Water Power Technologies Office

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

Hydropower's Changing Role in the Grid

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Water Power Technologies Office

Hydropower

Upgrades for Existing Hydropower

Non-Powered Dams and Conduits

New Low-Impact Projects

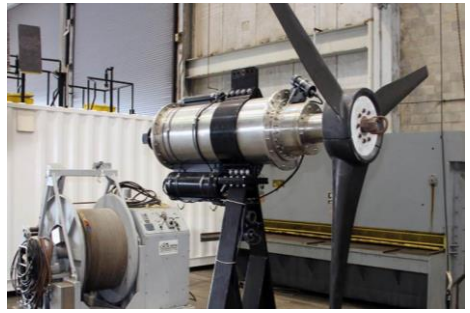
Pumped Storage

Marine Hydrokinetics

Wave

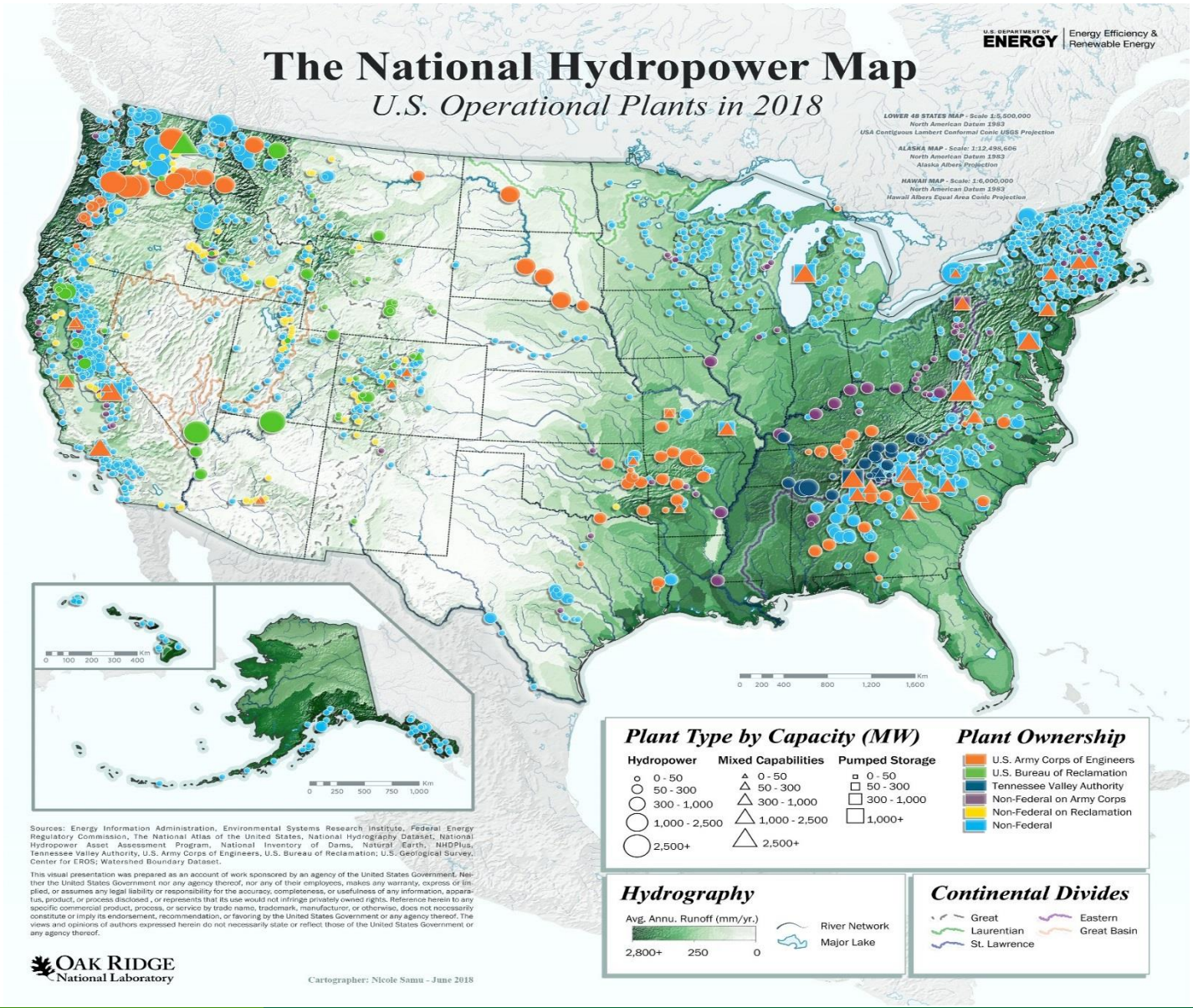
Tidal

River Current



Ocean Currents

U.S. Hydropower Overview

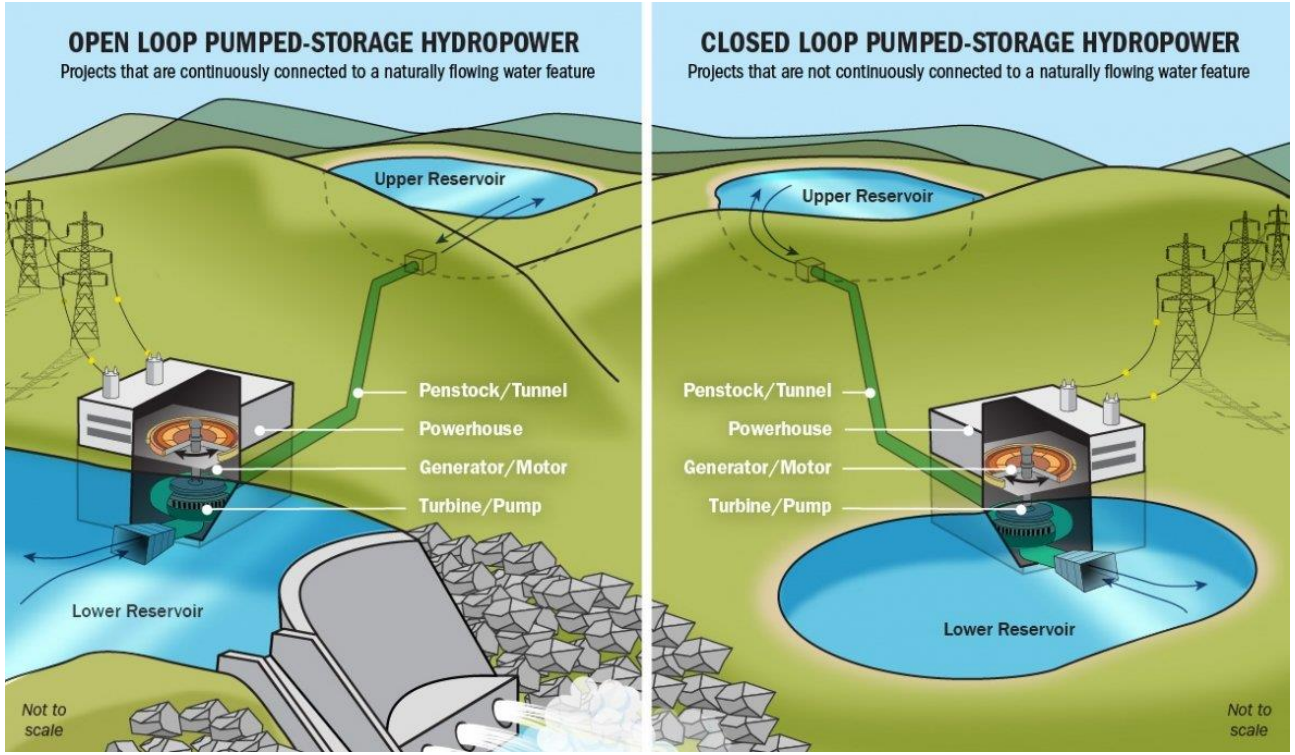


HYDROPOWER HIGHLIGHTS

- **80 GW** of hydro capacity– **7%** of U.S. power supply
- **22 GW** of pumped storage capacity – **97%** of U.S. utility-scale energy storage
- 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

