Pacific Northwest Regional Economic Conference

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

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Argonne NATIONAL LABORATORY

INL Idaho 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

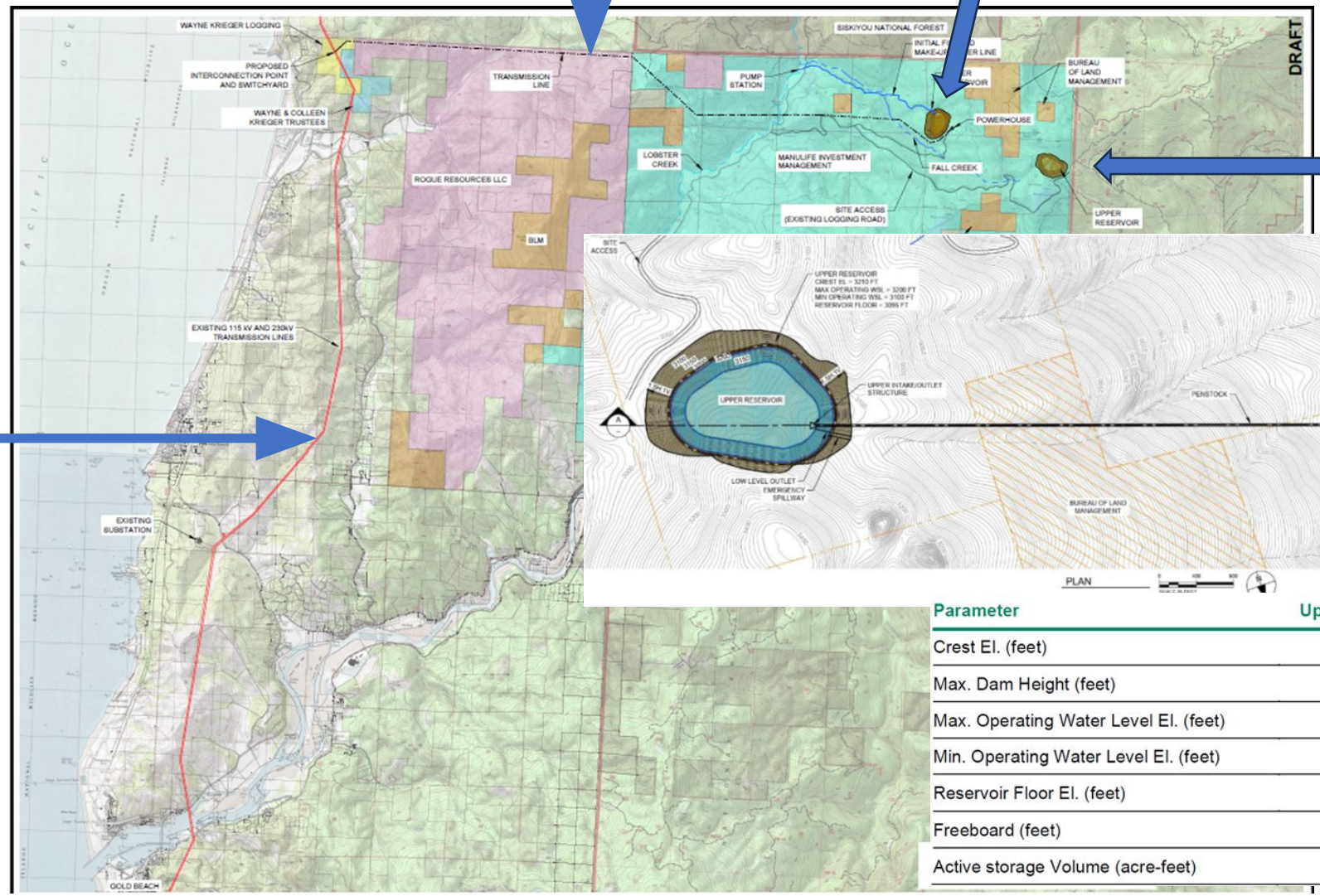
SOLDIER CAMP PSH – CURRY COUNTY

Interconnection
Transmission

Lower Reservoir

Upper Reservoir

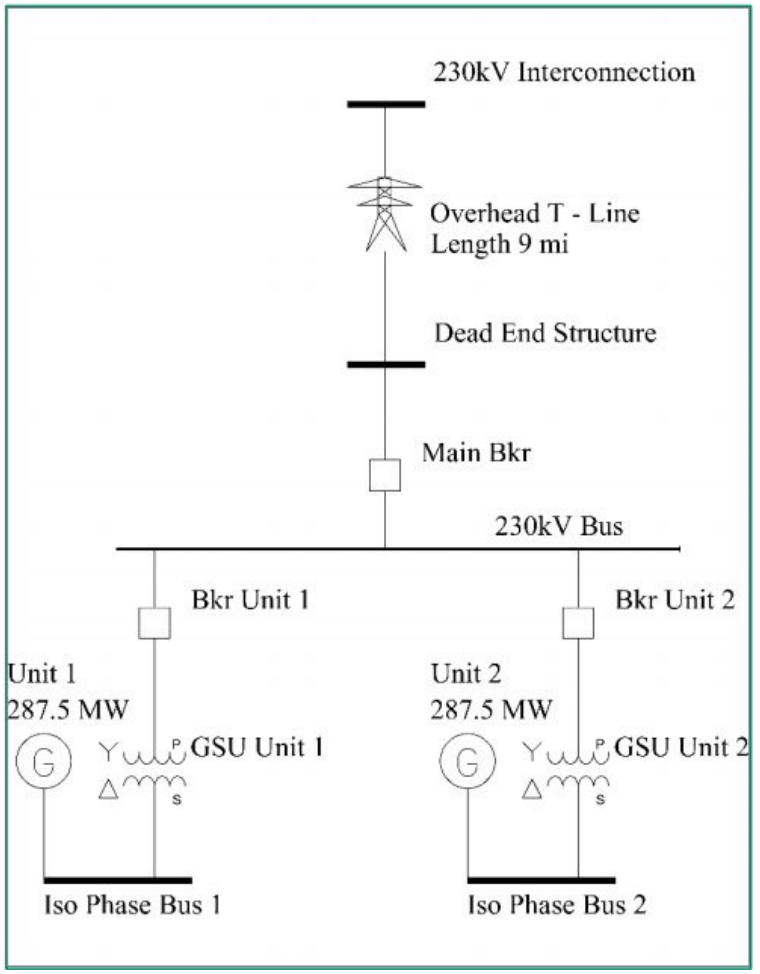
Fairview-Rogue
Transmission
230 kV
115 kV



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

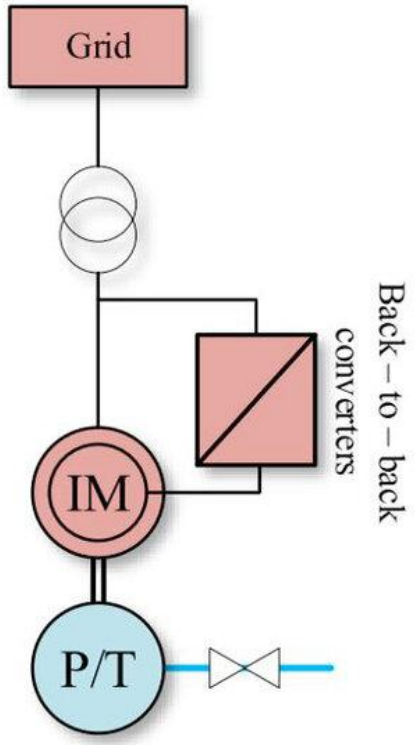
Soldier Camp PSH

- 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



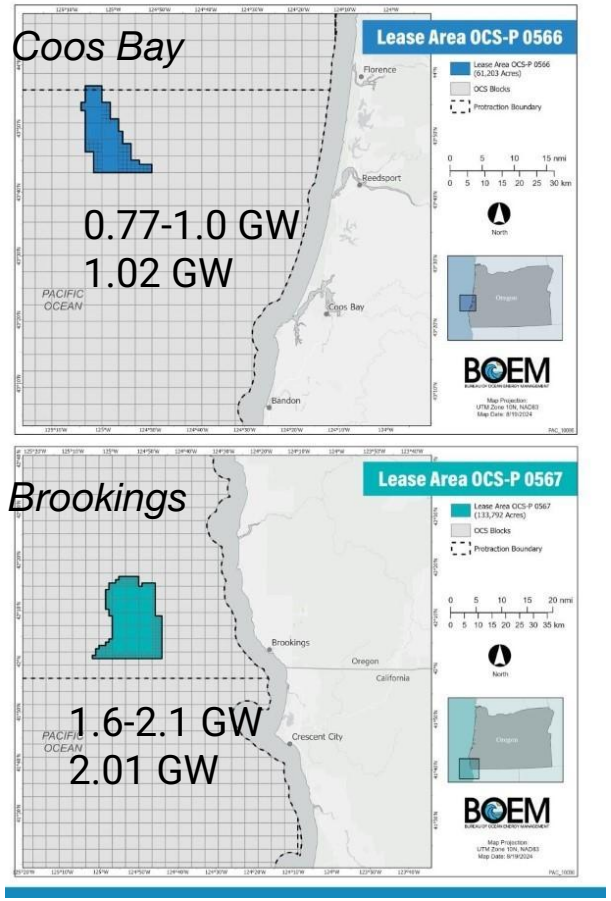
Adjustable Speed PSH (ASPSH)
Doubly-fed Induction Motor

