

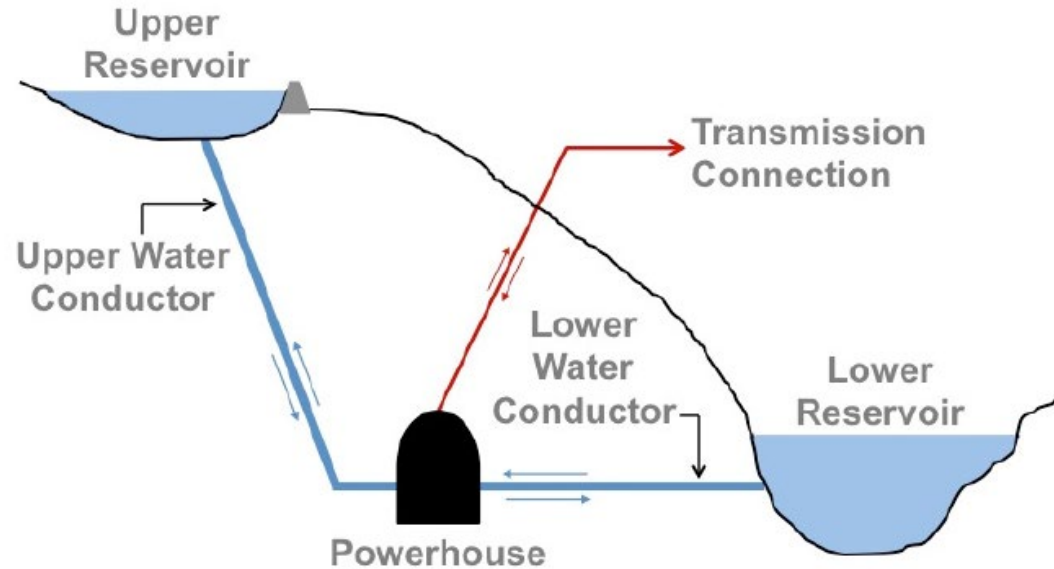
Introduction to Pumped Storage Hydropower (PSH) and the HydroWIRES Initiative

November 12, 2020

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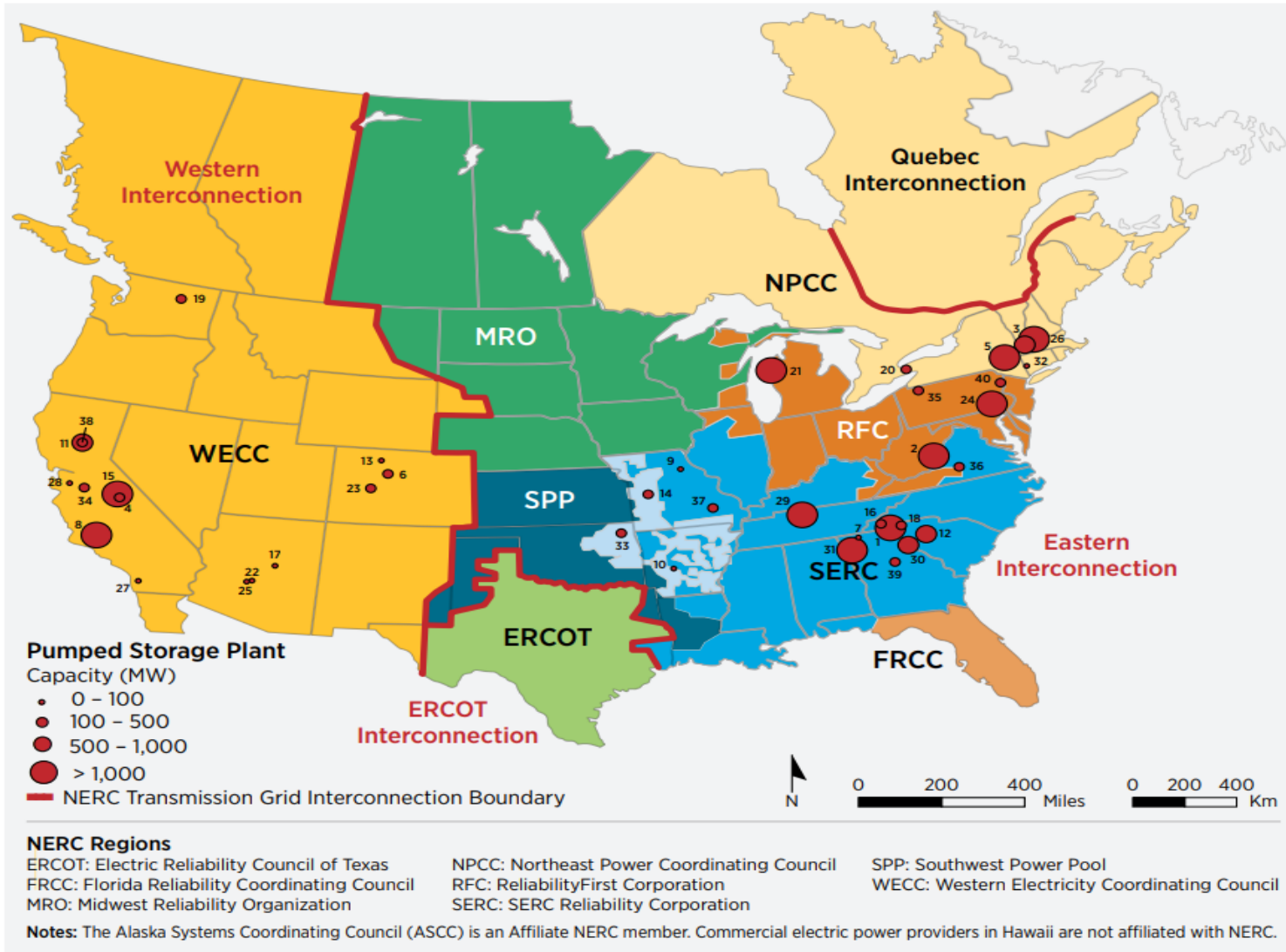
- Pumped storage hydropower (PSH) is a water battery:
 - Two water reservoirs are configured at different elevations that can generate power (**discharge**) as water moves down through a turbine; and that draws power as it pumps water (**recharge**) to the upper reservoir.
- Projects may be:
 - **Open 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
- 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
 - Flexible resource that supports reliability objectives



