Gridworks Connected West Study

Study Update to WECC LTPTF

March 14, 2024

GRIDWORKS

GridLAB

ENERGY STRATEGIES

Background and Approach

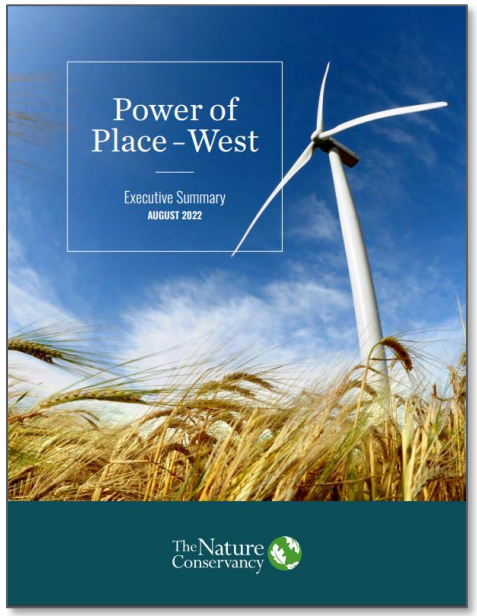
Connected West Study: Scope and Methods

- **The study is a 20-year transmission planning analysis designed to:**
  - Forecast long-range transmission needs of the Western grid for a **low-carbon & high electrification scenario**
  - Identify portfolios of potential **transmission expansion concepts** that meet those needs
    - Focus is on identifying the **"next generation"** of transmission investments
- **The study builds from recent planning assessments and existing models, especially the Nature Conservancy's *Power of Place: West* study**
- **The study endeavors to capture broad and "modern" set of transmission benefits when evaluating portfolios of transmission project concepts**

Key Attributes of Connected West Study

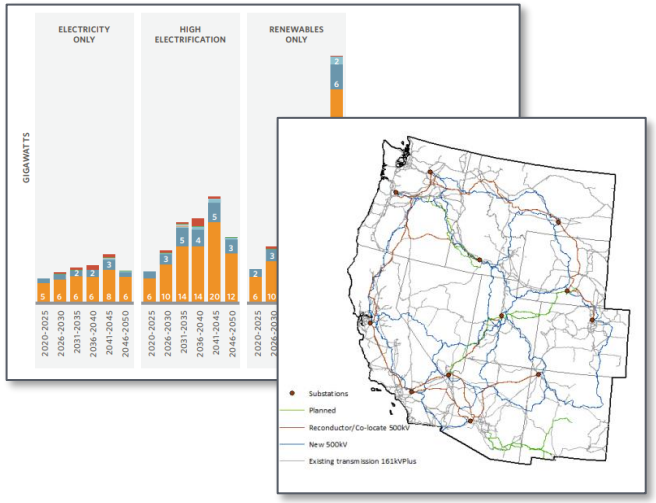
20-year assessment (~2045 study year)	Focused on US portion of WECC system	Detailed representation of grid	WECC 2032 ADS serves as "seed case"
Nodal dispatch modeling (GridView™)	Powerflow analysis (PowerWorld)	Resource plan per *Power of Place: West* study	Consideration of electrification-driven demand growth
Assumes planned and "anticipated" transmission is built	Candidate transmission upgrade concepts sourced from *Power of Place* study	Assumes West-wide day-head nodal market	Forecast of offshore wind in CA and OR
	Modernized transmission benefit assessment	Portfolio-based transmission approach	

Connected West Study: Building from *Power of Place: West*



Study effort sponsored by Nature Conservancy (link) featured economy-wide energy and transmission expansion model developed by Evolved Energy Research, which incorporated generation and transmission land use considerations to explore how the West can achieve both climate and land conservation goals in 2050.

Load forecasts and optimized resource and transmission plans from *Power of Place*



The Connected West Study builds on Power of Place, relying on outputs from that effort. Specifically, the "High Electrification" scenario results relating to load forecasts, resource buildouts, and transmission expansions will inform this study. In addition, extensive databases on land use and sensitivities will inform transmission analyses.

Connected West is transmission focused and will provide a new perspective based on a future consistent with *Power of Place*

- ☑ Identification of transmission needs / issues driving upgrades (based on optimal resource portfolio)
- ☑ Portfolio-based transmission assessment exploring both benefits and costs of sets of transmission solutions
- ☑ Focus on quantifying broad set of benefits useful for identifying valuable long-term upgrades

Connected West will leverage the *Power of Place's* optimized capacity expansion model results, helping to resolve the "chicken and egg" planning challenge. We assume the resource portfolio is reasonable, and then work to build the transmission needed for it (while evaluating the business case for such transmission).

