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HydroWIRES

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HydroWIRES Initiative Overview: A New Role for Hydropower

Hydro Power Summit
Trondheim, Norway
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(https://energy.gov/hydrowires)

Outline

- Motivation and Background: Changing roles for hydropower in a changing power system
- DOE-WPTO's HydroWIRES research initiative
- Examples of HydroWIRES projects you'll hear about today
- Forthcoming reports and next steps

Hydropower in the U.S.

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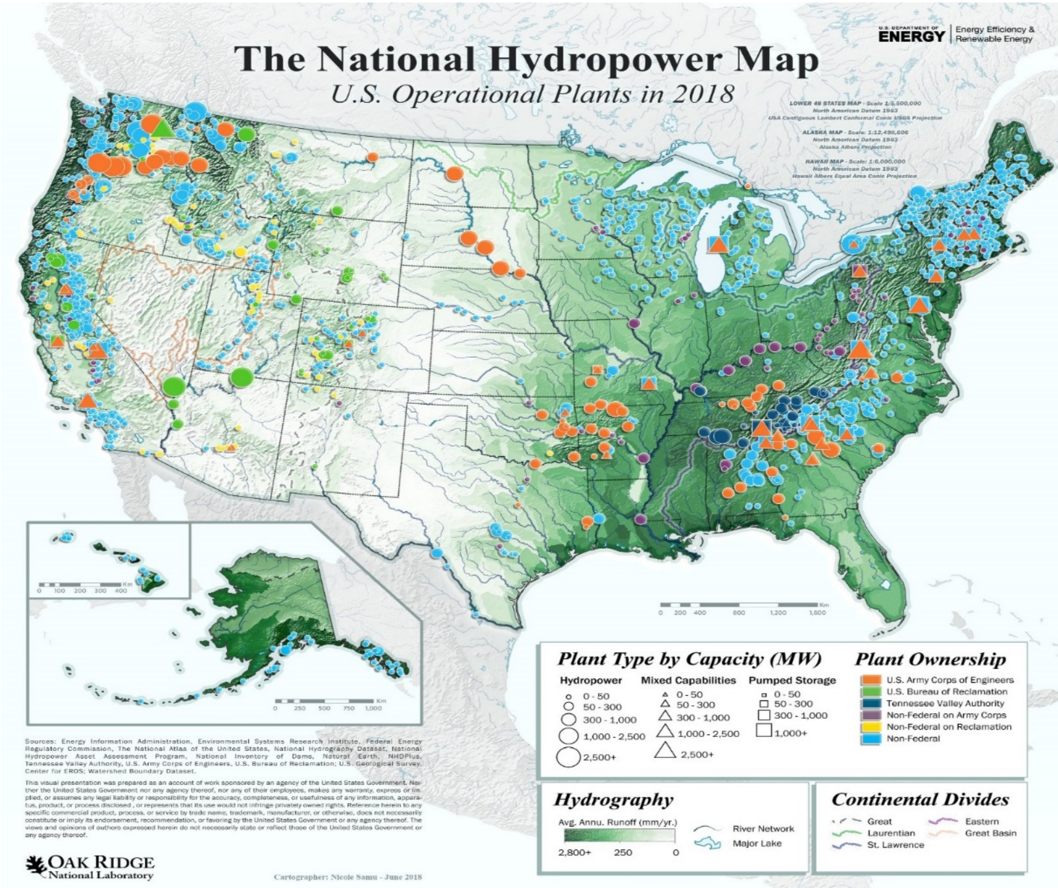

HYDROPOWER HIGHLIGHTS

- **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

Pumped storage hydropower (PSH)

