# Hydropower Flexibility and Environmental Tradeoffs Analysis

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Collaboration with multiple DOE national labs (ANL, ORNL, PNNL, INL) and institutions (Columbia River Inter-Tribal Fish Commission, RTI)

# Contents

# Grid services provided by Hydropower

| Grid Services | Grid Service Temporal Scale |
|---|---|
| Volt/VAR support | Continuous, <1 minute |
| Frequency regulation | Seconds to minutes |
| Spinning reserve | < 10 minutes |
| Non-spinning reserves | < 10 minutes |
| Load-following | Hourly plan, 5-10 minute |
| Replacement reserves | 60 minutes to 2 hours |
| System black start | As required |
| Firm capacity | As required |

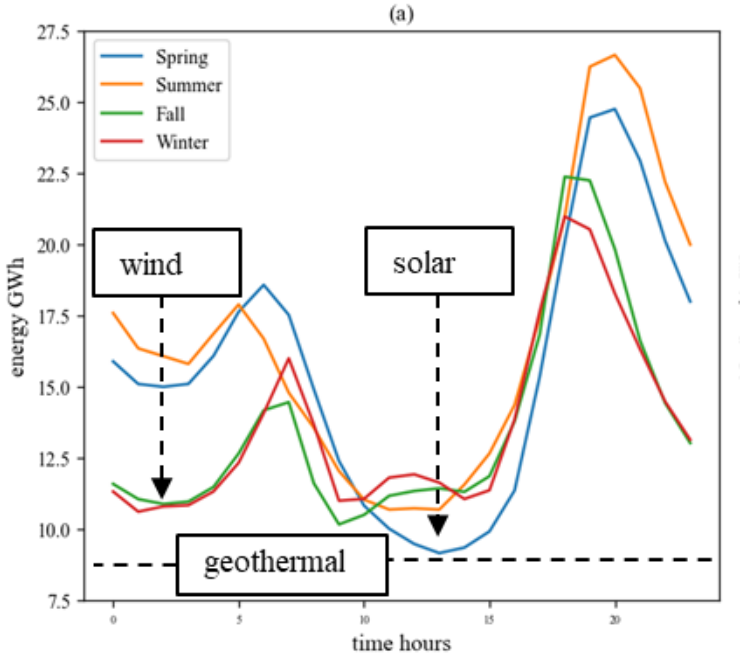


Fig. Seasonal average diurnal hydropower dispatch shape

- Hydropower generation can follow net load and complements variation in renewable generation
- Hydropower provides multiple power grid services, which is important due to growth in inverter-based technologies and associated reductions in thermal power plant output

# Many Considerations for Planning Dam Water Releases

- Habitat/ecological requirements/objectives
- Recreation and multiple water uses
- Water availability now and in the future
- Power generation
- Hydropower revenue

