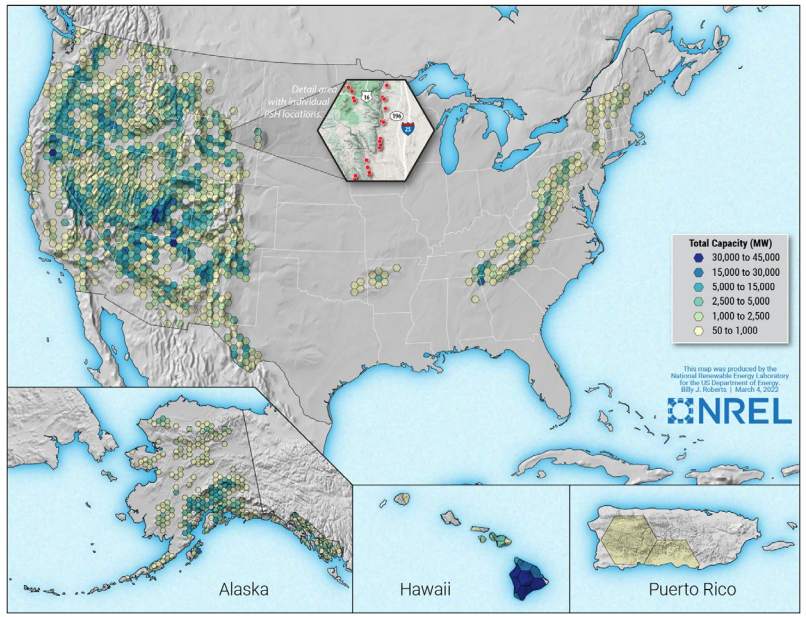
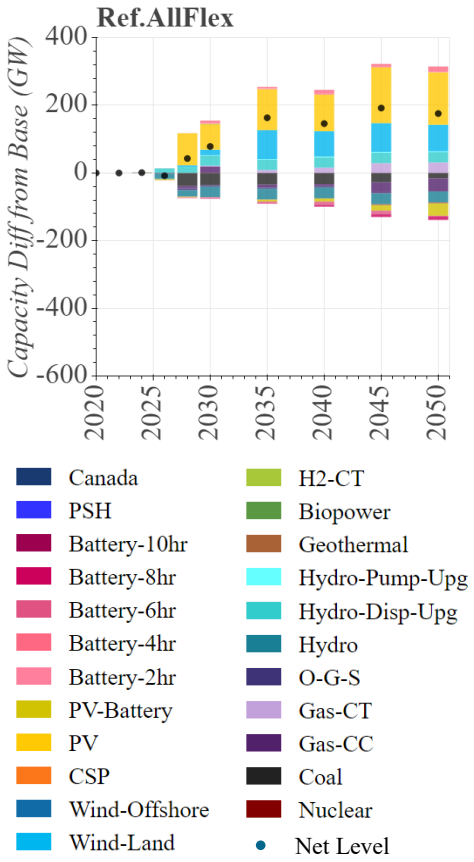
1.2.2.405 HydroWIRES Topic D1: Capacity Expansion Model (CEM) Enhancements





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Project Overview

Project Summary

Capacity expansion models (CEMs) used widely for grid planning have difficulty representing detailed hydropower and pumped storage hydropower (PSH) operating considerations and investment opportunities. This project develops new CEM capabilities and data to represent and understand hydropower and PSH flexibility, upgradeability, and deployment opportunities. It includes a new dataset for closed-loop PSH technical potential and cost in the United States, including Alaska, Hawaii, and Puerto Rico. This work improves our ability to understand the future role of hydropower and PSH in the U.S. electric grid.

Intended Outcomes

- Technical Report: *Advanced Hydropower Representations in National Capacity Expansion Models* will demonstrate new CEM data and modeling techniques and their importance for grid analysis.
- Technical Report: *Closed-Loop Pumped Storage Hydropower Resource Assessment for the United States* will describe methods for PSH resource and cost data.
- PSH resource data are publicly available online with an interactive visualization tool and are integrated into the NREL Annual Technology Baseline.
- CEM model formulation and data available on GitHub.

