Integration of Generation, Transmission, Distribution, & Load

Breakthrough Energy/ESIG/GPST Integrated Planning Workshop

ESIG 2024 Fall Technical Workshop

Providence, Rhode Island

Dr Christopher T M Clack, Vice President

integrated Energy Systems Planning

October 21st, 2024

Pattern

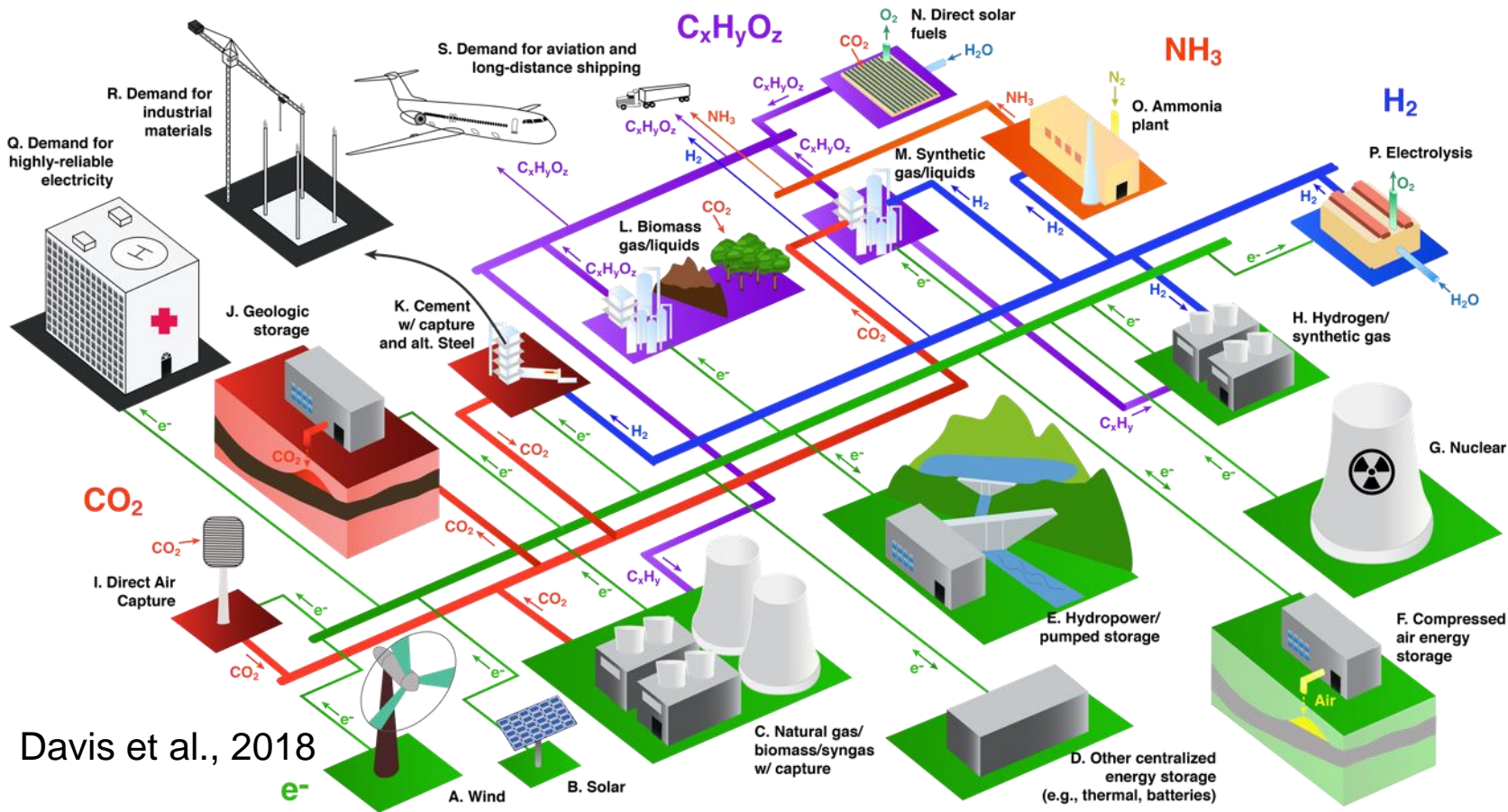**ESIG**
ENERGY SYSTEMS
INTEGRATION GROUP

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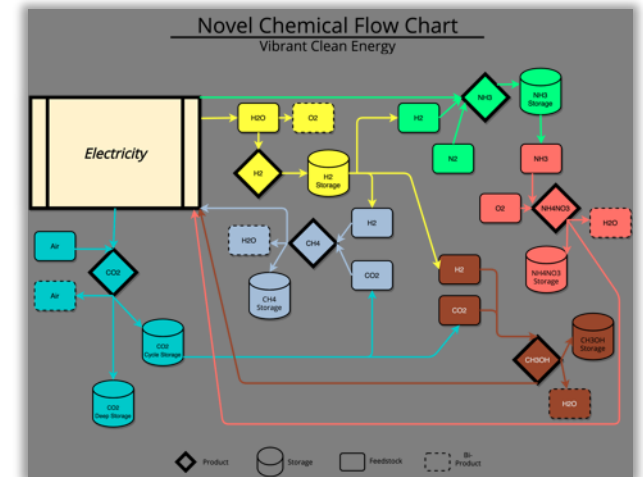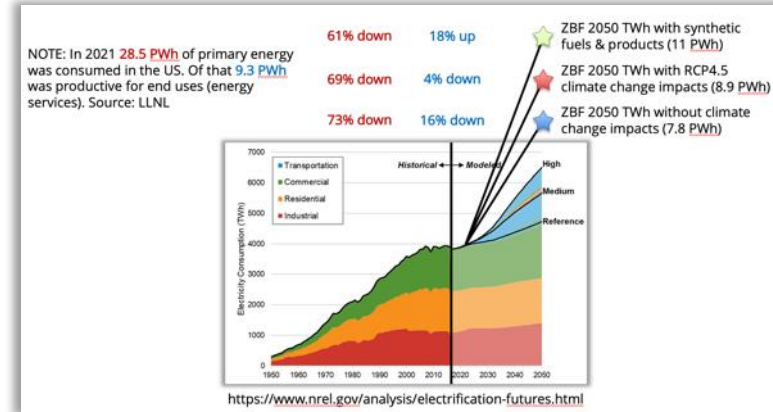
Headquartered in the United States, Pattern has a global portfolio of more than 35 power facilities and transmission assets, serving various customers that provide low-cost clean energy to millions of consumers.

