HydroWIRES

U.S. DEPARTMENT OF ENERGY

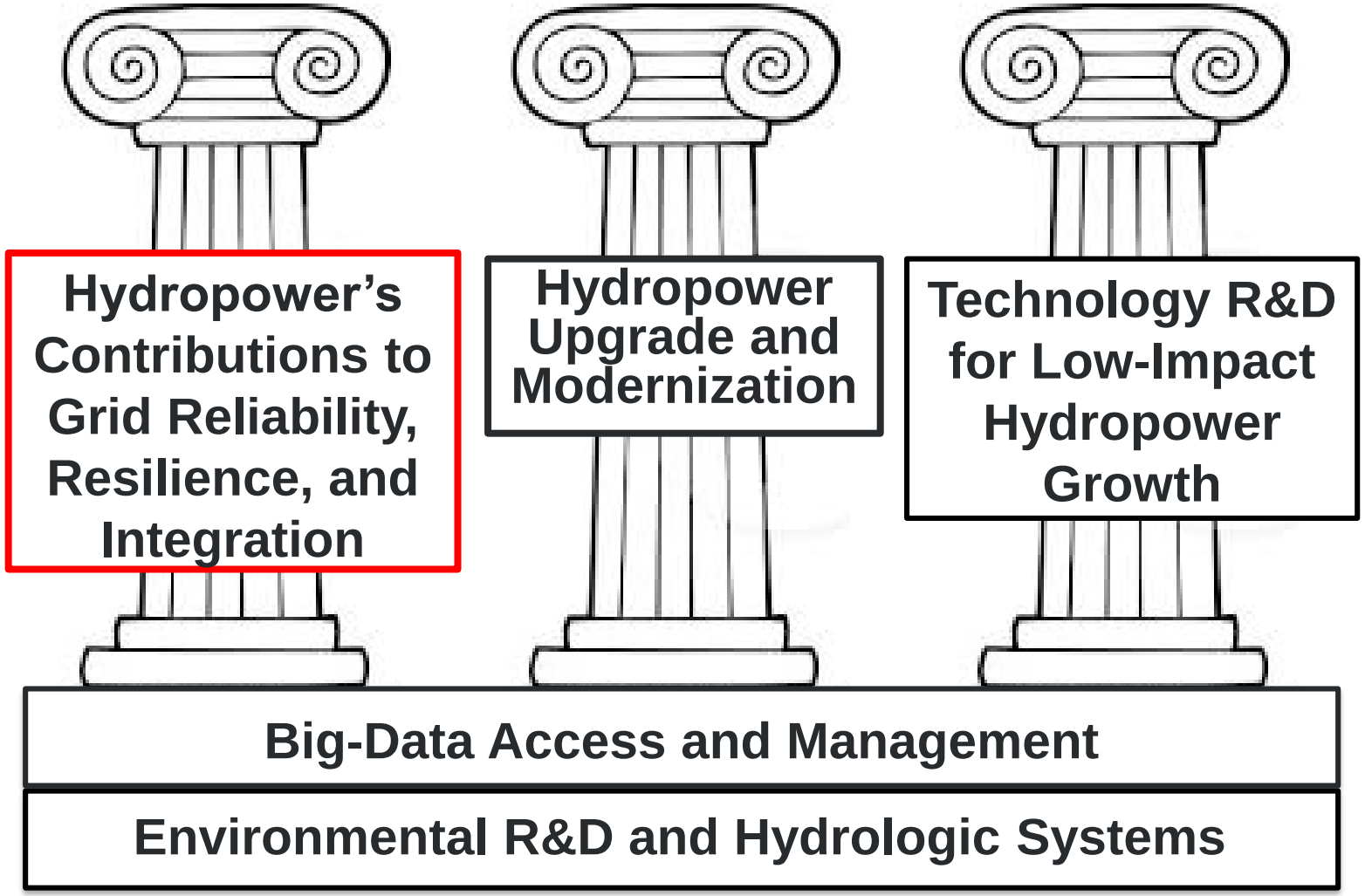
Pumped Storage Technology R&D

Dr. Mark Christian

Argonne National Laboratory
Management & Operations Contractor

Water Power Technologies Office

Hydropower Program Strategic Priorities



Pumped storage hydropower

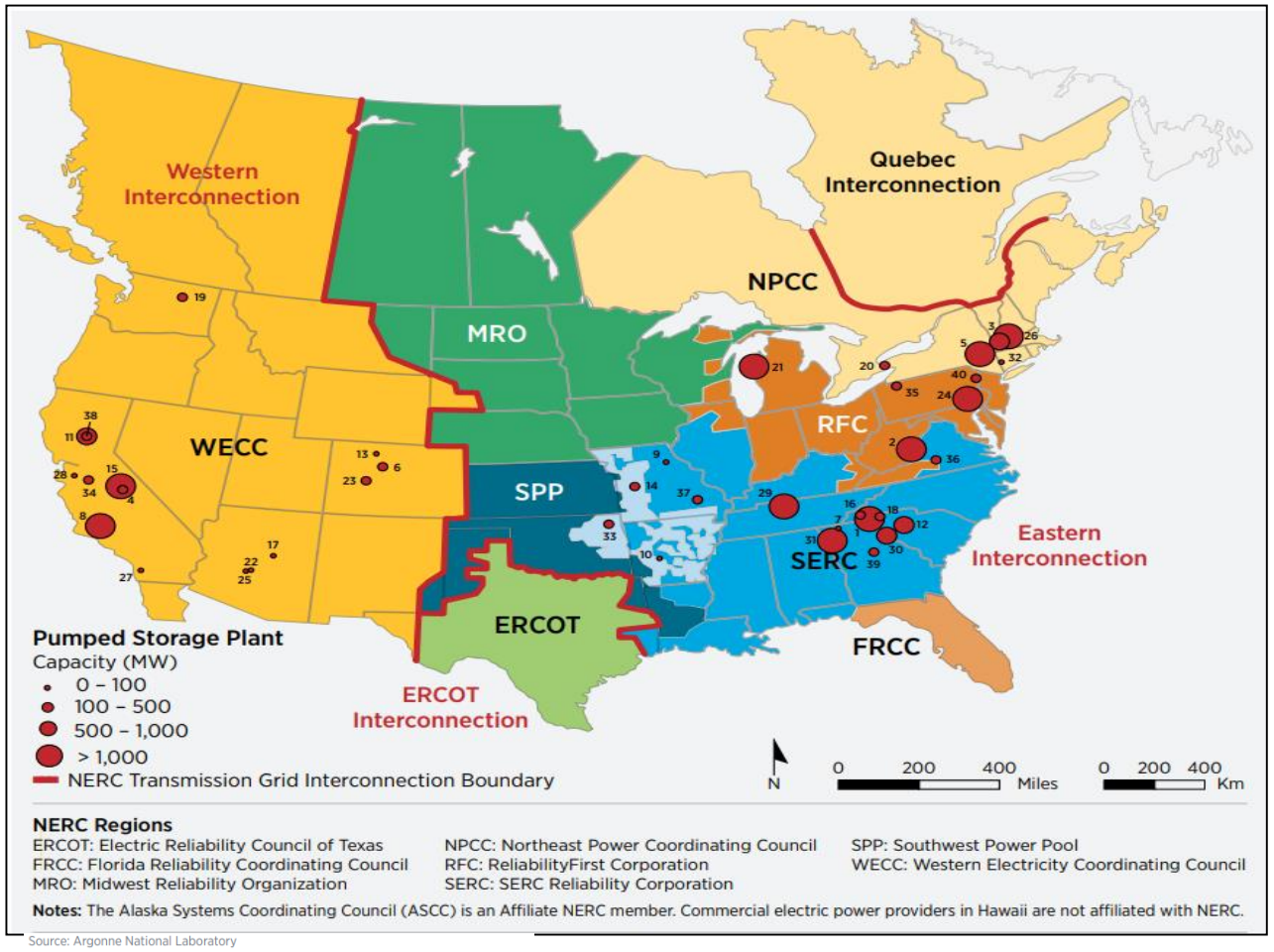


Figure 2-41. Existing pumped storage hydropower plants in the United States

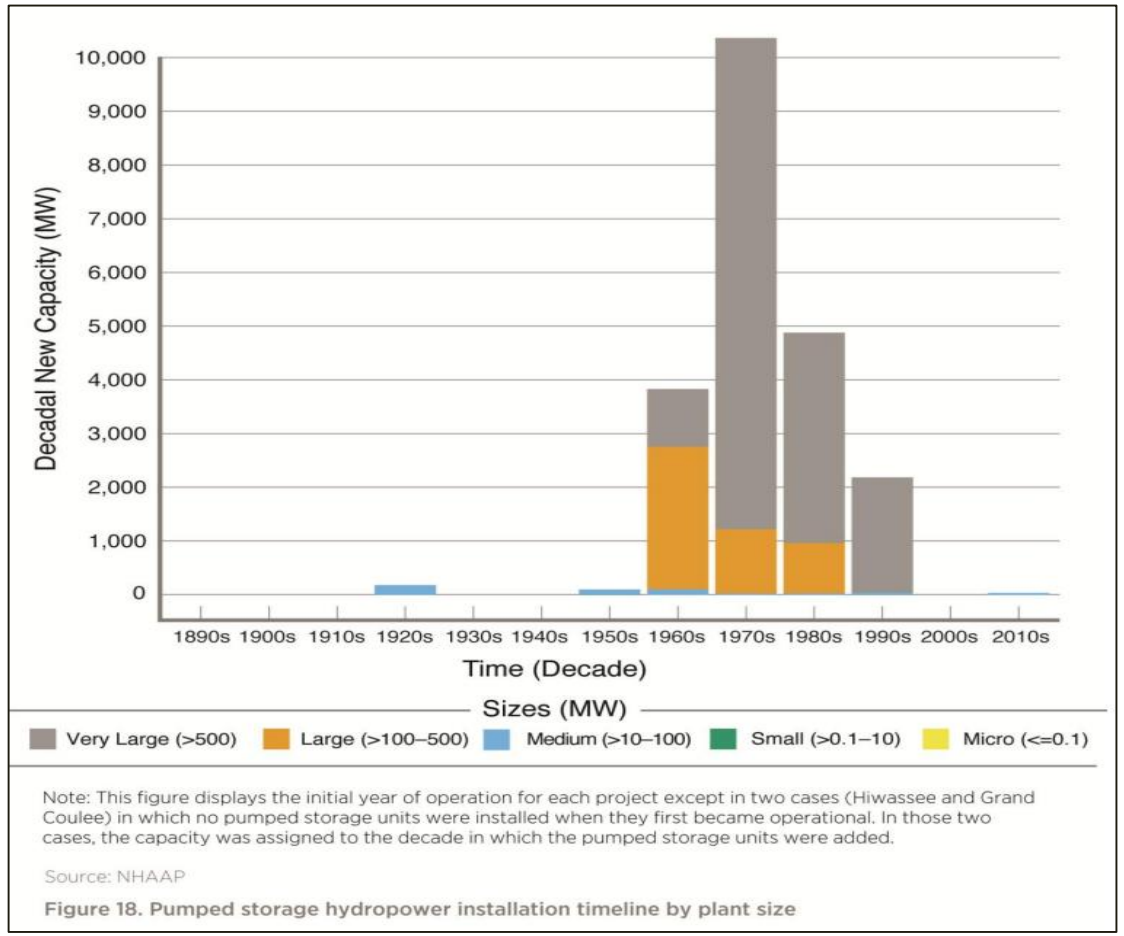
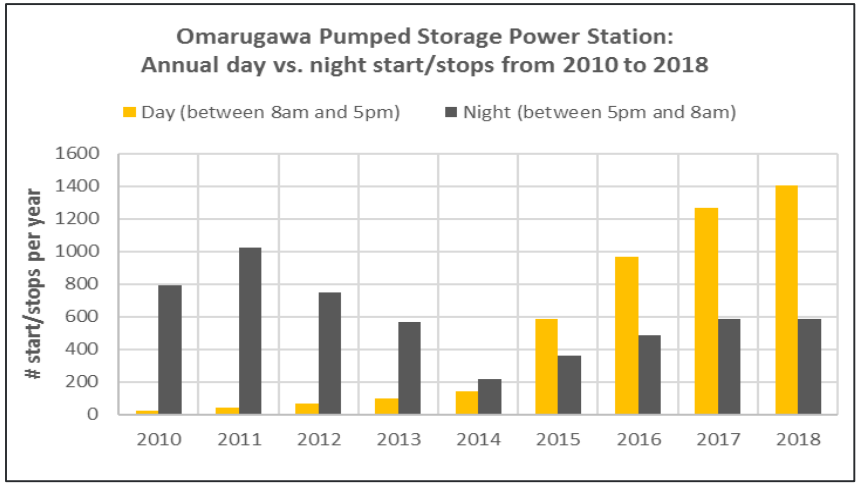


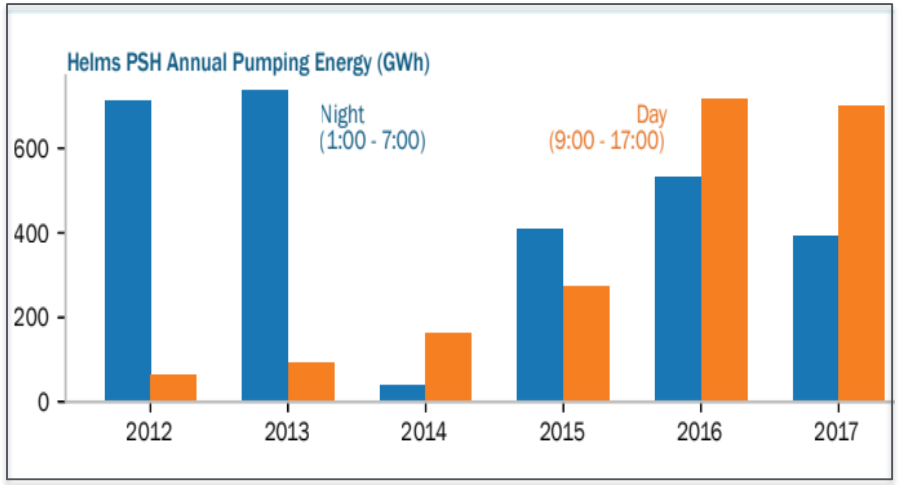
