Interregional impacts of resources availability: hydroelectric availability in the West

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Regional Planning Across the Continuous US

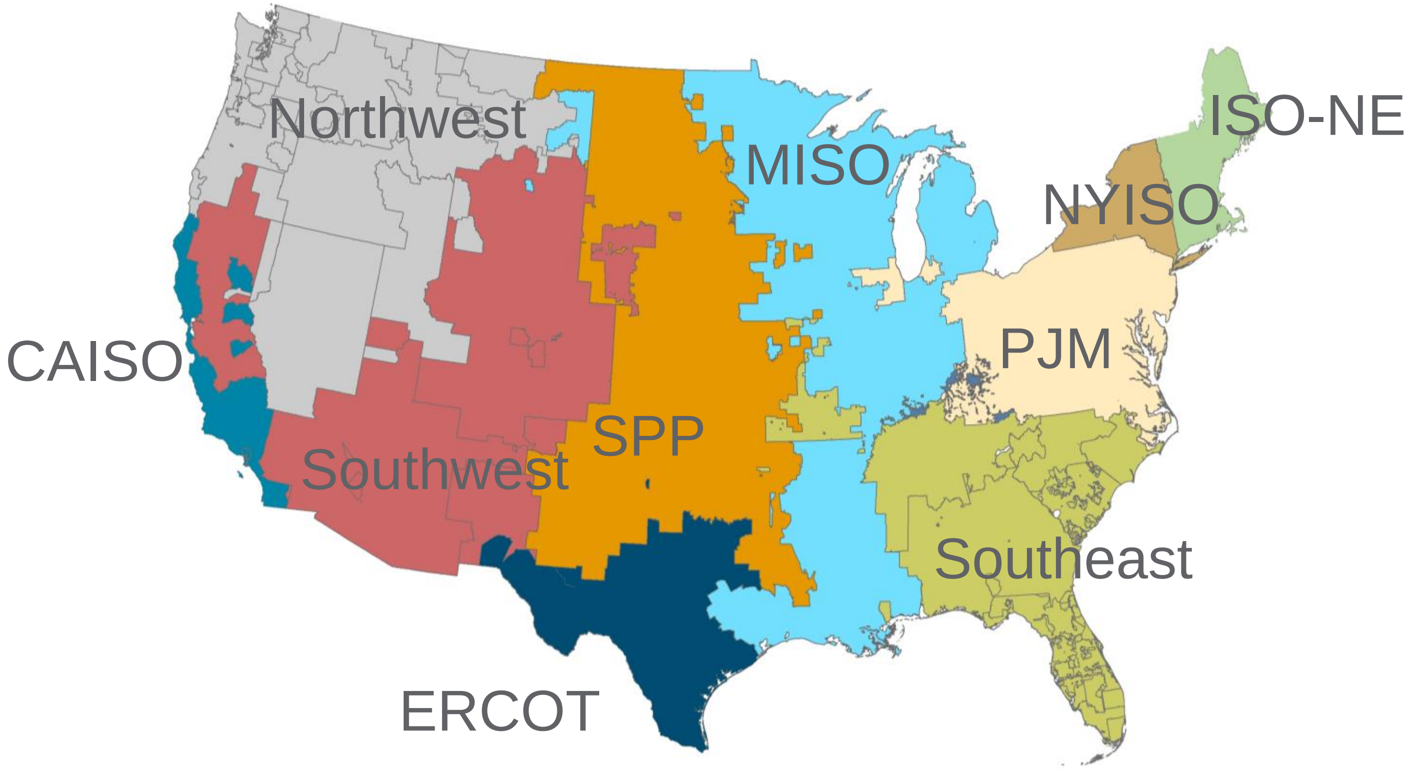
- Historically, resource adequacy studies have been performed regionally
- Regional dependencies have been held "stationary"
- Scenarios support reliability studies and evaluate the new generation portfolio

ISO regions

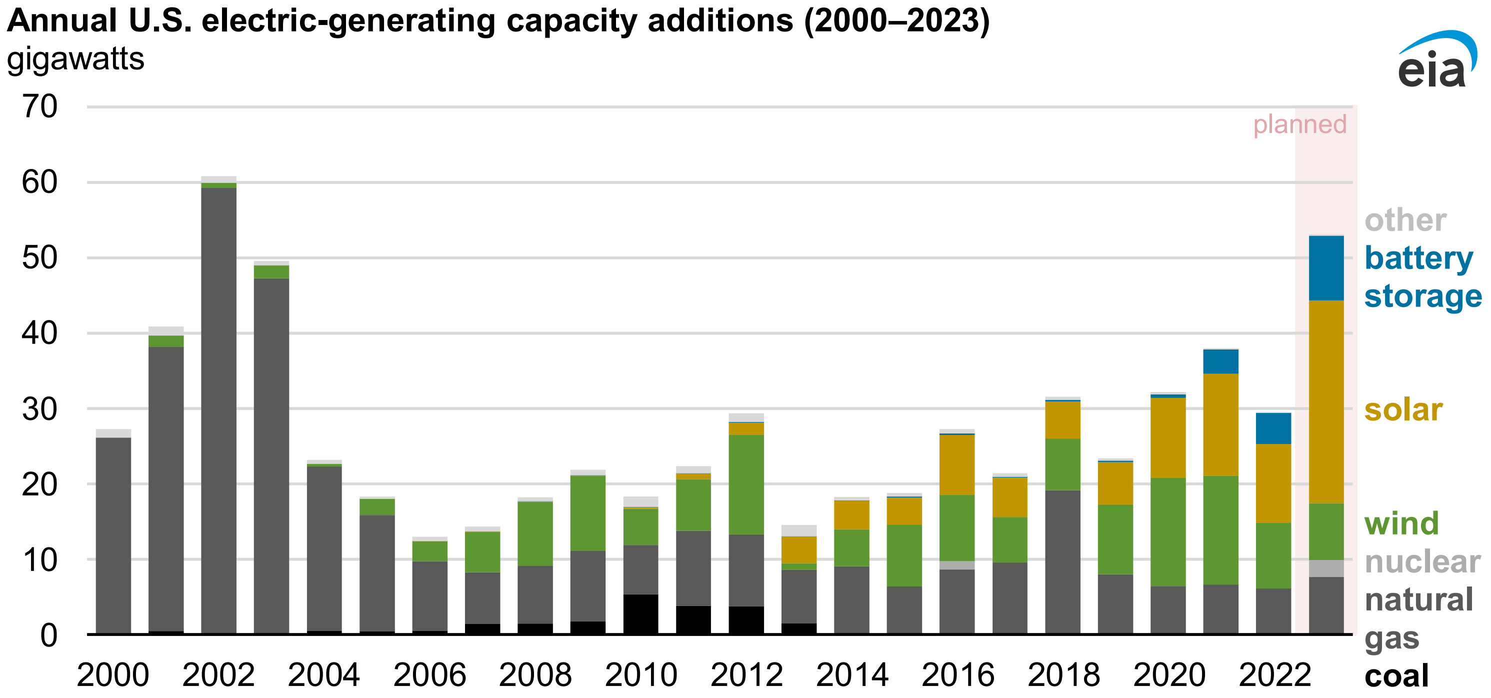
- Southwest Power Pool (SPP)
- Electric Reliability Council of Texas (ERCOT)
- Midcontinent Independent System Operator (MISO)
- California Independent System Operator (CAISO)
- ISO New England (ISO-NE)
- PJM Interconnection (PJM)
- New York Independent System Operator (NYISO)