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 is a combined capacity expansion and production cost models. It combines:

- ✓ Continental-scale, spatially-determined co-optimization of transmission, generation and storage expansion while simultaneously determining the dispatch of these sub systems up to 3-km, 5-minutely resolution (most modeling performed at county-level & hourly for long-term planning);

- ✓ 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;
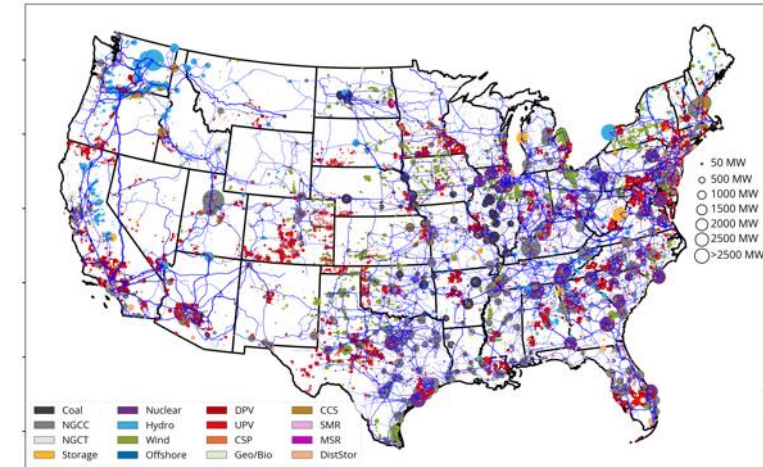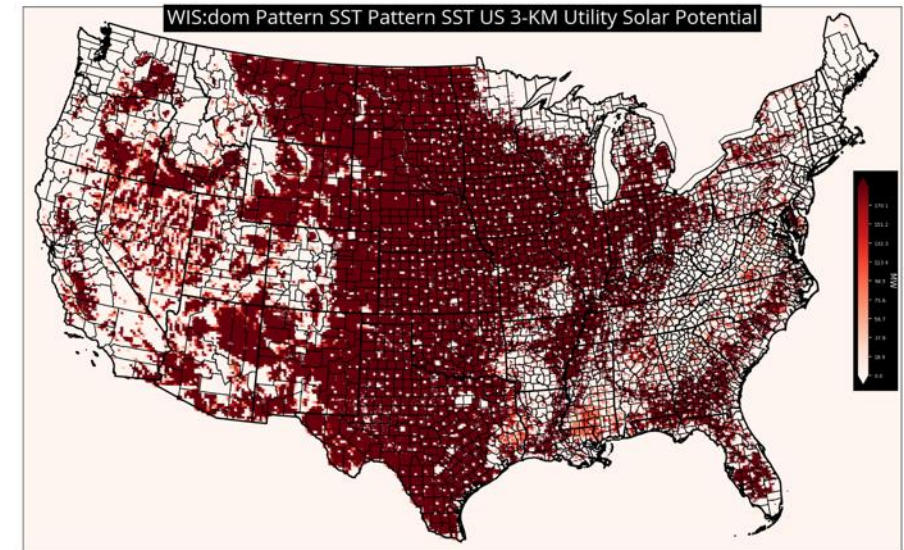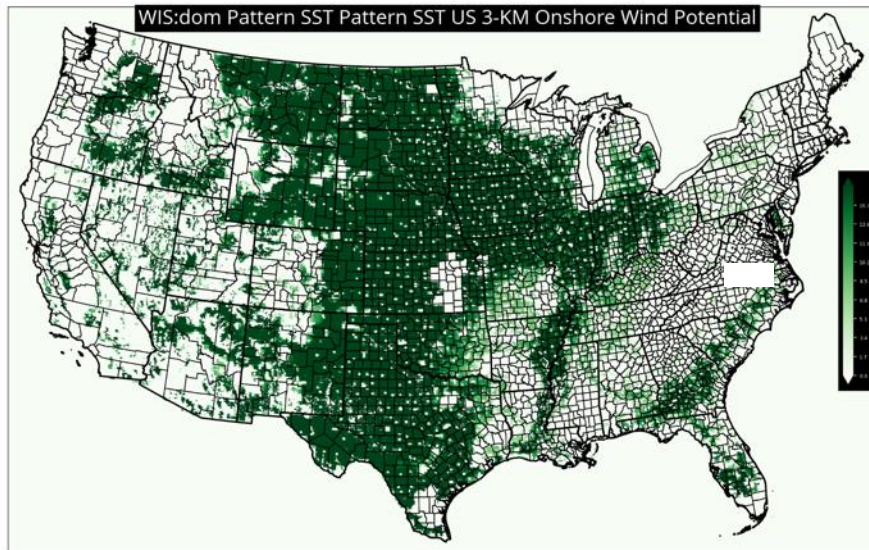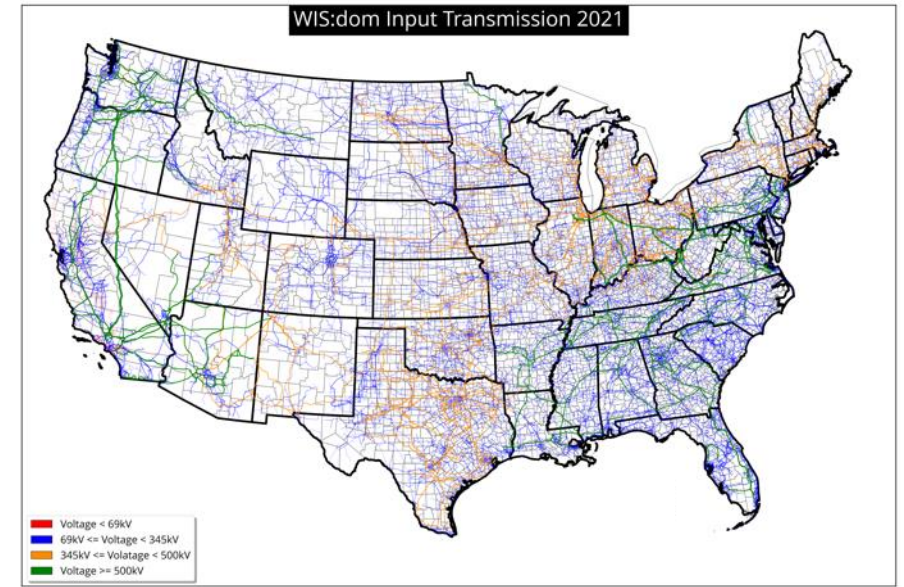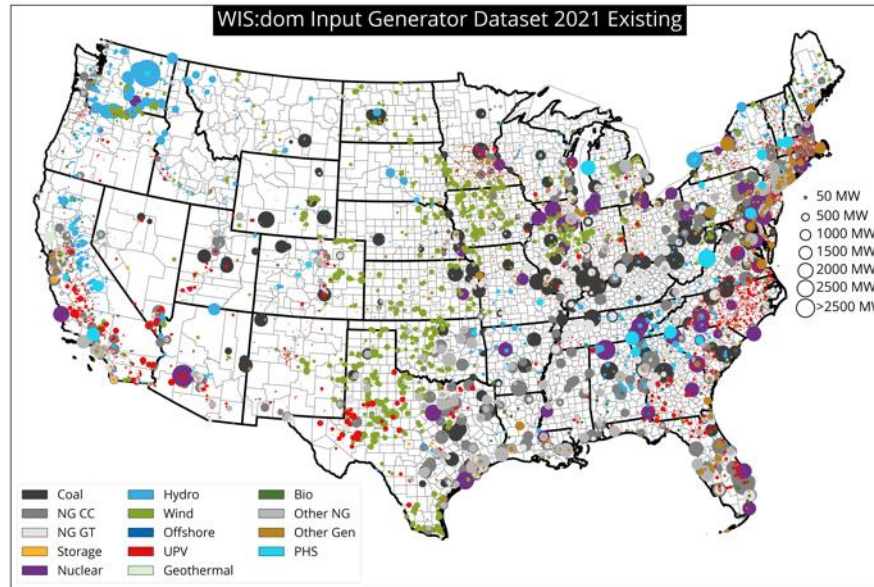
Datasets