Pumped Storage Hydropower Overview

- Pumped storage hydropower (PSH) is a **water battery**:
  - Two water reservoirs are configured at different elevations that can generate power (**discharge**) as water moves down through a turbine; and that draws power as it pumps water (**recharge**) to the upper reservoir.
- Projects may be:
  - **Open loop** – There is an ongoing hydrologic connection to a natural body of water
  - **Closed loop** – Reservoirs are not connected to an outside body of water
  - **Fixed speed** or **variable speed**
- New innovations radically re-imagining what PSH can look like and deliver

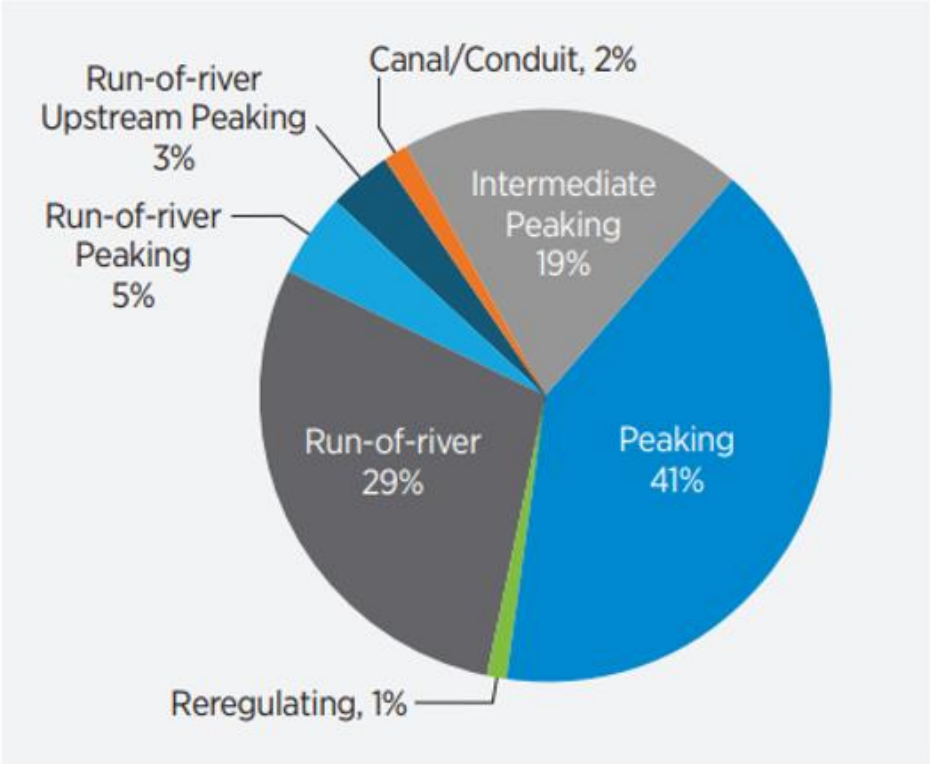


Conceptual Figure (Courtesy of John Frenzl, NREL)

Rocky Mountain, Oglethorpe Power and Georgia Power

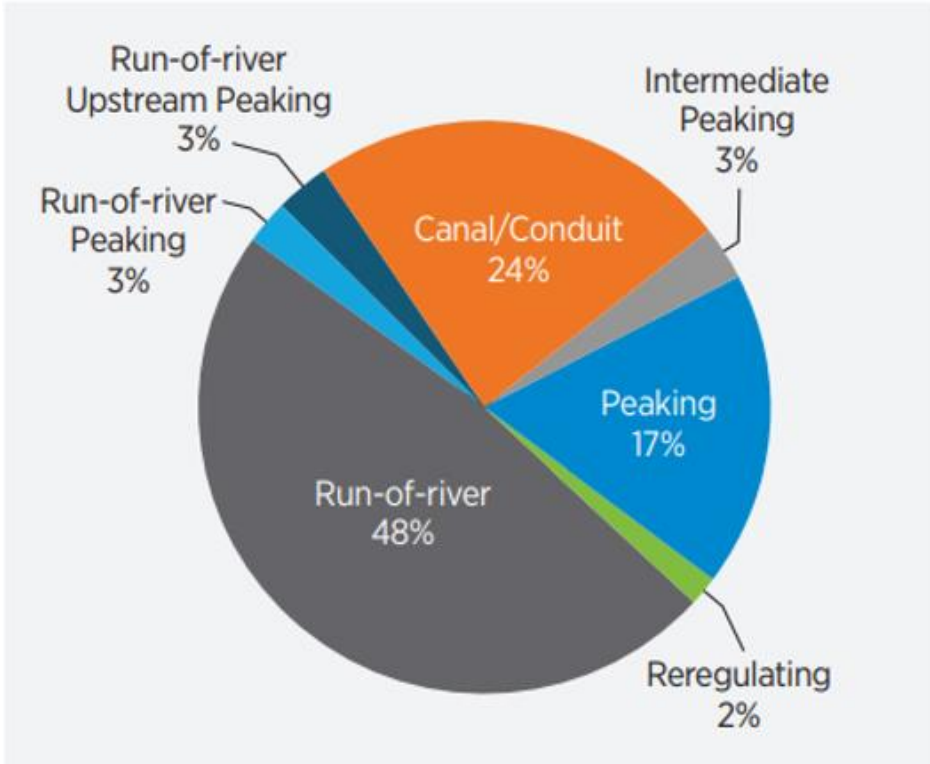
Hydro operations vary significantly, but can be key source of flexibility

Almost 70% of hydropower capacity provides flexibility to grid operators
But operations vary by plant; flexibility an be constrained and is mostly concentrated in larger projects



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

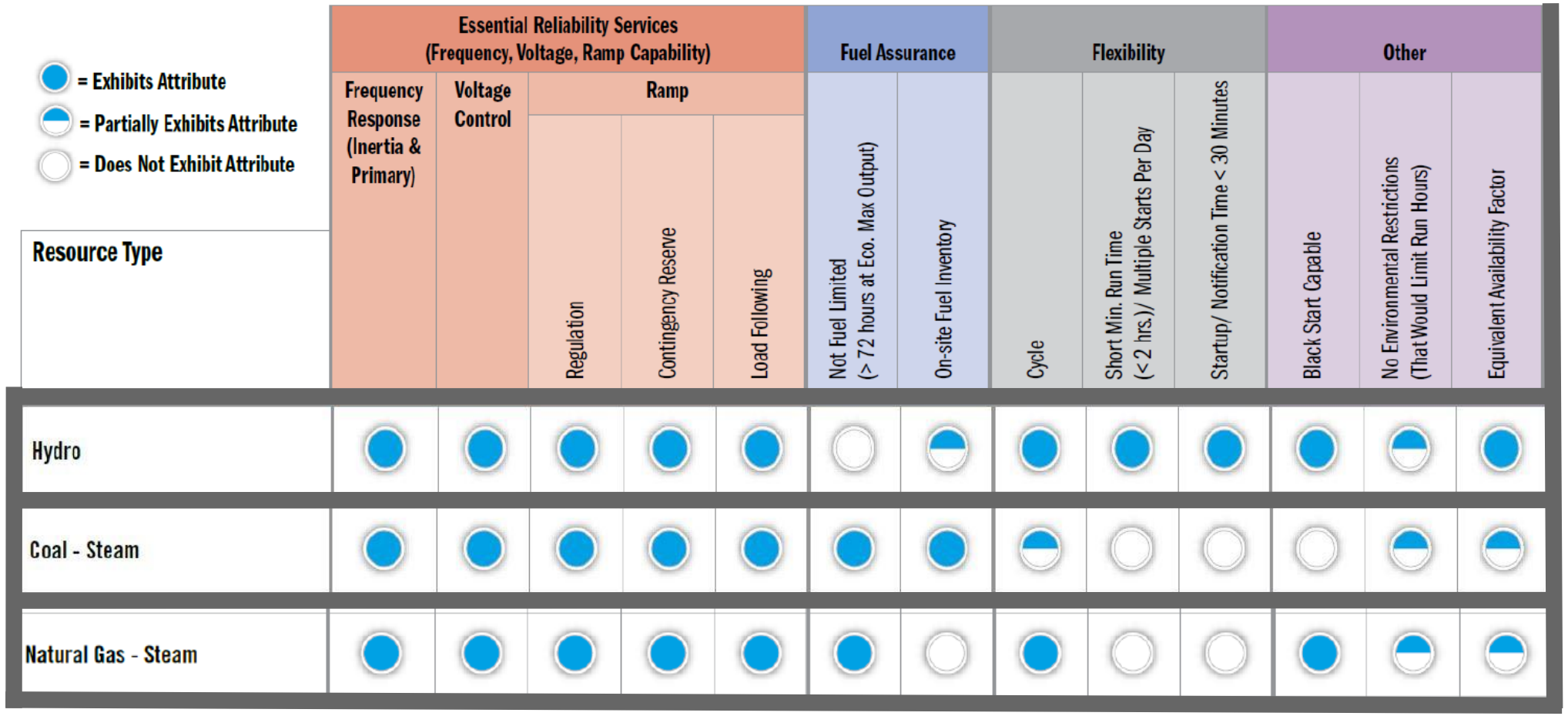
Figure 2-9. Distribution of operating modes for hydropower facilities, by capacity