Project Information

Principal Investigator(s)

- Stuart Cohen, Evan Rosenlieb, Donna Heimiller (NREL)

Project Partners/Subs

- Matthew Mowers (M.M.LLC)

Project Status

New

Project Duration

- Start Date: October 1, 2019
- End Date: September 30, 2022

Total Costed (FY19–FY21)

$479,502

Project Objectives: Relevance

Relevance to Program Goals:

Hydropower Multi-Year Program Plan

- Supports low-impact hydropower growth through PSH site identification and improves capabilities for understanding hydropower and PSH upgrade and new deployment potential (Activity 1)
- Enables better understanding of hydropower's effect on future grid reliability, resilience, and renewables integration (Activity 2)
- Improves understanding of hydropower upgrade value and opportunity (Activity 3)
- Uses open data and code for enhanced data access and analytics (Activity 5).

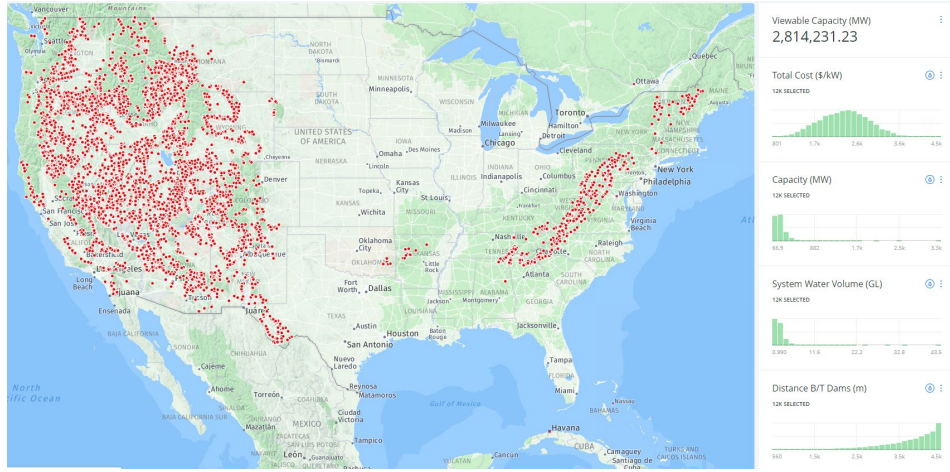
HydroWIRES Research Road Map

- Improves power system model representation of hydropower (Research Area 2)
- Establishes baseline cost and performance of PSH and other storage (Research Area 3)
- Contributes to quantifying reliability/resilience contributions (Research Area 3) and value of hydropower and PSH under alternative scenarios (Research Area 1).

Project Objectives: Approach

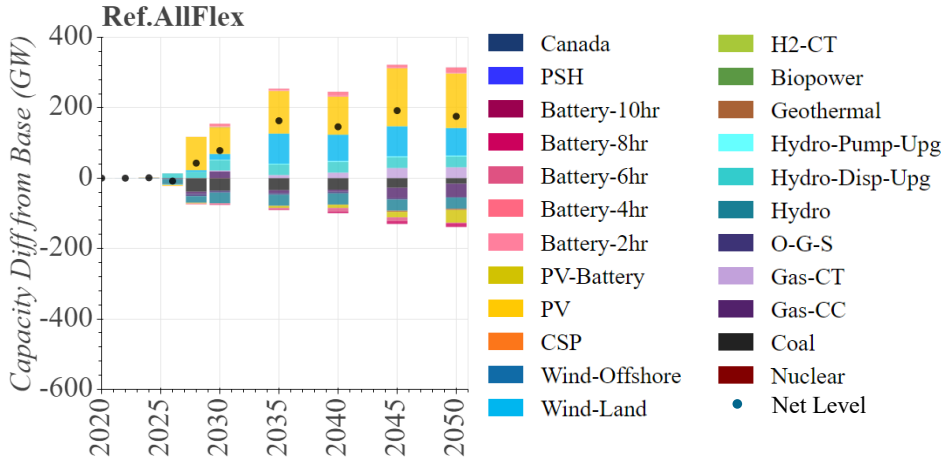
Closed-Loop PSH Resource Assessment

- Geospatial analysis to create the first comprehensive, consistent, site-level PSH technical potential and cost dataset for the U.S.
- Advances prior work by Australia National University to better match U.S. context
- Algorithm identifies reservoirs, imposes exclusion criteria, matches reservoir pairs, assigns costs, and removes overlaps to generate nationwide PSH supply curve
- Explores how alternative technical and environmental specifications affect resource base (FY22).



CEM Model Enhancements

- Integrates PSH supply curve and plant-level existing PSH storage duration and pump/generator capacities
- Adds water constraints for filling new PSH reservoirs (FY22)
- Adds new options to independently upgrade hydropower flexibility, capacity, and energy storage
- Adds new capability to explore inter-seasonal energy arbitrage and net load following, and explores methods for representing long-duration storage.



Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- Report: *Advanced Hydropower Representations in National Capacity Expansion Models*
- Report: *Closed-Loop Pumped Storage Hydropower Resource Assessment for the United States*
- Online interactive visualization tool for PSH resource and cost data
- PSH resource/cost data integrated into the NREL Annual Technology Baseline
- CEM model formulation and data available on GitHub
- Presentations on PSH data and CEM modeling at HydroVision International
- Webinars, newsletters, and press releases to disseminate results.

Outcomes:

- PSH data used by industry in site development and grid planning
- Users of NREL CEM have expanded tools to study hydropower and PSH role in the U.S. grid
- Planning model improvements incorporated into other models and approaches
- Improved capability to study hydropower deployment and dispatch opportunities
- Raised profile for hydropower and PSH in U.S. and global discussions of their role in a sustainable, decarbonized energy future.

Project Timeline

FY 2020

Build stakeholder review committee.

Begin CEM enhancement.

Go/No Go: PSH resource assessment (RA) methods evaluation.

FY 2021

Complete national PSH RA.

Submit draft reports on PSH RA and CEM enhancements.

Prepare release of PSH RA website.

Complete enhanced CEM and release code and data.

Project Budget

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
$0K	$217K	$262K	$479K

- Scope/budget was increased
  - PSH resource assessment expanded to include Alaska, Hawaii, and Puerto Rico
  - Added an activity to integrate PSH data into the NREL Annual Technology Baseline
- $50k came from DOE Office of Strategic Programs and Impact Assessment (currently Strategic Analysis)

End-User Engagement and Dissemination

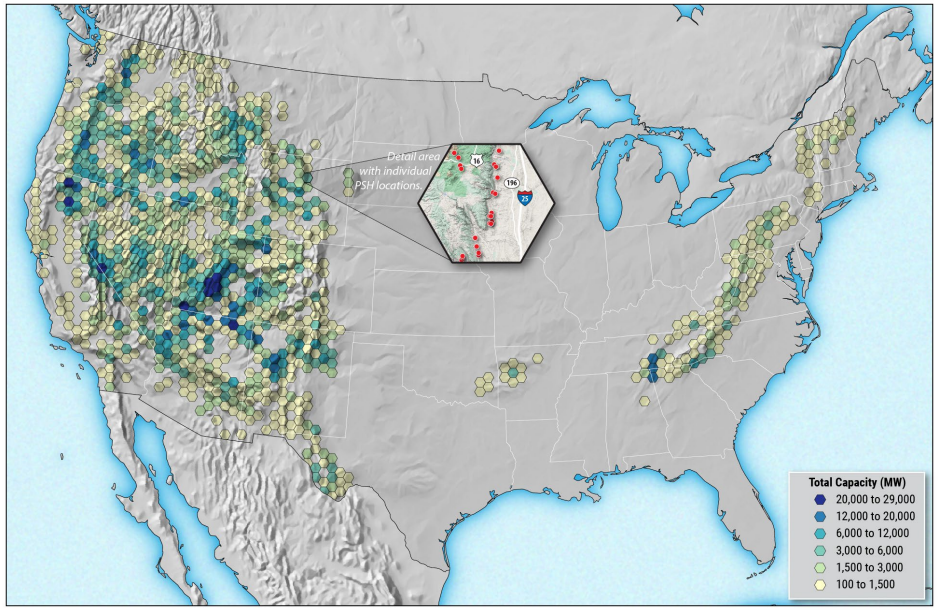
Diverse stakeholder engagement occurred throughout the project to ensure credibility and impact:

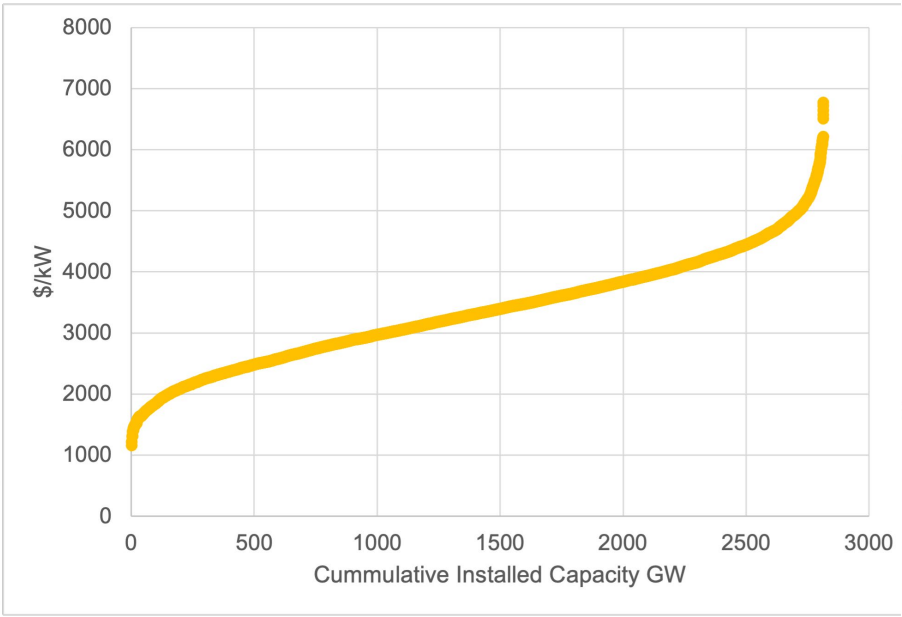
- Stakeholders participated in quarterly review meetings throughout the project, including representatives from Western Electricity Coordinating Council, Reclamation, HDR Inc., Natel, Pacific Northwest National Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory.
- Report reviews included feedback from Electric Power Research Institute, OnLocation, Idaho National Laboratory, and Australia National University
- Additional communications with equipment manufacturers and developers further improved assumptions.

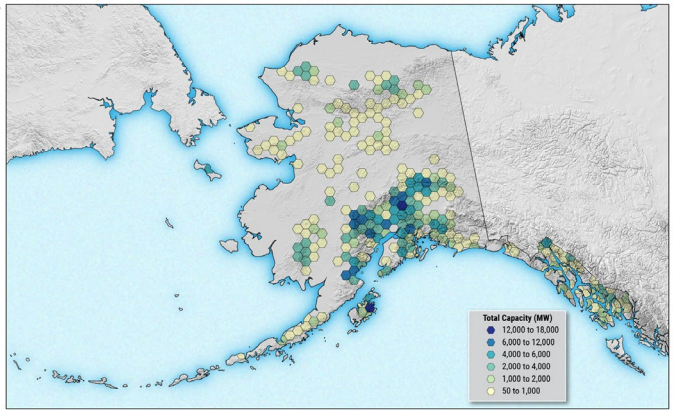
Dissemination is taking many forms:

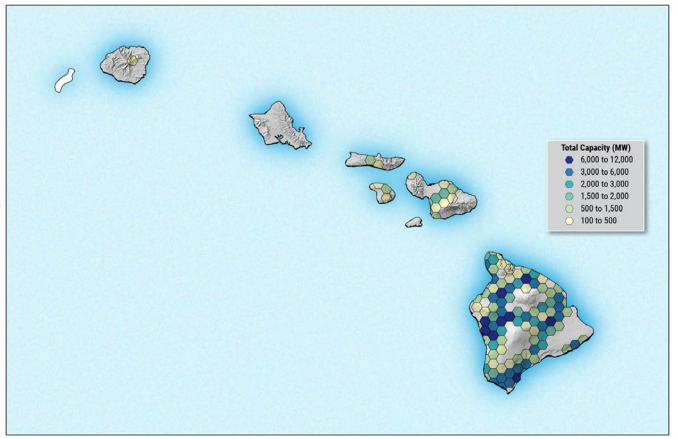
- Open-access code
- Interactive web visualization tools
- Query-able, downloadable data
- Conference presentations and online webinars
- Newsletters, press releases, and social media posts.