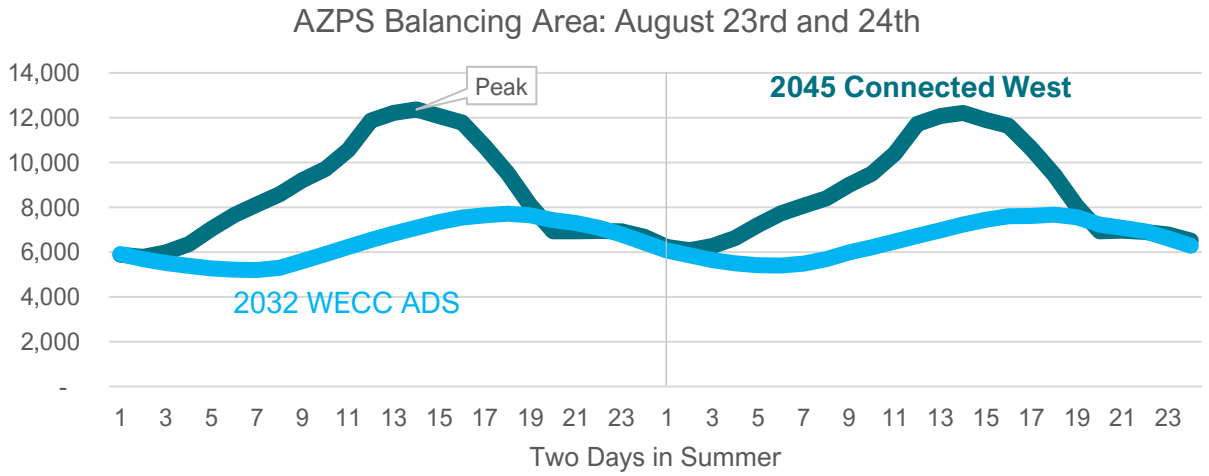
Assumptions and Inputs

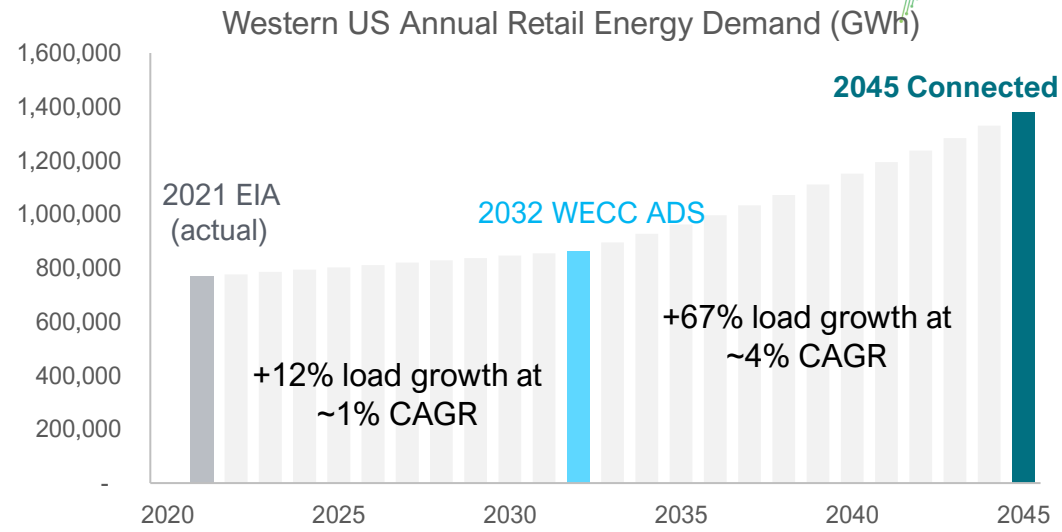
Assumption Overview: 2045 Reference Case

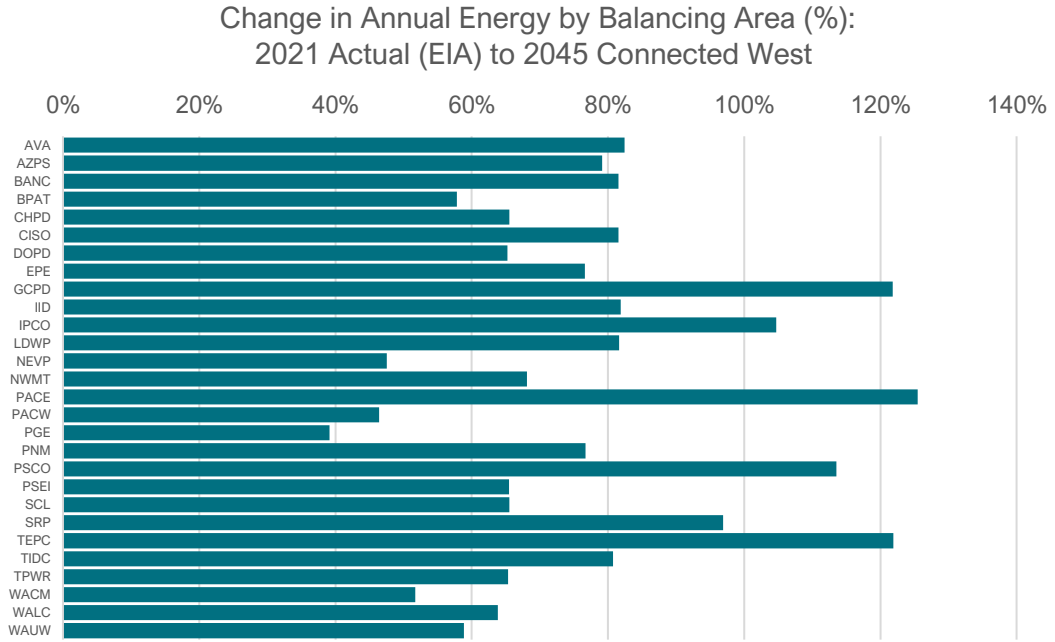
Assumption	WECC 2032 ADS*	Connected West 2045 Reference Case	Notes & Methodology
Seed Case	N/A	WECC 2032 ADS*	The ADS case represents a 2032 1-in-2 load forecast and the resource plan in as submitted to WECC by the Balancing Authorities. The 22-23 CAISO TPP transmission upgrades and planned generation were added to the ADS case by Energy Strategies to create the seed case.
Load Forecast	Peak demand: 282 GW Annual energy: 116 aGW	Peak demand: 381 GW Annual energy: 173 aGW	Connected West assumption sourced from Power of Place: West (electrification scenario) and assigned to GridView balancing areas using historical allocation factors between states and BAs. Adopted hourly profiles per PoP-West.
Generation Capacity (WECC-US)	328.1 GW *includes generation from CAISO TPP not in ADS	745.6 GW (+127%)	Existing and planned generation through 2032 were sourced from the WECC 2032 ADS. 2033-2045 additions sourced from Power of Place (high electrification scenario). Geospatial analysis assigned reasonable interconnection point for future generation from Power of Place.
Transmission Additions	N/A	>15 major projects in development added, representing 5,300 line miles and 27 GWs of new capacity	Connected West assumes all transmission lines included in the 2032 ADS are in-service (sourced from WECC 2032 HS1 Base Case). In addition, study assumes many projects “in-flight” or planned are built to focus the study on future transmission needs. Focus was on adding large scale upgrades.
Market Modeling	No regional energy markets assumed.	West-wide day-ahead market	Connected West assumes the West forms a day-ahead market that features a flexibility reserve product to assist the region in efficiently integrating renewables. There is no hurdle rate discouraging economic trade.
Transmission Monitoring	TBD	All 300-kV and higher facilities, plus any 200-kV and higher facilities that intersect state borders or BA or were otherwise deemed regional in nature	Connected West focuses “monitoring” (i.e., constraint modeling) on major transmission lines, paths, and inter-area or inter-state transmission, consistent with the purpose of the study.