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

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

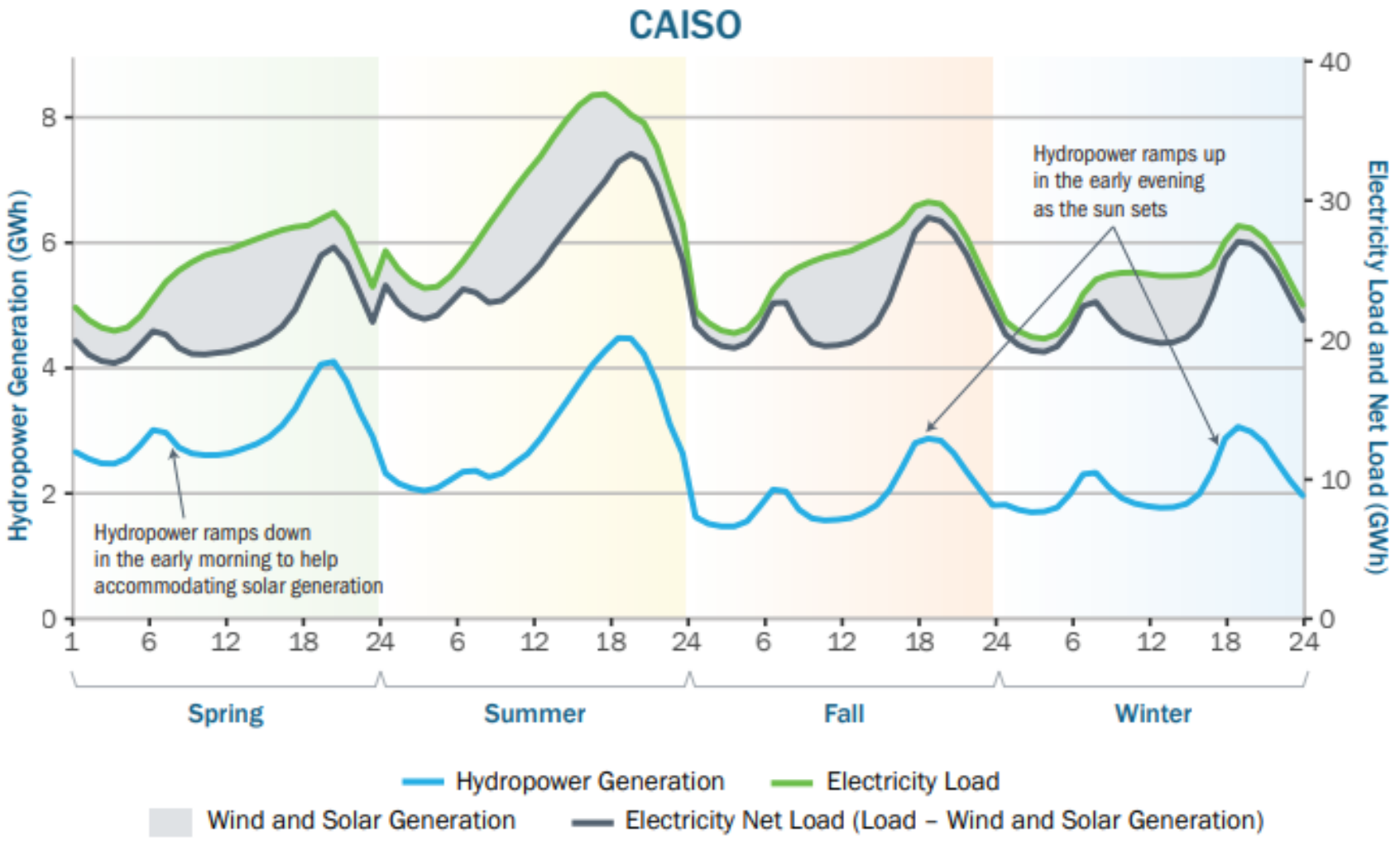
When hydropower is flexible, it is one of the most valuable assets on the grid



PJM, PJM's Evolving Resource Mix and System Reliability, 2017

https://www.pjm.com/~/media/library/reports-notices/special-reports/20170330-pjms-evolving-resource-mix-and-system-reliability.ashx