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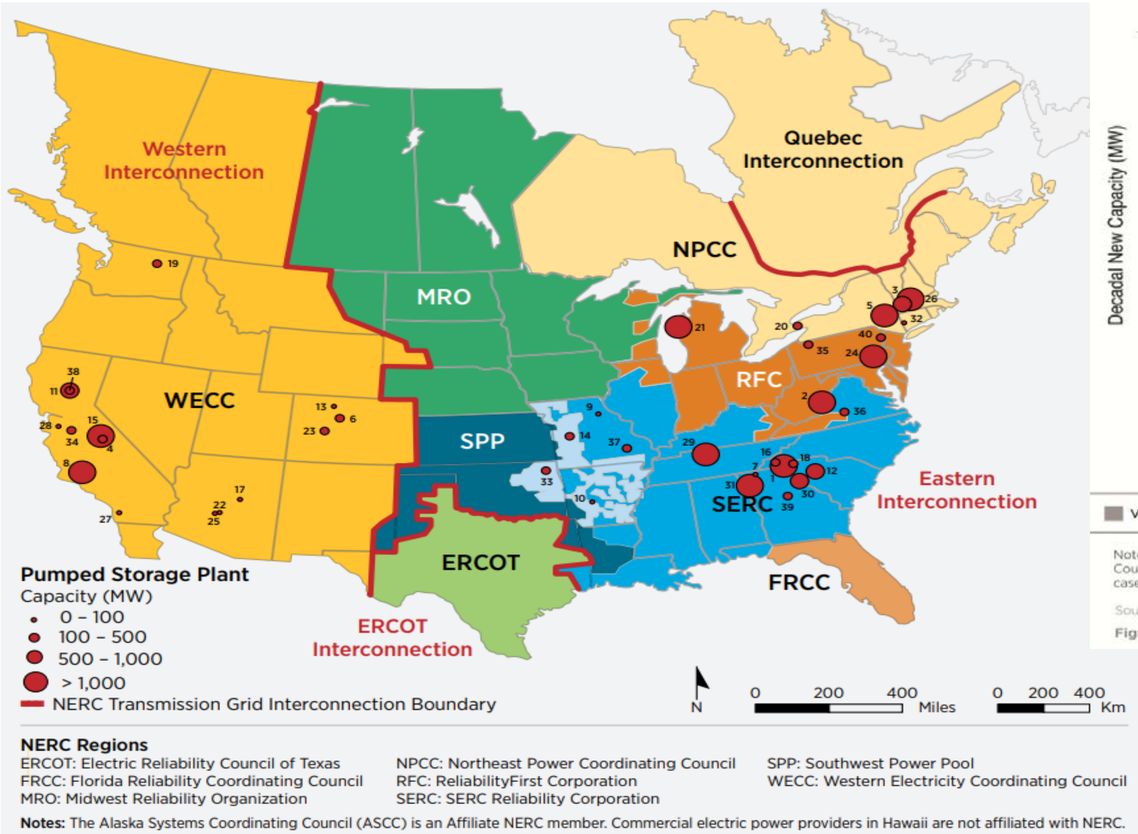
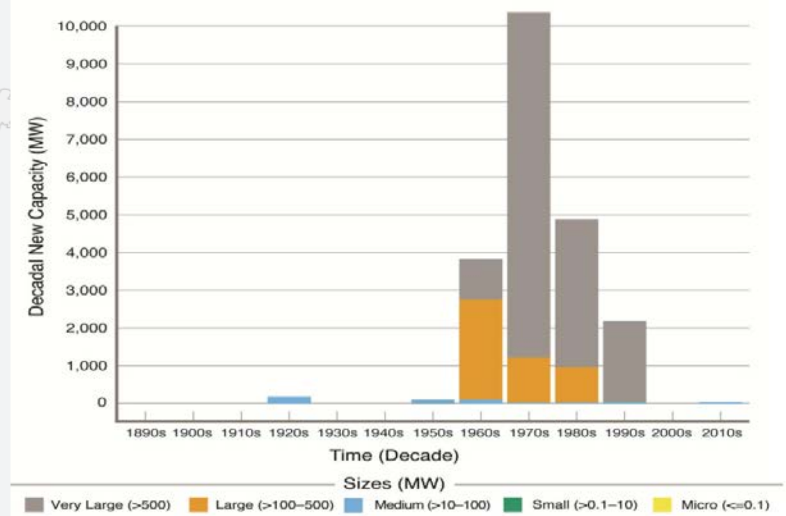


Source: Argonne National Laboratory

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



Note: This figure displays the initial year of operation for each project except in two cases (Hiwassee and Grand Coulee) in which no pumped storage units were installed when they first became operational. In those two cases, the capacity was assigned to the decade in which the pumped storage units were added.

Source: NHAAP

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

Hydropower and PSH are Changing Rapidly

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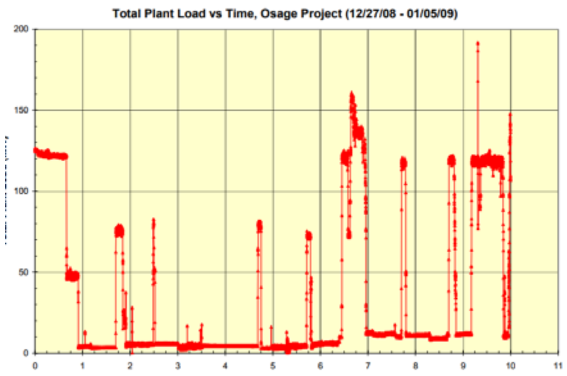
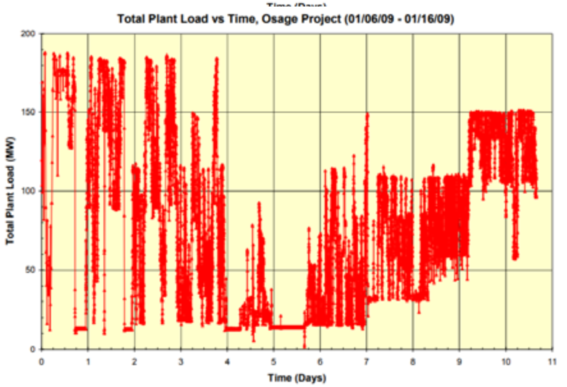
Traditional Hydro: from steady or predictable patterns to fast and frequent ramping



Weekly generation: (Osage Power Plant, MO)

