



# Data and Tools for Exploring New Pumped Storage Hydropower Deployment Opportunities

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

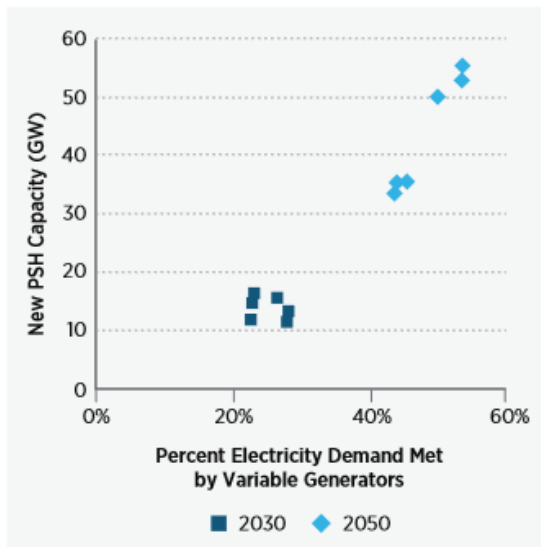
HydroVision International 2023

Charlotte, NC, USA

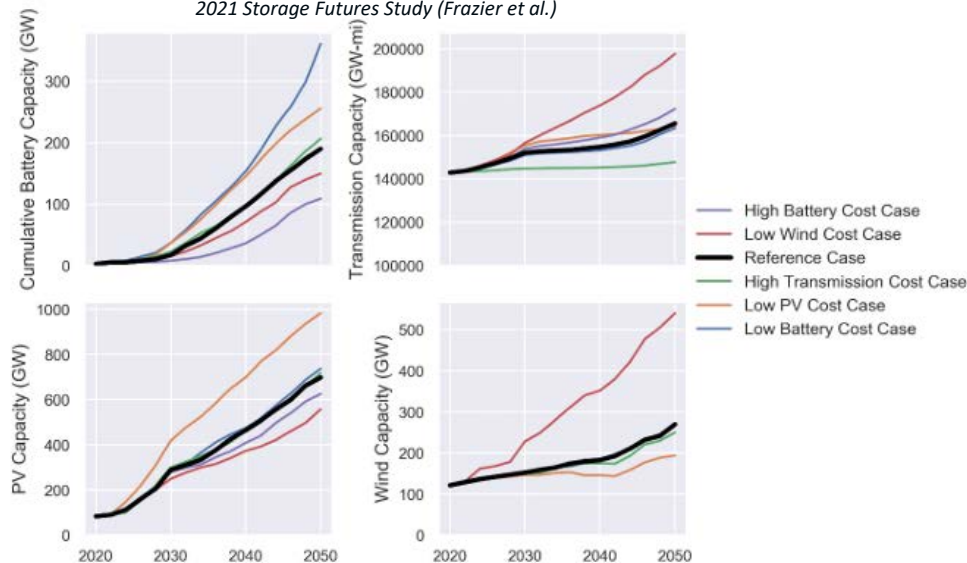
July 13, 2023

# Pumped Storage Hydropower (PSH) Can Help Balance the Grid and Integrate Variable Renewables

2016 DOE Hydropower Vision



2021 Storage Futures Study (Frazier et al.)



- PSH provides many critical grid services without direct emissions
  - Energy balancing
  - Firm capacity
  - Operating reserves
  - Grid stability
- Storage helps facilitate renewable deployment at lower cost

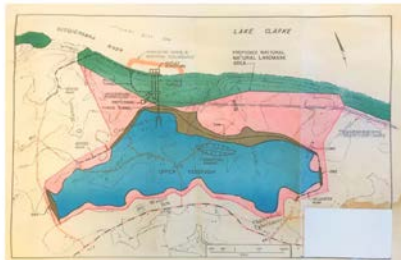
# PSH Value is Being Recognized, but Siting and Cost Hurdles Hinder Deployment

**The Philadelphia Inquirer** SIGN

BUSINESS

## Is this Pa.'s new hydropower moment?

A proposal calls for water to be pumped into a newly created reservoir and then pass through turbines to generate electricity as it falls hundreds of feet to the Susquehanna River downstream.



