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
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
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 by:
  - Linking infrastructure data between different sources and connecting to hydrologic data
  - Conveying confidence and uncertainty in information

### Dataset
- Existing Hydropower Assets Power plants (ORNL)
- National Inventory of Dams (USACE)
- Dams and reservoirs in the GRanD
- HydroLAKES
- ResOpsUS

### Information relevant to nominal energy storage capacity
- Installed capacity, mode of operation
- Reservoir storage capacity, dam height
- Reservoir storage capacity
- Historical records of storage and elevation

More complete description of hydropower facility locations, type, and key physical characteristics

Links created via GIS processing and common identifiers
Approach:

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

<table>
<thead>
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<th>Level</th>
<th>Description</th>
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| 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: |
## 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
Data review & proof of concept

- Literature and methodology review
- Proof of concept
- Go/No-go used to finalize scope and plan for creating a national-scale dataset

Initial national-scale analysis

- Analysis for nominal energy storage capacity based on inventoried data and historical records

Dissemination

- Created user guide and accompanying documentation for underlying dam-powerplant-waterbody-river linkage dataset
- Published the HESC dataset (v1) on HydroSource
## Project Budget

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<th>FY20</th>
<th>FY21</th>
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End-User Engagement and Dissemination

**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

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

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

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

- Conducting national-scale assessments
- Managing and studying reservoir characteristics
- Feedback on facility information
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)

Global: 1500 TWh [1]
US hydropower facilities with basic volume/height information (n=2,075): 45.1 TWh [2]
US conventional hydropower facilities (n=1,083): 37.3 TWh [2]
US. PSH facilities: 553 GWh [3]
US other storage technologies: 1.75 GWh [3]

[1] [EIA, 2021] Hydropower Special Market Report (Figure 4.7)
[2] Present study (50% maximum volume, 90% efficiency)
• 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
Q&A