Hydropower provides load following in all ISO/RTO Markets



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

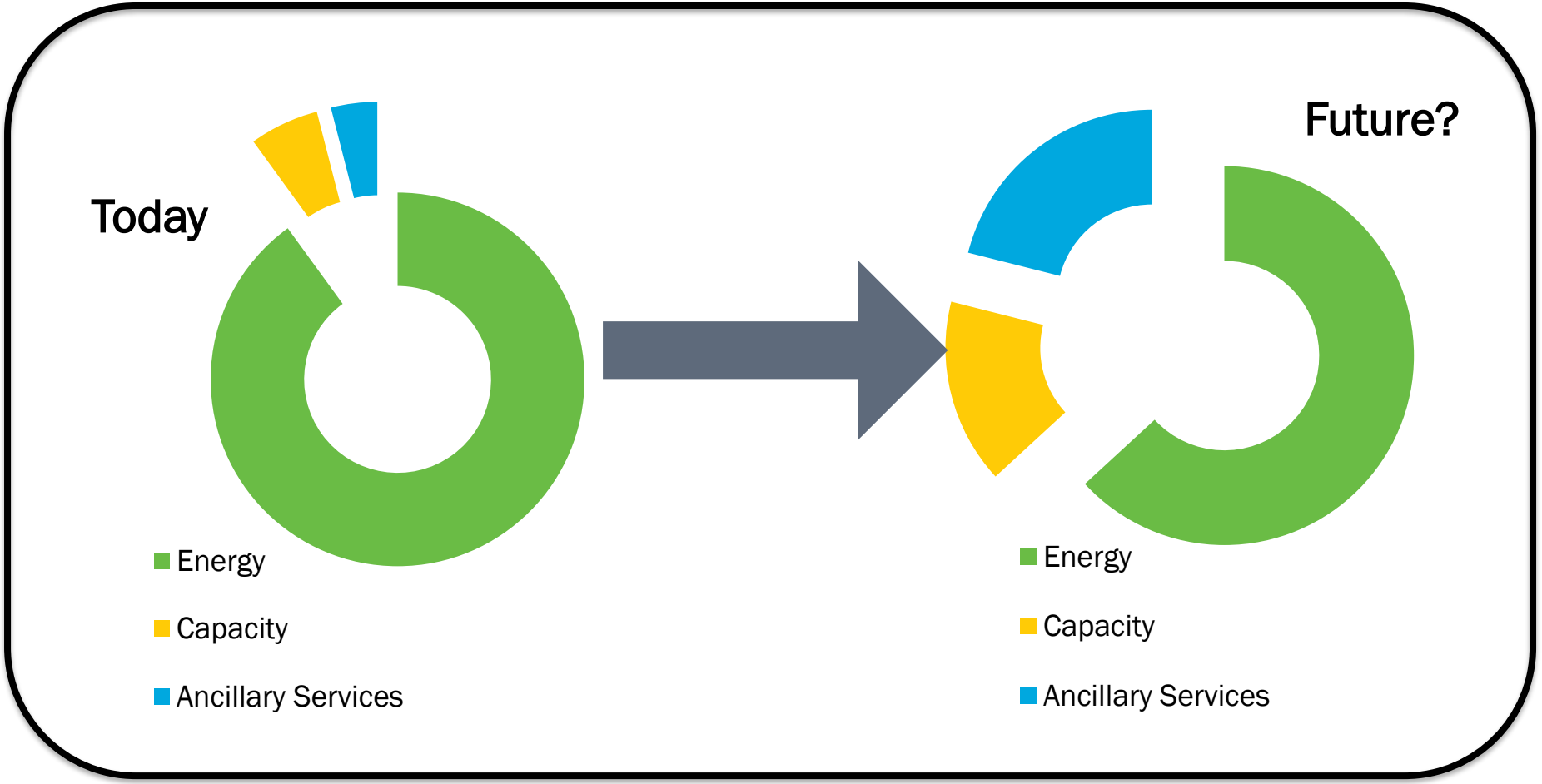
Oak Ridge National Laboratory, 2017 Hydropower Market Report, 2017
https://www.energy.gov/sites/prod/files/2018/04/f51/Hydropower%20Market%20Report.pdf

But operational value can be far broader than arbitrage

	PSH Contribution
1	Inertial response
2	Governor response, frequency response, or primary frequency control
3	Frequency regulation, regulation reserve, or secondary frequency control
4	Flexibility reserve
5	Contingency spinning reserve
6	Contingency non-spinning reserve
7	Replacement/Supplemental reserve
8	Load following
9	Load leveling/Energy arbitrage
10	Generating capacity
11	Reduced environmental emissions
12	Integration of variable energy resources (VERs)
13	Reduced cycling and ramping of thermal units
14	Other portfolio effects
15	Reduced transmission congestion
16	Transmission deferral
17	Voltage support
18	Improved dynamic stability
19	Black-start capability
20	Energy security

- Pumped storage hydropower characteristics:
  - Large (>100 MW), long duration
  - 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
- 43 PSH plants with a total capacity of 21.6 GW provide 95% of utility-scale electrical energy storage in the United States

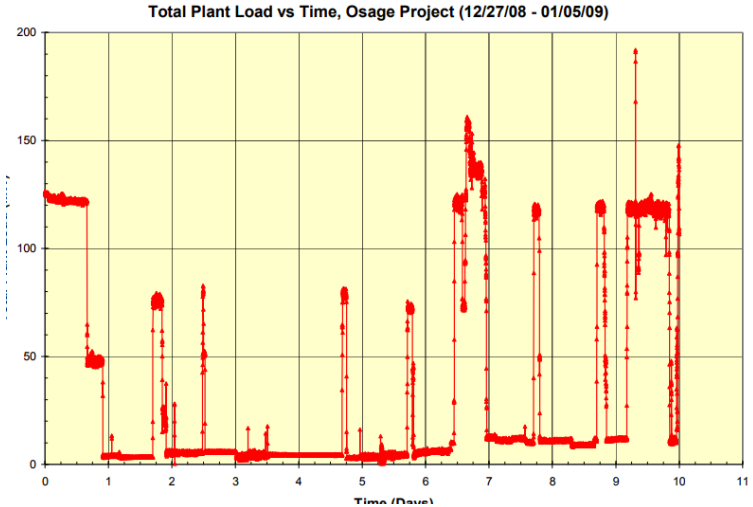
Hydropower's Changing Role: What will the future of hydro look like?



Source: Electric Power Research Institute (EPRI), Capacity and Energy in the Integrated Grid, 2015.
https://www.epri.com/#/pages/product/000000003002006692/

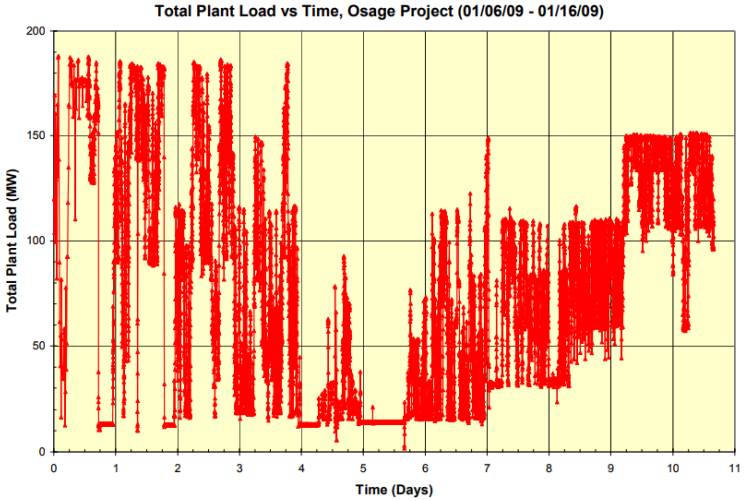
Flexible generation means new operational demands

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



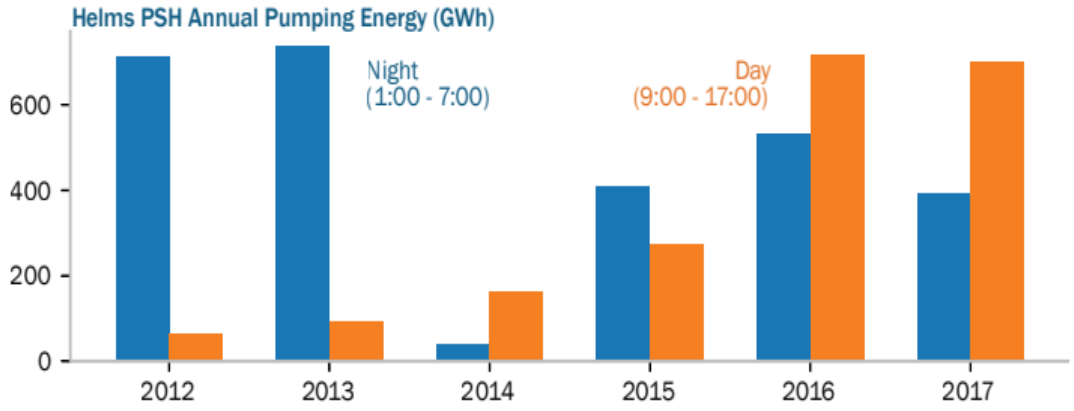
Weekly generation:
(Osage Power Plant, MO)