Generators

Transmission

Buildable Areas
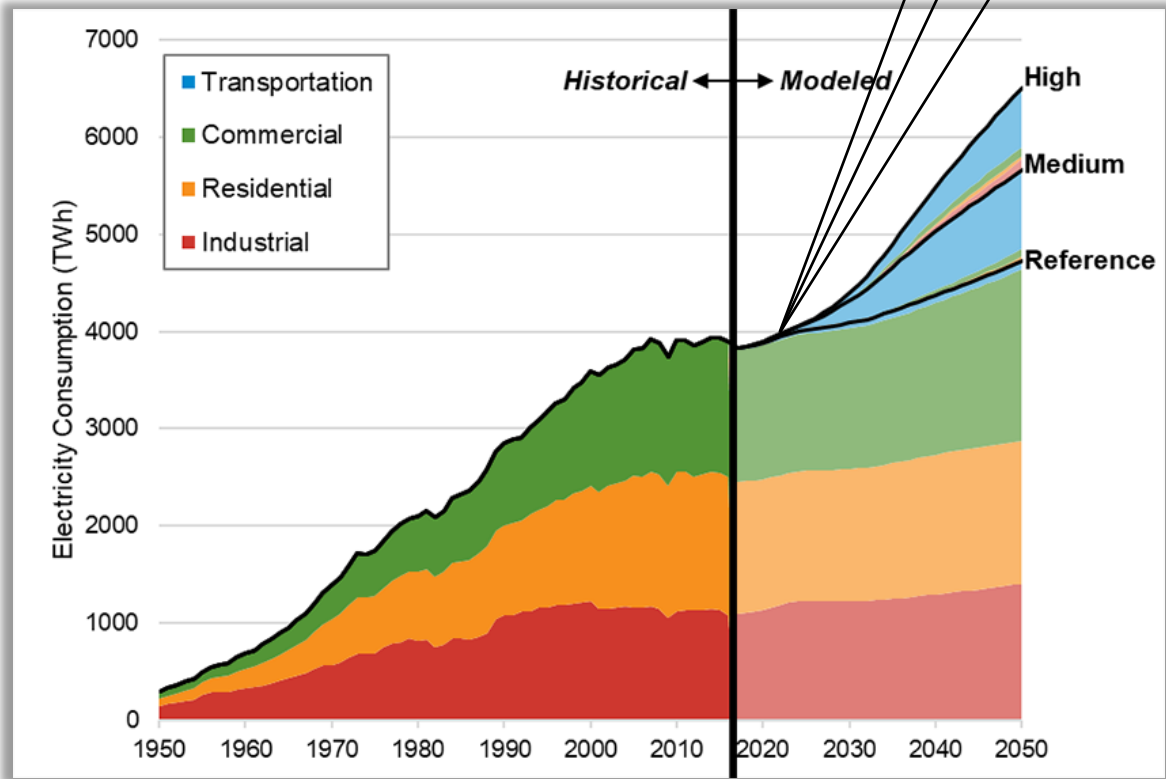
Demands

Climate Change

Electrification will drive electricity demand up

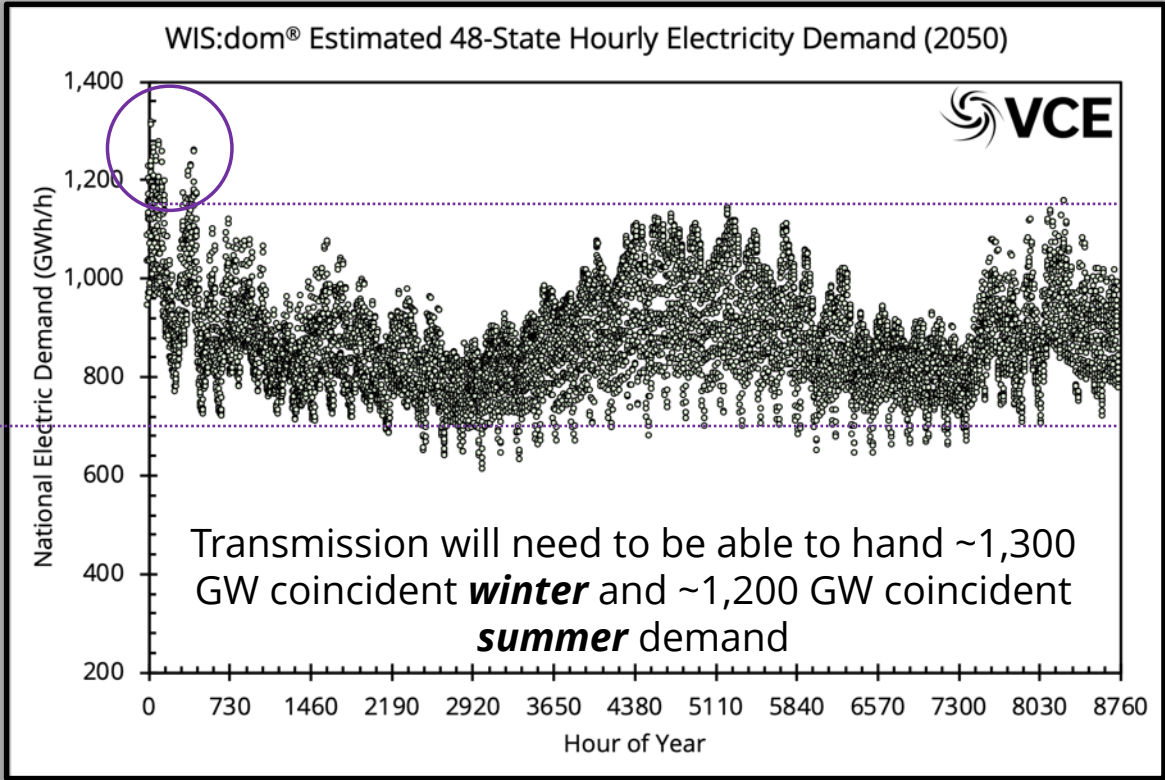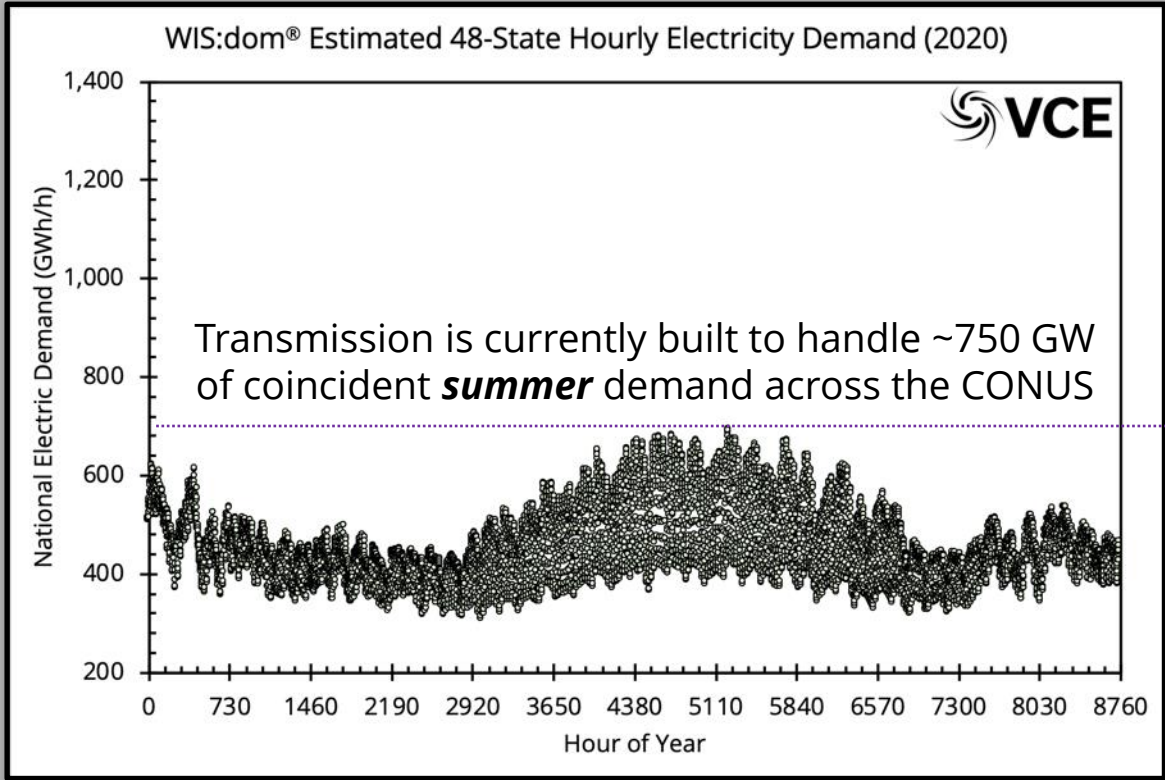NOTE: In 2021 **28.5 PWh** of primary energy was consumed in the US. Of that **9.3 PWh** was productive for end uses (energy services).
Source: LLNL

