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LONG-TERM PLANNING, RESOURCE ADEQUACY, AND REVENUE SUFFICIENCY IN LOW-CARBON MARKETS

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U.S. DEPARTMENT OF ENERGY
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CONTEXT AND MOTIVATION

- Challenges
  - Ability of markets to provide adequate signals for investments and retirements
  - Potential to revisit existing reliability metrics and mechanisms
  - Need for adequate financial tools/markets for market participants to manage risk

- Overarching research questions
  - To what extent can energy-only markets ensure market efficiency, resource adequacy and provide incentives for new investment in a zero-carbon system?
  - What is the role of a long-term energy market or capacity remuneration mechanism in contributing to resource adequacy and cost recovery?
  - How might remuneration mechanisms for resource adequacy be best designed in future low-carbon systems?

RESEARCH OBJECTIVES AND APPROACH

RESEARCH OBJECTIVES

- Investigate the outcomes for different long-term “market designs” within the context of near-zero carbon markets, focusing on:
  – Market outcomes
  – System costs
  – Hydropower operations and revenues
  – Revenue sufficiency

- Two cases analyzed:
  1. No PRM case – “energy only”
  2. PRM case – “capacity-based”

	No PRM Case	PRM Case
Unmet Demand Penalty (VOLL)	$9,000/MWh	$2,000/MWh*
Reserve Violation Penalty	$3,500/MWh	$750/MWh*
Unforced Capacity (UCAP) Requirement	None	35,500 MW*

PRM = Planning Reserve Margin

**Current NYISO market parameters*

CASE STUDY: NEW YORK ISO

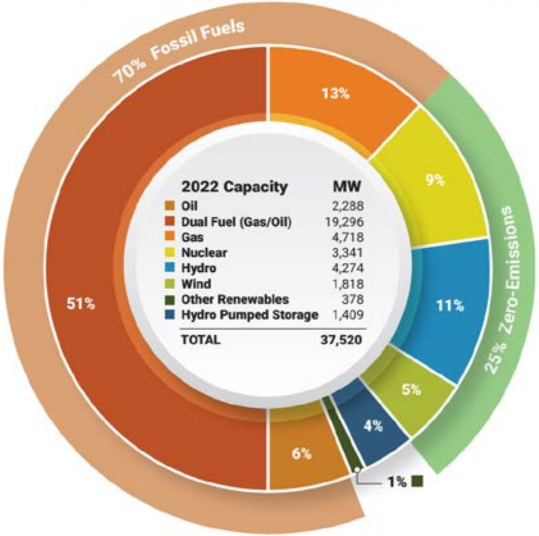
- Test system is based on 2022 New York power grid

- New York state has multiple clean energy and carbon reduction goals
  - Including zero-emissions power grid by 2040

- High amounts of hydroelectric capacity
  - Conventional hydro: 23% of annual energy, 11% of installed capacity
  - Pumped storage hydro: <1% of energy, 4% of installed capacity

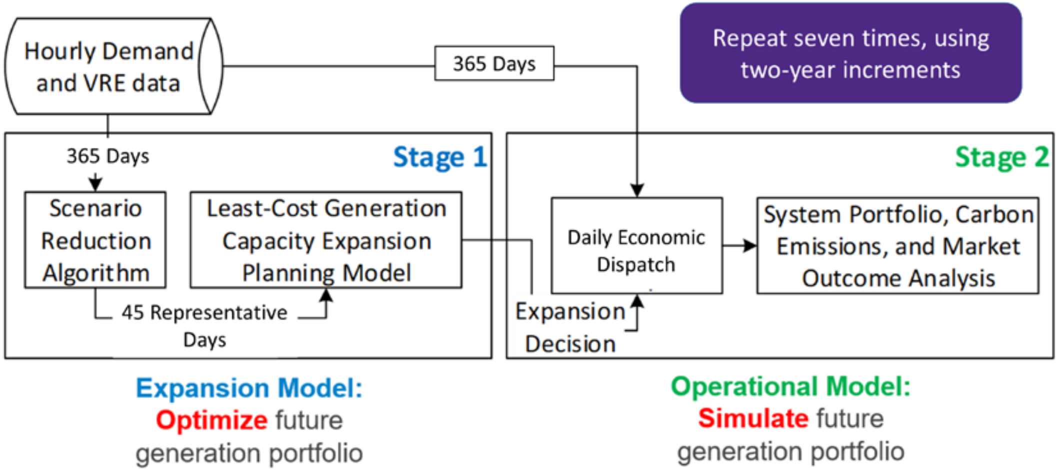
New York Control Area Summer Installed Capacity