Before



Now

Pumped Storage: from day/night arbitrage to fast response



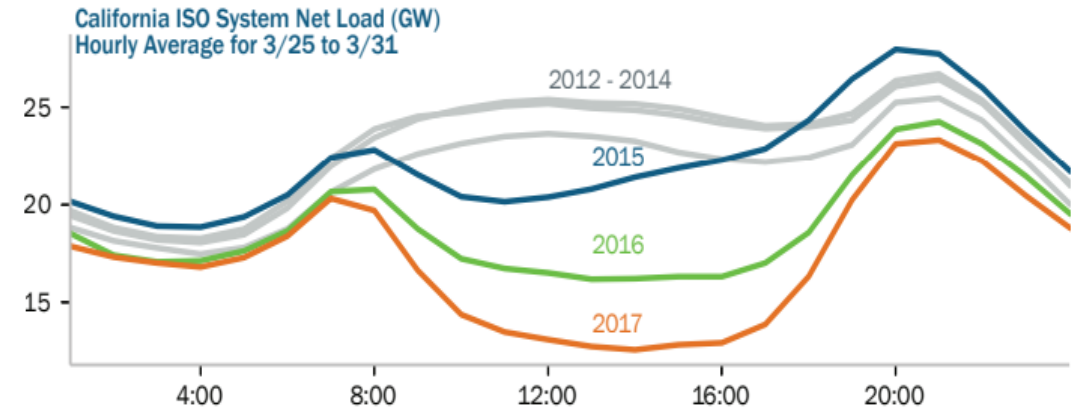
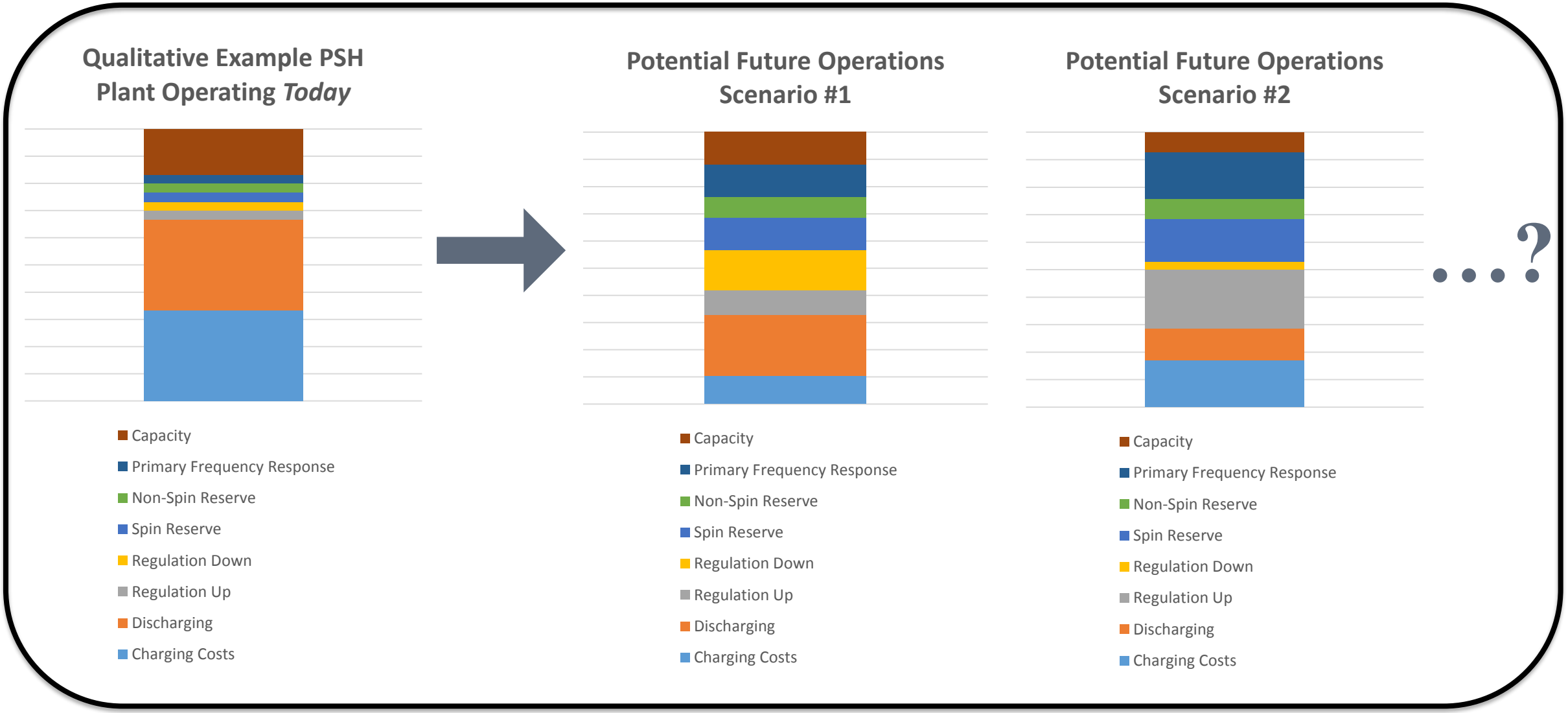
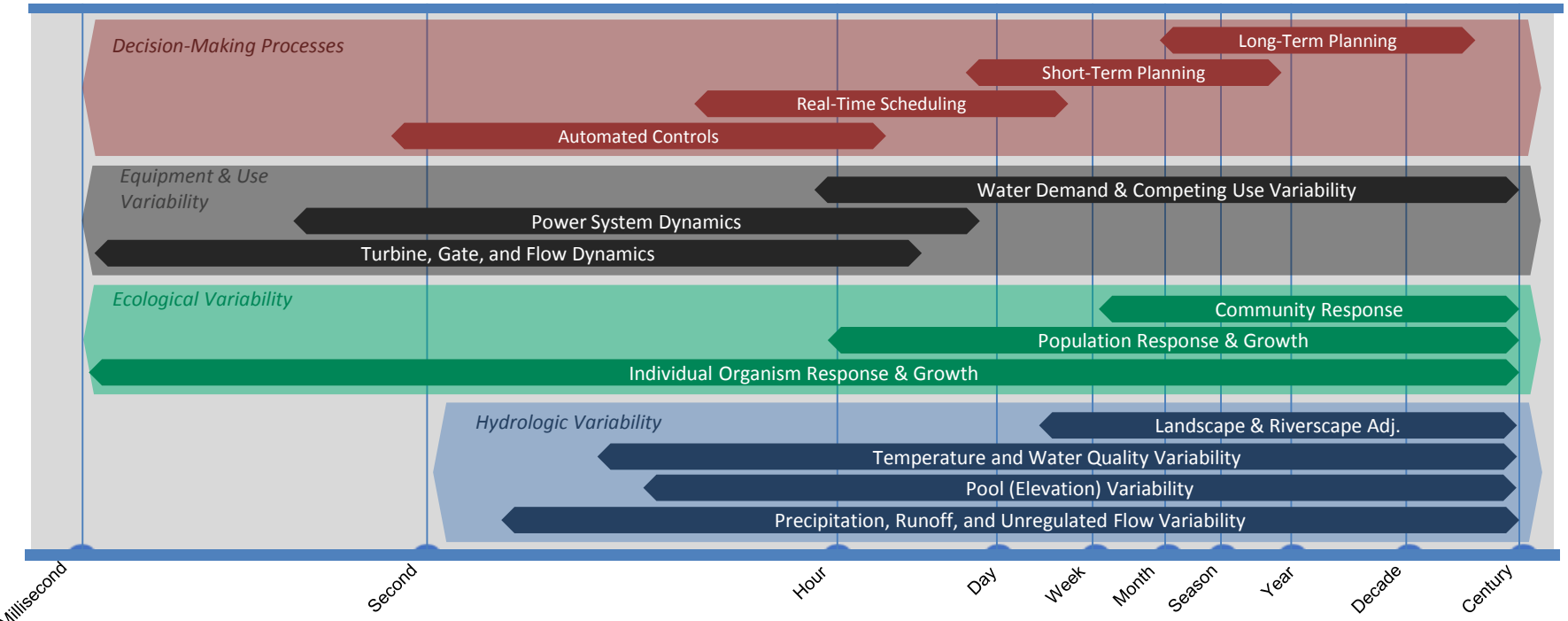


Figure 34. Annual pumping energy consumption by Helms PSH versus CAISO net load in the last week of March (2012-2017)

Many potential sources of value (and revenue)



