Existing Generation Gross ACRs and Energy Efficiency Net CONE

Preliminary Results

PRESENTED TO

Market Implementation Committee

PRESENTED BY

Brattle and S&L Project Teams

February 28, 2020

THE Brattle GROUP

Purpose

- To implement the FERC order on MOPR issued in December 2019, PJM requested that Brattle and S&L analyze:
  - **Existing generation gross avoidable cost rates (Gross ACRs)**
  - **New energy efficiency net cost of new entry (EE Net CONE)**
- PJM will estimate the energy and ancillary services (E&AS) net revenues and calculate the *Net* ACRs for existing generation
- PJM will use the results as threshold prices to determine which offers to the capacity market must seek a "unit-specific exemption" to price their offer below the applicable threshold value; the Net ACRs and Net CONE do not represent a price floor for each resource type

Note: The purpose of the analysis is to provide PJM the inputs necessary to operate its market given the FERC order. Our analysis takes no position on the economic or policy merits of this order.

Existing Generation Gross ACR

Existing Generation Gross ACR Scope

Technologies: PJM requested that we estimate Gross ACRs for the following existing generation resources:

- Single-unit nuclear plants
- Multi-unit nuclear plants
- Coal plants
- Natural gas combined-cycle plants
- Natural gas simple-cycle combustion turbine plants
- Diesel generator plants
- Onshore wind plants
- Large-scale (>1 MW) solar photovoltaic plants

Costs: Gross ACR costs include the total fixed costs expected to be incurred on an annual basis to operate an existing generation resource an additional year

- Gross ACR costs do not include operating and maintenance costs directly attributable to the production of electricity
- Nor costs that are incurred to significantly extend the life of the resource

Approach to Estimating Existing Generation Gross ACRs

Identified a "representative plant" for each technology:

- Reviewed the range of characteristics for the entire population of plants
- Identified the primary drivers of cost differences across the fleet
- Developed characteristics of a plant that is widely representative of the fleet

Estimated the costs of the representative plant:

- Reviewed publicly-reported costs for the representative plants and compared them to confidential cost estimates within S&L's project database
- For nuclear, relied on data in NEI's Sept 2019 *Nuclear Costs in Context* with adjustments for technology type and market structure
- Developed cost estimates for the representative plants to determine the Gross ACRs as well as the variable O&M for use in PJM's E&AS analysis

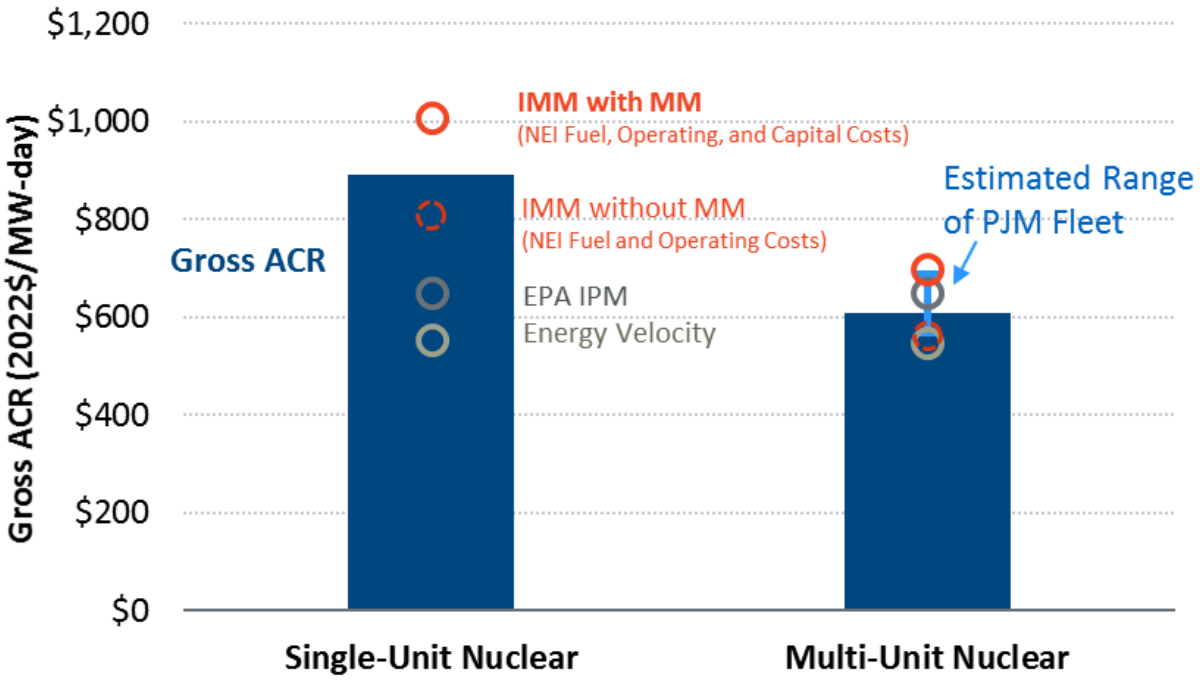
Also estimated costs for "representative-low" and "representative-high" plants to inform the likely range of costs of existing resources in PJM

- The characteristics we developed for the three plant types (representative plant, representative-low, and representative-high) are included in the appendix slides

Existing Nuclear Gross ACRs

- Gross ACRs are about 12% lower than the IMM primarily due to lower assumed capital costs and an estimated VOM of $1/MWh (which will reduce net E&AS revenues)
- Publicly available references (other than NEI) show limited differences between single-unit and multi-unit plants; seem to be more applicable to multi-unit plants

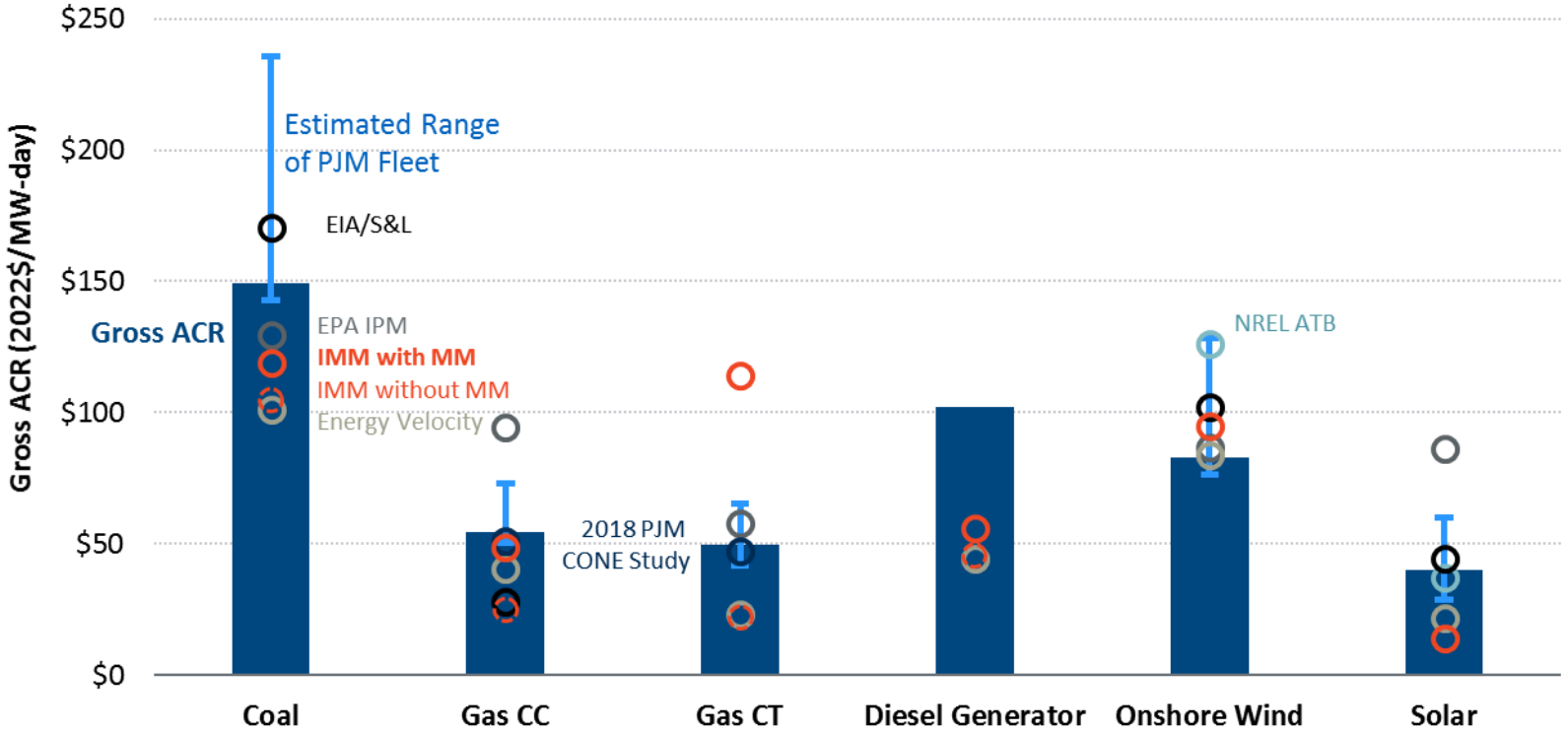
Preliminary Nuclear Gross ACRs ($/MW-day)



Notes: IMM values are from January 2020 preliminary report. IMM relied on NEI costs with no adjustments. Sources for publicly-available reference points provided in appendix. EPA IPM does not include fuel cost assumptions; added NEI fuel costs to be comparable to other estimates.

