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Evaluating the Grid Impact of Oregon Offshore Wind

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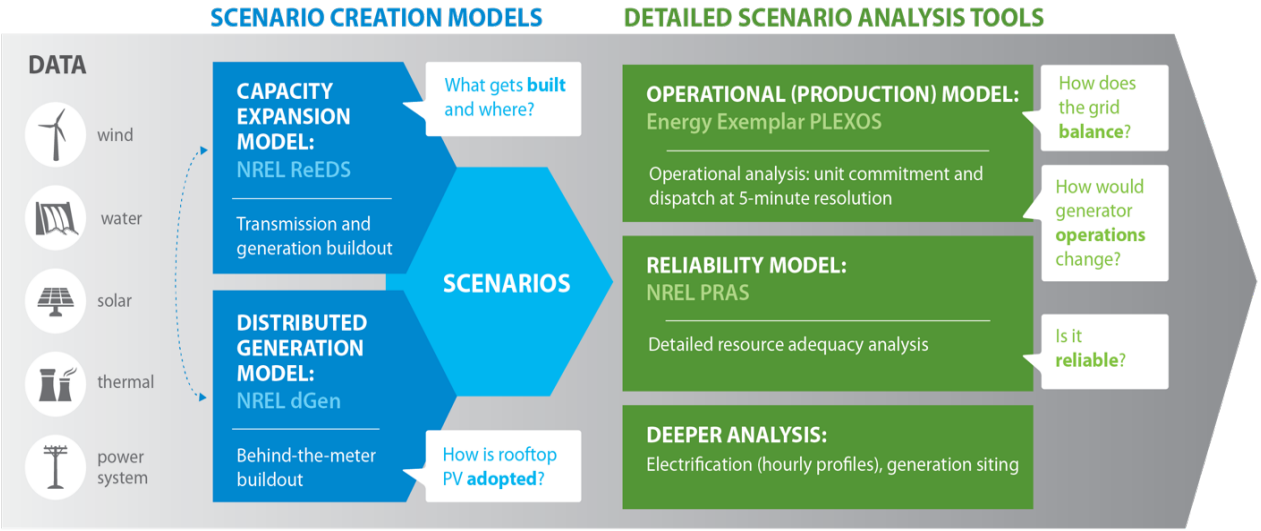
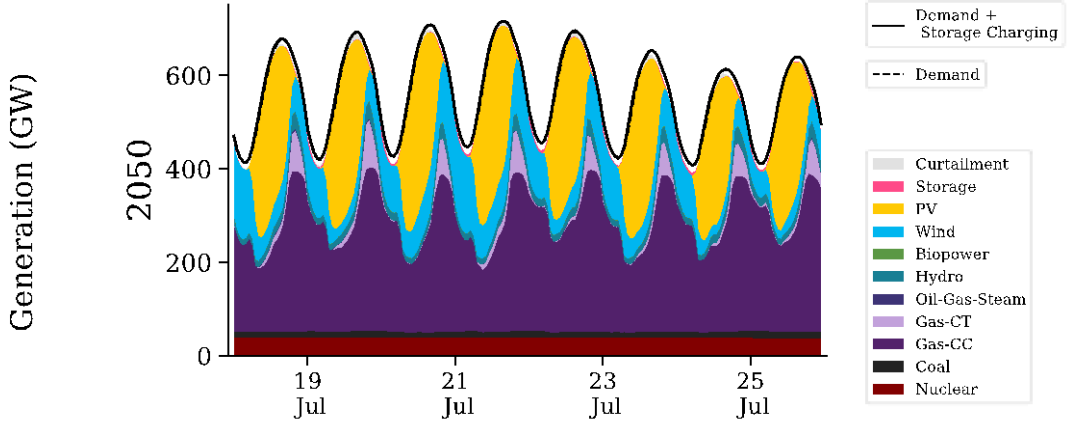
Study Objectives





Using high resolution data sets and modeling developed through past studies, explore value and impact of offshore wind (OSW) integration into Oregon's power system.

