L develops EPC costs for each plant

- Current cost for each component: major equipment from OEMs, materials from current quotes/markets; labor using current specialized local labor rates (*Note that this will incorporate premium for scarce inputs, as stakeholders have identified for turbines)*
- Other typical EPC costs (e.g., contractor fees, contingency) consistent with S&L's recent experience

CAPEX: Brattle/S&L develop Non-EPC Owners' costs

- Electrical and gas interconnection, net startup fuel, fuel inventories, land, working capital, financing fees, sales tax

FOM: Brattle/S&L develop FOM Costs

- Major maintenance (LTSA fixed payments) or O&M contract fixed payments (BESS only), BOP and substation, miscellaneous owner costs, labor, supplies & minor repairs, administrative, asset management, insurance, firm gas contract, and property taxes or land leases

Capital cost escalated from today to construction midpoint and FOM costs escalated to every operating year, each at the rate of inflation (then both are levelized in the CONE model)

CC: CAPEX

Observations Relative to 2022 estimate

- Labor and turbine costs are the largest line items and the largest contributors to real cost increase; current OEM quotes and labor rates reflect tight markets
- Then EPC fees & contingency
- Non-EPC Costs contribute little to cost increases

Key Assumptions

- EPC fee is 10% of EPC and OFE costs; EPC contingency is 10% of EPC, OFE, and contractor costs
- Project development 5% of total EPC costs
- Gas interconnection assumes 5 miles at $6.2m/mile with a $4.9m substation
- Owner's contingency is 8% of other Owner's costs

Capital Costs (in $millions)	Nominal Yearly Escalation Rate	2024 Preliminary CAPEX	Change from 2022		
Units		2024$	$2024 Absolute Difference	% Percentage Difference	% Share of Cost Difference
Summary Net Capacity		Rest of RTO *1147 MW*			
OFE + EPC Costs		**$1,340**	**$255**	**24%**	**93%**
Owner Furnished Equipment (OFE)					
Gas Turbines	2.20%	$210	$54	34%	19%
HRSG / SCR	2.20%	$109	$28	34%	10%
Steam Turbines	2.20%	$115	$29	34%	11%
Equipment, Procurement, and Construction (EPC) Costs					
Equipment					
Condenser	2.20%	$67	$5	7%	2%
Other Equipment	2.20%	$97	$10	11%	4%
Construction Labor	2.20%	$353	$71	25%	26%
Other Labor	2.20%	$61	-$5	-7%	-2%
Materials	2.20%	$96	$19	26%	7%
EPC Contractor Fee		$111	$21	24%	8%
EPC Contingency		$122	$23	24%	8%
Non-EPC Costs		**$177**	**$20**	**13%**	**7%**
Project Development		$67	$13	24%	5%
Mobilization and Start-Up		$13	$3	24%	1%
Non-Fuel Inventories		$7	$1	24%	0%
Emission Reduction Credits	2.20%	$2	$0	-1%	0%
Net Start-Up Fuel Costs	2.20%	-$14	-$3	23%	-1%
Electrical Interconnection	2.20%	$22	-$3	-11%	-1%
Gas Interconnection	2.20%	$33	$0	0%	0%
Land	2.20%	$3	$1	133%	1%
Fuel Inventories	2.20%	$0	$0	-	0%
Owner's Contingency		$11	$1	13%	0%
Financing Fees		$33	$6	22%	2%
Total Capital Costs		**$1,517**	**$275**	**22%**	
Overnight Capital Costs ($million)		$1,517	$275	22%	
Overnight Capital Costs ($/kW)		$1,322	$237	22%	

Notes: All costs are shown in 2024$ except OFE, which is nominal for the delivery time if ordered today.

CC: O&M

Observations Relative to 2022 estimate

- Firm gas contract, property taxes, and insurance are largest components and explain the increase
- Property taxes and insurance increase due to capital cost increases (on previous slide)

Key Assumptions

- Firm gas costs are based on most recent FT-1 rate schedules for firm transportation reservation and usage charges for pipelines servicing each CONE area
- Property taxes are calculated for representative counties in each CONE area
- Insurance is 0.6% of overnight capital costs

O&M Costs	2022 CONE	2024 Preliminary	Change from 2022
Units	2024$	2024$	2024$
CONE Area	Rest of RTO	Rest of RTO	Absolute Difference
Summer Net Capacity	*1144 MW*	*1147 MW*	
Fixed O&M ($ million)			
LTSA Fixed Payments	$0.8	$1.0	$0.2
Labor	$3.6	$3.3	-$0.3
Maintenance and Minor Repairs	$5.9	$6.2	$0.4
Administrative and General	$1.1	$1.2	$0.0
Asset Management	$1.2	$1.0	-$0.1
Property Taxes	$9.2	$10.9	$1.7
Insurance	$7.0	$9.1	$2.1
Firm Gas Contract	$15.4	$21.6	$6.3
Total Fixed O&M ($million/year)	$44.1	$54.4	$10.3
Levelized Fixed O&M ($/kW-yr)	$38.5	$47.4	$8.8
Variable O&M ($/MWh)			
Total Variable O&M ($/MWh)	$2.8	$2.2	-$0.7
Major Maintenance - Hours Based	$2.1	$1.5	-$0.6
Consumables, Waste Disposal, Other VOM	$0.8	$0.7	-$0.1

Notes: All costs are shown in 2024$, assumed to escalate at the rate of inflation. Property taxes shown are from the first year of operation.

CT: CAPEX

Observations Relative to 2022 Estimate

- Turbines are the largest cost component and largest proportion of the cost increase
- Next largest increase is labor, EPC fees & contingency
- Non-EPC costs remain similar except fuel inventories for a dual-fuel plant which the 2022 CT ref tech did not have

Key Assumptions

- EPC contractor fee is 10% of EPC and OFE costs; EPC contingency is 10% of EPC, OFE, and contractor costs
- Project development 5% of total EPC costs
- Gas interconnection assumes 5 miles at $6.2m/mile with a $4.9m substation
- Owner's contingency is 8% of other Owner's costs and Financing fees are 4% of EPC and OFE costs

Capital Costs (in $millions)	2022 CONE	2024 Preliminary CAPEX	Change from 2022		
Units	2024$	2024$	2024$	%	%
	Rest of RTO	Rest of RTO	Absolute Difference	Percentage Difference	Share of Cost Difference
Summer Net Capacity	*353 MW*	*355 MW*			
OFE+ EPC Costs	**$237**	**$325**	**$87**		**81%**
Owner Furnished Equipment (OFE)					
Gas Turbines	$78	$106	$28	35%	26%
HRSG / SCR	$33	$45	$11	34%	10%
Steam Turbines	$0	$0	$0	-	0%
Equipment, Procurement, and Construction Costs (EPC)					
Equipment					
Condenser	$0	$0	$0	-	0%
Other Equipment	$24	$31	$6	27%	6%
Construction Labor	$38	$53	$15	40%	14%
Other Labor	$15	$21	$6	43%	6%
Materials	$8	$14	$6	70%	5%
EPC Contractor Fee	$20	$27	$7	37%	7%
EPC Contingency	$22	$30	$8	37%	7%
Non-EPC Costs	**$68**	**$89**	**$21**		**19%**
Project Development	$12	$16	$4	37%	4%
Mobilization and Start-Up	$2	$3	$1	37%	1%
Non-Fuel Inventories	$1	$2	$0	37%	0%
Emission Reduction Credits	$0	$0	$0	-	0%
Net Start-Up Fuel Costs	$0	-$1	-$1	-552%	-1%
Electrical Interconnection	$8	$8	$0	1%	0%
Gas Interconnection	$33	$33	$0	0%	0%
Land	$0	$0	$0	133%	0%
Fuel Inventories	$0	$12	$12	-	11%
Owner's Contingency	$5	$6	$1	30%	1%
Financing Fees	$7	$9	$2	35%	2%
Total Capital Costs	**$305**	**$413**	**$108**	**35%**	
Overnight Capital Costs ($million)	$305	$413	$108	35%	
Overnight Capital Costs ($/kW)	$864	$1,163	$299	35%	

Notes: All costs are shown in 2024$ except OFE, which is nominal for the delivery time if ordered today.

