GRID PLANNING IMPACTS OF HYDROPOWER GROWTH AND DECLINE

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HydroVision International 2024
July 17, 2024
Denver, Colorado

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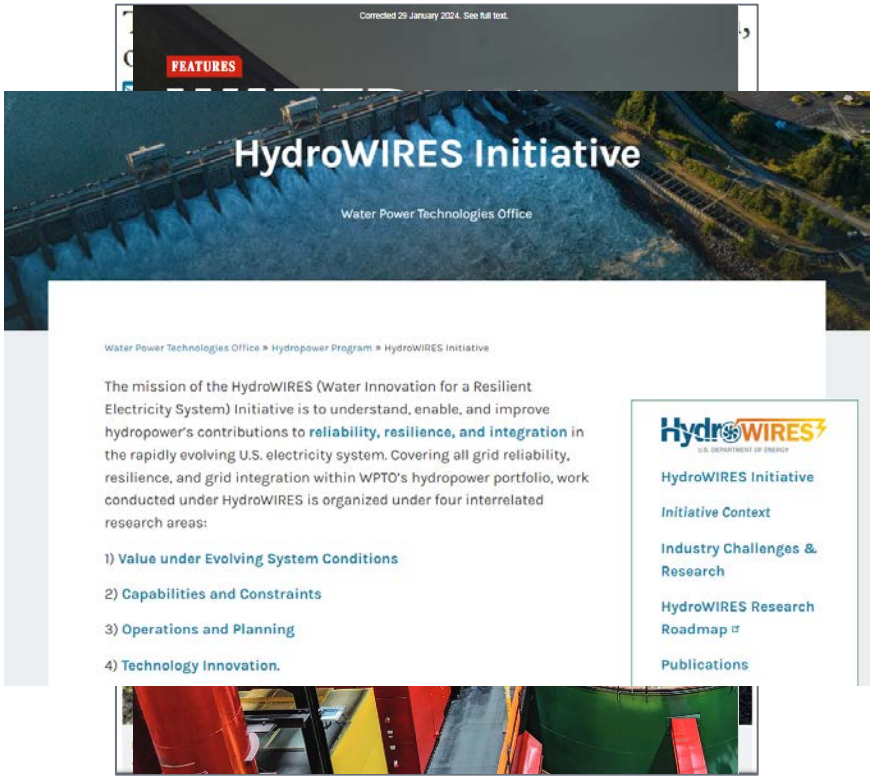
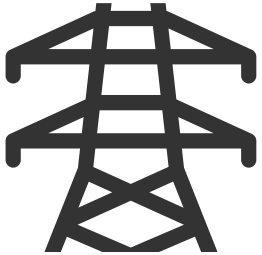
Contents

The Hydropower Industry Landscape is Becoming More Dynamic in the United States

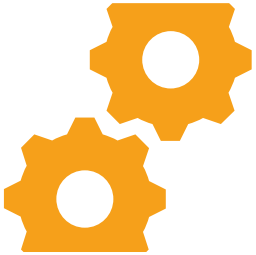
- Drought and climate change impacts
- Push for dam removals and reassessing environmental priorities and operations
- Interest in PSH for long-duration storage
- Interest in flexibility, reliability, and stability services



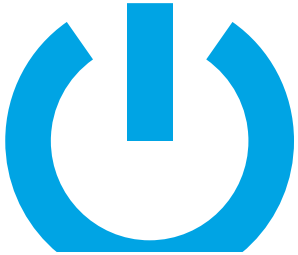
There are Many Ways That Changing the Hydropower Fleet Can Affect the Future Grid