Before participation in ancillary services market



After participation in ancillary services market

Pumped Storage: from day/night arbitrage to fast response

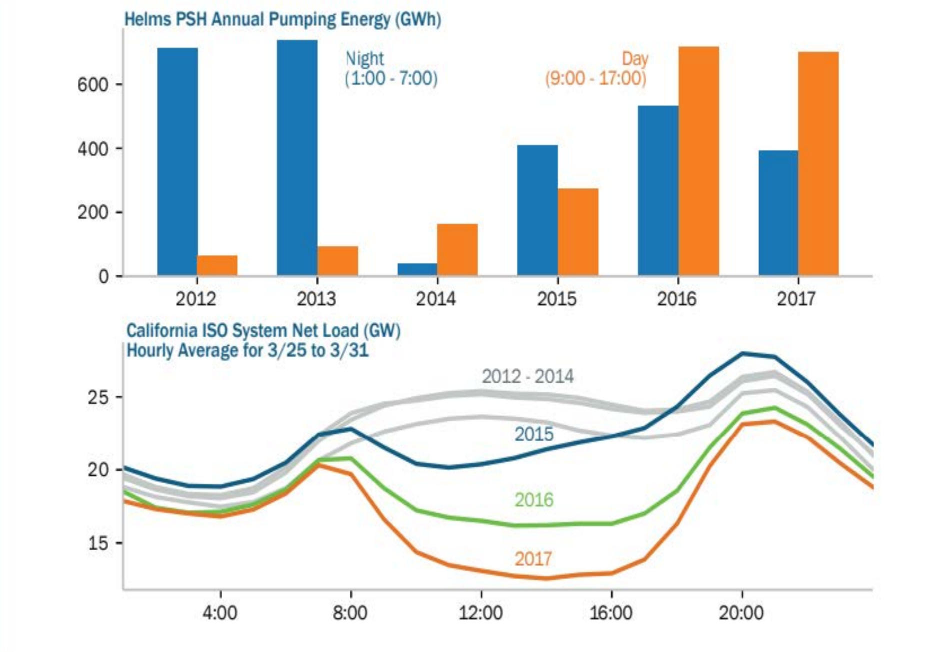
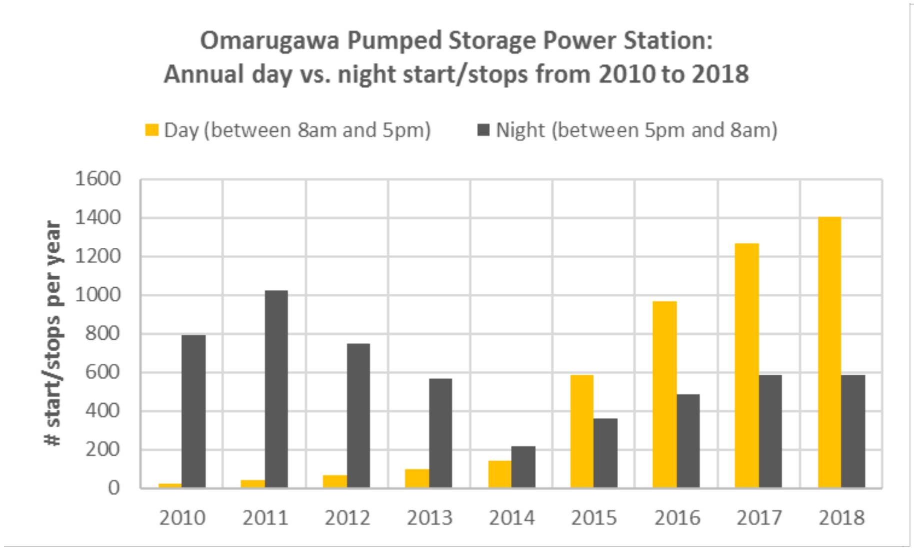
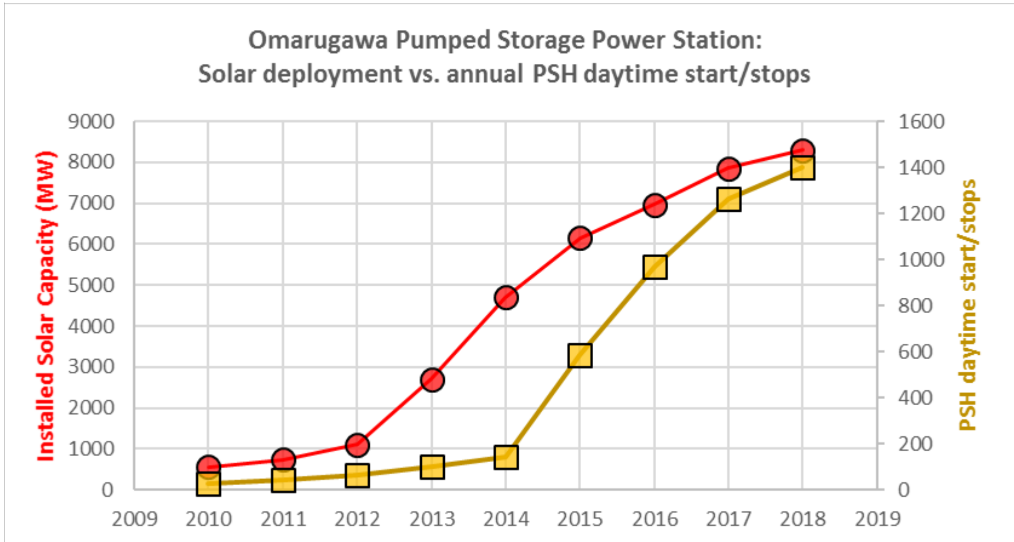


Figure 34. Annual pumping energy consumption by Helms PSH versus CAISO net load in the last week of March (2012-2017)

