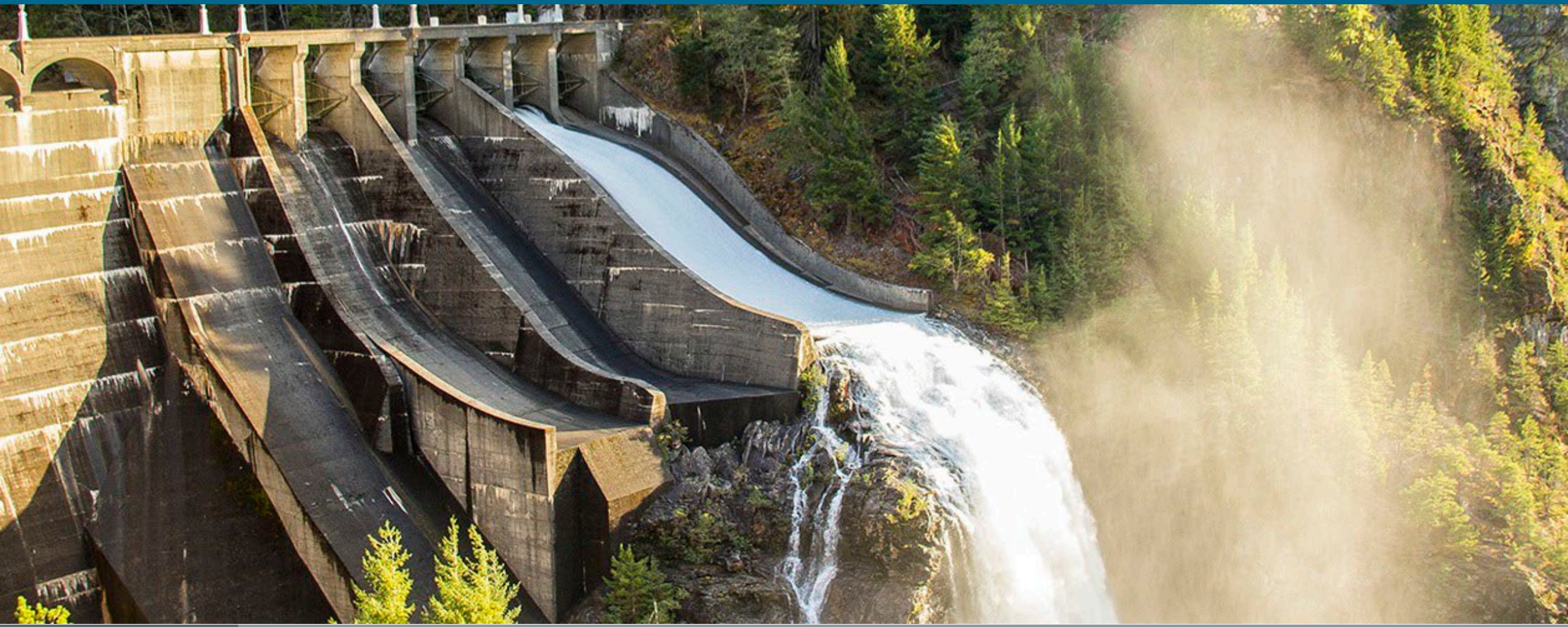
HydroWIRES Initiative

Samuel Bockenhauer, Ph.D.
HydroWIRES Initiative Lead

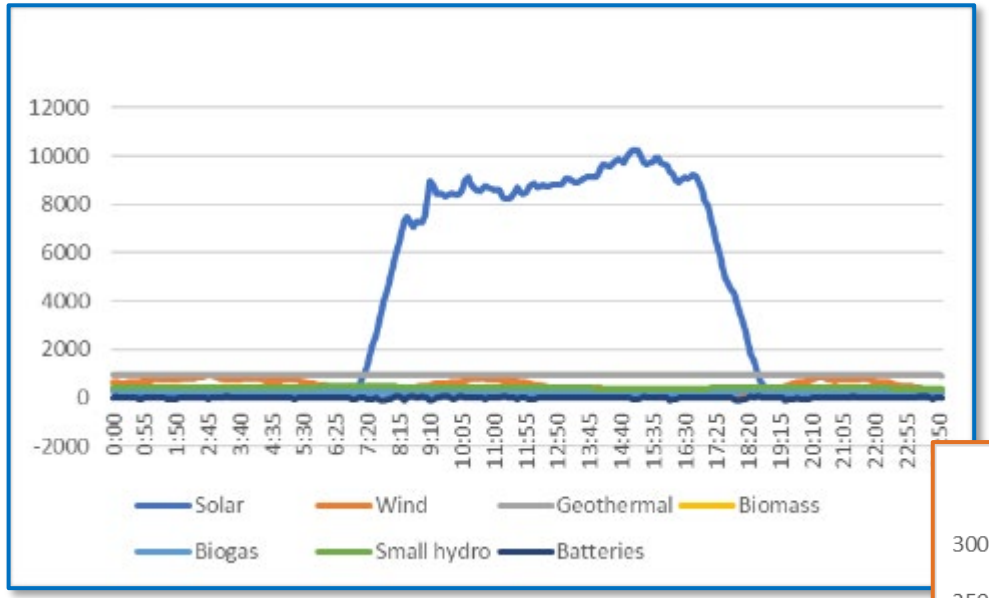


Outline

- **Activity Area Overview**
  - Challenges the Activity Area Addresses
  - Examples of How Stakeholder Engagement Informed Strategy
- **Strategy**
  - Performance Goals
  - Objectives
- **Implementation and Progress**
  - Research Priorities
  - Key Accomplishments
  - Future Work
- **Agenda Overview**
- **Reviewer Introductions**

Activity Area Overview

The power system is changing…



California Example

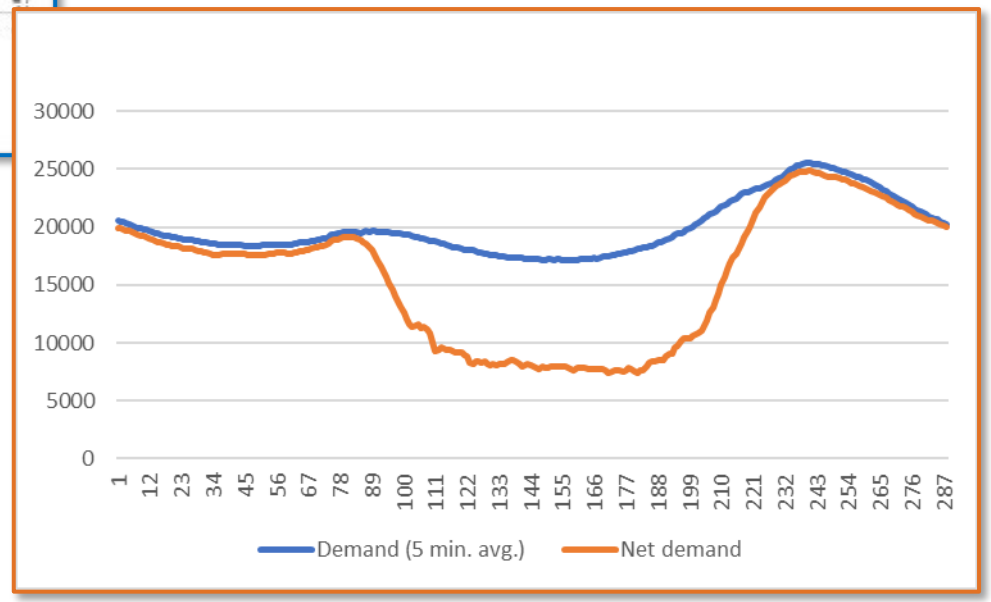
March 31, 2019

Total Generation from Renewable Resources

California Example

March 31, 2019

Demand and Net Demand



Hydropower is changing in response!

- Existing pumped storage hydropower (PSH) operations are changing due to more variable renewable energy
- And, the ability of hydropower and PSH to store energy and operate flexibly could enable additional variable renewables to come online