Photo credit: Dennis Schroeder/NREL, Brenda Pracheil, PNNL

# Energy – Environmental Tradeoffs

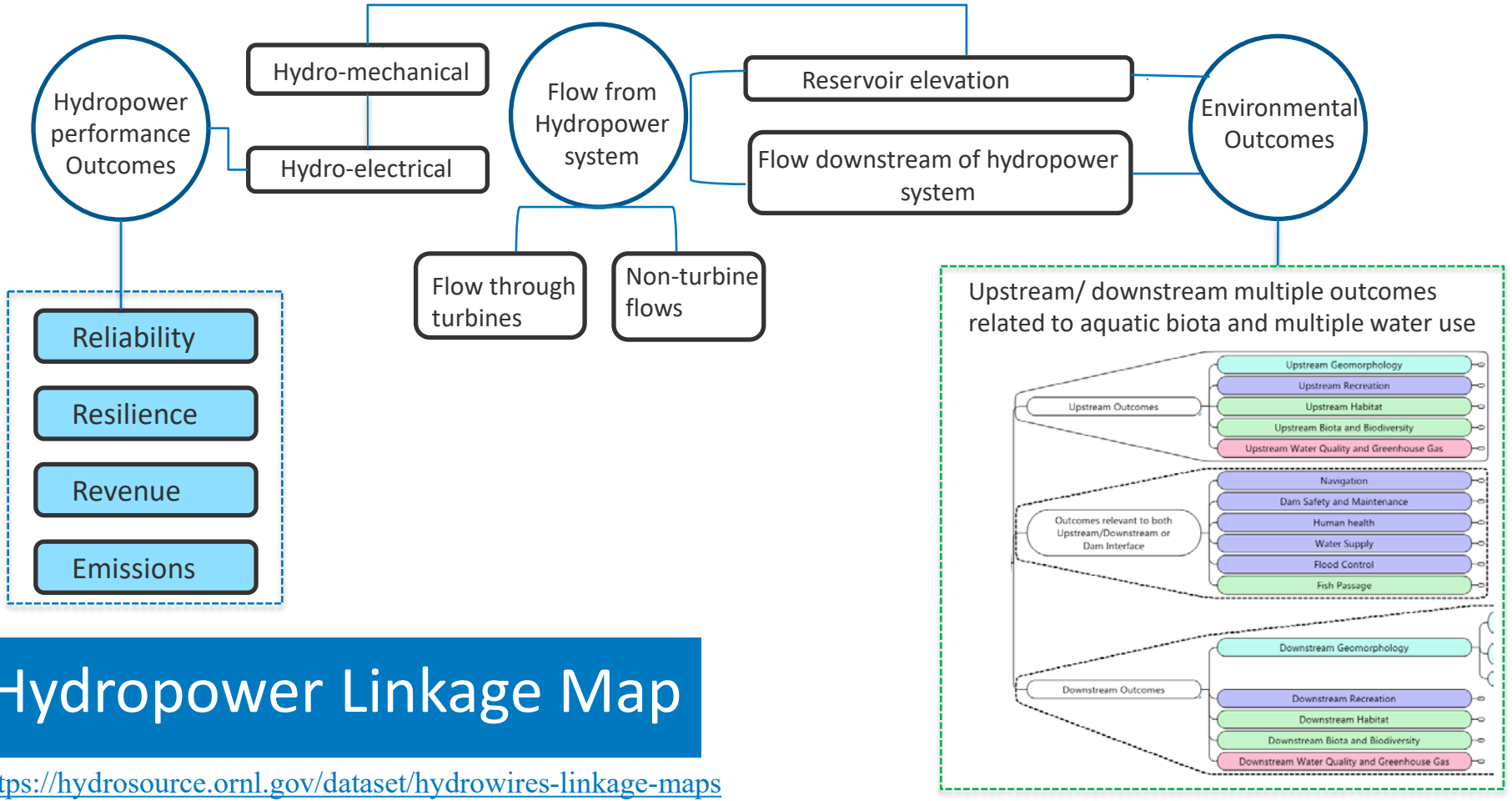
| Grid Services | Grid Service Temporal Scale | Minimum Flow | Prescribed Flow | Ramp Rate Restriction |
|---|---|---|---|---|
| Load-following | Hourly plan, 5-10 minutes |  |  |  |
| Volt/Var support | Continuous, <1 minute |  |  |  |
| Frequency regulation | Seconds to minutes |  |  |  |
| Spinning reserve | <10 minutes |  |  |  |
| Non-spinning reserve | <10 minutes |  |  |  |
| Replacement reserves | 60 minutes to 2 hours |  |  |  |
| System black start | As required |  |  |  |
| Firm capacity | As required |  |  |  |

 mild limitation

 moderate limitation

 significant limitation

*Prescribed flow is a set amount of flow for a set time period (e.g., 800 cfs from 8:00-15:00)*