Conceptual Figure (Courtesy of John Frenzl, NREL)

Rocky Mountain, Oglethorpe Power and Georgia Power

Pumped Storage Hydropower (PSH) in the United States



- About 22 GW existing PSH
- No new large PSH in last 20 years
- Value proposition over long asset life is a challenge

PSH has been deployed internationally at larger scales

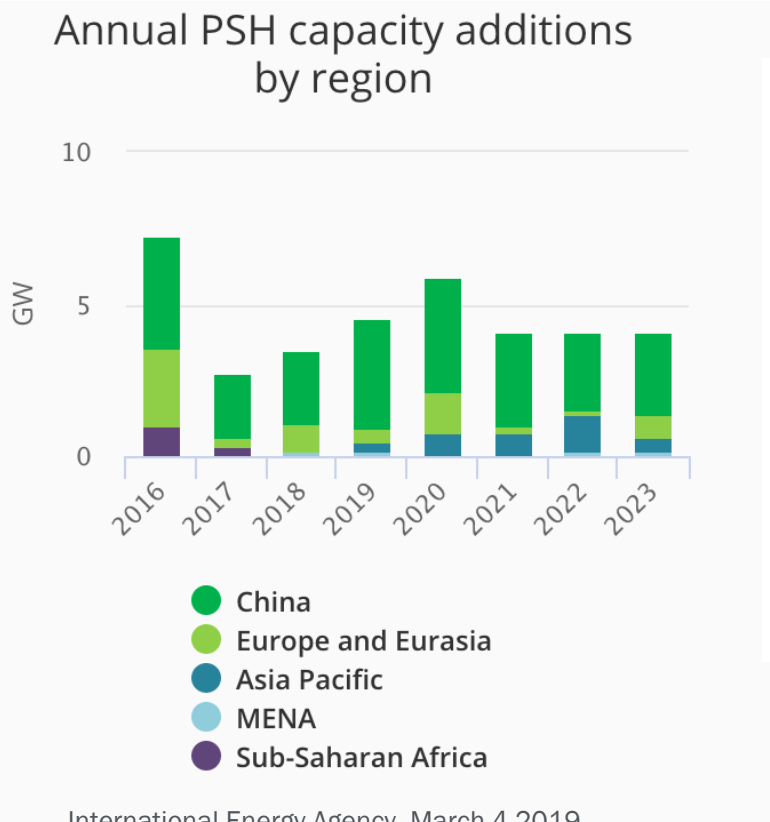


Table 2.1. Worldwide Deployment by Technology Type, 2018

Technology	MW Deployed
Sodium sulfur	189
Lithium-ion	1,629
Lead acid	75
Sodium metal halide	19
Flow battery	72
PSH	169,557
CAES	407
Flywheels	931
Electrochemical capacitor	49
Total	172,928

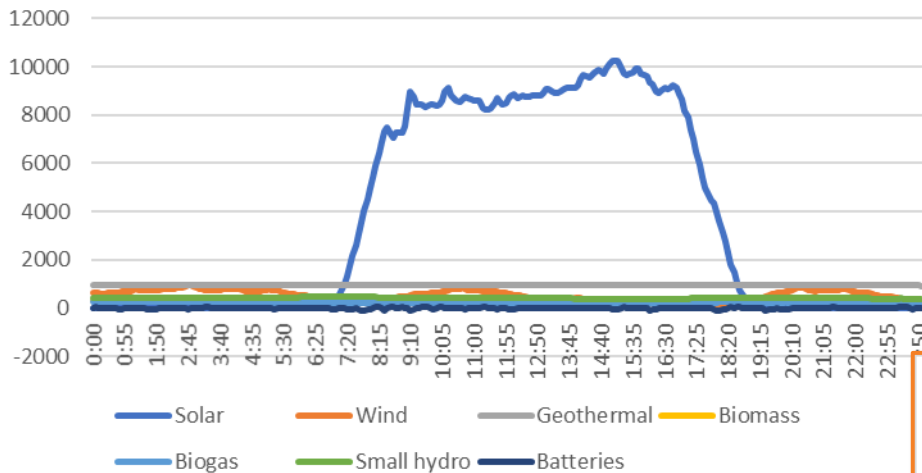
DOE Global Energy Storage Database, <https://www.energystorageexchange.org/> 2018.

International Energy Agency, March 4 2019.
<https://www.iea.org/newsroom/news/2019/march/will-pumped-storage-hydropower-capacity-expand-more-quickly-than-stationary-b.html>

The power system is changing...