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

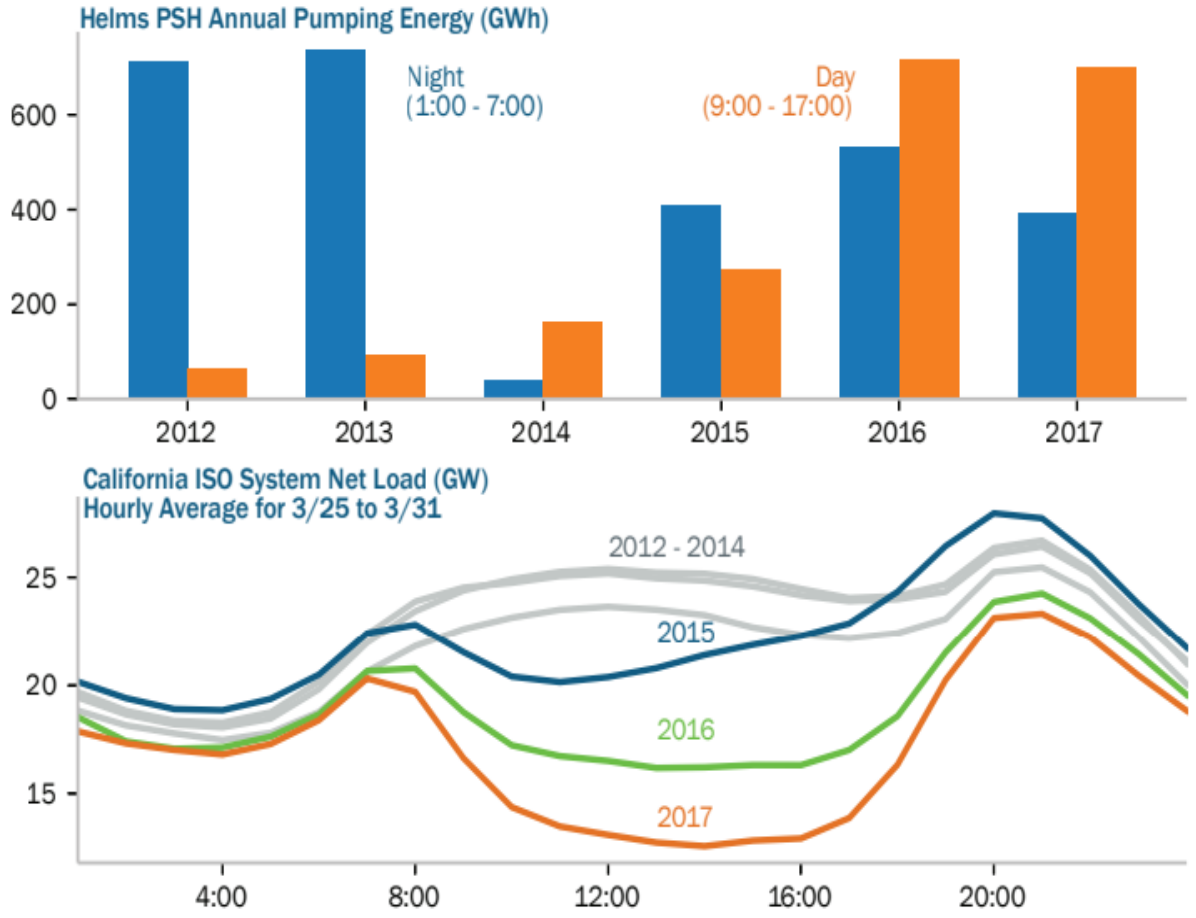
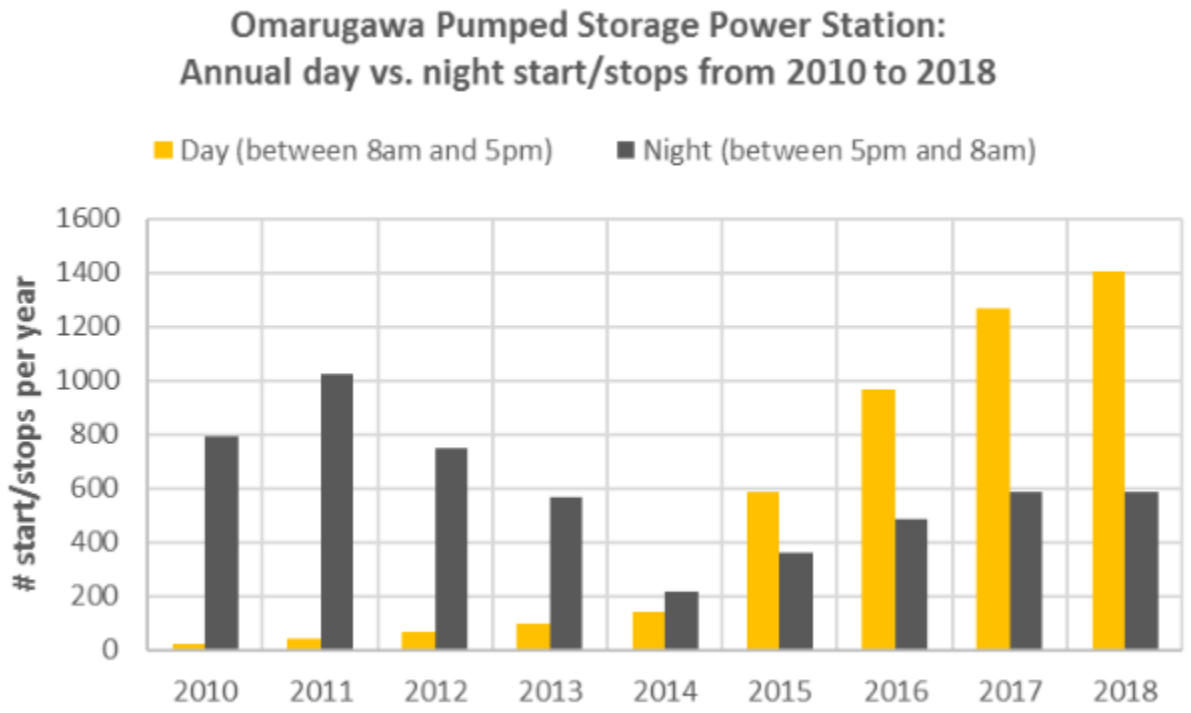
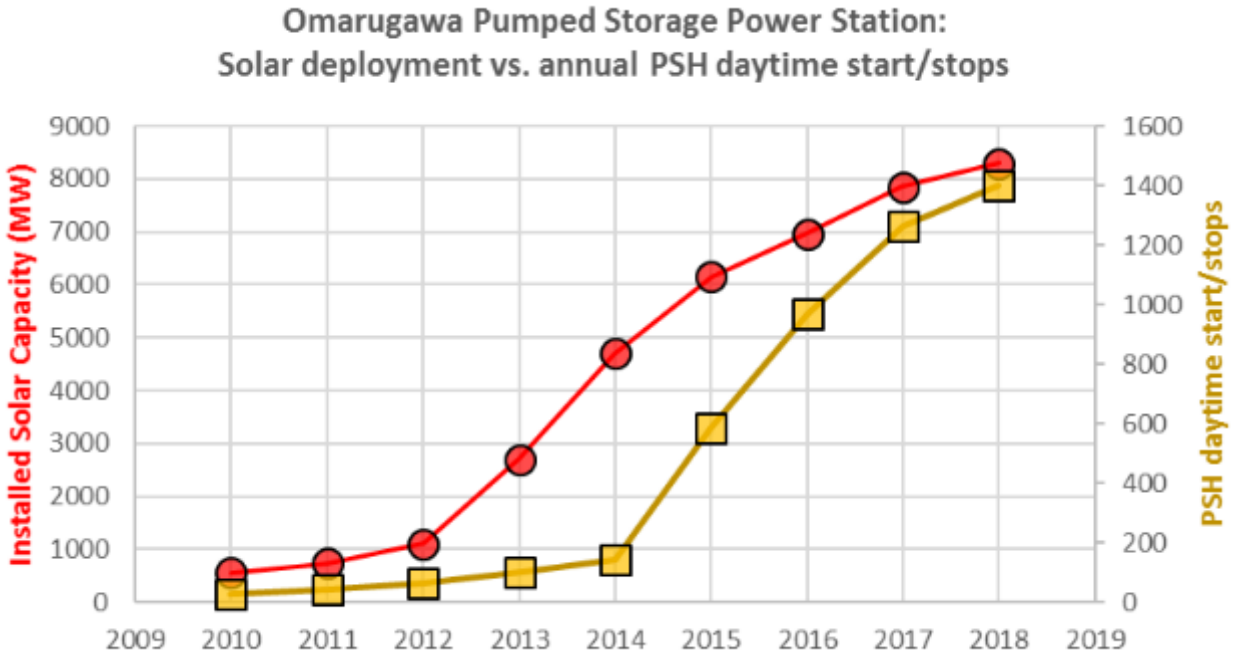


Figure 34. Annual pumping energy consumption by Helms PSH versus CAISO net load in the last week of March (2012-2017)

Hydropower is changing in response!

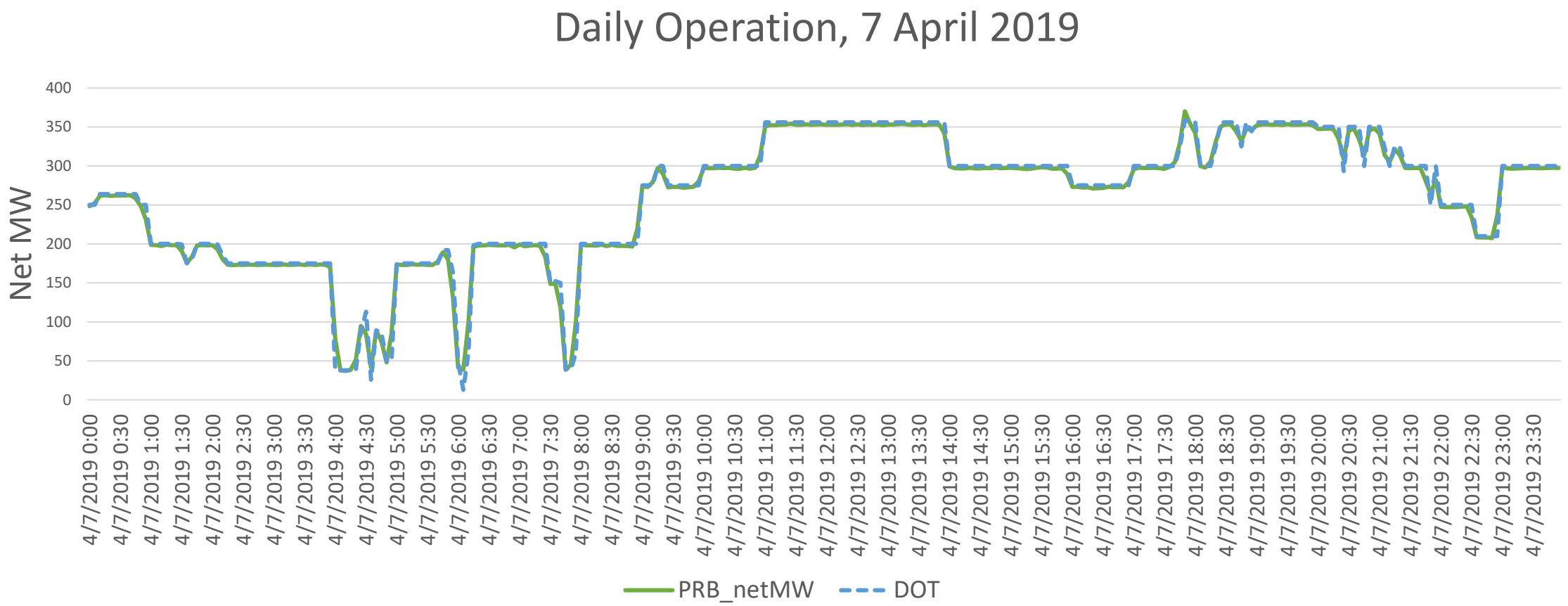


We see this pattern in the US and around the world, e.g. in Japan



Hydropower is changing in response!

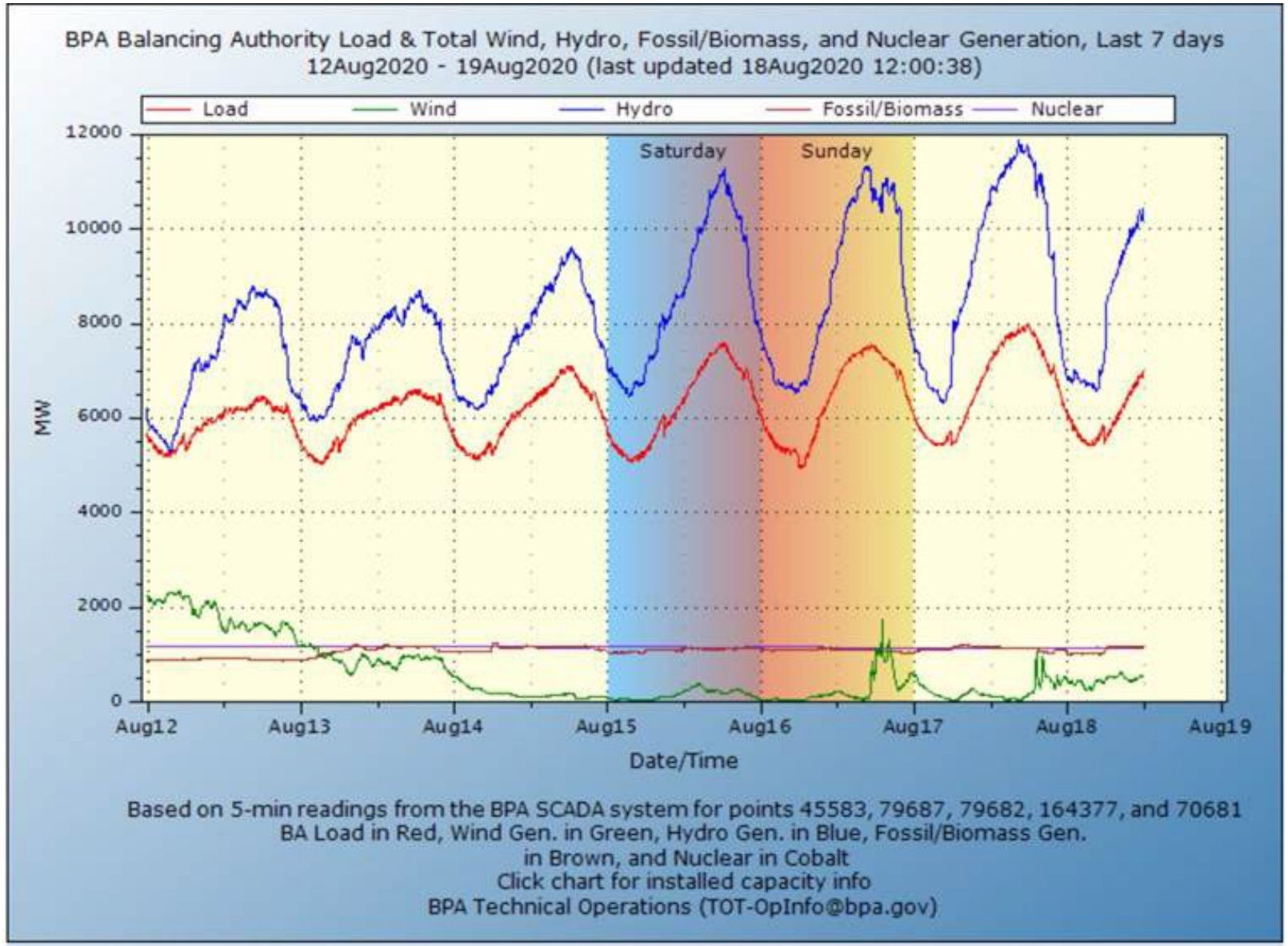
New market opportunities such as the Western EIM are causing owners to operate their plants much more flexibly



