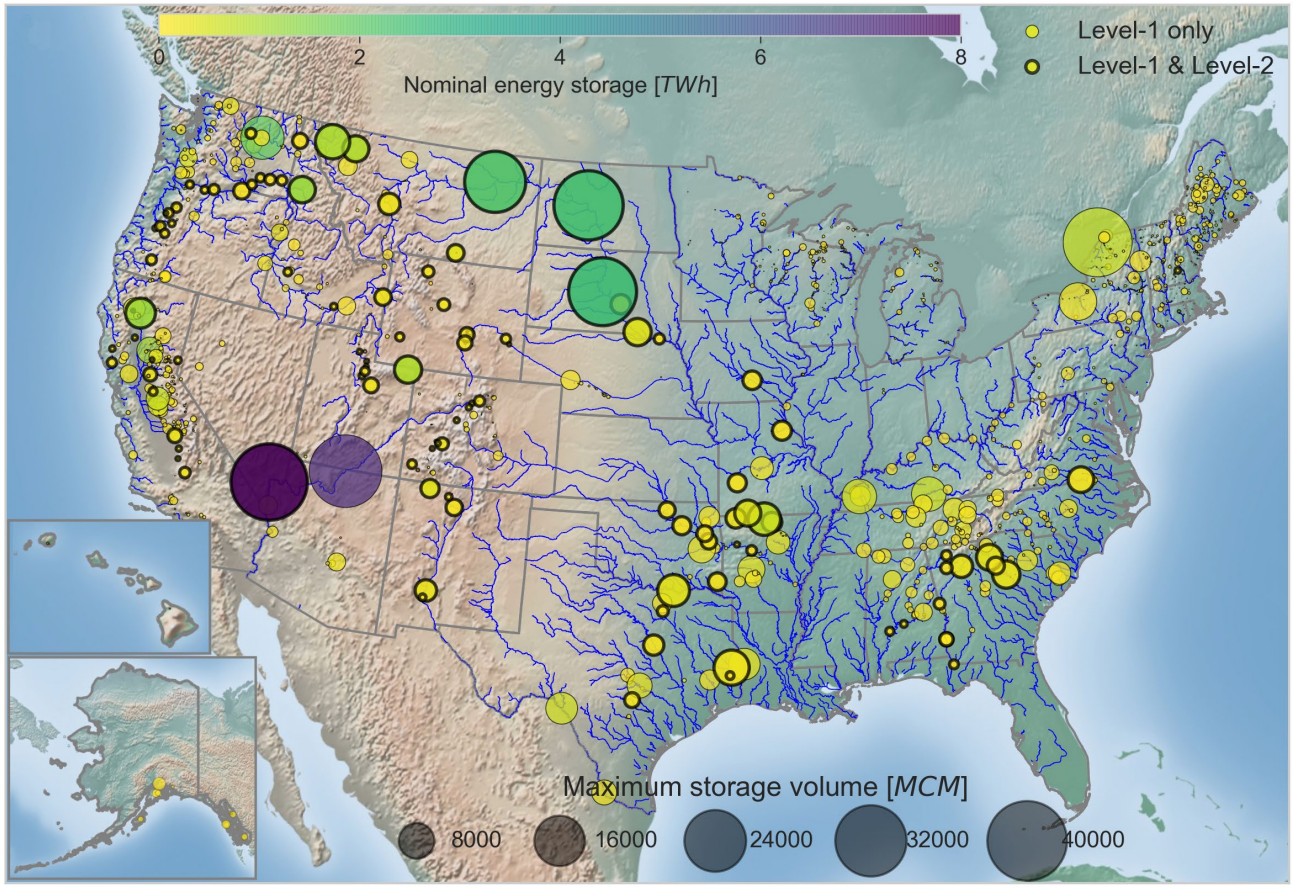
WBS 1.2.2.504 – Hydropower Energy Storage Capacity Dataset



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Project Overview

Project Summary

The Hydropower Energy Storage Capacity (HESC) Dataset project documents and analyzes water storage patterns at existing hydropower facilities and translates this information into energy storage. In creating a national-scale dataset, we bring together storage and facility characteristics from a variety of sources to describe boundary conditions and summarize patterns more consistently and comprehensively than has been previously possible with any single dataset. The dataset provides a foundation for understanding potential resources that may support increasing storage needs of the evolving grid.

