Early Results of the 100% Study

Briefing to the 100% Study Working Group

May 4, 2023

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Study Scope

Scope based on requirements in the Clean Energy Jobs Act (CEJA) of 2019 and correspondence with State Senator Brian Feldman in February 2021.

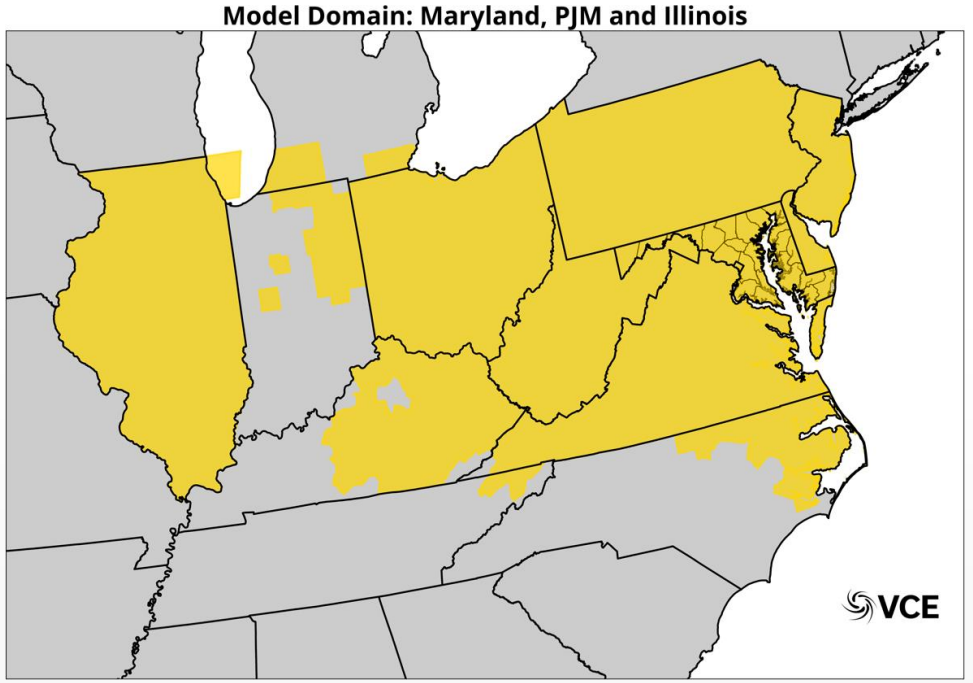
- Redo selected portions of the Maryland RPS Study that PPRP submitted to the Maryland General Assembly in December 2019
- Assess the costs and benefits of a 100% RPS and a 100% clean energy standard by 2040
- Determine which industries and communities could be positively and negatively impacted
- Design mechanisms to alleviate any negative impacts on affected workers and communities
- Provide recommendations for changes to the Maryland RPS or make recommendations for incorporation into future proposals for a Maryland clean energy standard

Status

- Four scenarios have been modeled
  - Base case (economic run with current Maryland RPS)
  - 100% RPS (assumes Calvert Cliffs goes off-line when operating license expires)
  - 100% clean energy (modeled after proposed, but not enacted, Clean and Renewable Energy Standard)
  - 100% RPS with Calvert Cliffs
- A fifth scenario was used to make technical corrections
- We have 20 scenarios budgeted and have 15 left
- One goal of this meeting is to get feedback on what scenarios to model next

Important Assumptions

- Modeling PJM only plus the entire state of Illinois
- Using 2020 early release data from EIA, with constraints for 2021 and 2022
- County-by-county modeling for Maryland; statewide elsewhere
- Except for the 100% RPS with Calvert Cliffs scenario, we assume Calvert Cliffs goes offline after the expiration of the NRC operating license in 2034 (Unit 1) and 2036 (Unit 2)
- EmPOWER MD assumed to expire at the end of 2023
- All "Round 1" and "Round 2" offshore wind capacity in Maryland is assumed to come online in 2027
- Recently enacted legislation setting targets for 8.5 GW of offshore wind by 2031 and 3 GW of energy storage by 2033 are not reflected in these results
- Climate Solutions Now Act (and other state greenhouse gas (GHG) emission reduction goals) were **NOT** modeled as binding constraints



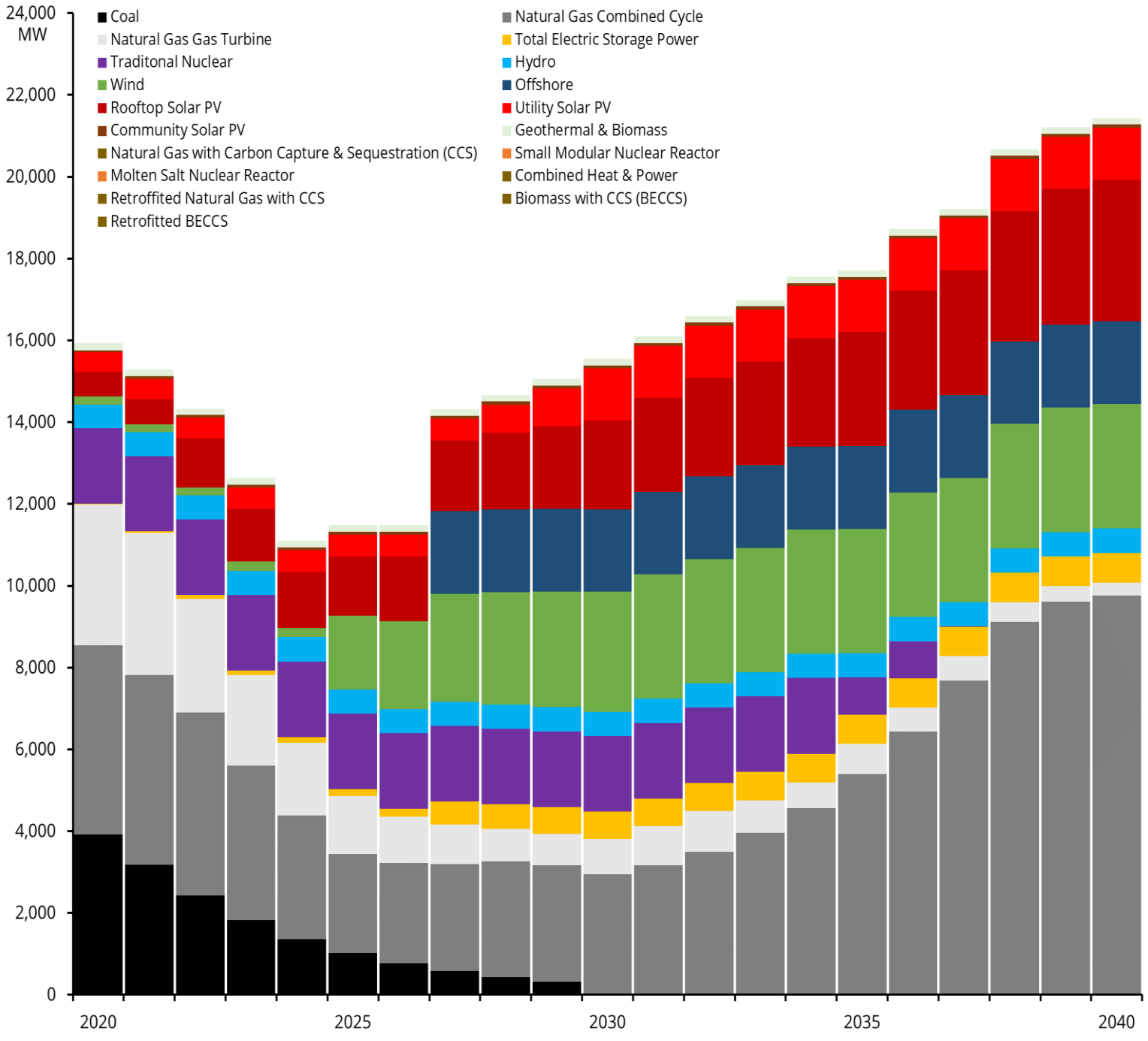
High-Level Findings (Maryland)

- Not a lot of difference in capacity and generation in Maryland between Business as Usual (BAU) and 100% RPS
  - Substantial amounts of renewables are added in all four scenarios
  - Natural gas capacity is added as coal capacity and Calvert Cliffs are retired (assuming Calvert Cliffs is not relicensed)
- Keeping Calvert Cliffs online results in slightly less natural gas capacity in Maryland but a more significant reduction of natural gas capacity in PJM
- 100% Clean results in additional advanced nuclear and CCS capacity and generation
- Maryland becomes a power exporter in all scenarios
  - Access to gas transportation
  - Access to transmission
  - Proximity to major loads

High-Level Findings (Maryland) (cont.)

- For all scenarios, the quantity of individual air pollutants decline rapidly but increase towards the end of the forecast period, although not to the levels at the beginning of the forecast period
  - Methane emissions an exception, projected to increase by nearly 50% over 2020 levels in all scenarios except where Calvert Cliffs remains online
  - Nitrogen oxides also increase by 2040, although not nearly as much as methane
- Results point to the need for "clean firm" capacity, especially in the latter half of the forecast period, to meet Maryland GHG emission reduction goals

Business as Usual Scenario

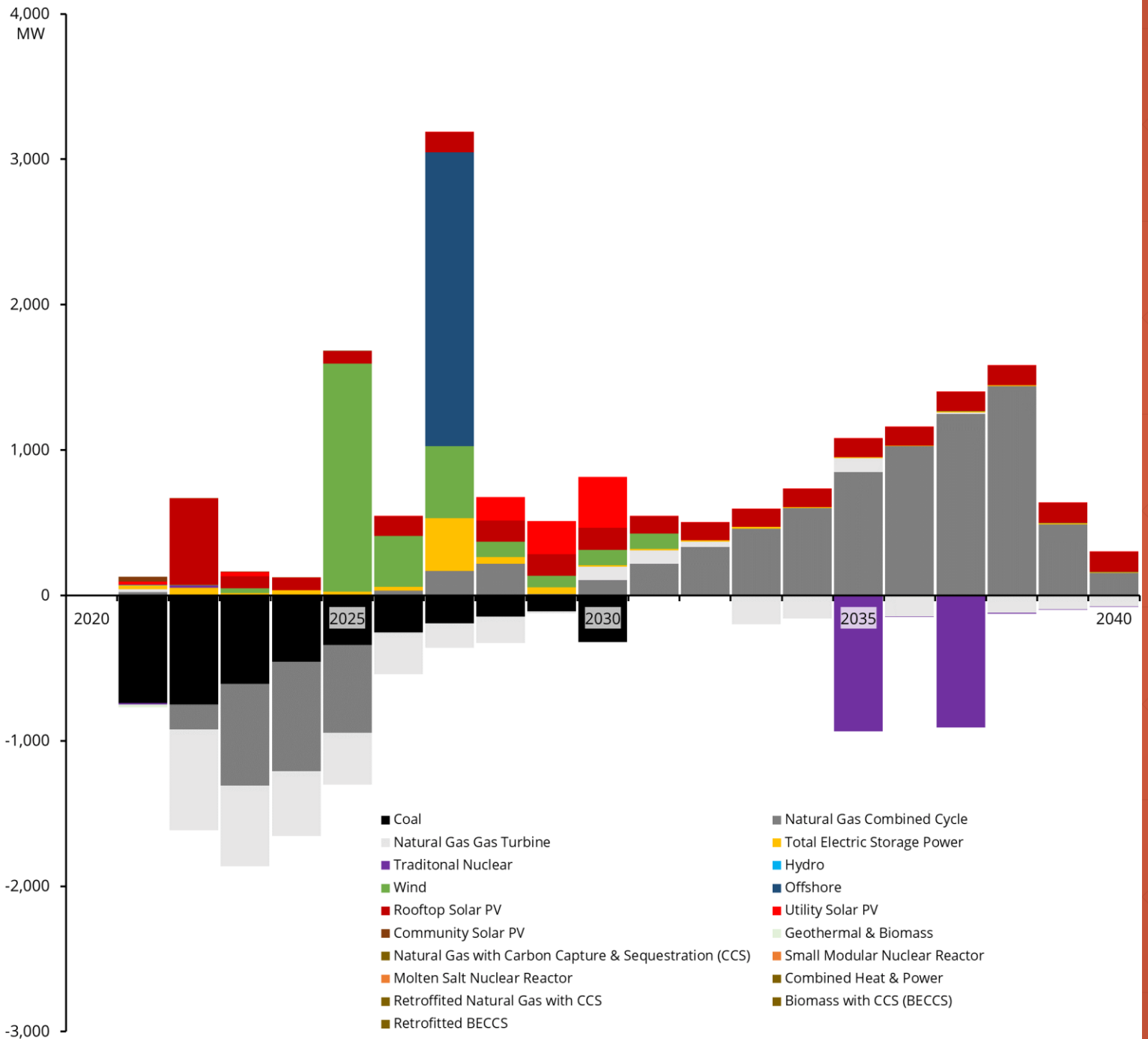


Installed Capacity in Maryland, 2020-2040 (BAU Scenario)

Steady increases in onshore wind and solar capacity

Retirement of coal by 2030

Reduction in natural gas combined cycle capacity by 2030, then sharp increases after that

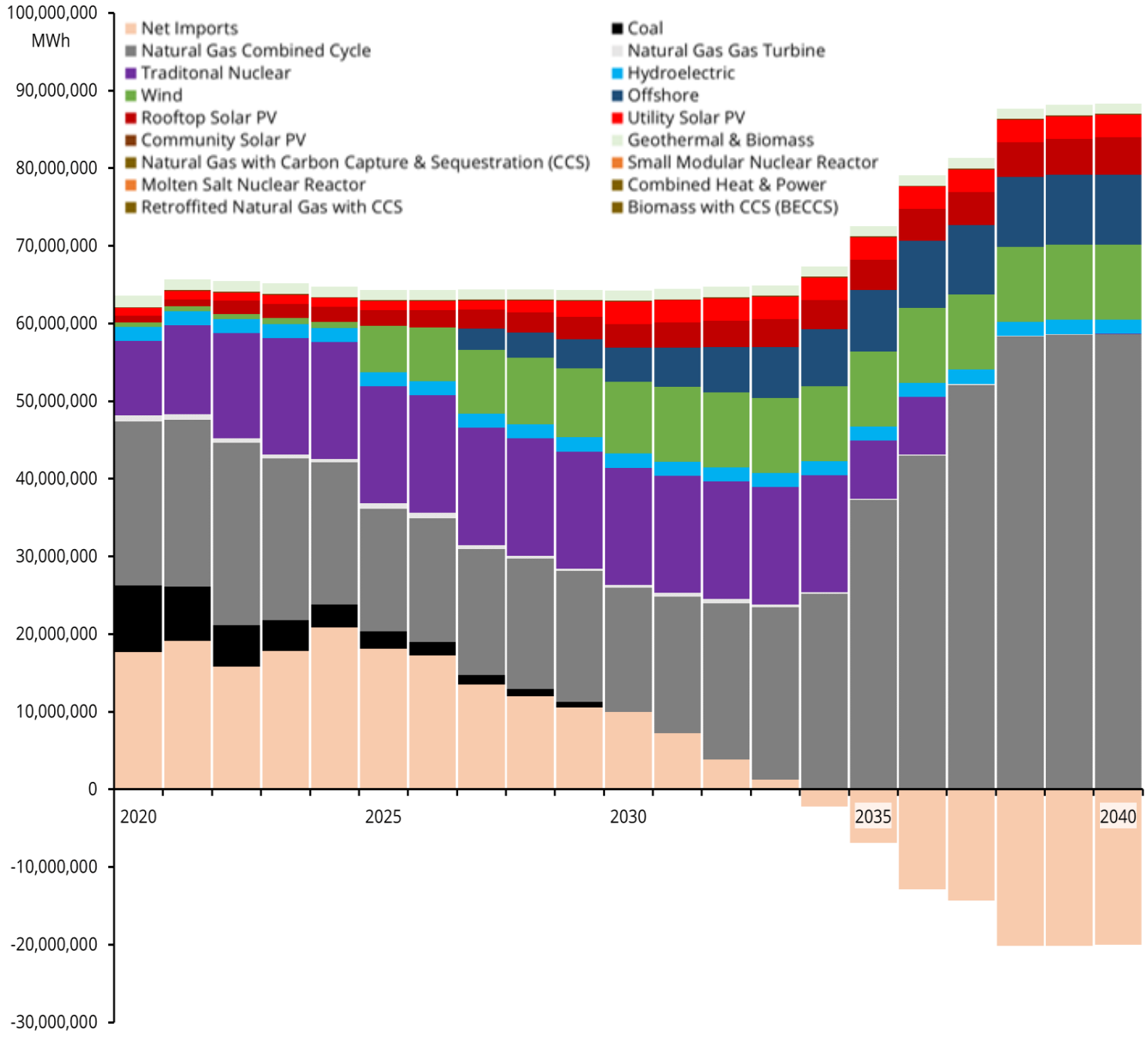


Annual Capacity Installations and Retirements by Technology in Maryland, 2020-2040 (BAU Scenario)

Retirement of coal and natural gas facilities by 2030 accompanied by new renewables

New renewables capacity largely stops by 2030

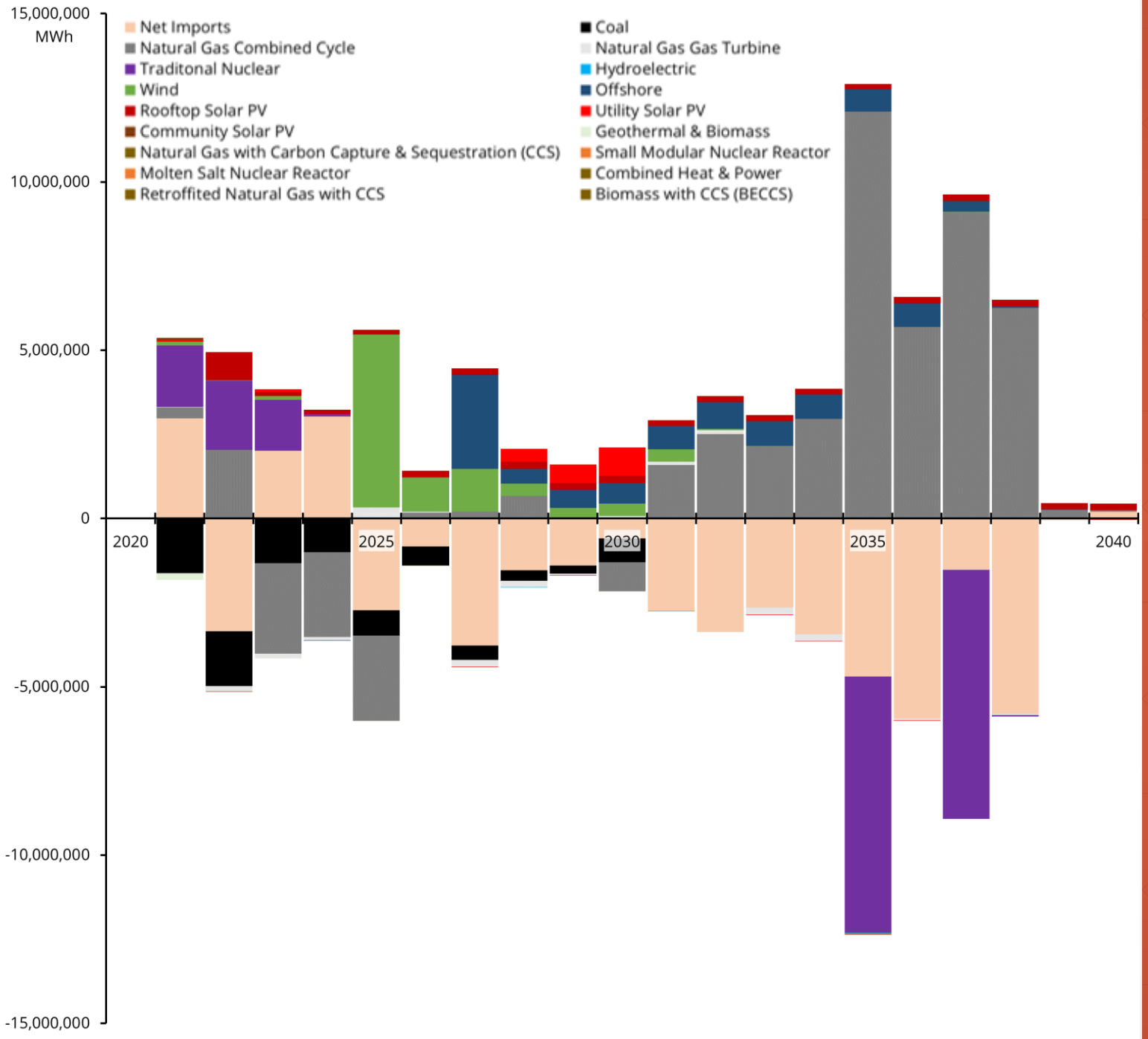
New natural gas installations increase from about 2029 to 2036, especially when Calvert Cliffs is retired



Generation in Maryland, 2020-2040 (BAU Scenario)

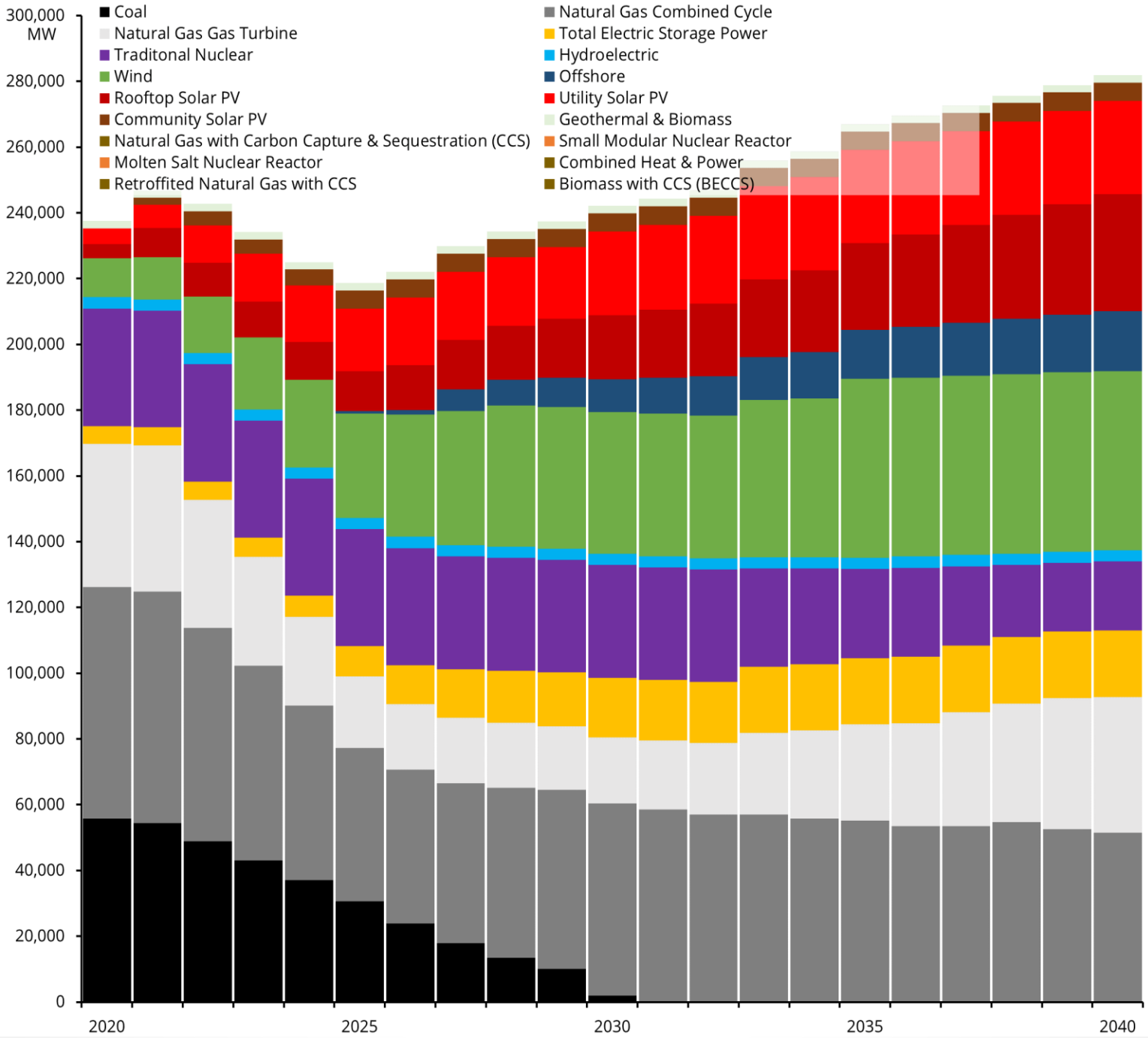
Rapid rise in combined cycle natural gas generation when Calvert Cliffs retires

Maryland turns from power importer to power exporter by 2034



Annual Change in Generation in Maryland, 2020-2040 (BAU Scenario)

Increase in natural gas generation is seen due to Calvert Cliffs retirements

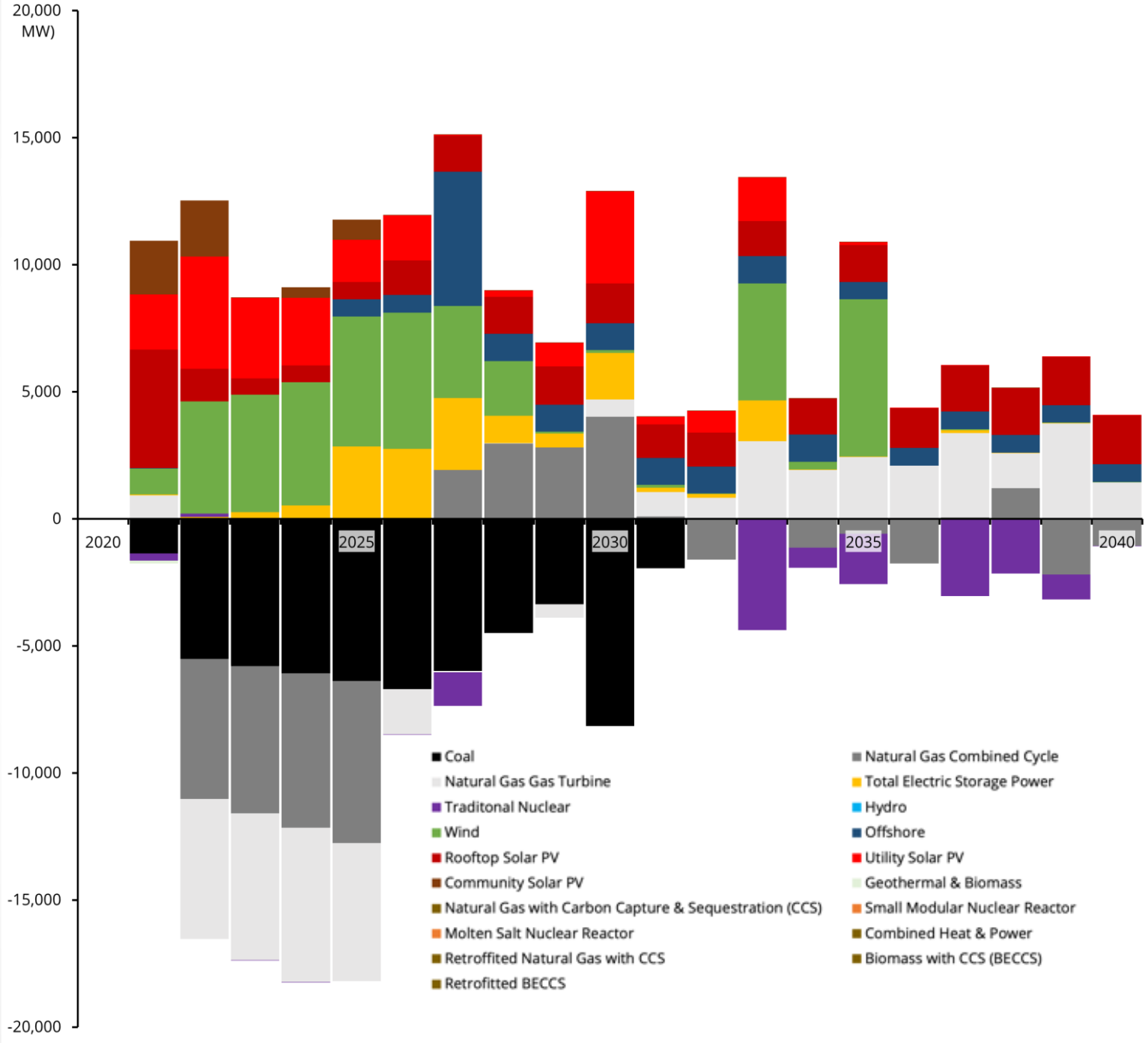


Total Installed Capacity in PJM/IL, 2020-2040 (BAU Scenario)

Total installed coal capacity vanishes by 2031

Rapid growth of utility-scale solar, distributed solar, onshore wind, and, to a lesser extent, battery storage

Although overall nuclear power capacity decreases over time, nuclear power remains in the mix for the entire forecast period



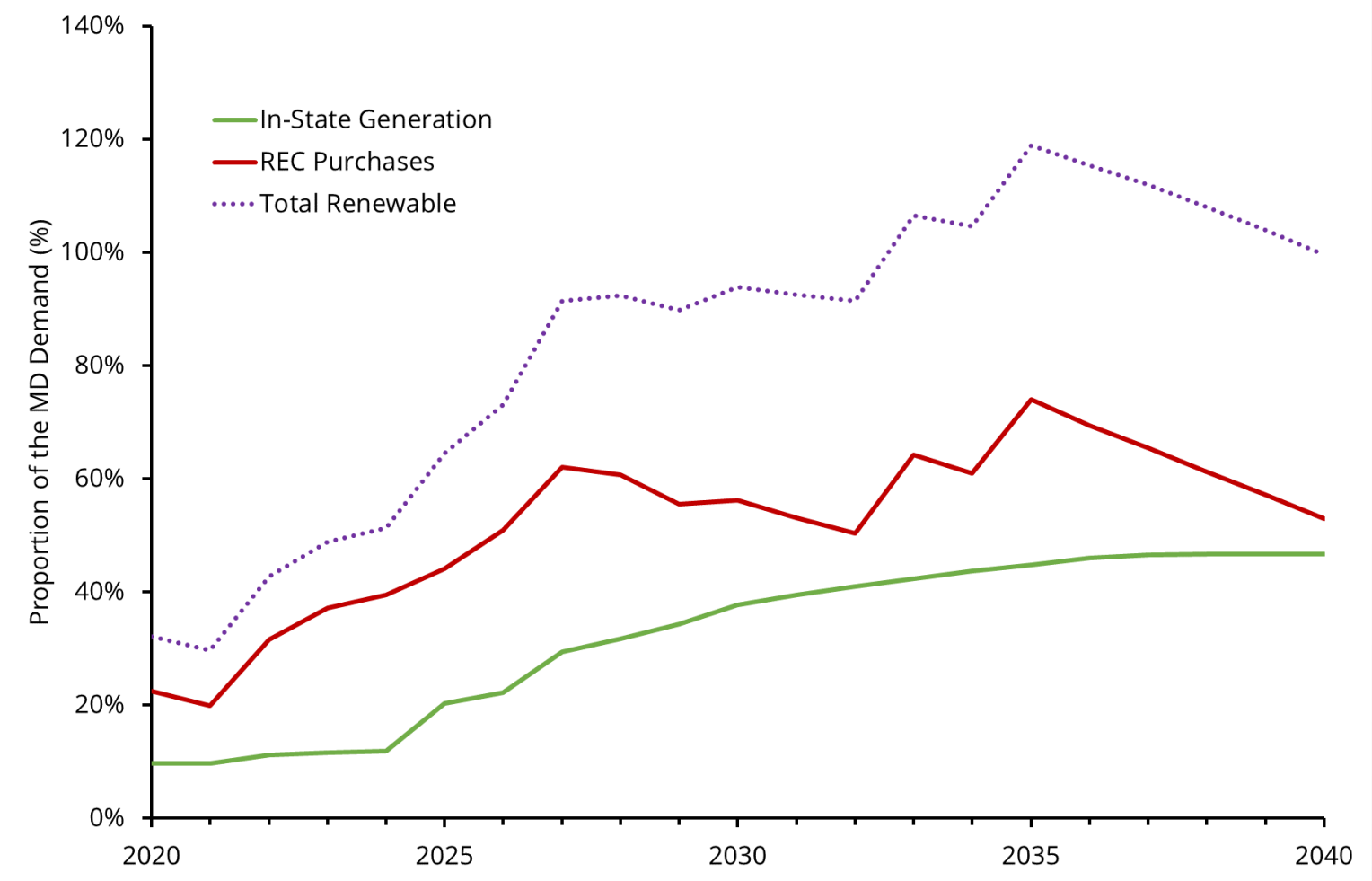
Annual Capacity Installed/Retired in PJM/IL by Year, 2020-2040 (BAU Scenario)

Steep retirements of coal and natural gas in PJM until 2031. Some of this is presumably driven by the Illinois Climate and Equitable Jobs Act

Some natural gas capacity retirements offset by new additions of natural gas combined cycle and combustion turbines beginning in 2026