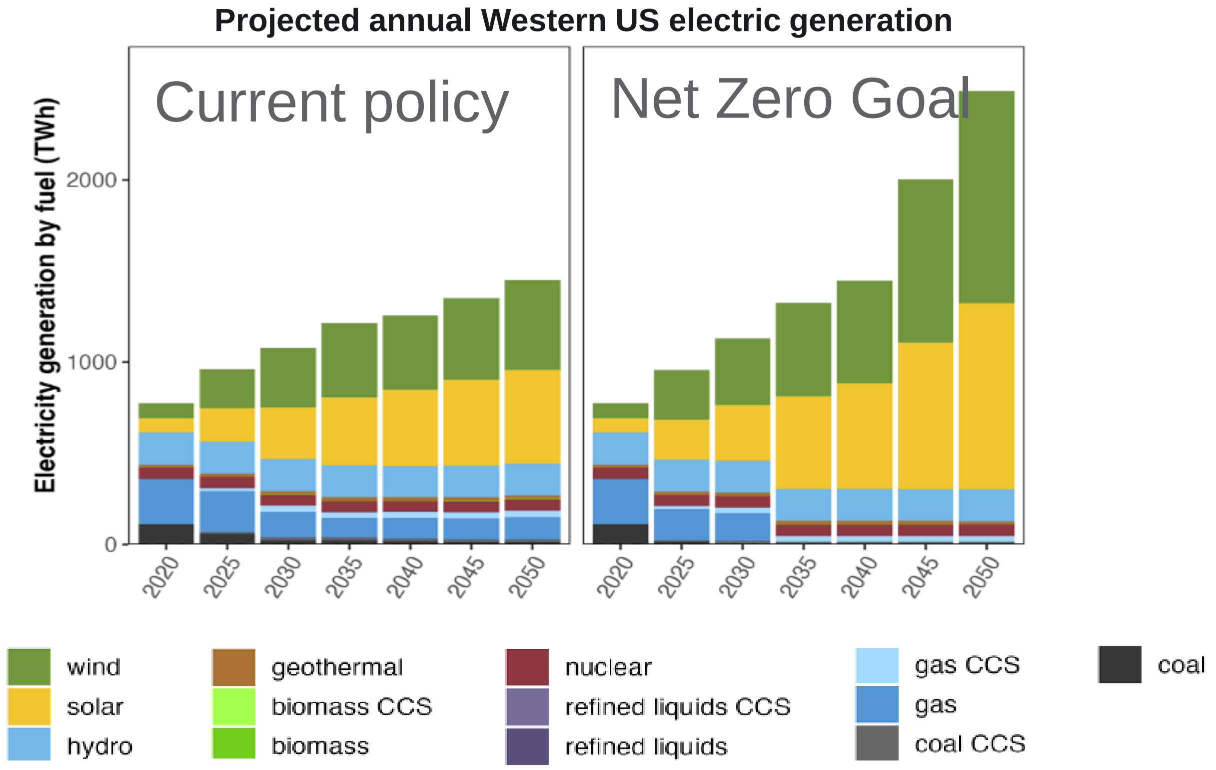
Non-ISO regions

- Northwest
- Southwest
- Southeast



Increased reliance on renewables, specifically wind and solar, across different projections





Ou, Y., & Iyer, G. (2023). GCAM-USA Decarbonization Pathways for GODEEEP (2.0.0) [Dataset]. https://doi.org/10.5281/zenodo.7838872

Increased reliance on renewables requires understanding droughts (and floods)

Hydrologic Drought

Months to Years

Energy Drought

Hours to Days and Seasons

Sensitive to natural resources drought

Thermo-electric with cooling

Biomass, coal, natural gas

Solar

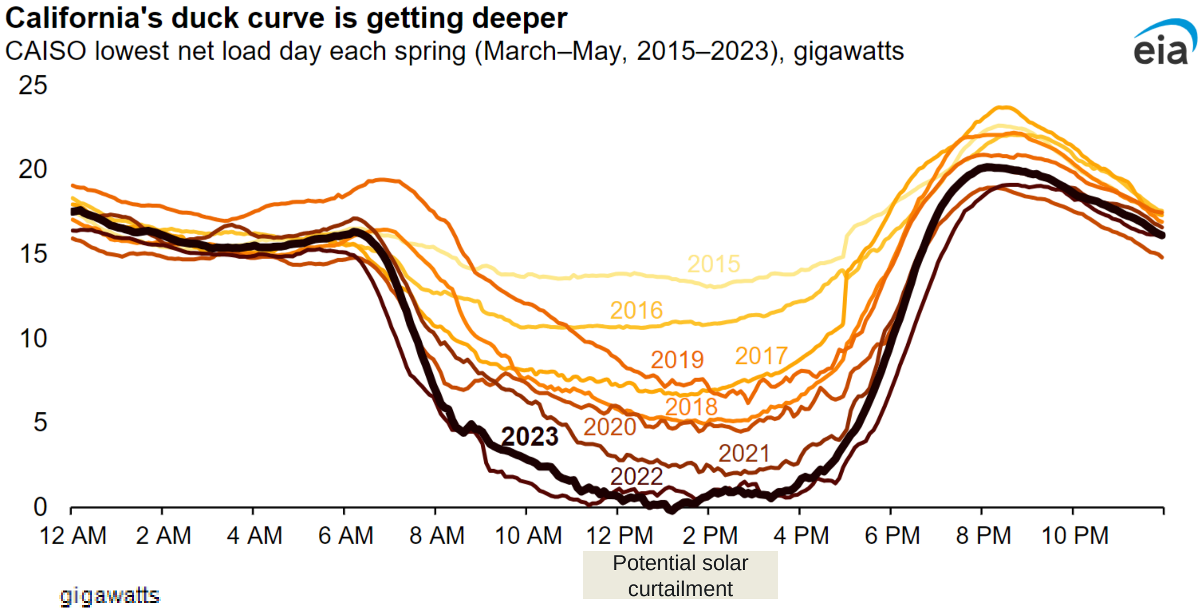
Hydro

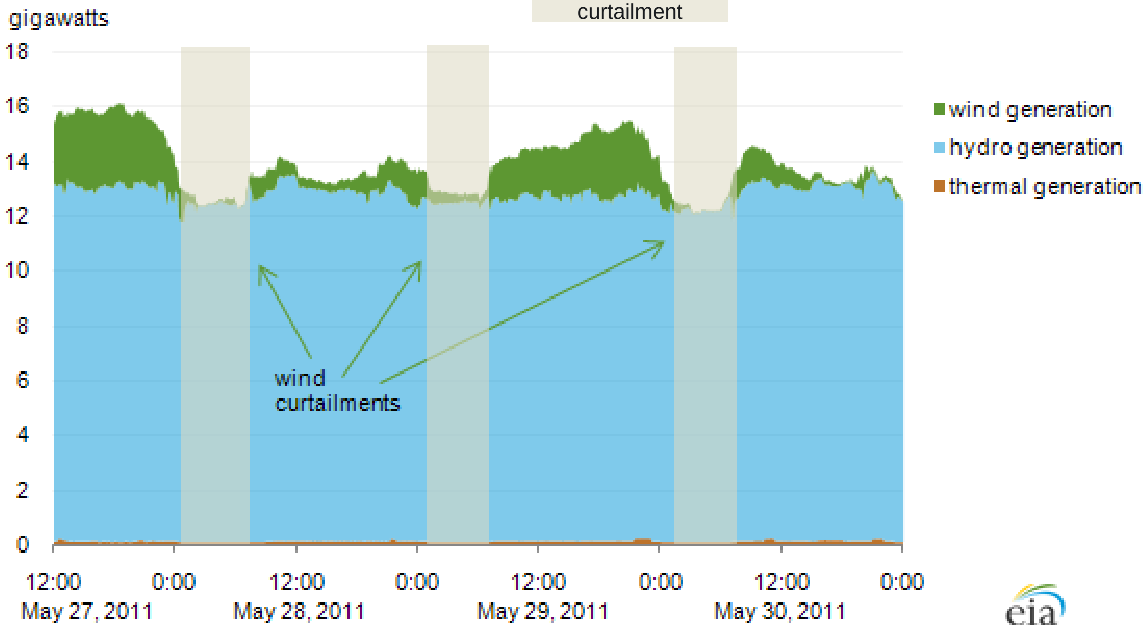
Wind

Thermo-electric w/ combustion turbine

Oil

Wind and solar variations propagate onto other technologies





Electric power generation by fuel type on the Bonneville Power Administration system

Diurnal cycle of solar results in a net load curve (duck curve) that transforms ramping needs of the power grid.

Similarly, wind variations propagate onto other technologies. Some technologies can ramp up and down more than others albeit at a cost.

With the uptake of wind and solar in regional generation portfolios, too much can result in curtailment and too little and a generation shortfall.

