



The Future Role of Transmission in Resource Adequacy

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DOE's 17 **national laboratories** tackle critical scientific challenges





PNNL is one of DOE's **most diversified** national laboratories



5,700 Staff



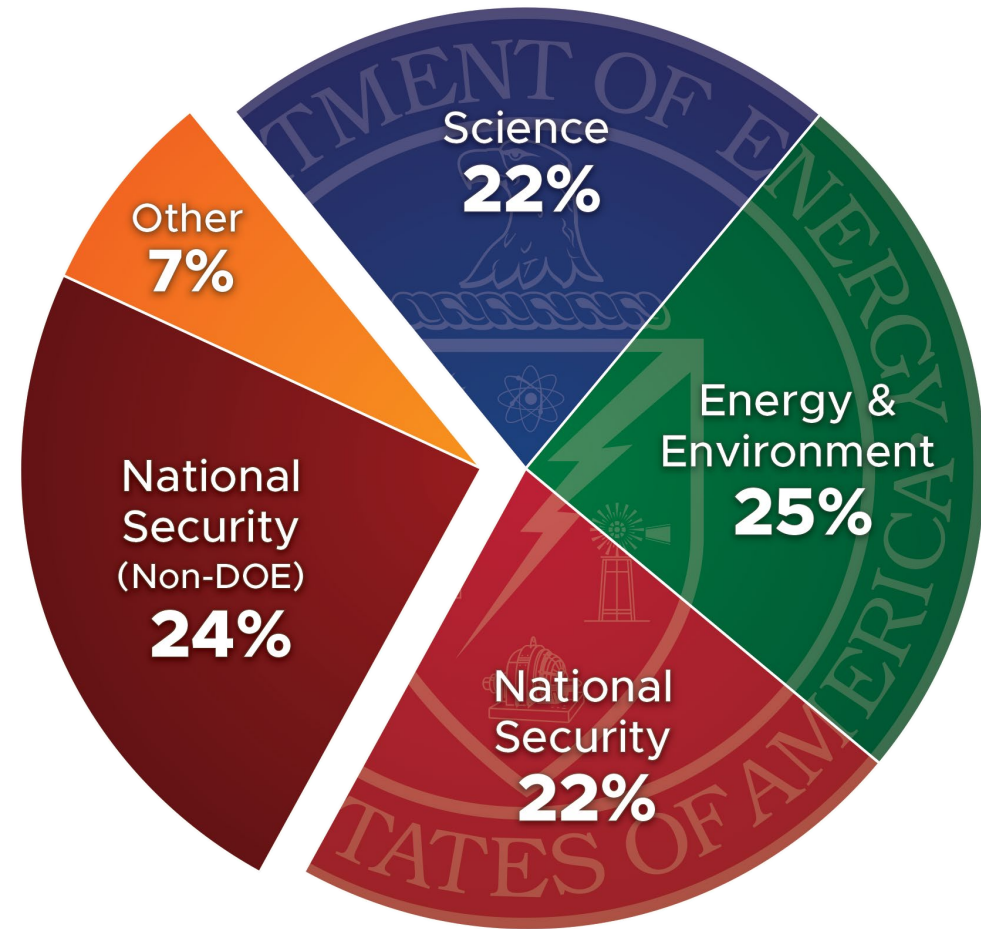
\$1.34B Spending



1,755 Peer-reviewed Publications*



272 Invention Disclosures

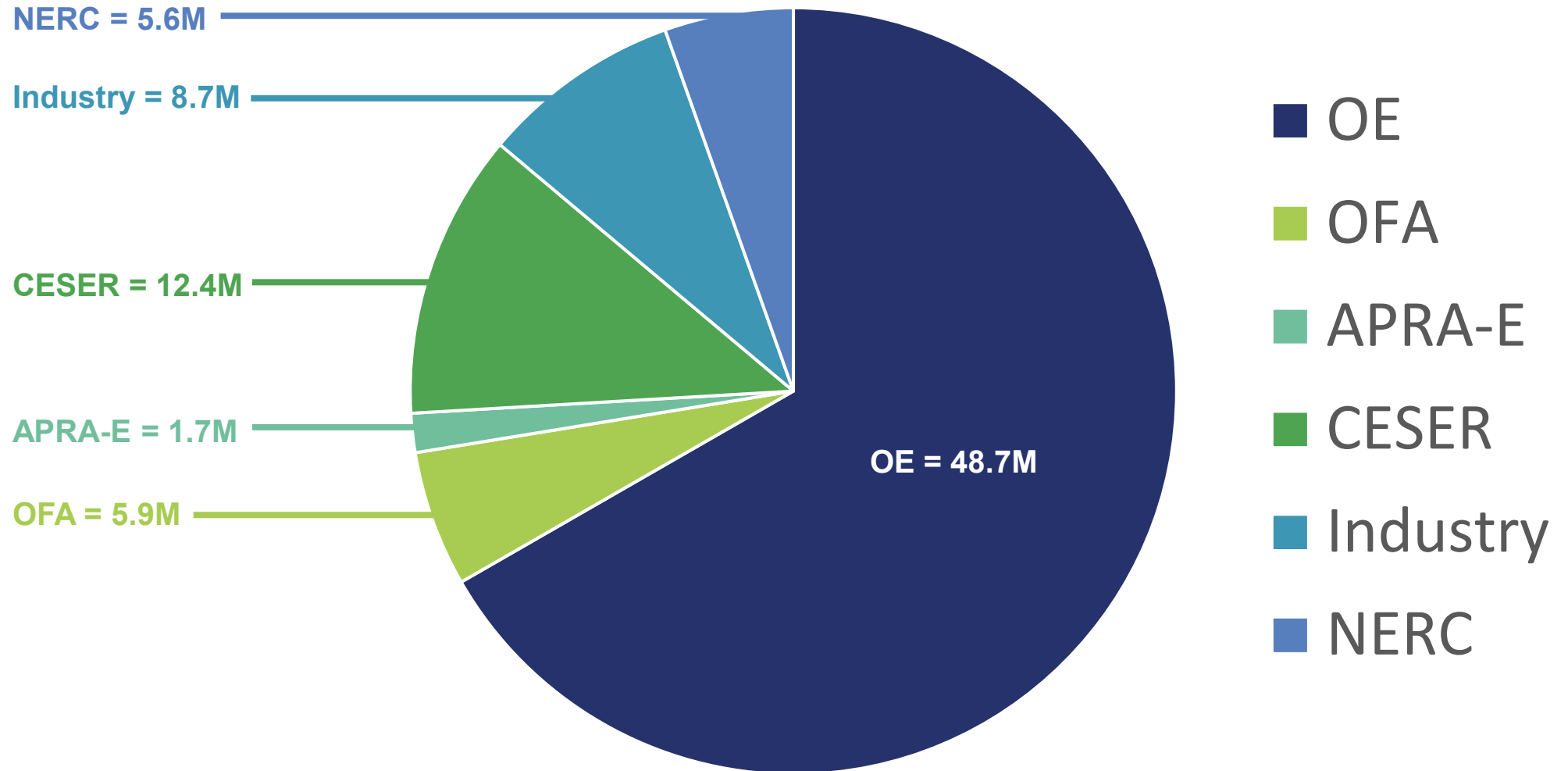


FY 2022 Staff

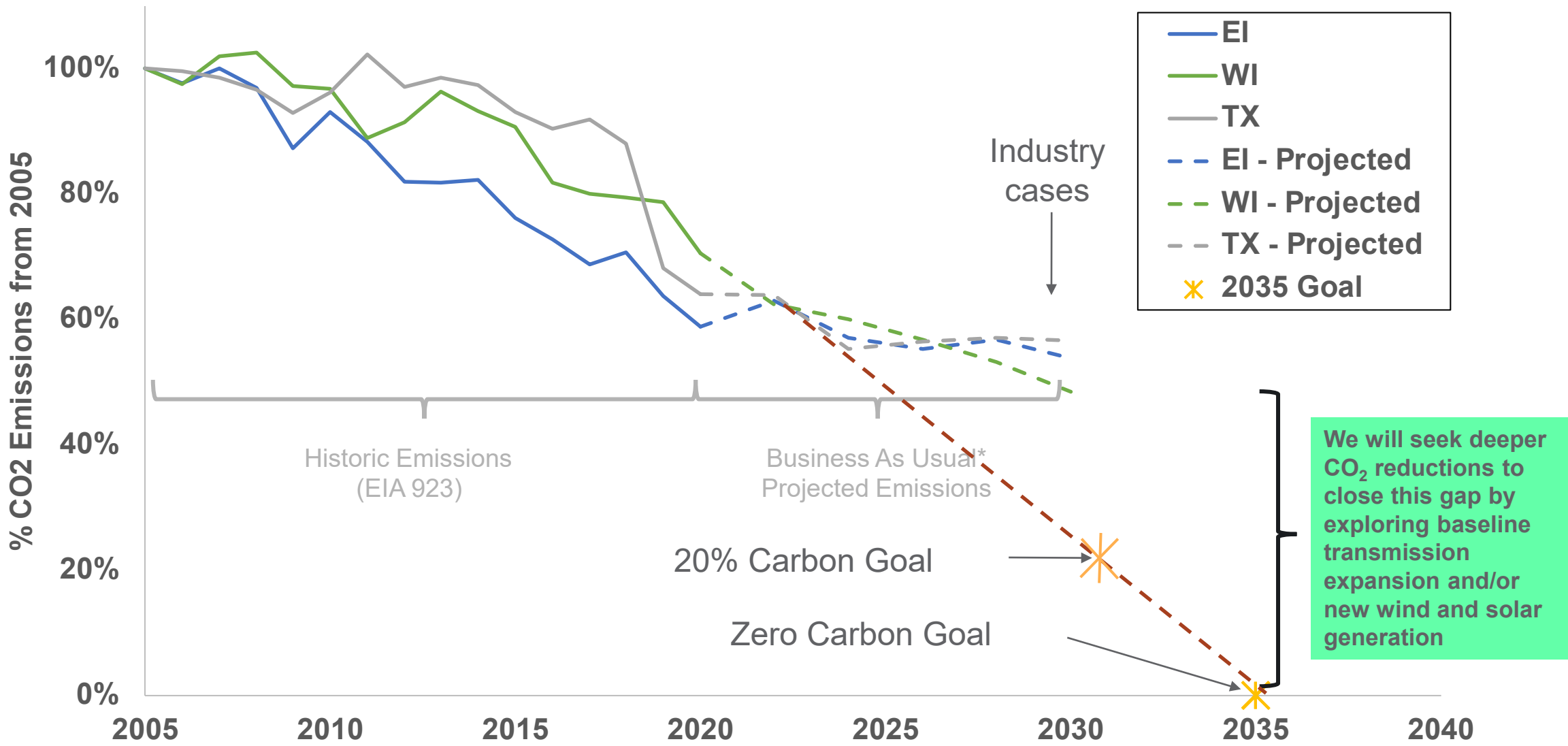
