NEW REPORT DEVELOPED FOR NDIC / NDTA / LEC:

Forecasting Resource Adequacy in Southwest Power Pool Through 2035

May 15, 2023

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Funded by the ND Enhance Preserve Protect Program

Objectives: Model Resource Adequacy and Cost Under Two Scenarios

Step 1: Develop Reasonable Accreditation Values for Wind and Solar

a. 2018-2022 hourly dataset
   i. Peak load availability.
   ii. Net peak load availability.

Step 2: Reference Scenario

- SPP/EIA planned additions (2.9 GW Gas, 1.4 GW Wind, 740 MW Solar, 60 MW Battery Storage) and retirements (2.9 GW Coal, 2.4 GW Gas, 40 MW Other) by 2035.
- Replace rest with modeled wind (15.7 GW), solar (23.2 GW), and four-hour storage (9.8 GW)
- Peak load and net load.

Step 3: Ozone Transport Rule (OTR) and Coal Combustion Residual (CCR) Scenario

- Loss of 22 GW of coal and 6.3 GW of gas by 2035.
- Replace with natural gas (2.9 GW), wind (69.7 GW), solar (101.7 GW), and four-hour storage (29.9 GW).
- Peak load and net load.

Why Do We Care About SPP Resource Adequacy?

- SPP experienced rolling blackouts during Winter Storm Uri due to natural gas supply disruptions and low wind output.
- Planned retirements and additions show a continued decline in thermal generation and an increase in weather-dependent renewables.
- Given these trends, there is critical need to assess short term reliability risks to the SPP region.

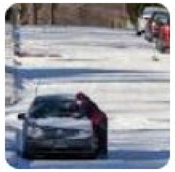
14 states face rolling blackouts amid massive winter storms after a major power operator declared an energy emergency

Kelly McLaughlin Feb 15, 2021, 3:23 PM

A highway on Monday in Hou

The Topeka Capital-Journal

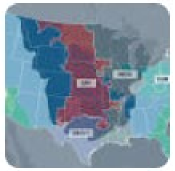
Year after rolling blackouts, Kansas lawmakers want to prevent repeat



Legislators want to ensure Kansas can deal with another dose of extreme winter weather, like a historic cold front that slammed the state...

KGOU

Southwest Power Pool Addresses Problems From February Winter Storm



The Southwest Power Pool, responsible for the electrical grid in Oklahoma and several other states, released a report addressing the power...

Jul 29, 2021

Disappearance of Wind and Natural Gas Fuel Supply Issues Led to Load Shedding During Winter Storm Uri

- Wind turbines suffered from icing, taking much of the SPP wind fleet offline for multiple days.
- Natural gas fuel supply issues led to significant outages.
- Coal outages remained relatively constant during the storm.

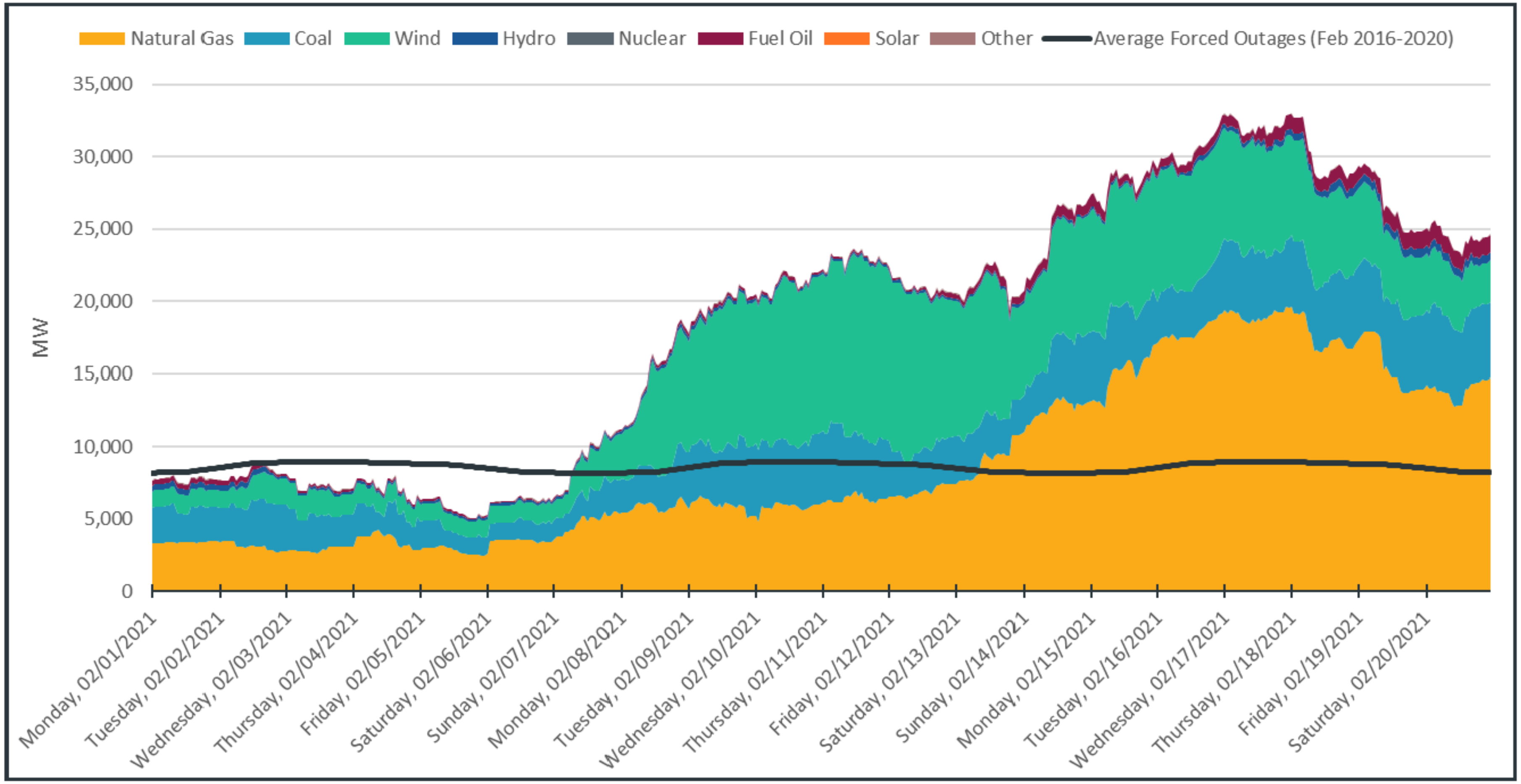


Figure 16: Forced generation outages as submitted in CROW by Fuel Type

Falling Reserve Margins

- In 2022 SPP expected to see its reserve margin fall from 22 percent to 13.6 percent by planning year 2027, approaching the then-planning reserve margin of 12 percent.
- SPP has since updated its planning reserve margin to 15 percent.

Figure 2: SPP BA Area Planning Reserve Margin Summary

Wind and Solar ELCC Methodology Reversed At FERC

- SPP had planned to base wind and solar accreditation on their effective load carrying capacities (ELCC).
- After initially being approved by FERC, the Commission reversed its decision arguing all generators should be required to undergo an ELCC analysis, not just wind and solar.
- FERC Commissioners also disagreed on whether SPP had failed to define seasonal net peak load.
- This leaves the accreditation of wind and solar in limbo as SPP continues to go through the FERC rehearing process.

FERC reverses its approval of SPP's capacity accreditation plan for wind, solar resources

Published March 7, 2023

Ethan Howland
Senior Reporter

Laurent Fady via Getty Images

SPP's 2022 Capacity Accreditation

- SPP's 2022 UCAP mix was:
  - 46.3 percent natural gas
  - 35 percent coal
  - 7 percent wind
  - 5.4 percent hydro
  - 3 percent nuclear
  - 2.6 percent petroleum
  - 0.3 percent other
  - 0.2 percent solar

- This mix will change rapidly moving forward based on planned retirements and Environmental Protection Agency (EPA) regulations.

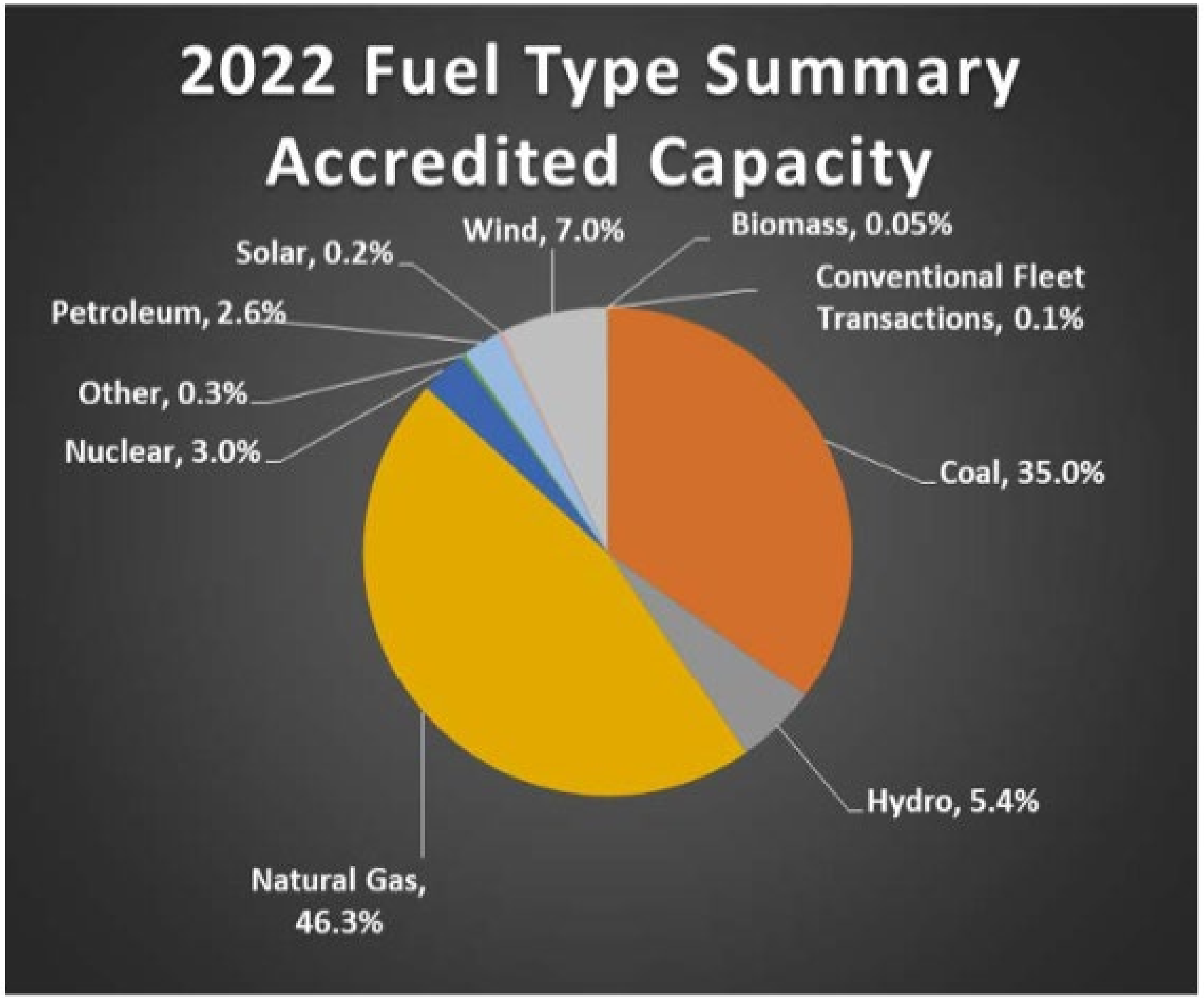
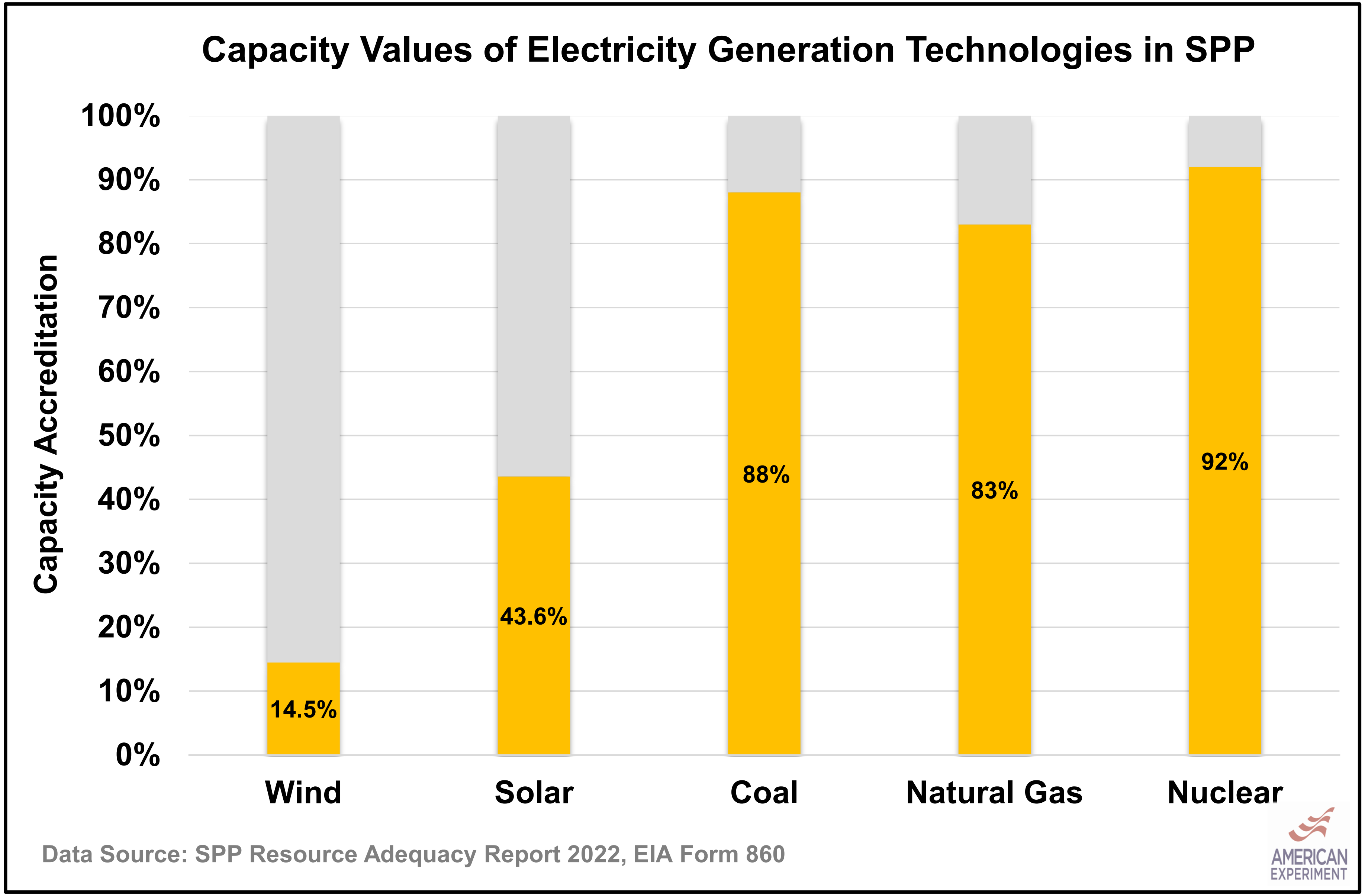


Figure 7: 2022 Summer Season Fuel Type Summary

SPP's 2022 Capacity Accreditation by Resource

- Technologies are given different accreditation values based on their reliability during times of peak electricity demand.
- Nuclear, coal, and natural gas get the highest accreditation values.
- Wind and solar get much lower accreditation values.



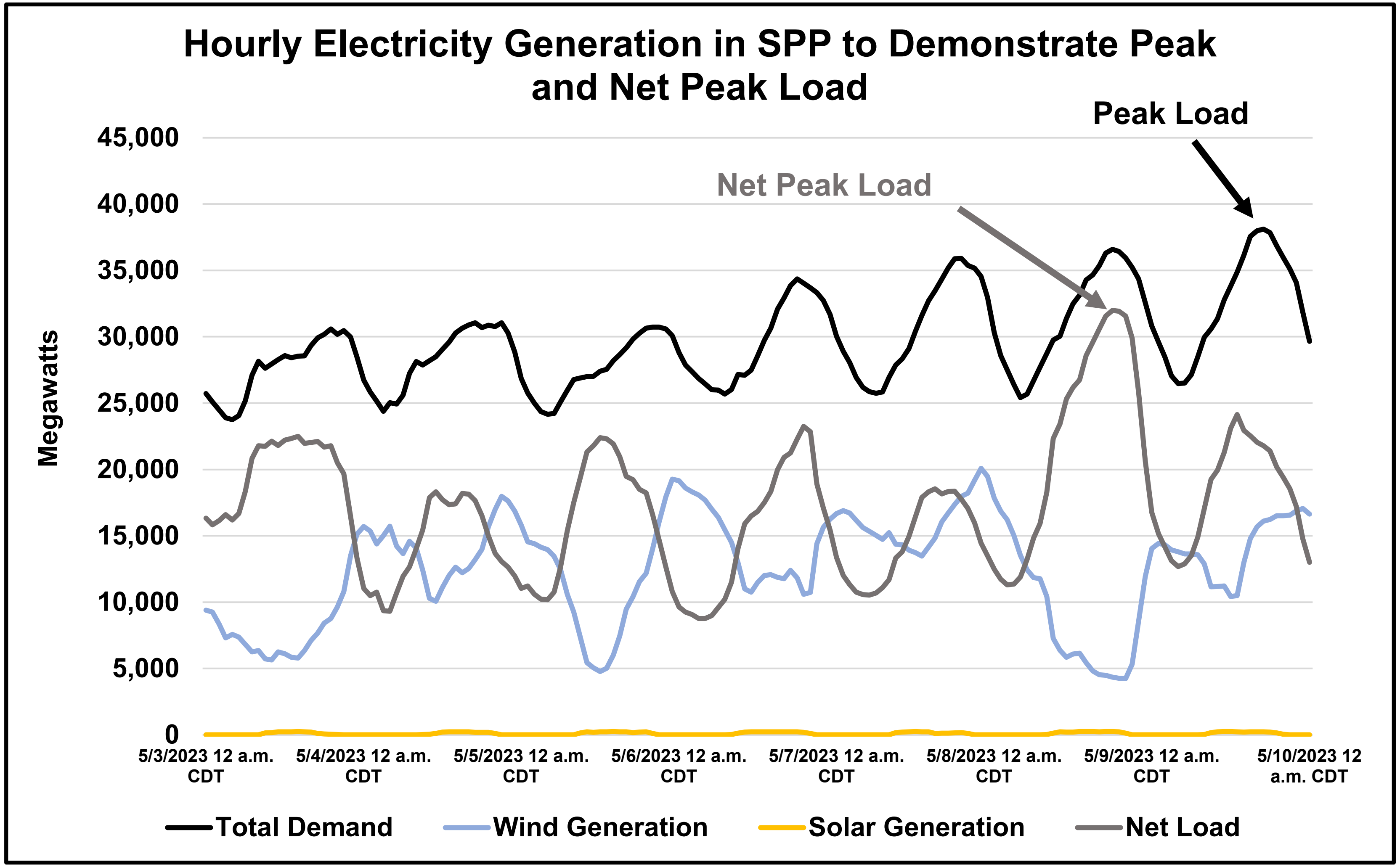
“Phantom Firm” Resources Could be Overstating Wind and Solar Contributions

- The previous slides may ***overstate*** the amount of accredited capacity on the system due to SPP’s prior capacity accreditation method for wind and solar.
- Wind was assumed to produce 14.5 percent of potential output during peak hours and new solar was expected to produce 43.6 causing “Phantom Firm” resources to potentially be counted as accredited capacity.
- SPP may be moving toward seasonal ELCC accreditation to more accurately accredit wind and solar, but this may or may not solve the problem because ELCC is based on the marginal ability to serve load with an existing thermal fleet.
- We need a standard that treats each resource type as an independent variable to model resources adequacy as more thermal plants retire and the grid becomes increasingly reliant upon wind, solar, and battery storage.

Methodology- Developing a Standardized Capacity Accreditation for Renewable Resources

Assess wind and solar variability during peak load and net peak load hours

- **Peak Load:** The hours with the highest electricity demand.
- **Net peak load:** Gross demand minus wind and solar generation, which allows us to assess the highest demand hours where wind and solar output is the lowest. This is the standard new wind and solar resources should be judged by going forward.