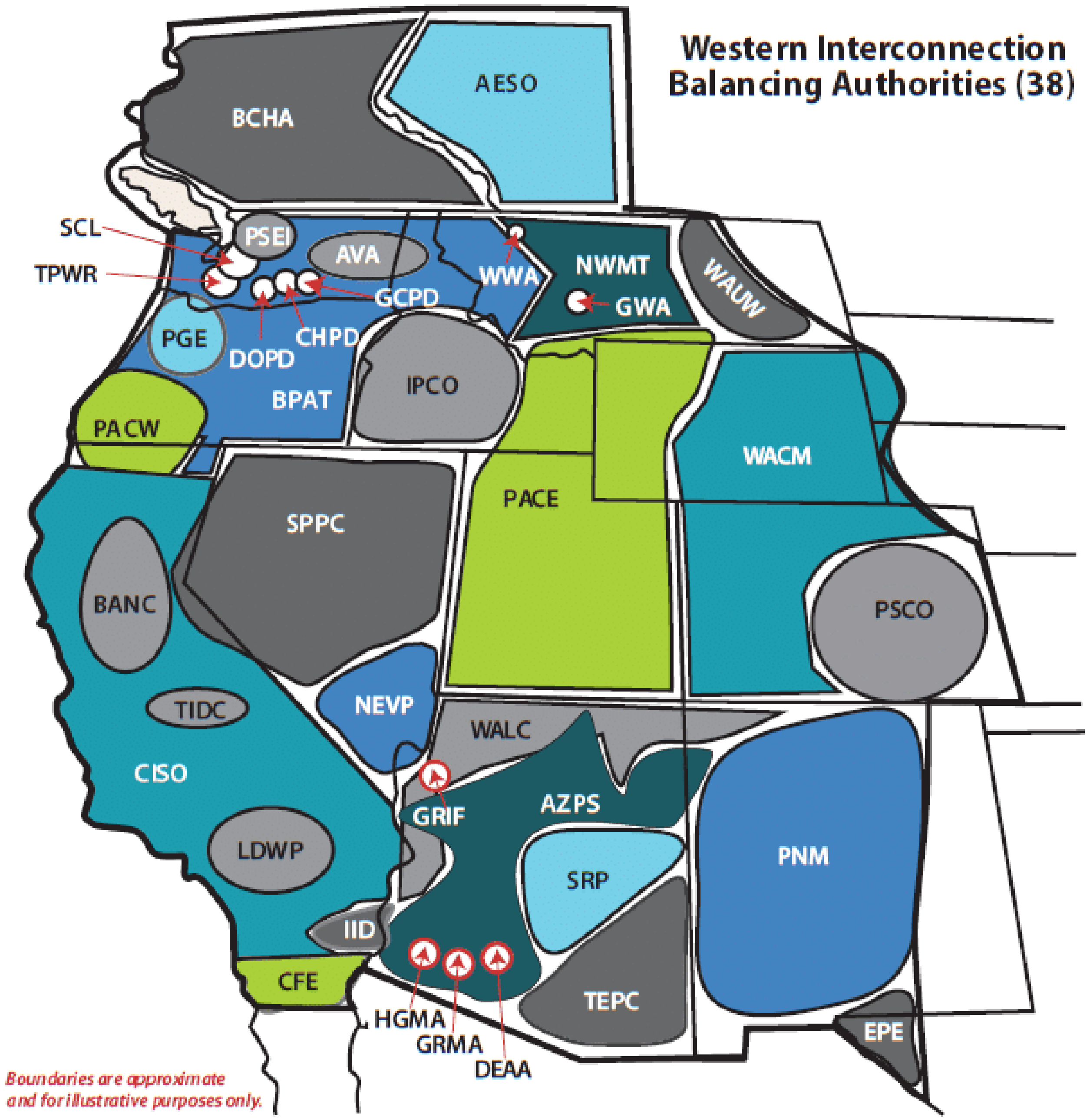
Renewable integration happens at the balancing authority scale

Balancing Authority

Wind & solar are "must take"
Wind and solar are "non-dispatchable" without storage

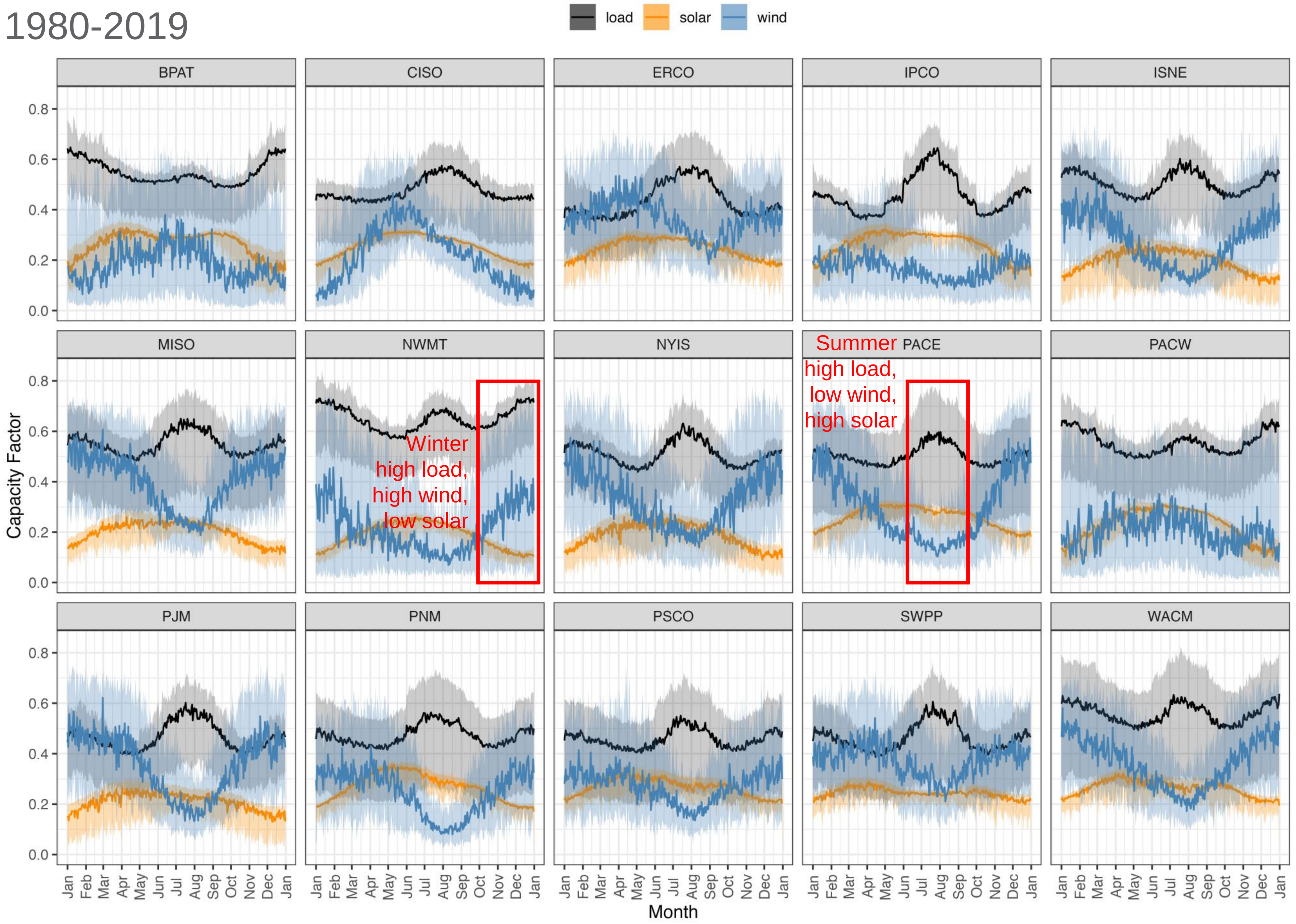
1) Wind + Solar shortfalls: uptake by other regional technologies or imports
2) Wind + Solar > Load : potential curtailment

- BAs are the grid-relevant scale to evaluate energy droughts, and extreme events from a resource adequacy perspective
- Each BA presents unique integration challenges due to regional load differences and renewable profiles