Figure 18. Pumped storage hydropower installation timeline by plant size

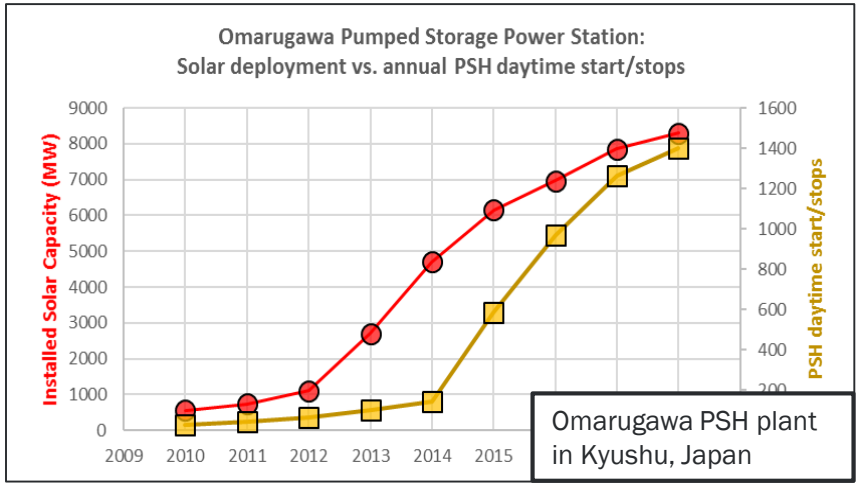
- **About 22 GW of PSH capacity deployed in the US, but no new large projects in the last 20 years**

PSH Status

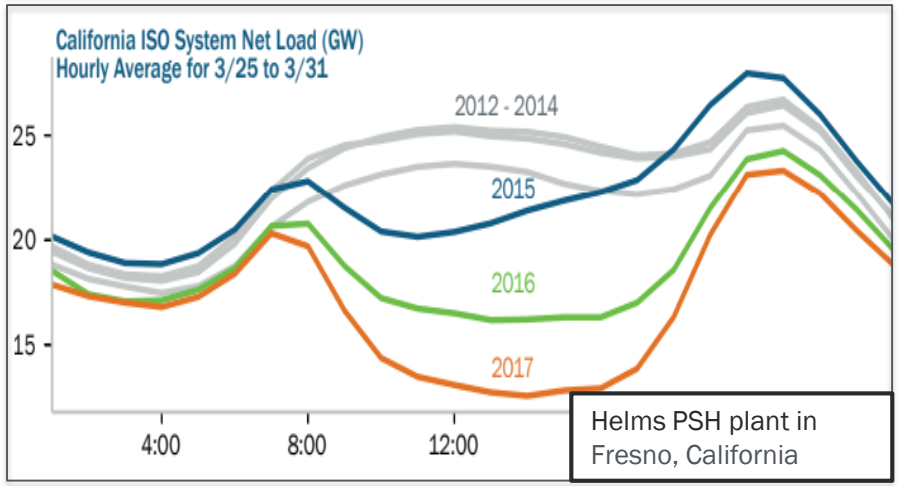
- Existing Pumped Storage Plants are being dispatched in increasingly variable ways to support Variable Energy Resources.
- As VER penetration continues to expand, energy storage will become increasingly important.
- This phenomenon appears to be international, pointing to the potential for international collaboration