Methodology- Developing a Standardized Capacity Accreditation for Renewable Resources

- Used the last 4 years of data from EIA Hourly Grid Monitor and Form 923. Peak and net peak occurred on July 19, 2022, and August 6, 2019, respectively.
- Highest Certainty Deliverability (HCD) to assess wind and solar accreditation.
  - Sample size of 2,000 hours for wind & solar of the highest peak & net peak hours across 4 years.
  - Took the mean of the lowest 25 percent of wind and solar output during those hours to come up with our accredited capacity values for peak and net peak.
- Using this methodology, we developed peak capacity and net peak capacity values for wind and solar.

	Peak Accreditation	Net Peak Accreditation
Wind	11.8%	7.5%
Solar	16.4%	20.4%

Comparing Highest Certainty Deliverability (HCD) Approach to the New Seasonal ELCC Approach SPP is Considering

- SPP is making well-intended (but potentially insufficient) changes to the accreditation process as they try to account for weather-dependent renewable penetration.
- They are attempting to switch to a seasonal ELCC accreditation model. However, ELCC is based on the marginal ability to serve peak load based on existing thermal resources. This means the ability of wind and solar to serve load is dependent on the thermal fleet on the system.
- We need a metric that measures the *absolute* ability of wind and solar to serve load independent of the other resources on the grid, which leads us to our HCD methodology.
- HCD examines wind & solar accreditation values for peak & net-peak hours to provide consistent, year-round metrics for availability & reserve margins & provides a basis for a realistic (apples-to-apples) comparison of renewable & thermal performance.
    - Net peak HCD values measure the marginal ability of wind and solar to meet net peak demand based on existing wind and solar on the grid.
    - Peak HCD values measure the ability of wind and solar to meet peak demand regardless of existing capacity.

Methodology- Developing a Standardized Capacity Accreditation for Wind

SPP ELCC

Table 10. Incremental Average ELCC for Wind

Wind Tier	Incremental Tier Method	Nameplate Wind of Tier (MW)	Incremental average ELCC MWs for each Tier (MW)	Tier ELCC percentage (%)
Tier 1	Difference in Wind Base Case and Wind Change Case A	Summer = 13,211 Winter = 11,745	Summer = 2,952 Winter = 2,949	Summer = 22% Winter = 25%
Tier 2	Difference in Wind Change Case A and Wind Change Case B	Summer = 2,808 Winter = 4,274	Summer = 404 Winter = 654	Summer = 14% Winter = 15%
Tier 3	Difference in Wind Change Case B and Wind Change Case C	Summer = 16,448 Winter = 16,448	Summer = 1,978 Winter = 2,083	Summer = 12% Winter = 13%

HCD

Highest Certainty Deliverability	Peak Accreditation	Net Peak Accreditation
Wind	11.8%	7.5%
Solar	16.4%	20.4%
Reserve Margin	15.0%	15.0%

- SPP states that the thresholds for Tier 1 resources are measured using the individual LRE's actual average seasonal net peak load from the previous three years.
- However, this issue is still pending because FERC has asked for additional clarification for how Tiers are determined and how capacity values are calculated.

Methodology- Developing a Standardized Capacity Accreditation for Solar

SPP ELCC

Table 13. Incremental Average ELCC for Solar				
Solar Tier	Incremental Tier Method	Nameplate wind of Tier (MW)	Incremental average ELCC MWs for each Tier (MW)	Tier ELCC percentage (%)
Tier 1	Difference in the solar base case and solar Change case A	Summer = 235 Winter = 235	Summer = 181 Winter = 87	Summer = 77% Winter = 37%
Tier 2	Difference in solar Change case A and wind Change case B	N/A	N/A	N/A
Tier 3	Difference in wind Change case B and wind Change case C	Summer = 327 Winter = 327	Summer = 202 Winter = 86	Summer = 62% Winter = 26%

HCD

Highest Certainty Deliverability	Peak Accreditation	Net Peak Accreditation
Wind	11.8%	7.5%
Solar	16.4%	20.4%
Reserve Margin	15.0%	15.0%

- SPP states that the thresholds for Tier 1 resources are measured using the individual LRE's actual average seasonal net peak load from the previous three years.
- However, this issue is still pending because FERC has asked for additional clarification for how Tiers are determined and how capacity values are calculated.

How does the ND Study's HCD Approach Differ from SPP's Proposed New Seasonal ELCC Approach?

- HCD peak accreditation values for wind and solar are consistent with SPP's ELCC values (summer and winter for wind, winter for solar).
- HCD net peak accreditation values for wind and solar are lower than SPP's ELCC values.

HCD approach is valuable for a few reasons:

- As more wind & solar are added to the grid, net peak will become more challenging than peak load demand.
- HCD manages the downside of wind & solar at net peak compared to ELCC and is more empirical than the options MISO is considering as they move away from ELCC to a Direct-LOL accreditation approach.

SPP APPROACH

Table 1. Summer Wind ELCC Tier Result

2022 Allocated ELCC Summer Wind by Tier (MW)			
	TIER 1	TIER 2	TIER 3
Tier ELCC (MW)	2,952	404	1,978
Tier Nameplate (MW)	13,211	2,808	16,448
Tier ELCC (%)	22%	14%	12%

Table 2. Winter Wind ELCC Tier Result

2022 Allocated ELCC Winter Wind by Tier (MW)			
	TIER 1	TIER 2	TIER 3
Tier ELCC (MW)	2,949	654	2,083
Tier Nameplate (MW)	11,745	4,274	16,448
Tier ELCC (%)	25%	15%	13%

Table 3. Summer Solar ELCC Tier Result

2022 Summer ELCC Solar			
	TIER 1	TIER 2	TIER 3
Tier ELCC (MW)	181	0	202
Tier Nameplate (MW)	235	0	327
Tier ELCC (%)	77%	0%	62%

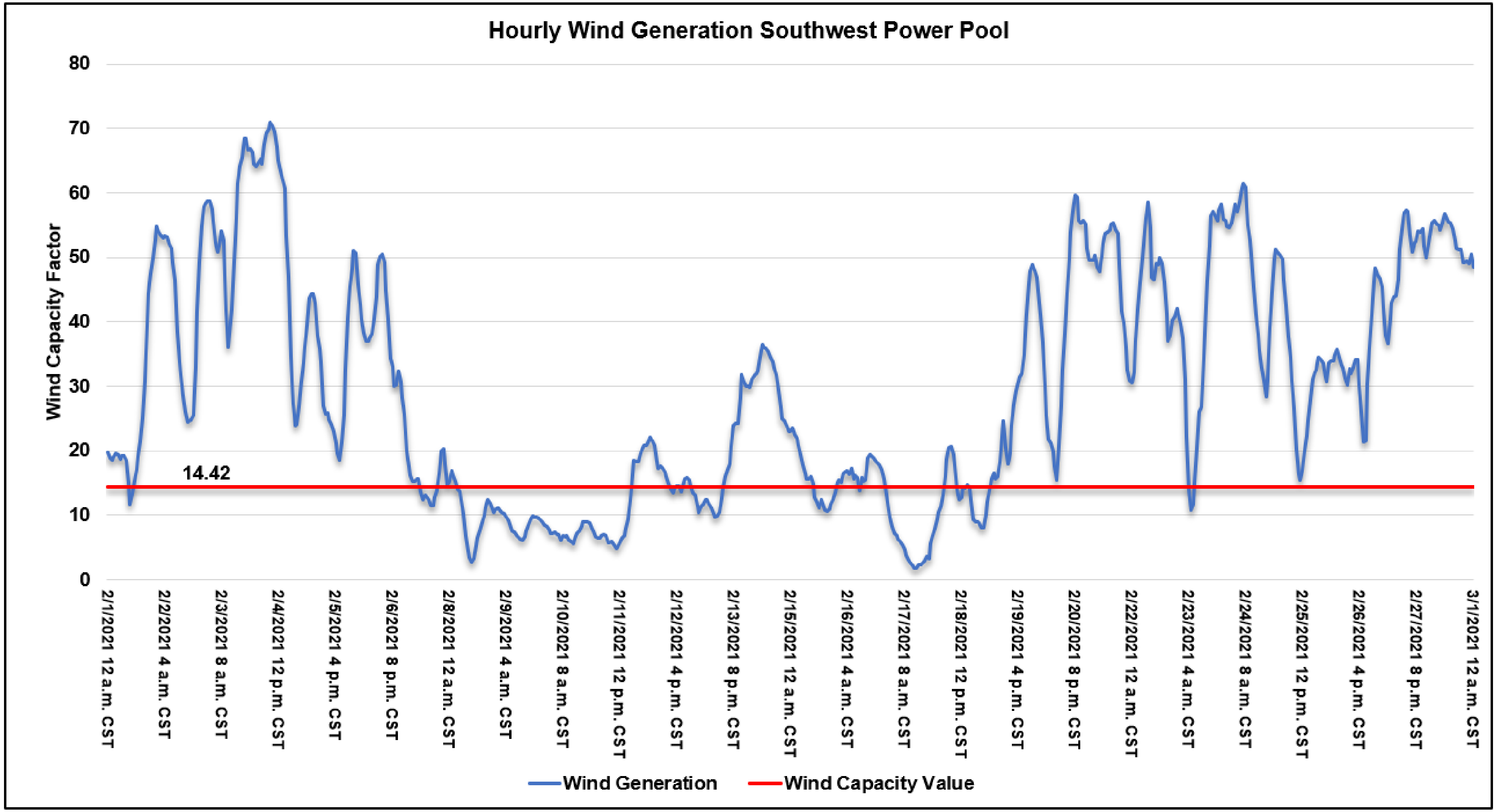
Table 4. Winter Solar ELCC Tier Result

2022 ELCC Winter Solar			
	TIER 1	TIER 2	TIER 3
Tier ELCC (MW)	87	0	86
Tier Nameplate (MW)	235	0	327
Tier ELCC (%)	37%	0%	26%

HCD ALTERNATIVE APPROACH

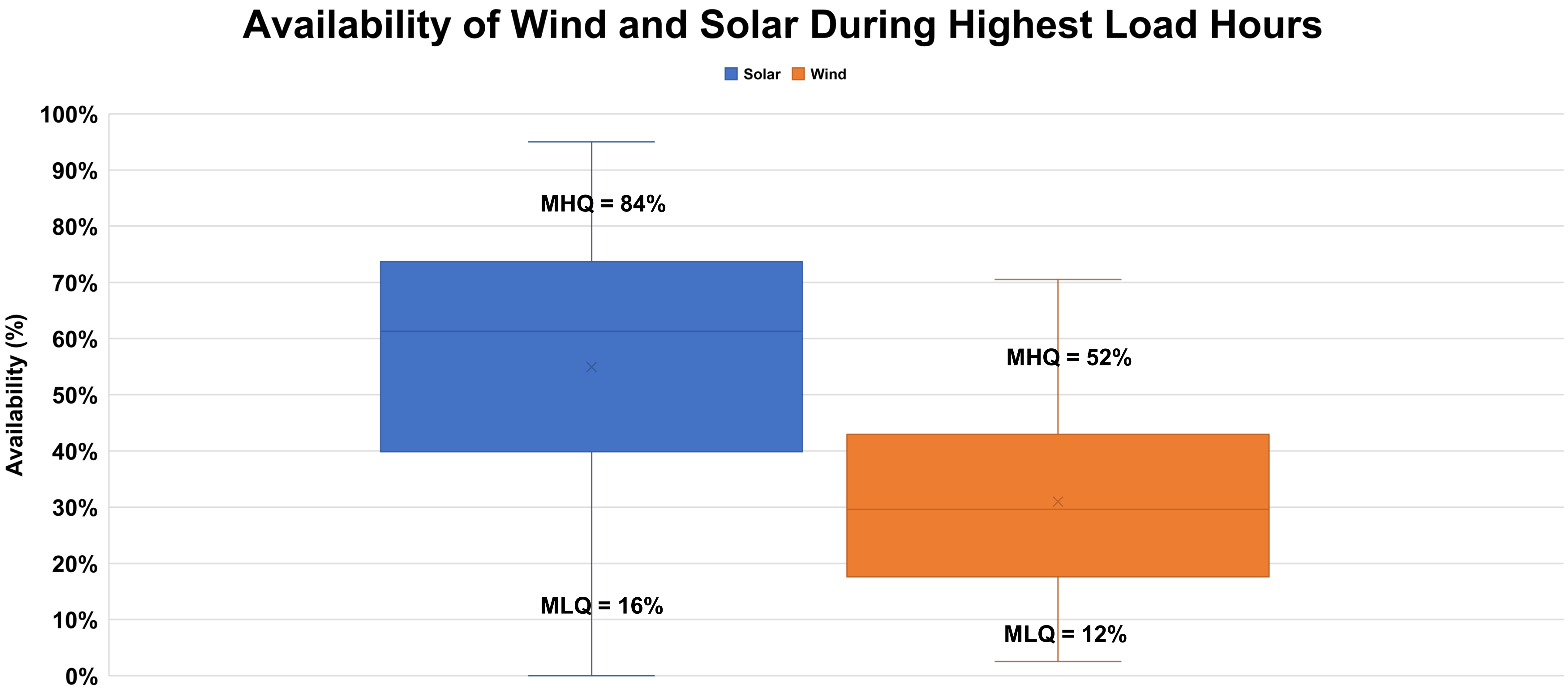
Highest Certainty Deliverability	Peak Accreditation	Net Peak Accreditation
Wind	11.8%	7.5%
Solar	16.4%	20.4%
Reserve Margin	12.0%	12.0%

SPP Wind Capacity Factors During Winter Storm Uri

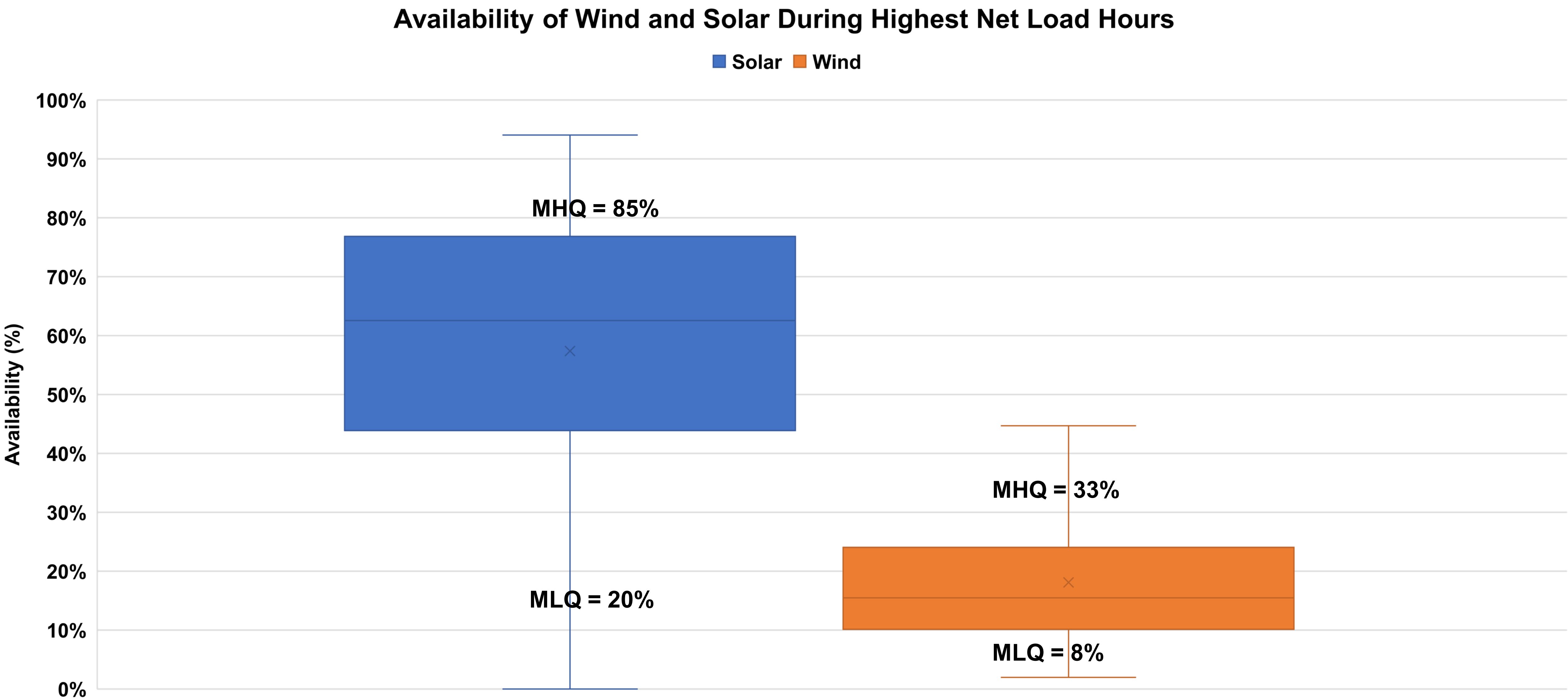


- On several occasions during Storm Uri, SPP wind capacity factors fell below expected values based on SPP’s then-14.4 percent capacity accreditation. SPP’s high winter value for wind capacity accreditation has the potential of masking capacity shortfalls on the system.

Peak Load Availability Hours Wind and Solar



Net Peak Load Availability Hours Wind and Solar



Methodology- Capacity Additions and Retirements

Assessment of resource adequacy to 2035.

- Assumed both planned retirements per EIA data and hypothetical retirements under proposed EPA rules. Did not assume additional premature retirements or CCUS additions under the new regime of expanded and extended federal subsidies.
- Capacity additions of wind and solar would come online in proportion to coal and gas retirements to maintain SPP's reserve margin. (Ex: if 15 percent of retirements occur in 2025, 15 percent of new additions come online in that year).
- Coal capacity retirements in the reference scenario occur from 2023 to 2037.
- Coal capacity retirements in the OTR+CCR scenario occur from 2023 to 2029.
- The replacement resource mix (the mix of wind, solar, and battery storage added to replace retiring coal and natural gas power plants) is optimized for cost.
    - The model selected the amount of wind and solar additions based on the retirements of coal and natural gas and the need to build capacity to meet SPP's reserve margin.
    - The ratio of wind and solar (40/60) was determined by the least cost of serving load to consumers through 2035.
    - More solar was chosen due to its higher capacity accreditation.
    - This is in line with SPP's interconnection que, where 42 percent of requests are for solar facilities.

Methodology- Cost

Assessment of the retail cost of replacing existing coal and natural gas resources with planned natural gas, wind, solar, and battery storage capacity.

- SPP Interconnect queue data were used to input 2.9 GW of new natural gas to replace retiring coal and gas facilities.
- Wind, solar, and 4-hour battery storage capacities were determined based on a cost-optimized model.

Assumptions include:

- Capital costs based on weighted average of SPP regions in EIA's Assumptions to the Electricity Market Module.
- Rate of return assumption of 9.88 percent with debt/equity split of 47.06/52.94 based on the rate of return and debt/equity split of the six-largest investor-owned utilities in SPP.
- Property tax costs of 1.3 percent of the rate base.
- Transmission costs in accordance with NREL's estimates for achieving 80 percent wind and solar and average cost of active projects at the point of interconnect, which is about $48,000 per MW of wind and solar installed.
- New natural gas fuel cost of $4.49 per MMBtu.