Fast Response with pump mode flexibility

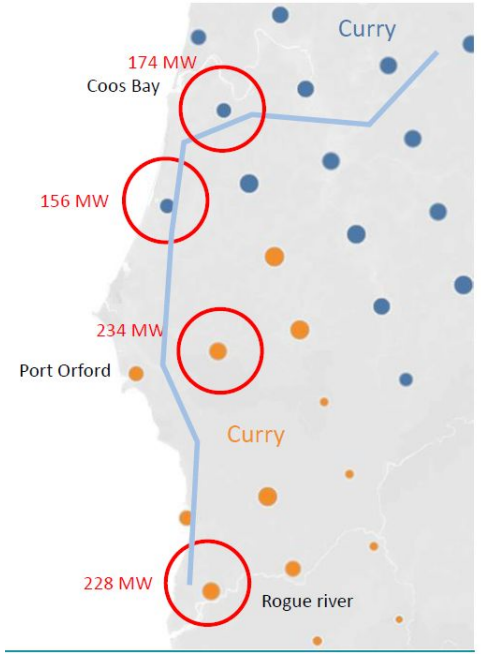


LOCATION OF VIRTUAL WIND FARMS

- 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



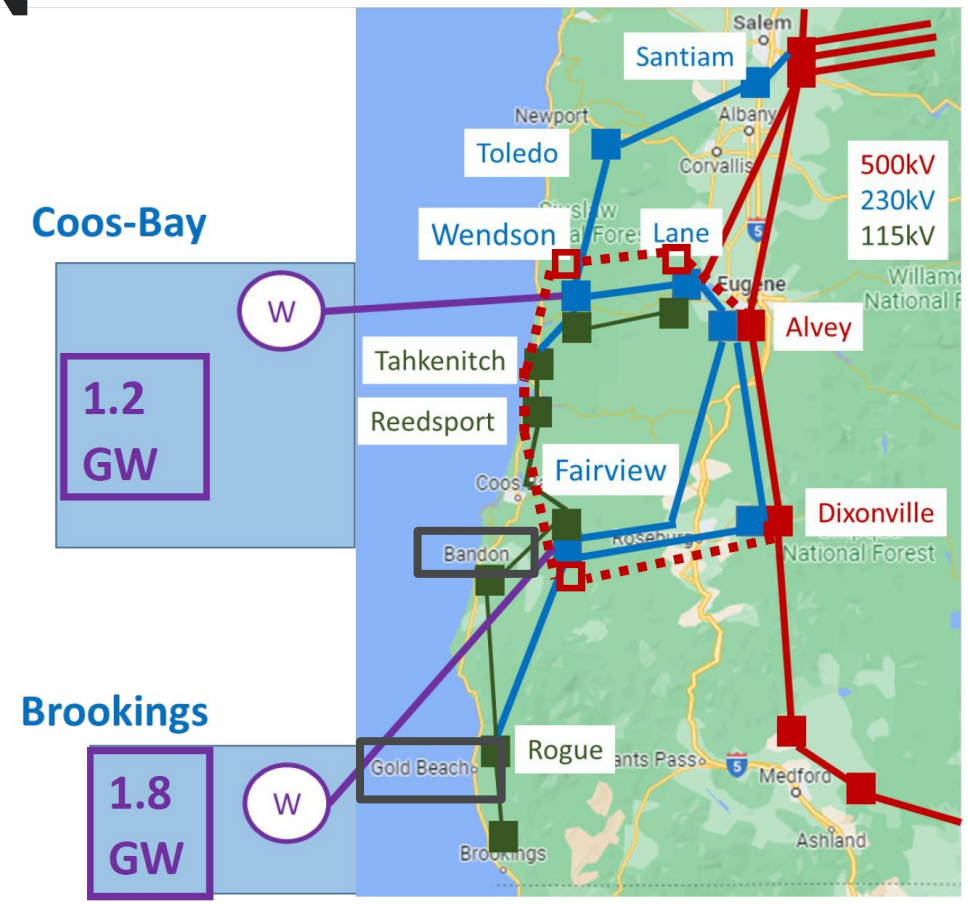
Onshore wind farms



	sc_point_gid	hub_height	turbine_capacity	n_turbines
Curry	23567	115	6000	38
	22428	115	6000	39
Coos	21668	115	6000	26
	21289	115	6000	29

*Locations provided by Rye Development

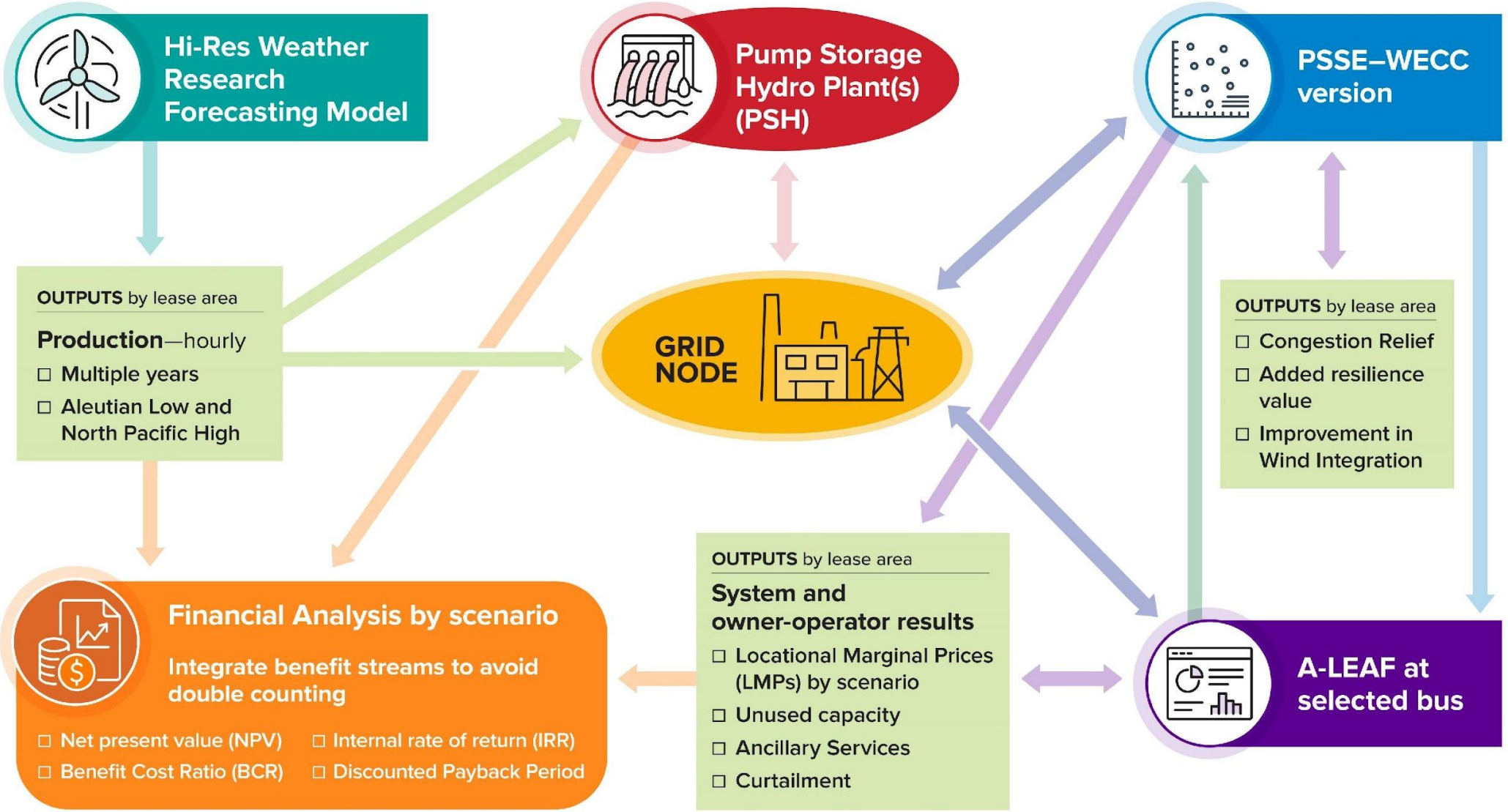
POINTS OF INTERCONNECTION AND GRID CAPACITY



Wind turbine locations:

- Off-shore: Coos bay (1.2GW) at Wendson and Brookings (1.8GW) at Fairview substations
- On-shore: Coos county (174 MW and 156 MW) at Bandon substation and Curry County (234 MW and 228 MW) at Rogue substation, respectively.