Electric Sector Investments

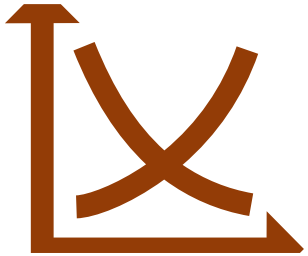


Plant and Grid Operation

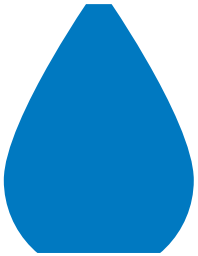


Grid Reliability

Grid Strength & Stability



Market Outcomes and Needs



Water Management

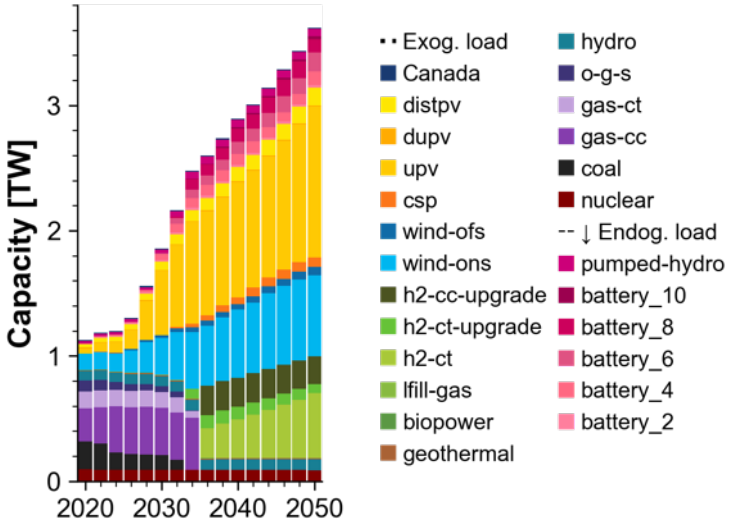
Emissions

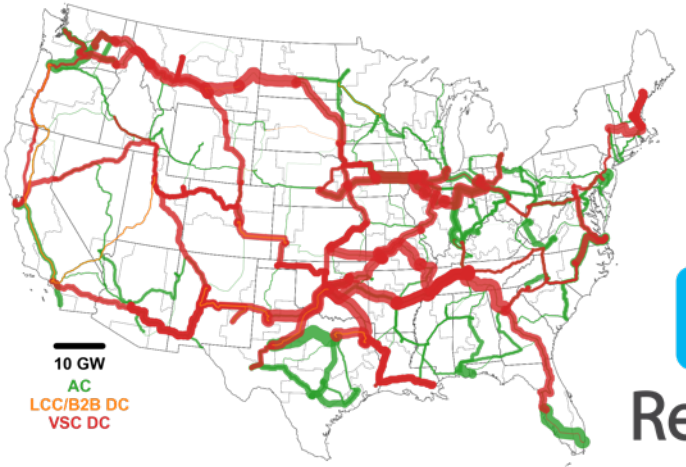
Cost

NREL Explores Some of These Impacts with the Regional Energy Deployment System (ReEDS) Grid Planning Model

- Linear program minimizes cost of U.S. electric sector capacity expansion and operation through 2050
- Satisfies energy and capacity requirements under resource, transmission, policy, and power system constraints
- Simulates competition between an extensive suite of generation, storage, and transmission technologies
- Spatial resolution: default 134 balancing areas, up to county-level possible
- Temporal resolution: default 42 diurnal profiles with 6x4-hr periods, up to hourly possible, plus 7 years of hourly data are used to estimate curtailment and capacity credit

Planning models can help understand the future role of hydropower & PSH in the grid.