Changing PSH operations worldwide





- The Omarugawa PSH plant in Kyushu, Japan now averages ~4 start-stops per day, increasing in close correlation with installed solar PV capacity
- Other countries are experiencing similar changes, suggesting opportunities for sharing knowledge

Pumped Storage Hydropower (PSH) can provide essentially all grid services

- Large (>100 MW), long-duration storage
- Historically built for daily swings in load and as a companion to large thermo-electric generators
- Can provide nearly all possible grid services at low levelized cost
- Not all of these services are compensated in organized markets, but all have value in some situations
- Accurate valuation of these services (for PSH as well as hydropower and other resources) is a fundamental challenge

The US conventional hydropower fleet can also provide significant flexibility

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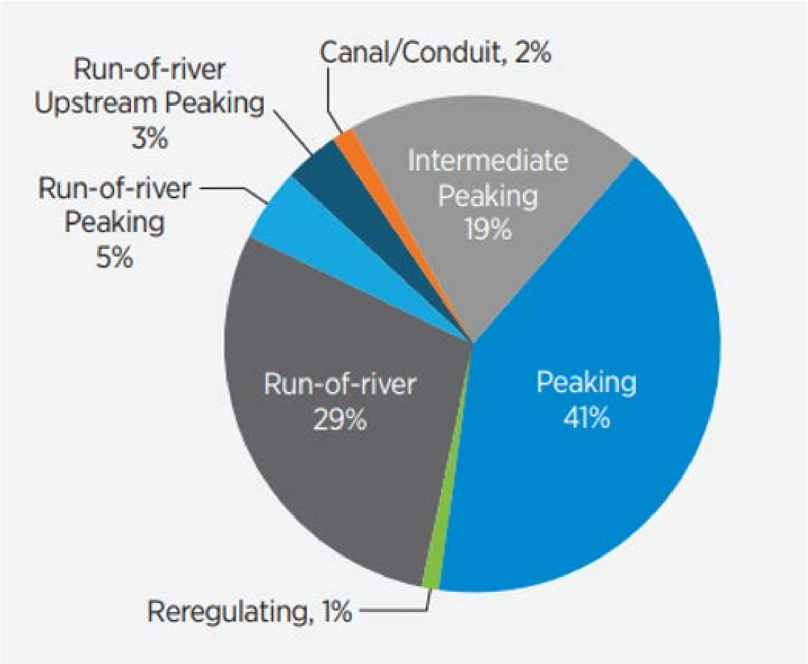
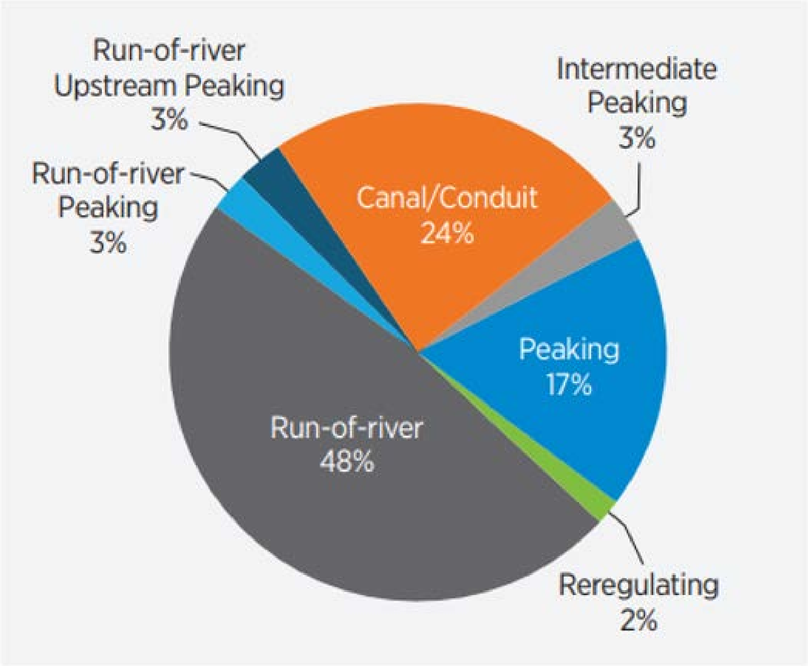
- About 70% of hydropower capacity has capabilities for flexible operation
- But operations vary by plant; flexibility is mostly concentrated in larger projects



Source: National Hydropower Asset Assessment Program FY15 Plant Database [15]

Figure 2-9. Distribution of operating modes for hydropower facilities, by capacity



Source: National Hydropower Asset Assessment Program FY15 Plant Database [15]

Figure 2-8. Distribution of operating modes for hydropower facilities, by number of projects