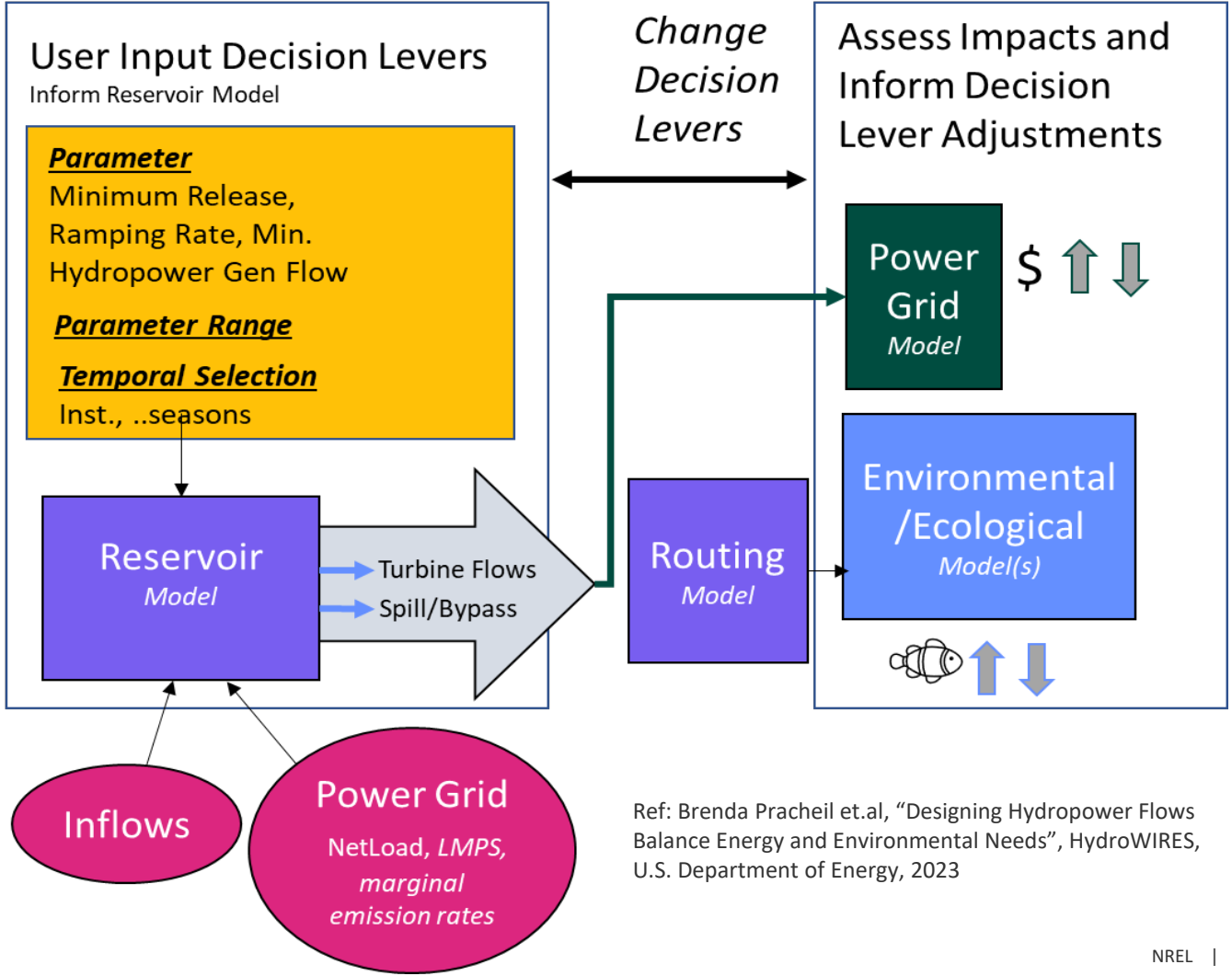

# Hydropower Linkage Map

https://hydrosource.ornl.gov/dataset/hydrowires-linkage-maps

Ref: Brenda Pracheil et.al, "Designing Hydropower Flows Balance Energy and Environmental Needs", HydroWIRES, U.S. Department of Energy, 2023

# Environment Energy Flexibility Evaluation Tool

New tools to evaluate hydropower for the changing power grid considering ecological water needs




Ref: Brenda Pracheil et.al, "Designing Hydropower Flows Balance Energy and Environmental Needs", HydroWIRES, U.S. Department of Energy, 2023

# Power Grid impacts for Fish-Friendly way of Operating Columbia River Hydropower Project

Case Study with Columbia River Inter-Tribal Fish Commission (CRITFC)