CT: O&M

Observations Relative to 2022

- Switch from firm gas to dual fuel reduces annual O&M costs
- Property taxes and insurance increase due to capital cost increases

Key Assumptions

- Property taxes are for representative counties in each CONE area
- Insurance is 0.6% of overnight capital

O&M Costs	2022 CONE	2024 Preliminary	Change from 2022
Units	2024$	2024$	2024$
CONE Area	Rest of RTO	Rest of RTO	Absolute Difference
Summer Net Capacity	*353 MW*	*355 MW*	
Fixed O&M ($ million)			
LTSA Fixed Payments	$0.3	$0.4	$0.1
Labor	$0.8	$0.7	-$0.1
Maintenance and Minor Repairs	$0.5	$0.4	-$0.1
Administrative and General	$0.2	$0.2	$0.0
Asset Management	$0.4	$0.4	$0.0
Property Taxes	$2.1	$2.7	$0.6
Insurance	$1.7	$2.5	$0.8
Firm Gas Contract	$6.7	$0.0	-$6.7
Total Fixed O&M ($million/year)	$12.7	$7.4	-$5.3
Levelized Fixed O&M ($/kW-yr)	$36.0	$20.8	-$15.2
Variable O&M			
Major Maintenance - Starts Based ($/Start)	$20,724	$22,931	$2,206.8
Consumables, Waste Disposal, Other VOM ($/MWh)	$1.1	$1.0	-$0.2

Notes: All costs are shown in 2024$, assumed to escalate at the rate of inflation. Property taxes shown are from the first year of operation.

BESS 4hr: CAPEX

Observations Relative to 2022

- BESS equipment costs are largest cost components and responsible for most of the increase
- Construction & Materials next largest line item and second largest source of cost increase
- For non-EPC costs, project development and owner's contingency are the largest components but with slight cost increase relative to 2022

Key Assumptions

- EPC contractor fee, EPC contingency, and spare parts inventories are included in Project Management
- Project development (5%), mobilization and start-up (1%) are based on total EPC costs
- Owner's contingency is 5% of other Owner's costs
- Financing fees are 4% of other non-EPC costs

Capital Costs (in $millions)	2022 CONE	2024 Preliminary CAPEX	2024 Preliminary Overnight Costs		
Units	2024$	2024$	$2024	%	%
	Rest of RTO	Rest of RTO	Absolute Difference	Percentage Difference	Share of Cost Difference
Summer Net Capacity	*200 MW*	***200 MW***			
Equipment, Procurement and Construction (EPC) Costs	**$323**	**$386**	**$63**	**20%**	**89%**
BESS Equipment					
Batteries and Enclosures	$222	$263	$41	19%	58%
PCS and BOP Equipment	$33	$44	$11	32%	15%
Project Management	$11	$14	$2	22%	3%
Construction & Materials	$57	$66	$9	16%	13%
Non-EPC Costs	**$40**	**$49**	**$8**	**20%**	**11%**
Project Development	$16	$19	$3	20%	4%
Mobilization and Start-Up	$3	$4	$1	20%	1%
Owner's Contingency	$13	$15	$3	21%	4%
Land Lease or Property Taxes During Construction	$3	$4	$1	53%	2%
Electrical Interconnection	$4	$4	$0	0%	0%
Financing Fees	$1	$2	$0	17%	0%
Total Capital Costs	**$363**	**$435**	**$72**	**20%**	
Overnight Capital Costs ($million)	$363	$435	$72	20%	
Overnight Capital Costs ($/kW)	$1,817	$2,175	$358	20%	

Notes: All costs are shown in 2024$ except OFE, which is nominal for the delivery time if ordered today. Property taxes shown are from the first year of operation.

BESS 4hr: O&M incl. Augmentation

Observations Relative to 2022

- Land lease is the largest cost component and largest contributor to the cost increase
- Next largest is the fixed O&M contract which accounts for most of remaining cost increase
- Insurance increased due to capital cost increase (on previous slide)

Key Assumptions

- Property taxes are used as a proxy for land lease costs
- Insurance is 0.6% of overnight capital costs
- Augmentation costs are based on the overnight capital cost trajectory from the 2024 NREL ATB (Moderate Case) for years 5, 10, and 15 after COD to maintain capacity rating of the 20-year BESS, versus only in years 5 and 10 for the 15-year BESS from 2022 CONE study

O&M Costs	2022 CONE	2024 Preliminary	Change from 2022
Units	2024 $	2024$	$2024
Summer Net Capacity	Rest of RTO *200 MW*	Rest of RTO *200 MW*	Absolute Difference
Fixed O&M ($ million)			
O&M Contract Fixed Payments	$3.0	$3.5	$0.5
BOP and Substation O&M	$0.1	$0.1	$0.0
Station Load / Aux Load	$0.4	$0.4	$0.0
Miscellaneous Owner Costs	$0.3	$0.3	$0.0
Operating Insurance	$1.4	$1.7	$0.3
Land Lease or Property Taxes	$2.5	$3.9	$1.4
Total Fixed O&M ($million/year)	$7.8	$9.8	$2.1
Levelized Fixed O&M ($/kW-yr)	$38.0	$46.7	$8.7

Notes: Does not include augmentation costs, which will be included separately as 20-year nominal levelization of $29m, $26m, and $24m (nominal) in years 5, 10, and 15 respectively.

Notes: All costs are shown in 2024$, assumed to escalate at the rate of inflation. Property taxes shown are from the first year of operation.

"Overnight Cost": Escalate CAPEX to Mid-point of Construction

Objective: Escalate November 2024 cost estimates provided by Sargent & Lundy to express the Overnight Cost

S&L's CapEx costs reflect quotes as if buying or ordering all of the inputs today, but all of the components will be ordered later, during the construction period, at prices that we assume increase at the rate of inflation