**The Salt Lake Tribune**

## Pumped hydro storage: Can mountain lakes be our batteries?

The West has the vertical drops to generate clean power when renewables aren't producing.



(Rob Swearer/AP) Jet skis move through Red Canyon on Friday, Aug. 6, 2022, in Flaming Gorge National Recreation Area, in the northeastern corner of Utah. One proposal for a pumped hydrostorage project would draw water from Flaming Gorge and pump it to a new reservoir in the mountains above.

By Tim Fitzpatrick | Oct. 20, 2022, 6:35 a.m. | Updated: Oct. 21, 2022, 8:38 a.m.

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## Xcel Energy ends controversial plan for Unaweep Canyon hydropower project

The move comes a day after Colorado's largest electric company received federal permission to build the project.

Jason Blevins 12:24 PM MDT on Nov 10, 2022

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LOCAL NEWS

## Proposed Missouri River pumped-storage project discontinued

by Eric Mayer  
Posted: May 23, 2023 / 03:55 PM CDT

Gregory County Pumped Storage  
MidAmerican Energy

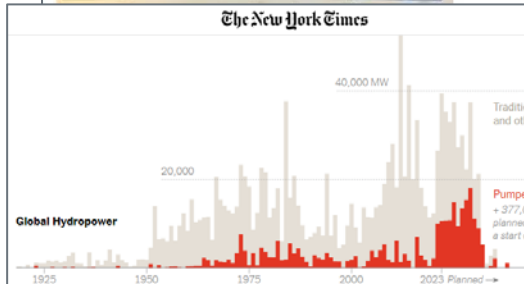
**Oklahoma Watch** No Favoritism. No Fossil Fuels. No Fear.

