Forward-looking Forecasting of Demand & Renewable Generation

2023 Long-term Load Forecasting Workshop

June 13th, 2023

Pattern

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

Pattern Energy

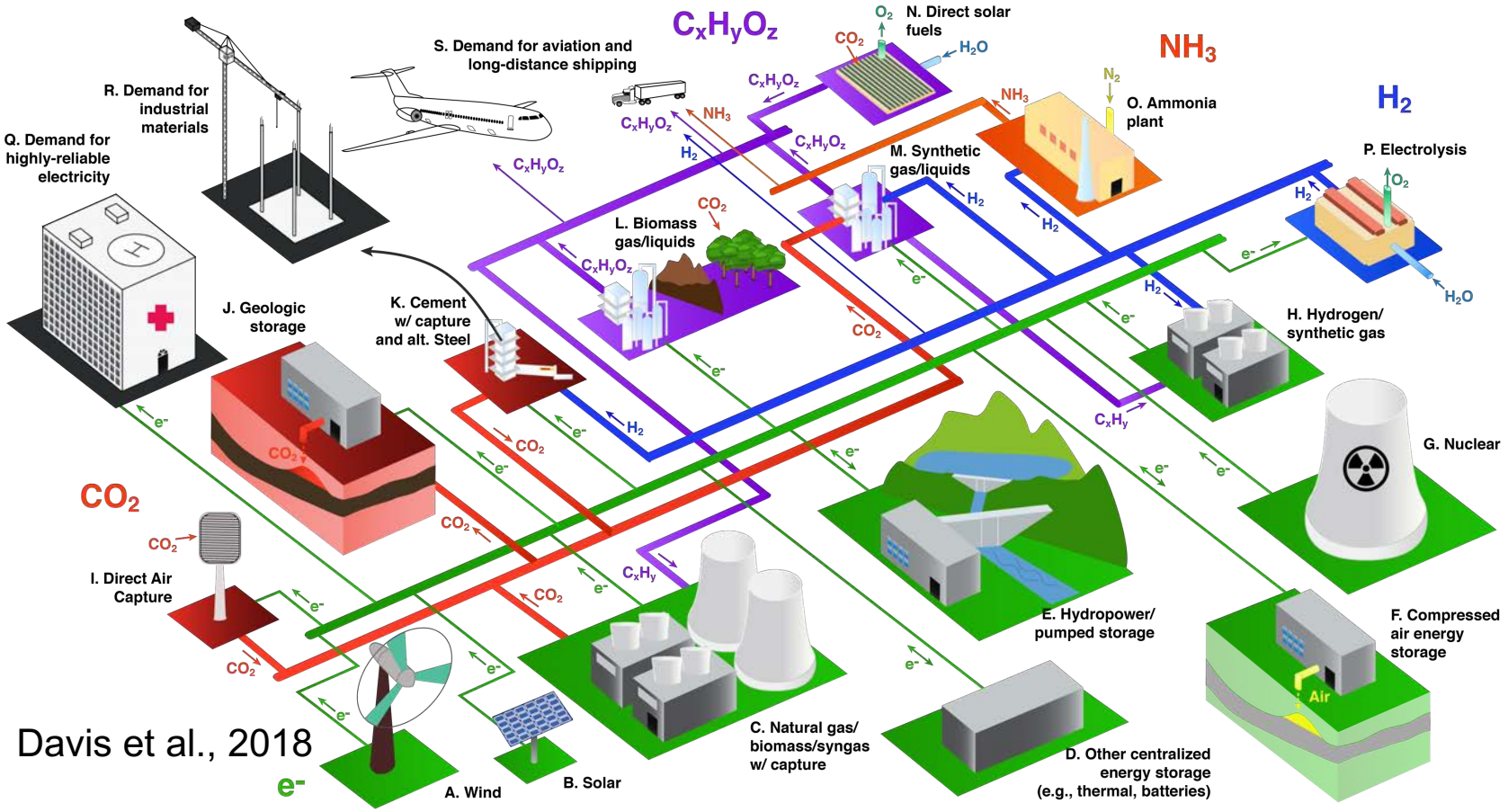
Pattern Energy is a leading renewable energy company that develops, constructs, owns, and operates high-quality wind and solar generation, transmission, and energy storage facilities. Our mission is to transition the world to renewable energy through the sustainable development and responsible operation of facilities with respect for the environment, communities, and cultures where we have a presence.

Our approach begins and ends with establishing trust, accountability, and transparency. Our company values of creative spirit, pride of ownership, follow-through, and a team-first attitude drive us to pursue our mission every day. Our culture supports our values by fostering innovative and critical thinking and a deep belief in living up to our promises.

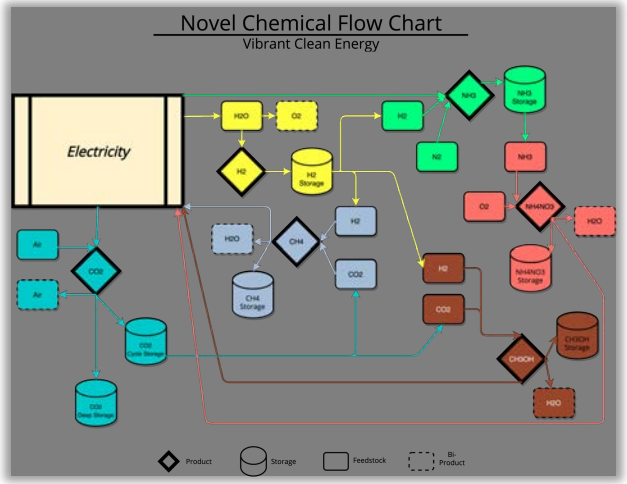
Headquartered in the United States, Pattern has a global portfolio of more than 35 power facilities and transmission assets, serving various customers that provide low-cost clean energy to millions of consumers.

Weather-Informed energy Systems:

for design, operations & markets



Davis et al., 2018



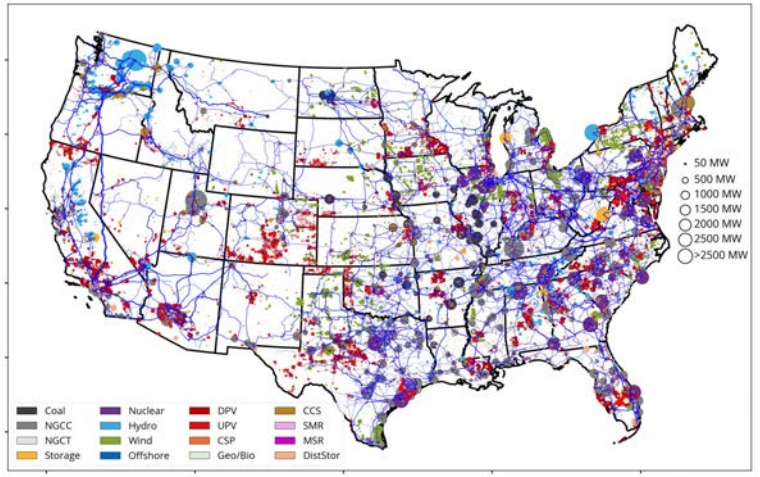
The modeling is designed to encompass as much of the energy economy as possible

WIS:dom-P (Planning)

WIS:dom-P & WIS:dom-G are fully combined capacity expansion and production cost model. They combine:

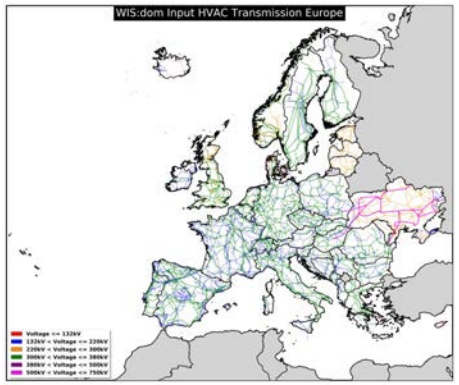
- ✓ Continental-scale, spatially-determined co-optimization of transmission, generation and storage expansion while simultaneously determining the dispatch of these sub systems at 3-km (USA) or 30-km (Global) , 5-minutely or hourly resolution;

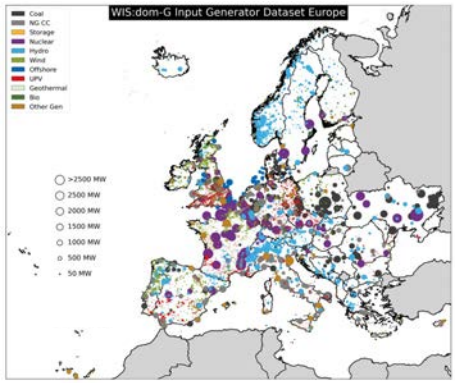
- ✓ Includes ***climate change data from CMIP-5/6 modeling*** to climate stress scenarios;



- ✓ Dispatch includes:
  - ➢ Individual unit commitments, start-up, shutdown profiles, and ramp constraints;
  - ➢ ***Transmission power flow, planning reserves***, and operating reserves;
  - ➢ ***Distribution planning*** & hybrid optimization;
  - ➢ ***Weather forecasting and physics of weather engines***;
  - ➢ ***Detailed hydro modeling***;
  - ➢ ***High granularity for weather-dependent generation*;**
  - ➢ Existing generator and transmission asset attributes such ***as heat rates, line losses, power factor,*** variable costs, fixed costs, capital costs, fuel costs, etc.;

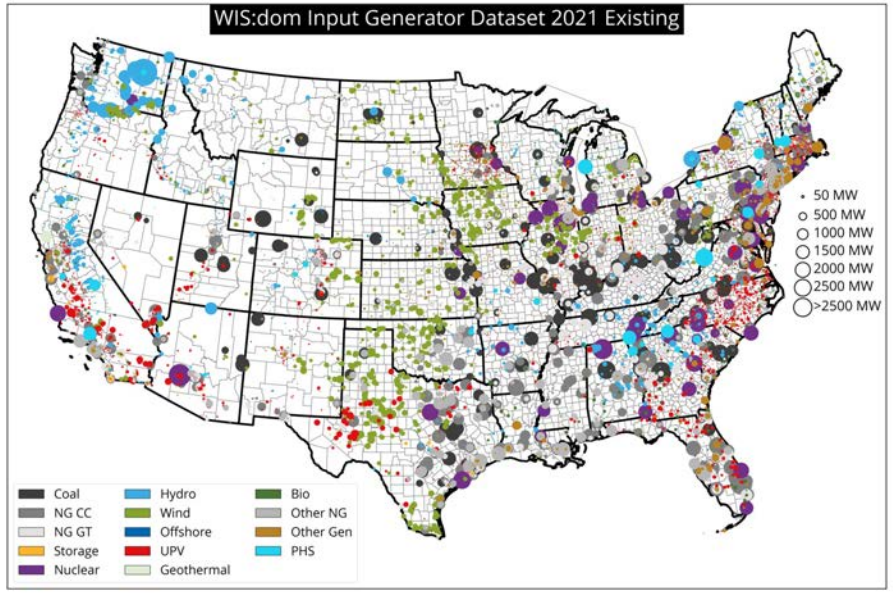
- ✓ Large spatial and temporal horizons;
- ✓ Policy and regulatory drivers such as PTC, ITC, RPS, etc.;
- ✓ Detailed investment periods (1-, 5-, or 10- year) out past 2050;

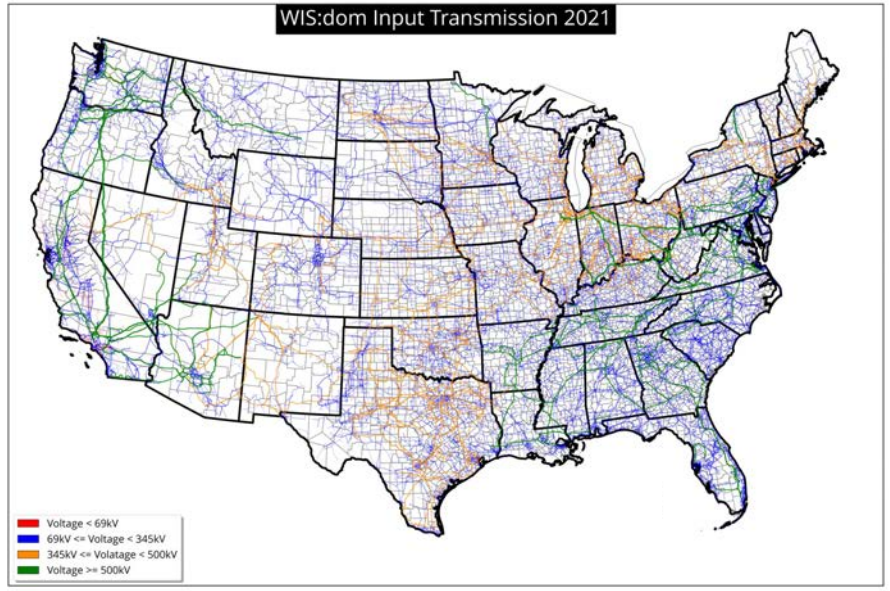


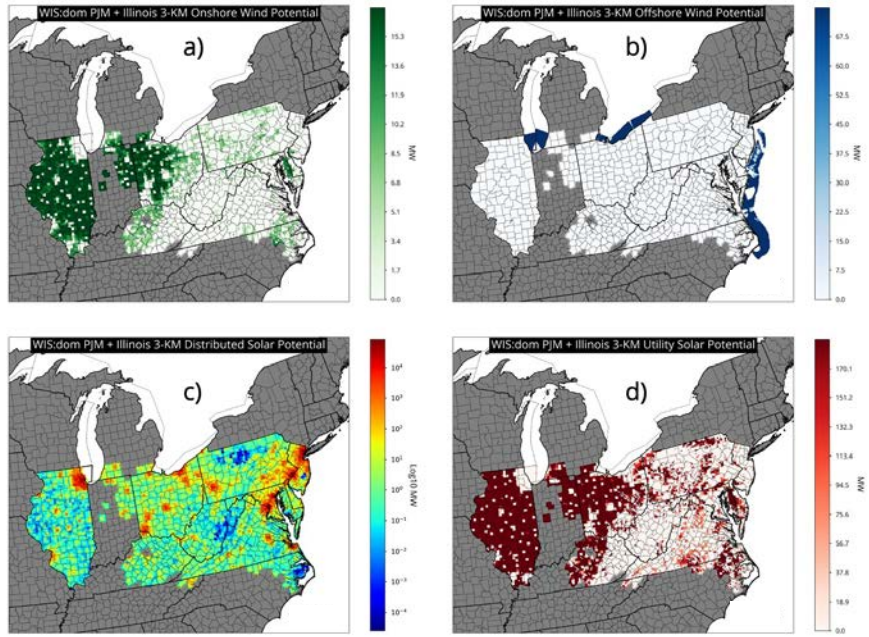


Datasets

- Generators
- Transmission
- Buildable Areas
- Demands
- Climate Change







Datasets (Annual Demand)

