Sources for Techno-Economic Inputs (Order No. 1920 Scenarios' Factor Category Four)

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TEAC Special Session - Order 1920

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Agenda

- Fixed Costs
  - capital, fixed O&M, geographic adjustments coefficients
- Variable Costs
  - heat rates, fuel costs, variable O&M
- Financial Assumptions
  - Fixed charge rate and discount rate
- Renewable Capacity Factors

Key Takeaways

- Use Energy Exemplar' Eastern Interconnection dataset but replace certain inputs:
  - Capital, FOM, and VOM costs, and financial assumptions from Quadrennial Review where available (combustion turbine, combined cycle, and possibly battery)
    - Otherwise use S&P inputs to the North American Power Outlook (solar, onshore wind, offshore wind, solar + battery hybrid)
    - or NREL's Annual Technology Baseline (e.g., for combined cycle with carbon capture and sequestration)
  - Use Henry Hub natural gas price and discount rate from PJM's Market Efficiency

Fixed Cost Assumptions

Utility Scale Solar (Tracking)

		Units	Overnight Capital Cost (weighted)	Overnight Capital Cost (unweighted)	FOM
EIA 2022 (a,e,f)	150MW	2021$/kW	1327	1323	16.0
EIA 2023 (b)	150MW	2022$/kW	1448	1443	17.2
NREL 2023 (c)	100MW	2021$/kW		1285	21.5
S&P 2023 (d)		2021$/kW		1321	11.8

Note: before applying IRA

(a) Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2022 Tab 1; Levelized Costs of New Generation Resources in the Annual Energy Outlook 2022 Tab 1a