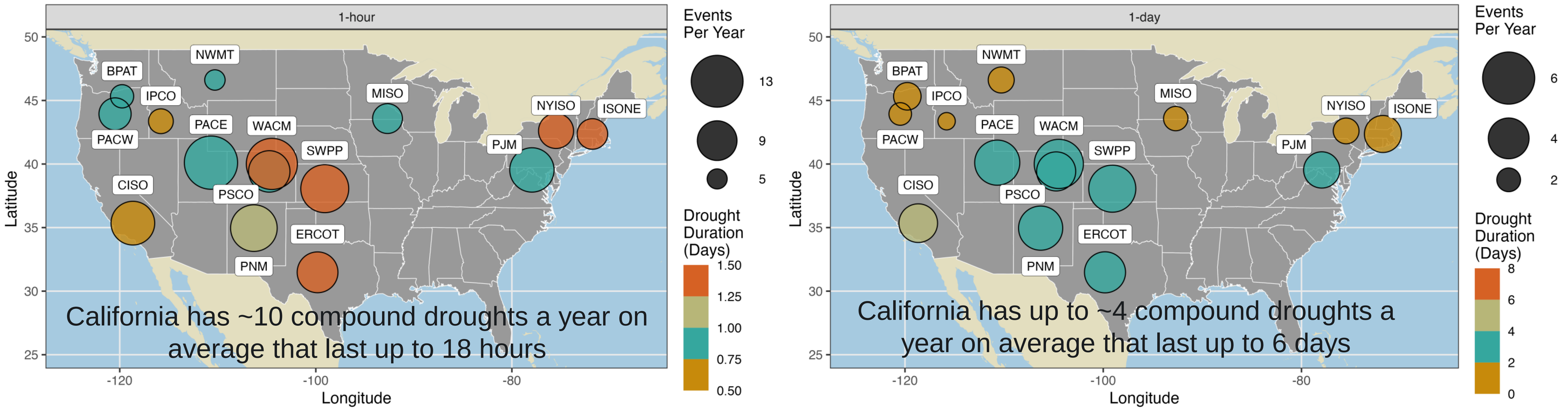
Wind solar and load cycles vary depending on the region and season

At the seasonal time scale, there is often complementarity between wind and solar to address high load periods. For seasonal droughts, hydro, natural gas and transmission also need to be considered.



Hourly and daily compound droughts have distinct characteristics

1980-2019 average frequency and maximum wind and solar drought duration

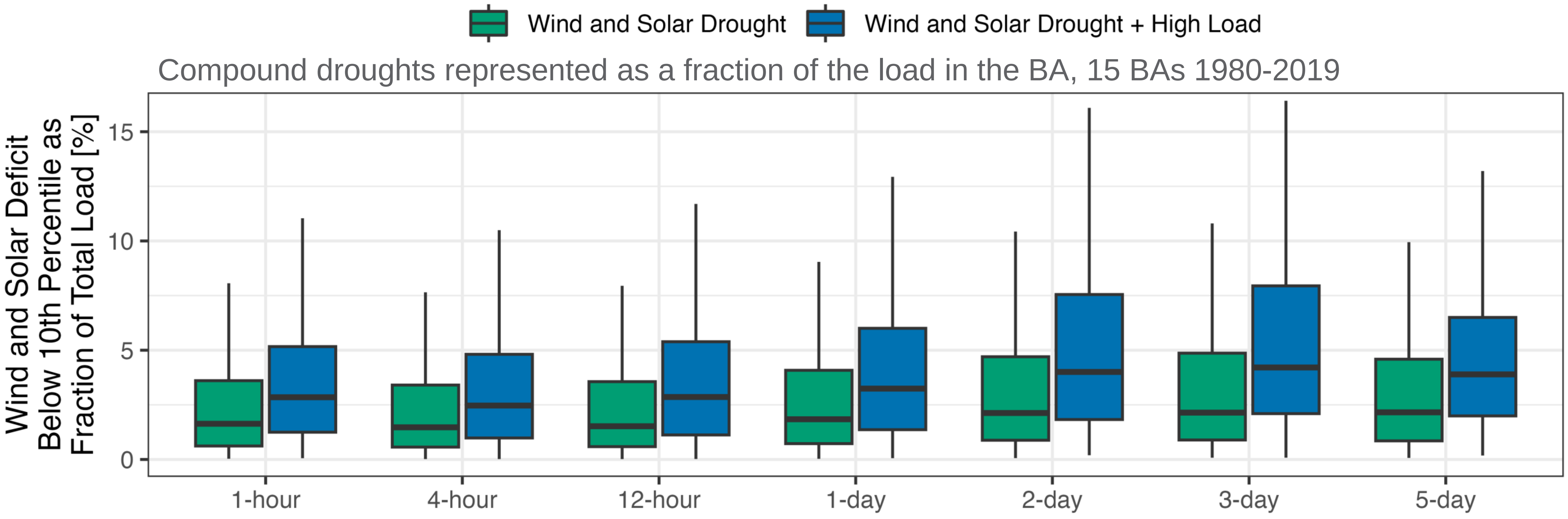


Spatial drought patterns change with time scale

- Frequency of droughts decreases with longer time scales
- California has the shortest hourly compound droughts, but the longest daily droughts

Bracken, C., Voisin, N., Burleyson, C.D., Campbell, A.M., Hou, Z.J. and Broman, D. 2024. Standardized benchmark of historical compound wind and solar energy droughts across the Continental United States. Renewable Energy 220, 119550.

While less frequent, compound wind and solar drought with high load represent up to 10-15% of peak load



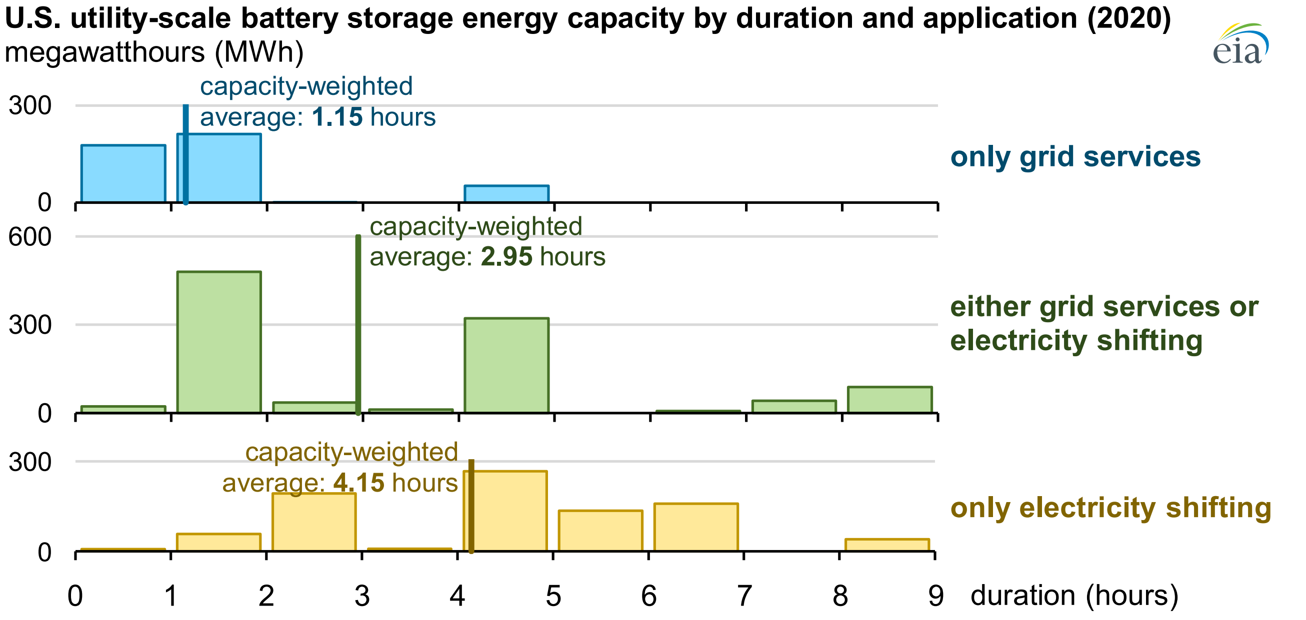
Compound Wind and Solar droughts + High Load are less frequent but more severe on average