Pelton Round Butte, Portland General Electric, Oregon USA

Hydropower is changing in response!

During heat waves and other extreme events, hydropower can ramp up its generation to meet demand and prevent outages



And there are corresponding changes in community attitudes

- **PSH developers:** Best environment for PSH development in decades; less firm capacity from natural gas; need to let PSH compete on its capabilities
- **Grid operators and regulators:** New and pressing needs for long-duration storage; increasingly considering PSH as an option
- **NHA/owners:** Enhanced coordination with wind and solar industries; sessions on flexibility; Clean Currents; but big questions about compensation
- **Manufacturers:** New requests from customers to design more flexible equipment
- **Environmental NGOs:** Growing awareness of climate benefits of flexible hydro
- **Federal hydropower:** Reclamation/WAPA trying to plan for high-renewable future scenarios; TVA kicking off PSH assessment
- **International community:** Many countries are facing the same challenges; advanced economies seeing new value in hydro/PSH; emerging economies need storage and firm capacity; IEA Focus Report on Hydropower

But there are challenges...

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.

...and opportunities

Hydropower and Water Innovation for a Resilient Electricity System

HydroWIRES

U.S. DEPARTMENT OF ENERGY

A 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.

HydroWIRES Research Areas

Value under Evolving System Conditions

- Quantify value of hydro/PSH
- Understand market and policy implications

Capabilities and Constraints

- Improve model capabilities
- Quantify operational tradeoffs

Operations and Planning

- Increase flexibility through operational strategies
- Distinguish hydro from other resources

Technology Innovation

- Increase flexibility through technology innovation
- Develop PSH and hydropower hybrids

Stakeholder Engagement to Inform HydroWIRES Strategy

- Request for Information (RFI) in 2018 to scope out and launch the HydroWIRES Initiative
- Second RFI in 2020 to gather feedback on the draft HydroWIRES Roadmap, finalized in January 2022

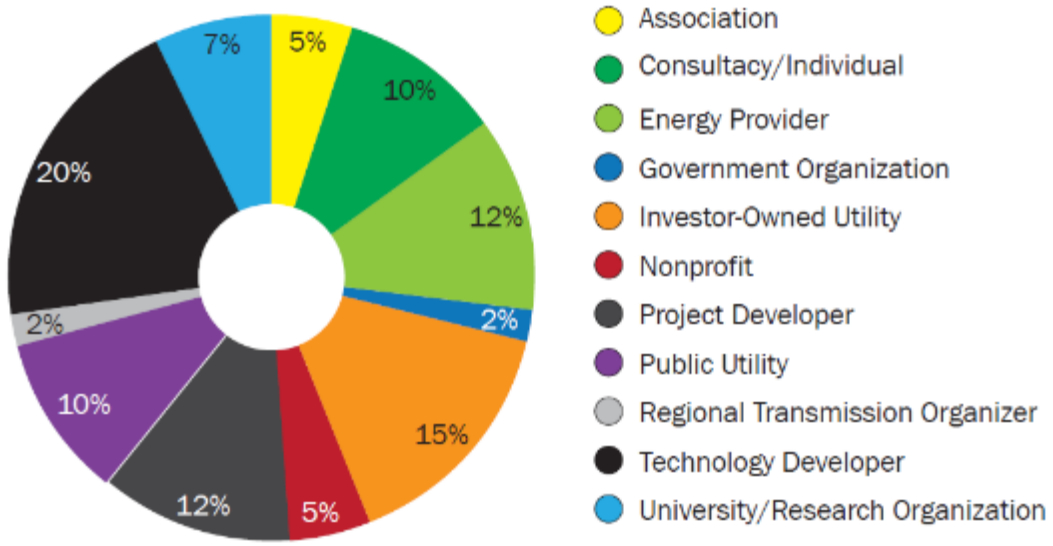
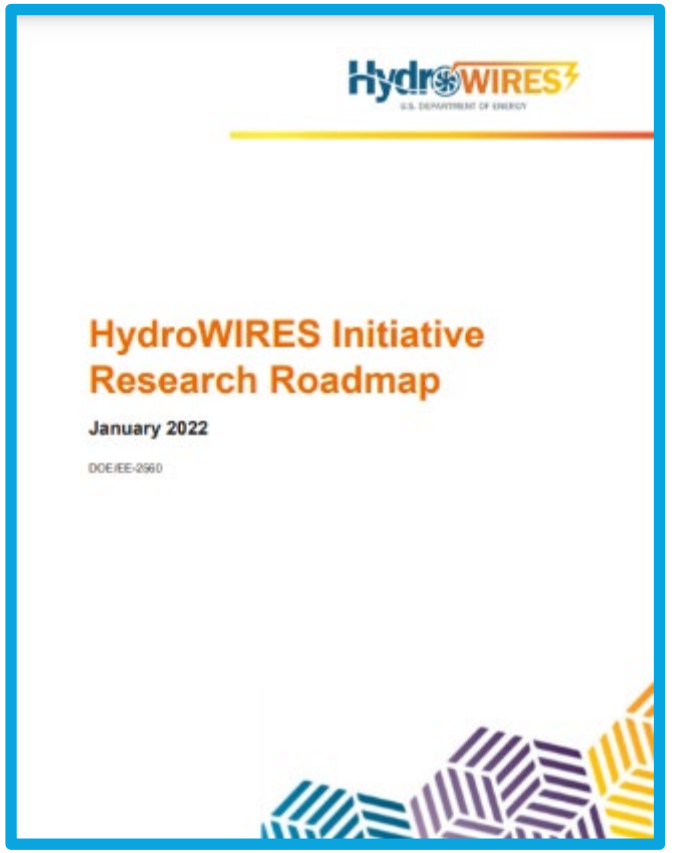


Figure 2. Distribution of respondents to the 2018 Request for Information



Stakeholder Engagement to Inform HydroWIRES Strategy

Consistent engagement with stakeholders to get feedback on ongoing work and future directions (both Initiative- and project-level)

- Hydropower and PSH owners and developers
  - Multiple presentations and discussion with NHA PSH Council, NHA Markets Committee
  - Presentations to CEATI HOPIG of forecasting work
  - Relationships with PSH developers to understand development process and how DOE can support (WPTO-HydroWIRES and also other offices like the Loan Programs Office)
- Federal fleet
  - New collaborative projects with WAPA and BOR on hydropower's changing role in the Colorado basin, and PSH valuation of Reclamation projects considering upgrades (through Hydropower MOU involving USACE, BOR, and DOE)
- Manufacturers
  - Active feedback through projects with major manufacturers, and collaborative events and panels at industry conferences

Stakeholder Engagement to Inform HydroWIRES Strategy

- Grid operators and regulators
  - Partnerships with ISO/RTOs in FOA and lab call projects to incorporate their perspective and ensure relevance of results
  - Participation in MISO proceedings with PSH-as-transmission white paper
  - Strategic efforts to plan panels at the Energy Systems Integration Group workshops and similar cross-technology events
- Environmental NGOs
  - Engagement with Uncommon Dialogues working groups, including presentations of environment-flexibility tradeoffs work
- International
  - Collaborative MOU with Norway on hydropower R&D, including focus on hydropower's value to the grid
  - Manage DOE support of the International Forum on Pumped Storage Hydropower, gaining many valuable insights into PSH development worldwide that could apply to the US
  - Chairmanship of IEA Hydro TCP, which enables new perspectives from other countries and multiple collaborative efforts that further HydroWIRES goals

Strategy

US Decarbonization Goals

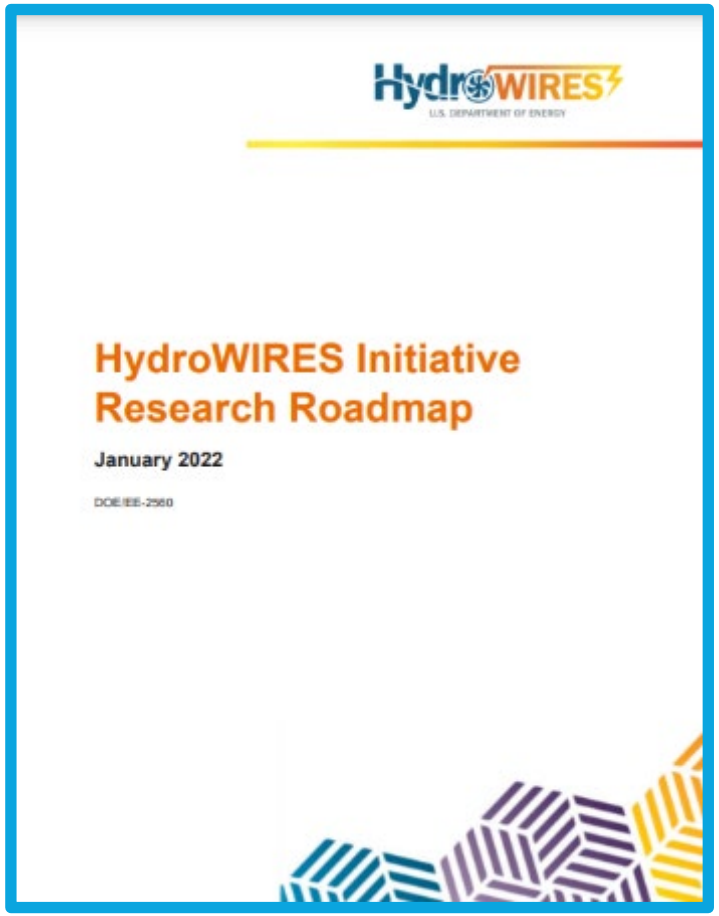
2030	2035	2050
50% reduction in greenhouse gas pollution from 2005 levels	100% carbon pollution-free electricity	Net zero emissions economy-wide





HydroWIRES Outcomes: Supporting Hydro's Role in Decarbonization

- Understanding across the hydropower community of the value hydropower provides in different regions and system conditions.
- High-fidelity modeling of hydropower and PSH that represents flexible operations, enhanced market participation, varying water availability, and multipurpose constraints and benefits should become standard practice.
- Quantifiable improvement of hydropower plant operations, including coordination or co-location with other resources, to increase system flexibility.
- Increased inclusion of hydropower and PSH in generation and transmission planning.
- Commercialization of new hydro flexibility and PSH technologies that can dramatically lower costs and/or increase cost-competitive PSH deployment opportunities.