Robust expansion of wind, solar and battery storage

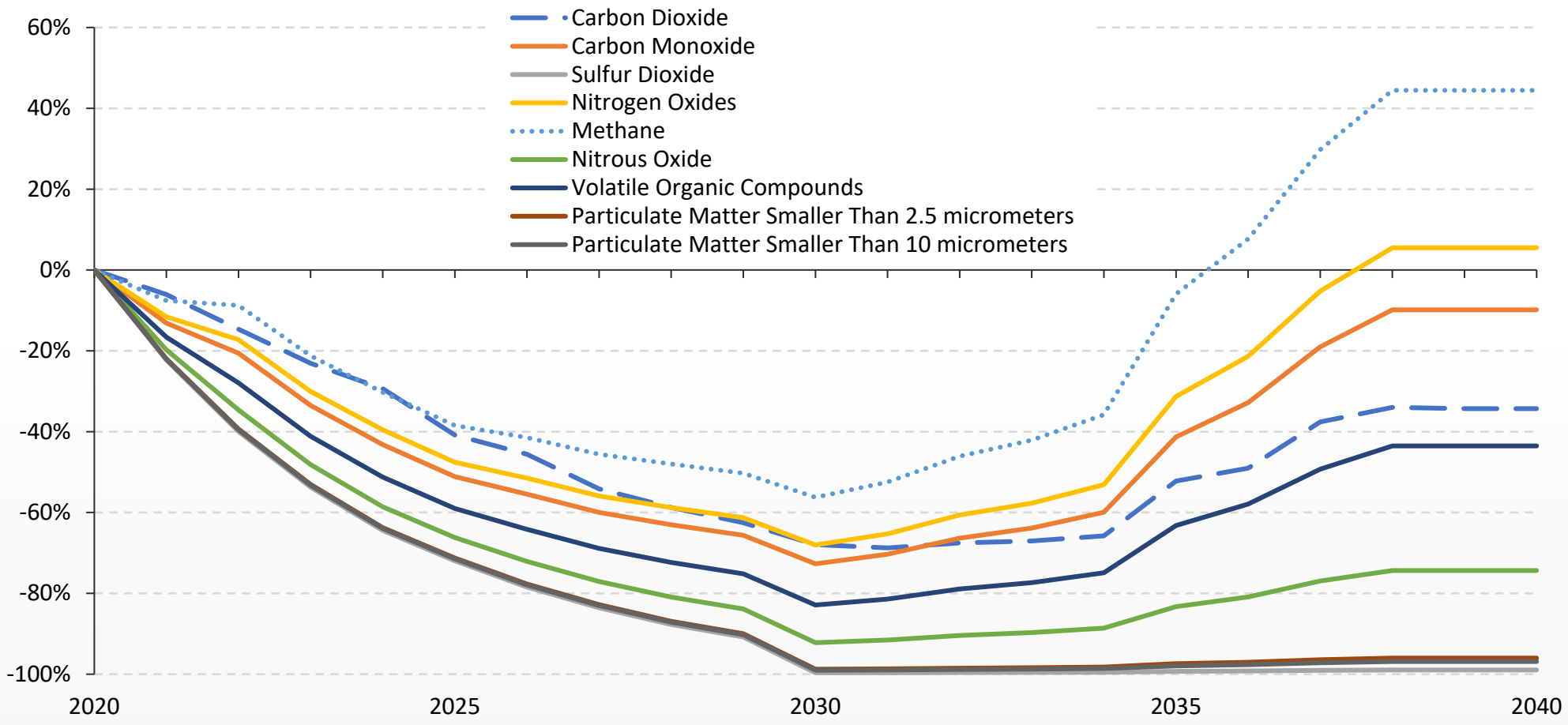
Nuclear replaced by 3x capacity in 2033



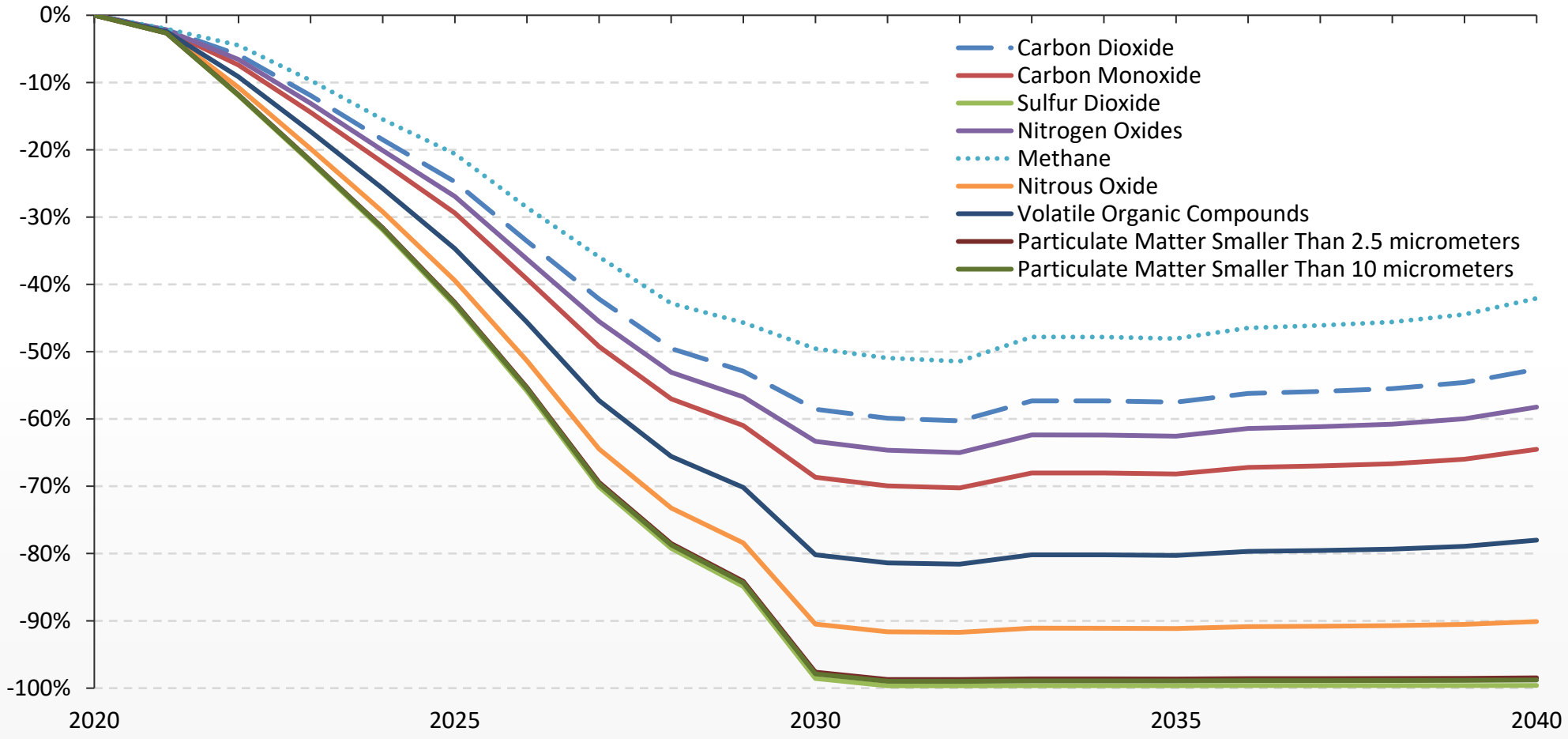
RPS Compliance Mix (BAU Scenario)

Although the amount varies by year, Maryland RPS compliance under the BAU scenario has slightly more REC purchases than in-state generation

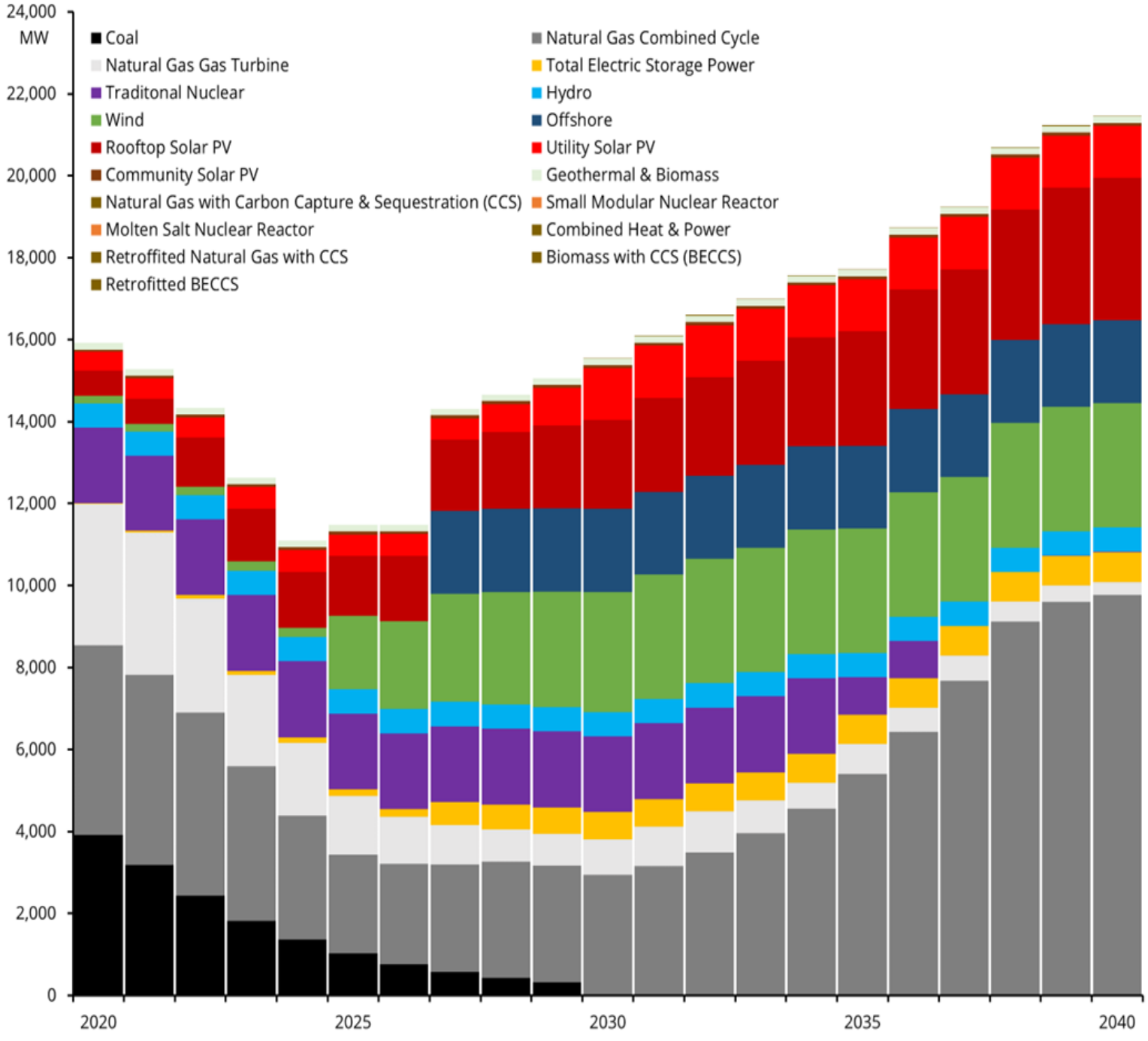
Percent Change in Air Emissions in Maryland, 2020-2040 (BAU Scenario)



Percent Reduction in Air Emissions in PJM/IL, 2020-2040 (BAU Scenario)

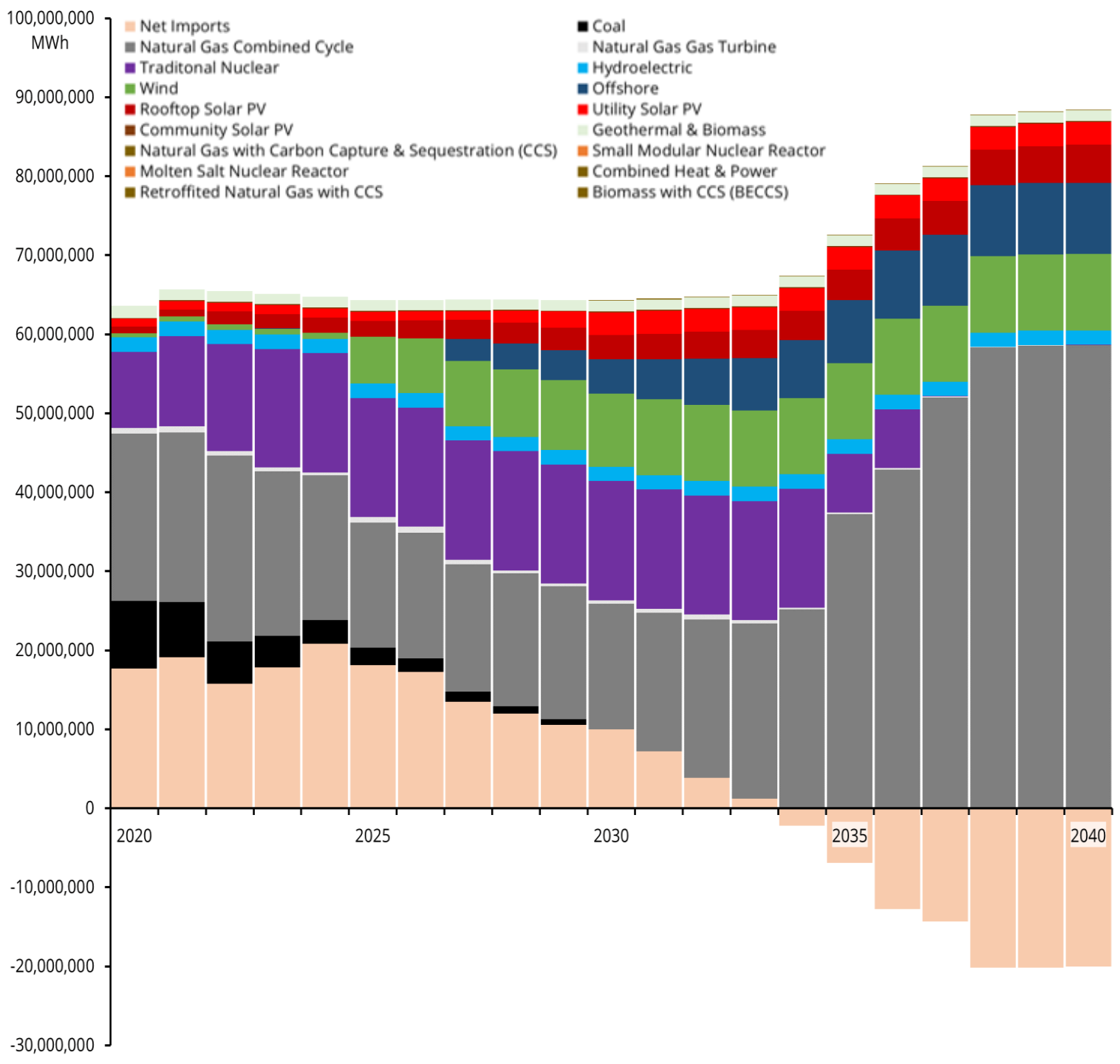


100% RPS Scenario



Installed Capacity in Maryland, 2020-2040 (100% RPS Scenario)

Very similar results to BAU scenario, with retirement of coal by 2030 and increase in natural gas combined cycle capacity in the second half of the forecast period

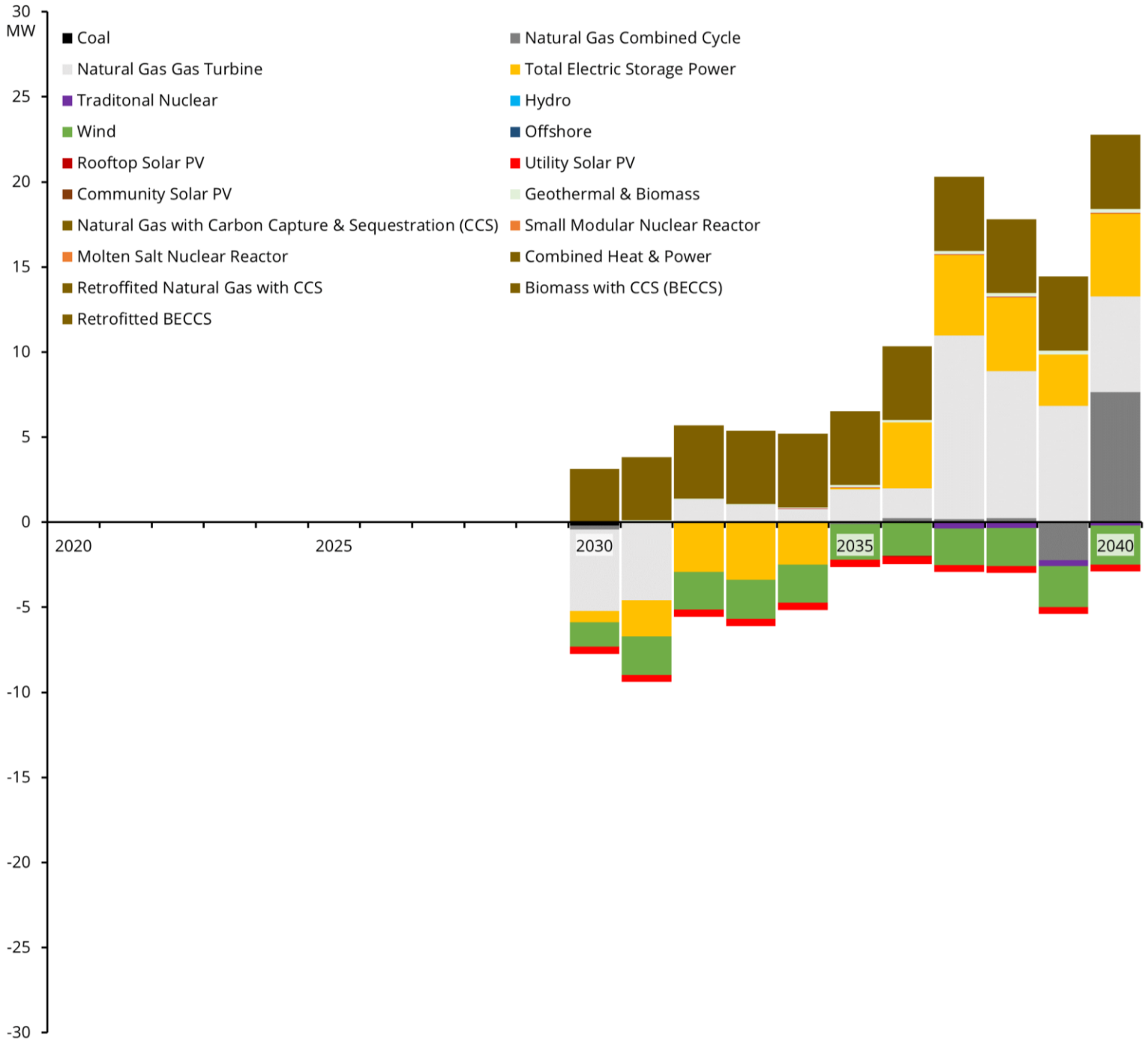


Generation in Maryland, 2020-2040 (100% RPS Scenario)

Again, very similar results to BAU scenario

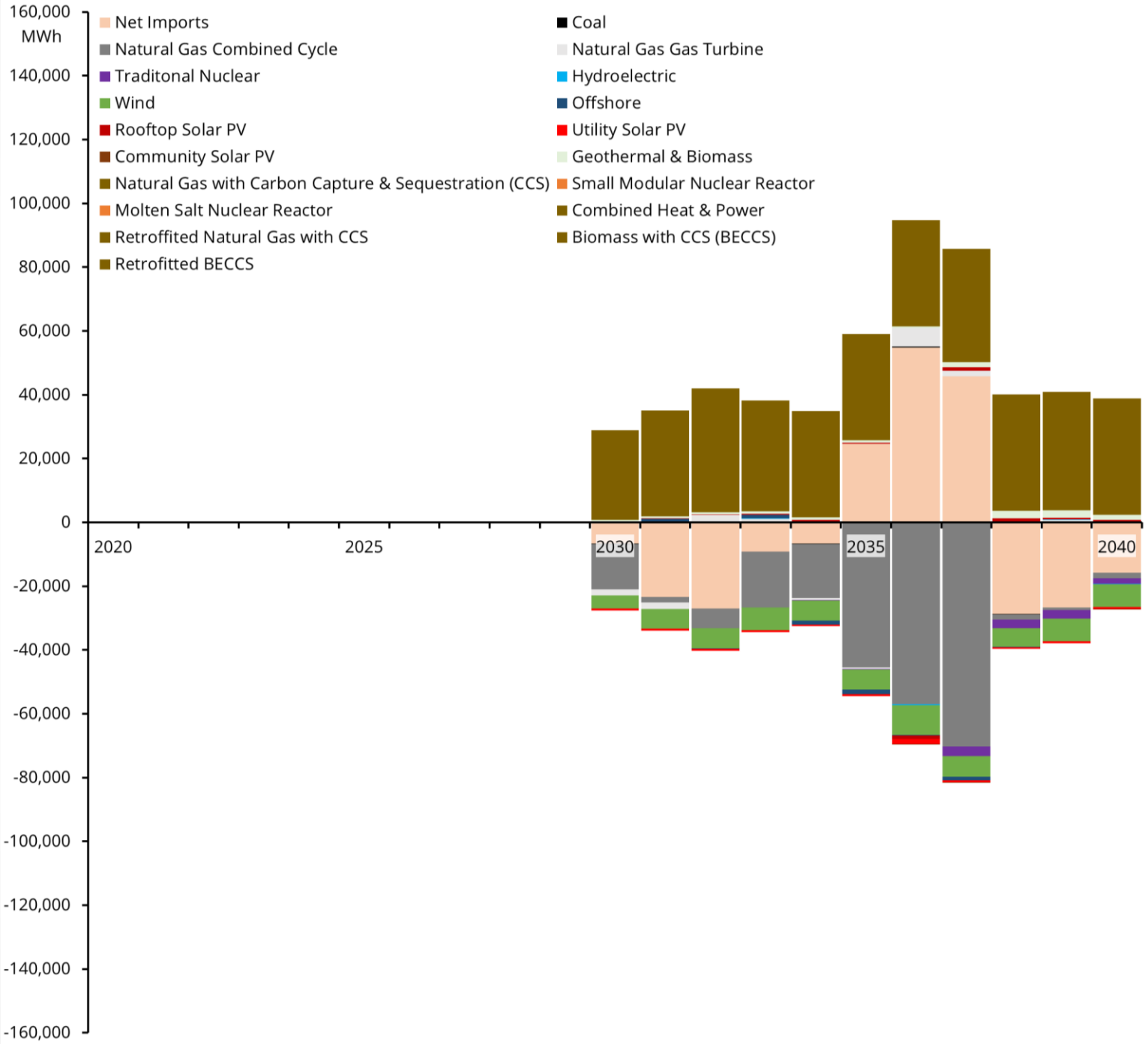
Rapid rise in combined cycle natural gas generation when Calvert Cliffs retires

Maryland turns from power importer to power exporter by 2034



Difference in Installed Capacity in Maryland Between 100% RPS Scenario and BAU

Very small differences between the two scenarios (note scale)



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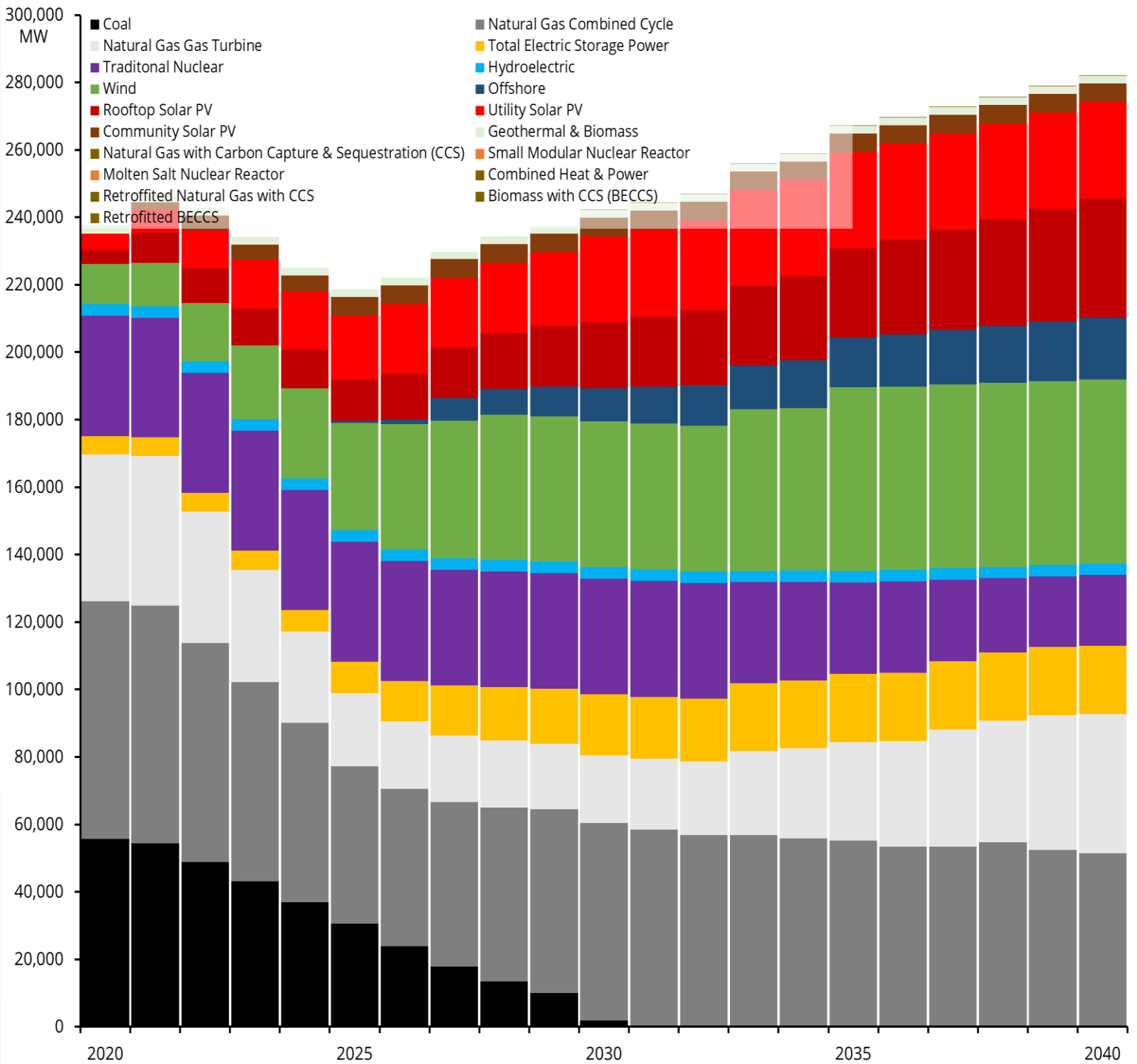
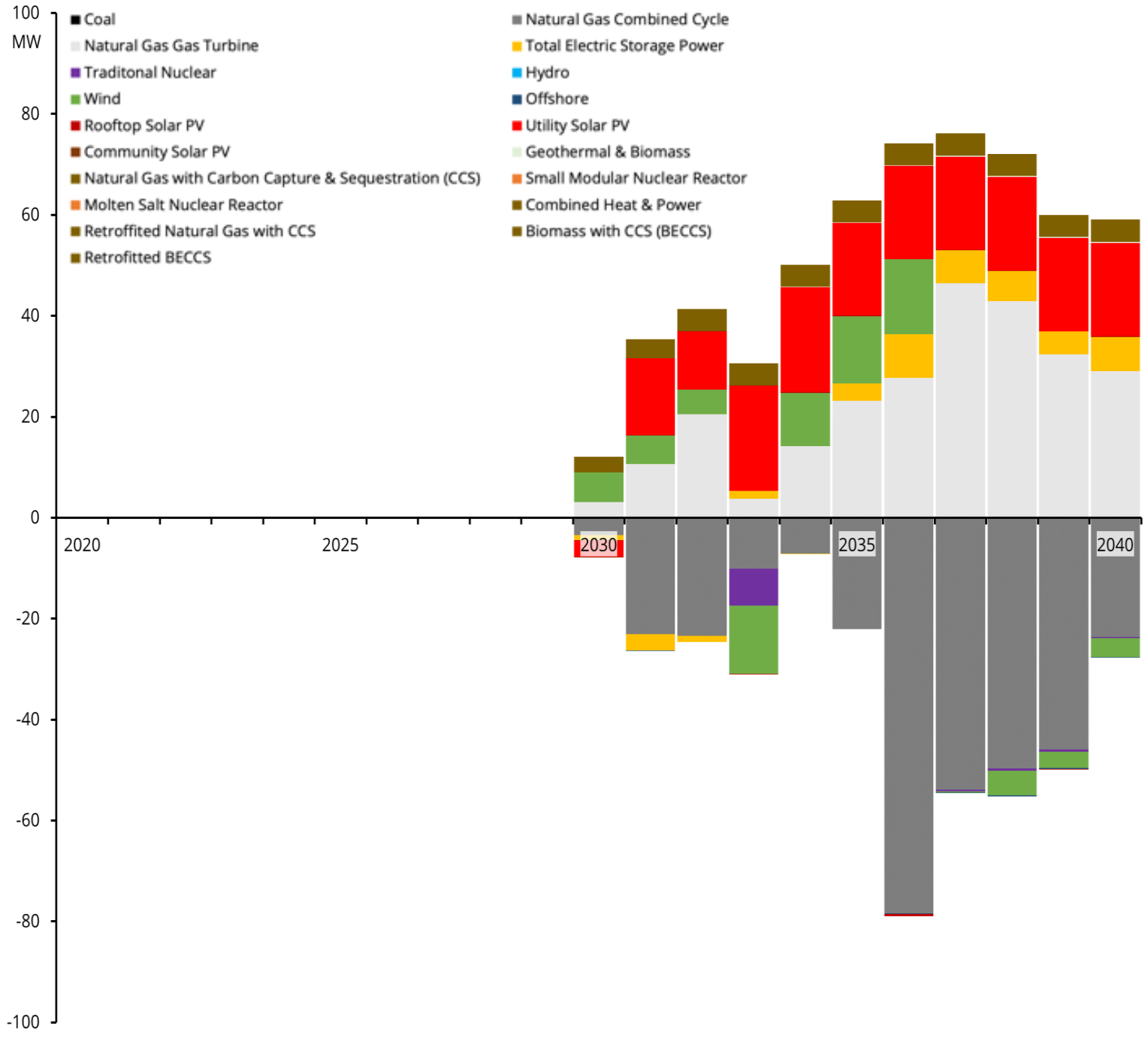


Total Installed Capacity in PJM/IL, 2020-2040 (100% RPS Scenario)

Total installed coal capacity vanishes by 2031

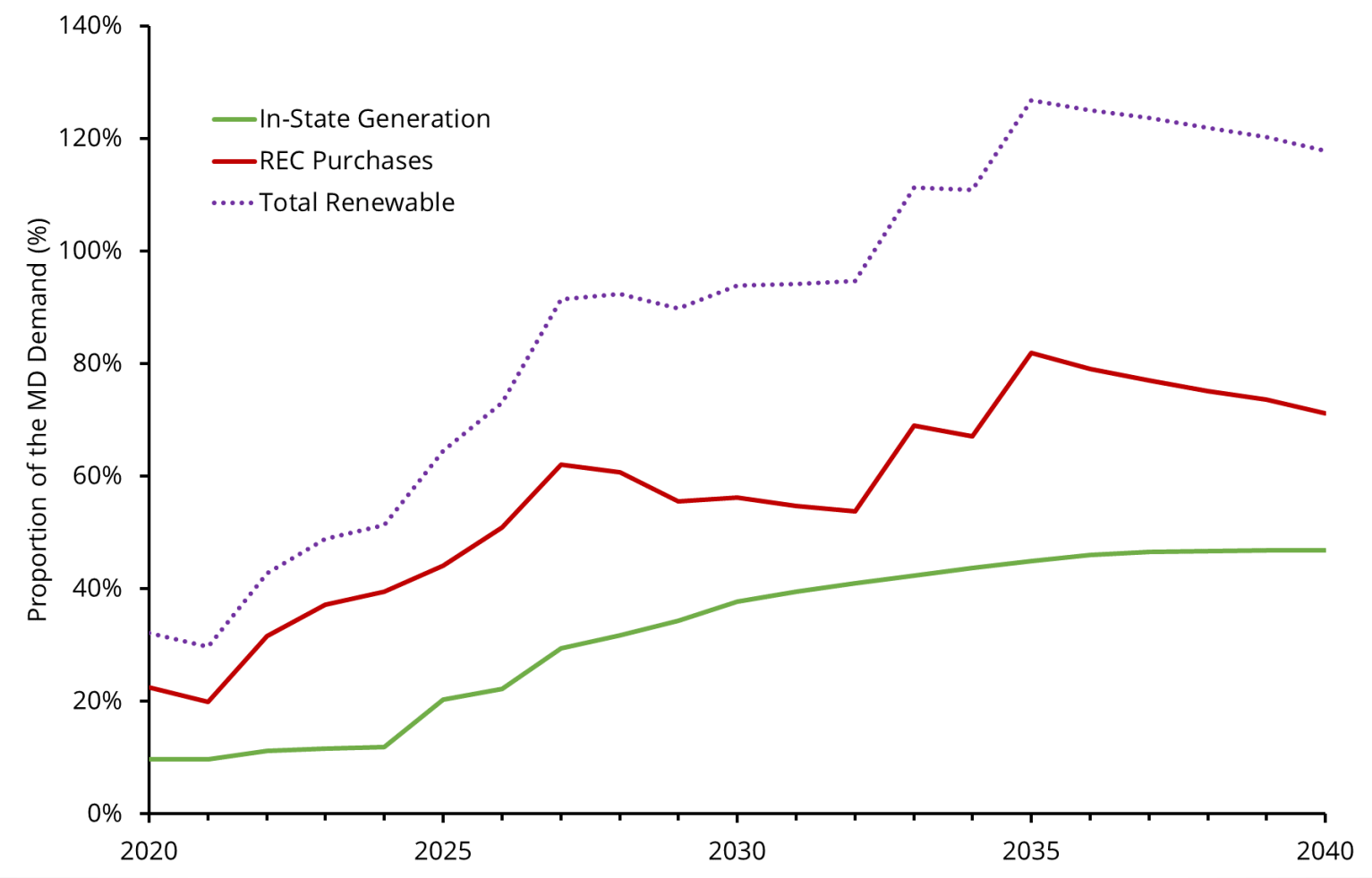
Rapid growth of utility-scale solar, distributed solar, onshore wind, and, to a lesser extent, battery storage