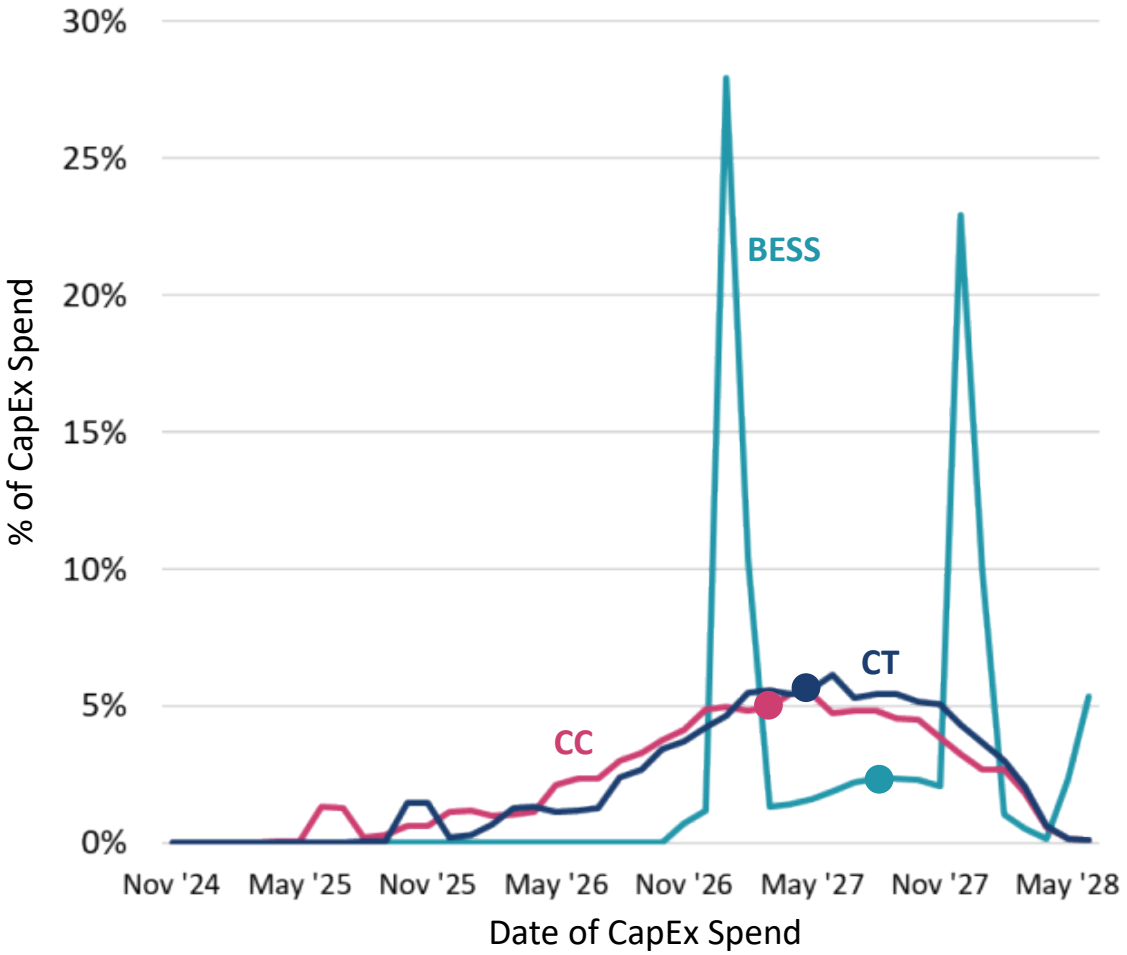
The capital drawdown schedule describes the distribution of nominal capital expenses that will be incurred over the construction period

The **overnight cost** is the nominal sum of expenditures during construction period, which we develop by **escalating** the capital expenditures from the date of our quotes (Nov 2024) to the **midpoint** of our construction schedule

- **Estimate cost escalation rate** based on inflation expectations to the mid-point of the construction period projected by the Federal Reserve Bank of Cleveland (see inflation curve on slide 33)
- **Establish mid-point construction date** based on June 1st, 2028 online date and the number of months needed for 50% of the capital drawdown schedule during construction
  - **CC**: T – 15 months, so escalate costs to **Mar 1, 2027** (28 mo. from today)
  - **CT**: T – 13 months, so escalate costs to **May 1, 2027** (30 mo. from today)
  - **BESS**: T – 10 months, so escalate costs to **Aug 1, 2027** (33 mo. from today)

The **Installed Cost** is equal to the NPV of the nominal expenditures at the time of the Commercial Operation Date, so includes interest and ROE during construction

Capital Drawdown Schedules by Technology



Preliminary Overnight Capital Costs for CC

Capital Costs (in $millions)	Nominal Yearly Escalation Rate	2024 Preliminary CAPEX					2024 Preliminary Overnight Costs				
Units		2024$	2024$	2024$	2024$	2024$	Nominal$	Nominal$	Nominal$	Nominal$	Nominal$
		EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED	EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED
Summer Net Capacity		*1174 MW*	*1177 MW*	*1147 MW*	*1136 MW*	*1172 MW*	*1174 MW*	*1177 MW*	*1147 MW*	*1136 MW*	*1172 MW*
OFE + EPC Costs		**$1,457**	**$1,344**	**$1,340**	**$1,390**	**$1,537**	**$1,533**	**$1,414**	**$1,410**	**$1,462**	**$1,617**
Owner Furnished Equipment (OFE)											
Gas Turbines	2.20%	$210	$210	$210	$210	$210	$221	$221	$221	$221	$221
HRSG / SCR	2.20%	$109	$109	$109	$109	$109	$115	$115	$115	$115	$115
Steam Turbines	2.20%	$115	$115	$115	$115	$115	$121	$121	$121	$121	$121
Equipment, Procurement, and Construction (EPC) Costs											
Equipment											
Condenser	2.20%	$67	$67	$67	$67	$67	$70	$70	$70	$70	$70
Other Equipment	2.20%	$97	$97	$97	$97	$97	$102	$102	$102	$102	$102
Construction Labor	2.20%	$445	$356	$353	$392	$509	$468	$375	$371	$413	$535
Other Labor	2.20%	$66	$62	$61	$63	$69	$69	$65	$65	$67	$72
Materials	2.20%	$96	$96	$96	$96	$96	$101	$101	$101	$101	$101
EPC Contractor Fee		$120	$111	$111	$115	$127	$127	$117	$117	$121	$134
EPC Contingency		$132	$122	$122	$126	$140	$139	$129	$128	$133	$147
Non-EPC Costs		**$187**	**$176**	**$177**	**$180**	**$145**	**$197**	**$185**	**$186**	**$189**	**$153**
Project Development		$73	$67	$67	$69	$77	$77	$71	$70	$73	$81
Mobilization and Start-Up		$15	$13	$13	$14	$15	$15	$14	$14	$15	$16
Non-Fuel Inventories		$7	$7	$7	$7	$8	$8	$7	$7	$7	$8
Emission Reduction Credits	2.20%	$2	$2	$2	$2	$2	$2	$2	$2	$2	$2
Net Start-Up Fuel Costs	2.20%	-$19	-$19	-$14	-$18	-$8	-$20	-$20	-$14	-$19	-$9
Electrical Interconnection	2.20%	$22	$22	$22	$22	$0	$23	$24	$23	$23	$0
Gas Interconnection	2.20%	$33	$33	$33	$33	$0	$35	$35	$35	$35	$0
Land	2.20%	$6	$6	$3	$6	$7	$7	$6	$3	$6	$7
Fuel Inventories	2.20%	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Owner's Contingency		$11	$11	$11	$11	$8	$12	$11	$11	$11	$9
Financing Fees		$35	$33	$33	$34	$36	$37	$34	$34	$36	$38
Total Capital Costs		**$1,644**	**$1,520**	**$1,517**	**$1,569**	**$1,683**	**$1,730**	**$1,599**	**$1,596**	**$1,651**	**$1,770**
Overnight Capital Costs ($million)		$1,644	$1,520	$1,517	$1,569	$1,683	$1,730	$1,599	$1,596	$1,651	$1,770
Overnight Capital Costs ($/kW)		$1,400	$1,292	$1,322	$1,381	$1,435	$1,473	$1,359	$1,391	$1,453	$1,510

Notes: Escalated costs will decrease after we switch to escalating OFE quotes only to the assumed order date, earlier in the construction period.