Challenges in representing hydropower in power system models

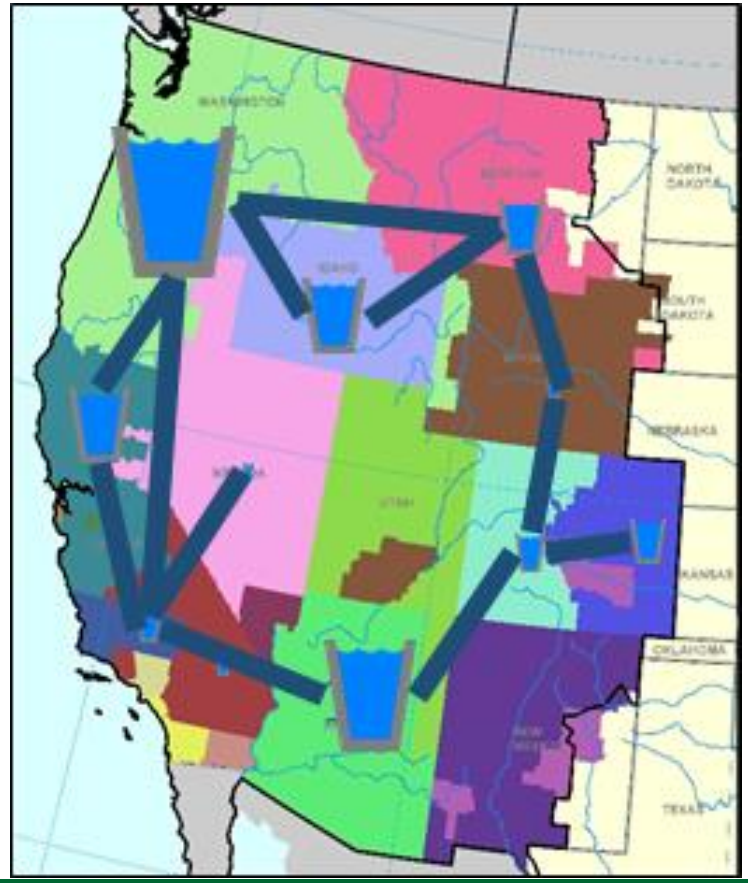


Comparison of Hydropower Operations Time Scales and Power System Time Scales (courtesy of ORNL)

Water Management Timescales

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

Hydropower in power system operations



Hydropower represented as a monthly potential at the balancing authority scale

(Voisin et al. 2017)

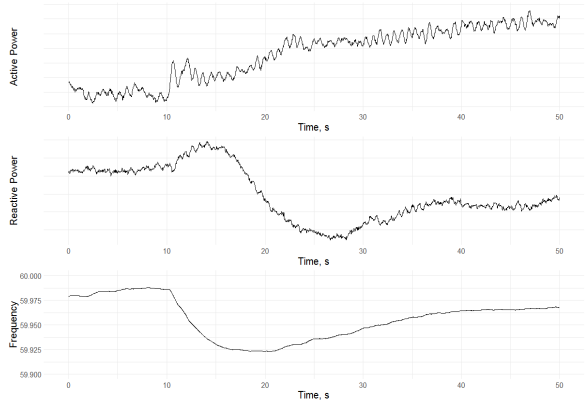
Technical capabilities for new use cases not always well understood

PMU Data Analysis for Inertial Response in Pacific Northwest

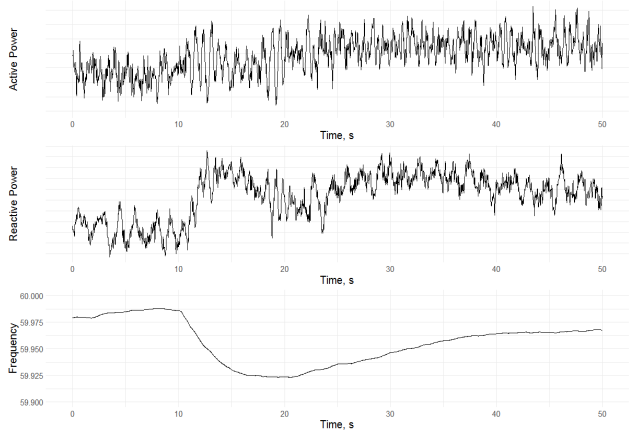
- Not all hydropower responds in the same way during the same event
- The same hydropower does not respond the same way during different events

Hydropower Response to Frequency Deviations Can Vary

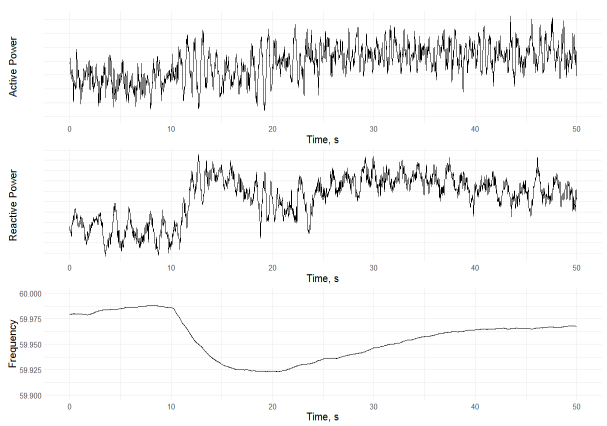
Hydro Plant 1

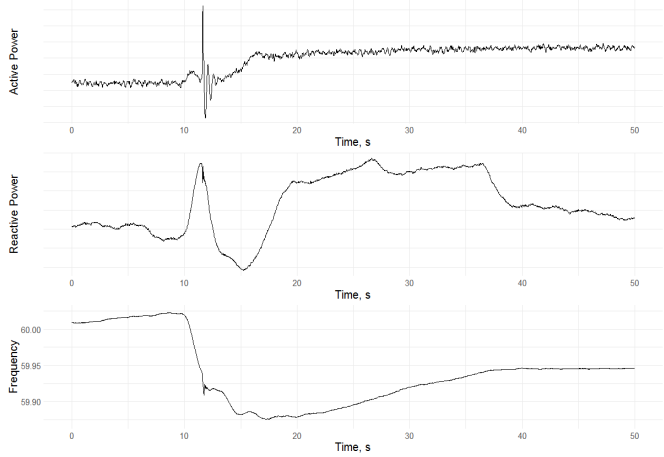


Hydro Plant 2



Hydro Plant 1





How can DOE help?

Cutting-edge research and development to support next generation hydropower and pumped storage technologies for a flexible, reliable grid.

- **Technology R&D for Low-Impact Hydropower Growth (HydroNext)**: early-stage research in **technologies and systems** to reduce costs and unlock new resources
- **Grid Reliability and Resilience**: research to evaluate and improve the ability of hydro and pumped storage to provide **essential flexibility and reliability services** for the rapidly evolving electric grid
- **System Optimization and Environmental R&D**: research to **improve environmental performance and reduce regulatory delays** for existing and future hydropower technologies, and evaluate system-level risks & opportunities for hydropower and other water uses
- **Data Sharing and Analysis**: supply objective **data and analysis,** often based on information collected over the course of other WPTO research efforts, to decision makers and important hydropower industry stakeholders