Although overall nuclear power capacity decreases over time, nuclear power remains in the mix for the entire forecast period



Difference in Installed Capacity in PJM/IL Between BAU and 100% RPS Scenario

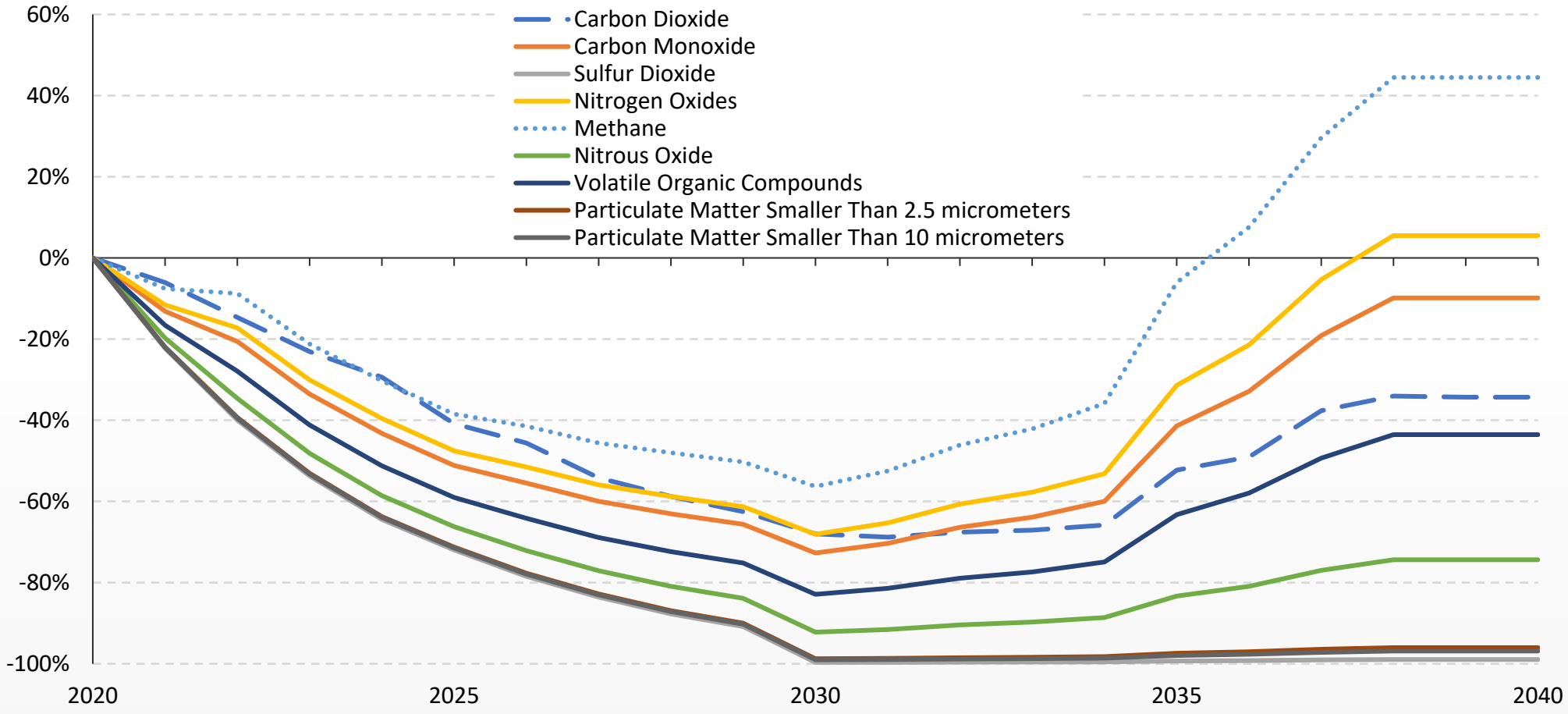
- Very small difference in capacity between the two scenarios (note scale)
- More utility-scale solar capacity is added
- Wind capacity is also added in some years but reduced in other years
- Natural gas combustion turbine capacity is added in place of combined cycle units



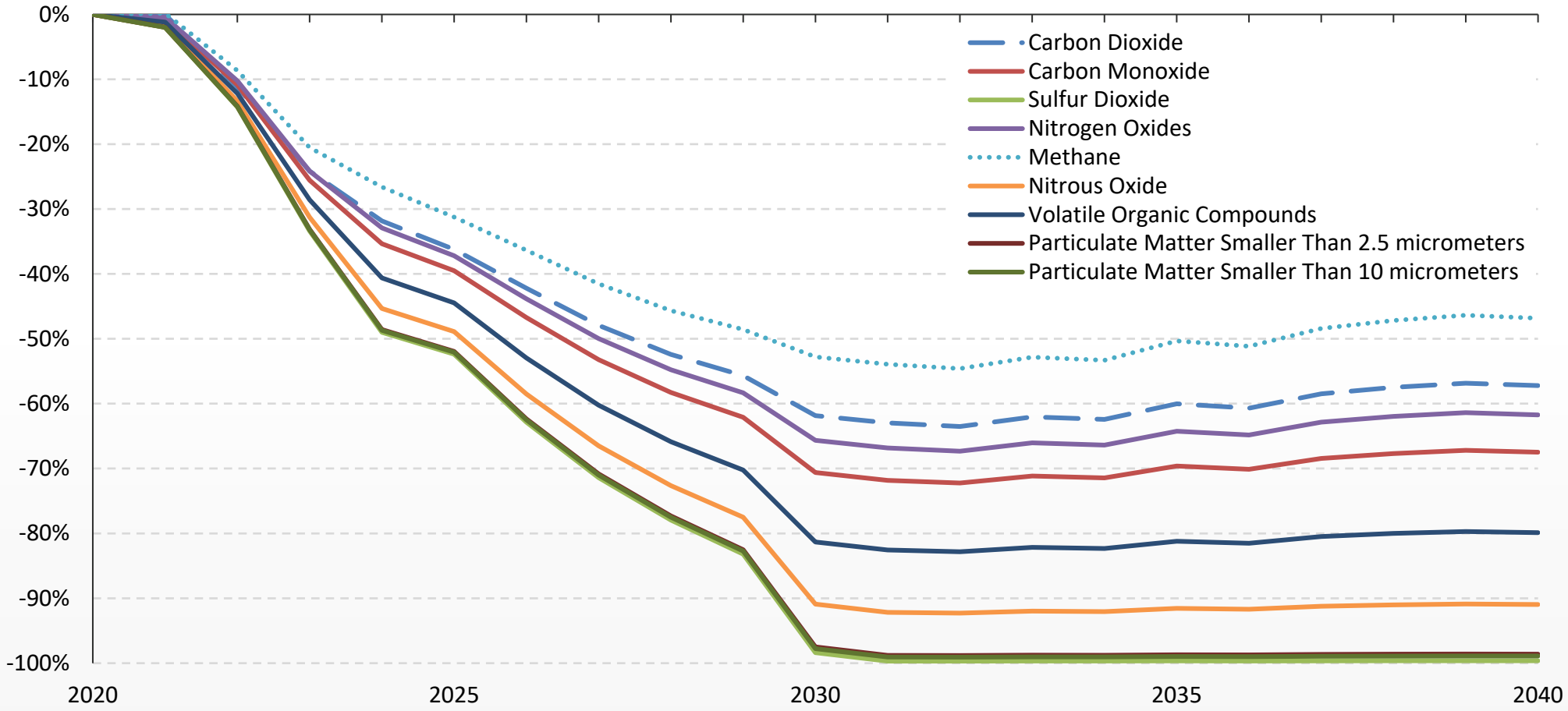
RPS Compliance Mix (100% RPS Scenario)

Although the amount varies by year, Maryland RPS compliance under the 100% RPS scenario has more REC purchases than in-state generation

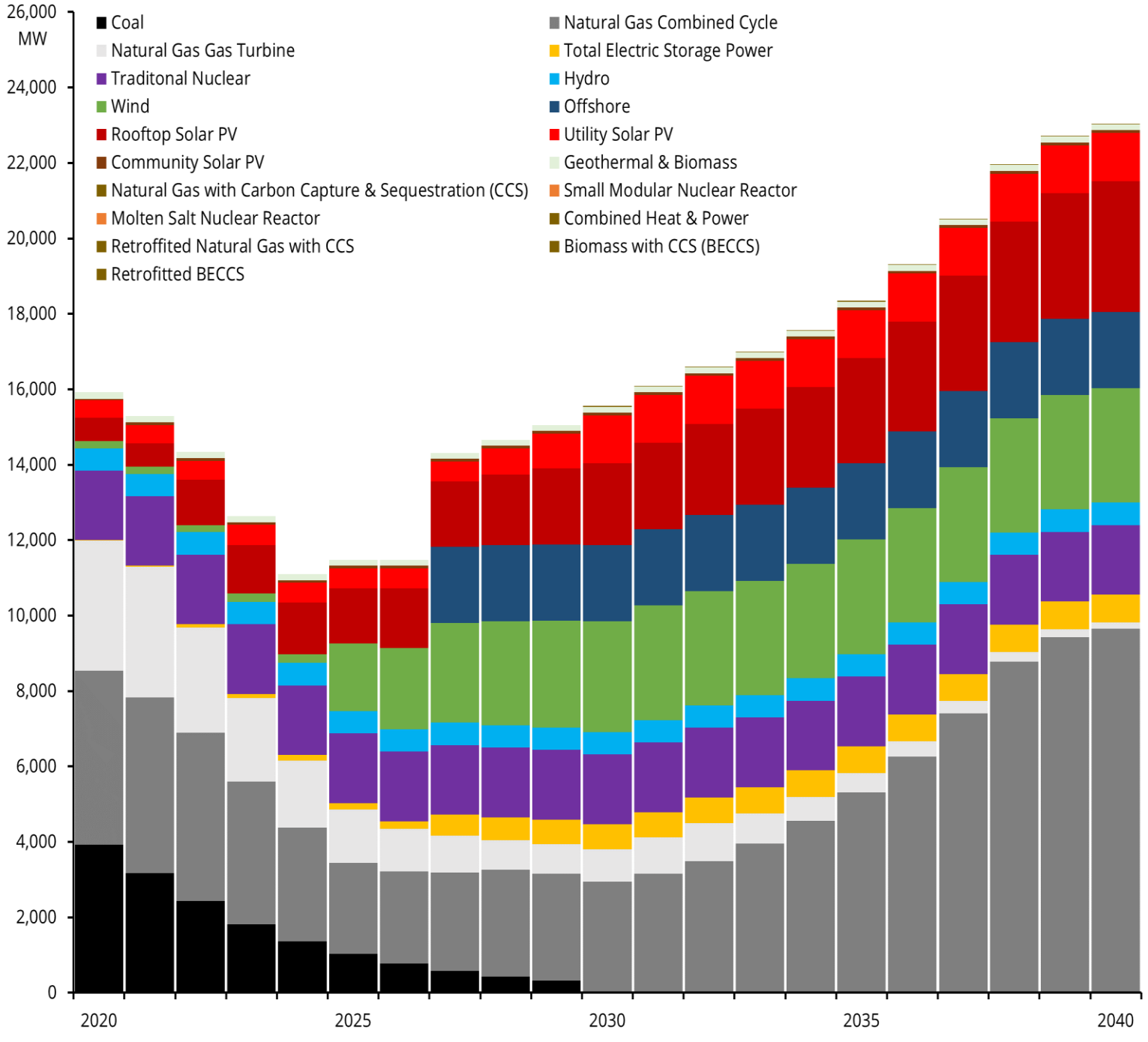
Percent Change in Air Emissions in Maryland, 2020-2040 (100% RPS Scenario)



Percent Reduction in Air Emissions in PJM/Illinois, 2020-2040 (100% RPS Scenario)



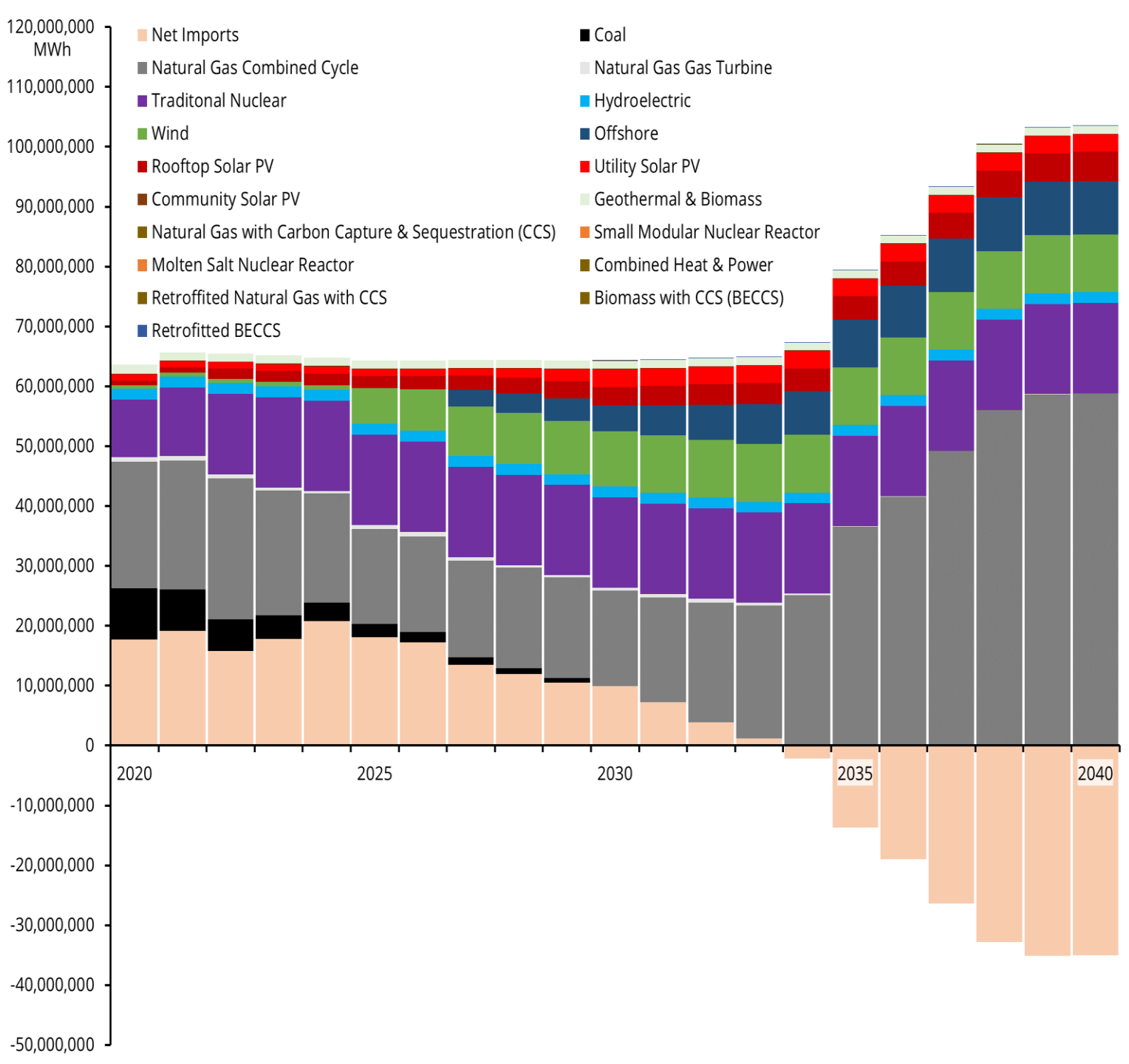
100% RPS Scenario with Calvert Cliffs



Installed Capacity in Maryland (100% RPS Scenario with Calvert Cliffs)

Very similar to 100% RPS scenario

Overall capacity increases with continuation of Calvert Cliffs

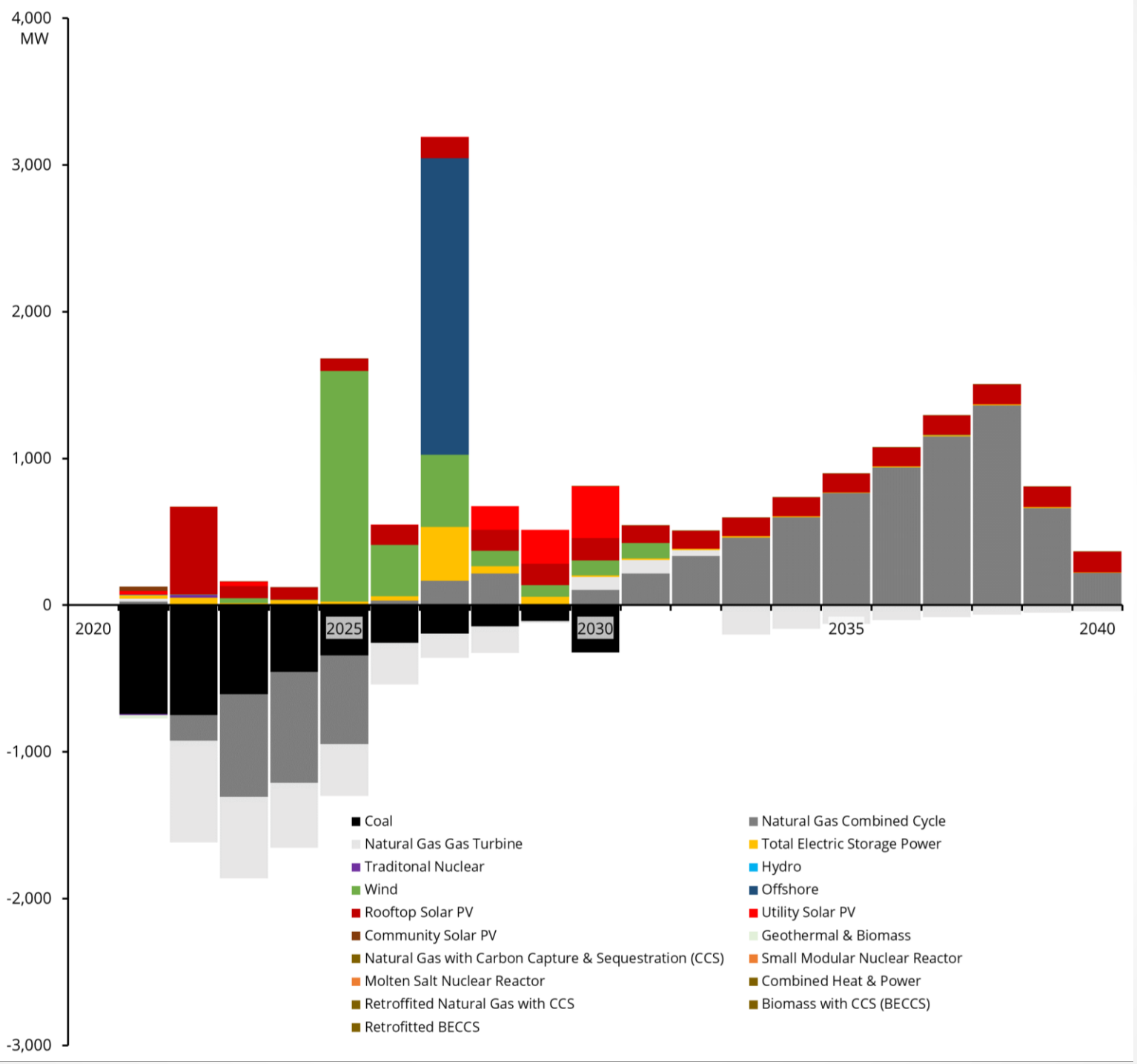


Generation in Maryland, 2020-2040 (100% RPS Scenario with Calvert Cliffs)

Very similar to 100% RPS scenario

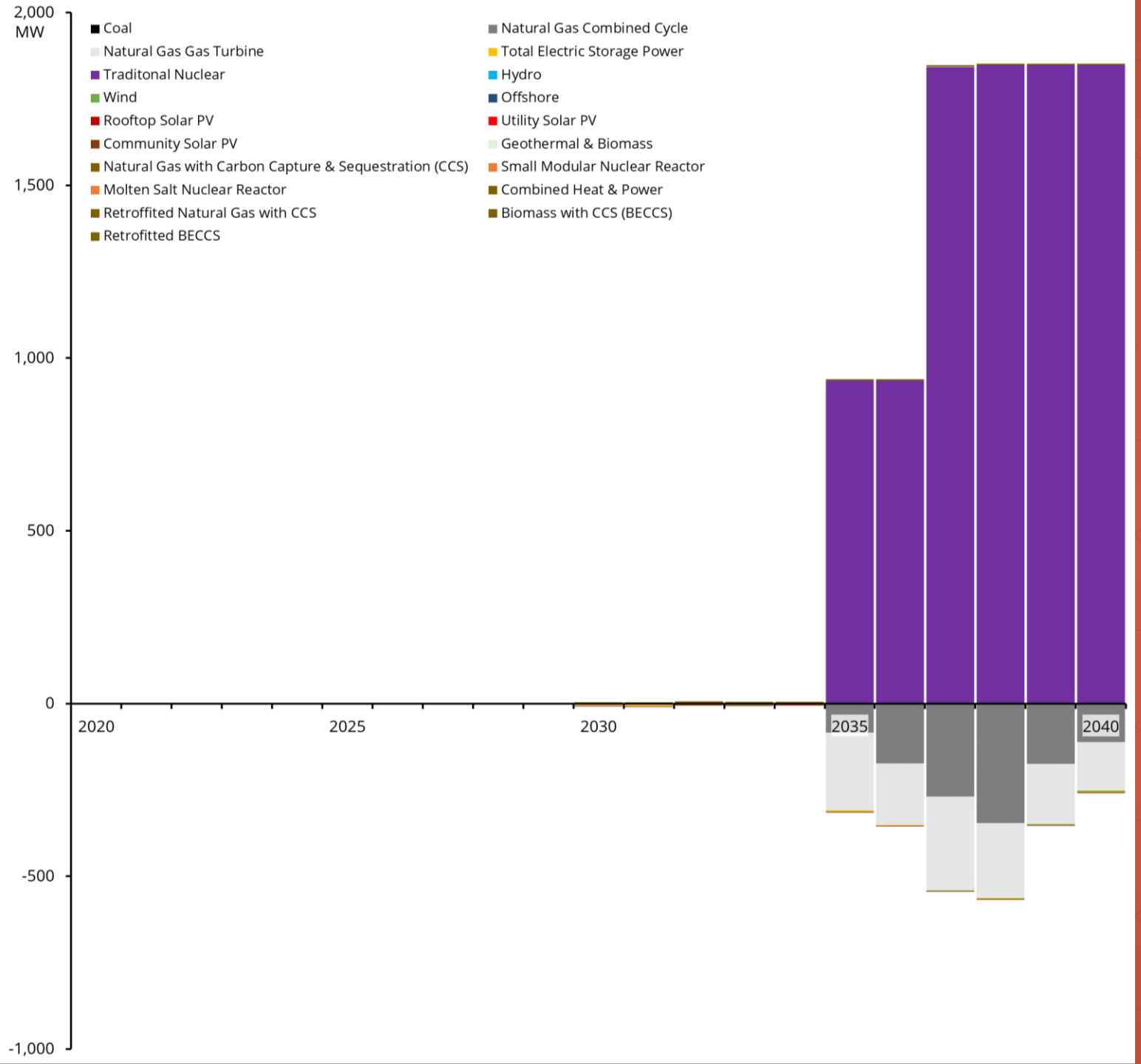
Some natural gas generation displaced by nuclear compared to 100% RPS scenario

Exports slightly increase compared to 100% RPS scenario



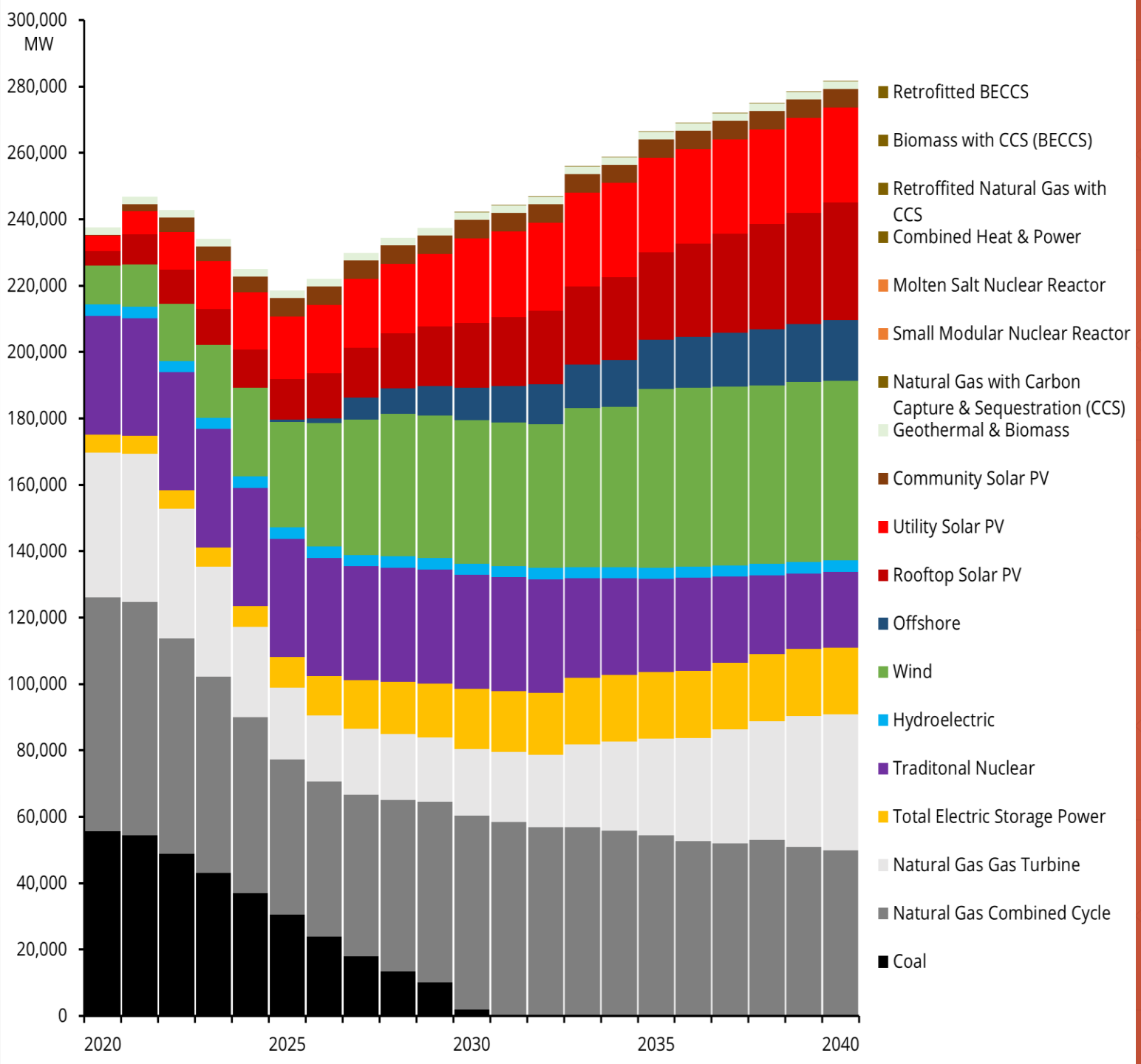
Annual Capacity Installed in Maryland (100% RPS Scenario with Calvert Cliffs)

About 500 MW less natural gas capacity installed after 2033 as compared to other scenarios, but not a lot less

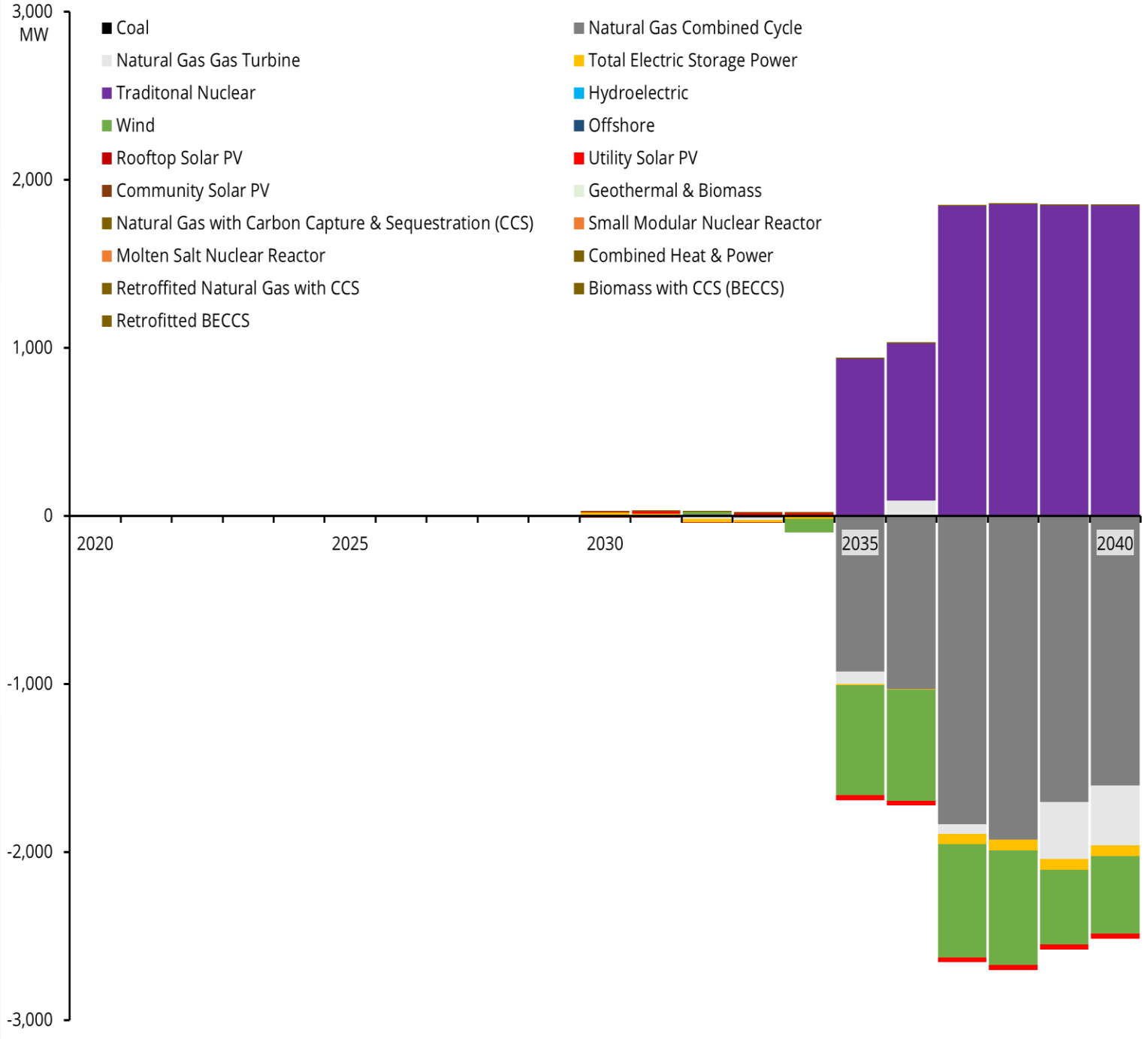


Difference in Installed Capacity in Maryland Between 100% RPS Scenario with Calvert Cliffs and BAU

Additional nuclear capacity does not displace an equal amount of natural gas

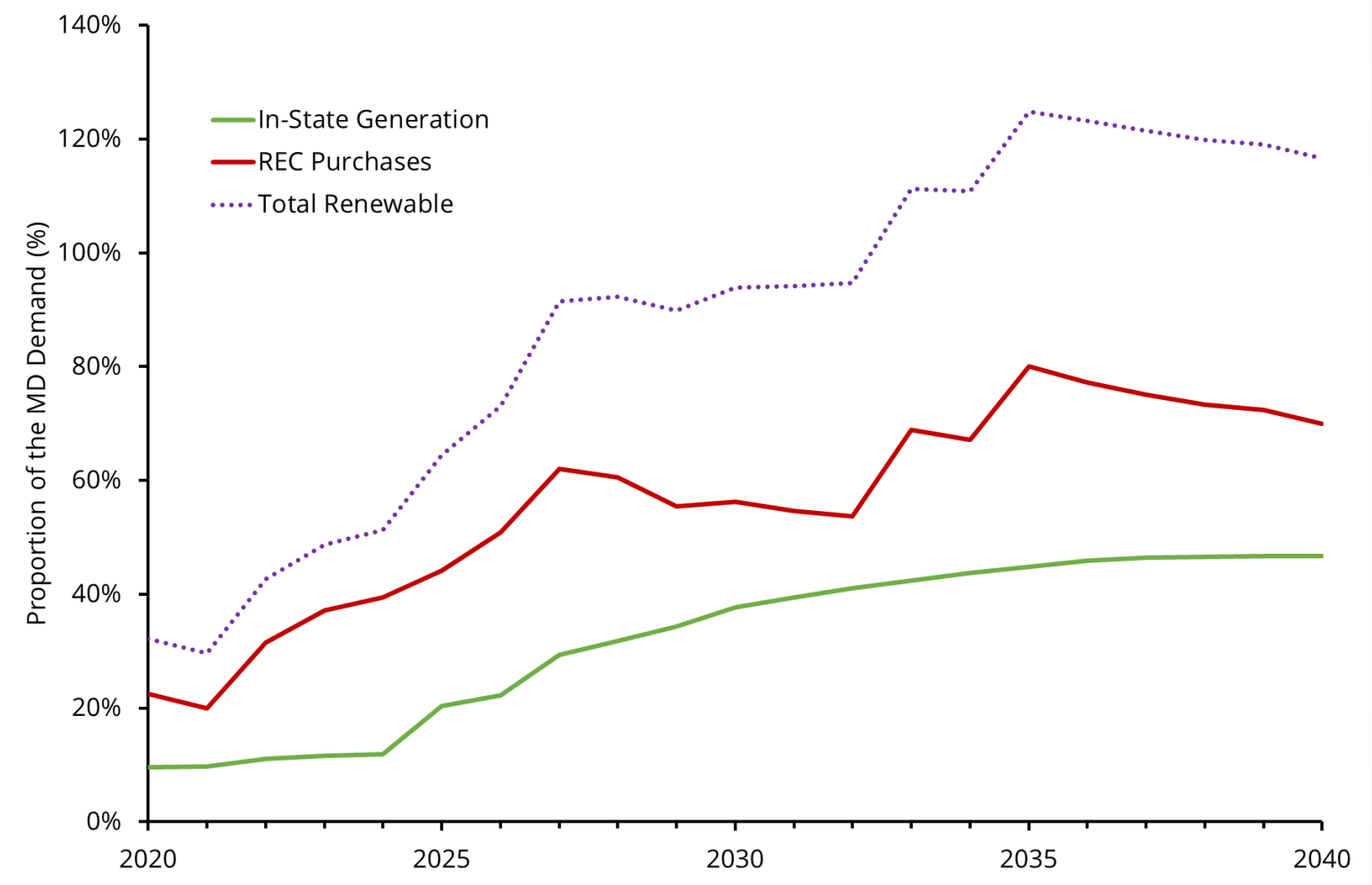


Total Installed Capacity in PJM/IL, 2020-2040 (100% RPS Scenario with Calvert Cliffs)



