Representing the Future Role of Hydropower and Pumped Storage Hydropower (PSH) in Electricity Planning Tools

Stuart M. Cohen, Ph.D., National Renewable Energy Laboratory

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Motivation for Improving Planning Model Representations of Hydropower

Electric Sector Planning Tools are Used Frequently for System Planning and Policy Discussions

Studies

- NREL Standard Scenarios
- EIA Annual Energy Outlook
- DOE Hydropower Vision
- Princeton Net-Zero America
- EPRI Powering Decarbonization

Tools

- NREL ReEDS
- EIA NEMS
- Princeton GenX
- Energy Exemplar Aurora
- EPRI US-REGEN
- ICF IPM

Yet These Tools Struggle to Represent Nuanced Site-Specific Hydropower Characteristics

Inadequate spatial and temporal resolution

Model structure and computational limits prohibit detailed hydropower operating constraints

Unable to represent the unique value of reservoir storage

Inadequate data to parameterize operating constraints and investment opportunities

Little to no integration with hydrological and water management models and data

The U.S. DOE HydroWIRES Program Supported a Multi-Year Effort to Address Some of These Gaps

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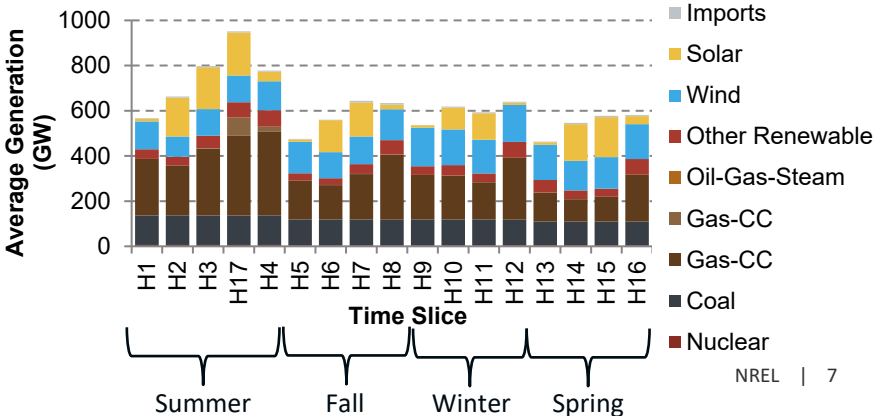
Enhancing Model Capabilities to Study Hydropower

New Capabilities are Developed Using NREL's Regional Energy Deployment System

- Linear program minimizes the cost of 2010–2050 U.S. electric sector investment and operation
- Satisfies energy and capacity requirements under resource, transmission, policy, and power system constraints
- Detailed suite of generation and storage technologies with transmission expansion
- Spatial resolution includes 134 balancing areas with state and regional aggregations
- Temporal resolution uses 17 chronological time slices and 7-years of hourly data to characterize variable renewables and storage
- Hydropower categories include PSH, existing non-PSH, upgrades, non-powered dams, and new stream-reach
- Hydropower can be classified as dispatchable or non-dispatchable



Model and Data Enhancements Focused on Hydropower's Role in a High-Renewables System

Hydropower Upgrades

What hydropower upgrade types are most valuable and under what conditions?

Hydropower Flexibility

How can hydropower flexibility be better valued in investment decisions?

PSH

What new PSH deployment and dispatch opportunities exist?

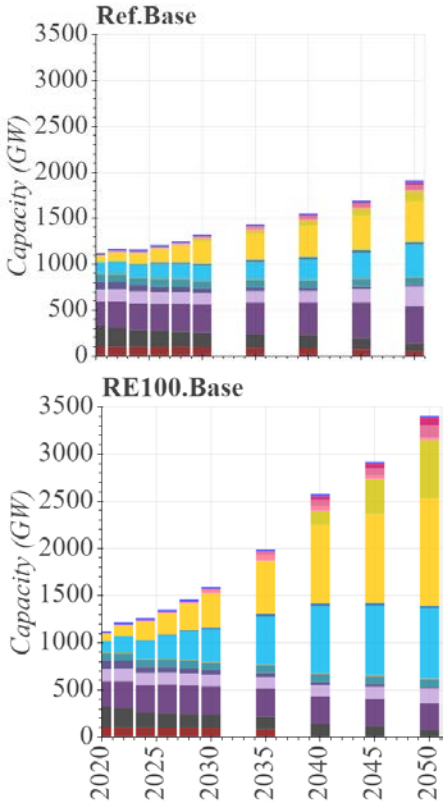
Scenarios Demonstrating Possible Future Hydropower Opportunities