Existing Generation Gross ACRs

Preliminary Existing Generation Gross ACRs ($/MW-day)



Notes: IMM values are from January 2020 preliminary report. Sources for publicly-available reference points provided in appendix. All capacity is in terms of installed capacity. NREL ATB and 2018 PJM CONE Study values are for a new plant.

Representative plants tend to be at the lower end of the range since smaller units have significantly higher costs per-MW, while larger plants have slightly lower costs per-MW

Existing Generation Gross ACRs Summary

Preliminary Existing Generation Gross ACRs (2022$/MW-day)

Technology	Representative-Low	Representative Plant	Representative-High
Single-Unit Nuclear		**$892**	
Multi-Unit Nuclear	$568	**$609**	$689
Coal	$143	**$149**	$235
Gas CC	$50	**$55**	$73
Gas CT	$42	**$50**	$65
Diesel Generator		**$102**	
Onshore Wind	$76	**$83**	$128
Solar PV	$29	**$40**	$60

New Energy Efficiency Net CONE

Energy Efficiency Net CONE Scope

We reviewed a wide range of EE programs across the PJM market and identified several utilities with sufficient program costs and EE performance data to estimate a Net CONE value

The estimate of the EE Net CONE accounts for the total economic costs and benefits from the overall ratepayer perspective, including:

- EE program costs spent by utilities with funds collected from ratepayers, including incentives provided to ratepayers for implementing EE measures
- Incremental costs to the participant of implementing the EE measure, i.e., their additional costs of implementing more efficient equipment
- Cost savings from reduced purchases from the wholesale energy market
- Cost savings from reduced investment in the T&D system

Approach to Estimating New Energy Efficiency Net CONE

- **Identify utility EE programs** that participate in the PJM market with sufficient cost/performance data to estimate Net CONE, including program and participant costs, annual and lifetime energy savings, and peak demand savings
- **Create a portfolio of programs** that are likely to be included in a package of EE capacity offering into the capacity market
- **Calculate total costs per UCAP MW** by grossing up peak savings by T&D losses (9-26% based on utility assumptions) and PJM pool requirement (1.087)
- **Calculate Gross CONE** based on total costs per kW, estimated program lifetime, and PJM's assumed CONE ATWACC (8.2%)
- **Estimate wholesale energy savings** based on the 3-year average of historical (2017-19) load-weighted average prices in each zone ($26-$34/MWh) and assuming EE hourly savings are distributed in proportion to the overall load
- **Estimate T&D savings** based on assumptions in the cost-effectiveness tests of $33-$54/kW-yr
- **Calculate Net CONE** by subtracting wholesale energy savings and T&D savings from Gross CONE

Preliminary New EE Net CONE

We identified 4 utilities in PJM (AEP, BGE, ComEd, and PPL) with sufficient data regarding annual energy & peak savings and program costs to estimate an EE Net CONE

- Total UCAP value of new EE included in our analysis is 328 MW UCAP per year

Preliminary EE Net CONE is higher than similar estimates in ISO-NE due to significantly lower assumed wholesale energy prices in PJM

- $29/MWh in PJM compared to about $60/MWh in ISO-NE
- T&D benefits are similar
- Total costs are about 30% lower

Preliminary New EE Net CONE

PJM Technology: EE

EE Impacts		
Customer Peak Savings	*Retail MW*	0.85
Losses Gross-Up	*%*	17.6%
Nominated EE Value	*MW ICAP*	1.00
Forecast Pool Requirement		1.087
UCAP Value of EE	*MW UCAP*	1.09
Annual Energy Savings	*MWh*	6,302
EE Costs and Benefits Assumptions		
Total Costs	*$/kW ICAP*	$2,166
Estimated Lifetime	*years*	11
PJM CONE ATWACC	*%*	8.2%
Energy Benefit	*$/MWh*	$29
Avoided T&D Costs	*$/kW ICAP-yr*	$41
Calculations		
Gross CONE	*$/kW ICAP-yr*	$289
Energy Savings	*$/kW ICAP-yr*	$170
T&D Savings	*$/kW ICAP-yr*	$36
Net CONE	***$/kW ICAP-yr***	**$84**
Net CONE	***$/MW ICAP-day***	**$230**
Net CONE	***$/MW UCAP-day***	**$211**

Appendix

Existing Single Unit Nuclear Plants

Overall population characteristics:

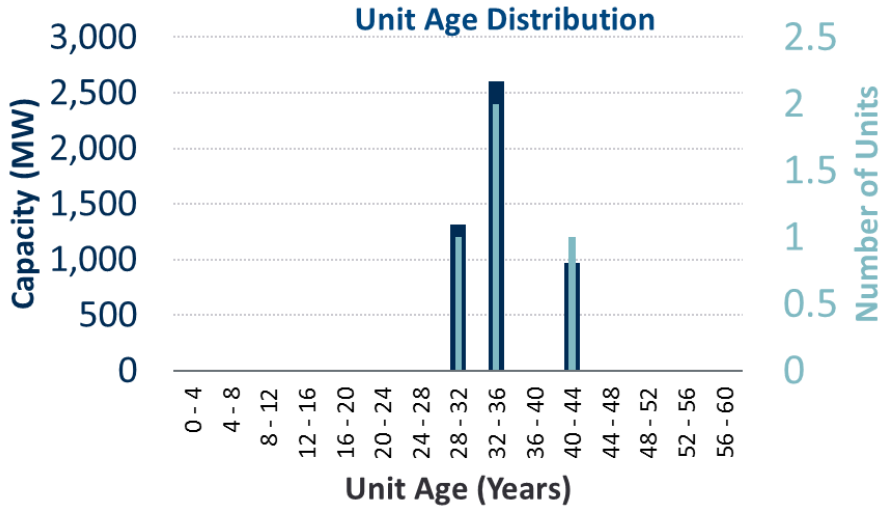
- Only 3 in PJM, 2 in Ohio
- 1,000 – 1,300 MW
- 33 – 43 years of operations

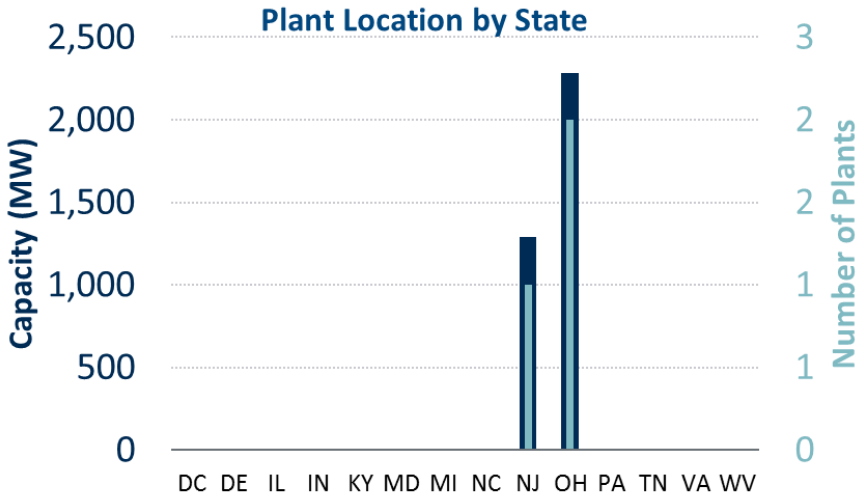
Primary drivers of cost variability:

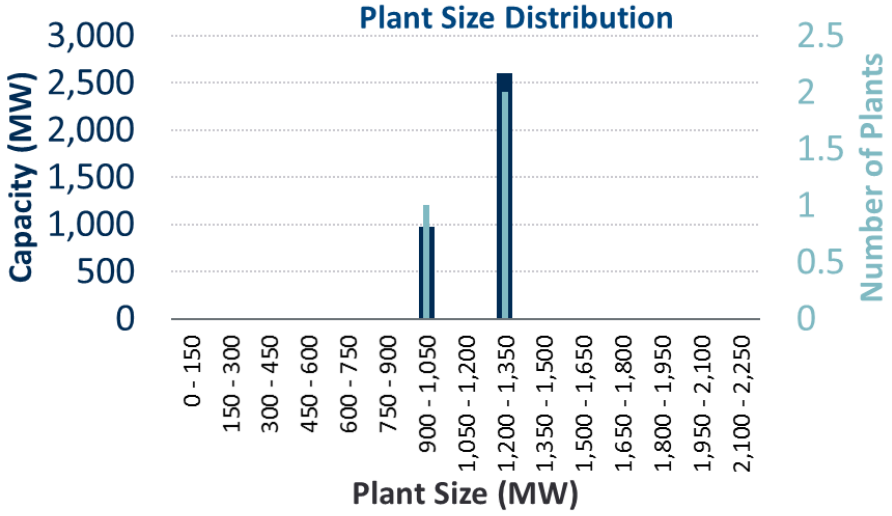
- Due to the limited number of plants and similar designs, we do not plant on analyzing high end or low end single unit nuclear plants

Technology	Low End Characteristics	Representative Characteristics	High End Characteristics
Single Unit Nuclear	• Only 3 plants in PJM • Too few units to estimate a range	• 1,200 MW • Boiling Water Reactor • Ohio • 35 years old	• Only 3 plants in PJM • Too few units to estimate a range

Single Unit Nuclear Fleet







Existing Multi Unit Nuclear Plants

Overall population characteristics:

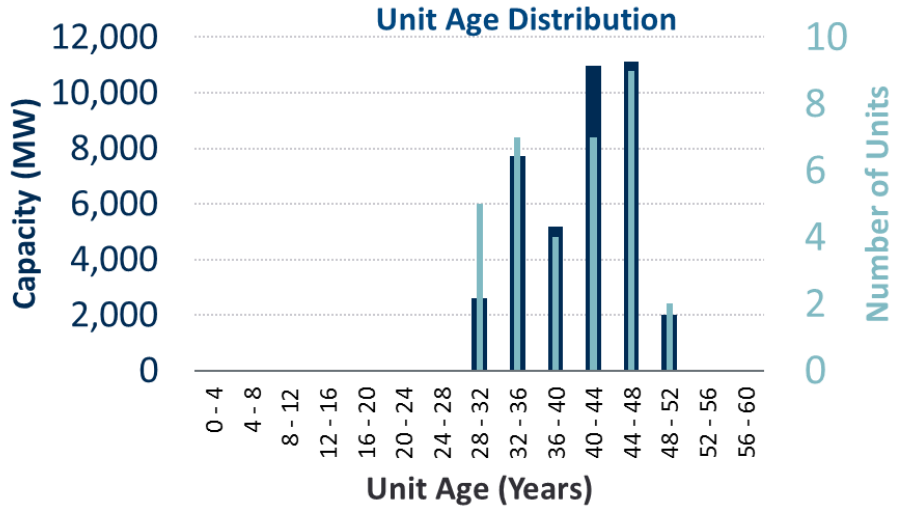
- 1,900 – 2,800 MW
- Most capacity in PA and IL
- 30 – 50 years of operations

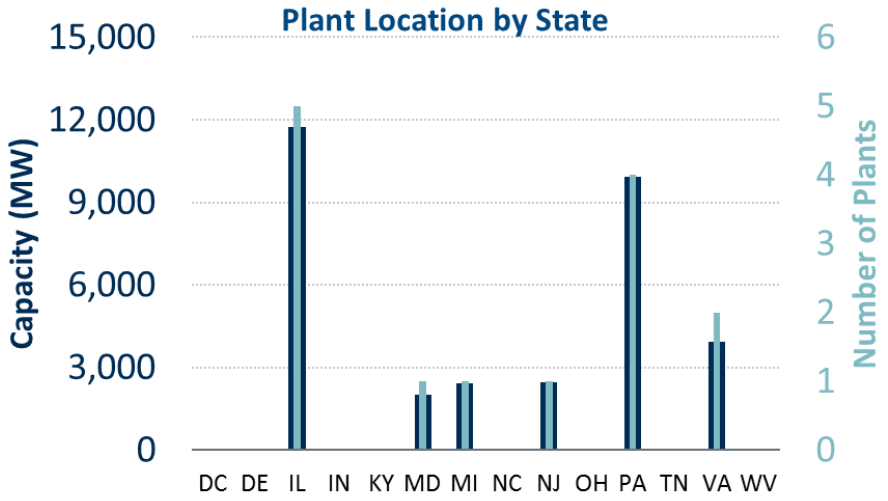
Primary drivers of cost variability:

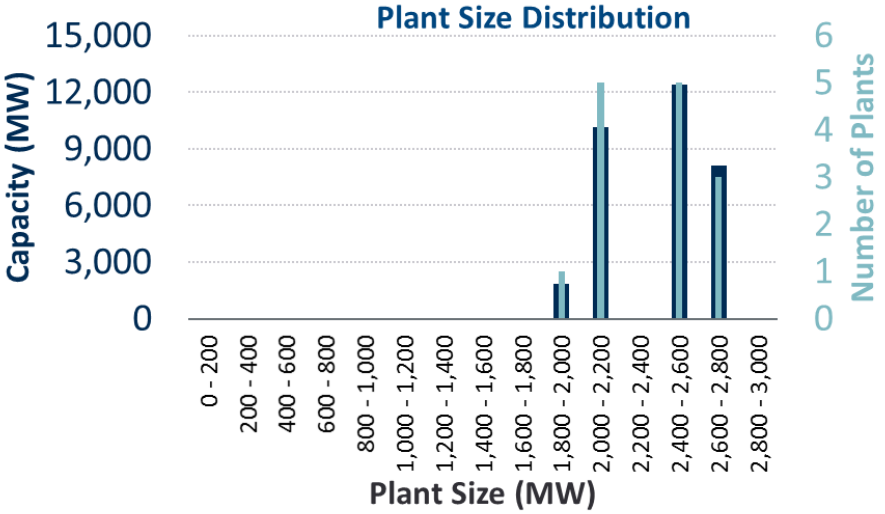
- Plant design: PWR vs BWR
- Going-forward regulatory commitments
- Location

Technology	Low End Characteristics	Representative Characteristics	High End Characteristics
Multi Unit Nuclear	• 2,400 MW (2 x 1,200 MW) • Pressurized Water Reactor • Illinois • 35 years old • Minimal regulatory costs	• 2,400 MW (2 x 1,200 MW) • Boiling Water Reactor • Pennsylvania • 35 years old • Minimal regulatory costs	• 2,400 MW (2 x 1,200 MW) • Boiling Water Reactor • Pennsylvania • 35 years old • Potential regulatory costs

Multi Unit Nuclear Fleet







Existing Coal Plants

Overall population characteristics:

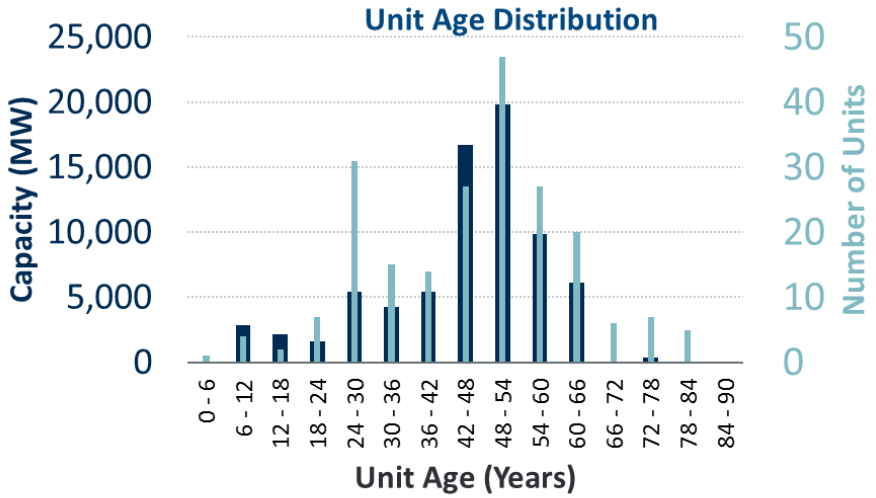
- Wide range of capacities (mostly 500 – 3,000 MW); average is 1,100 MW
- Nearly all plants have an FGD
- Most capacity in WV, PA, OH
- Over half are 35 – 55 years old