Wind, Solar, and Weather Data Sets

Land-Based Resource and Infrastructure Data

WIND Toolkit

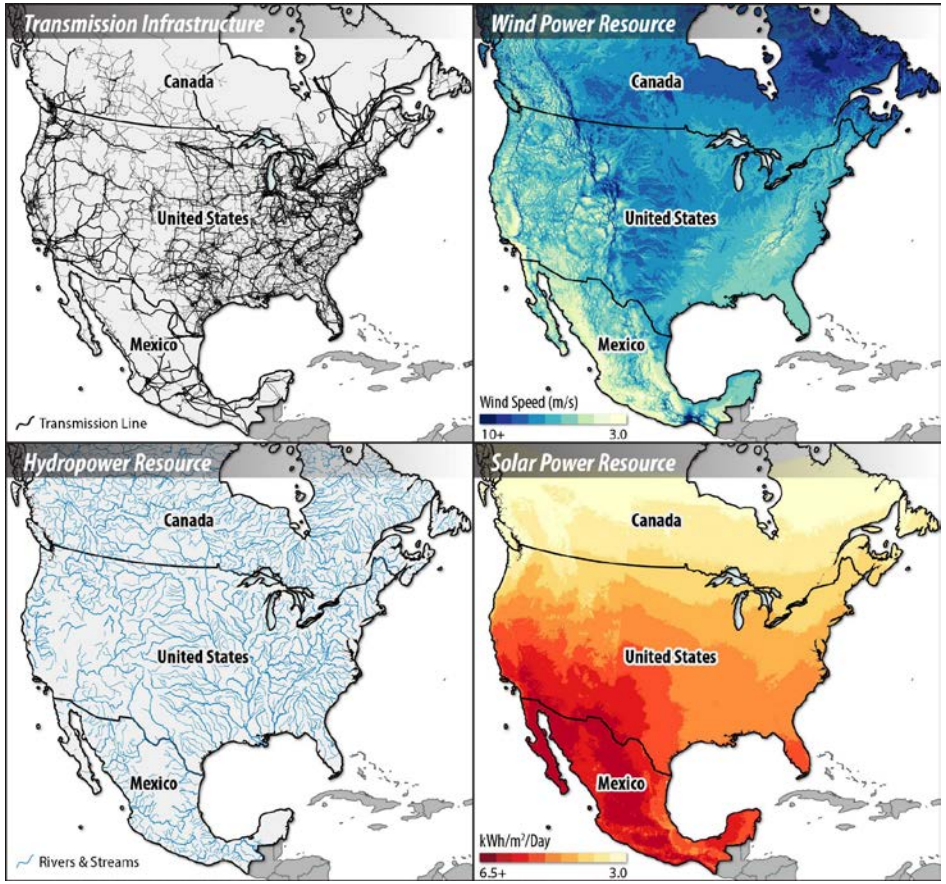
- 2007 – 2013
- 5-minute resolution
- 2km x 2km spatial resolution

National Solar Radiation Database (NSRDB)

- 1998 – 2020
- 30-minute resolution
- 4km x 4km spatial resolution

Hydropower Resource

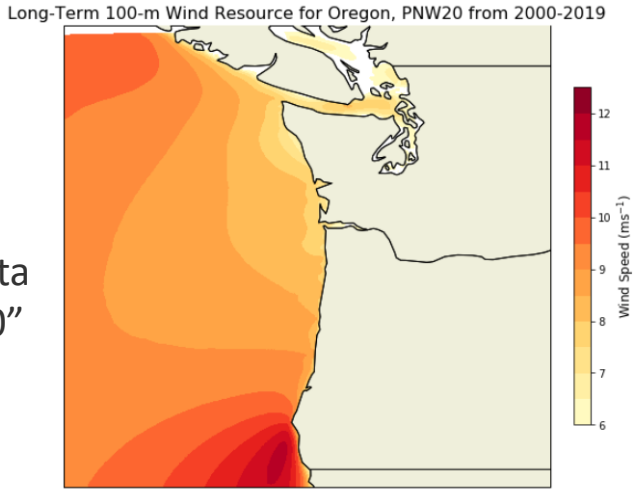
- EIA-923 plant level generation data to adjust maximum energy limits.



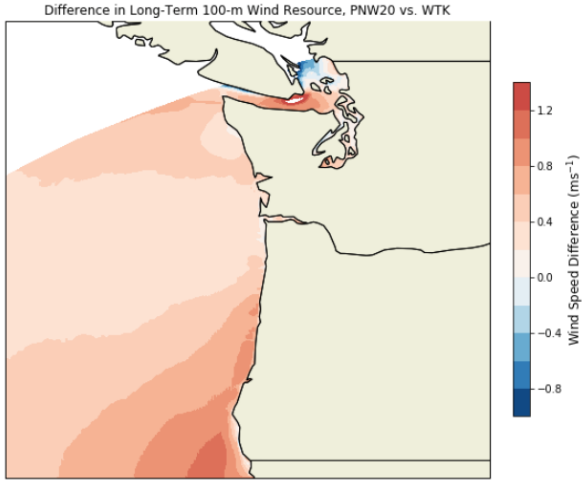
Updated PNW OSW 2000-2019 Year Data Set

Updated offshore data set 10m wind speed vs 5m buoy measurements from NOAA

Updated offshore data set,"PNW20"



Difference between PNW20 and WINDToolkit data sets (red = higher wind speed)



Scenario Description

Five scenario dimensions

1. **OSW penetration**: Base (0 GW), Mid (2.6 GW), or High (5 GW)

2. **WECC infrastructure year**: Current grid (~22% Wind/Solar penetration by generation), or future system (~46% Wind/Solar) based on past NREL studies.

3. **Trans-coastal range transmission expansion**: no expansion, or expansion along trans-coastal corridors to avoid congestion with 5 GW of OSW.

4. **Co-located energy storage**: no storage, or co-located storage at the onshore point of interconnection. The storage systems are sized at 10% of the associated OSW plant power, and 24-hour duration.