Load Forecast: Connected West "High Electrification" in 2045

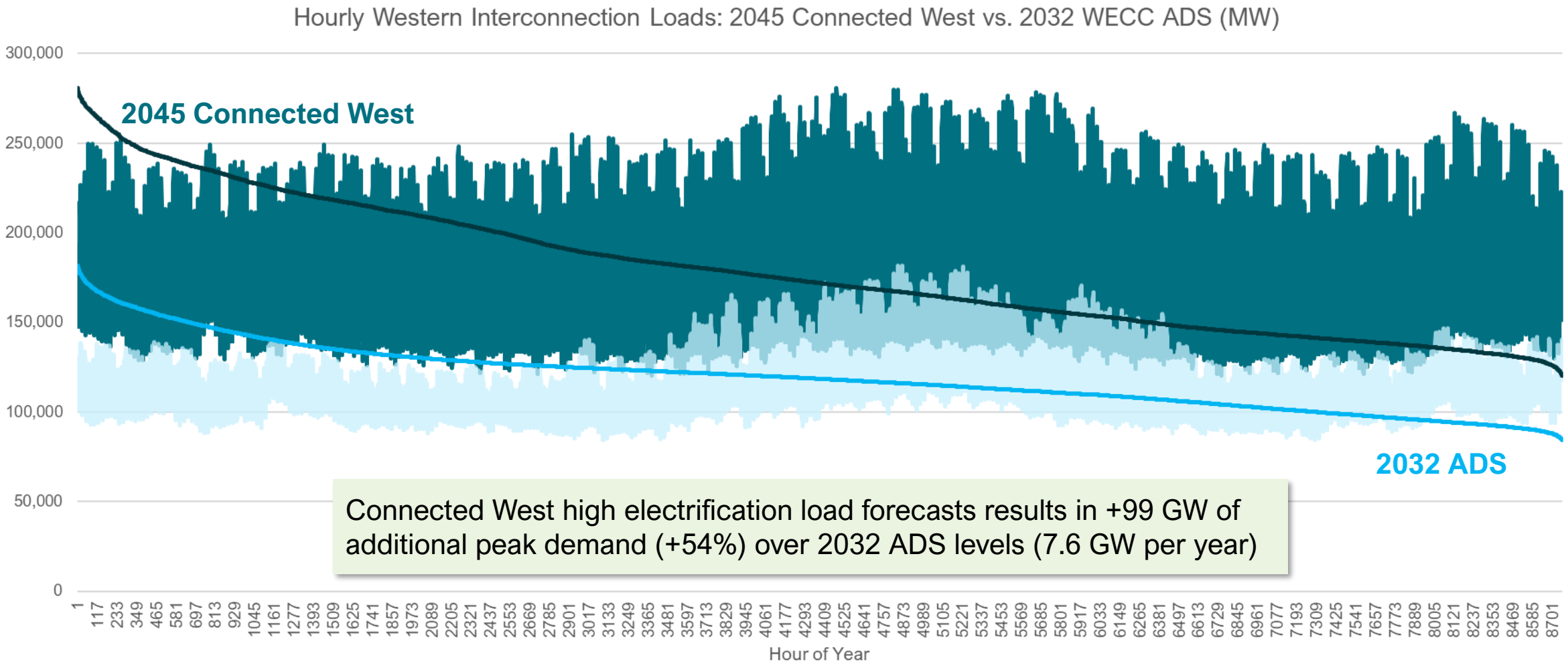
- **Load forecasts for Connected West were sourced from the *Power of Place: West* "high electrification" scenario, which assumes 100% sales of electric building technologies by 2040, 100% ZEV sales by 2040, and some fuel switching for industrial production required to achieve net-zero economy-wide emissions by 2050**
  - Demand response sourced from PoP forecast and modeled as energy-limited dispatchable resource
  - Load shapes reflect flexible loads modeled in PoP study
- **State-level forecasts from Power of Place: West were disaggregated to balancing areas based on historical BA-state load factors**