Existing battery storage is intended for short term use

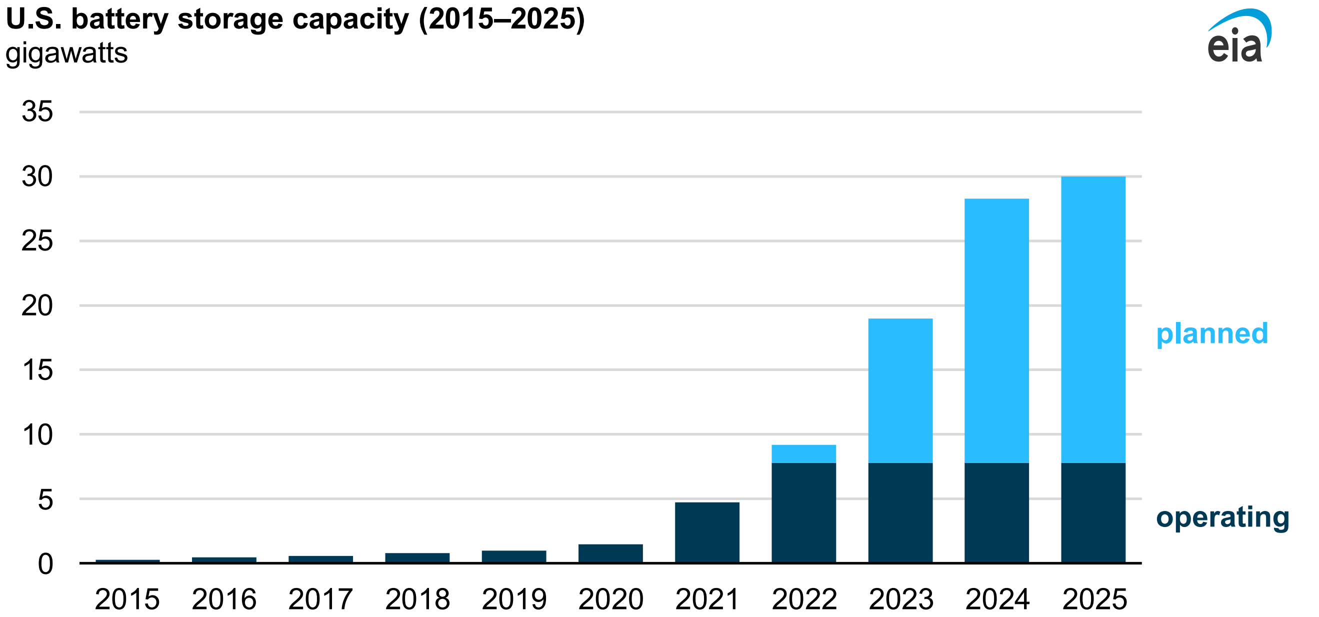
Battery storage durations:

- <u>1 - 2 hours</u>: grid stability, non spinning reserve, intraday storage management
- <u>4 - 8 hours</u>: Load shifting, storage management for charge/recharge

60% of new battery storage installation is intended to be hybridized with wind and solar plants

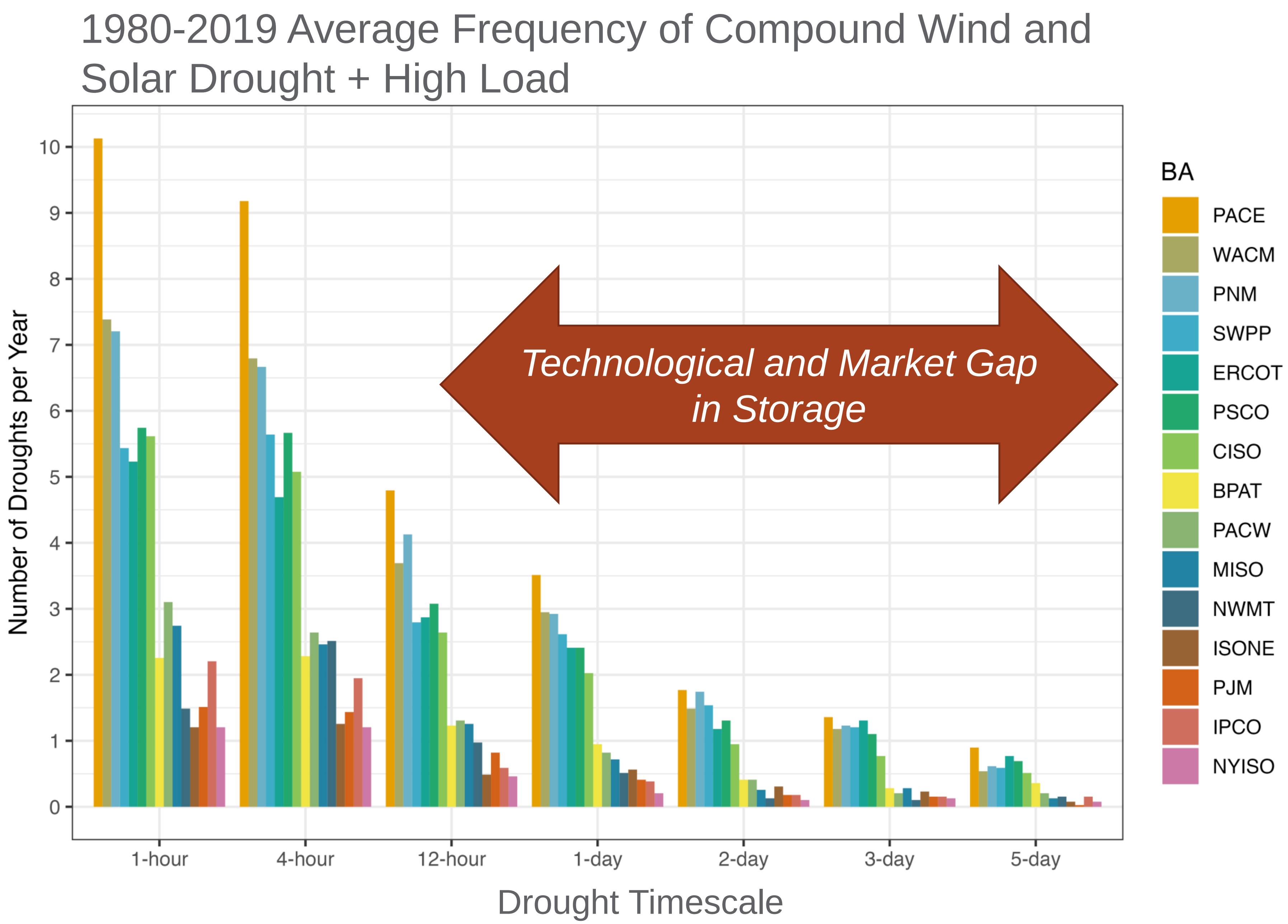


https://www.eia.gov/todayinenergy/detail.php?id=51798



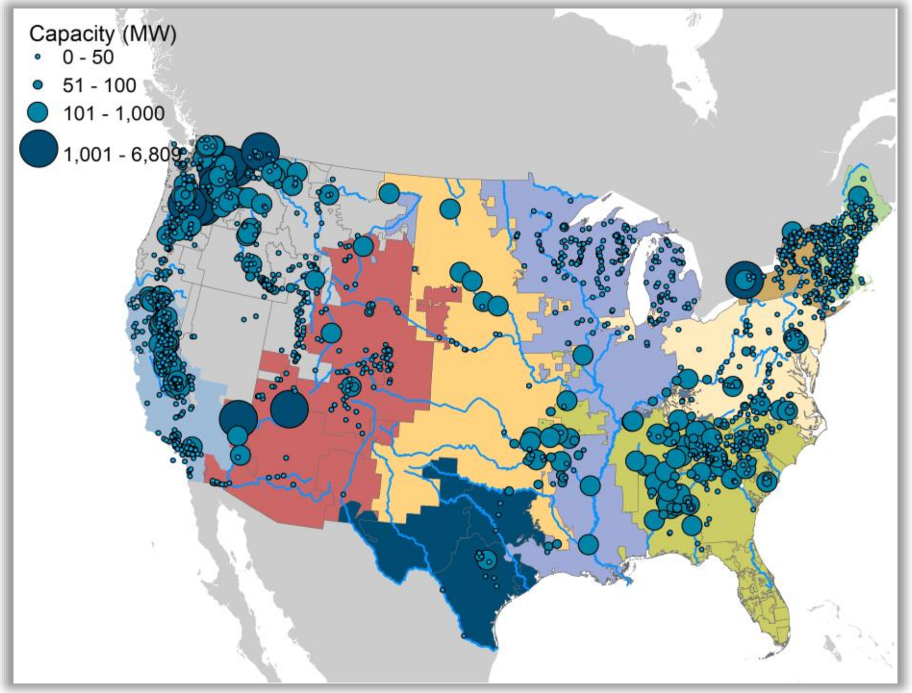
https://www.eia.gov/todayinenergy/detail.php?id=54939

