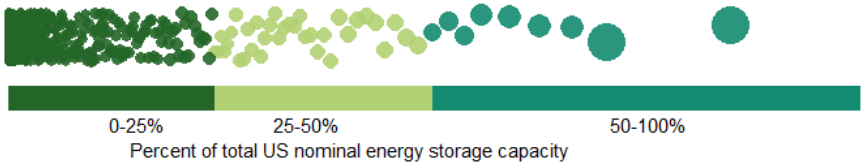
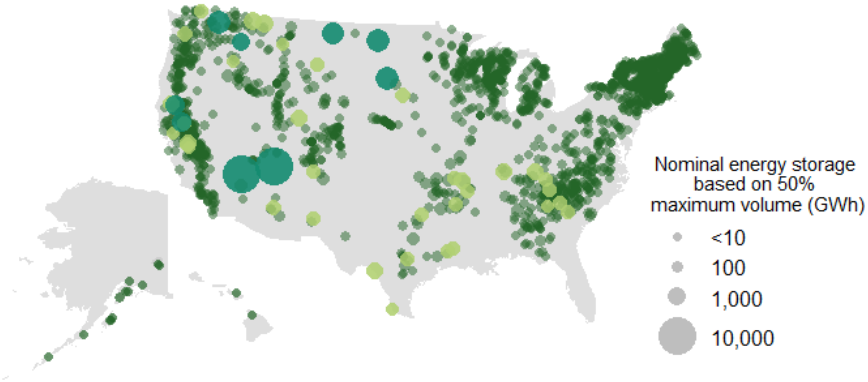
Hydropower Energy Storage Capacity (HESC) Dataset

What is HESC and why is it important?

The Hydropower Energy Storage Capacity (HESC) Dataset contains estimates of energy storage capacity for existing hydropower reservoirs based on varying levels of available information. To increase grid resilience and support intermittent renewable energy sources, it is important to understand the potential for existing hydropower facilities to store energy and provide flexibility to the grid.



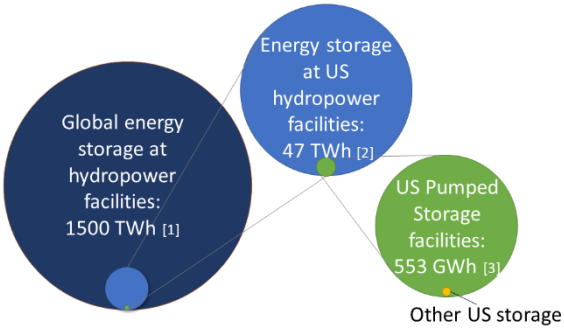


The top 10 resrevoirs (according to maximum storage capacity) make up over half of the total *nominal energy storage capacity* – what could be generated if half of the maximum volume were available for generation and assuming inflow equals outflow – for the US. Smaller reservoir systems are more common and make up the rest of the energy storage capacity.

2,100+ hydropower facilities have estimates of nominal energy storage capacity in HESC. Hydropower dams with known reservoir information form the backbone of the dataset.

47 TWh of total nominal energy storage are estimated across existing hydropower facilities in the US. This estimate is based on reservoir elevation and volume from dam inventories.

230+ facilities include estimates of storage capacity based on historical reservoir data. Energy storage is also modeled at **150+** facilities using basic volume–elevation relationships, flow, and operational constraints.



[1] IEA 2021 Hydropower Special Market Report
[2] HESCv2 (50% maximum volume, 90% efficiency)
[3] Uria-Martinez, et al. 2021 US Hydropower Market Report

Where can I find it?

HESC is hosted on hydrosource.ornl.gov. Information in version 2 includes key facility characteristics and estimates of storage capacity. The dataset can be downloaded as an Excel workbook.

OAK RIDGE National Laboratory

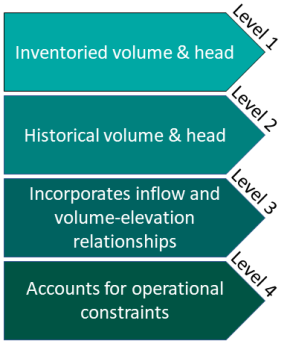
Oak Ridge National Laboratory is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY | Office of Science

Who can use HESC?

- **Hydrodynamic and power system modelers** benefit from the robust documentation of reservoir characteristics including storage, hydraulic head, and volume-elevation relationships, which are key to accurate modeling of reservoirs.
- **Water/energy planning and management entities** can use estimates of energy storage and discharge duration to help inform long-term modeling and planning for grid and water systems.
- **Asset owners and operators** can identify facilities for exploring in detailed flexibility studies.

What is in the dataset?



- Dam location
- Type of project, mode of operation, and known issues with source data quality
- Installed capacity
- Volume and hydraulic head from inventories including the National Inventory of Dams, GRanD, HydroLAKES, and historical records
- Modeled volume-elevation relationships
- Nominal energy storage capacity based on inventoried volumes (Level 1 estimates) and historical records (Level 2 estimates)
- Discharge duration (length of time at which a plant could generate at its installed capacity)
- Modeled generation based on historical reservoir storage volume, basic volume-elevation relationships (Level 3 estimates), and normal operating ranges (Level 4 estimates)

How is energy storage capacity estimated?

We can translate available reservoir volume and elevation information into estimates of potential energy storage using the following equation:

$$Nominal\ Energy\ Storage\ Capacity\ [MWh] = \frac{\eta \times \rho \times g \times V \times H}{3.6 \times 10^9}$$

Where η is efficiency, ρ is the density of water [kg/m^3], g is the gravitational constant [9.81 m/s^2], V is the available reservoir water volume [m^3], H is the hydraulic head [m], and 3.6×10^9 is a unit conversion factor.

Nominal energy storage capacity is a convenient way describe the energy stored in a given reservoir volume. However, it relies on major simplifications: inflow is equal to outflow, and no other constraints on storage volume, releases, or turbine performance are accounted for.

Where facilities have additional information such as operational targets and historical records of inflow, volume, and elevation, we can model how elevation varies with changes in volume and estimate energy storage based on operational targets. This offers a simplified representation of a facility's physical and operational constraints.

The Hoover Dam has a reported maximum storage volume of 36,700 million cubic meters (MCM) and hydraulic head of 156 m. Assuming the volume available is half of the reported capacity, nominal energy storage capacity for the Hoover Dam is 7.8 TWh. If we use half the historical 25th percentile volume (15,675 MCM) instead, the Nominal Energy Storage Capacity would be 5.7 TWh.

What are future plans for HESC?

In reality, there are other constraints on the volume that can be stored and how this translates to energy generation: coordination with up/downstream facilities, variable turbine performance, and obligations to meet non-power purposes.

Priorities for better understanding storage and flexibility on an individual basis include:

- Establish up/downstream links between facilities by integrating hydropower infrastructure information with established river network data structures
- Incorporate detailed facility or unit-level information
- Account for the uncertainty and variability in future water availability due to changing climate conditions

Questions?
Contact Carly Hansen, Water Resources Engineer
hansench@ornl.gov