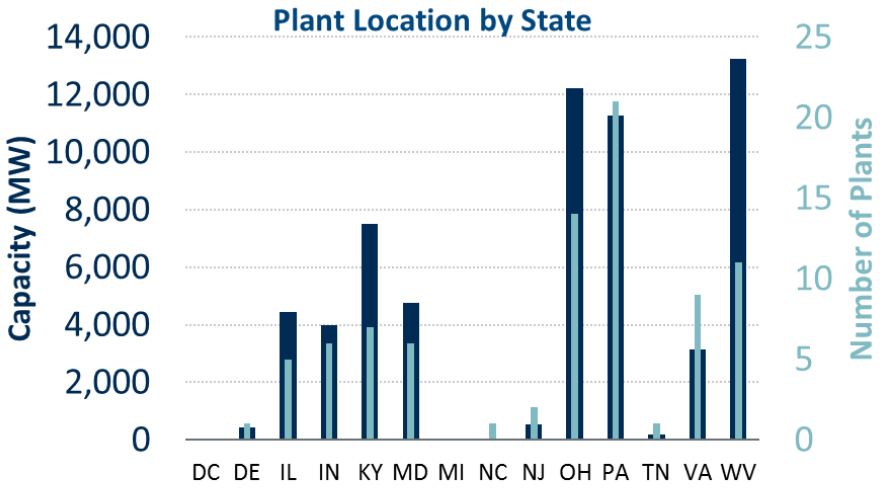
Primary drivers of cost variability:

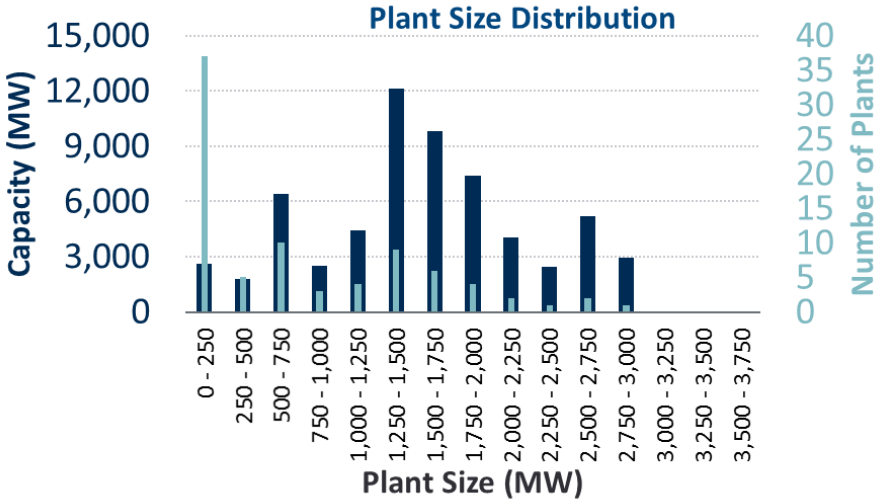
- Range of capacity (primary driver included below)
- Post-combustion control technologies (FGD is largest cost driver)
- Location

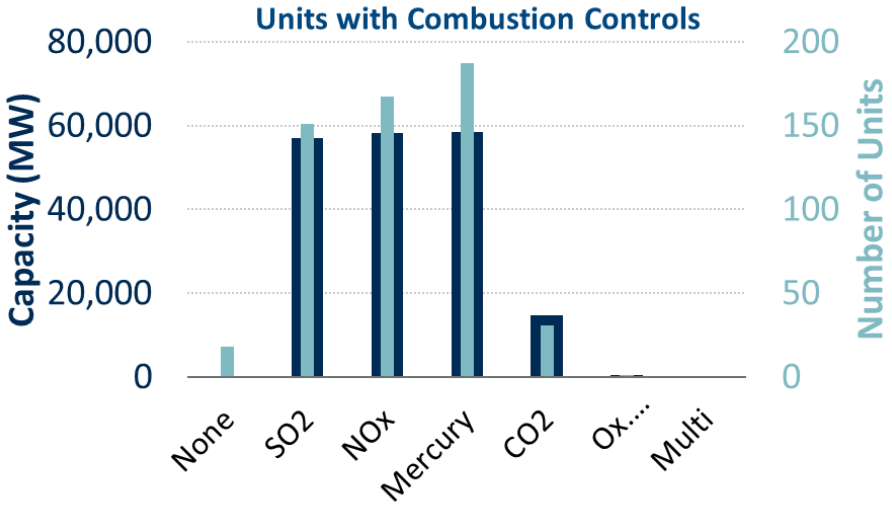
Technology	Low End Characteristics	Representative Characteristics	High End Characteristics
Coal	• 1,800 MW (2 x 900 MW) • Appalachian coal (high sulfur) • Wet limestone FGD • West Virginia • 45 years old	• 1,200 MW (2 x 600 MW) • Appalachian coal (high sulfur) • Wet limestone FGD • West Virginia • 45 years old	• 300 MW (2 x 150 MW) • Appalachian coal (high sulfur) • Wet limestone FGD • West Virginia • 45 years old

Existing Coal Fleet









Existing Natural Gas CC Plants

Overall population characteristics:

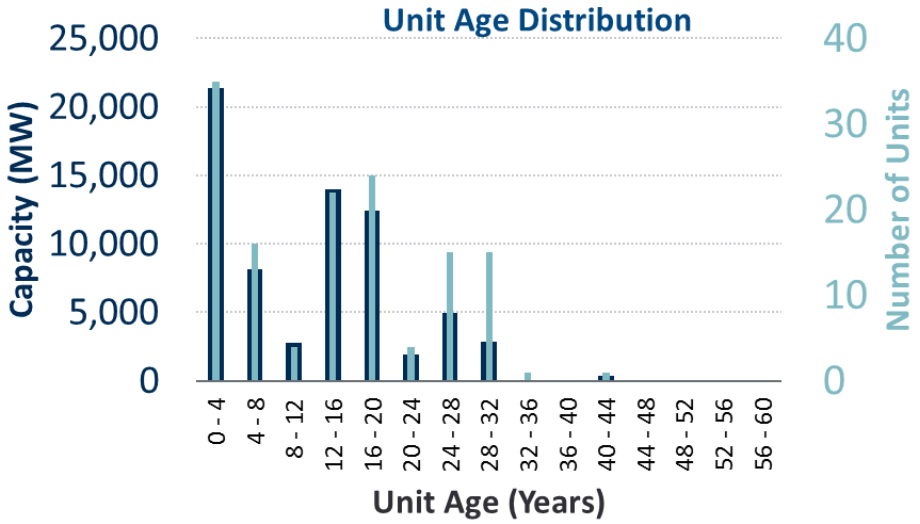
- Mostly built 15-20 years ago or in the past 5 years
- 600–1,000 MW common in early 2000s, mostly F-class
- SCRs are common on CCs
- Most capacity in PA, VA, NJ, OH

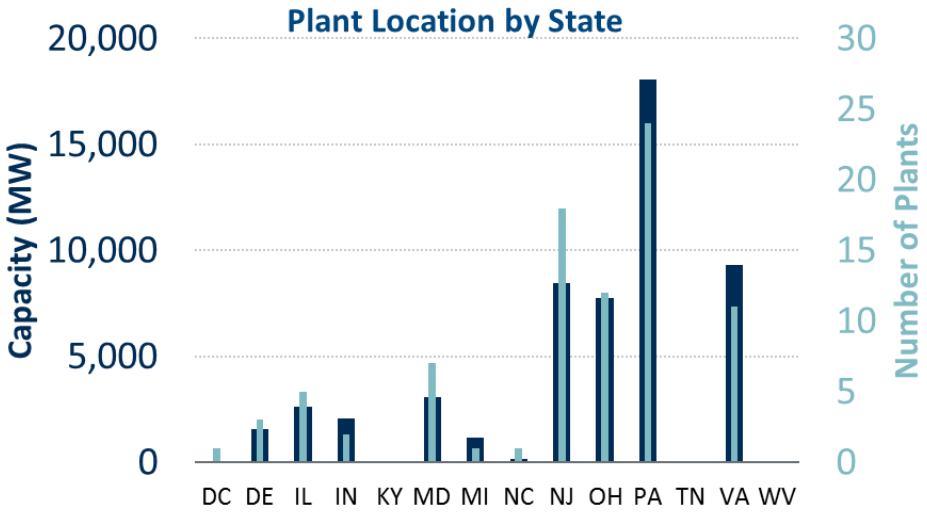
Primary drivers of cost variability:

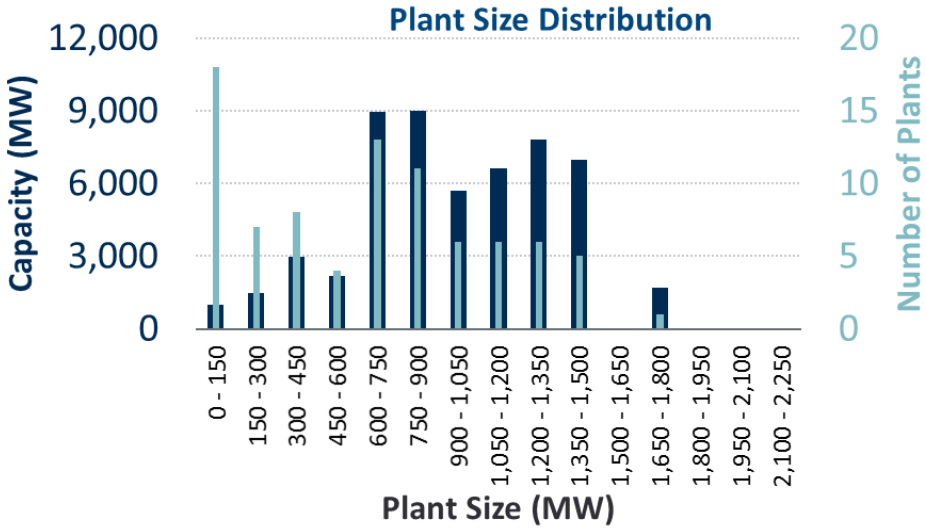
- Range of capacity, configuration, and turbine type
- Operating years
- Location

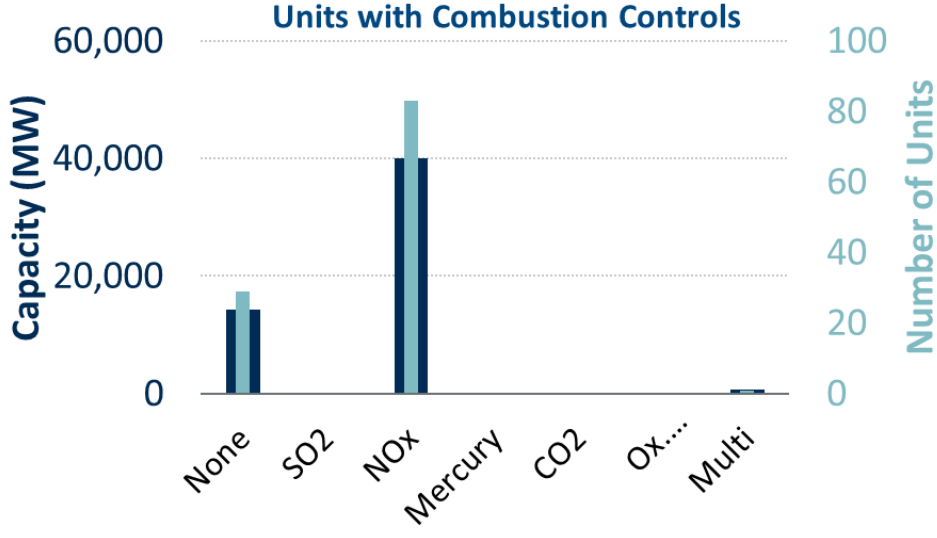
Technology	Low End Characteristics	Representative Characteristics	High End Characteristics
Gas CC	• 1,100 MW • H-class turbines (2x1) • SCR • Pennsylvania • 5 years old	• 750 MW • F-class turbines (2x1) • SCR • Pennsylvania • 15 years old	• 360 MW • F-class turbines (1x1) • SCR • Pennsylvania • 15 years old

Existing CC Fleet









Existing Natural Gas CT Plants

Overall population characteristics:

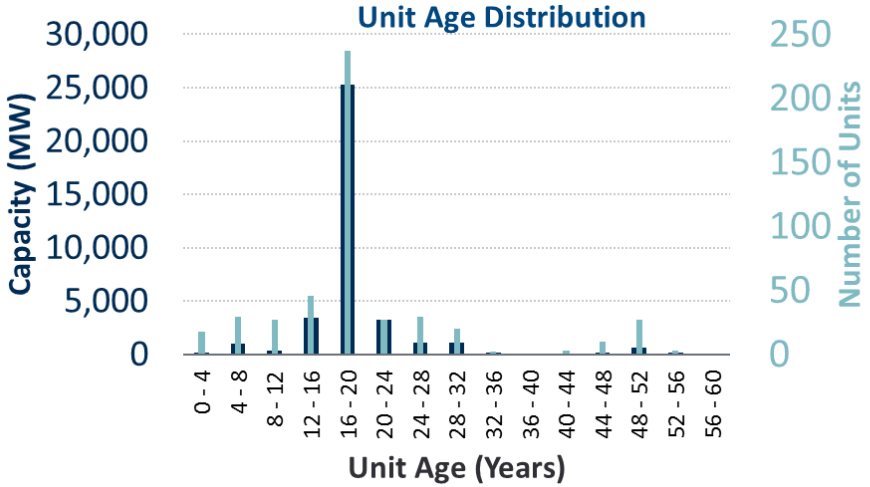
- Wide range of size, number and type of turbines
- SCR not common on CTs
- Primarily built 15-20 years ago
- Most capacity in IL, OH, VA

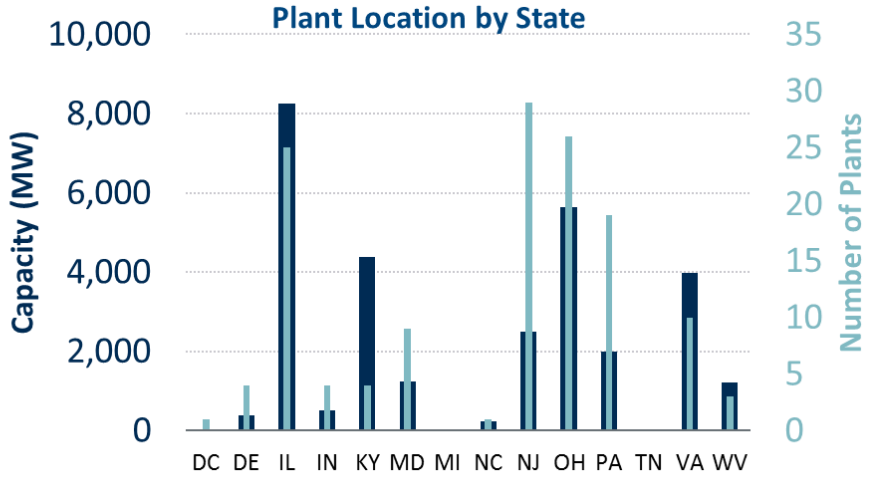
Primary drivers of cost variability:

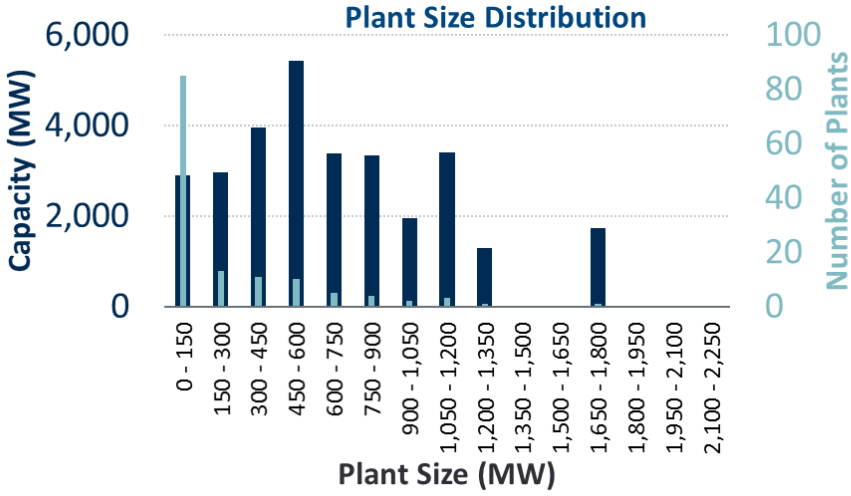
- Range of capacity, configuration, and turbine type
- Location