Intended Outcomes

- Estimates of nominal energy storage capacity at a facility level provide an upper-bound for understanding potential storage flexibility.
- A publicly-available, national-scale dataset of energy storage at existing hydropower facilities helps support a range of modeling applications and analysis of hydropower systems.

Project Information

Principal Investigator(s)

- Carly Hansen, Ganesh Ghimire, Yang Chen, Bilal Iftikhar, Paul Matson
- Additional support from: Sudershan Gangrade, Shih-Chieh Kao

Project Partners/Subs

- N/A

Project Status

New

Project Duration

Start date: October 2020
Planned end date: September 2023

Total Costed (FY19–FY21)

$140, 867

Project Objectives: Relevance to Program Goals

Challenge highlighted in Hydropower Program Logic Model for HydroWIRES initiatives: "Untapped potential for hydro and pumped storage to support a rapidly evolving grid"

Can existing hydropower facilities help meet the increasing needs of storage from intermittent renewables?

- Current data is insufficient

Outcomes from the Logic Model:

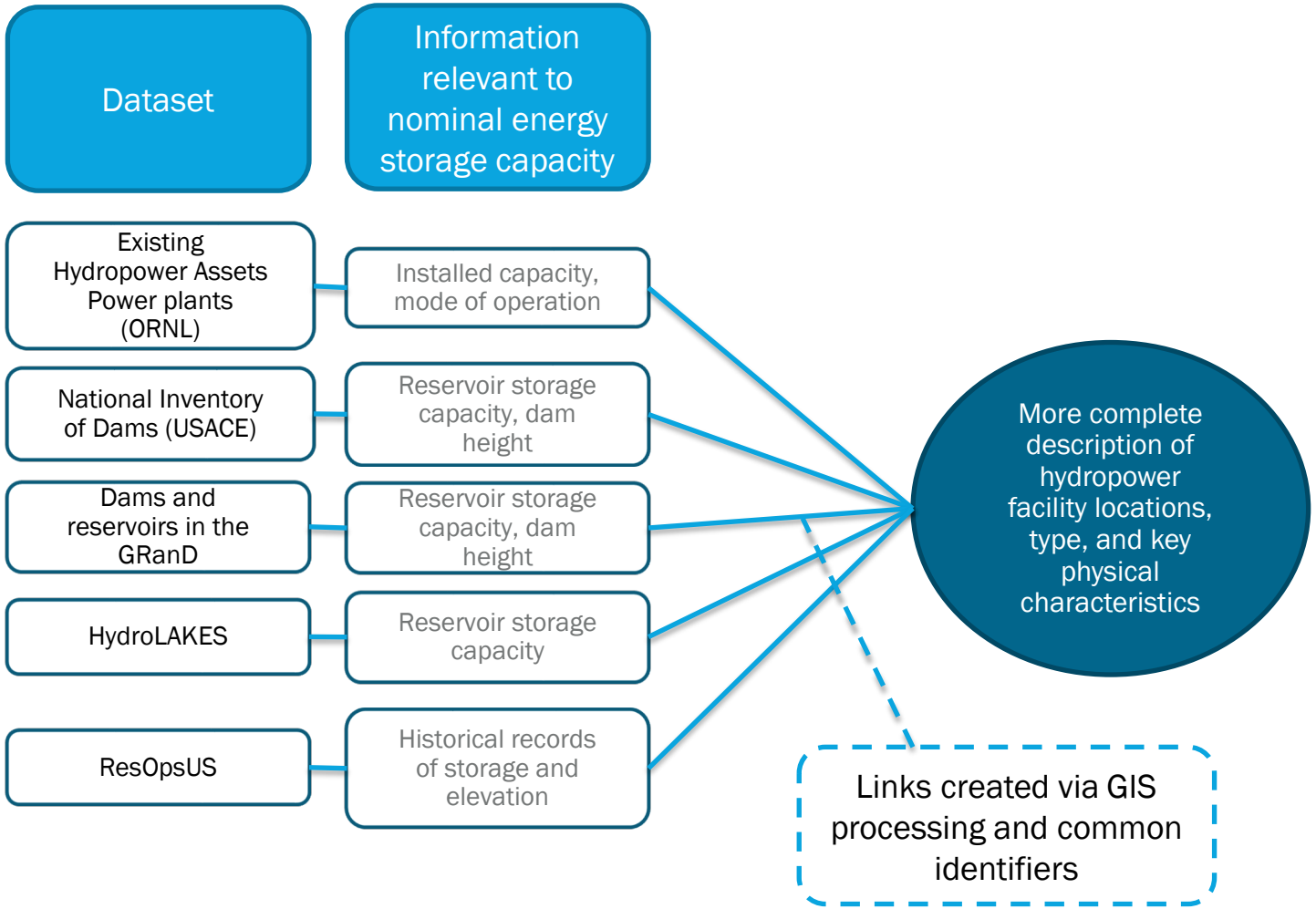
- **Intermediate to Long-term:** provide a more "accurate representation … of hydropower capabilities" leading to "increase in U.S. hydropower fleet flexibility and greater value provided to the power system"