*Available peer-reviewed publication data are from FY 2021

PNNL Electricity Infrastructure Sector

Research Expenditures: \$83M (FY22)



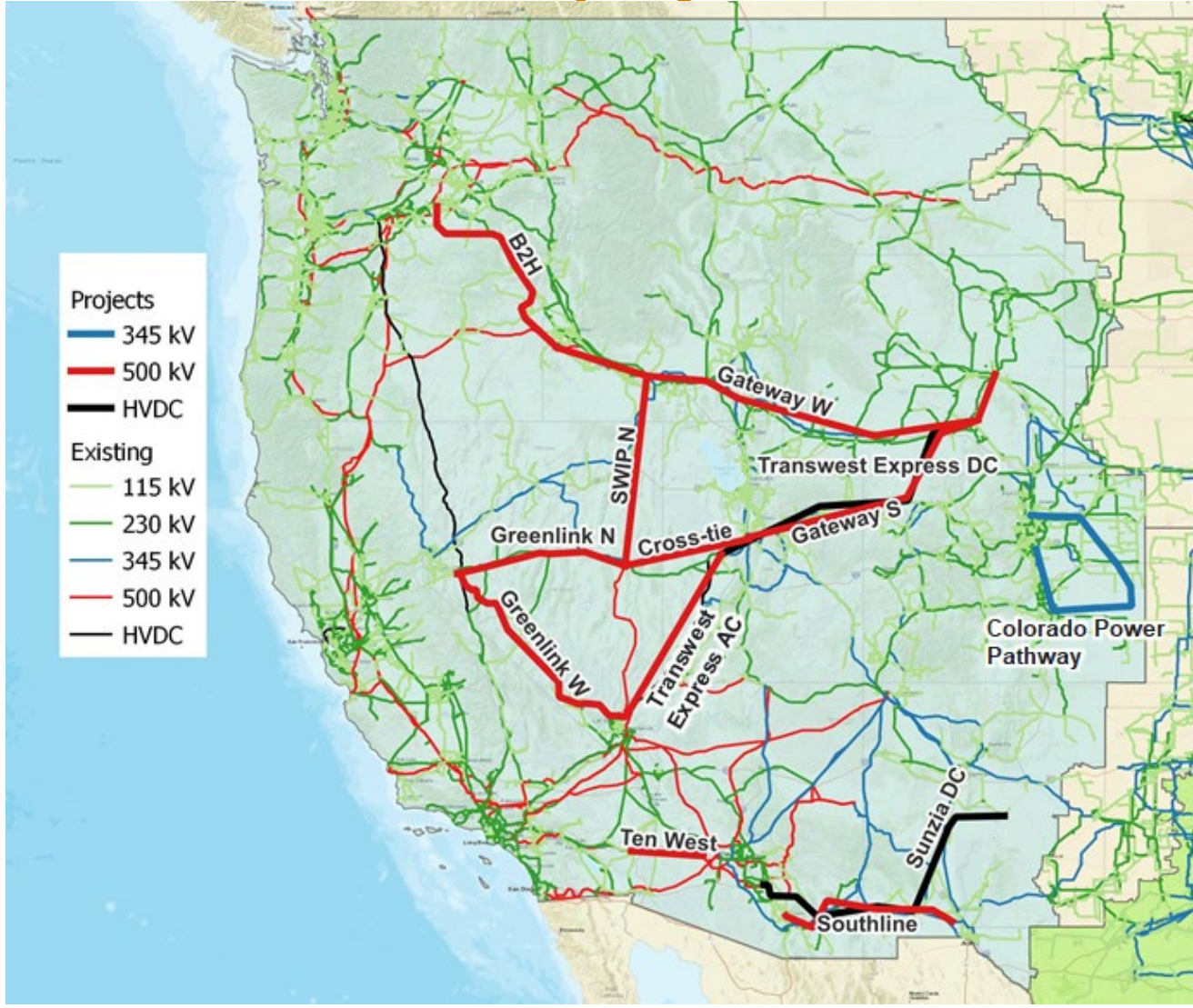
National Transmission Planning Study: Electricity CO2 Emissions Trajectory and Gap to 2035 Goal



EIA 923 Emissions (<https://www.eia.gov/electricity/data.php#elecenv>)

*Based on 2021 Standard Scenarios Mid-Case emissions, results are consistent with Basecase 2030 PCM results

National Transmission Planning Study: WECC Baseline projects at advanced development stage