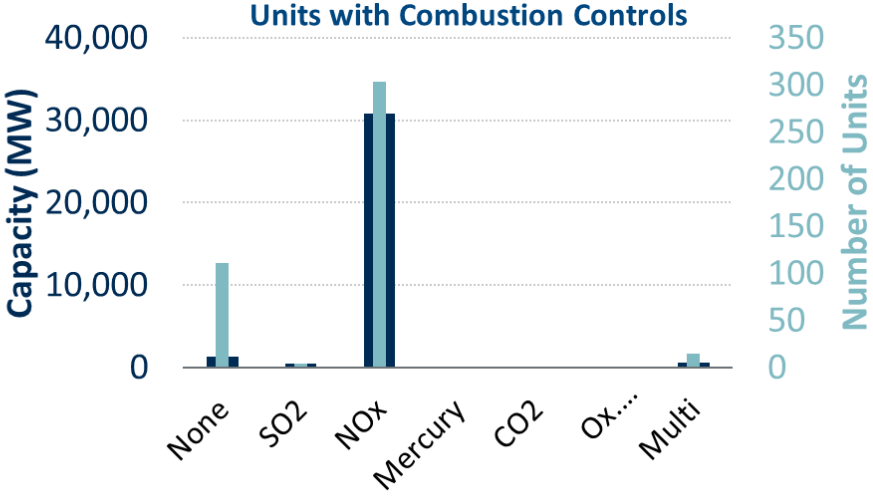
Technology	Low End Characteristics	Representative Characteristics	High End Characteristics
Gas CT	• 320 MW (2 x 160 MW) • F-class turbines • No SCR • Illinois • 15 years old	• 640 MW (8 x 80 MW) • E-class turbines • No SCR • Illinois • 15 years old	• 100 MW (2 x 50 MW) • LM6000 • No SCR • Pennsylvania • 15 years old

Existing CT Fleet









Existing Diesel Plants

Overall population characteristics:

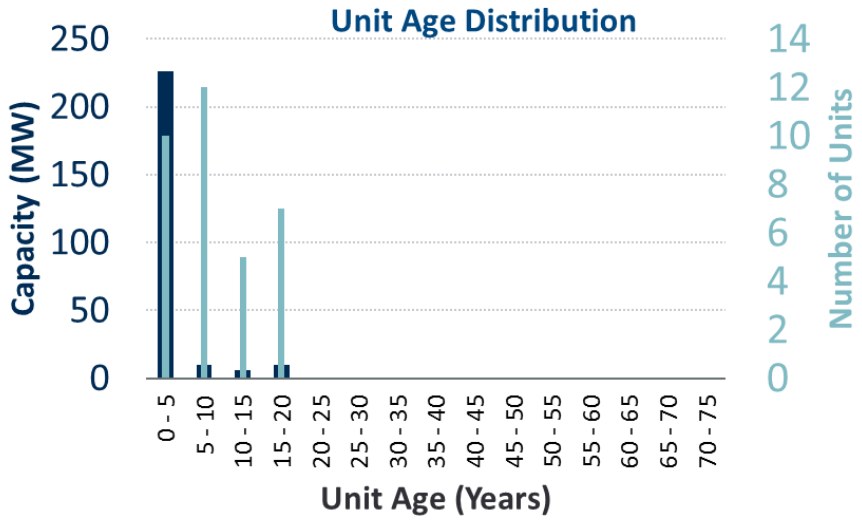
- Units range from 2 MW to 6 MW and plants from 10 MW to 22 MW
- Most plants built in past 5 – 10 years

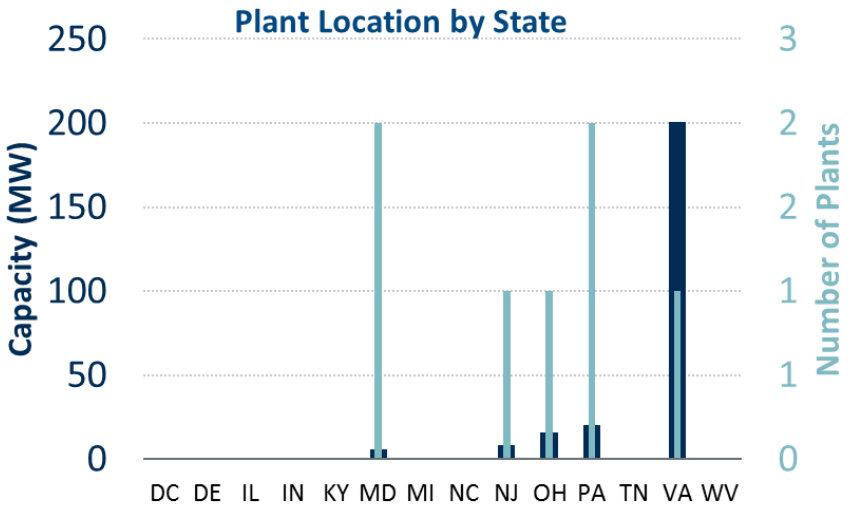
Primary drivers of cost variability:

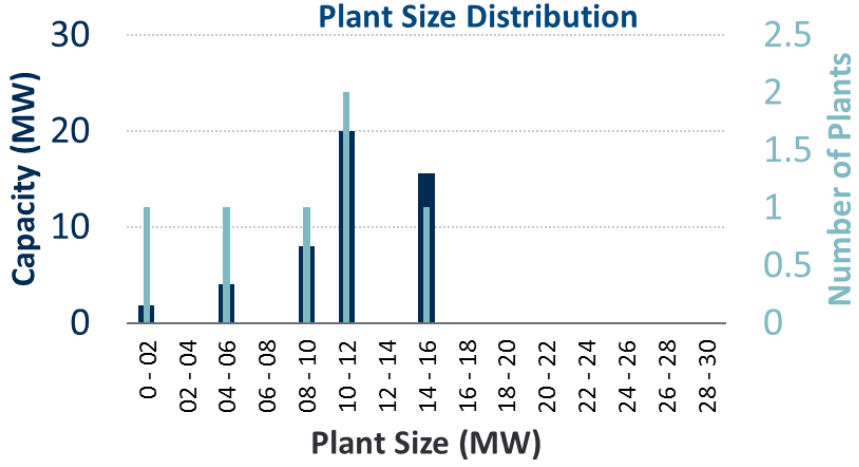
- Too few units to estimate a range

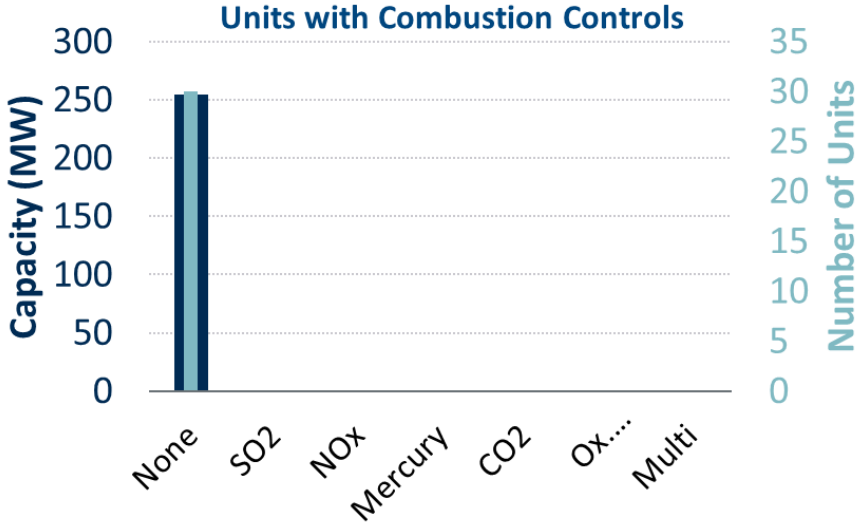
Technology	Low End Characteristics	Representative Characteristics	High End Characteristics
Diesel	• Too few units to estimate a range	• 15 MW (5 x 3 MW) • Caterpillar or Wartsilla • Virginia • 10 years old	• Too few units to estimate a range