NOTE: In 2021 28.5 PWh of primary energy was consumed in the US. Of that 9.3 PWh was productive for end uses (energy services).
Source: LLNL

61% down 18% up

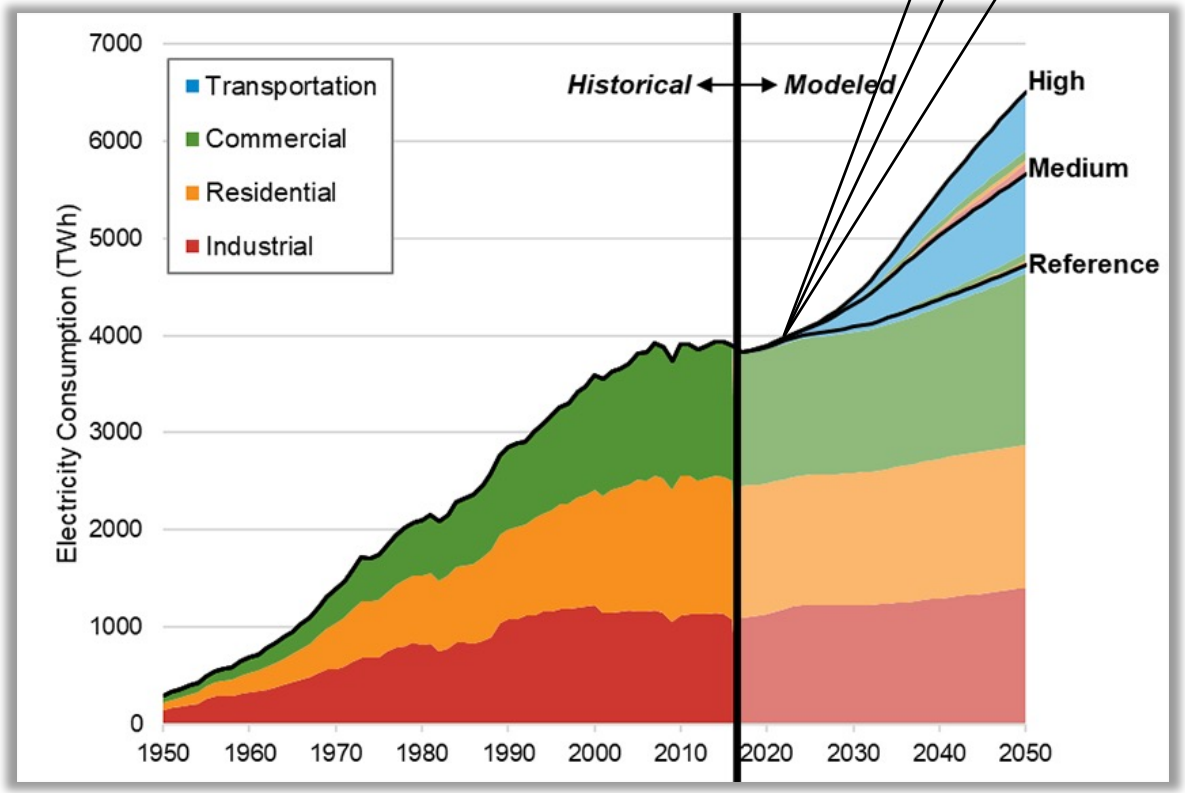
69% down 4% down

73% down 16% down

ZBF 2050 TWh with synthetic fuels & products (11 PWh)

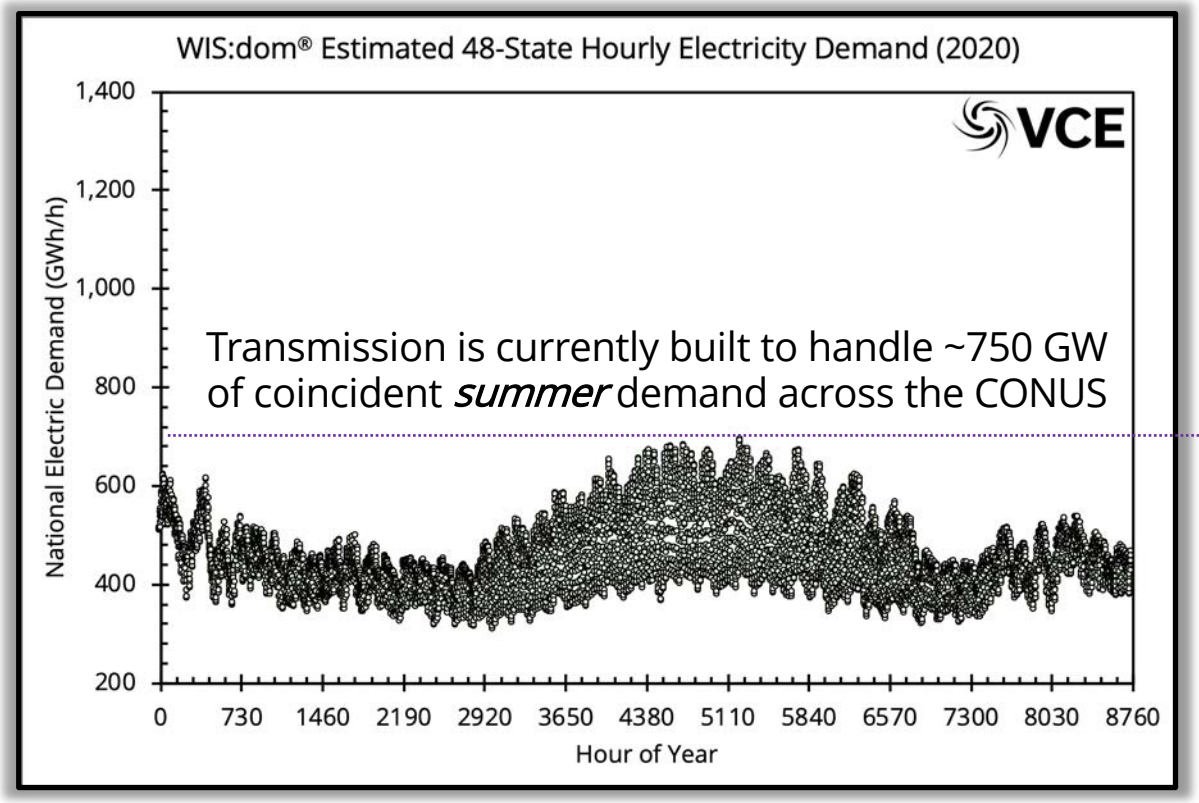
ZBF 2050 TWh with RCP4.5 climate change impacts (8.9 PWh)

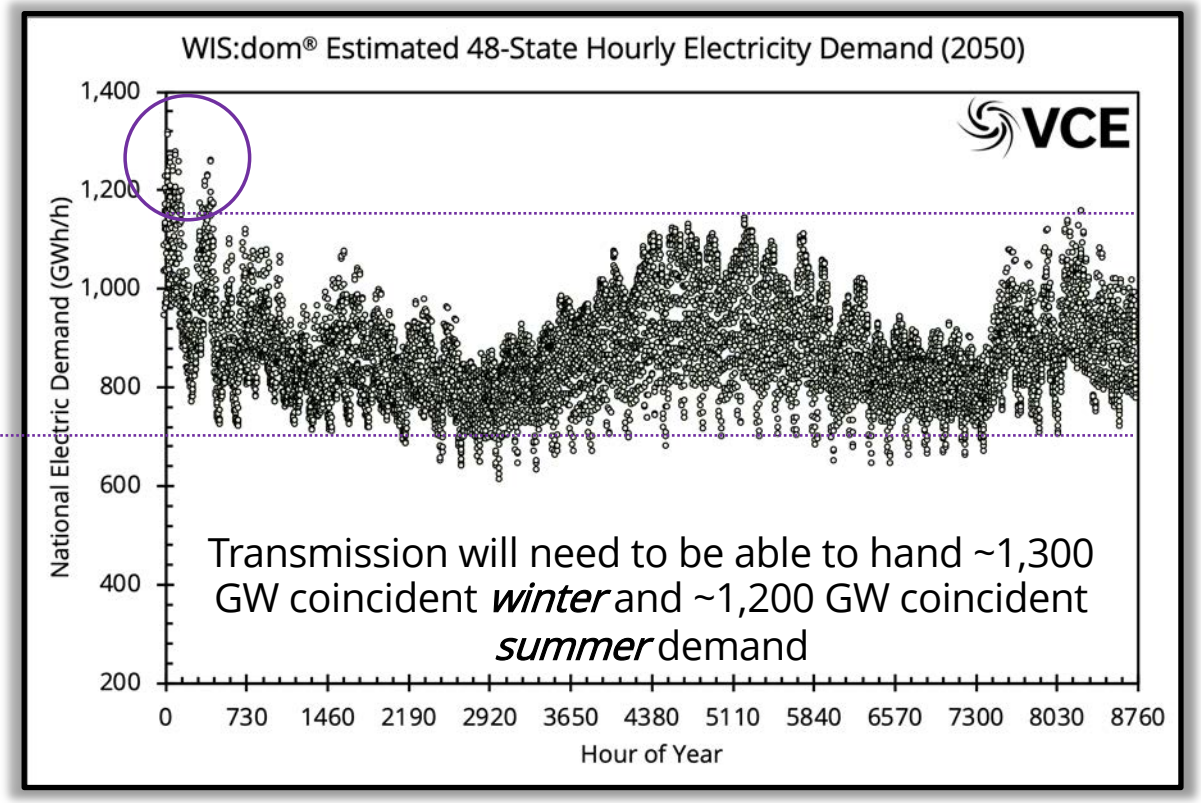
ZBF 2050 TWh without climate change impacts (7.8 PWh)



https://www.nrel.gov/analysis/electrification-futures.html

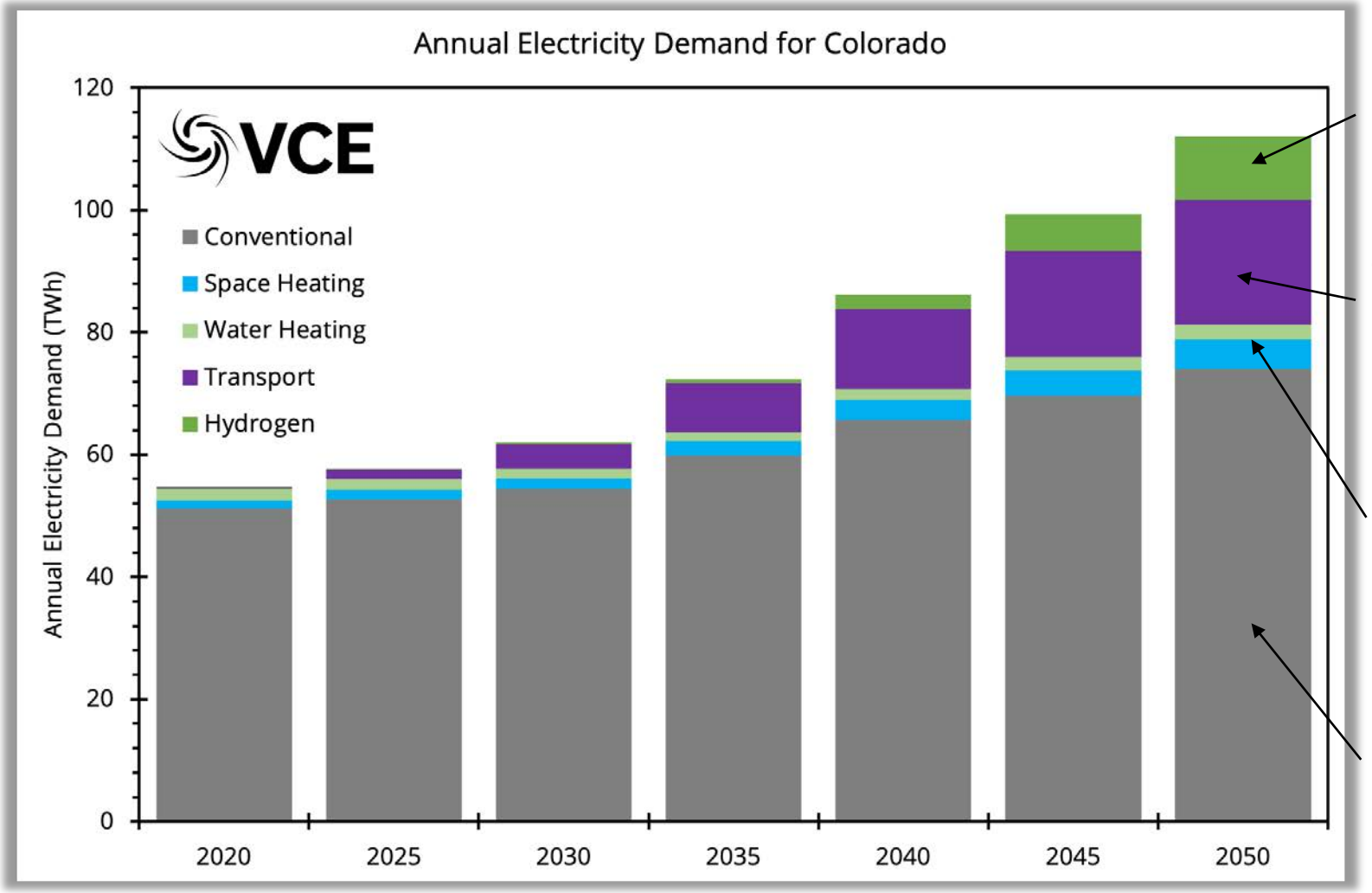
Datasets (Profiles)