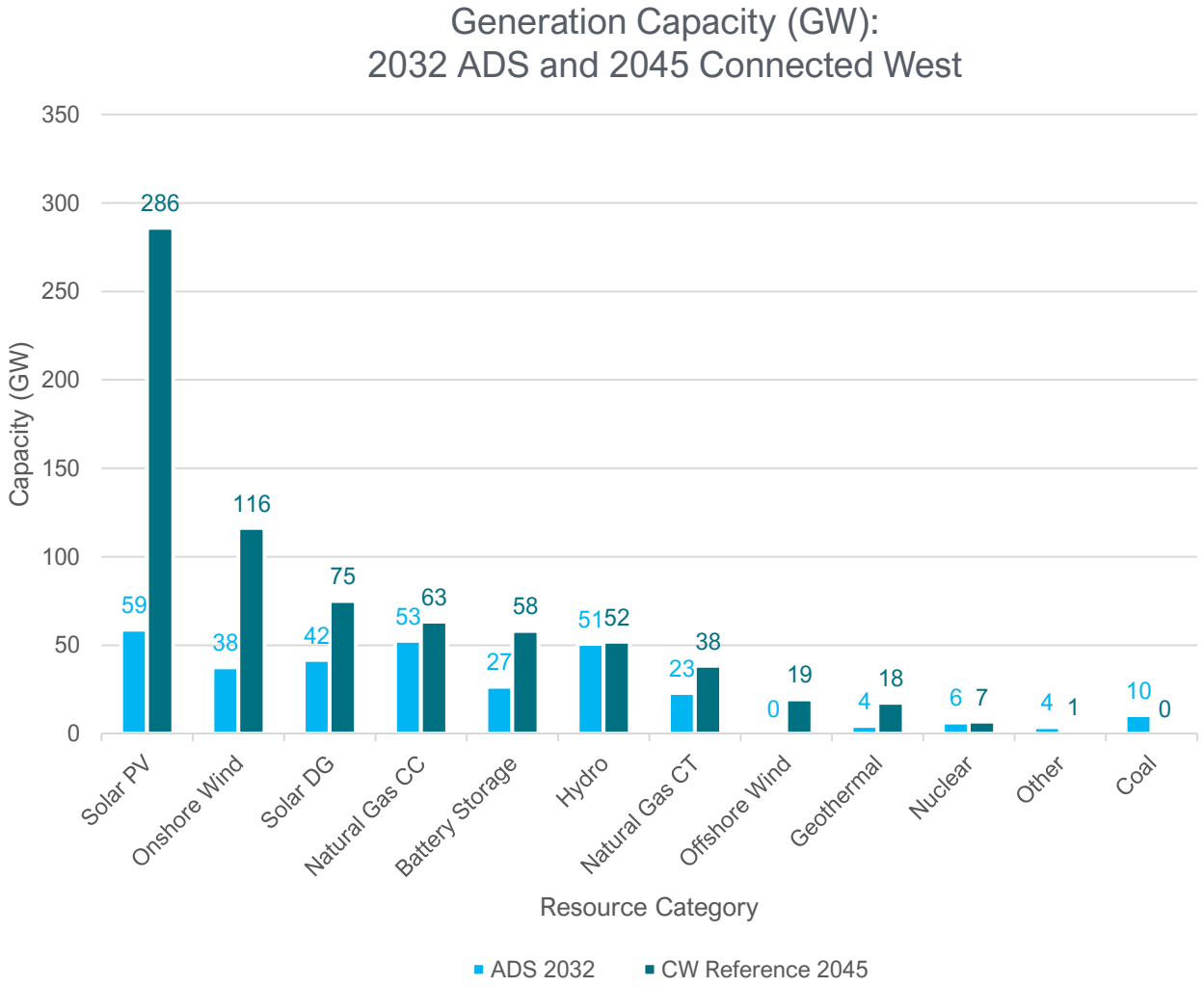


Load Forecast: Hourly Comparison with WECC ADS



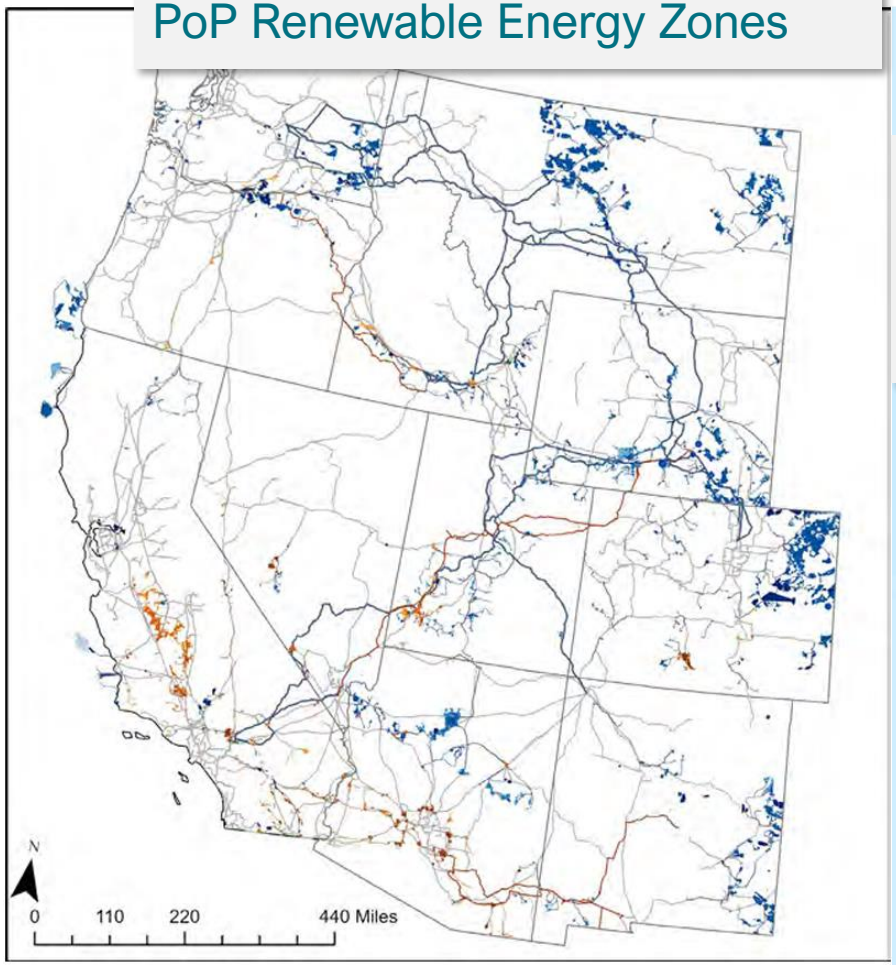
Generation Capacity: Matching 2045 Connected West to Power of Place: West Resource Mix

- **Energy Strategies implemented a methodology to represent a generation fleet consistent with the Power of Place-West Study in 2045**
  - Generation capacity in 2045 Reference Case is consistent with PoP for each state & resource category (e.g., wind in Wyoming is aligned with 2045 outcomes from PoP-West)
- **Approach to adding and siting included:**
  1. Added generation consistent with CAISO TPP to WECC ADS
  2. Aggregated all unique WECC-US generation units into resource categories that aligned with PoP-West
  3. Calculated delta between WECC ADS (2032) and PoP-West (2045) by state and resource category
  4. Reconciled minor deltas by repowering or retiring units based on unit in-service date
  5. For remaining deltas, added new, generic generating units with location-specific characteristics based on in-house siting algorithm
- **Unless "repowered" to help a state meet its delta, default generation retirement dates were retained from WECC ADS**
  - No coal is operational in study
- **Approximately 19GW of offshore wind was added to California and Oregon consistent with CAISO 23-24 TPP and forecasts from PoP for Oregon wind**