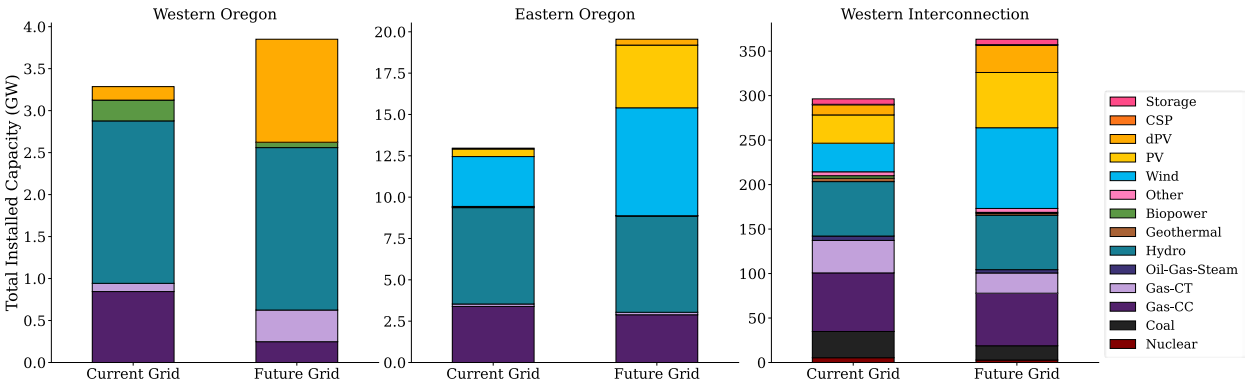
5. **Historical year:** The 2012 historical weather year was run for all scenario combinations. We ran 7 historical weather years (2007-2013) for three select scenario combinations.

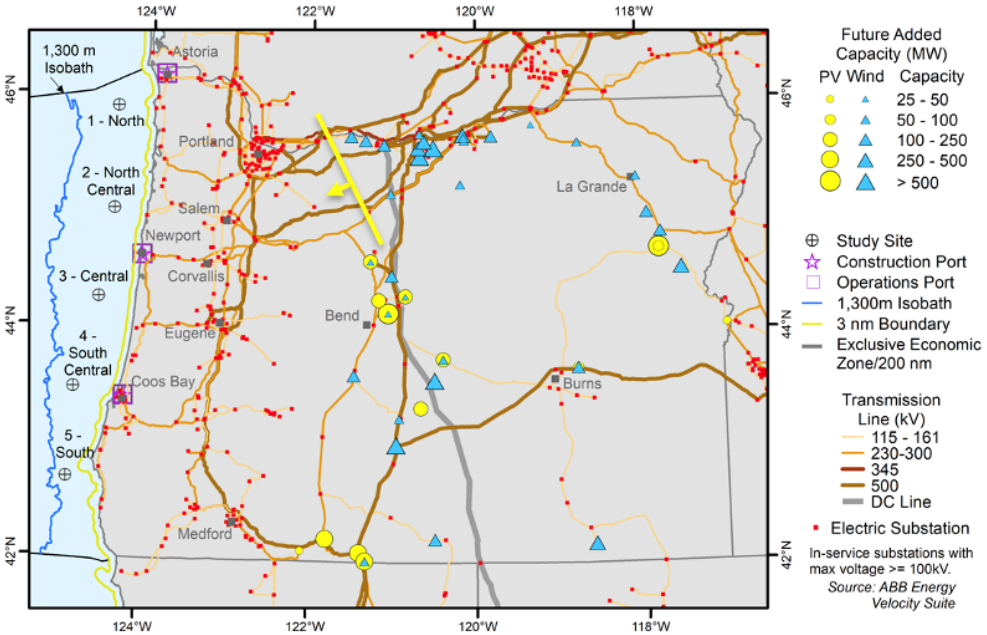
Analytical Scope: *Western Oregon (West of the Cascade Range), Eastern Oregon, and the full Western Interconnection*

Scenario Name	OSW Penetration	WECC Infrastructure Year	Trans-Coastal Transmission	Co-Located Storage	Meteorological Years
Base – Current Grid (CG)	0 GW	Current Grid (2024)	Existing capacity	No Storage	2012 only
Base – Future Grid (FG)		Future Grid (2036)			2007-2013
Mid Offshore – CG	2.6 GW	Current Grid	Existing capacity	No Storage	2012 only
Mid Offshore - CG - Storage				Storage	2012 only
Mid Offshore - FG		Future Grid		No Storage	2007-2013
Mid Offshore - FG - Storage				Storage	2012 only
High Offshore - FG	5 GW	Future Grid	Existing capacity	No Storage	2012 only
High Offshore - FG - Storage				Storage	2012 only
High Offshore - FG – Transmission (Tx)			Expanded trans-coastal transmission	No Storage	2007-2013
High Offshore - FG - Tx - Storage				Storage	2012 only

Future Grid Scenario (2036)*

- Created using NREL's flagship capacity expansion model, *ReEDS*
- Land-based wind and solar penetration increases throughout interconnection (46% of annual load)
- Natural gas reduces in Eastern Oregon.
- Distributed PV capacity increases in Western Oregon
- Utility scale wind and PV increases in Eastern Oregon