Hydropower provides load following in all ISO/RTO markets

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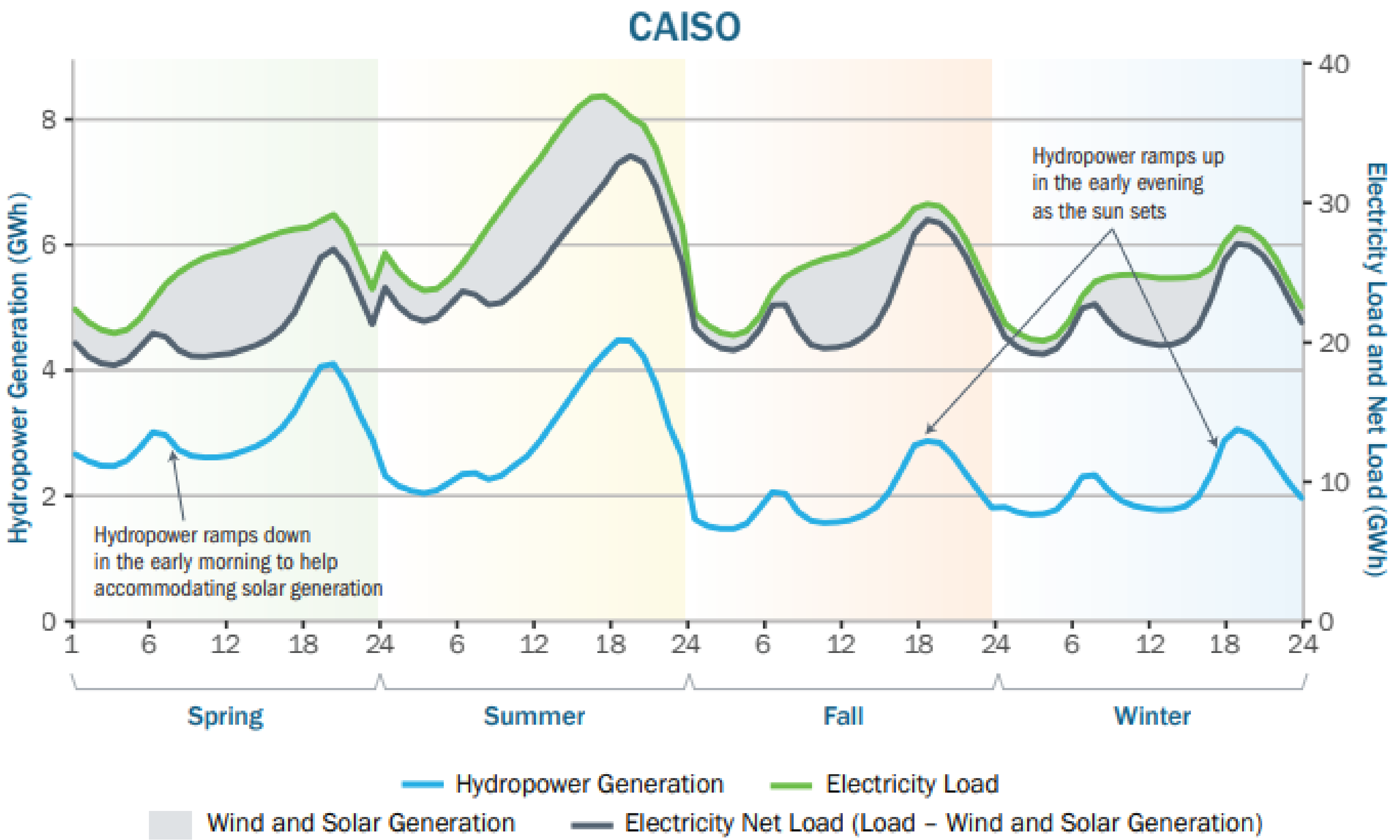

Average hourly hydropower and PSH generation, electricity load, and electricity net load by season in CAISO (2014-2017)

Oak Ridge National Laboratory, 2017 Hydropower Market Report, 2017
https://www.energy.gov/sites/prod/files/2018/04/f51/Hydropower%20Market%20Report.pdf

Challenges in representing hydropower in power system models

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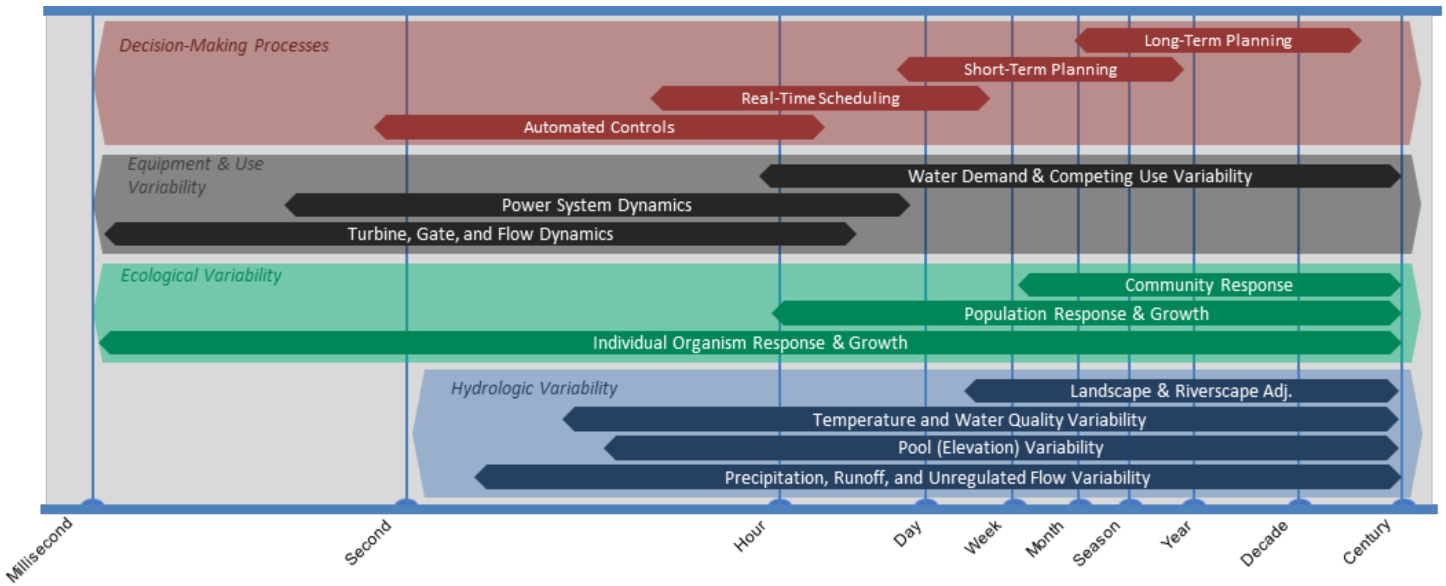
- Spatial, temporal, unit, and computational complexity can create a disconnect between water management and grid models
- Hydropower representation in current models does not capture complexity, diversity, and changed operational paradigm of the fleet