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

But weather will increasingly shape that demand

WIS:dom® Estimated 48-State Hourly Electricity Demand (2020)

Transmission is currently built to handle ~750 GW of coincident **summer** demand across the CONUS

WIS:dom® Estimated 48-State Hourly Electricity Demand (2050)

Transmission will need to be able to hand ~1,300 GW coincident **winter** and ~1,200 GW coincident **summer** demand

* Before considering synthetic fuel production

Transmission ratings & Heat rates are weather-driven

Transmission Ratings
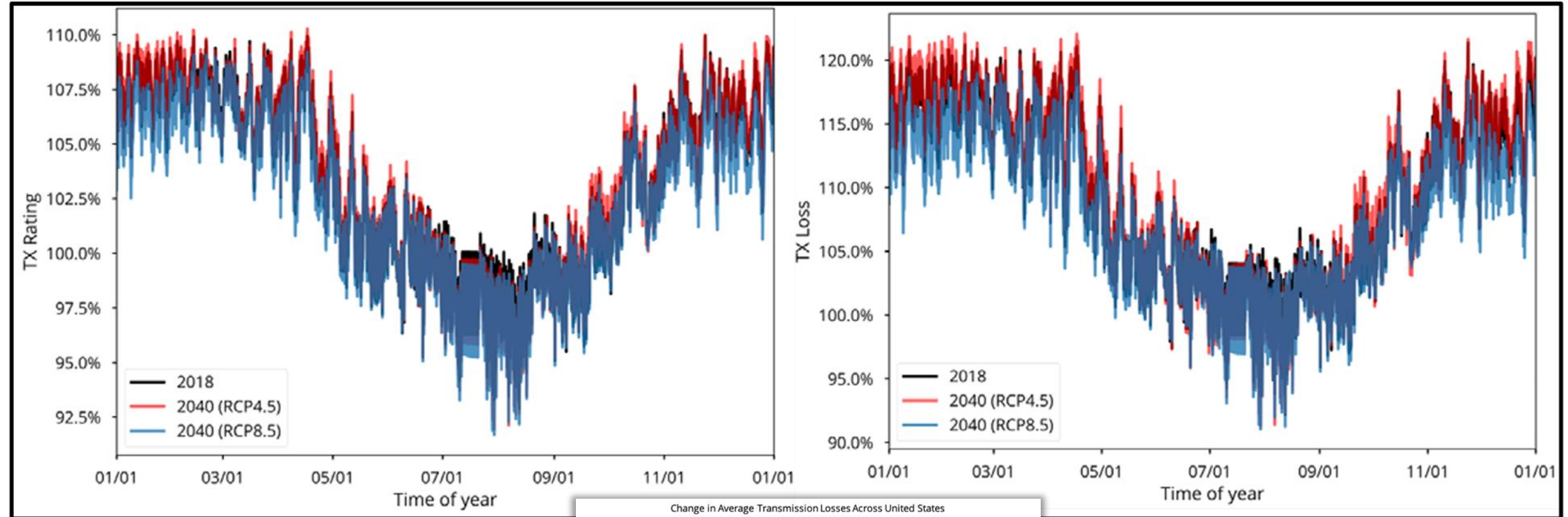
Transmission Losses