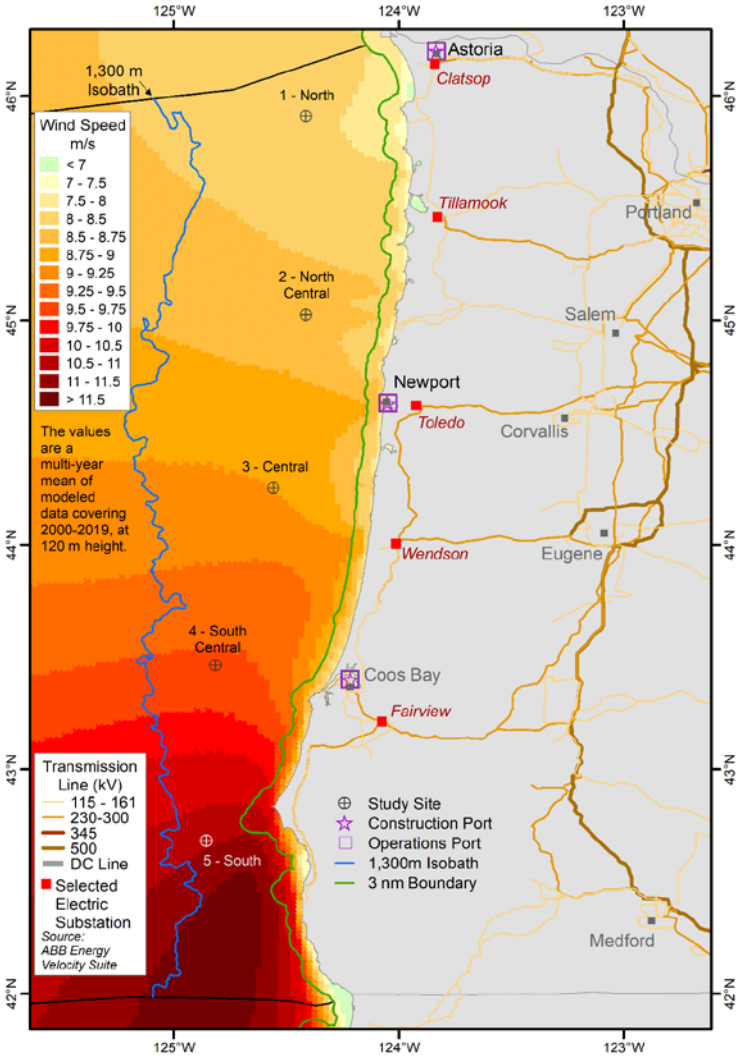
Key Findings

Finding 1: Existing system may support up to 2.6 GW of OSW

OSW Point of Interconnection	Max Nameplate Capacity (MW)	Max Injected power* (MW)
Clatsop (1-North)	361	301
Tillamook (2-North Central)	553	461
Toledo (3-Central)	156	130
Wendson (4-South Central)	613	512
Fairview (5-South)	941	785
Total	**2625**	**2189**

- The OSW capacity is not evenly distributed amongst coastal substations, rather the capacities were chosen based the ratings of the of associated trans-coastal transmission lines.
- Southern sites were maximized to their superior capacity factor.

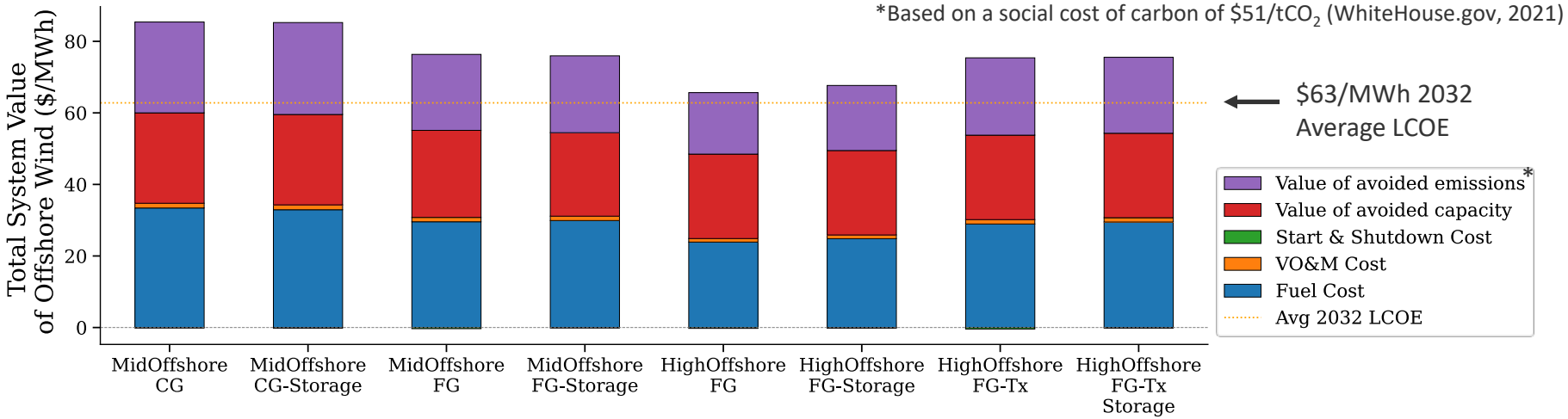
*Due to internal loses, max injected power is 83.4% of nameplate.