Comparison of Hydropower Operations Time Scales and Power System Time Scales (courtesy of ORNL)

Workshop: Hydropower in Production Cost Models

Salt Lake City, March 2019

Consensus on the need for:

- Improvements in the organization of publicly available data;
- Improved approaches for validation and characterizing uncertainty;
- New modeling frameworks that can address multiple competing objectives, and;
- Increased collaboration among the hydropower and power grid modeling communities

More flexible operations have implications for equipment design and O&M

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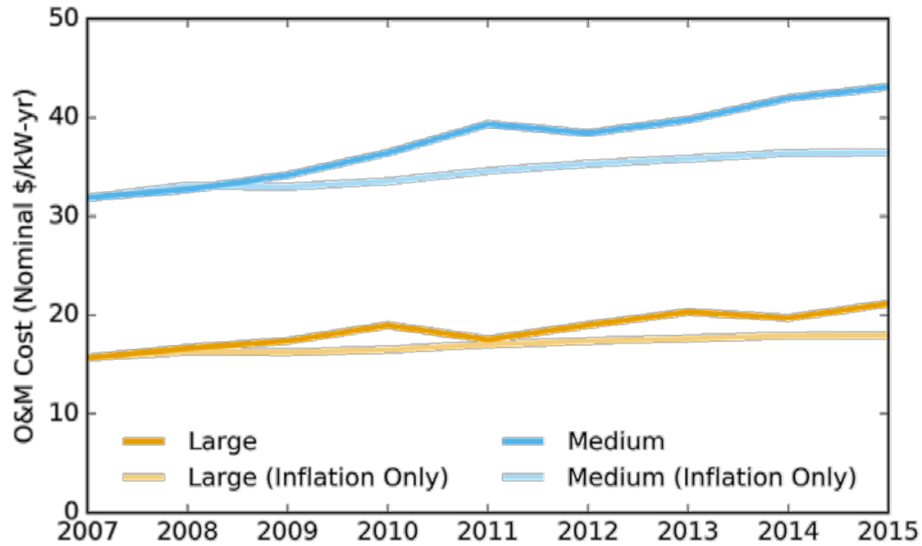
Strain gauge amplitude spectrum from tests at Vattenfall's Stornorrfors hydro plant [2016]

Since 2007, growth in O&M cost has outstripped inflation.



- More flexible operations required by the changing power system may be challenging for turbines designed for baseload operation
- Major OEMs have already seen changes in performance specifications that customers ask for

The Challenge: Untapped Opportunities for Hydropower and PSH to Support a Rapidly Evolving Grid

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- As the electricity system is changing rapidly, there is limited understanding of which services will be needed, as well as limited ability to accurately value those services.
- Hydropower and PSH capabilities are bounded by the interaction of machines, water, and institutions, and some of these bounds may result from legacy decisions that did not consider evolving grid needs.
- There are gaps in information regarding how to optimize hydropower and PSH operations and planning in coordination with other resources.
- Current hydropower and PSH technology may not be designed for flexible operation.

The Opportunity: New, More Valuable Roles for Hydropower and PSH?