Figure 11: Summer Installed Capacity (MW) by Fuel Source - Statewide, Upstate and Downstate New York: 2022



Source for figures: 2022 NYISO Reliability Needs Assessment

METHODOLOGY OVERVIEW (A-LEAF)

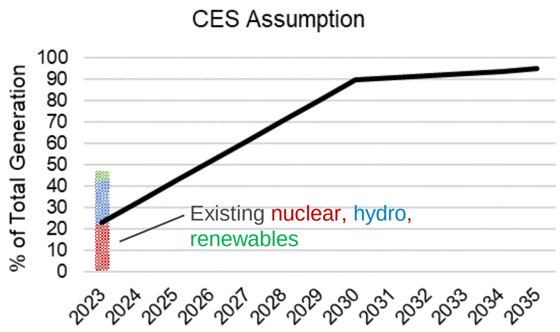


ALEAF = Argonne Low-carbon Electricity Analysis Framework

- Least-cost capacity expansion using 45 representative days
  - Gives investment decisions and investment costs
  - Objective: minimize total system cost, including costs of investment, energy production, fixed O&M, etc.
- Operations for all 365 days
  - Gives more detailed results for dispatch patterns and energy prices (LMPs)
- Three types of hydro
  - Impoundment (reservoir)
  - Pumped hydro storage
  - Run-of-river

OTHER KEY ASSUMPTIONS

- Clean energy standard (CES) reaches 95% by 2035
  - To ensure a near-zero-carbon grid
- Economic investment and retirements
  - No hardcoded additions or age-based retirements
- Constant total peak demand and energy and load shape
- Two zones (upstate and downstate) with 4GW transmission link
  - Upstate region has existing large hydro and nuclear
  - Downstate region has more thermal generation, higher load and prices
- $10/ton carbon price (RGGI)
- Cost and market parameter assumptions largely taken from NREL ATB and NYISO
- All results presented are in 2020 (real) dollars



SUMMARY OF FINDINGS

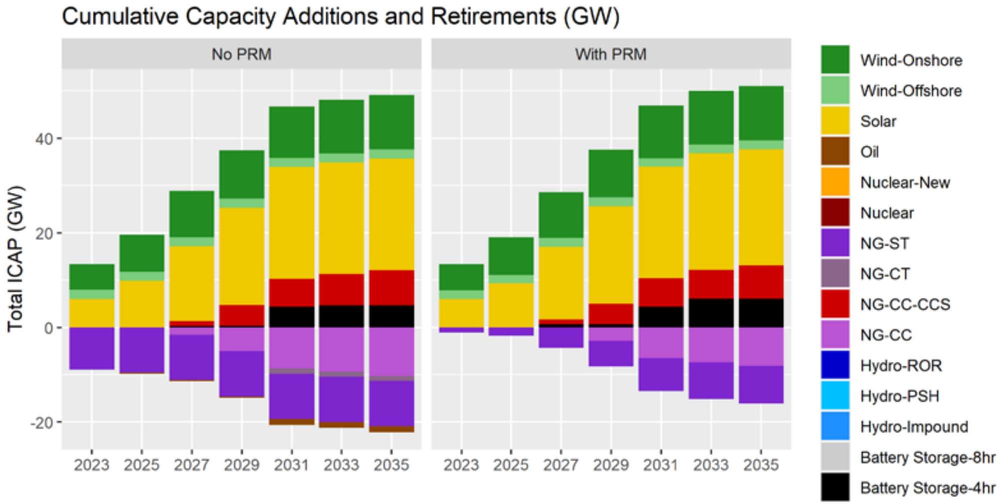
PRM CASE YIELDS MORE INSTALLED CAPACITY THAN NO PRM CASE; NEW BUILDS ARE SIMILAR

Greatest difference is retirements in early years

- No PRM case retires ~9 GW of existing units in first year
  - Saves on fixed O&M costs
  - Compare to ~1 GW of existing units retired in PRM case; others are retained to satisfy PRM requirement