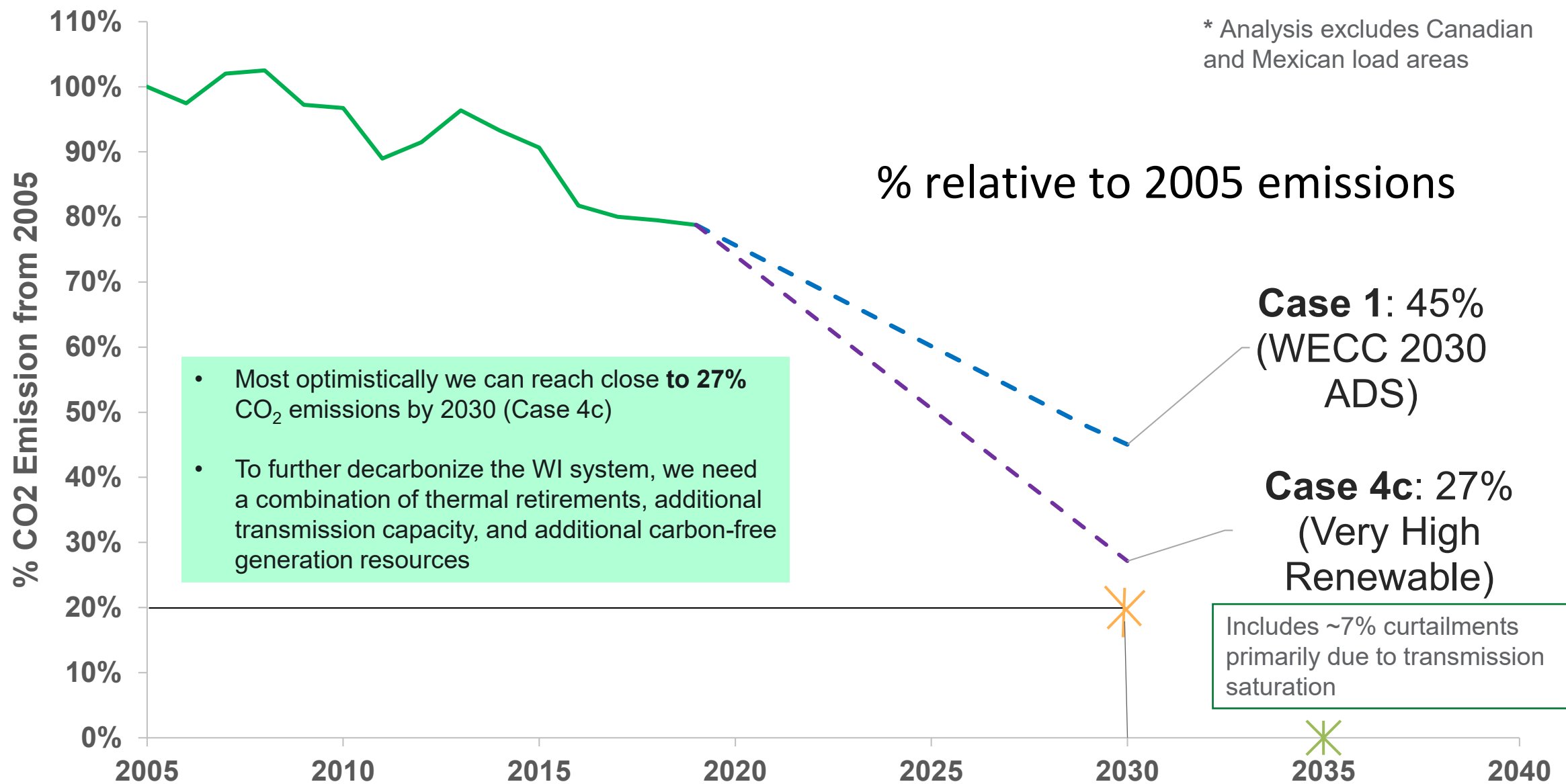
- Boardman to Hemmingway (B2H)
- Ten West Link
- Gateway West (several segments completed, others are under construction)
- Gateway South
- Gateway West
- SWIP North
- Transwest Express DC
- Cross-Tie
- SunZia DC
- Southline
- Greenlink Nevada West
- Greenlink Nevada North
- Colorado Power Pathway

<https://hifld-geoplatform.opendata.arcgis.com/search?collection=Dataset&groupIds=4fd22faa66a547f784bdf7779eda969f>

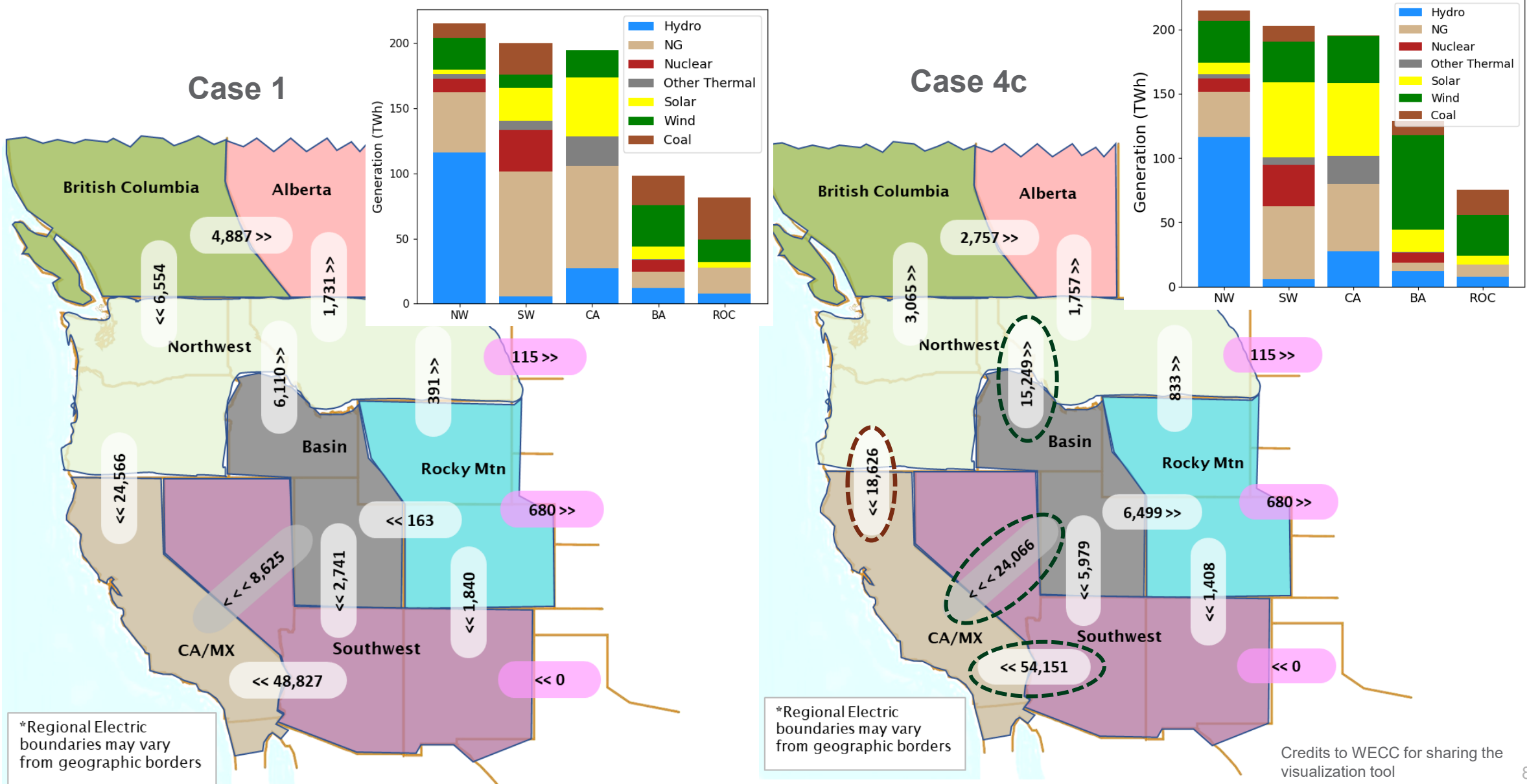
Most lines have the objective of connecting renewable resources with load centers

National Transmission Planning Study: CO₂ emissions change with respect to year 2005 (WECC*)

* Analysis excludes Canadian and Mexican load areas



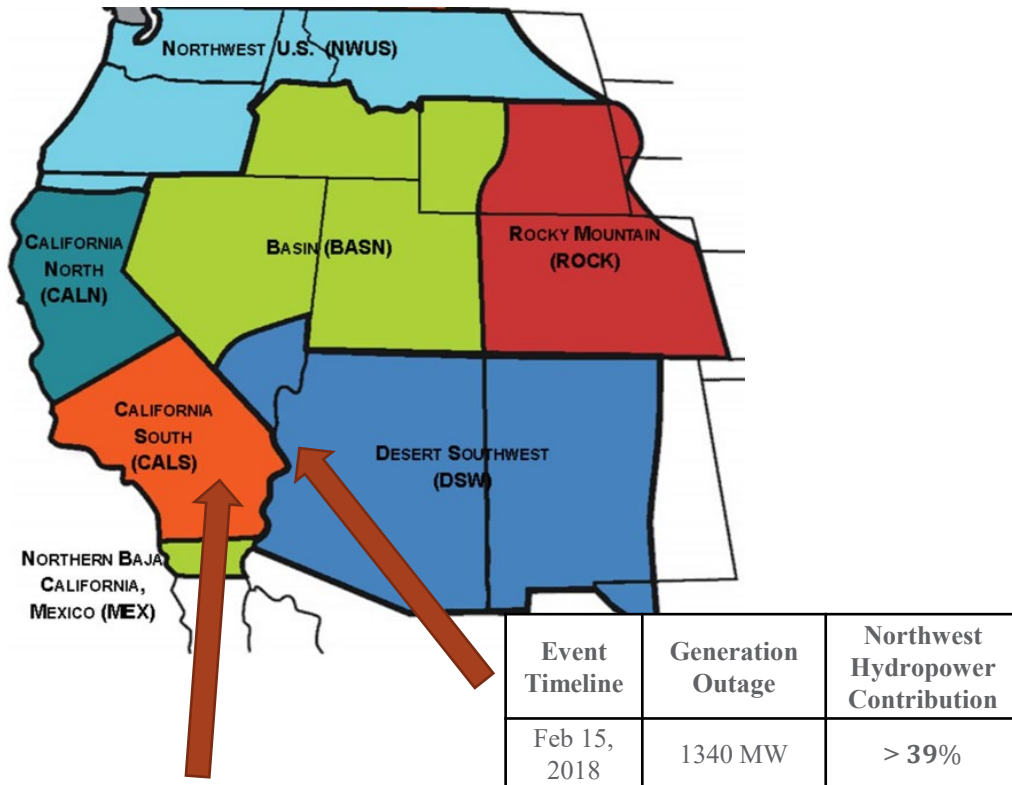
National Transmission Planning Study: Total Net Regional Transfers (GWh)