HydroWIRES Outcomes → Example Written Product Types

- Understanding across the hydropower community of the value hydropower provides in different regions and system conditions.
  - Guidebooks for industry users
- High-fidelity modeling of hydropower and PSH that represents flexible operations, enhanced market participation, varying water availability, and multipurpose constraints and benefits should become standard practice.
  - Documentation of model enhancements for planners and other model users
- Quantifiable improvement of hydropower plant operations, including coordination or co-location with other resources, to increase system flexibility.
  - Reports quantifying hydro's resilience role for operators and policymakers
  - Documentation of new hybrid configurations that other owners can use
- Increased inclusion of hydropower and PSH in generation and transmission planning.
  - Thought-leadership white papers on potential new value streams
- Commercialization of new hydro flexibility and PSH technologies that can dramatically lower costs and/or increase cost-competitive PSH deployment opportunities.

HydroWIRES Research Areas

Value under Evolving System Conditions

- Quantify value of hydro/PSH
- Understand market and policy implications

Capabilities and Constraints

- Improve model capabilities
- Quantify operational tradeoffs

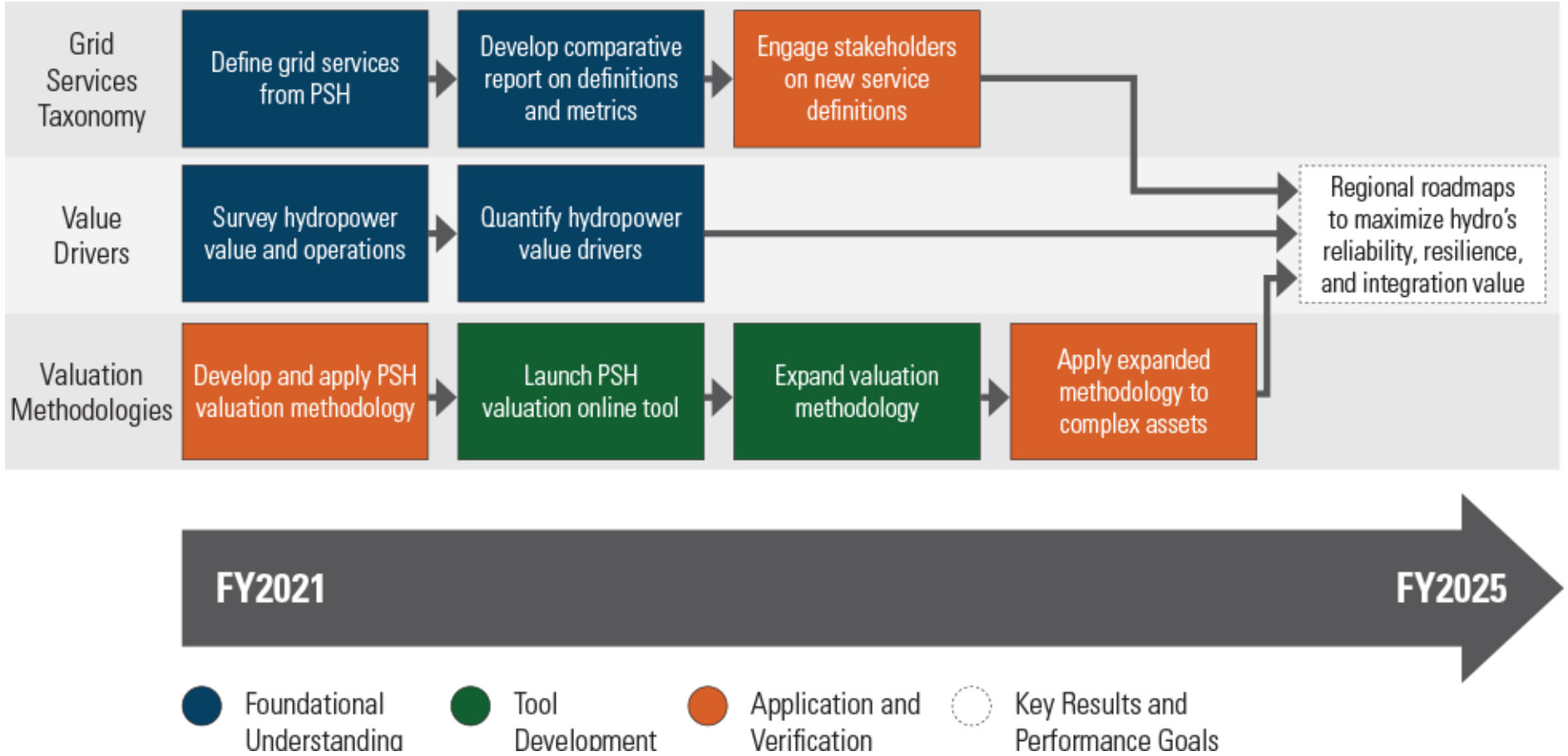
Operations and Planning

- Increase flexibility through operational strategies
- Distinguish hydro from other resources

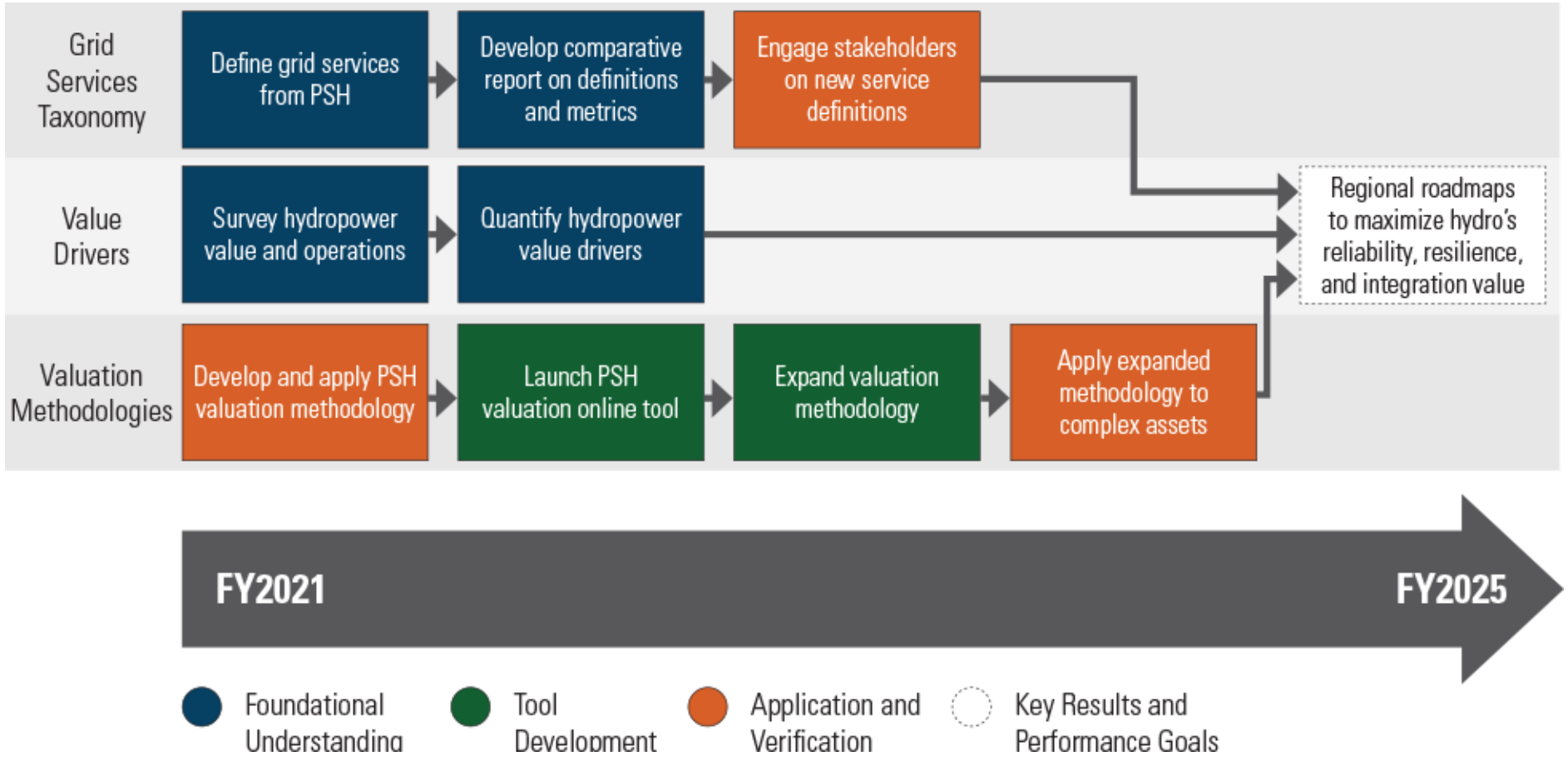
Technology Innovation

- Increase flexibility through technology innovation
- Develop PSH and hydropower hybrids