(b) Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2023 Tab 1

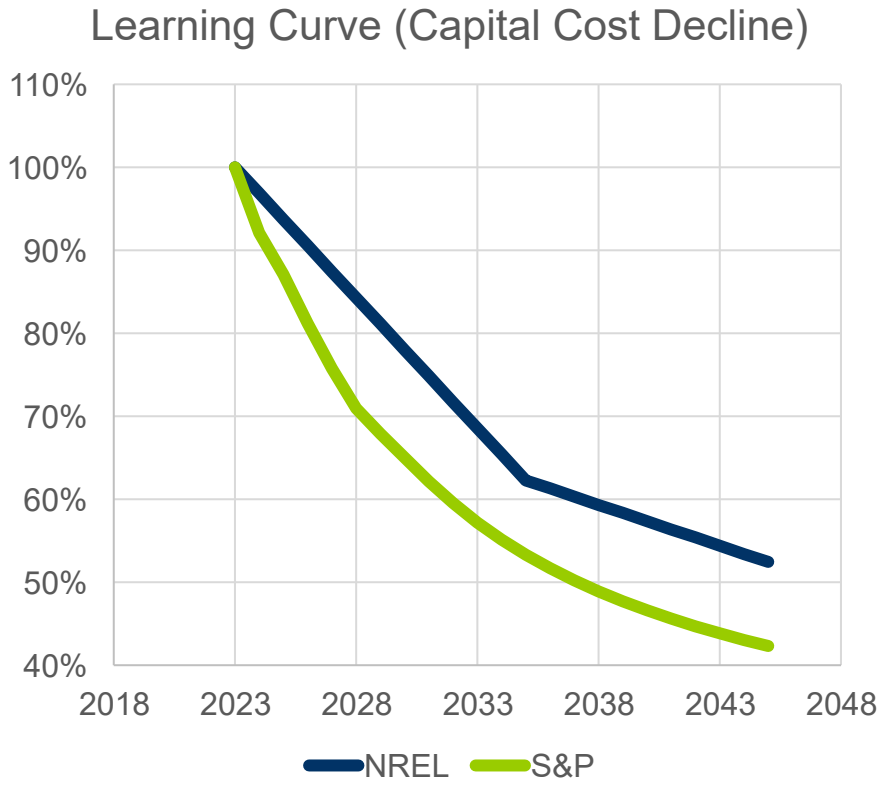
(c) Annual Technology Baseline 2023

(d) North America Solar PV Capital Cost and LCOE Outlook, Jan 2023

(e) Used for Energy Exemplar's Eastern Interconnection Dataset 2023

(f) Used for BRA 2026/2027 CONE

- PJM recommends using S&P



- S&P and NREL also provide forecasts for FOM and efficiency improving over time

Onshore Wind

		Units	Overnight Capital Cost (weighted)	Overnight Capital Cost (unweighted)	FOM
EIA 2022 (a,e,f)	200MW	2021$/kW	1718	1411	27.6
EIA 2023 (b)	200MW	2022$/kW	2098	1566	29.6
NREL 2023 (c)	Technology 1	2021$/kW		1363	29.57
S&P 2023 (d)		2021$/kW		1551	36.3

Note: before applying IRA

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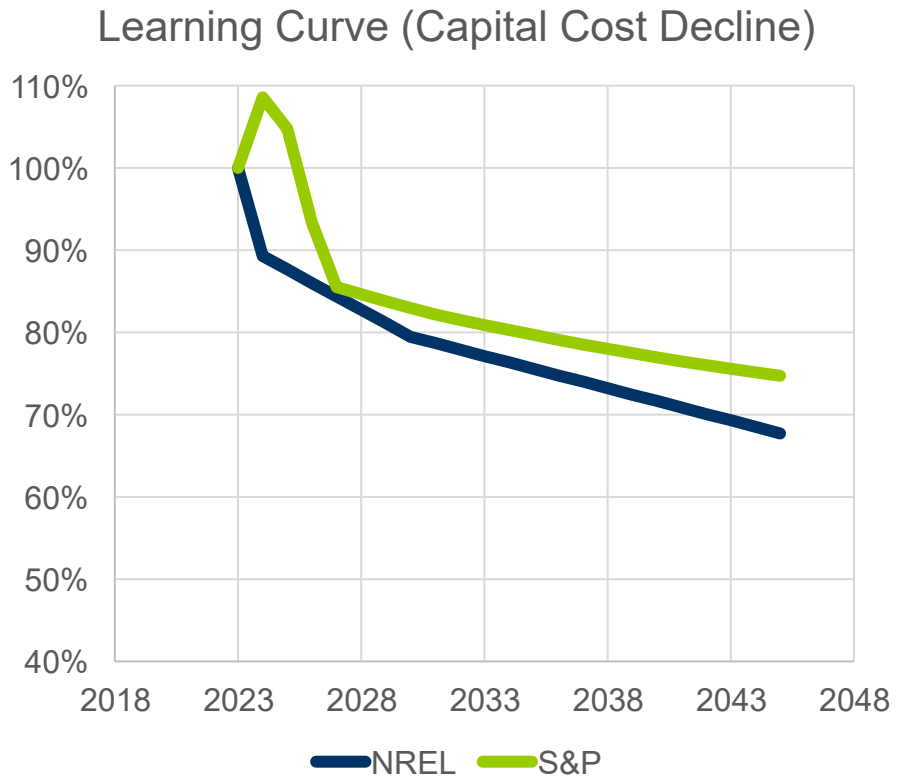

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- S&P and NREL also provide forecasts for FOM and efficiency improving over time

Offshore Wind

		Units	*Overnight Capital Cost (unweighted)*	*FOM*
EIA 2022 (a,e,f)	400MW	2021$/kW	6041	115.2
EIA 2023 (b)	400MW	2022$/kW	6672	123.8
NREL 2023 (c)	Class 5	2021$/kW	3456	108.1
S&P 2023 (d)		2021$/kW	4039	107.1