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ENVIRONMENT

## Protests Prompt Cancellation of \$1.5 Billion Power Project in Southeast Oklahoma

by Lisset Ramos December 19, 2022

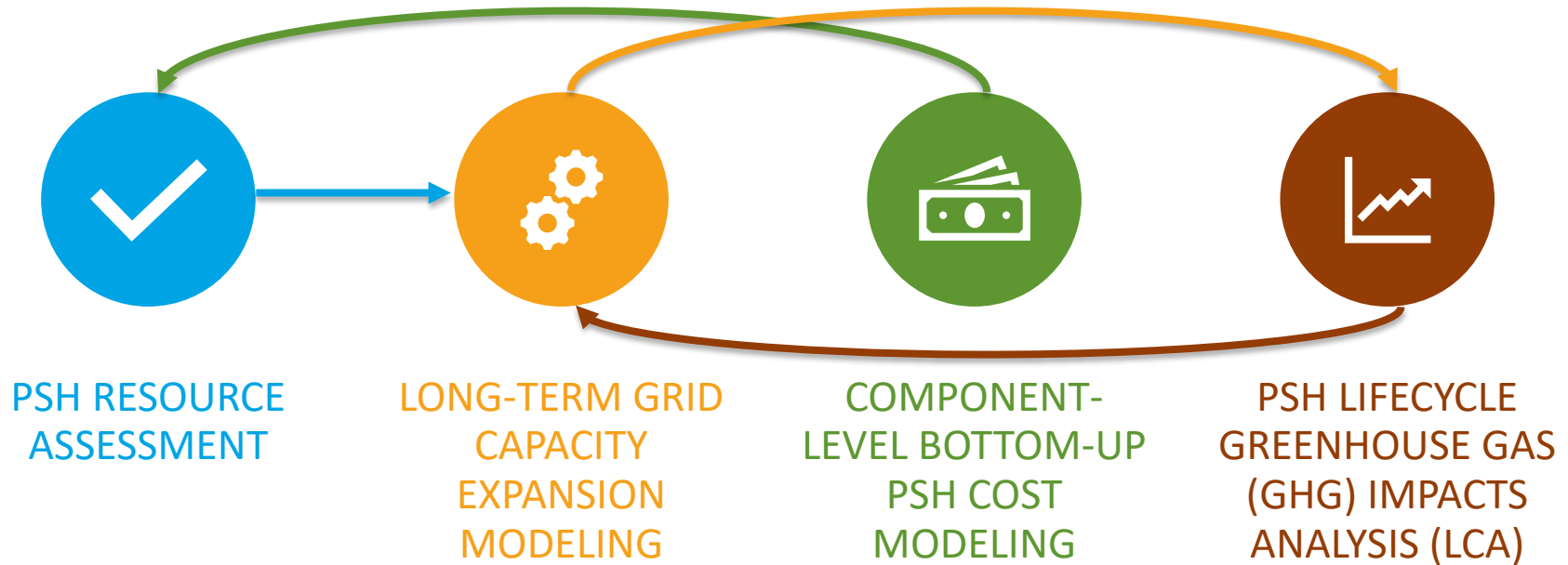


## Is It a Lake, or a Battery? A New Kind of Hydropower Is Spreading Fast.

By Mira Rojanasakul and Max Bearak May 2, 2023

er storage project in south-central South

# NREL is Developing Data and Tools to Better Inform Discussions About PSH Deployment



# LCA Enables GHG Impacts Comparisons with Other Technologies

- NREL has completed the first-ever LCA for new closed-loop PSH
  - Includes GHG impacts from construction and operation but not yet end-of-life
  - Accounts for future changes in the carbon intensity of the charging electricity mix
  - Future versions will use region-specific grid data and estimate reservoir emissions
  - Manuscript in press at *Environmental Science & Technology*

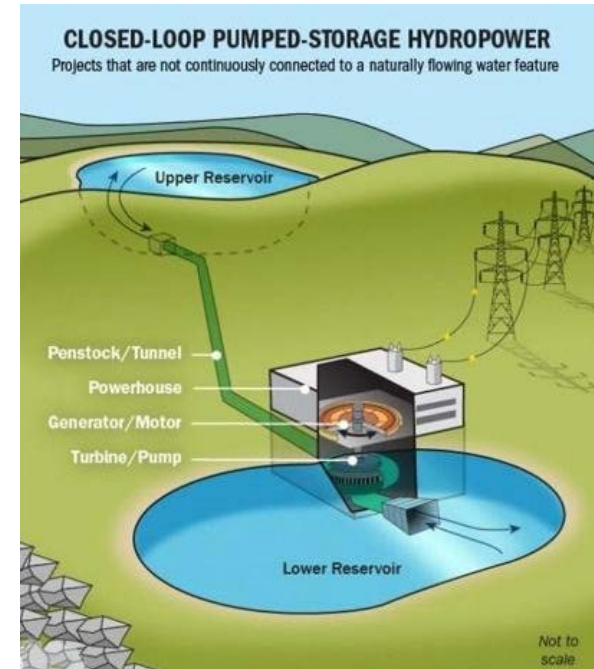


Illustration by John Frenzl

# A Versatile Web App Will Allow Users to Explore Lifecycle GHG Impacts of Any Candidate Site

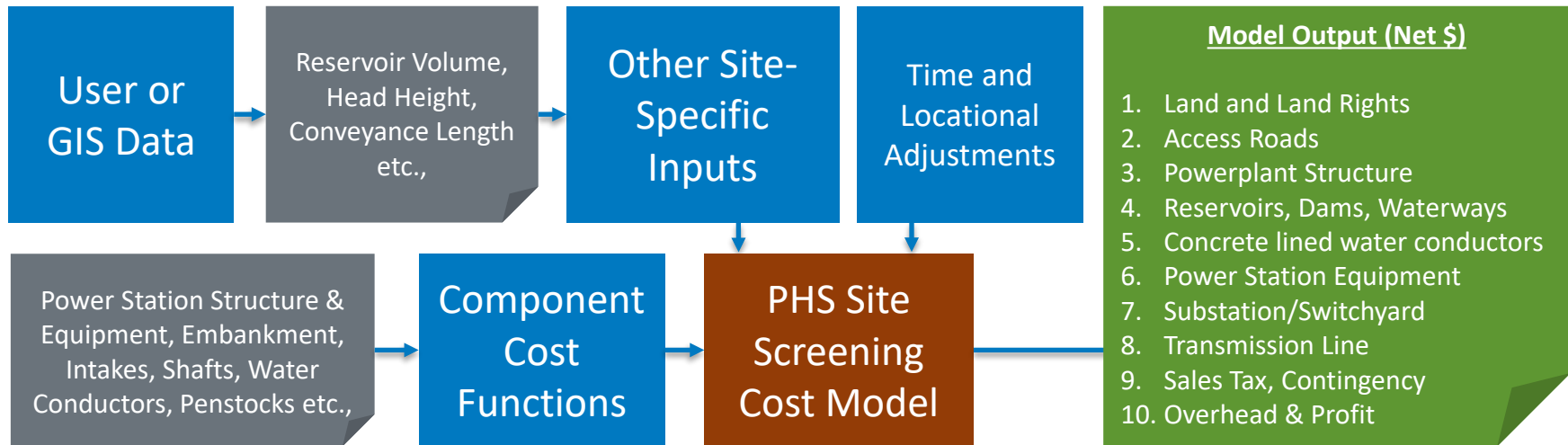
- **Scenario Mode** will allow users to choose from pre-determined parameter values and compare representative PSH facilities
- **Design Mode** will allow users to enter custom parameter values to evaluate a specific PSH site
- Tool is in alpha testing with beta testing to begin September 2023

