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Integrating critical water issues into long-term planning for WECC




PRESENTED BY

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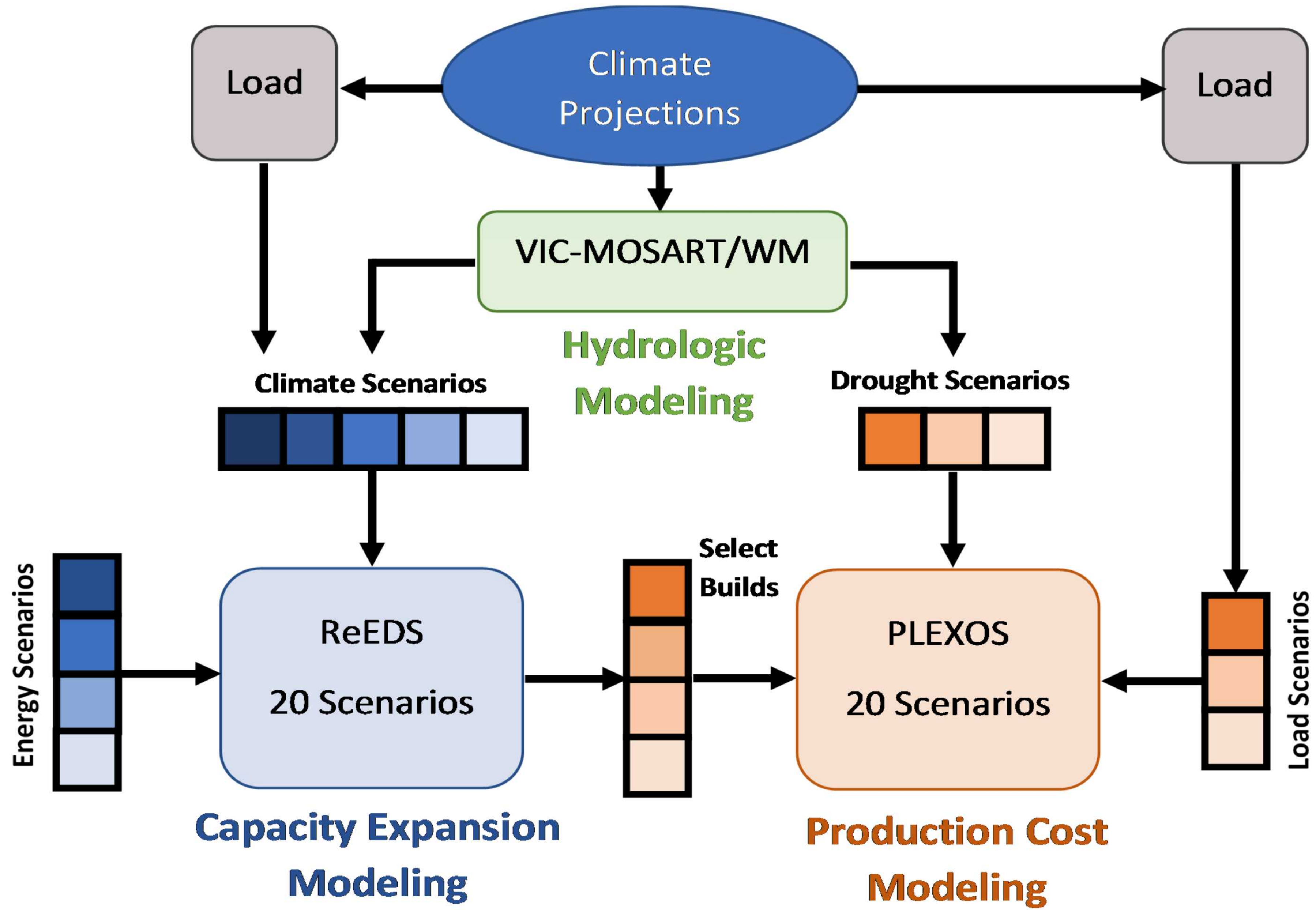
Modeling Platform



Key Sensitivities Quantified in this Work

Changes in climate impact investment decisions:

- Up to 17 GW additional Western Interconnection generating capacity could be needed by 2038 to meet peak loads (6.6% increase).
- Cumulative 20-year investment and operating costs increase by \$5–\$17 billion in climate impact scenarios.

System reliability was observed to remain robust under our drought scenarios:

- Over 99.9% of energy and reserves met in models.
- Thermal capacity buffer significantly higher when ReEDS build-out planned for certain climate conditions.

Climate change influenced system economics by increasing operational costs:

- +9 to +19% for drought/heat scenarios compared to baseline conditions.
- -2 to +4% for ReEDS build-outs which included climate foresight compared to those that didn't.

Hydropower flexibility had significant impact on production costs:

- -2 to +17% for hydropower flexibility.
- However, changing hydropower flexibility has a relatively small influence on capacity expansion in the Western Interconnection through 2038.

Collaboration

- WECC partners with the National Labs to leverage their expertise, data, models, and methods to assist WECC in answering those questions where WECC lacks the expertise to answer.
- National Labs benefit from WECC's understanding and perspective on the coordination of power system planning, operations, and reliability assurance of the Western Interconnection.
- National Labs benefit from the perspectives of WECC's broadly diverse stakeholder community ("what's on their radar?").

WECC EWCC Key Questions

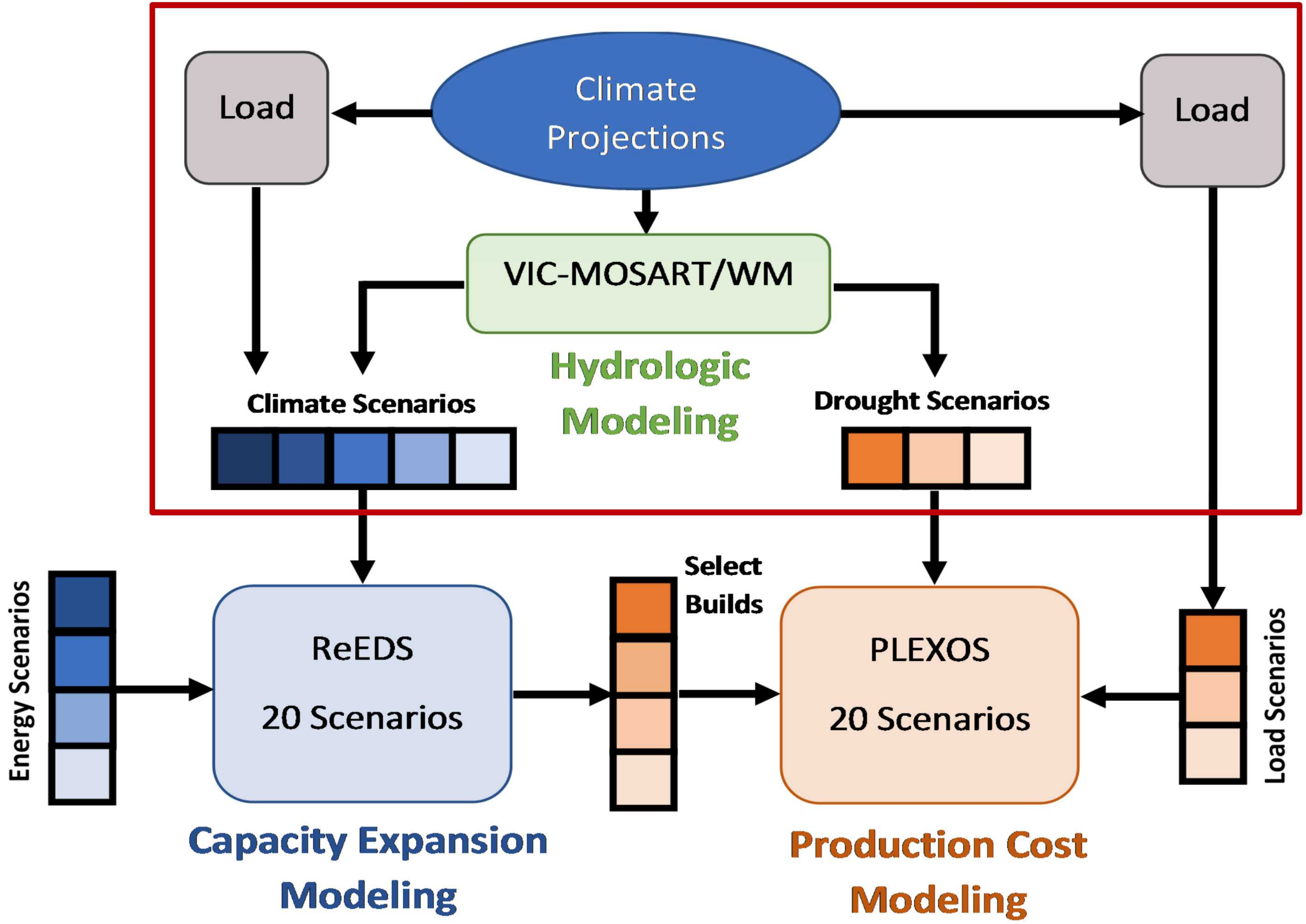
1. What risks to the reliability of the Bulk Electric System in the Western Interconnection might arise from the Energy-Water-Climate Change (EWCC) nexus?
2. How might EWCC increase risk exposure to extreme natural events?
3. How might EWCC impact reliability with regard to an accelerated dependence on renewables for energy production?
4. Will an accelerated dependence on renewables for energy production have a quantifiable impact EWCC?
5. How might EWCC impact reliability with regard to an increased dependence on natural gas fired generation for energy production and operational flexibility?

WECC EWCC Key Questions

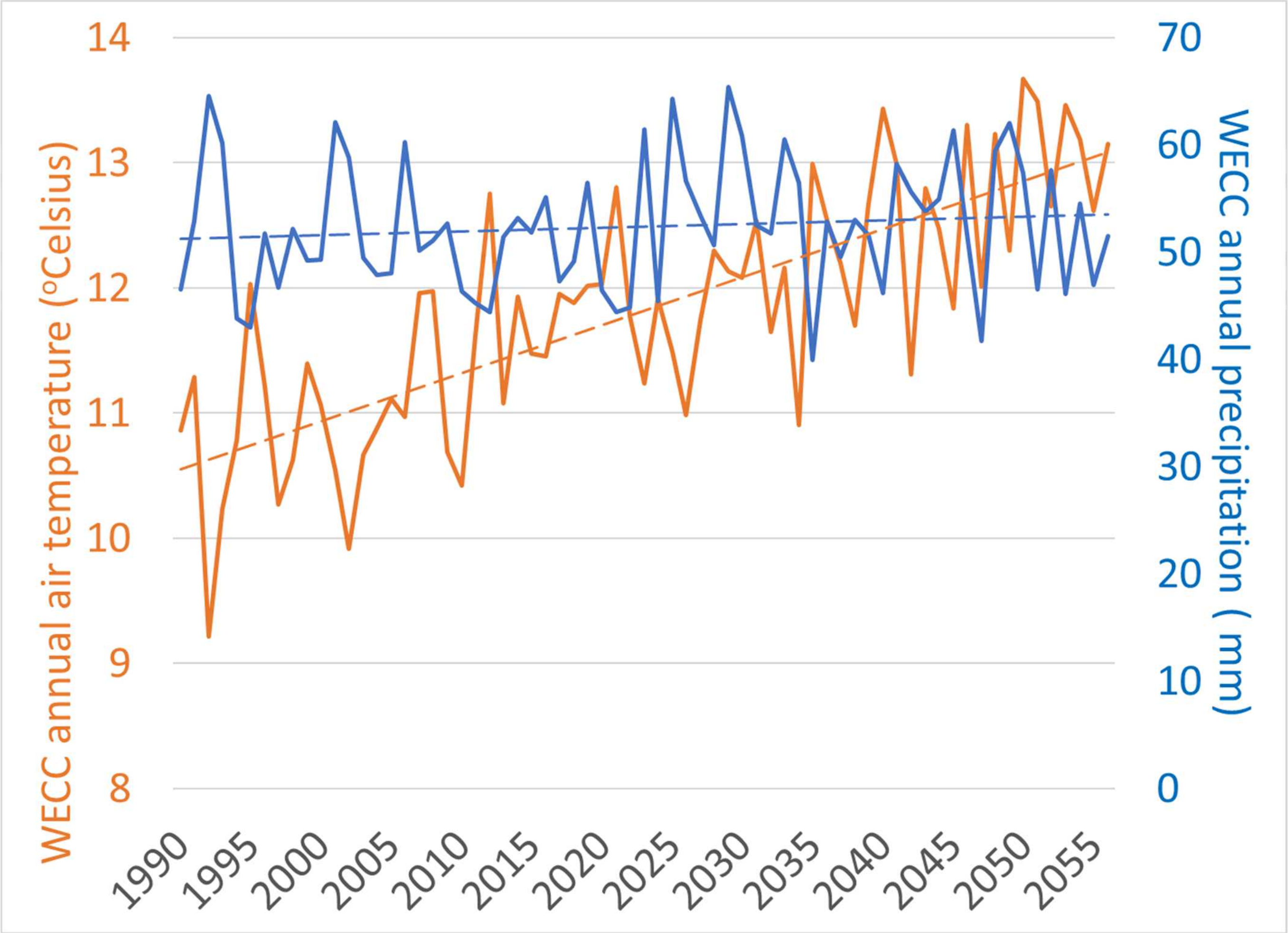
6. How might EWCC impact reliability with regard to continued dependence on hydropower for energy production?
7. To what extent can hydropower provide increased operational flexibility in response to increased variability arising from an increase of renewables in the resource mix?
8. What new operational and regional coordination challenges may arise from EWCC and how might they need to adapt to assure reliability?
9. What new tools and modeling improvements are needed to address the risk uncertainties arising from EWCC.
10. What decisions need to be made now to minimize risk and uncertainty arising from EWCC in terms of investment, operations, and grid reliability protocols?

From Climate To Generation Constraints: Modeling of Water Availability Trends and Critical Droughts

Modeling Platform



Long Term Climate Trends Differ From Inter-annual Variability



Critical Droughts Specifically Affects The Electricity Infrastructure

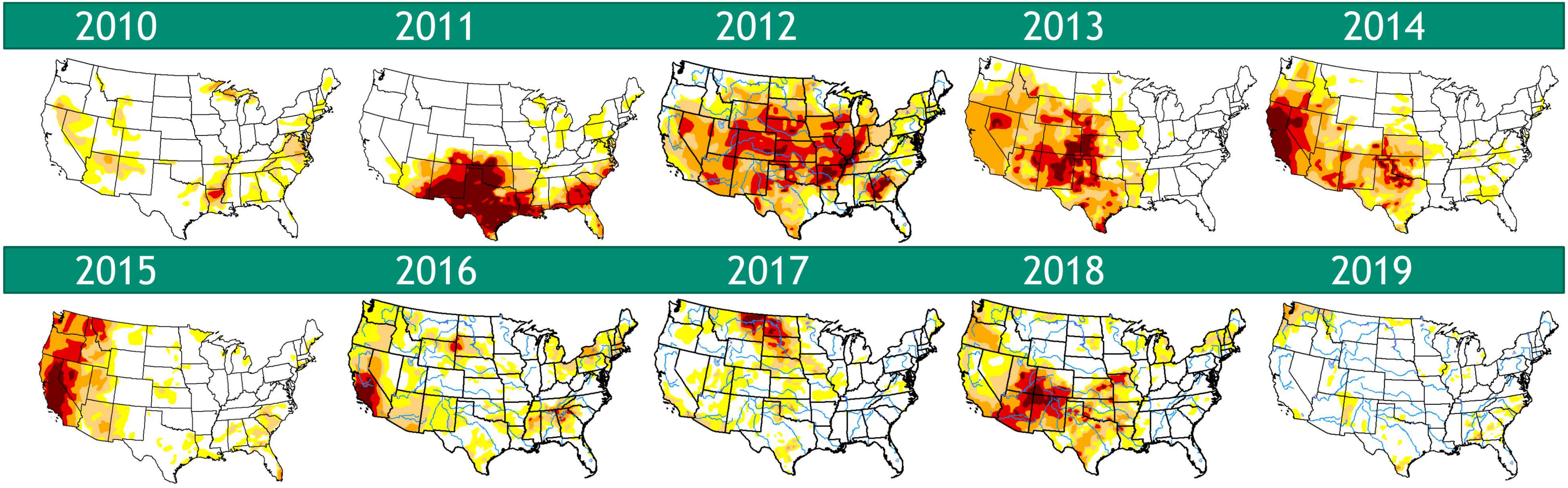
Intensity:
- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Brad Rippey
U.S. Department of Agriculture

droughtmonitor.unl.edu

Conditions are never average everywhere at once

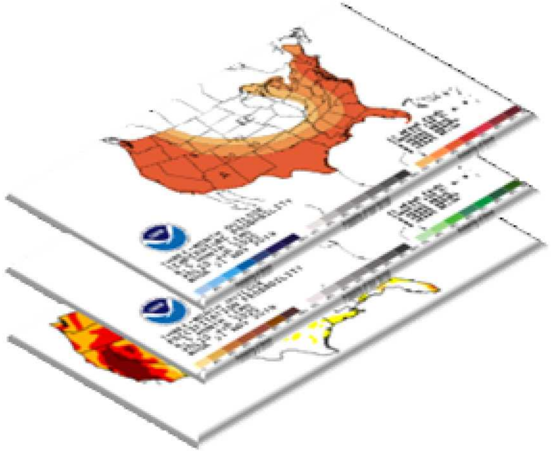


Last week of July is presented for each year. Only dry conditions are presented.