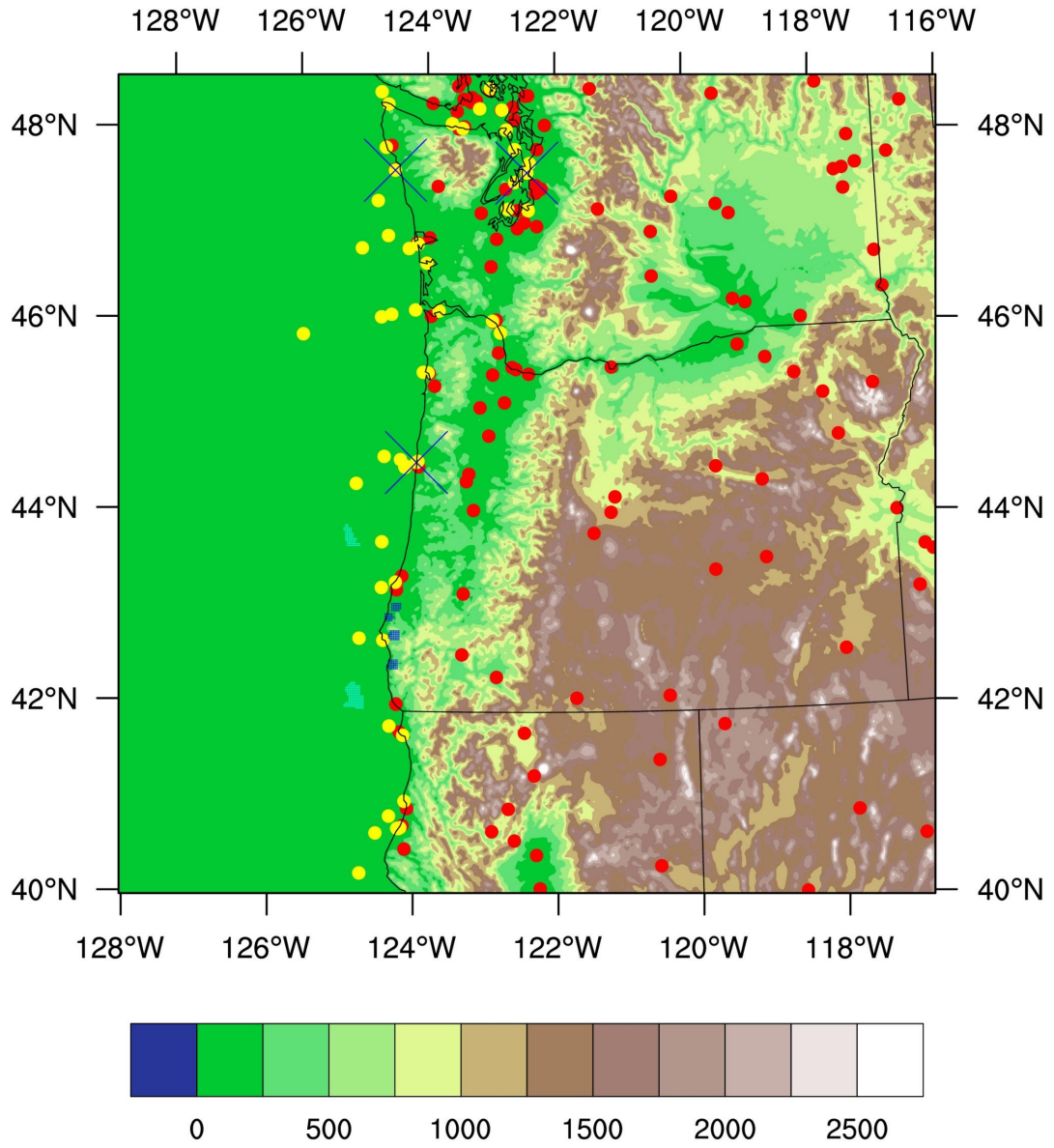
RYE PSH + OSW MODEL STRUCTURE



WIND MODEL EXPERIMENTAL DESIGN

- **Model:** Weather Research and Forecasting (WRF) model simulates atmospheric conditions over a large spatial footprint, covering several wind farms.
  - 1 turbine / 2-km model grid cell

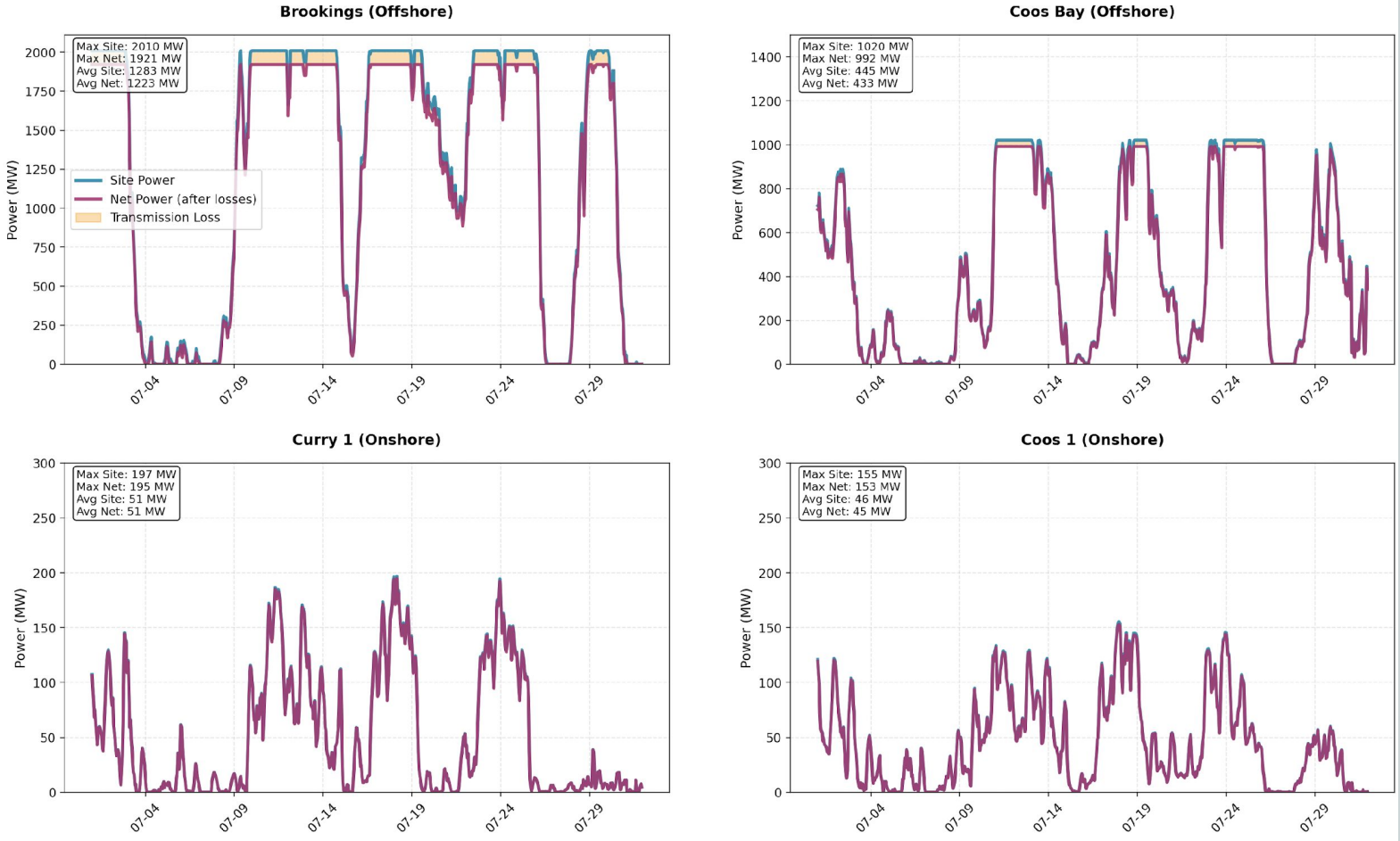
Model version	WRFv4.6.1
Boundary Layer Scheme	MYNN
Wind Farm parameterization	Fitch
Initial/Background Conditions	ERA5
Period	2022-2024
Spatial Resolution	2km
Output	Atmospheric variables and wind power

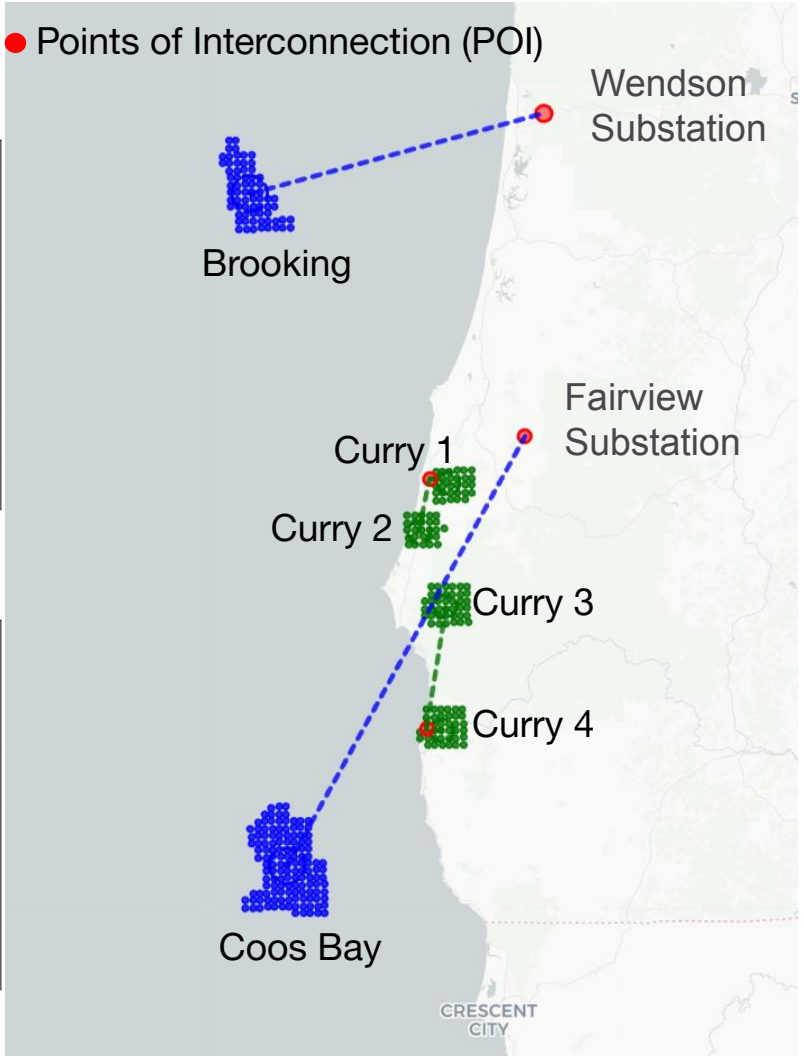


Simulated WRF model domain and surface observations for model validation.

