Pacific Northwest Regional Economic Conference

Does Matching Pumped Storage Hydropower with Offshore and Onshore Wind in Southern Oregon Make Economic Sense?
Part 1: Methodology

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Table of Contents

PROGRAM GOALS AND OBJECTIVES

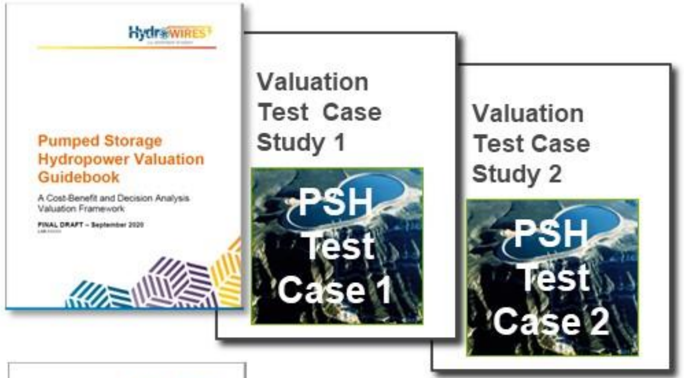
Objective: Advance the state of the art in the assessment of value of PSH plants and their role and contributions to the power system

Specific goals:

- Develop a comprehensive and transparent valuation guidance that will allow for consistent valuation assessments and comparisons of PSH projects
- Test the PSH valuation methodology by applying it to two selected PSH projects
- Transfer and disseminate the PSH valuation guidance to the hydropower industry, PSH developers, and other stakeholders
- Provide technical assistance to project sponsors

KEY PRODUCTS OF THE PSH VALUATION PROGRAM

- PSH Valuation Guidebook (published)
- Two technical reports illustrating test case studies for actual PSH projects (published)

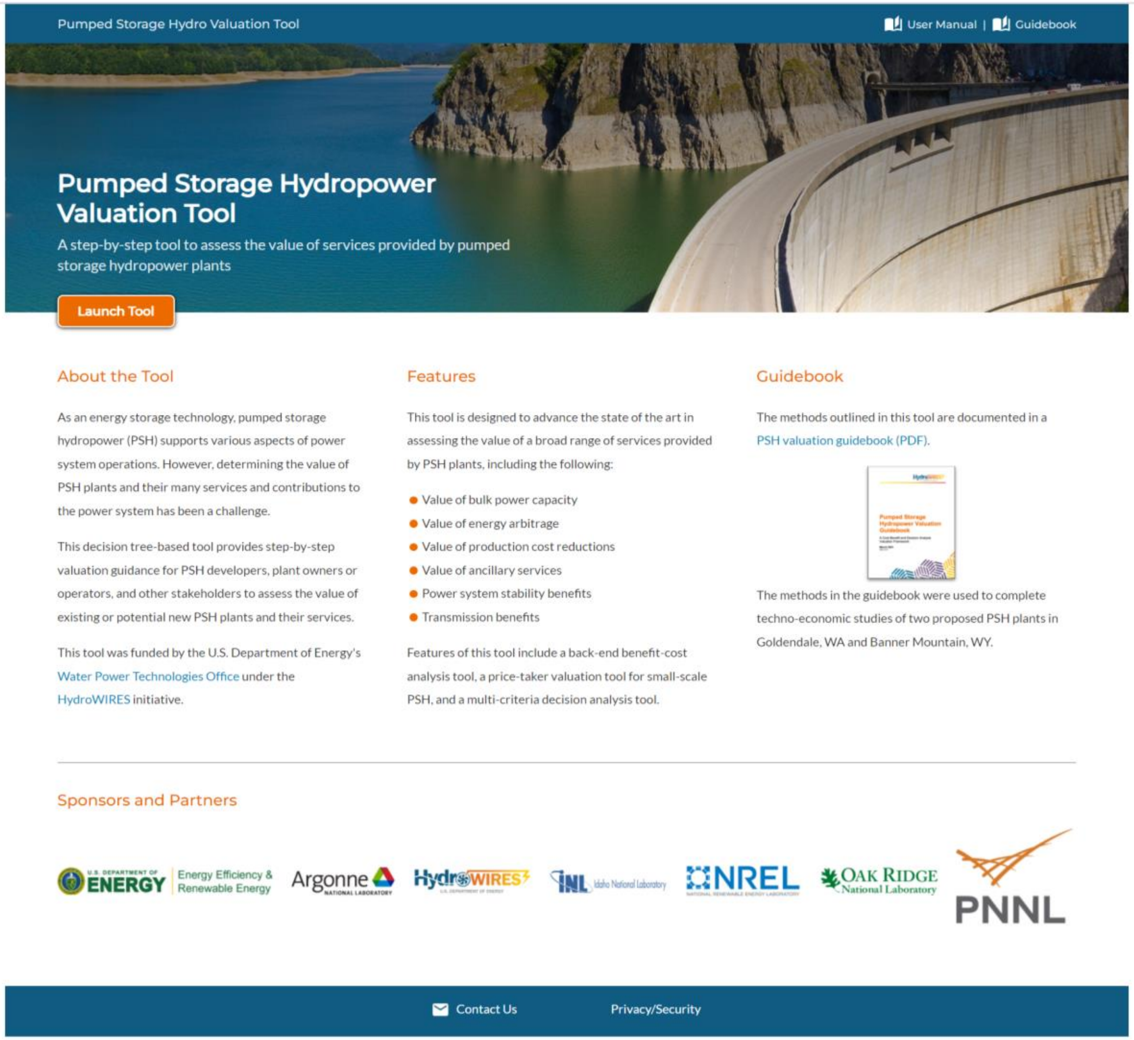


- Energy storage cost and performance study (published)

- PSH valuation tool to help the users navigate the PSH valuation process (https://pshvt.egs.anl.gov/)

PSH VALUATION TOOL

- PSH valuation tool (PSHVT) provides step-by-step valuation guidance for PSH developers, plant owners or operators, and other stakeholders
- PSH tool advances the state of the art in evaluating a broad set of use cases from three perspectives: owner/operator, system, and society
- PSH tool has several advanced features:
  - Embedded price-taker model
  - Multi-criteria decision analysis (MCDA) tool
  - Embedded financial worksheets and benefit-cost analysis (BCA) model
  - Embedded price-influencer model (A-LEAF)
- The PSHVT can be accessed at https://pshvt.egs.anl.gov/.