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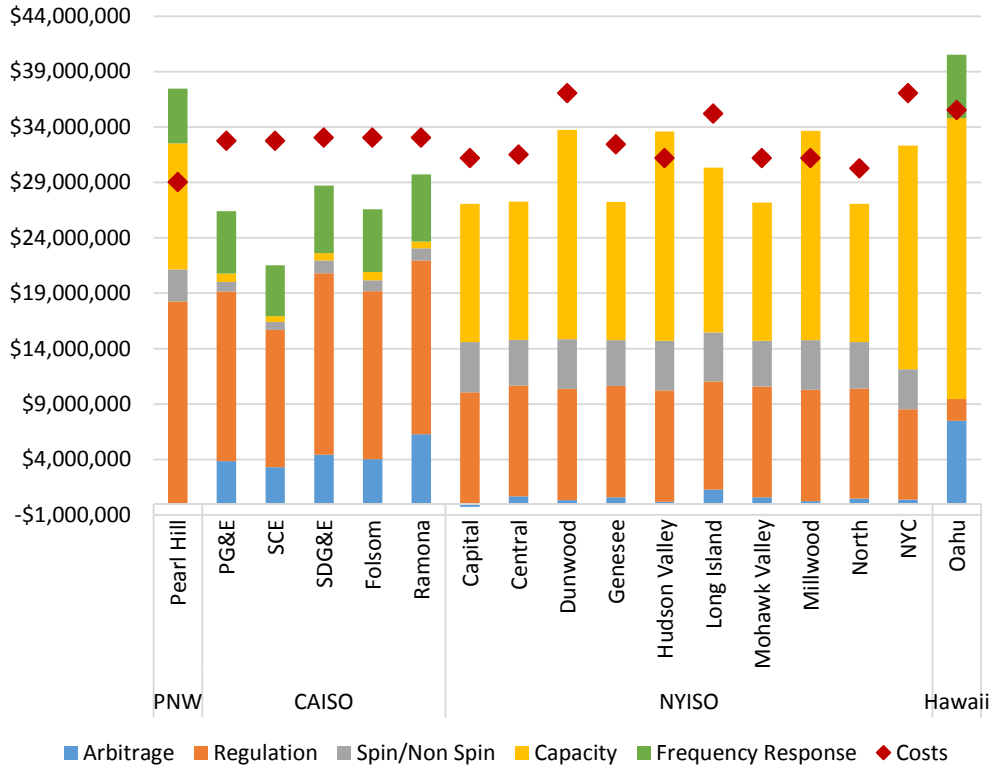
WPTO's Hydropower Grid Research Portfolio

	Value under Future System Conditions	Plant Capabilities and Constraints	Operations and Planning	Technology Innovation
RESEARCH	• Definitions and associated values of non-market services (black start, inertia) • Evaluation of future electric system conditions for correlation of likely futures to hydropower technical capabilities	• Fundamental accounting of plant and fleet level capabilities, costs, and subsequent tradeoffs • Effects of water availability and forecasting on flexibility • Assess the impact and costs of increased flexible operation on system equipment	• Resource competitiveness, compatibility, and longevity • Integrating electricity dispatch and water management models to improve the characterization of hydropower • Resiliency	• New PSH technologies and designs that reduce time to commissioning, access new sites or value streams, or increase value streams • Technology innovations that enable hydropower to preserve or expand capabilities linked to electric system futures

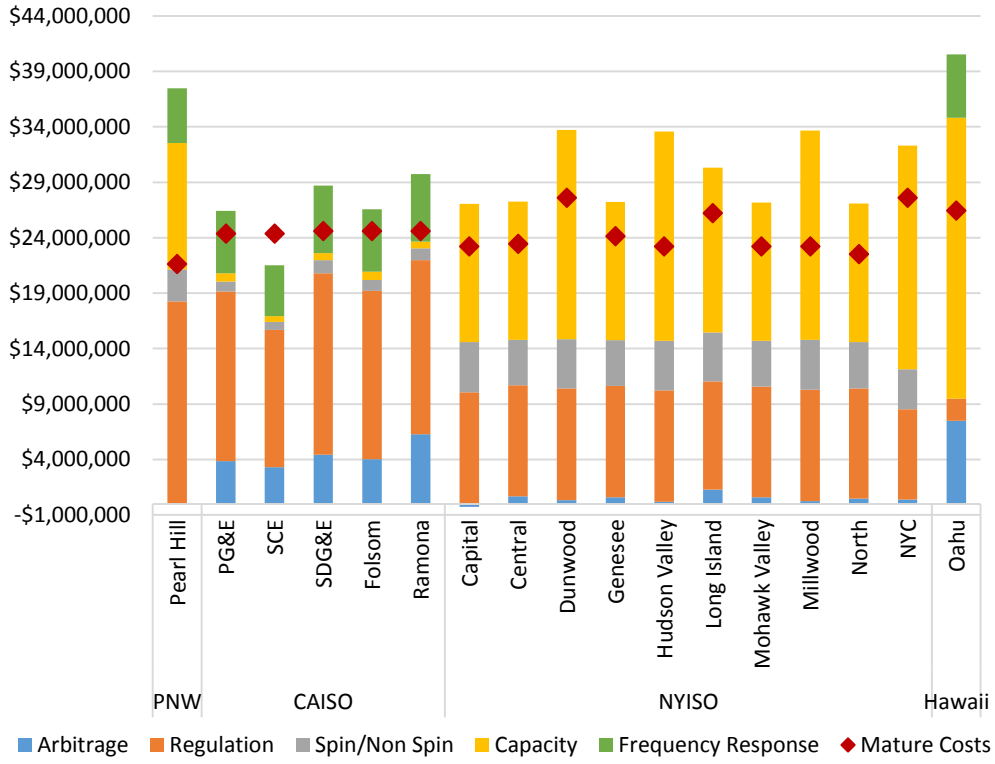
New tools to evaluate the value of PSH and hydro grid services

Market Assessment for Small, Modular PSH (Shell Project)

Benefits vs. Base Costs



Benefits vs. Mature Costs

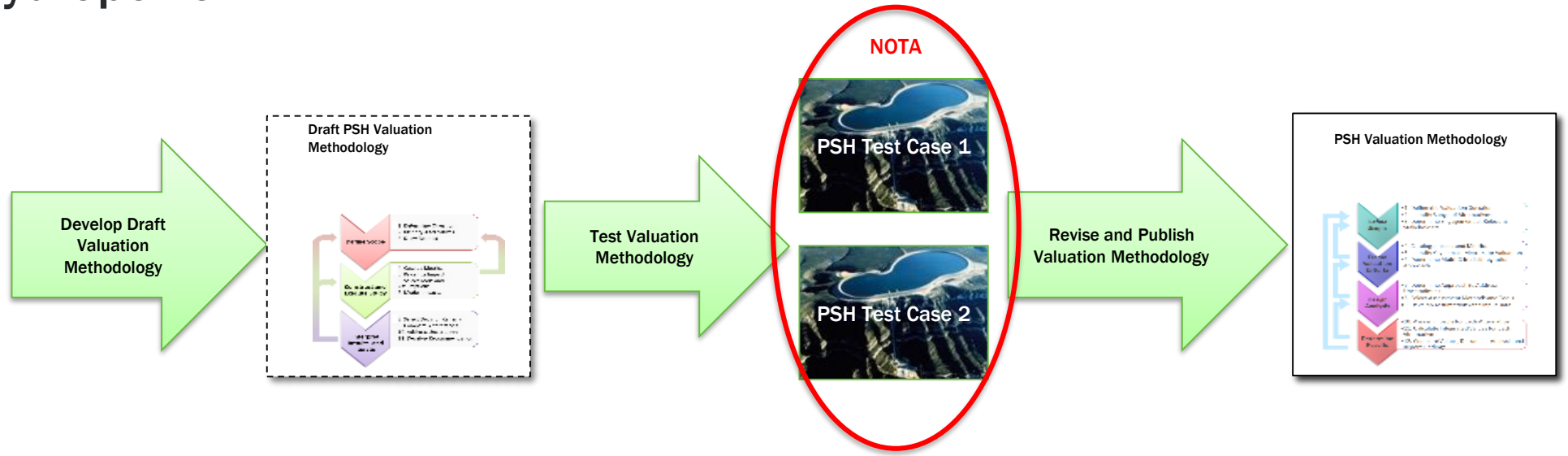


(The Base Costs case is set in terms of current market structures. The assumption is that economies of scale and lessons learned from the regulatory process can help realize the Mature Cost scenario, which includes 30% lower capital costs and only $1 million for licensing costs.)