- Early wind and solar build is driven by favorable economics, not CES

- Some minor differences in new investments between the two cases (next slide)



New builds:
- Solar
- Onshore and offshore wind
- 4-hr storage
- NG-CC with CCS

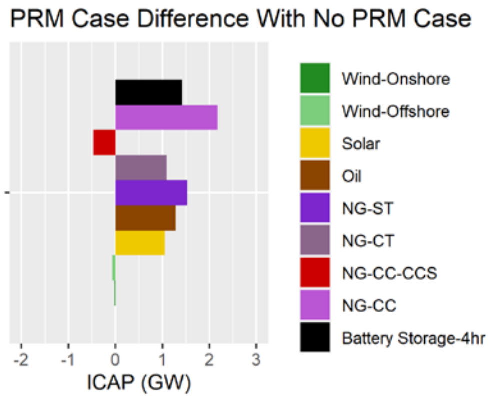
Not built:
- NG-CT
- New nuclear
- 8-hr storage

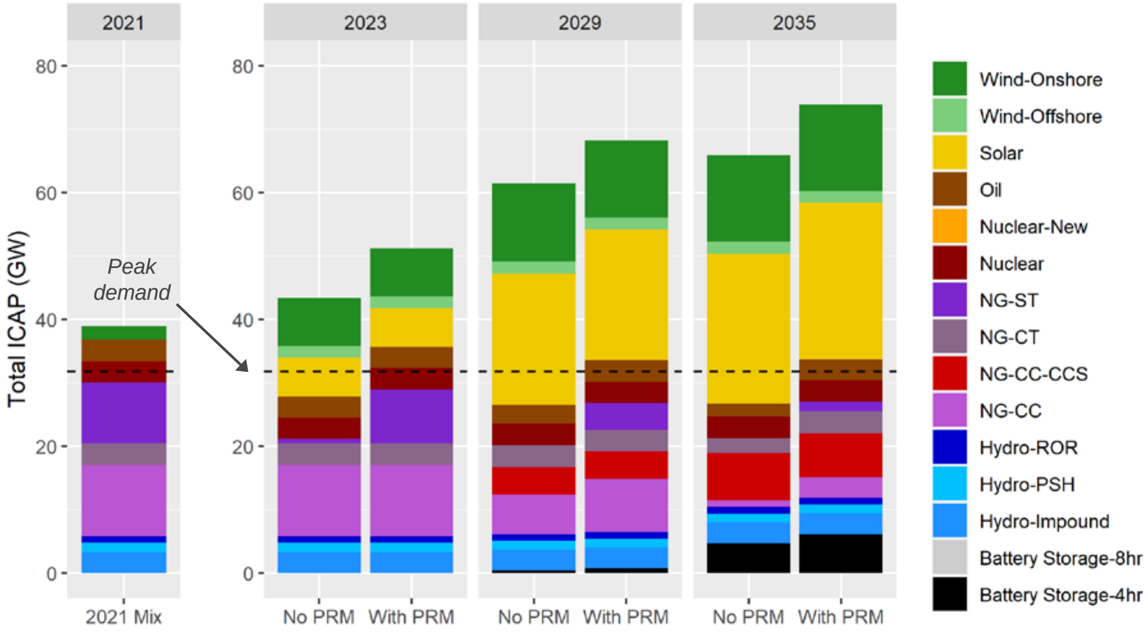
Note: total annual new build limited to 3 GW per year for solar, wind, and storage technology, 5 GW for other technologies

PRM CASE YIELDS MORE INSTALLED CAPACITY THAN NO PRM CASE; NEW BUILDS ARE SIMILAR

CES-eligible resources make up vast majority of installed capacity by 2035

- PRM Case has more thermal, solar and storage and less NG-CC-CCS
  - Substitution between NG-CC and NG-CC-CCS