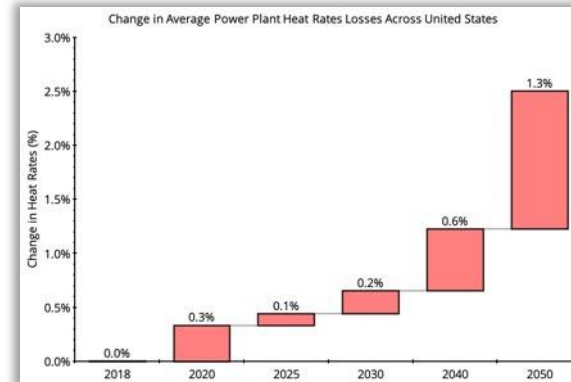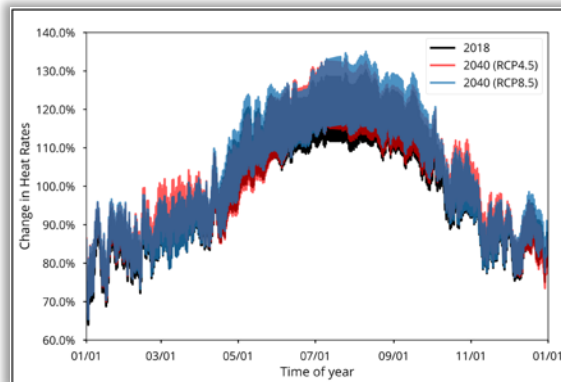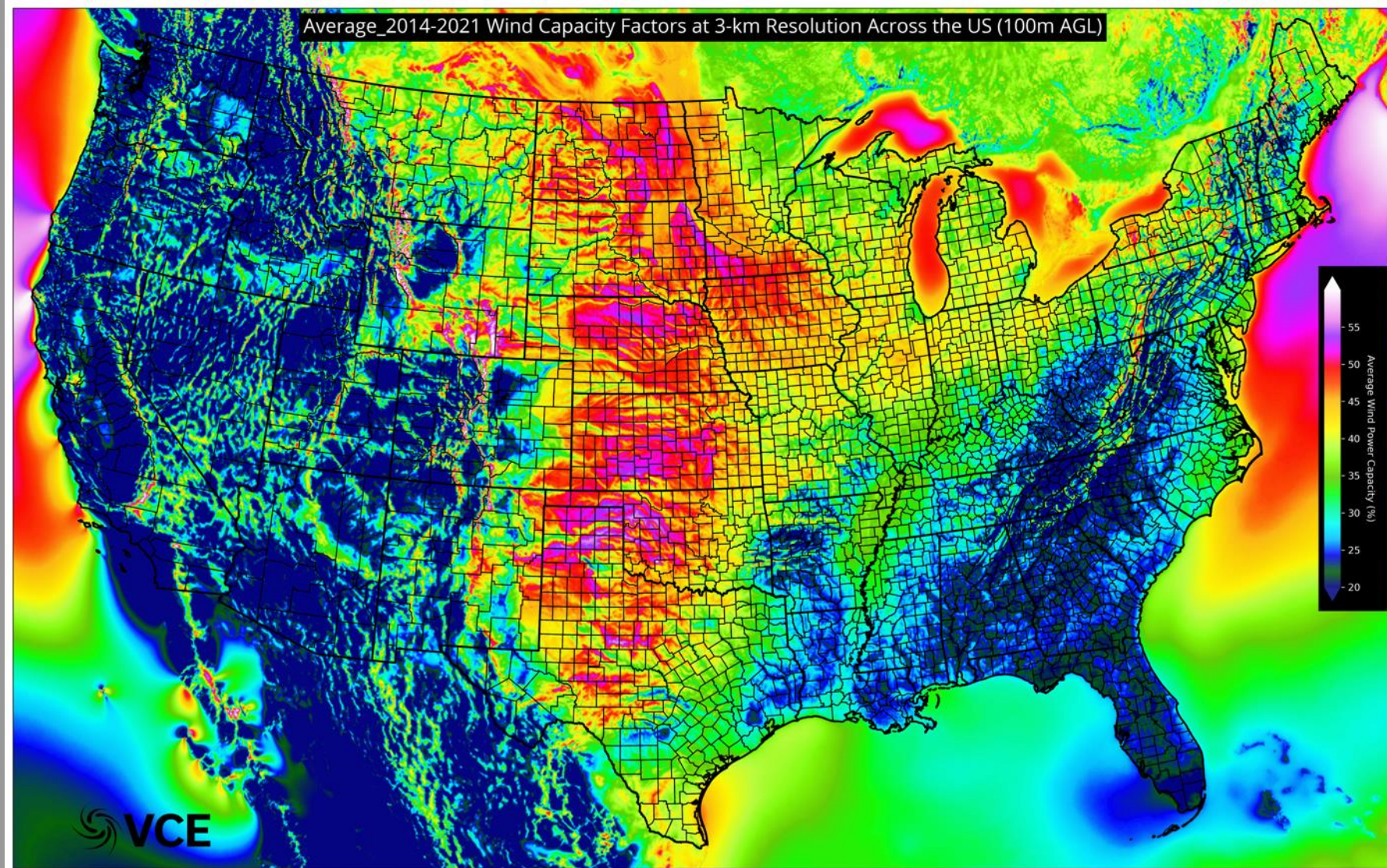*Psst… it appears that climate change makes heat rates & transmission availability worse…*