* Before considering synthetic fuel production

Datasets (Demand Example: Colorado)



55 TWh 62 TWh 86 TWh 112 TWh

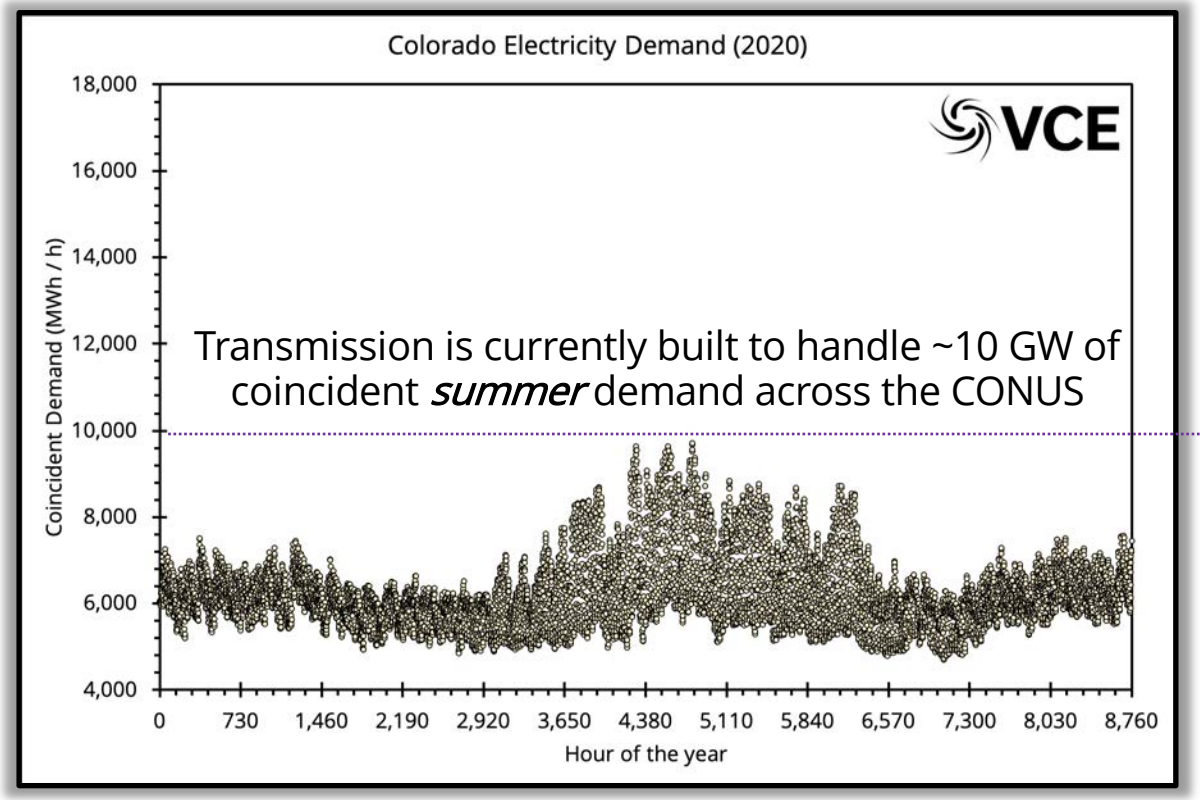
Hydrogen for agriculture, transport & industry grows rapidly after 2035

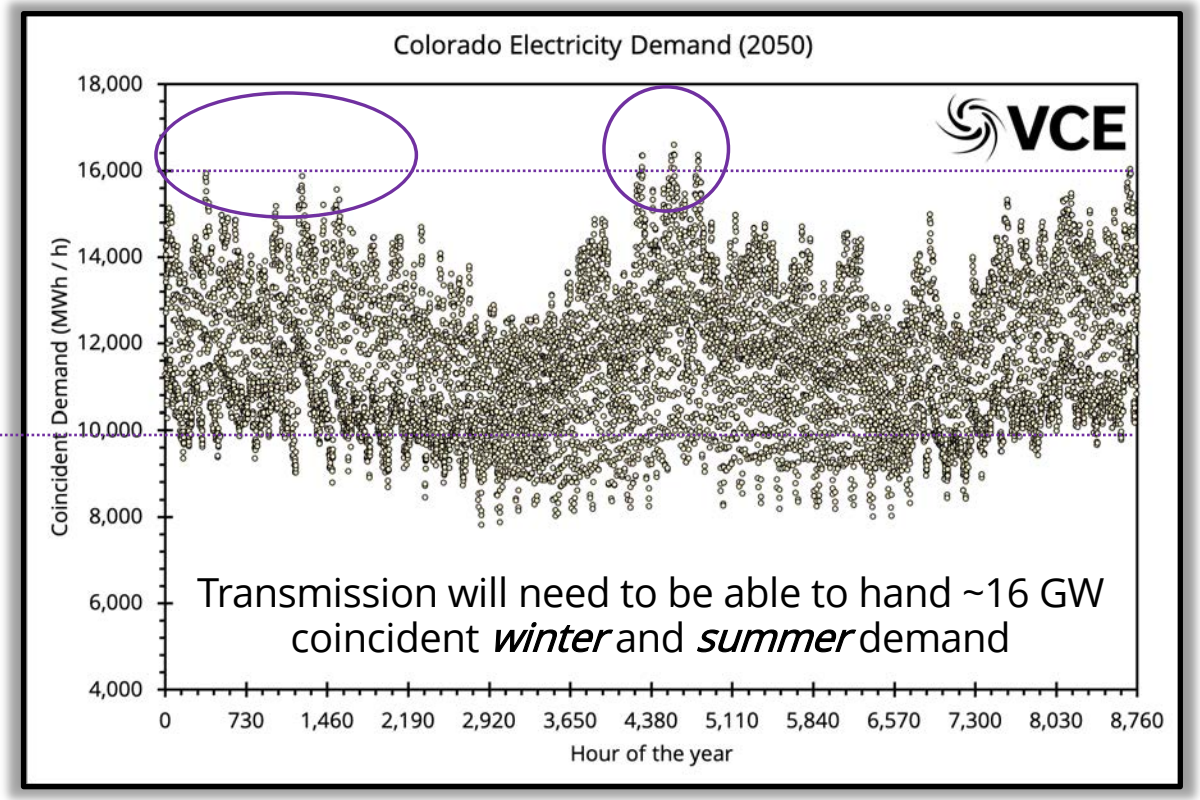
Transportation electrification is fastest growing demand

Building electrification does not add large electric demand, but shifts timing of peaks dramatically

Conventional demand is seen to grow rapidly with increasing economic activity within the state

Datasets (Demand Example: Colorado)



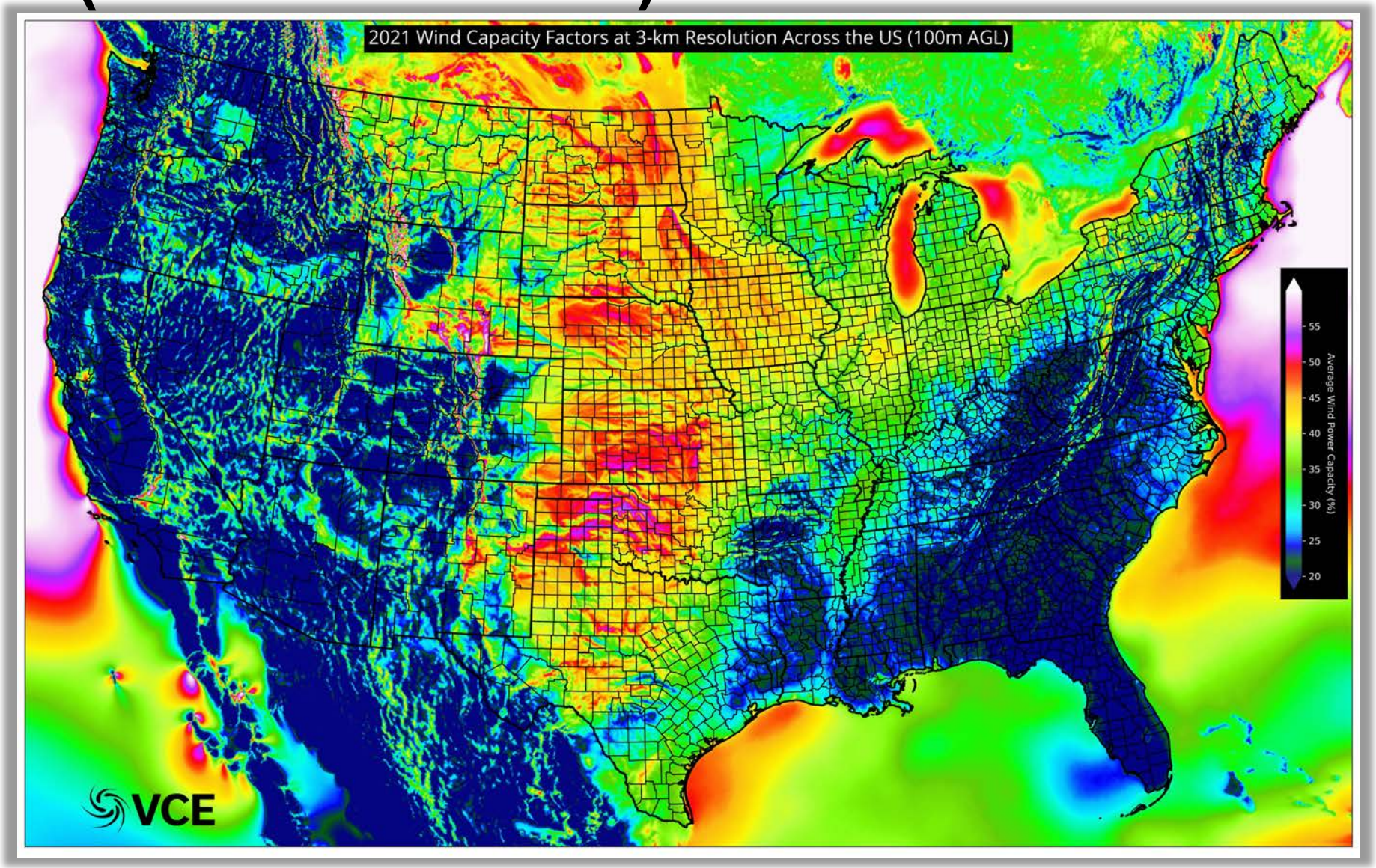


* Before synthetic fuel production

Datasets (Basic Demand Creation Components)

1. Split demands into categories:
    a. Conventional Demands;
    b. Space Heating;
    c. Space Cooling;
    d. Water Heating;
    e. Transportation;
    f. Synthetic Fuel Production.
2. Compute the weather influence over each category along with societal behavior components:
    a. e.g. Temperature impacts space heating and cooling; but so, does solar irradiance; as does insulation, building type, etc.
3. Calculate the climate change adjustments to the weather for each future simulation year:
    a. Historical values are “nudged” by the multi-model ensemble of Climate data (CMIP-5/6) to provide future weather years.
4. Use the climate-adjusted weather datasets to create the new annual and hourly (5-minutely) profiles for the demands at chosen resolution (down to 3-km spatially; typically, county-level).
5. Adjust the current/initialization year to align with known values (particularly profiles for conventional demands) to ensure limited double counting of growth of destruction of annual and peak demands.