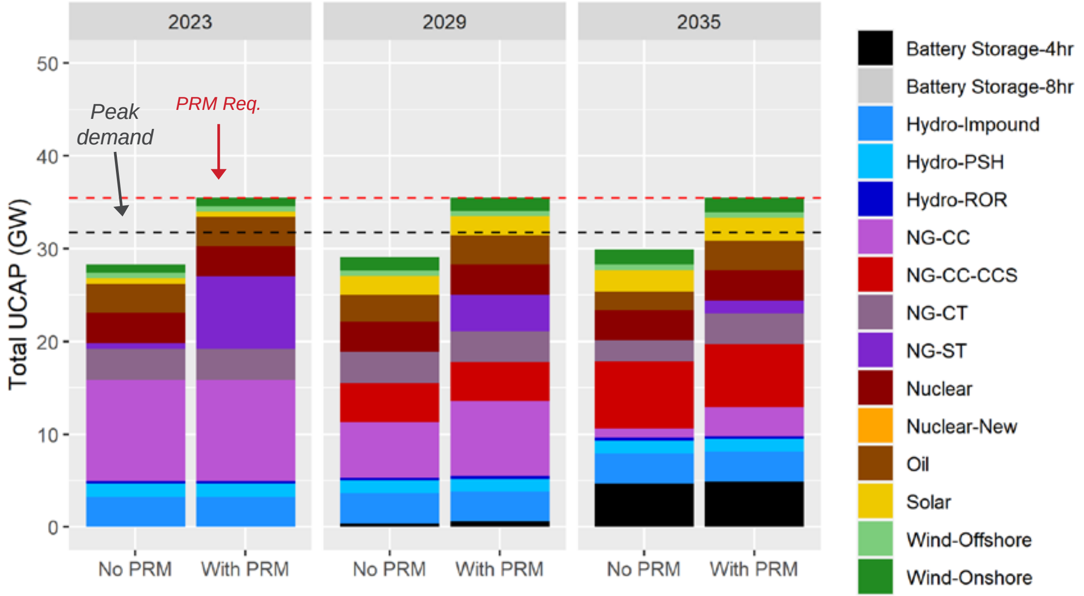


NO PRM CASE YIELDS TOTAL UNFORCED CAPACITY (UCAP) WELL BELOW THE PRM REQUIREMENT

Tradeoff between meeting PRM target and increasing system costs

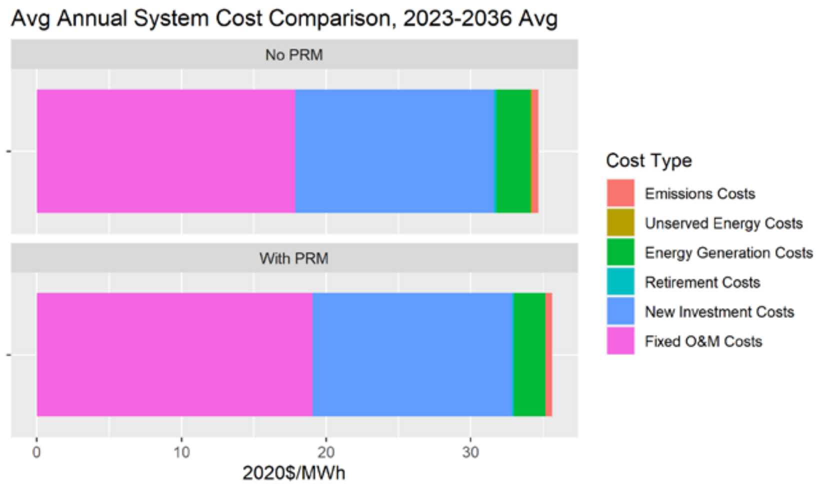
- Key assumptions for UCAP accounting:
  - 35,500 MW UCAP requirement
  - Capacity credits: 10% solar, 12% onshore wind, 30% offshore wind, 80% 4-hr storage; others 90%-97%

Ongoing work tests the effect of variable capacity credits for VRE and storage



SYSTEM COSTS ARE SLIGHTLY HIGHER IN THE PRM CASE

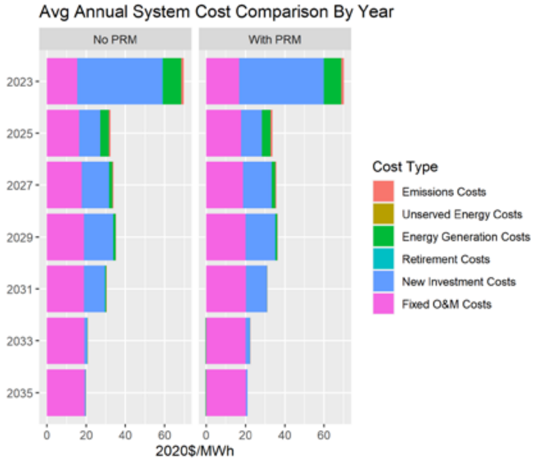
Total system costs from 2023-2036 are ~3% higher