SUMMARY OF THE POWER AND LOSS

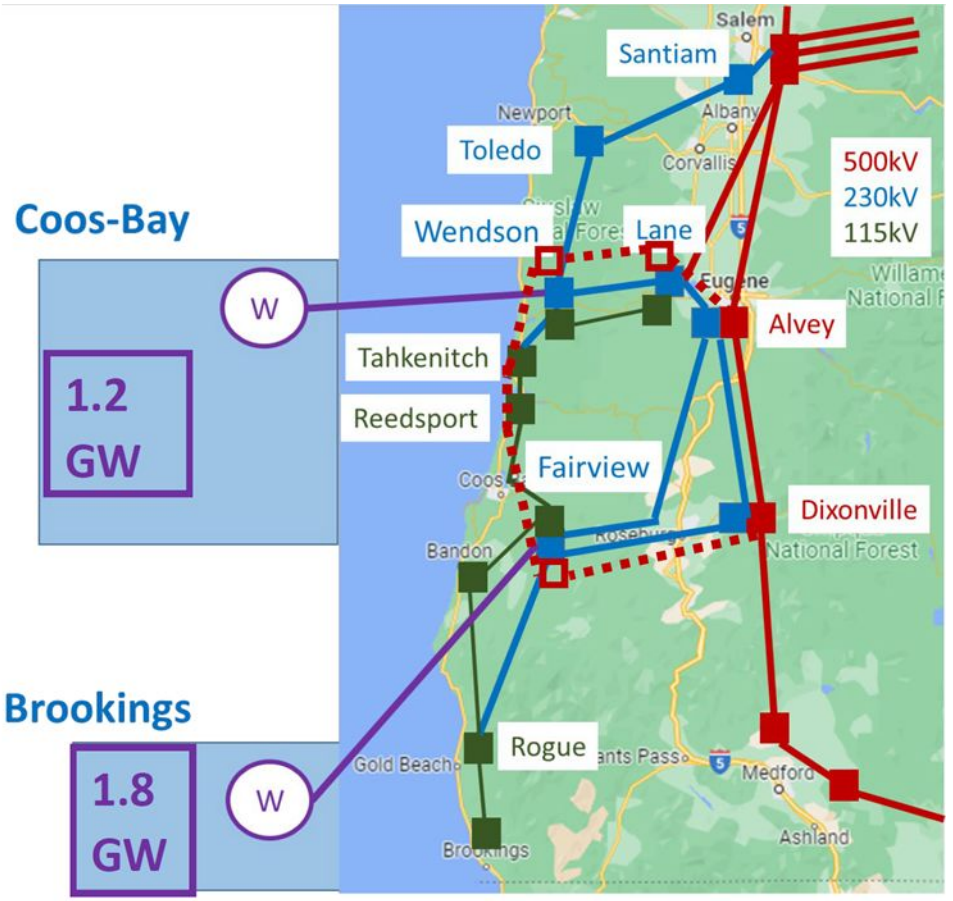
Example of the final timeseries





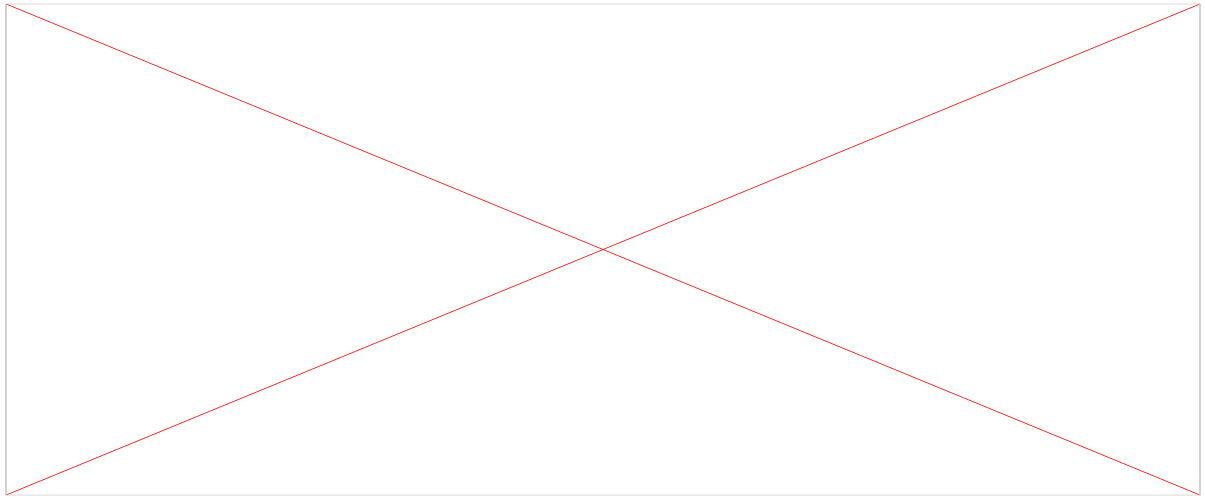
SUMMARY OF WIND POWER AND LOSS

Wind Farmot	POI	Distance (km)	Rated power (MW)	Site power (MW)	Net power (MW)	Loss (%)
Brooking (42.140, -124.882)	Fairview 230 kV (43.213199, -124.075840)	136.29	2,010	1,116	1,061	3.67
Coos Bay (43.812, -125.010)	Wendson 230 kV (44.007475, -124.010613)	83.15	1,020	490	476	3.27
Curry1 (42.48, -124.356)	Gold beach 115 kV (43.107, -124.397)	4.22	228	82	81	1.04
Curry2 (42.789, -124.345)		34.26	234	104	101	2.50
Coos1 (42.975, -124.434)	Bandon 115 kV (42.484, -124.407)	14.97	156	60	59	1.33
Coos2 (43.097,-124 .335)		5.17	174	56	55	1.04
Total			3,822	1,980	1,833	7.43



ARGONNE LOW-CARBON ELECTRICITY ANALYSIS FRAMEWORK (A-LEAF)

- Integrated national-scale power system simulation framework developed at the Argonne National Laboratory, used to analyze various issues related to the evolution of the nation's power system.
- Suite of least-cost generation & transmission expansion, unit commitment, and economic dispatch models
- Determine system optimal generation portfolio and hourly or sub-hourly unit dispatch under a range of user-defined input assumptions for technology characteristics and system/market requirements

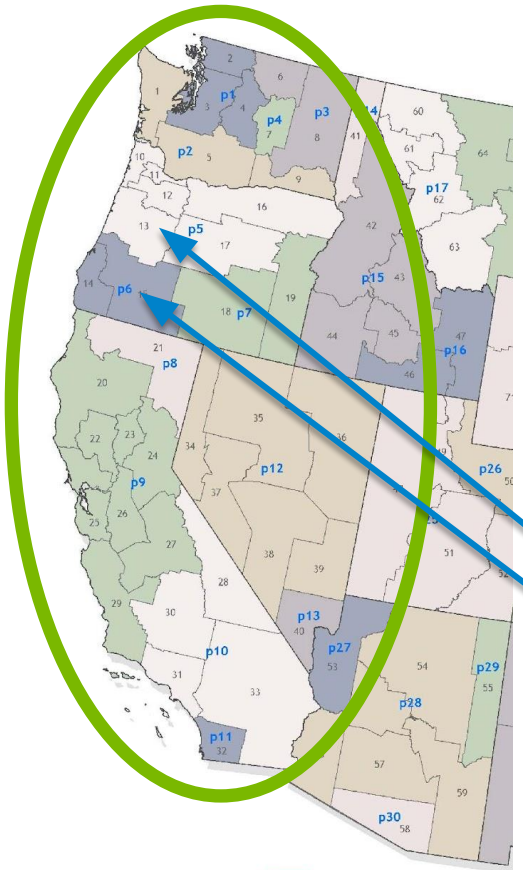


Embedded A-LEAF Tool

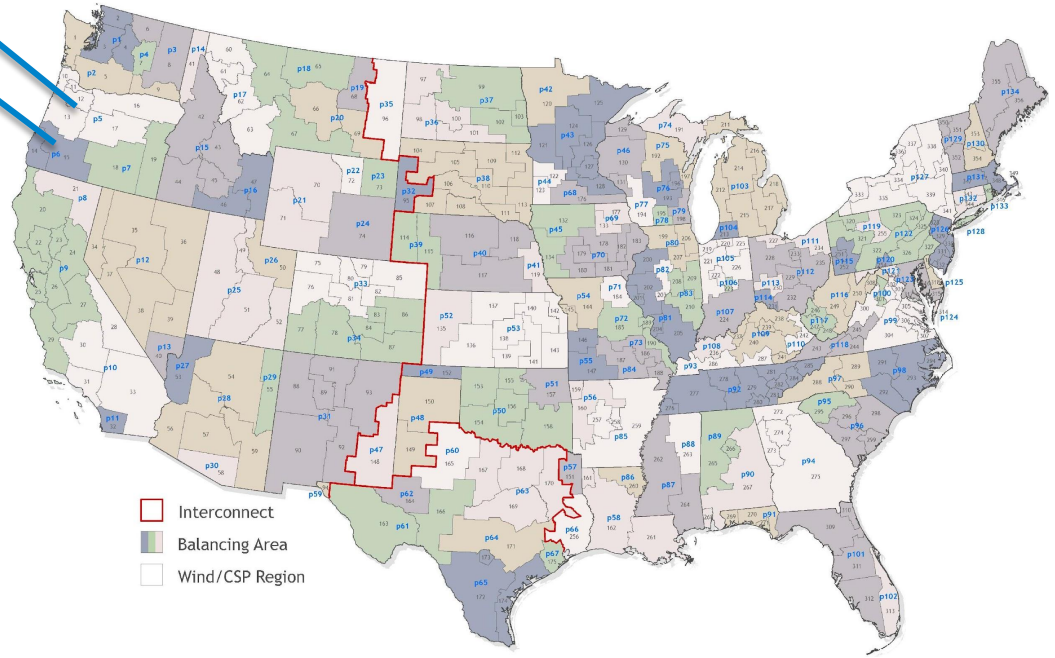
POLICY OPTIONS OF THE PSHVT

Category	Price-influencer
Policy and Regulation **State renewable portfolio standard target/ Clean Energy Standards (all cases)**	Baseline: Investment Tax Credit (ITC) for PSH and Batteries, through 2027 for wind and solar
	Adverse: No ITC for any resource
	Aggressive: ITCs for all resource reinstated at a later date
Renewable Energy Costs **NLR 2024 Annual Technology Baseline**	Baseline: Expect Renewables Cost
	Adverse: High Cost
	Aggressive: Low Cost
Natural Gas Prices **2025 Annual Energy Outlook**	Baseline: Expected Natural Gas Prices
	Adverse: High NG prices
	Aggressive: Low NG prices
Load Growth	Baseline: Current growth at 1.6 percent per year
	Low: 1.1 percent
	High: 2.1 percent