Datasets (Wind Resource)



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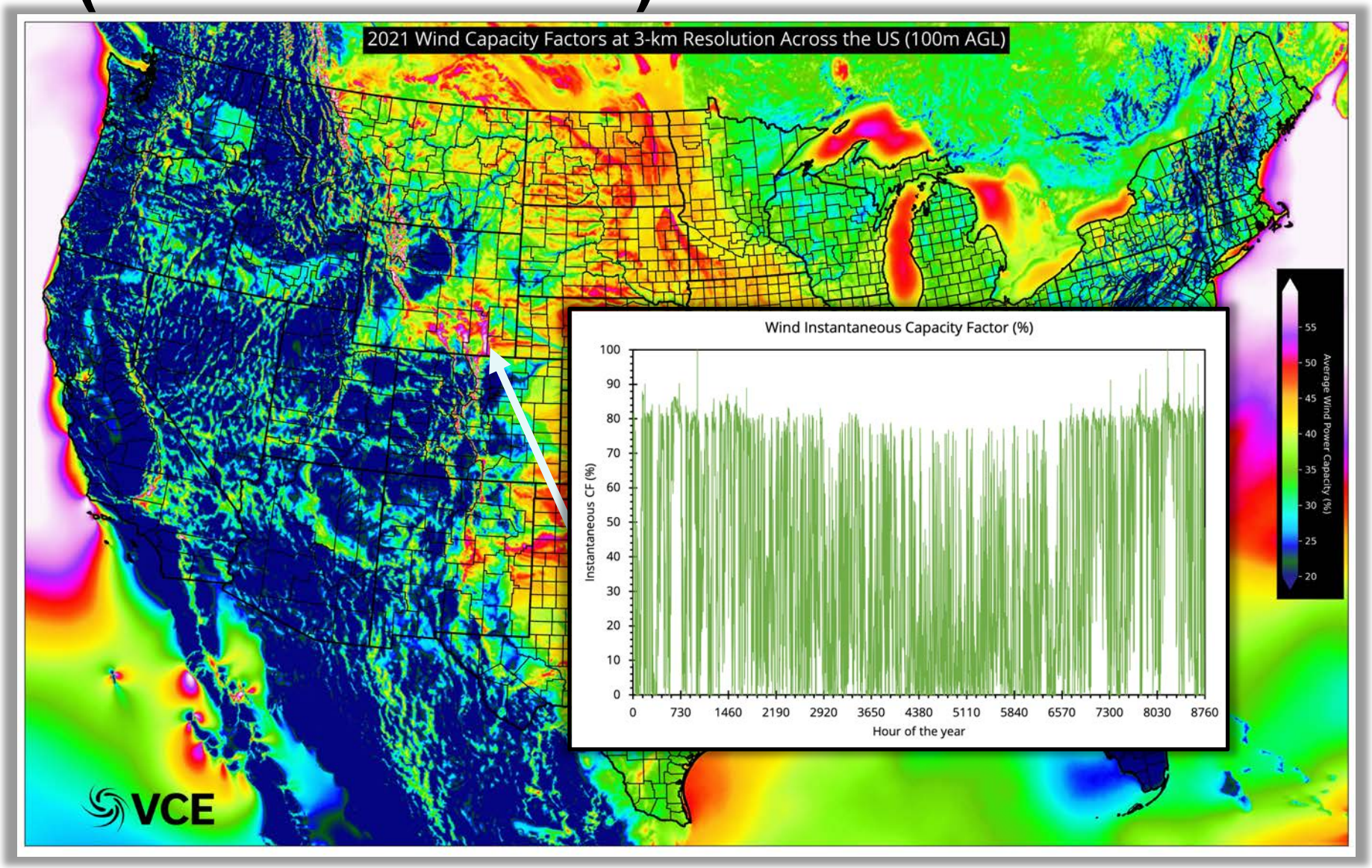
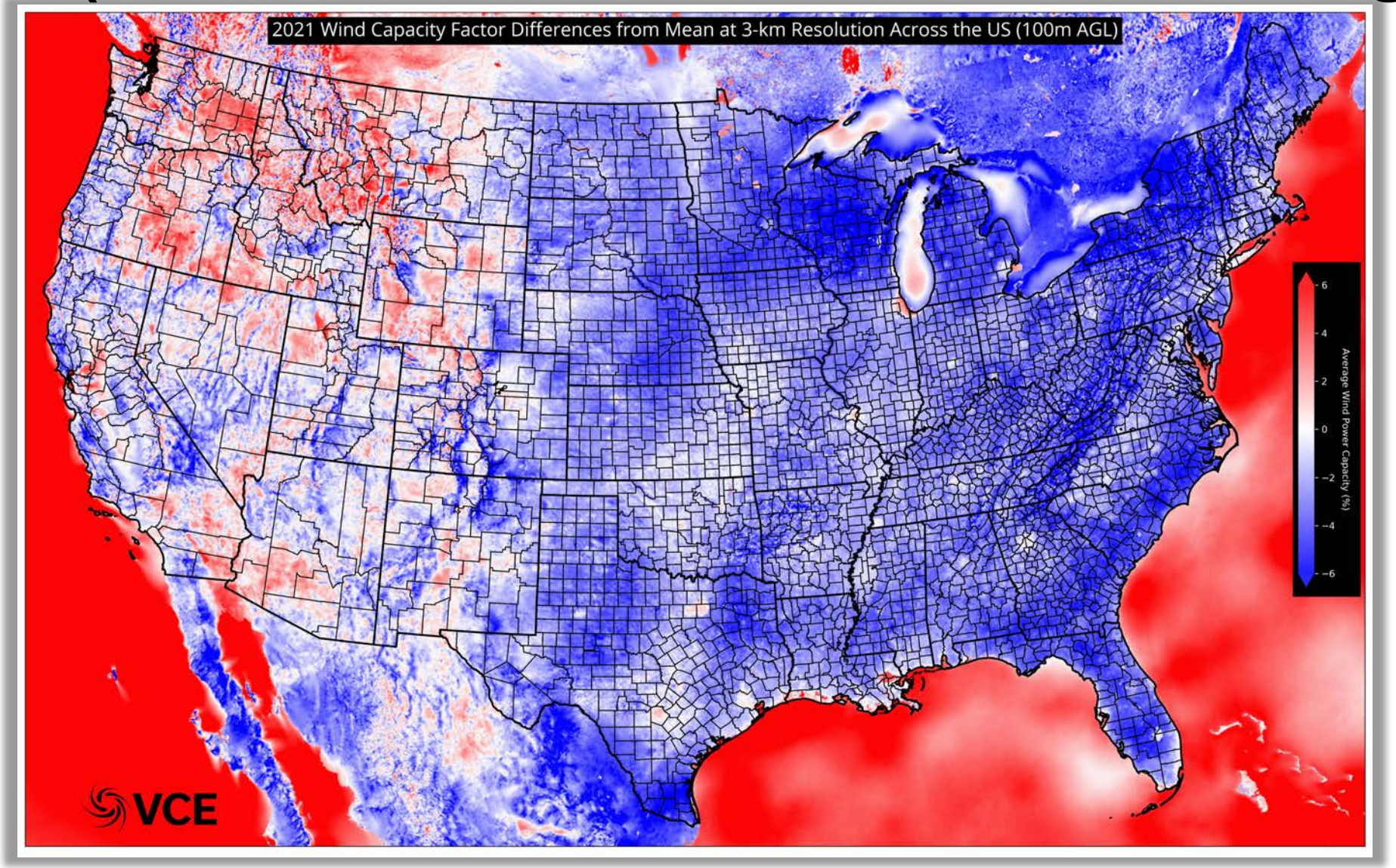
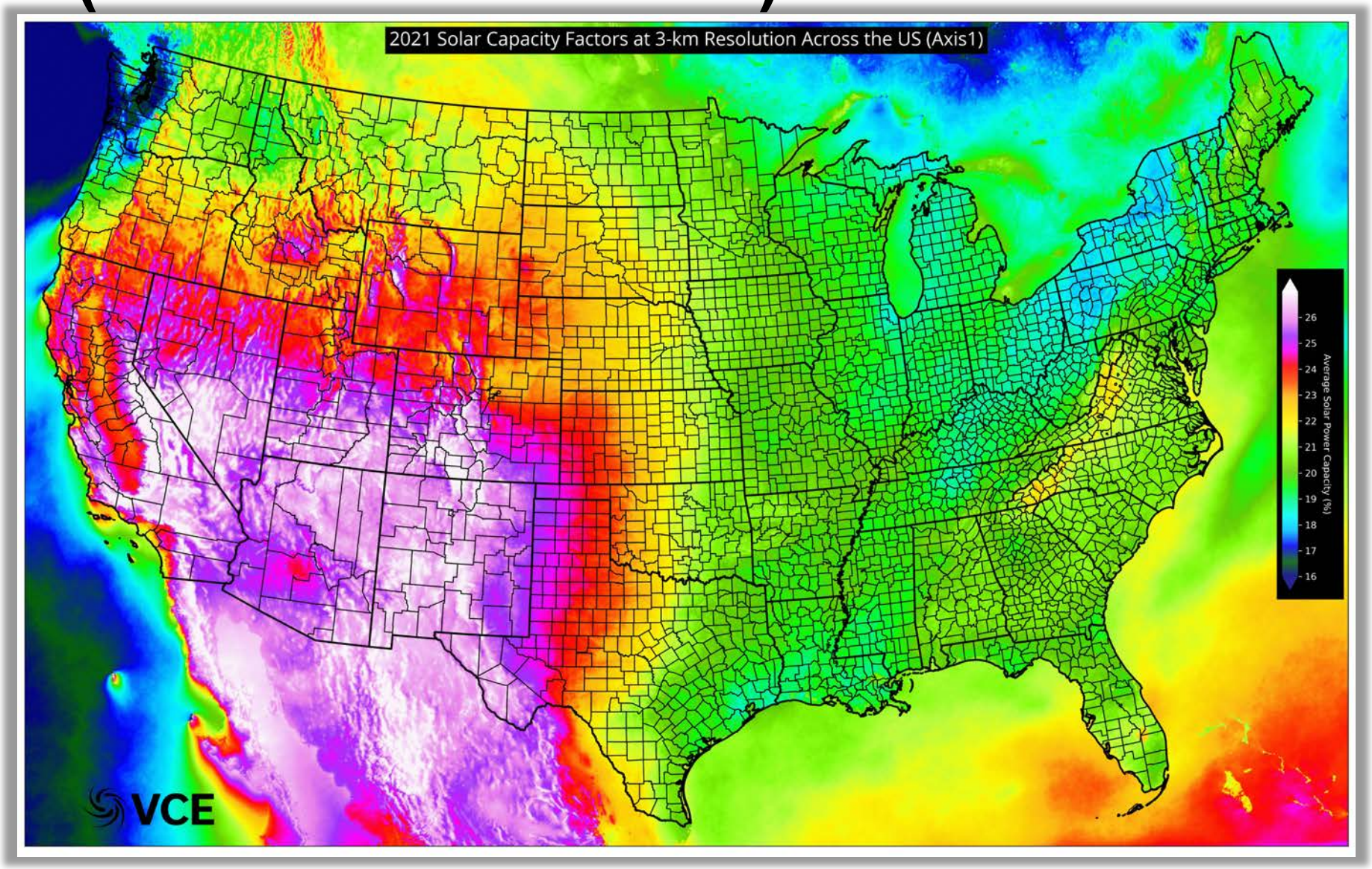


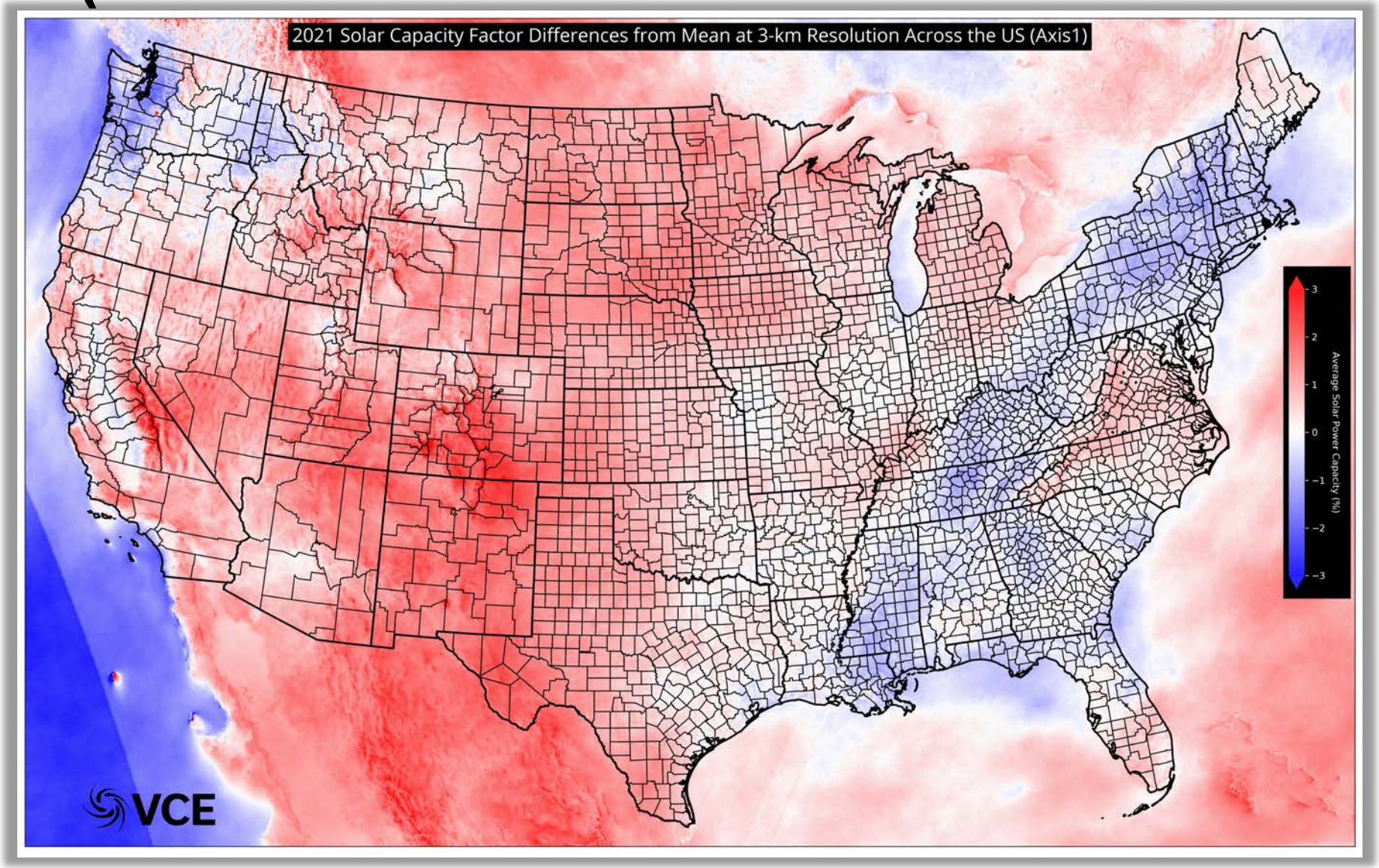
Datasets (Wind Resource: Difference to Average)