This challenge was also highlighted in the 2021 IEA Special Market Report which included a global-level assessment of nominal energy storage capacity

Project Objectives: Approach

Approach:

- Challenges in describing hydropower facility storage :
  - Datasets do not always agree with each other and do not describe all the key information
  - Infrastructure is disconnected from hydrology and other facilities
  - Other estimates of storage (i.e., IEA global estimate) are aggregated, do not consider constraints, only consider very large dams
- We created a national-extent, facility-level energy storage dataset dataset by:
  - Linking infrastructure data between different sources and connecting to hydrologic data
  - Conveying confidence and uncertainty in information



Project Objectives: Approach (cont.)

Approach:

- Addressed challenges posed by limited data availability by producing estimates that incorporate different levels of details

Least detailed, largest # of facilities included

More realistic, fewer # of facilities included

Level	Description
1	$Nominal\ energy\ storage\ capacity = f(volume, head)$ Volume and head reported in dam or reservoir inventories; n=2,075
2	$Nominal\ energy\ storage\ capacity = f(volume, head)$ Volume and head based on historical records; n=120
3	Modeled energy available in the historical average volume, constrained by physical inputs and characteristics of the reservoir.
4	Modeled energy available in the historical average volume factoring in seasonally variable operations/restrictions:

Completed in FY21

Ongoing work

Project Objectives: Expected Outputs and Intended Outcomes

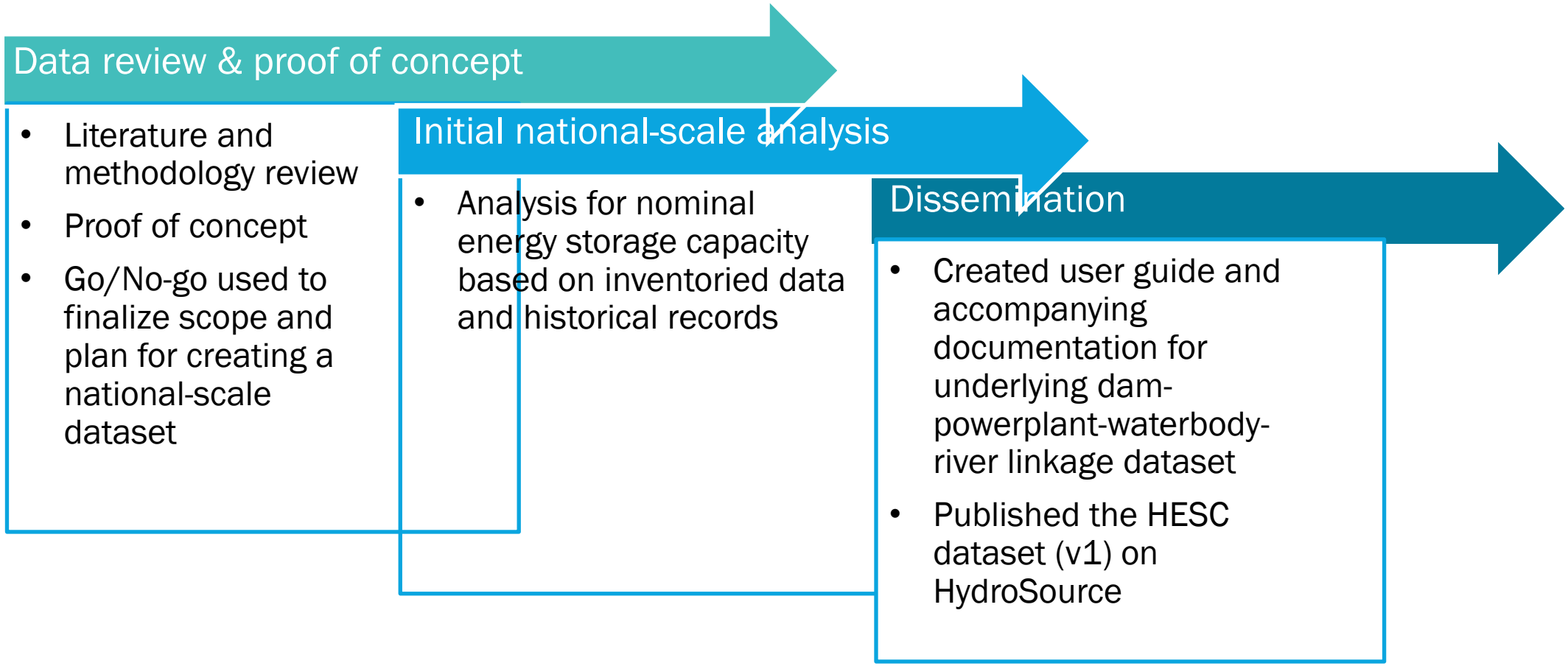
Outputs:

- Dataset that describes storage (water volume and energy) at different levels of detail, published on HydroSource
- Conference presentations and publications (under review and in preparation) describing the challenges of linking infrastructure + hydrologic/hydrographic datasets and findings from estimating energy storage on a national scale

Outcomes:

- Understanding of potential energy storage at a facility-level rather than aggregated summaries
- Support for large-scale summaries/analysis and models that require understanding of key physical and operational characteristics of hydropower facilities
- An upper-bound on storage to help better describe potential flexibility

Project Timeline



Project Budget

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
N/A	N/A	$141k	$141k

End-User Engagement and Dissemination

End users
+ Needs

Conducting national-scale assessments

- Other HydroWIRES PIs and National Lab researchers
- Federal agencies
- Universities/research institutions