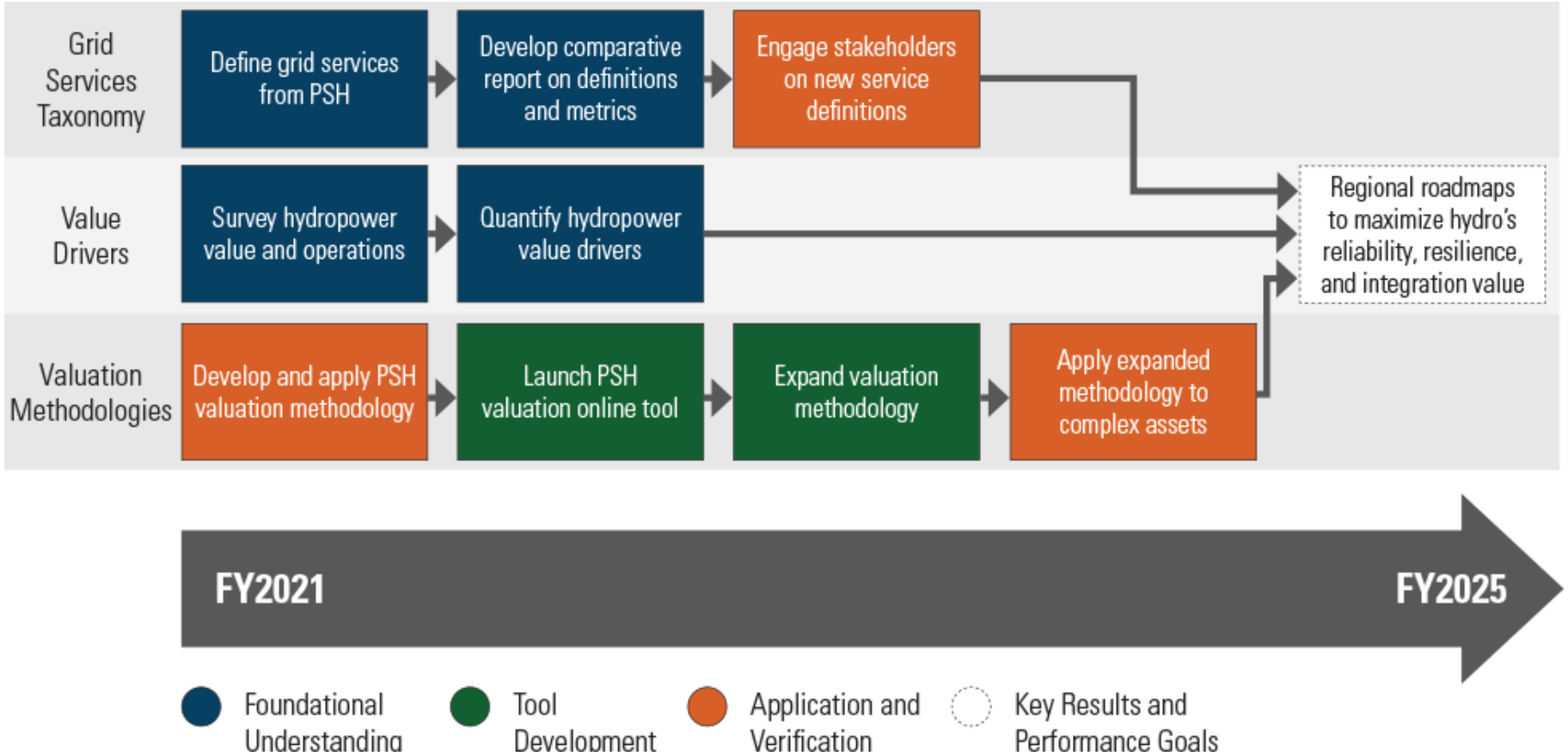
Value Under Evolving System Conditions



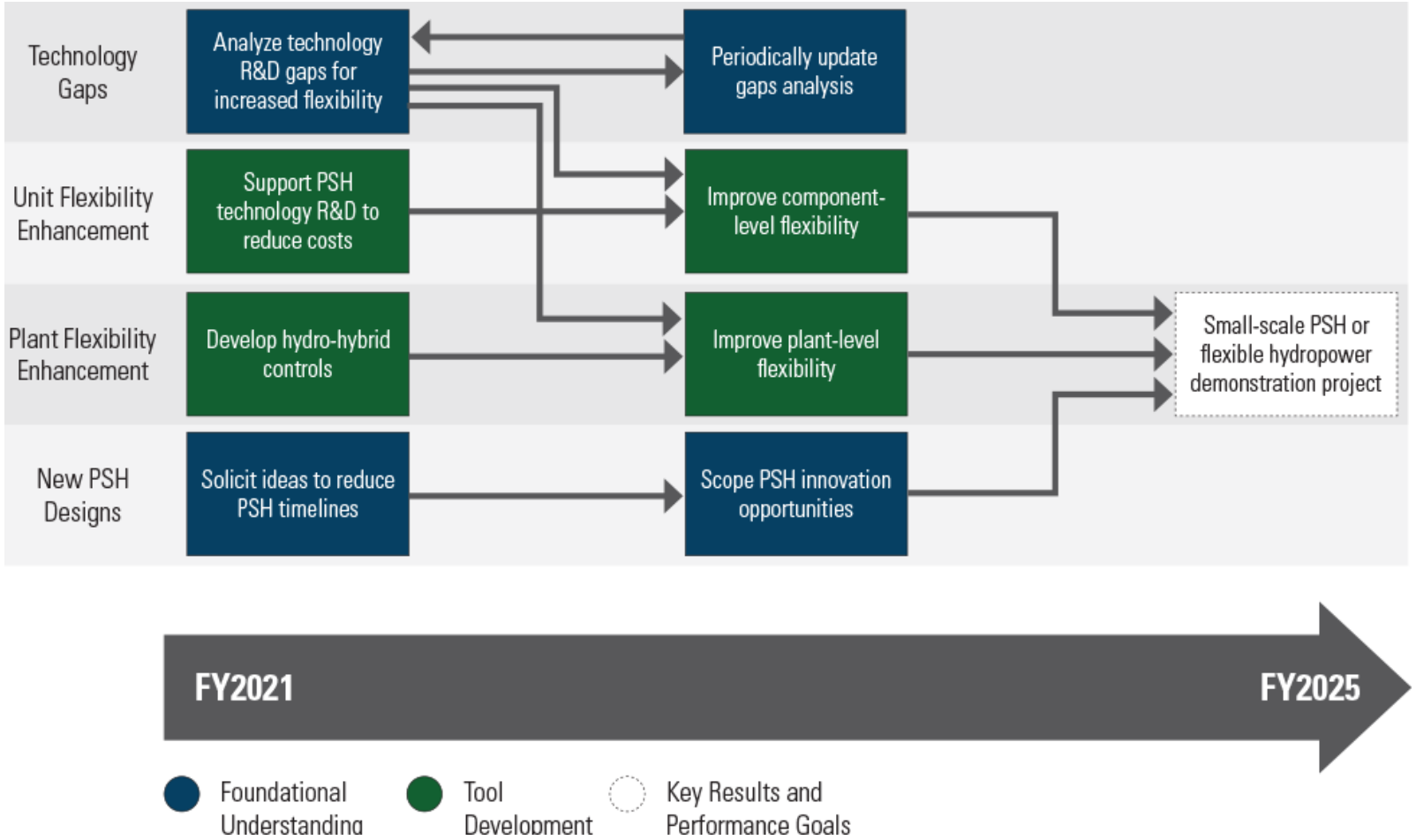
Capabilities and Constraints



Operations and Planning



Technology Innovation



Funding mechanisms we use for our work

- **Funding Opportunities:** FY18 PSH modeling and tech, FY19 operational flexibility, FY21 equipment flexibility
- **Lab Calls:** FY19 competitive, FY20 competitive+non-competitive, FY22 competitive with some continuing projects
- **Technical Assistance:** PSH valuation NOTA, FY21 NOTA, ad-hoc TA, FY22 lab-led TA currently being planned
- **Subcontracts:** Consultant white papers, water modeling, PSH cost estimators
- **Quick wins/seedlings:** more lab-led in FY19-20; more HQ-led in FY21+
- **Prize:** FAST prize for PSH designs, Hydropower Operations Optimization (H2Os) as our first data prize
- **SBIR:** PSH topic in FY22
- **Energy I-Corps:** Hydro+storage, GLIDES

Touch points with broader DOE and government

Existing:

- **EERE/OE grid initiatives:** Energy Storage Grand Challenge, RE Integration Plan
- **SETO:** Co-funding Eagle Creek hybrids and FPV lab projects, NARIS
- **WETO:** NARIS, GMLC projects
- **GTO:** Using HydroWIRES as rough model for grid program
- **SA:** Storage Futures Study, ReEDS enhancements, various NREL projects
- **LPO:** Exploring PSH finance mechanisms
- **PMAs, esp. WAPA:** Colorado River Storage Project renewables study
- **Reclamation:** Mt. Elbert PSH valuation
- **TVA:** Exploring PSH opportunities

Can do more with:

- **FERC:** Transmission-storage equivalence? Market design/compensation? Hybrids?
- **Army Corps:** Work with regional offices on modeling?

Implementation and Progress

Top Accomplishments in 2020-21

- First-of-a-Kind Tests Demonstrate How Small Hydropower Plants and Energy Storage Can Enhance Grid Reliability and Resilience National laboratories and local utility demonstrate how small hydropower and energy storage technologies can provide emergency power to communities during regional grid disruptions.
- New Guidebook and Tool Help Developers Calculate the Value of Potential Pumped Storage Hydropower Projects National laboratory team details approaches and develops a tool for developers and other stakeholders to value a full range of pumped storage hydropower services and contributions to the grid.
- National Labs Partner With General Electric To Understand Value of Pumped Storage Hydropower Under Increasing Renewables WPTO partners with General Electric to learn how pumped storage hydropower can accelerate the transition to a clean energy economy while helping to reduce local electricity costs.

Top Accomplishments in 2020-21

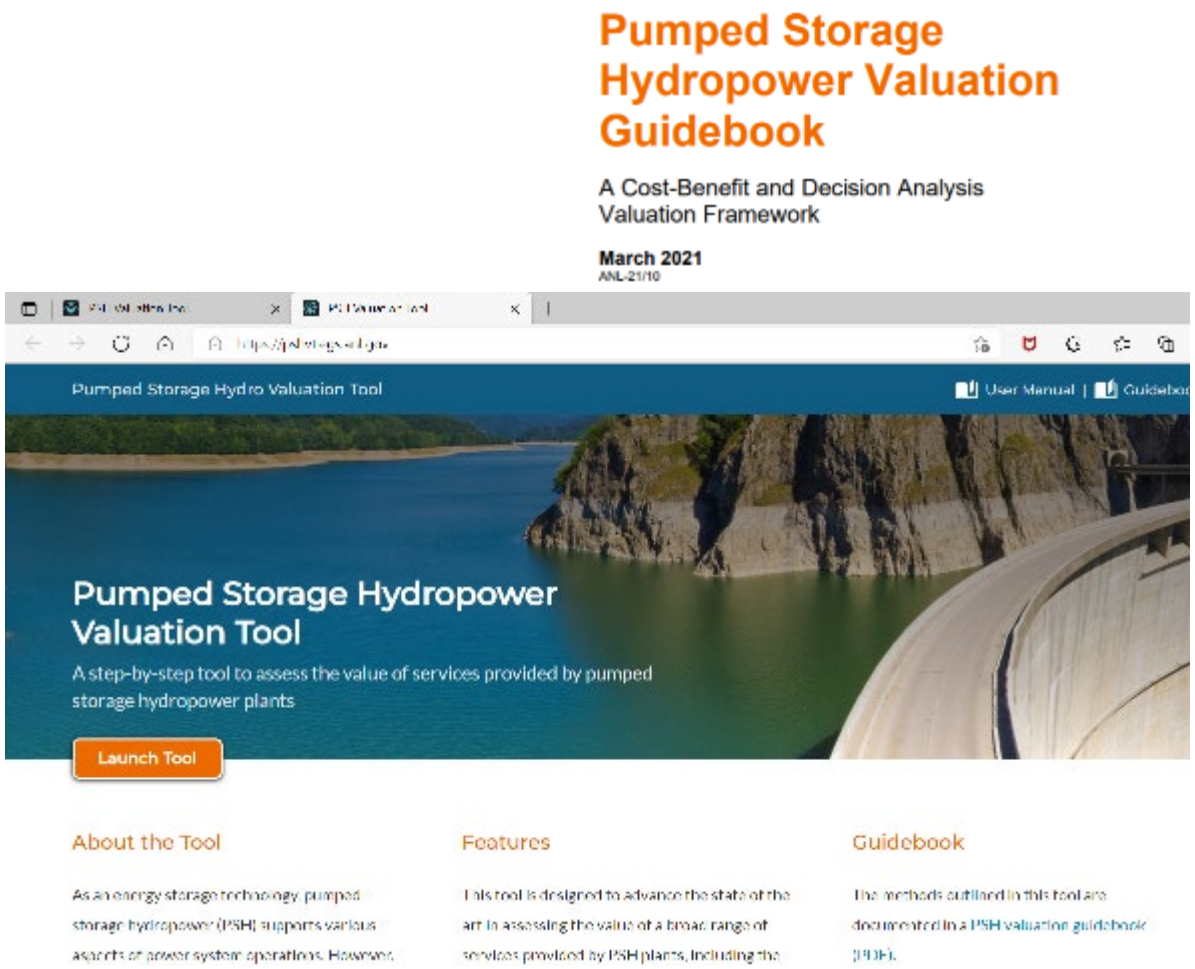
- New Report and Accompanying Toolkit Highlight Hydropower's Contributions to Grid Resilience - Researchers develop a report quantifying hydropower's contributions to grid resilience and release an accompanying framework and toolkit to allow stakeholders to assess hydropower's role under various extreme grid conditions.
- Oak Ridge National Lab Fills Critical Data Gaps in Hydropower Resource and Energy Storage Potential - Oak Ridge National Laboratory creates a centralized dataset that provides an overview of available resources at hydropower facilities and their energy storage potential.
- National Labs Identify Modeling Gaps in Studies Needed To Improve Understanding of Hydropower Capabilities - National laboratories develop report outlining ways to improve plant models to better represent hydropower's capability to support the electric grid.