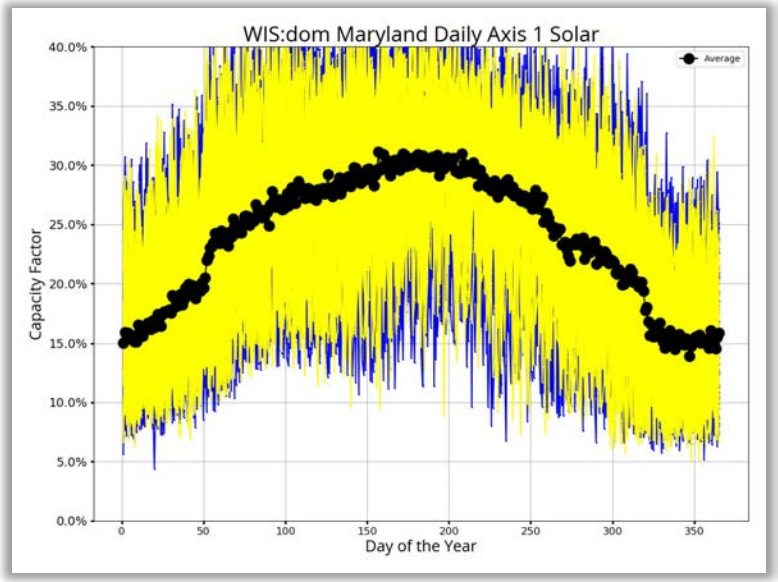
Datasets (Solar PV Resource)

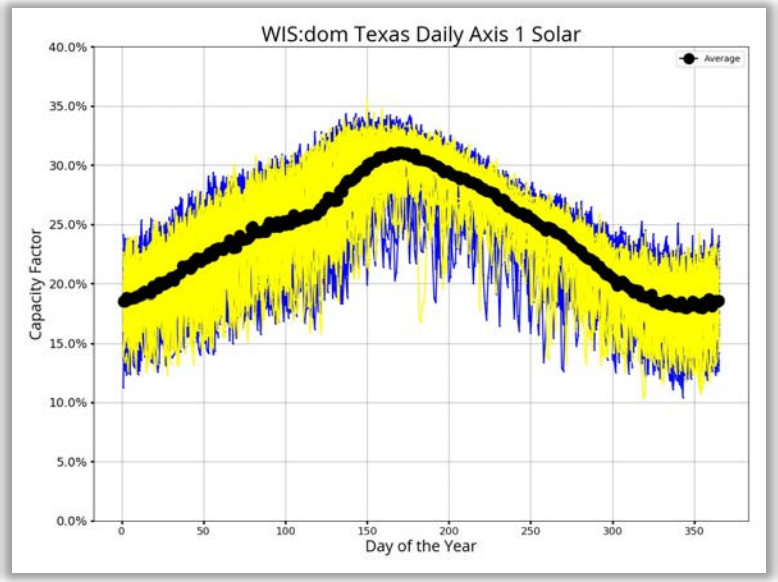


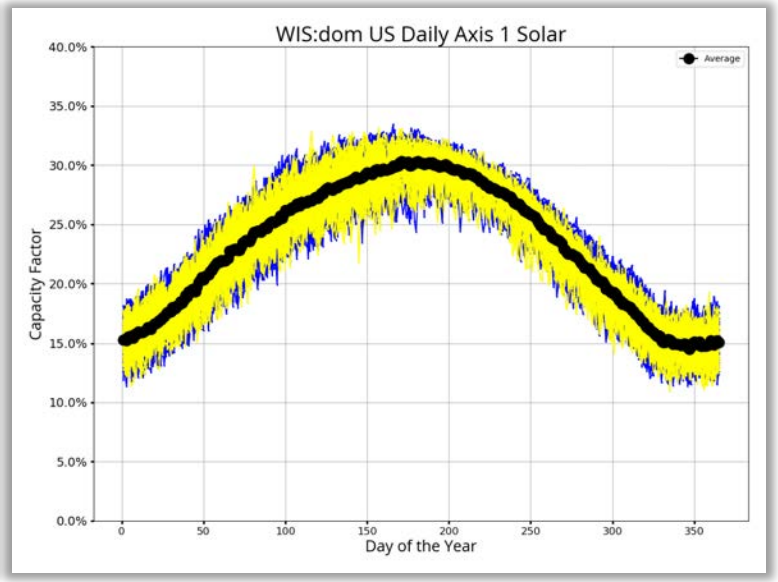
Datasets (Solar PV Resource: Difference to Average)

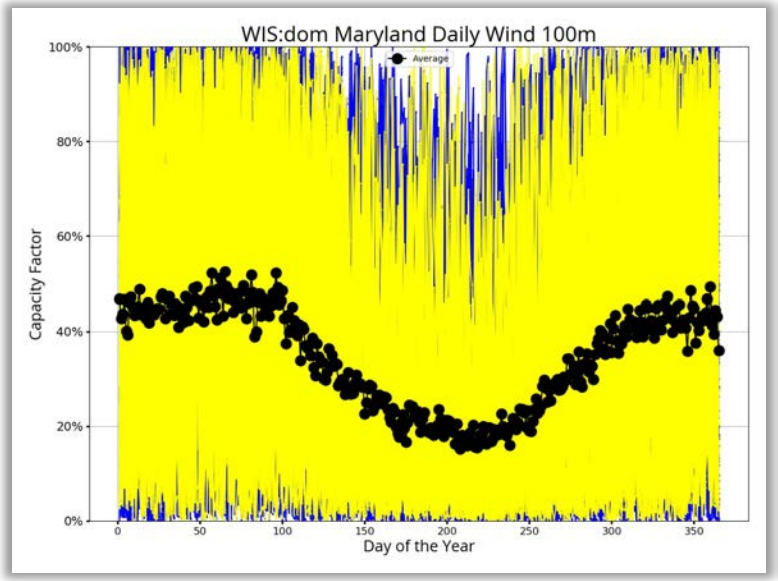


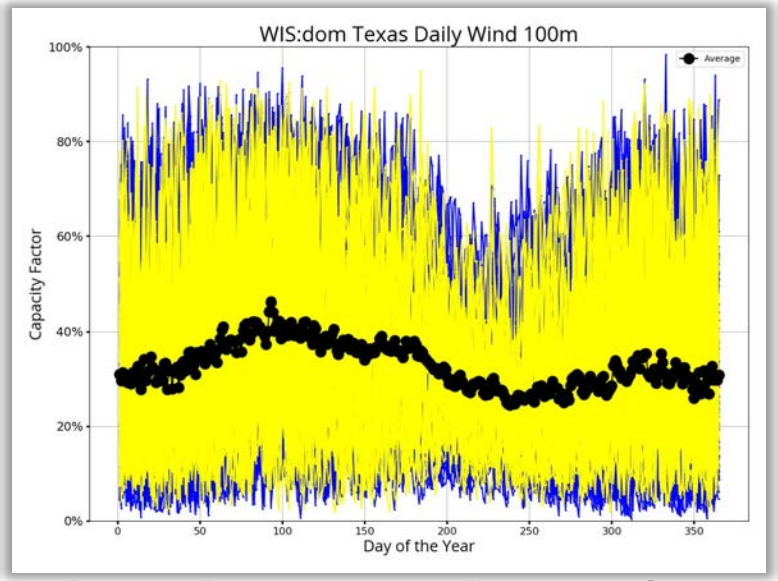
Datasets (Long-term Historical Reanalysis)

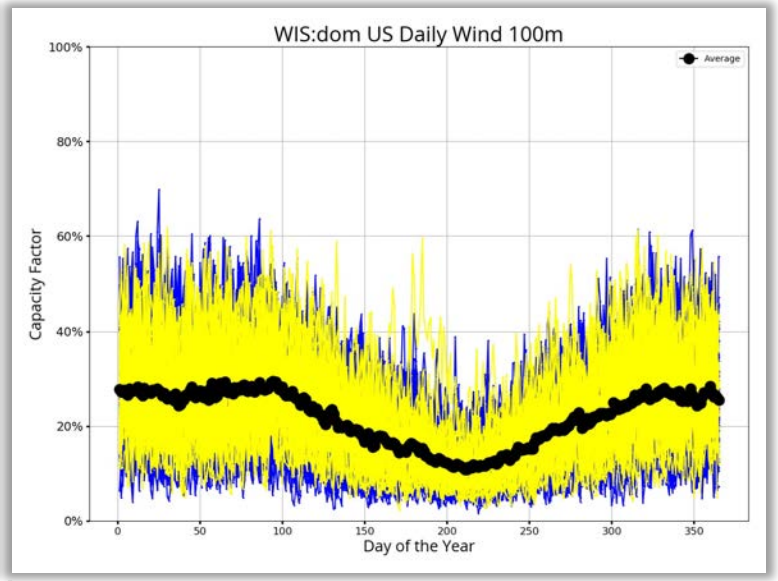






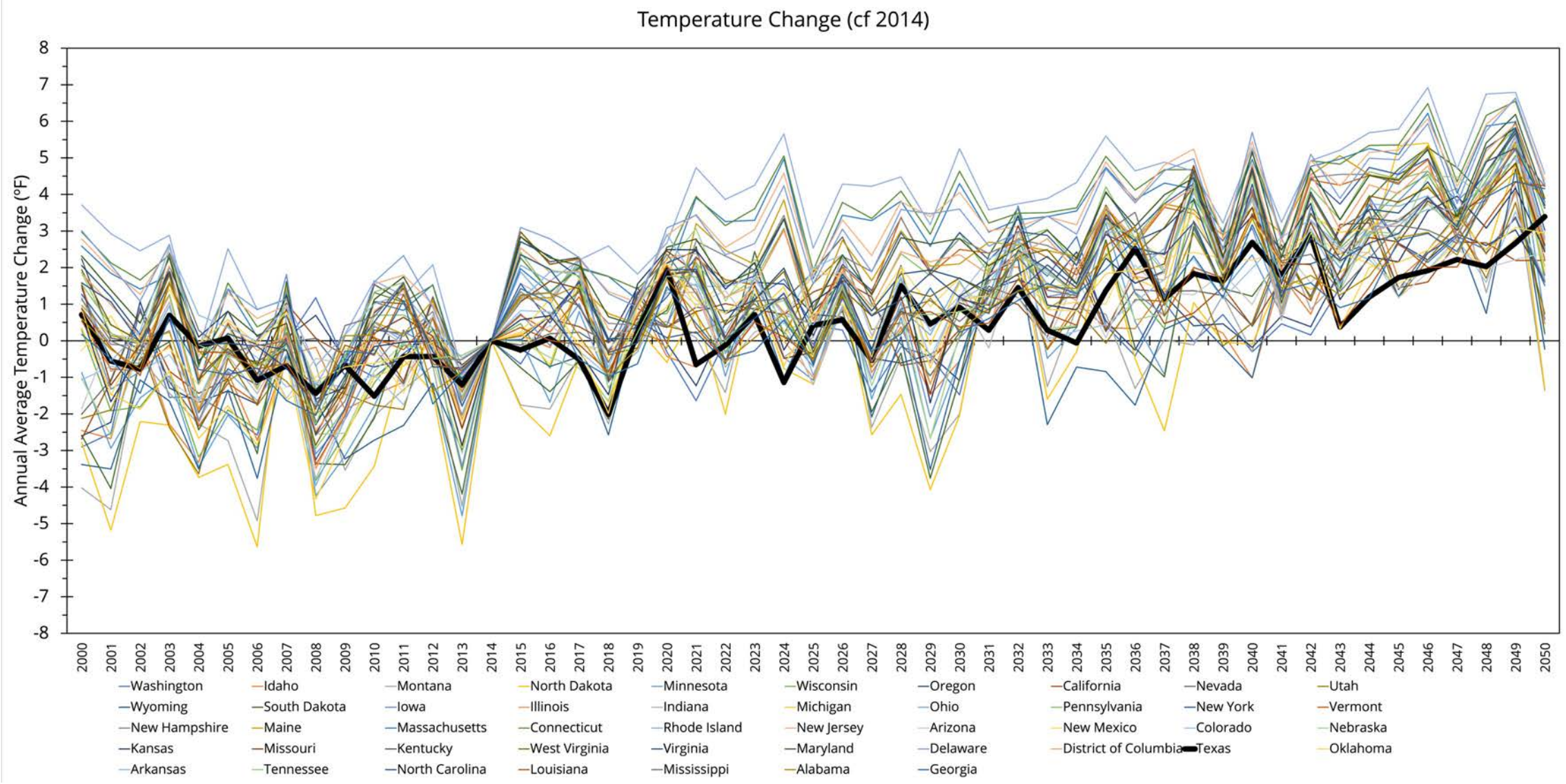






Daily hypothetical production from the VCE long-term dataset (1900-2015)