Preliminary Overnight Capital Costs for CT

Capital Costs (in $millions)	Nominal Yearly Escalation Rate	2024 Preliminary CAPEX					2024 Preliminary Overnight Costs				
Units		2024$	2024$	2024$	2024$	2024$	Nominal$	Nominal$	Nominal$	Nominal$	Nominal$
		EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED	EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED
Summer Net Capacity		*363 MW*	*365 MW*	*355 MW*	*352 MW*	*362 MW*	*363 MW*	*365 MW*	*355 MW*	*352 MW*	*362 MW*
OFE+ EPC Costs		$340	$325	$325	$331	$354	$359	$343	$343	$349	$374
Owner Furnished Equipment (OFE)											
Gas Turbines	2.20%	$106	$106	$106	$106	$106	$112	$112	$112	$112	$112
HRSG / SCR	2.20%	$45	$45	$45	$45	$45	$47	$47	$47	$47	$47
Steam Turbines	2.20%	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Equipment, Procurement, and Construction Costs (EPC)											
Equipment											
Condenser	2.20%	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Other Equipment	2.20%	$31	$31	$31	$31	$31	$32	$32	$32	$32	$32
Construction Labor	2.20%	$65	$53	$53	$58	$76	$68	$56	$56	$61	$80
Other Labor	2.20%	$21	$21	$21	$21	$22	$23	$22	$22	$22	$23
Materials	2.20%	$14	$14	$14	$14	$14	$14	$14	$14	$14	$14
EPC Contractor Fee		$28	$27	$27	$27	$29	$30	$28	$28	$29	$31
EPC Contingency		$31	$30	$30	$30	$32	$33	$31	$31	$32	$34
Non-EPC Costs		$92	$91	$89	$88	$95	$97	$96	$94	$93	$100
Project Development		$17	$16	$16	$17	$18	$18	$17	$17	$17	$19
Mobilization and Start-Up		$3	$3	$3	$3	$4	$4	$3	$3	$3	$4
Non-Fuel Inventories		$2	$2	$2	$2	$2	$2	$2	$2	$2	$2
Emission Reduction Credits	2.20%	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Start-Up Fuel Costs	2.20%	$0	$1	-$1	-$2	$2	$0	$1	-$1	-$2	$2
Electrical Interconnection	2.20%	$8	$8	$8	$8	$8	$8	$8	$8	$8	$8
Gas Interconnection	2.20%	$33	$33	$33	$33	$33	$35	$35	$35	$35	$35
Land	2.20%	$1	$1	$0	$1	$1	$1	$1	$0	$1	$1
Fuel Inventories	2.20%	$12	$12	$12	$12	$12	$13	$13	$13	$12	$13
Owner's Contingency		$6	$6	$6	$6	$6	$6	$6	$6	$6	$7
Financing Fees		$9	$9	$9	$9	$10	$10	$9	$9	$10	$10
Total Capital Costs		$432	$416	$413	$419	$449	$456	$439	$436	$443	$474
Overnight Capital Costs ($million)		$432	$416	$413	$419	$449	$456	$439	$436	$443	$474
Overnight Capital Costs ($/kW)		$1,190	$1,139	$1,163	$1,190	$1,240	$1,256	$1,203	$1,229	$1,257	$1,309

Notes: Escalated costs will decrease after we switch to escalating OFE quotes only to the assumed order date, earlier in the construction period.

Preliminary Overnight Capital Costs for BESS

Capital Costs (in $millions)	Nominal Yearly Escalation Rate	2024 Preliminary CAPEX					2024 Preliminary Overnight Costs				
Units		2024$	2024$	2024$	2024$	2024$	Nominal$	Nominal$	Nominal$	Nominal$	Nominal$
		EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED	EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED
Summer Net Capacity		*200 MW*	*200 MW*	*200 MW*	*200 MW*	*200 MW*	*200 MW*	*200 MW*	*200 MW*	*200 MW*	*200 MW*
Equipment, Procurement and Construction (EPC) Costs		$405	$386	$386	$394	$421	$430	$410	$410	$418	$447
BESS Equipment											
Batteries and Enclosures	2.20%	$263	$263	$263	$263	$263	$279	$279	$279	$279	$279
PCS and BOP Equipment	2.20%	$44	$44	$44	$44	$44	$47	$47	$47	$47	$47
Project Management	2.20%	$17	$14	$14	$15	$20	$18	$15	$15	$16	$21
Construction & Materials	2.20%	$81	$66	$66	$72	$94	$86	$70	$70	$76	$100
Non-EPC Costs		$45	$45	$49	$47	$51	$52	$48	$51	$50	$54
Project Development		$20	$19	$19	$20	$21	$21	$21	$21	$21	$22
Mobilization and Start-Up		$4	$4	$4	$4	$4	$4	$4	$4	$4	$4
Owner's Contingency		$12	$15	$15	$16	$17	$17	$16	$16	$17	$18
Land Lease or Property Taxes During Construction		$2	$1	$4	$2	$3	$3	$1	$4	$2	$3
Electrical Interconnection	2.20%	$4	$4	$4	$4	$4	$5	$5	$5	$5	$5
Financing Fees		$2	$2	$2	$2	$2	$2	$2	$2	$2	$2
Total Capital Costs		$449	$432	$435	$441	$472	$482	$458	$462	$468	$501
Overnight Capital Costs ($million)		$449	$432	$435	$441	$472	$482	$458	$462	$468	$501
Overnight Capital Costs ($/kW)		$2,247	$2,158	$2,175	$2,203	$2,359	$2,408	$2,291	$2,308	$2,338	$2,504

Notes: The ITC will be applied in the CONE calculation; escalated costs will decrease after we switch to escalating BESS equipment quotes only to the assumed order date, earlier in the construction period.

Agenda

Introduction: Motivation, Context, Scope, and Approach

Preliminary Gross CONE

- Overview
- Resource Specifications
- CapEx and O&M Costs
- **Calculate CONE**
- Annual CONE Updating Methodology

E&AS Methodology Review

- Review of the E&AS Purpose and Current Approach
- Construction of Hourly Forward Prices
- Assumptions on Other Cost and Resource Characteristics
- E&AS Estimation w/Plexos Virtual Dispatch
- Electricity Hub Mapping
- Natural Gas Hub Mapping

Indicative Net CONE

- Preliminary E&AS

Next Steps

CONE Calculation Overview

$$\text{CONE} = \underbrace{\text{Overnight Capital Cost}}_{\text{from prior section}} \times \underbrace{\text{Capital Charge Rate}}_{\textit{The focus of this section}} + \underbrace{\text{Levelized FOM}}_{\text{from prior section}}$$

Capital Charge Rate (CCR) expresses the fraction of CapEx that investors would have to expect to recover in year 1 to be willing to enter

CCR thus depends on

- Investors' long-term view of economics (economic lifetime, trajectory of net revenues)
- ATWACC available to merchant investors

These are incorporated into the CONE Model, which also accounts for interest/COE during construction, and lifetime income taxes net of depreciation

Recall that the CCR for CCs will be sensitive to the impacts of 111(b) and possible repeal or replacement, and state policies

EAS CCR is sensitive to future revenue trajectory amid tech progress

Levelization

Levelization is the method of translating investment costs into 1-st year annualized costs and reflects expectations for capital recovery over the entire economic life, such that the investment has NPV of 0

When determining the levelization approach, we consider the drivers of long-term cost recovery and long-term trends in power plant equipment costs and how they can impact the future economics of a plant built for the 2028/29 delivery year

- **CC**: long-term economics may be affected by 111(b) or, even if overturned, by potential future carbon regulations
- **CT**: may be less affected by environmental regulations due to lower capacity factor
- **BESS:** long-term economics deteriorating if future competitors benefit from cost declines or technology progress

Design Levelization Approach

Proposal for Gas CC and CT: use 20-year level-nominal levelization like with 2022 Quad Review

- **Level-nominal levelization**: assumes that future revenues are constant in nominal terms
  - Future entrants have increasingly competitive costs and performance, which will set market prices lower and reduce the revenues of a plant built today, at approximately the rate of inflation in real terms
  - Assumes resource does not become uneconomic to build due to new technologies, or changes in market or regulatory conditions (that possibility can also be addressed through lifetime)
- **Economic Lifetime**: assume a 20-year economic lifetime
  - This does not mean the useful life is only 20-years since new natural gas-fired plants can physically operate for 30 years or longer, only that developers commonly expressed a preference to recover their capital in 20 years
  - For CC also calculate a 15-year level-nominal to test sensitivity to future regulations that impair revenues

Proposal for 4-hr BESS: use 20-year instead of 15-year level-nominal from 2022 Quad Review