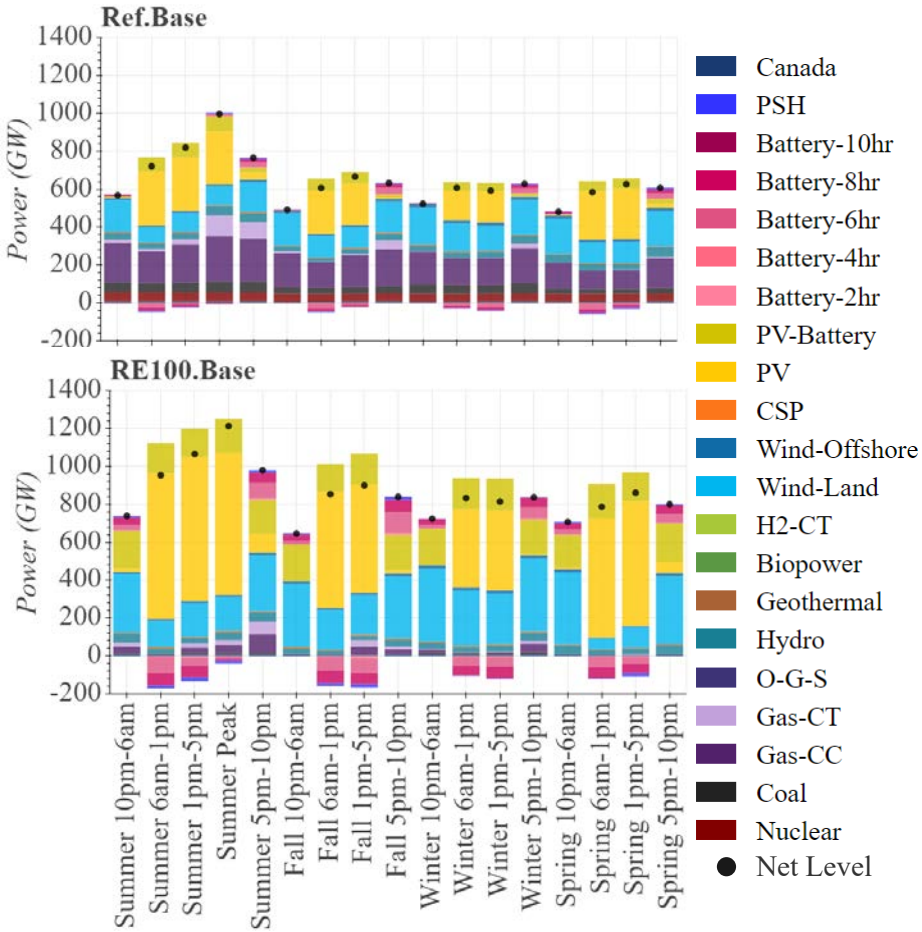
New Capabilities are Demonstrated for Reference and 100% Renewable Futures

Reference (Ref) uses default assumptions from NREL 2021 Standard Scenarios Mid Case