ReEDS

https://www.nrel.gov/analysis/reeds/

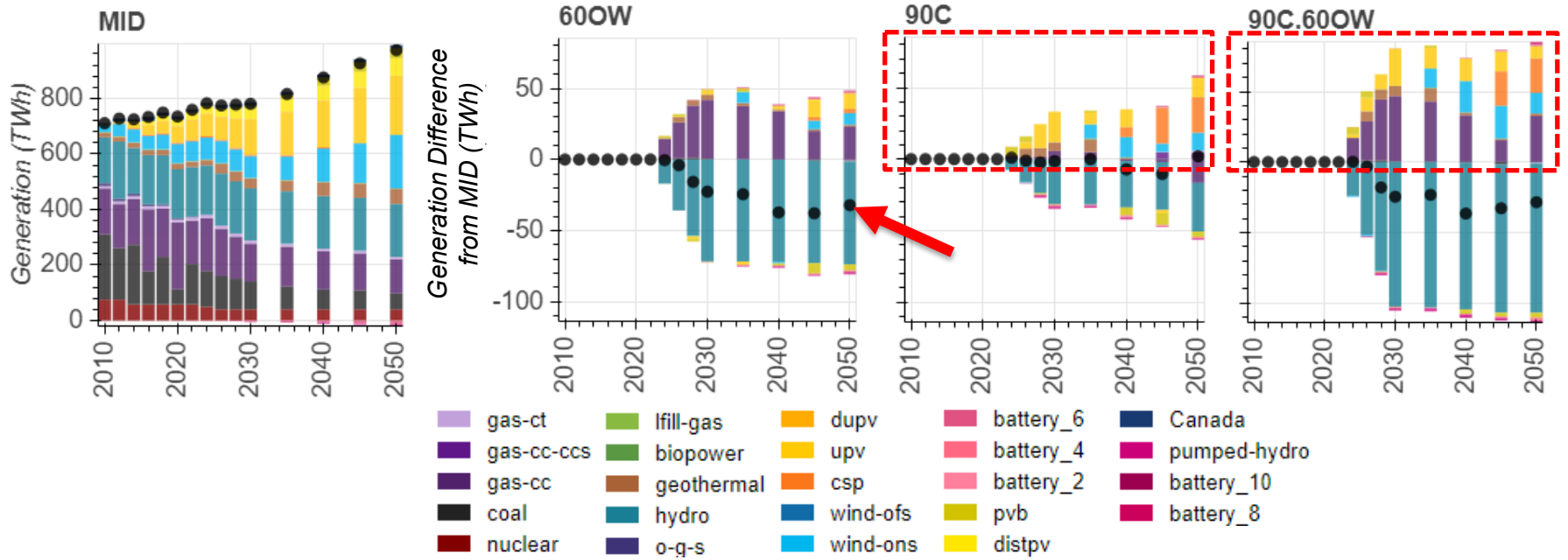
Decline

Scenarios with reduced hydropower energy or capacity

One Set of Scenarios Reduces Hydropower Energy Output

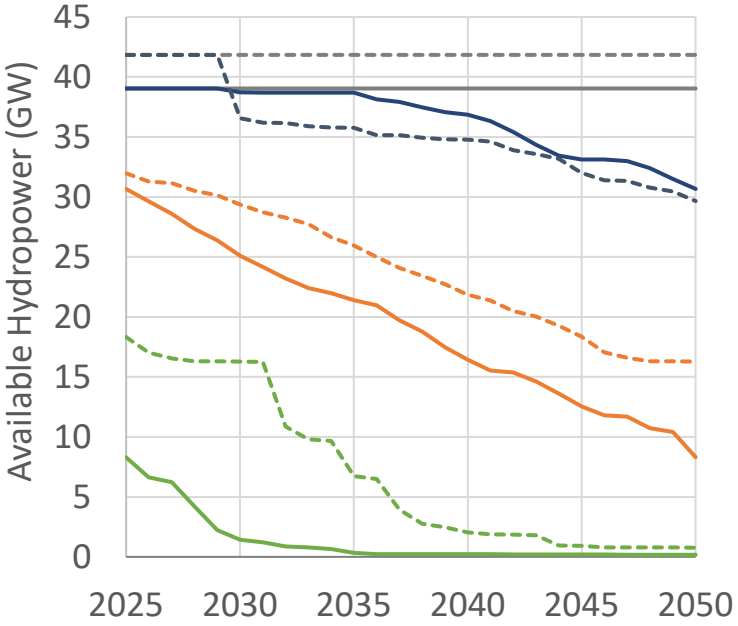
- Hydropower energy (not capacity) declines from 2022 to 2030 where it remains fixed thereafter. Nine scenarios include:
  - 10/30/60% reductions in Oregon/Washington (OW)
  - 30/60/90% reductions in California (C)
  - Combination scenarios for each of the low/mid/high levels, so 90C.60OW is the most extreme case
  - All scenarios are compared to a reference (MID) case
- Declining energy availability could be attributed to drought or any other reason for changing operating plans