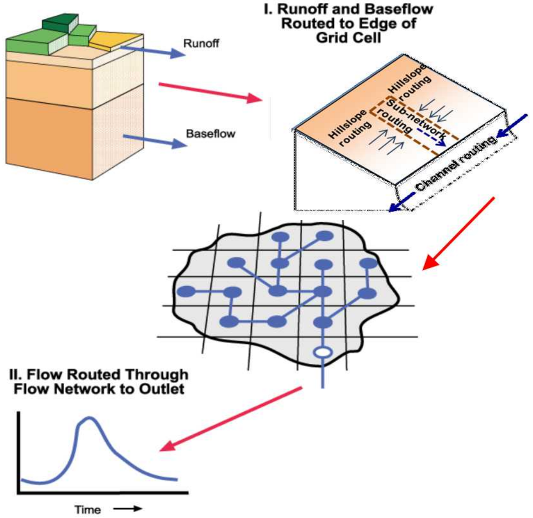
Using MOSART-WM to develop water constraints for capacity build-out and production cost models

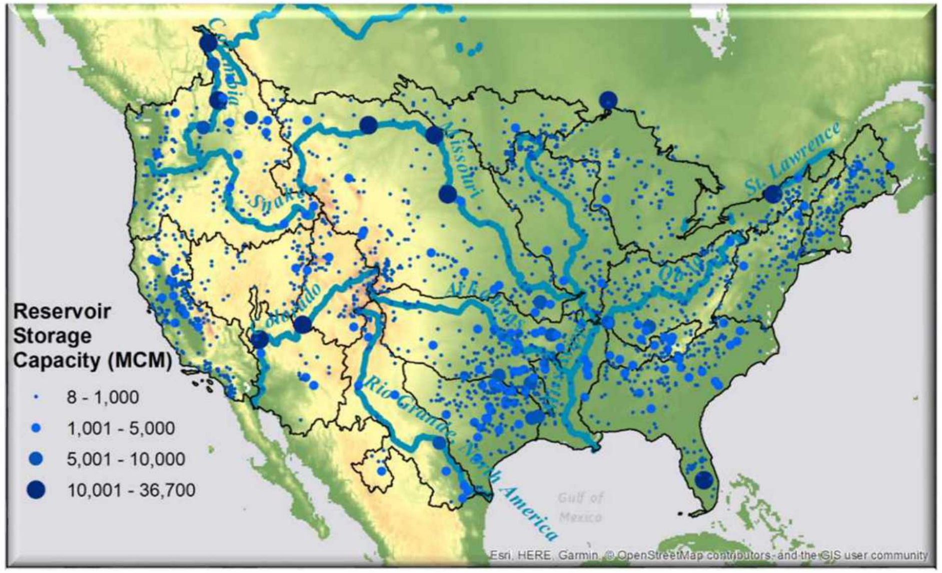
Climate

Hydrology

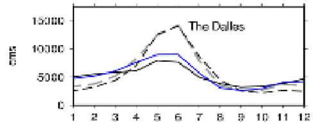


River Model



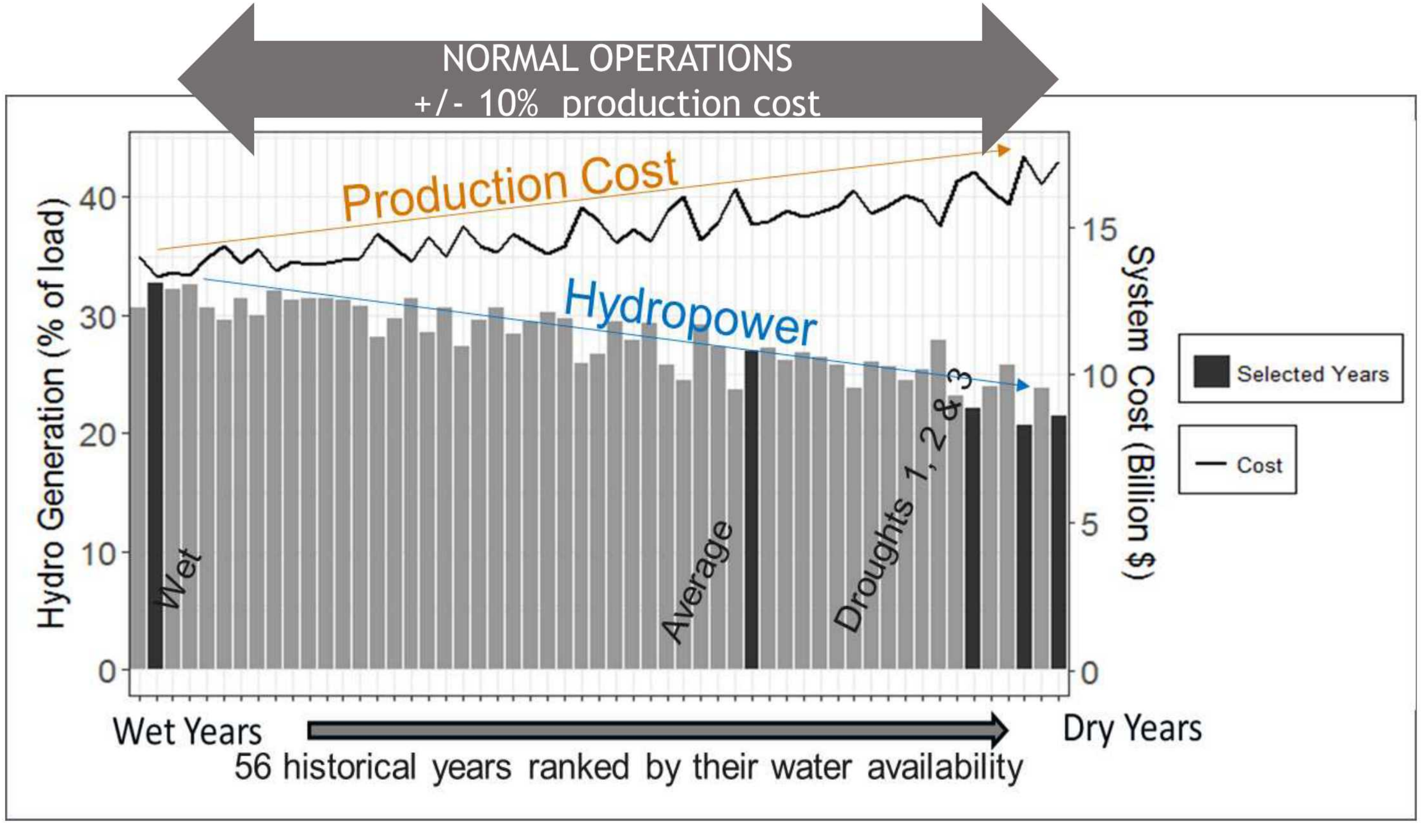


- *1840 dams with significant reservoir storage*
- *18 large river basins*
- *10 x 10 miles spatial resolution*
- *Seasonal operations for flood control, water supply and irrigation*



“Water Scarcity Grid Impact Factor”

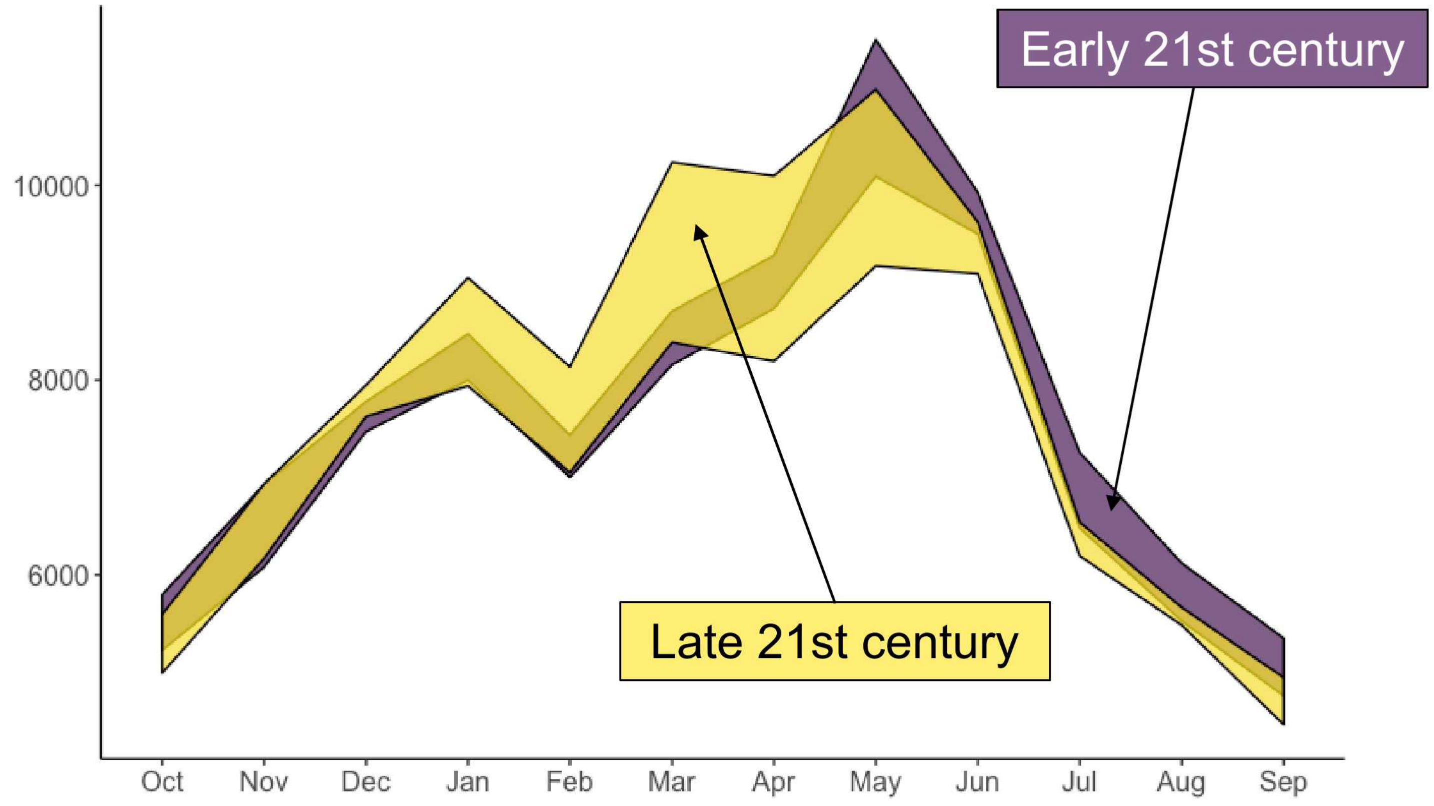
A grid-centric water availability index summarizes the compounded generation constraints from individual power plants to the scale of bulk power system operations

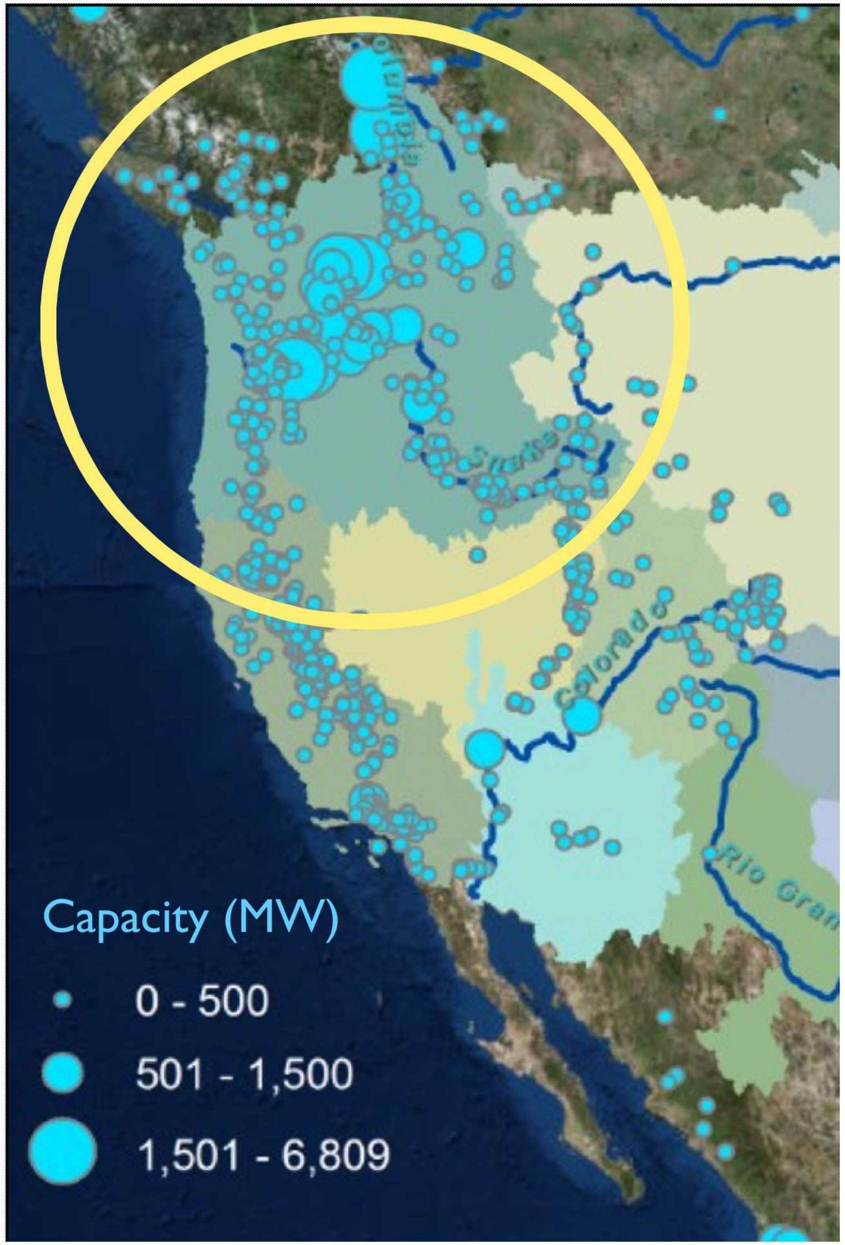


Voisin et al. 2016. « Vulnerability of the US Western Electric Grid to Hydro-Climatological Conditions: how bad can it get? » Energy
O'Connell et al. 2019. "Sensitivity of Western U.S. power system dynamics to droughts compounded with fuel price variability." Applied Energy