Capital Costs:
https://www.eia.gov/outlooks/aeo/assumptions/pdf/electricity.pdf

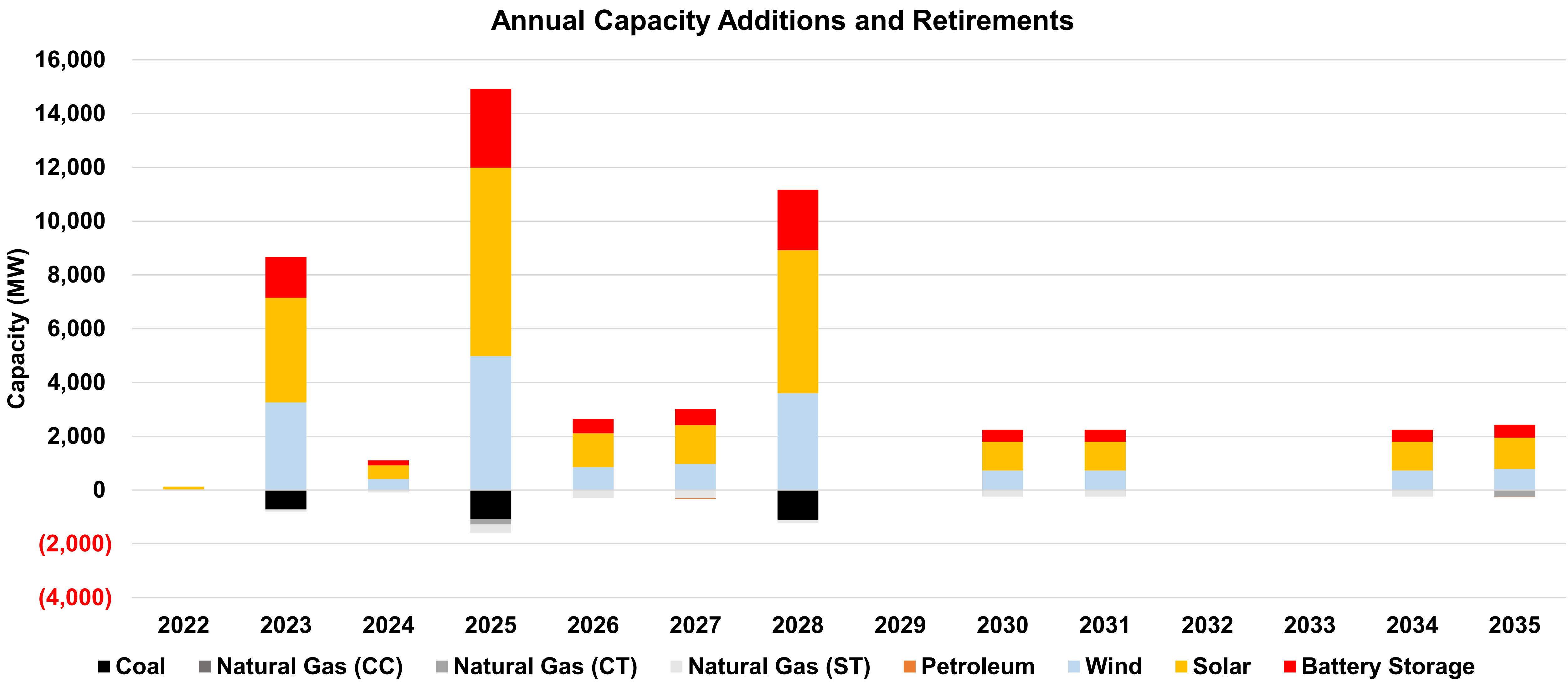
Reference Scenario: Retirements

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Coal	0	(721)	0	(1,080)	0	0	(1,116)	0	0	0	0	0	0	0	(2,917)
Natural Gas (CC)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas (CT)	0	0	0	(204)	0	0	0	0	0	0	0	0	0	(258)	(462)
Natural Gas (ST)	0	(84)	(90)	(315)	(291)	(304)	(114)	0	(248)	(248)	0	0	(248)	0	(1,941)
Petroleum	0	0	0	0	0	(28)	0	0	0	0	0	0	0	(10)	(38)

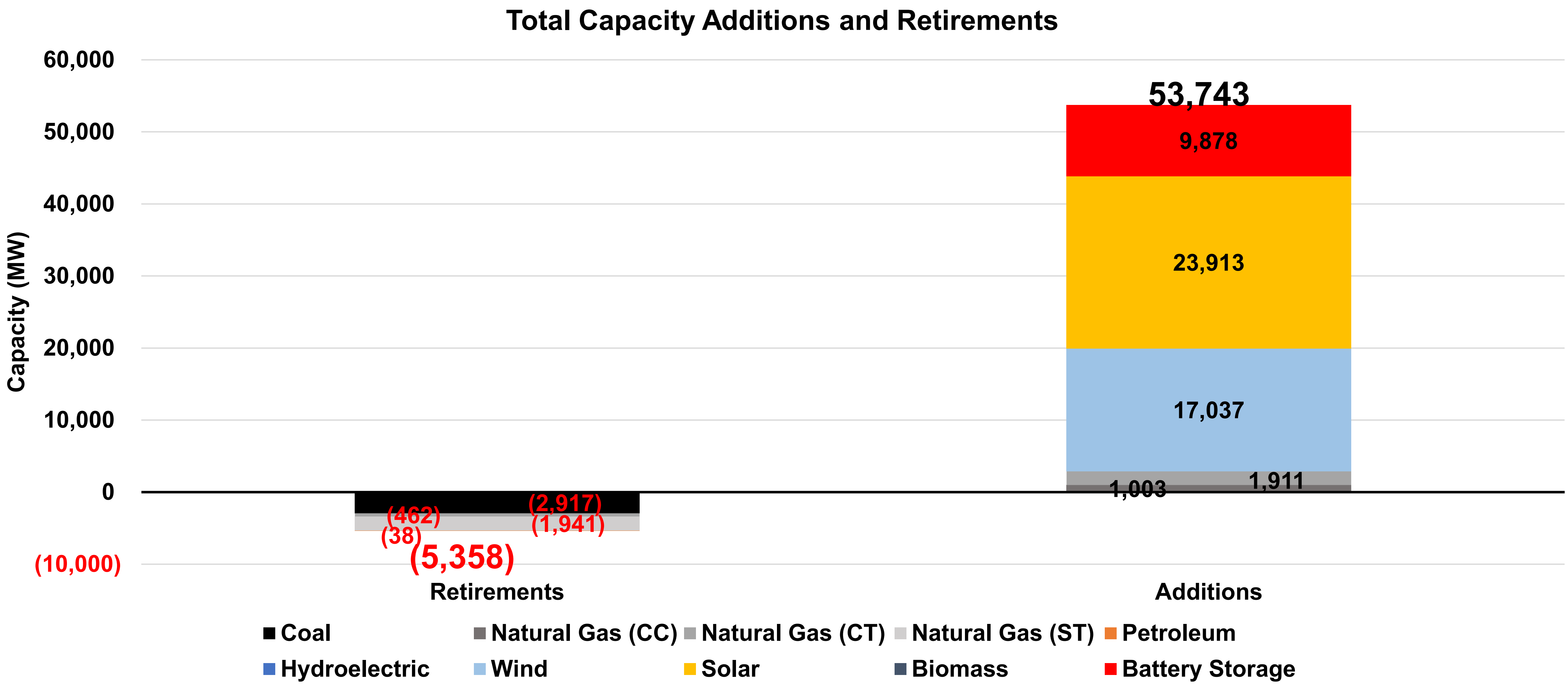
Reference Scenario: Additions

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas (CC)	0.0	0.0	0.0	0.0	1,003.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,003.0
Natural Gas (CT)	44.2	857.6	759.0	250.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,910.7
Natural Gas (ST)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petroleum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind	0.0	3,260.2	414.3	4,982.4	852.0	971.7	3,598.8	0.0	724.4	724.4	0.0	0.0	724.4	784.4	17,037.0
Solar	128.0	3,891.9	504.8	7,004.6	1,259.1	1,436.0	5,318.4	0.0	1,070.5	1,070.5	0.0	0.0	1,070.5	1,159.2	23,913.5
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Battery Storage	0.0	1,515.1	184.9	2,931.6	533.4	608.4	2,253.2	0.0	453.5	453.5	0.0	0.0	453.5	491.1	9,878.4

Reference Scenario: Retirements and Additions



Reference Scenario: Retirements and Additions



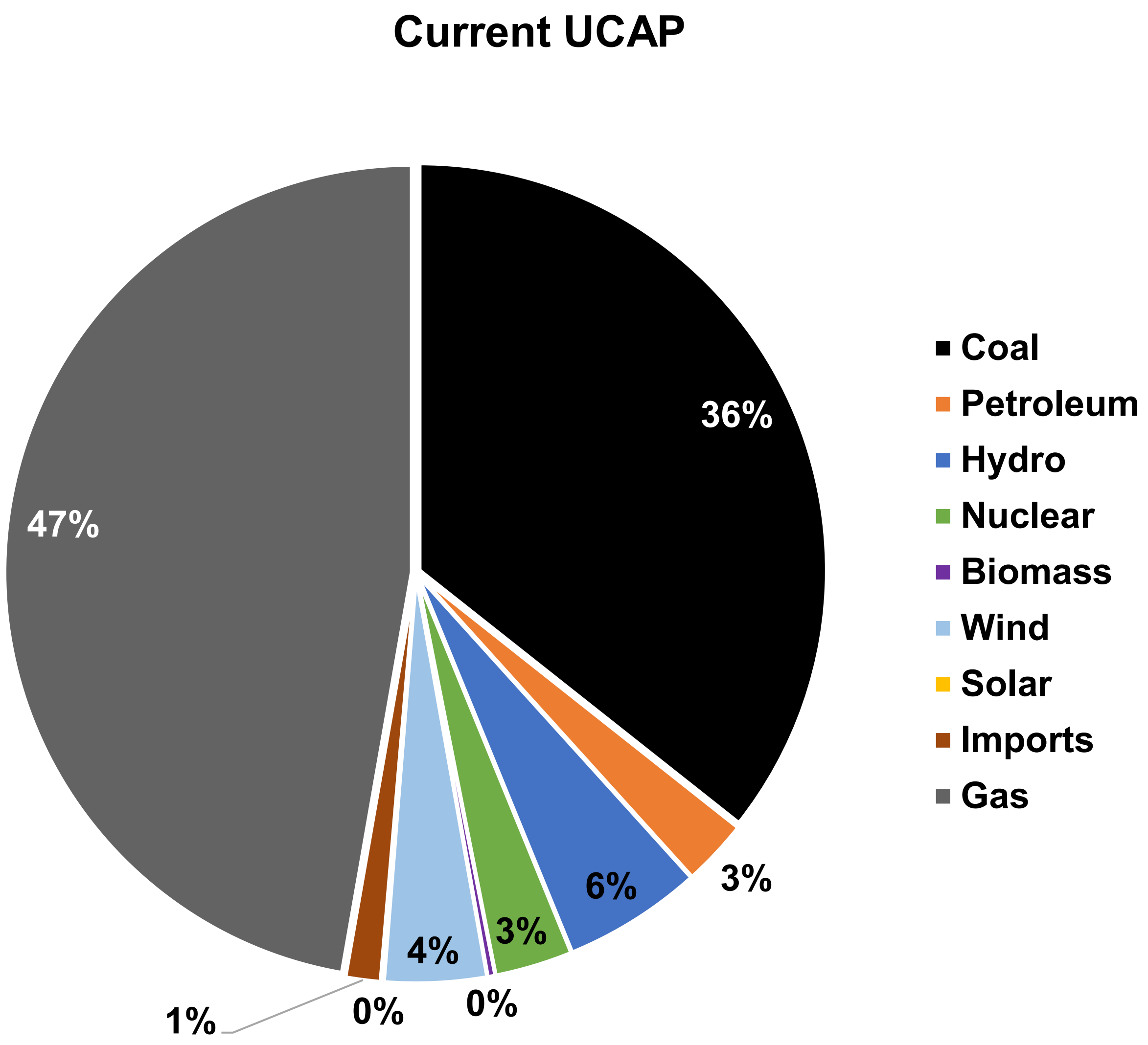
Reference Scenario: Annual ICAP Mix (MW)

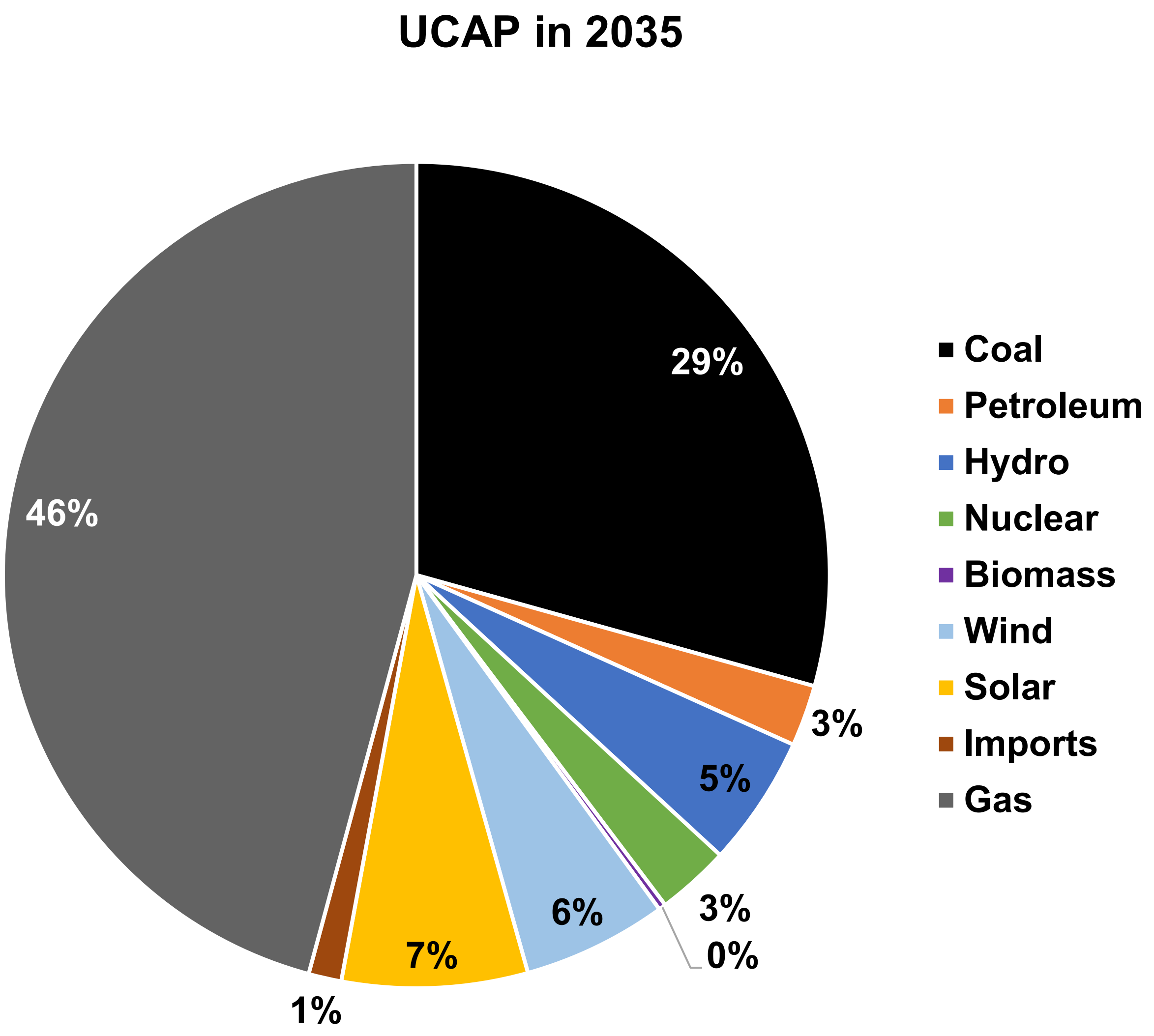
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	
Coal	25,628	24,907	24,907	23,827	23,827	23,827	22,711	22,711	22,711	22,711	22,711	22,711	22,711	22,711	15%
Natural Gas (CC)	11,697	11,697	11,697	12,777	13,780	13,780	13,780	13,780	13,780	13,780	13,780	13,780	13,780	13,780	9%
Natural Gas (CT)	11,732	12,589	13,348	13,394	13,394	13,394	13,394	13,394	13,394	13,394	13,394	13,394	13,394	13,136	9%
Natural Gas (ST)	12,679	12,595	12,505	12,190	11,899	11,595	11,481	11,481	11,234	10,986	10,986	10,986	10,739	10,739	7%
Petroleum	1,687	1,687	1,687	1,687	1,687	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,649	1%
Hydroelectric	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	4%
Existing Nuclear	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	1%
Onshore Wind	33,987	37,247	37,662	42,644	43,496	44,468	48,066	48,066	48,791	49,515	49,515	49,515	50,240	51,024	33%
Utility Solar	444	4,336	4,841	11,846	13,105	14,541	19,859	19,859	20,930	22,000	22,000	22,000	23,071	24,230	14%
Biomass	211	211	211	211	211	211	211	211	211	211	211	211	211	211	0%
Storage	0	1,515	1,700	4,632	5,165	5,773	8,027	8,027	8,480	8,934	8,934	8,934	9,387	9,878	6%
Total	106,819	115,539	117,312	131,961	135,317	138,001	147,942	147,942	149,943	151,944	151,944	151,944	153,945	156,112	

Reference Scenario: Annual UCAP Mix (MW)

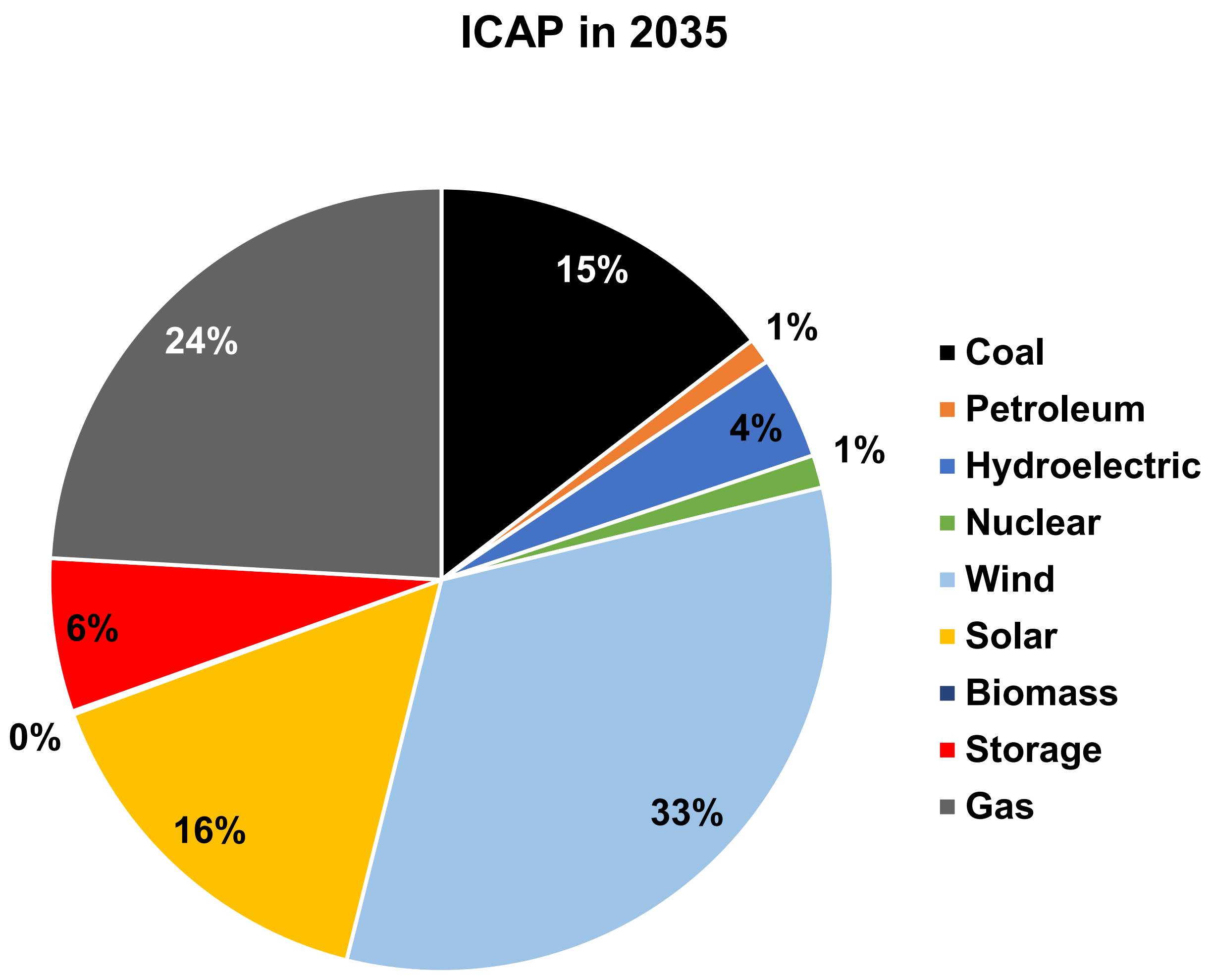
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	
Coal	22,540	22,540	21,906	21,906	20,956	20,956	20,956	19,974	19,974	19,974	19,974	19,974	19,974	19,974	19,974	29%
Natural Gas (CC)	9,688	9,688	9,688	9,688	10,582	11,413	11,413	11,413	11,413	11,413	11,413	11,413	11,413	11,413	11,413	17%
Natural Gas (CT)	9,680	9,716	10,427	11,055	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093	10,879	16%
Natural Gas (ST)	10,501	10,501	10,432	10,357	10,096	9,855	9,603	9,509	9,509	9,304	9,099	9,099	9,099	8,894	8,894	13%
Petroleum	1,671	1,671	1,671	1,671	1,671	1,671	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,633	2%
Hydro	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	5%
Nuclear	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	3%
Biomass	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	0%
Wind	2,563	2,563	2,809	2,840	3,216	3,280	3,354	3,625	3,625	3,680	3,734	3,734	3,734	3,789	3,848	6%
Solar	65	91	885	988	2,418	2,675	2,968	4,054	4,054	4,273	4,491	4,491	4,491	4,710	4,946	7%
Imports	876	876	876	876	876	876	876	876	876	876	876	876	876	876	876	1%
Total UCAP	63,212	63,275	64,322	65,010	66,537	67,448	67,535	67,817	67,817	67,885	67,953	67,953	67,953	68,021	68,093	