Caveats to Finding 1

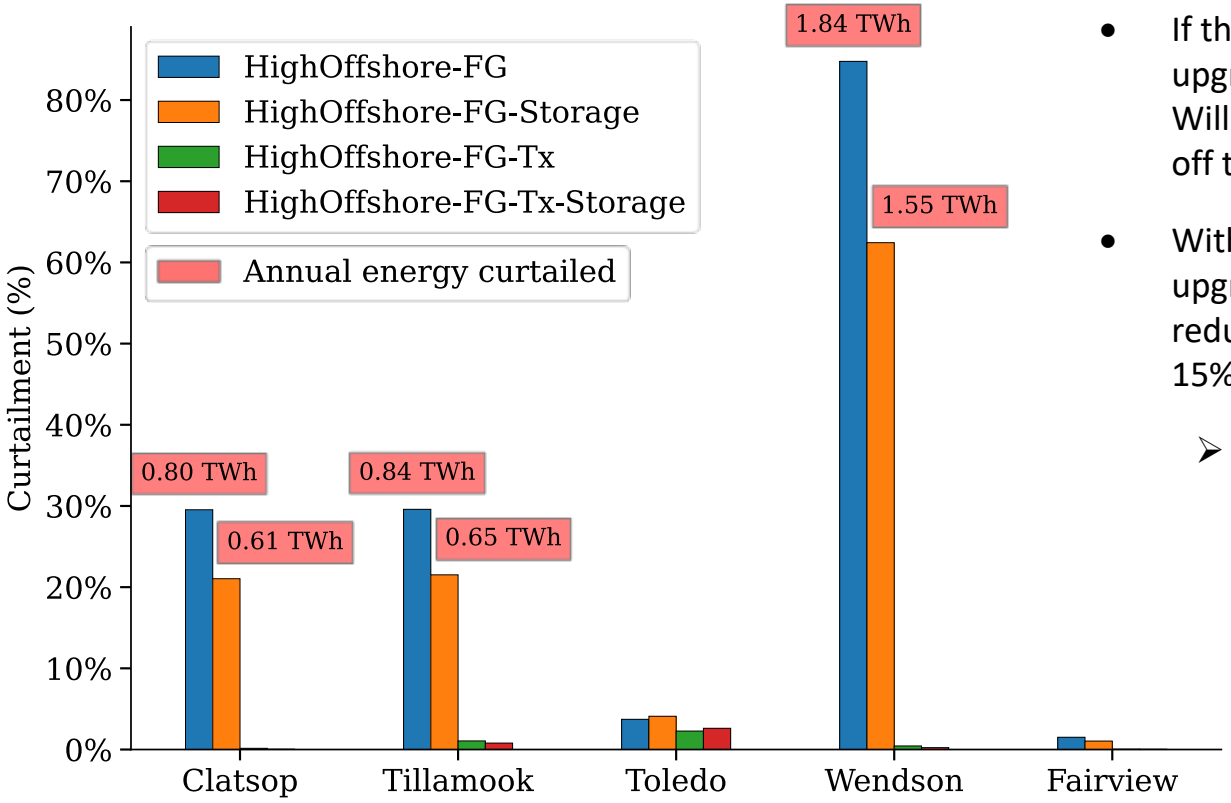
- Detailed power flow analysis is needed to refine the distribution of OSW, the total OSW capacity, and identify small upgrades to the trans-coastal system.
- This study does not capture the costs and barriers of using smaller scale transmission to interconnect the offshore wind turbines with the five high voltage coastal substations within the existing transmission system limits (e.g., right-of-way, reactive power support, and upgrades to the existing system to accommodate interconnection)."
- The southern sites included in this study have higher average wind speeds than the northern sites, but they are also farther from existing coastal substations. An investigation of the trade-off between the cost of interconnection and capacity factor was not included in this study scope. A previous NREL study that estimated the LCOE of new OSW did include the cost of undersea transmission.
- The OSW locations used in this study do not represent the results of a comprehensive siting study.
- As this study is not a comprehensive power flow or resource adequacy analysis, it does not capture line outage contingencies.

Finding 2: OSW grid value is between $68-$74/MWh



- Quantified value streams include operational (fuel, VO&M, start and shutdown), capacity, and emissions reduction value. Most of the operational value comes from reduced gas-CC generation.
- The average projected 2032 LCOE for Oregon OSW is $63/MWh (Musial et al. 2021). Across all scenarios, the system value is above this reference.
- System value changes between the seven meteorological years, with a maximum range of $11/MWh.
- The value of OSW decreases in the future grid scenarios, as it displaces more efficient gas generation and competes with more land-based VRE.

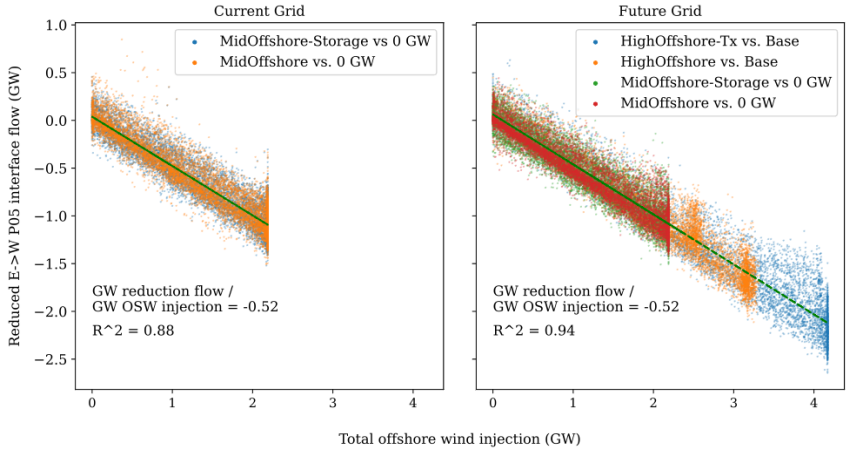
Finding 3: Trans-coastal transmission congestion is the main driver of OSW curtailment, when OSW penetration >2.6 GW