## *Scenario Mode Alpha Demo*



*Preliminary Data: Do Not Cite or Distribute*

# Bottom-Up Cost Modeling Will Offer Unprecedented Detail in a Public-Facing Tool



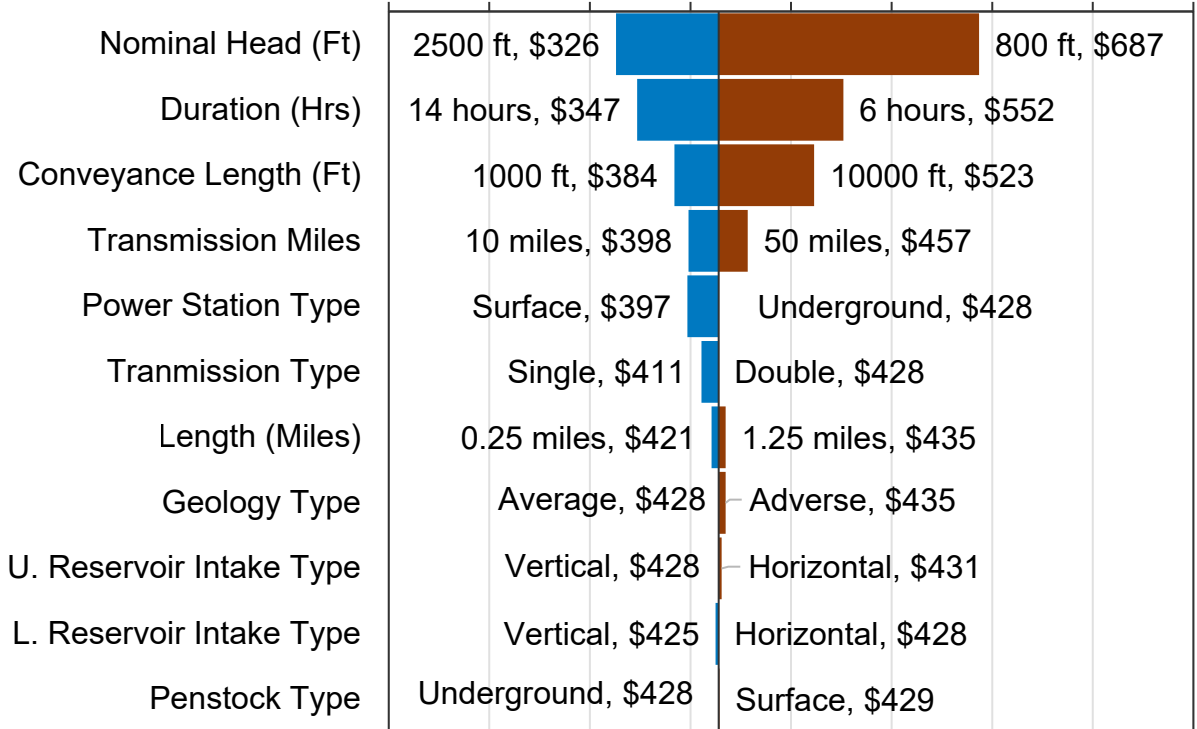
- Spreadsheet model allows user-input site specifications and assumptions
- Calculations use industry-vetted formulas and data (e.g., EPRI PSH guide)
- Cost results can be explored for one site or many