Datasets (Climate Change Stressors)



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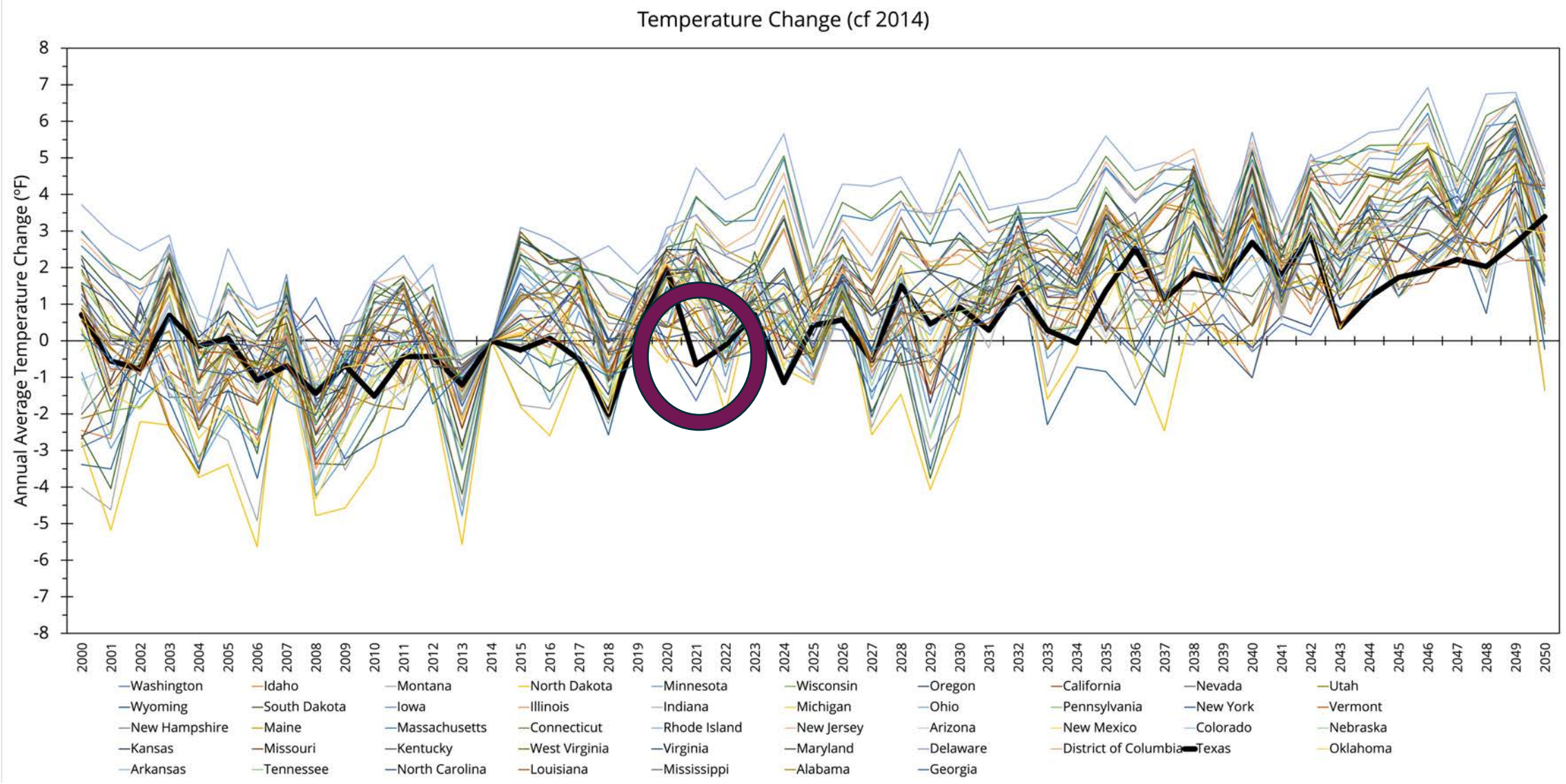
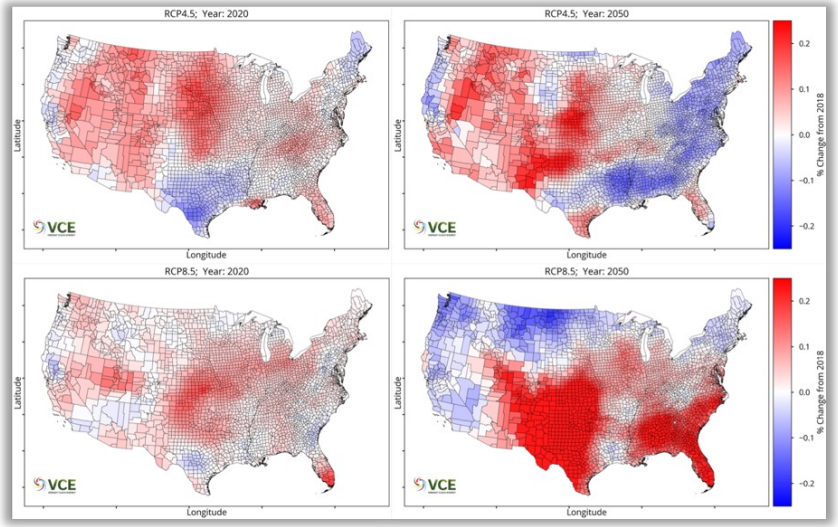
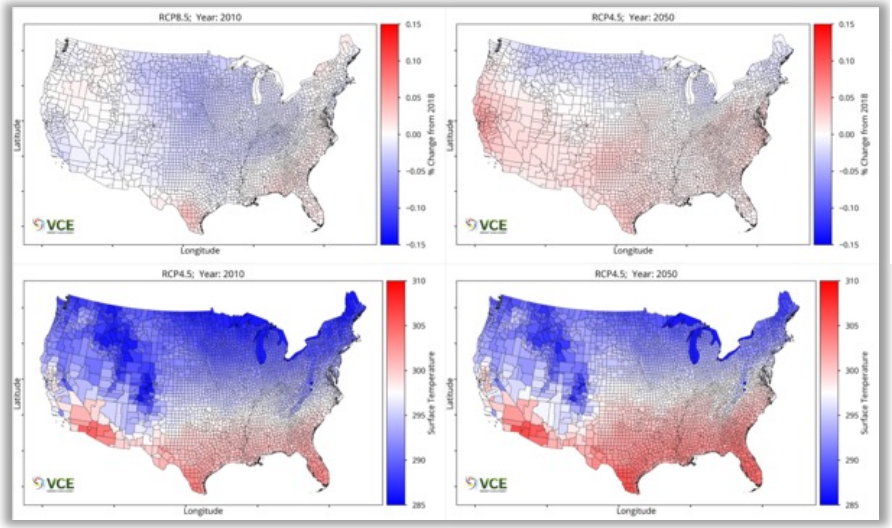


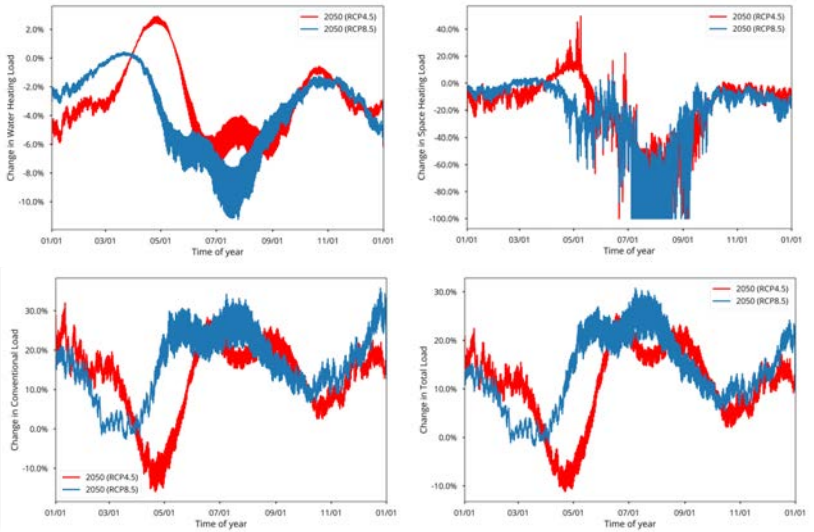
Datasets (Climate Change System Stressors)