# Columbia River Basin Fish Passages

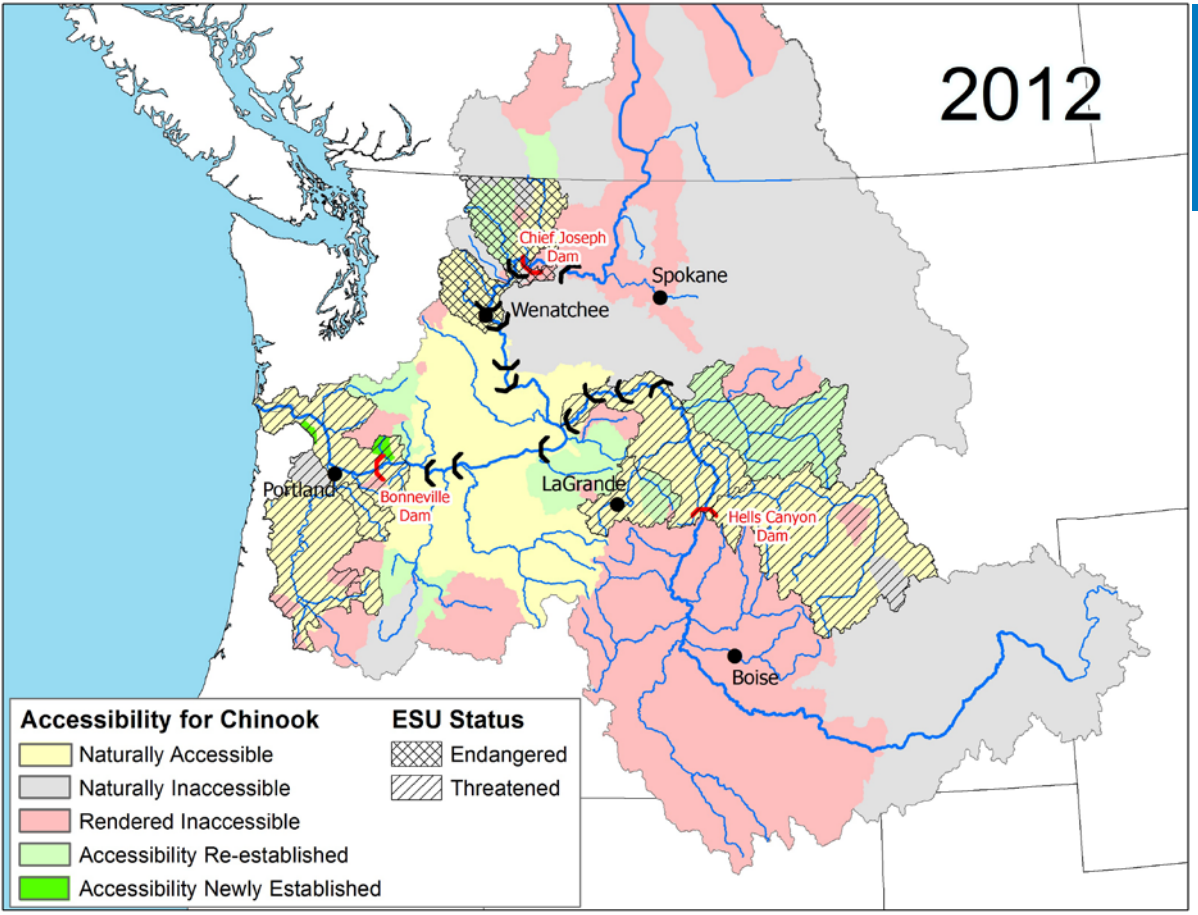



Fig: Year 2012 Chinook accessibility range analysis

- The Columbia River Treaty Tribes in the Pacific Northwest hold treaty-reserved fishing rights
- Accessible range for Chinook, salmon and steelhead species are after river flow augmented
- CRITFC energy vision includes recommendations to secure fish and treaty rights

Ref: CRITFC and NOAA Northwest Fisheries Science Center, https://www.youtube.com/watch?v=KpDGDyDARFo

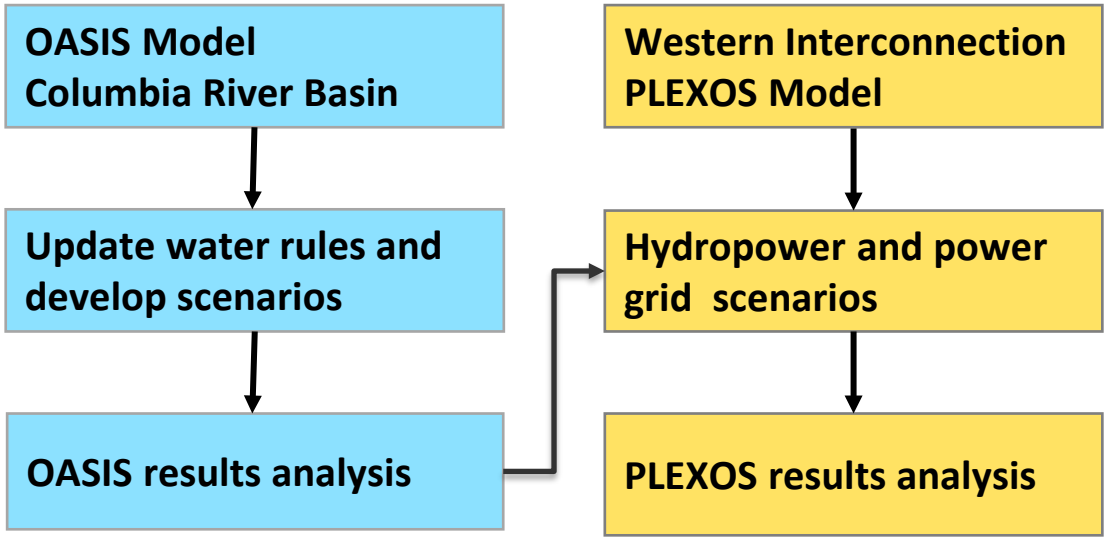
# What are the Grid Impacts of Reservoir Operating Water Rules?