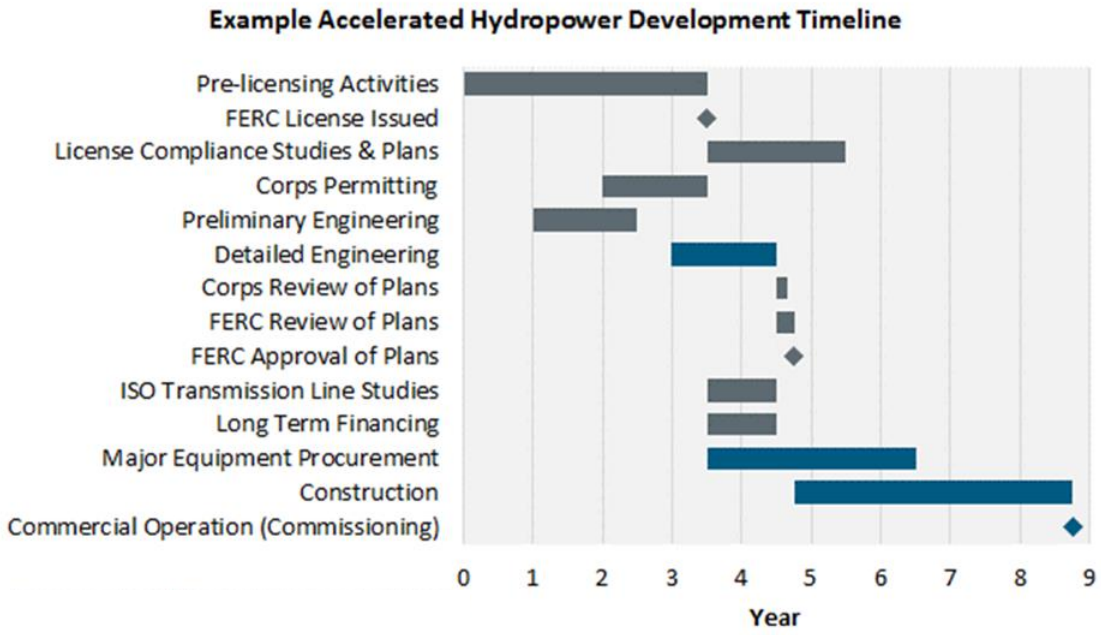
Omarugawa PSH plant in Kyushu, Japan



Helms PSH plant in Fresno, California

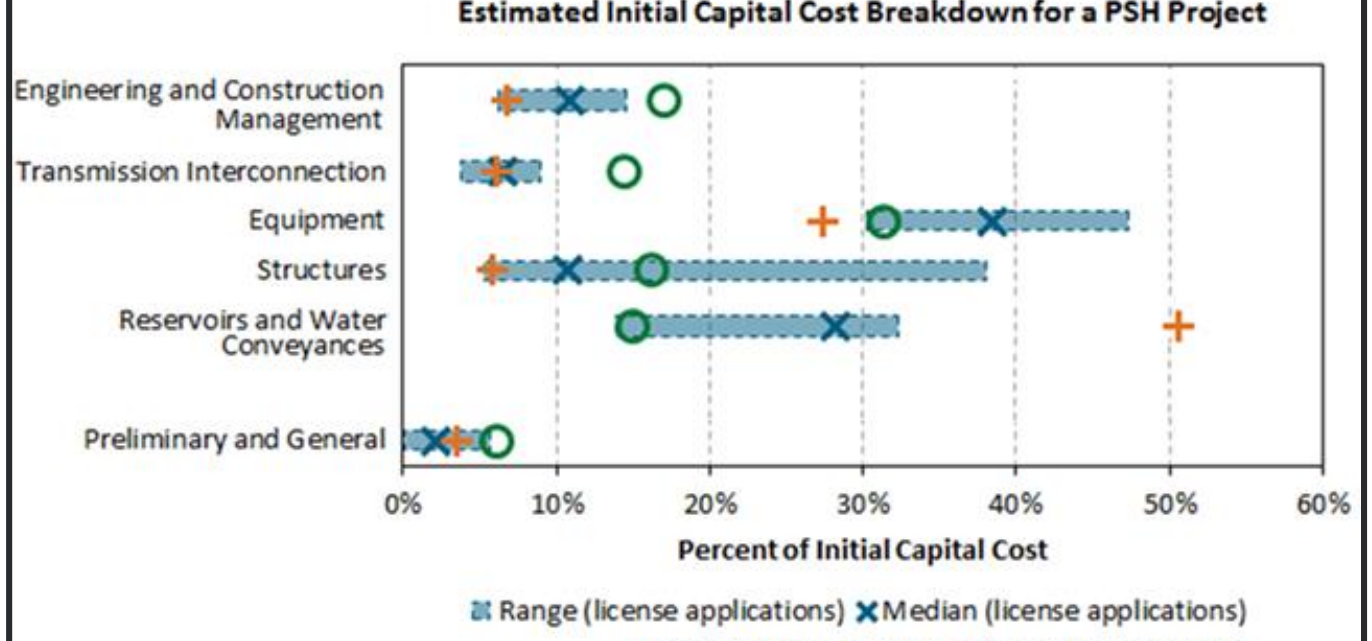
PSH Challenges to Deployment

Timeline



Source: Adapted from Meier et al. (2010)

Cost



Sources: ORNL and Industry 2019

HydroWIRES Projects

1) Hydropower Value Study

3) PSH Valuation Guidance

2) NARIS

Value under Evolving System Conditions
Understand the needs of the rapidly evolving grid and how they create opportunities for hydropower and PSH.
"What will the grid need?"

Capabilities and Constraints
Investigate the full range of hydropower's capabilities to provide grid services, as well as the machine, hydrologic, and institutional constraints to fully utilizing those capabilities.
What can hydropower do?"

Operations and Planning
Optimize hydropower operations and planning—alongside other resources—to best utilize hydropower's capabilities to provide grid services.
"How can hydropower best align what it can do with what the grid will need?"

4) Integrated Hydro and Storage Systems

5) Networked Small Hydropower

Technology Innovation
Invest in innovative technologies that improve hydropower capabilities to provide grid services.
"What new technology could expand what hydropower can do to meet grid needs?"