Note: before applying IRA

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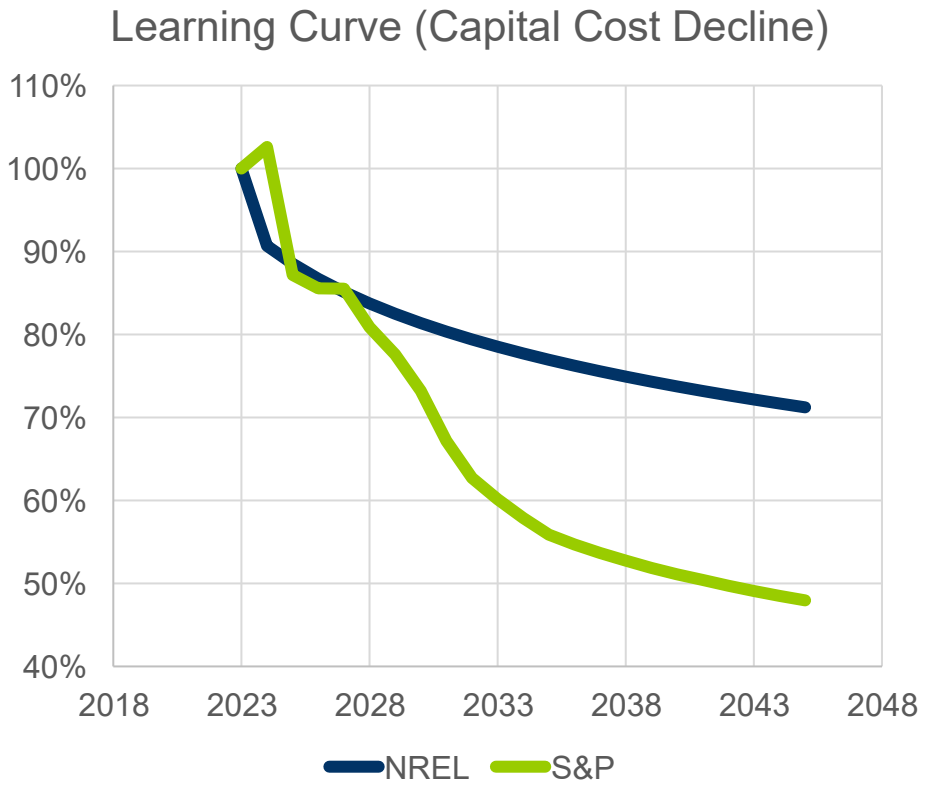

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- S&P and NREL also provide forecasts for FOM and efficiency improving over time

Battery Storage

		Units	*Overnight Capital Cost (unweighted)*	*FOM*
EIA 2022 (a,e)	50MW	2021$/kW	1316	26.0
EIA 2023 (b)	50MW	2022$/kW	1270	45.8
NREL 2023 (c)	60MW	2021$/kW	1716	42.9
S&P 2023 (d)		2022$/kW	1236	15.0
Quadrennial Review		$/kW	1638	66.0