Top Accomplishments in 2020-21

- New Study Assesses the Future of Renewables Across North America - Study reveals how cross-continental integration of large amounts of wind, solar, and hydropower could support a low-carbon future grid and quantifies system benefit of hydropower flexibility.
- U.S. National Laboratories Contribute to Global Information Sharing on Hydropower's Role in Transitioning to a Clean Energy System - National laboratories contribute to International Energy Agency report on the unique role hydropower plays in service to power systems around the world.
- National Laboratory and International Industry Organization Develop Recommendations To Enable Deployment of Pumped Storage Hydropower - Pacific Northwest National Laboratory partners with the International Forum on Pumped Storage Hydropower to develop a series of reports on pumped storage hydropower capabilities, costs, and innovations.

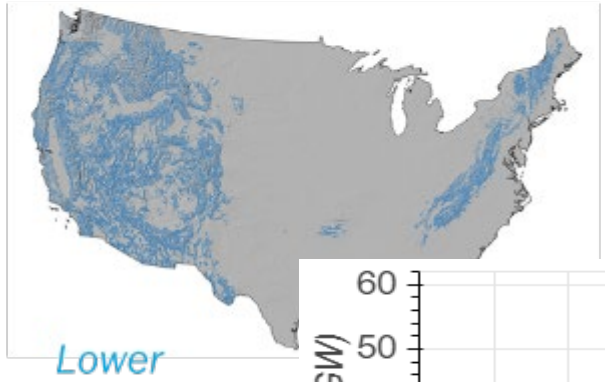
PSH Valuation Guidebook – How Is It Used?

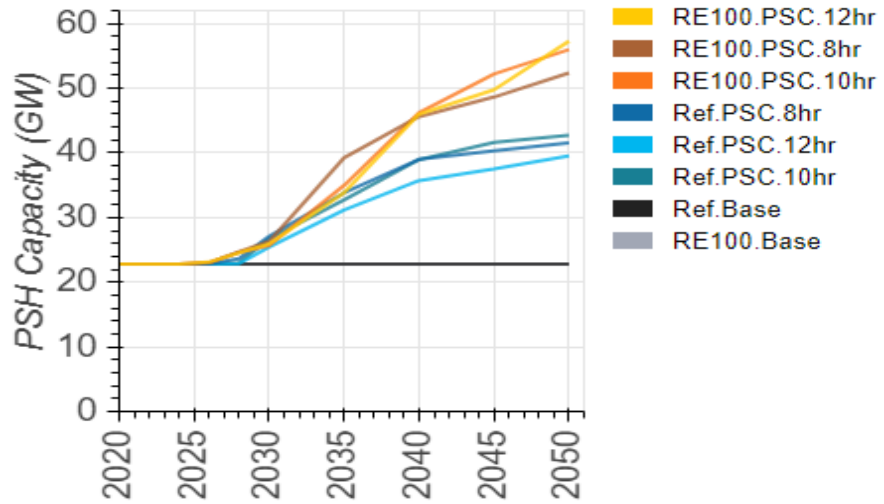
- Applied to Goldendale and Banner Mountain proposed PSH projects
- Applied to Reclamation's existing Mt. Elbert project, arising from Hydro MOU
- Applied to Alaska Railbelt study, based on IE collaboration
- Showing guidebook to TVA and Southern, getting feedback and further engagement



PSH Resource Assessment – How Is It Used?

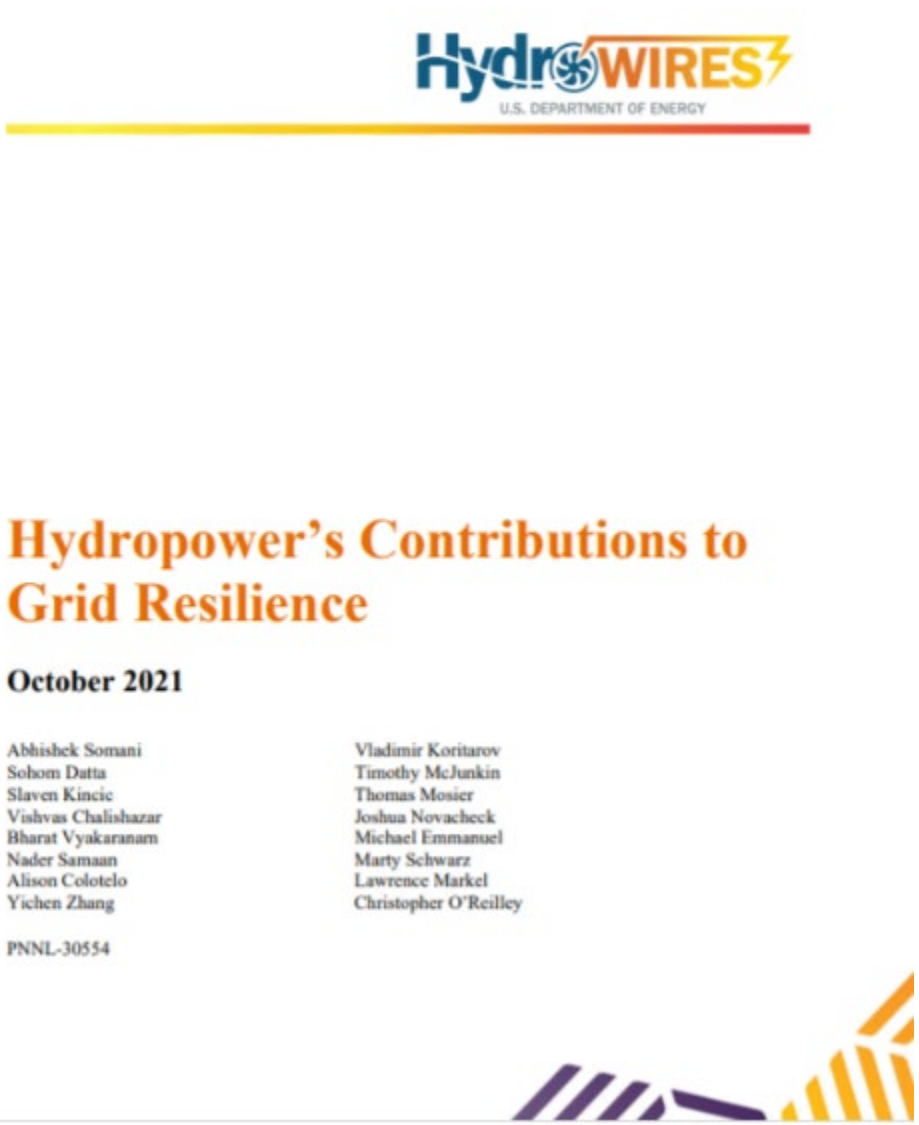
- First resource assessment DOE has done on PSH; previous studies used simplified estimates
- Will enable *all* users of ReEDS and other capacity expansion models to have detailed PSH site data for their buildouts





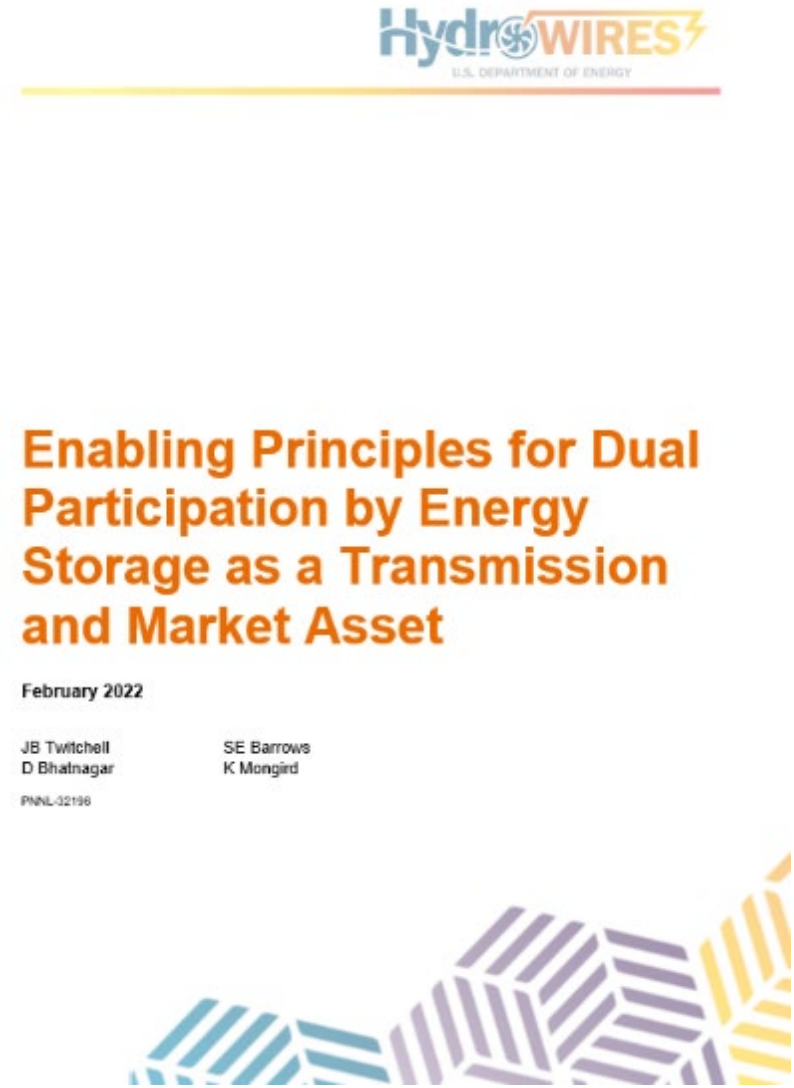
Hydro's Contributions to Grid Resilience – How Is It Used?