- **Level-nominal levelization**: assumes that future revenues are constant in nominal terms (as above)
- **Economic Lifetime**: 20-year economic lifetime is based on S&L's experience with recent PPA term lengths and developers' financial models which have extended BESS asset economic lifetimes relative to last Review; include all the costs of augmentation to counter degradation

Adjust Prior May 2024 PJM ATWACC Estimate for Today

Later we will conduct a full ATWACC study; for now, assume initial ATWACC of 9.5% based on our PJM ATWACC study in May, 2024, adjusted for changes in the risk-free rate

Starting point (10% ATWACC)

- Brattle's May 22nd, 2024 estimate for merchant generation in PJM
- $ATWACC = \big((Cost\ of\ Equity) \times (Equity\ Ratio)\big) + \big((Cost\ of\ Debt) \times (Debt\ Ratio) \times (1 - Tax\ Rate)\big)$

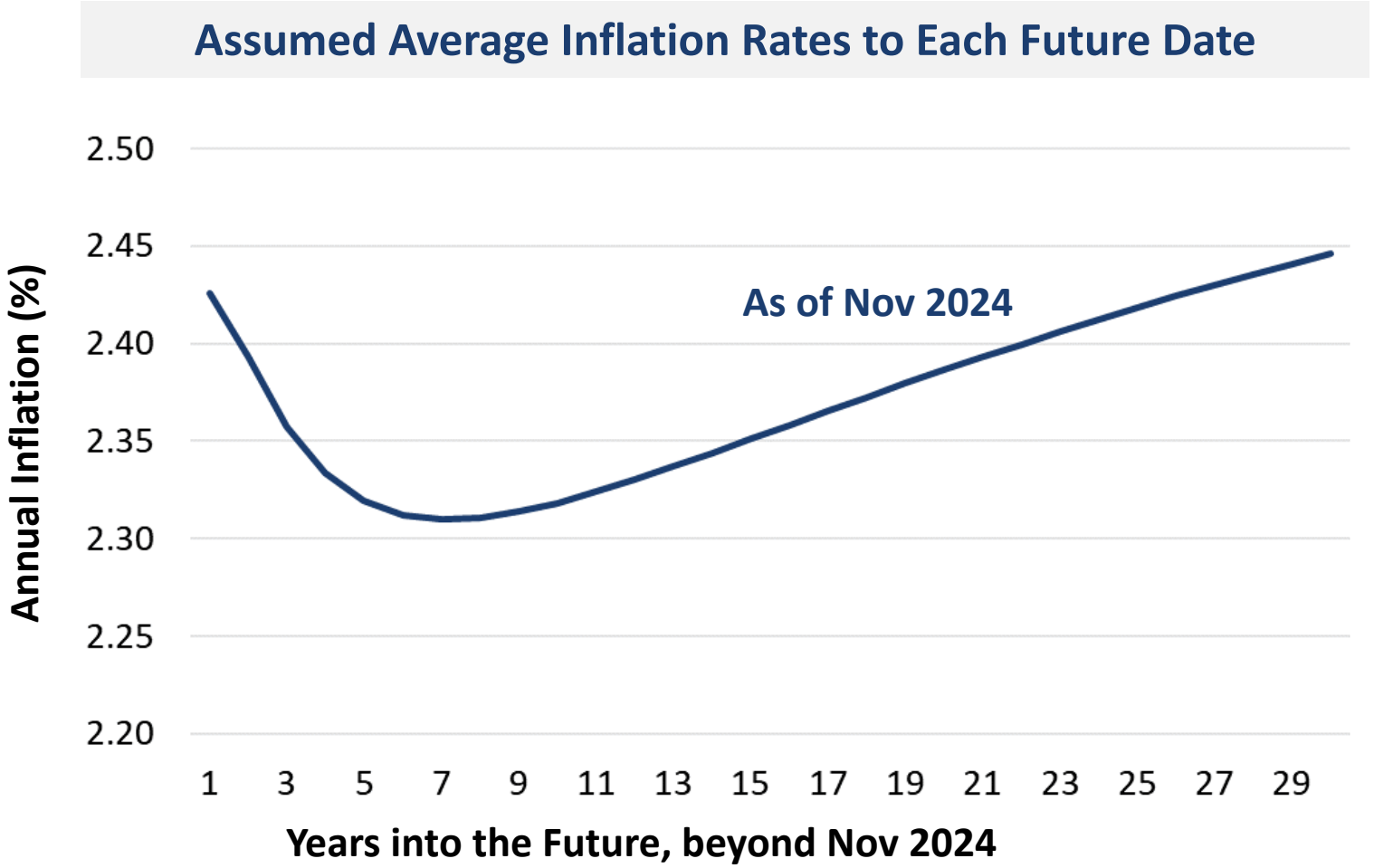
Adjustment for Preliminary ATWACC: Risk Free Rate Decrease (→ 9.5% ATWACC)

- 20-year Treasury Bond yield decreased by 55 bps between May 22, 2024 and October 5, 2024, based on a 15-trading day average
- This decreases the ATWACC by 55 bps to result in 9.45%, which we round to 9.5%

Notes and Sources: Federal Reserve Economic Data (FRED), 20-year treasury bond yield.

Other Financial Assumptions

- **Bonus Depreciation**: Decreases to 0% by 2026
- **Inflation**: Use inflation expectations based on the projections by the Federal Reserve Bank of Cleveland



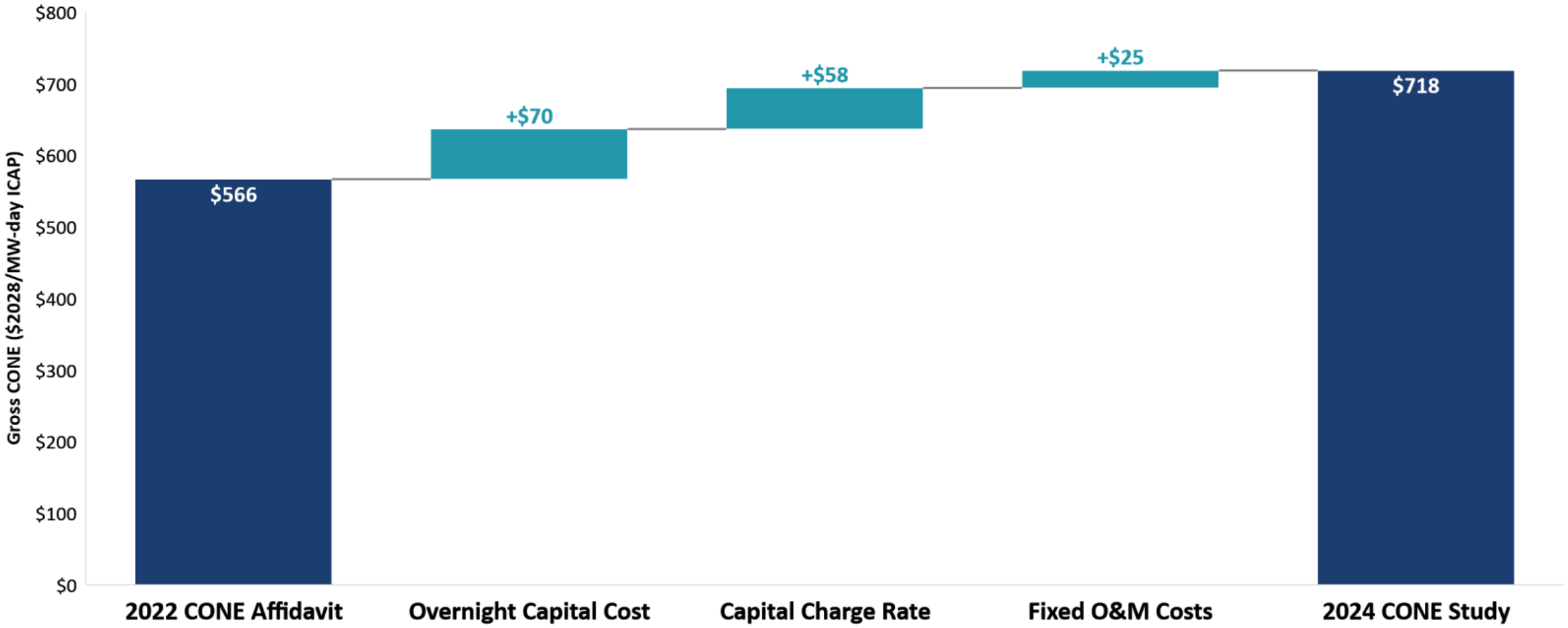
Notes and Sources: Federal Reserve Bank of Cleveland, Expected Inflation Term Structure, November 2024.