PSHVT Homepage

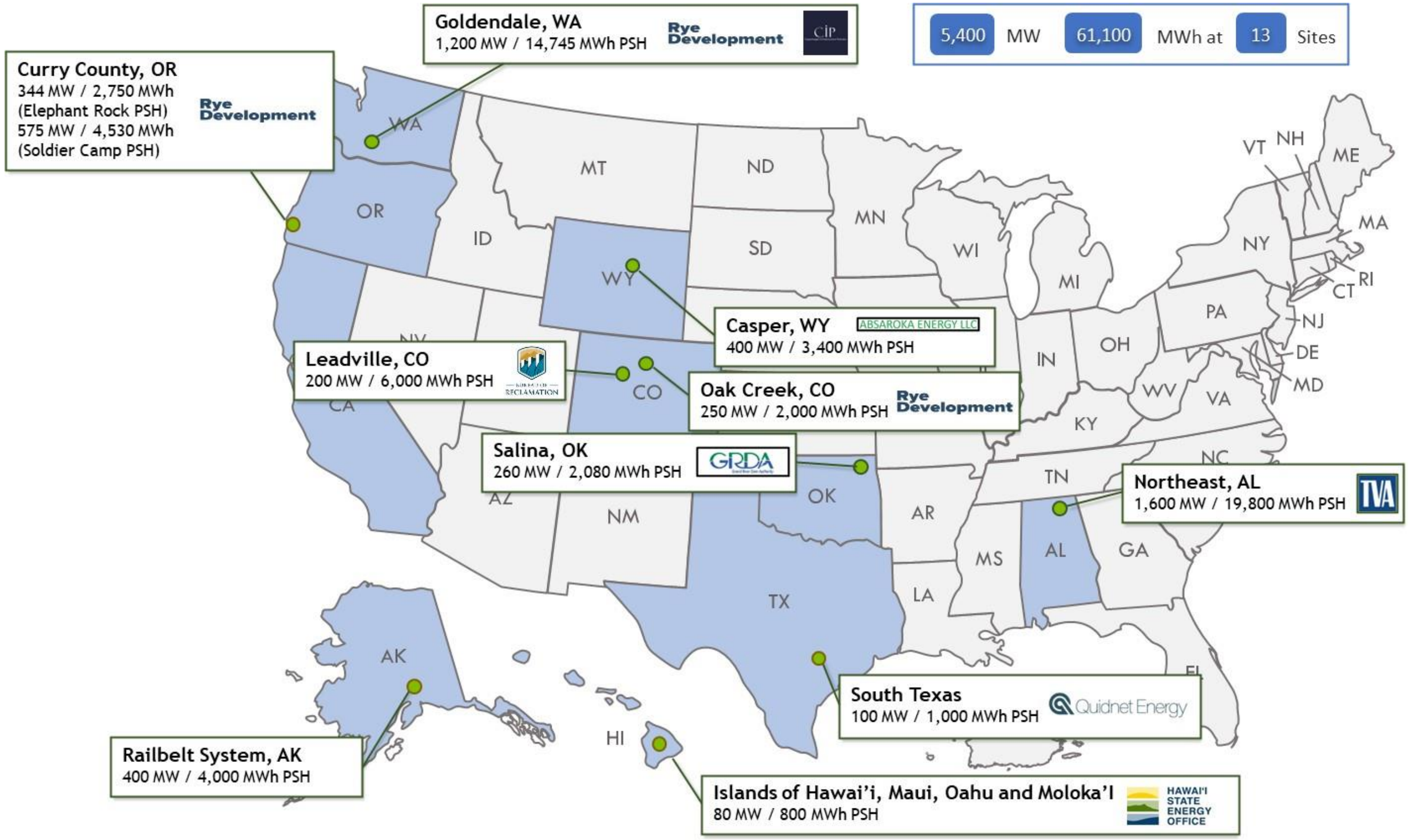
PRICE-INFLUENCER MODELING IN THE PSHVT

- A-LEAF is embedded as an option
  - Users can choose the current approach for estimating PSH values using multiple external tools or select the A-LEAF option
- Data
  - Users can use the default national scale dataset provided in A-LEAF
  - The tool supports users as they define input data for their own analysis
- Alternative Scenarios
  - Natural gas prices and technology costs
  - Environmental policies and tax credits
  - 134 balancing areas around US
- Use Cases
  - A-LEAF is customized to support several use cases in the PSH valuation tool

Category	Price-taker	Price-Influencer	
		System	Owner-Operator
Bulk Energy	Energy Arbitrage		Energy Arbitrage
	Capacity	Capacity	Capacity
Ancillary Services	Frequency Regulation	Frequency Regulation	Frequency Regulation
	Spin/Non-Spin	Contingency Reserve	Contingency Reserve
		Flexibility Reserve	Flexibility Reserve
			Black Start Service
Transmission and Distribution Services	Transmission Congestion Relief	Transmission Congestion Relief	
	Volt-VAR	Upgrade Deferral	
	Upgrade Deferral		
Customer Energy Management	Power Reliability		
	Behind-the-Meter Charge Management		
Indirect System Benefits		Reduced Electricity Generation Costs	
		Reduced Curtailment of Variable Generation	
		Reduced Outages	
		Reduced Ramping of Thermal Units	
		Fuel Savings and Diversification	

Use Cases Evaluated in the PSHVT

PUMPED STORAGE HYDRO TECHNICAL ASSISTANCE WORK AT ARGONNE NATIONAL LABORATORY



Technoeconomic Studies of Pumped Storage Hydro with Offshore and Onshore Wind Located on the So. Oregon Coast

Technology Summary

- Rye Development has obtained FERC preliminary permits at two proposed pumped storage hydro (PSH) sites in Southwest Oregon: Soldier Camp PSH project, with 575 MW or 4,600 MWh of capacity.
- Rye requires assistance in conducting a power market study and grid stability analysis of the proposed PSH plants paired with large offshore wind (OSW) developments.

Rye Development Portfolio

Technology Impact

- Ideal opportunity to demonstrate the value of paired PSH+OSW investment.
- Site development would have large economic development & grid benefits.

Key Idea/Takeaway

This research will advance commercial opportunities for paired PSH+OSW in the U.S., PSHVT will serve as screening tool.

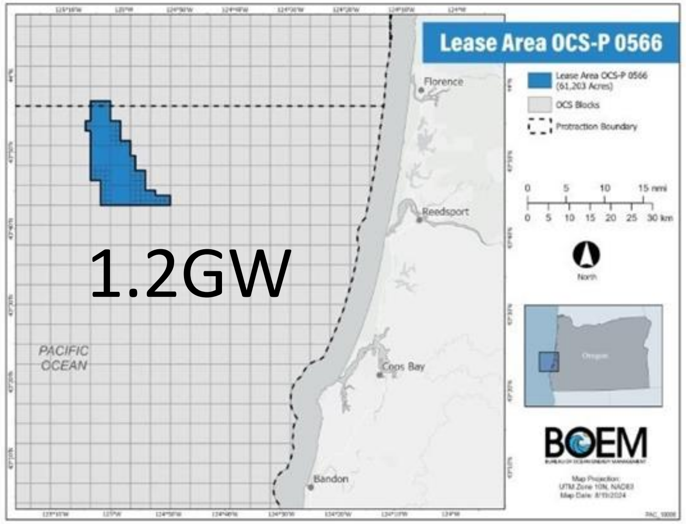
Project Goals

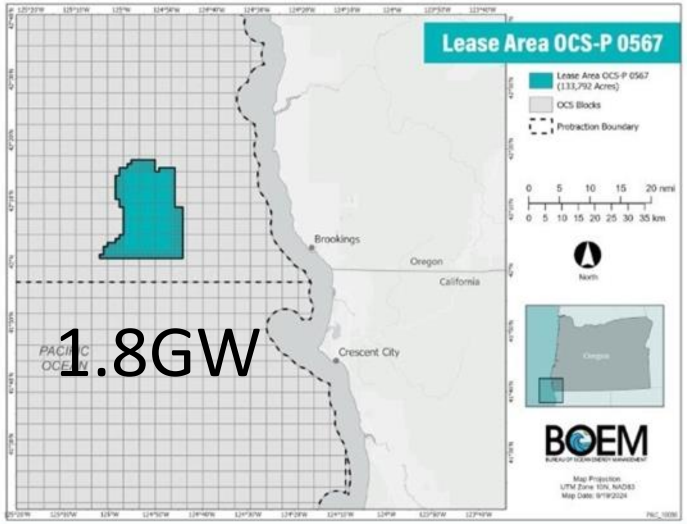
- Demonstrate feasibility of PSH+OSW and Onshore wind under multiple future grid and policy scenarios.
- Explore value of PSH in optimizing system value, reducing transmission congestion, and in firming OSW.
- Develop replicable framework for valuing and optimizing PSH+OSW.