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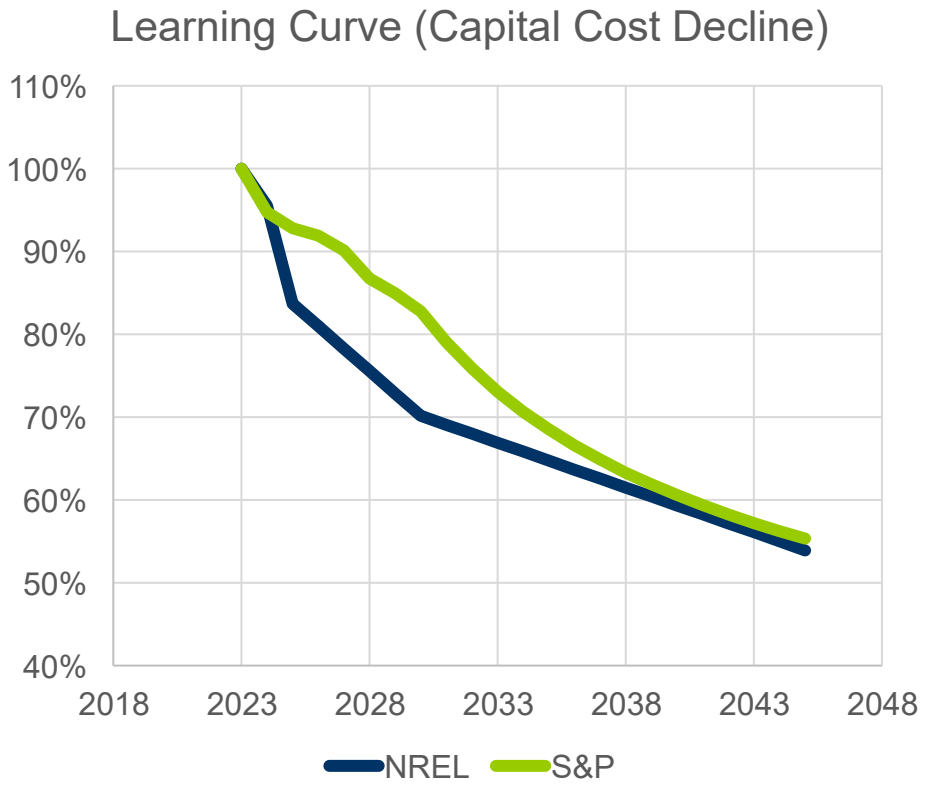
(b) Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2023 Tab 1

(c) Annual Technology Baseline 2023

(d) US Battery Storage Capital and Levelized Cost Outlook, Nov 2023

(e) Used for Energy Exemplar's Eastern Interconnection Dataset 2023

- PJM recommends using the Quadrennial Review



- S&P and NREL also provide forecasts for FOM improving over time

Solar/Battery Hybrid

		Units	*Overnight Capital Cost (unweighted)*	*FOM*
EIA 2022 (a,e,f)	150MW:50MW	2021$/kW	1748	33.7
EIA 2023 (b)	150MW:50MW	2022$/kW	1808	32.4
NREL 2023 (c)	130MW:50MW	2021$/kW	2769	59.6
S&P 2023 (d)	100MW:50MW	2021$/kW	1978	14.5

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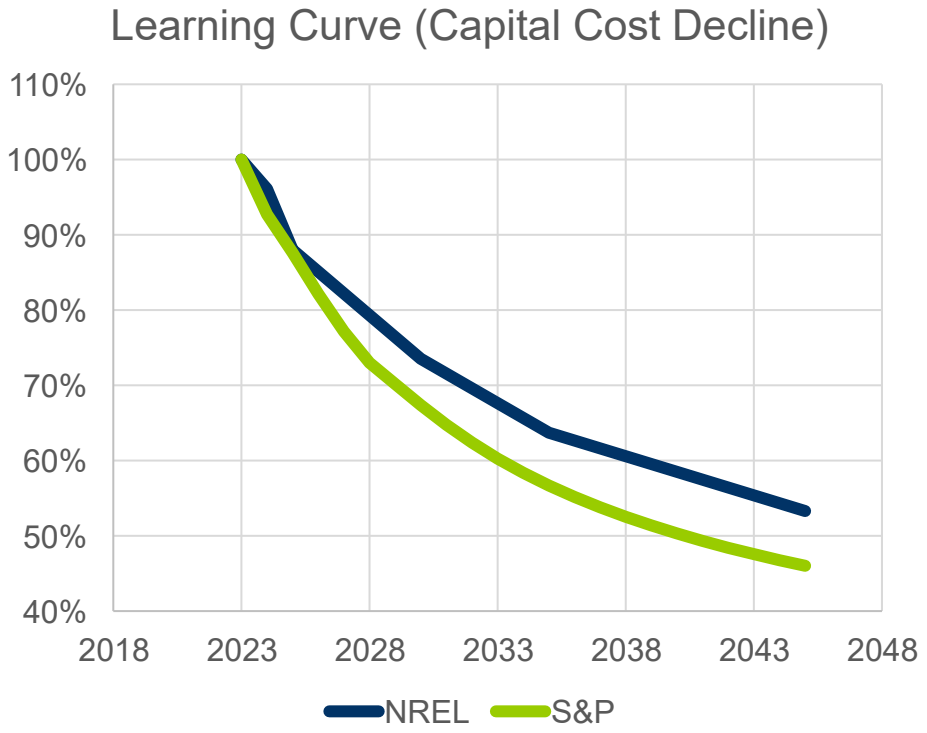