- USACE Walla Walla District is in discussions with PNNL to use framework from report to assess contribution of their dams to grid resiliency
- USACE Walla Walla District is helping to disseminate the report to relevant parties as they feel it is an important perspective on hydro that is not part of the current conversation



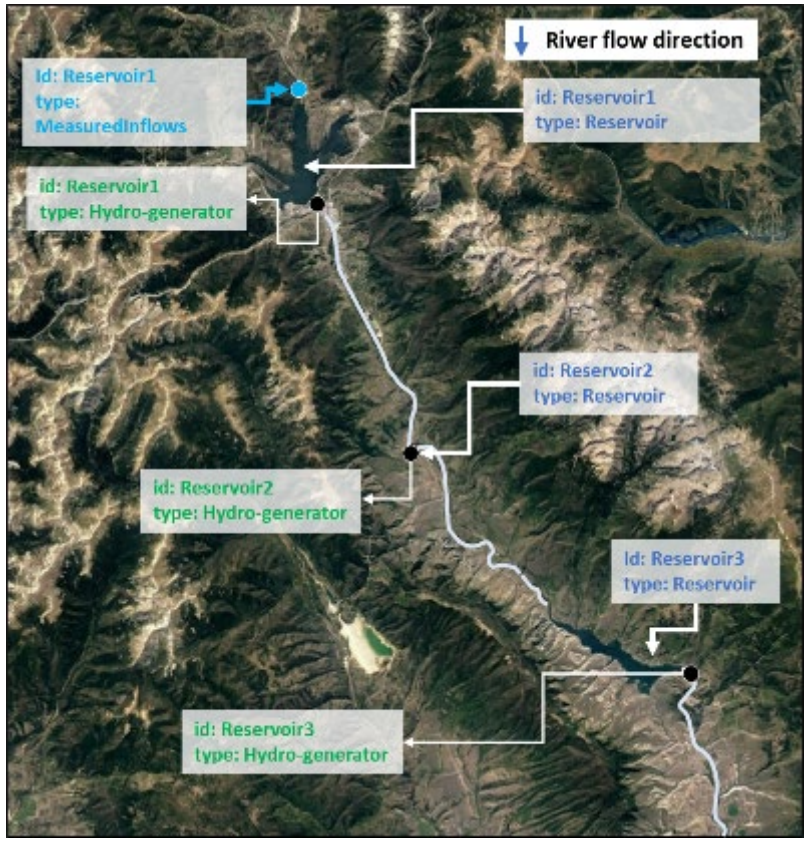
PSH as a Transmission Asset – How Is It Used?

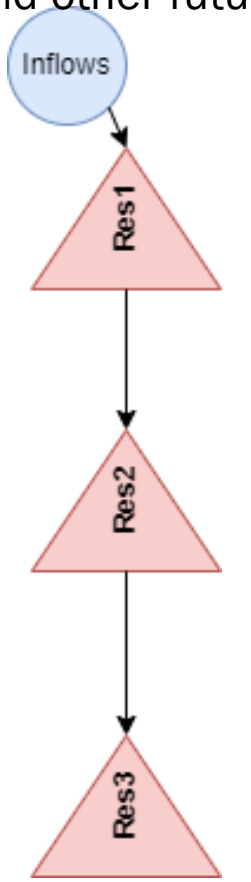
- Report was requested by multiple parties in February 2022 involved in the reopened MISO FERC proceedings on the topic of dual-use assets
- After presentation on a panel at WPW in 2021, NHA asked for a briefing and wrote up a Powerhouse article

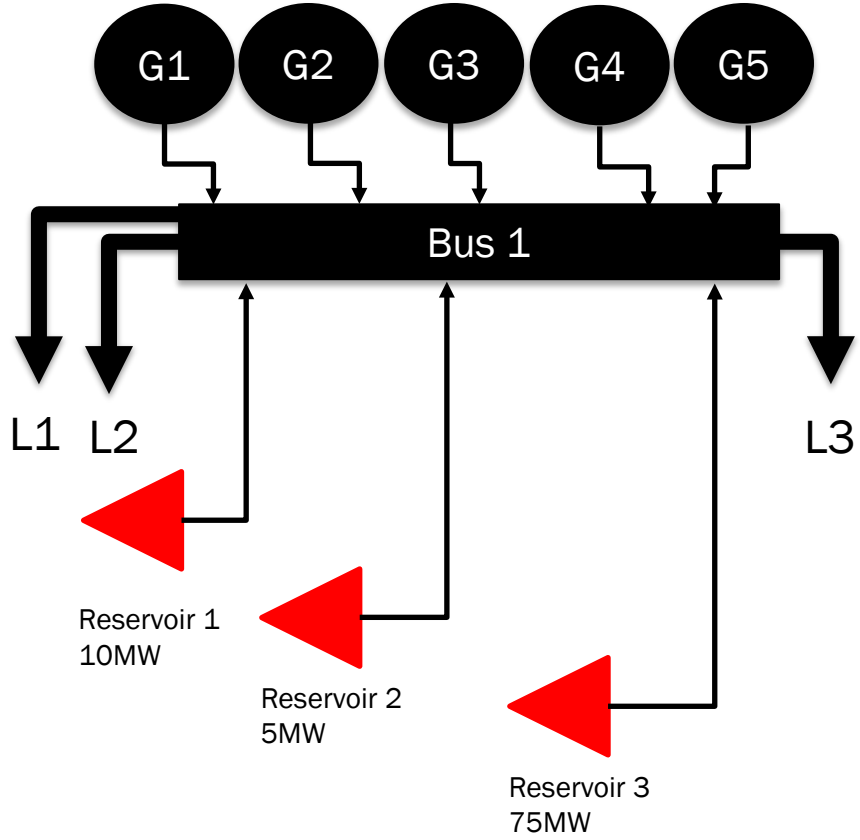


Hydropower Operations Optimization Prize (H2Os)

- As our first “data prize” in hydropower, H2Os asks competitors to optimize operations of a hydropower test system
- Winners share a $250k prize pool in successive stages
- We’re using this prize to encourage solvers outside the hydropower industry to get excited and involved, and potentially feed model improvements and other future work







H2Os Prize: Phase 1 Winners

- But stay tuned for Phase 2 – more $ and more complexity…

Submission	Location	New to WPTO?	Description	Approach	Solution Method
ajfarley99	University of Utah | Salt Lake City, UT	★	Mathematical optimization model implemented in Python (non-linear programming) and a visualization interface designed for convenient interaction of the users.	mixed-integer programming	co-simulation
tangwenyuan	North Carolina State University | Raleigh, NC	★	Market power analysis to determine desired power system market clearing results + numerical computation of release schedule with equilibrium formulation of constraints	linear interpolation	direct calculation
vassarlabs	Vassar Labs | Boston, MA	★	Uses a mixed integer and binary linear programming-based optimization approach to replicate real water and power grid systems and provide optimized solutions for their operation based on the objectives.	mixed-integer programming	co-simulation
mst_power	Missouri University of Science & Technology | Rolla, MO		Modeled mass balance and reservoir capacity to capture the physical constraints and used a 14-day optimization horizon to avoid myopic decisions. Supplemented with optimization models.	equilibrium modeling	optimization
yypark	Entrepreneur | Austin, TX	★	The submitted approach is a combination of utilizing a power system analysis open-source package (power system part) and implementing mass-balance equation of reservoir system (water system part) to decide an optimum release schedule for hydropower generation.	mixed-integer programming	co-simulation
sungkwang	Mississippi State University | Mississippi State, MS	★	Employed dynamic programming to optimize the power dispatch schedule of given hydropower generators. Used a simple scalar to control the water release to achieve the best economic and environmental benefit while avoiding the physical constraints.	dynamic programming	optimization
mathsitect	Entrepreneur | Houston, TX	★	Linear dependence of the power generated by a hydropower plant on the head of the reservoir. Increasing the outflow linearly with time as the head is decreasing to maintain equilibrium and achieve maximum power output. Increases outflow when demand is high and decreases when demand is low	linear interpolation	direct calculation
	ver New		Incorporate a smooth nonlinear objective type with bound and linear constraints. Uses heuristic problem-based approach to simulate the multivariable optimization problem.	heuristic	direct calculation

New HydroWIRES FOA projects selected in May 2022

•**General Electric Research's "Increasing Operational Flexibility of Existing Hydropower through Non-Intrusive Feedback Control and Hybridization."** *(Award amount: $3,000,000)* This project seeks to develop a cost-effective and easy-to-implement method to increase hydropower units' ability to ramp electricity generation up and down using non-intrusive sensors and other tools that do not require replacement of large equipment. The team will also develop strategies such as combining hydropower with batteries and implementing operational improvements for pumped storage hydropower. The project team estimates approximately 80% of U.S. electricity capacity from hydropower could apply these methods and strategies to enhance plant operations. Partners on this project include General Electric Company, Eagle Creek Renewable Energy, and First Light Power.

•**Littoral Power Systems, Inc.'s Turbine/Generator Upgrade System with Control Suite for Increasing Hydropower Plant Flexibility."** *(Award amount: $3,080,020)* This project aims to design, build, and field test a rapidly deployable upgrade system for existing hydropower plants. The system consists of a novel pump-turbine that can be added to existing dams that, along with associated controls and software, will enhance a plant's ability to adjust electricity output while decreasing wear and tear on equipment. Partners on this project include Littoral Power Systems, Inc., Penn State University's Applied Research Laboratory, Electric Power Research Institute, American Electric Power, Hydro Performance Processes Inc., McCullough Consulting LLC, Norm Bishop Consulting LLC, Clear Energy Hydro, and HydroDyne Energy.

•**Oregon State University's "Hybrid Hydropower-Storage Units for Greater Operational Flexibility."** *(Award amount: $1,930,909)* This project's goal is to demonstrate and quantify the value of a hybrid hydroelectric-storage generation unit, which combines a hydropower unit that does not have storage capability with supercapacitors. This project will involve the construction of a 200 kW lab-based hybrid hydroelectric-storage generation unit that will serve as a testbed for performance analysis and model validation. The project team will then develop a high-resolution, real-time, wide-area grid model to investigate the benefits – which can include improvements to response time, ramp rate, active and reactive power capability and flexibility, and virtual inertia – and challenges arising from large-scale integration of hybrid hydropower and energy storage units.