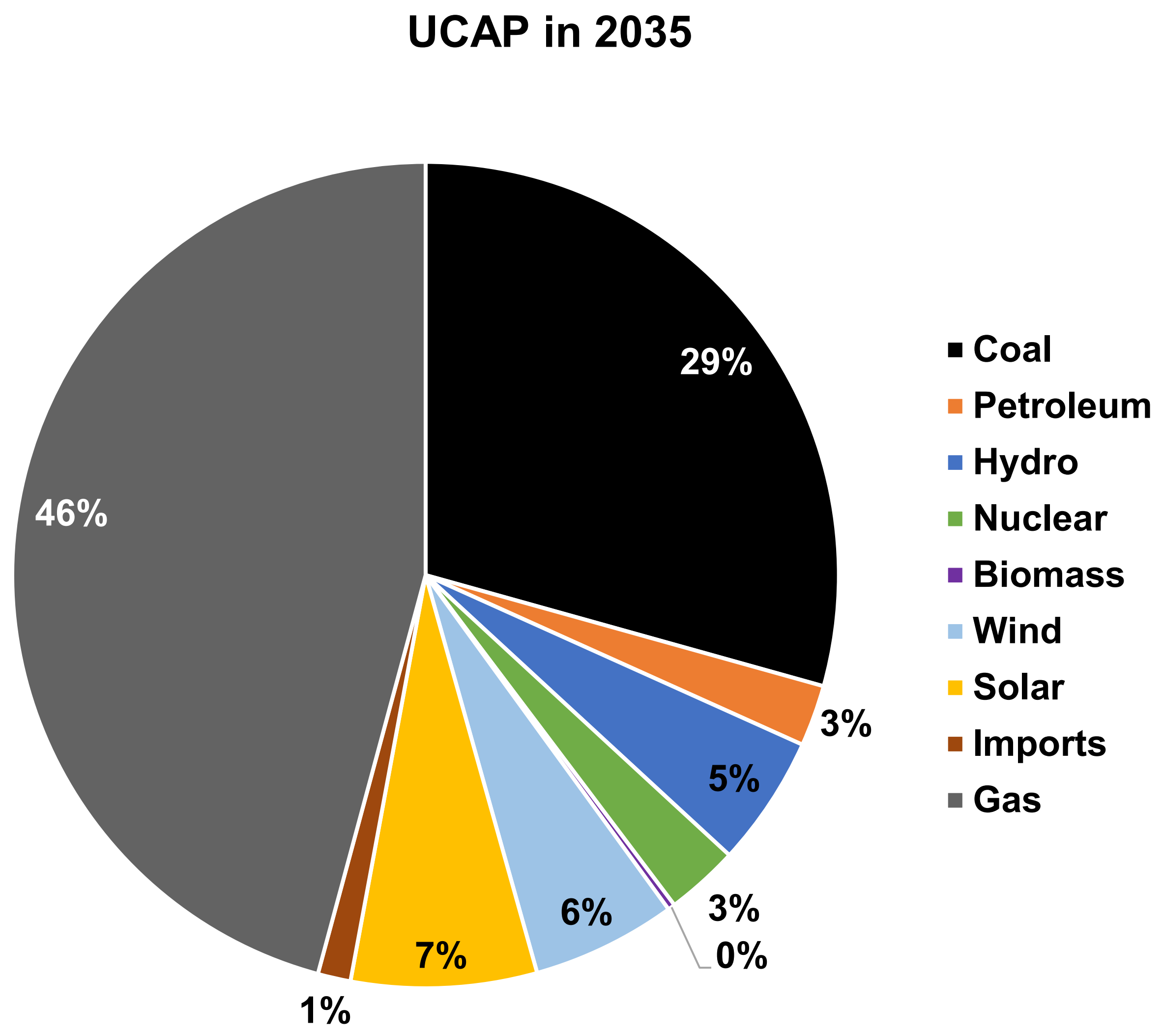
Reference Scenario: Current UCAP Mix vs. 2035



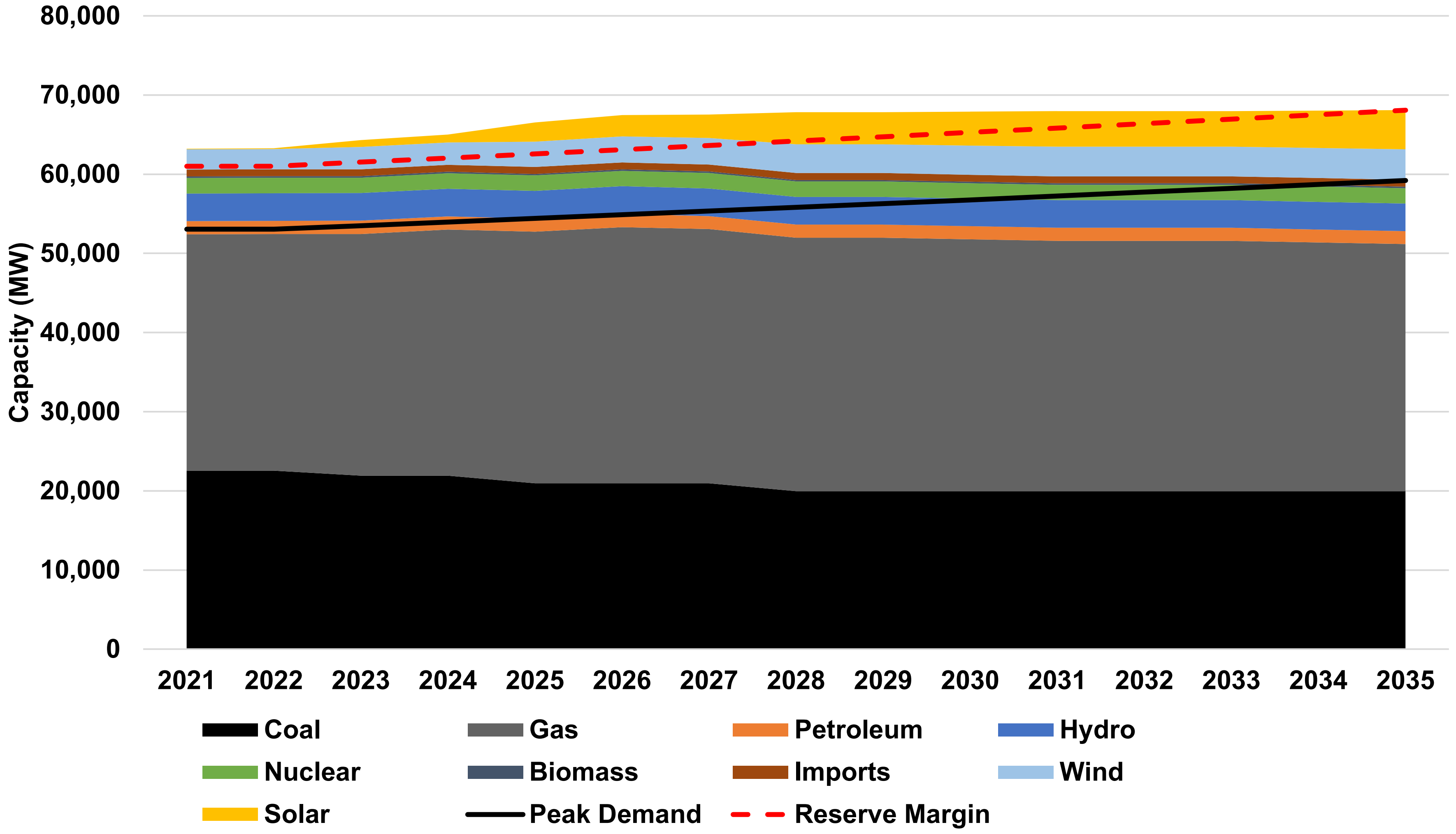


Reference Scenario: 2035 ICAP vs. UCAP





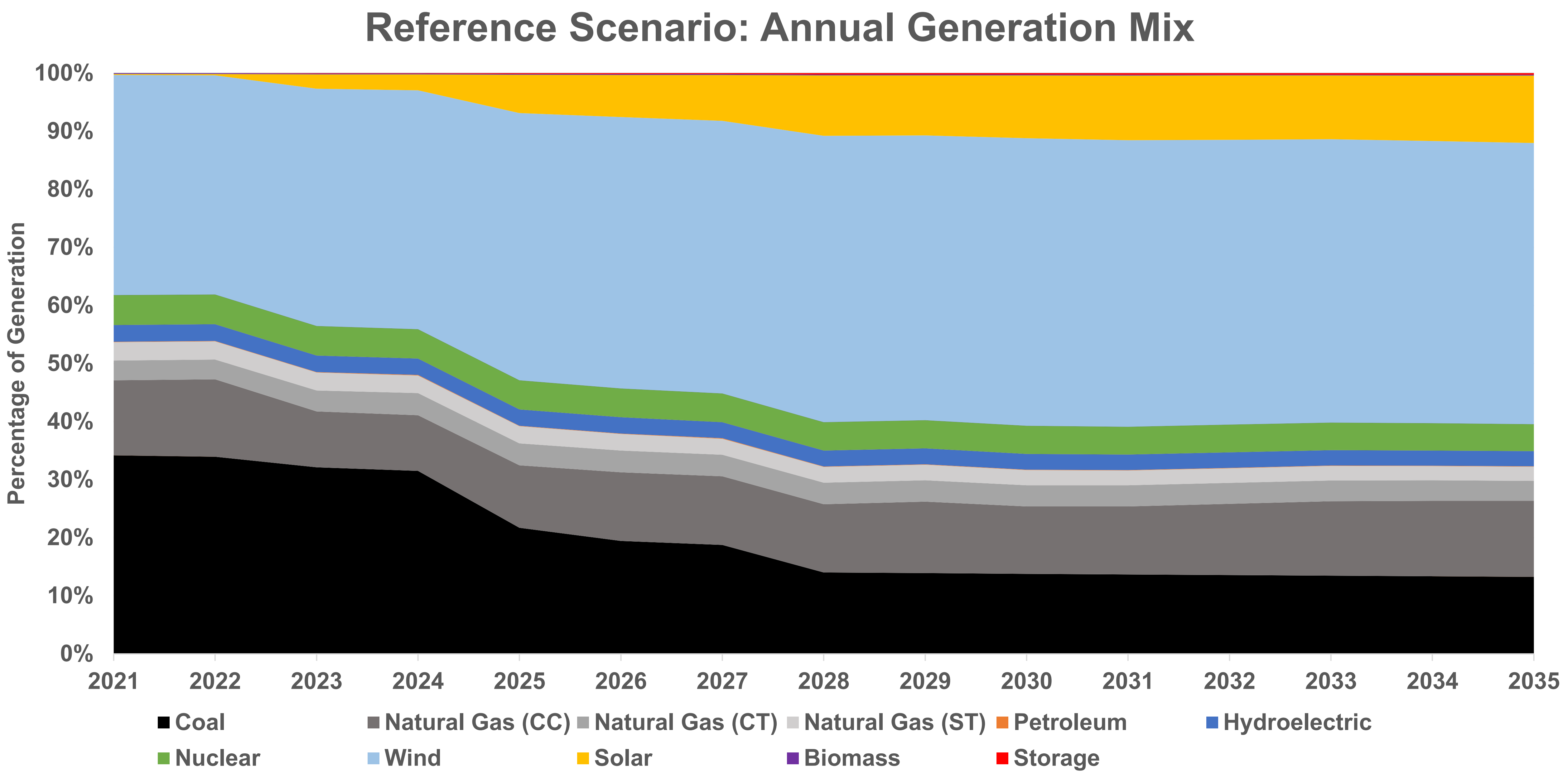
Even With No EPA impact, SPP Relying Upon Weather & Imports for Reserve



Estimated firm capacity using net peak load capacity accreditation values for wind (7.5%) and solar (20.4%), 92% for nuclear, 88% for coal, 83% for natural gas, and 90% for other thermal generators.

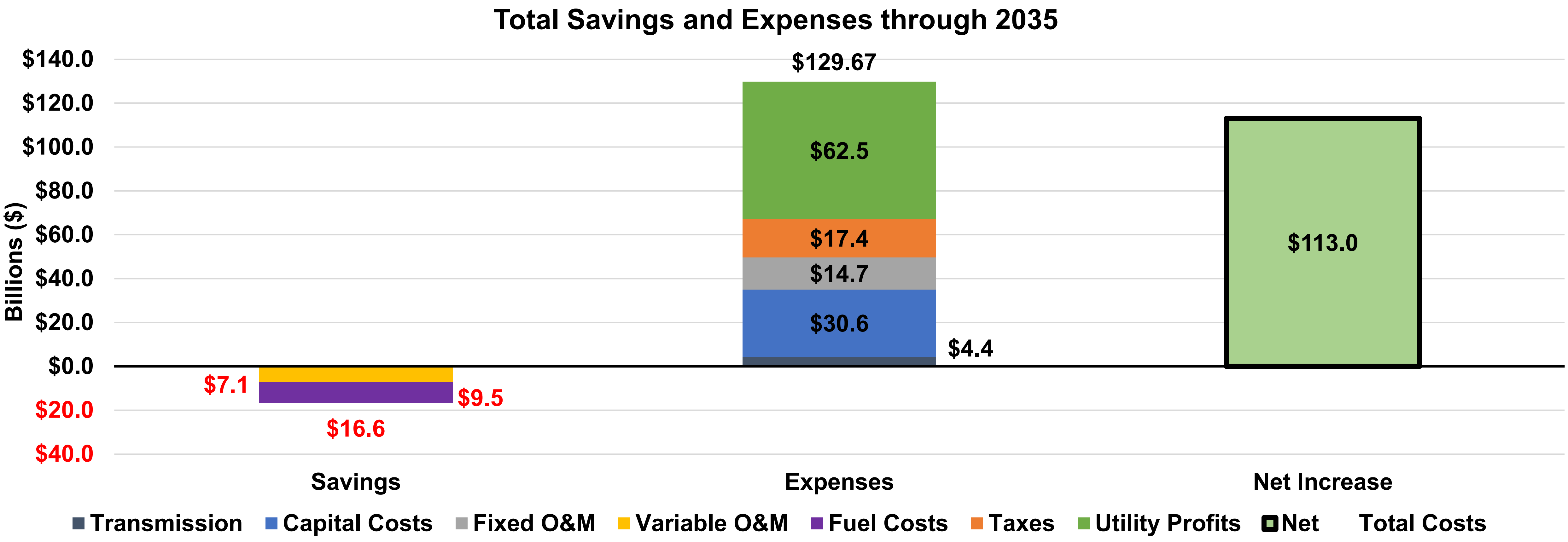
Year	Reserve Margin
2022	19%
2023	**20%**
2024	**21%**
2025	**22%**
2026	**23%**
2027	**22%**
2028	**22%**
2029	**20%**
2030	**20%**
2031	**19%**
2032	**18%**
2033	**17%**
2034	**16%**
2035	**15%**

Reference Scenario: Annual Generation Mix



Cost of Reference Scenario

The total additional cost to ratepayers in the Reference Scenario would be $113 billion through 2035 using net peak accreditation for wind and solar after fuel savings are accounted for.

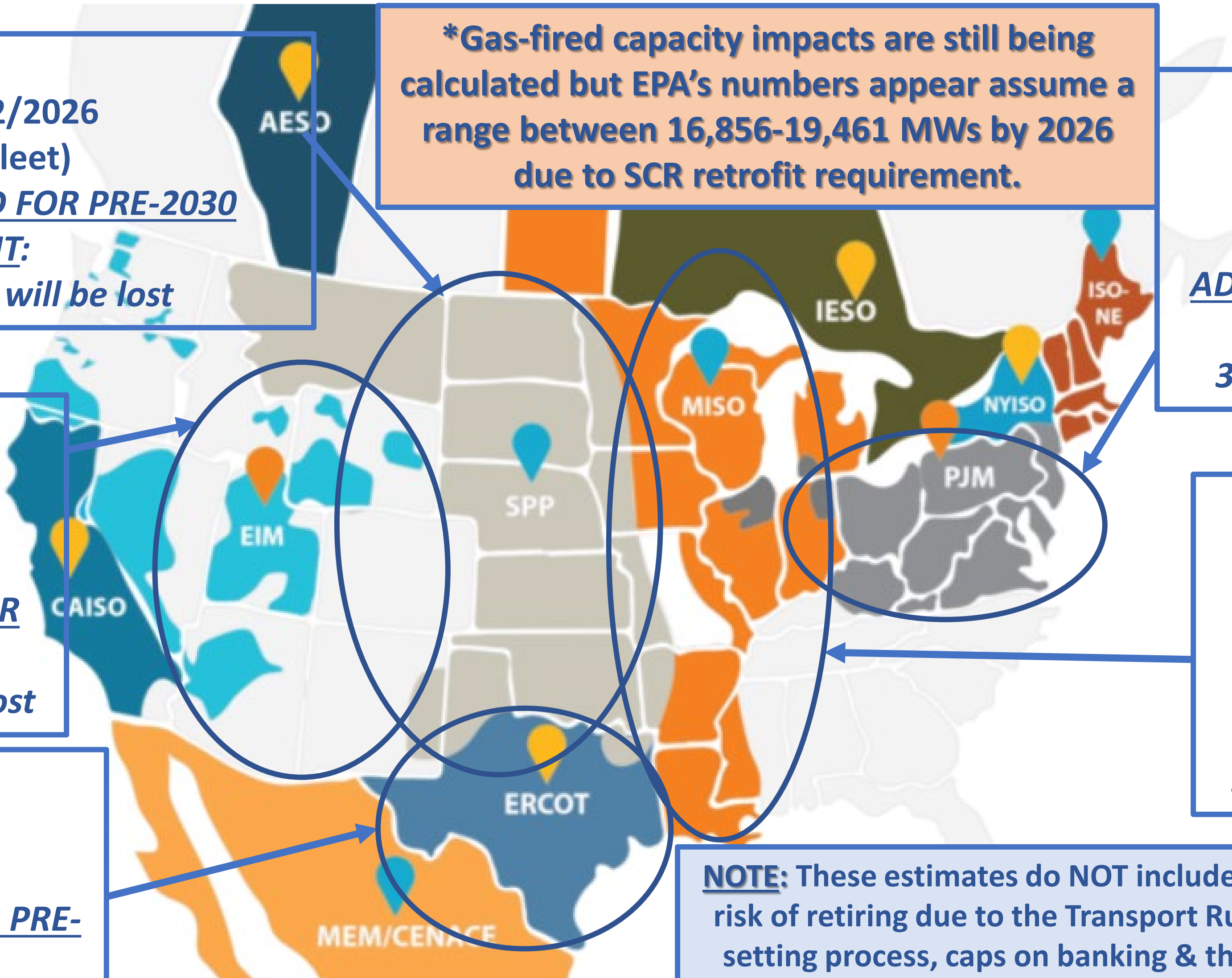


Ozone Transport Rule (OTR) and Coal Combustion and Residual (CCR) Scenario

Ozone Transport Rule (OTR) and Coal Combustion Residual (CCR) Scenario

- Assumes all of the closures in the reference scenario will occur.
- Increases closures due to OTR and CCR rules.
- The CCR rule is less impactful in SPP than in MISO, so the analysis combines both rules into one scenario.
- The ORT & CCR scenario experiences a loss of 22 GW of coal and 6.3 GW of gas by 2035.
- This capacity will be replaced with natural gas (2.4 GW), wind (65 GW), solar (94.7 GW), and four-hour storage (32.4 GW).