Existing Diesel Fleet









Existing Solar PV Plants

Overall population characteristics:

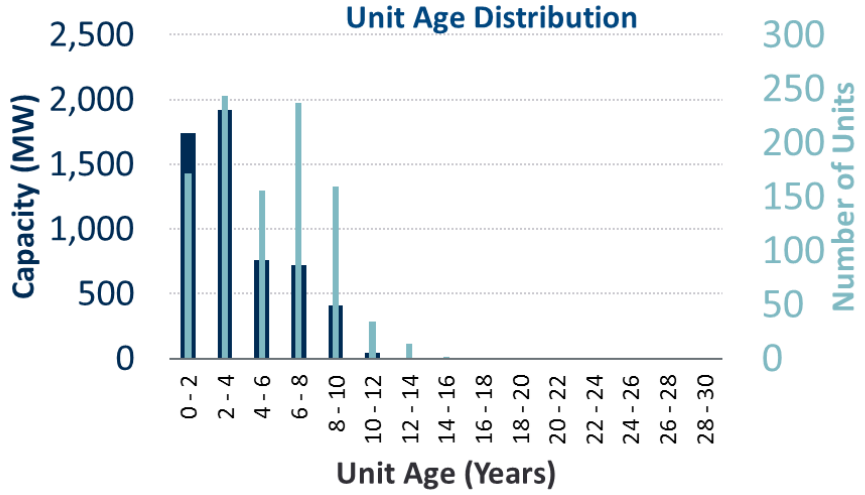
- Most capacity is <10 MW
- Most capacity in NJ and NC
- Built in past 10 years old

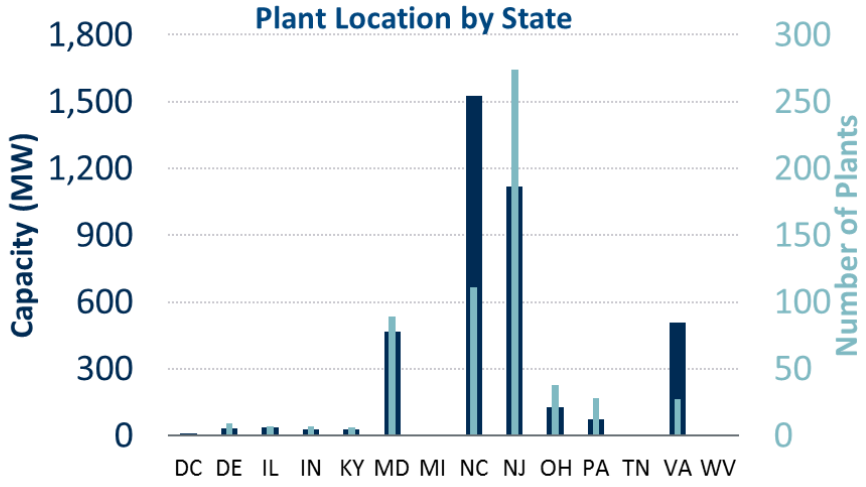
Primary drivers of cost variability:

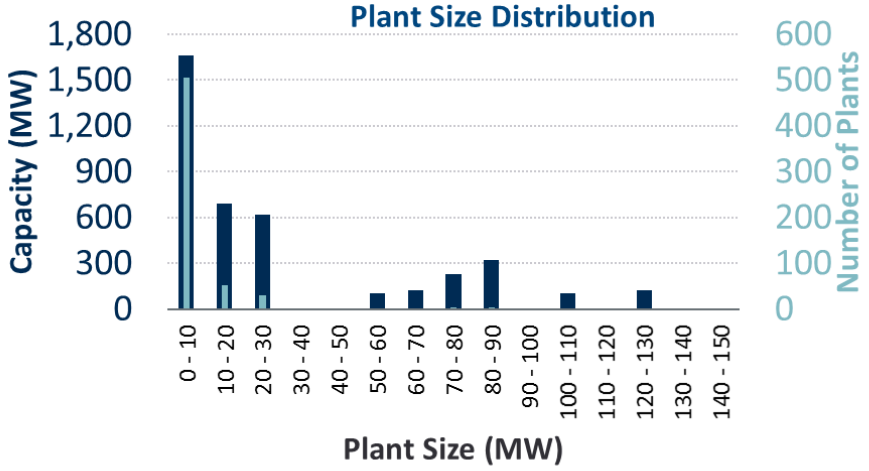
- Capacity
- Location

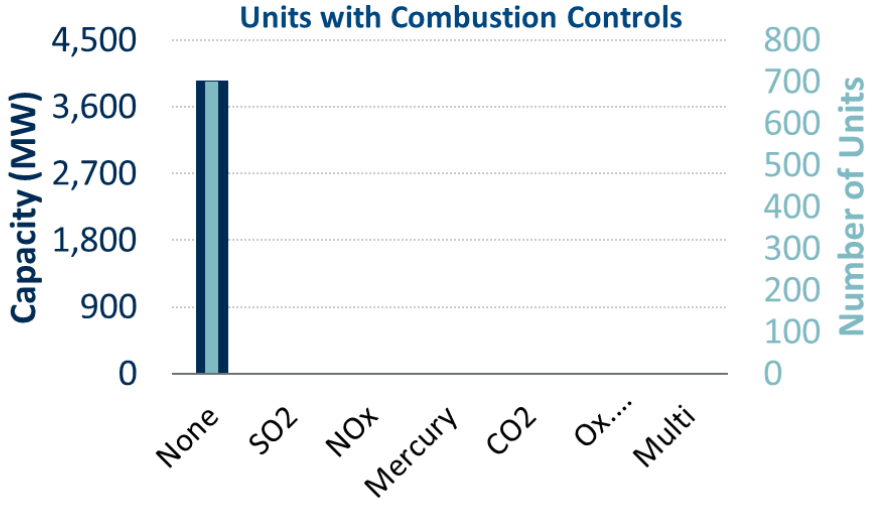
Technology	Low End Characteristics	Representative Characteristics	High End Characteristics
Solar	• 80 MW • Polysilicon • Single axis tracking • North Carolina • 5 years old	• 10 MW • Crystalline silicon • Single axis tracking • New Jersey • 5 years old	• 2 MW • Crystalline silicon • Single axis tracking • New Jersey • 5 years old

Existing Solar PV Fleet









Existing Onshore Wind Plants

Overall population characteristics:

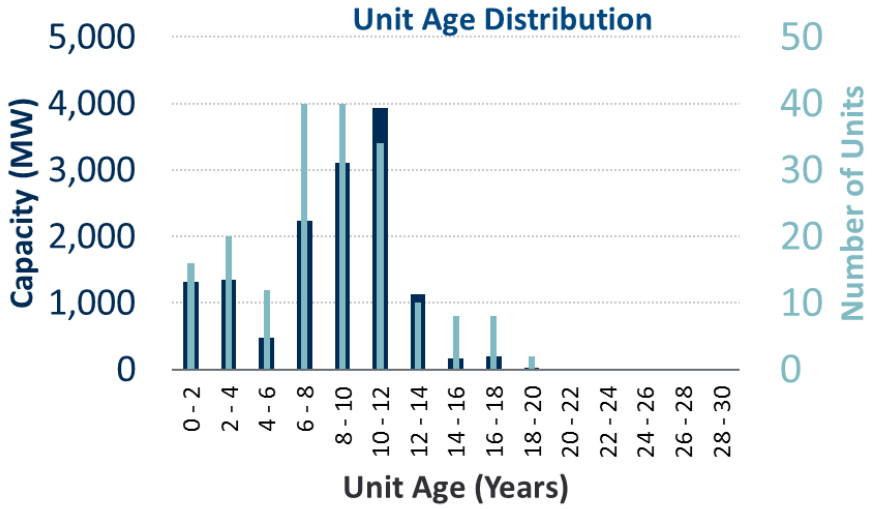
- Wide range of sizes, average (100 MW) skewed by a few large plants (>750 MW)
- Most capacity in IL and IN, but mainly larger plants; smaller plants mostly in PA
- 5 – 15 years of operations