HydroWIRES: Quantify hydropower's role in ensuring a reliable and decarbonized power grid

Hydropower represents ~25% of installed capacity, but contributes 30-60% of frequency response in the Western Interconnection

Capabilities developed under OE/EERE projects are being used to understand the impact of compounding set of extreme events, and the role of hydropower in future



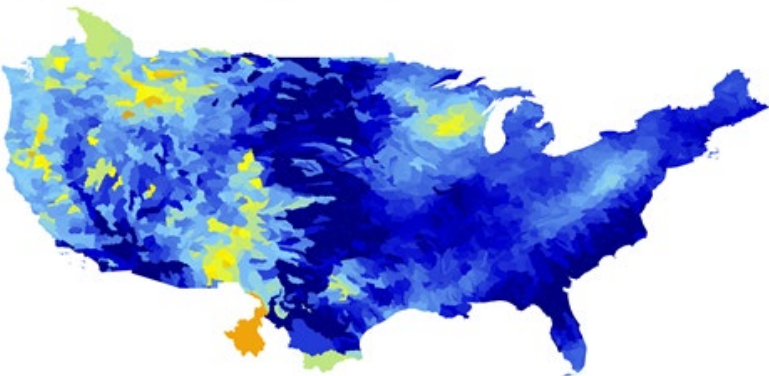
Event Timeline	Generation Outage	Northwest Hydropower Contribution
Apr 20, 2018	700 MW	> 61%



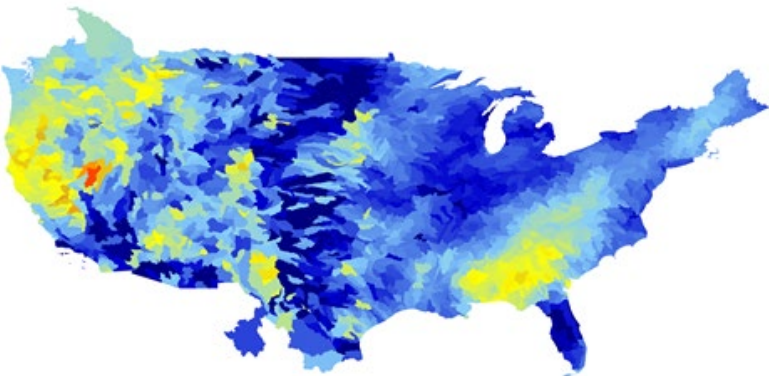
Water Availability Modeling

Runoff Projections

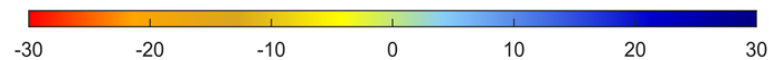
(a) ACCESS-CM2 ssp585 r1i1p1f1



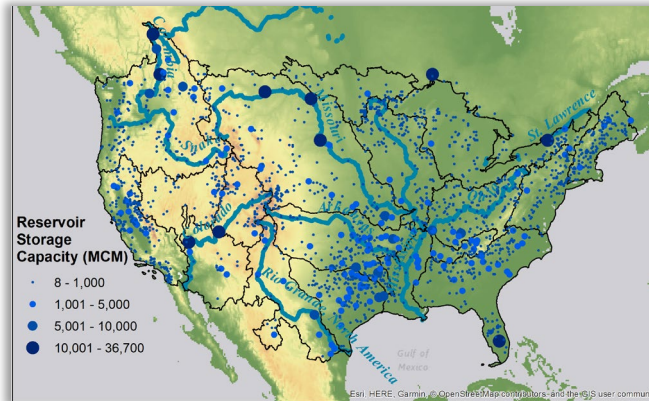
(c) CNRM-ESM2-1 ssp585 r1i1p1f2



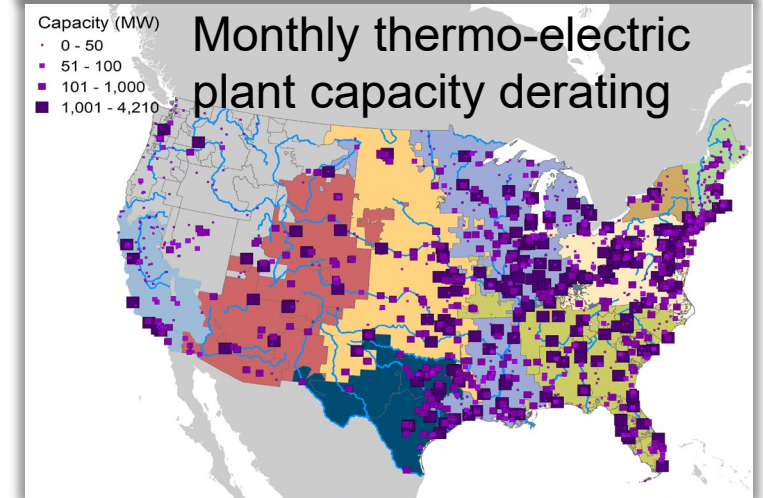
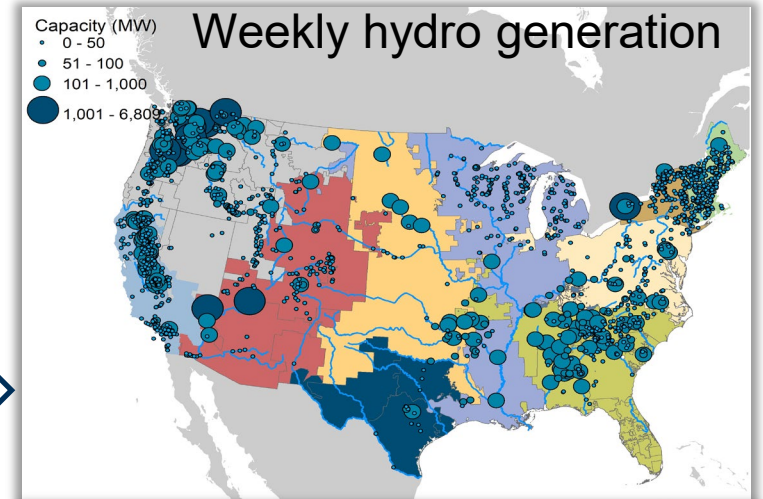
Percent Change - Mean Annual Runoff



Regulated flow, reservoir storage and release, and water withdrawals



Data-driven reservoir operations and water management model + hydropower model + derating model





Thermal derating due to changing climate

Thermal power production relies on a temperature differential. Changes in ambient air temperatures, humidity, river water temperatures, and water availability all directly impact generation efficiency.