Methodology- Retirement Assumptions (OTR)



SPP:
8,184 MW by 12/2026
(37% of Coal Fleet)
ADDED TO UNITS SLATED FOR PRE-2030 RETIREMENT:
37% of coal capacity will be lost

***Gas-fired capacity impacts are still being calculated but EPA's numbers appear assume a range between 16,856-19,461 MWs by 2026 due to SCR retrofit requirement.**

PJM:
6,626 MW
by 12/2026
(15% of Coal Fleet)
ADDED TO UNITS SLATED FOR PRE-2030 RETIREMENT:
33% of coal capacity will be lost

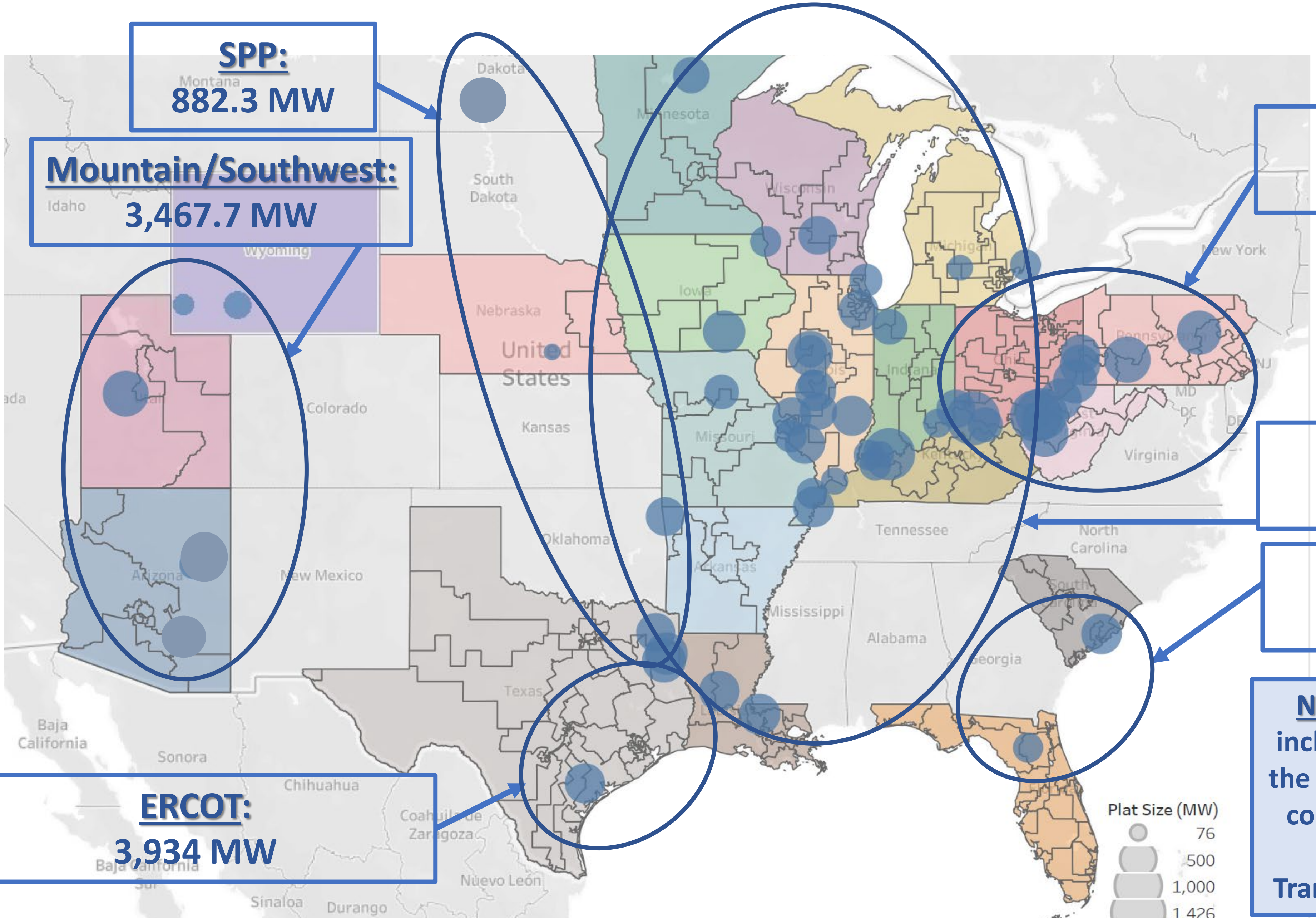
MOUNTAIN WEST:
8,892 MW
by 12/2026
(38% of Coal Fleet)
ADDED TO UNITS SLATED FOR PRE-2030 RETIREMENT:
44% of coal capacity will be lost

MISO:
16,996 MW
by 12/2026
(34% of Coal Fleet)
ADDED TO UNITS SLATED FOR PRE-2030 RETIREMENT:
51% of coal capacity will be lost

ERCOT:
7,867 MW by 12/2026
(55% of Coal Fleet)
ADDED TO UNITS SLATED FOR PRE-2030 RETIREMENT:
55% of coal capacity will be lost

NOTE: These estimates do NOT include SCR-controlled units that are also at risk of retiring due to the Transport Rule FIP's stringent & dynamic budget setting process, caps on banking & the daily max NOx emission rate. Nor does this capture retirements due to new interpretations of the CCR Rules EPA is attempting to impose on the states (i.e. this is the low end of impact).

Methodology- Retirement Assumptions (CCR)



SPP:
882.3 MW

Mountain/Southwest:
3,467.7 MW

PJM:
17,768.2 MW

MISO:
12,576.9 MW

SOUTHEAST:
894.7 MW

ERCOT:
3,934 MW

NOTE: These estimates do NOT include units already retired (or in the process) because of cost of CCR compliance or or the threatened imposition of EPA's Ozone Transport Rule FIP (> 50,000 MWs)

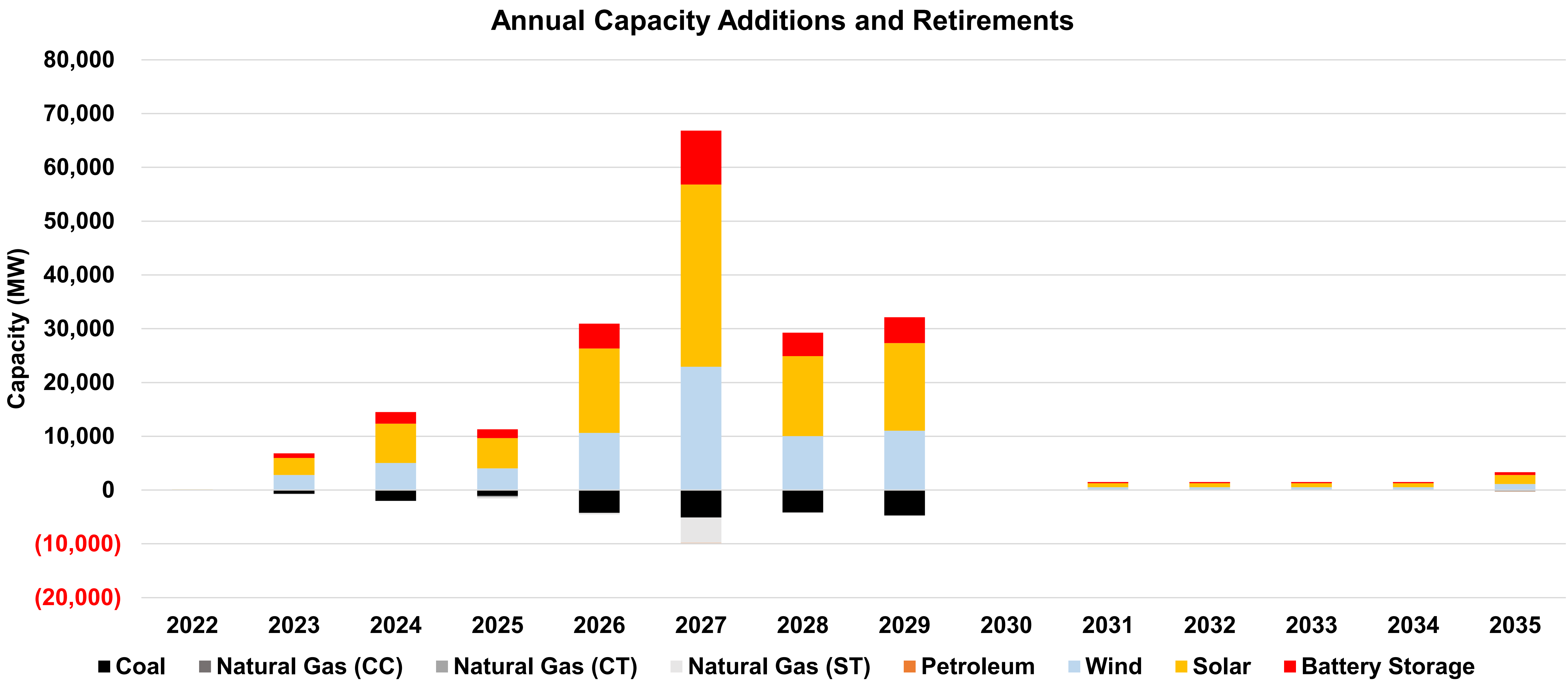
Ozone Transport and CCR: Retirements (MW)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Coal	0	(721)	(1,998)	(1,080)	(4,252)	(5,110)	(4,184)	(4,719)	0	0	0	0	0	0	(22,064)
Natural Gas (CC)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas (CT)	0	0	0	(204)	0	0	0	0	0	0	0	0	0	(258)	(462)
Natural Gas (ST)	0	(84)	(90)	(315)	(291)	(4,672)	(114)	0	0	0	0	0	0	0	(5,566)
Petroleum	0	0	0	0	0	(28)	0	0	0	0	0	0	0	(10)	(38)

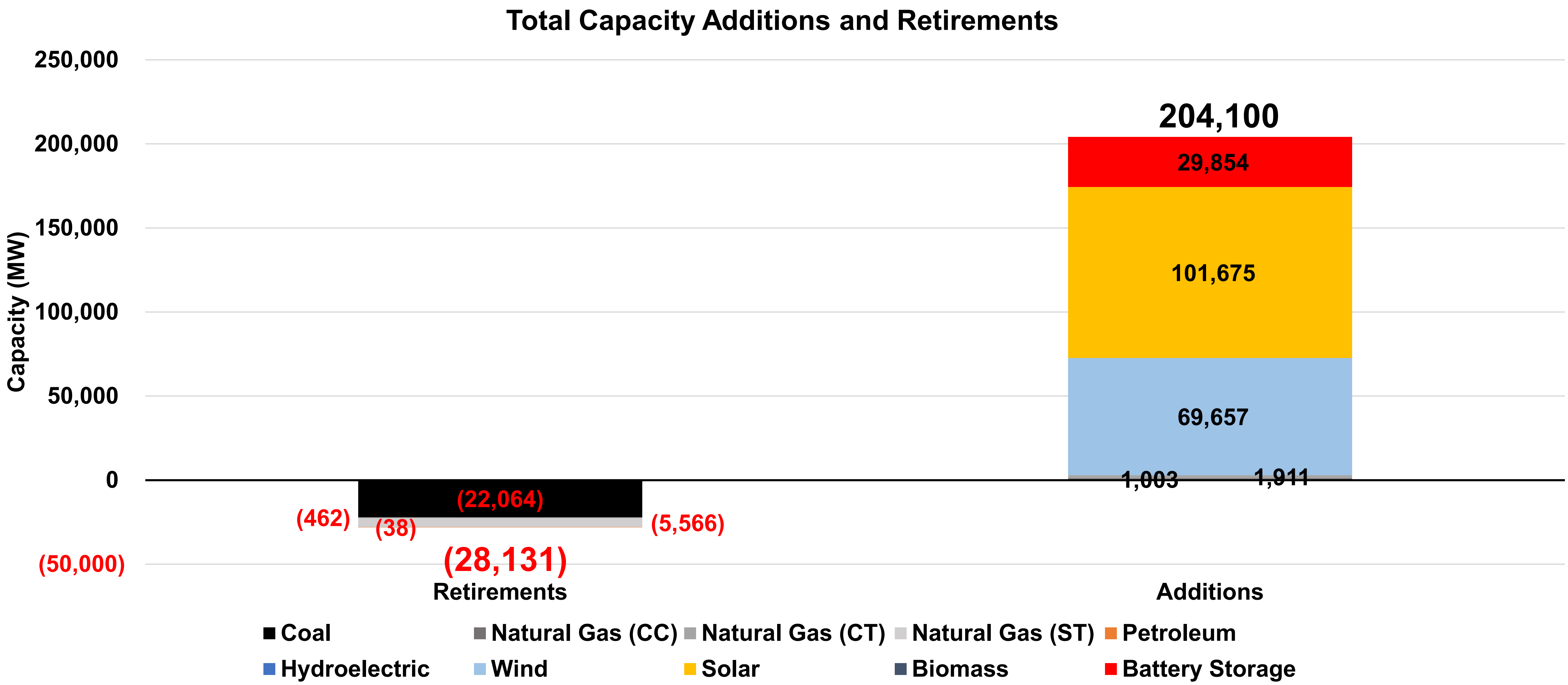
OTR & CCR Scenario: Additions (MW)

Additions	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas (CC)	0.0	0.0	0.0	0.0	1,003.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,003.0
Natural Gas (CT)	44.2	857.6	759.0	250.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,910.7
Natural Gas (ST)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petroleum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wind	0.0	2,785.9	5,031.9	4,039.8	10,620.2	22,932.4	10,046.3	11,031.4	0.0	508.5	508.5	508.5	508.5	1,135.0	69,656.8
Solar	128.0	3,191.0	7,328.7	5,611.7	15,694.6	33,889.7	14,846.5	16,302.3	0.0	751.4	751.4	751.4	751.4	1,677.3	101,675.5
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Battery Storage	0.0	860.9	2,149.1	1,631.3	4,632.6	10,003.2	4,382.2	4,812.0	0.0	221.8	221.8	221.8	221.8	495.1	29,853.6

OTR &CCR Scenario: Retirements and Additions



OTR & CCR Scenario: Retirements and Additions



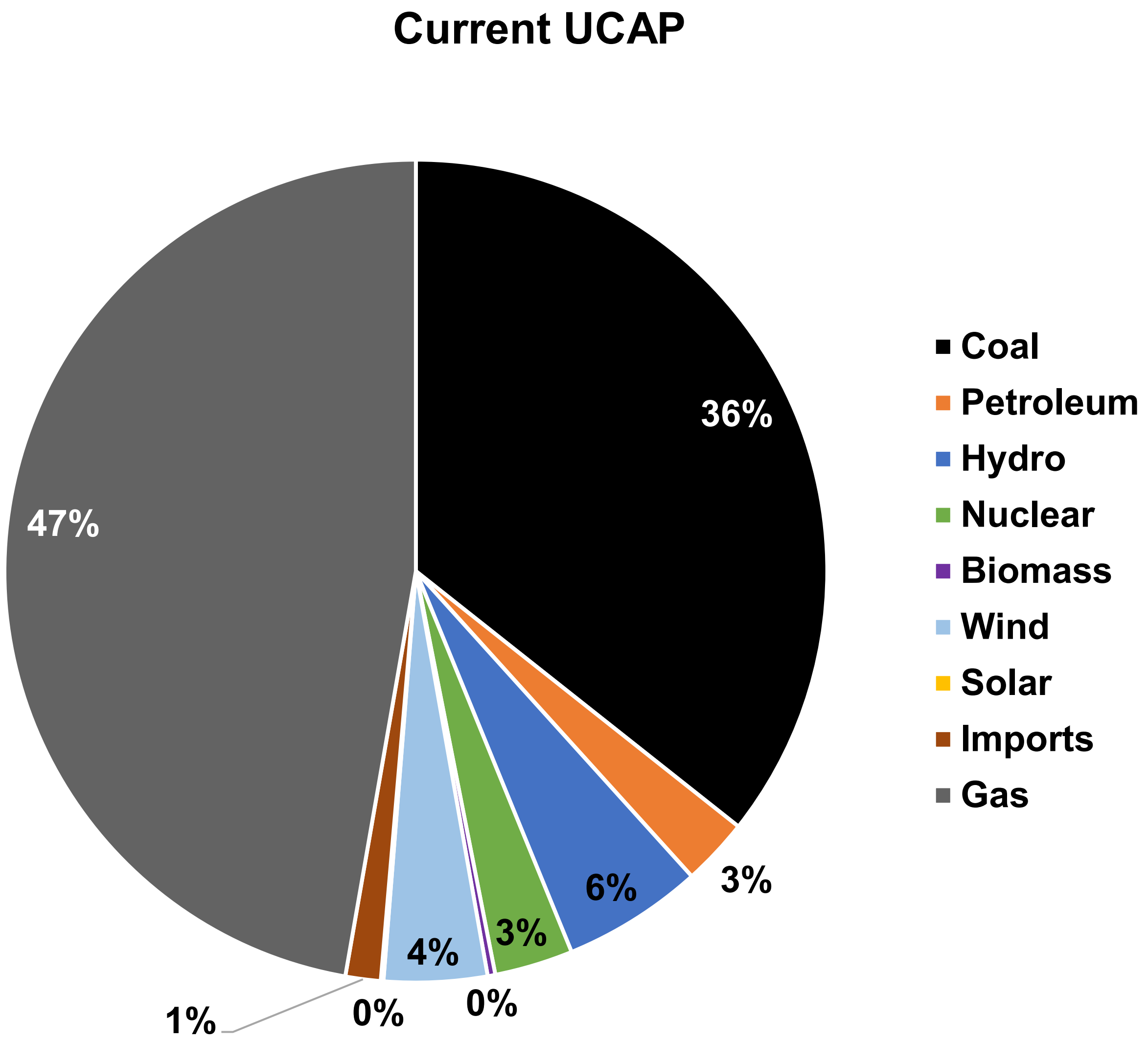
OTR & CCR: Annual ICAP Mix

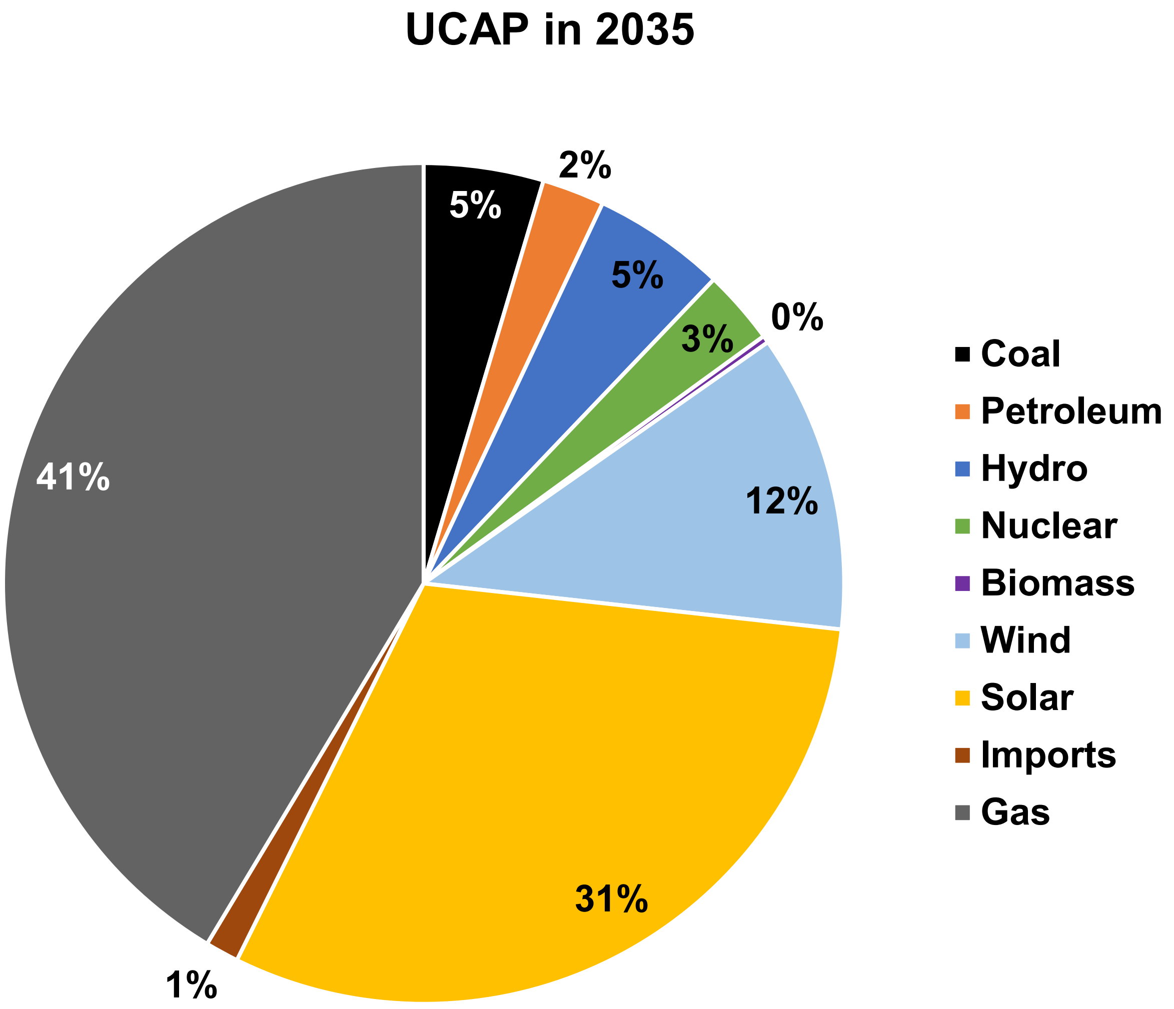
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	
Coal	25,628	24,907	22,909	21,829	17,577	12,467	8,283	3,564	3,564	3,564	3,564	3,564	3,564	3,564	1%
Natural Gas (CC)	11,697	11,697	11,697	12,777	13,780	13,780	13,780	13,780	13,780	13,780	13,780	13,780	13,780	13,780	5%
Natural Gas (CT)	11,732	12,589	13,348	13,394	13,394	13,394	13,394	13,394	13,394	13,394	13,394	13,394	13,394	13,136	5%
Natural Gas (ST)	12,679	12,595	12,505	12,190	11,899	7,227	7,113	7,113	7,113	7,113	7,113	7,113	7,113	7,113	3%
Petroleum	1,687	1,687	1,687	1,687	1,687	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,649	1%
Hydroelectric	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	6,644	2%
Existing Nuclear	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	2,109	1%
Onshore Wind	33,987	36,773	41,805	45,845	56,465	79,397	89,443	100,475	100,475	100,983	101,492	102,000	102,509	103,644	37%
Utility Solar	444	3,635	10,964	16,576	32,270	66,160	81,007	97,309	97,309	98,060	98,812	99,563	100,315	101,992	35%
Biomass	211	211	211	211	211	211	211	211	211	211	211	211	211	211	0%
Storage	0	861	3,010	4,641	9,274	19,277	23,659	28,471	28,471	28,693	28,915	29,137	29,359	29,854	10%
Total	106,819	113,710	126,890	137,903	165,311	222,326	247,303	274,730	274,730	276,212	277,693	279,175	280,657	283,696	