Existing and planned storage is not adequate to mitigate long duration energy droughts

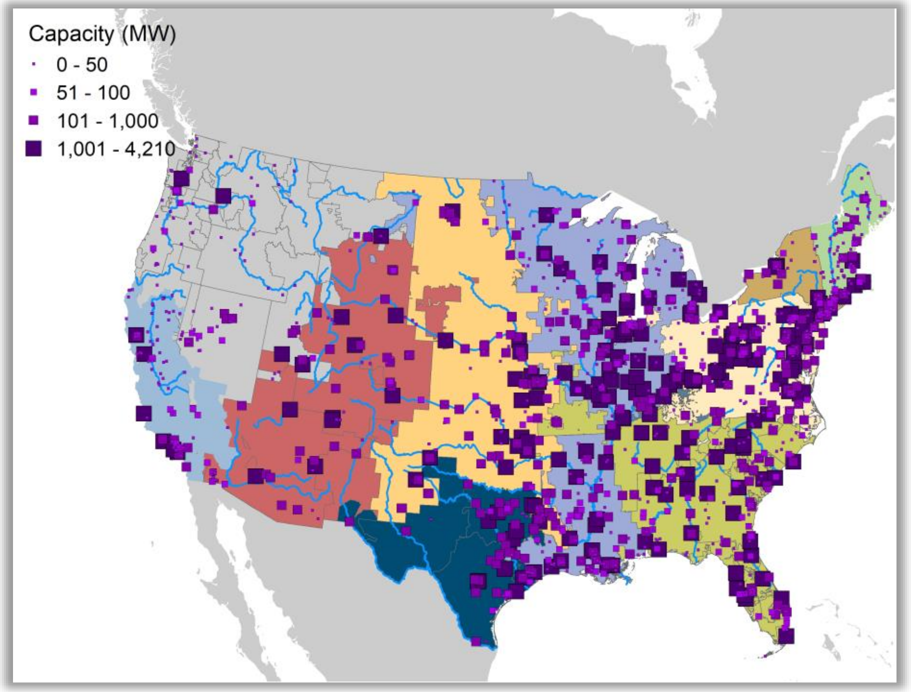


Both hydropower and thermo-electric plants are impacted by hydrologic/reservoir droughts

HYDRO



COOLANT & STEAM

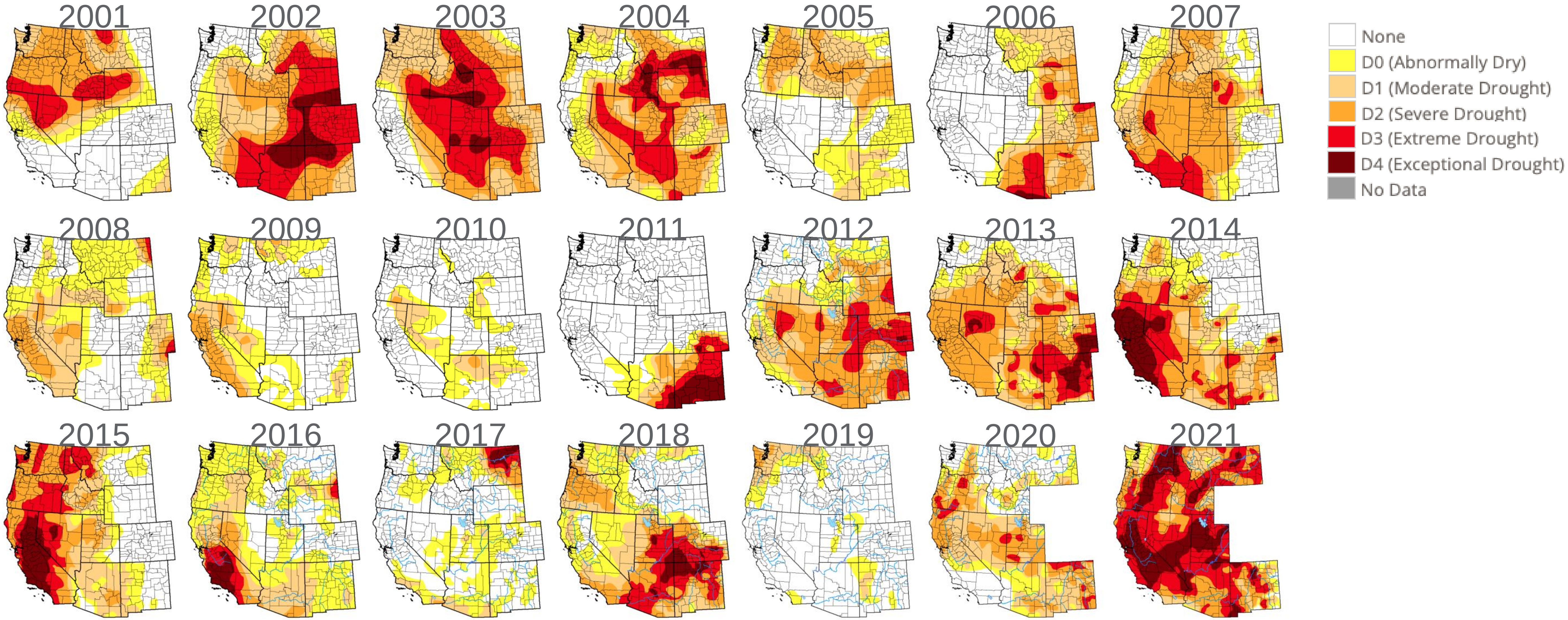


Water quantity and quality!

- Inter-annual variability in annual precipitation increases
- Relative storage capacity of reservoir increases

Every hydrologic drought is unique

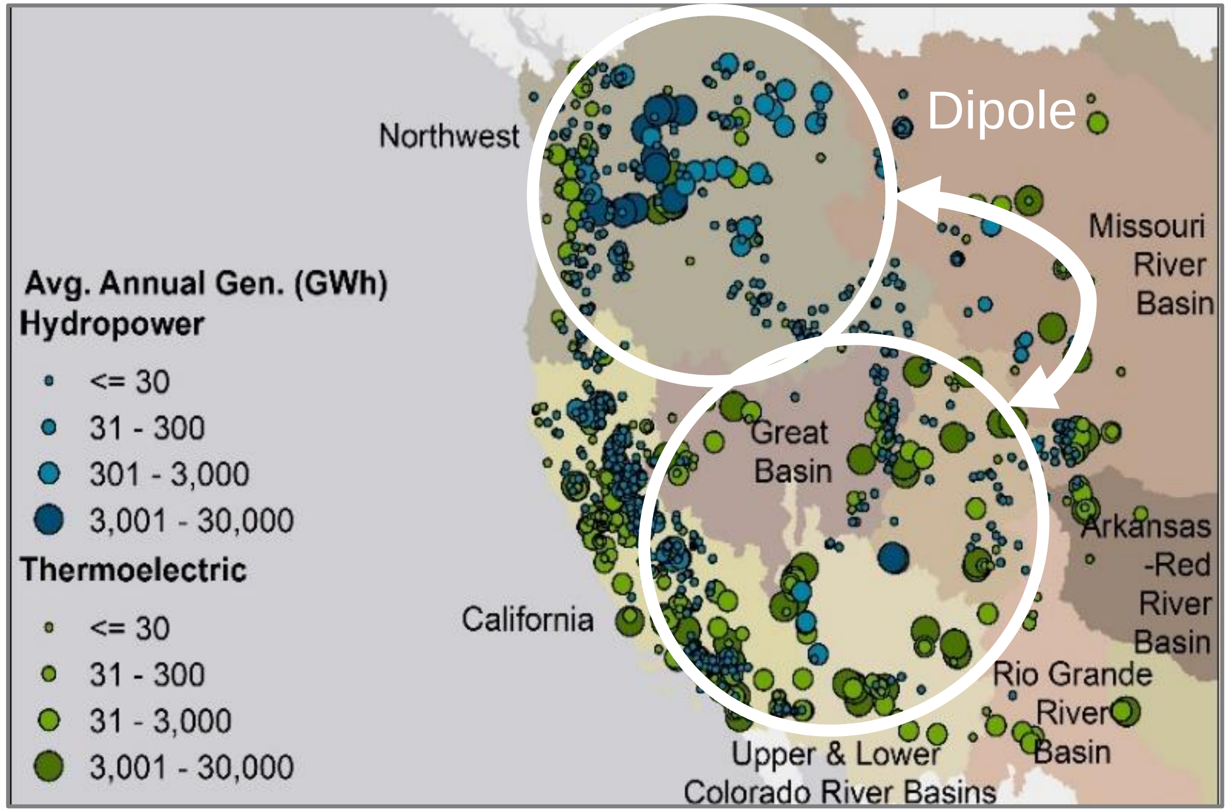
U.S. drought monitor for final week of July in each year