Managing and studying reservoir characteristics

- Facility owners/operators
- Other HydroWIRES PIs and National Lab researchers

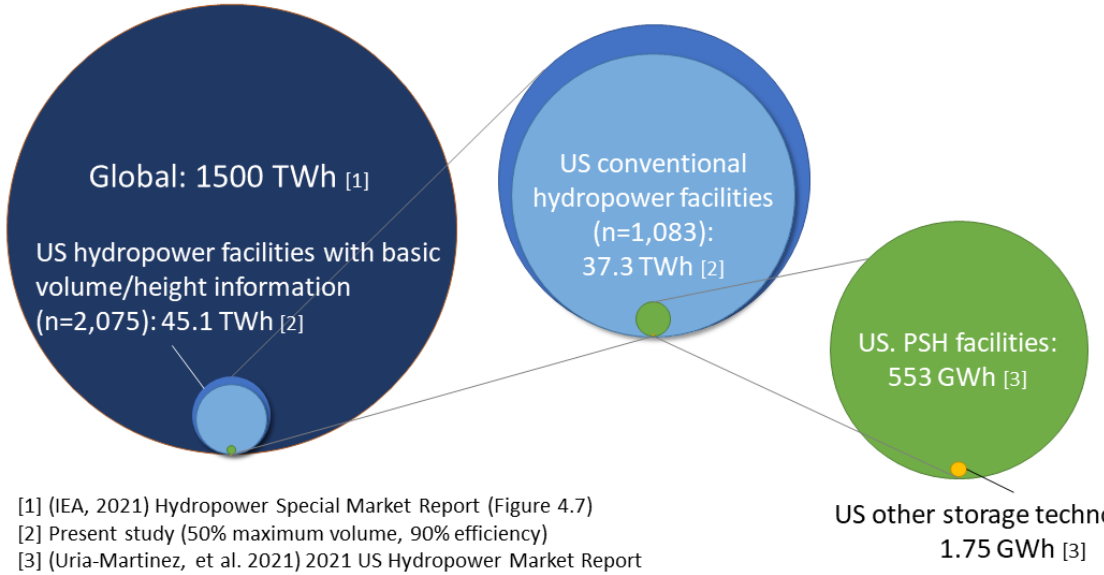
Feedback on facility information

- Managers of datasets (USACE [National Inventory of Dams])

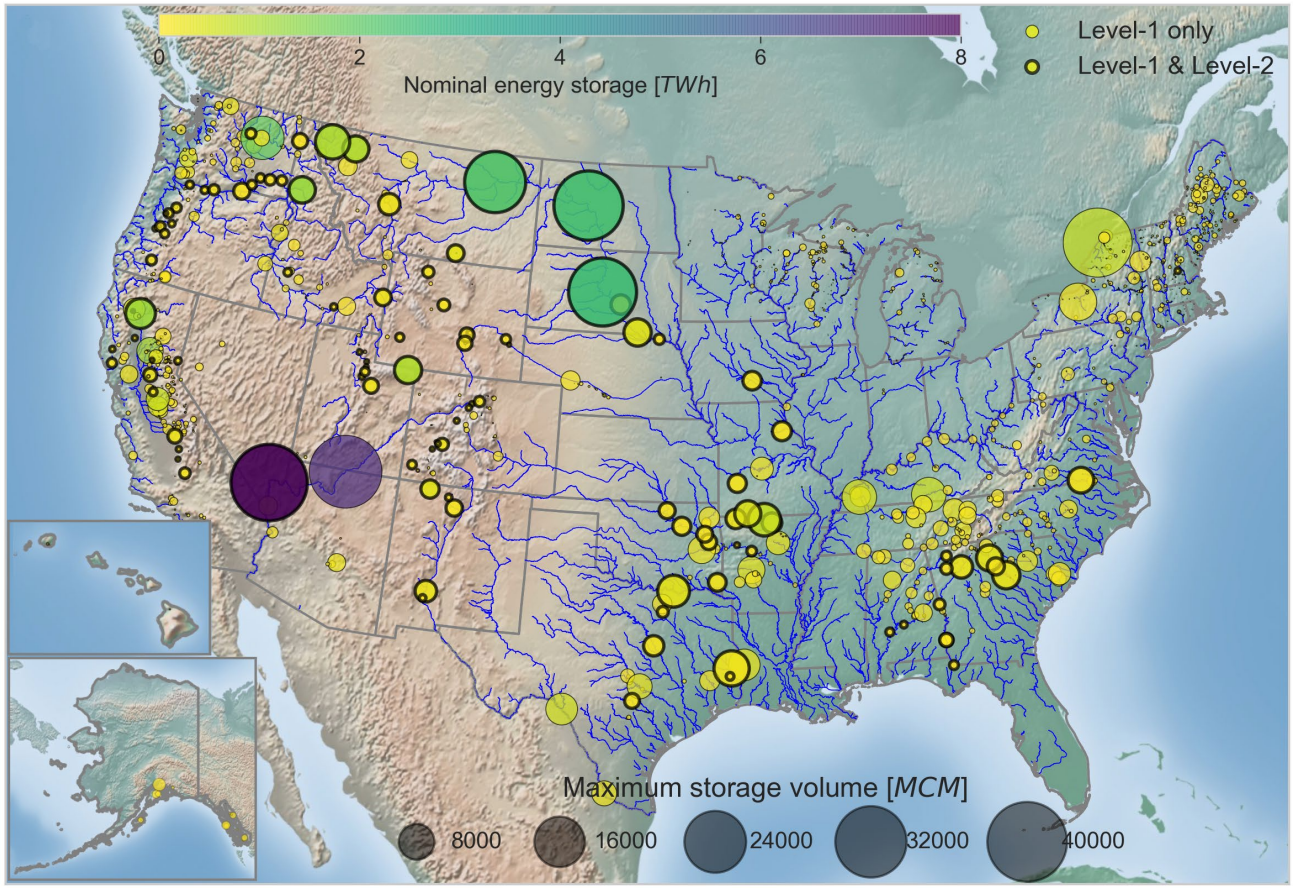
- **Engagement and strategy:**
  - Feedback from other HydroWIRES PIs and data producers
  - Document datasets produced so users have all the information they need
  - Communicate with researchers to set reasonable expectations for what this data can provide (resolutions, coverage, etc.)
- **Dissemination:**
  - Resulting datasets have been published on the HydroSource website
    - Hydropower Energy Storage Capacity (HESC) dataset version 1
    - Hydropower Infrastructure – LAkes, Reservoirs, and Rivers (HILARRI) dataset version 1, including user guide for understanding relationships between power plants – dams – waterbody inventories
  - Highlighted the datasets at professional conferences