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

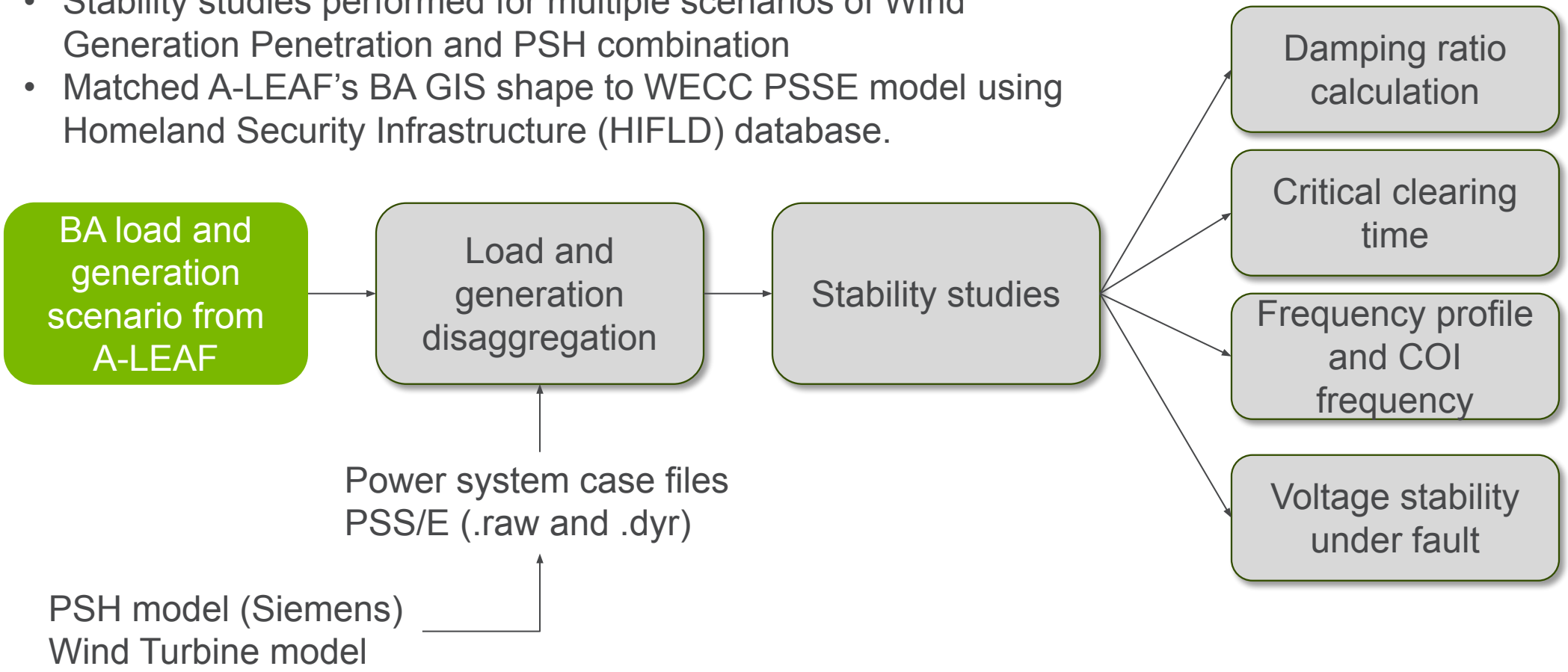
CASES TO BE EVALUATED

- Brookings Oregon offshore wind to Fairview substation; Balancing Area (BA) 6
- Coos Bay Oregon offshore wind to Wendson substation BA-5
- Onshore wind – 4 wind farm Coos and Curry counties
- All Offshore wind and onshore wind

- Evaluation performed for both System and Owner-Operator with and without Soldier Camp PSH
  - System evaluates whether load-serving entity can afford to pay for the facility due to reduced costs from with and without Soldier Camp PSH
  - Owner-Operator determines whether developer could make an economic return on the facility

POWER FLOW, TRANSIENT STABILITY, TRANSMISSION AND CONTINGENCY ANALYSIS

- Stability studies performed for multiple scenarios of Wind Generation Penetration and PSH combination
- Matched A-LEAF's BA GIS shape to WECC PSSE model using Homeland Security Infrastructure (HIFLD) database.



REPRESENTATION OF A-LEAF RESULTS IN WECC

Different WECC scenarios summer, spring and winter conditions are used to represent A-LEAF results

Load + Generation (8760 hours)

Appropriate scaling

PSS®E SIEMENS

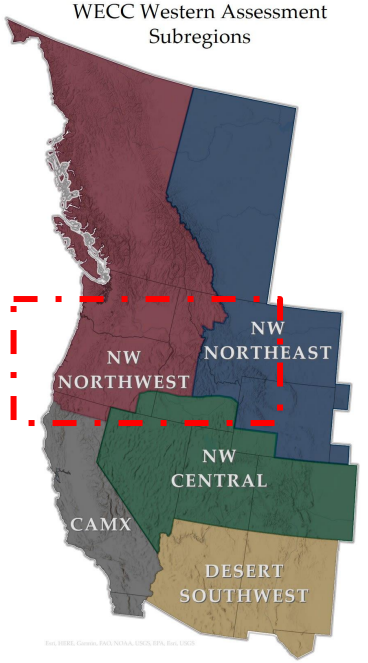
Scenario generation

Convergence status

(Day 227 Hour 15)

Generation	WECC Capacity (MW)	WECC case Dispatch (MW)	ALEAF Desired Capacity (MW)	ALEAF Desired Dispatch (MW)	WECC Scaled Dispatch (MW)
Hydro	30145	24899	30925	20764	20240
PSH	NA	NA	575	550	550
Thermal	6217	5902	9440	6839	4504
Wind	5873	5103	11398	604	311
IBR (Includes BESS)	3260	1348	2852	1651	1887

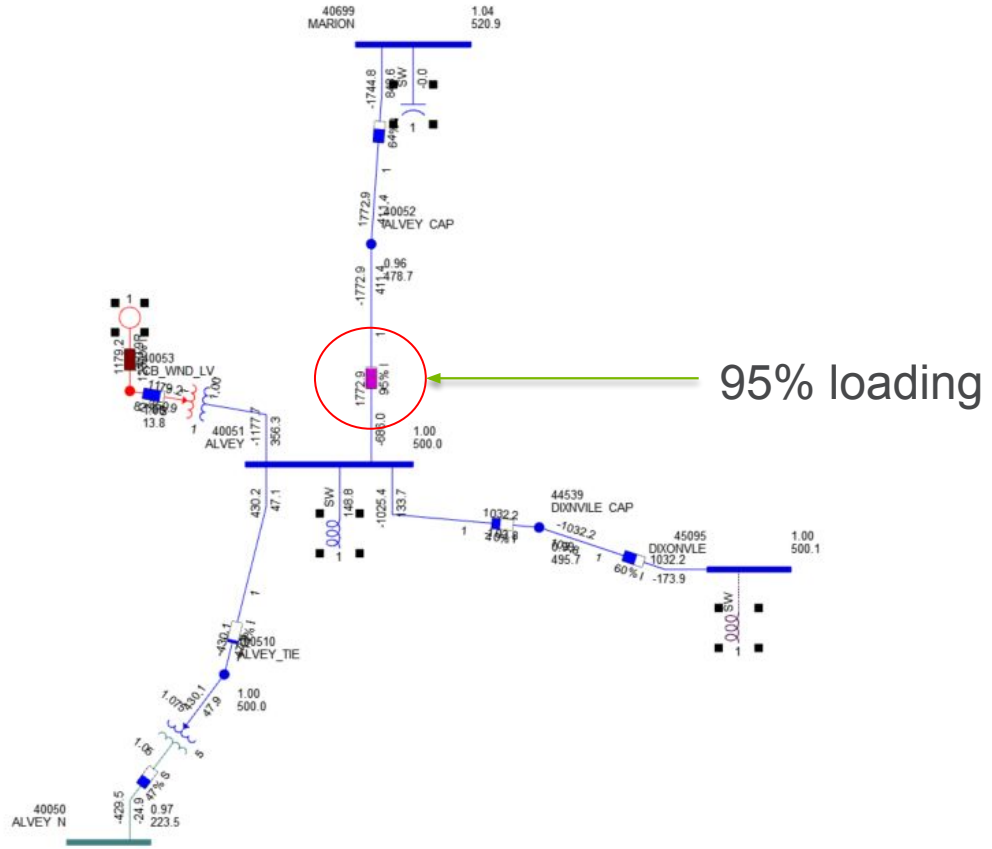
New scenario



CONGESTION REDUCTION USING PSH (DAY 99 HOUR 16)

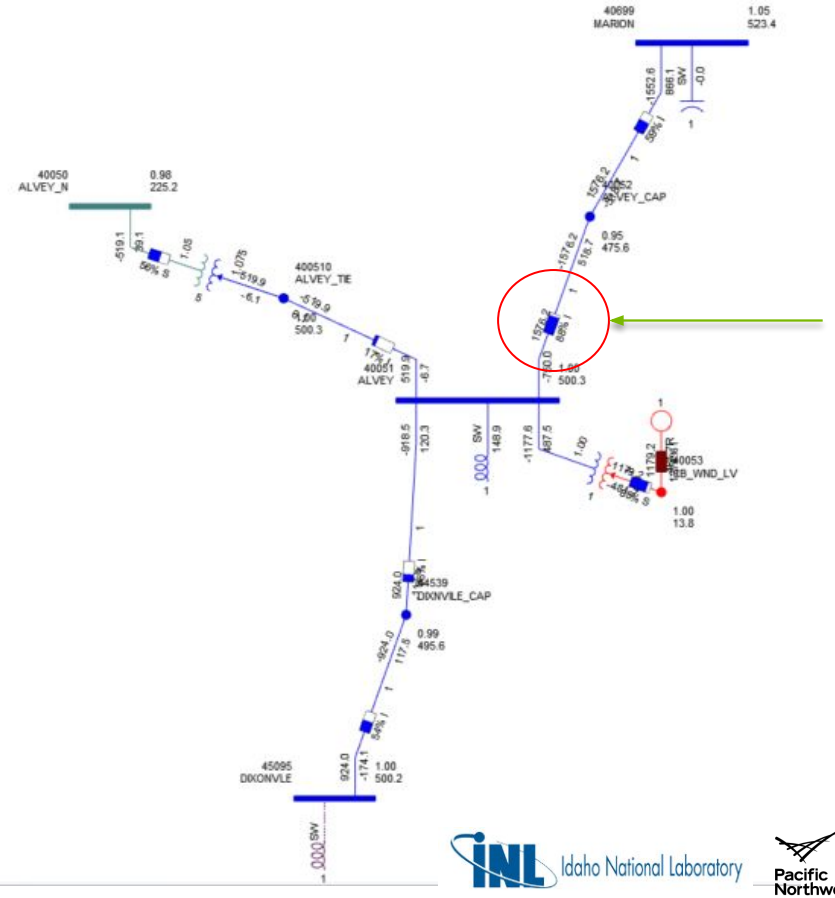
Displaying the impact of PSH in peak wind hours with all 4 new wind farms integrated. Pump mode operation reduces congestion.