Huge deployment of variable renewables creates new challenges for reliability and market design

Generation (MW)



California Example

March 31, 2019

Total Generation from
Renewable Resources



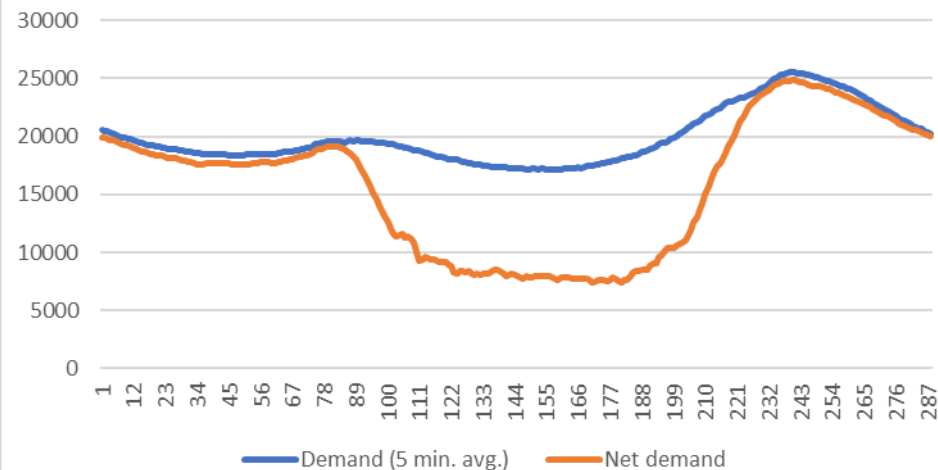
California Example

March 31, 2019

Demand and Net Demand



Demand (MW)



Changing PSH operations in the US and abroad

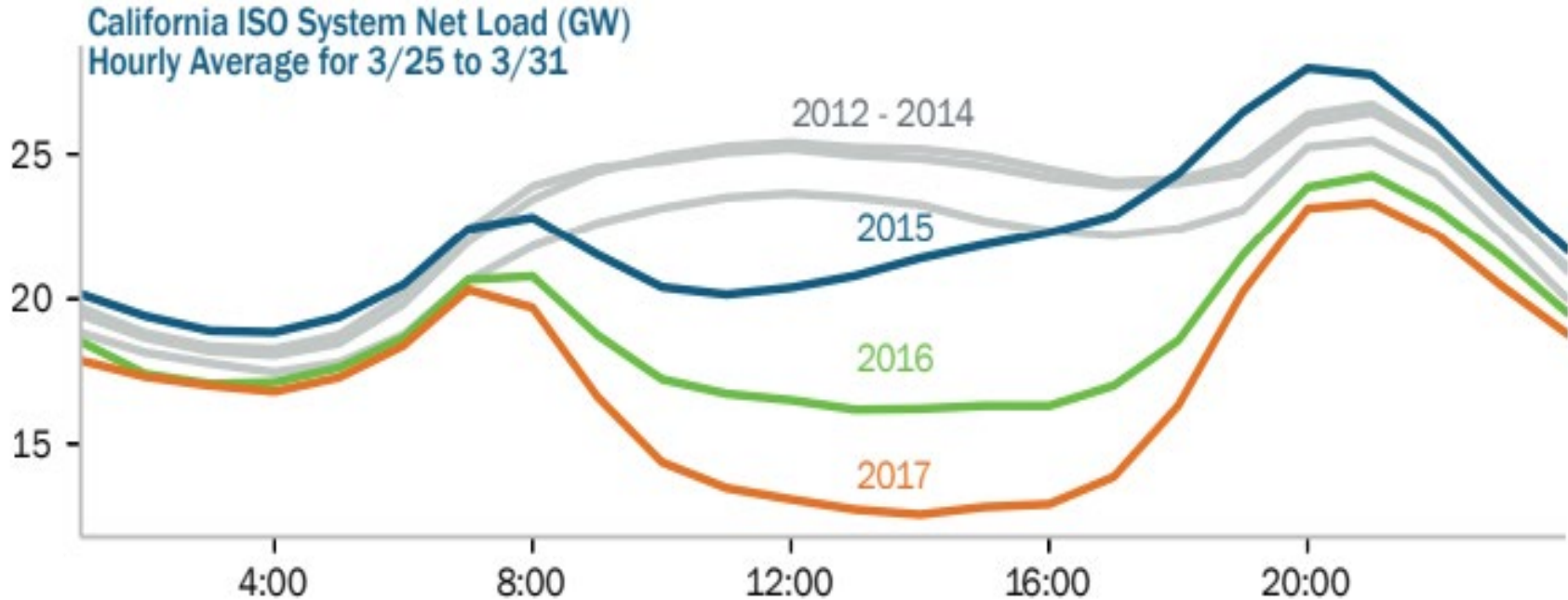
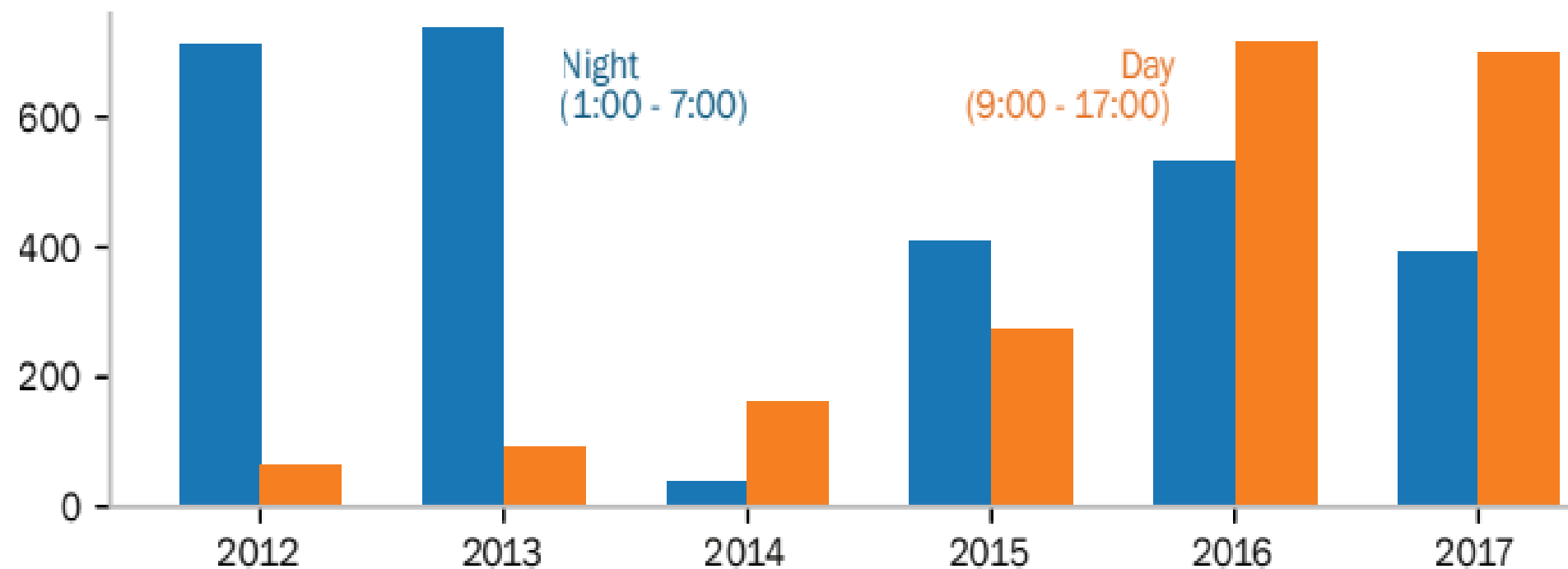