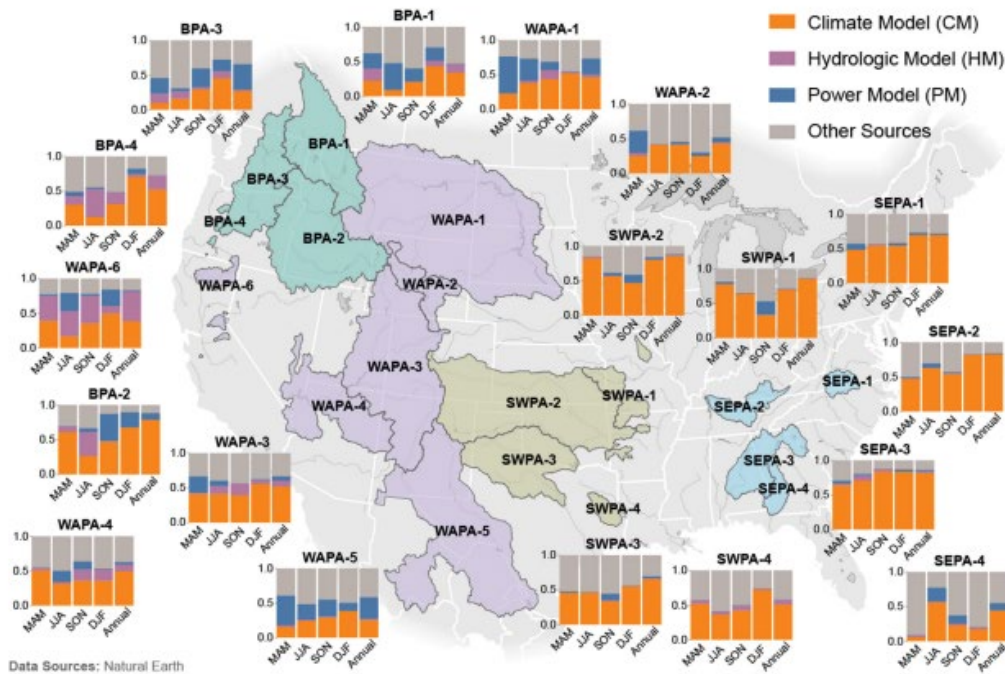
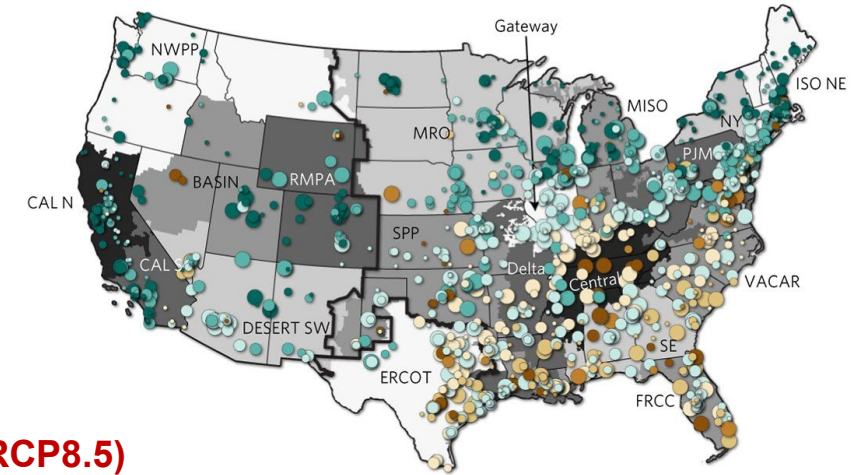


Figure 7.8. ANOVA of projected annual and seasonal hydropower generation in each of the PMA study areas.

Shi-Chieh et al 2022 <https://doi.org/10.2172/1887712>
 Work funded through DOE EERE

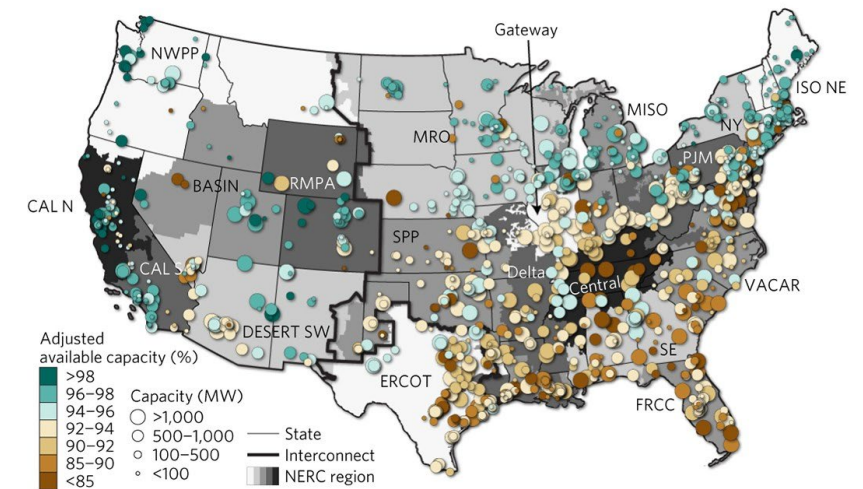
Today

Contemporary



Future (RCP8.5)

RCP8.5

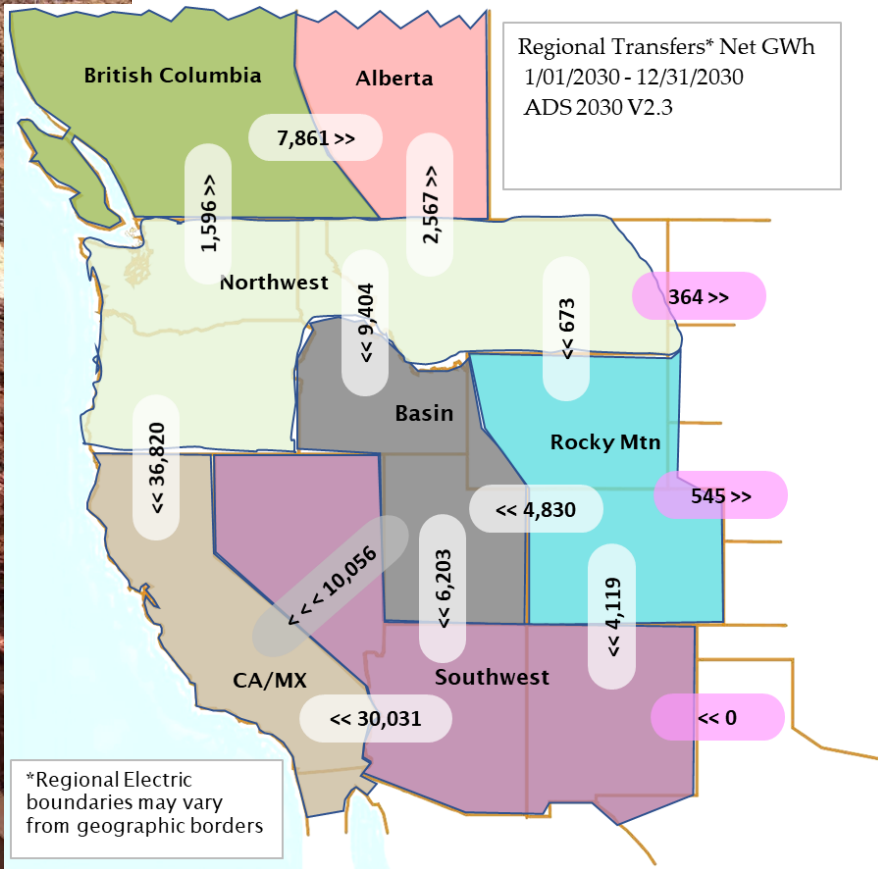


Miara et al 2017 <https://doi.org/10.1038/nclimate3417>
 Work funded through NSF Water Sustainability and Climate grant #1360445

Coincident drought & heatwave can pose resource challenges (unserved energy and increased dependence on thermal power)