Courtesy of PNNL

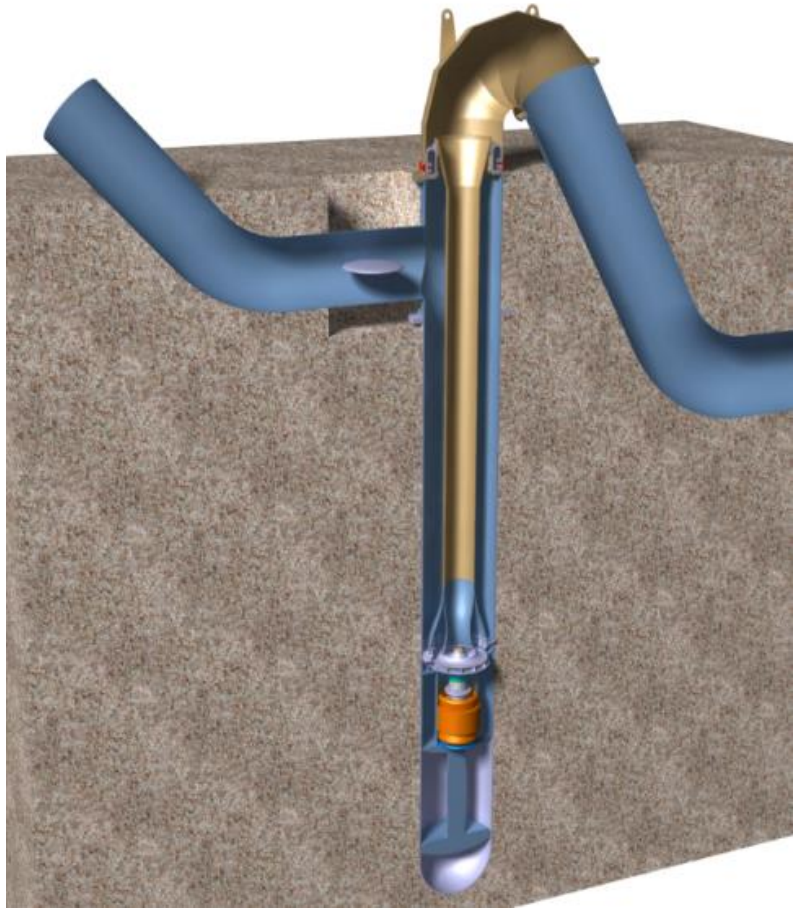
Valuation guidebook for pumped storage hydropower

- Development of an advanced valuation methodology for pumped storage hydropower that can be used by PSH developers, plant owners and operators, and other stakeholders to assess the economic value of existing or planned PSH projects.
- The draft valuation methodology will be tested at two proposed pumped storage project sites to be selected through DOE's Notice of Opportunity for Technical Assistance (NOTA): Techno-Economic Studies of Pumped-Storage Hydropower.



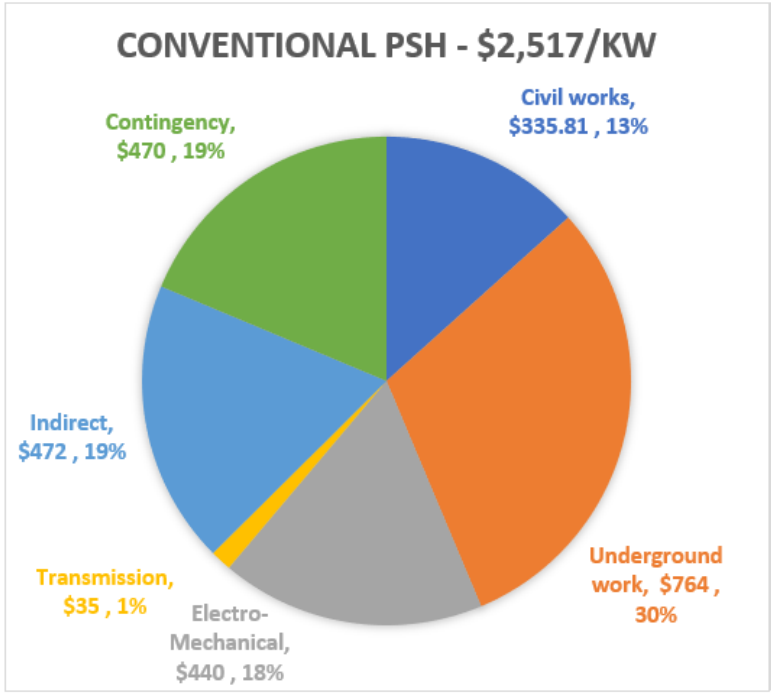
Pumped storage technology innovations to address critical barriers

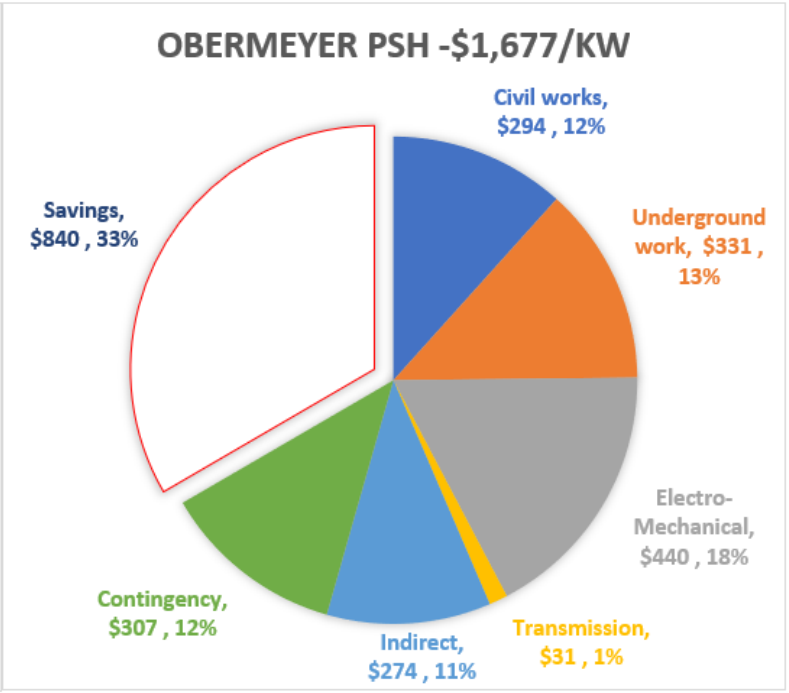
Obermeyer Hydropower



Reversible pump turbine with submersible permanent magnet motor generators installed in vertical shafts

Potential for 1/3 cost reduction





New Funding Opportunity for Pumped Storage

Released a new funding **solicitation *Innovative Design Concepts for Standard Modular Hydropower and Pumped Storage Hydropower* (DE-FOA-001836) on July 30**

- Innovative design concepts that can reduce costs of deployment, expand siting access, speed the time to commissioning, and provide additional non-electric value streams
- Analysis and modeling enhancements that illustrate how pumped storage can improve electricity system resilience, reliability, and economic efficiency
- **Application deadline is November 30**

https://eere-exchange.energy.gov/#Foald27fcaee4-3832-4a59-9a1e-b10d572c8827

Recent Hydropower and PSH Activities

- RFI to solicit feedback on priorities and strategic direction, issued February 2018
  - *Hydropower Capability, Operational Impacts, and Costs*
  - *Current Operations Landscape*
  - *Role and Value of Hydropower in Future Power Systems*
  - *Additional Research Needs*

  https://www.energy.gov/eere/water/articles/request-information-hydropower-and-grid

- Funding and technical assistance solicitations
- Organized collaboration of all five national laboratories in the Hydropower Program

Argonne NATIONAL LABORATORY
INL Idaho National Laboratory
NREL NATIONAL RENEWABLE ENERGY LABORATORY
OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY

Questions?

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