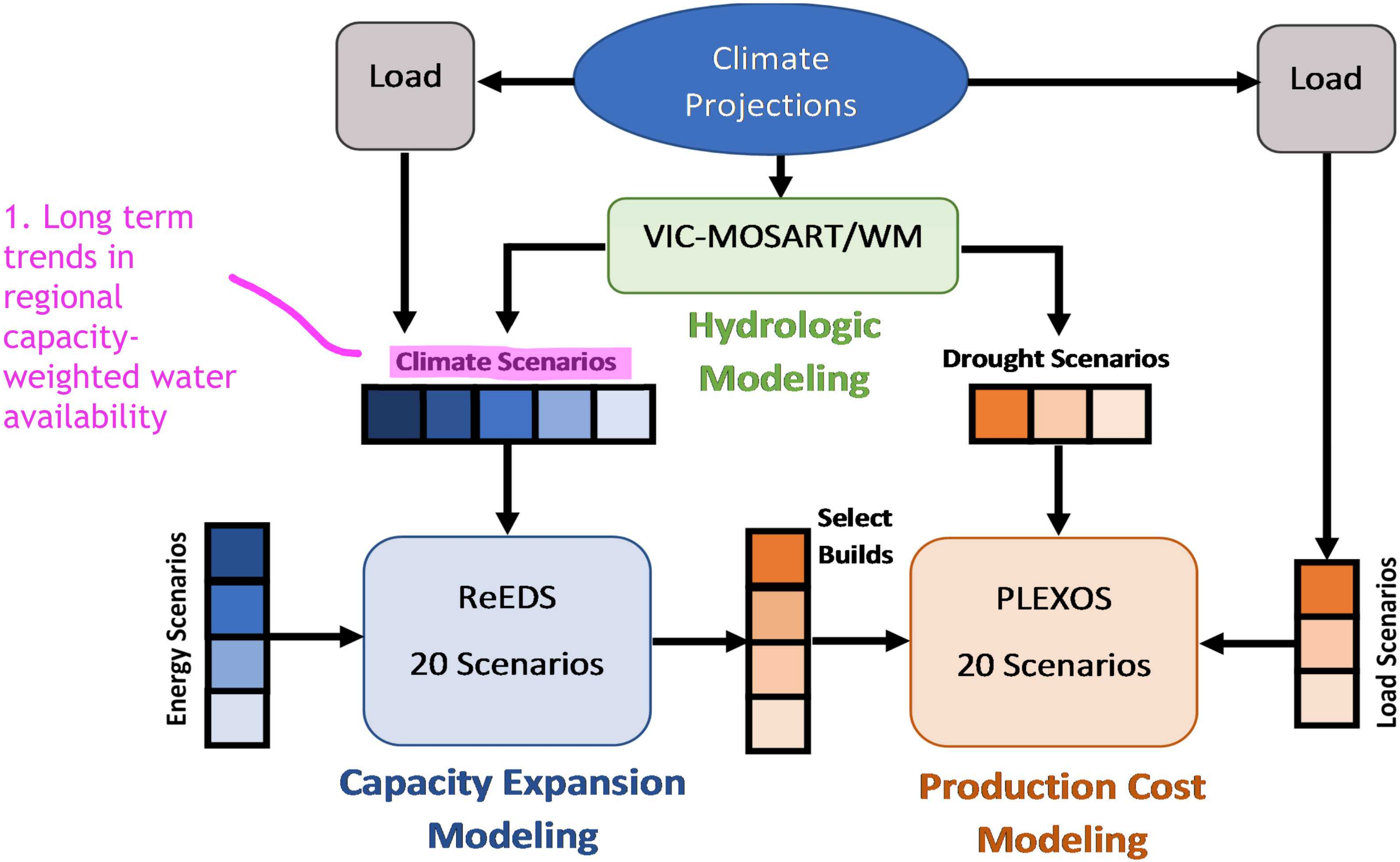
Drought scenarios at hydropower plants

Seasonal hydropower availability (GWh) in the NW





Water availability trends for capacity build-out

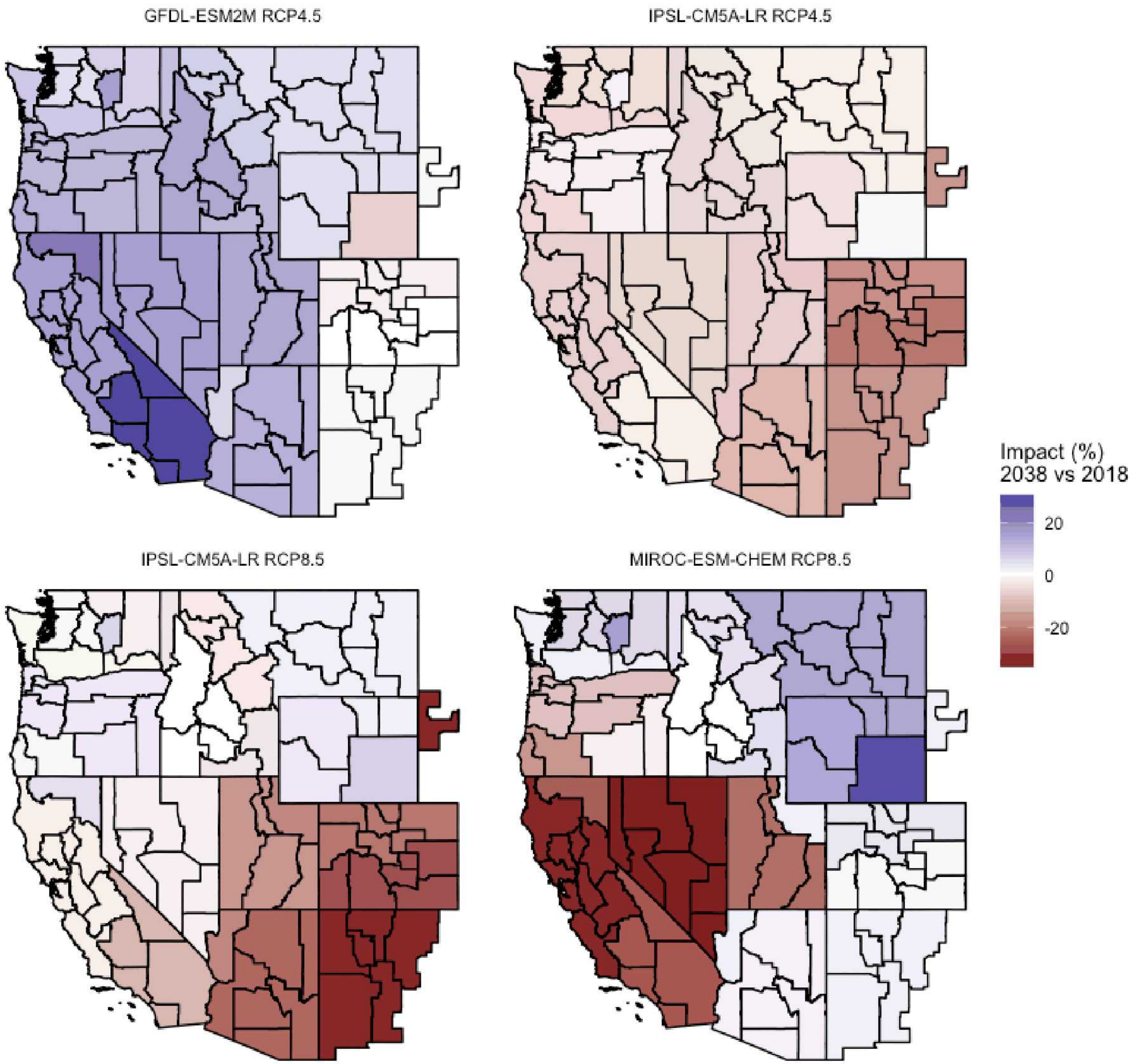


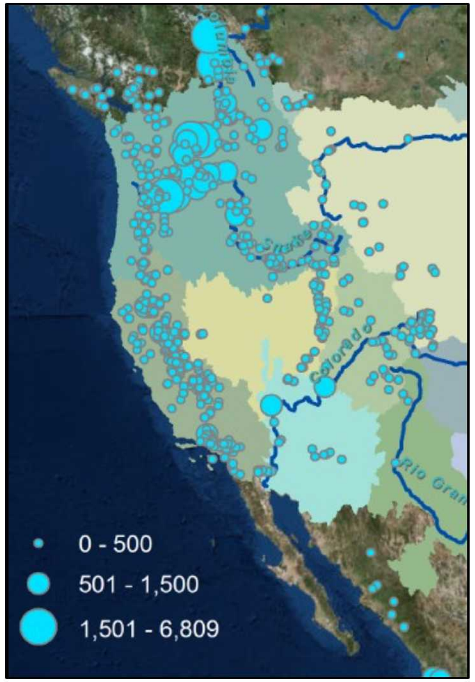
Climate model water projections diverge

Relative trends in available hydropower

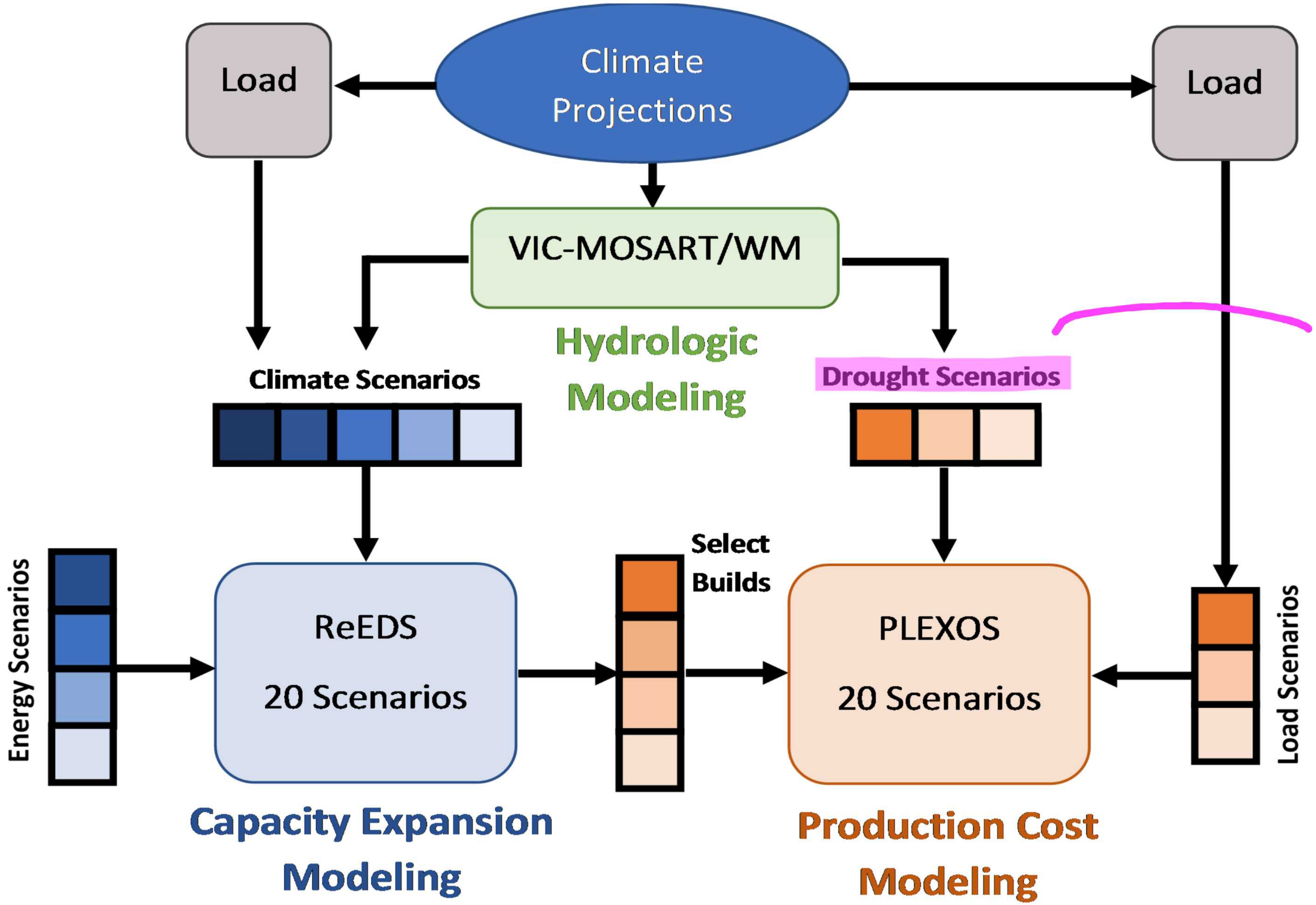
Moderate emissions pathway

Extreme emissions pathway





Monthly hydro for reliability modeling



2. Plant-level, monthly hydropower generation

Selection of Critical Drought Scenarios

Criteria

Three distinct water years

Extreme conditions to stress the system...