Figure from ORL Hydropower Market Report

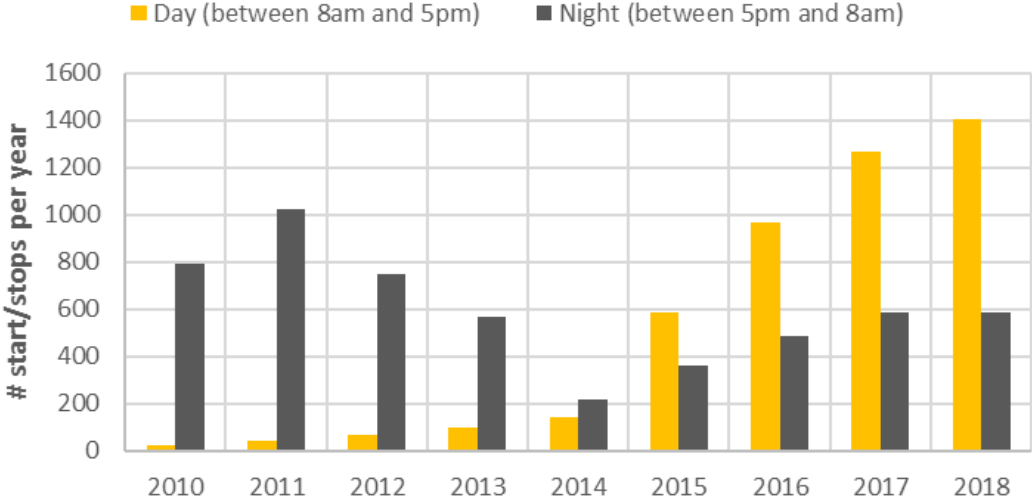
Hydropower is changing in response!

Helms PSH
Pacific Gas & Electric
Annual Pumping Energy (GWH)



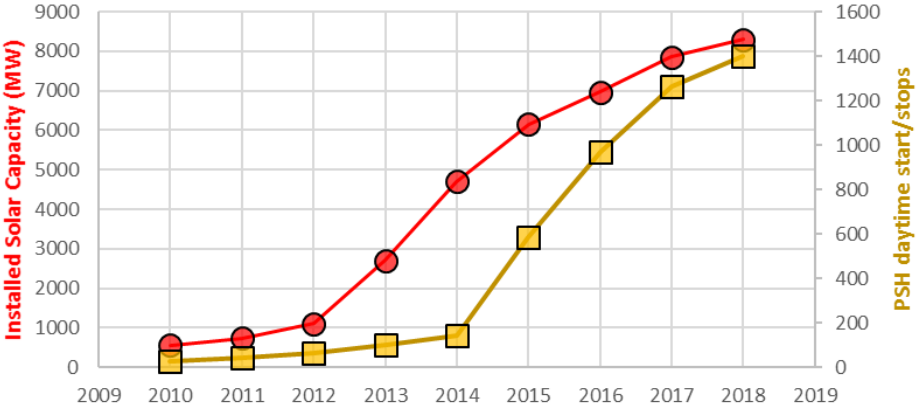
Hydropower is changing in response!

Omarugawa Pumped Storage Power Station:
Annual day vs. night start/stops from 2010 to 2018