Without PSH (Day 99 Hour 16)



95% loading

With PSH



88% loading

PRICE-INFLUENCER MODELING IN THE PSHVT

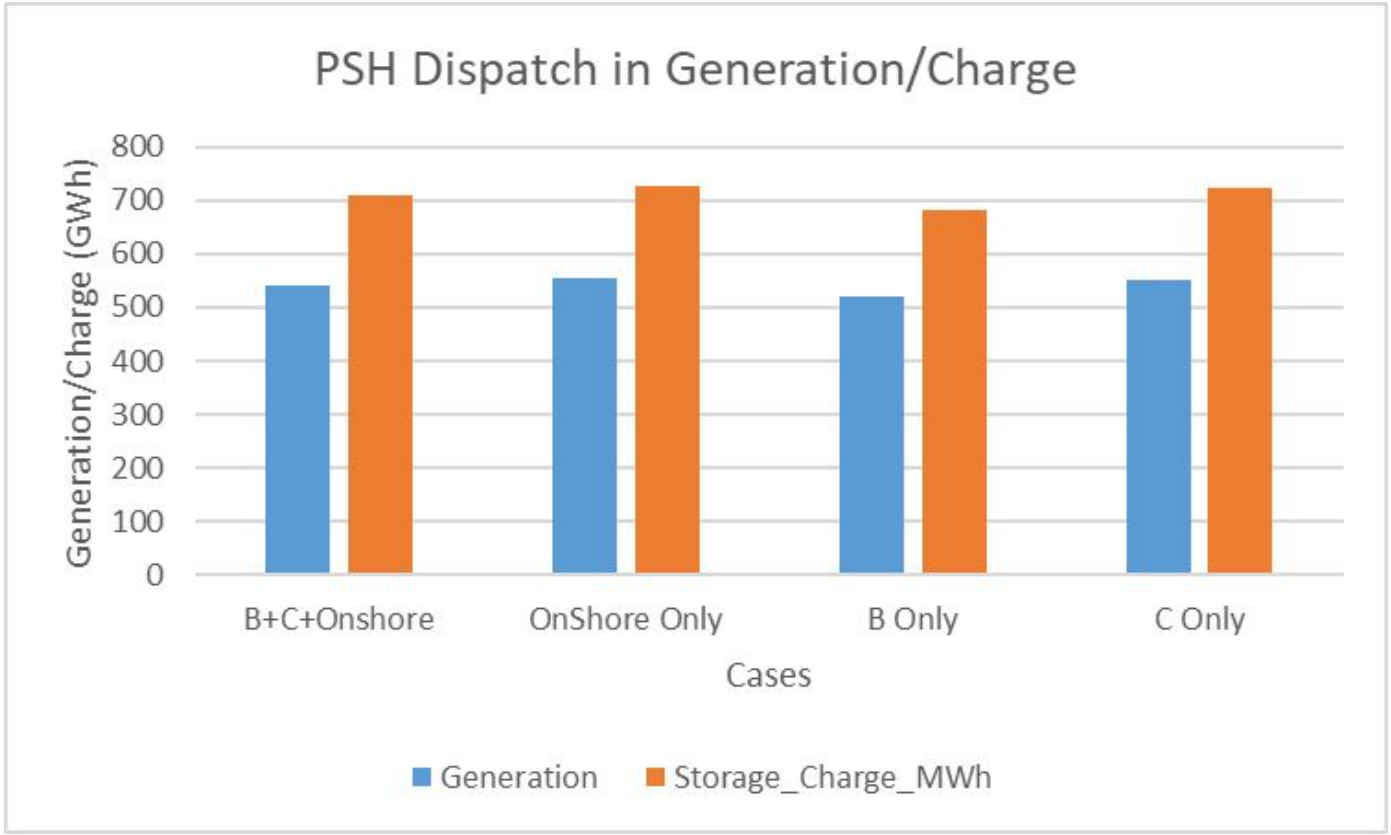
- A-LEAF is embedded as an option
  - Users can choose the current approach for estimating PSH values using multiple external tools or select the A-LEAF option
- Data
  - Users can use the default national scale dataset provided in A-LEAF
  - The tool supports users as they define input data for their 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

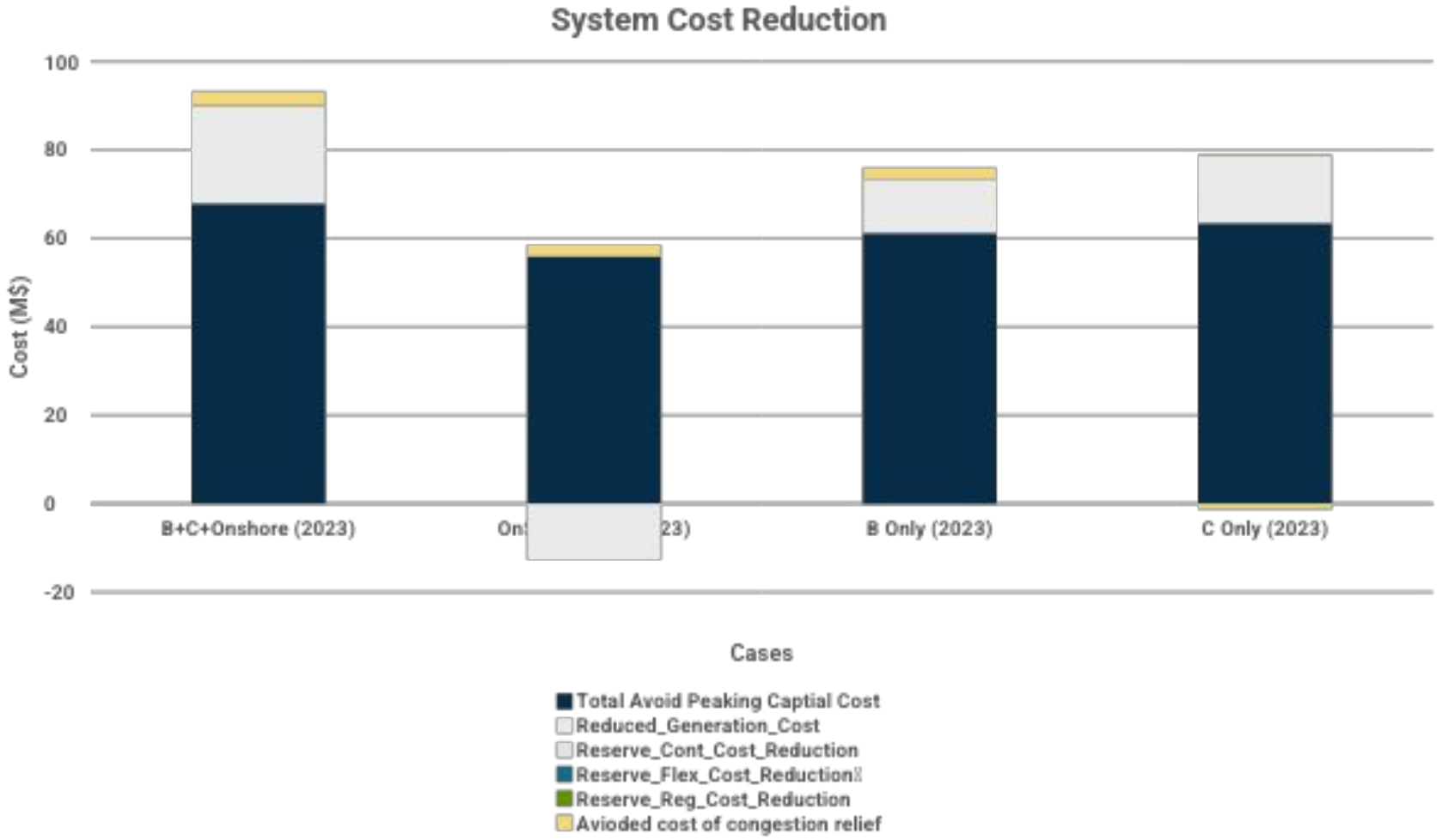
PSH Owner-Operator Results by Wind Scenarios

- Dispatch and revenue at PSH
  - The revenue of PSH is ranged from $23.25 million to $24.5 million.
  - PSH is dispatched more and makes more revenue in the onshore wind case, because the prices are more volatile at the bus where PSH is located when the system has more solar in this case.