PSH / OSW in S. Oregon	
Lead Lab	Argonne
PI	Patrick Balducci
Support Labs	INL PNNL
Total budget	$975,000
Duration	2 years

WIND PROJECTS

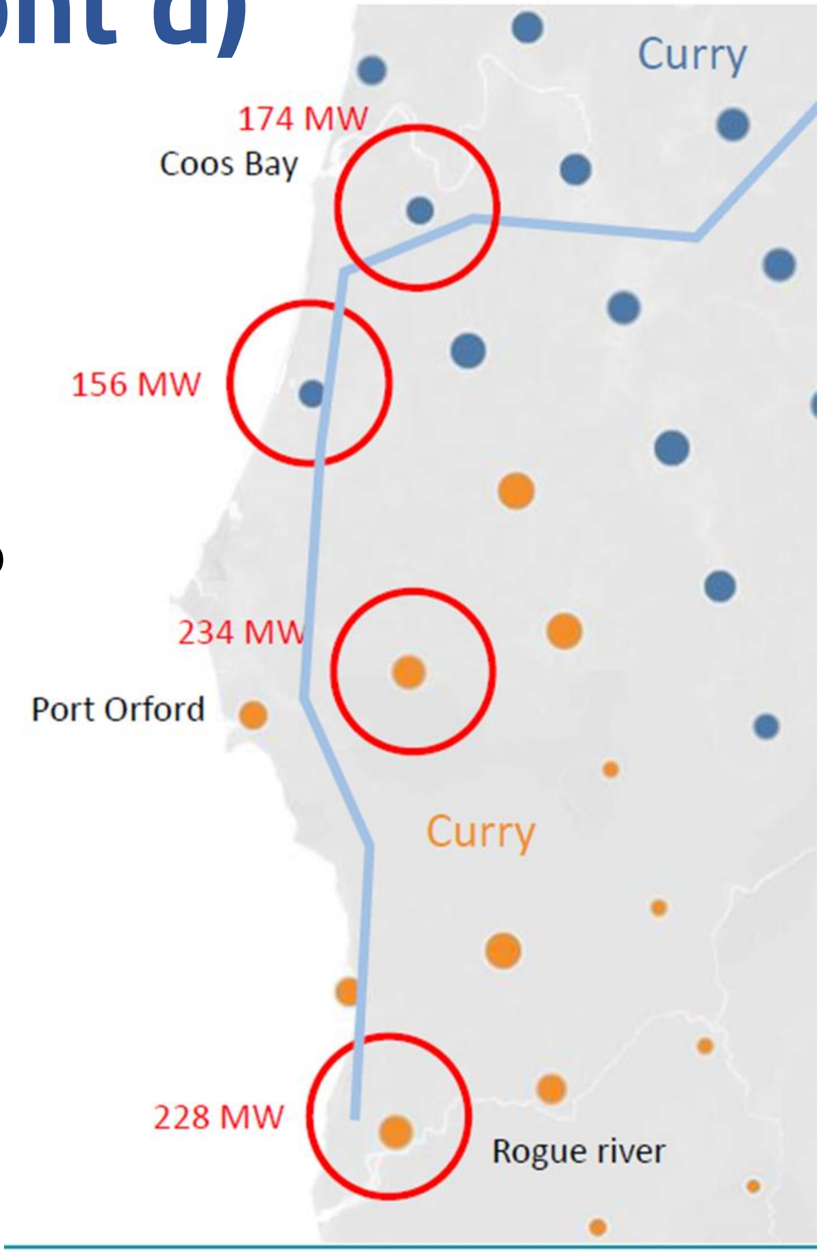
- Evaluating two Southern Oregon Offshore Wind (OSW) potential lease areas and four potential Onshore Wind Projects
  - ➢ Three years of wind profiles will be provided (2021-2023)
  - ➢ Planning 15 MW turbines offshore
  - ➢ Planning 6 MW turbines for on-shore
    - 12 MW turbines will be likely by 2030.
    - Will use the Fitch Scheme to calculate production profiles
    - One mile between turbines
  - ➢ Connecting OSW to grid at nearest point of interconnect with HVAC including losses





WIND PROJECTS (cont'd)

- The four onshore sites are located along the So. Oregon coastline
  - ➢ From Brookings to just south of Coos Bay
  - ➢ Two are in Coos County and two are in Curry County – 792 MW capacity
    - Curry County 462 MW
    - Coos County – 330 MW
  - ➢ Currently the transmission capacity is inadequate to carry the capacity of any of the projects to the rest of Western Interconnection