- S&P and NREL also provide forecasts for FOM and efficiency improving over time

Geographic Adjustment Coefficients

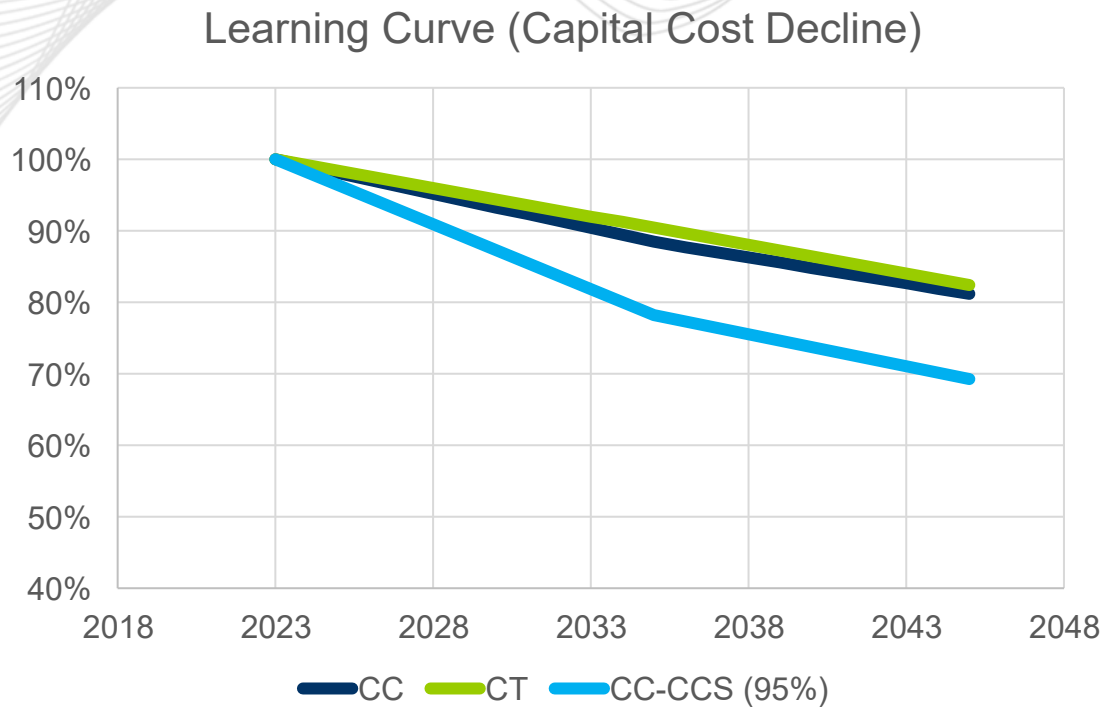
	Solar	*Onshore*	*Offshore*	*Battery*	*Hybrid*
Delaware	1.07	1.07	1.06	1.01	1.06
DC	1.01	1.03		1.01	1.01
Illinois	1.13	1.20	1.19	1.07	1.12
Indiana	1.00	1.02		1.02	1.00
Kentucky	1.00	1.01		1.02	1.01
Maryland	1.01	1.01	1.01	1.01	1.01
Michigan (Grand Rapids)	1.00	1.00	1.00	1.00	1.00
New Jersey	1.12	1.19	1.18	1.06	1.11
North Carolina	0.99	0.99	0.99	1.00	0.99
Ohio	0.99	0.98		0.99	0.99
Pennsylvania (Philadelphia)	1.11	1.18		1.06	1.10
Pennsylvania (Scranton)	1.02	1.03		1.01	1.02
Tennessee	1.00	1.02		1.04	1.01
Virginia (Alexandria)	1.00	1.02	1.02	1.01	1.01
Virginia (Roanoke)	0.99	0.98	0.98	1.00	0.99
West Virginia	1.01	1.00		1.00	1.01