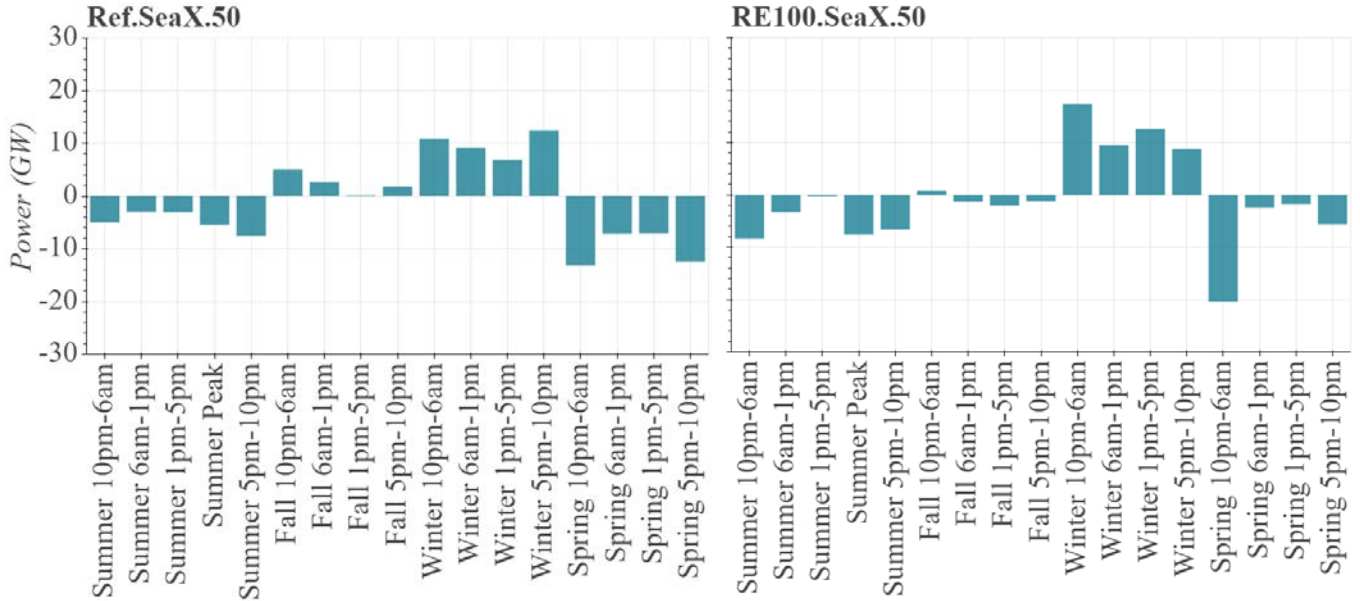
100% renewable (RE100) requires 100% RE generation in 2050

New features are explored independently and in combination



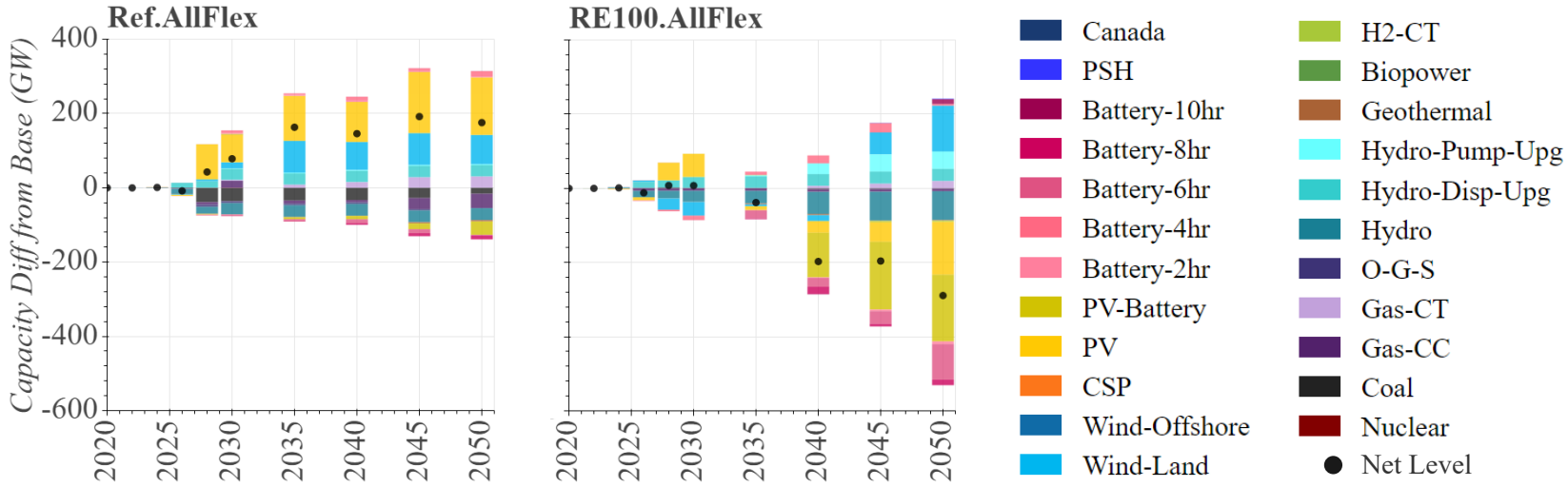


Where practical, it appears valuable to consider shifting available hydropower energy across long-duration timescales up to a season.