Cost Type	No PRM	With PRM	PRM Case Difference
Investment	$13.71	$13.79	$0.07
Fixed O&M	$17.88	$19.08	$1.19
Energy Generation	$2.39	$2.20	-$0.19
Retirement	$0.18	$0.12	-$0.06
Unserved Energy	$0.08	$0.00	-$0.08
Emissions Cost	$0.43	$0.44	$0.00
System Cost	***$34.68***	***$35.62***	***$0.94***

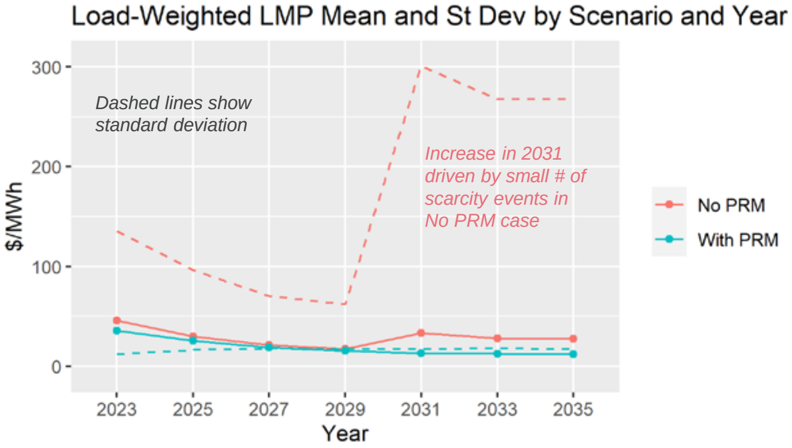
3% higher in PRM Case

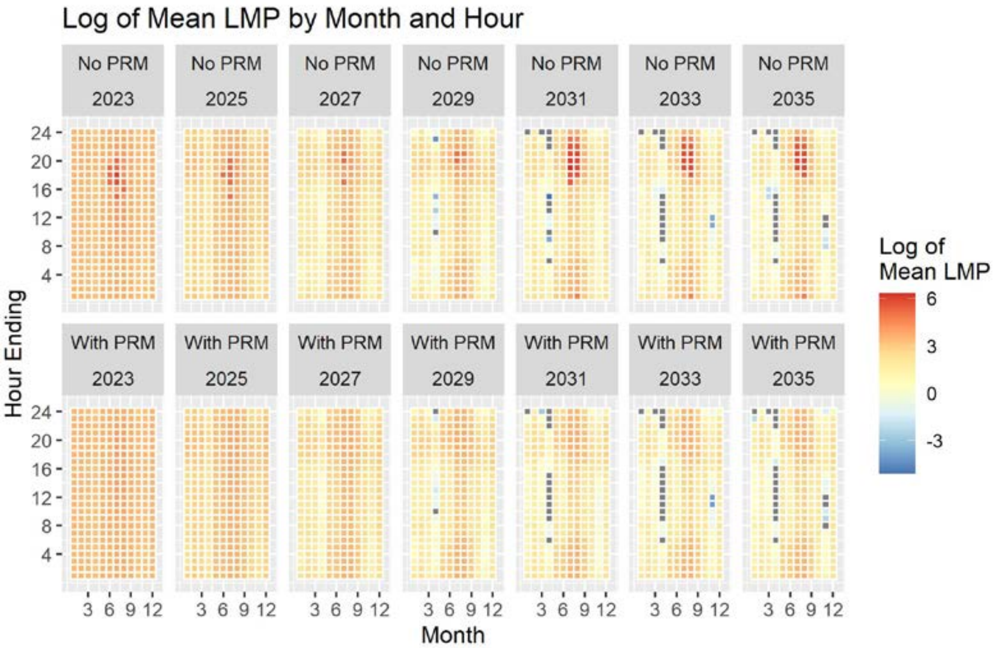
- Driven mainly by higher fixed O&M costs in PRM case
  - Magnitude of difference may be sensitive to fixed cost assumption
- Figure below shows that generation costs decline over time to ~0 (after PTC)