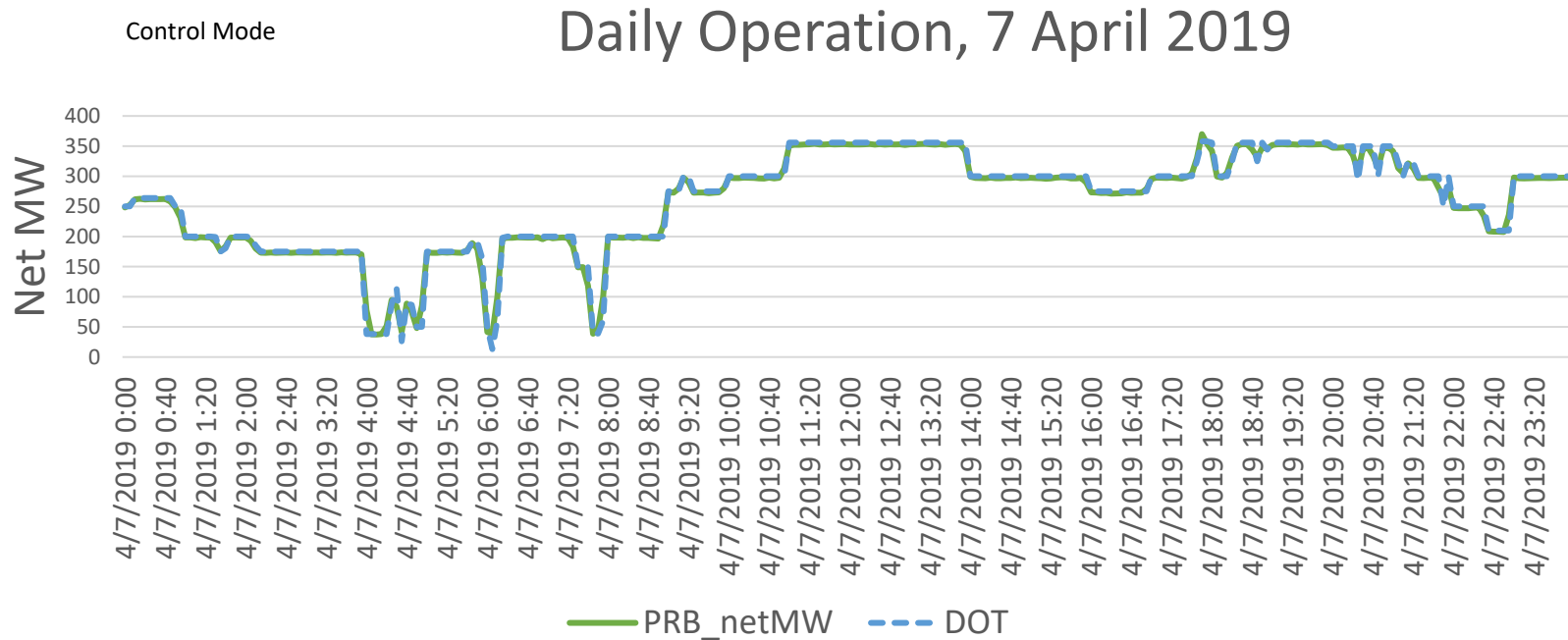
We see the same story in Japan, and elsewhere around the world...

Omarugawa Pumped Storage Power Station:
Solar deployment vs. annual PSH daytime start/stops



Hydropower is changing in response!

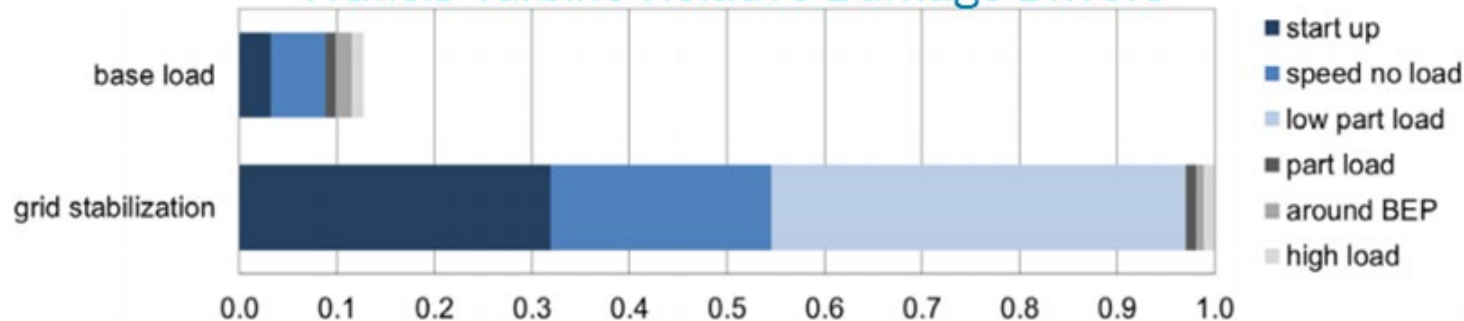
Resources are starting to switch operations multiple times a day providing them the flexibility to operate in new markets, while following dispatch orders very accurately



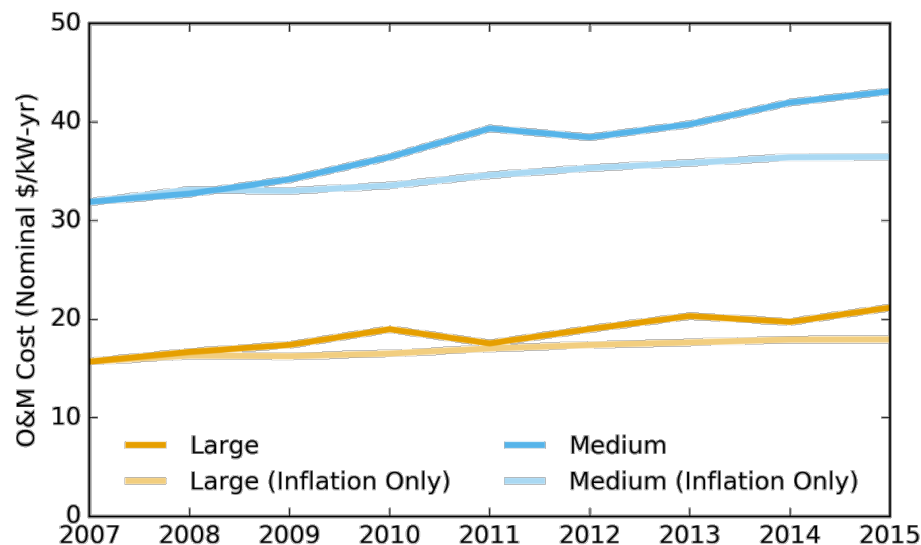
Pelton Round Butte, Portland General Electric, Oregon USA

Hydropower is changing in response!