… but also plausible

Dry conditions throughout WECC

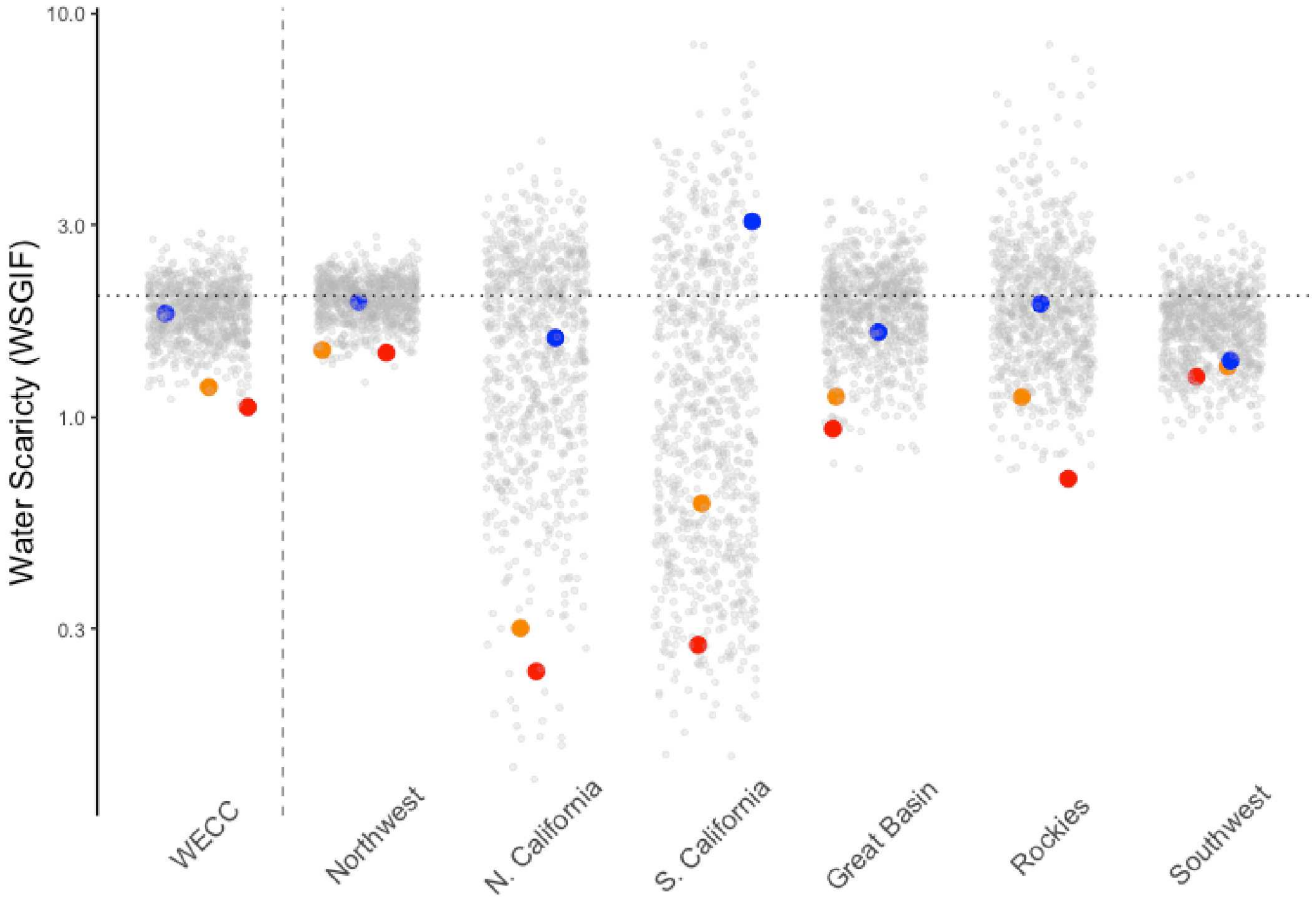
Selection

Extreme drought from climate models

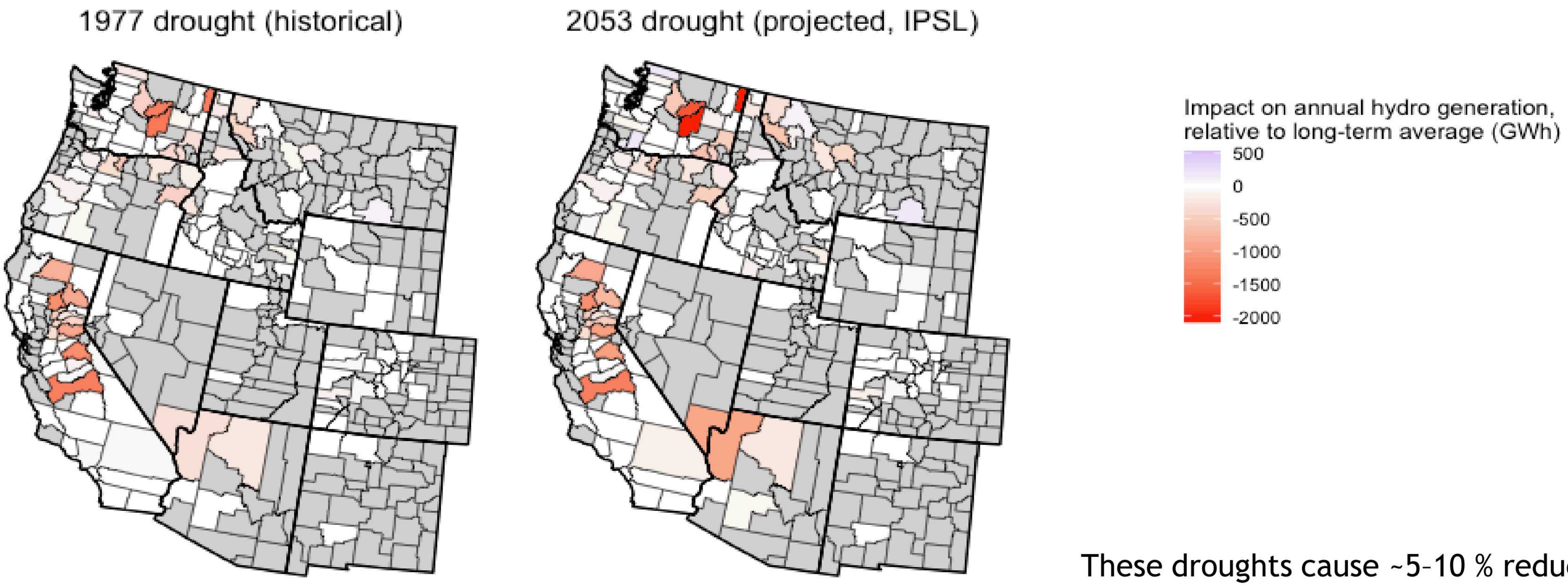
Average water year from climate models

Drought from history (**1977**)

Water scarcity based on flow impacts at both **thermal** and **hydro** plants



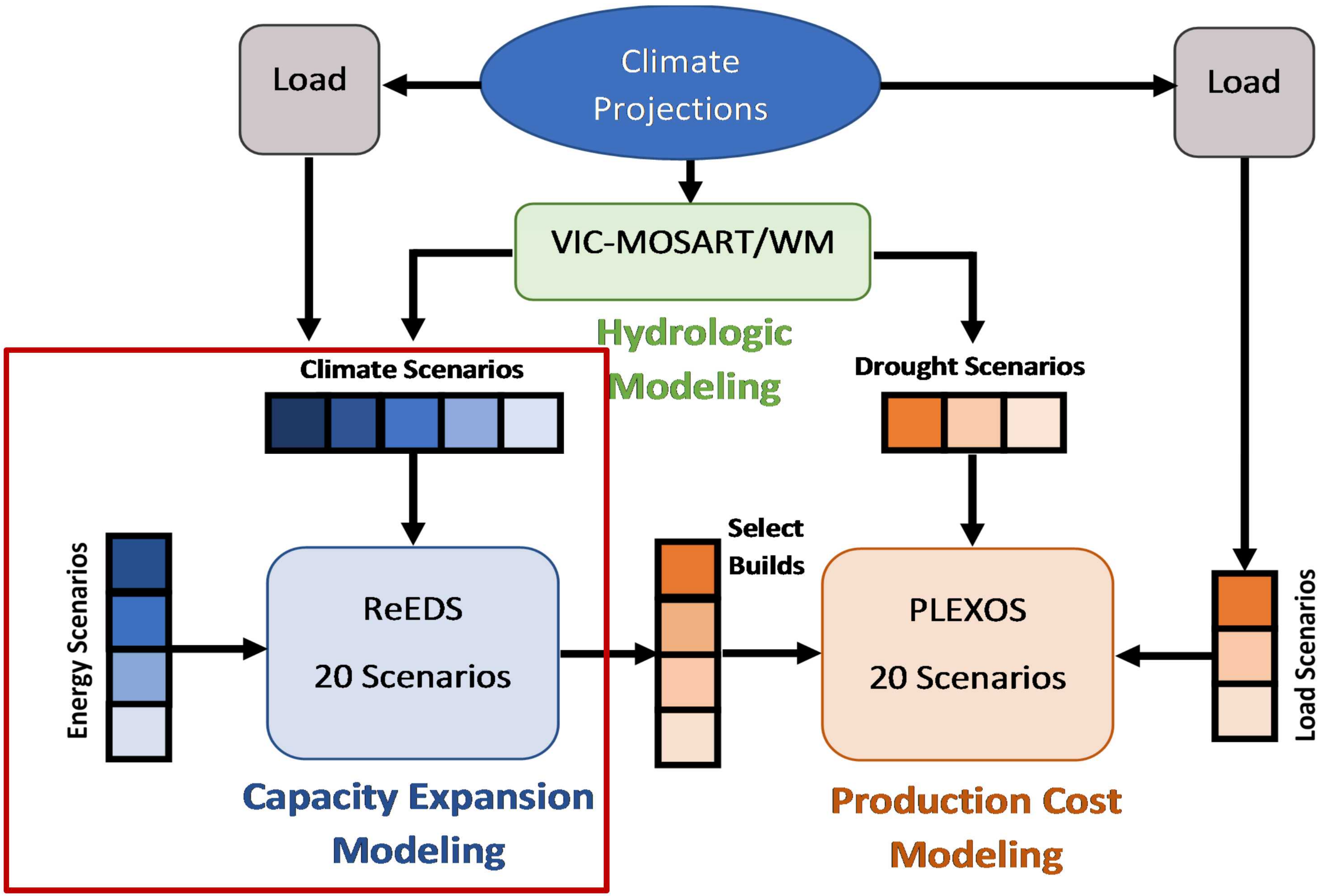
Droughts scenarios at hydropower plants



These droughts cause ~5–10 % reduction in **total hydro** generation …
… and ~5% reduction in **total thermal capacity** through derating across individual plants

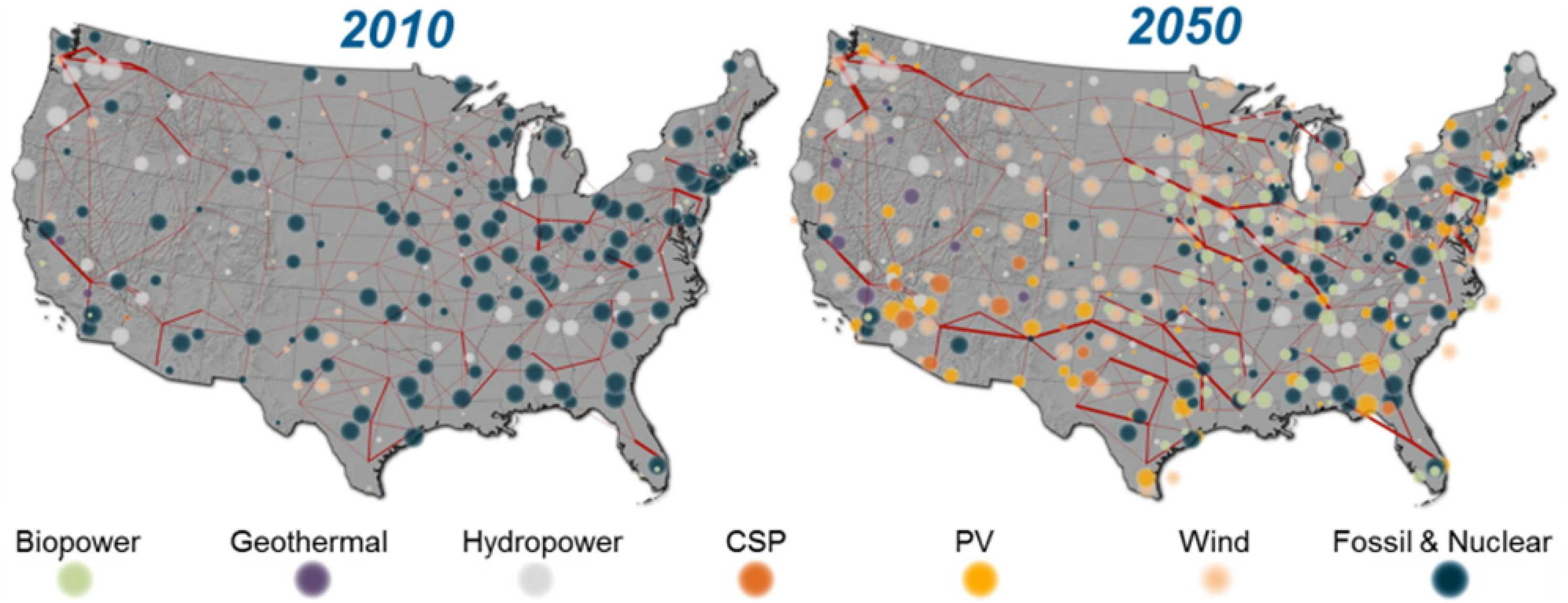
Electric Sector Capacity Expansion Modeling

Modeling Platform



Capacity Expansion Analysis Uses the Regional Energy Deployment System (ReEDS)

ReEDS generates scenarios of the future U.S. power system



Source: Renewable Electricity Futures (2012)

ReEDS finds the regional mix of technologies that meet requirements of the electric sector *at least cost.*

ReEDS is An Advanced and Well-Established Model

Finds the lowest-cost investment and operation of generation, transmission, and storage in the continental United States through 2050

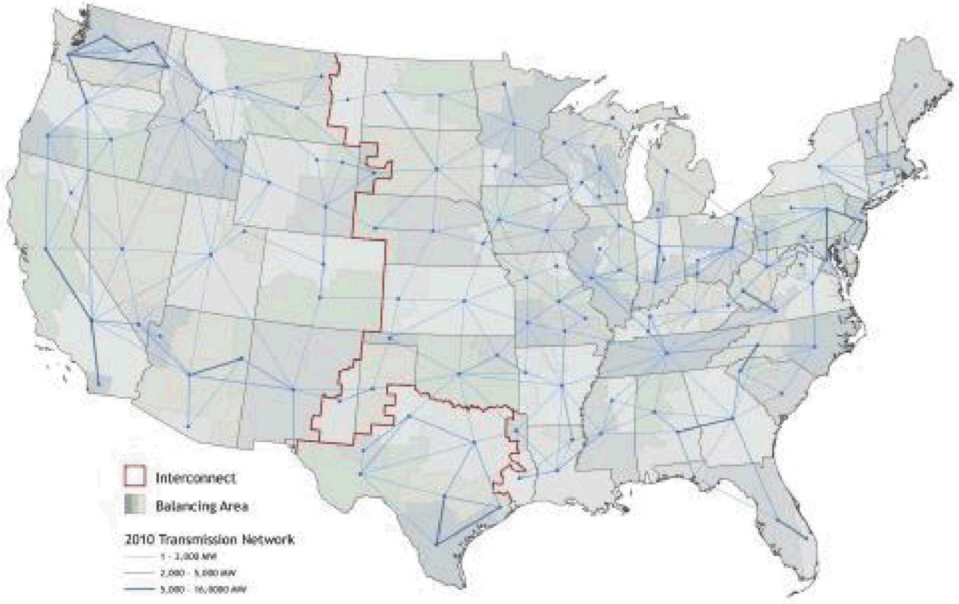
Satisfies energy and capacity requirements under resource, transmission, policy, and power system constraints

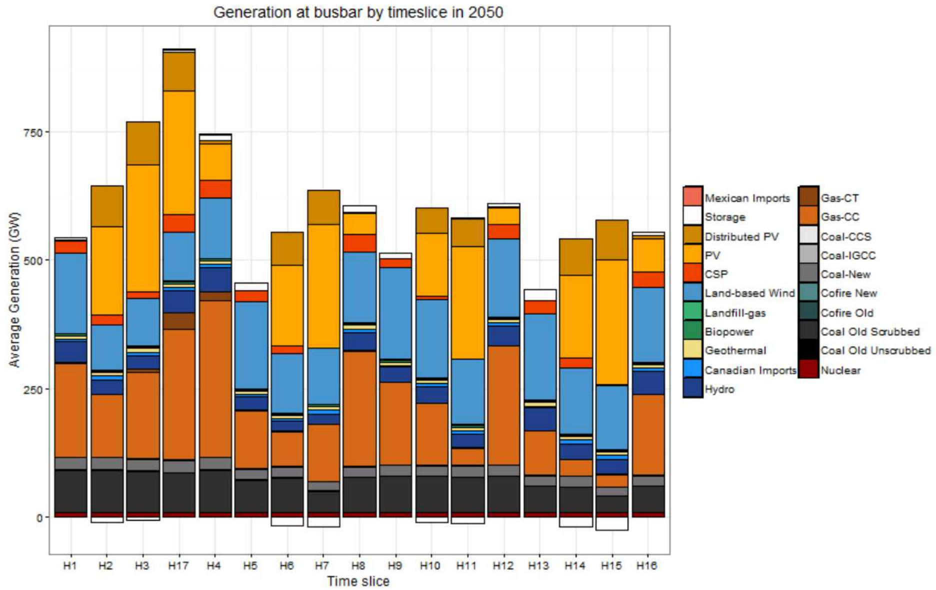
Extensive suite of generation and storage technologies with additional detail for variable renewables

134 balancing areas and 356 renewable resource regions describe regional differences

17 sub-annual time slices represent seasonal and diurnal load and resource availability

Used extensively for DOE and other federal, industry, and academic electric sector scenario analysis, e.g., DOE Vision reports, NREL Standard Scenarios