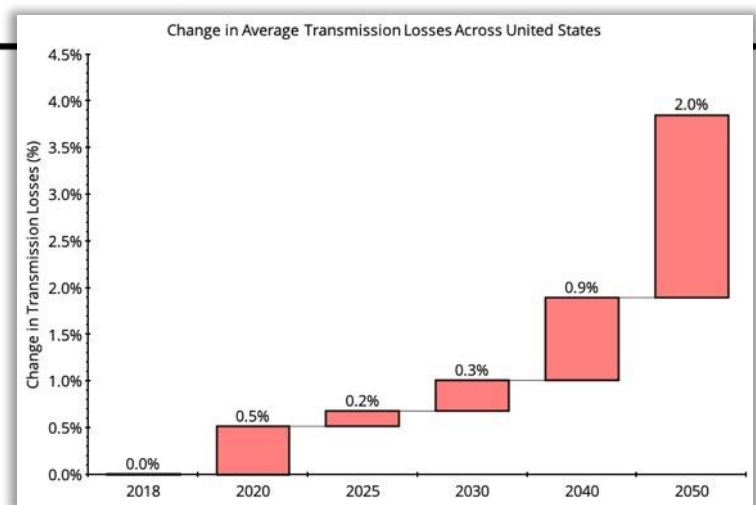
Transmission ratings & Heat rates are weather-driven
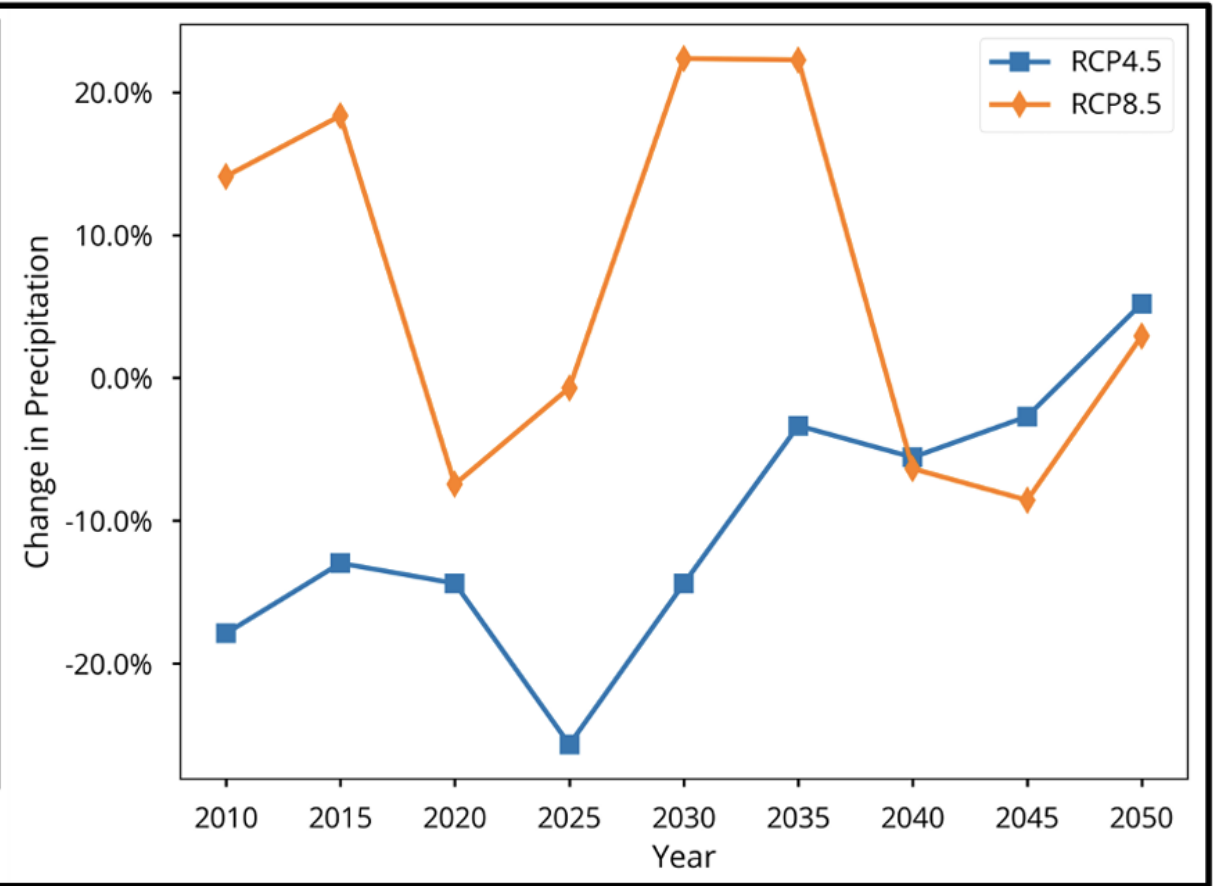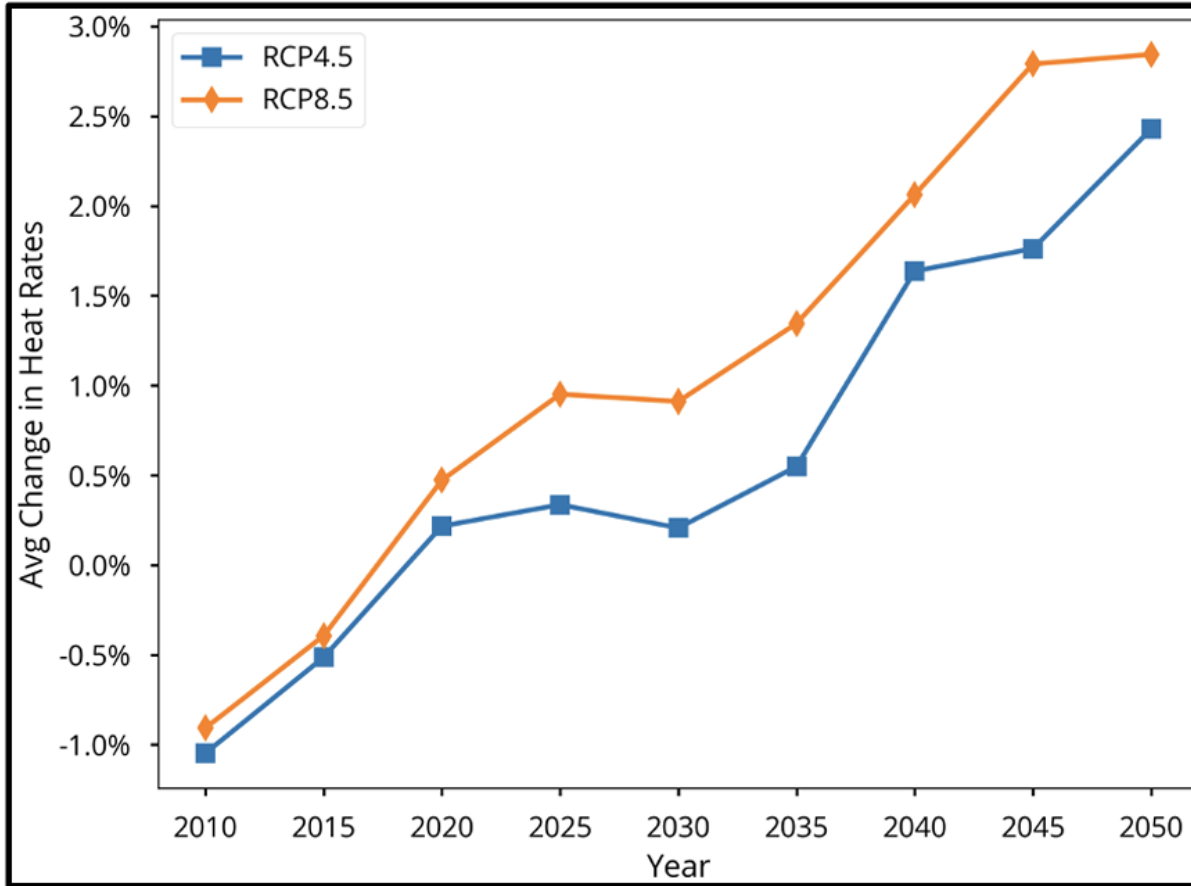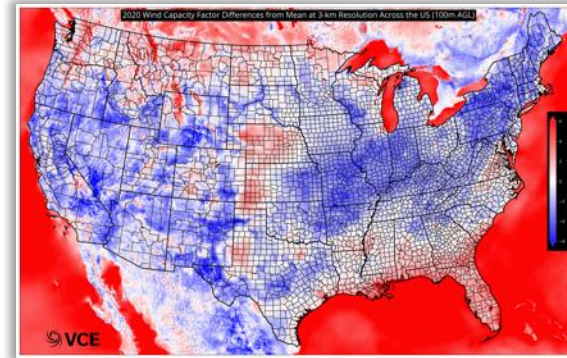