6) Ternary PSH

7) GLIDES PSH

8) Shell Hydro Battery

9) No-Powerhouse PSH

Pumped storage technology innovations on the horizon

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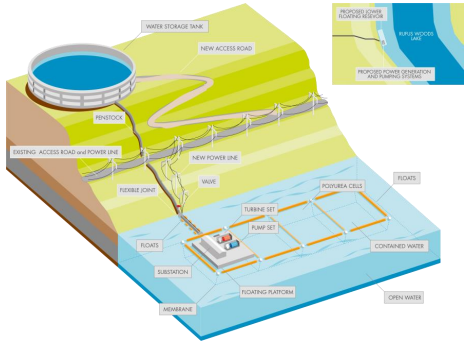
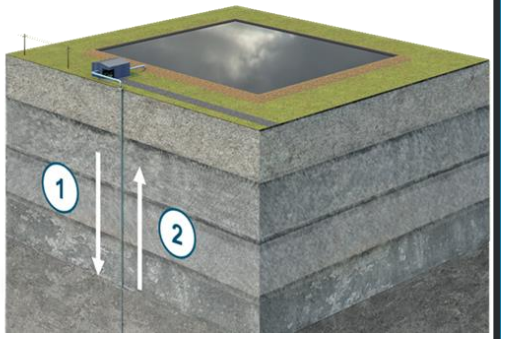
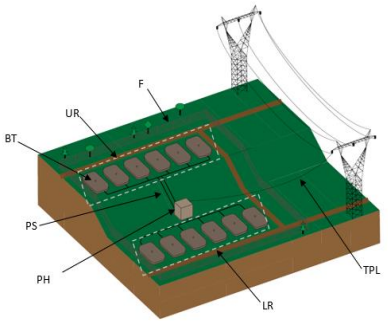
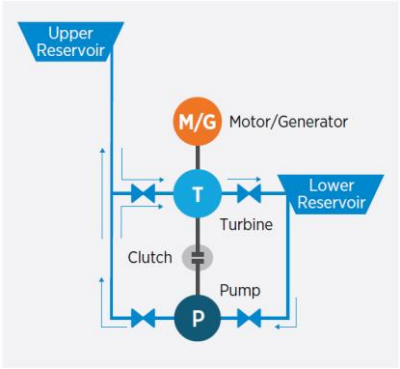
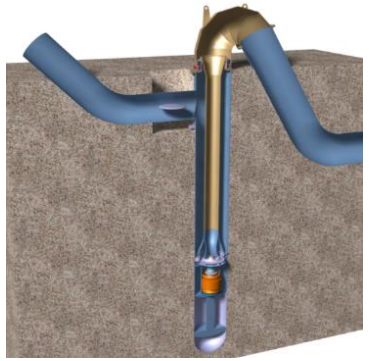
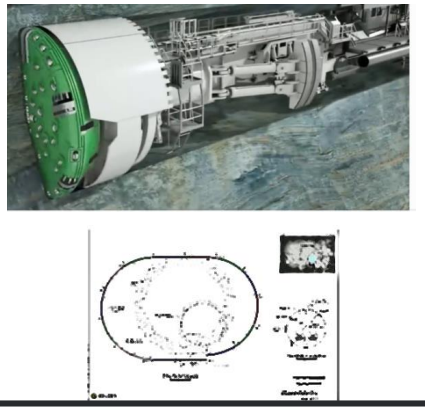
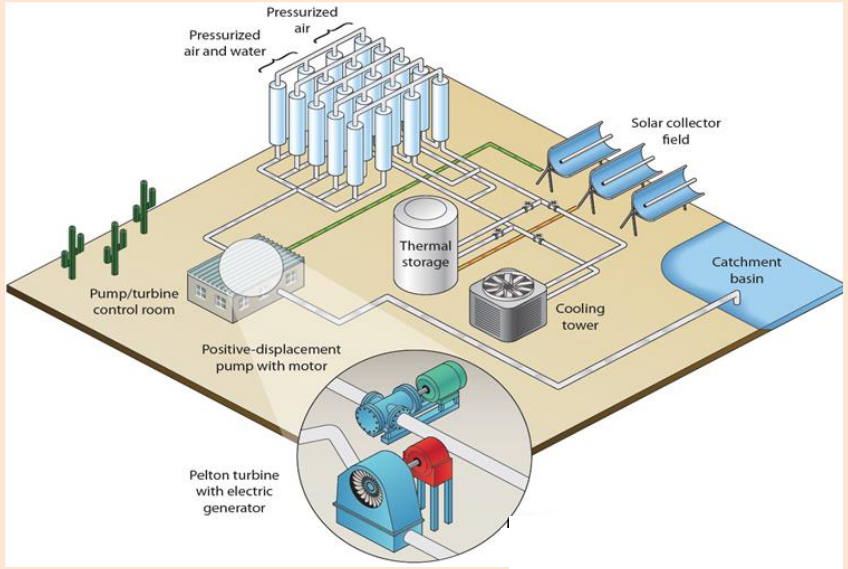
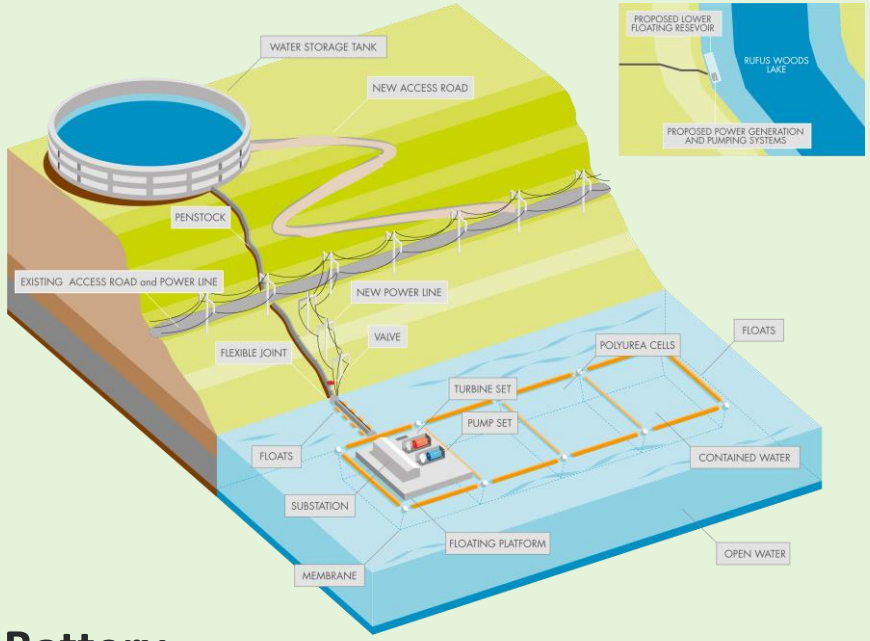
Modular Compressed-Air PSH (ORNL)	Small Modular Hydro Battery (Shell)	Geomechanical PSH (Quidnet)	Steel Dams (FAST Prize Winner)	Modular Closed-Loop Scalable Pump Storage (FAST Prize Winner)
				
Ternary PSH System (NREL)	No-Powerhouse PSH (Obermeyer)		Mobile Track Machines plus Autonomous Truck Haulage in a Continuous Tunneling Process (FAST Prize Winner)	Modern TBMs for Underground Pumped Storage (FAST Prize Winner)
				

Cost and Performance Innovation



GLIDES Grid-Scale Modular PSH System

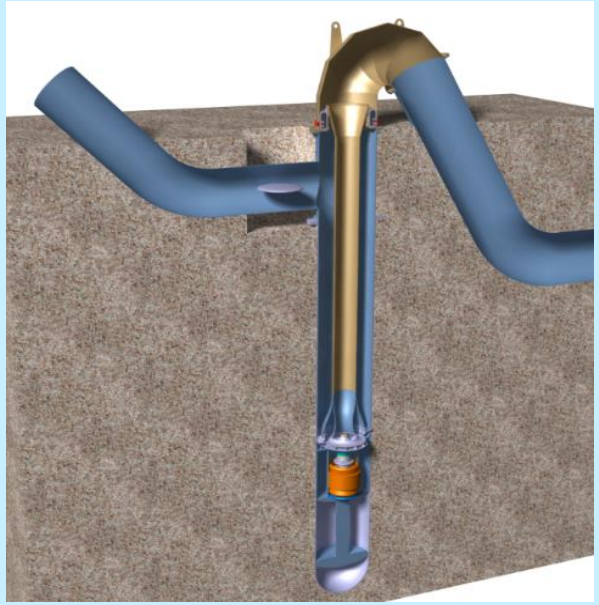
- Evaluate the feasibility of the novel Ground-Level Integrated Diverse Energy Storage (GLIDES) as a modular PSH across multiple US regions.
- Pressure vessels are the main cost driver substantial effort is dedicated toward vessel manufacturing and potential alternative materials/processes to reduce cost.



Hydro Battery

- Investigate the feasibility of building a modular 5MW closed-loop PSH facility, the Hydro Battery.
- The Hydro Battery consists of a corrugated steel tank as the upper reservoir, a floating membrane as the lower reservoir, and a floating powerhouse.