International Forum on Pumped Storage Hydropower (IFPSH)

- Kicked off in November 2020, the IFPSH is a government-led multi-stakeholder platform to shape and enhance the role of PSH in future power systems.
- DOE and IHA serve as co-chairs of the forum.
- Working groups and industry leads within the forum include:
  - Policy and Market Frameworks (GE Renewables)
  - Sustainability (EDF Hydro)
  - Capabilities, Costs, and Innovation (Voith Hydro)
- Concluded in November 2021, presenting results at the World Hydropower Congress

Pumped Storage Hydropower International Forum

EDF

VOITH

WPTO Involvement in Other Hydropower International Efforts

- Sam Bockenhauer is Chair of the IEA Hydropower Technology Collaboration Programme (TCP)
  - Annex IX: Hydropower services
  - Annex XIII: Hydropower and fish
  - Annex XVI: Hidden Hydro
- US-Norway MOU on Hydropower R&D
  - Optimization and Modeling
  - Digitalization and Modernization
  - Environmental Performance
- IRENA Hydropower Collaborative Framework

IEA

HydroCen
NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

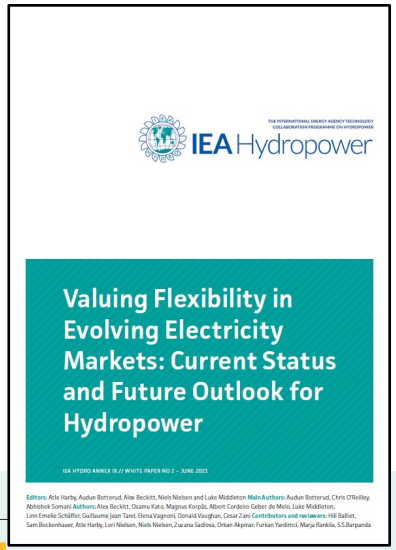
IRENA
International Renewable Energy Agency

International Perspectives Can Help Show Value of US Hydro

1. Hydropower is an important contributor to essential reliability services
2. Mechanisms for procurement and compensation of grid services vary across countries
3. Lack of market signals for long-duration storage
4. Stored energy is presently compensated through markets for reserve and energy products
5. Market rules and regulations can distort market-based arbitrage signals for storage
6. New market opportunities for flexibility services are emerging
7. Flexibility services require increased cycling, which leads to accelerated wear and tear
8. Long-term contracts offer stability but mask the true cost and value of flexibility
9. Standardized product definitions facilitate efficient use of resources across different markets
10. Transmission capacity is a key enabling factor for hydropower

IEA Hydro TCP:
https://www.ieahydro.org/annex-ix-hydropower-services

IEA Hydropower Special Market Report
https://www.iea.org/reports/hydropower-special-market-report



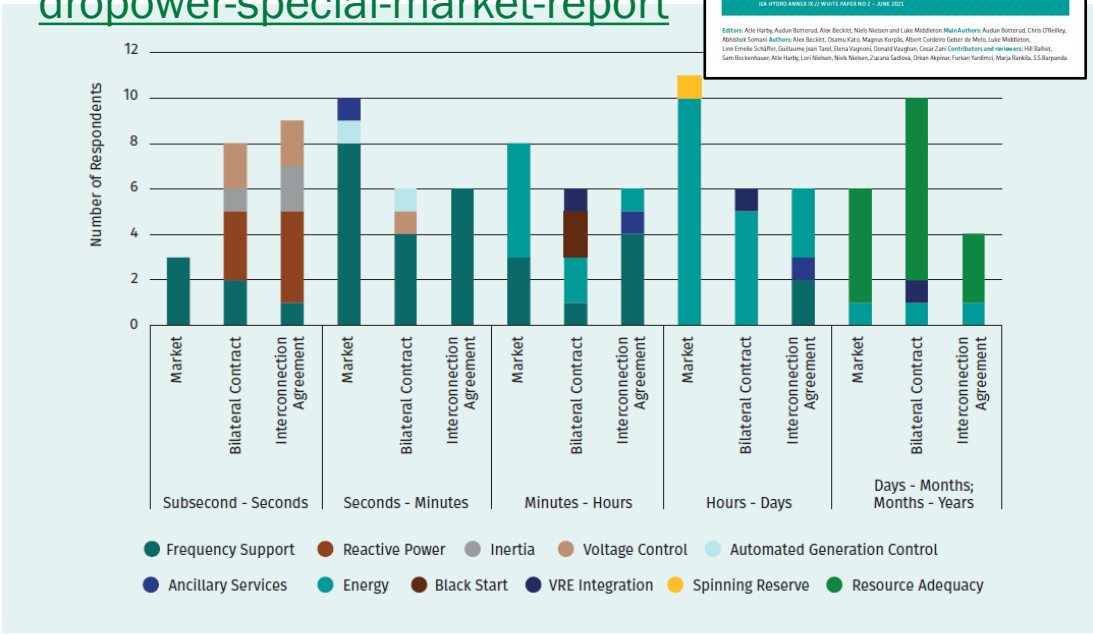


Figure 4. *Response summary of procurement methods by timescale, as reported by survey responders.*

HydroWIRES Future Work

- Hydropower Futures Study
  - Comprehensive, national-scale study on hydropower and PSH's evolving role in the power system and future potential, taking advantage of significant modeling enhancements, and including technology opportunities.
  - After the publication of the study, next steps would be the development of regional roadmaps—developed through extensive stakeholder workshops—to map out the opportunities for hydropower in different geographic, hydrologic, and market regions of the US.
- PSH Valuation Guidebook Technical Assistance
  - Continue and expand technical assistance to PSH developers based on the PSH valuation guidebook
  - Discussions with industry and previous opportunities suggest strong interest from the community
- Hydropower Hybrids Demonstrations
  - Building on existing National Lab efforts, demonstrate new hydro+storage configurations for increased revenue, reduced cost, environmental mitigation, and other purposes, as well as multi-resource configurations such as floating PV and hydrogen storage.
  - Parallel efforts could include federal partnerships for hydro+storage at federal facilities or NPDs

HydroWIRES Reviewer Introductions

Tom Acker, *Review Panel Lead*
Sr. Principal Research Engineer, Salt River Project

Bente Brunes
Head of Project Management Office, Rainpower

Elaine Hart
Founding Principal, Moment Energy Insights LLC

Debbie Mursch
Director of Business Development, GE Renewable Energy Hydro

Prize Reviewers

Donna Vincent Roa, *Prize Reviewer*
Partnership Director, USAID's Partnerships Incubator, The Kaizen Company

Sally Gutierrez, *Prize Reviewer*
Senior Advisor, Center for Environmental Solutions & Emergency Response Office of Research & Development, U.S. Environmental Protection Agency

Craig Connelly, *Prize Reviewer*
Director of Research and Development, New York State Energy Research and Development Authority (NYSERDA)

Schedule Overview – July 26

START (ET)	END (ET)	PRESENTATION TOPIC	ORGANIZATION	SPEAKER
10:00 AM	10:40 AM	HydroWIRES Initiative Overview	WPTO	Sam Bockenhauer
10:40 AM	11:05 AM	Hydropower Flexibility Framework	Electric Power Research Institute, Inc.	Francisco Kuljevan
11:05 AM	11:30 AM	Increasing Operational Flexibility of Francis Turbines at Low Head Sites, Through Analytical and Empirical Solutions	GE Renewable Energy Hydro	Guillaume Rudelle
11:30 AM	11:40 AM	**BREAK**		
11:40 AM	12:05 PM	Exploring Multidimensional Spatial-Temporal Hydropower Operational Flexibilities by Modeling and Optimizing Water-Constrained Cascading Hydroelectric	Stevens Institute of Technology	Lei Wu

Schedule Overview – July 26 continued

12:05 PM	12:30 PM	Identifying Hydropower Operational Flexibilities in Presence of Streamflow and Net-Load Uncertainty	University of California, Irvine	Soroosh Sorooshian and Bita Analui
12:30 PM	1:00 PM	**LUNCH BREAK**		
1:00 PM	1:25 PM	Geomechanical Pumped Storage	Quidnet Energy Inc.	Howard Schmidt
1:25 PM	1:50 PM	Modeling And Optimizing Pumped Storage in A Multi-Stage Large Scale Electricity Market Under Portfolio Evolution	University of Missouri System	Rui Bo
1:50 PM	2:15 PM	Value And Role of Pumped Storage Hydro Under High Variable Renewables	GE Power	Christina Bisceglia
2:15 PM	2:40 PM	Predicting Unique Market Pumped Storage Significance (PUMPSS)	Electric Power Research Institute, Inc.	Aidan Tuohy
2:40 PM	3:00 PM	**Reviewer Debrief**	**Reviewers**	

Schedule Overview – July 27

START (ET)	END (ET)	PRESENTATION TOPIC	ORGANIZATION	SPEAKER
10:00 AM	10:30 AM	FAST Commissioning Prize for Pumped Storage Hydropower	NREL	Tessa Greco
10:30 AM	10:55 AM	PSH-TES Tool	PNNL, ANL	Mark Weimar, Patrick Balducci
10:55 AM	11:20 AM	HydroWIRES Topic D1: CEM Enhancements	NREL	Stuart Cohen
11:20 AM	11:30 AM	**BREAK**		
11:30 AM	11:55 AM	Value Drivers Quantification	ANL, NREL, PNNL	Todd Levin

Schedule Overview – July 27 continued

11:55 AM	12:20 PM	HydroWIRES Topic A: Environment-Flexibility Win-Wins	ORNL	Brenda Pracheil
12:20 PM	1:00 PM	**LUNCH BREAK**		
1:00 PM	1:25 PM	PSH Portfolio Evaluation and Innovation Study	ANL	Vladimir Koritarov
1:25 PM	1:50 PM	Life Cycle Assessment of Storage Technologies	NREL	Greg Stark
1:50 PM	2:15 PM	Scope Improvements to Power Flow and Stability Models	PNNL	Slaven Kincic
2:15 PM	2:30 PM	**Reviewer Debrief**	**Reviewers**	

Schedule Overview – July 28

START (ET)	END (ET)	PRESENTATION TOPIC	ORGANIZATION	SPEAKER
10:00 AM	10:25 AM	HydroWIRES Topic C: Quantifying Reliability/Resilience	PNNL, ANL, INL, NREL, ORNL	Abishek Somani
10:25 AM	10:50 AM	HydroWIRES Topic D2: Transmission/Storage Equivalence	PNNL, ANL	Jeremy Twitchell, Zhi Zhou
10:50 AM	11:15 AM	Idaho Power Run-of-River Hydropower and Battery Modeling	PNNL	Feng Pan
11:15 AM	11:25 AM	**BREAK**		
11:25 AM	11:50 AM	Hydropower Plant Controller Prototyping using Remote Hardware in the Loop	NREL	Mayank Panwar

Schedule Overview – July 28 continued

11:50 AM	12:15 PM	Integrated Hydropower and Energy Storage: Providing Essential Reliability and Ancillary Services using Individual or Coordinated Hydropower Plants	INL, NREL	Thomas Mosier, Vahan Gevorgian
12:15 PM	1:00 PM	**LUNCH BREAK**		
1:00 PM	1:25 PM	Hydropower Storage Capacity Dataset	ORNL	Carly Hansen
1:25 PM	1:50 PM	HydroWIRES Topic B1: Enhancing the Representation of Conventional Hydropower Flexibility in Production Cost Models	NREL, PNNL	Greg Stark, Nathalie Voisin
1:50 PM	2:15 PM	HydroWIRES Topic B2: Improving the Representation of Hydrologic Processes and Reservoir Operations in Production Cost Models	NREL, PNNL	Greg Stark, Nathalie Voisin
2:15 PM	2:40 PM	HydroWIRES Topic D3: Forecasting	PNNL, INL	Nathalie Voisin, Thomas Mosier
2:40 PM	3:00 PM	**Reviewer Debrief**	**Reviewers**	

Q&A