Heat Rates

Water Availability

Weather will drive our electricity supply (Wind)

Average_2014-2021 Wind Capacity Factors at 3-km Resolution Across the US (100m AGL)
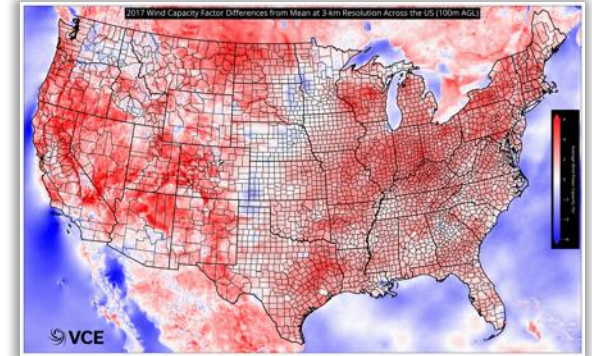
Weather will drive our electricity supply (Solar PV)

Average_2014-2021 Solar Capacity Factors at 3-km Resolution Across the US (Axis1)

DC Capacity Factors
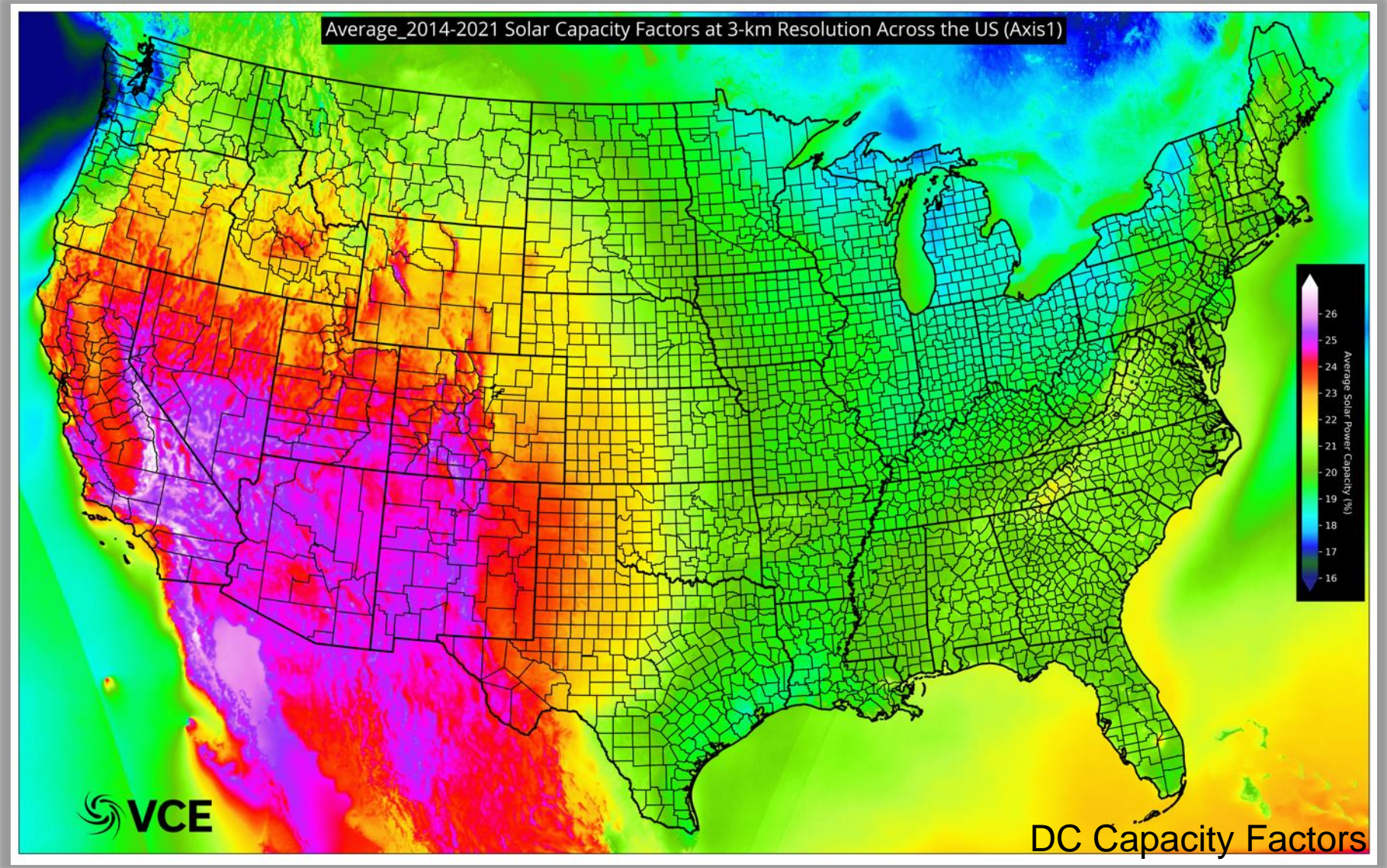
Inter-annual variability needs to be considered
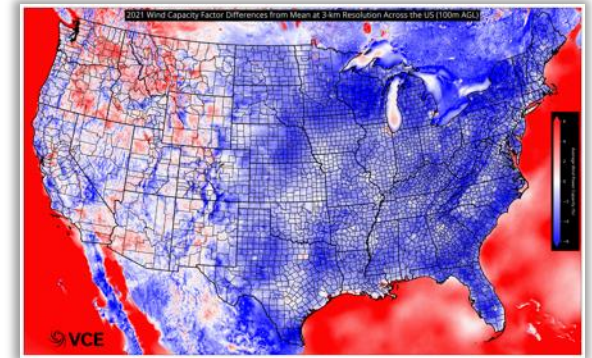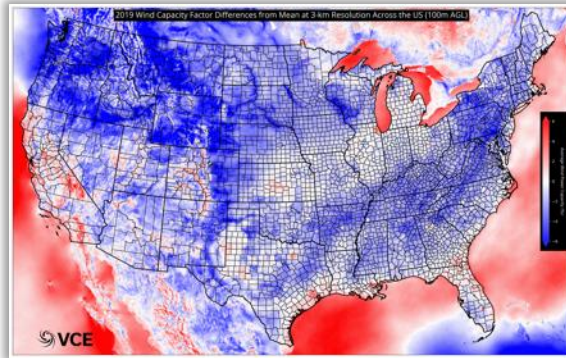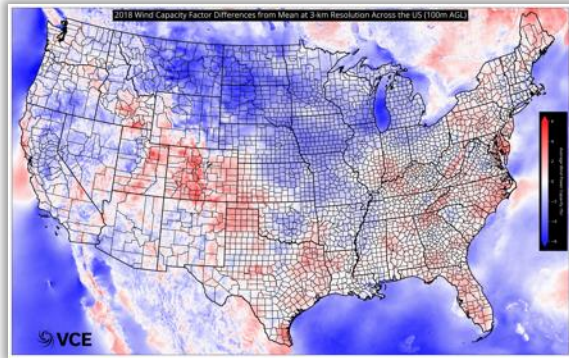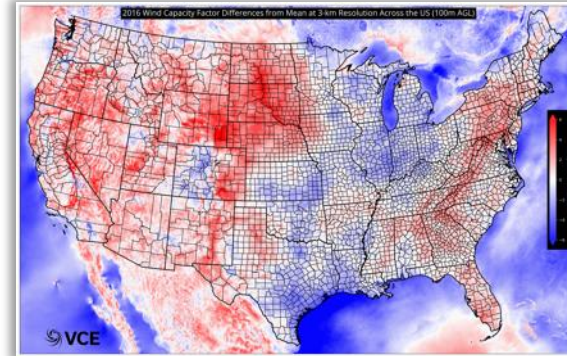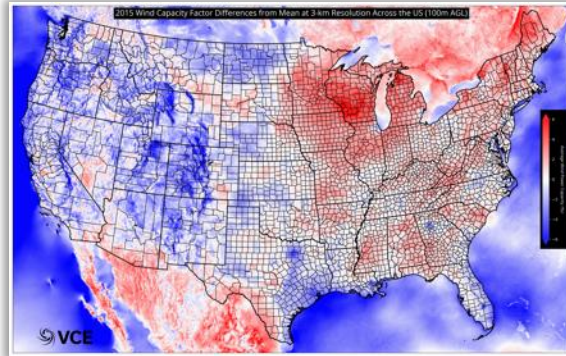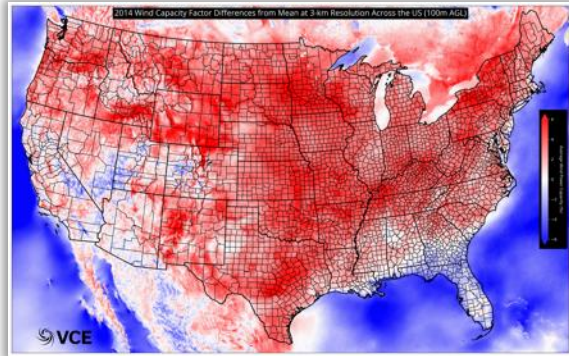
VCE, Catalyst & GridLab release open-source dataset