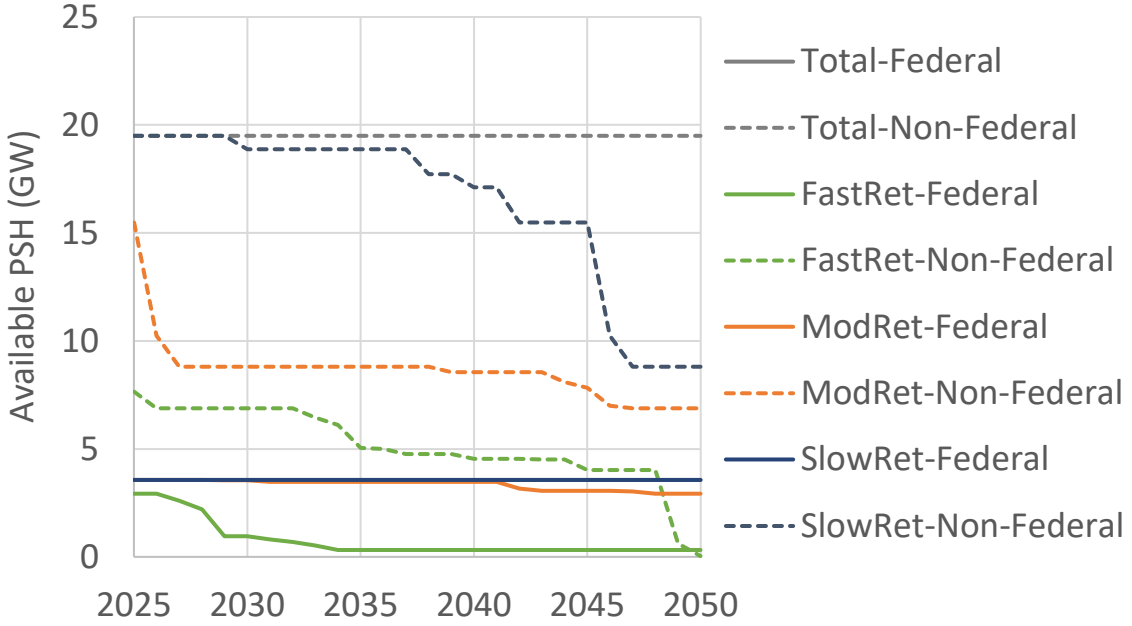
In These Scenarios, Lost Hydropower is Replaced by Natural Gas and Some Renewables



- Natural gas usage increases in the near-term, and wind/solar in the long-term.
- California relies almost entirely on renewables for lost hydropower.
- Reduced net generation corresponds to increased imports.

Another Recent Study Reduces *Both* Capacity and Energy of Hydropower *and* PSH





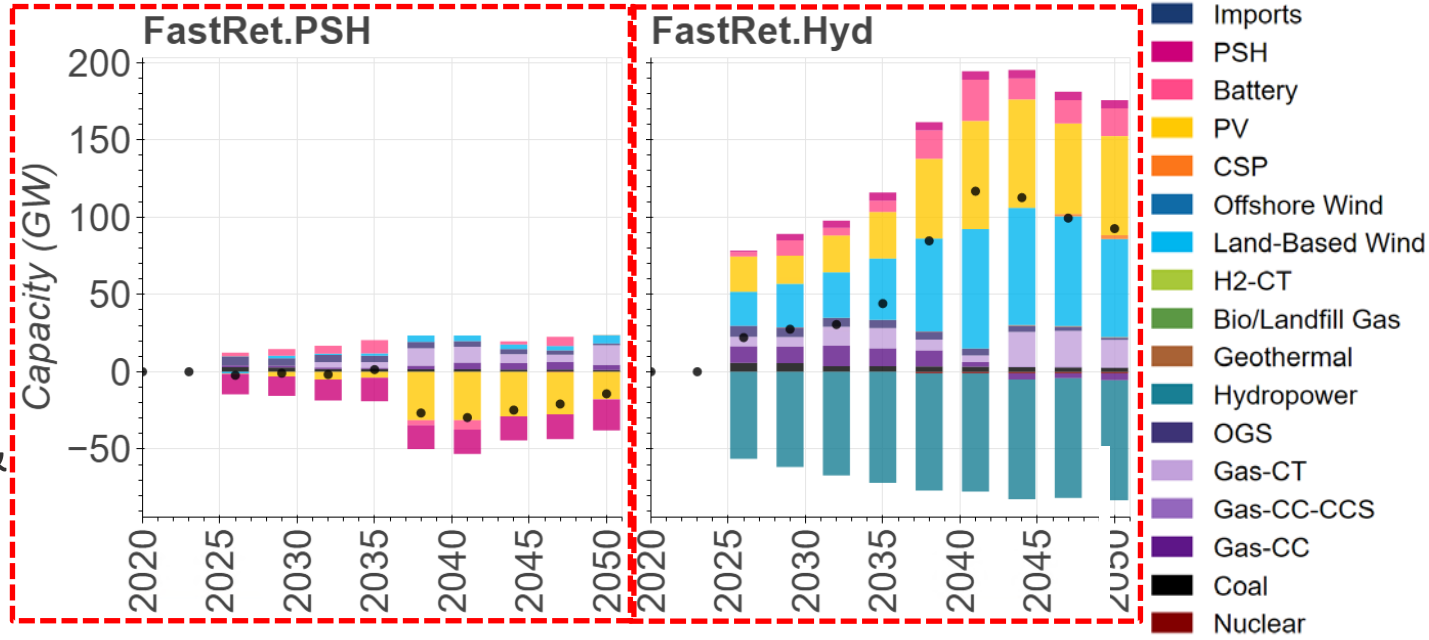
- Slow, Moderate, and Fast Retirement scenarios extend to a nearly full retirement of all hydropower and PSH, based on varying assumed license expiration or lifetime
- Trajectories retire hydro/PSH in reference to FERC license expiration year or lifetime