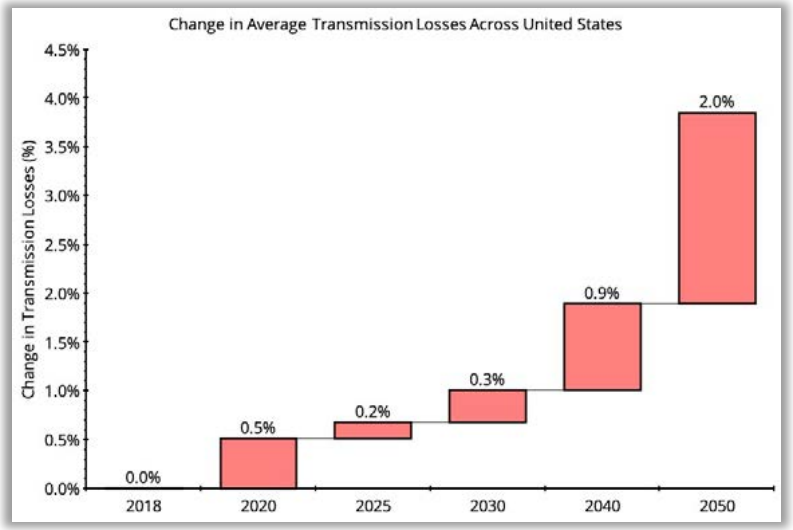
Wind



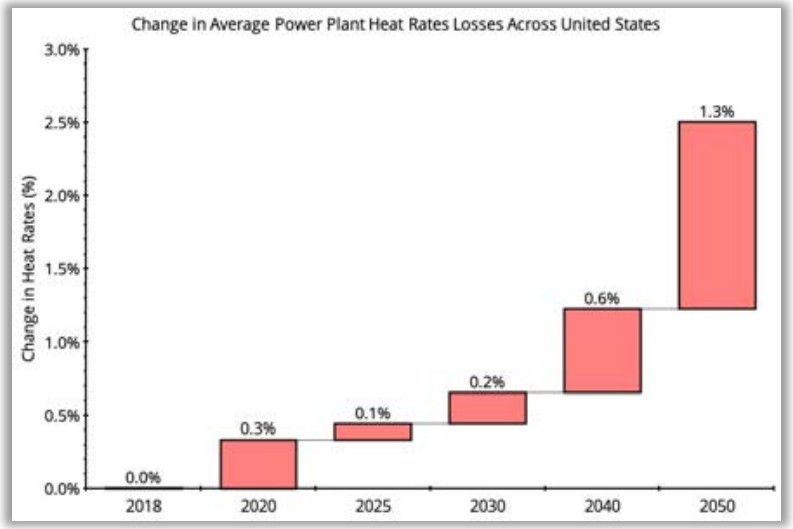
Solar



Demands

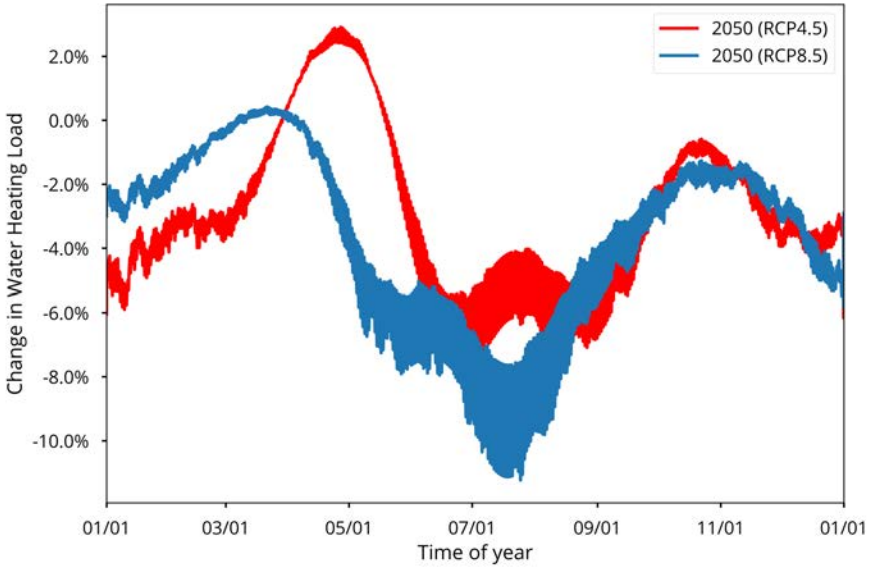


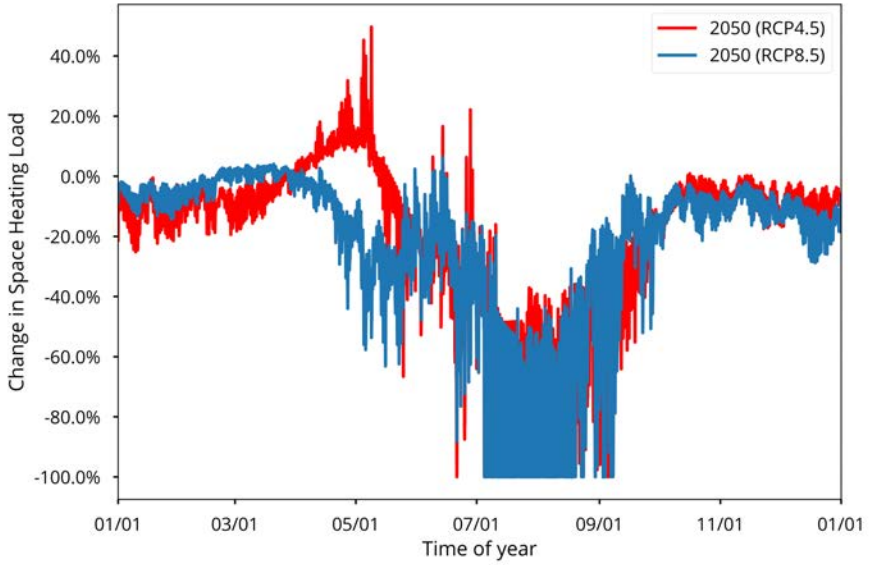
Tx Losses

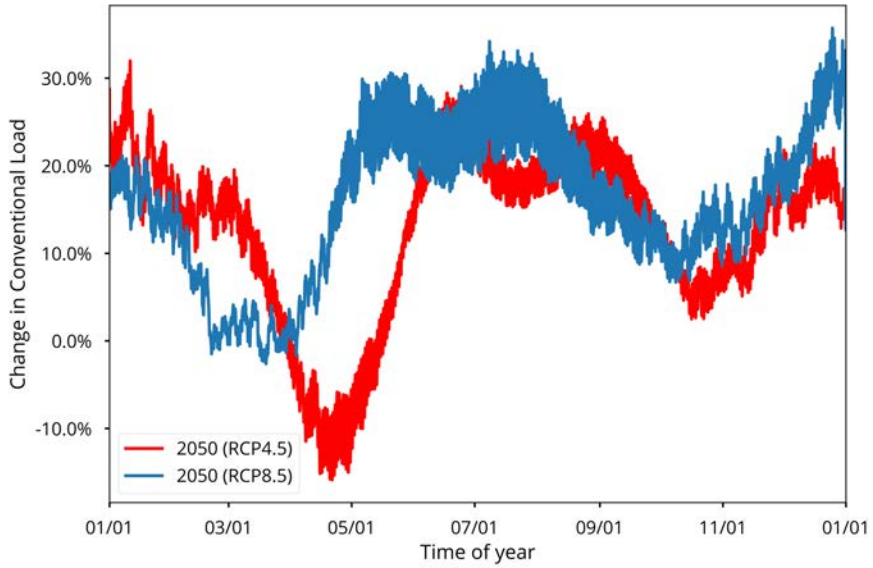


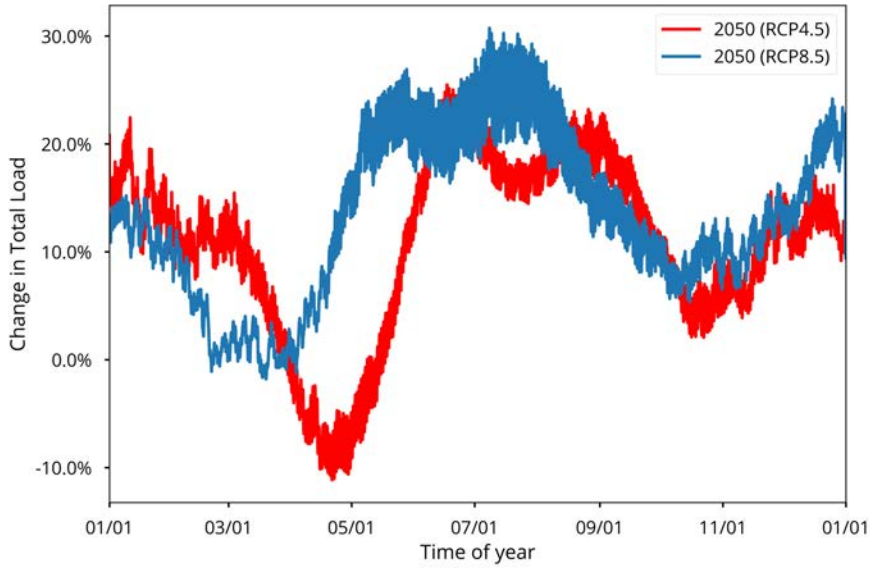
Heat rates

Datasets (Climate Change System Stressors)

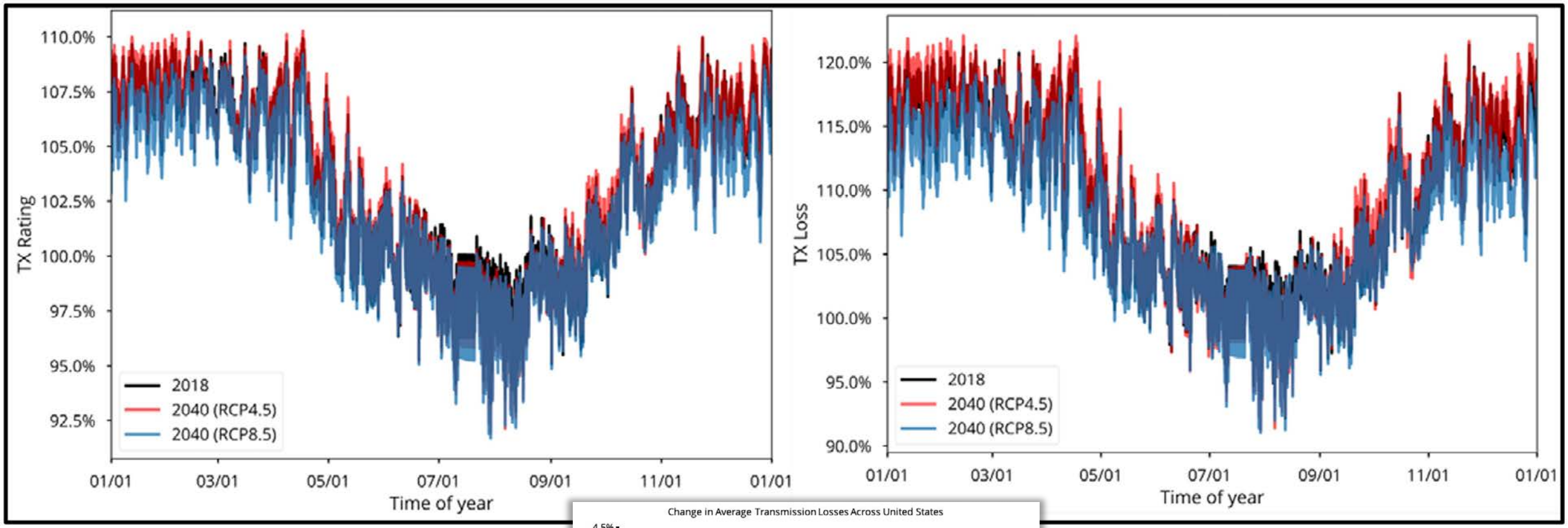




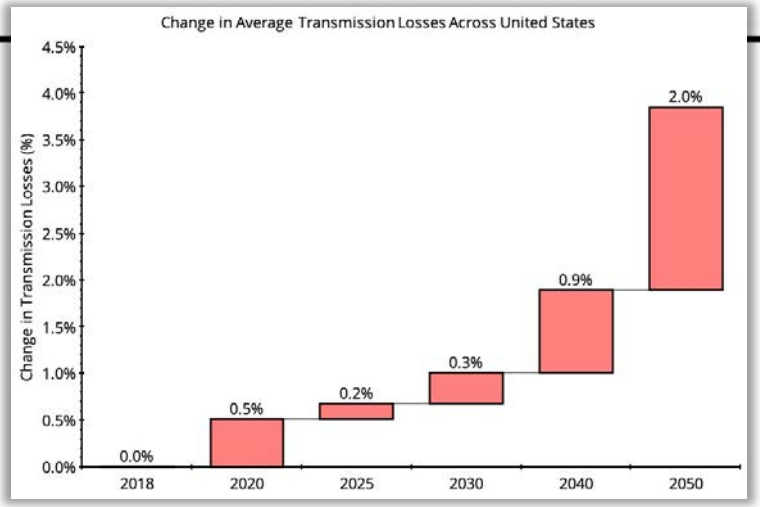




Datasets (Climate Change System Stressors)

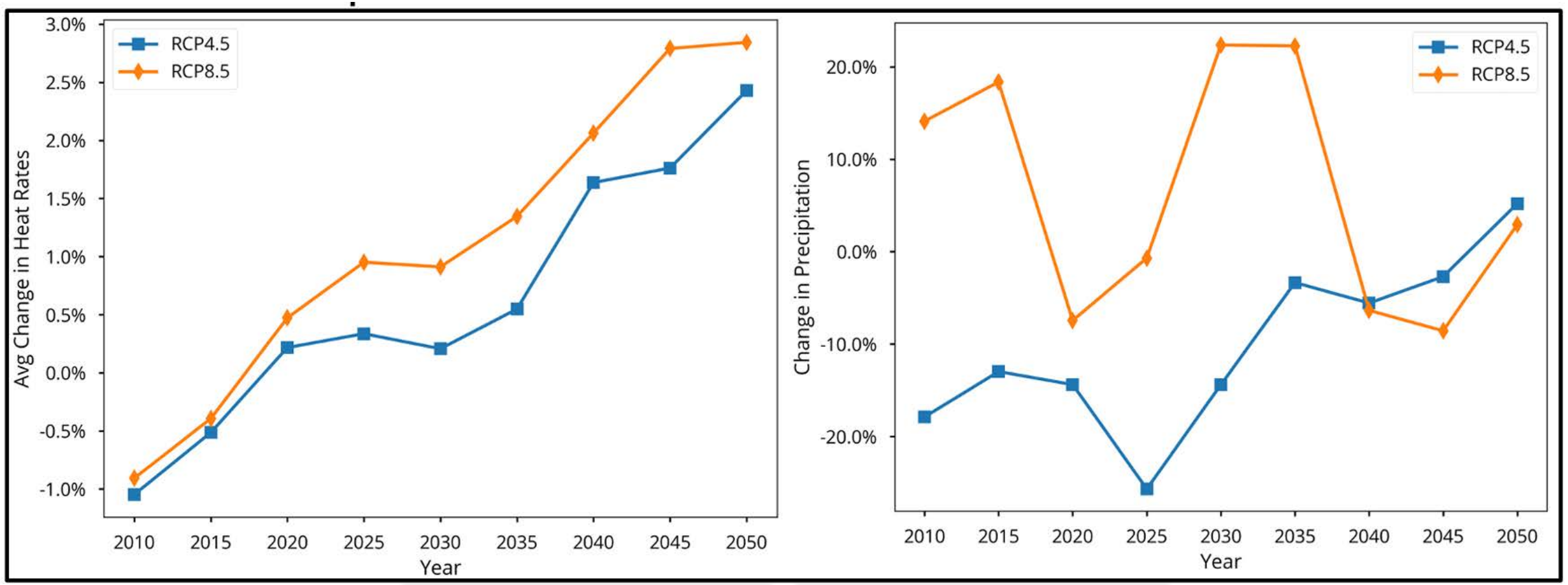


Transmission Ratings

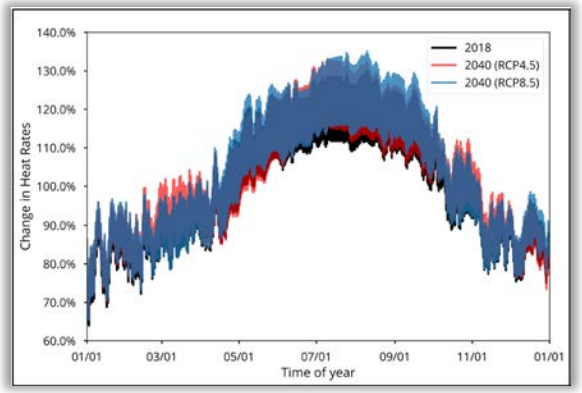


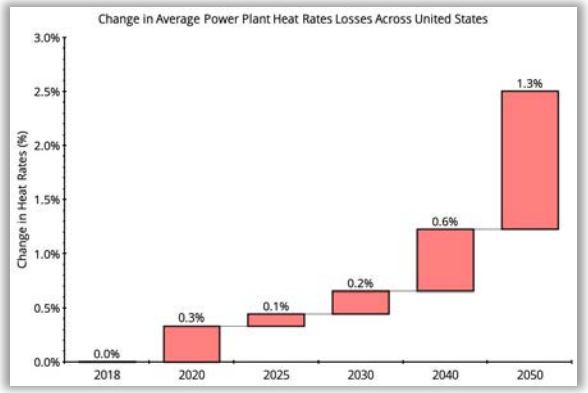
Transmission Losses

Datasets (Climate Change System Stressors)