Difference in Installed Capacity in PJM/IL Between 100% RPS Scenario with Calvert Cliffs and BAU

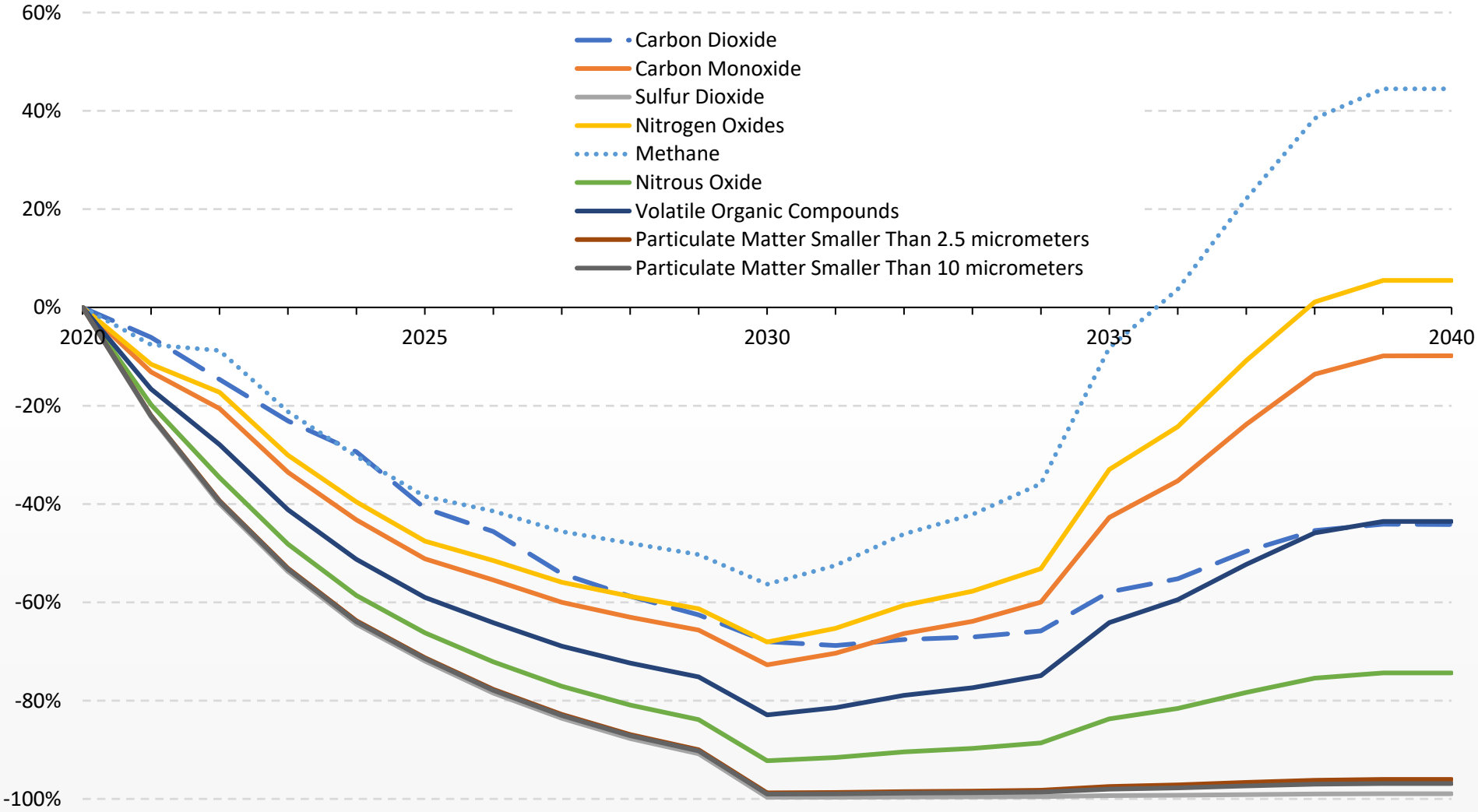
- Relatively small change overall (note scale)
- Larger drop in capacity of combined cycle natural gas plants in PJM overall than in just Maryland
- Smaller but noticeable drop in capacity of natural gas combustion turbines and onshore wind



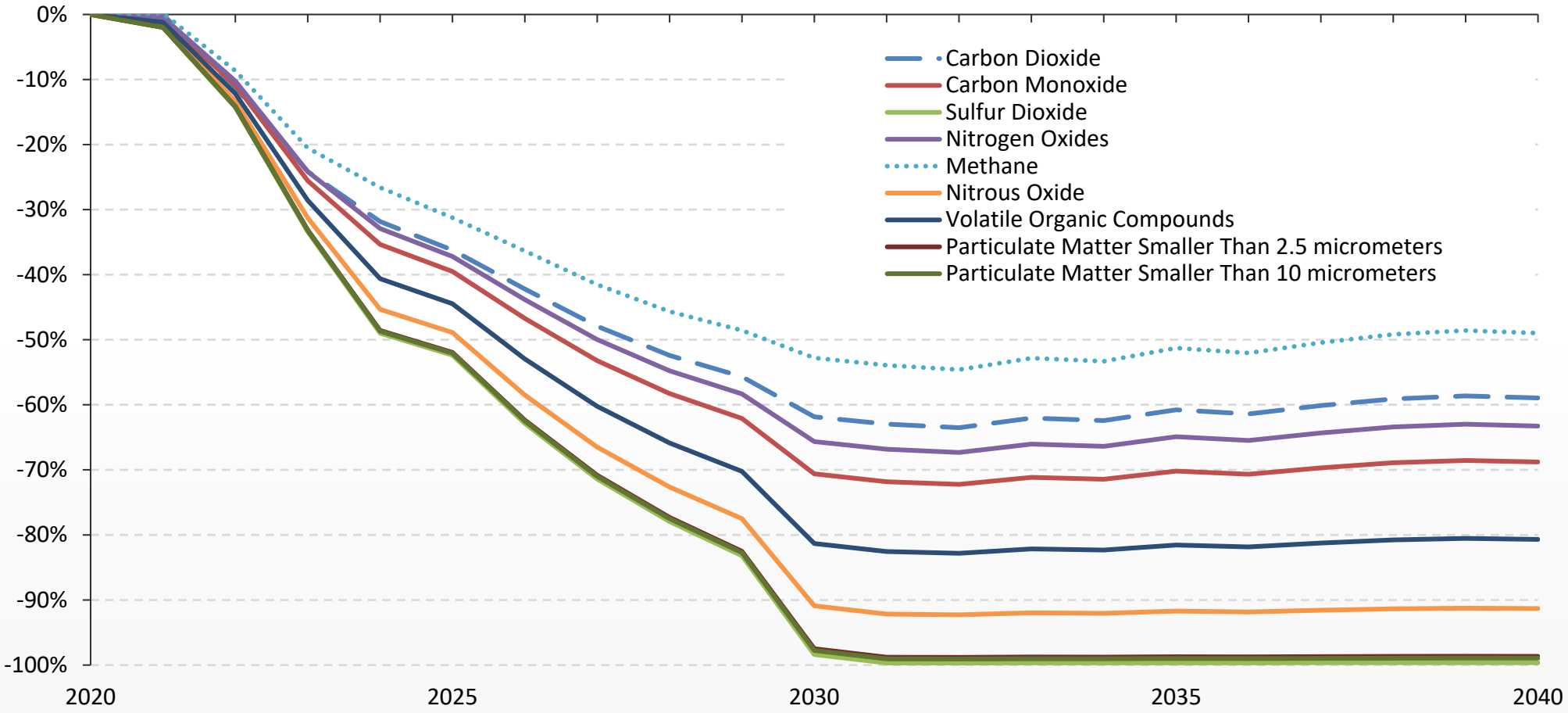
RPS Compliance Mix (100% RPS Scenario with Calvert Cliffs)

Although the amount varies by year, Maryland RPS compliance under the 100% RPS scenario with Calvert Cliffs has more REC purchases than in-state generation

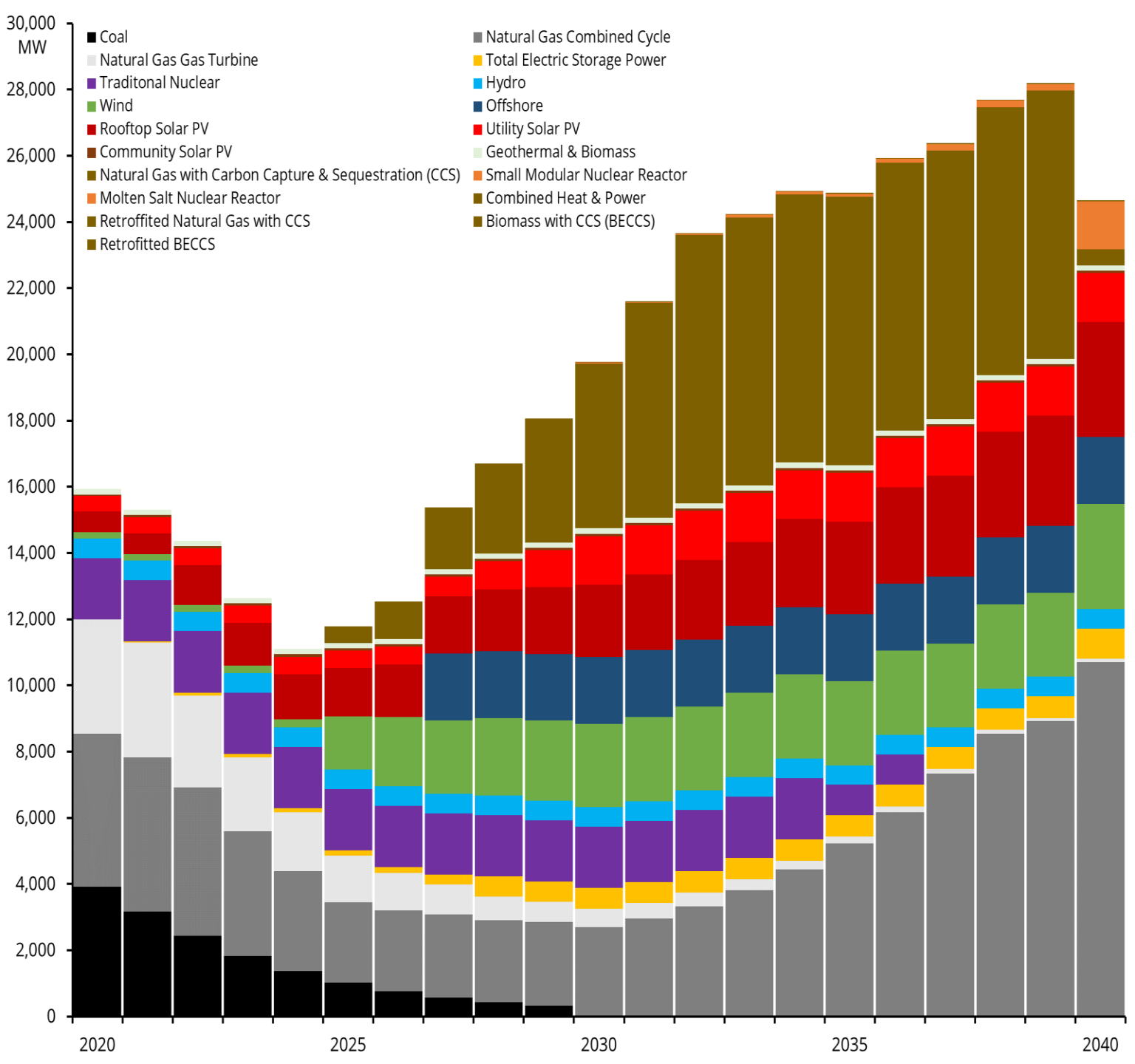
Percent Change in Air Emissions in Maryland, 2020-2040 (100% RPS Scenario with Calvert Cliffs)



Percent Reduction in Air Emissions in PJM/Illinois, 2020-2040 (100% RPS Scenario with Calvert Cliffs)



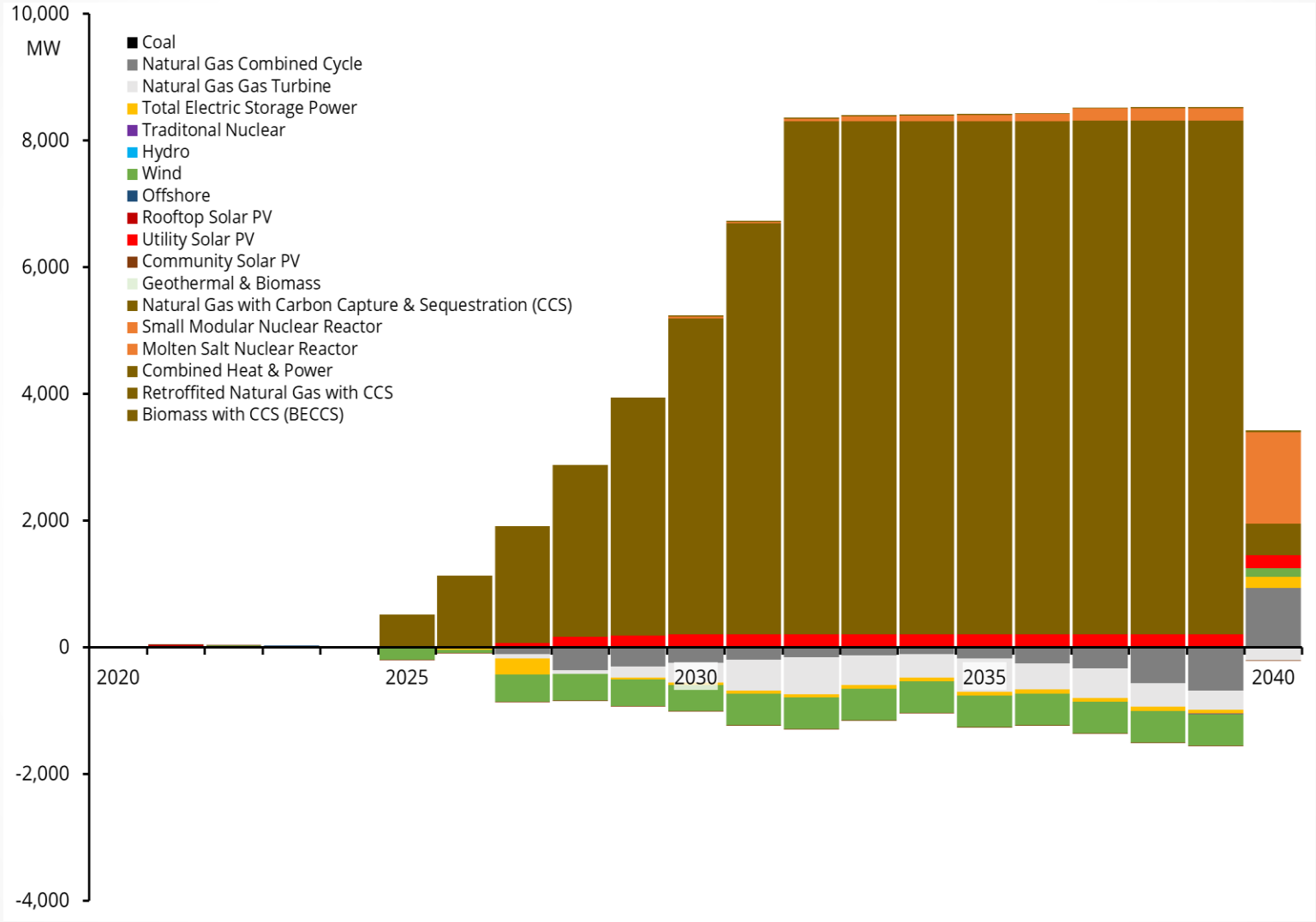
100% Clean Scenario



Installed Capacity in Maryland, 2020-2040 (100% Clean Scenario)

Most notable difference is addition of natural gas with carbon capture and storage (taking advantage of 45Q)

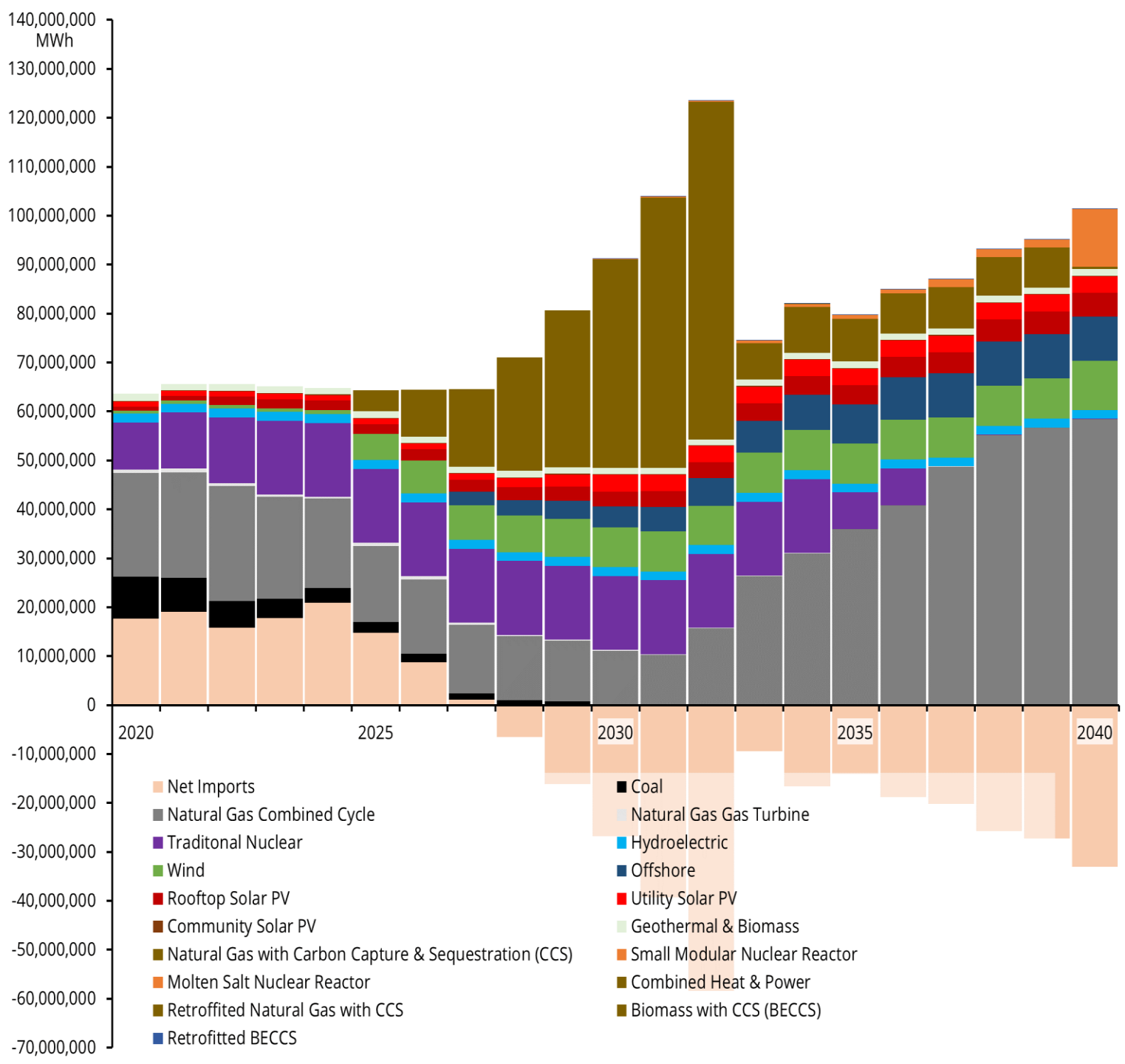
Also note addition of advanced nuclear reactor capacity, especially between 2037 and 2040



Difference in Installed Capacity in Maryland Between 100% Clean Scenario and BAU

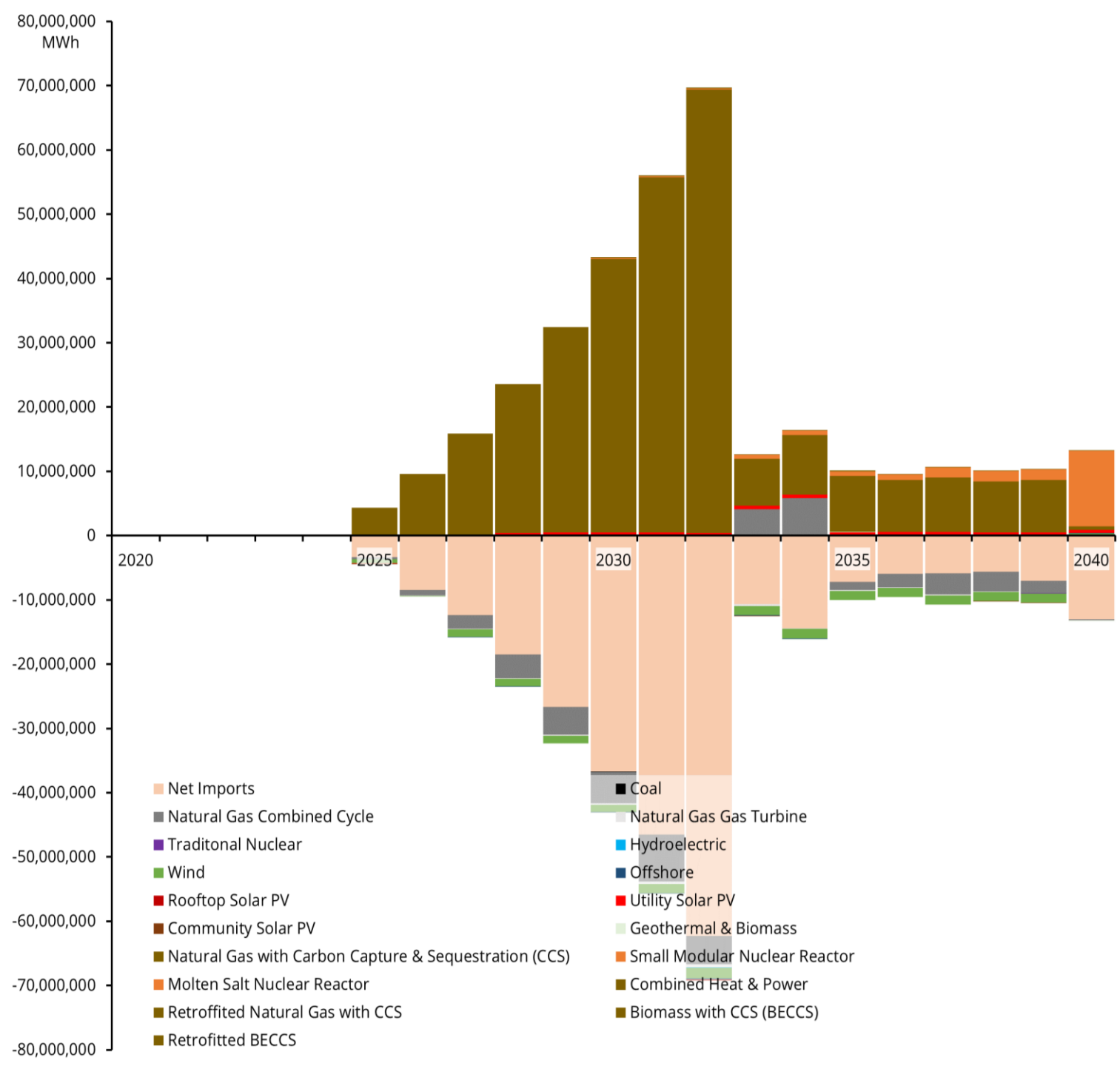
Large amount of natural gas with carbon sequestration added

Advanced Nuclear Reactor capacity added, especially in 2040



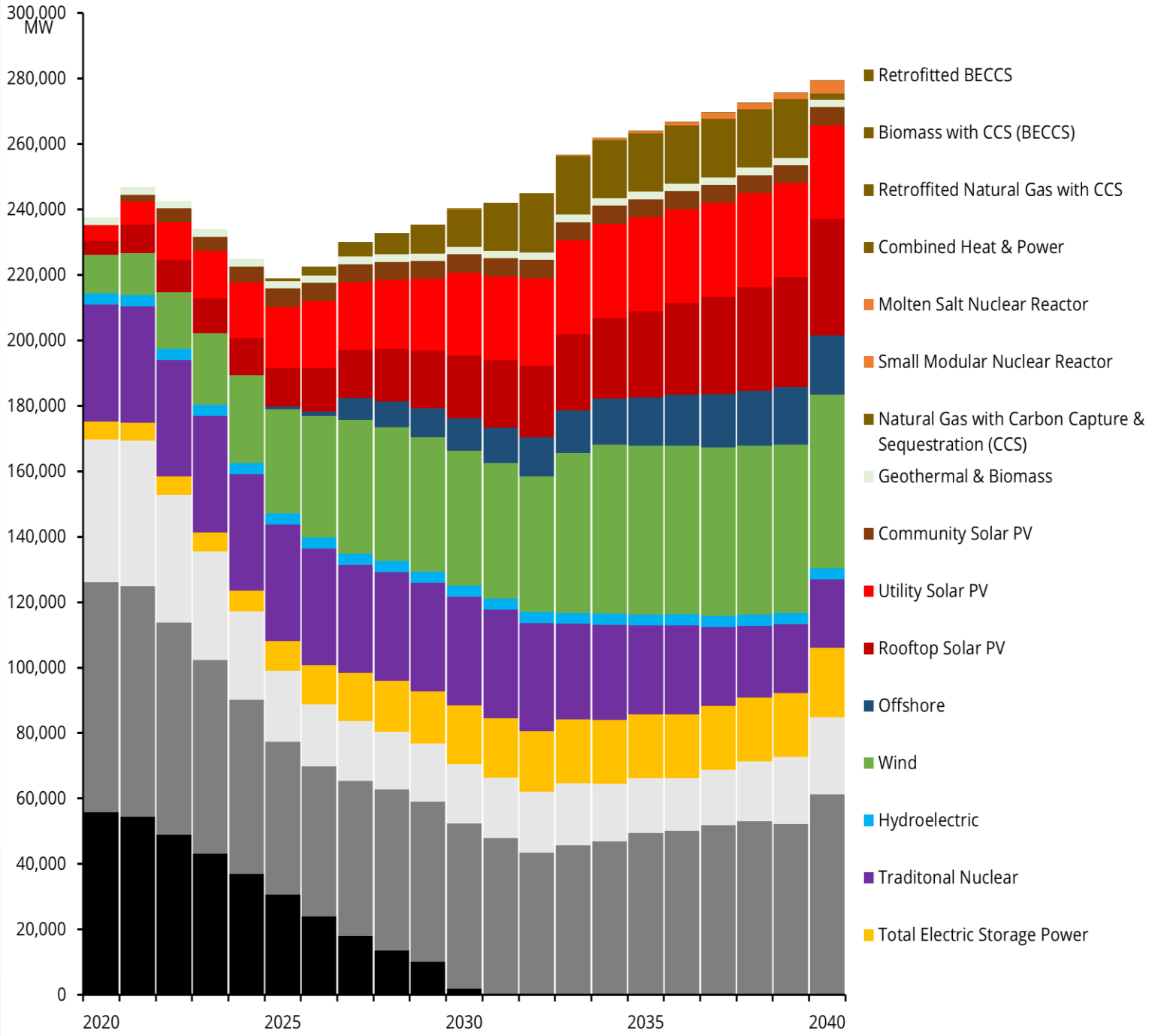
Generation in Maryland, 2020-2040 (100% Clean Scenario)

Maryland becomes power exporter by 2028, sooner than in other scenarios



Difference in Generation in Maryland Between 100% Clean Scenario and BAU

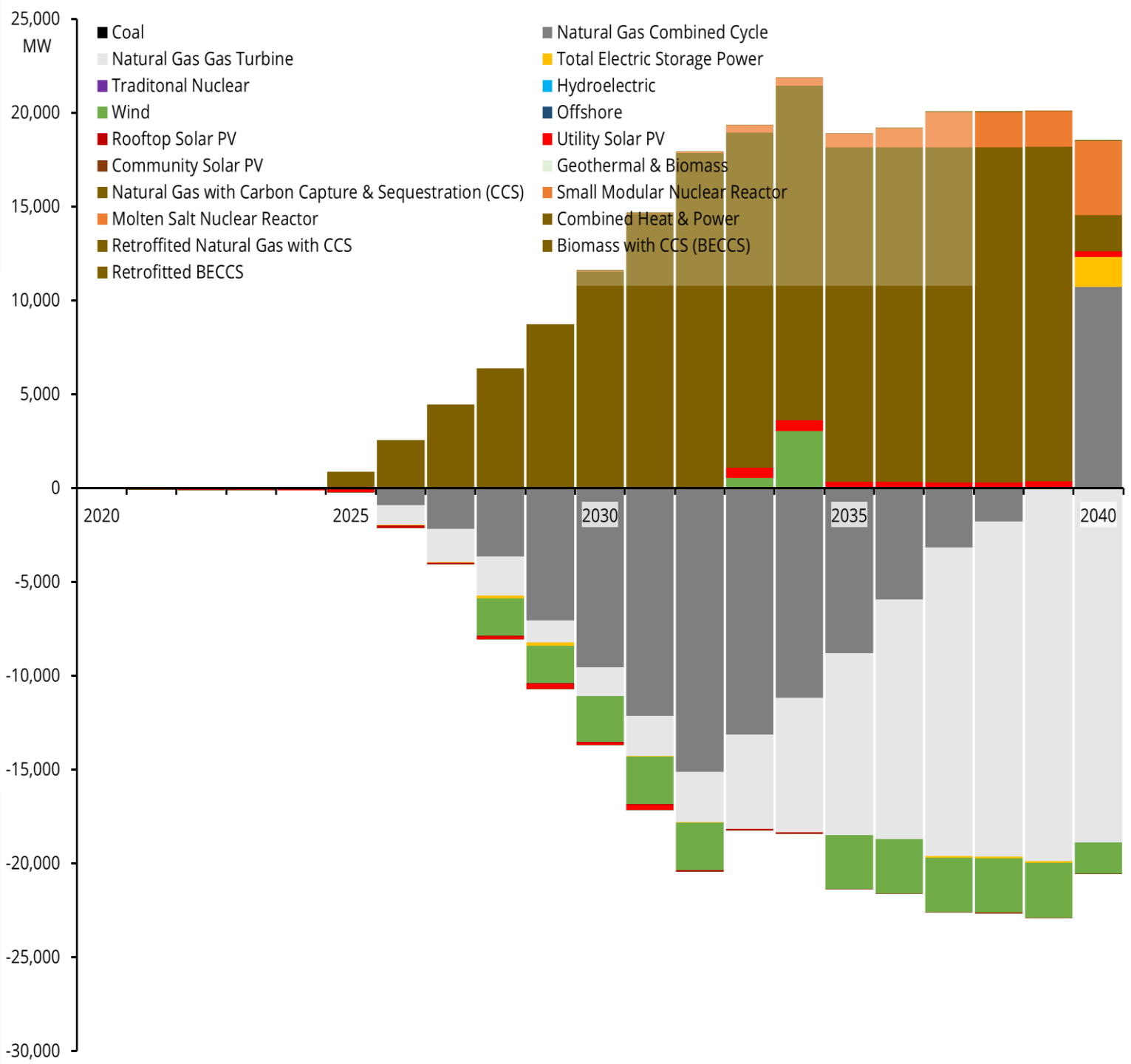
Maryland is using almost all the natural gas with CCS to export to neighboring states, while purchasing RECs to cover RPS requirements



Total Installed Capacity in PJM/IL, 2020-2040 (100% Clean Scenario)