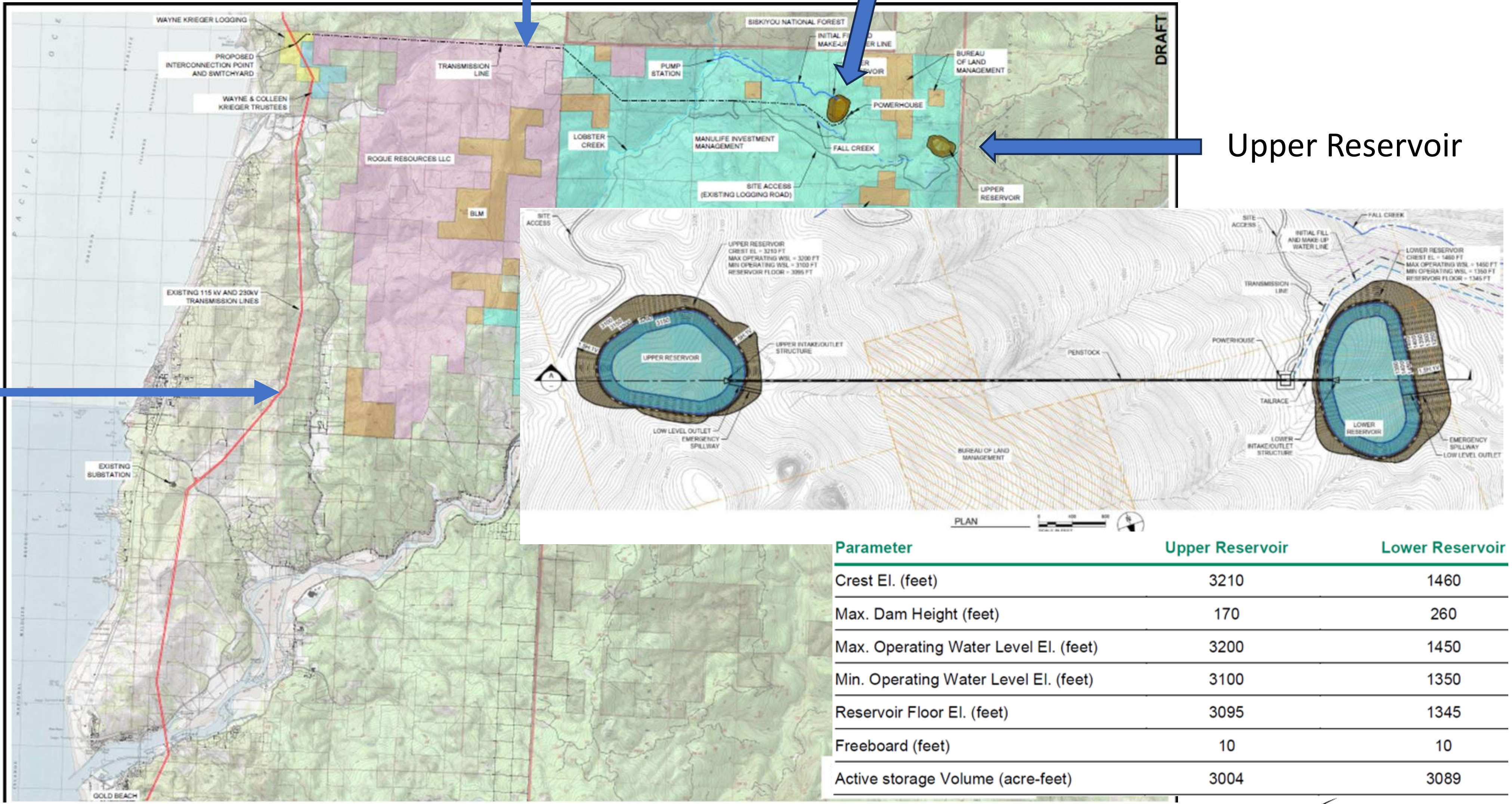
SOLDIER CAMP PSH – CURRY COUNTY

Interconnection Transmission

Lower Reservoir

Upper Reservoir

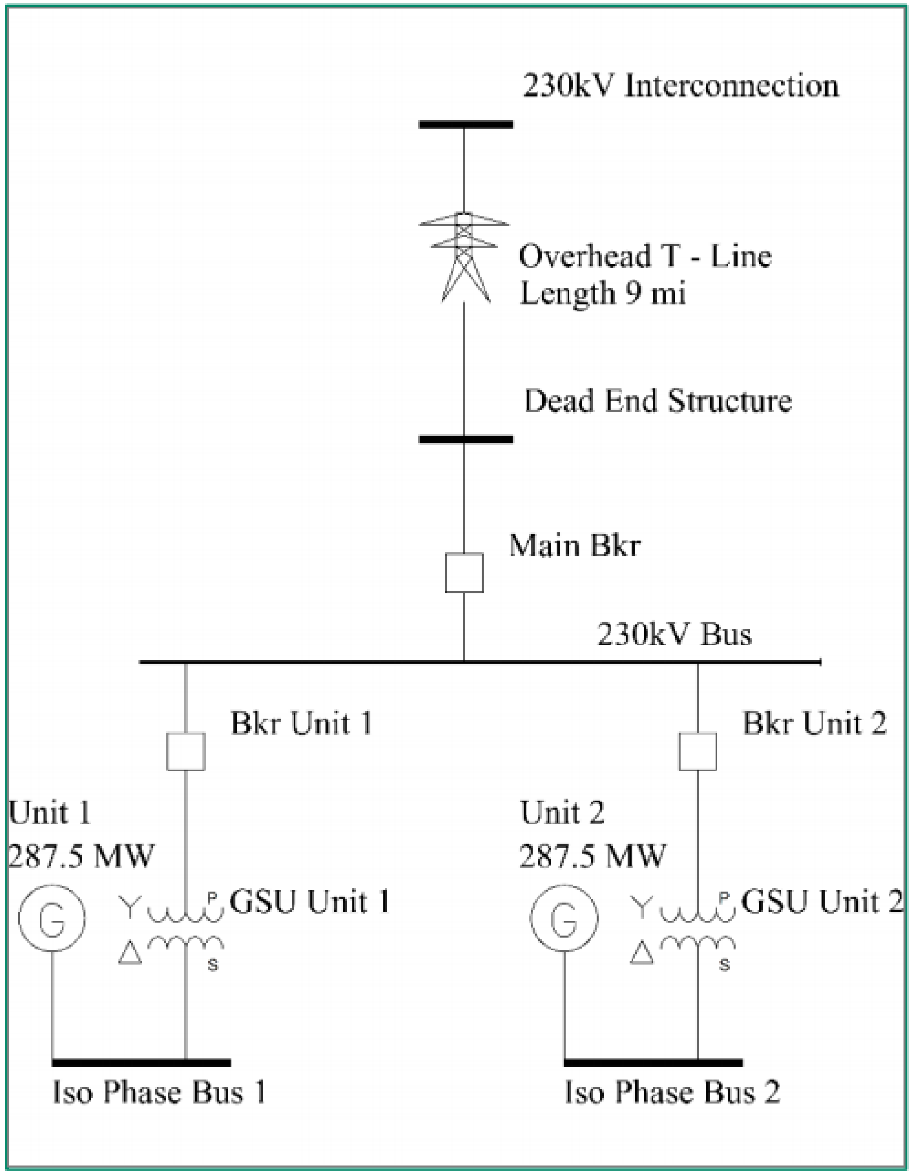
Fairview-Rogue Transmission
230 kV
115 kV



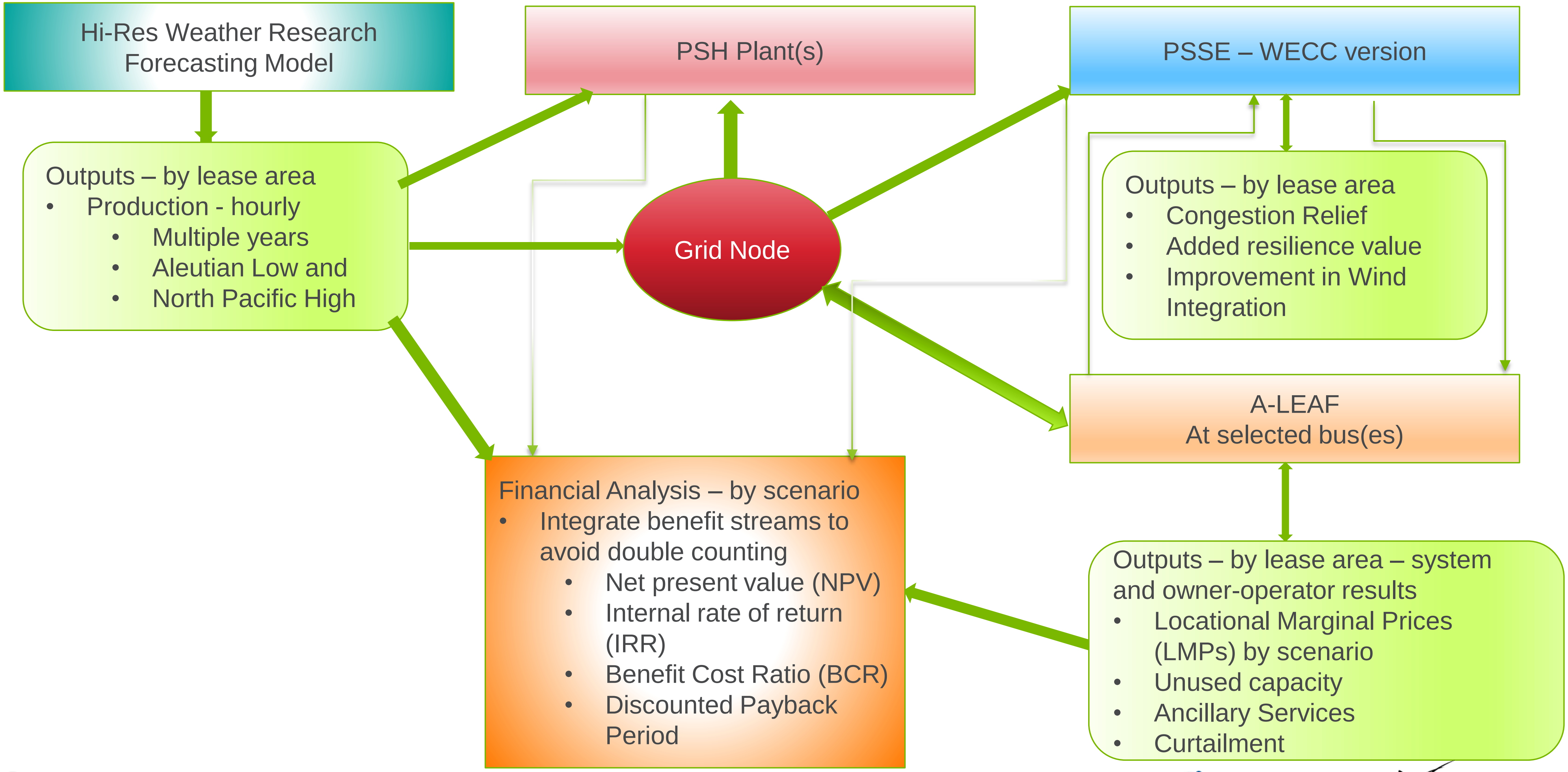
Parameter	Upper Reservoir	Lower Reservoir
Crest El. (feet)	3210	1460
Max. Dam Height (feet)	170	260
Max. Operating Water Level El. (feet)	3200	1450
Min. Operating Water Level El. (feet)	3100	1350
Reservoir Floor El. (feet)	3095	1345
Freeboard (feet)	10	10
Active storage Volume (acre-feet)	3004	3089