Cost and Performance Innovation

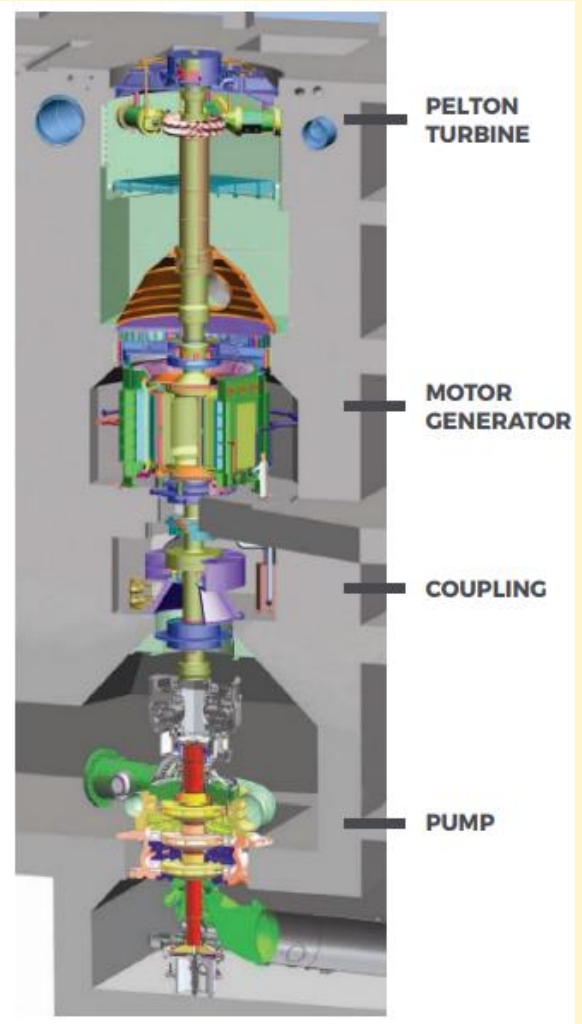


Cost Effective Small-Scale Pumped Storage

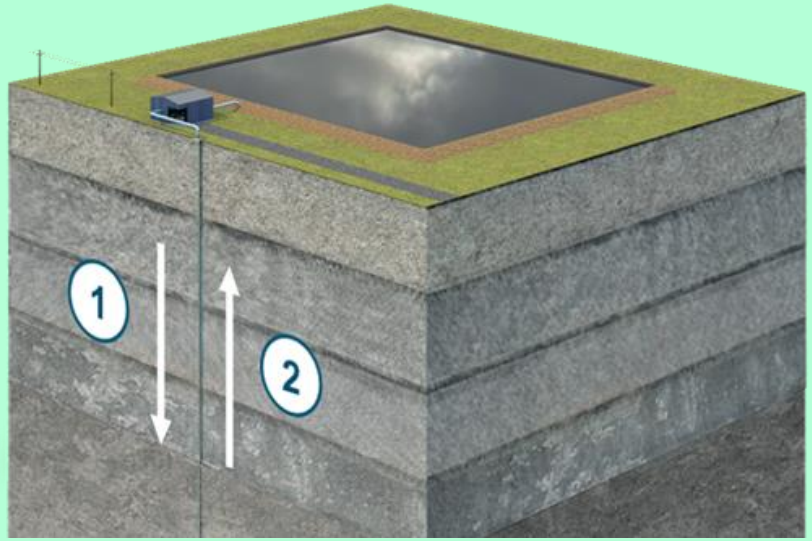
- Design, modeling, and analysis of a reversible pump turbine with submersible permanent magnet motor generators are installed in vertical shafts.
- This design reduces environmental footprint and eliminates the need for an underground powerhouse, reducing initial construction cost.

Application of Ternary-Type Pumped Storage

- Feasibility studies of ternary pumped storage coupled with an innovative dynamic transmission system using transmission monitoring and control equipment.
- Turbine, generator, and pump are stacked on a shaft. It pumps and generates at the same time, moving from pumping to generating at an estimated 20-40 MW/sec.



Cost and Performance Innovation



Geomechanical Pumped Storage

- Charging the system – water is pumped down to compress the rock body. Discharging the system – the rock body pushes water through the turbine
- The system has may potential advantages including: no need for elevation differential, modular deployment and 10+ hours of duration.

Furthering Advancements to Shorten Time (FAST) Commissioning for Pumped-Storage Hydropower Prize

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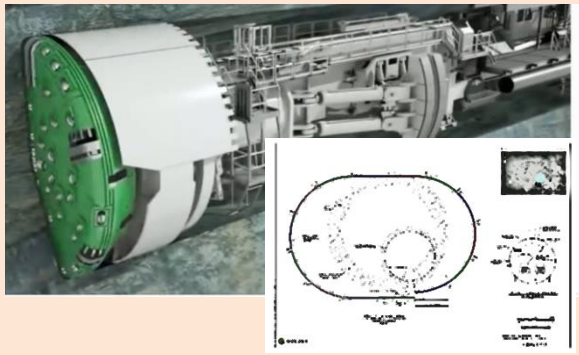
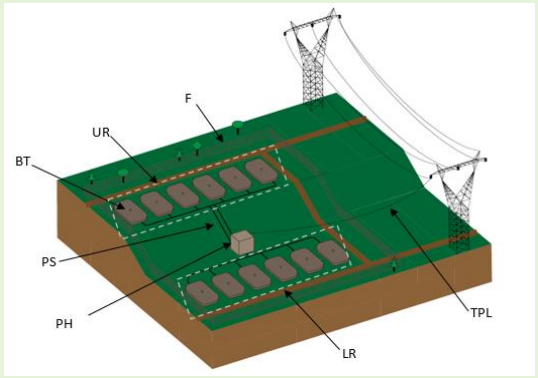


TBM for Underground Pumped Storage

- Use of tunnel boring machines for underground excavation, which can decrease excavation time by 50% and reduce costs

Reduced Excavation Duration, Cost and Risk

- Excavation equipment modifications and process optimizations to achieve up to 50% reduction in excavation timelines.



Modular Closed Loop, Scalable PSH

- Modular closed-loop, scalable PSH system with a range of 1–10 megawatt, adaptable to sites without natural bodies of water.

Steel Dams for PSH Construction

- Modular steel concept for dams that cuts costs by one-third and cuts construction schedules in half.

Competitors were assessed based on: Cost Reduction, Accelerate Timelines, Reduce Risk. Winners divided $550,000 of combined cash prizes and voucher support from National Labs

Upcoming items for release

Near-Final Drafts:

- A review of storage in transmission planning (white paper)
- A review of pumped storage market participation and FERC Order 841 (white paper)
- Hydropower-battery hybrids (technical report)
- NREL ternary pumped storage (technical report)
- Fast commissioning challenge baseline report (technical report)
- Hydropower representation in production cost modeling (workshop report)

Work in Progress:

- Hydropower Value Study (HVS) series of reports:
  - Hydropower Value Study Executive Summary
  - Historical Analysis of Hydropower Operations in MISO
  - Historical Analysis of Hydropower Operations in WECC
  - Historical Analysis of Hydropower Operations in ISONE
  - Case Study – Chelan Public Utility District
  - Case Study – Tennessee Valley Authority
  - Value of Non-monetized Services by Hydropower
  - Review of Market Rules for Hydropower
  - The Value of Water
  - Value Drivers for Hydropower Operations
  - Power Systems vs. Hydropower Operational Timeframes
  - Hydropower Capabilities & Technology Gap + Cost Analysis
- North American Renewable Integration Study (technical report)
- Ground-Level Integrated Diverse Energy Storage (technical report)

HydroWIRES
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Thank you for your attention.

Questions?

Project Lead: Sam Bockenhauer
samuel.bockenhauer@ee.doe.gov

About the Water Power Technologies Office

WPTO **invests in early-stage research** to accelerate development of innovative water power technologies while **ensuring that long-term sustainability and environmental issues are addressed**.

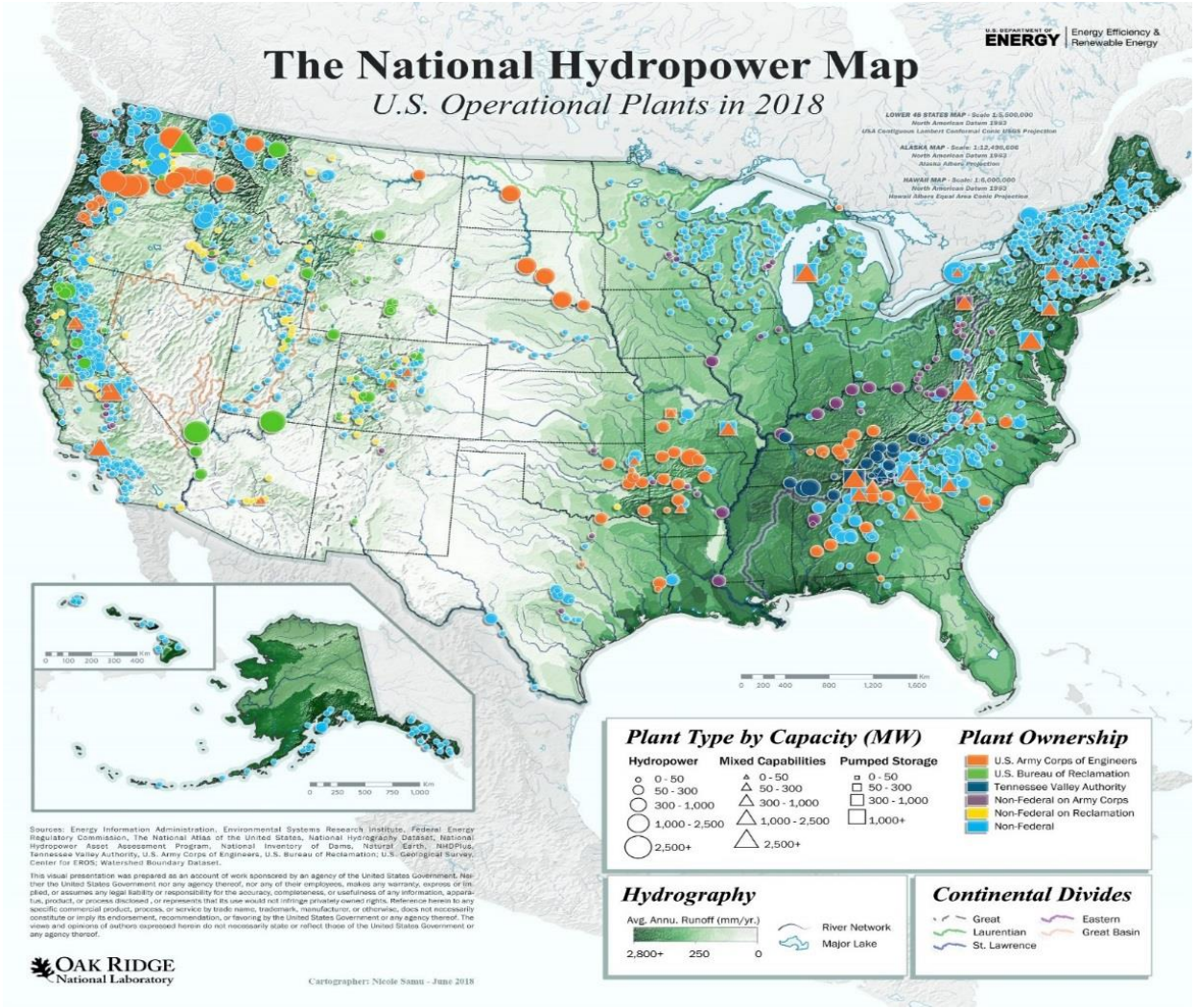
WPTO supports efforts to **validate performance and grid-reliability** for new technologies, develop and increase accessibility to **necessary testing infrastructure**, and evaluate **systems-level opportunities and risks**.