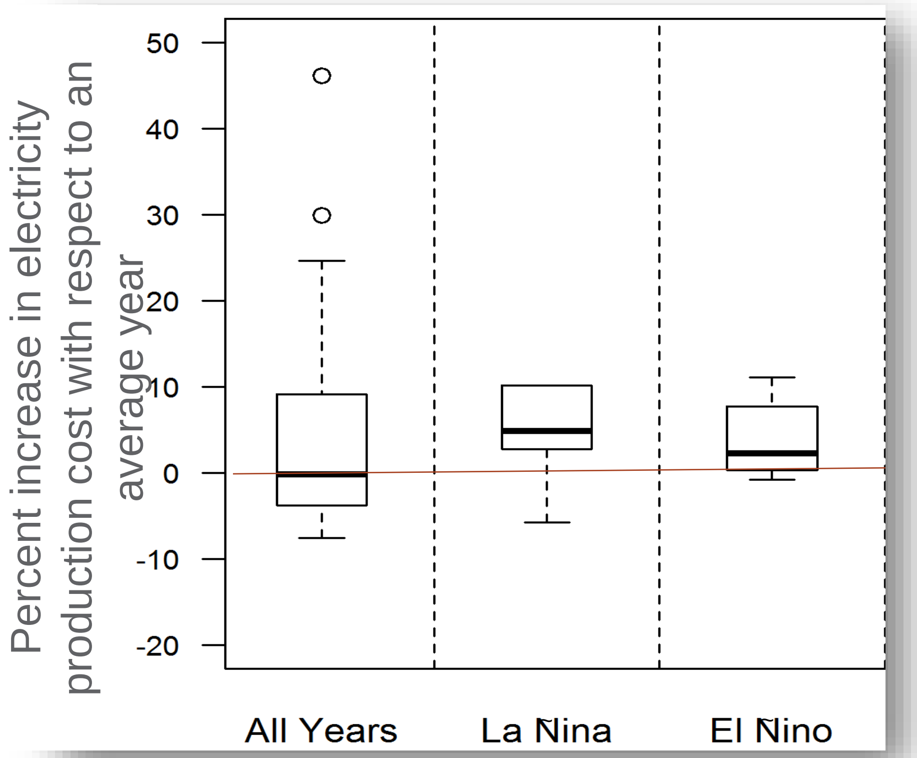
Regional dynamics help alleviate regional droughts; grid-wide droughts are less frequent, but vulnerability is higher

Predictability of climate periods provide opportunities for joint Water-Energy Management

ENSO is an inter-annual climate oscillations impacting temperature and precipitation over the Western U.S.



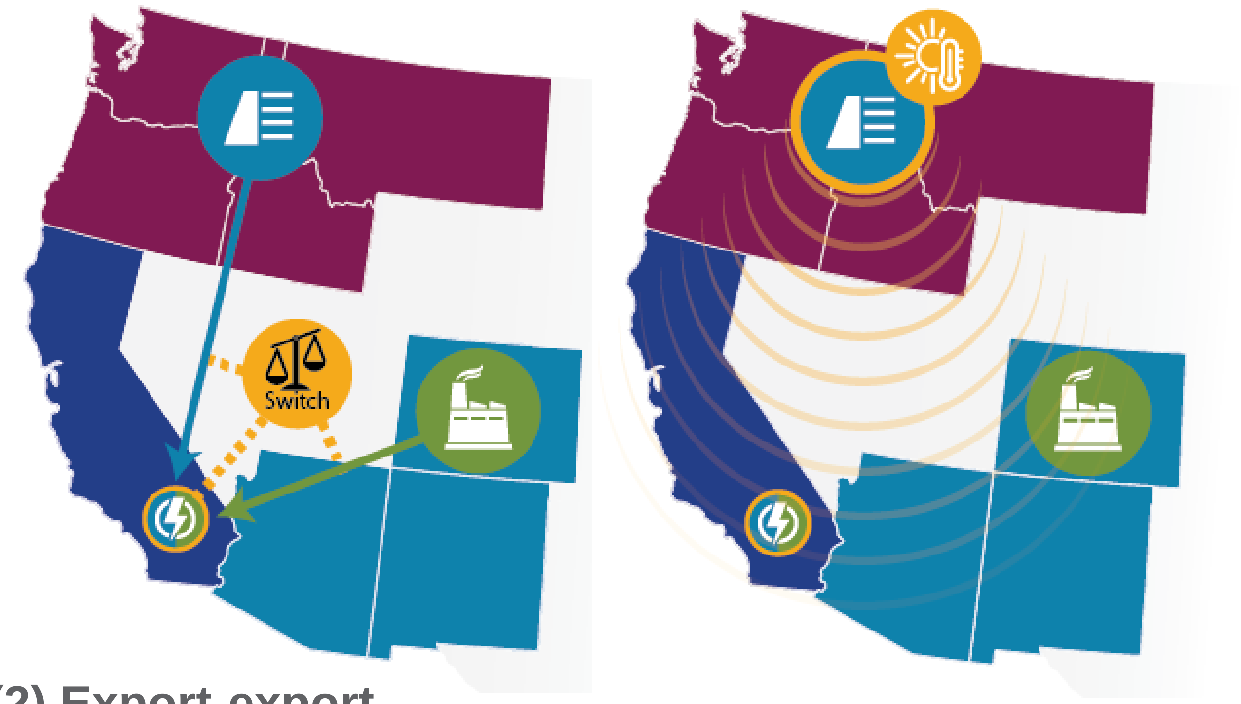
Neutral ENSO showed lowest cost and highest number of years with unserved energy (4 out of 6)



Voisin N, Kintner-Meyer M, Wu D, Skaggs R, Fu T, Zhou T, et al. Opportunities for Joint Water–Energy Management: Sensitivity of the 2010 Western U.S. Electricity Grid Operations to Climate Oscillations. Bulletin of the American Meteorological Society. 2018;99(2):299-312.

Understanding regional dynamics under resources drought conditions is critical for grid resilience planning

(1) Regional Generation impacted in California and Northwest



(2) Export-export-import regional dependency associated with water availability

(3) Regional dependency is conserved supporting a way for climate change impact in the Northwest to propagate through other regions

Regional dynamics both alleviate and propagate drought stress

Dynamics

- Regional import/export of electricity
- Markets "spill overs"