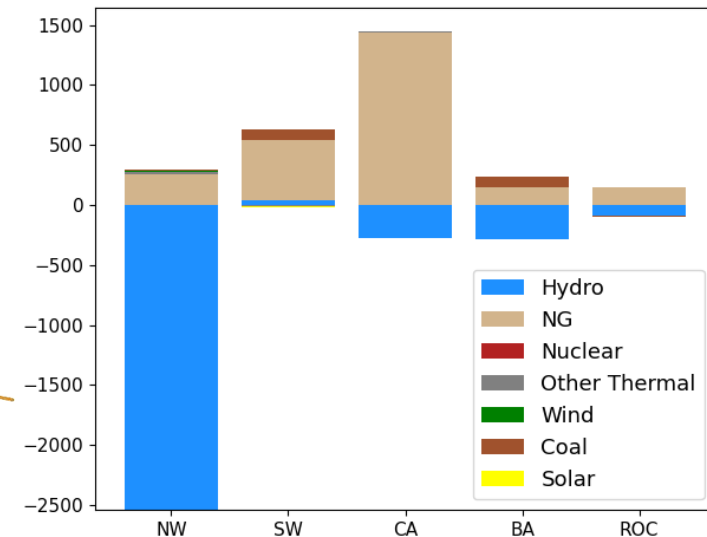
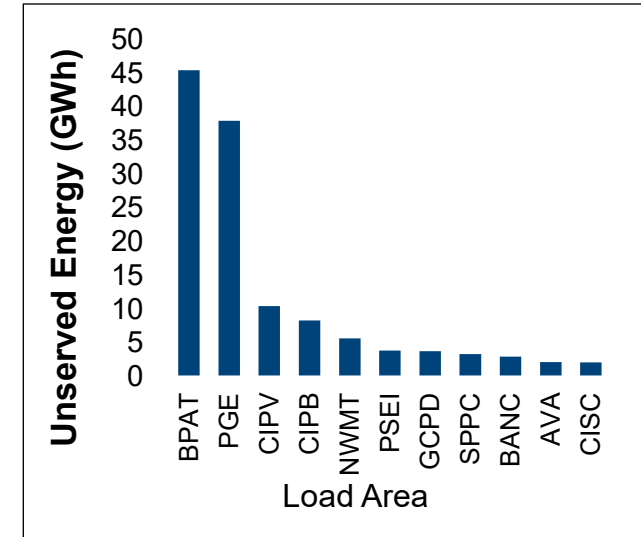
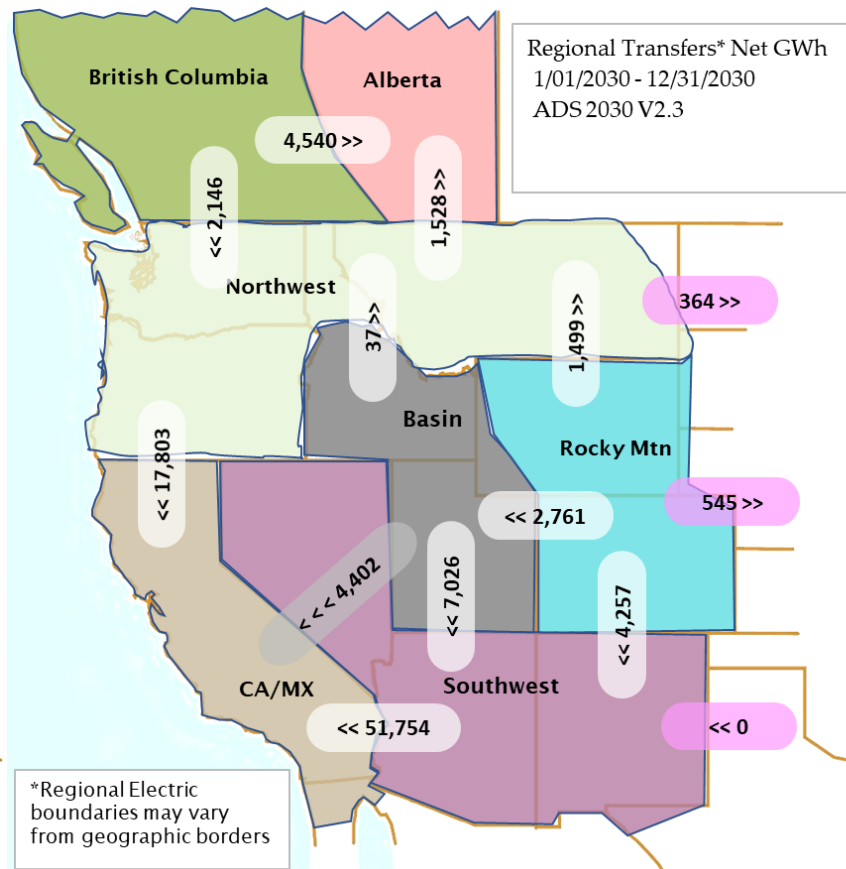
Control

Heatwave in Week 26;
no Drought



Experiment

Heatwave in Week 26;
Drought in Week 26



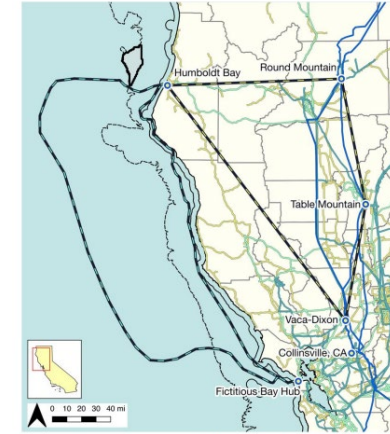
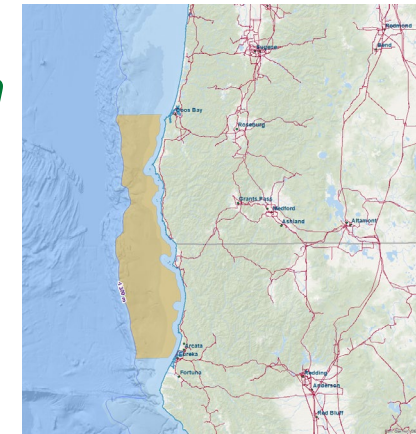
Source: EERE-WPTO HydroWIRES project: Hydropower's Contribution to Grid Resiliency under Compounding Set of Extreme Events

NOWRDC/BOEM OSW Integration Study

Informing state and federal efforts along the CA/OR Outer Continental Shelf

An Offshore Wind Energy Development Strategy to Maximize Electrical System Benefits in Southern Oregon and Northern California

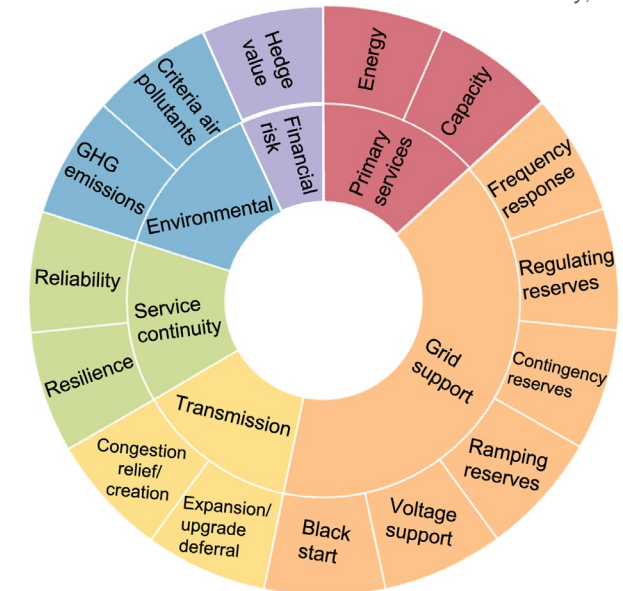
- Optimization of generation footprints for system value
- Evaluation of three conceptual transmission scenarios:
 - Incremental land-based transmission upgrades
 - New high voltage land-based transmission, or
 - Offshore high voltage transmission
- Guided by industry groups
- Extended by BOEM to evaluate Bay Area power flows



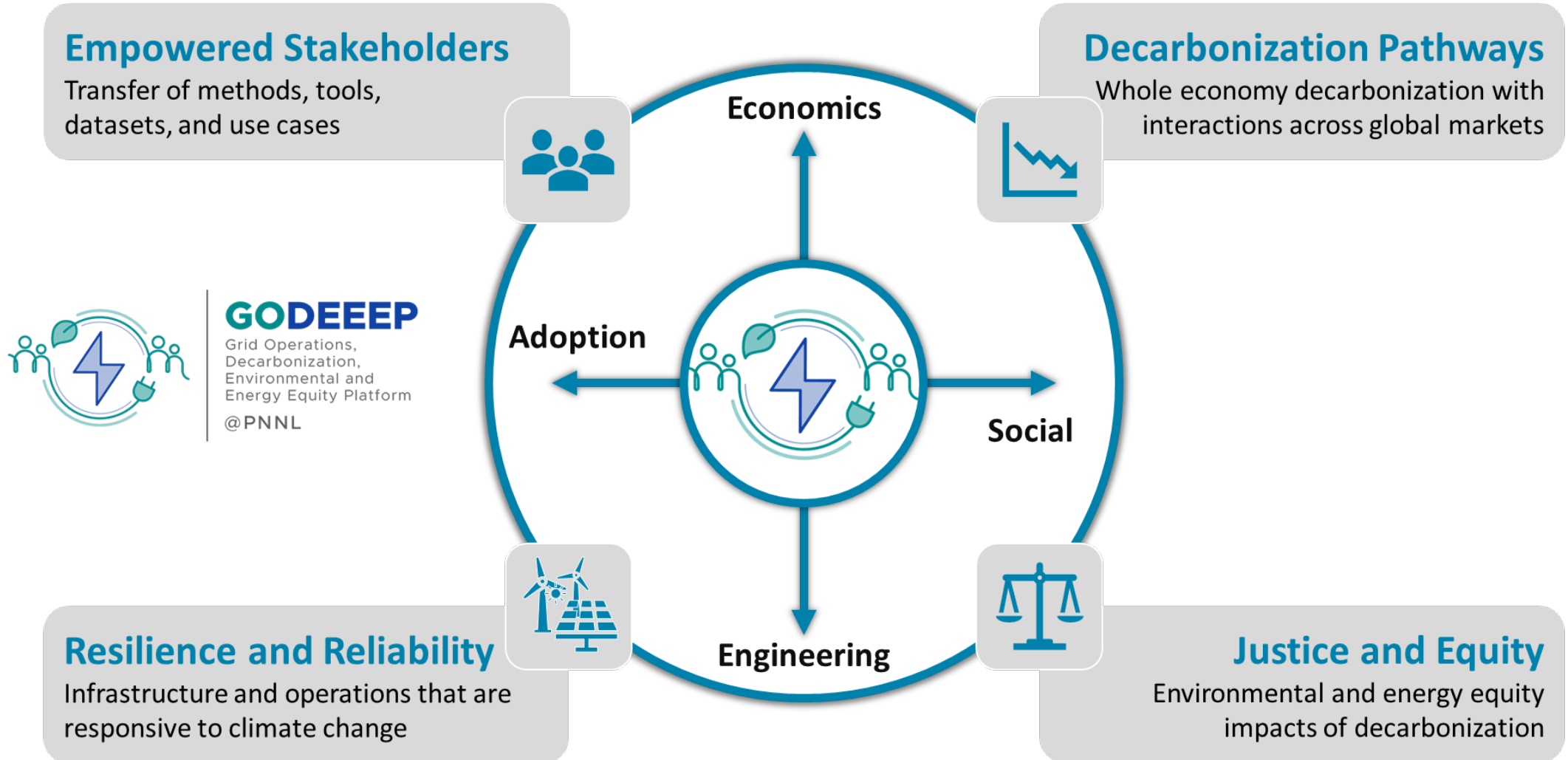
Severy, et. al (2020)