WPTO aggregates, analyzes and disseminates **relevant, objective, technical information** on water power technologies and related issues to stakeholders and decision-makers.

Emerging priorities: In 2018, WPTO announced **two new research portfolios** within our hydropower and marine energy programs:

- **HydroWIRES: A hydropower-grid** research portfolio focused on current conditions as well as potential future value drivers
- **Powering the Blue Economy:** Analysis of marine energy technologies' potential to power **the blue economy** (ocean industries & missions)

Hydropower in the U.S.



HYDROPOWER HIGHLIGHTS

- **80 GW** of hydropower capacity – 7% of U.S. capacity
- **22 GW** of pumped storage capacity – greater than 95% of U.S. energy storage capacity
- Existing plants provide low-cost and reliable generation, **87,542 jobs** across 48 states
- **49%** of hydro capacity owned by the U.S. Government
- **Nearly 1.5 GW of capacity** added in the last decade but new opportunities often limited by regulations, high costs, and environmental concerns
- **$8.9 billion** in refurbishments and upgrades was invested across 158 hydropower dams in the U.S. between 2007-2017

- **Large existing resource, including the vast majority of grid-scale storage**

- **Significant complexity and variety in the fleet**

How WPTO's Hydropower Portfolio Aligns with EERE Priorities: Affordability

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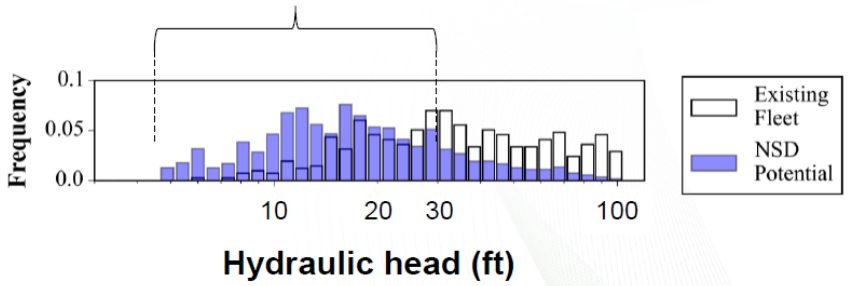
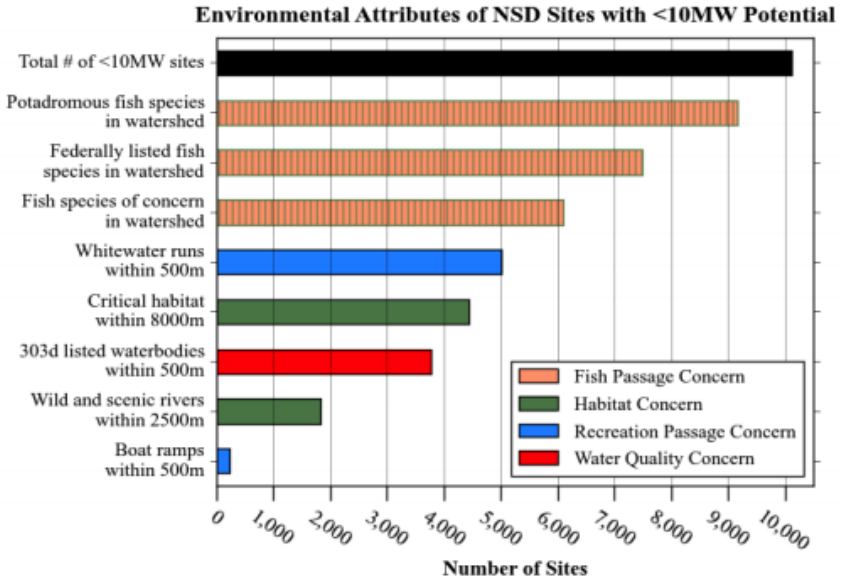
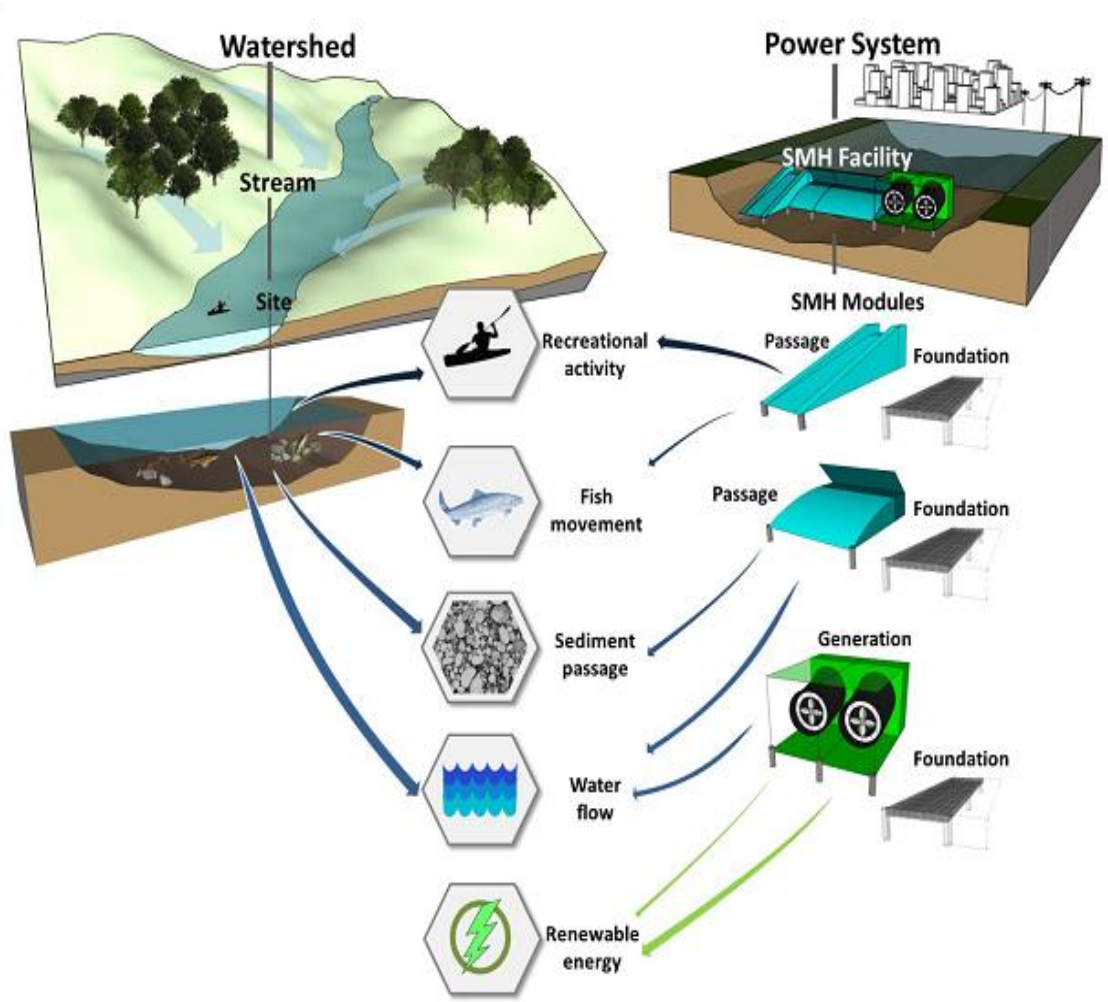
New Stream Reach Development