https://www.nrel.gov/docs/fy24osti/86295.pdf

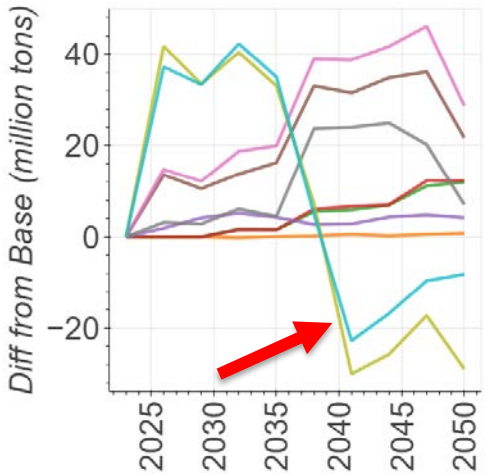
Hydropower is Replaced by a Mix of Technologies

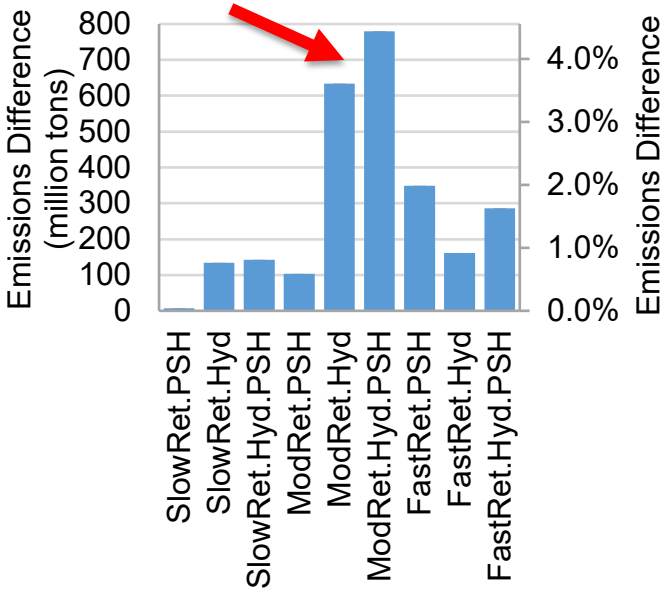
PSH retirements → less PV, more gas, battery, & wind

Hydro retirements → more gas, wind, PV, & battery



Emissions and Costs Increase by 1–5%





Scenario	Change in Undiscounted 2023–2050 Costs (billion $)	Percent Change (%)
SlowRet.PSH	22	0.20%
SlowRet.Hyd	55	0.60%
SlowRet.Hyd.PSH	76	0.80%
ModRet.PSH	38	0.40%
ModRet.Hyd	185	1.90%
ModRet.Hyd.PSH	221	2.30%
FastRet.PSH	76	0.80%
FastRet.Hyd	273	2.90%
FastRet.Hyd.PSH	340	3.60%

- Hydro retirements could delay the IRA tax-credit phaseout, reducing emissions in some years
- IRA interactions result in highest emissions in Moderate Retirement scenarios
- Cost impacts are proportional to hydro/PSH capacity retired