Questions addressed in this analysis:

- How would fish-friendly water rules impact total grid operations costs, local marginal prices (LMP), reliability, transmission congestion, reserve shortages, or dropped load (if any)?
- How would hydropower generation patterns change with a higher variable renewable energy (VRE) power grid?
- How would different weather patterns and water rules impact power grid operations?

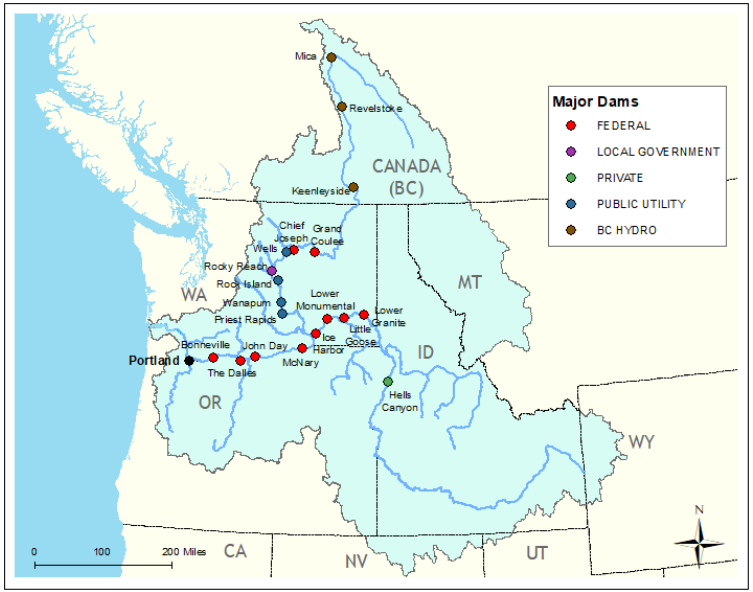
# Integrated Modeling Approach

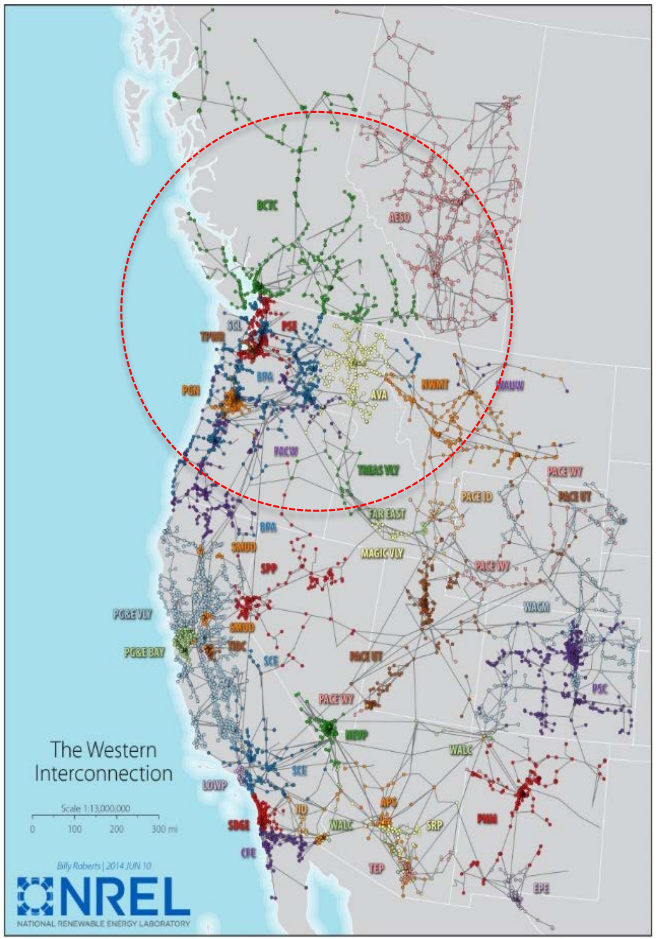
- An integrated water resource and power grid modeling approached was used
- CRITFC simulates Columbia River basin hydropower operations using a water resources planning tool, OASIS
- NREL simulates western interconnection grid operations using a production cost model, PLEXOS