Sargent & Lundy (2023) "Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies"

Combined Cycle and Combustion Turbines

	Overnight Capital Cost (2026$/kW)	*FOM (2026$/kW-yr)*
Combined Cycle		
EMAAC	1160	39.0
SWMAAC	1057	49.0
Rest of RTO	1104	47.0
WMAAC	1154	42.0
Combustion Turbine		
EMAAC	902	33.0
SWMAAC	846	44.0
Rest of RTO	882	45.0
WMAAC	906	39.0

Brattle (2022) "PJM CONE 2026/2027 Report" (Quadrennial Review)



NREL (2023) "Annual Technology Baseline"

- NREL also provide forecasts for FOM improving over time
- Based on NREL's ATB 2023, the overnight capital cost for combined cycle with 95% carbon capture and sequestration (CCS) is 1.96 times higher than without CCS in 2023, and the FOM is 1.91 times higher

Variable Costs

Variable Cost Components

	VOM (2026$/MWh)	Heat Rate (Btu/kWh)
Combined Cycle		
EMAAC	2.08	6365
SWMAAC	2.07	6383
Rest of RTO	2.12	6359
WMAAC	2.14	6368
Combustion Turbine		
EMAAC	1.19	9320
SWMAAC	1.18	9317
Rest of RTO	1.15	9304
WMAAC	1.22	9311

Heat rate for combined cycle is without duct firing

Brattle (2022) "PJM CONE 2026/2027 Report" (Quadrennial Review)

- NREL also provide forecasts for VOM and heat rate improving over time
- Based on NREL's Annual Technology Baseline 2023, the heat rate of combined cycle with 95% Carbon Capture and Sequestration (CCS) is 12% higher than without CCS, and the VOM is 2.2 times higher
- Henry Hub natural gas price from PJM's Market Efficiency

Financial Assumptions

Financial Assumptions

- Annualization coefficient for overnight capital cost (referred to as “effective charge rate” in Quadrennial Review)
    - Reflects after tax weighted average cost of capital (ATWACC), asset’s useful life, tax rates, depreciation, interest during construction

	Solar	*Onshore*	*Offshore*	*Battery*	*Hybrid*
EIA 2022 (a,e)	5.0%	5.9%	6.6%	4.3%	4.9%
NREL 2023 (b)	6.0%	6.5%	7.0%		6.0%
S&P 2023 (c,e)	7.1%	7.5%	8.1%	12.3%	7.5%
Quadrennial Review (d)				11.1%	

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(d) Brattle (2022) “PJM CONE 2026/2027 Report” (Quadrennial Review)

(e) PJM calculations

	Combined Cycle	*Combustion Turbine*
EMAAC	12.4%	11.7%
SWMAAC	12.2%	11.6%
Rest of RTO	12.3%	11.6%
WMAAC	12.3%	11.6%

Brattle (2022) “PJM CONE 2026/2027 Report” (Quadrennial Review)

- PJM’s modeling approach uses this coefficient to annualize capital costs in the capacity expansion model along with PJM’s Market Efficiency discount rate for time discounting

Renewable Capacity Factors

Renewable Capacity Factors

- Use Energy Exemplar's Eastern Interconnection hourly profiles for renewable capacity factors which are defined at the zonal level

- Possible consideration in the future of NREL data for more granular modeling

Contact

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Sources for Techno-Economic Inputs

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