Preliminary CC CONE (2028/29 DY)

				CONE Area				
				EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED
[1]	**Net Capacity**	***MW***		**1174**	**1177**	**1147**	**1136**	**1172**
	Capital Costs							
[2]	Overnight Cost	*Nominal $ million*		$1,730	$1,599	$1,596	$1,651	$1,770
[3]	Overnight Cost	*Nominal $/kW*	= [2] x 1000 / [1]	$1,473	$1,359	$1,391	$1,453	$1,510
[4]	Installed Cost	*Nominal $ million*		$1,947	$1,800	$1,796	$1,858	$1,992
[5]	Installed Cost	*Nominal $/kW*	= [4] x 1000 / [1]	$1,658	$1,529	$1,566	$1,636	$1,700
[6]	Levelized Capital Cost	*Nominal $/kW-yr*	= [3] x [10]	$219	$201	$206	$215	$225
	O&M Costs							
[7]	First Year FOM	*Nominal $ million/yr*		$39	$41	$57	$43	$37
[8]	Levelized FOM	*Nominal $/kW-yr*		$40	$41	$56	$45	$37
[9]	**After-Tax WACC**	***%***		**9.5%**	**9.5%**	**9.5%**	**9.5%**	**9.5%**
[10]	Capital Charge Rate	*%*		14.8%	14.8%	14.8%	14.8%	14.9%
[11]	**Levelized CONE**	***Nominal $/kW-yr***	**= ([6] + [8])**	**$258**	**$242**	**$262**	**$260**	**$262**
[12]	**Levelized CONE**	***Nominal $/MW-day***	**=[11] x 1000/365**	**$707**	**$662**	**$718**	**$712**	**$718**
	2022 CONE Affidavit							
[13]	PJM 2026/27 CONE	*$/MW-day*		$543	$529	$542	$547	
[14]	Escalated to 2028	*$/MW-day*	= [13] x (1.022)^(2028 - 2026)	$567	$552	$566	$571	
	Difference between Updated CONE and Escalated 2022 CONE Affidavit							
[15]	Absolute Difference	*$/MW-day*	= [11] - [14]	$140	$110	$152	$141	
[16]	Percent Change	*%*	= [15] / [14]	25%	20%	27%	25%	

Notes: [13]: Affidavit of Samuel A. Newell, John M. Hagerty, and Sang H. Gang on Behalf of PJM, September 30, 2022.

Drivers of Increased CC CONE (RTO, $2028/MW-day ICAP)



Overnight Capital Cost
driven by supply chain tightness for major equipment, higher labor rates, and higher EPC costs

Capital Charge Rate
driven by longer construction timeline and higher ATWACC

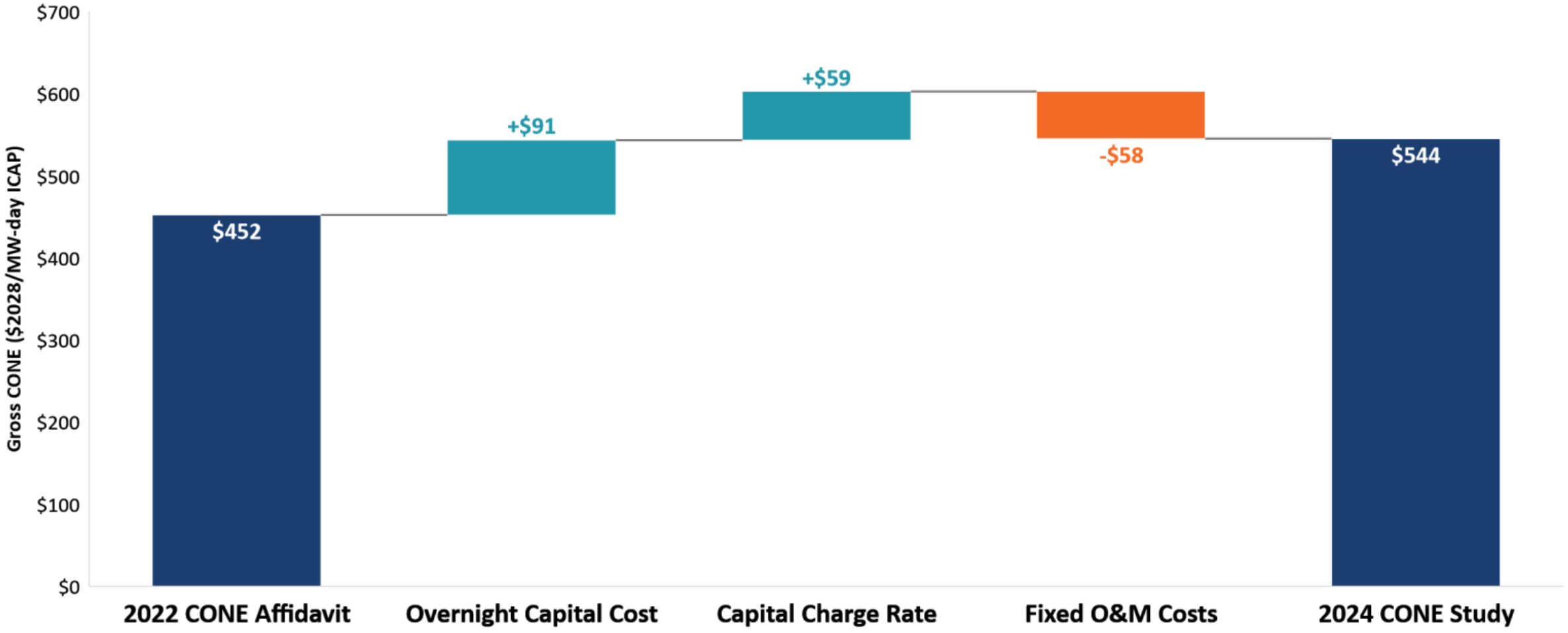
Fixed O&M Costs
driven by higher firm gas transportation costs and property taxes

Preliminary CT CONE Values (2028/29)

				CONE Area				
				EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED
[1]	**Net Capacity**	***MW***		**363**	**365**	**355**	**352**	**362**
	Capital Costs							
[2]	Overnight Cost	*Nominal $ million*		$456	$439	$436	$443	$474
[3]	Overnight Cost	*Nominal $/kW*	= [2] x 1000 / [1]	$1,256	$1,203	$1,229	$1,258	$1,309
[4]	Installed Cost	*Nominal $ million*		$507	$488	$485	$492	$527
[5]	Installed Cost	*Nominal $/kW*	= [4] x 1000 / [1]	$1,396	$1,338	$1,367	$1,398	$1,456
[6]	Levelized Capital Cost	*Nominal $/kW-yr*	= [3] x [10]	$179	$171	$175	$179	$188
	O&M Costs							
[7]	First Year FOM	*Nominal $ million/yr*		$6	$6	$8	$6	$6
[8]	Levelized FOM	*Nominal $/kW-yr*		$20	$19	$24	$19	$20
[9]	**After-Tax WACC**	***%***		**9.5%**	**9.5%**	**9.5%**	**9.5%**	**9.5%**
[10]	Capital Charge Rate	*%*		14.3%	14.2%	14.2%	14.2%	14.3%
[11]	**Levelized CONE**	***Nominal $/kW-yr***	**= ([6] + [8])**	**$199**	**$190**	**$199**	**$198**	**$208**
[12]	**Levelized CONE**	***Nominal $/MW-day***	**=[11] x 1000/365**	**$546**	**$520**	**$544**	**$542**	**$569**
	2022 CONE Affidavit							
[13]	PJM 2026/27 CONE	*$/MW-day*		$408	$417	$432	$424	
[14]	Escalated to 2028	*$/MW-day*	= [13] x (1.022)^(2028 - 2026)	$427	$436	$452	$443	
	Difference between Updated CONE and Escalated 2022 CONE Affidavit							
[15]	Absolute Difference	*$/MW-day*	= [11] - [14]	$119	$84	$93	$99	
[16]	Percent Change	*%*	= [15] / [14]	28%	19%	21%	22%	

Notes: [13]: Affidavit of Samuel A. Newell, John M. Hagerty, and Sang H. Gang on Behalf of PJM, September 30, 2022.