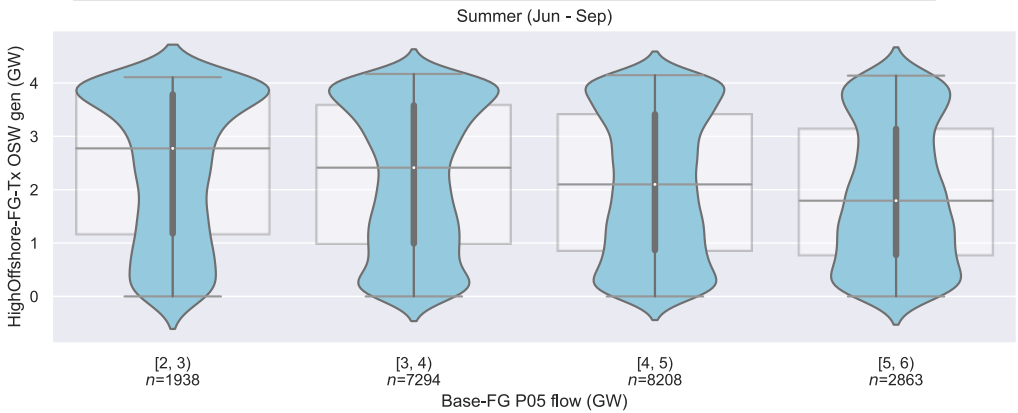


- If the trans-coastal transmission is upgraded, power can be delivered into the Willamette Valley and curtailment of OSW off the coast of Oregon becomes minimal.
- Without trans-coastal transmission upgrades, co-located energy storage can reduce OSW curtailment by approximately 15%.
  - ➢ More detailed investigation of storage sizing could help determine the full curtailment and congestion management value of co-located storage.

FG: Future Grid
Tx: Transmission

Finding 4: East/West cross-Cascade range power flow reduces 500-550 MW for every 1000 MW of OSW output but does not eliminate high flow periods





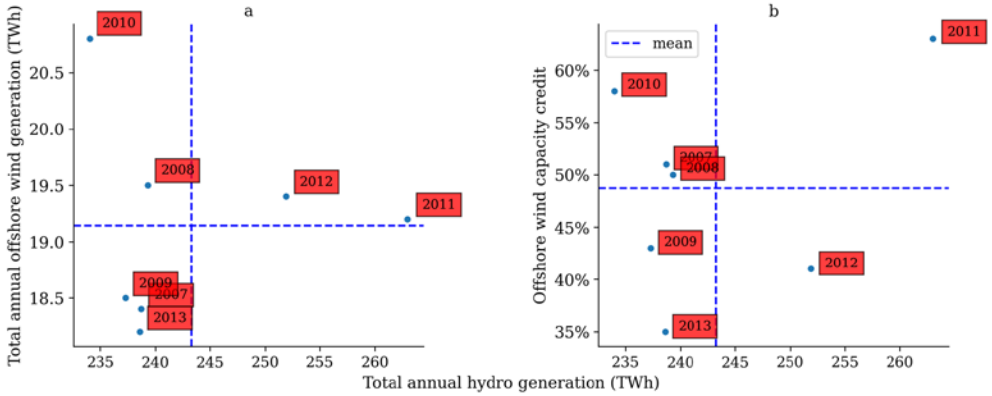
- OSW is not consistently available during hours with high cross-Cascade transmission flow. This limits the extent to which OSW can be considered a non-wires alternative to defer further for the cross-Cascade transmission expansion.
- Further investigation of the non-wires alternative potential of OSW would require more detailed resource adequacy and reliability modeling.

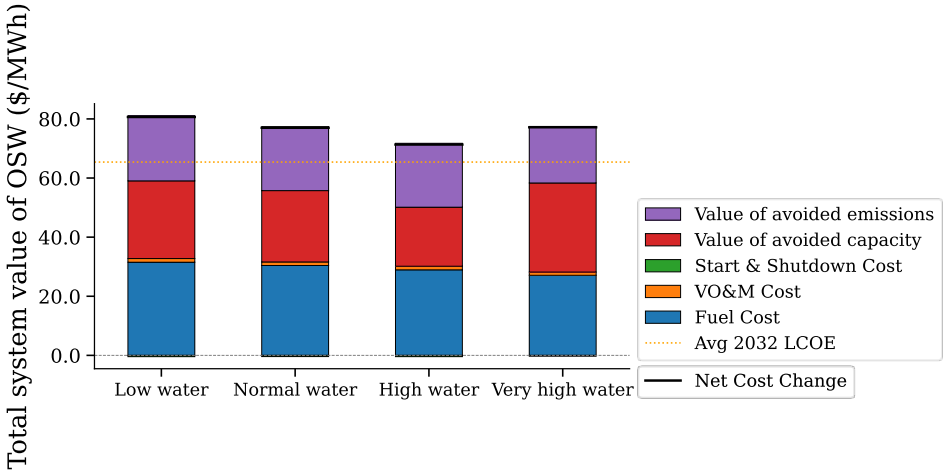
Finding 5: OSW can serve over 84% of hourly coastal Oregon loads (2007-2013)