Representative Sample Results

ReEDS Scenarios Include Future Climate-Water Impacts

Cooling Water Constraints

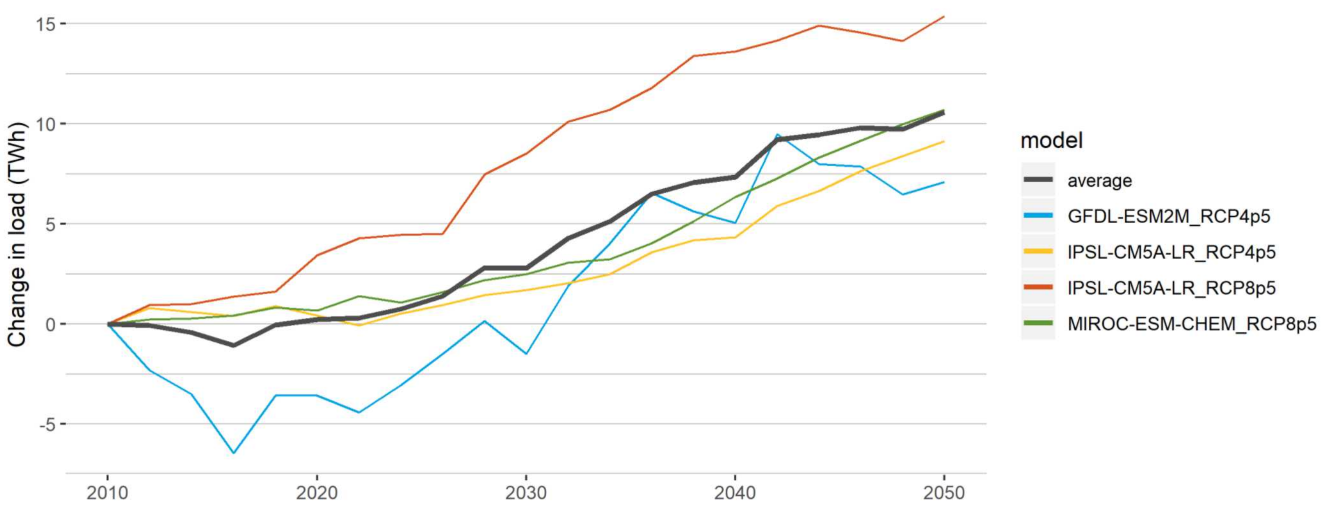
New thermal generating capacity must purchase water access from SNL-developed water supply curves

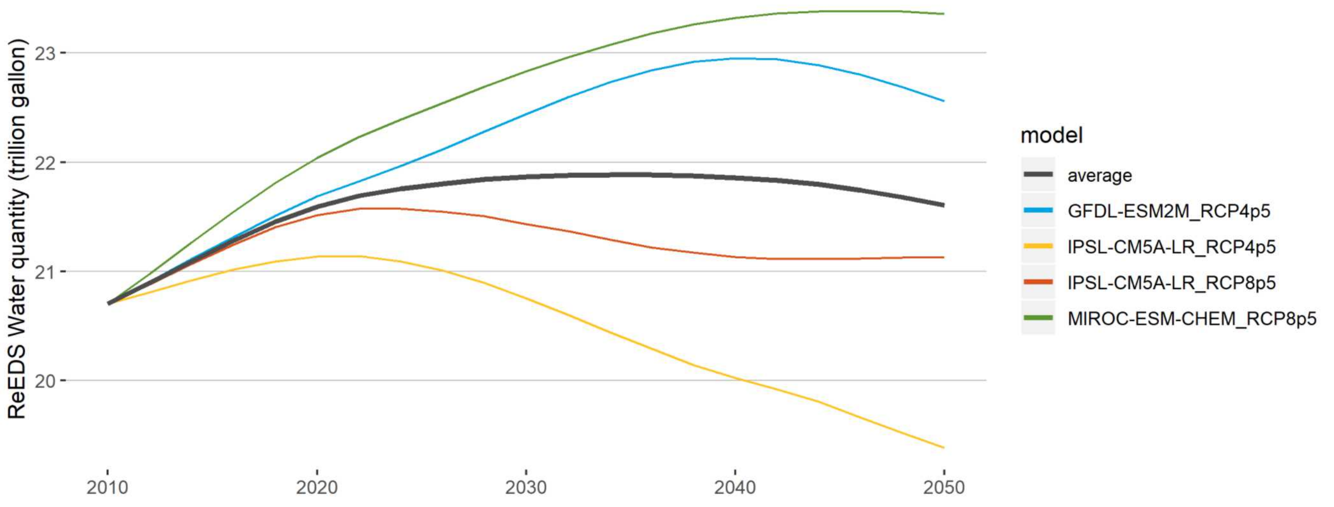
Water withdrawals are limited by water access purchases and any future changes to water availability

Climate Impacts

Temperature changes affect electricity demand, power plant performance, and transmission line capacity

Surface water and hydropower energy availability changes based on hydrology modeling from VIC-MOSART/WM





WECC Scenario Analysis Includes a Range of Infrastructure and Climate Scenarios

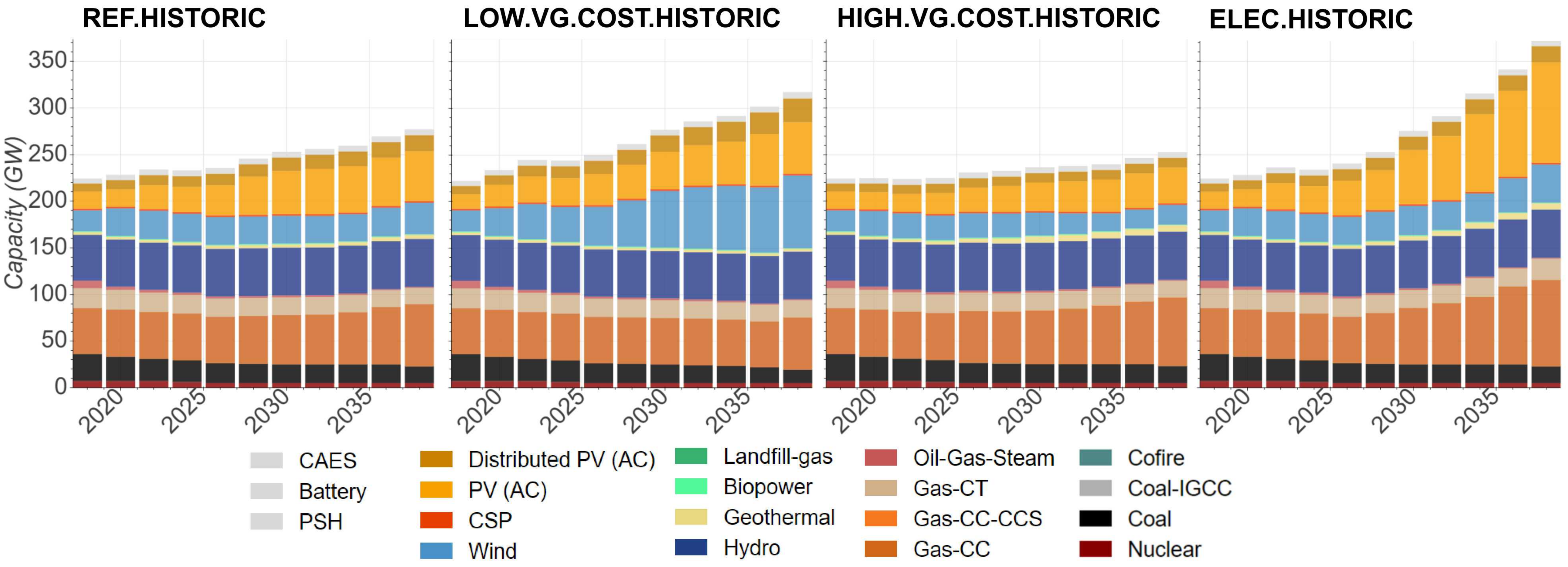
Infrastructure expansion scenarios vary the possible future generation mix

1. REF: default ReEDS v2018 assumptions
2. LOW.VG.COST: NREL ATB 2018 Low Cost case for wind and solar
3. HIGH.VG.COST: NREL ATB 2018 High Cost case for wind and solar
4. ELEC: NREL Electrification Futures High Technology Adoption, Moderate Technology Advancement case with moderate demand flexibility (in review)

Climate scenarios bound future temperature and precipitation

1. HISTORIC: Static historical climate conditions
2. IPSL85: Uses data from the IPSL climate model under RCP8.5 conditions
3. MIROC85: Uses data from the Miroc climate model under RCP8.5 conditions
4. IPSL45: Uses data from the IPSL climate model under RCP4.5 conditions
5. GFDL45: Uses data from the GFDL climate model under RCP4.5 conditions

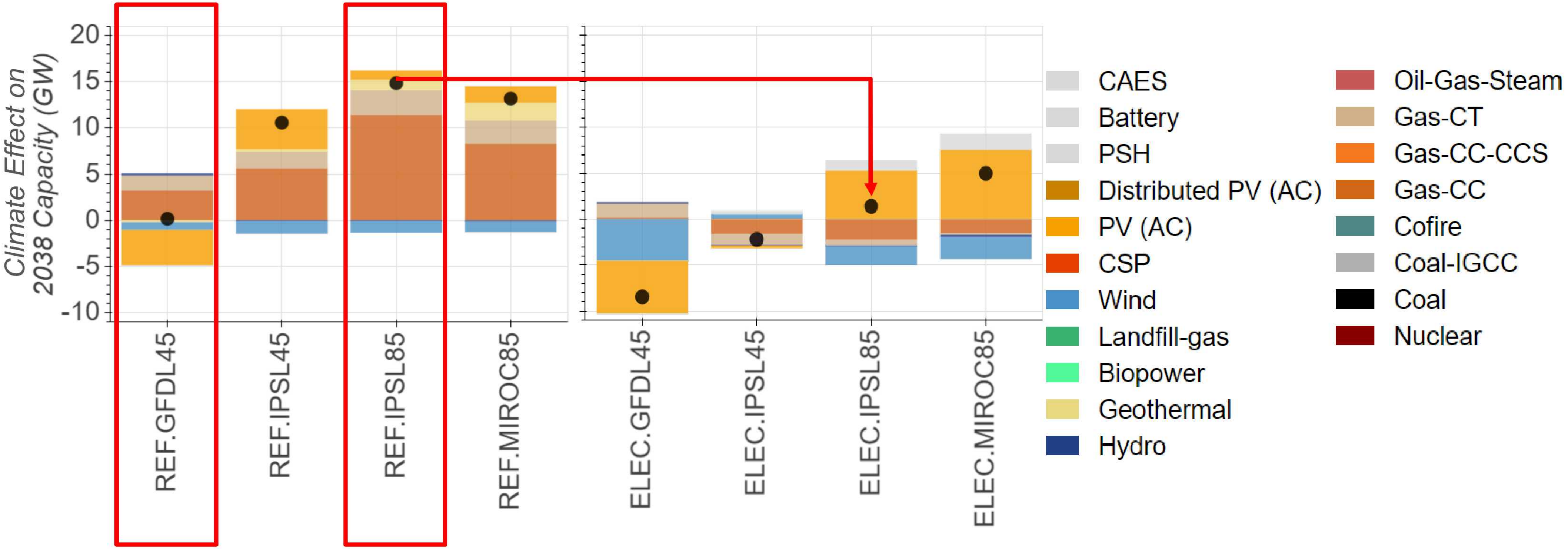
The Infrastructure Scenario Determines Future Expansion Trends



Modeled capacity investment is primarily a combination of PV, wind, and natural gas

The relative competitiveness of technologies depends on assumed technology costs and demand

Changes in climate impact capital investment decisions



Climate change primarily affects PV and gas capacity, with up to a 7% increase in total 2038 capacity

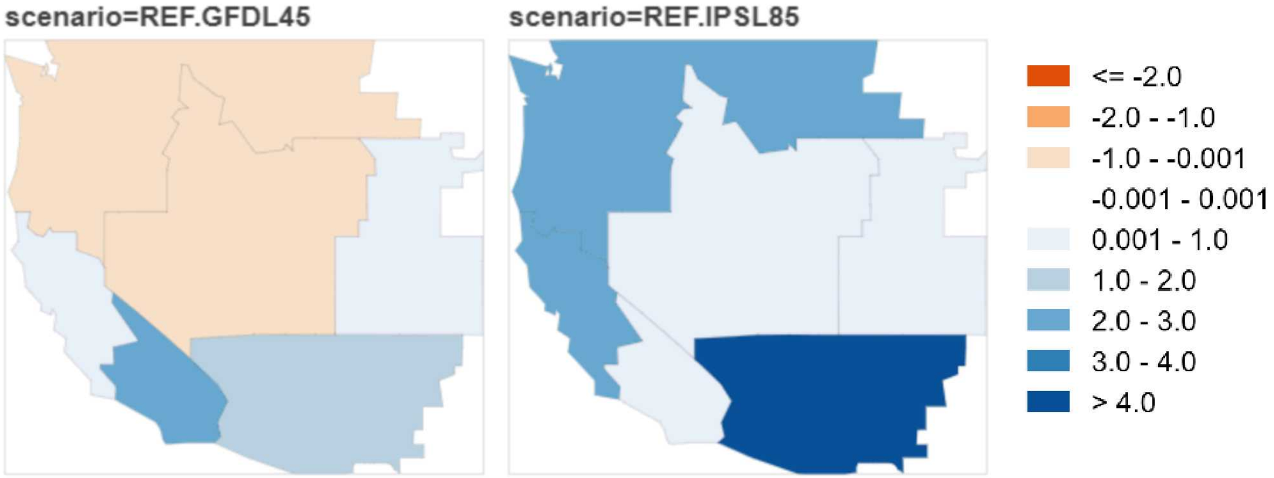
Hotter climate requires more total capacity

Wetter climate can reduce capacity needs with additional hydropower generation

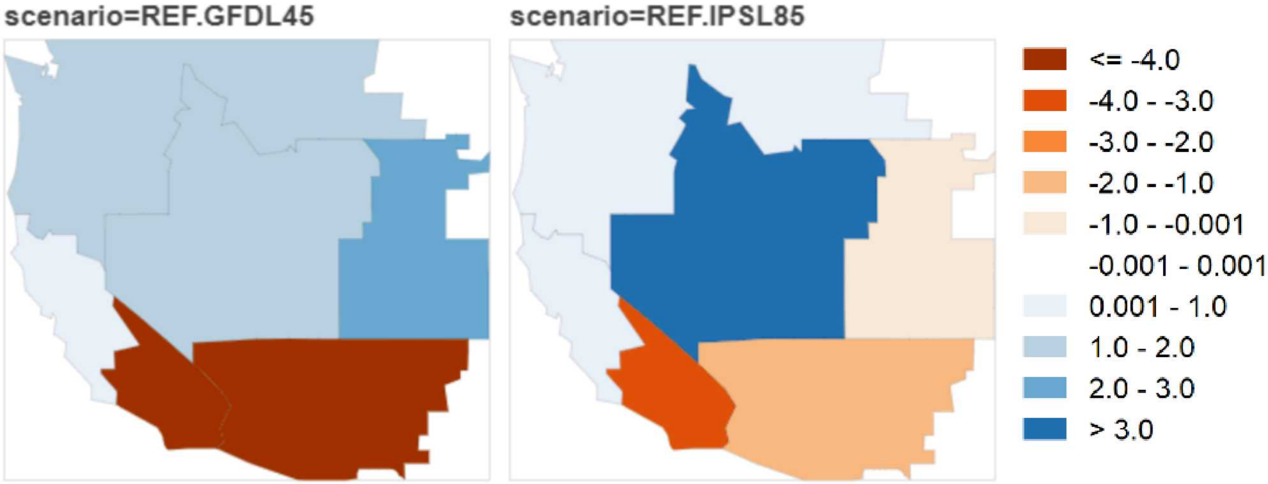
Electrification can reduce capacity needs through flexible demand

Capacity Impacts Vary by Region

Climate Effects on 2038 Gas-CC Capacity (GW)



Climate Effects on 2038 Utility PV Capacity (GW)