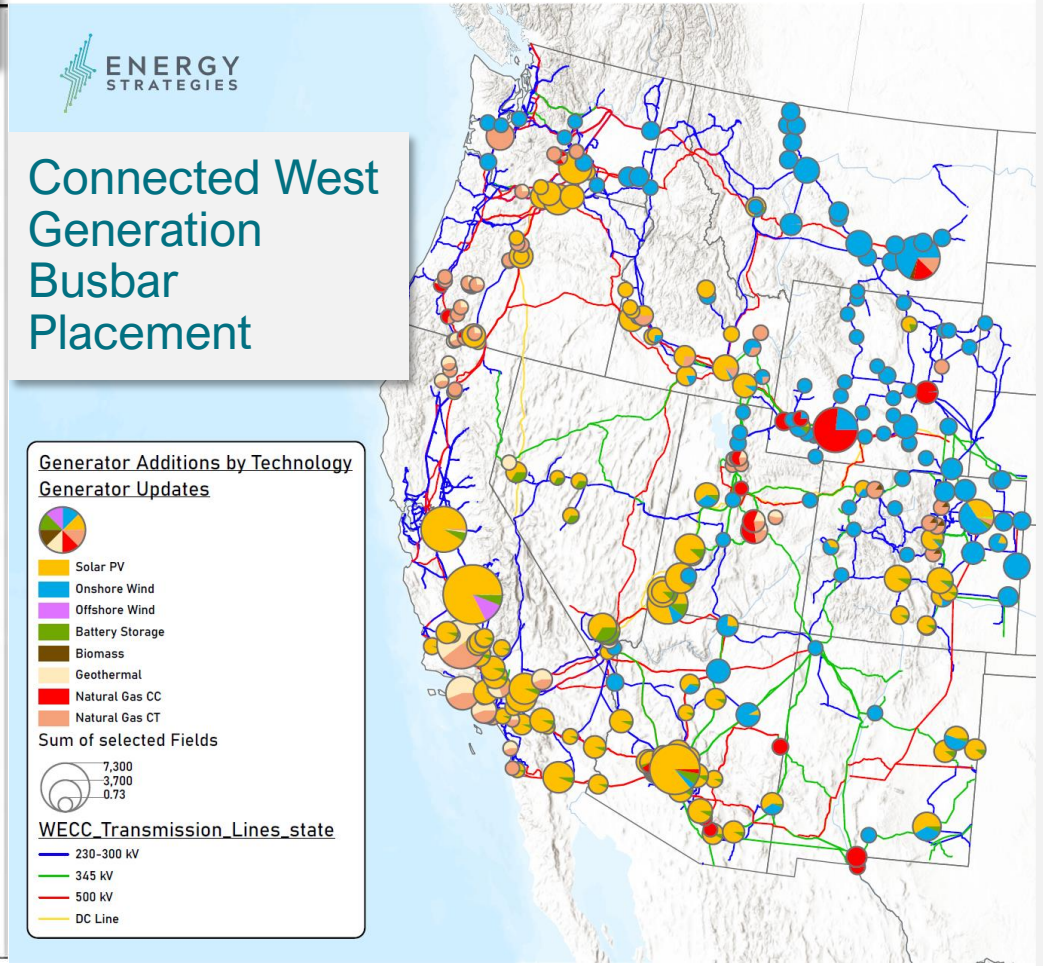


Generation Added to 2032 ADS to Create 2045 Connected West Reference Case

PoP Renewable Energy Zones



Connected West Generation Busbar Placement



The Power of Place-West study prioritizes high-quality resource locations and avoiding sensitive natural areas and working lands.

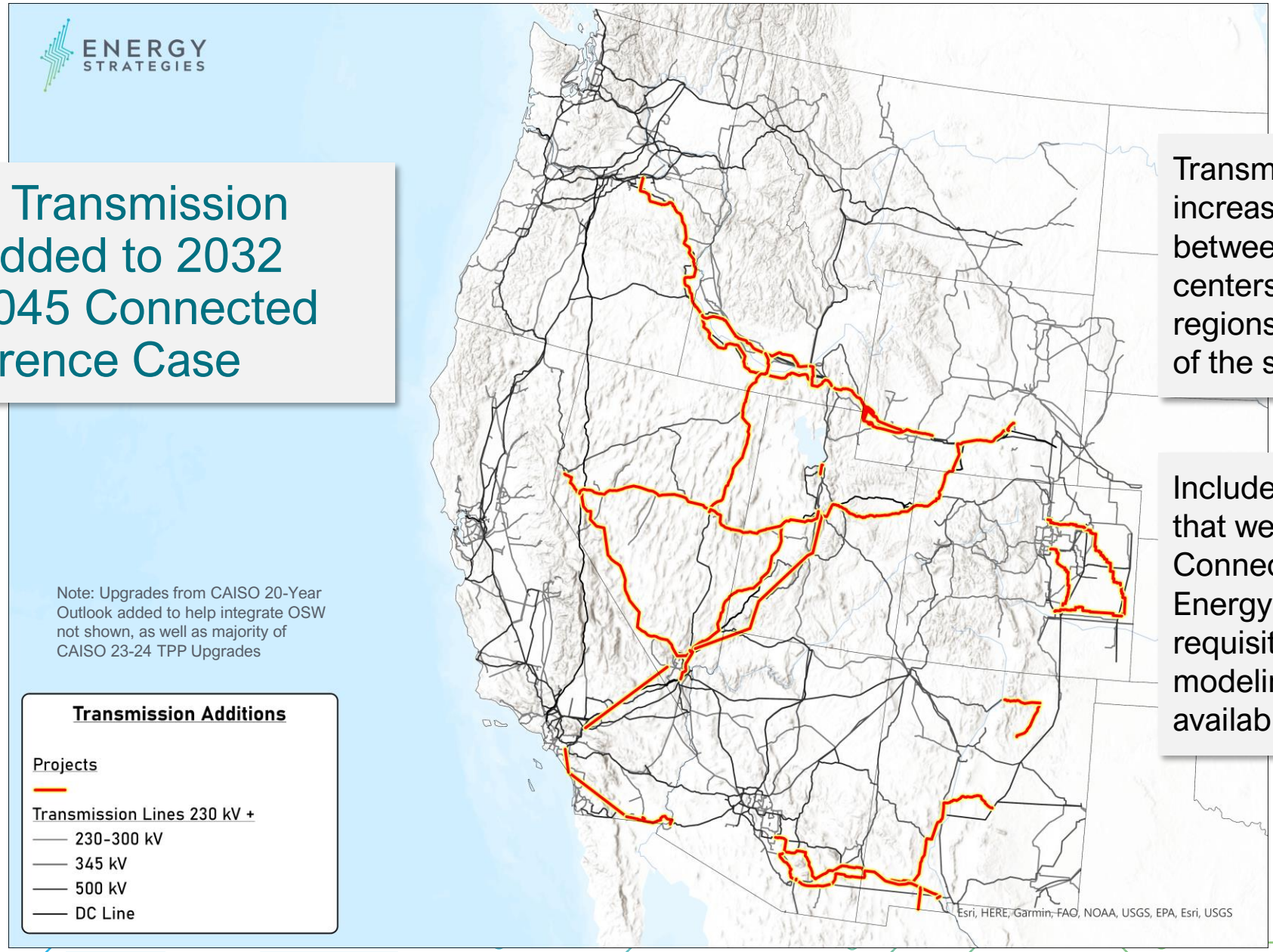
- The Power of Place-West siting methodology was augmented to bias towards transmission efficiency and commercial interest
- Siting algorithm was adopted to find reasonable injection points on the grid based on proximity to the project location and a voltage-based approximation of injection capability
- We maintain that development feasibility results from PoP apply to this study
- Siting approach and PoP-West data is a key factor in forming the findings of this study

Connected West 2045 Reference Case assumes significant high-voltage transmission expansion over approaching 20-years