Performance: Accomplishments and Progress

- Produced initial estimates of energy storage:
  - 2,075 facility-level estimates of nominal energy storage with a sum of 45.1 TWh
- Overcame technical barriers:
  - Limited data availability resulted in revising plans for the scope of data (providing estimates with different levels of detail)

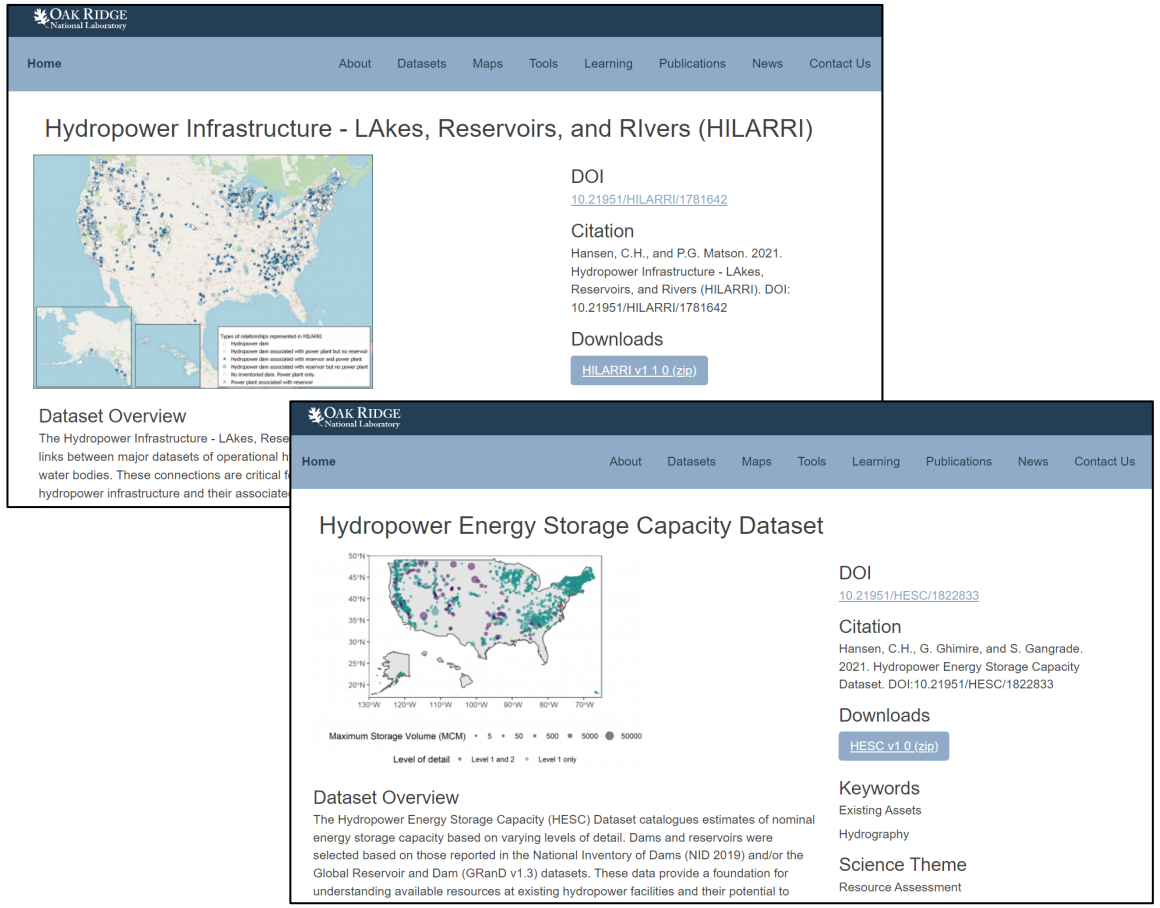


[1] (IEA, 2021) Hydropower Special Market Report (Figure 4.7)
[2] Present study (50% maximum volume, 90% efficiency)
[3] (Uria-Martinez, et al. 2021) 2021 US Hydropower Market Report