OTR & CCR Scenario: Annual UCAP Mix

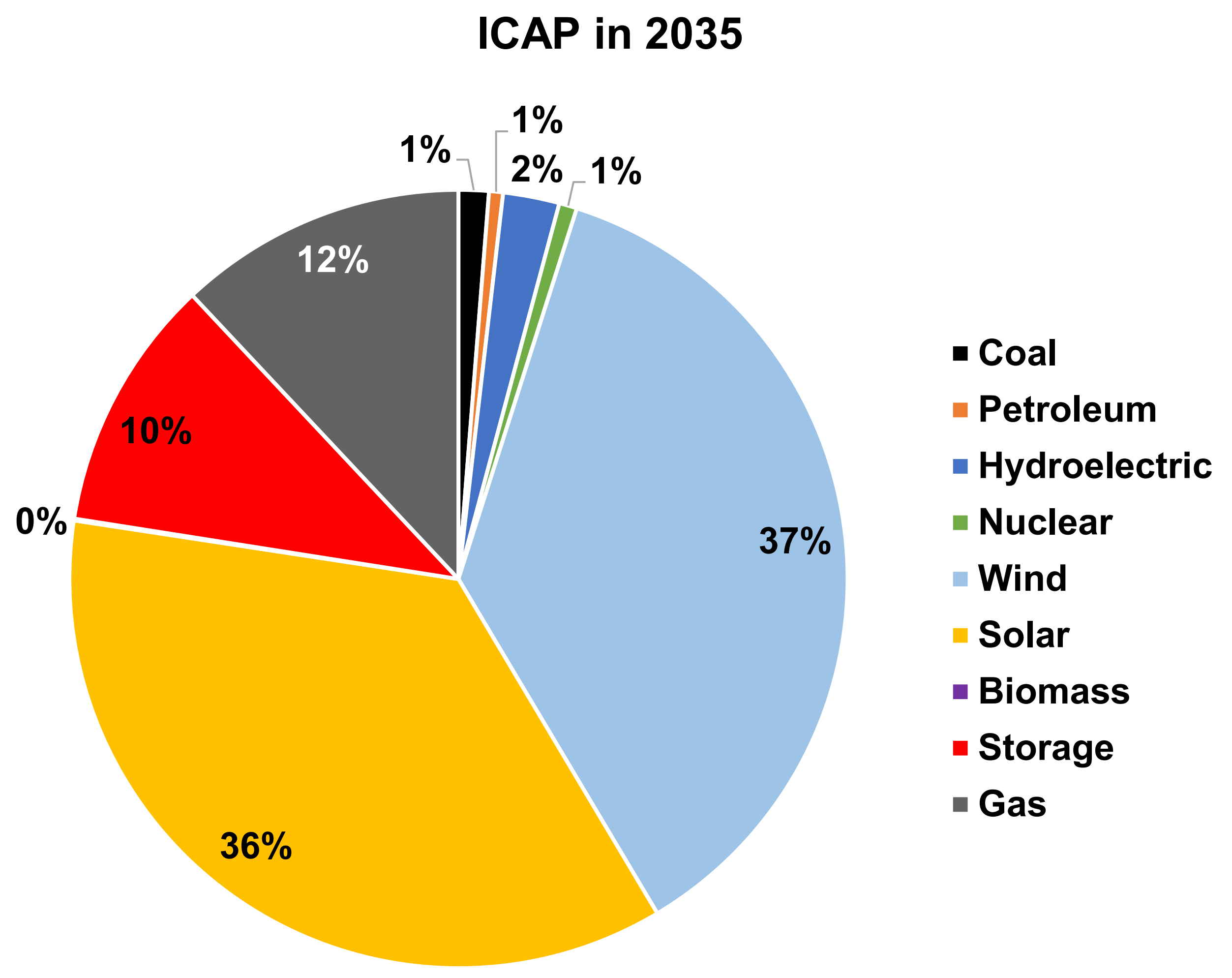
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	
Coal	22,540	22,540	21,906	20,149	19,199	15,459	10,965	7,285	3,134	3,134	3,134	3,134	3,134	3,134	3,134	5%
Natural Gas (CC)	9,688	9,688	9,688	9,688	10,582	11,413	11,413	11,413	11,413	11,413	11,413	11,413	11,413	11,413	11,413	17%
Natural Gas (CT)	9,680	9,716	10,427	11,055	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093	11,093	10,879	16%
Natural Gas (ST)	10,501	10,501	10,432	10,357	10,096	9,855	5,985	5,891	5,891	5,891	5,891	5,891	5,891	5,891	5,891	9%
Petroleum	1,671	1,671	1,671	1,671	1,671	1,671	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,633	2%
Hydro	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	3,490	5%
Nuclear	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	3%
Biomass	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	0%
Wind	2,563	2,563	2,773	3,153	3,458	4,259	5,988	6,746	7,578	7,578	7,616	7,654	7,693	7,731	7,817	11%
Solar	65	91	742	2,238	3,384	6,588	13,506	16,537	19,865	19,865	20,018	20,171	20,325	20,478	20,820	31%
Imports	876	876	876	876	876	876	876	876	876	876	876	876	876	876	876	1%
Total UCAP	63,212	63,275	64,143	64,816	65,987	66,842	67,098	67,112	67,122	67,122	67,314	67,505	67,697	67,889	68,093	

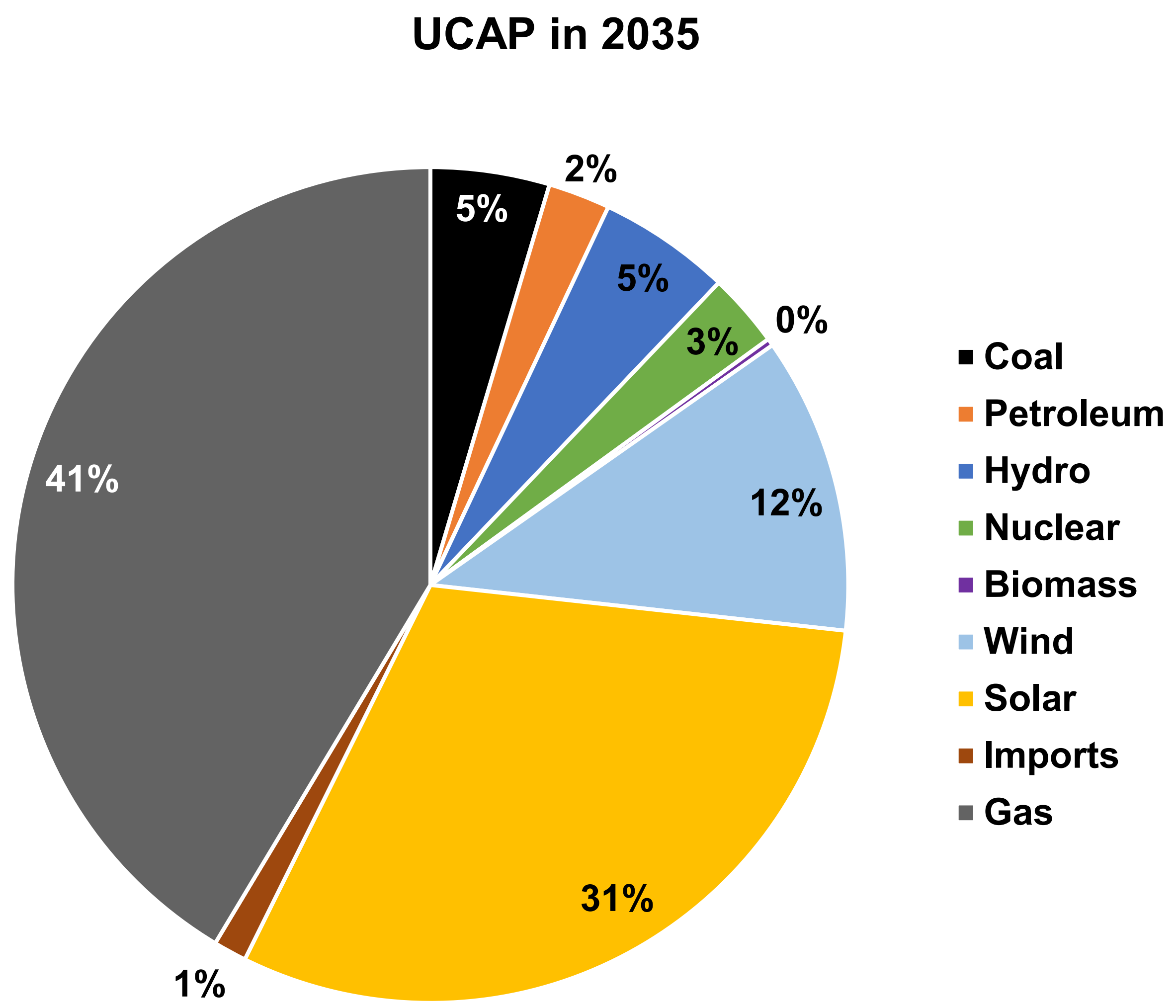
OTR & CCR Scenario: Current UCAP Mix vs. 2035



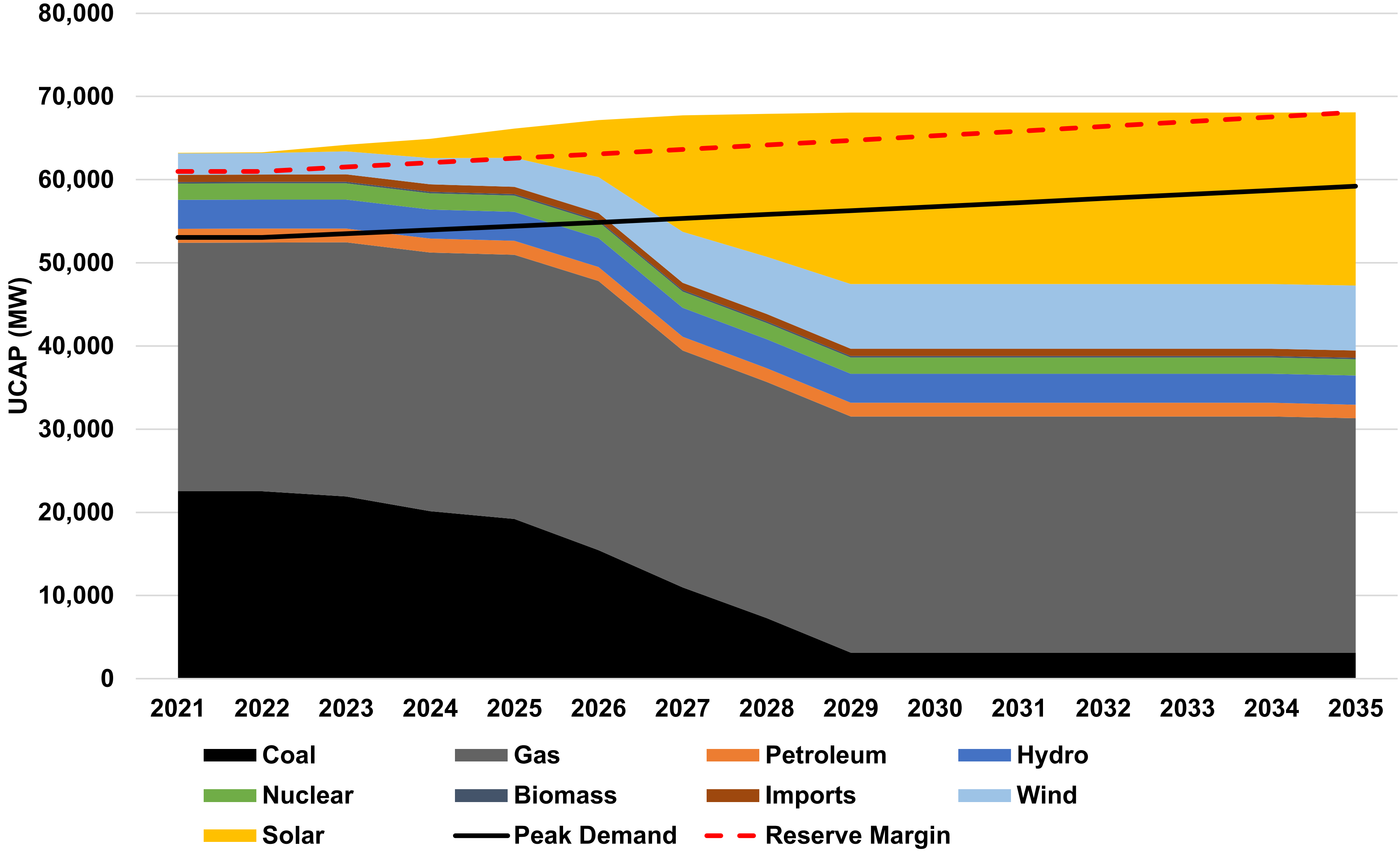


OTR & CCR Scenario: Current UCAP Mix vs. 2035





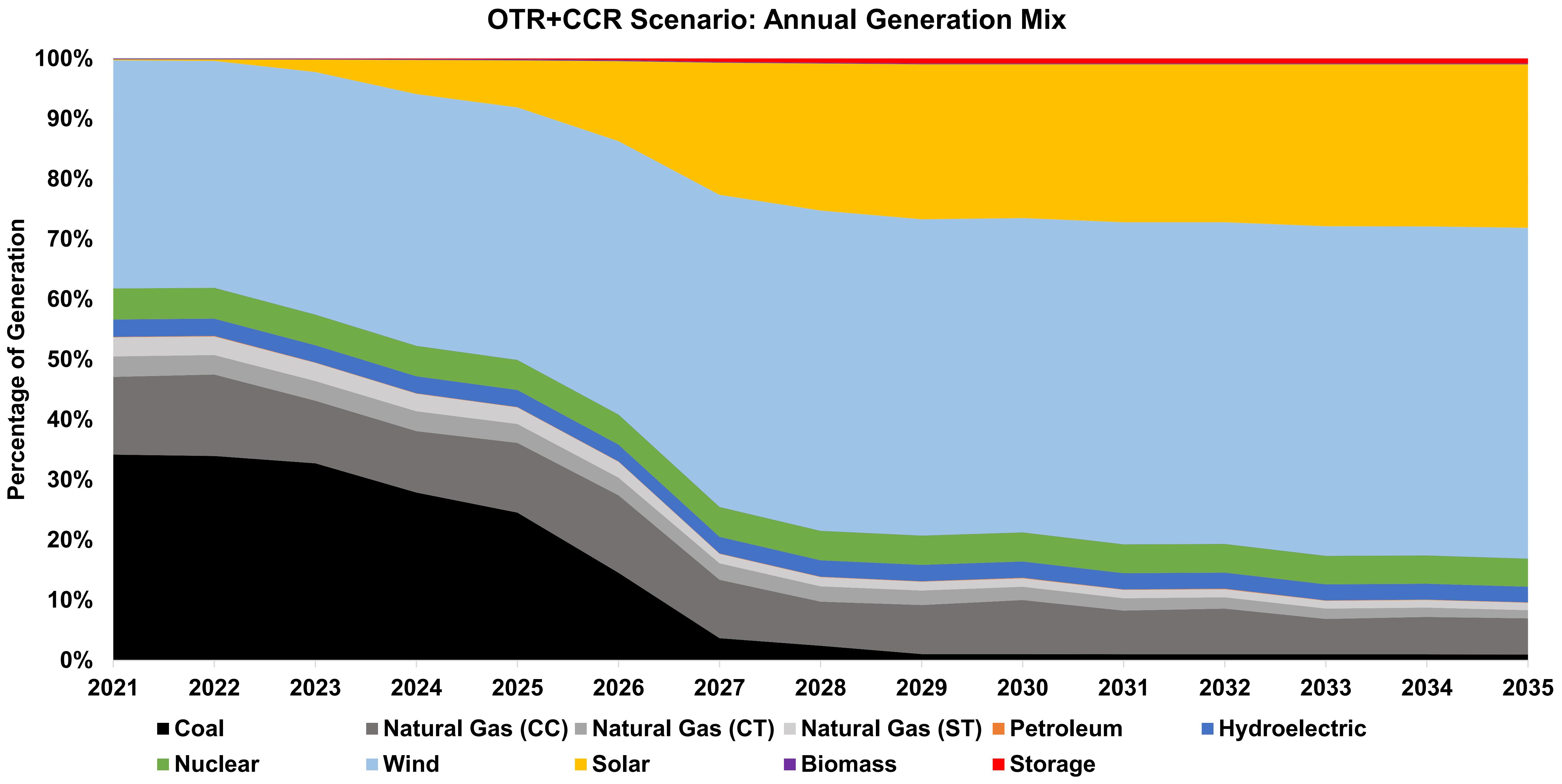
OTR & CCR Scenario: Capacity Shortfall Risk



Year	Reserve Margin
2022	19%
2023	**20%**
2024	**20%**
2025	**21%**
2026	**22%**
2027	**21%**
2028	**20%**
2029	**19%**
2030	**18%**
2031	**18%**
2032	**17%**
2033	**16%**
2034	**16%**
2035	**15%**

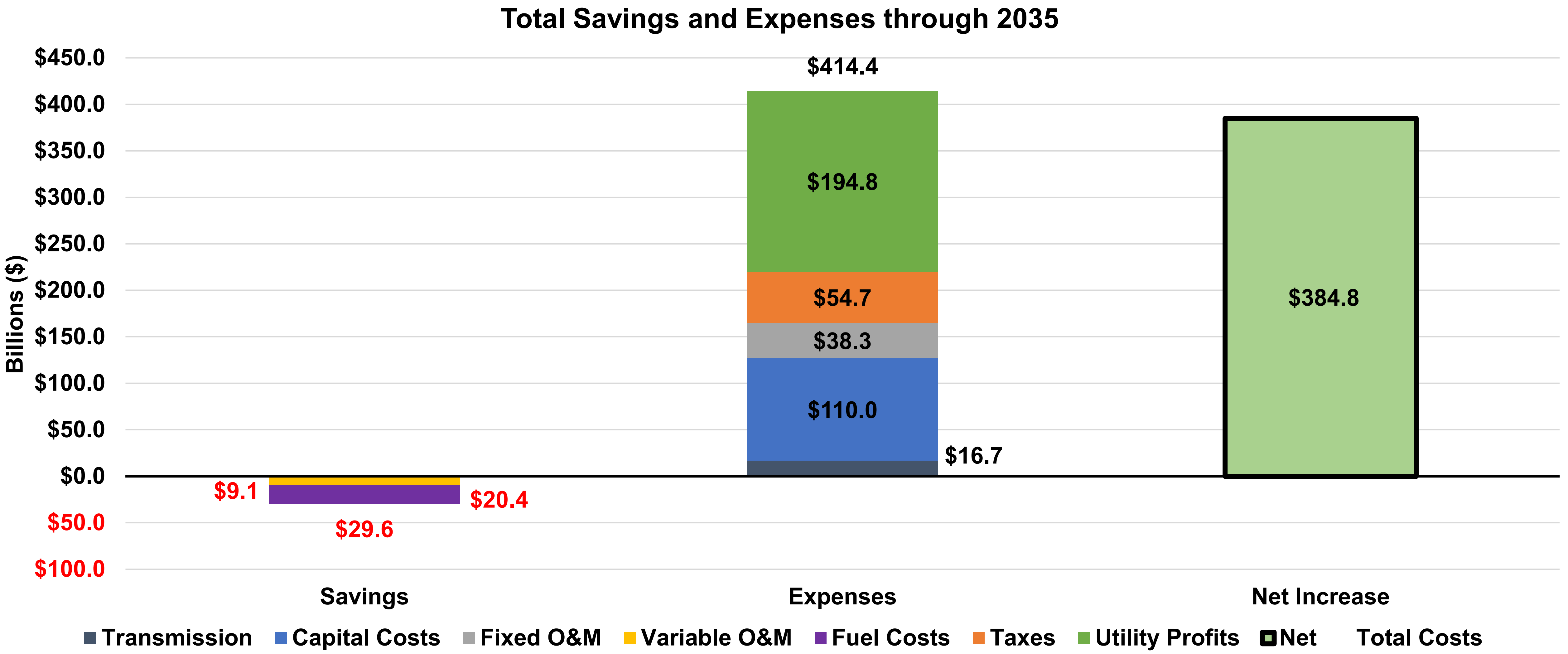
Estimated firm capacity using net peak load capacity accreditation values for wind (7.5%) and solar (20.4%), 92% for nuclear, 88% for coal, 83% for natural gas, and 90% for other thermal generators. Under this scenario, SPP is dependent on intermittent resources to meet peak load by 2026.