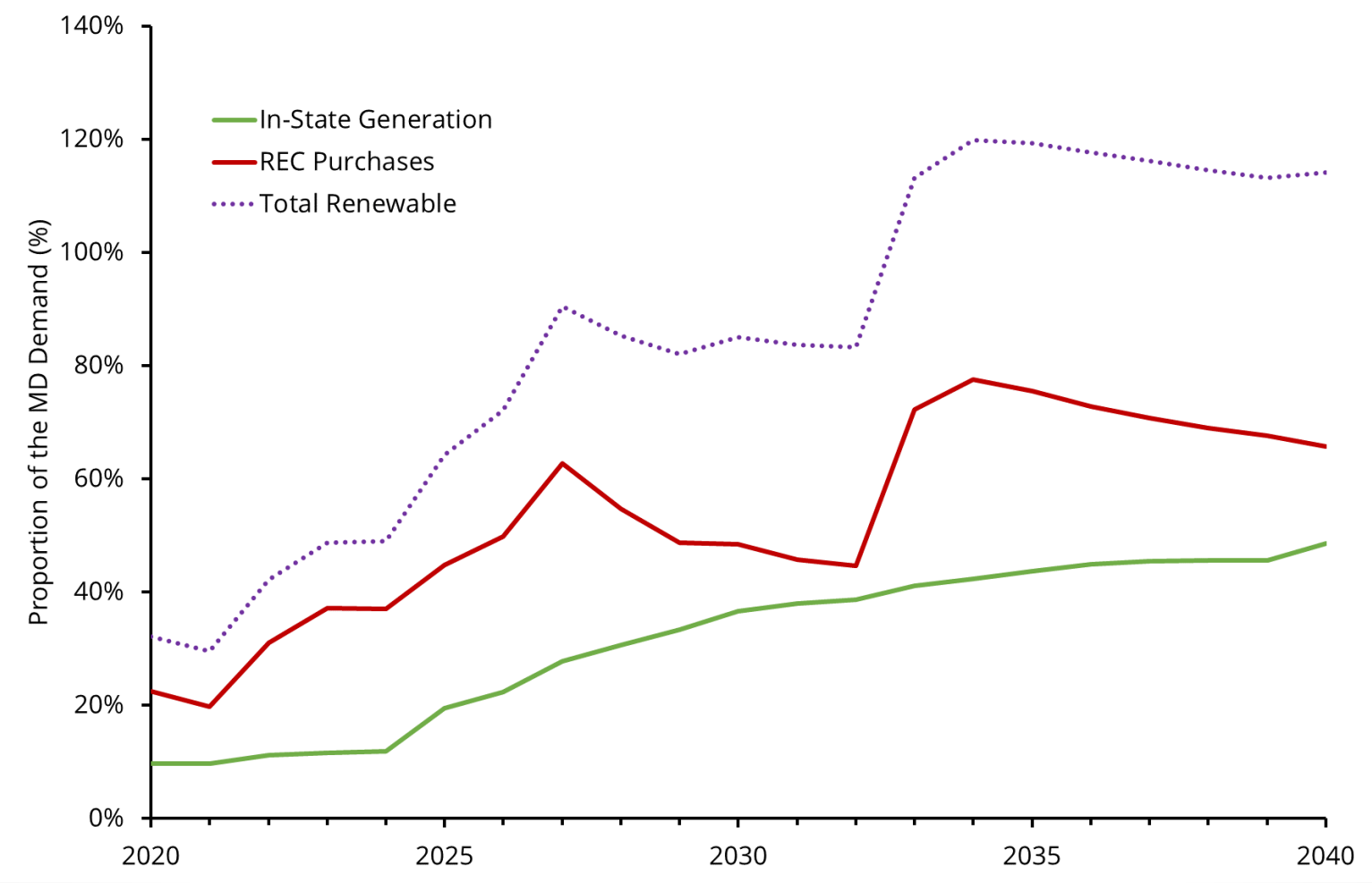
Total installed coal capacity vanishes by 2031

Although overall nuclear power capacity decreases over time, nuclear power remains in the mix for the entire forecast period



Difference in Installed Capacity in PJM/IL Between 100% Clean Scenario and BAU

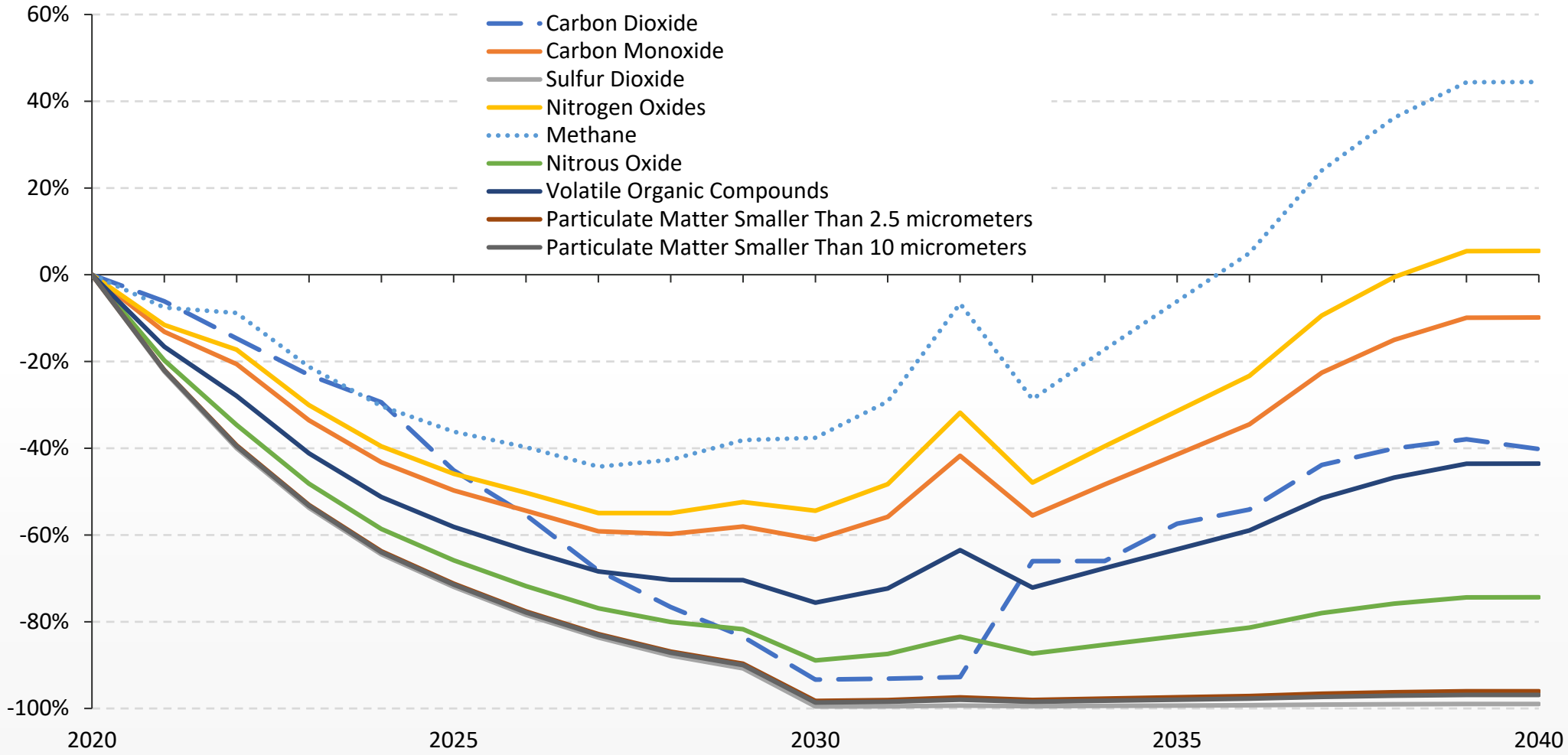
- Natural gas carbon capture and storage capacity installed in place of natural gas combined cycle and combustion turbine capacity
- Not nearly as much wind capacity installed as compared to the BAU and 100% RPS scenarios
- Some crowding out of wind and energy storage, particularly in the second half of the forecast period
- Note addition of advanced nuclear capacity in latter half of forecast period



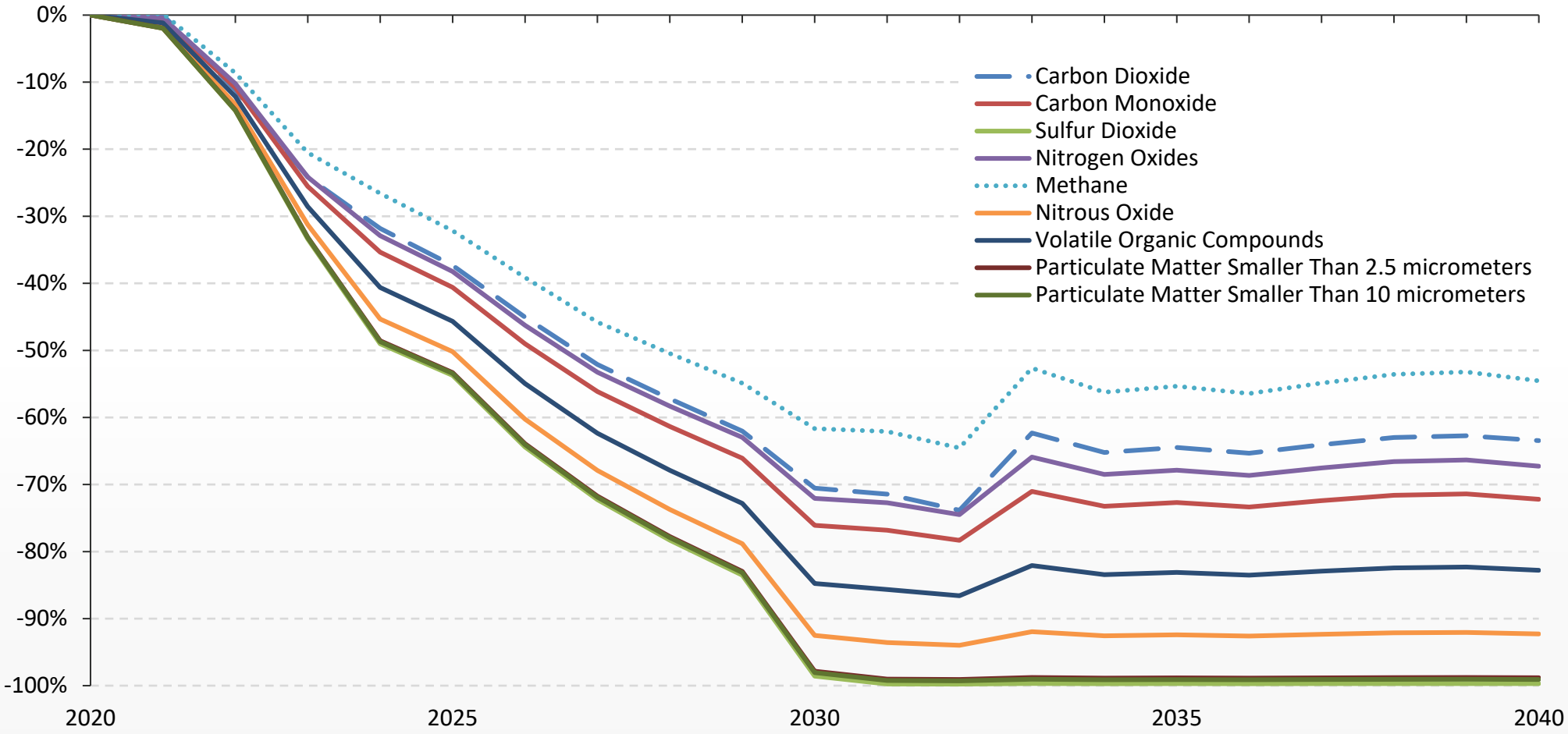
RPS Compliance Mix (100% Clean Scenario)

Similar to the other scenarios, Maryland RPS compliance under the 100% Clean scenario has more REC purchases than in-state generation

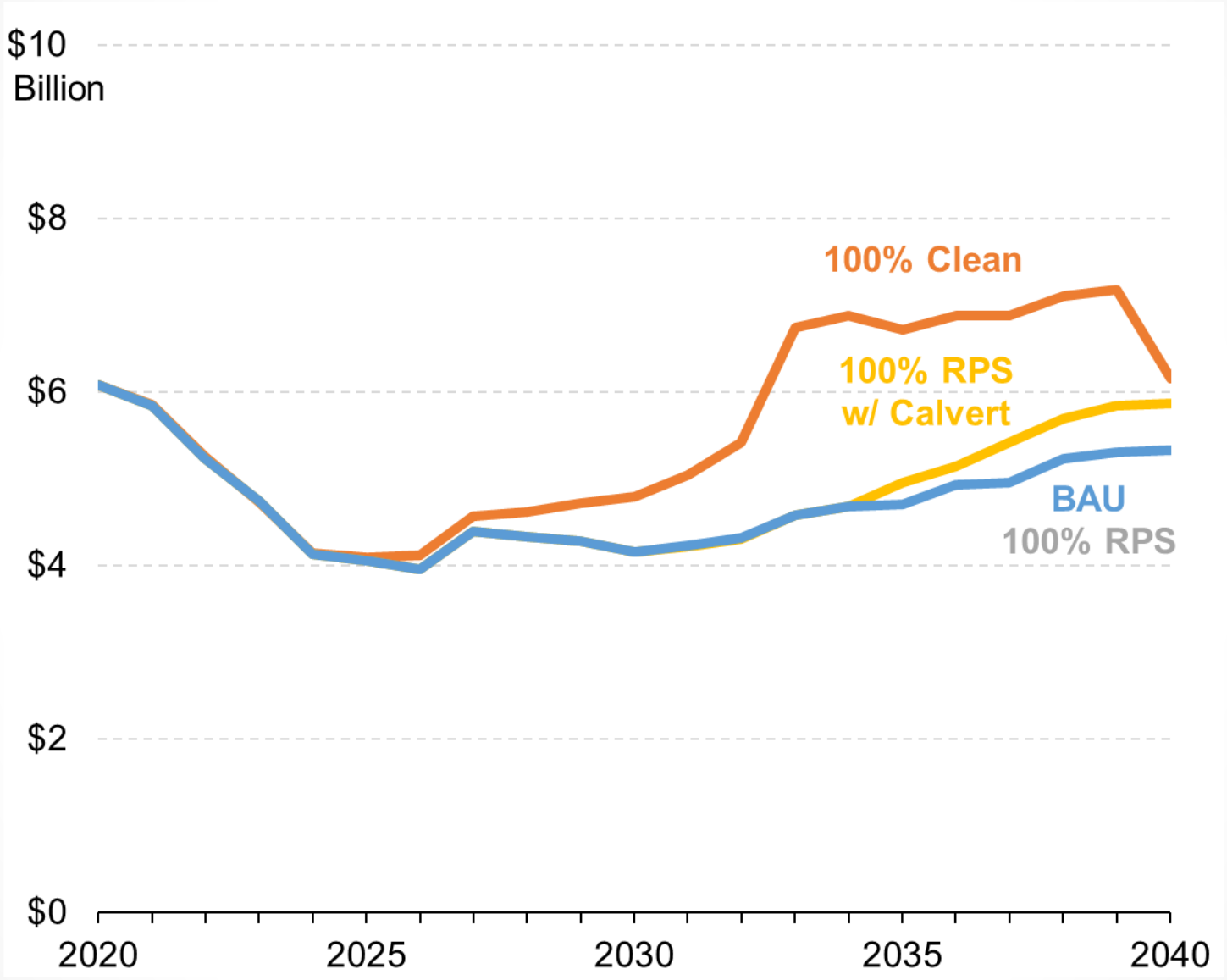
Percent Change in Air Emissions in Maryland, 2020-2040 (100% Clean Scenario)



Percent Reduction in Air Emissions in PJM/Illinois, 2020-2040 (100% Clean Scenario)



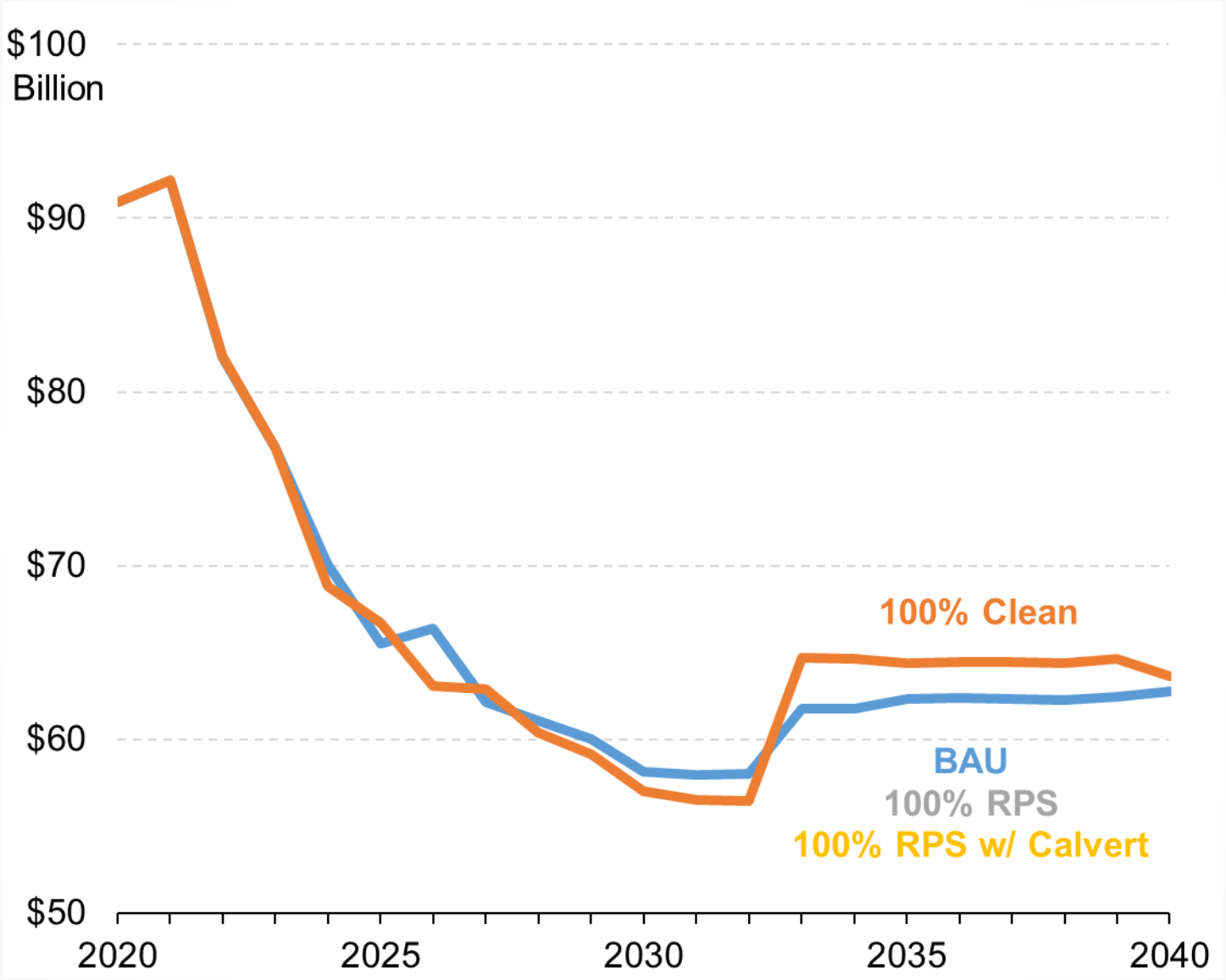
Additional Findings



Total Resource Cost in Maryland

Annual costs decrease as high-cost resources retire, then increase as Maryland adds new capacity

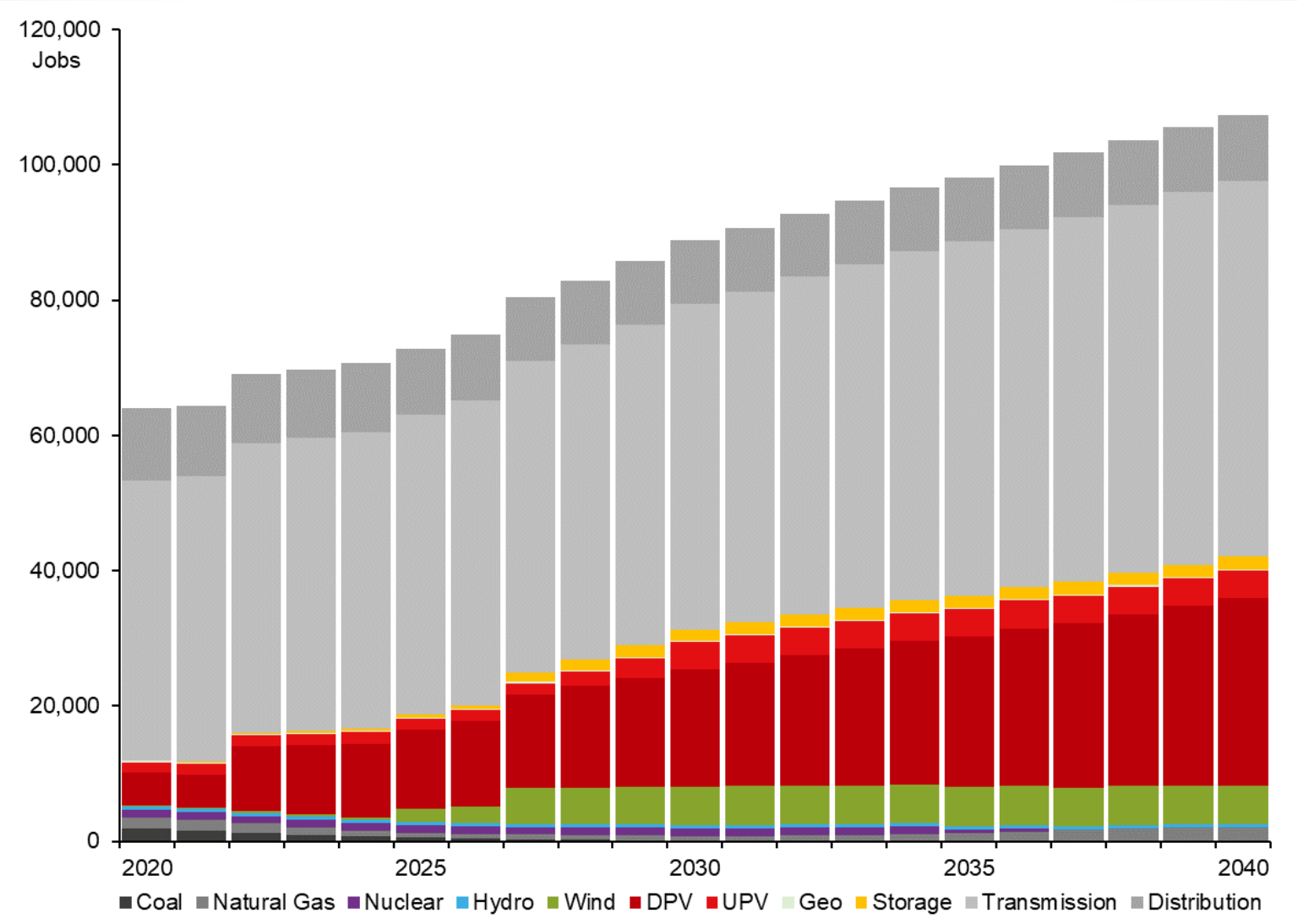
	Total Cost over 20 years (Billions)	Change in Annual Cost from 2020 to 2040 (billions)
100% Clean	$118.0	$0.1
100% RPS	99.4	-0.7
100% RPS w/ Calvert	101.9	-0.2
BAU	99.5	-0.7



Total Resource Cost in PJM/IL

Annual costs decrease substantially as low variable-cost resources replace existing fossil fuel assets

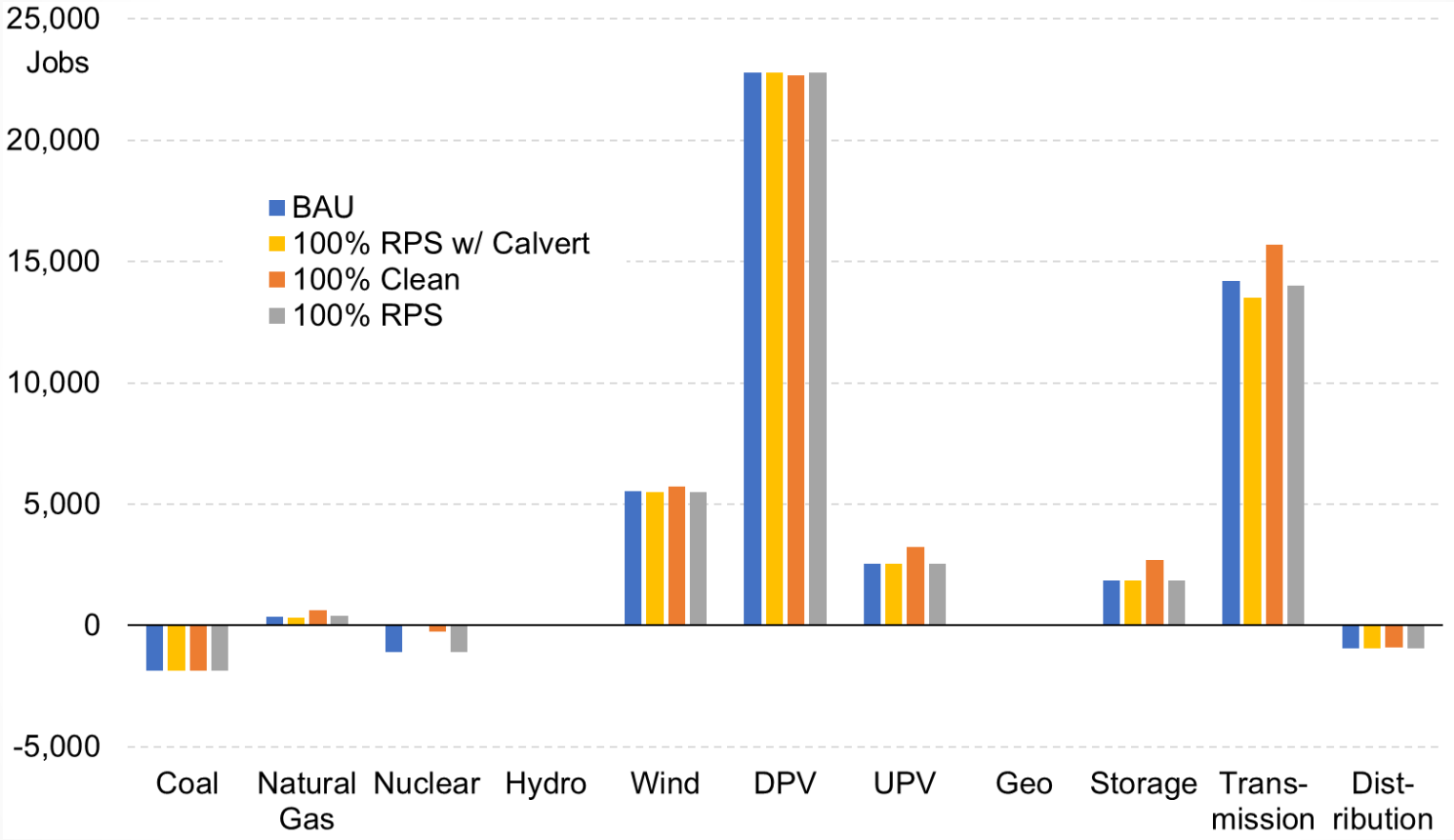
	Total Cost over 20 years (Billions)	Change in Annual Cost from 2020 to 2040 (billions)
100% Clean	$1,408.1	($27.3)
100% RPS	1,399.2	(28.2)
100% RPS w/ Calvert	1,399.2	(28.1)
BAU	1,399.2	(28.2)



Total Jobs, Maryland, BAU

Shows direct and indirect jobs

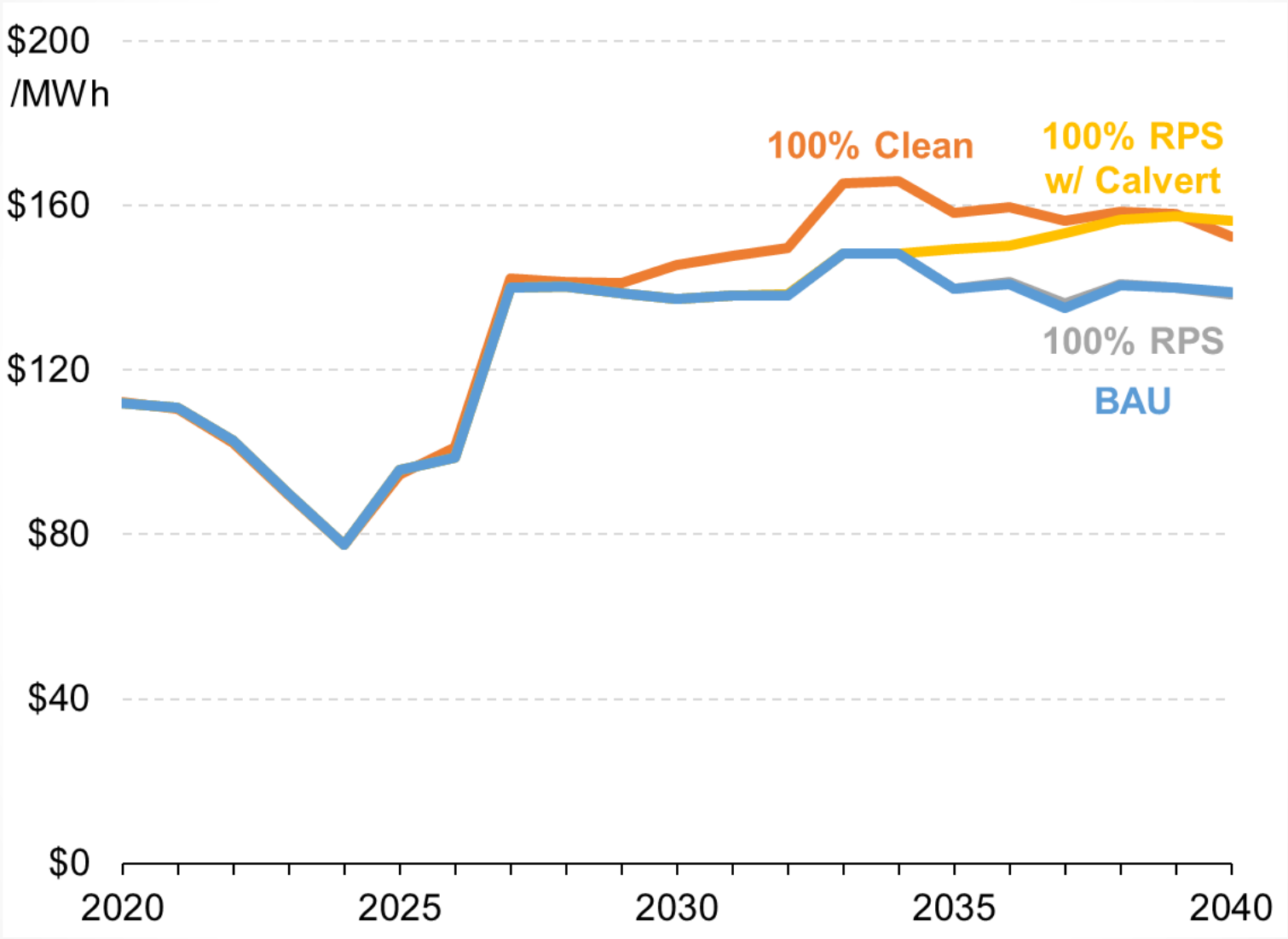
Transmission is the largest driver of employment, followed by distributed solar PV



Change in Total Jobs, Maryland, 2020 to 2040

Shows which industries gain or lose jobs over the next 20 years, by scenario

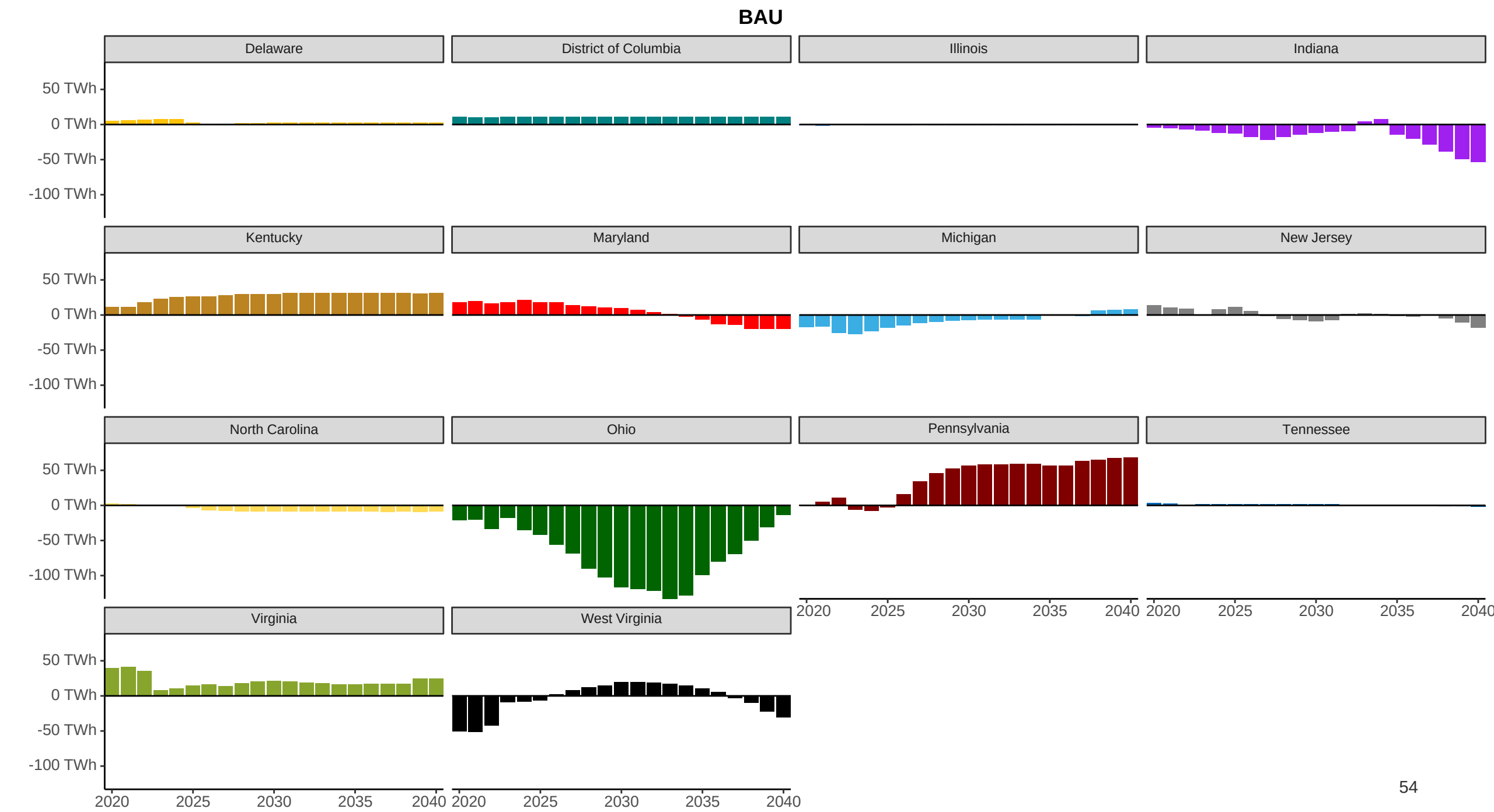
Despite the addition of natural gas capacity, the change in jobs is minimal due to retirements of older gas units at beginning of period