Growth

Scenarios for growth and deployment of new pumped storage hydropower

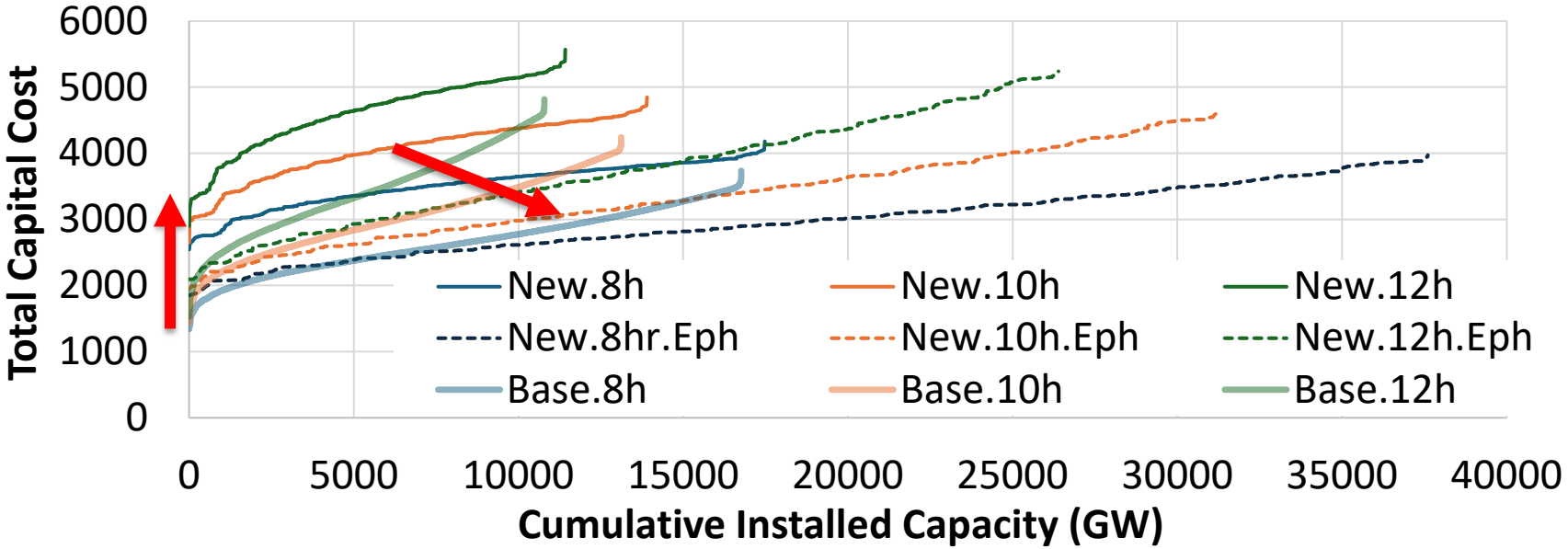
New Closed-Loop PSH Resource and Cost Estimates are Now Available and Implemented in ReEDS

PSH deployment scenarios compare old and new data

- **Base**: 2nd Gen PSH supply curves using Australian Natl. Univ. cost model
- **New**: Updated 3rd Gen PSH supply curves using new NREL cost model
  - Capital cost reductions by 2050: **low** = 15%, **2Xlow** = 30% .
  - Durations: **8**, **10**, and **12** hours
  - Ephemeral streams: **eph** = reservoirs allowed to intersect
- E.g., "**New.12h.Eph.Low**" = 3rd Gen supply curve, 12-hr duration, reservoirs allowed over ephemeral streams, 15% cost reduction by 2050
- New datasets also have the option to include sites that utilize existing reservoirs

https://www.nrel.gov/gis/psh-supply-curves.html https://www.nrel.gov/water/pumped-storage-hydropower-cost-model.html