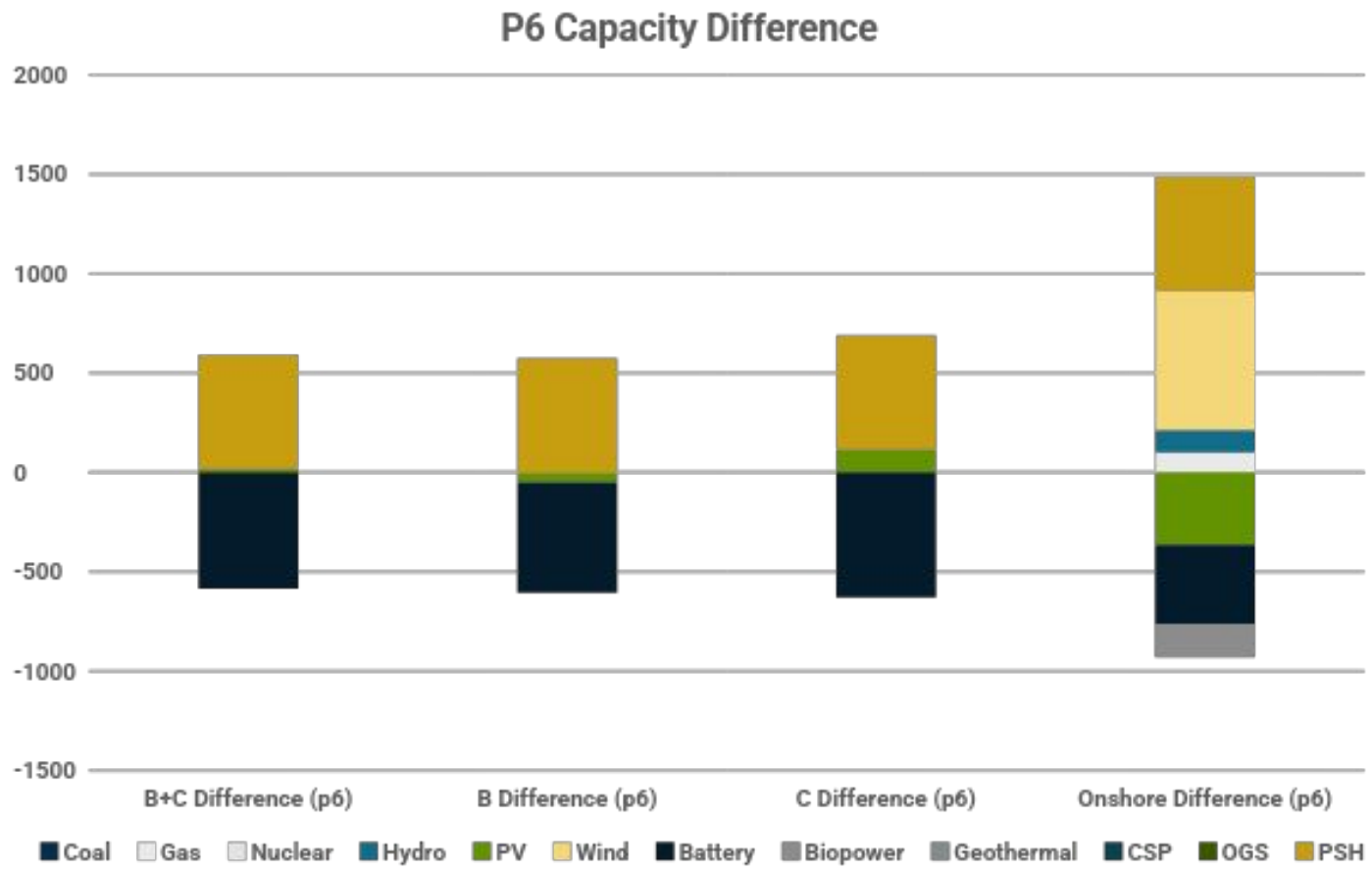


SYSTEM COST REDUCTION

- The system avoided capital, avoided congestion cost, and reduced generation costs are the major benefits of the candidate PSH from a system perspective.



CAPACITY DIFFERENCE



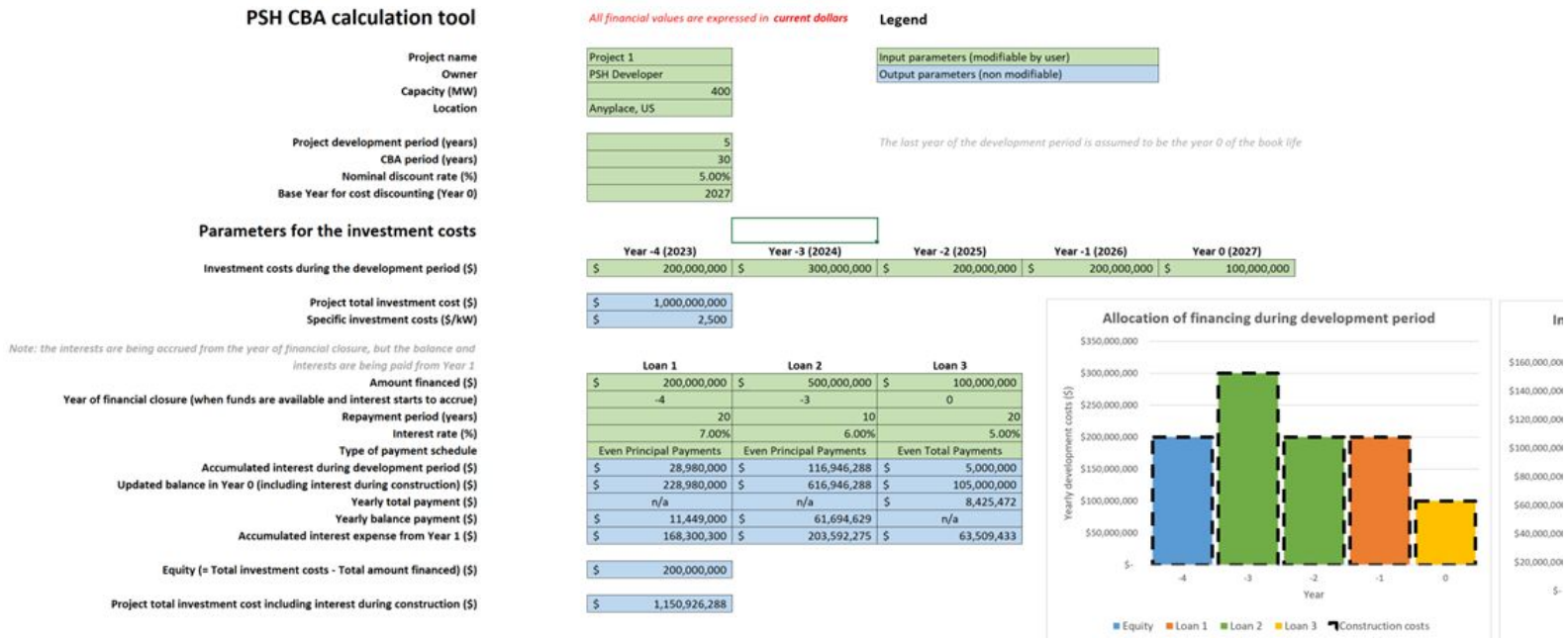
B=Brooking offshore wind; C=Coos Bay offshore wind

Takeaway:

- PSH avoid investment in battery and peak gas units, it is more prominent with the case o onshore wind only, where additional more PV is invested.
- Offshore wind replaced investment on PV investment if compared offshore wind and onshore wind cases.

BCA CALCULATOR & FINANCIAL WORKSHEETS

- BCA calculator runs the user through a series of data requests
- Model enables the user to define alternative scenarios, evaluate many use cases, and consider alternative debt structures, alternative depreciation methods, tax implications, salvage value, all capital and operations and maintenance costs, and refurbishment costs



PSH CBA calculation tool

Project name	Project 1
Owner	PSH Developer
Capacity (MW)	400
Location	Anyplace, US
Project development period (years)	5
CBA period (years)	30
Nominal discount rate (%)	5.00%
Base Year for cost discounting (Year 0)	2027

Parameters for the investment costs

	Year -4 (2023)	Year -3 (2024)	Year -2 (2025)	Year -1 (2026)	Year 0 (2027)
Investment costs during the development period ($)	$ 200,000,000	$ 300,000,000	$ 200,000,000	$ 200,000,000	$ 100,000,000

Project total investment cost ($)	$ 1,000,000,000
Specific investment costs ($/kW)	$ 2,500

Note: the interests are being accrued from the year of financial closure, but the balance and interests are being paid from Year 1

	Loan 1	Loan 2	Loan 3
Amount financed ($)	$ 200,000,000	$ 500,000,000	$ 100,000,000
Year of financial closure (when funds are available and interest starts to accrue)	-4	-3	0
Repayment period (years)	20	10	20
Interest rate (%)	7.00%	6.00%	5.00%
Type of payment schedule	Even Principal Payments	Even Principal Payments	Even Total Payments
Accumulated interest during development period ($)	$ 28,980,000	$ 116,946,288	$ 5,000,000
Updated balance in Year 0 (including interest during construction) ($)	$ 228,980,000	$ 616,946,288	$ 105,000,000
Yearly total payment ($)	n/a	n/a	$ 8,425,472
Yearly balance payment ($)	$ 11,449,000	$ 61,694,629	n/a
Accumulated interest expense from Year 1 ($)	$ 168,300,300	$ 203,592,275	$ 63,509,433

Equity (= Total investment costs - Total amount financed) ($)	$ 200,000,000
Project total investment cost including interest during construction ($)	$ 1,150,926,288

All financial values are expressed in current dollars

Legend

Input parameters (modifiable by user)
Output parameters (non modifiable)

The last year of the development period is assumed to be the year 0 of the book life

PSHVT BCA Calculator

- BCA calculator defines a benefit-cost ratio, discounted payback period, net present value, and an internal rate of return for each case

FINANCIAL MODEL ASSUMPTIONS

Assumptions	
Project name	Soldier Camp
Owner	Rye Development
Capacity (MW)	575
Location	Curry County, Oregon
Equity %	50%
Project development period (years)	6
CBA period (years)	50
Economic Life (years)	50
Nominal discount rate (%)	9%
Start year of Development and Construction	2025
Base Year (Year 0)	2031
ITC %	50%
ITC Application (how funds received)	ITC Progress Expenditures
Percent reduction in ITC from Basis	50%
Letter of Commitment Required	No
Economy Inflation Rate (%)	2.3%
Percent of Life Remaining -any refurbishment	40%

Key Assumptions
CBA Life = 50 years
Equity % = 50%
Discount rate = 9%
ITC = 50%
Remaining Value 40%

FINANCIAL FEASIBILITY OF OWNER-OPERATOR APPROACH

Results dependent on capacity payment

	All Sites		Brookings		Coos Bay		Onshore Only	
	No Capacity Payment	Potential CAISO Payment	No Capacity Payment	Potential CAISO Payment	No Capacity Payment	Potential CAISO Payment	No Capacity Payment	Potential CAISO Payment
Total Revenue (2022$)	24,407	104,112	24,212	103,918	25,112	104,817	24,999	104,705
Net Present Value (NPV) (2025$)	(616,526)	62,899	(618,330)	61,280	(609,987)	68,765	(611,034)	67,827
Benefit to cost ratio (BCR)	0.32	1.06	0.32	1.06	0.33	1.06	0.32	1.06
Internal Rate of Return (IRR)	#NUM!	10.2%	#NUM!	10.2%	#NUM!	10.3%	#NUM!	10.3%
Discounted payback period (years)	Unsolved	25.00	Unsolved	25.00	Unsolved	24.00	Unsolved	24.00
Minimum Debt Service Coverage Ratio	(1.81)	0.32	(1.82)	0.32	(1.79)	0.34	(1.79)	0.34