Majority of NSD sites are **low-head** (< 30ft) compared to existing fleet



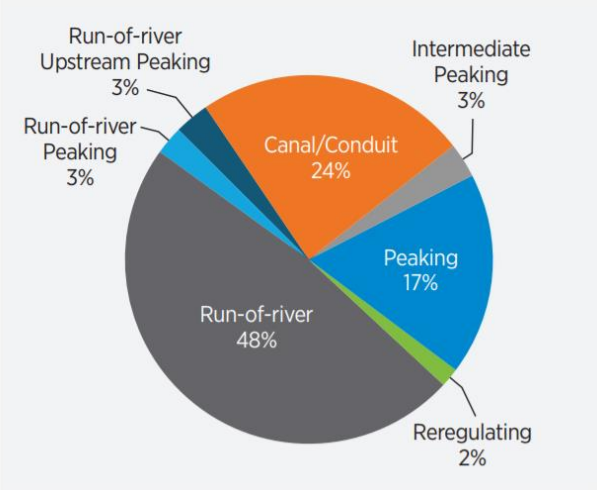


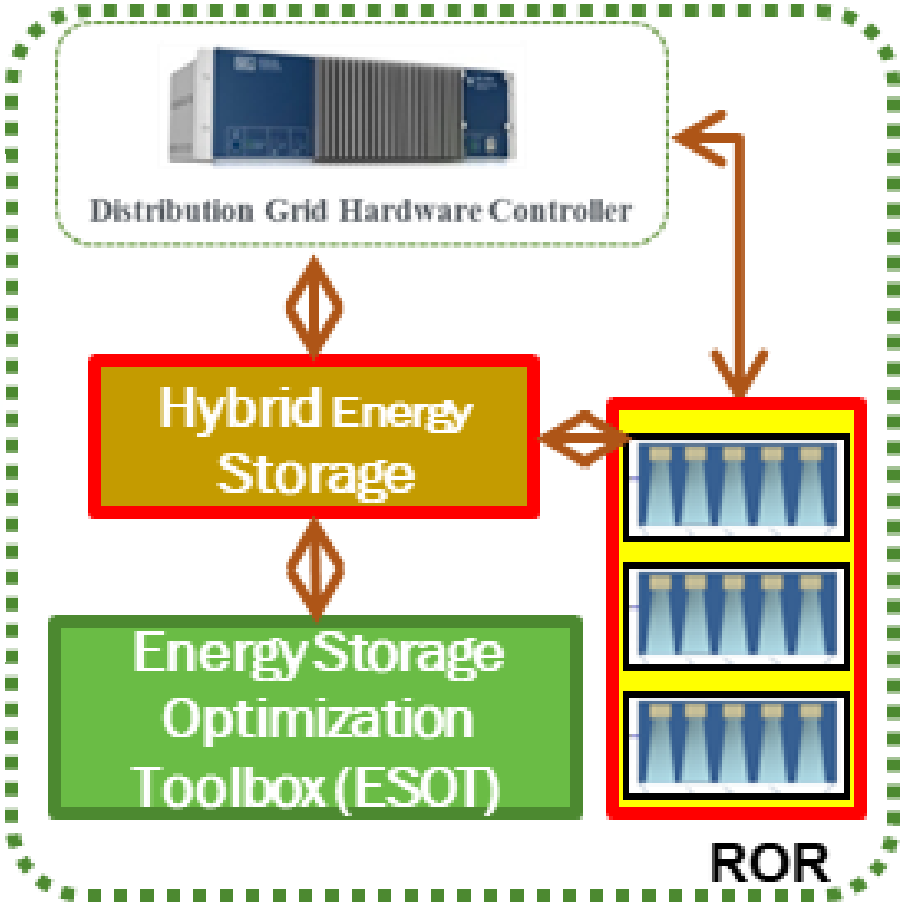
New Approaches to Designing and Developing New Hydro

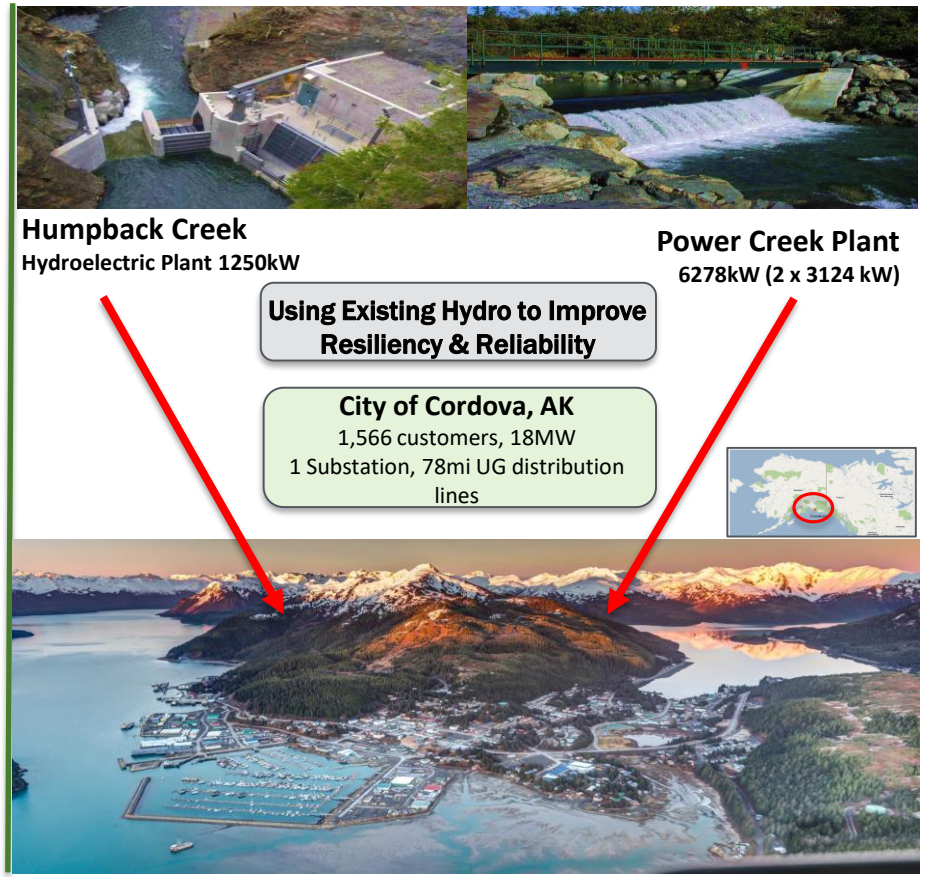


How WPTO's Hydropower Portfolio Aligns with EERE Priorities: Integration

Increasing flexibility of run-of-river (ROR) hydro plants through use of hybrid energy storage systems