Climate affects where new capacity is built

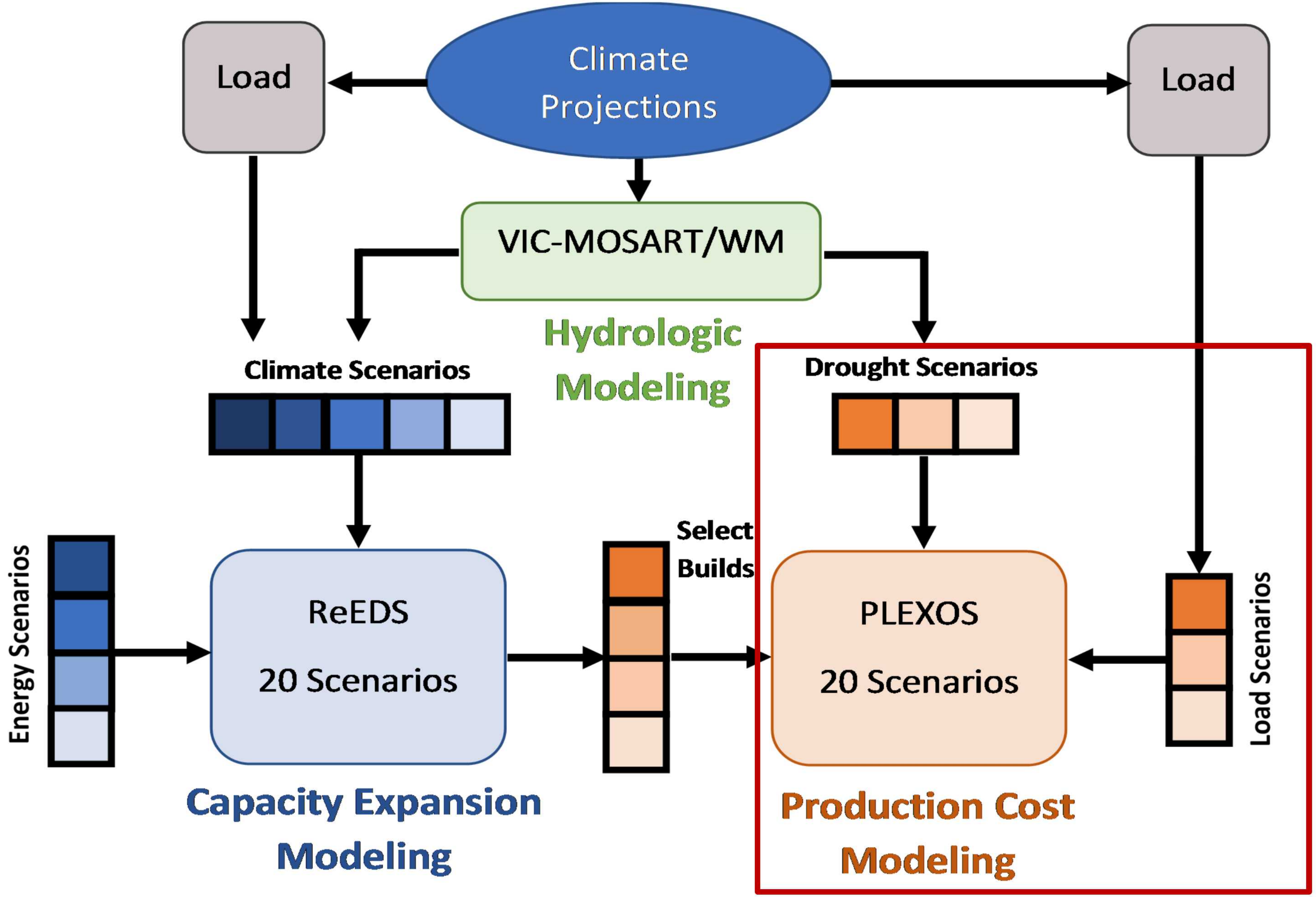
Regional results reflect the interplay of climate impacts, demand, resource availability, policies, and transmission

Aggregate WECC-wide results do not always reflect regional variations

Some results are robust across climate scenarios (e.g., more Gas-CC in DSW), while others are not (e.g., PV in RMPP)

Electric Sector Production Cost Modeling

Modeling Platform



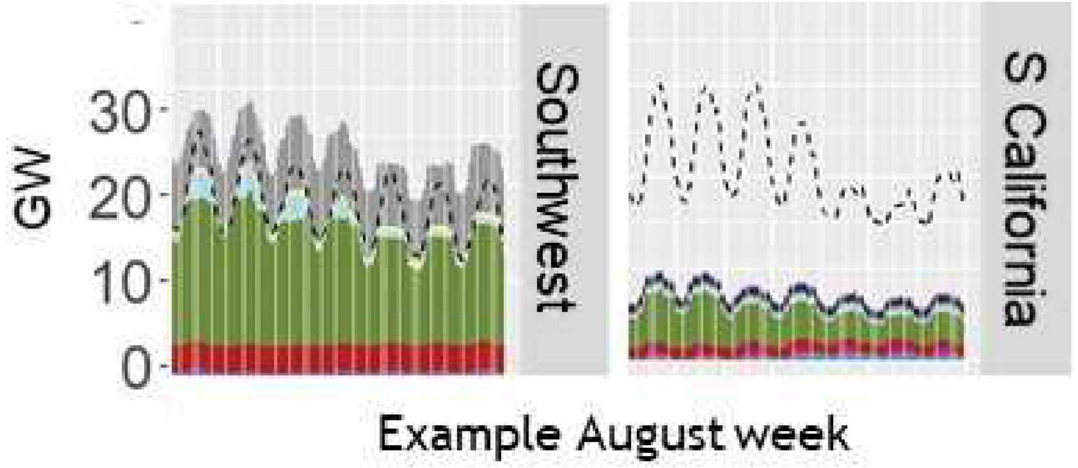
Production Cost Modeling

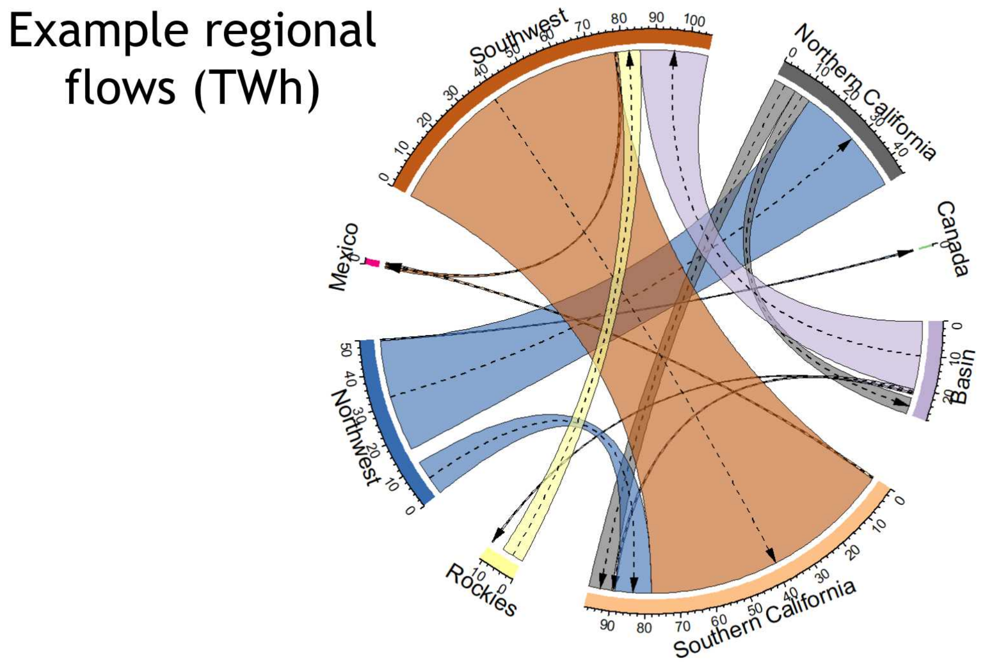
Simulation of a specific electric infrastructure

Optimized operation for system-wide production cost

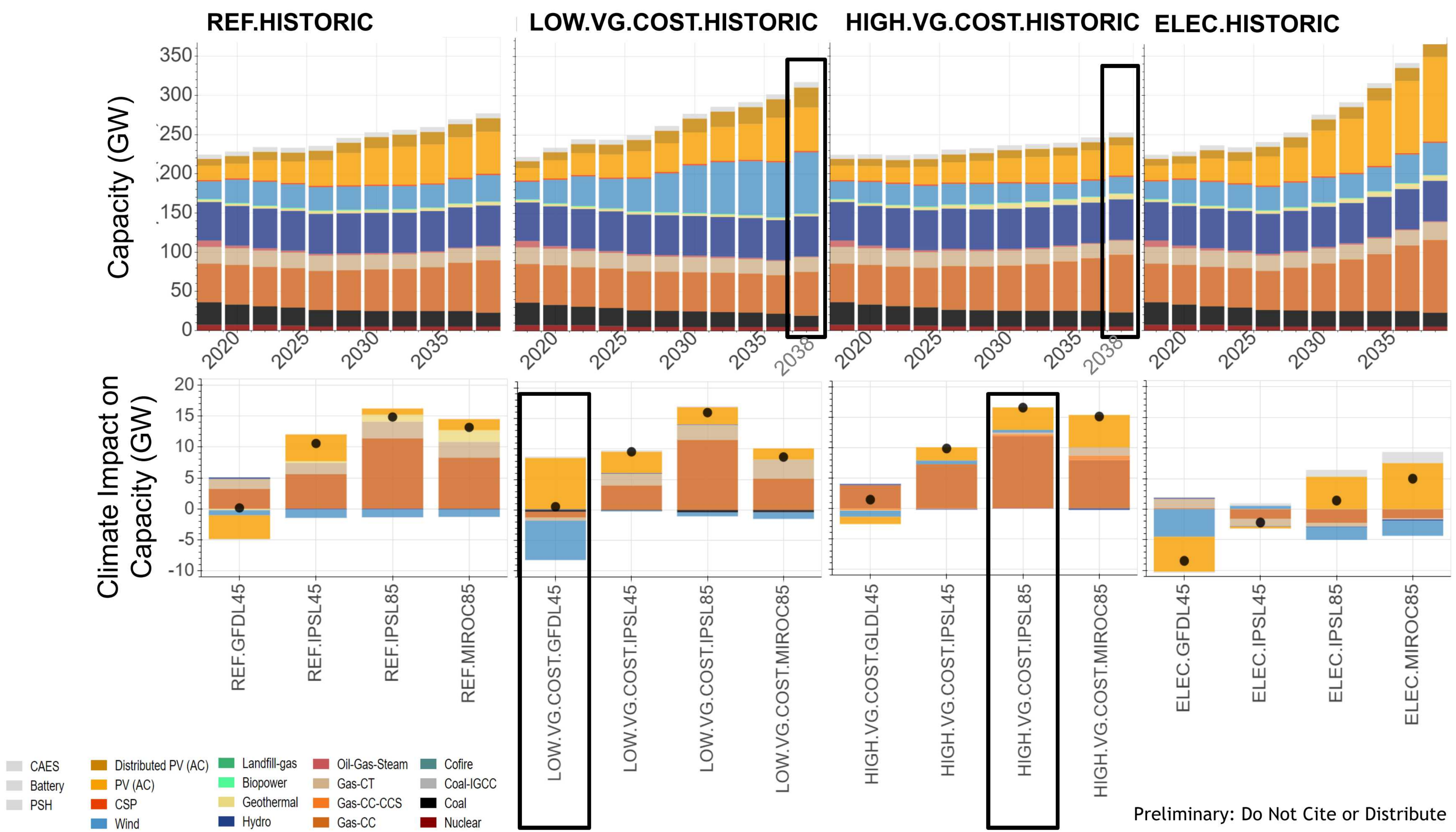
Relevant outputs:

- Total production cost
- Transmission congestion
- Emissions
- Dispatch information
- Reliability metrics: unserved energy, reserve shortages



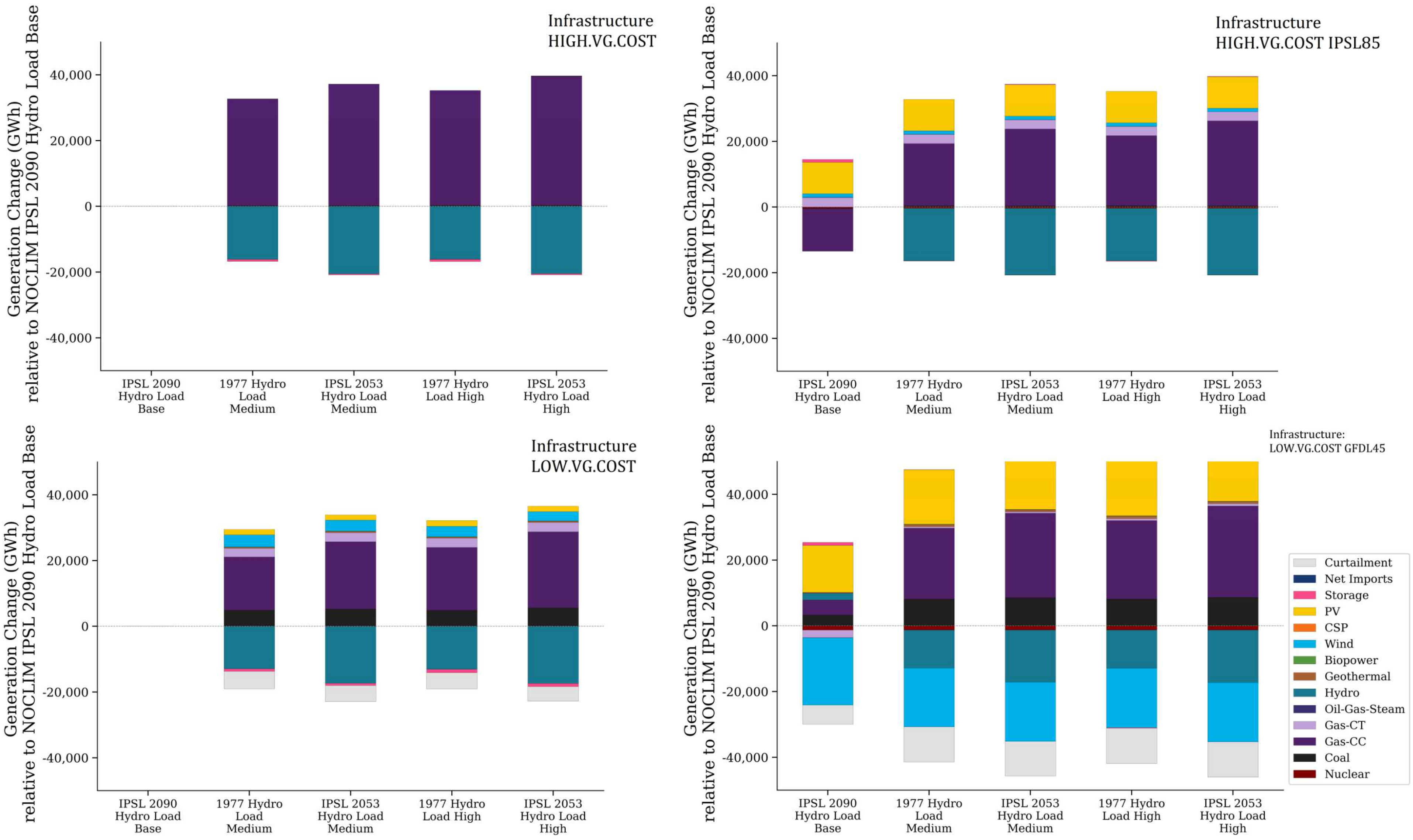


Scenarios for Production Cost Modeling



Preliminary: Do Not Cite or Distribute

Climate impact on system operations



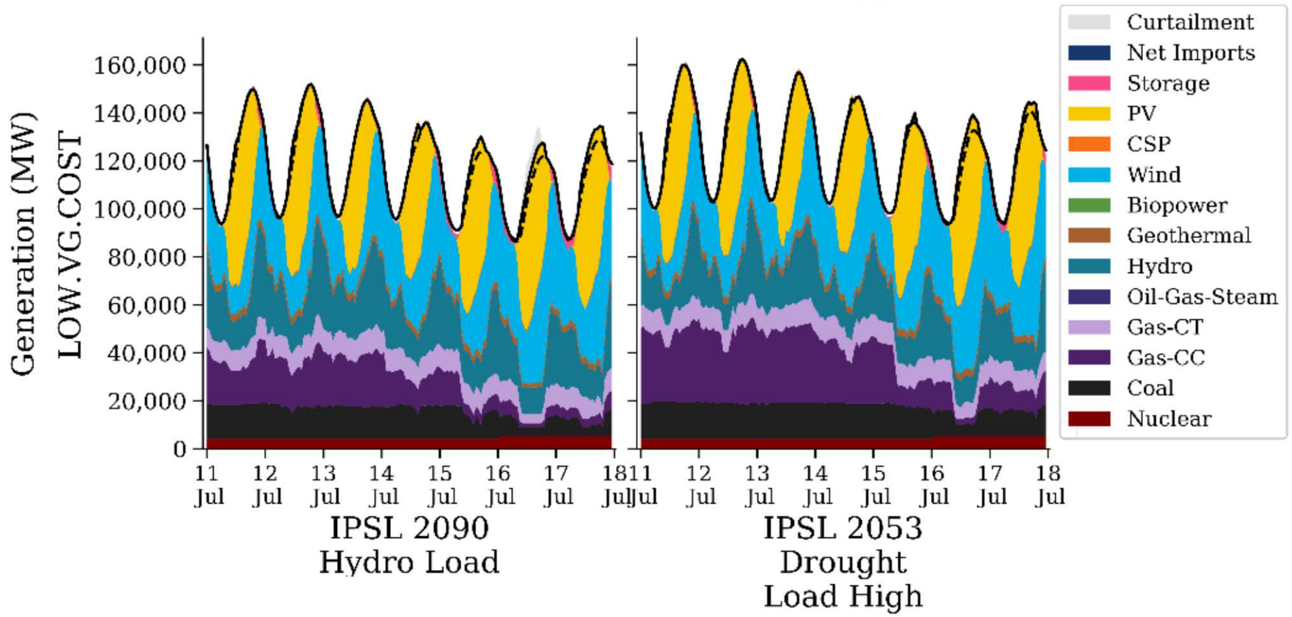
Resource expansions that are high in thermal and low in renewable generation respond to changes in climate mostly through usage of Gas-CC across the Western Interconnection.