Soldier Camp PSH

- Two reversible pump turbines
  - 287.5 MW each
- 8 hours duration
- 9 miles interconnection
- Power at interconnection – 566.4 MW
- 4,531 MWh per cycle

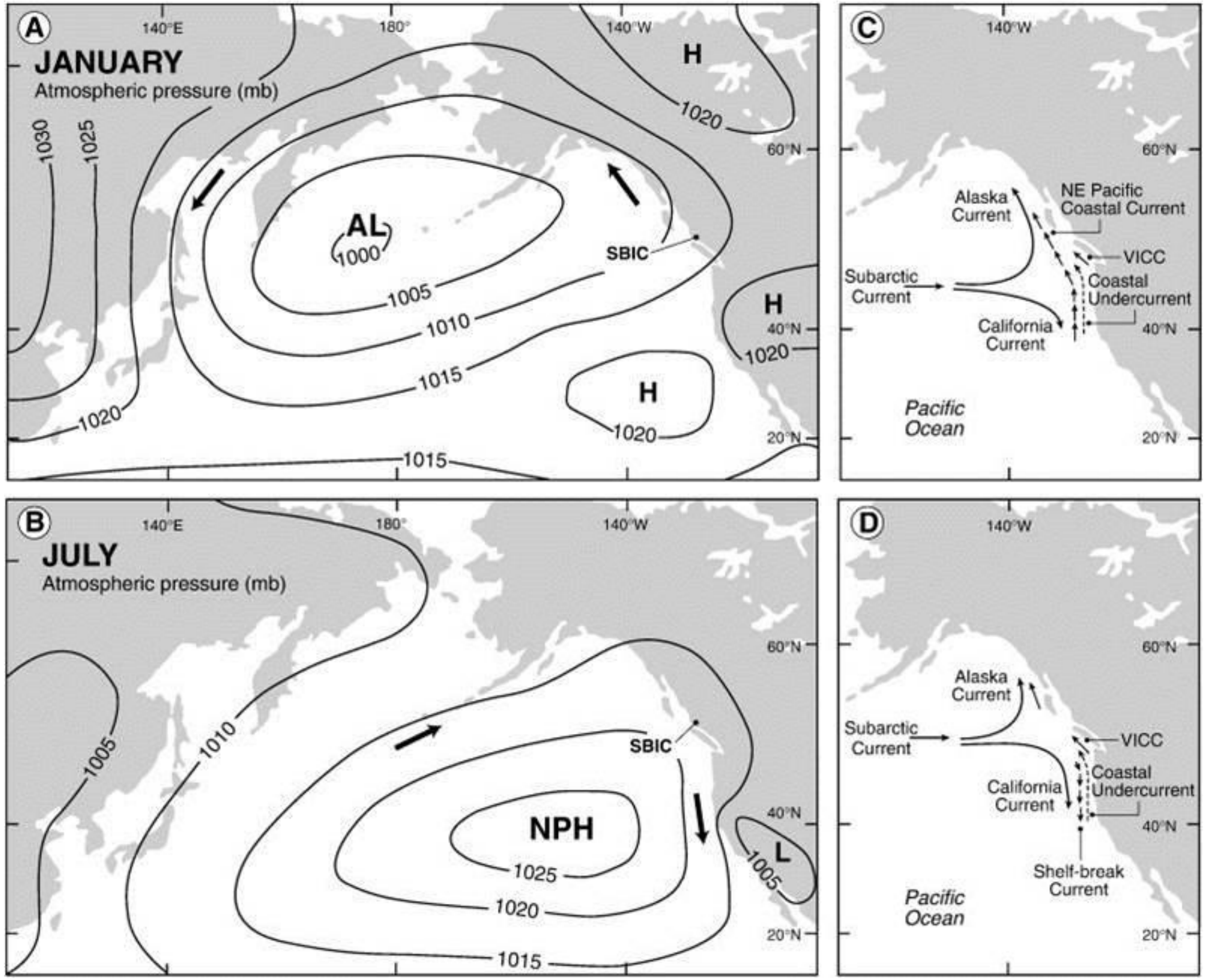


RYE PSH + OSW MODEL STRUCTURE



PLACING THE WIND-LEASE AREAS IN THE CONTEXT OF THE NORTHEAST PACIFIC (NEP) CLIMATE

- **Winter:** Onset of **Aleutian Low** brings **southerly winds**, generating a northward drift of the NE Pacific Coastal Current and consequent onshore Ekman transport. Accumulation of low density, less saline water on the surface, thus restricting the upwelling of deep water.
- **Summer: North Pacific High (NPH)** brings **northerly winds** generate the southward Shelf-Break Current at the surface and consequent offshore Ekman transport induces upwelling.



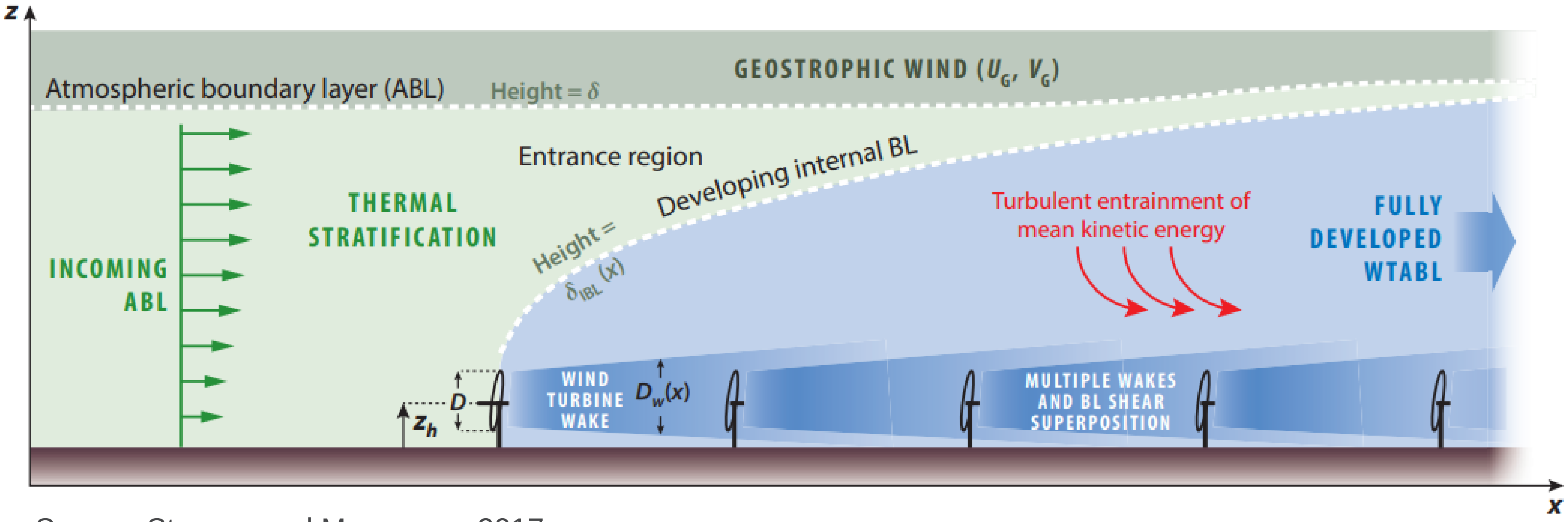
Galloway et al. (2010); https://doi.org/10.1016/j.marmicro.2010.03.001