Ref: Thushara De Silva et.al., “Fish Friendly Water Rules' Impact On the Power Grid with High VRE Levels”, NREL

# Integrating Water and Power Grid Model



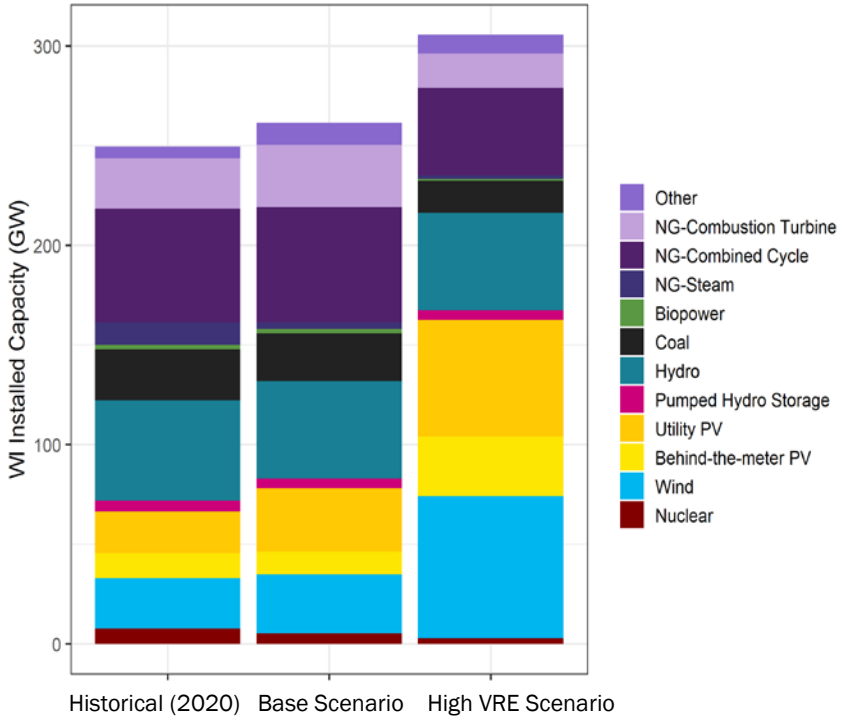




- CRB water model (OASIS) and Western Interconnection PCM (PLEXOS) are integrated and simulate water rules, weather variability and grid scenarios
- Detailed transmission modeling in Bonneville Power Administration (BPA) and neighboring region

# Study scenarios

- Current water rules and base grid
- Current water rules and HRE grid
- Ecosystem water rules and base grid
- Ecosystem water rules and HRE grid

Four scenarios are modeled with 2008-2013 weather years. (HRE: high renewable energy)