	Breakeven Capacity Payment	Potential C/	Breakeven Capacity Payment	Potential CAISO Payment	Breakeven Capacity Payment	Potential CAISO Payment	Breakeven Capacity Payment	Potential CAISO Payment
Total Revenue (2022$)	96,666	104,112	96,666	103,918	96,666	104,817	96,666	104,705
Capacity Payment ($2022)	72,260	79,706	72,454	79,706	71,555	79,706	71,668	79,706
Capacity Payment ($2022) ($/kW-month)	11.80	13.02	11.83	13.02	11.69	13.02	11.70	13.02
Inflator	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Capacity Payment ($2025) ($/kW-month)	12.86	14.18	12.89	14.18	12.73	14.18	12.75	14.18

FINANCIAL FEASIBILITY OF SYSTEM PERSPECTIVE

	Brookings + Coos Bay + Onshore	Brookings	Coos Bay	Onshore	Brooking + Coos Bay + Onshore Breakeven
	50 years				
Net Present Value (2025$) ($ Mil.)	(29.00)	(177.34)	(161.41)	(429.41)	0.00
Benefit to cost ratio (BCR)	0.97	0.83	0.84	0.55	1.00
Internal Rate of Return (IRR)	8.38%	#NUM!	#NUM!	#NUM!	9.00%
Discounted payback period (years)	Unsolved	Unsolved	Unsolved	Unsolved	50.00
Minimum Debt Service Coverage Ratio	0.03	(0.44)	(0.39)	(1.23)	0.12
Revenue ($ Mil.)	93.24	75.73	77.61	45.98	96.67

CONCLUSIONS

- All base cases from the owner-operator perspective provide approximately the same capacity payment requirement
  - If only one wind farm location came online, a similar capacity payment requirement would make the project potentially feasible
  - If Rye can feasibly bid into the CAISO market, they would have a profitable project with the given assumptions
- From the System perspective, only if all the farms came online would the project be feasible
  - If only Coos Bay or Brookings wind farms came online, Soldier Camp would be almost feasible registering near 9 percent IRRs
    - Indicates PSH not dependent on all wind farms coming online
  - Only if the onshore wind farm came online, would the PSH be infeasible


QUESTIONS?

Contact Information

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BACKUP SLIDES

OFFSHORE INTERCONNECTION POINTS

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

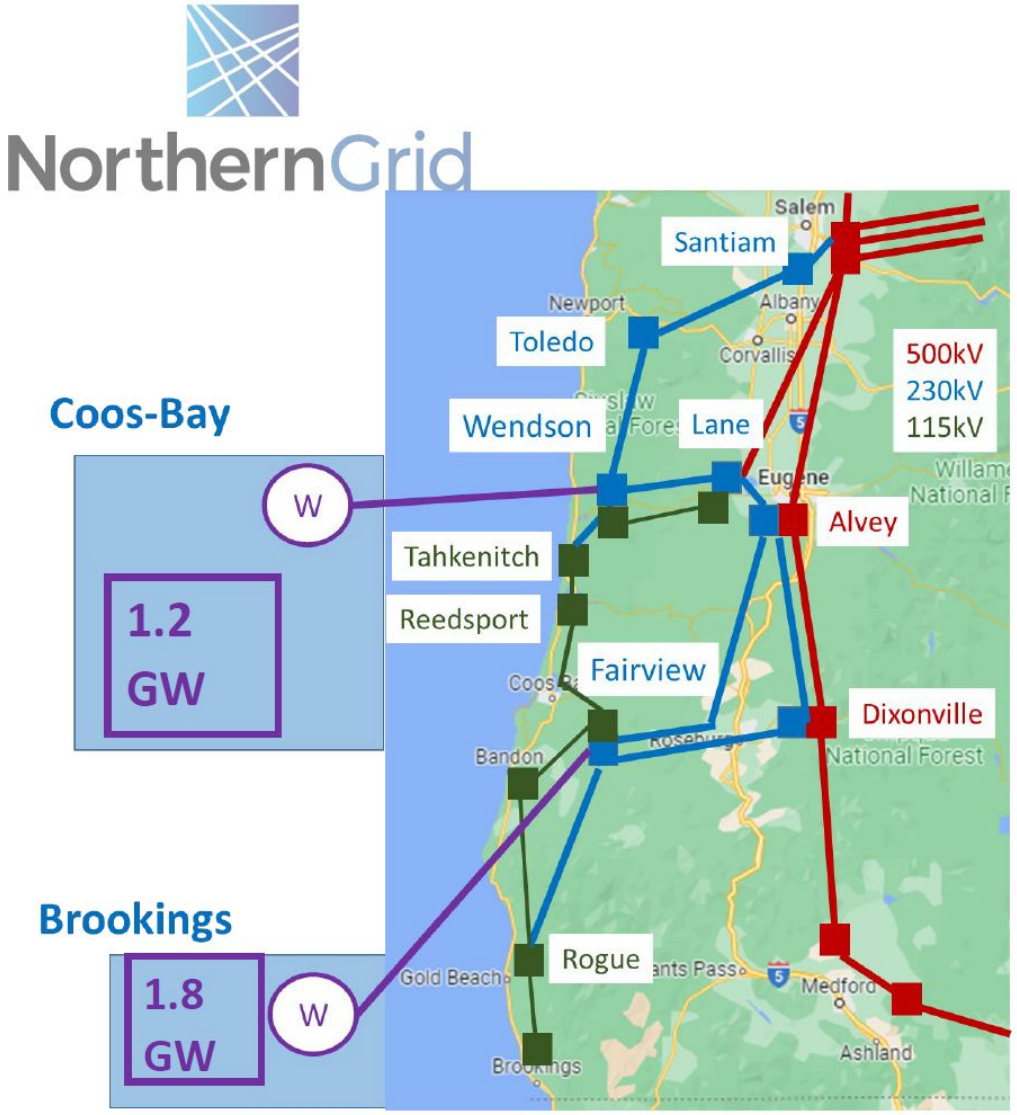

Figure 2: Offshore wind request

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

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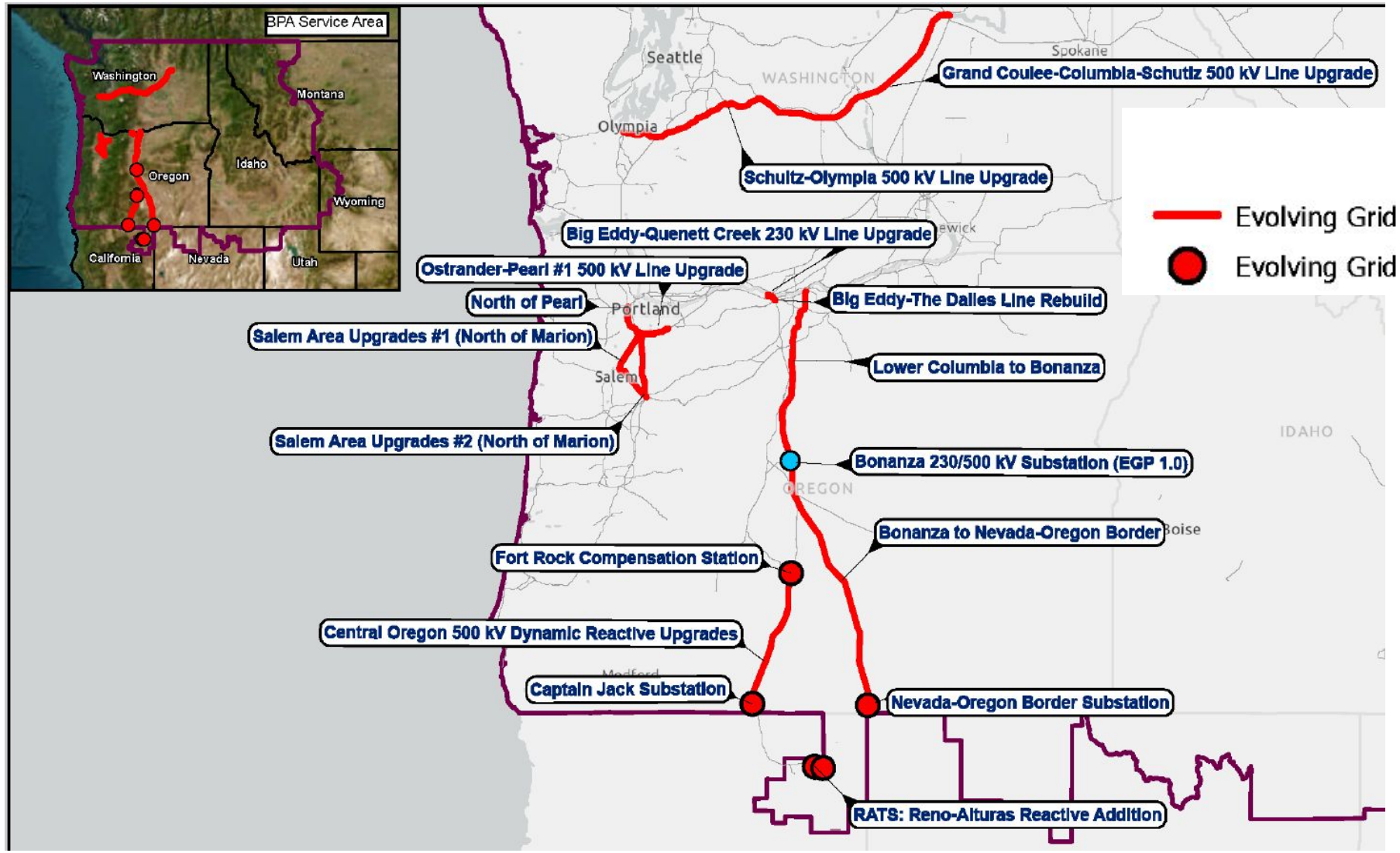

- Upgrading transmission in Coos and Curry Counties not on BPA's current project lists
- Major upgrade within the WECC-PSSE model