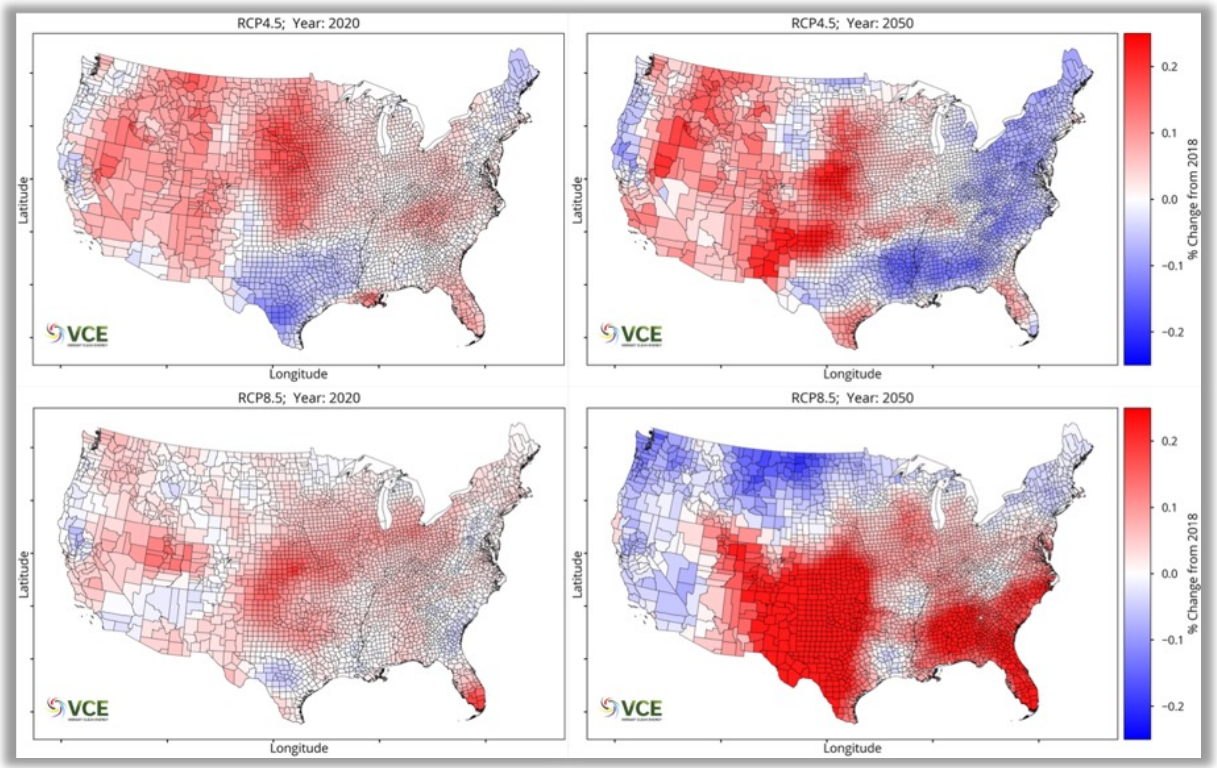
Heat Rates



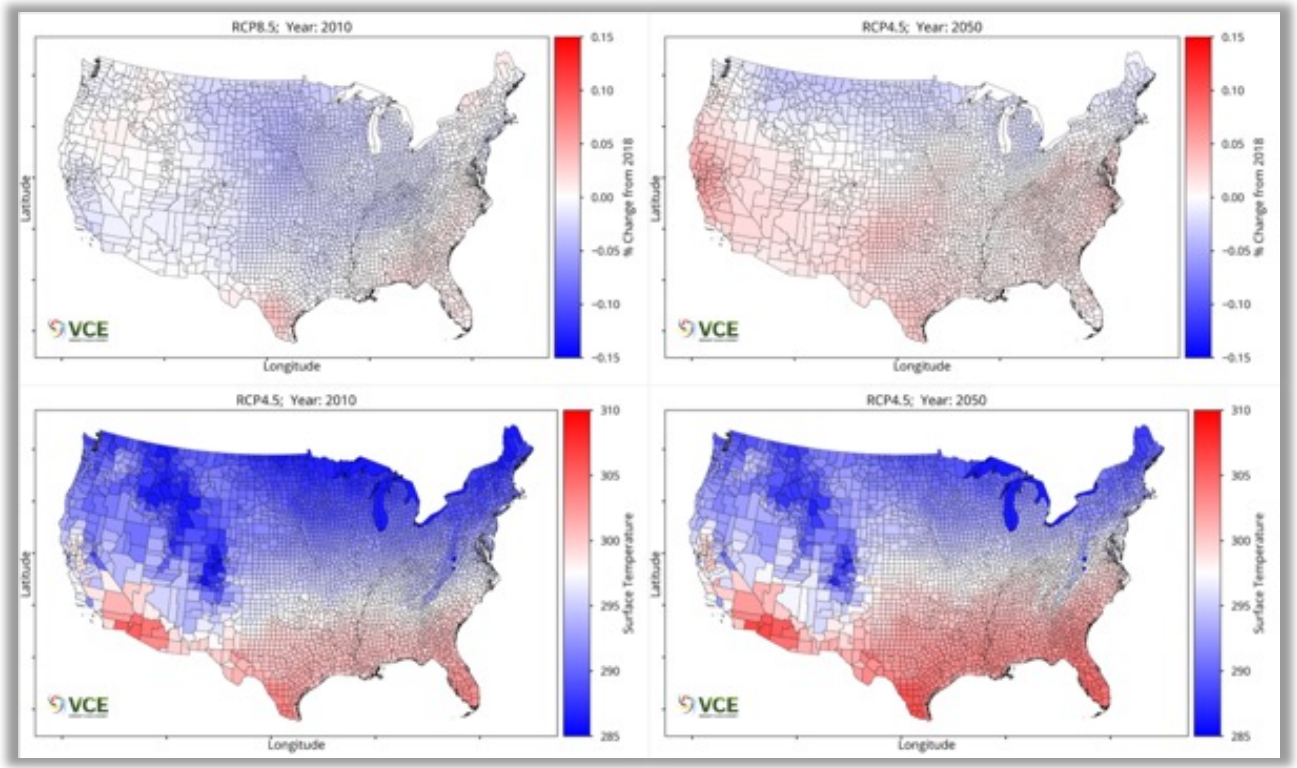


Water Availability

Datasets (Climate Change System Stressors)

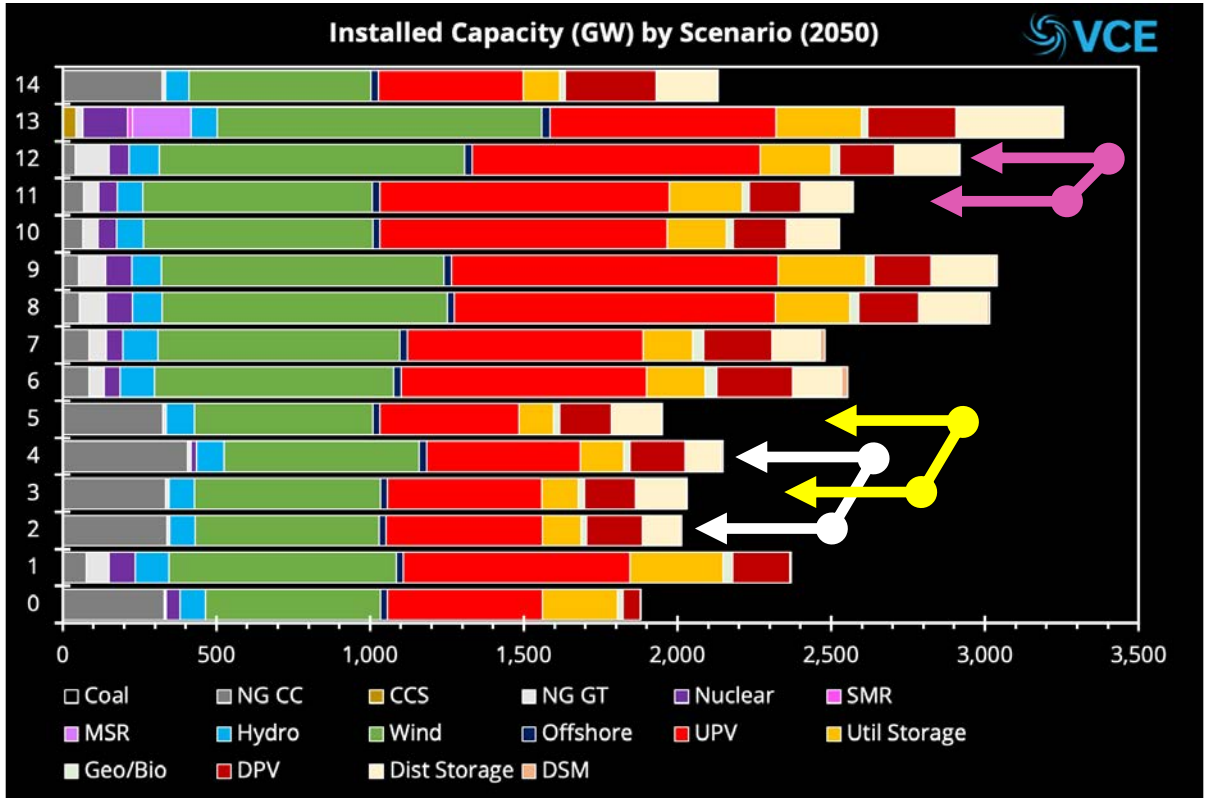


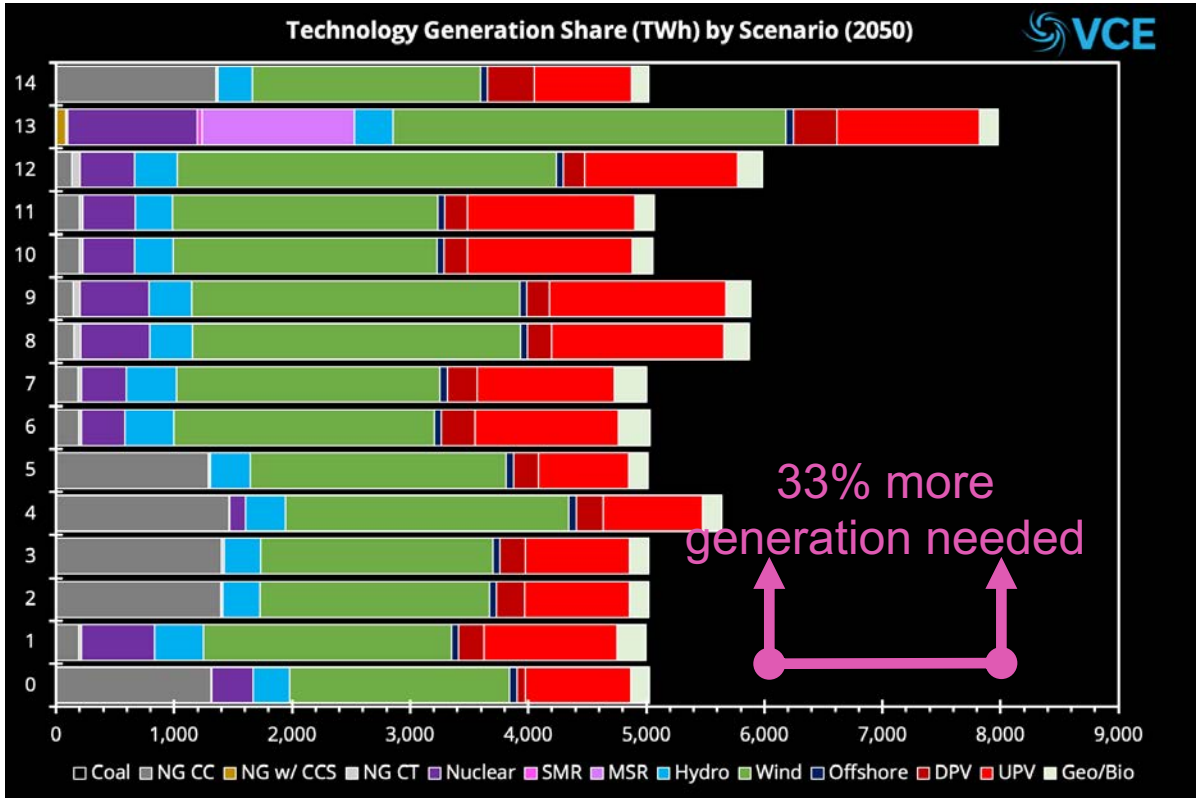
Wind



Solar

WIS:dom-P Results (How it all manifests)





Thank You

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