Drivers of Increased CT CONE (RTO, $2028/MW-day ICAP)



Preliminary BESS CONE (2028/29 DY)

				CONE Area				
				EMAAC	SWMAAC	Rest of RTO	WMAAC	COMED
[1]	**Plant Capacity**	***MW***		**200**	**200**	**200**	**200**	**200**
	Capital Costs							
[2]	Overnight Cost	*Nominal $ million*		$479	$457	$458	$466	$498
[3]	Overnight Cost Net of ITC	*Nominal $ million*		$335	$320	$320	$326	$349
[4]	Overnight Cost	*Nominal $/kW*	= [3] x 1000 / [1]	$1,676	$1,601	$1,602	$1,631	$1,743
[5]	Installed Cost	*Nominal $ million*		$519	$496	$496	$505	$540
[6]	Installed Cost	*Nominal $/kW*	= [5] x 1000 / [1]	$2,596	$2,480	$2,481	$2,526	$2,700
[7]	Levelized Capital Cost	*Nominal $/kW-yr*	= [4] x [12]	$174	$164	$164	$168	$183
	O&M Costs							
[8]	First Year FOM	*Nominal $ million/yr*		$7	$5	$8	$6	$7
[9]	Levelized FOM	*Nominal $/kW-yr*		$41	$31	$45	$35	$43
[10]	Levelized Augmentation	*Nominal $/kW-yr*		$18	$18	$18	$18	$18
[11]	**After-Tax WACC**	***%***		**9.5%**	**9.5%**	**9.5%**	**9.5%**	**9.5%**
[12]	Capital Charge Rate	*%*		10.4%	10.2%	10.2%	10.3%	10.5%
[13]	**Levelized CONE**	***Nominal $/kW-yr***	**= ([7] + [9] + [10])**	**$233**	**$213**	**$227**	**$221**	**$244**
[14]	**Levelized CONE**	***Nominal $/MW-day***	**=[13] x 1000/365**	**$639**	**$582**	**$623**	**$605**	**$667**

Notes: [14]: Affidavit of Samuel A. Newell, John M. Hagerty, and Sang H. Gang on Behalf of PJM, September 30, 2022.

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Annual CONE Updates

Recall that the prior method was to start with the CONE value from the Quad Review (for a plant in the first applicable delivery year) then escalate using most recent changes in cost indexes for labor, materials, and turbines, with weights on each of those indexes

Recent/ongoing rate of price and capital cost changes suggest **more granular method**:

- **Update escalations** *that had been projected* in CONE analysis using observed prices from the cost-snapshot date of the study to the near-present, and from near-present to the construction period using updated inflation forecasts
- **Escalate FOM separately** from overnight cost, based on each one's applicable indexes and weights for each technology (for BESS, possibly using NREL rather than BLS indexes for components)
- **Update the Capital Charge Rate** using a simplified ATWACC index

We would provide a model that readily translates these updates into updated CONE values

Basis for updating ATWACC 1:1 based on RFR Change

Conceptually, ATWACC is the sum of the Risk-Free Rate (RFR) and Genco's industry risk premium. The 100% RFR change is justified since, over the short term:

- the RFR is most likely to change, and
- the industry risk premium or the industry risk is expected to stay constant

Some utility regulators allow "formulaic" return on equity (ROE) adjustment:

- **CA**: change in ROE = 0.5 × change in RFR
- **Alberta / Toronto**: change in ROE = 0.5 × change in RFR + 0.5 × change in bond yield

Assuming both RFR and the bond yield increase by a similar magnitude, the ATWACC adjustment would be about 75% of the RFR change

Empirically, Brattle's prior recommended ATWACCs roughly support a 100% RFR adjustment

ATWACC and RFR

	RFR	ATWACC	Change in RFR	Change in ATWACC	Sensitivity
PJM 2011	4.30%	8.50%			
PJM 2014	3.40%	8.00%	-0.90%	-0.50%	0.56
PJM 2017 @ 35% Tax Rate	2.65%	7.00%	-0.75%	-1.00%	1.33
PJM 2017 @ 21% Tax Rate	2.65%	7.50%			
PJM 2018 @ 21% Tax Rate	2.96%	8.0%	0.31%	0.50%	1.61
PJM 2022 (1)	2.62%	8.0%	-0.34%	0.00%	-
PJM 2022 (2)	3.43%	8.85%	0.81%	0.85%	1.05
PJM 2024 (Preliminary)	4.70%	10.00%	1.27%	1.15%	0.91
Average Sensitivity (Excl. 2024)					**0.91**
Average Sensitivity (Incl. 2024)					**0.91**

Note Brattle's ATWACCs in 2018 and 2022 were based partially on the 100% RFR adjustments to Genco M&A discount rates (from 2016 and 2017)

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Review of the E&AS Purpose and Current Approach

Recall the purpose of the E&AS Offset:

- CONE expresses the total revenue requirement the Reference Resource would need to earn in year 1 to be willing to enter (with NPV = 0), given the investors' view of all-in cash flows (and cost of capital) over the life of the asset.
- The amount the resource would need to earn in the capacity market, Net CONE, is CONE minus the E&AS offset representing net revenues expected from the energy and ancillary services markets.
- Thus Net CONE = CONE – E&AS Offset becomes the anchor price for the VRR curve to be able to attract investment in the Reference Resource in equilibrium.
- *Observation*: EAS variability has moved the VRR curve considerably (e.g., 2026/27 Net CONE being zero)

Recall the E&AS Estimation Methodology:

1. Develop forward hourly zonal DA and RT energy and AS prices for the delivery year
   - Shaped by hourly prices in each of the last three years
   - Scaled to be consistent with forward market expectations for the delivery year (this was the main new element from the last Quad Review)
2. Identify other relevant resource costs and characteristics
3. Estimate Net E&AS Revenues for each resource in each area
   - Conduct a "virtual dispatch" using Plexos, given the hourly prices and each resource's operating characteristics and costs
   - Average the net revenues across the three simulated years to yield the EAS revenue per resource type

The next several slides describe each of these elements in more detail, identifies key questions for evaluating the continued appropriateness of each element, then answers those questions.

1. Construction of Hourly Forward Prices

Elements of Method

Obtain monthly power and gas futures prices at liquid hubs for each month of delivery year

Extend forward prices <u>to each zone and to AS</u>

- **Energy:** adjust zonal price for congestion (using forward LT FTRs) and losses (from history)
- **Gas:** add historical basis adjustment for illiquid hubs
- **AS**: multiply historical prices by an hourly ratio of future to historical energy price for the same hour

Convert monthly hub prices to <u>hourly</u>

- Shape future prices by historical hourly patterns of zonal prices for three most recent years

Evaluation

Forward E&AS continues advantages over historical because it is forward-looking and more normalized; Confirmed selected hubs are still liquid by reviewing open interest on ICE

- **Energy:** confirmed continued competitive LT FTRs indicating market expectations
- **Gas:** confirmed approach remains reasonable
- **AS**: confirmed scaling approach remains reasonable

Sources and Notes: Affidavit of Samuel A. Newell, James A. Read Jr., and Sang H. Gang on Behalf of PJM, September 30, 2022.