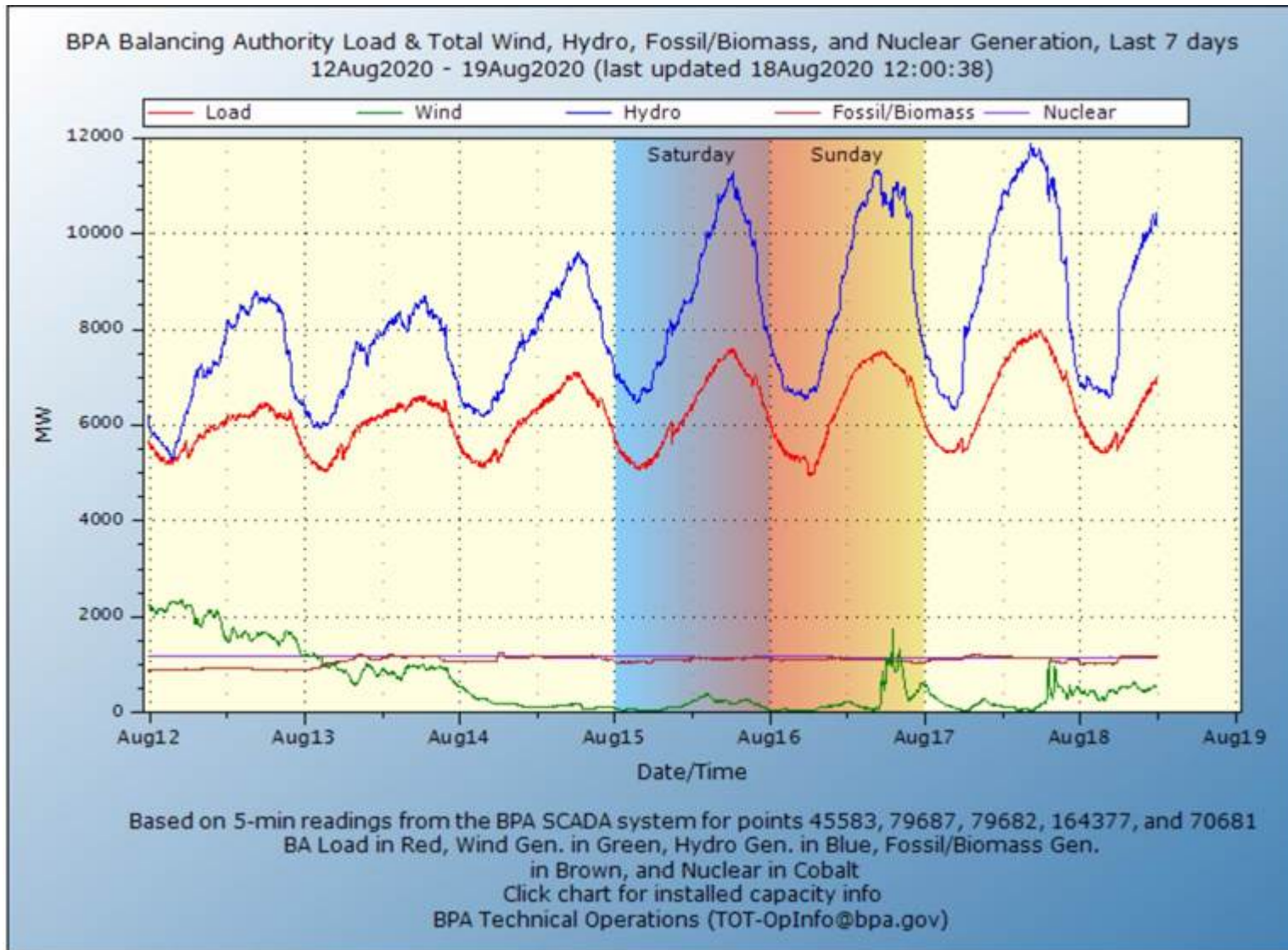
Francis Turbine Relative Damage Drivers



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



Hydropower can support grid reliability during CA heatwaves



- 1** 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.
- 2** 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.
- 3** There are gaps in information regarding how to optimize hydropower and PSH operations and planning in coordination with other resources.
- 4** Current hydropower and PSH technology may not be designed for flexible operation.

Hydropower and Water Innovation for a Resilient Electricity System



A new research initiative by DOE's Water Power Technologies Office **to understand, enable, and improve hydropower's contributions to reliability, resilience, and integration** in a rapidly evolving electricity system.



U.S. DEPARTMENT OF ENERGY

Value under Evolving System Conditions

Understand the rapidly changing grid and how these changes create opportunities for hydropower and PSH to provide new value.

Capabilities and Constraints

Investigate hydropower's technical capabilities to provide flexibility, as well as how constraints related to equipment, water, and policy affect these capabilities.

Operations and Planning

Optimize hydropower operations and planning—alongside other resources—to meet increased needs for flexibility in the changing grid.

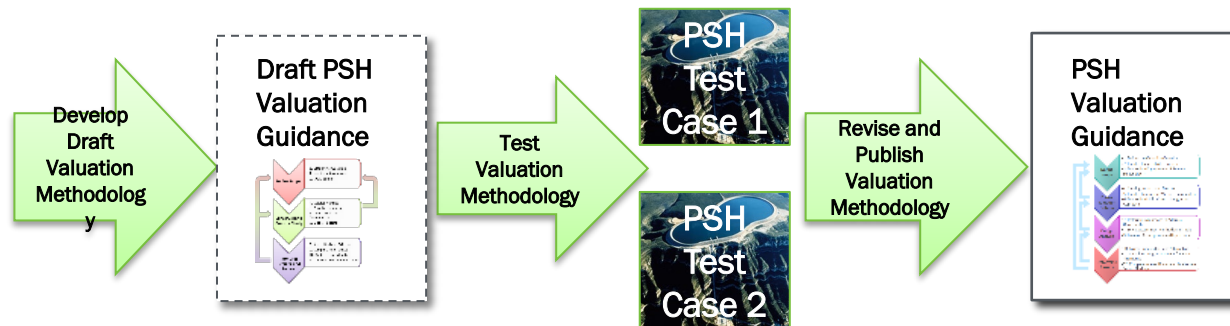
Technology Innovation

Invest in innovative technologies that improve hydropower flexibility.