# Parametric Analysis Can Explore Component Cost Sensitivity

Simulated \$/kWh vs Base Case \$/kWh for a Large-PSH system

\$100 \$200 \$300 \$400 \$500 \$600 \$700 \$800 \$900

- Users can identify which input assumptions are most important to total cost
- Cost sensitivities can be compared between small and large PSH



*Preliminary Data: Do Not Cite or Distribute*



# Resource Assessment Identifies Opportunities for Detailed Site Evaluation

1. Geospatial analysis generates potential reservoirs from a digital elevation model.
2. Reservoirs are excluded if they intersect with incompatible land uses, e.g., critical habitats, national parks. Because these are closed loop, reservoirs intersecting waterways are excluded.
3. Upper and lower reservoirs are joined based on distance, head, and size similarity.
4. A set of non-overlapping systems are selected based on lowest \$/kW capital cost.

Input Parameter	Value/Description/Source
Max Distance	Dynamic based on l:h ratio
Min Head	200 m
Max Head	750 m
Max l:h ratio	12
Glaciers/Ice Exclusion	NLCD 2019
Wetlands Exclusion	NLCD 2019
Urban Areas Exclusion	GHSL 2022 Classes 30:12
Flowlines Exclusion	No Ephemeral as scenario
Roads Exclusion	Major Roads as scenario
Size Similarity Constraint	10%
Reservoir Search Buffer	7 km
Dam Heights	40m, 60m, 80m, 100m

# Resource Data Can Be Explored With an Interactive Web Tool

1. Select scenario: storage duration, dam height range, technical exclusions (left)
2. Use filters to screen sites: cost, capacity, etc. (right)
3. Determine one or more reservoirs to assess further by clicking on sites or querying custom regions
4. Gather site-specific details
5. Download data



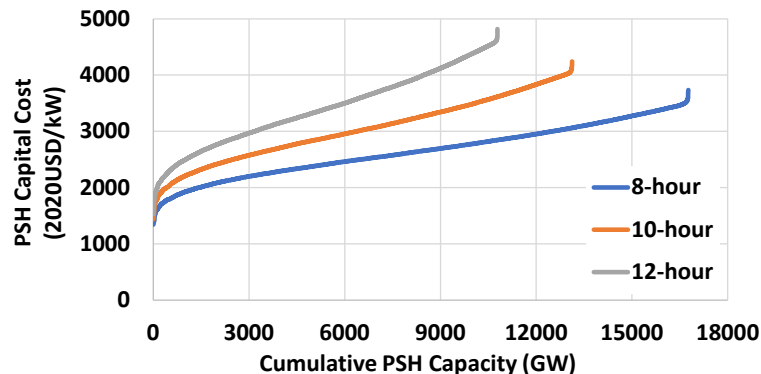
<https://www.nrel.gov/gis/psh-supply-curves.html>

**Join a webinar July 18, 10-11a MDT for a deep dive and demo of PSH resource assessment and visualization!**

[https://nrel.zoomgov.com/webinar/register/WN\\_uxMTUP-tQAqcaLCCyLqIQa](https://nrel.zoomgov.com/webinar/register/WN_uxMTUP-tQAqcaLCCyLqIQa)