2. Assumptions on Other Cost and Resource Characteristics

Elements of Method	Evaluation
Unit characteristics: unit heat rates, VOM and operating characteristics (heat rate curves, startup cost/time, min up/down times) come from S&L	Plant specs remain nearly the same; S&L updating HR curves
NOx and SOx allowances apply everywhere, but with low emissions rates and low prices from Evo Markets (trivial effect on result)	Consider applying a chance of PA returning to RGGI, as developers are, e.g., 50/50? (But hard to update)
RGGI applies in NJ, MD, DE; PJM has been assuming not in PA because of current stay, pending state supreme court decision likely in 2025; PJM has been assuming no RGGI for "RTO"	Consider calculating RTO Net CONE as an average or other statistic of all LDAs' EAS (rather than EAS for averaged energy and gas prices and zero RGGI)
RGGI allowance prices from Evo Markets	Consider using RGGI forwards
Currently no limit on annual CO_2 emissions w/111	Apply 40% limit on CTs now and CCs in 2032+, or should we now assume 111 rules will be revoked?

Sources and Notes: Affidavit of Samuel A. Newell, James A. Read Jr., and Sang H. Gang on Behalf of PJM, September 30, 2022.

3. E&AS Estimation w/Plexos Virtual Dispatch

Elements of Method	Evaluation
CC: optimize DA commitment & dispatch, then RT adjust dispatch and can extend commitments at end of cycle (never uncommit)	**CC**: aim to validate virtual dispatch with benchmarking actual units using historical prices
CT: similar, but can add new commitments based on 3-hr look-ahead; observing many run-hours	**CT**: suggest not locking in DA commitment; 3-hour look-ahead reasonable (vs. 2 in reality, but participants can offer lower startup if anticipate longer payoff); no comparable units to benchmark
BESS: optimize DA schedule, then reoptimize for RT with only 4-hour horizon	**BESS**: try optimizing RT against a 24-hour look-ahead against an average of DA and RT prices for imperfect foresight; possible "over/under optimization" difficult to benchmark since few energy participants, but estimate uncertainty
AS: omit regulation per last Quad Review because thin market (500-800 MW)	**AS**: observe Sync Res is ~30% of BESS EAS; consider omitting or limiting since market is <2.8 GW

Sources and Notes: Affidavit of Samuel A. Newell, James A. Read Jr., and Sang H. Gang on Behalf of PJM, September 30, 2022.

Electricity Hubs and Mapping to Zones

Previous Quad Review determined that Northern Illinois (NI), AEP Dayton, and Western Hub were the most liquid electricity trading hubs and mapped LDAs to one of each based on historical price correlations

Recommend maintaining current mapping and continuing to use ICE electricity futures for these three hubs

And continuing to use LT FTR prices (plus historical losses) for basis differentials

Electricity Futures Zonal Mapping of Trading Hubs

Mapped Hub	Zone	Correlation	Mapped Hub	Zone	Correlation
N. Illinois	COMED	1.00	Western Hub	APS	1.00
				PEPCO	1.00
				BGE	0.99
AEP-Dayton	AEP	1.00		DPL	0.93
	ATSI	1.00		PENELEC	0.99
	DAY	1.00		PPL	0.99
	DEOK	1.00		METED	0.99
	DOM	0.98		PECO	0.96
	DUQ	1.00		AECO	0.96
	EKPC	1.00		PSEG	0.95
				JCPL	0.97
				RECO	0.94

Sources and Notes: Affidavit of Samuel A. Newell, James A. Read Jr., and Sang H. Gang on Behalf of PJM, September 30, 2022.

Natural Gas Hubs

Previous Quad Review determined that Dominion South, MichCon, Chicago, Transco Zone 6 (non-NY), Columbia-Appalachia TCO, and TETCO M3 hubs were most liquid and mapped illiquid hubs to one of each based on historical price correlations

Recommend maintaining current mapping and continue to use ICE gas future prices for these hubs

And continue applying historical basis from liquid hubs to illiquid ones

Gas Futures Zonal Mapping of Trading Hubs

Gas Hub	Zone
Dominion South	APS, PENELEC
Chicago	COMED
Michcon	DAY, DEOK, ATSI
Transco Zone 6 (non NY)	AECO, BGE, DPL, JCPL
TETCO M3	DUQ, METED, PECO, PPL
TCO Basis	AEP
Transco Zone 5	DOM, PEPCO
Tennessee 500L	EKPC
Transco Z6 (NY)	PSEG, RECO

Gas Illiquid to Liquid Hub Mapping

Gas Hub	Mapped Gas Hub	DY 19/20-21/22 Correlation
Transco Zone 5	Transco Zone 6 (non NY)	0.990
Tennessee 500L	MichCon	0.845
Transco Z6 (NY)	TETCO M3	0.995

Sources and Notes: Affidavit of Samuel A. Newell, James A. Read Jr., and Sang H. Gang on Behalf of PJM, September 30, 2022.

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Indicative Net CONE

Technology	Overnight Capital Cost	Capital Charge Rate	Year-1 Capital Recovery	Levelized FOM	E&AS Offset	Net CONE ICAP	ELCC	Net CONE UCAP
All 2028$	($/kW)	(%/year)	($/MW-day)	($/MW-day)	($/MW-day)	($/MW-day)	(%)	($/MW-day UCAP)
Base Cases	[A]	[B]	[C]: [A] × [B]	[D]	[E]	[F]: [C]+[D]-[E]	[G]	[H]: [F] × [G]
Gas CC (20-year Life)	$1,391	14.8%	$563	$155	$571	$147	81.0%	$181
Gas CT (20-year Life and 40% CF Limit)	$1,229	14.2%	$479	$65	$254	$290	80.0%	$363
BESS 4-hr	$1,602 net of ITC	10.2%	$450	$173	$280	$343	55.0%	$623
Sensitivities								
Gas CC (20-year Life and 40% CF Limit)	$1,391	16.6%	$634	$151	$571	$214	81.0%	$264
Gas CC (15-year life)	$1,229	16.0%	$539	$64	$254	$350	80.0%	$437
Gas CT (15-year life)	$1,391	14.8%	$563	$155	$411	$307	81.0%	$380
Gas CC (9-year Historical Average E&AS Offset)	$1,391	14.8%	$563	$155	$321	$397	81.0%	$490
Gas CT (9-year Historical Average E&AS Offset)	$1,229	14.2%	$479	$65	$127	$417	80.0%	$521

Sources and Notes: All costs in ICAP terms unless otherwise noted.
[A],[D]: Capital Cost and FOM from previous Preliminary numbers. [B]: CCR for level-nominal levelization with 9.5% ATWACC; no bonus depreciation; 20-year life (except where specified); 20-year MACRS for CC, 15 for CT, and 7 for BESS; and ITC . [E]: E&AS offset provided by PJM staff. Historical E&AS offsets from PJM, MOPR parameters, delivery years 2017/18-2026/27, escalated to $2028. [G]: 2028/29 ELCC values from PJM, Supplementary Information about ELCC Class Ratings calculated for DY 2027/28 – DY 2034/35.

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Next Steps

Plan for Next Stakeholder Meeting (December 17, 2024)

Present Updated Net CONE Values

Present E&AS Methodology Update

Present VRR Curve Concepts

- Marginal Reliability Impact based design methodology
- Potential interactions with updated reliability modeling, accreditation, and seasonal risks