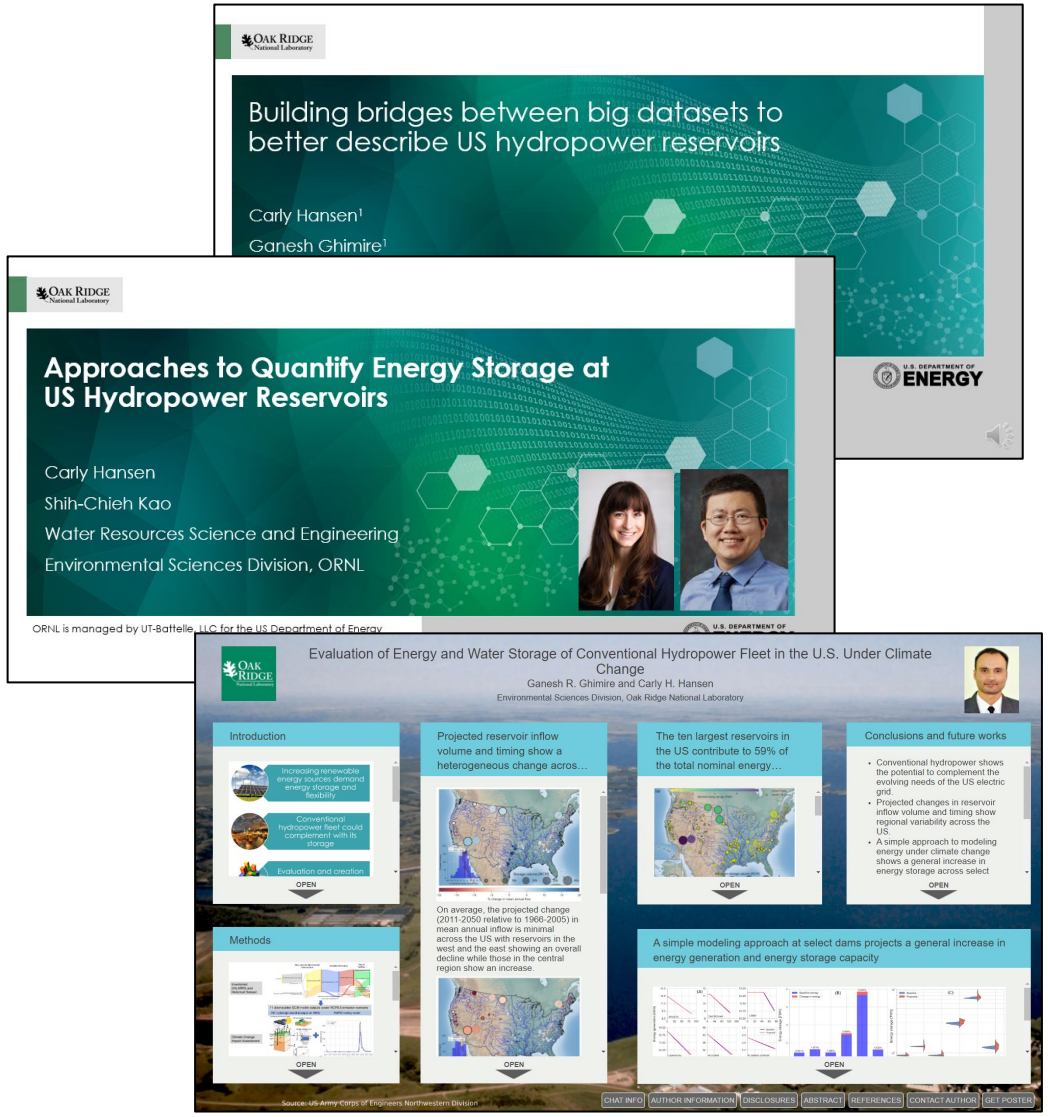
Performance: Accomplishments and Progress (cont.)

- Published datasets
  - Hydropower Infrastructure – LAkes, Reservoirs, and Rivers (HILARRI) and
  - Hydropower Energy Storage Capacity (HESC) published on HydroSource
- Success will be measured by # of projects using this data
  - National-scale assessments of dams and/or reservoir characteristics (e.g., GHG emissions in reservoirs, evaluating recent retrofits of non-powered dams)
  - Production cost modeling or other models that require definitions of storage limits
  - Feedback for USACE and the National Inventory of Dams



Performance: Accomplishments and Progress (cont.)

- Presentations at professional conferences
  - Environmental and Water Resources Institute Annual Meeting (virtual presentation) 2021
  - American Geophysical Union Fall Meeting (e-lightning talk) 2021
  - Joint Aquatic Sciences Meeting (Session on open data initiatives) 2022
- Paper under review describing initial estimates of energy storage
  - Overview of methodology behind linking data
  - Summary of nominal energy storage capacity



Future Work

- Publish version 2 (with increased levels of detail) planned for end of FY22
  - Updates based on newer facility-level data (National Inventory of Dams published in 2021, updated Existing Hydropower Assets)
  - Expansion of dataset to include modeled energy storage
- Demonstrate optimization of storage/operations for a multi-reservoir system planned for FY23
- Evaluate national hydropower fleet storage and operational flexibility through a variety of metrics

Version 1: Dataset of nominal energy storage capacity

- Nominal Energy Storage = f(Volume, Hydraulic Head)

Version 2 (end of FY22): Include updates and modeled energy storage

- Energy constrained by inflow and physical characteristics of the reservoir (volume – elevation)
- Energy constrained by operational targets for storage or releases

Q&A