OTR & CCR Scenario: Annual Generation Mix

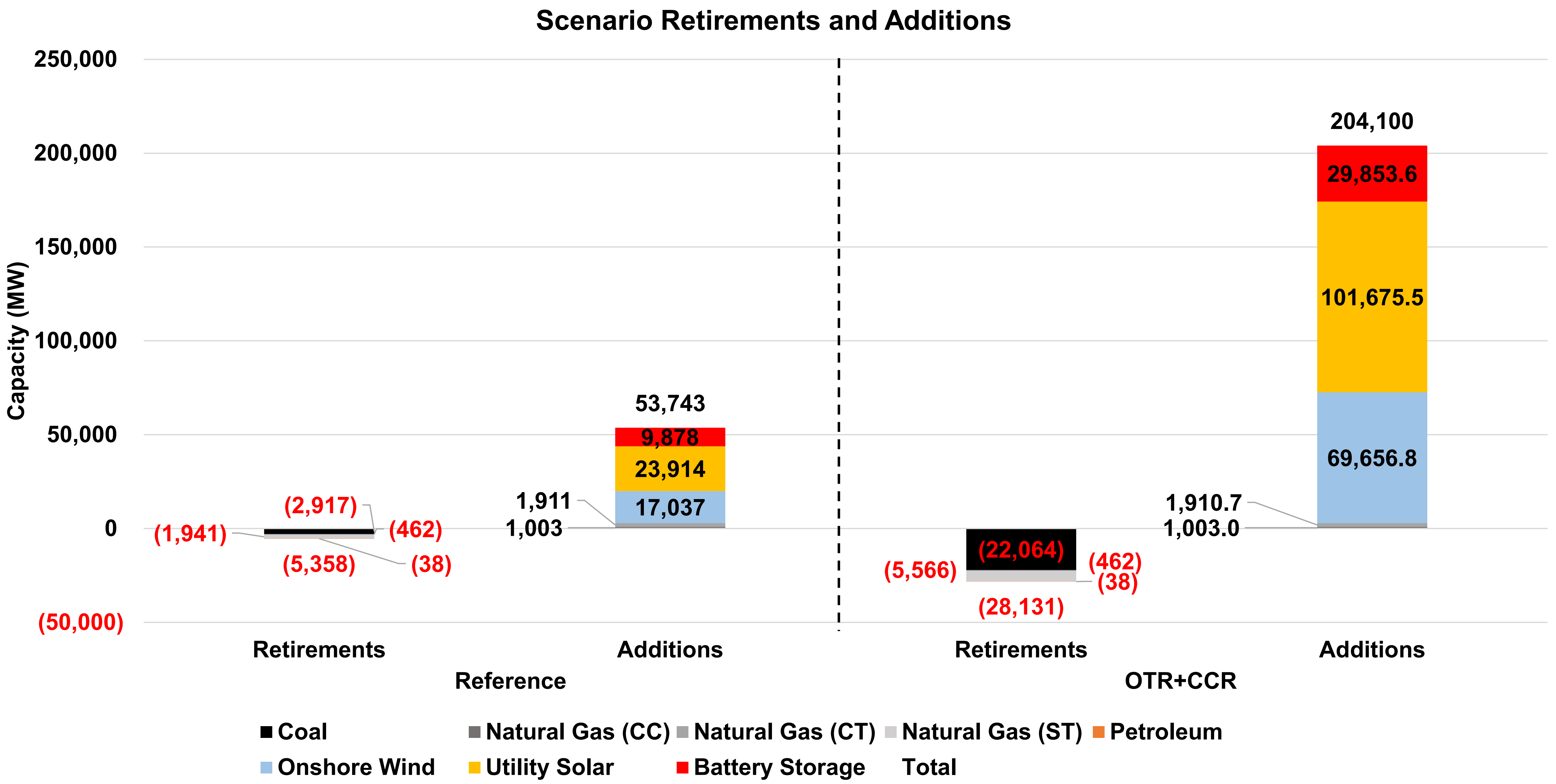


OTR & CCR Scenario Costs

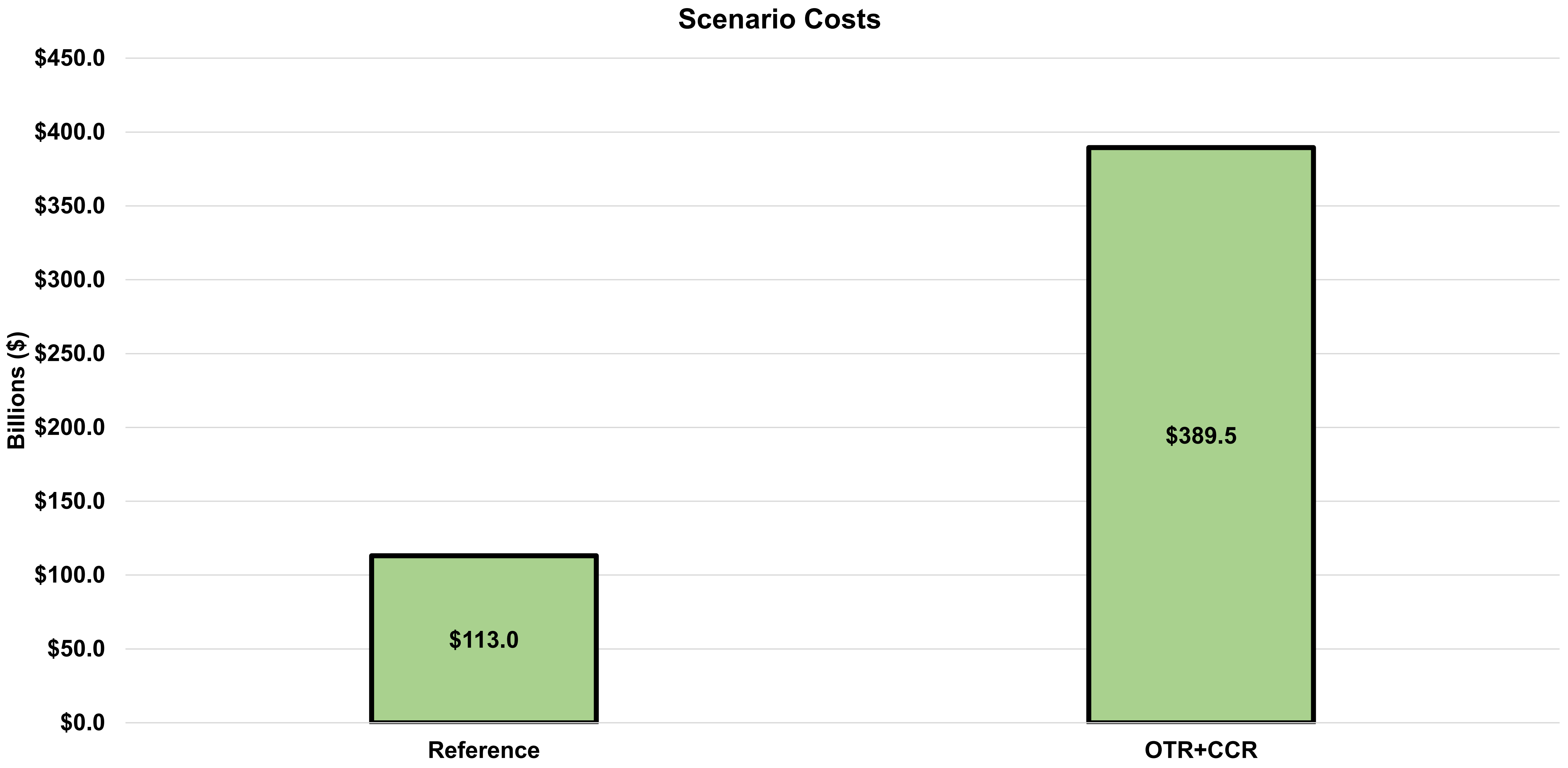
The total additional cost to ratepayers in the OTR & CCR Scenario would be $385 billion through 2035 after fuel savings are accounted for.



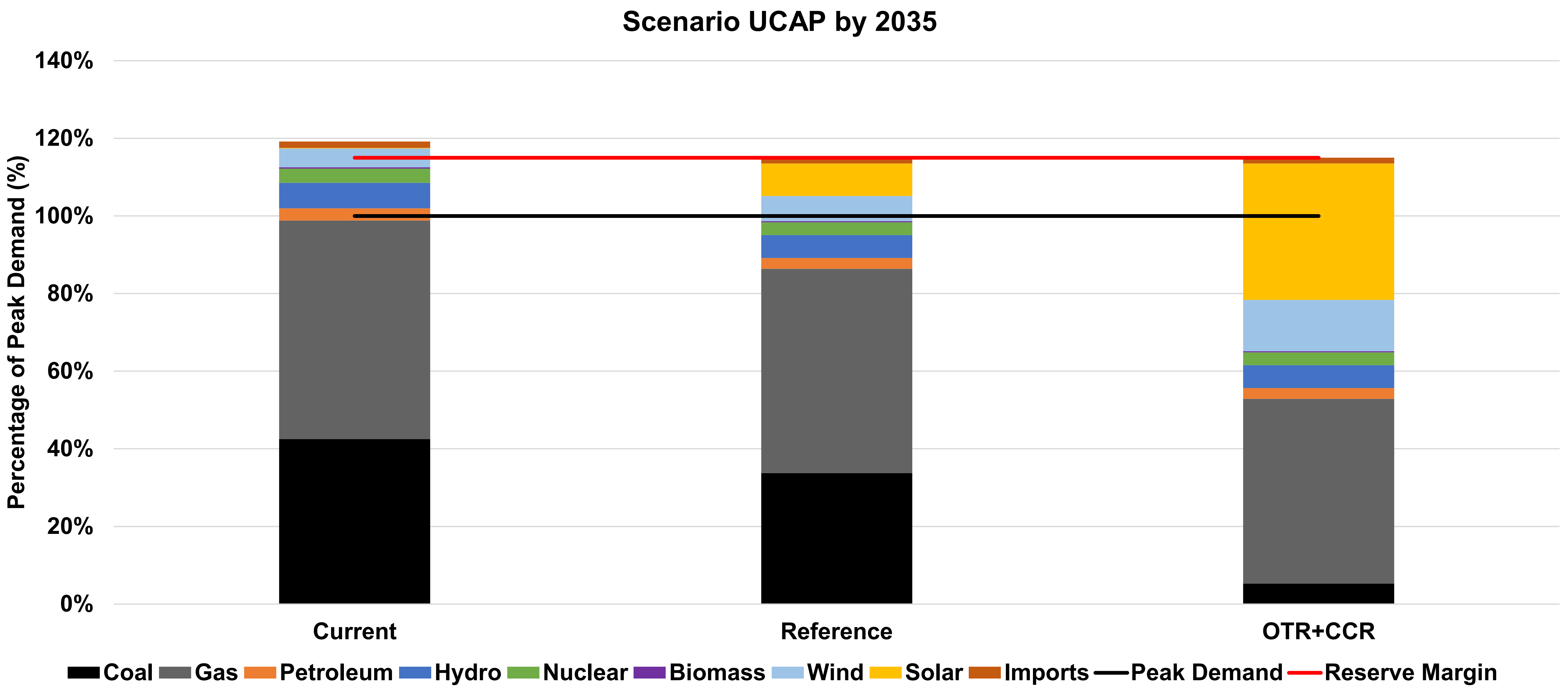
In Summary: If EPA Rules Force Early Retirements by 2035



Costs for Each Scenario Through 2035



Recap of Increasing Risk of Capacity Shortfall



Estimated firm capacity using net peak load capacity accreditation values for wind (7.5%) and solar (20.4%), 92% for nuclear, 88% for coal, 83% for natural gas, and 90% for other thermal generators. SPP would be dependent on intermittent resources to meet peak load in both scenarios.

Conclusions

1. **Our findings represent a best-case scenario for reliability due to our HCD accreditation standard.**

2. **Different standards, such as seasonal accreditation ELCC being explored by SPP, will produce varying levels of reliability that must be examined in light of these results.**

3. **Costs were relatively modest due to the large amount of thermal capacity remaining on the SPP system through 2035, but costs increase <u>substantially</u> as more thermal retirements occur and Load Responsible Entities (LREs) attempt to replace this lost generation with wind, solar, and battery storage.**

4. **Policymakers must understand the challenges regarding reliability, resiliency and affordability that are growing every year.**

Recommendations

<u>Policy Recommendations in Light of Findings of the Study</u>:

1. **PAUSE RETIREMENTS:** The timeline of coal and natural gas retirements in SPP, even in the reference case, is too short for replacement capacity to come online.

2. **STUDY THE IMPACT OF THE MERCURY AND AIR TOXICS STANDARDS:** EPA's MATS rule could force the closure of lignite-fired generators, posing large regional risks to SPP and MISO.

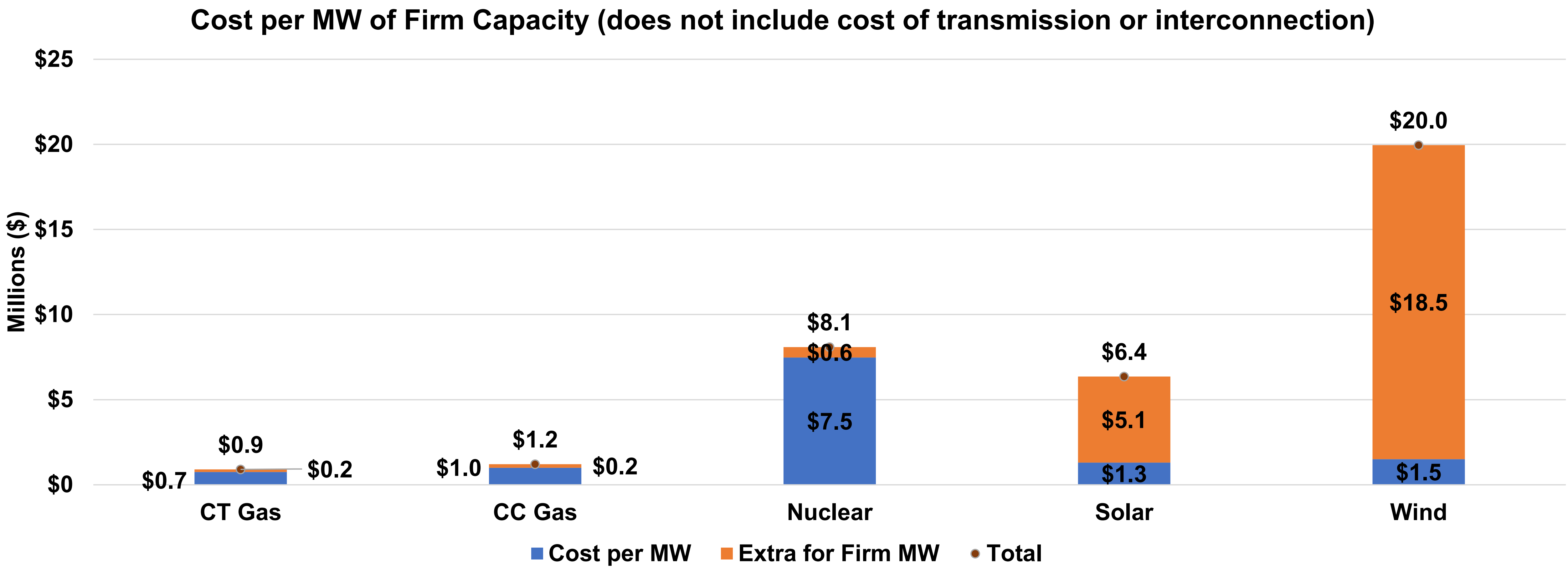
3. **ANCHOR ACCREDITATION TO FORESEEABLE WEATHER RISKS:** Even if wind and solar resources are built in time, there is still a chance that they may be performing under SPP's and our updated accredited values, meaning capacity shortfalls may still present challenges to grid operators. This is because at any given time, wind and solar may be producing no electricity at all.

    - SPP should have the same reliability standards for wind and solar as it does dispatchable energy sources like coal, natural gas, and nuclear, meaning it would require wind and solar to meet capacity obligations 7/8^{ths} of all peak hours of the year, which is a standard dispatchable units meet or exceed. Our method of accreditation – the Highest Certainty Deliverability– can better assess wind and solar reliability based on this standard.

    - Ultimately, the goal is to appropriately measure and price the variability of wind and solar, instead of foisting the costs of that variability on the entire system.

Recommendations (*continued*)

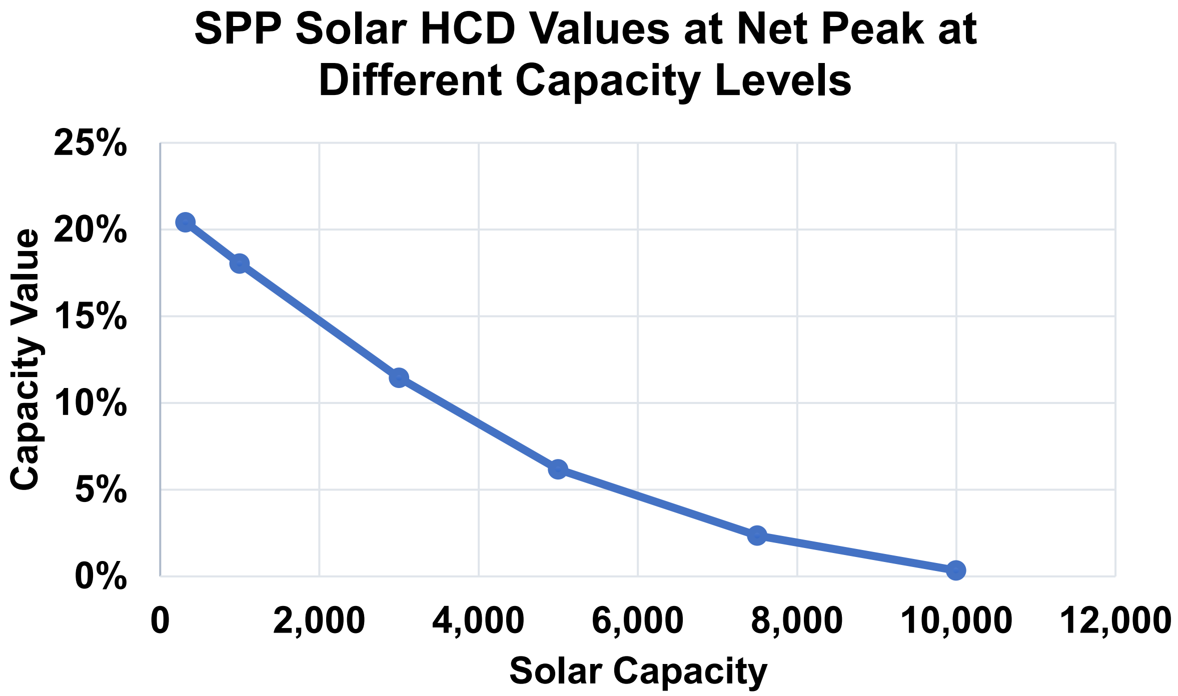
4. LOOK BEYOND LCOE: Make clear that capital cost per MW installed of wind and solar is vastly different than capital cost per FIRM MW installed of wind and solar. Example below:

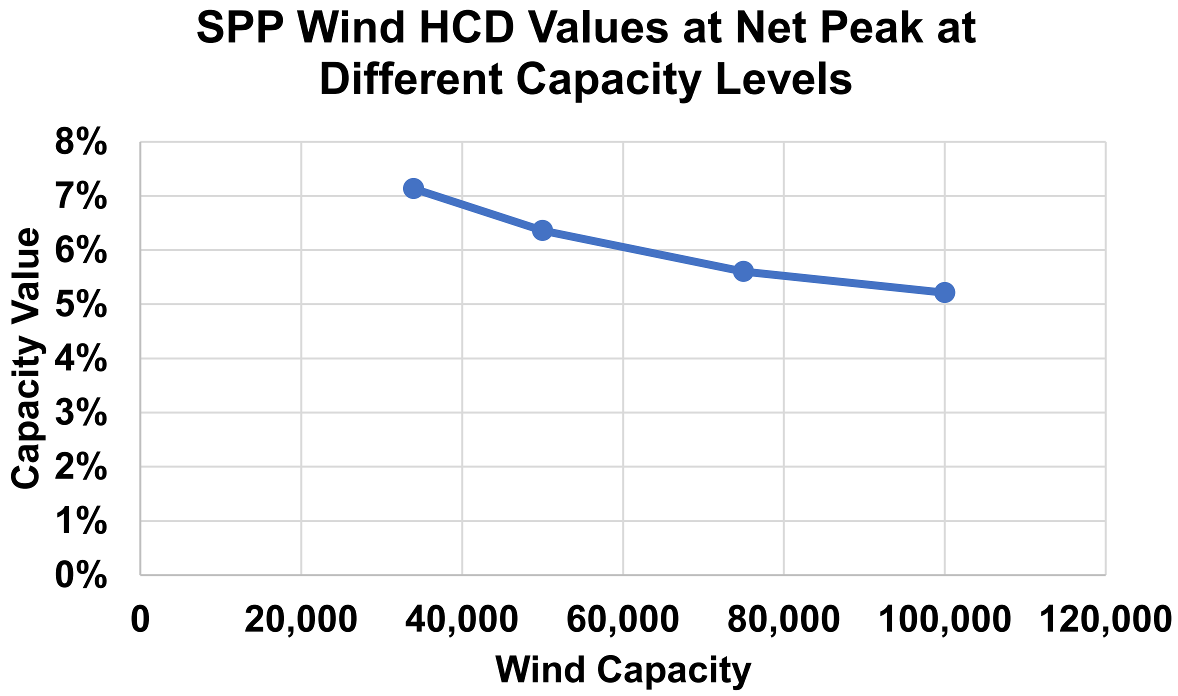


The cost per firm MW of capacity for wind and solar are based on net peak HCD values of 7.5% and 20.4%, respectively. These values will decline as more wind and solar are connected to the grid, and thus the cost per firm MW will increase.