AVERAGE ENERGY PRICES ARE HIGHER, MORE VOLATILE IN NO PRM CASE

- Frequency of zero and negative-priced hours increases from <1% of hours in 2023 to 43% in 2035
- No PRM case features higher average prices due to higher price caps and more frequent scarcity events



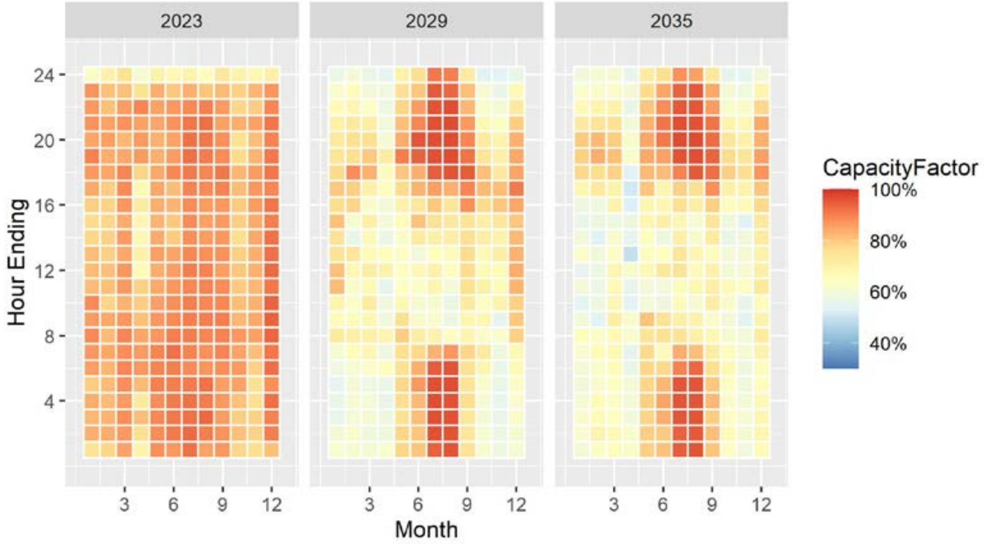


Gray squares in figure indicate LMPs were on average negative or zero

HYDROELECTRIC GENERATION RESPONDS TO INCREASED VRE PENETRATION

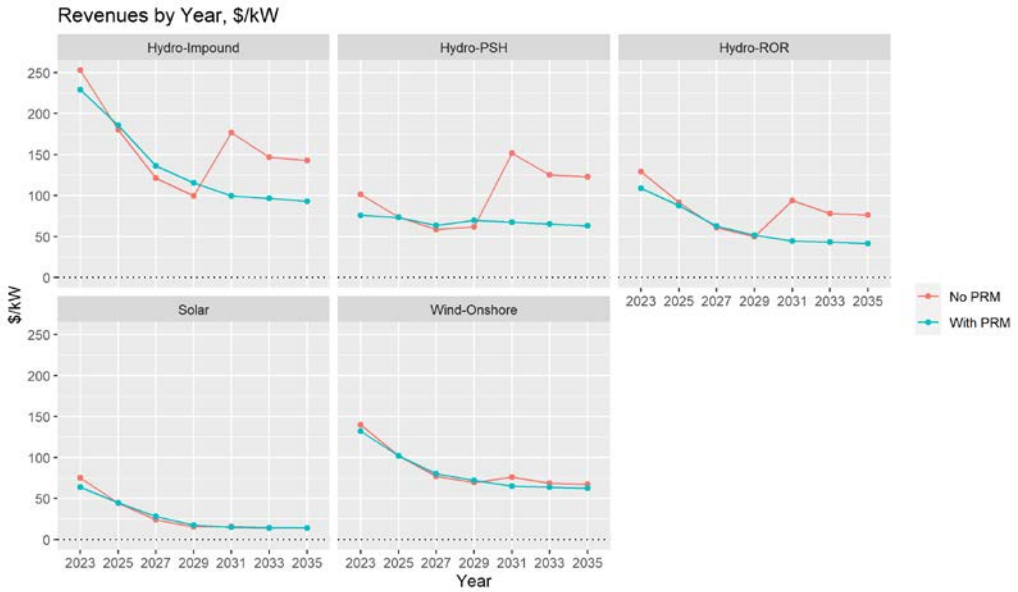
Output concentrates in higher-priced net peak load hours