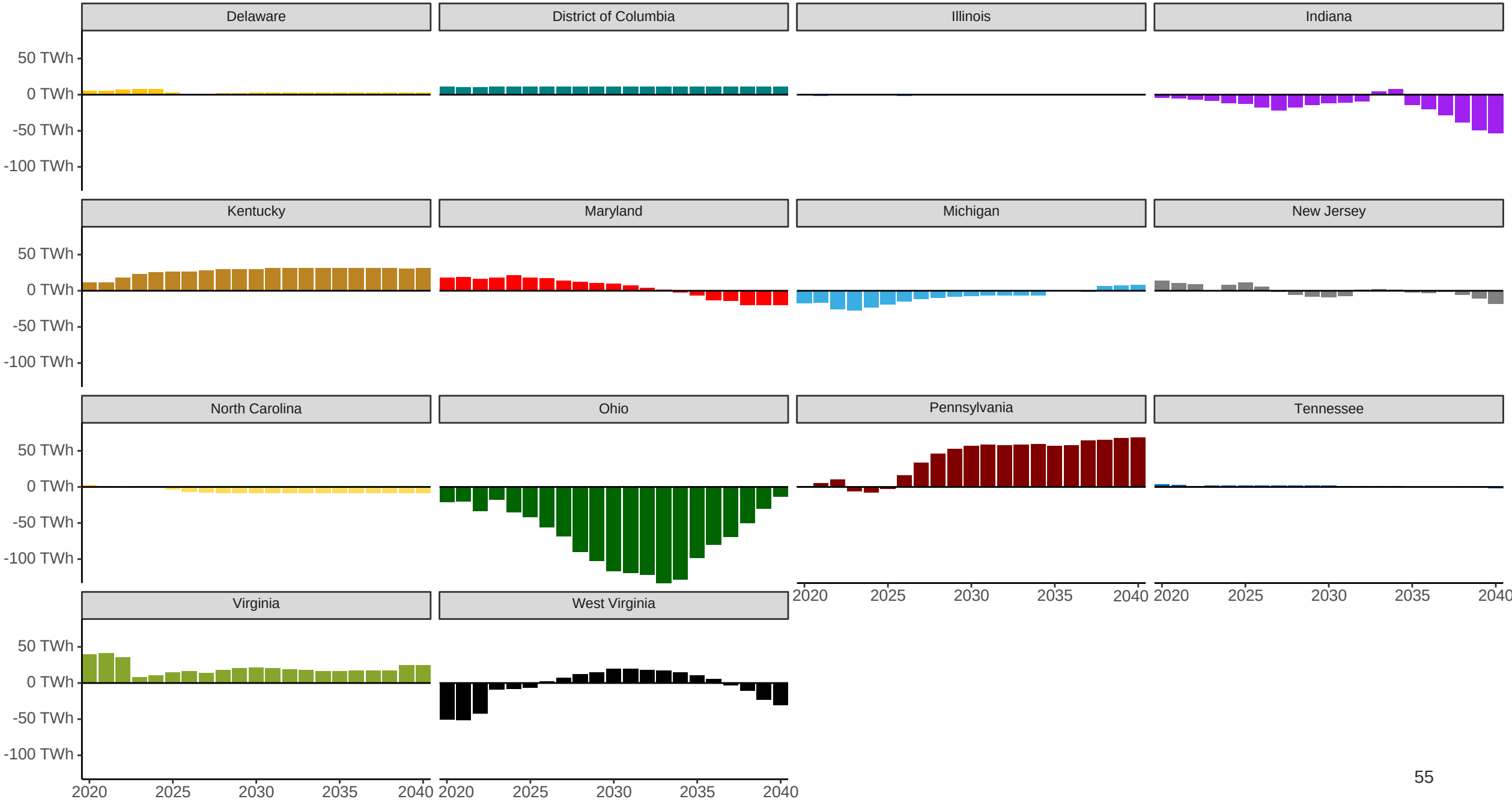
Retail Rates, Maryland

Retail rates are higher for the 100% RPS with Calvert Cliffs scenario due to the estimated cost of policy supports after relicensing

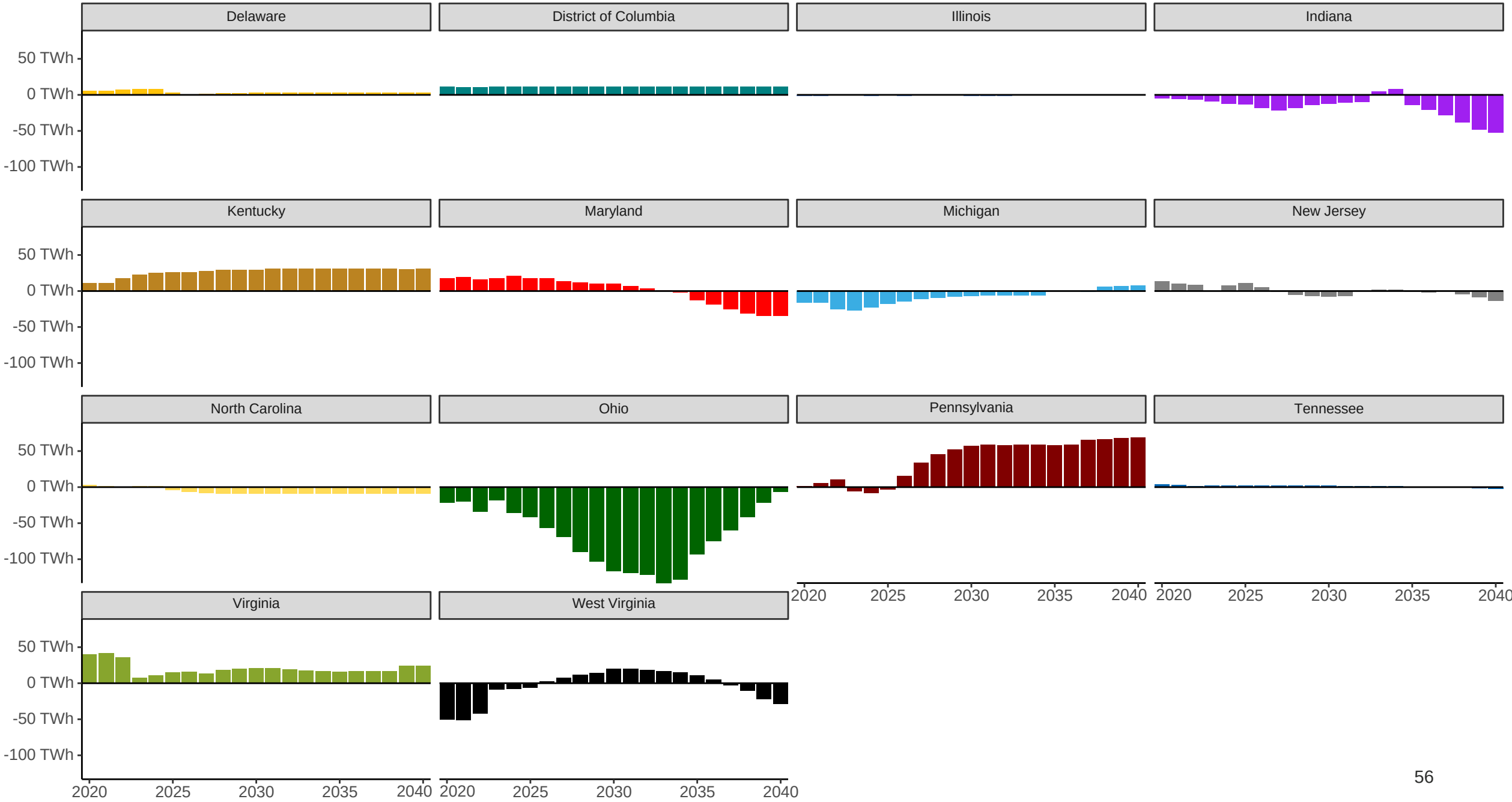
Net Exchange by State by Scenario

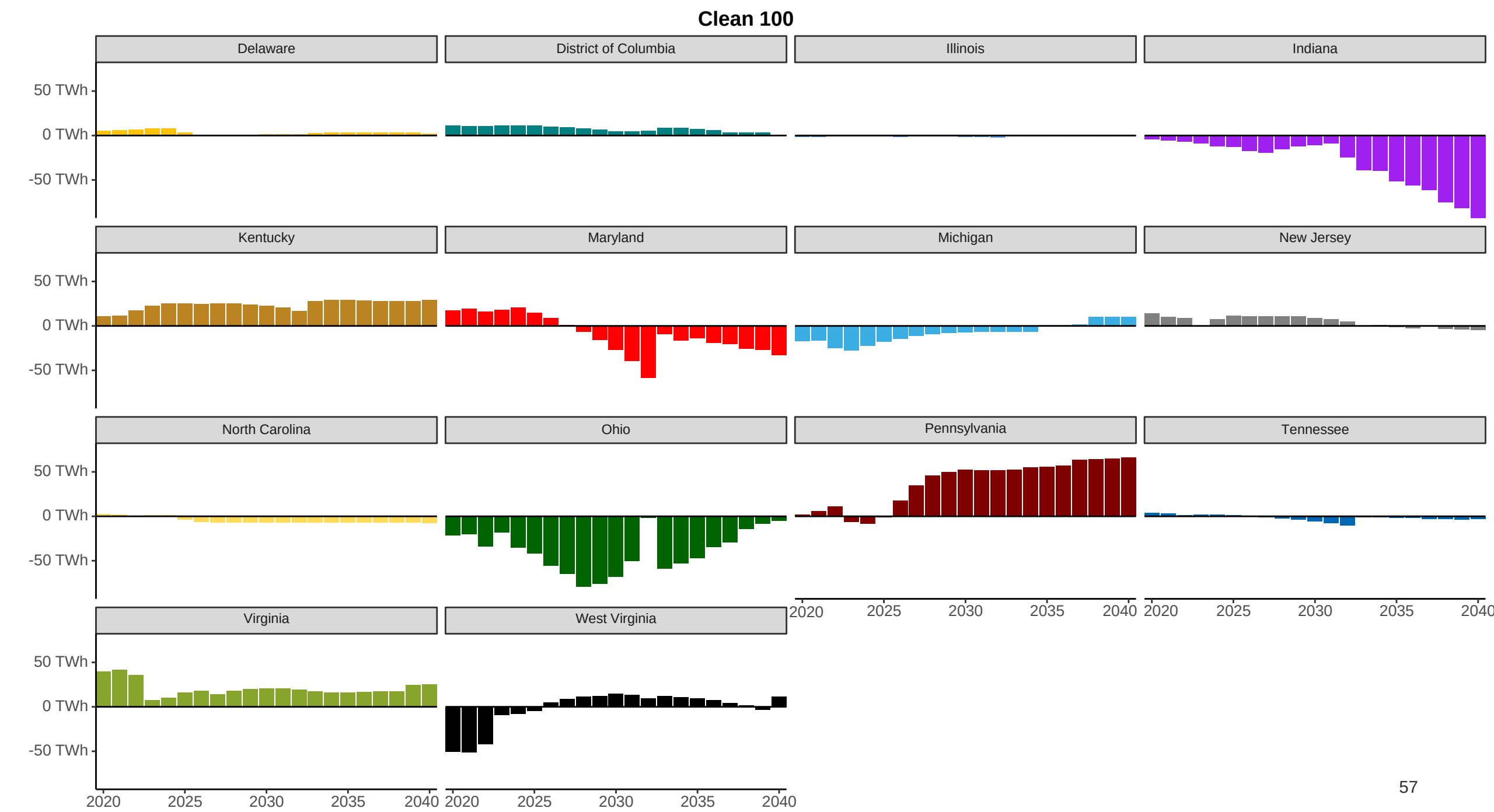

BAU
Delaware
District of Columbia
Illinois
Indiana
Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
50 TWh
0 TWh
-50 TWh
-100 TWh
2020
2025
2030
2035
2040

RPS 100


Delaware
District of Columbia
Illinois
Indiana
Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
50 TWh
0 TWh
-50 TWh
-100 TWh
2020
2025
2030
2035
2040

RPS 100 w/Calvert




Clean 100
Delaware
District of Columbia
Illinois
Indiana
Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
50 TWh
0 TWh
-50 TWh
2020
2025
2030
2035
2040

Immediate Next Steps

- Still a lot of data to review and analyze
- Decide on possible sensitivity scenarios (see next slide)
- Run sensitivities and present results to PPRP and working group
- Preparation of draft and final report

Possible Sensitivity Scenarios

- Limit addition of natural gas capacity in Maryland
- Maximize in-state generation in Maryland rather than relying on RECs
- Assume targets in Climate Solutions Now Act are binding
- High renewables/clean energy in PJM (50% PJM-wide)
- High electrification
- High transmission costs
- Remove the Maryland RPS
- More flexible demand [+conservation and other demand efforts]
- High offshore wind in Maryland
- Keep natural gas carbon capture sequestration and storage in operation throughout forecast period rather than having it retire all at once
- High transmission expansion (2x existing transmission)
- Decrease the natural gas depreciation schedule (from 30 years)

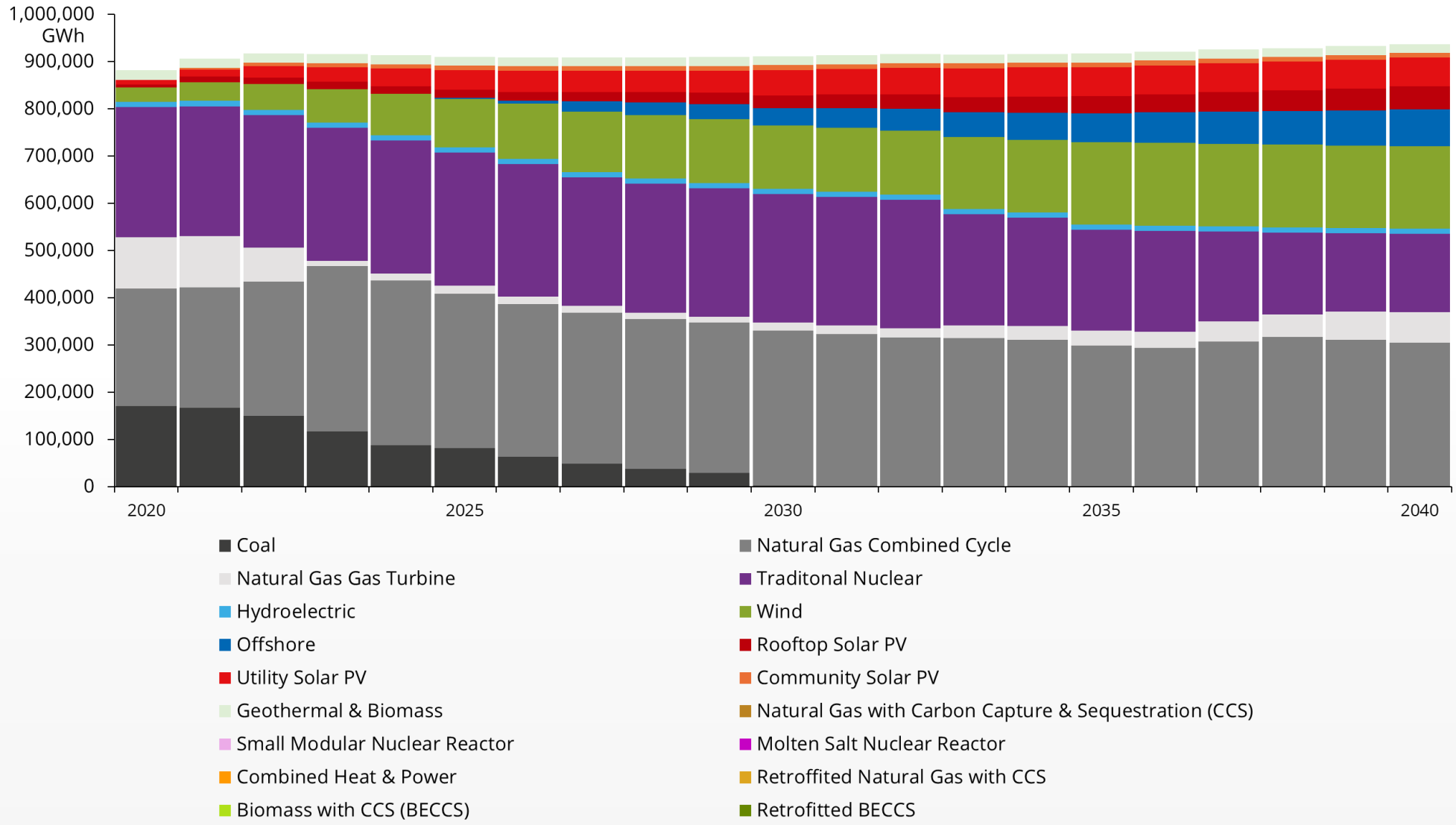
Survey:
https://qfreeaccountssjc1.az1.qualtrics.com/jfe/form/SV_1zXxOT7HHKo1rAG

Questions for Working Group

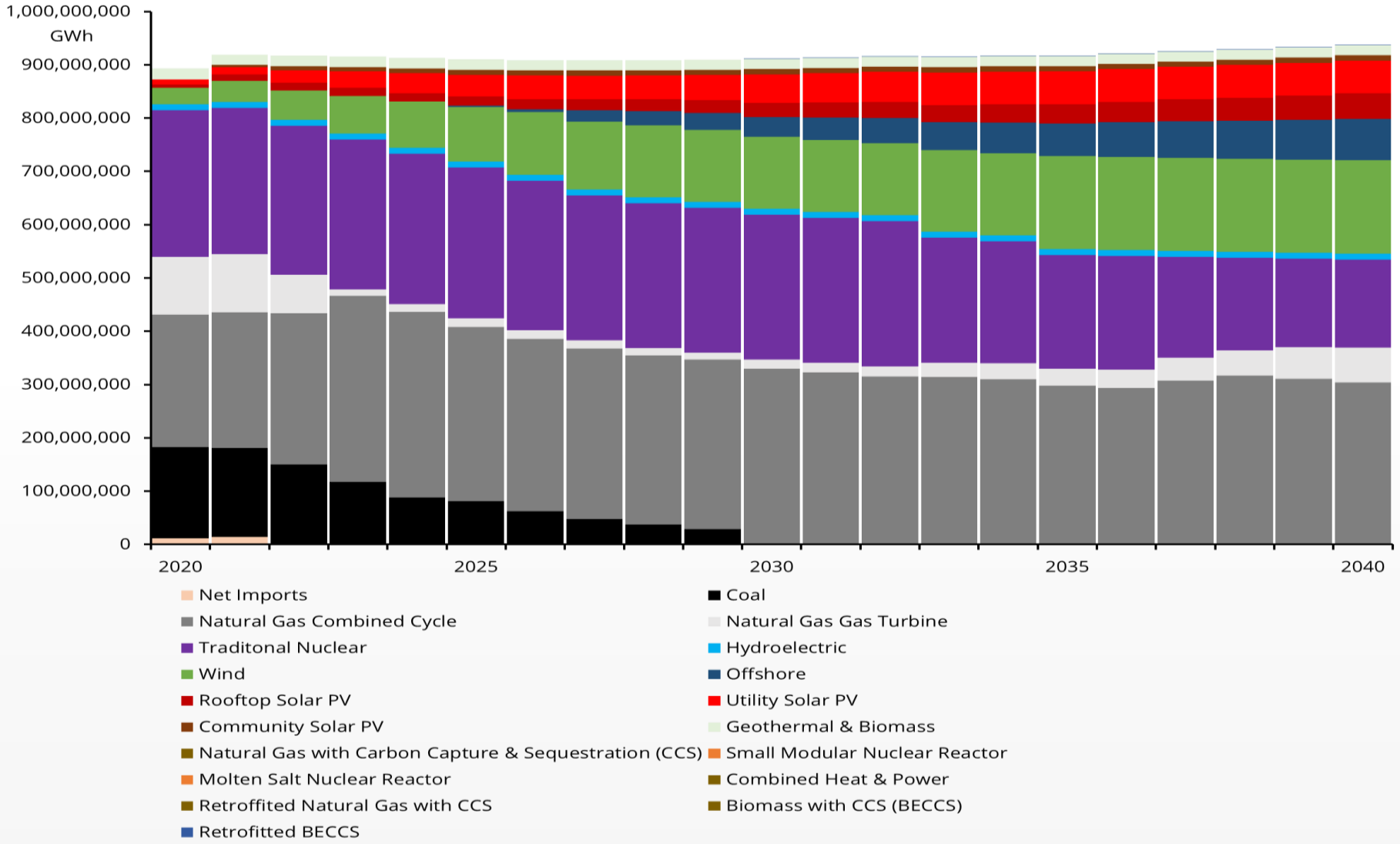
- For other sensitivity scenarios, we propose to rerun the BAU, 100% Clean, 100% RPS and 100% RPS with Calvert Cliff scenarios incorporating the offshore wind and energy storage laws passed earlier this year. Does that seem reasonable?
- Given that Governor Moore supports a 100% clean energy requirement, is CARES still a reasonable proxy or should we rely on something else?

Appendix

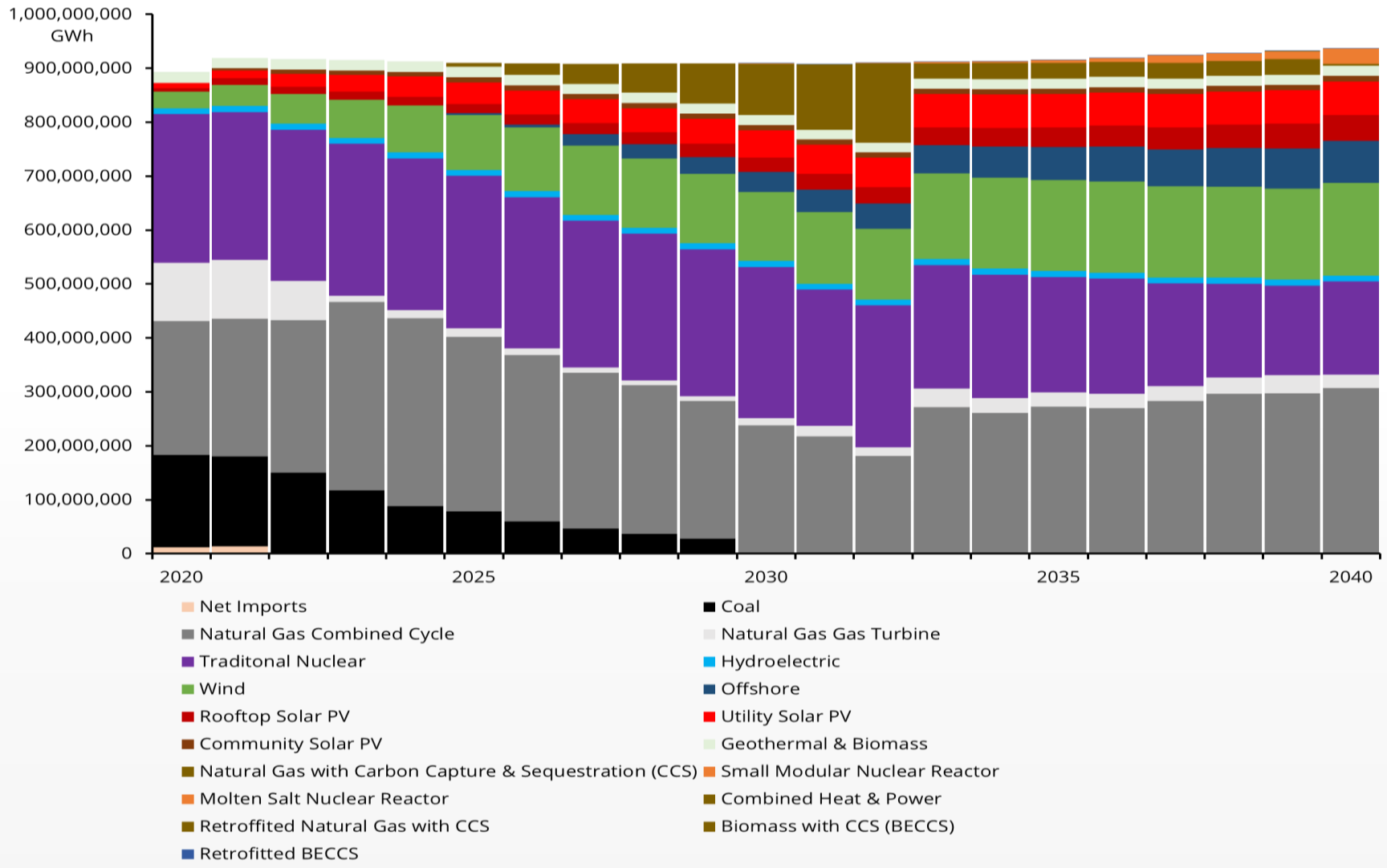
Total Generation in PJM and Illinois, 2020-2040 (BAU Scenario)

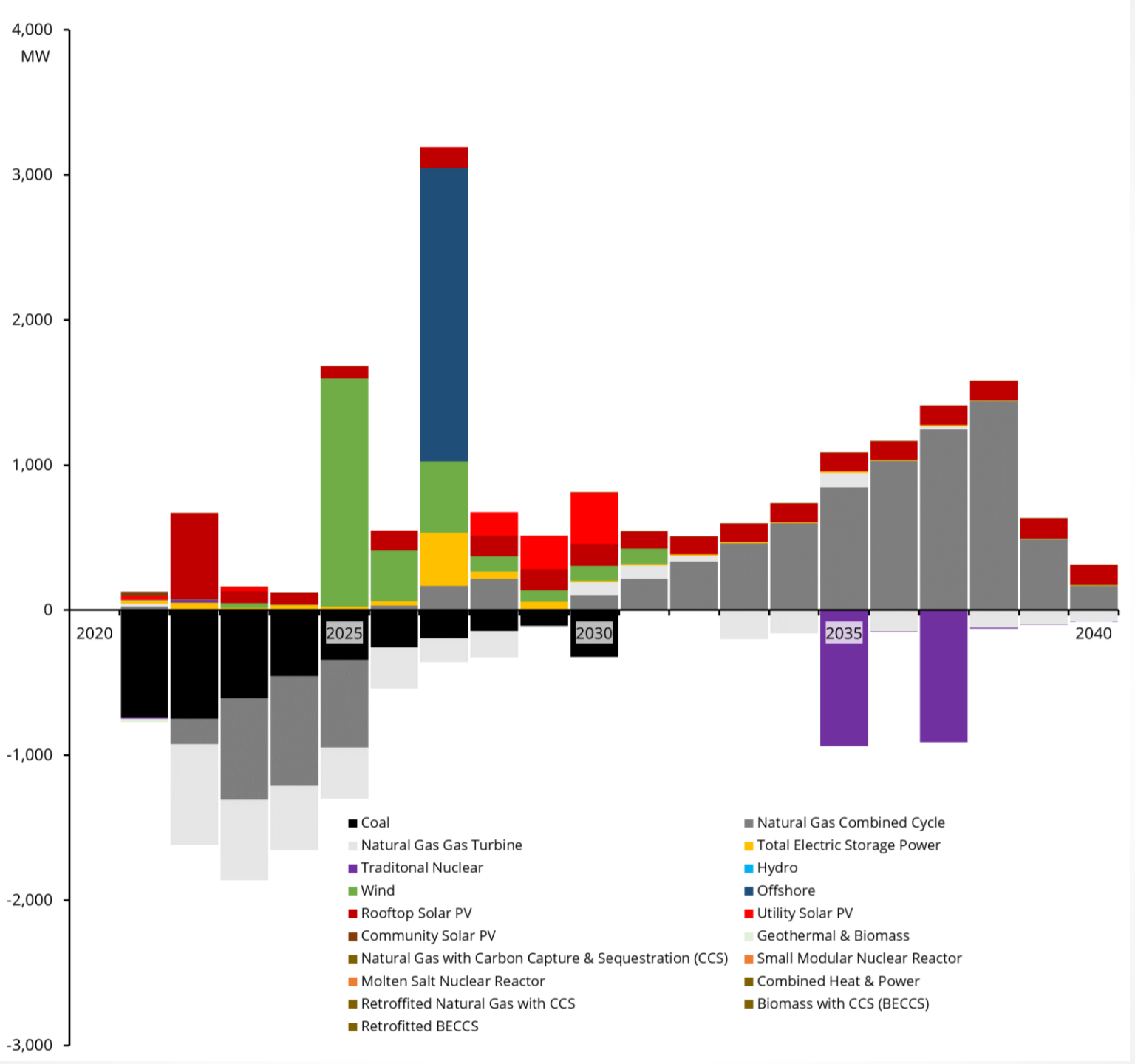


Total Generation in PJM and Illinois, 2020-2040 (100% RPS Scenario)



Total Generation in PJM and Illinois, 2020-2040 (100% Clean Scenario)



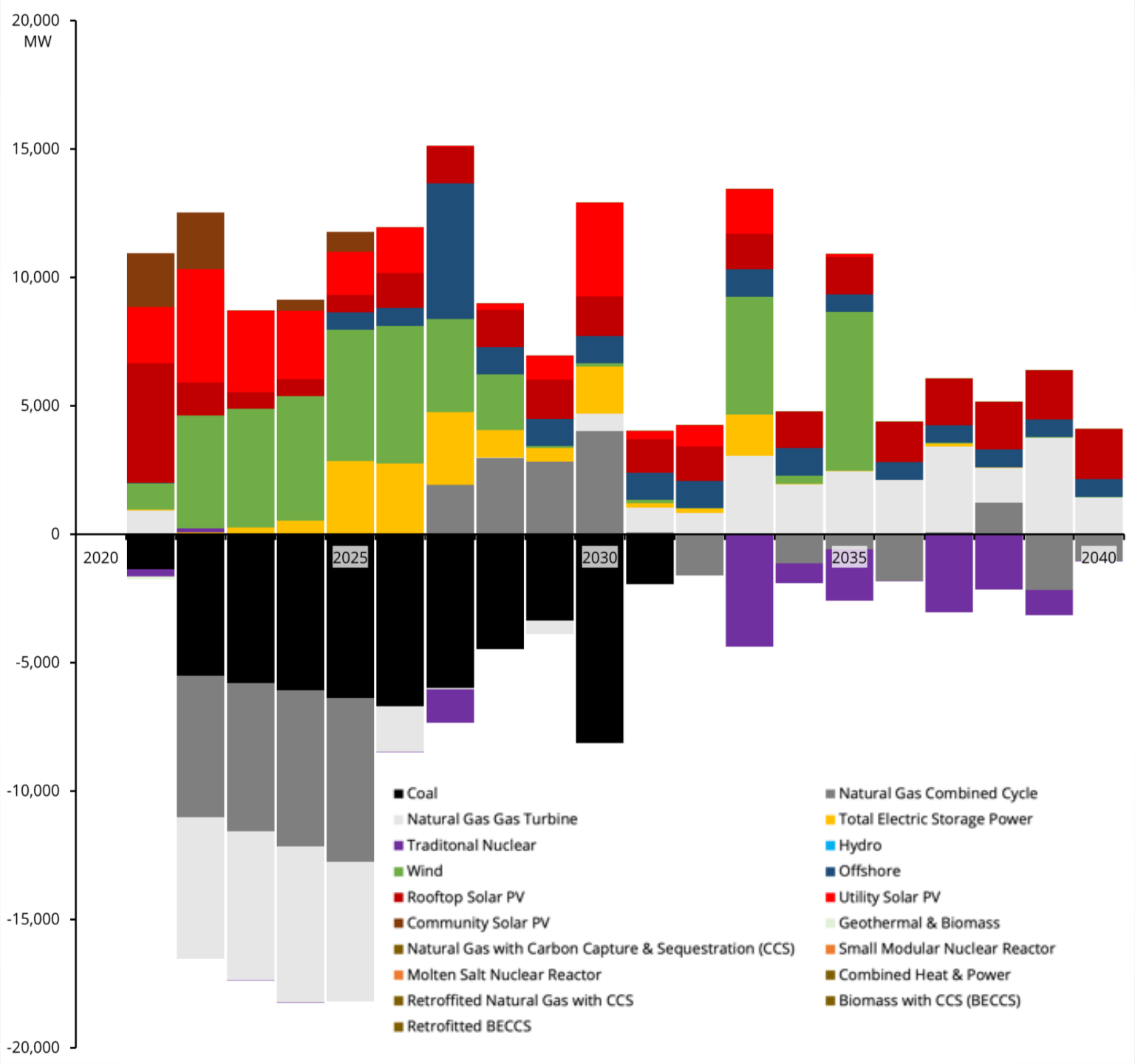


Annual Capacity Installations and Retirements by Technology in Maryland, 2020-2040 (100% RPS Scenario)

Retirement of coal and natural gas facilities by 2030 accompanied by new renewables

New renewables capacity largely stops by 2030

New natural gas installations pick up from about 2029 to 2036, especially when Calvert Cliffs is retired

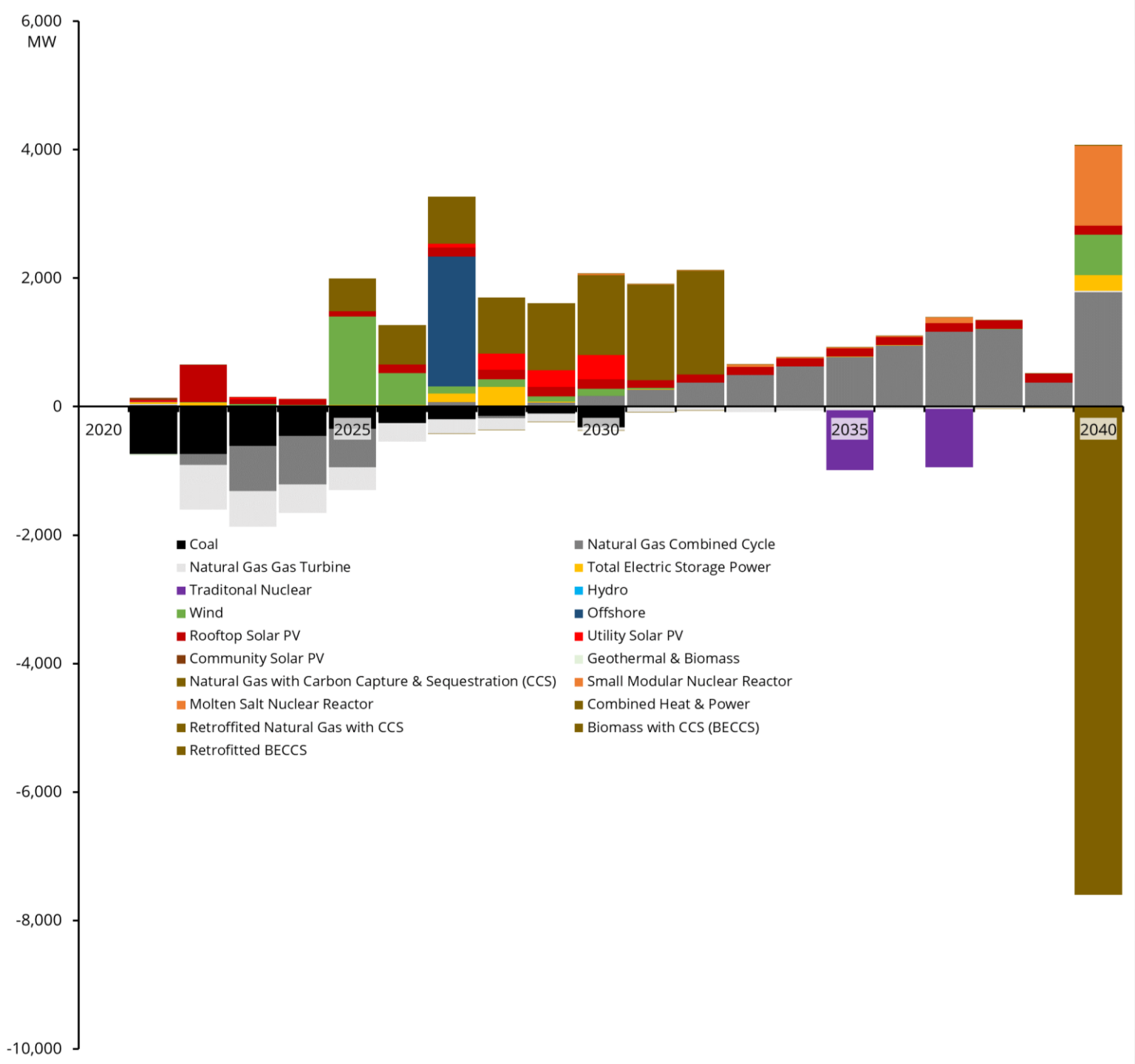


Annual Capacity Installations and Retirements by Technology in PJM/IL, 2020-2040 (100% RPS Scenario)

Steep retirements of coal and natural gas in PJM until 2031. Some of this is presumably driven by the Illinois Climate and Equitable Jobs Act

Some natural gas capacity retirements offset by new additions of natural gas combined cycle and combustion turbines beginning in 2026.