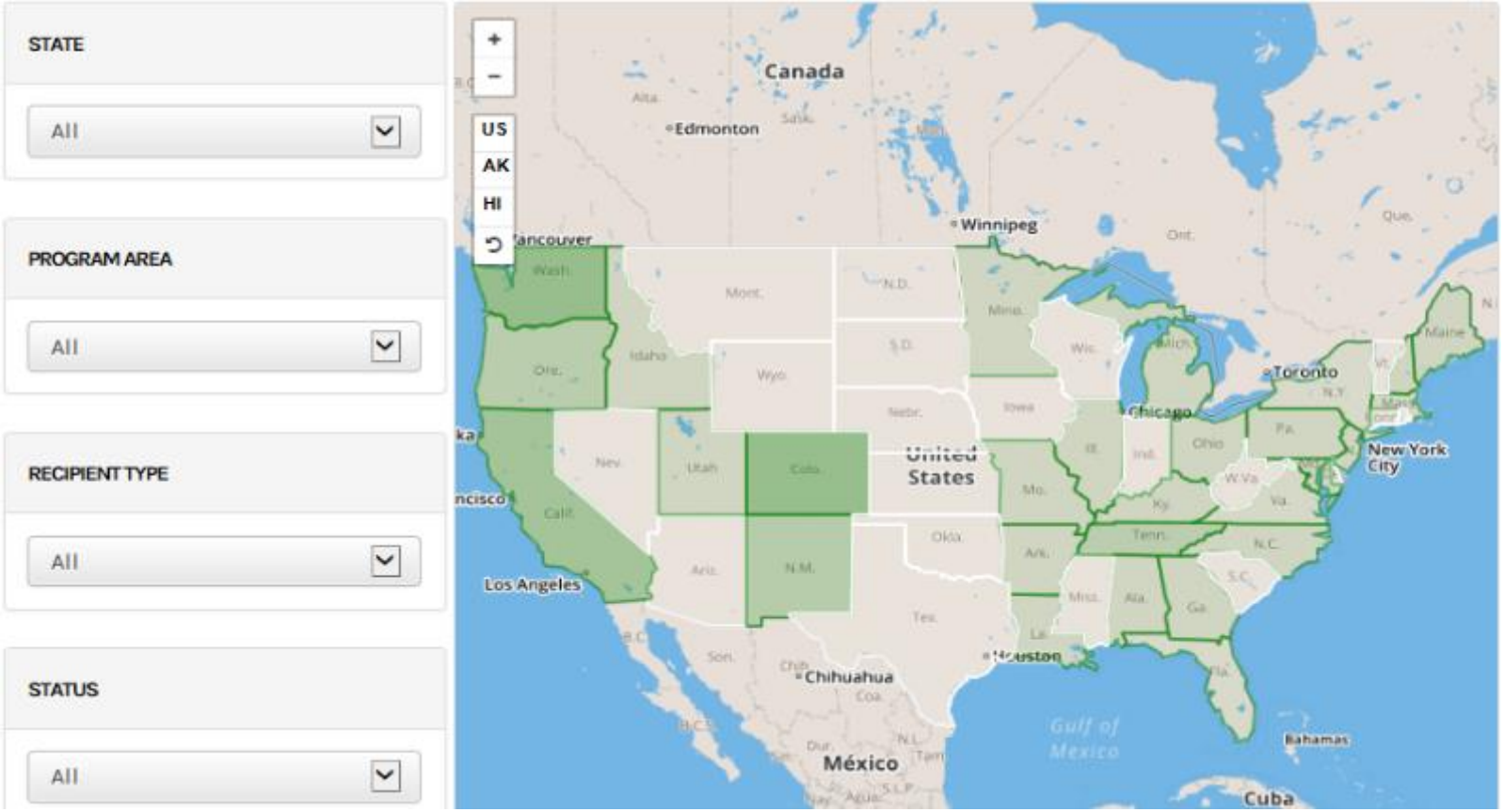




Pictured: RADIANCE project in Cordova, Alaska

Learn about more WPTO projects with our projects map

- Interactive map
- Provides information on WPTO's R&D portfolio
- Features multiple filters to isolate specific details on DOE hydropower and marine energy projects throughout the U.S.
- Contains historical information on completed projects with associated materials, research findings, and publication links



https://energy.gov/eere/water/water-power-technologies-office-projects-map

Guidelines

1. DOE/EERE overview
2. PSH overview
3. Industry challenges; operational changes/costs/cap costs and permitting
4. Danny's priorities
5. Example projects for each priority
6. How to partner? Priming questions
7. Upcoming items for release

Ways to work with WPTO & stay in the know

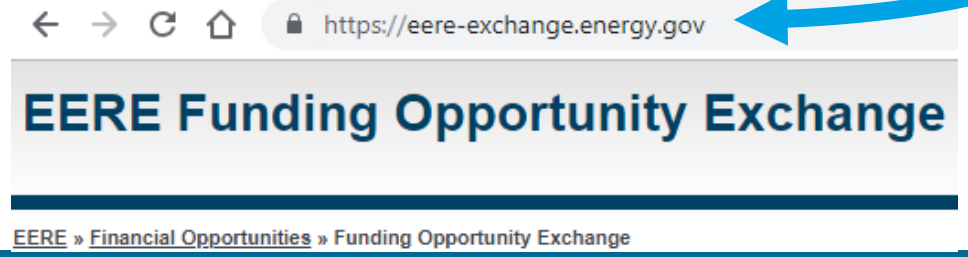
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

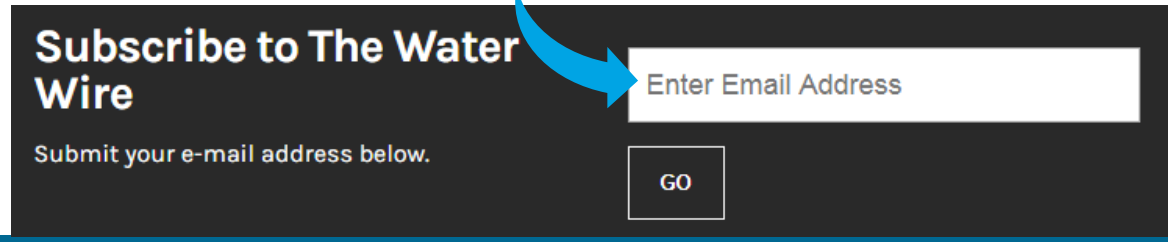
- **Competitive funding opportunities** through which organizations can apply for financial support. These projects, established through cooperative agreements, generally require some level of cost-share from the awardee.
- Innovative funding mechanisms such as **prizes and challenges** are also being used more frequently across DOE and other federal agencies.
- The **Small Business Innovations Research (SBIR) and Small Business Technology Transfer (STTR) Programs** are competitive programs targeted to small businesses.
- WPTO and other DOE offices often utilize a public **Requests for Information** (RFI) to solicit feedback from stakeholders on WPTO's programmatic strategy and industry's research and development needs.
- DOE's **National Laboratories** have research centers that can help water power researchers and manufacturers (there are a number of different options for working with Labs).

Most of these opportunities are publicly posted on **EERE Exchange** *(SBIR and STTR can be found on **https://science.energy.gov**).*

You can **reach out to WPTO** to ask a question, offer feedback, or request a meeting by writing to WaterPowerTechnologiesOffice@EE.DOE.GOV

Want **periodic updates** on water power funding opportunities, events, and publications?





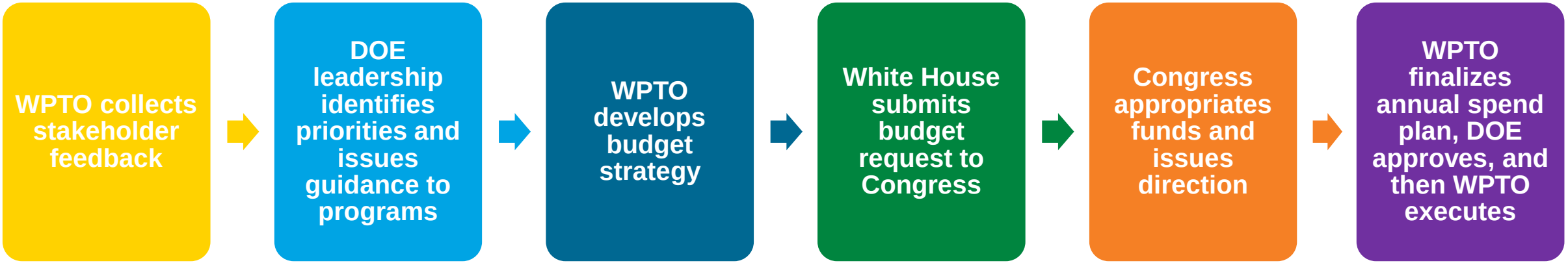
WPTO budget planning

Federal fiscal years (FY) run October – September. At any time, WPTO is working on budgets for three FYs:

- **Executing the current fiscal year** (e.g. implementing the budget appropriated by Congress for the current FY)
- **Formulating or developing for the next fiscal year** (e.g. justifying the President's budget request for the next FY by outlining how WPTO would use requested funds)
- **Planning for the fiscal year after next** (e.g. outlining funding needs/priorities for the FY after next)

WPTO is currently **executing** FY19, **formulating** FY20, and **planning** for FY21.

The simplified flow diagram below typically takes an entire year in practice.



Hydropower Program Vision and Mission

***Vision**:*

*A U.S. hydropower and pumped storage industry that is fully utilized to **support grid reliability** and the integration of other energy resources; capitalizes on new, low-impact opportunities for growth; **maintains and optimizes existing assets**; and continues to improve the **environmental sustainability** of hydropower systems .*

Mission:

*Conduct early-stage R&D and applied science to further the development of **transformative, cost-effective, reliable and environmentally-sustainable hydropower and pumped storage technologies**; better understand and capitalize upon opportunities for hydropower and pumped storage to **support a rapidly evolving grid**; and support the use of hydro to **improve U.S. energy-water infrastructure and water security**.*

WPTO Strategic Approaches

DOE Hydropower Program Strategy

Hydropower Program's Strategic Approaches

Big-Data Access and Management

Environmental R&D and Hydrological Systems Science

Impact Hydro Growth	, Upgrades, and Security	Reliability, Resilience, and Storage

Big-Data Access and Management

Environmental R&D and Hydrologic Systems Science

Technology R&D for Low-Impact Hydropower

Modernization, Upgrades and Security

Grid Reliability, Resilience, and Storage

MORE COST-EFFECTIVE HYDRO & MORE FLEXIBLE / VALUABLE HYDRO AND PUMPED STORAGE