Point of Interconnection	Load		Mid Offshore		High Offshore	
	Annual Total (TWh)	Annual Peak (MW)	Servable Load	Capacity Credit	Servable Load	Capacity Credit
Clatsop	0.41-0.41	63-70	74-80%	30-58%	82-87%	30-58%
Tillamook	1.36-1.37	262-316	67-75%	34-64%	74-82%	34-64%
Toledo	0.96-0.98	237-286	43-51%	34-61%	75-83%	34-61%
Wendson	0.34-0.35	76-93	82-86%	35-55%	84-88%	35-55%
Fairview	1.03-1.03	201-239	80-84%	39-58%	80-85%	39-58%
Total	**4.11-4.13**	**833-1004**	**84-89%**	**34-61%**	**90-94%**	**33-62%**

- The ranges in this table represent the max/min results from the seven historical data years.
- The capacity credit values indicate that, depending on the weather year (2007-2013), 880-1,580 MW and 1,650-3,100 MW can be counted on to serve coastal loads for the Mid Offshore and High Offshore scenarios, respectively.
- These results suggest that OSW could provide a sizable contribution to coastal reliability and resilience, but a specific resource adequacy model is be required to fully address coastal reliability and resilience.

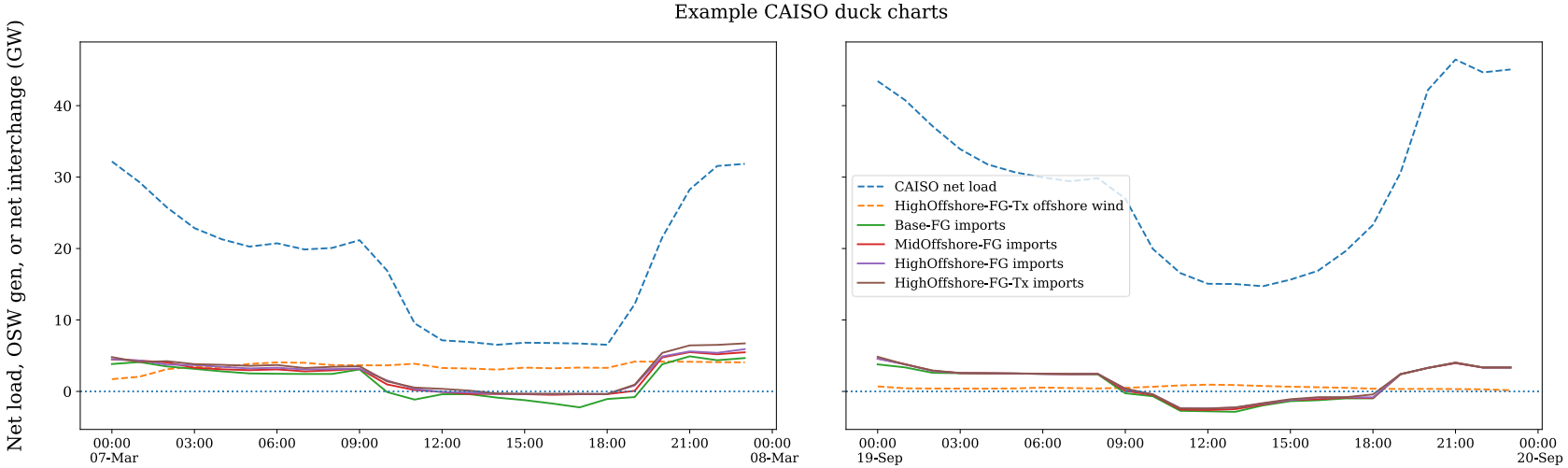
Finding 6: OSW allows for more optimal hydropower dispatch, while hydro availability (i.e., wet vs dry year) has little impact on OSW system value.





- Based on the 7-year data set, there is little relationship between the inter-annual variability of OSW and water availability for hydro generation
- Other inter-annual variation (availability of OSW, land-based wind, and solar) has greater influence on OSW system value than inter-annual water availability.

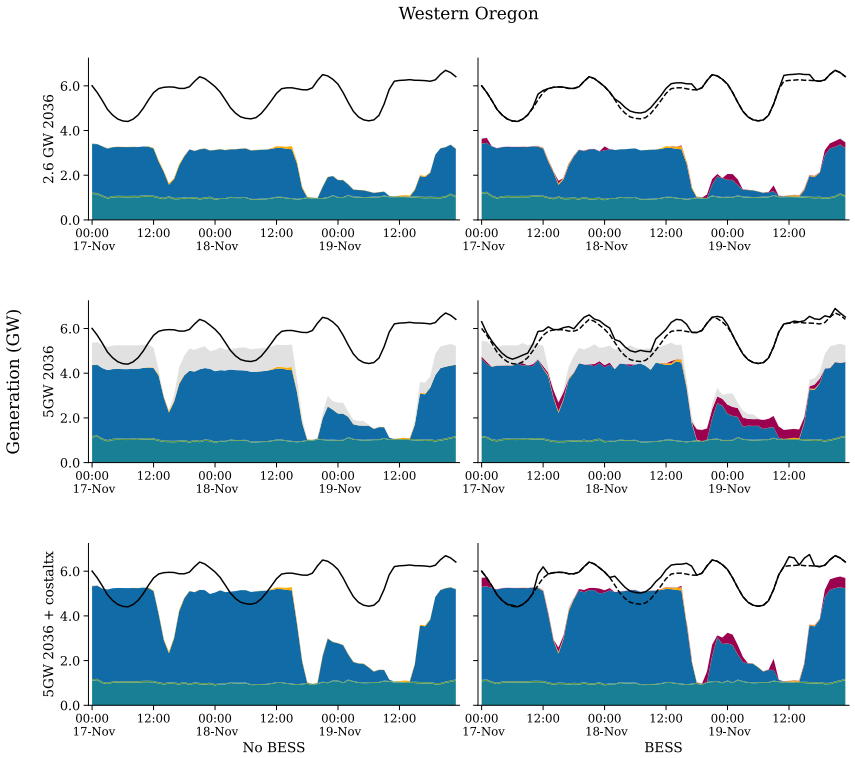
Finding 7: OSW increases exports from Oregon to serve evening net load peak in California (i.e., duck curve), but further contribution is limited by congestion