Robust expansion of wind, solar and battery storage.



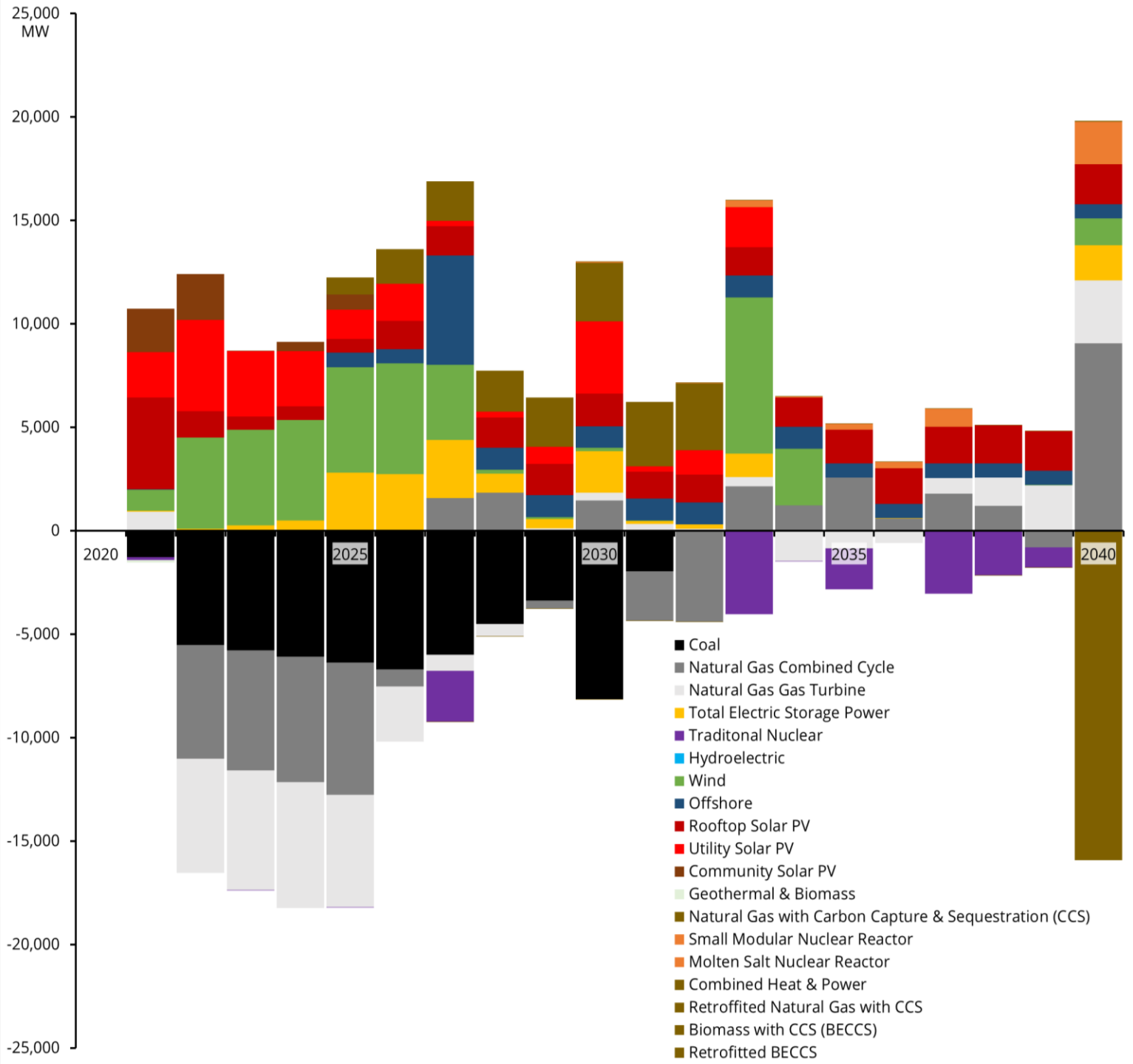
Annual Capacity Installations and Retirements by Technology in Maryland, 2020-2040 (100% Clean Scenario)

Natural gas carbon capture and sequestration capacity added between 2025 and 2032, then is retired in 2040

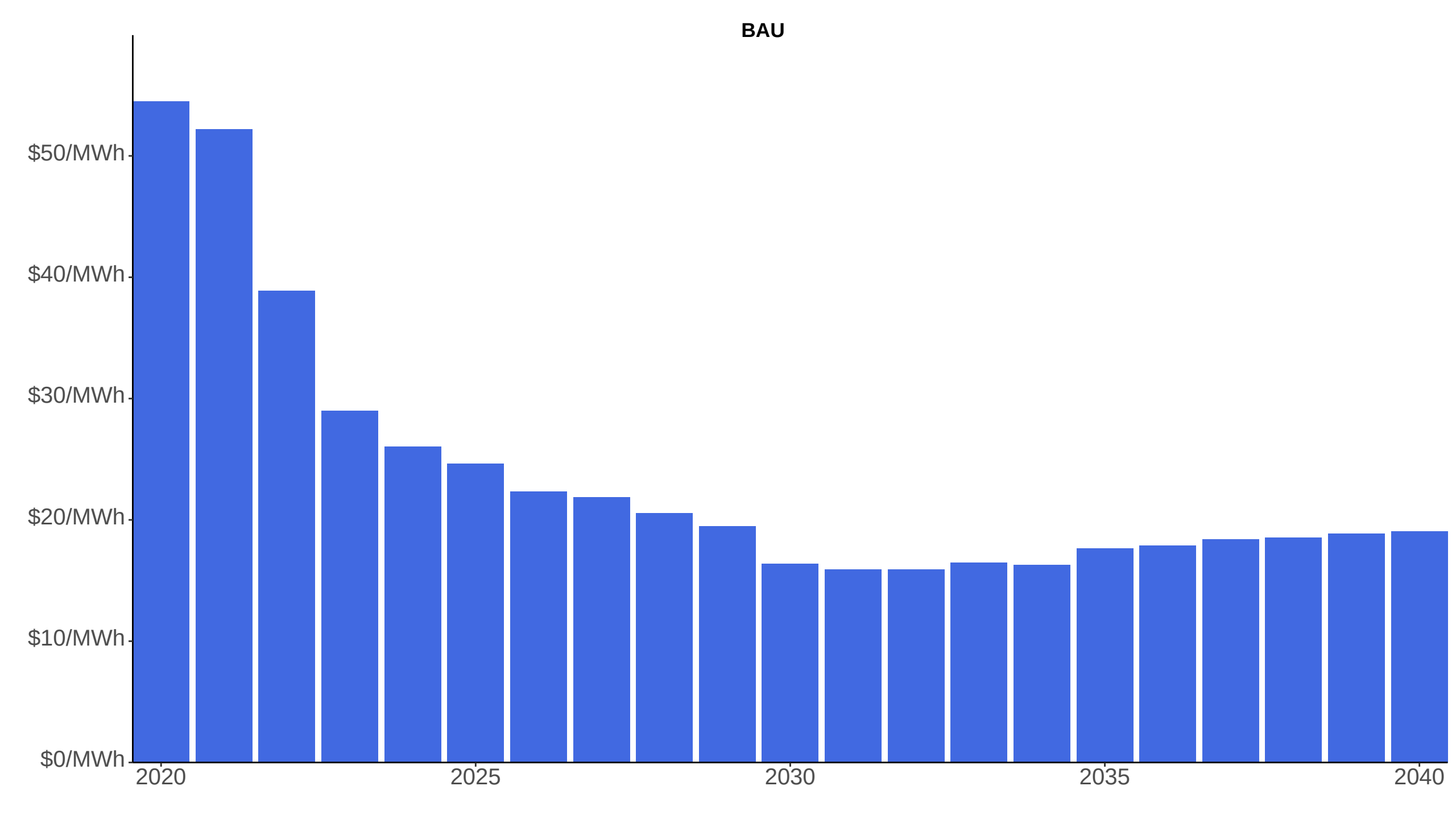
Not as much wind and solar capacity installed in this scenario as compared to the BAU and 100% RPS scenarios

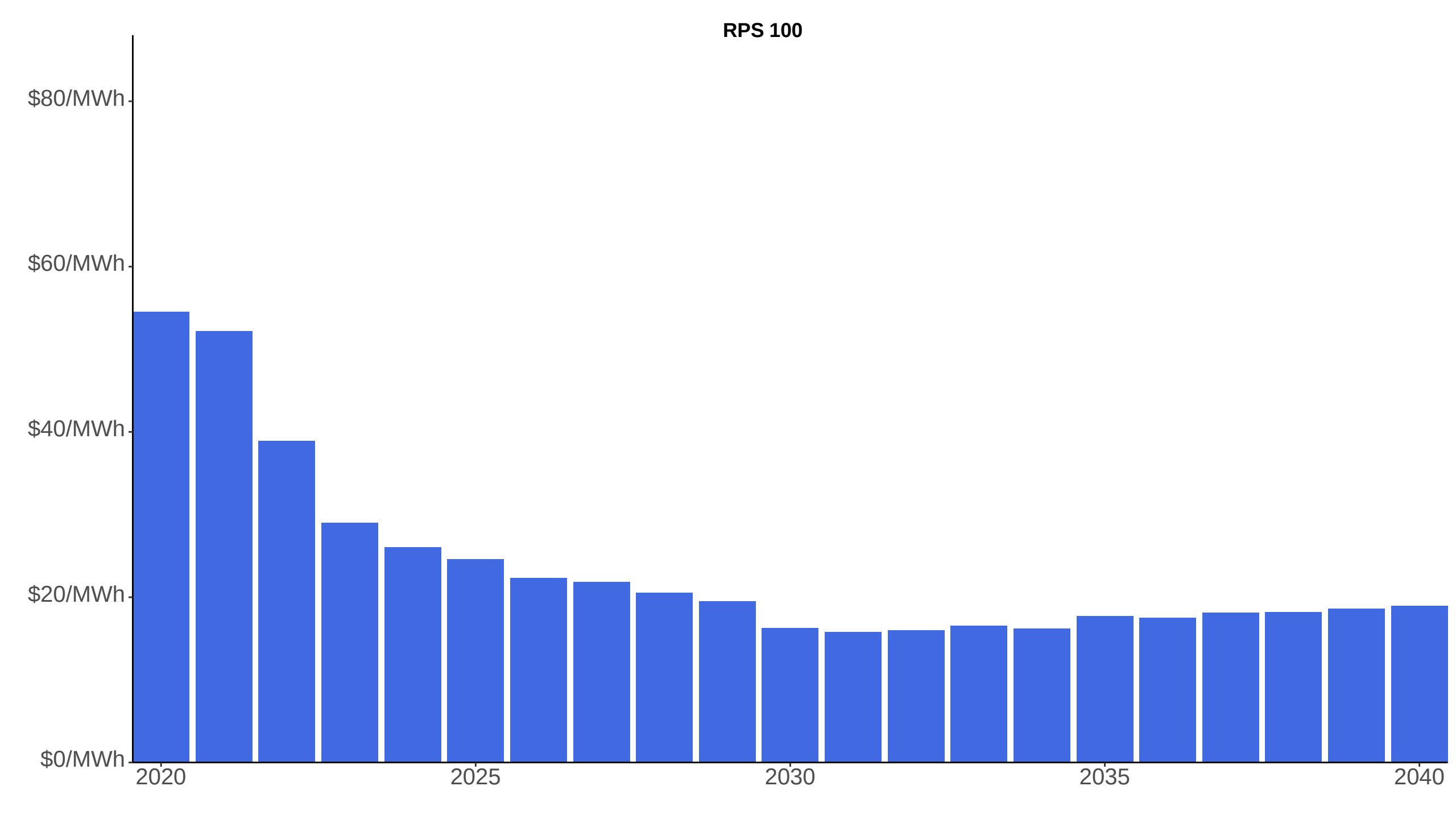
New natural gas installations pick up from about 2029 to 2036, especially when Calvert Cliffs is retired, but not as much as compared to the other two scenarios

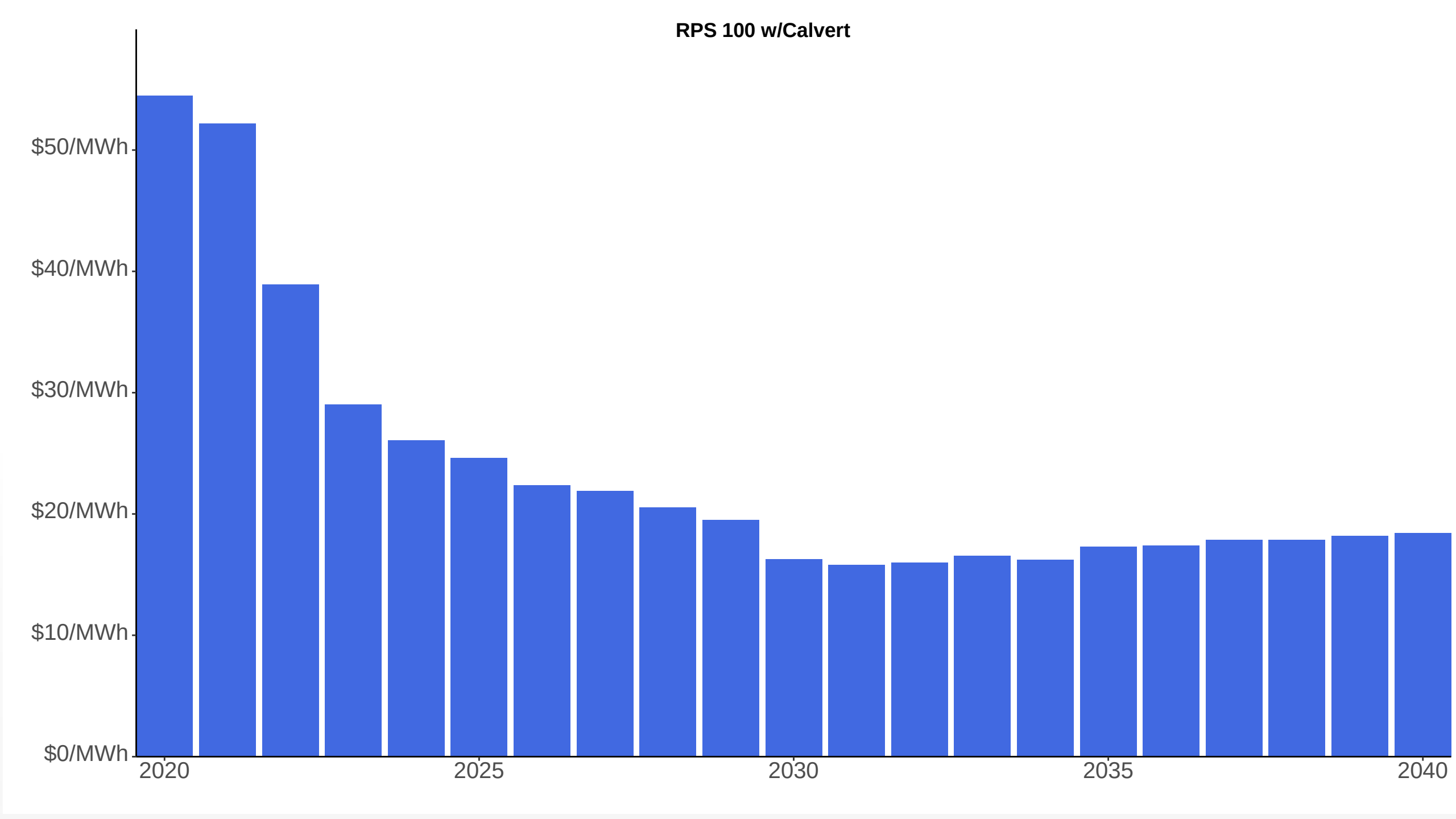
Annual Capacity Installations and Retirements by Technology in PJM/IL, 2020-2040 (100% Clean Scenario)

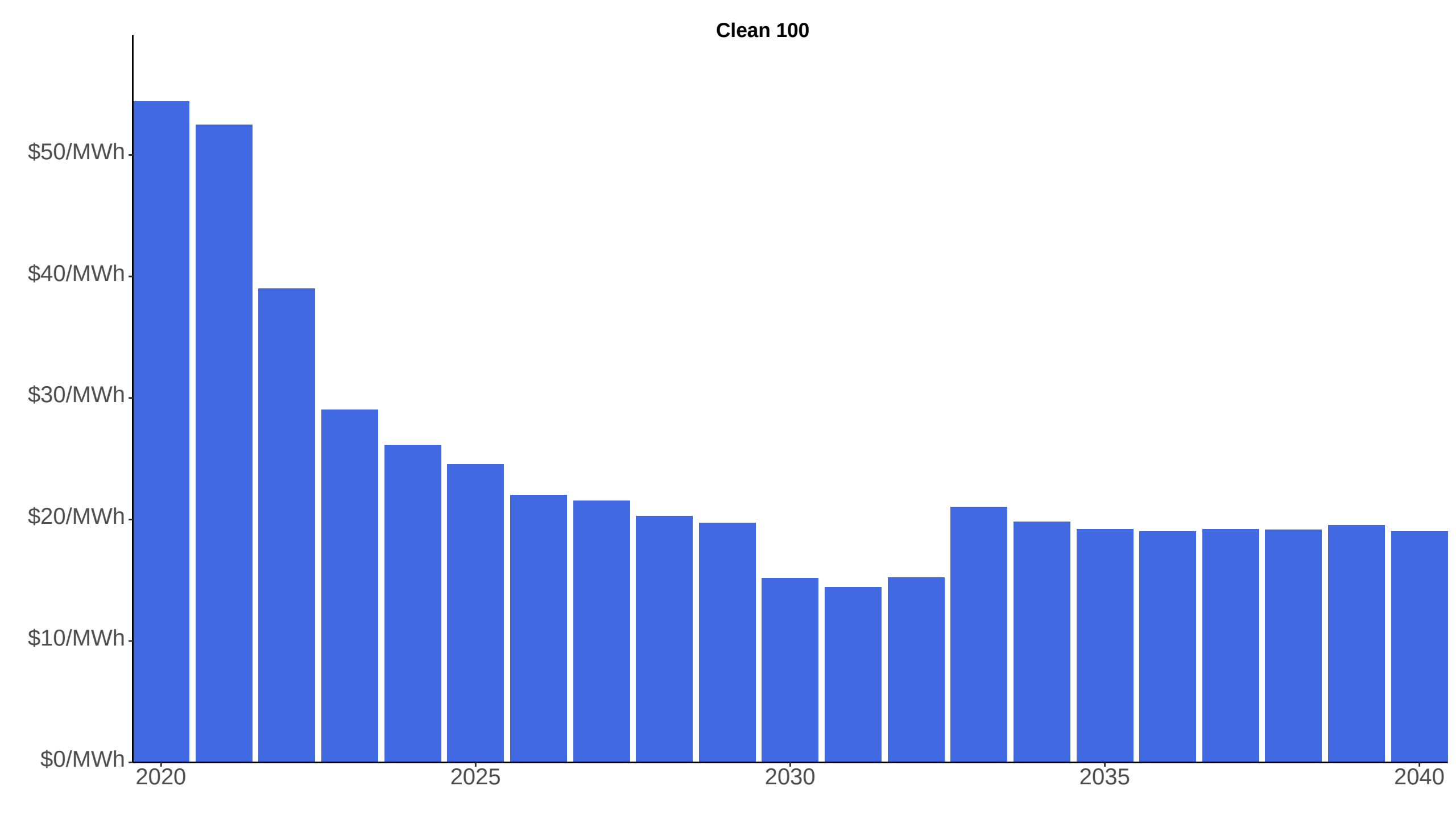


Average Marginal Cost

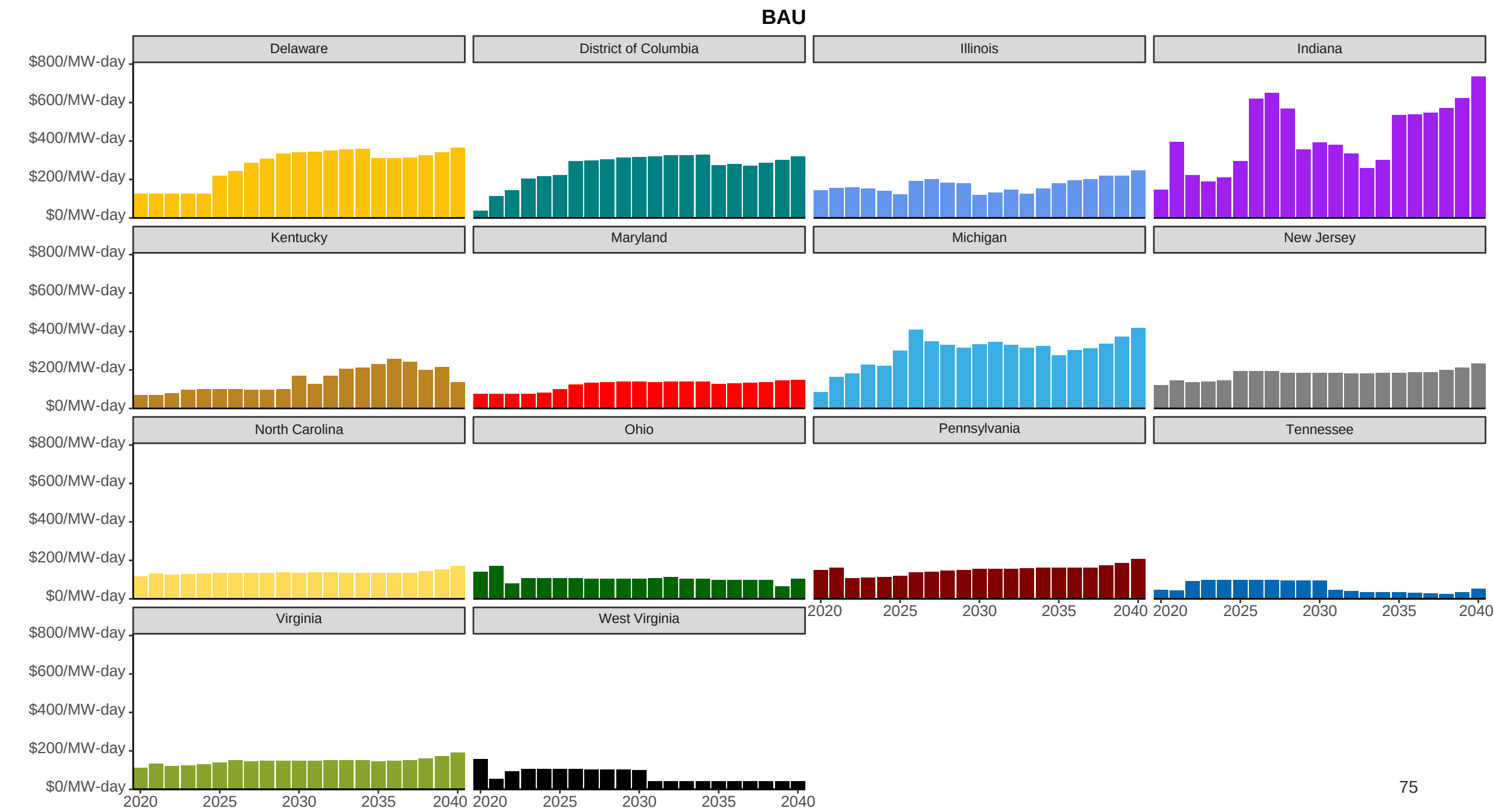

BAU
$50/MWh
$40/MWh
$30/MWh
$20/MWh
$10/MWh
$0/MWh
2020
2025
2030
2035
2040


RPS 100
$80/MWh
$60/MWh
$40/MWh
$20/MWh
$0/MWh
2020
2025
2030
2035
2040


RPS 100 w/Calvert
$50/MWh
$40/MWh
$30/MWh
$20/MWh
$10/MWh
$0/MWh
2020
2025
2030
2035
2040


Clean 100
$50/MWh
$40/MWh
$30/MWh
$20/MWh
$10/MWh
$0/MWh
2020
2025
2030
2035
2040

Capacity Cost by State and by Scenario


BAU
Delaware
District of Columbia
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Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
$800/MW-day
$600/MW-day
$400/MW-day
$200/MW-day
$0/MW-day
2020
2025
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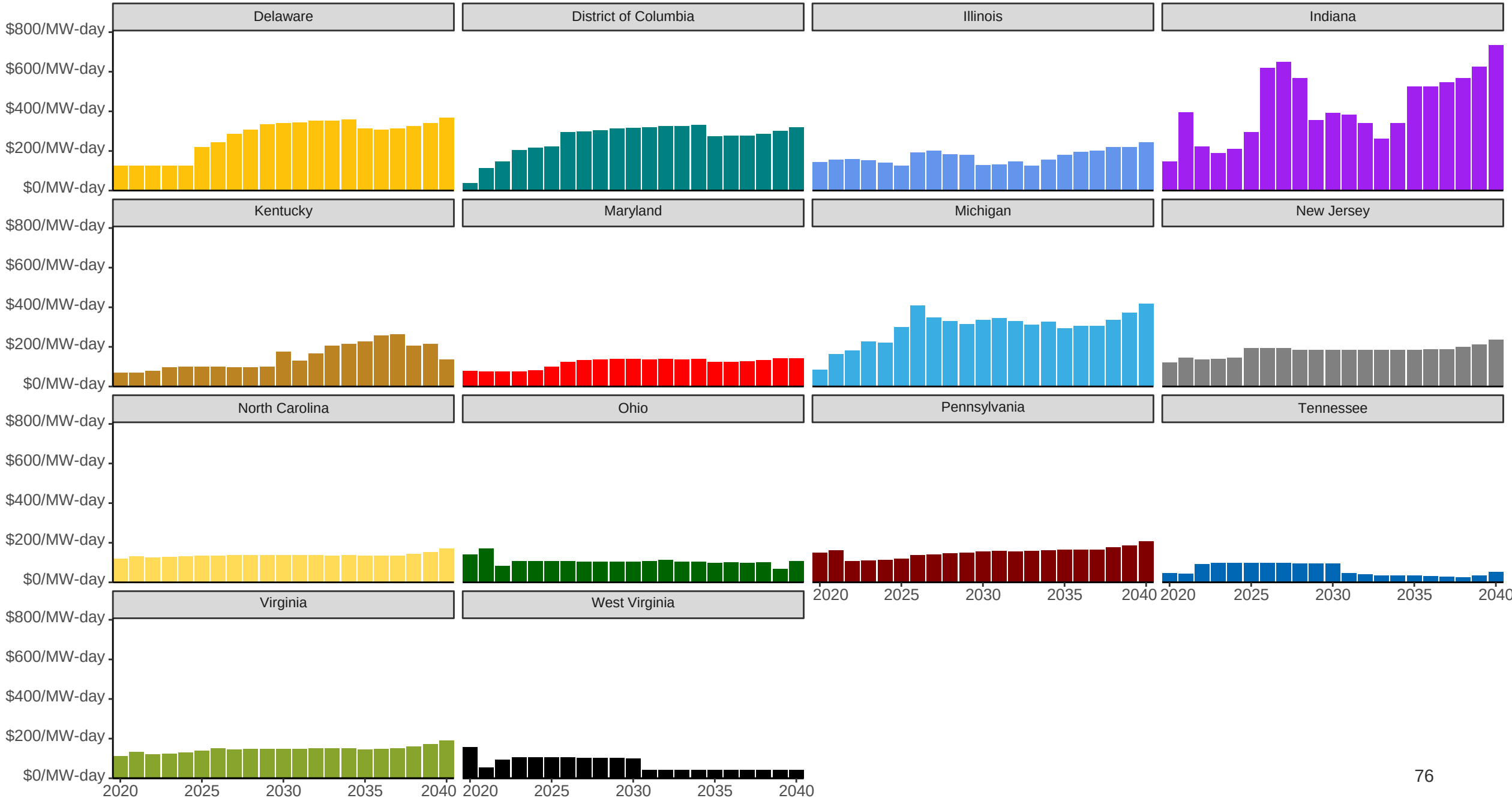
2040