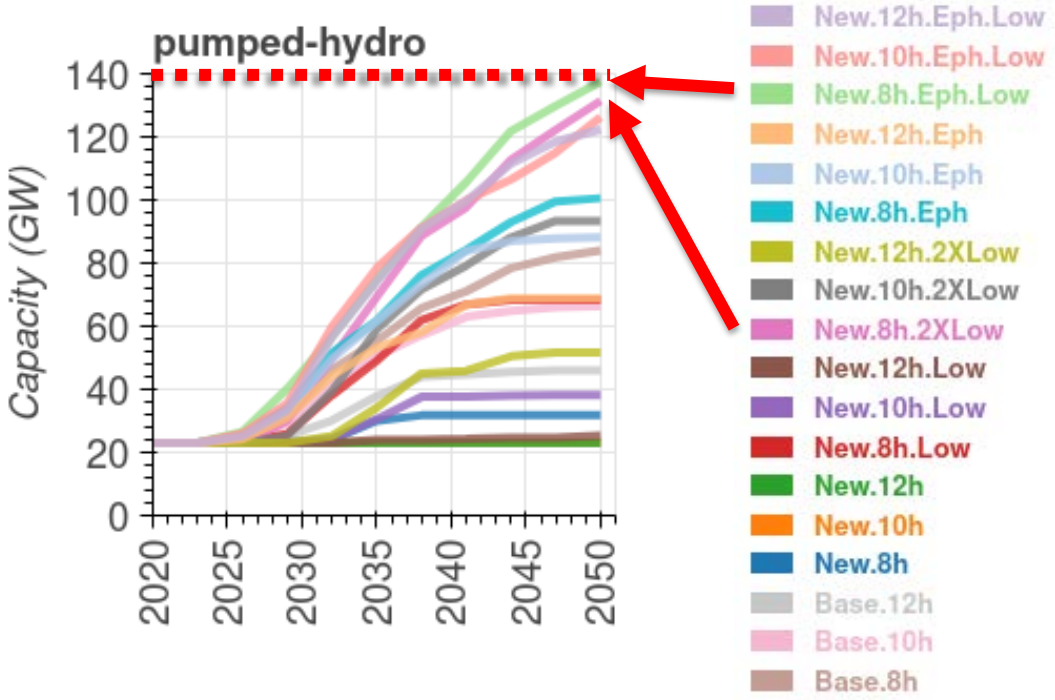
New Supply Curves Have Higher Costs That are Closer to Industry Expectations



- New cost model has a more detailed cost breakdown allowing better optimized configurations and assumes higher indirect costs
- Allowing reservoirs on ephemeral streams enables more resource *and* lower-cost systems

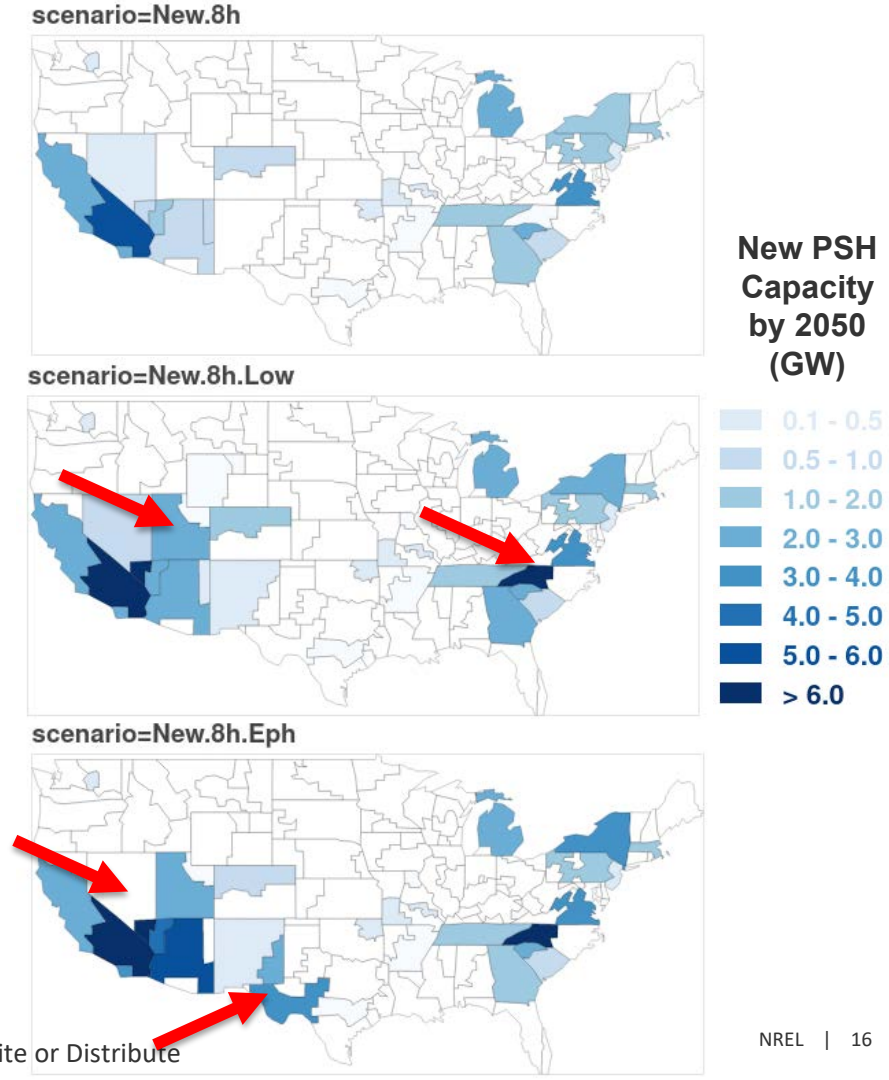
Sensitivity Scenarios Produce a Wide Range of PSH Deployment Pathways