Resource expansions that are high in renewables have a more diverse set of responses both in type of generation and in regional mix of generation types.

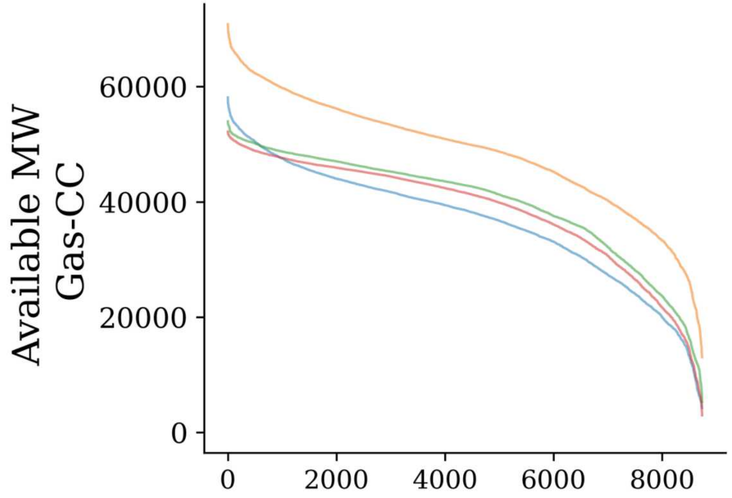
The change in generation relative to the baseline hydrology and load operated in the build-out without climate foresight.

Preliminary: Do Not Cite or Distribute

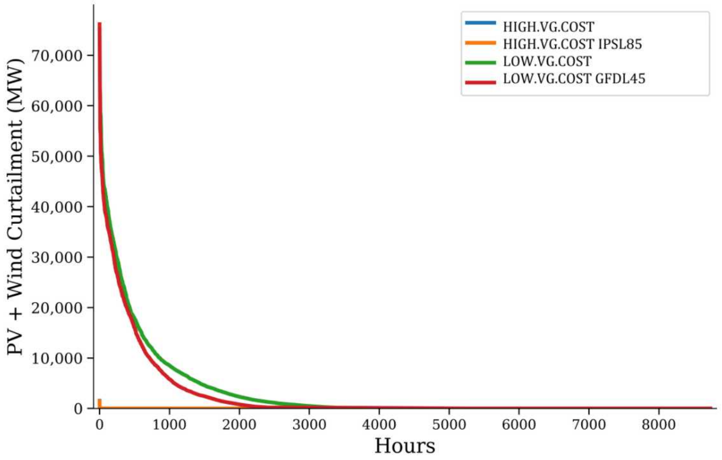
System reliability was observed to remain robust under our drought scenarios



- Over 99.999% of load being met in the PLEXOS simulations of the Western Interconnection.
- We note that this reliability assessment is limited to the assumptions of the production cost model and to the number of scenarios analyzed
- When using climate foresight in ReEDS with IPSL85, additional thermal buffer is available.



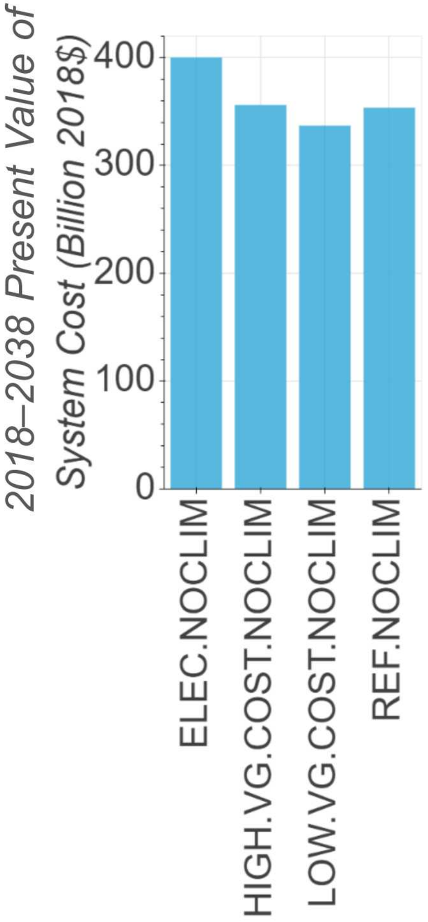
Duration curve of available capacity under IPSL 2053 drought and the high load case.

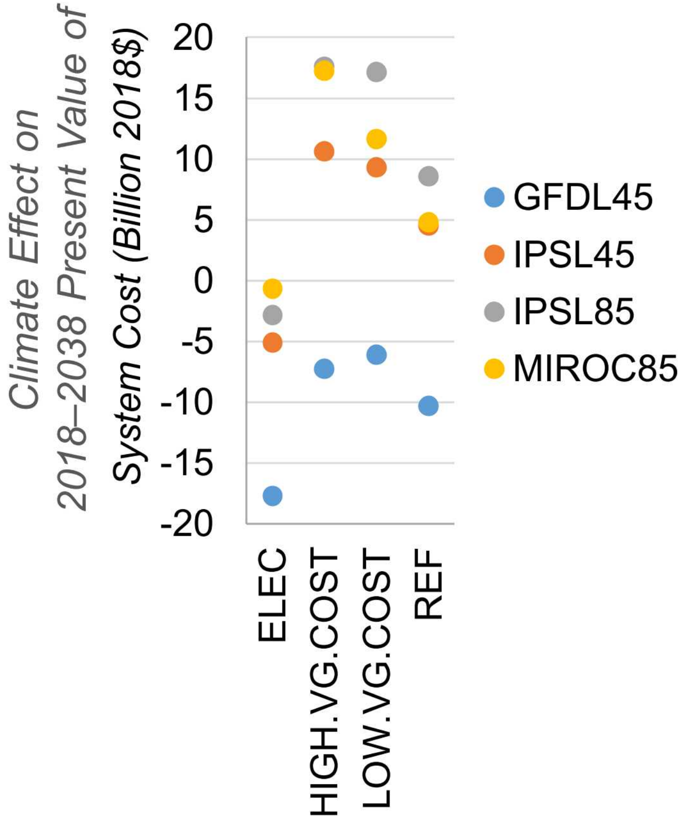


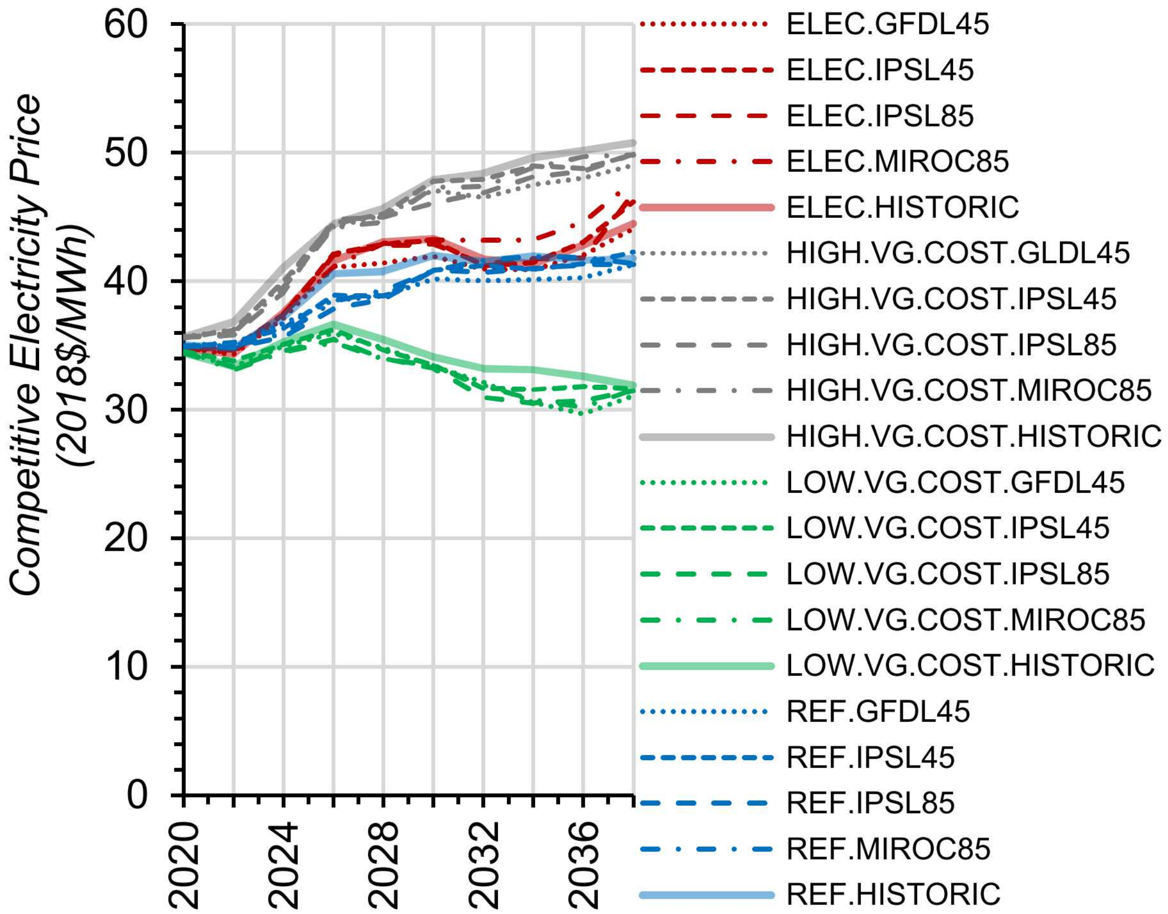
Curtailment duration curves under IPSL 2053 drought and high load case.

Economic and Environmental Impacts

Climate Change Can Influence System Economics







Heat-driven demand can increase costs, but increased hydropower can reduce costs

Cumulative climate impacts on cost range from -17.7–17.6 billion $

Climate impacts on electricity prices are small compared to technology and electrification

Climate impacted operating costs

VRE cost assumptions in ReEDS build-out	Climate foresight in ReEDS build-out	Absolute change in generation cost due to drought/heat from PLEXOS (Million $)	Relative change in generation cost due to drought/heat from PLEXOS (%)
HIGH.VG.COST	Historic climate	919-1,116	9-12%
	IPSL85	919-1,117	10-12%
LOW.VG.COST	Historic climate	453-620	14-19%
	GFDL45	460-618	13-18%

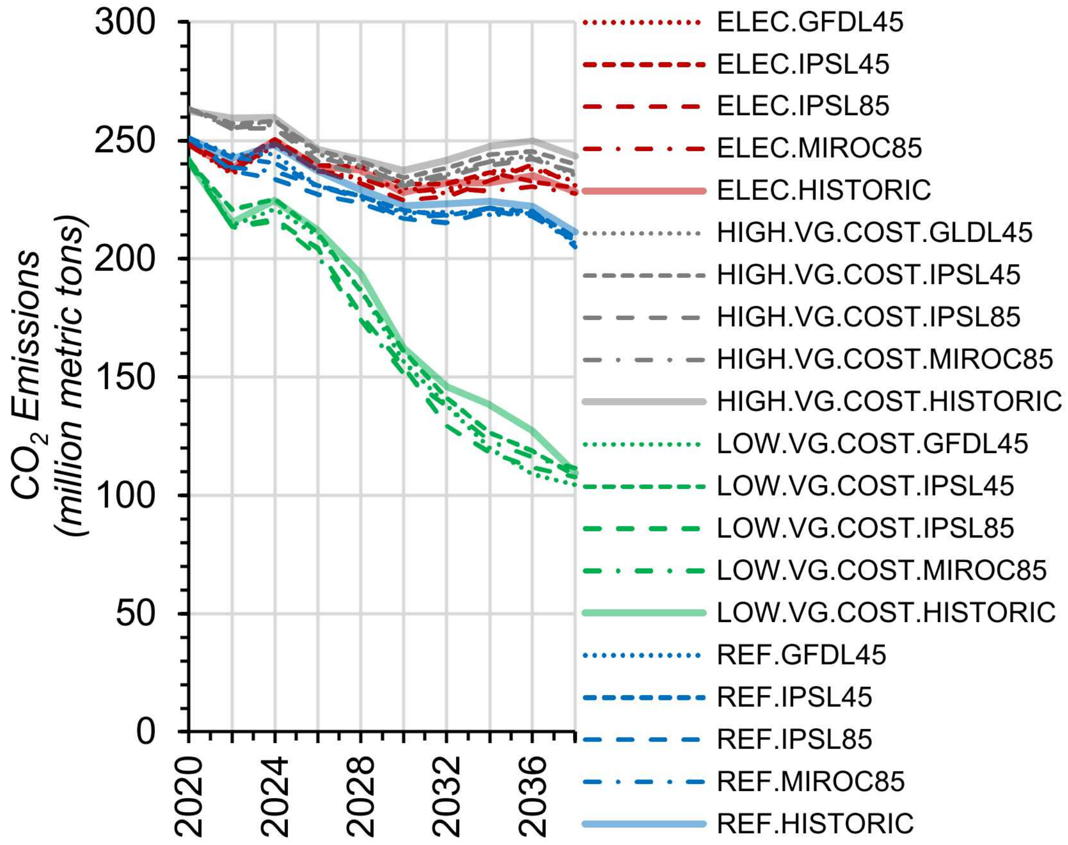
- Production cost modeling shows that generation costs increase under the drought/heat scenarios analyzed by 9 to 19%.