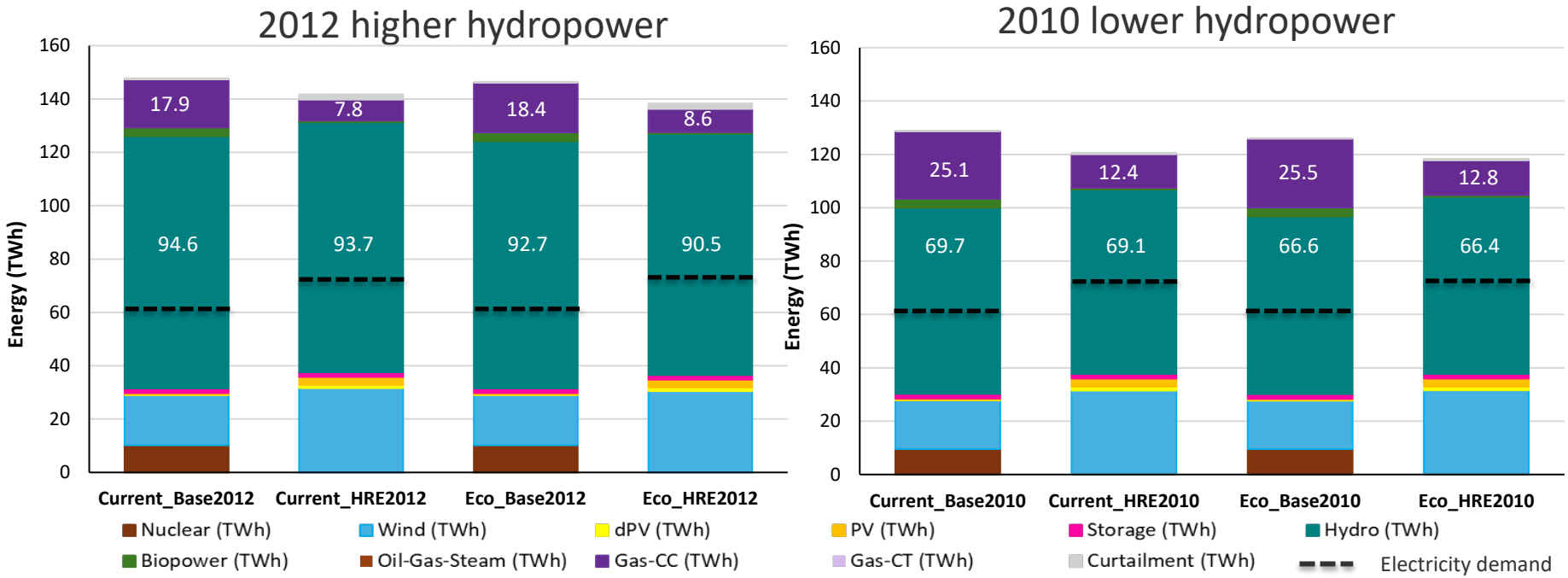



Capacity mix of grid scenarios

Wanapum Dam

Photo credit: Grant County Public Utility District

# Columbia river Basin: BPA generation mix

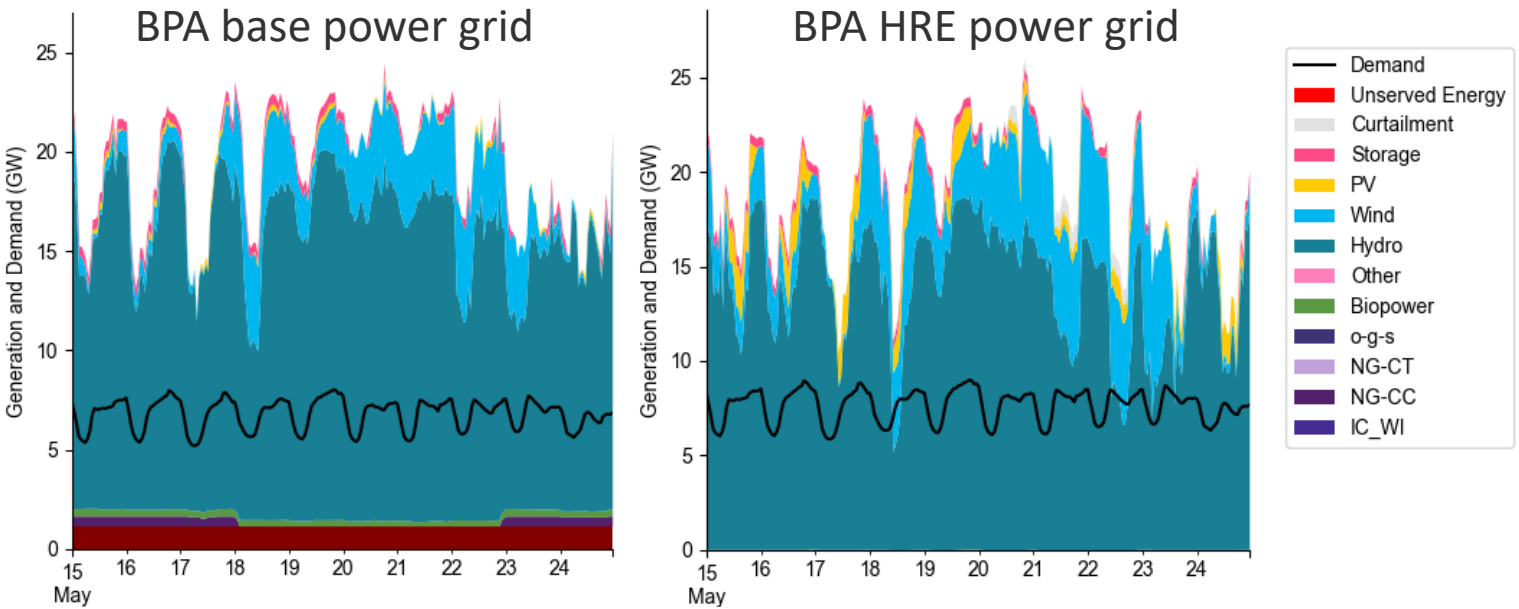



- Current and Ecosystem water rule scenarios have slight difference of total hydropower generation
- Low hydropower would increase gas combined cycle (CC) generation and total generation cost