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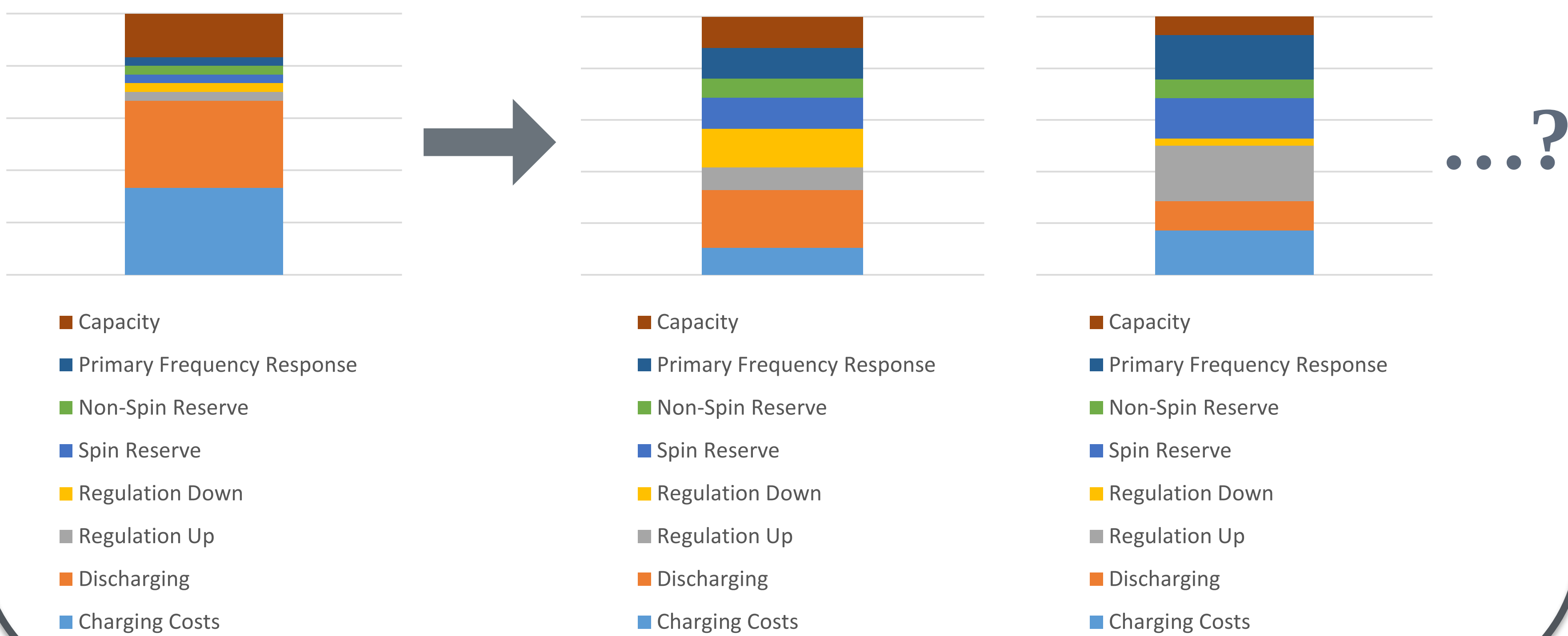
Qualitative Example PSH Plant Operating *Today*

Potential Future Operations Scenario #1

Potential Future Operations Scenario #2



HydroWIRES Initiative

- Given the rapid changes occurring in the U.S. electric system—and associated challenges and opportunities—WPTO has launched a new hydropower-grid research initiative titled **HydroWIRES: Water Innovation for a Resilient Electricity System.**
- The mission of HydroWIRES is <u>to understand, enable, and improve hydropower's contributions to reliability, resilience, and integration</u> in a rapidly evolving electricity system.
- HydroWIRES includes ~$15M annual funding for modeling, analysis, technical assistance, and technology R&D to inform decisionmakers and improve their capabilities.

https://energy.gov/HydroWIRES

Organization of Research Areas

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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?"

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?"

HydroWIRES Projects in Today's Sessions

Hydropower Value Study

PSH Valuation

Session 1

B1) Dynamic Hydro Classification for PCMs

B2) Water Model/PCM Integration

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What can hydropower do?"

A) Environmental-Flexibility Tradeoffs

Session 3

Operations and Planning

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FAST Prize

Geomechanical Storage

Ternary PSH

GLIDES PSH

Shell Hydro Battery PSH

No-Powerhouse PSH

Session 2

HydroWIRES Initiative Organization

- To support HydroWIRES research efforts and sharing of ideas, we have convened a collaborative group of national lab researchers to support the research areas.

- These lab researchers provide leadership and strategic direction to inform the research portfolio and build connections within WPTO and to broader DOE efforts.

Argonne NATIONAL LABORATORY

Lemont, Illinois

INL Idaho National Laboratory

Idaho Falls, Idaho

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Golden, Colorado

OAK RIDGE National Laboratory

Oak Ridge, Tennessee

Pacific Northwest NATIONAL LABORATORY

Richland, Washington

Stakeholder Engagement, Outreach, and Dissemination

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- RFI to solicit feedback on priorities and direction, issued February 2018
- HydroWIRES announced by Assistant Secretary Simmons in April 2019
- Engagement with hydropower and broader power system communities
  - Waterpower Week
  - HydroVision International
  - NHA Regional Meetings
  - Northwest Hydropower Association
  - Energy Storage Integration Group
  - CEATI working groups
  - EPRI technical workshops
  - IHA World Hydropower Congress
  - IEA Hydropower Technical Collaboration Programme (Annex IX)

About 40 respondents to initial RFI

- New RFI on the HydroWIRES Research Roadmap to be released March 2020
- “Quick Wins” mechanism to enable flexibility to stakeholder needs
- Also planning targeted technical workshops with external experts

HydroWIRES Reports (more coming soon!)