5,300 line miles | **$27B of investment** | **26 GW of new capacity**

Project Name	Description	Length (miles)	Cost* ($M)	Capacity (MW)	Estimated Completion**
Boardman to Hemmingway (B2H)	500-kV line from Longhorn (Boardman) to Hemingway	290	$1,200	1,000	2026
CAISO 22-23 TPP	~46 transmission upgrades of varying size	460	$7,300	N/A	2034 or sooner
CAISO OSW upgrades	Conceptual upgrades from CAISO 20-Year Outlook	TBD	TBD	TBD	TBD
Colorado Power Pathway	Double-circuit 345-kV transmission connecting Denver front range to NE, E, and SE Colorado (5 segments)	610	$2,000	3,500	2027
Crosstie Project	500-kV line from Clover to Robinson Summit	214	$750	1,500	2027
Gateway South	500-kV line from Aeolus to Mona/Clover	416	$2,500	2,000	2024
Gateway West (all segments)	Includes all remaining 500-kV segments west of Bridger/Anticline (D3 & E)	500	$2,880	2,000	2028
Greenlink West and North	525-kV loop from Robinson Summit to Reno area to Las Vegas	700	$2,420	2,800	2028
Lucky Corridor - Mora Line	345/115-kV line between Springer and Arriba substations	115	$83	180	2025
Lucky Corridor - Vista Trail Line	345-kV line between Springer and Taos substations	65	$800	850	2027
Southline	345-kV line between NM and AZ	280		1000	2028
SunZia (Line 1)	525 kV HVDC line from eastern NM to Pinal Central (AZ)	550	$3,000	3,000	2026
SWIP North	500-kV line between Midpoint and Robinson Summit	285	$1,090	2,070	2027
TransWest Express	HVDC line from Wyoming to Utah to Nevada with AC component terminating at Eldorado 500-kV	732	$3,000	3,000	2027
TenWest Link	500-kV line between Delaney and Colorado River substations	125	$400	3,200	2024

15+ Major Transmission Projects Added to 2032 ADS for 2045 Connected West Reference Case

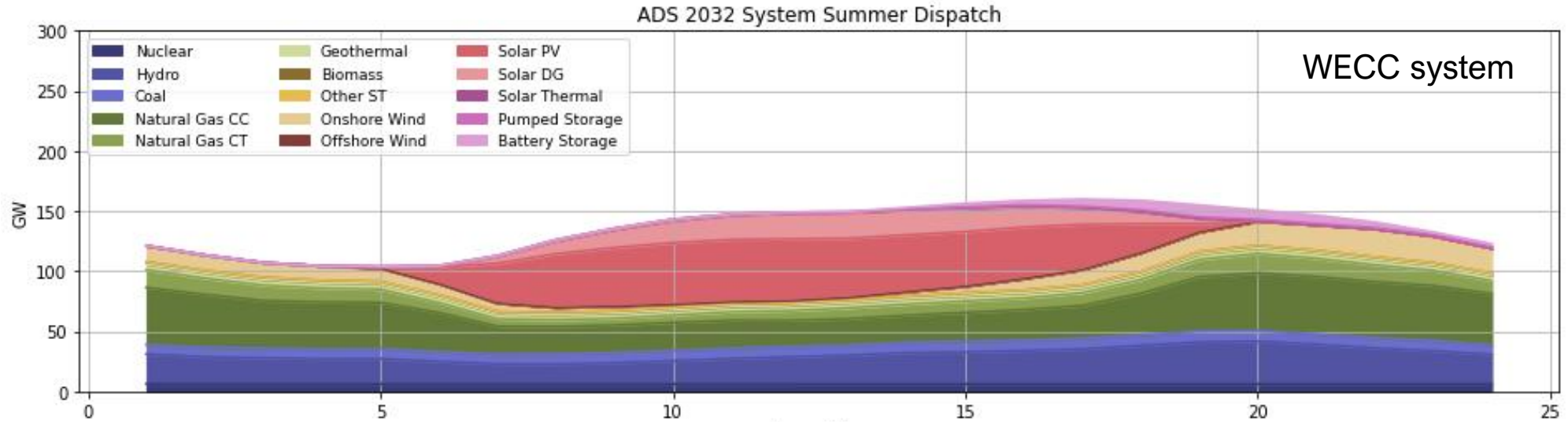


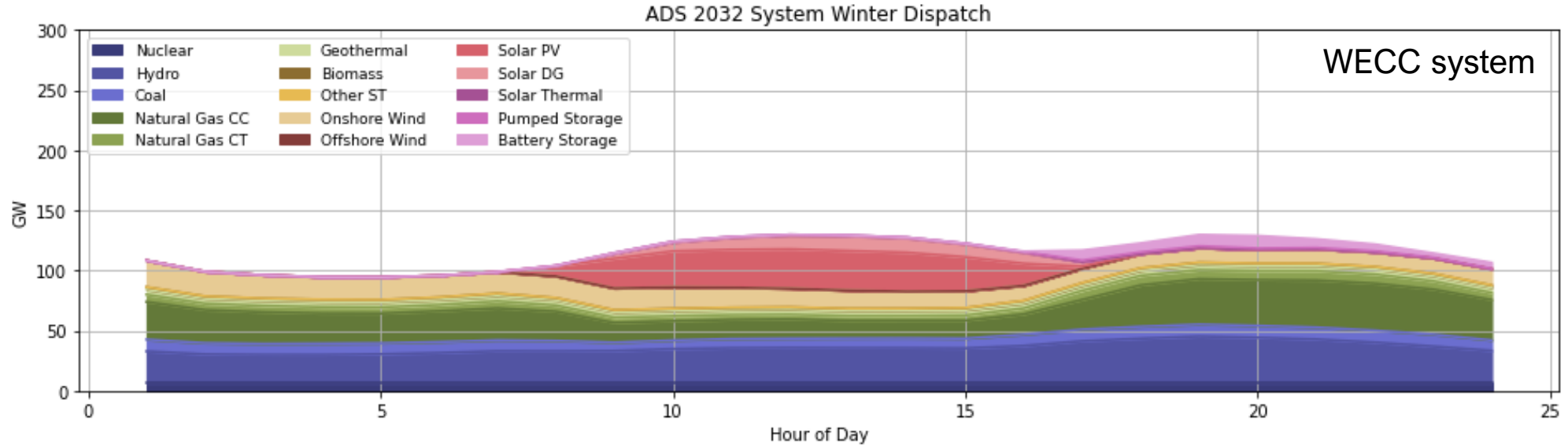
Transmission additions increase connectivity between West coast load centers and wind and solar regions on the eastern half of the system

Included proposed projects that were recommended by Connected West TRC & Energy Strategies that had requisite powerflow modeling data readily available