Objective: Advance the state of the art in the assessment of value of PSH plants and their role and contributions to the power system

Specific goals:

1. Develop a comprehensive and transparent valuation guidance that will allow for consistent valuation assessments and comparisons of PSH projects
2. Test the PSH valuation methodology by applying it to two selected PSH projects
3. Transfer and disseminate the PSH valuation guidance to the hydropower industry, PSH developers, and other stakeholders



Absaroka Energy

Banner Mountain PSH

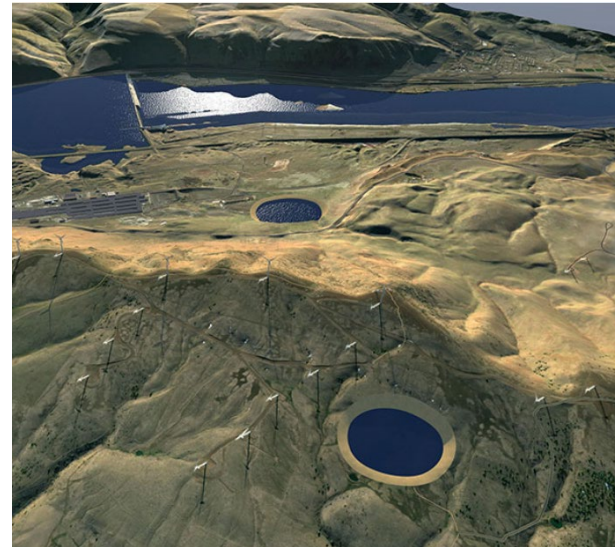
- 400 MW, quaternary technology
- Closed loop
- Site near Casper, WY



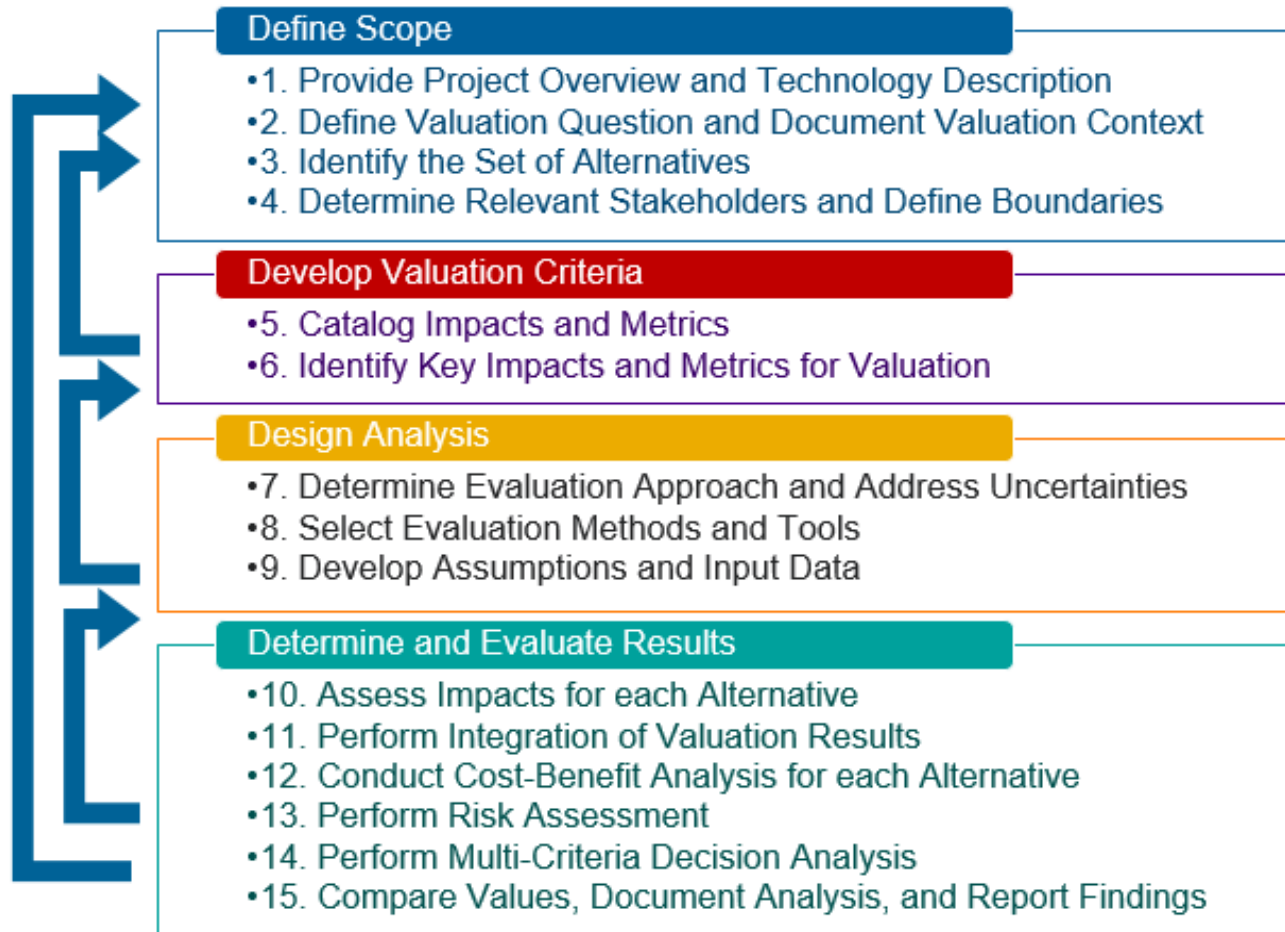
National Grid & Rye Development

Goldendale Energy Storage Project

- 1,200 MW, adjustable speed technology
- Closed loop
- Site just north of OR/WA border