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Published:

- Hydropower Plants as Black Start Resources
- Energy Storage Technology and Cost Characterization Report

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)
- Closed-loop pumped storage environmental effects (technical report)
- Hydropower-battery hybrids (technical report)
- NREL ternary pumped storage (technical report)
- Fast commissioning challenge baseline report (technical report)

- 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
  - The Value of Water
  - Power Systems vs. Hydropower Operational Timeframes
  - Hydropower Capabilities & Technology Gap + Cost Analysis
- …

https://energy.gov/HydroWIRES

HydroWIRES Partners and Awardees

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Internal Collaboration

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Pacific Northwest NATIONAL LABORATORY

OAK RIDGE National Laboratory

DOE Executive Board:

- GMI
- OE
- EERE-SPIA

GRID MODERNIZATION INITIATIVE U.S. Department of Energy

International Collaborators

iea

Hydro Tasmania

HydroCen NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

Awardees

nationalgrid

Quidnet Energy

STEVENS INSTITUTE of TECHNOLOGY THE INNOVATION UNIVERSITY

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Rye Development

RTI INTERNATIONAL

ABSAROKA ENERGY LLC

CADS WES

OBERMEYER HYDRO, INC. Ideas that hold water™

GE

MISSOURI S&T University of Science & Technology

University of California, Irvine

Shell

Thank you!

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Questions?

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HydroWIRES Research Areas

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

Research Area 1: Value under Evolving System Conditions

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Technical Objectives:

- **1.1 Grid Services Taxonomy.** Enable unified understanding of grid services and system benefits through consistent taxonomies.
- **1.2 Value Drivers.** Understand value drivers for hydropower in today's power system and investigate how this value might evolve under different future system scenarios.
- **1.3 Valuation Methodologies.** Develop rigorous, widely applicable methodologies that accurately value hydropower assets.

Projects (proposed, subject to change):

PAST →	PRESENT →	FUTURE
PSH valuation studies	Taxonomy of services	Define or project potential new services
Hydropower Value Study	Analyze prices and market dynamics	Analysis of market design initiatives
PSH valuation guidebook	Extension of PSH guidebook and technical assistance	ISO/RTO engagement
		Evaluation of emerging PPA structures

Research Area 2: Capabilities and Constraints

Technical Objectives:

- **2.1 Flexibility Framework.** Quantify the different types of flexibility available in hydropower plants as a first step to assessing the total flexibility available in the hydropower fleet.
- **2.2 Flexibility Tradeoffs.** Understand the tradeoffs between operating flexibly and meeting other objectives related to environmental performance, revenue opportunities, and machine wear and tear.
- **2.3 Hydrologic Forecasting.** Quantify and improve the accuracy and resolution of inflow forecasting tools to enable more flexible operation.
- **2.4 Modeling Representation.** Improve the representation of hydropower in power system models to more accurately capture its unique capabilities.

Projects (proposed, subject to change):

PAST →	PRESENT →	FUTURE
Operational flexibility that hydropower can provide	Hydropower Fleet Intelligence	Fleet-wide assessment of flexibility
Environmental-flexibility tradeoffs	Targeted support for inflow forecasting enhancements	Hydropower Fleet Intelligence
Hydropower Fleet Intelligence	Technical assistance for model enhancements	Targeted support for inflow forecasting enhancements
Power system value of improved inflow forecasting		Technical assistance for model enhancements
Workshop on power system models		
Representation in production cost models		
Representation in capacity expansion models		

Research Area 3: Operations and Planning

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Technical Objectives:

- **3.1 System Reliability and Resilience Contributions.** Quantify hydropower plant- and fleet-level contributions to system reliability and resilience requirements
- **3.2 Comparison with Other Resources.** Understand hydropower's unique benefits and costs—in comparison with other resources—to best inform planning decisions.
- **3.3 Operations Optimization.** Develop operational strategies and associated tools that enable hydropower to better optimize its operations to provide grid services.
- **3.4 System Effects of Operations.** Quantify effects of hydropower plant- and fleet-level operations on water availability, emissions, environment, and other system properties.

Projects (proposed, subject to change):

PAST → PRESENT → FUTURE

PAST
- Framework for quantifying hydropower and PSH
- Comparison of costs and performance of energy storage technologies
- Industry and academic-led projects on value of PSH
- Industry and academic-led projects on operational strategies or more flexible hydropower operations

PRESENT
- Representation and case studies in DOE's North American Energy Resilience Model
- Comparison with different storage technologies
- Online comparison tool
- Assistance to utilities, regulators, and system operators
- Technical assistance to owners and operators

FUTURE
- Technical assistance to end-users
- Assistance to utilities, regulators, and system operators
- Technical assistance to owners and operators
- Study of system-level changes associated with more flexible hydropower operations

Research Area 4: Technology Innovation

Technical Objectives:

- **4.1 Technology Gaps.** Identify and map out technology innovations that enable hydropower plants to improve provision of grid services.
- **4.2 Unit Flexibility Enhancement.** Develop technology solutions that enable enhanced flexibility at the unit level.
- **4.3 Plant Flexibility Enhancement.** Develop technology solutions that enable enhanced flexibility at the plant or cascading system level.
- **4.4 New PSH Approaches.** Develop new technology concepts and approaches that overcome barriers associated with PSH deployment.

Projects (proposed, subject to change):

PAST →	PRESENT →	FUTURE
FAST Prize and baseline report	Analysis of hydropower and PSH innovation gaps	Analysis of hydropower and PSH innovation gaps
	Technical assistance to utilities and developers to investigate hybrid hydropower use cases	Technology enhancements to enable increased flexibility at the unit level
	Scoping study for PSH development as part of multi-use water projects	Technology R&D to enable increased plant flexibility

Thank you!

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Questions?

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