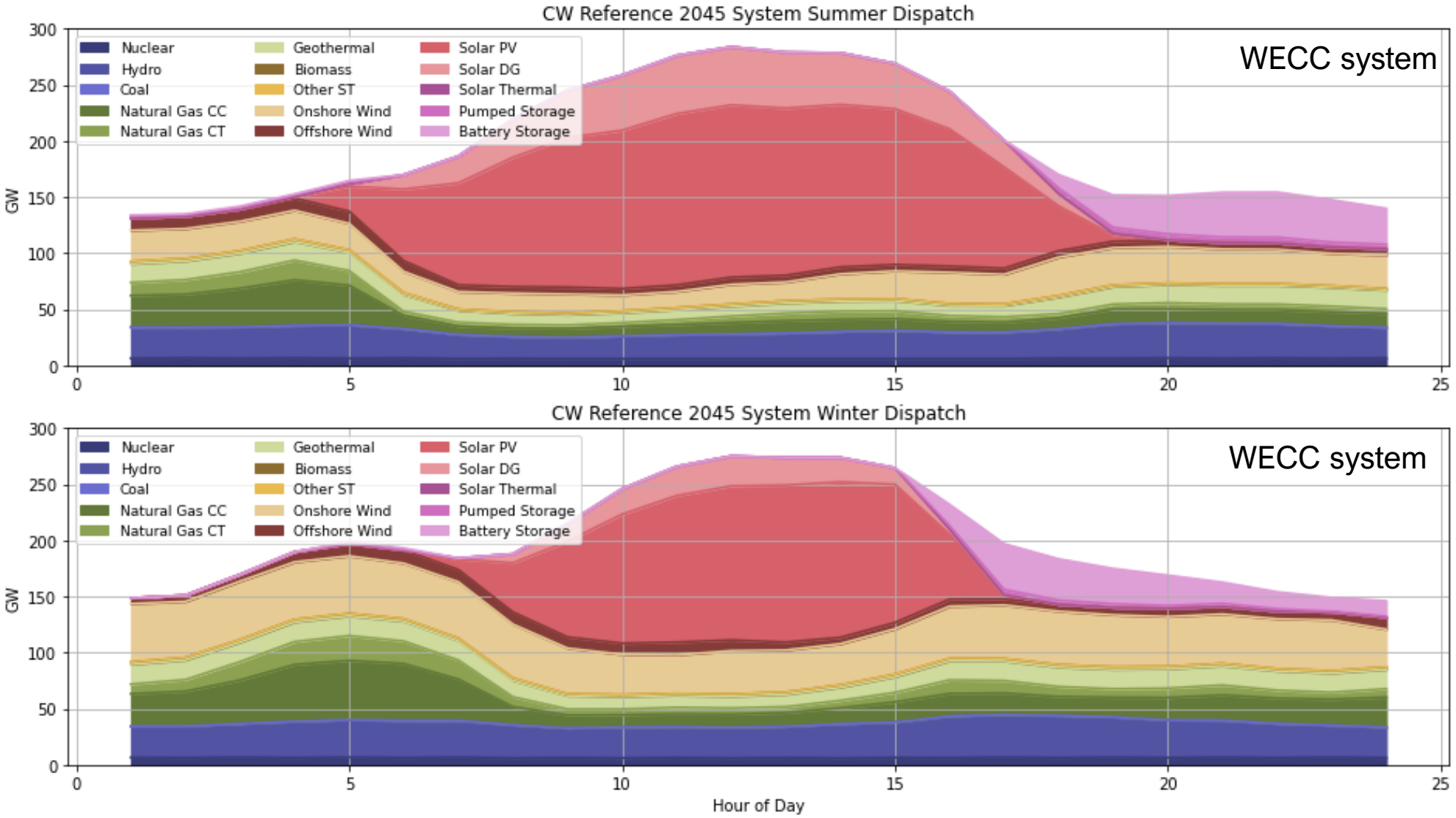
2045 Reference Case Results & Observations

Sample Day Dispatch: 2032 WECC ADS

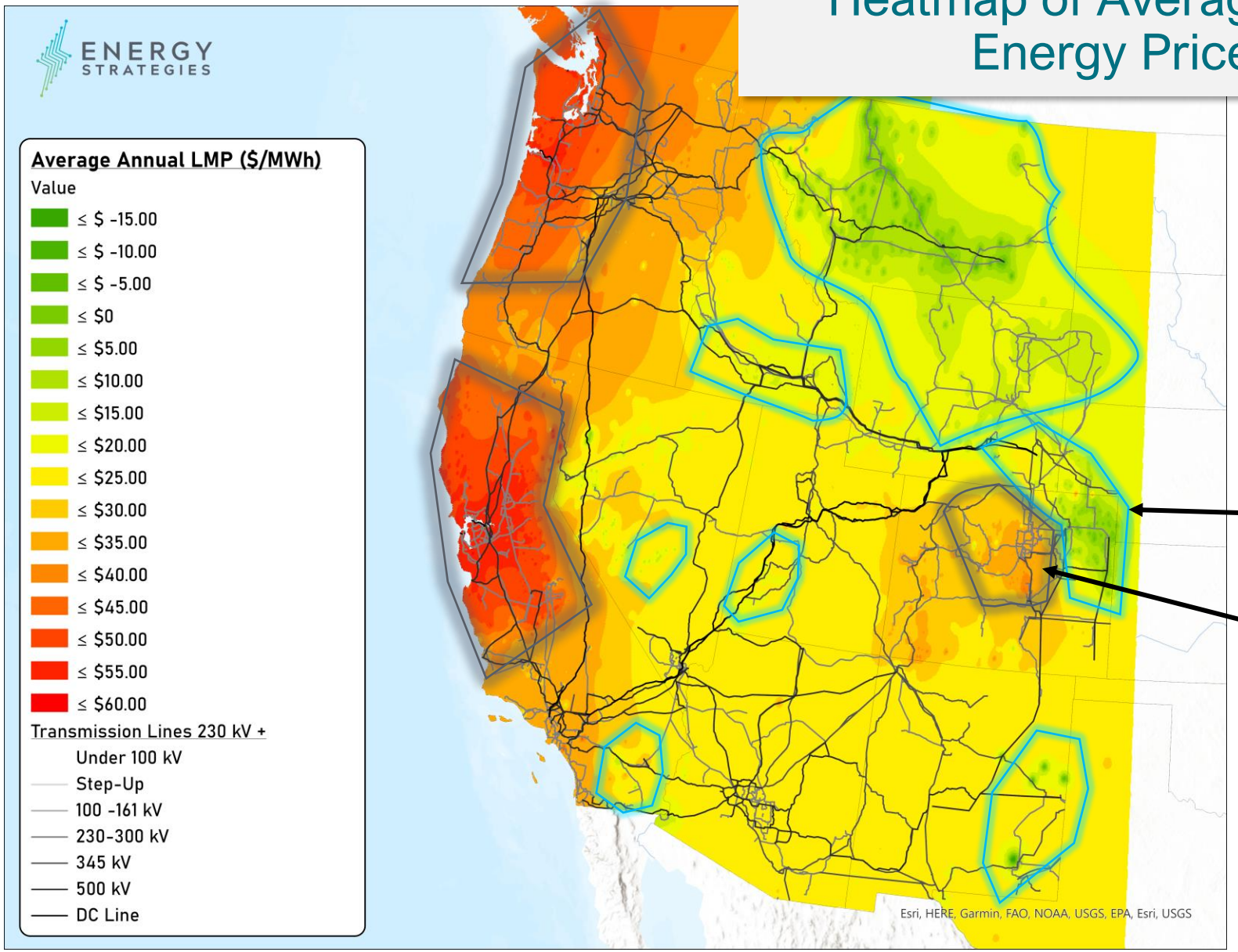




Sample Day Dispatch: Connected West 2045 Reference Case



Heatmap of Average Annual Nodal Energy Prices (LMPs)