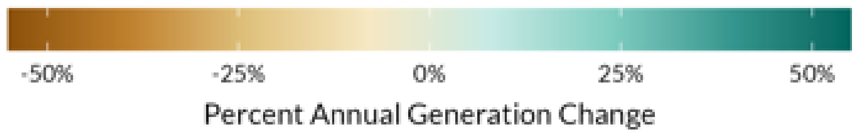
Stressors

- Climate change
- Drought with heat waves

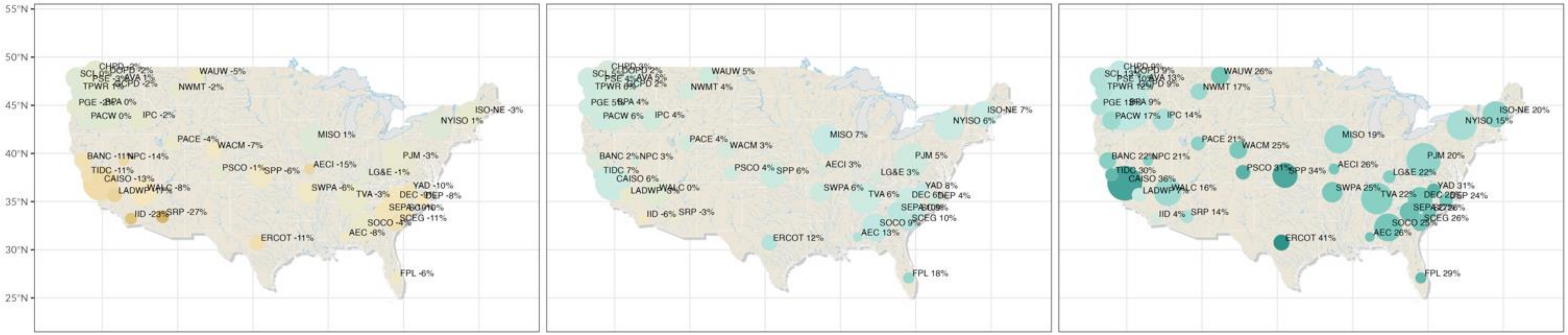
Voisin, N., Dyreson, A., Fu, T., O'Connell, M., Turner, S. W. D., Zhou, T., & Macknick, J. (2020). Impact of climate change on water availability and its propagation through the Western U.S. power grid. Applied Energy, 276, 115467.
Hill, J., Kern, J., Rupp, D.E., Voisin, N. and Characklis, G. 2021. The Effects of Climate Change on Interregional Electricity Market Dynamics on the U.S. West Coast. Earth's Future 9(12), e2021EF002400.
Dyreson, A., Devineni, N., Turner, S.W.D., De Silva M, T., Miara, A., Voisin, N., Cohen, S. and Macknick, J. 2022. The Role of Regional Connections in Planning for Future Power System Operations Under Climate Extremes. Earth's Future 10(6), e2021EF002554.

Impact of climate change on the hydropower fleet

Assessment is performed for individual balancing authorities
 (30 year horizon).

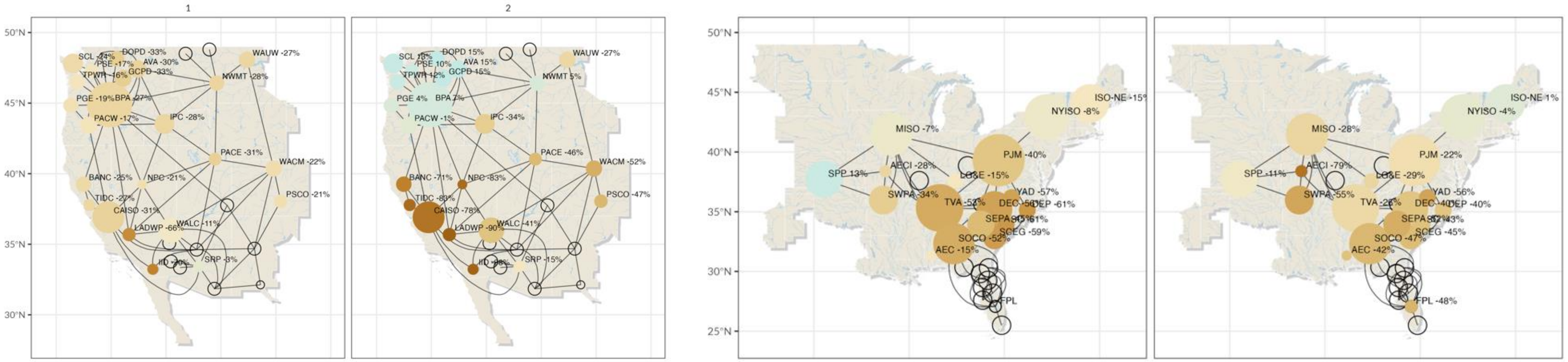


low hydro (5th percentile) ***median hydro*** ***high hydro (95% percentile)***



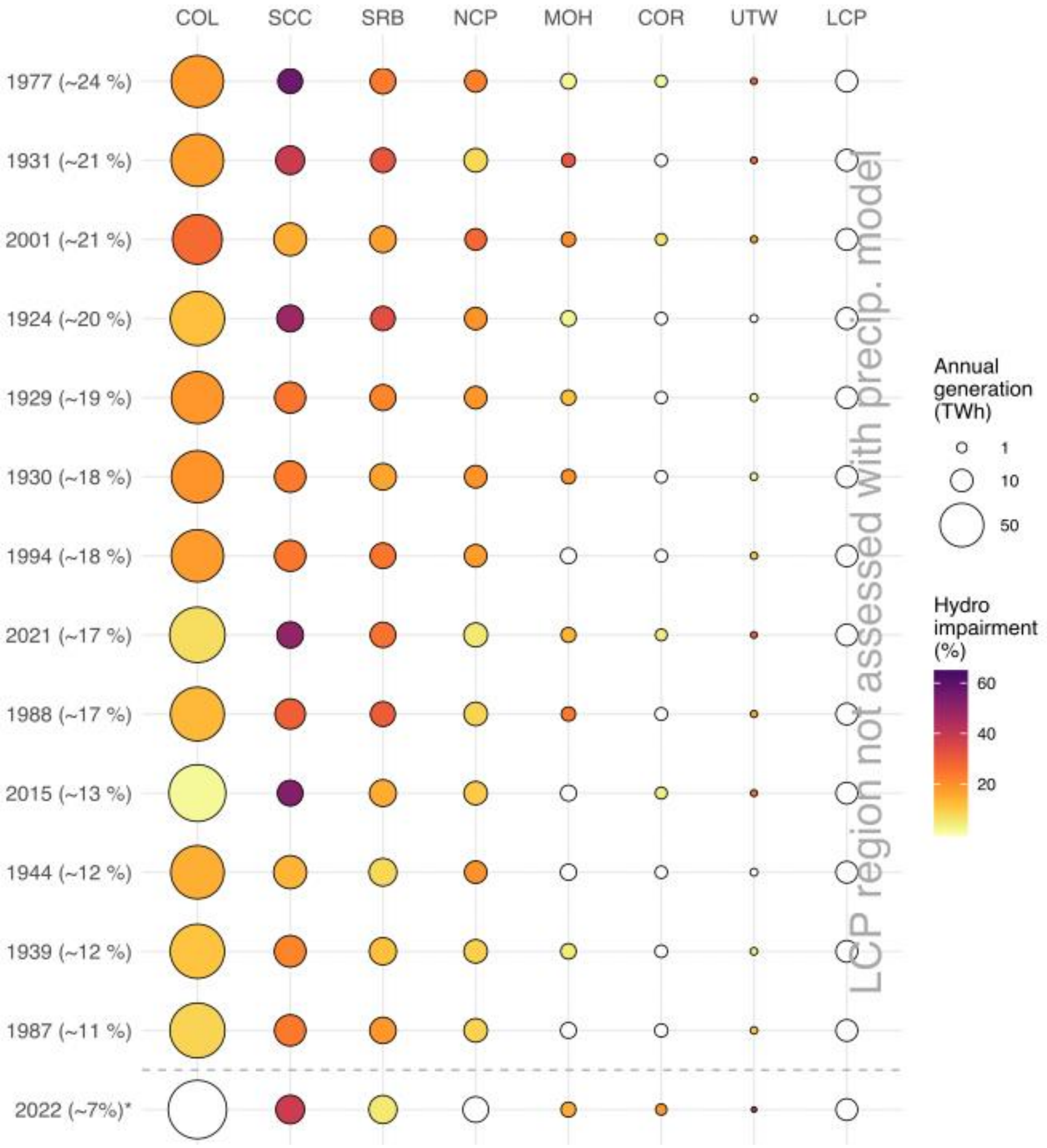
Drought scenario to support scenario-based reliability studies need to consider realistic drought conditions and regional variabilities. Multiple droughts should be considered, for each interconnect.

Worse low hydro conditions by interconnect (30 year horizon)



Broman, D., N. Voisin, A. Fernandez et al. (2024) in prep

Western Hydropower Drought Years Ranked



Take aways

With the increased reliance on renewable energies, we need to consider energy droughts in regional planning.

- At the interconnect scale:
  - the regional variability in available resources alleviate droughts
  - Resources adequacy and reliability studies need to consider multiple energy droughts that span different regions, temporal scales and include compound events
- At the utility or/and balancing authority scale:
  - The worse compound energy drought might be selected for informing planning
  - An ensemble of regional opportunities and constraints need to be considered, leveraging established regional dynamics

Catalog of extreme events, and associated impacts on load and generation resources on future infrastructures are developed and shared with system operators. More efforts are needed for the implementation of the scenarios.

Efforts are needed to explore dispatch opportunities across regions, and market opportunities that support storage management at the scale of critical energy droughts.

Thank you

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