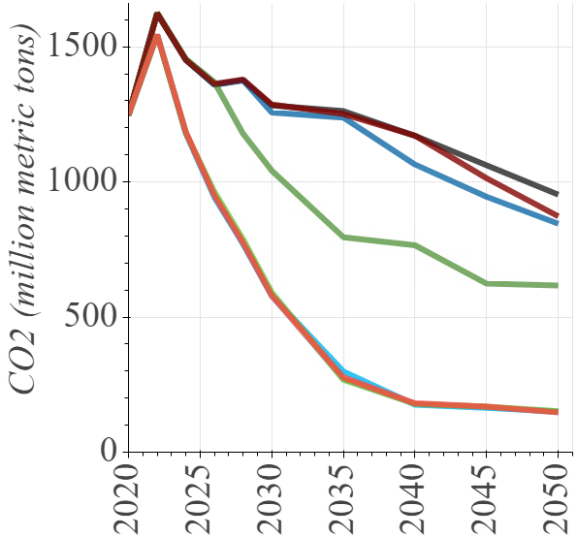
- Both hydropower and PSH shift energy from spring to winter when possible
- Seasonal shifting is largely driven by seasonal PV availability
- This demonstration is an initial step towards exploring storage durations >12 hr

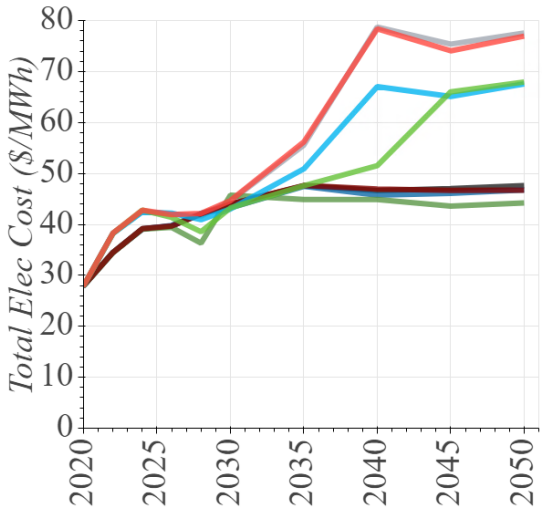
Improving flexibility of existing hydropower assets can have substantive impacts on the national generation mix.

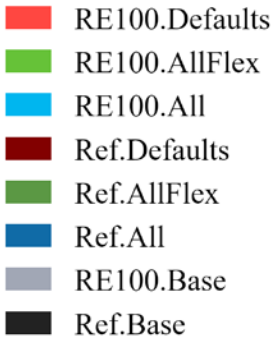


- AllFlex scenarios allow all upgrades and flexibility improvements at low cost
- Hydropower/PSH changes in Ref support additional wind and solar deployment
- RE100 scenarios achieve 100% renewables with less PV and battery capacity

Improving flexibility of existing hydropower assets has the potential to reduce CO_2 emissions and improve electricity system economics.







- Additional renewable generation in Ref reduces CO_2 emissions
- Reduced PV/battery needs in RE100 reduces total electricity costs (includes energy and capacity cost)

Key Takeaways

1. New model capabilities and a thorough scenario analysis with the NREL ReEDS electric sector capacity expansion model demonstrate new hydropower and PSH deployment and upgrade opportunities in the United States.
2. Improving flexibility in the existing hydropower fleet can help reduce CO_2 emissions, improve electricity system economics, and complement variable renewables in a future low-carbon grid.
3. New data and capabilities are publicly available and can help inform electricity system planners about the value and future role of hydropower and PSH.

Cohen SM, Mowers M. *Advanced Hydropower and PSH Capacity Expansion Modeling*. NREL/TP-6A40-80714. (forthcoming)

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Stuart Cohen: stuart.cohen@nrel.gov