Ref: Thushara De Silva et.al., “Fish Friendly Water Rules' Impact On the Power Grid with High VRE Levels”, NREL

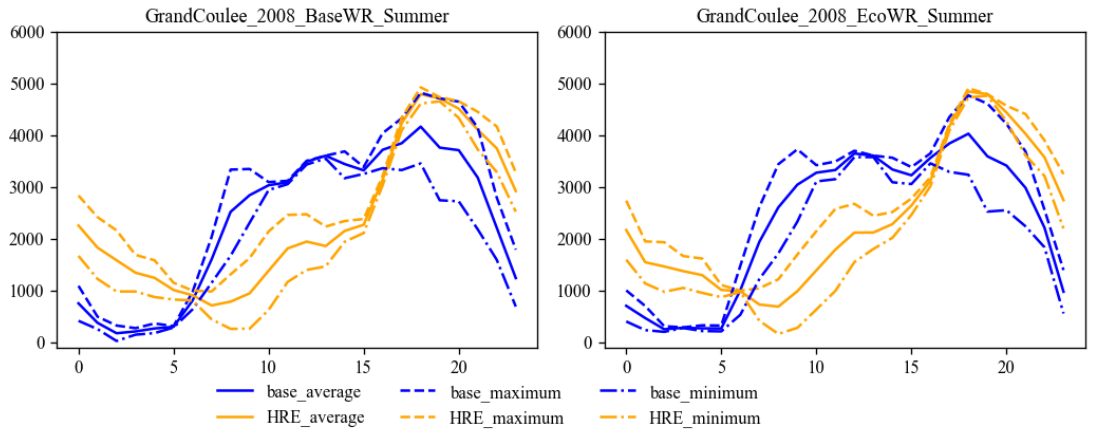
# Hydropower operation in high VRE power grid

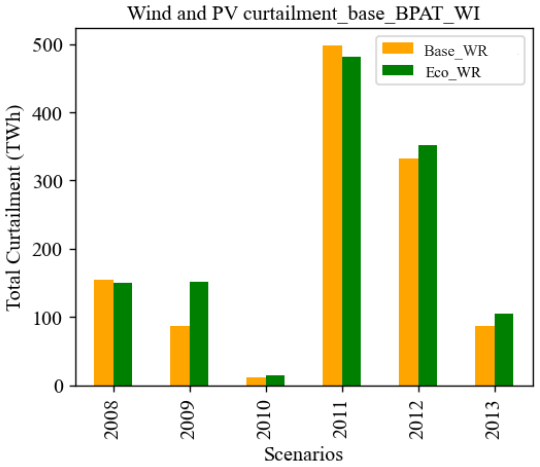



- Example of BPA hydropower dispatch for selected time window with generation differences for base and high variable renewable energy (VRE) grid scenarios
- Hydropower balance wind and solar variability while meeting environmental constraints

Ref: Thushara De Silva et.al., “Fish Friendly Water Rules' Impact On the Power Grid with High VRE Levels”, NREL

# Water Rules Impact on Power Grid




- No significant changes in hydropower flexibility between current and fish friendly water rules. Weather variability and generation resources mix make significant changes to the hydropower operation in the grid
- Wind and PV curtailment are not directly related to water rule scenarios. High hydropower generation years have higher wind and PV curtailment than low hydropower years

Ref: Thushara De Silva et.al., “Fish Friendly Water Rules' Impact On the Power Grid with High VRE Levels”, NREL

# Water rule impacts on grid operation

- Total operation cost varies -4% to 11% between current and Eco system rules
- Water rule scenarios impact prices, with prices varying between -2% -4%, High VRE scenario prices decrease by 7%-13% and Lower hydropower years increase prices by 22% -32% compared to higher hydropower years
- No transmission congestion, dropped loads, or reserve violations
- Grid has higher hydropower dispatch flexibility during Spring
- Ecosystem rules increase June, July hydropower generation, which could increase renewable curtailment

# Hydropower operation simulation inform many decisions

- Integrated modeling approaches for hydropower inform operational decisions, influence policies and strategies
- Power grid operation and water resources simulations help understanding hydrologic variability and constraints, water policy impacts on grid and hydropower capability to provide grid reliability services
- Long term water policy planning such as CRB fish-friendly water rules modeling indicate limited impacts on electricity system costs and reliability
- Integrated and iterative modeling of energy-water-ecology system can assist in resolving complexities in CRB hydropower planning

Fig. The ideal clean energy marriage of hydropower and wind power in the Pacific Northwest.
Photo credit: MWH Global

# References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# Q&A

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