- **Price differences between areas indicates transmission congestion**
  - Identifying congestion helps prioritize areas to evaluate for transmission upgrades
- **The 2045 Connected West Reference Case has two dominant types of congestion, based on annual average LMP data:**
  - **Export limited:** Areas in Montana, SE Wyoming, NE Colorado, Eastern New Mexico, and certain locations in Idaho, Utah, Nevada, and S. California
  - **Import limited:** Central California, PNW Coastal Loads, Denver Metro

Transmission Expansion Plan Approach

- **Potential transmission needs identified via review of LMPs, congestion, comparison with copper sheet study, and zonal deliverability analysis via powerflow modeling**
- **Zonal deliverability study uses DC load flow modeling to identify overloads that must be mitigated to enable reliable transfer of power out of export zones and into import zones**
  - For the most part, zone boundaries aligned with State borders
  - Representative dispatch for resource export limited areas (80th percentile net export)
  - Increase load to import limited areas to receive excess energy
  - Thematic portfolios of transmission explored: Address congestion and voltage stability issues through reconductoring, added AC and DC transmission, advanced transmission technologies (e.g. high capacity conductors)
- **The identified transmission upgrades will be routed through a GIS process developed for the POP-West study**

Data Needs from WECC to Support Future 20-year Assessments

- **Load forecasts collected and endorsed by WECC members**
  - 20-year hourly load provided by BAs or WECC data sources would be ideal
  - Absent this, WECC could initiate an effort, perhaps with support from National Labs, to generate a series of defensible 20-year hourly load forecasts
    - Base, High Electrification, etc.
- **20-year resource plans should also be generated**
  - They can be “generic” and setup as a starting point for future studies
  - They should ensure resource adequacy and align with the load forecasts
- **More transmission projects, including independent transmission, must be included in the study case**
  - WECC could develop a data dictionary of candidate projects and document which ones are included in the 20-year model via release notes
  - Today, WECC is including only proposed transmission that is included in a WECC power flow base case and this will not be sufficient for resource levels in 20-year horizon
- **Update transmission cost tool with advanced transmission technologies, like high-capacity conductors**
  - Such technologies are critical to maintaining reliability in 20-year horizon where corridors become even more constrained

Questions

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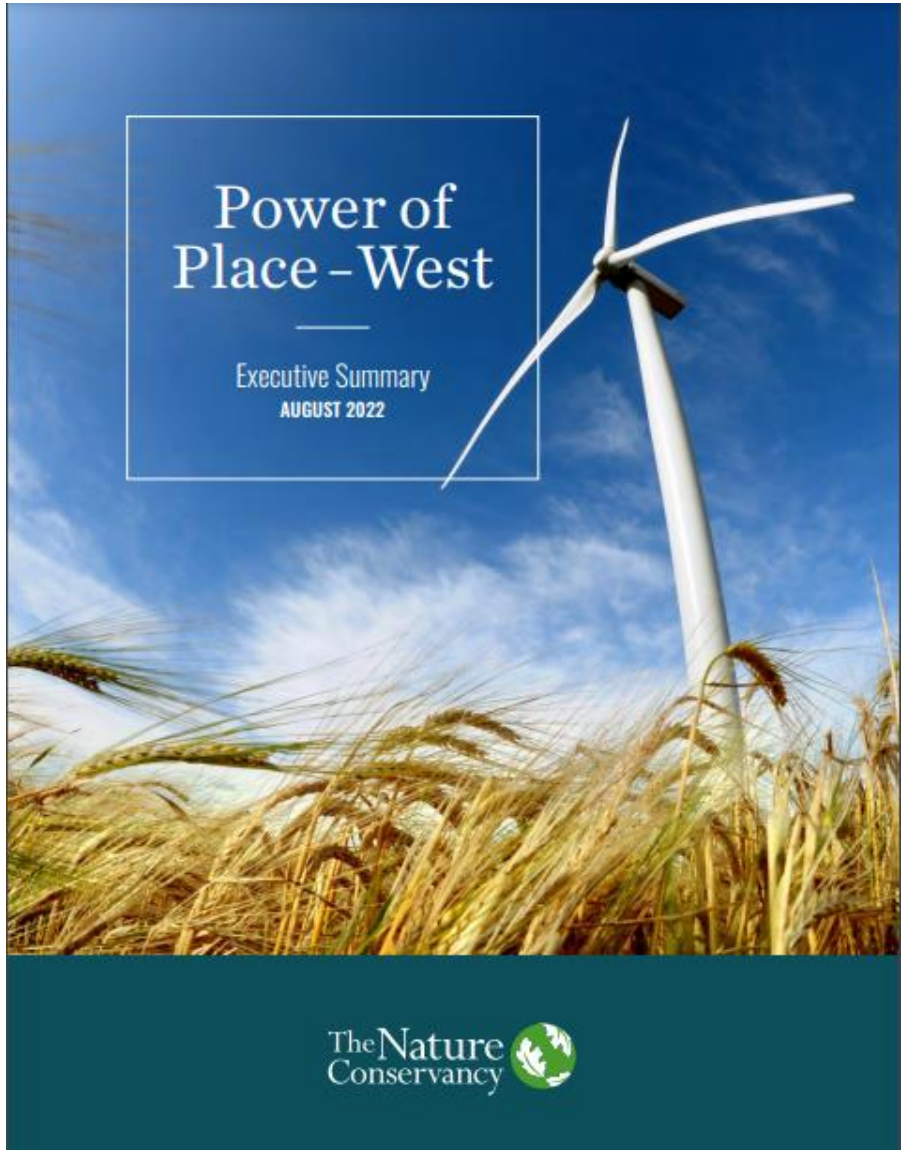
Appendix:
Additional Resources



Power of Place: West References

- Executive Summary
- Technical Briefing
- Publication
- Web presentation
- Geospatial data
- **PoP-West website by TNC**