# Capacity Expansion Modeling Ingests PSH Cost and Resource to Simulate Competitive Deployment

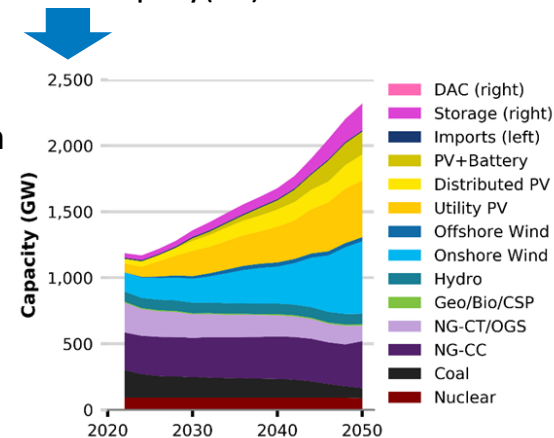
- Resource and cost data form a supply curve
- PSH supply curves are used along with other technology cost, resource, and performance data in the ReEDS grid planning model
- ReEDS finds the least-cost mix of generation, transmission, and storage technologies through 2050 or beyond
  - Sub-state level resolution
  - Chronological time slices and hourly data
  - High-resolution resource and load profiles
  - Constraints for energy, capacity, flexibility, and policy requirements
  - Open-access code and data



## Regional Energy Deployment System

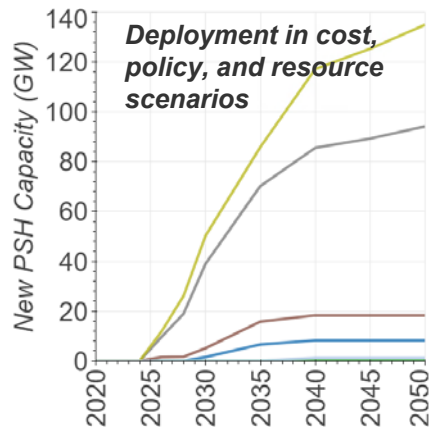


ReEDS



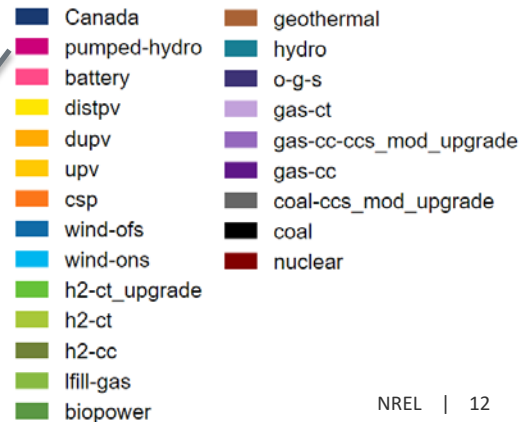
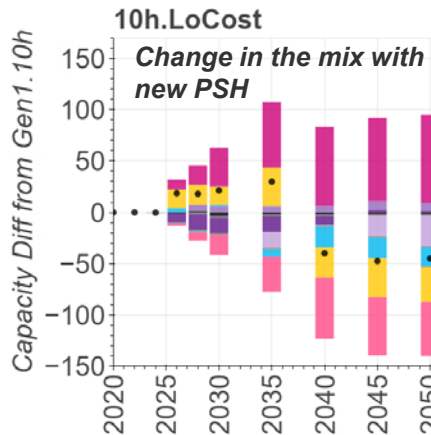
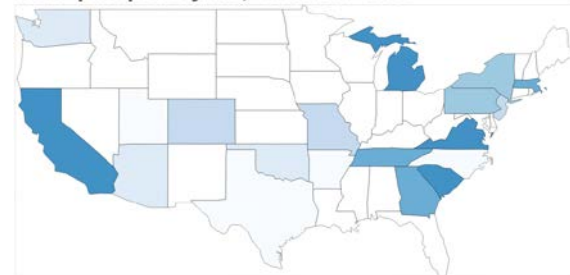
# ReEDS Enables Broad Scenario Analysis to Explore PSH Opportunities

- PSH deployment can be sensitive to scenario inputs
- Local deployments depend on both PSH site quality and grid needs
- PSH competes with other storage technologies and can influence variable renewable deployment



**State-level PSH deployment through 2050**

tech=pumped-hydro, scenario=10h





# Summary

- NREL is building a versatile suite of open data and tools to help understand the future role of PSH in the electric grid.
- Resource assessment and modeling suggest that PSH deployment is attractive under favorable economic and decarbonization conditions.
- Continued tool and data development will facilitate robust assessments of PSH cost-benefit tradeoffs.

# References

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**Thank You!**

Stuart Cohen  
[stuart.cohen@nrel.gov](mailto:stuart.cohen@nrel.gov)

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