VRE cost assumptions in ReEDS build-out	Climate foresight	Absolute change in PLEXOS generation cost due to climate foresight in ReEDS build-out (Million $)	Relative change in PLEXOS generation cost due to climate foresight in ReEDS build-out (%)
HIGH.VG.COST	Historic climate versus IPSL85	-234 to -236	-2.2 to -2.4%
LOW.VG.COST	Historical climate versus GFDL45	142 to 154	3.6 to 4.3%

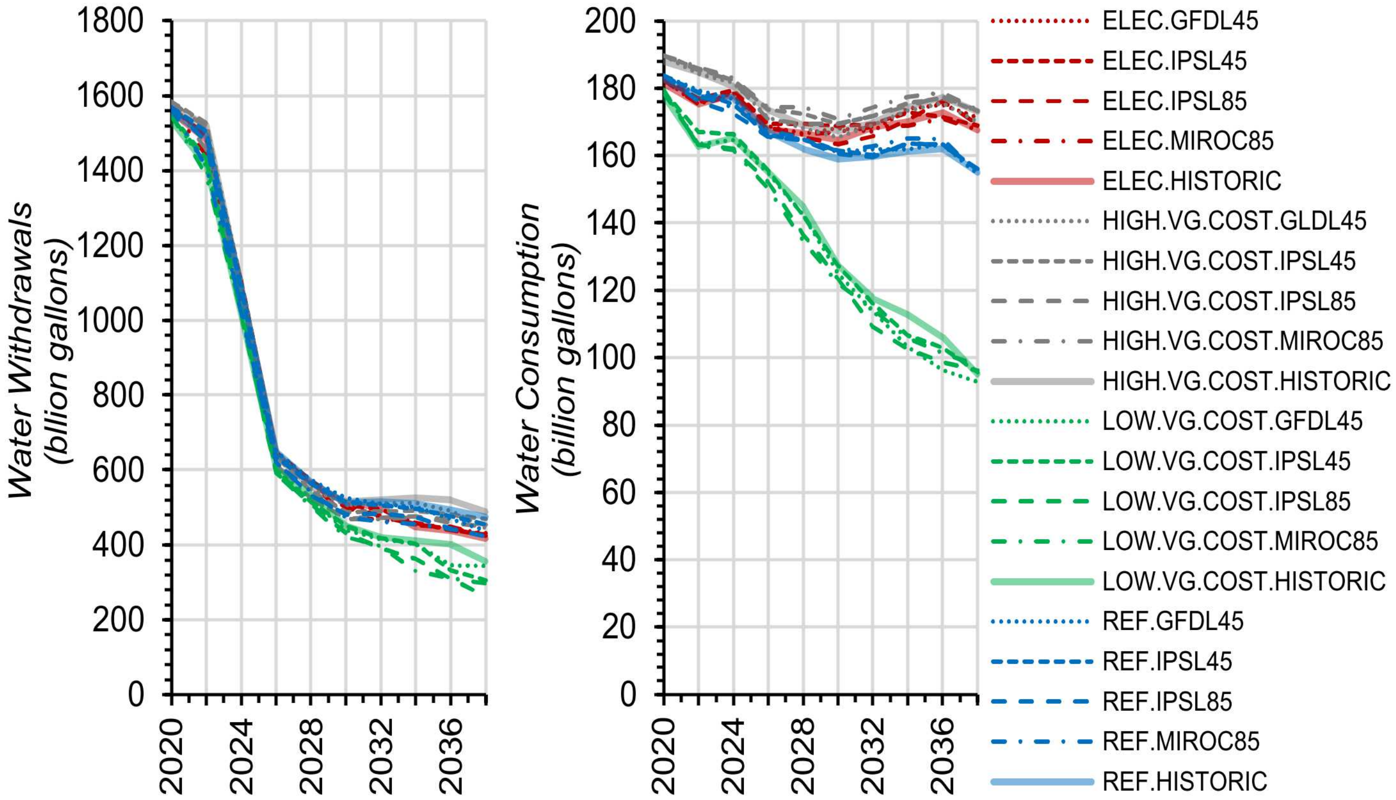
- Production cost modeling shows that the effect of climate foresight in operating the ReEDS built-outs changed the generation cost under any given drought/heat condition by -2 to +4%.

Projected CO_2 emissions and water use are driven primarily by the electricity scenario

CO_2 Emissions



Water Withdrawals and Consumption



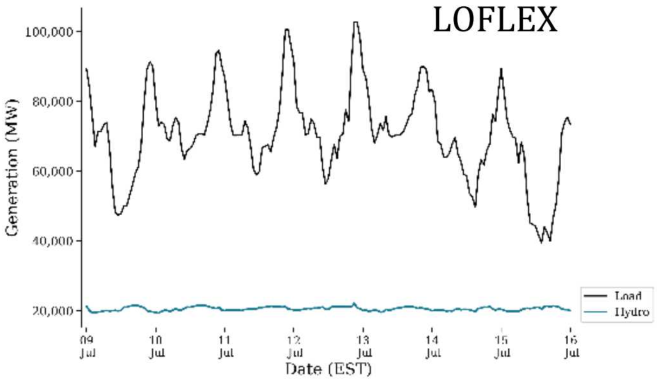
Sensitivity of Results to Hydropower Operational Representation

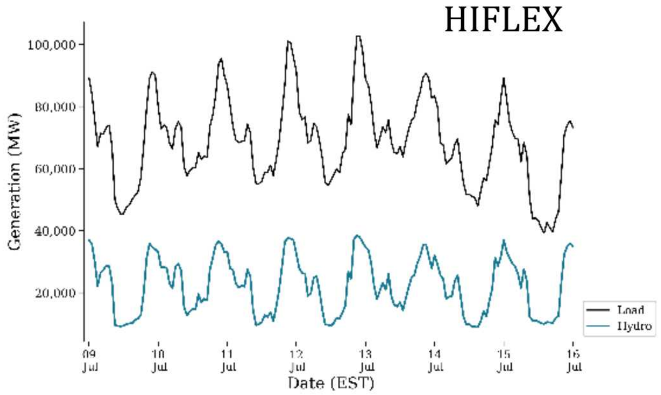
Additional scenarios examined impacts of varying hydropower flexibility

Scenarios represent bounding cases of increased (HIFLEX) or decreased (LOFLEX) flexibility of the dispatchable (non-run-of-river) hydropower fleet.

HIFLEX: Dispatchable hydropower can vary power output from zero to its maximum rated capacity at any time of the year.

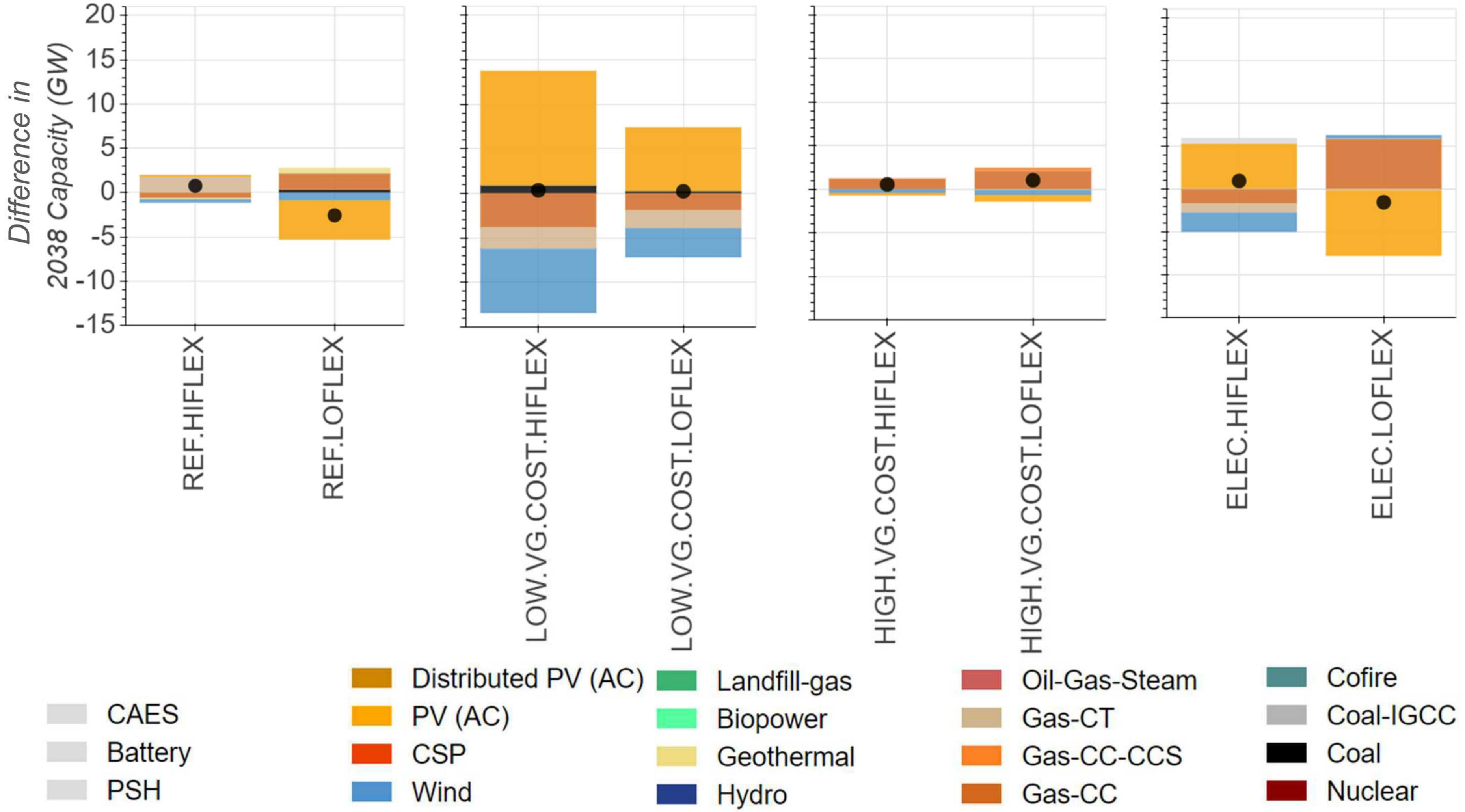
LOFLEX: Dispatchable hydropower produces constant output across a representative season (ReEDS) or month (PLEXOS) within energy limits.





Net load and hydro dispatch for LOW.VG.COST in PLEXOS, showing impact of hydropower flexibility on hourly dispatch.

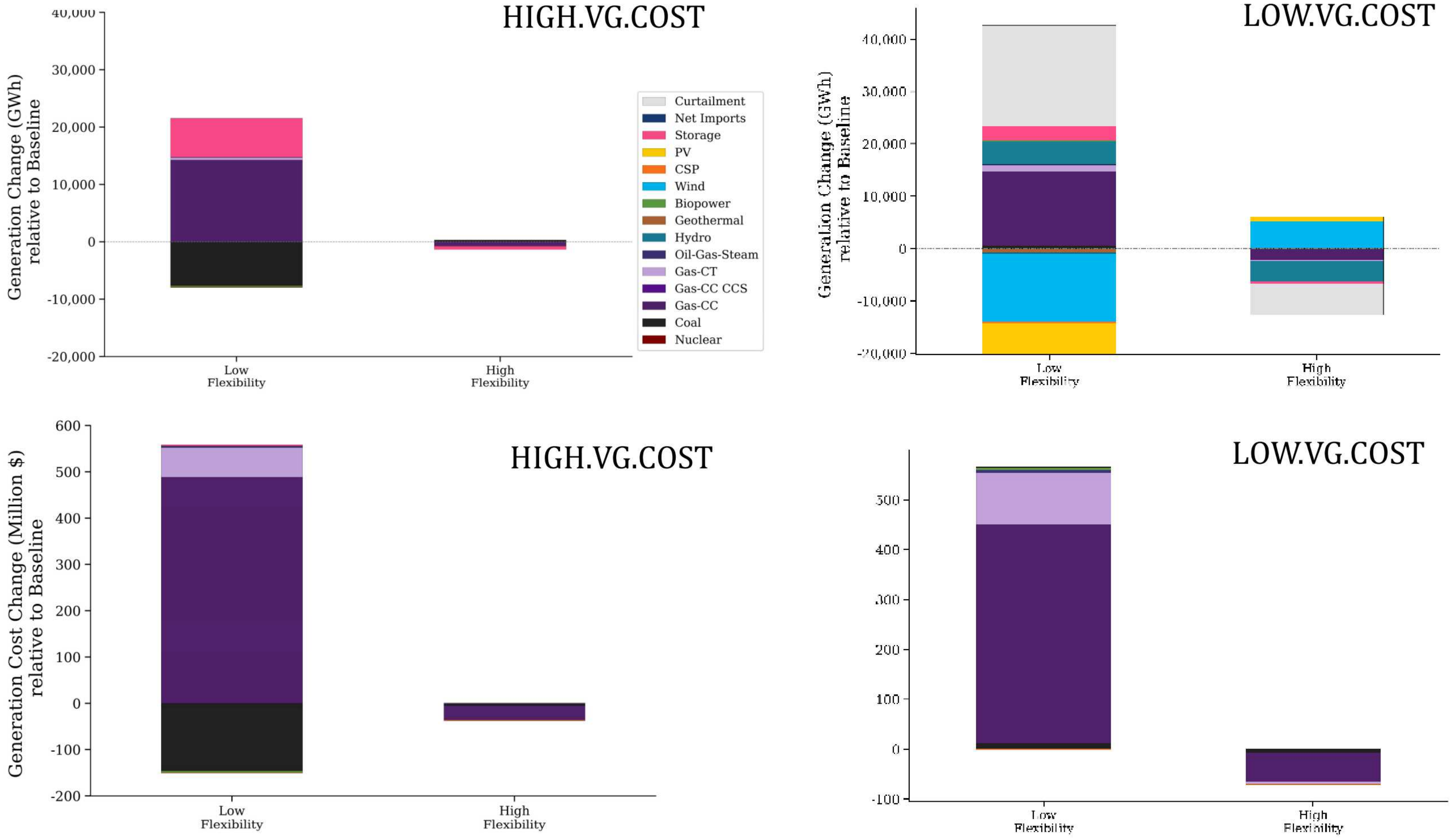
Varying hydropower flexibility has a relatively small influence on net capacity expansion



Net capacity impacts (black dots) are typically very small.

Changes to hydropower flexibility can have some influence on PV expansion.

Hydropower flexibility has a significant impact on production costs



- Hourly simulations show that increased need for flexibility in the system is met by increased deployments of Gas-CC generation in all systems and by additionally curtailing wind and PV in high renewable systems.
- The change in generation cost is -2 to +17% in the high renewable system (LOW.VG.COST), and up to 4% increase in the high thermal system (HIGH.VG.COST).

Change in generation (top) and cost (bottom) compared to baseline hydro flexibility.

Next Steps

Key Sensitivities Quantified in this Work

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Hydropower flexibility had significant impact on production costs:

- -2 to +17% for hydropower flexibility.
- However, changing hydropower flexibility has a relatively small influence on capacity expansion in the Western Interconnection through 2038.

Project Synergies

Project Synergies

HydroWIRES B1: Improving representation of hydropower availability and flexibility in production cost models for resources adequacy and reliability studies

- A weekly representation driven by water availability and environmental constraints that lets the production cost model defines realistic flexibility needs
- Multi-year datasets to understand risk associated with water availability

HydroWIRES D1: Improving capacity expansion model representations of hydropower and closed-loop PSH resource assessment

- Improved hydropower formulation will enable more detailed exploration of hydropower flexibility and value
- New PSH resource potential could be impacted by future water availability scenarios

9505 Report – Secure Water Act: Evaluate threat of climate change to federal hydropower

- Use of large-scale hydrology modeling, large ensemble of climate models and multi-hydropower model approach to evaluate uncertainties
- Project-specific calibration for accurate representation of environmental constraints at monthly time scale.

Integrated Multi-Scale, Multi-Sector Modeling (Office of Science): Developing understanding and tools needed to investigate the impact of various natural and human stressors on multi-sector dynamics

- Drought and heat impacts on Western Interconnection in PLEXOS at county-scale using simulated daily extreme temperatures, thermal power plant deratings, and WM-modeled historical drought impacts.
- Comparison of thermal power plant deratings including impacts of air temperature, water temperature, and water availability.
- Operational (PLEXOS) modeling of hundreds of water conditions using WM-modeled climate-forced hydropower and thermal plant impacts.

Water Risk for the Bulk Power System (GMLC/WPTO):

- To provide a comprehensive understanding of water-related impacts and risks from the asset level to the bulk power system scale, including sensitivities to varying climate-hydrologic drivers and infrastructure futures.
- To create a national-scale analysis and visualization platform that enables utilities and system operators to evaluate water-related impacts and risks of existing and new grid assets that can inform operations and investment decisions.