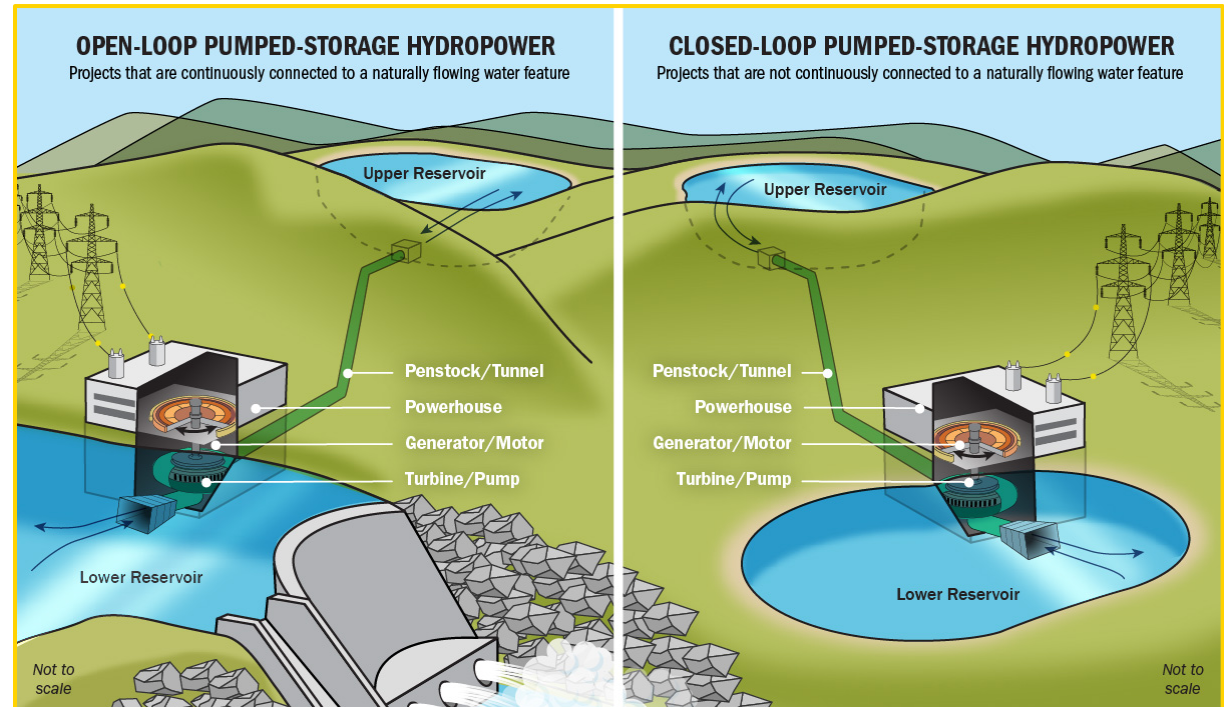


A Cost-Benefit and Decision Analysis Valuation Framework



Comparison of the Environmental Effects of Open-Loop and Closed-Loop Pumped Storage Hydropower

- Identify the potential environmental effects of closed-loop PSH projects, especially compared to open-loop PSH projects
- Describe how the effects are being avoided, minimized, or mitigated at existing projects in other countries and proposed projects in the US
- Discuss relative significance of the environmental issues

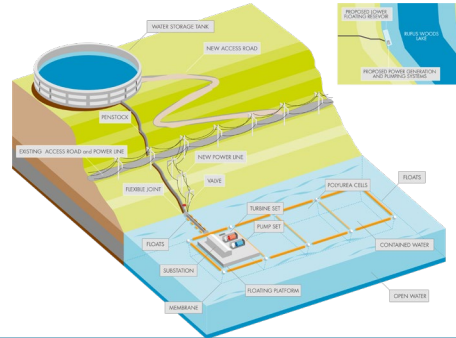


New PSH Technology R&D for Smaller-Scale Systems

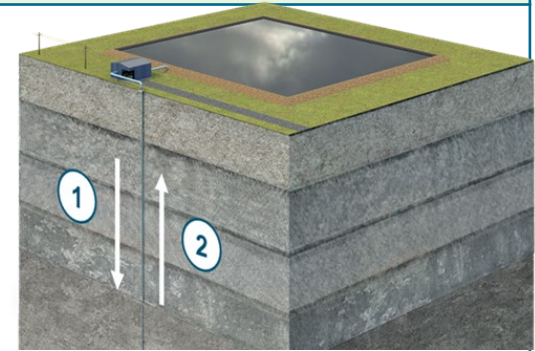
Modular Compressed-Air PSH (ORNL)



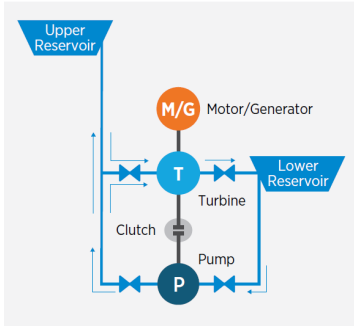
Small Modular Hydro Battery (Shell)



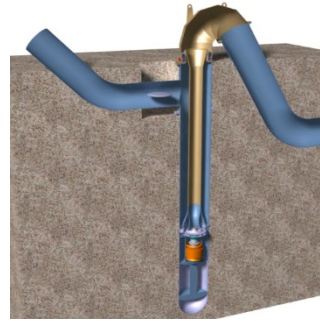
Geomechanical PSH (Quidnet)



Ternary PSH System (NREL)



No-Powerhouse PSH (Obermeyer)



HydroWIRES Partners and Awardees

Internal Collaboration



DOE Executive Board:

- GMI
- OE
- EERE-SPIA

International Collaborators



Awardees



ELECTRIC POWER RESEARCH INSTITUTE



Thank you!



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Learn more at:
energy.gov/HydroWIRE