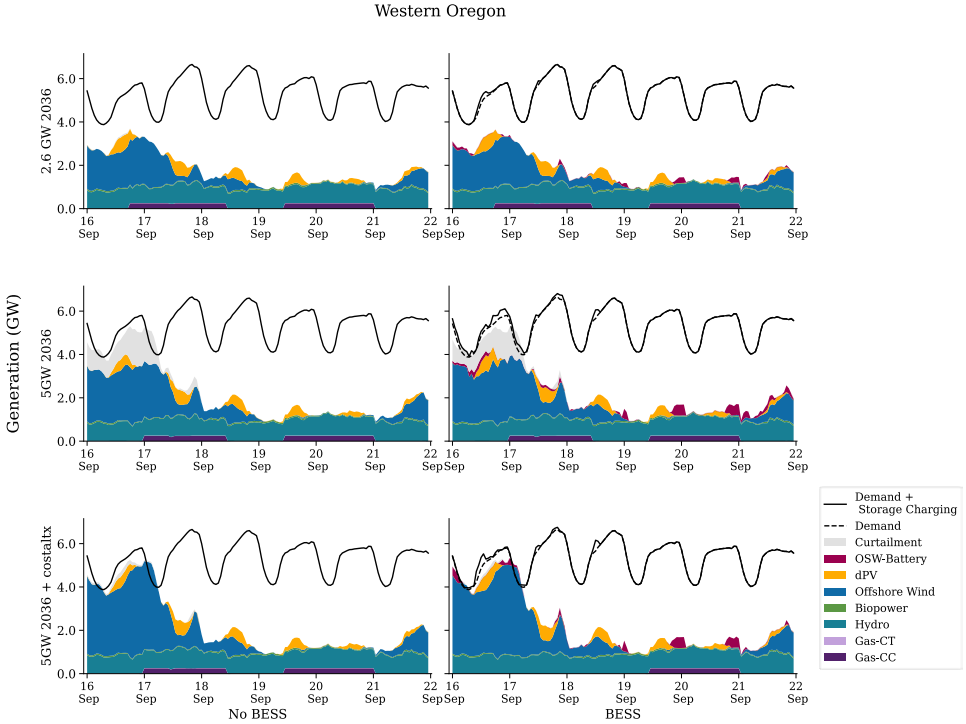
- With high OSW generation, OR to CA exports increase at all hours of the day relative to the 0 GW OSW base case, particularly during CA net load peak in evening. Little change in OR to CA exports, on days with low OSW generation.
- Interstate transmission congestion limits the ability for OSW to help in 41% of the evening ramps in the year. During 17% of the evening ramps, this congestion is not present in the 0 GW base case.
- OSW capacity factor during CAISO's summer evening net load peaks is 52% and 49% in the 2.6 and 5 GW scenarios, respectively.

Finding 8: Storage smooth short periods of low OSW

During short low OSW generation periods, storage shift wind energy to any low generation period



During multiday wind droughts storage dispatches during net load peaks only



Summary of Findings

Finding 1: Existing system can support up to 2.6 GW of OSW

Finding 2: OSW grid value exceeds its LCOE

Finding 3: Transmission congestion is main driver of OSW curtailment

Finding 4: OSW reduces flow on cross-Cascade transmission

Finding 5: OSW can serve over 84% of coastal Oregon loads

Finding 6: OSW allows for more optimal hydropower dispatch

Finding 7: OSW increases current OR to CA transmission exports

Finding 8: Batteries smooth short periods of low OSW

Future Work

- Model this system using stochastic reliability and resource adequacy tools. This would enable the:
  - Investigation of the opportunity for OSW's to provide a non-wires alternative to cross-Cascade transmission.
  - Robust calculation of capacity credit for OSW and co-located energy storage systems.
  - More accurate determination of the opportunity for OSW's to bolster the reliability and resistance of coastal Oregon loads specifically.

- Explore specific design options for upgraded trans-coastal transmission (e.g. cost right-of-way and robustness tradeoffs).

- Implement more detailed assumptions regarding the coastal transmission systems, and identify small and targeted upgrades that would facilitate the most cost effective options for the integration of OSW.

- Evaluate more options for co-located energy storage system sizes and operational parameters to analyze the costs of storage systems and large transmission investments, thereby determining which option facilitates the most cost-effective integration of OSW.

- Utilize more years of data for OSW, load, hydro, land-based wind and solar PV (2007-2020). Recent validation work has made this more feasible than previously thought.

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Thank you!

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