Recommendations (*continued*)

5. Change HCD Accreditation to reflect rising penetrations wind and solar: Solar's ability to help meet net peak load diminishes greatly over time because its hours of generation are constrained by daylight. Wind's ability to help meet net peak load diminishes less than solar because wind generation can occur at any time.





a. Wind values assume 10,000 MWs of solar capacity on the system.

Recommendations (*continued*)

6. Investigate capacity values for battery storage resources: Regional transmission organizations are currently trying to develop capacity accreditation metrics for storage. These capacity values should take into account the reliability of the electric system that would be responsible for charging the batteries.

SPP is considering seasonal capacity accreditation metrics for storage based on market penetration and storage duration.

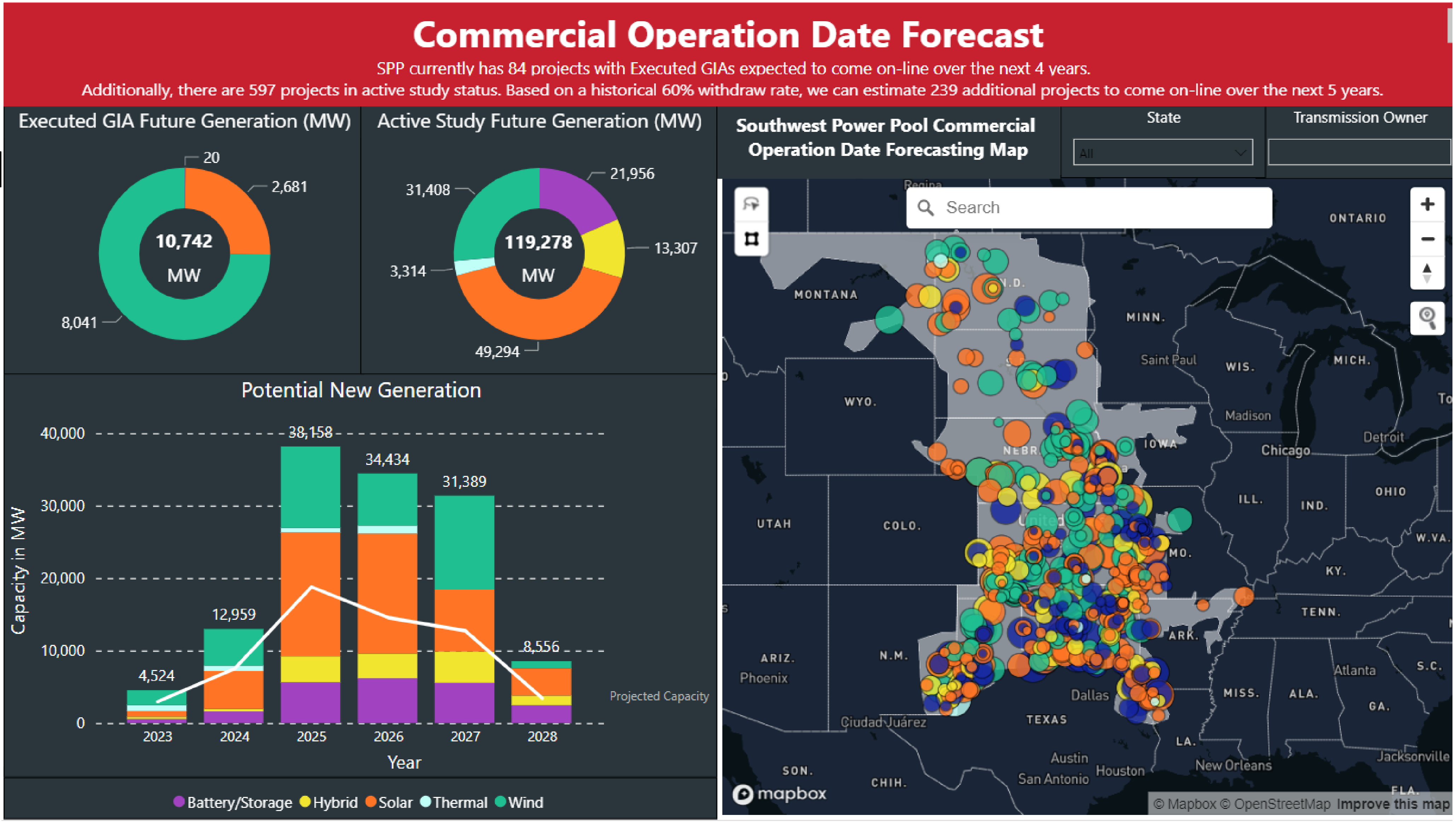
Table 3: Summer ELCC Accreditation of 4-hour, 6-hour, and 8-hour ESR

Duration \ Capacity	1,000 MW	3,000 MW	5,000 MW
4-hour	100%	96%	84%
6-hour	100%	98%	95%
8-hour	100%	97%	96%

Table 4: Winter ELCC Accreditation of 4-hour, 6-hour, and 8-hour ESR

Duration \ Capacity	1,000 MW	3,000 MW	5,000 MW
4-hour	83%	71%	51%
6-hour	83%	79%	58%
8-hour	89%	82%	61%

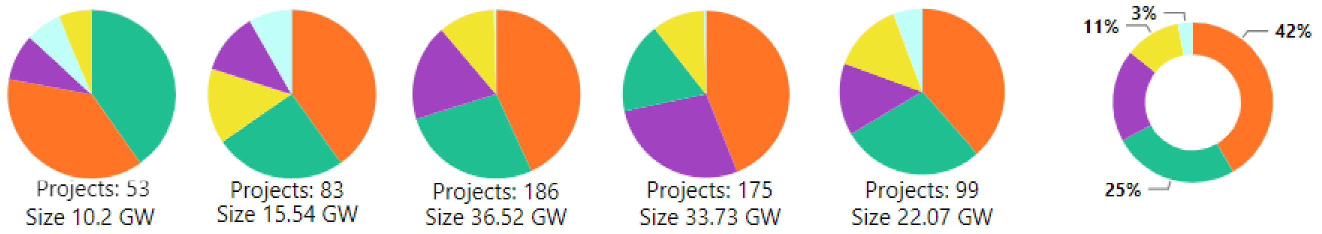
SPP Interconnection Queue



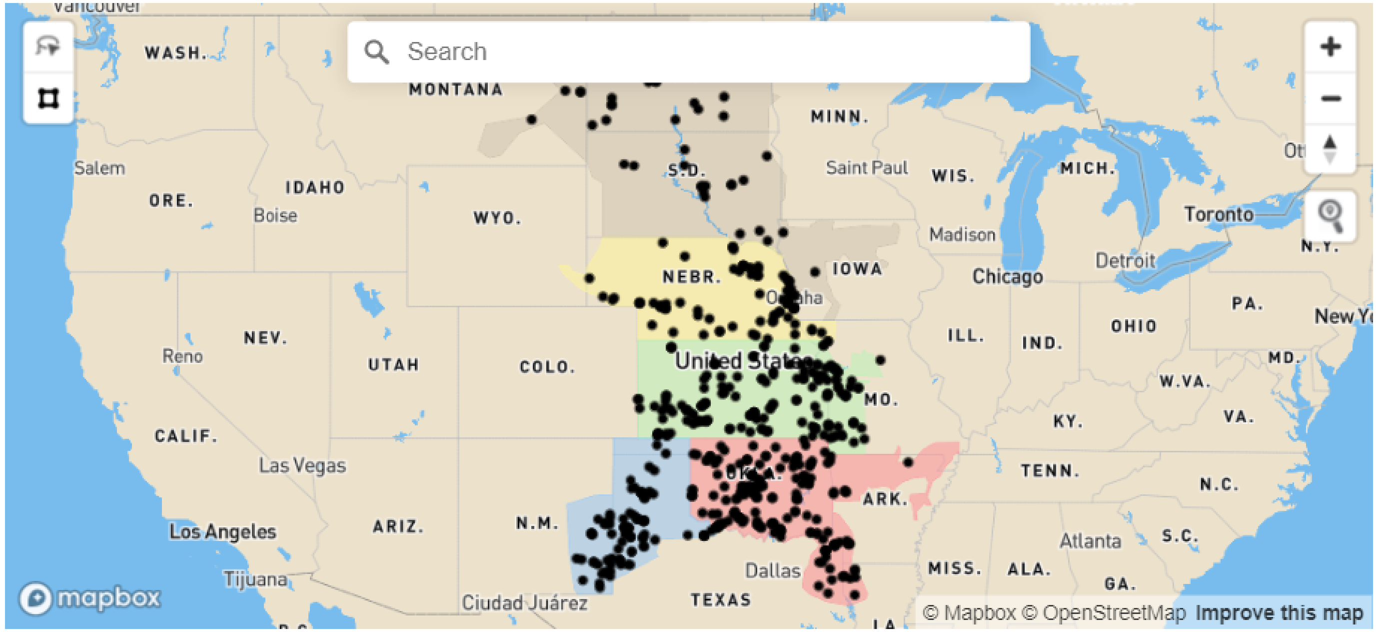
SPP Interconnection Queue

Southwest Power Pool Generation Interconnection Queue Dashboard

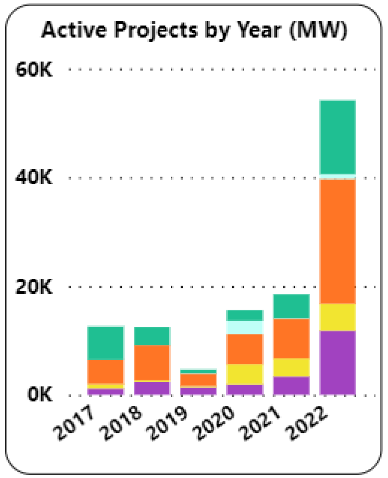
The current generator interconnection active queue consists of 596 projects totaling 118.1 GW

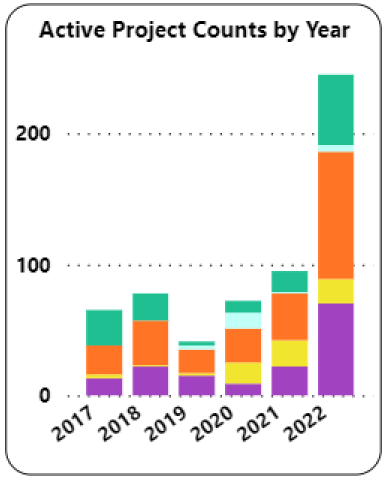


Filter by Request: All | Filter by GEN Type: All | Filter by Cluster: All | Filter by State: All | Filter by TO: All



Generation Type ● Battery/Storage ● Hybrid ● Solar ● Thermal ● Wind





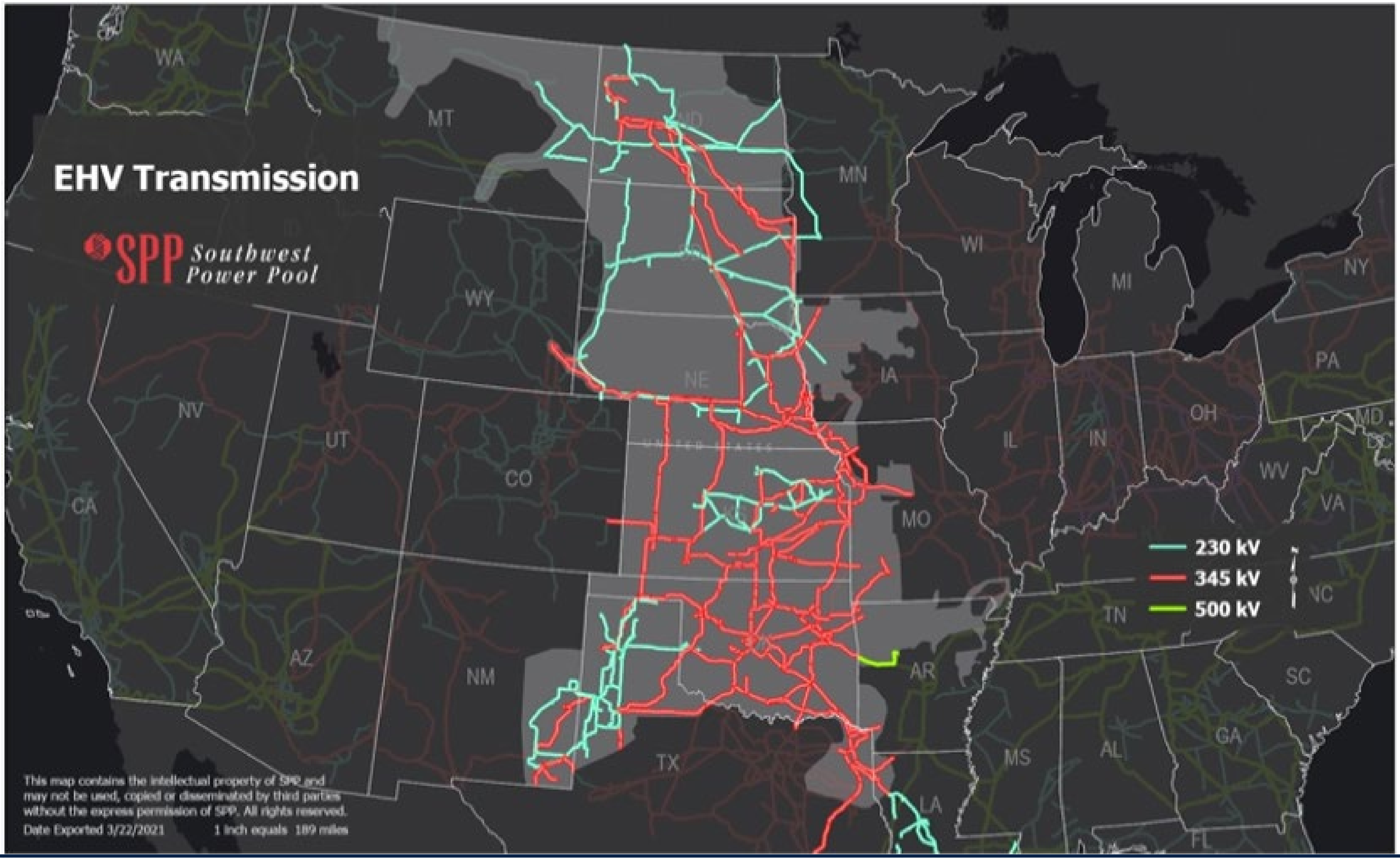
Cluster	MW	Projects
01 NORTH	**10,202.10**	**53**
Battery/Storage	901.10	6
Hybrid	650.00	4
Solar	3,851.00	17
Thermal	700.65	5
Wind	4,099.35	21
02 NEBRASKA	**15,537.60**	**83**
Battery/Storage	1,830.00	13
Hybrid	2,252.00	12
Solar	6,232.47	33
Thermal	1,285.56	7
Wind	3,937.57	18
03 CENTRAL	**36,522.08**	**186**
Battery/Storage	6,780.78	49
Hybrid	3,930.00	14
Solar	15,768.22	76
Thermal	166.56	4
Wind	9,876.52	43
04 SOUTHEAST	**33,726.95**	**175**
Battery/Storage	9,376.40	63
Hybrid	3,434.60	19
Solar	14,816.11	68
Thermal	139.00	2
Wind	5,960.84	23
05 SOUTHWEST	**22,065.56**	**99**
Battery/Storage	3,105.00	20
Hybrid	3,030.00	12
Solar	8,493.27	39
Thermal	1,262.00	3
Wind	6,175.29	25
Total	**118,054.29**	**596**

Disclaimer: The data provided is for information purposes only and is subject to change without notification. Questions? Email: gistudies@spp.org.
Click HERE for SPP GI Web Site. Click HERE for Study Region Map

SPP Transmission at a Glance

<u>Miles of Transmission</u>

- 69 kV 17,982
- 115 kV 16,677
- 138 kV 9,942
- 161 kV 5,677
- 230 kV 7,604
- 345 kV 12,052
- 500 kV 91



Who's in Charge of SPP's Resource Adequacy?

STATE REGULATORS' ROLE

- Regional State Committee —
  Retail regulatory commissioners from:

Arkansas	Missouri	Oklahoma
Iowa	Nebraska	South Dakota
Kansas	New Mexico	Texas
Louisiana	North Dakota	

- Primary responsibility for:
  - Cost allocation for transmission upgrades
  - Approach for regional resource adequacy
  - Allocation of transmission rights in SPP's markets

NERC Assessment vs Reality

- NERC assumes coal plants will stay online through 2032, giving SPP plenty of reserve margin.

SPP

Highlights

- ARMs do not fall below the RML for this assessment period.
- In 2022, the SPP Board approved an increase in PRMs for load responsible units from 12% to 15%. The Board also approved performance-based capacity accreditation rules for conventional resources. The two actions are aimed at ensuring sufficient resources are procured and available to meet peak demand as the resource mix evolves. Changes will go into effect in 2023.

SPP Fuel Composition (MW)										
Fuel	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Coal	24,226	24,226	24,226	24,226	24,226	24,226	24,226	24,226	24,226	24,226
Petroleum	1,849	1,849	1,849	1,849	1,849	1,849	1,849	1,849	1,849	1,849
Natural Gas	30,938	30,938	30,938	30,938	30,938	30,938	30,938	30,938	30,938	30,938
Biomass	43	43	43	43	43	43	43	43	43	43
Solar	631	2,506	2,506	2,486	2,482	2,478	2,477	2,473	2,468	2,468
Wind	10,188	11,038	14,288	14,291	14,289	14,288	14,286	14,284	14,284	14,282
Conventional Hydro	4,941	4,941	4,941	4,941	4,941	4,941	4,941	4,941	4,941	4,941
Run-of-River Hydro	18	18	18	18	18	18	18	18	18	18
Pumped Storage	444	444	444	444	444	444	444	444	444	444
Nuclear	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949	1,949
Other	601	661	661	661	661	661	661	661	661	661
Total MW	75,827	78,613	81,862	81,845	81,840	81,835	81,831	81,826	81,821	81,818

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