WIND FARM BOUNDARY LAYER DYNAMICS

- Steady state energy equation

$$\overbrace{\overline{u}_j\partial_j\left(\frac{1}{2}\overline{u}_i\overline{u}_i+\frac{1}{2}\overline{u_i'u_i'}\right)}^{\text{Kinetic energy flux}}+\overbrace{\partial_j\left(\frac{1}{2}\overline{u_j'u_i'u_i'}+\overline{u}_i\overline{u_i'u_j'}\right)}^{\text{Turbulent transport}}+\overbrace{\partial_j(\overline{u_i\tau_{ij}})}^{\text{SGS transport}}$$

$$=\overbrace{-\partial_i(\overline{pu_i})}^{\text{Flow work}}+\overbrace{g\beta(\overline{u_i\theta}-\overline{u}_i\theta_0)\delta_{i3}}^{\text{Buoyancy}}+\overbrace{f_c(\overline{u}_iU_g)\delta_{i2}-f_c(\overline{u}_iV_g)\delta_{i1}}^{\text{Geostrophic forcing}}+\overbrace{\overline{f_iu_i}}^{\text{Turbine power}}+\overbrace{\overline{\tau_{ij}S_{ij}}}^{\text{Dissipation}}$$

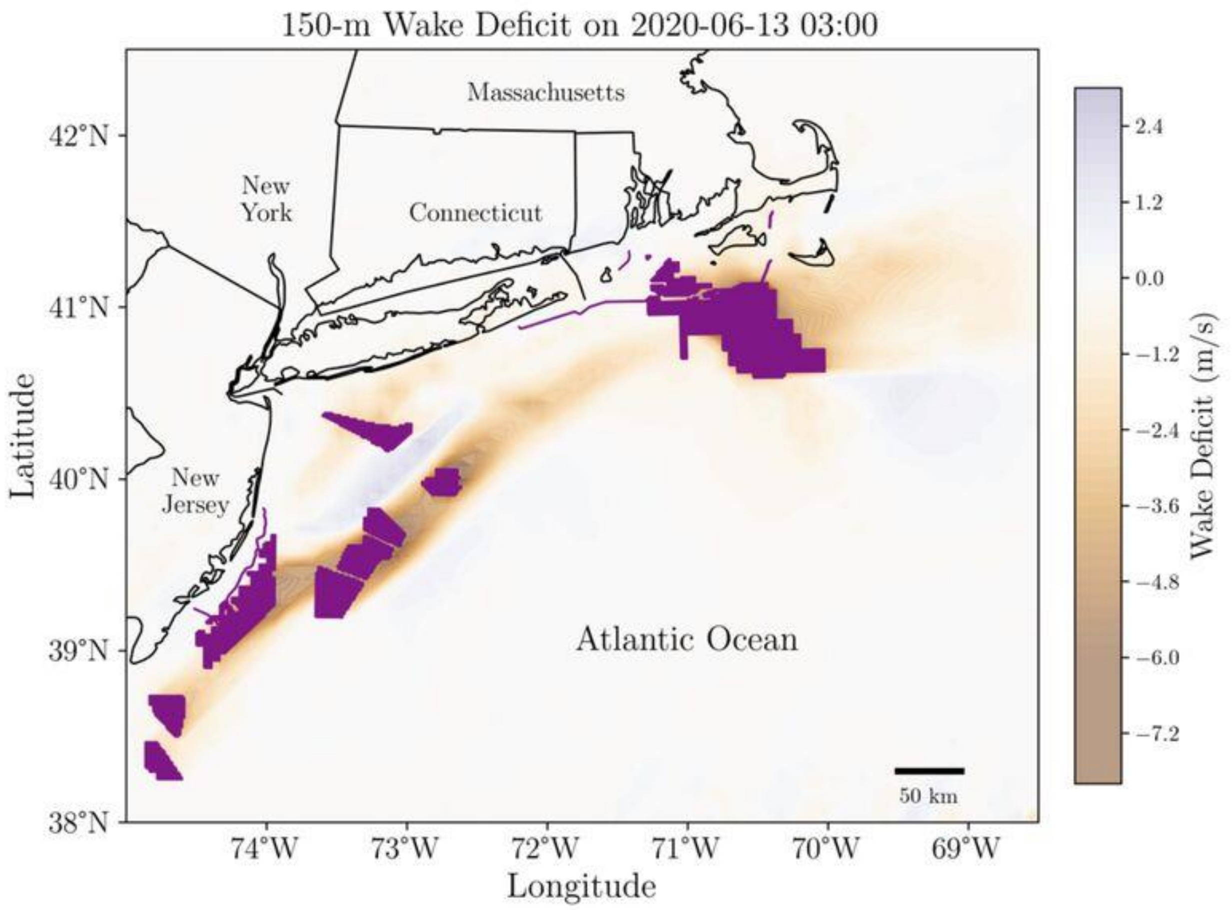


Source: Stevens and Meneveau, 2017

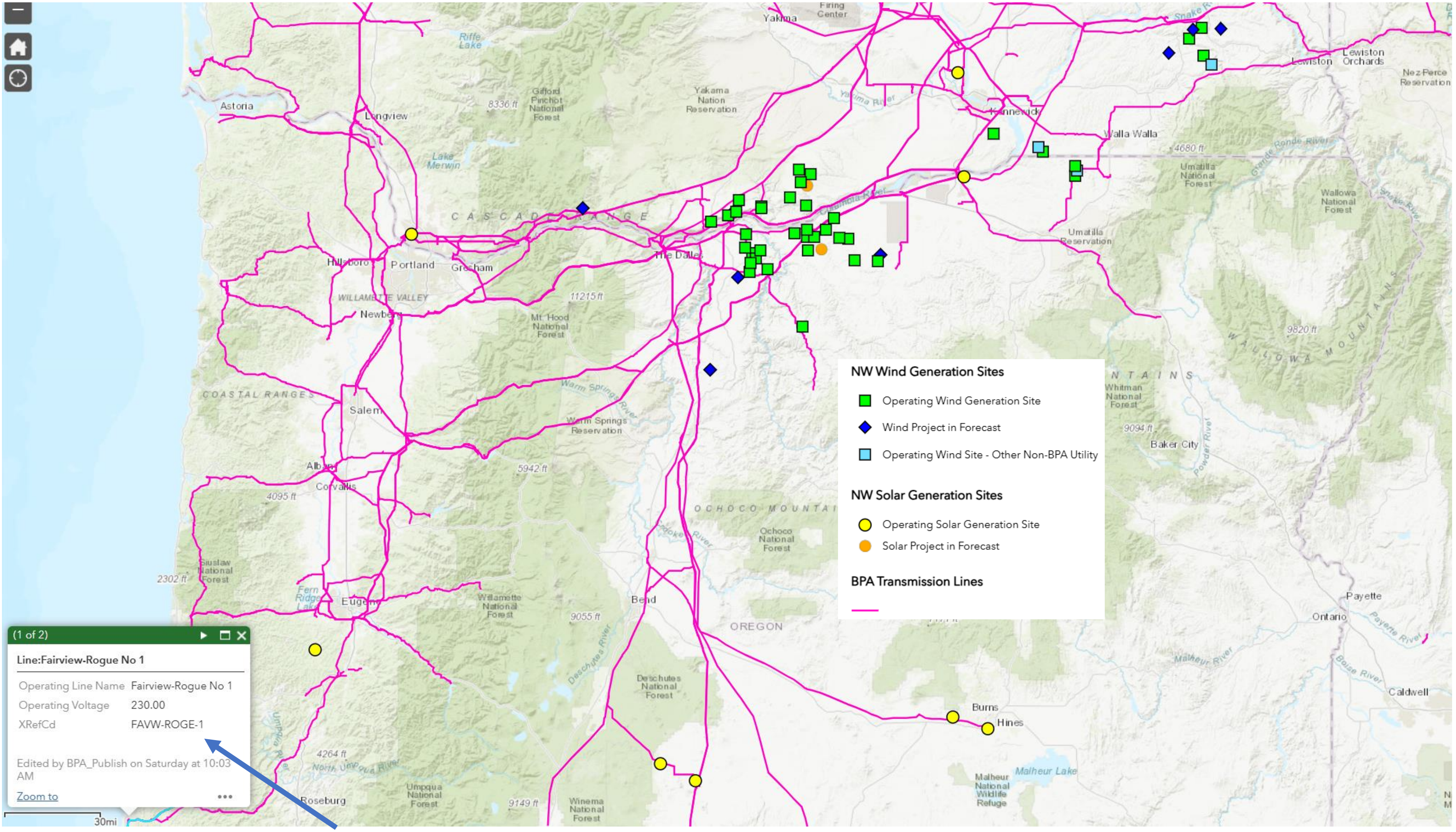
HOW DO WE GET POWER FROM WIND FARM MODEL