Performance: Accomplishments and Progress



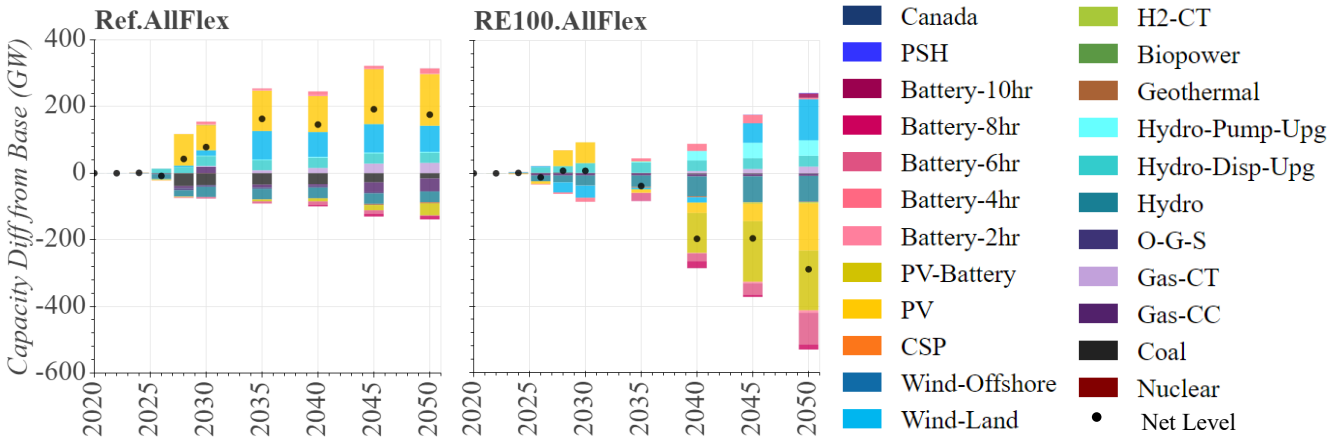






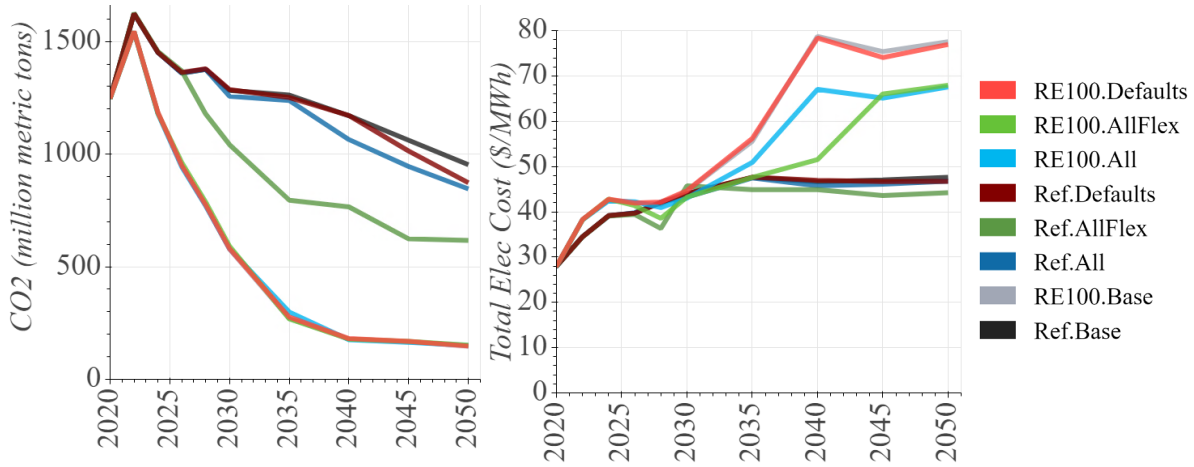
- Created a first-of-its kind dataset for closed-loop PSH resource and cost in the United States
- Data include site location and cost as an initial screening for regional PSH opportunities
- Data available online and used in the Annual Technology Baseline.

Performance: Accomplishments and Progress (cont.)



PV = solar photovoltaic
CSP = concentrating solar power
H2 = hydrogen
CT = combustion turbine

Disp = dispatchability
Upg = upgrade
O-G-S = oil- or gas-steam
CC = combined cycle



RE100 = scenario requiring 100% renewable energy by 2050
Ref = defaults for all non-hydropower inputs and assumptions
Defaults = defaults for all hydropower inputs and assumptions
AllFlex = all new hydropower capabilities enabled with enhanced hydropower flexibility and upgradeability at low cost
All = all new hydropower capabilities enabled with moderate cost and enhancement to hydropower flexibility and upgradeability
Base = baseline hydropower capabilities before model enhancements

- Demonstrated the value of improving hydropower flexibility on long-term grid performance and economics
- Code and data available on the ReEDS open-access GitHub repository
- Industry interest is already building in PSH data: Puerto Rico, Black & Veatch, Tennessee Valley Authority, Rye
- Conducted interview with Water Strategies trade publication, presenting at HydroVision International.

Future Work – FY22 Scope

PSH Resource Assessment

- Expand data to consider alternative technical and environmental assumptions (e.g., dam height, allowable head height, stream-type designation for closed-loop)
- Improve web visualization tools to display alternative resource assumptions.

CEM Improvements

- Incorporate water constraints on new PSH deployment
- Update existing hydropower capacity, energy, and flexibility parameters to match latest datasets
- Explore storage valuation >12 hours in the model.

Q&A