Outcomes:

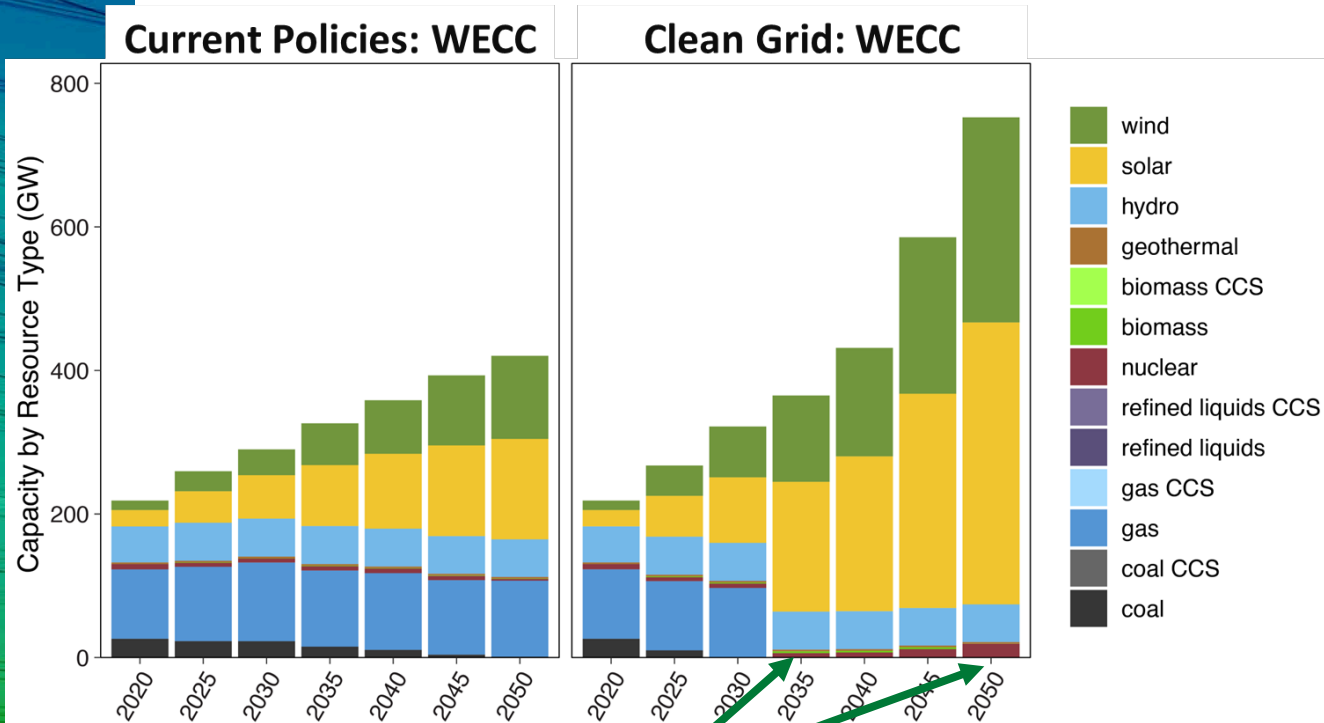
1. A system valuation methodology for concept prioritization
2. System dispatch and power flow simulations of three large-scale transmission concepts
3. Identification of mechanisms to further optimize system value



GODEEEP: Integrating climate and policy changes into long-term energy planning



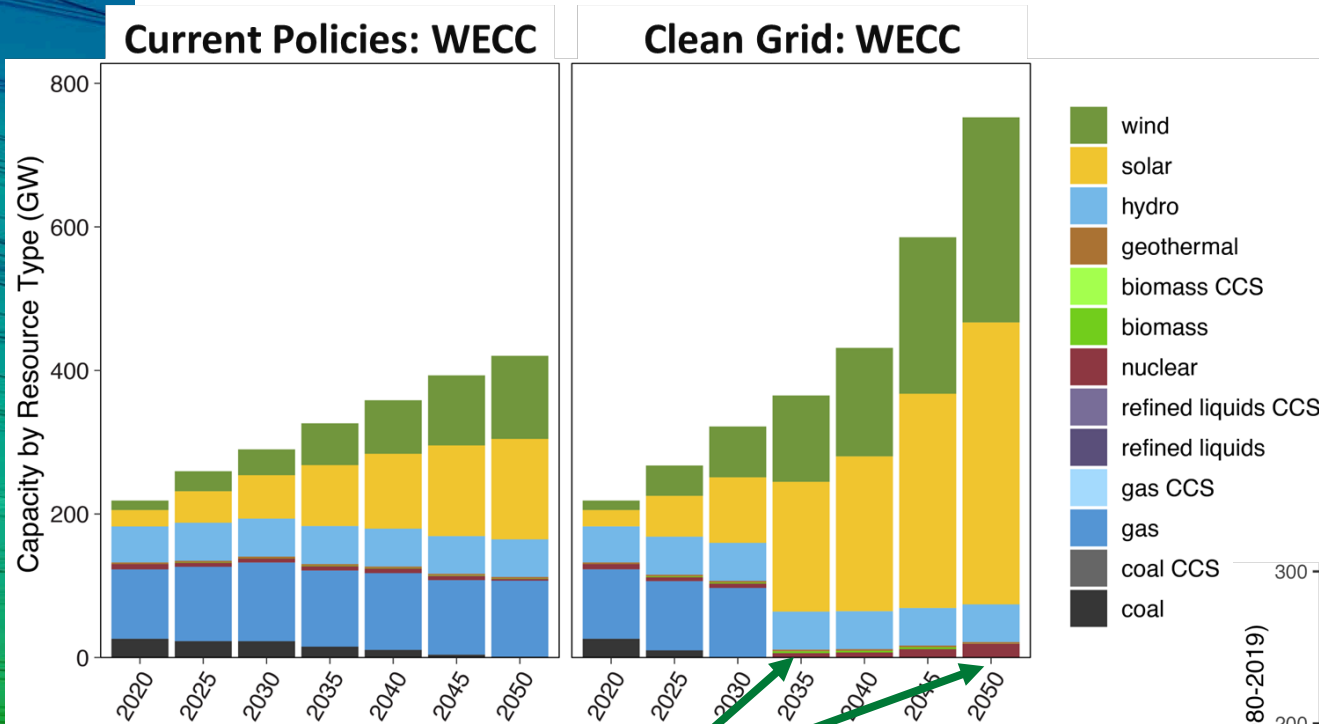
GODEEEP: Integrating climate and policy changes into long-term energy planning



No surprise:

- A carbon-free grid by 2035 requires a drastic change in resource mix
- And a carbon-free economy by 2050 requires significant capacity

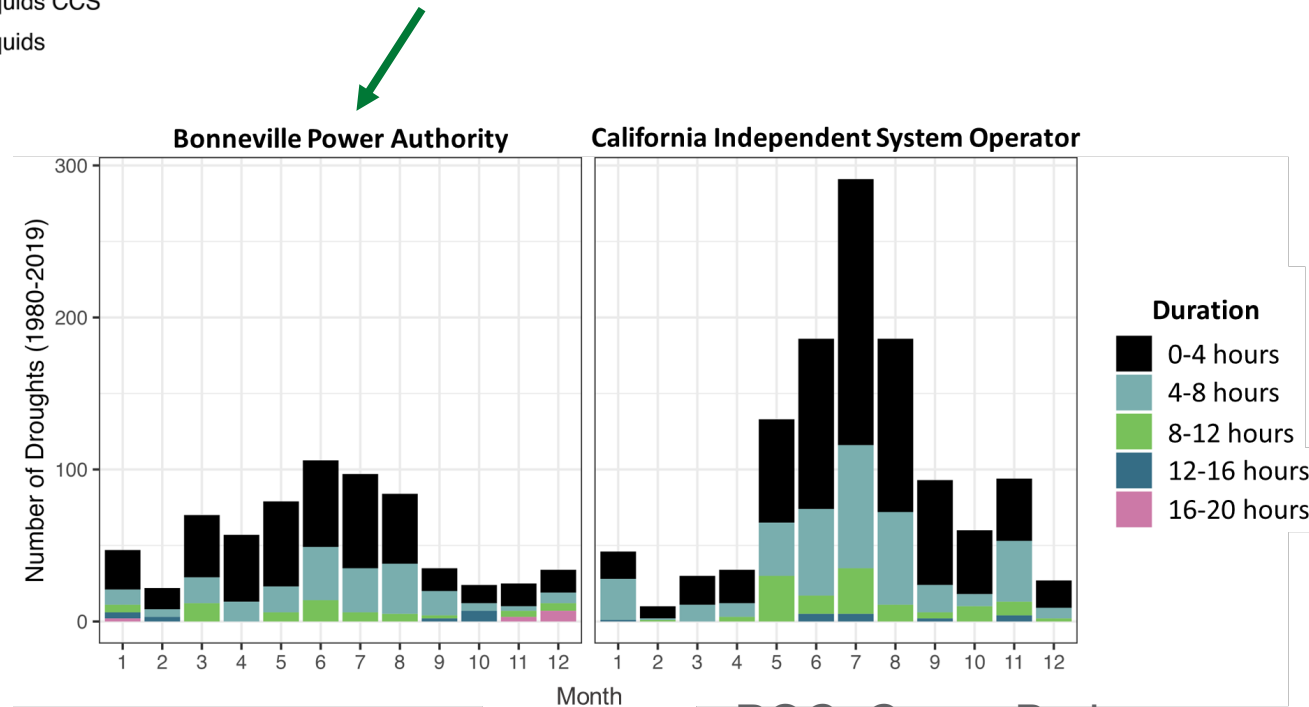
GODEEEP: Integrating climate and policy changes into long-term energy planning



No surprise:

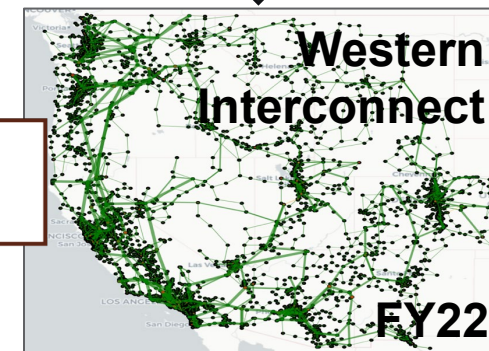
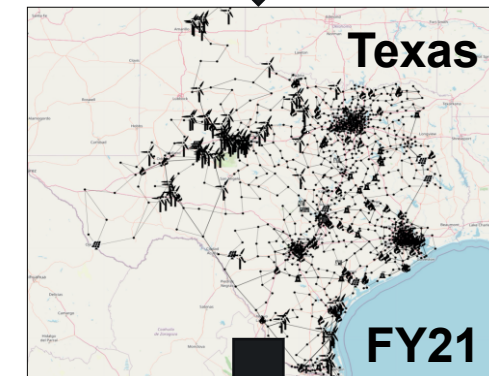
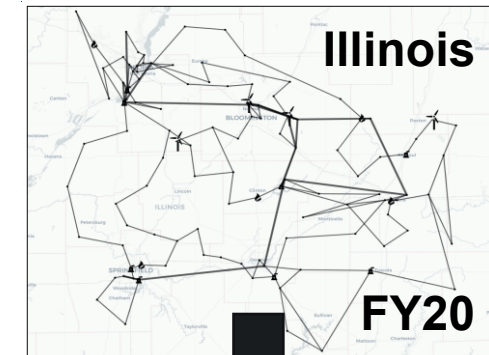
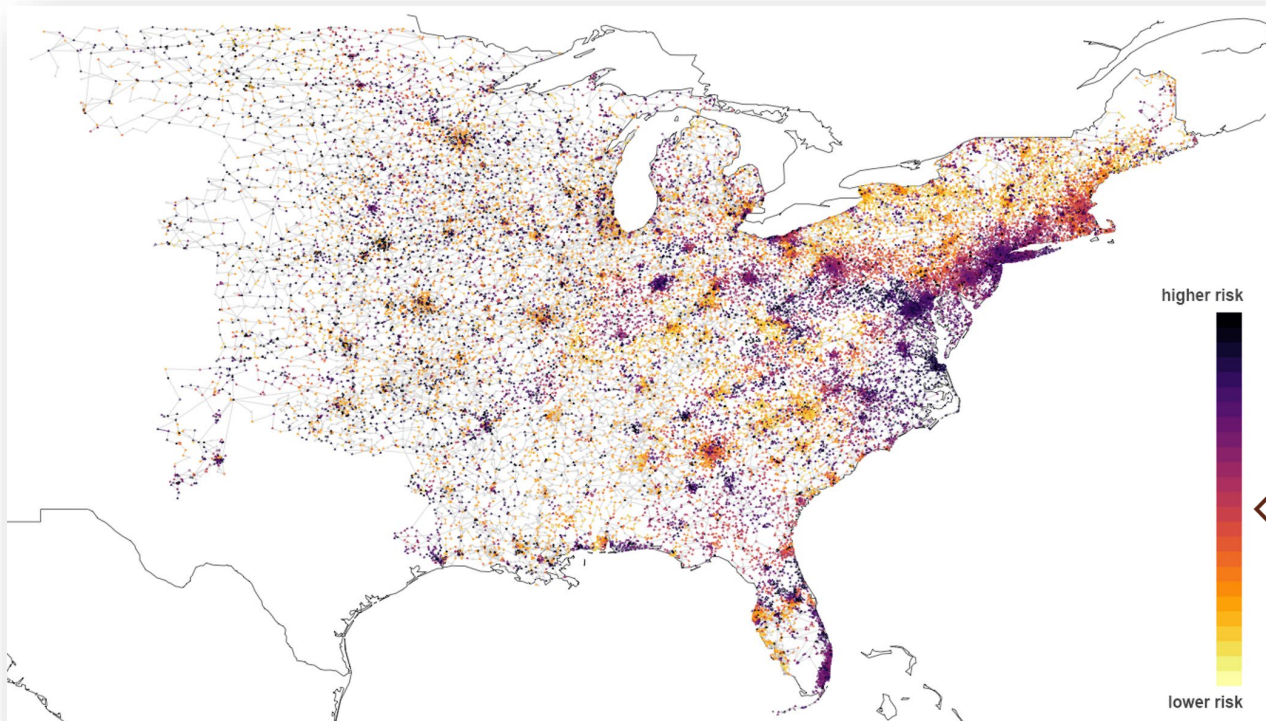
- A carbon-free grid by 2035 requires a drastic change in resource mix
- And a carbon-free economy by 2050 requires significant capacity

- Characterizing past versus future resource droughts will become an important part of planning (duration, frequency, and geographic scale)



Exascale Grid Optimization (ExaGO) Toolkit

- Open-source computational engine that calculates impacts of complex grid contingencies/failures under uncertain weather/climate scenarios
- Simultaneous optimization of millions of power system scenarios at operational time-scale
- First power grid application to run at scale on ExaScale HPC (Frontier)



FY23

Deterministic

Stochastic