- We use a simple Wind Farm Drag parameterization developed in Weather Research Forecasting (WRF) Model to represent individual turbines within each grid cell.
- The power extracted by the turbines, which is converted into useful electrical energy, is given by:

$$\frac{\partial P_{ijk}}{\partial t} = \frac{\frac{1}{2} N_t^{ij} C_P(|\mathbf{V}|_{ijk}) |\mathbf{V}|_{ijk}^3 A_{ijk}}{(z_{k+1} - z_k)}.$$

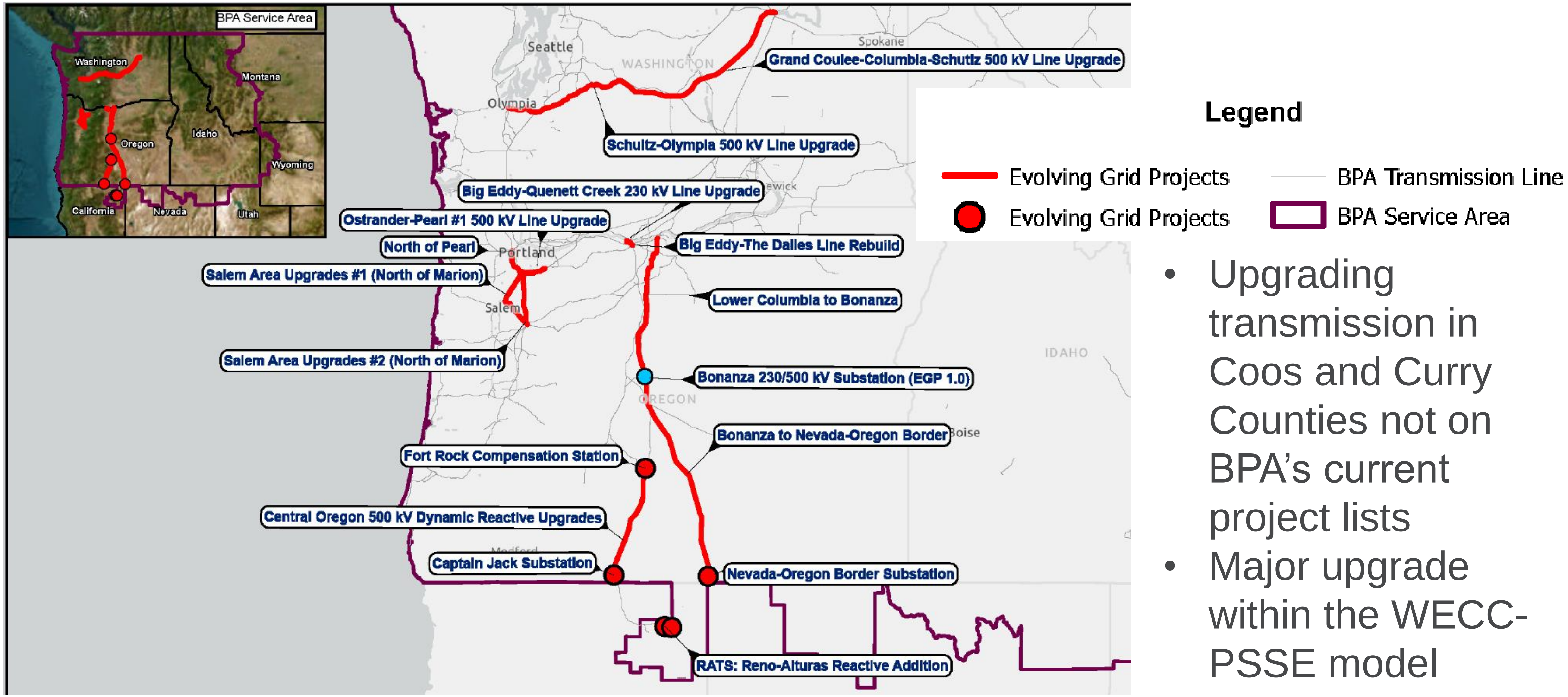


CURRENT BPA TRANSMISSION



Soldier Camp Site

BPA EVOLVING GRID PROJECT 2.0



- Upgrading transmission in Coos and Curry Counties not on BPA’s current project lists
- Major upgrade within the WECC-PSSE model

ANALYZING GRID STRENGTH FOR UPGRADES

- Coos Bay→ Fairview
- Brookings→ Del Norte
  - ➢ Does not show up on WECC Map
  - ➢ Isolated system
  - ➢ Vulnerable to transmission line outages as no local generation exists.
  - ➢ https://schatzcenter.org/docs/Transmission-Jacobson-forAAUW-20240202.pdf

Figure 55. Grid strength visualization for the 2035 Distributed Topology for high offshore wind penetration scenario (left) without contribution of IBRs (right) considering short-circuit contribution of large IBRs (>100 MW)

Image Source: https://www.pnnl.gov/publications/west-coast-offshore-wind-transmission-study