- Plot shows evolution of average hourly capacity factor for impoundment hydro over time
  - Pumped storage hydro (and battery storage) show similar shifts in generation patterns
  - Run-of-river hydro modeled as fixed shape



HYDROELECTRIC OPERATING REVENUES DIFFER BY TECHNOLOGY, GENERALLY DECREASE

- The two more flexible hydro technologies (impoundment hydro and PSH) have comparatively higher revenues per kW
  - Run-of-river hydro modeled as fixed shape similar to wind and solar



GENERATOR REVENUE SUFFICIENCY BY CASE, NO ADDITIONAL PAYMENTS

Profits are for entire 2023-2036 time period on a per-kW basis

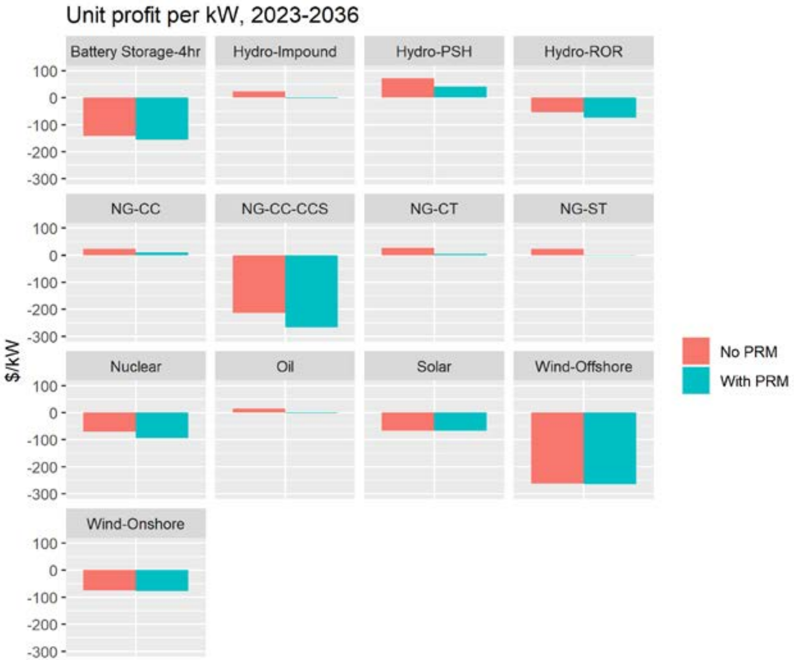
- Profits in figure include investment costs
- Many non-CES resources have negative profits
  - Retained to satisfy PRM constraint but not compensated in model
- CES-eligible resources have highly negative profits
  - Retained/built to satisfy CES constraint but not compensated in model

GENERATOR REVENUE SUFFICIENCY BY CASE, AFTER ADDITIONAL CAPACITY PAYMENT

Profits are for entire 2023-2036 time period on a per-kW basis

- Adding capacity payments makes whole all non-CES resources
  - Also awarded to other resources based on UCAP

- Most CES-eligible resources still have highly negative profits
  - Compensation level and method for CES-eligible resources is a major policy question
  - Exceptions: impoundment hydro and PSH



SUMMARY OF FINDINGS

- PRM case has 3% higher system costs than No PRM case, mainly due to differences in fixed costs and lack of thermal retirements
  - Not a very large cost differential, but may depend on fixed O&M assumptions
  - Future work might quantify the distribution of market/system outcomes in each case using probabilistic methods
- Energy prices become more volatile with greater penetration of VRE, and more so in the No PRM case
- Hydroelectric generation shifts in response to new VRE
- Revenue sufficiency issues exist for most CES-eligible resources
  - Additional cost to incentivize new CES-eligible resource may be substantial
  - Existing impoundment hydro and PSH are exceptions due to flexible operations, being existing units

FUTURE DIRECTIONS

- Implement dynamic capacity credits for wind, solar, and storage and compare to existing cases
- Investigate alternative methods of achieving near-zero-carbon emissions
  - Carbon emission reduction target
  - Carbon pricing
- Quantify total generator revenue shortfall for resources
  - To provide a sense of policy costs associated with 95% CES target
  - Compare to results without any CES constraint
- Compare to game-theoretic models that simulate competition between firms at the investment stage
- Investigate alternative market designs discussed elsewhere during this workshop

QUESTIONS?

THANK YOU!

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