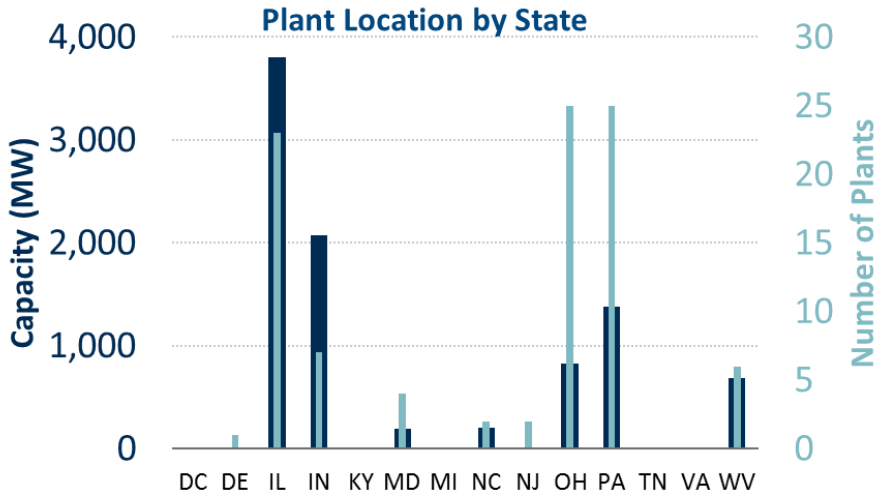
Primary drivers of cost variability:

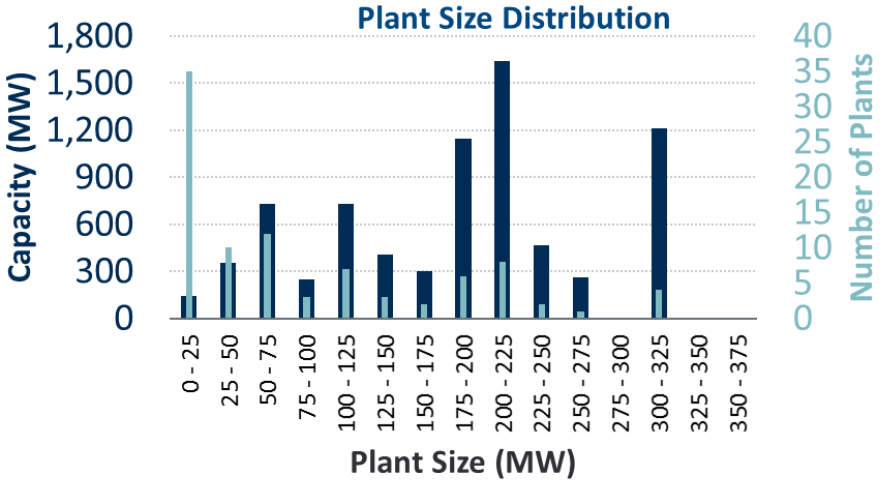
- Capacity
- Location

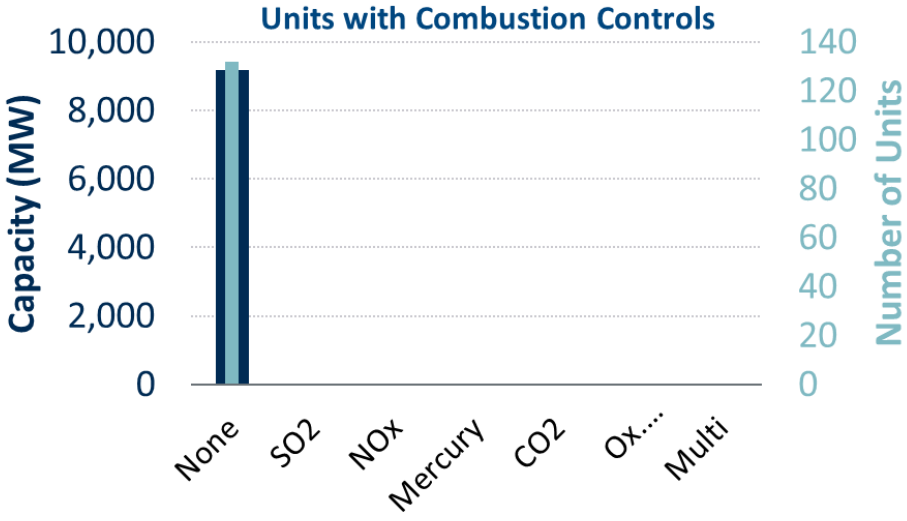
Technology	Low End Characteristics	Representative Characteristics	High End Characteristics
Wind	• 300 MW (150 x 2 MW) • Illinois • 10 years old	• 60 MW (40 x 1.5 MW) • Pennsylvania • 10 years old	• 30 MW (30 x 1.5 MW) • Pennsylvania • 10 year old

Existing Onshore Wind Fleet









Gross ACR References

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EE Net CONE Program Detail

Program Number	AEP Program Name	AEP Net CONE	AEP Peak MW	PPL Program Name	PPL Net CONE	PPL Peak MW	ComEd Program Name	ComEd Net CONE	ComEd Peak MW	BGE Program Name	BGE Net CONE	BGE Peak MW	Cross-Utility Portfolio Net CONE	Cross-Utility Portfolio Peak MW
1	Behavior Change	$4,205	0.2	EE Home	$1,579	3.6	Retro- Commissioning	$4,846	0.5	Quick Home Energy Check-up	$47,753	0.1		
2	Data Center	$2,755	0.6	LI WRAP	$1,464	1.6	Home Energy Assessments	$2,964	0.9	Home Performance with ENERGY STAR	$2,713	1.1		
3	Retro-Commissioning	$1,719	0.7	All Programs	$760	22.7	Elementary Energy Education	$2,157	0.2	Prescriptive	$1,113	3.5		
4	Continuous Energy Improvement	$1,475	3.1	Appliance Recycling	$13	1.6	Appliance Rebates	$1,821	0.9	Appliance Rebates	$992	0.7		
5	Community Assistance	$1,038	1.1	SEEE	-$101	0.6	Residential New Construction	$1,175	0.3	Smart Energy Manager	$940	10.4		
6	Self-Direct	$933	0.5	EE Kits & Education	-$146	1.1	Data Centers	$1,018	1.8	Smart Thermostats	$922	1.0		
7	Bid to Win	$883	7.4	Efficient Lighting	-$175	17.4	HVAC and Weatherization	$846	4.8	HVAC Rebates	$870	3.2		
8	Multifamily	$793	1.0	Home Energy Education	-$383	5.3	AirCare Plus	$790	0.3	Small Business Energy Solutions	$706	5.5		
9	Express	$707	3.8				Business Custom	$668	3.6	ENERGY STAR for New Homes	$502	2.5		
10	Efficient Products	$704	8.9				Multifamily - Tenant Area	$446	0.3	Building Tune-up	$273	1.0		
11	Efficient Products for Business	$504	18.6				Res Fridge and Freezer	$427	2.6	Combined Heat and Power	$247	3.6		
12	In-Home Energy	$470	2.0				Business New Construction	$323	8.6	Smart Energy Rewards	$196	115.2		
13	New Home	$218	3.1				Industrial Systems	$284	4.9	Instant Savings	$184	10.0		
14	New Construction and Major Renovation	$144	3.1				Business Standard	$284	25.8	Custom	$151	5.5		
15	e3smart	$84	0.5				Business Instant Lighting Discount	-$53	51.1	Appliance Recycling	$14	1.5		
16	Combined Heat and Power	$34	16.4				Business Instant Lighting Discount (Carryover)	-$387	6.3	Residential Lighting	-$501	19.5		
17	Process Efficiency	-$31	13.4											
18	Appliance Recycling	-$117	2.2											

	AEP Wtd Avg	AEP Total MW	PPL Wtd Avg	PPL Total MW	ComEd Wtd Avg	ComEd Total MW	BGE Wtd Avg	BGE Total MW	Cross-Utility Portfolio Wtd Avg	Cross-Utility Portfolio Total MW
All Programs	$436	86.7	$370	53.9	$210	112.9	$259	184.2	**$295**	**437.6**
Excluding Ineligible Programs	$530	70.3	$453	48.5	$245	106.6	$237	51.6	**$352**	**277.0**
Excluding Ineligible and Not Cost-Effective Programs	$428	64.5	$323	43.4	$164	102.0	$12	46.8	**$230**	**256.7**

Note: Net CONE numbers reported in $/MW ICAP-day. Highlighted programs are excluded.

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