- 2050 capacity ranges from 23 GW (no new PSH) to 138 GW
- Highest deployment scenarios
  - Lower cost
  - Shorter duration
  - Allow reservoirs on ephemeral streams
- Scenarios demonstrate value for flexibility that could also be met with non-PSH hydropower



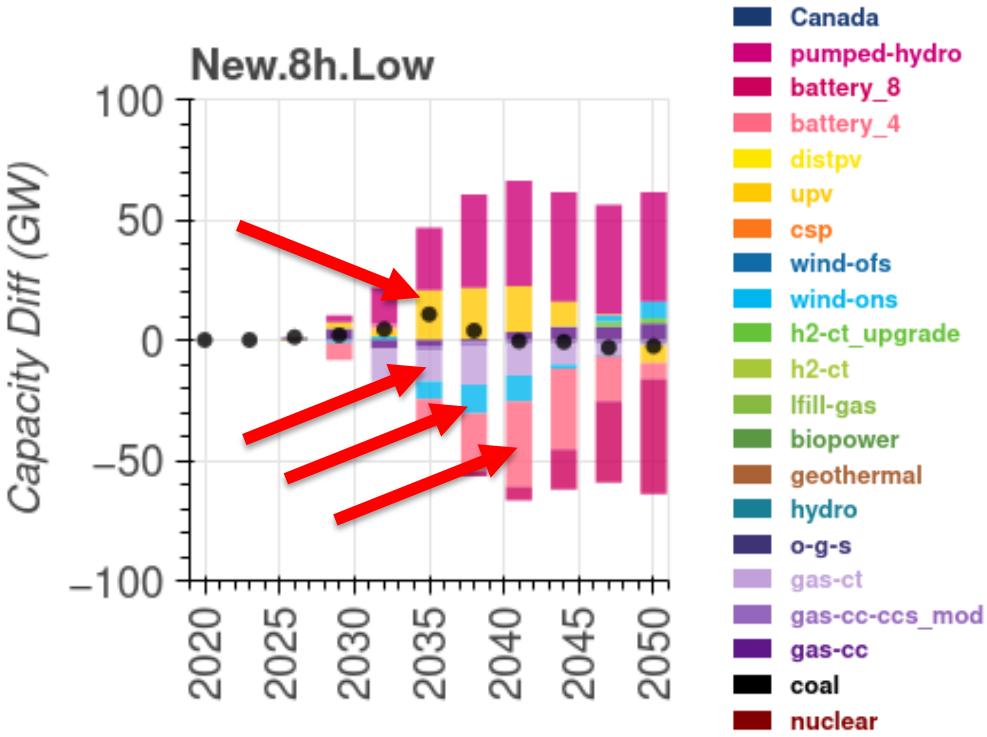
Higher Deployment Scenarios Both Concentrate and Expand PSH Investment

- Lower costs leads to expansion into new regions (e.g., NC, UT)
- Allowing sites on ephemeral streams results in further expansion (e.g., TX) and shifting of deployment (e.g., NV to AZ)



PSH Competes with Flexible Generation and Storage

- PSH generally displaces batteries and gas turbines (gas-ct)
- PSH deployment could accelerate solar PV deployment
- Relationship between PSH and wind is unclear with limited capability to represent multiday arbitrage



Final Thoughts

1. Any reduction in hydropower or PSH capacity and energy can increase costs and emissions, but non-hydro renewables also help fill the gap.
2. Closed-loop PSH has substantive potential for meeting energy storage needs and supporting variable renewable deployment with modest improvements in its value proposition.

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THANK YOU

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NREL/PR-6A40-90477

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Water Power Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.