RPS 100


Delaware
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New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
$800/MW-day
$600/MW-day
$400/MW-day
$200/MW-day
$0/MW-day
2020
2025
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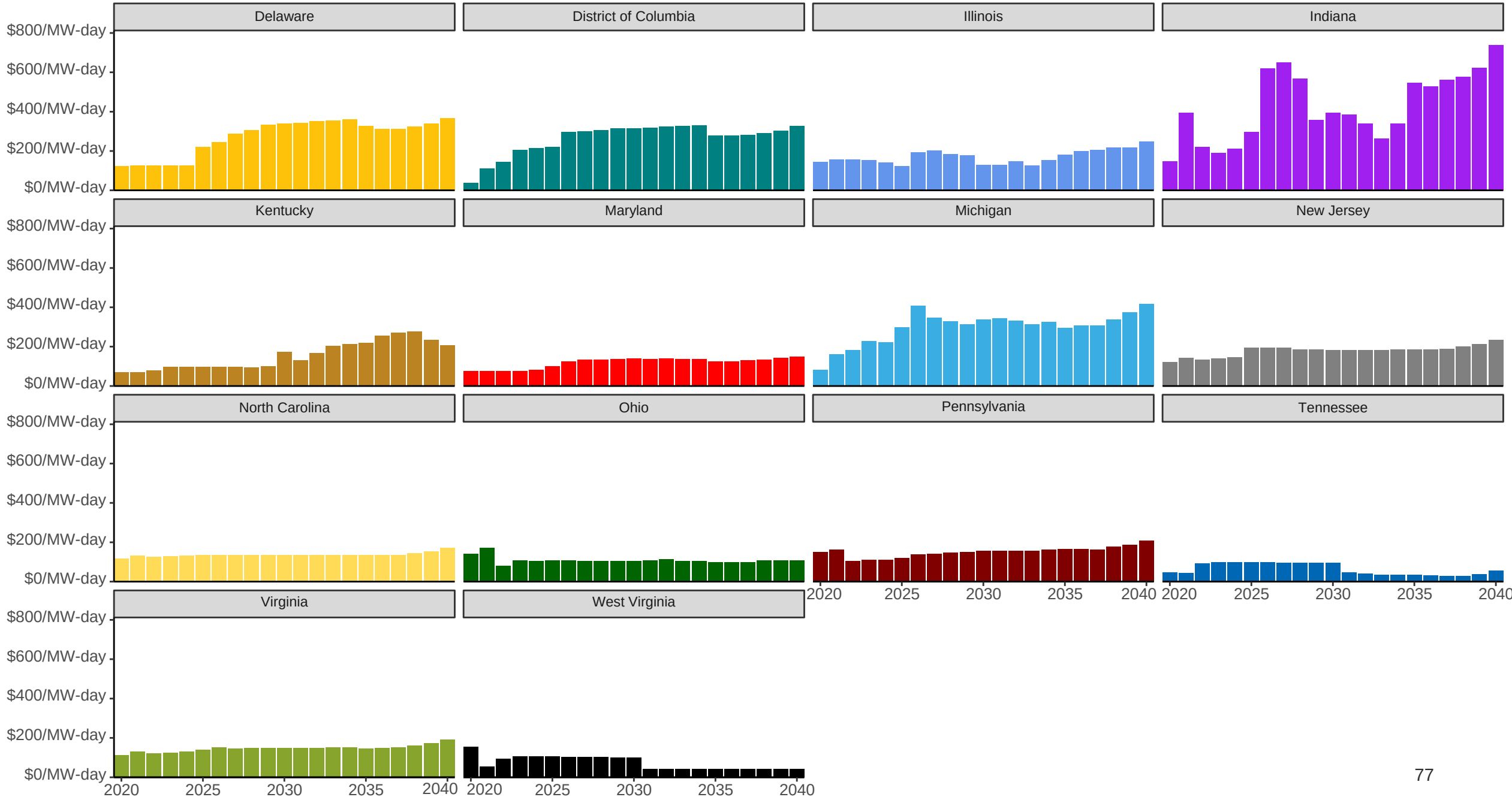
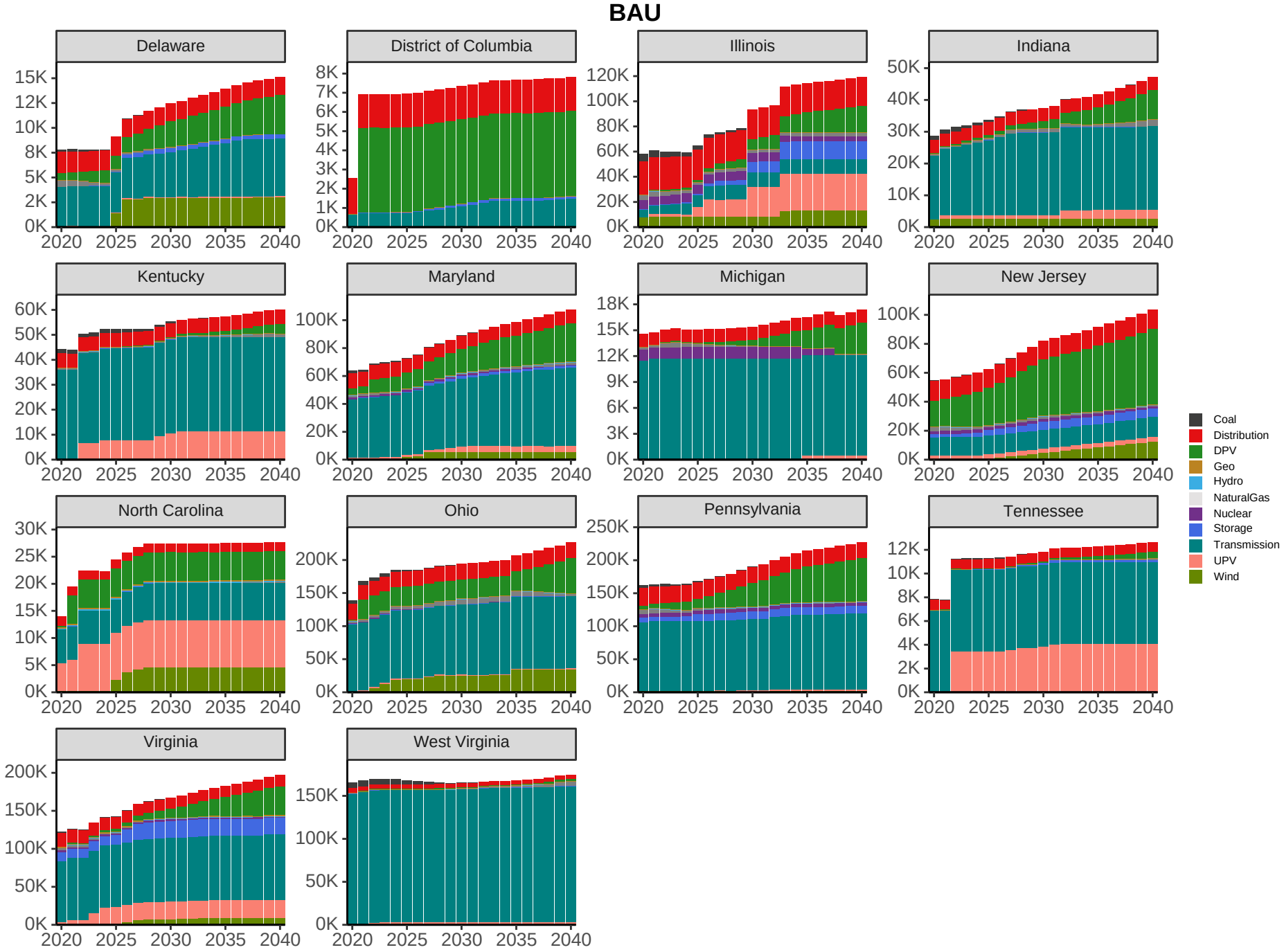
2035
2040

RPS 100 w/Calvert



Jobs by State by Scenario


BAU
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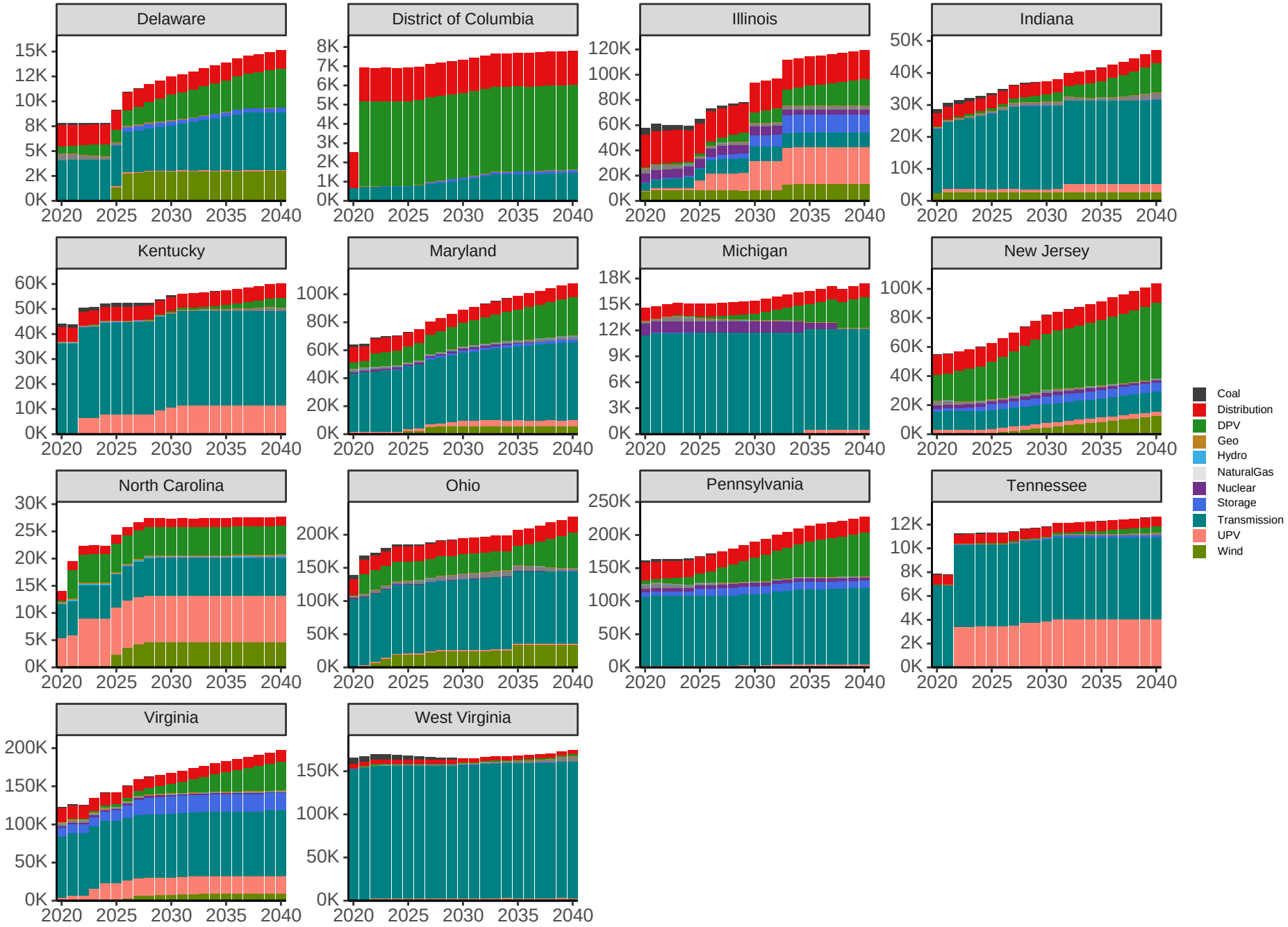
Indiana
Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
Coal
Distribution
DPV
Geo
Hydro
NaturalGas
Nuclear
Storage
Transmission
UPV
Wind

RPS 100


Delaware
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Virginia
West Virginia
2020
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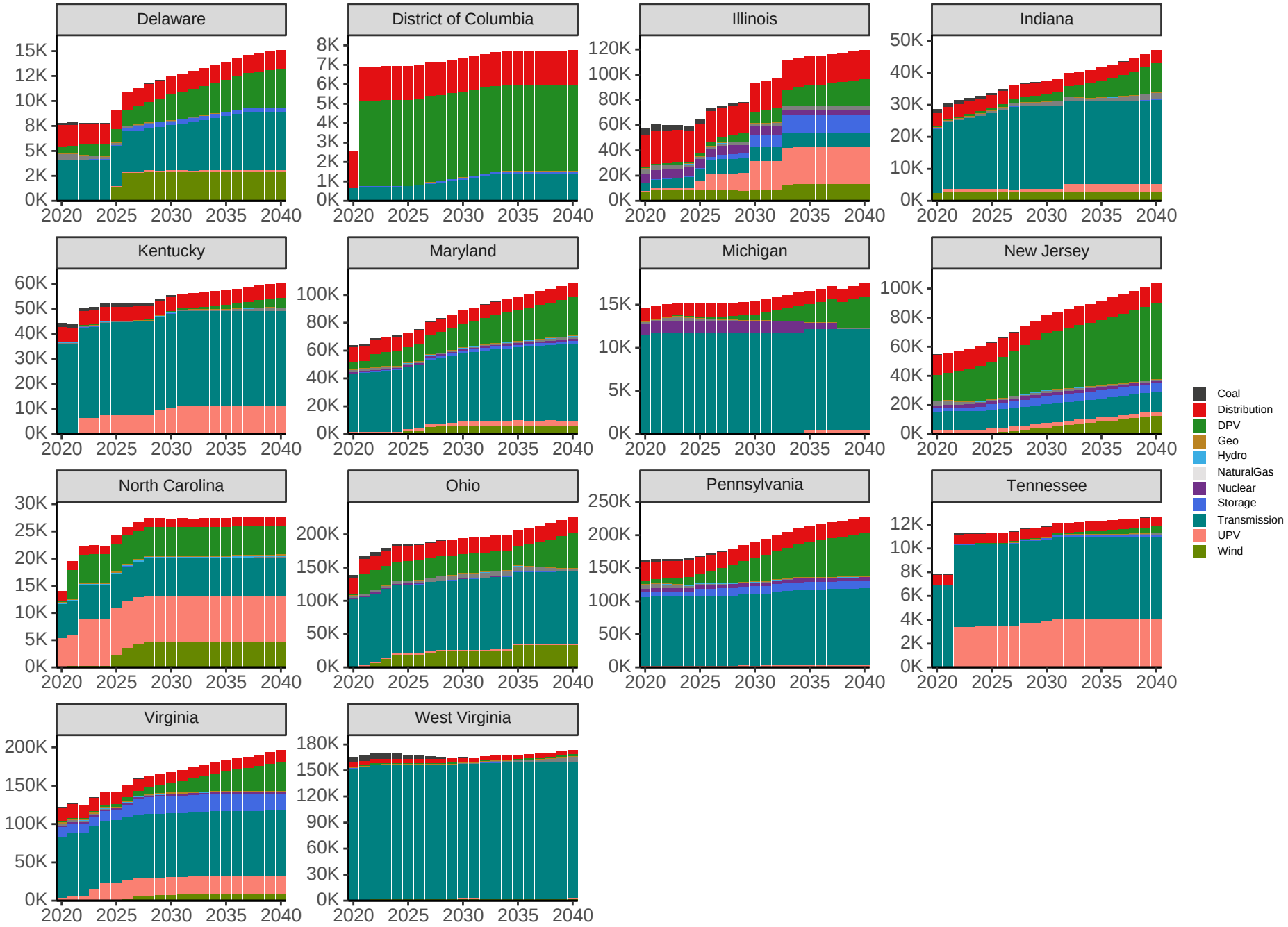
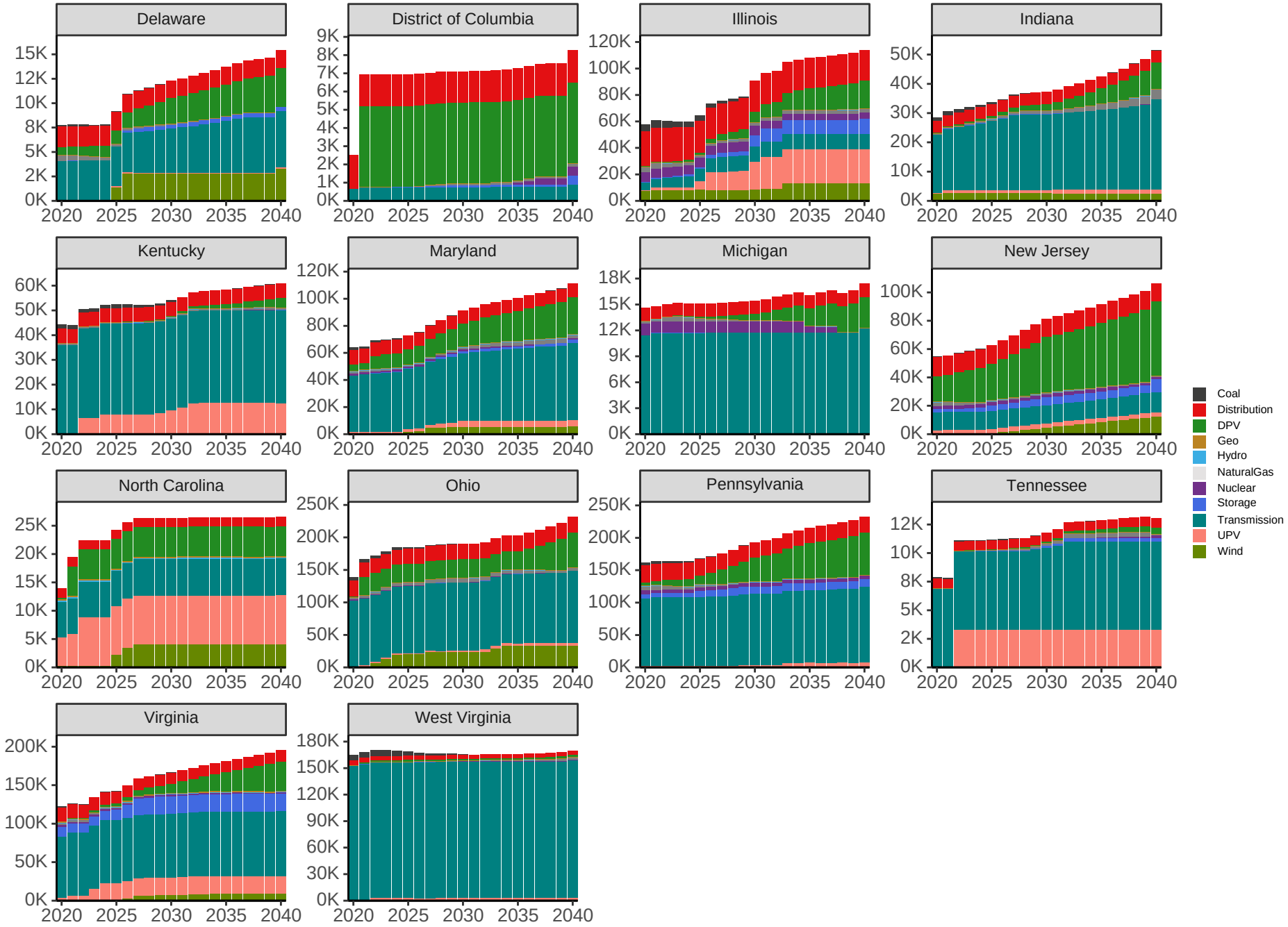
2040
Coal
Distribution
DPV
Geo
Hydro
NaturalGas
Nuclear
Storage
Transmission
UPV
Wind

RPS 100 w/Calvert



Clean 100


Delaware
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Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
2020
2025
2030
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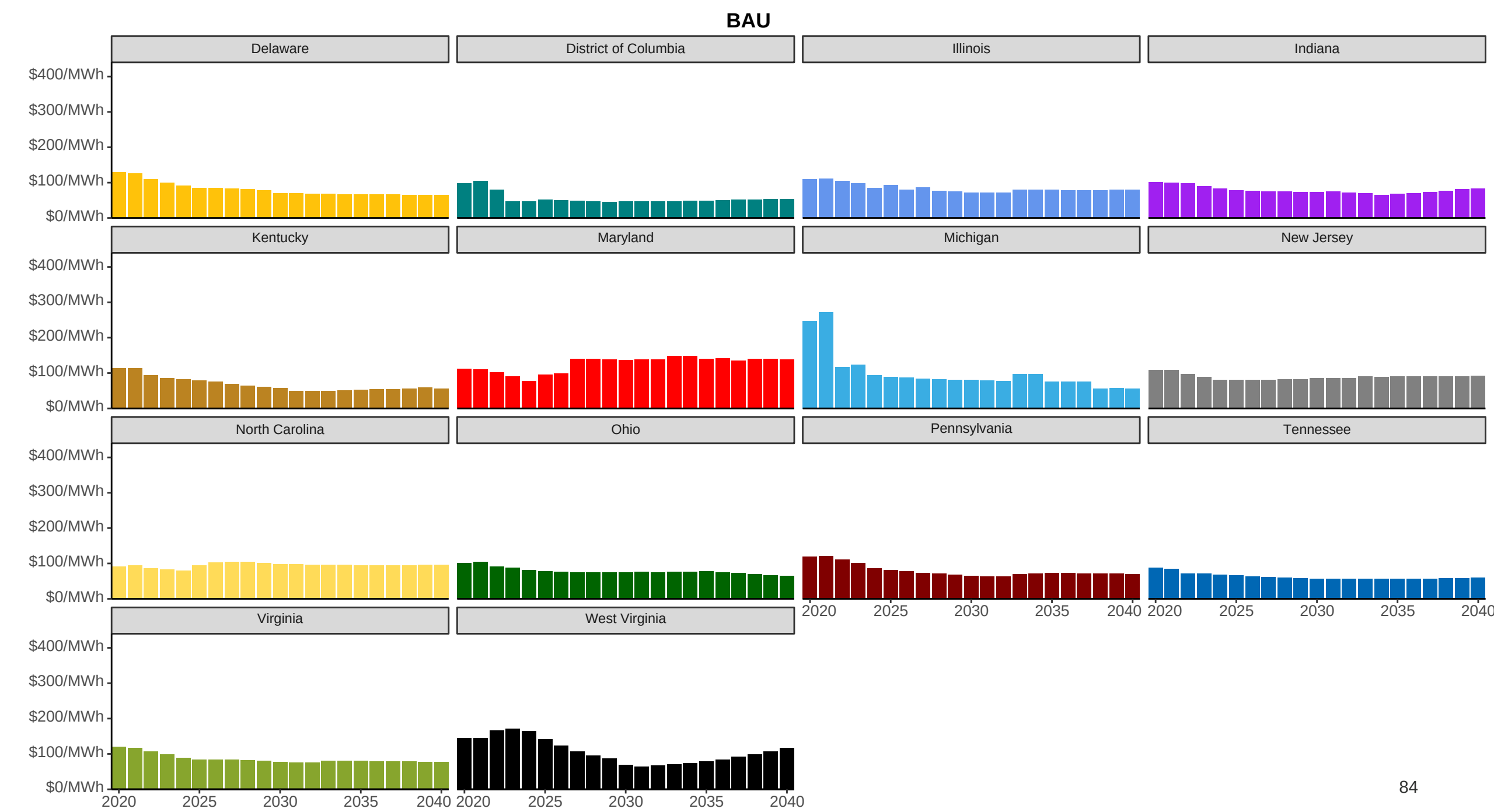
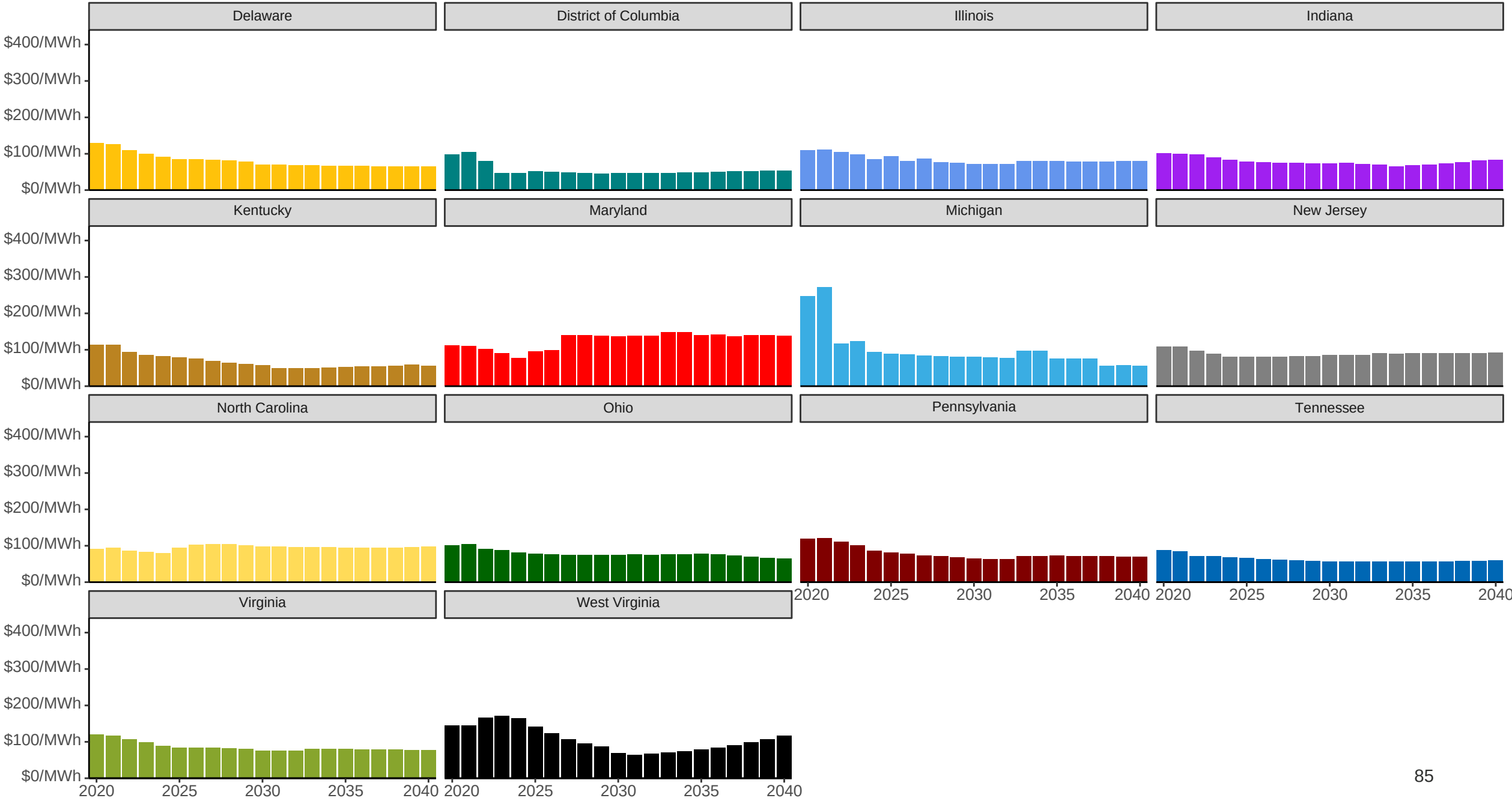
2040
Coal
Distribution
DPV
Geo
Hydro
NaturalGas
Nuclear
Storage
Transmission
UPV
Wind

Retail Rates by State by Scenario


BAU
Delaware
District of Columbia
Illinois
Indiana
Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
$400/MWh
$300/MWh
$200/MWh
$100/MWh
$0/MWh
2020
2025
2030
2035
2040

RPS 100


Delaware
District of Columbia
Illinois
Indiana
Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
$400/MWh
$300/MWh
$200/MWh
$100/MWh
$0/MWh
2020
2025
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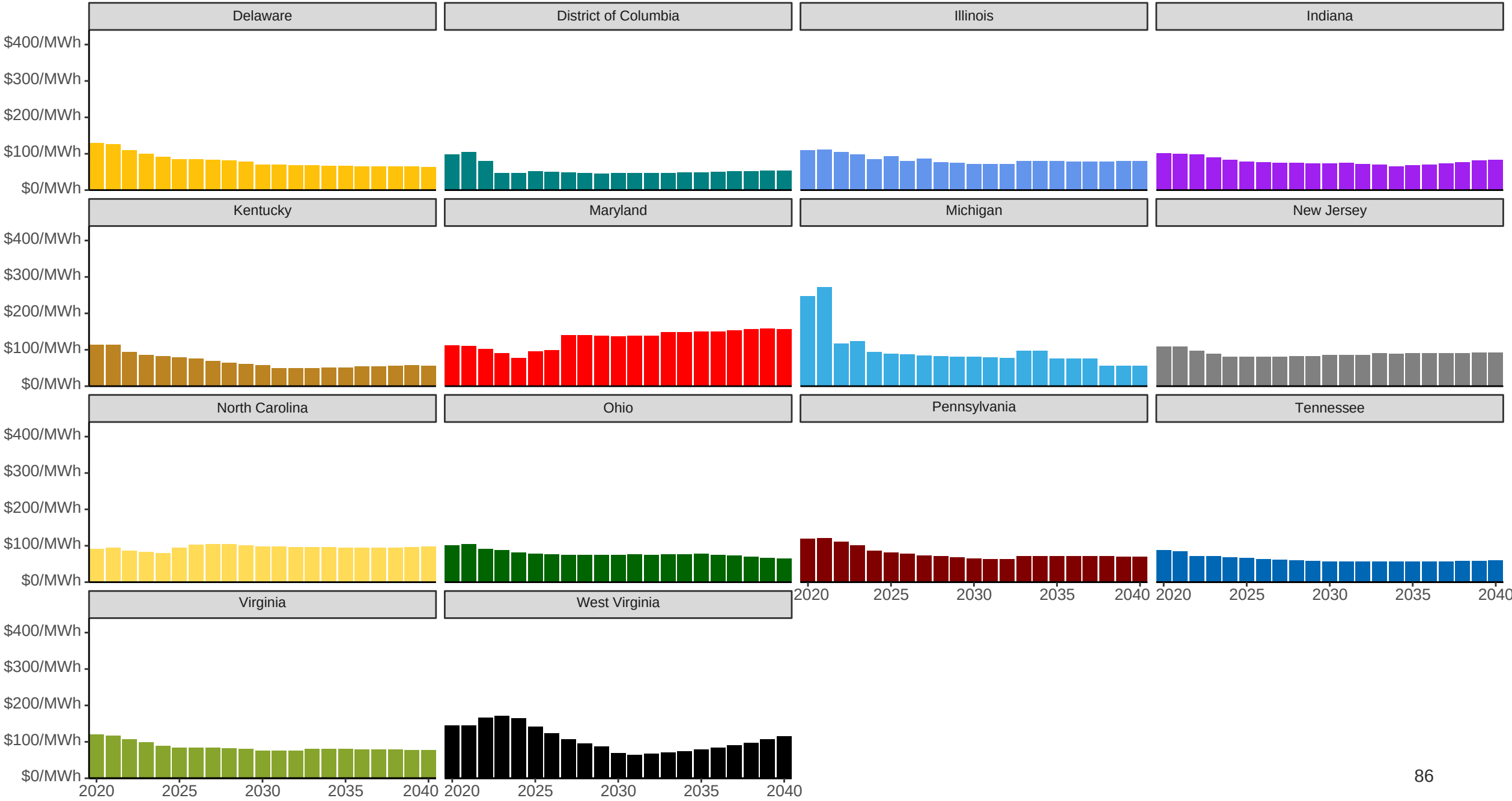
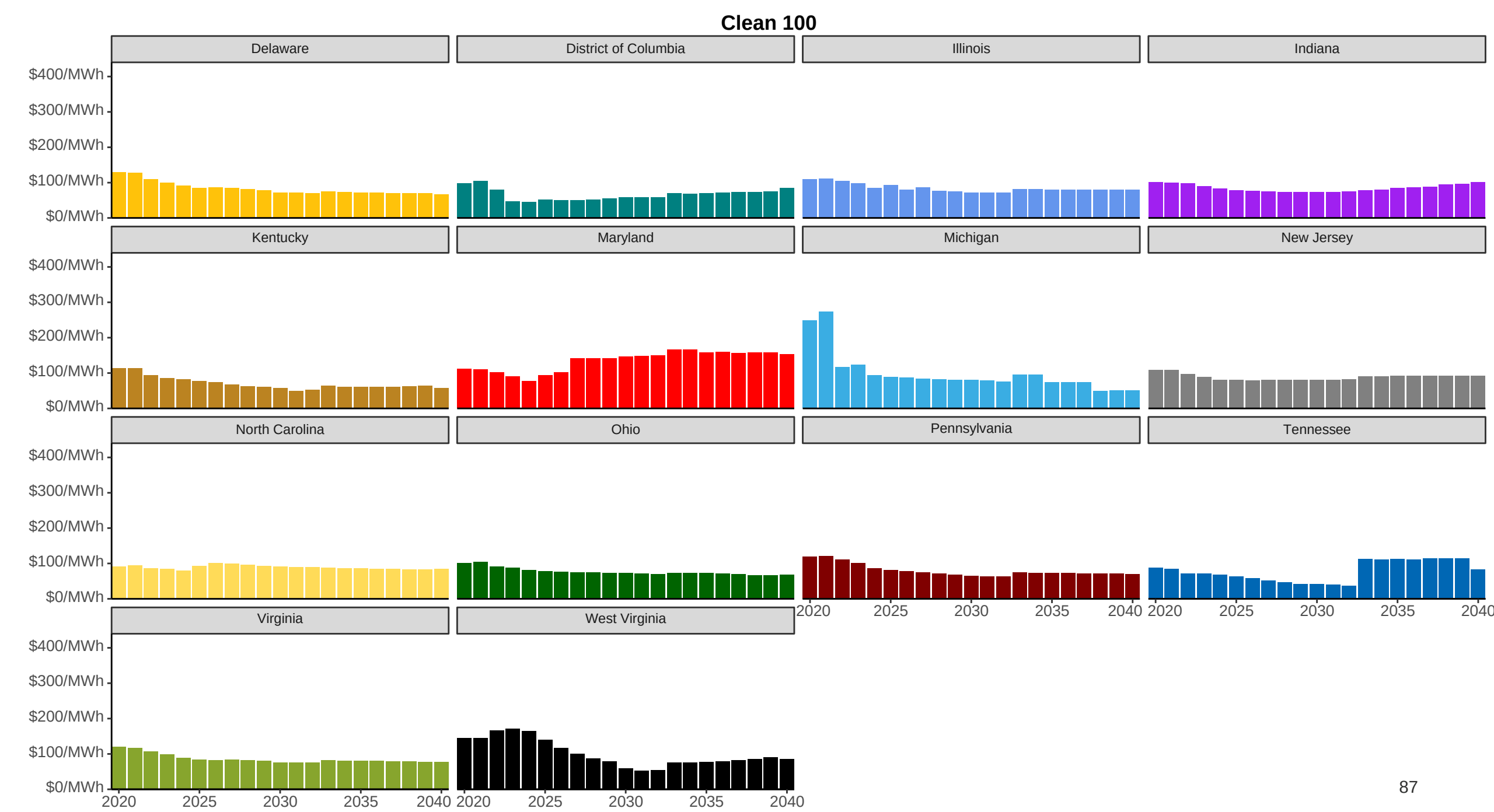
2040

RPS 100 w/Calvert




Clean 100
Delaware
District of Columbia
Illinois
Indiana
Kentucky
Maryland
Michigan
New Jersey
North Carolina
Ohio
Pennsylvania
Tennessee
Virginia
West Virginia
$400/MWh
$300/MWh
$200/MWh
$100/MWh
$0/MWh
2020
2025
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