OFFSHORE INTERCONNECTION POINTS

- Coos Bay→ Wendson (North of Fairview)
- Brookings→ Fairview

NorthernGrid

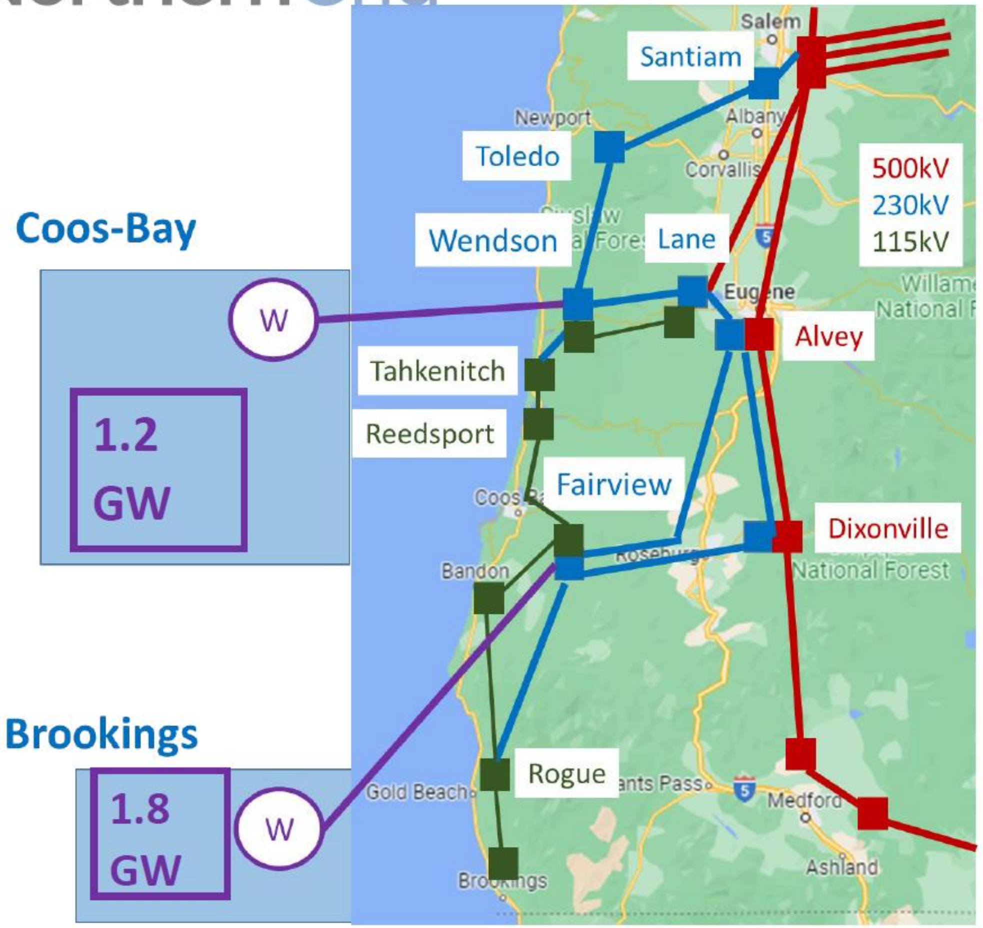
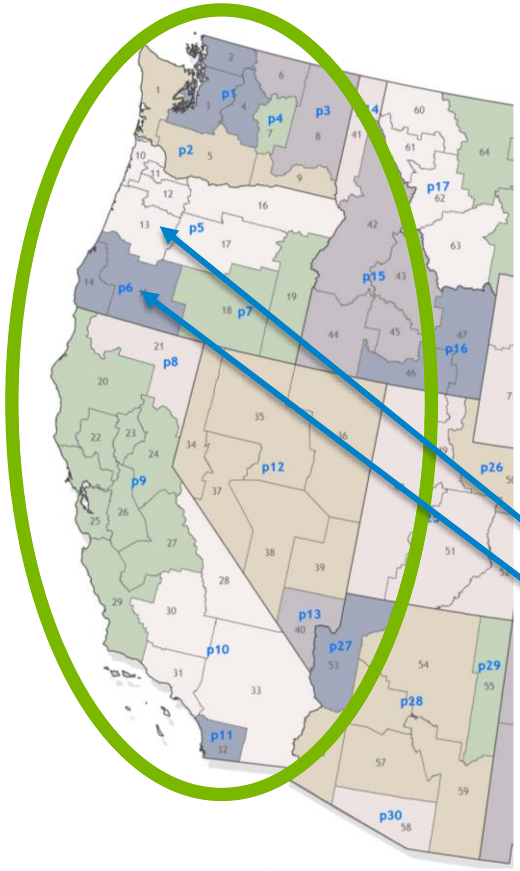


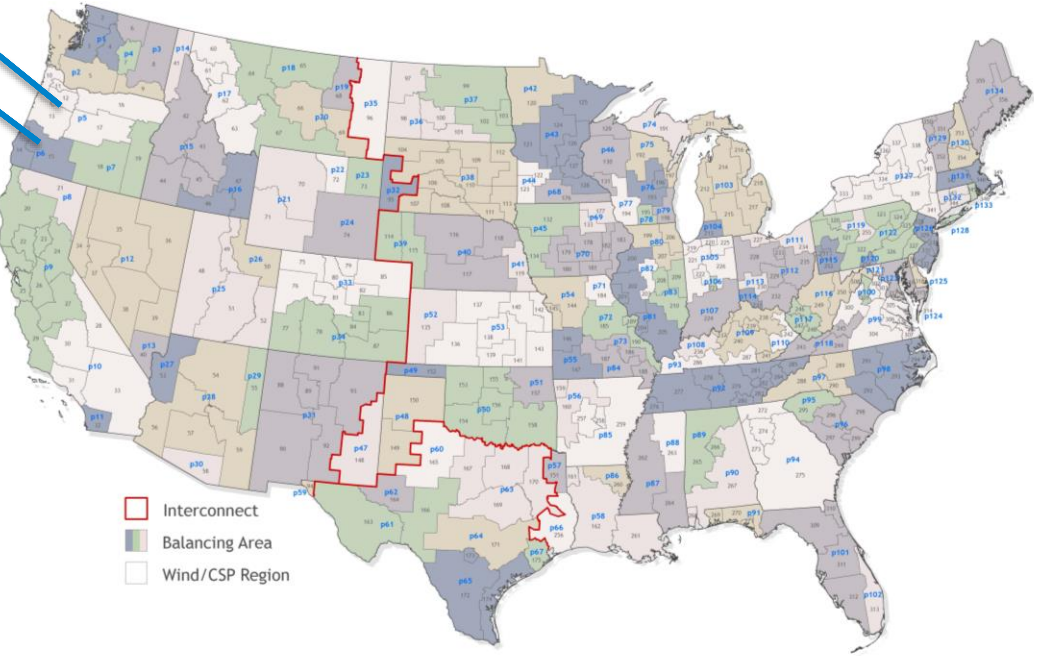
Figure 2: Offshore wind request

Image Source:
https://www.northerngrid.net/private-media/documents/2022_ESR_OSW_Approved.pdf

A-LEAF AREA OF INTEREST



- A-LEAF has 134 Balancing Areas
  - Only interested in those BAs in states adjacent to Oregon
  - Providing resources by BA to PSSE model
  - PSSE provides resources to A-LEAF
  - Process continues until both models are equivalent
- Working to develop a 2032 version based on potential resources by BA



- A-LEAF will implement model with and without PSH to determine change in curtailment
- PSSE will evaluate power flow and transient stability
- Adjustments made until system works

CASES TO BE EVALUATED

- Onshore wind (Aleutian Low/North Pacific High) 3 years with Soldier Camp PSH
- Offshore wind-OCS-P 0567 (Brookings OR) (Fairview substation – BA-6) (Aleutian Low/North Pacific High) with Soldier Camp PSH
- Offshore wind-OCS-P 0566 (Reedsport OR) (Wendson Substation-BA-5) (Aleutian Low/North Pacific High) with Soldier Camp PSH
- Offshore wind-OCS-P 0566 and 0567 and onshore wind (Aleutian Low/North Pacific High) with Soldier Camp PSH

A-LEAF ALTERNATIVES ANALYSIS

- Natural gas prices (high, medium, low)
- Demand Growth (high, medium, low)
- Technology Costs (high, medium, low)
- Investment Tax Credit Policies
  - Current law
  - No ITC
- Base case:
  - Natural gas prices, demand growth, technology costs (all medium)
  - Current law

NEXT STEPS

Determine production profiles for two OSW and onshore wind sites

→ Complete the resource balancing by BA between A-LEAF and PSSE

→ Provide wind profiles to A-LEAF

→ Run A-LEAF with and without PSH

- Undertake alternatives analysis

→ Provide results to PSSE and undertake:

- Power flow analysis
- Transient stability analysis
- Contingency analysis

→ Pass results between A-LEAF and PSSE until steady state reached

→ Conduct financial analysis

QUESTIONS?

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