Introducing the Resource Adequacy Renewable Energy (**RARE**) Power Dataset

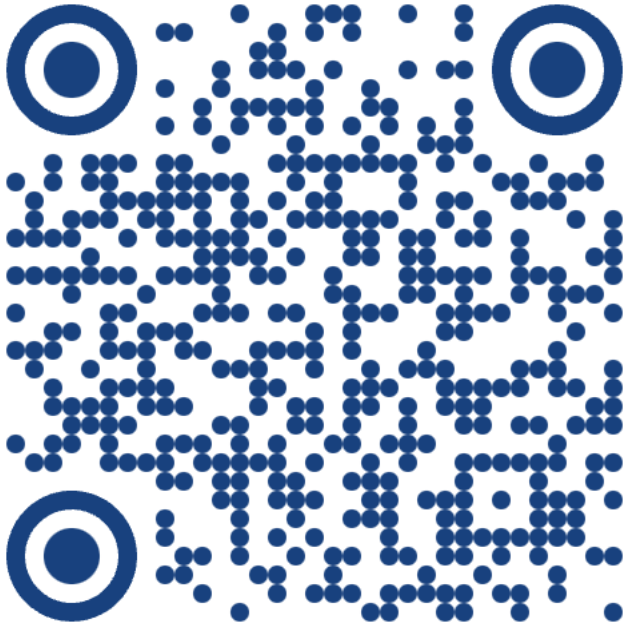First release is 2019 through 2023 hourly, county-granularity wind and solar PV capacity factors.
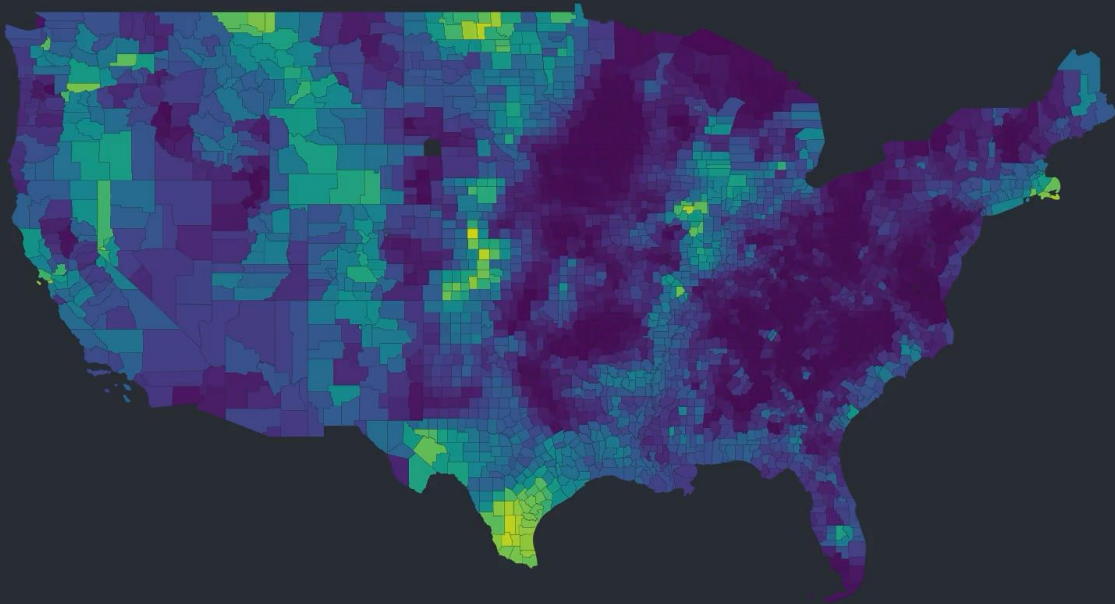
Second release in Q1 2025 will include 2014 through 2018. Annual releases while the HRRR remains operational at NOAA.

Use the QR code to get straight to the raw csv files
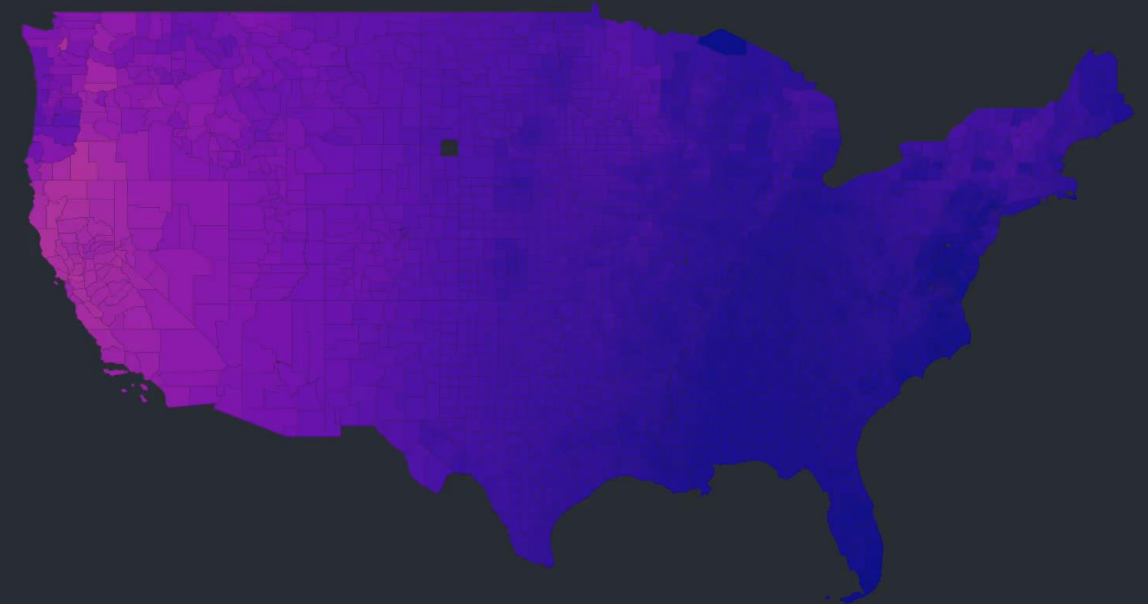
Please visit Catalyst Cooperative to download an exquisitely curated database of the data

VCE, Catalyst & GridLab release open-source dataset

Capacity Factor Onshore Wind 2020-06-21 00:00:00 UTC

Capacity Factor Solar Pv 2020-06-21 00:00:00 UTC
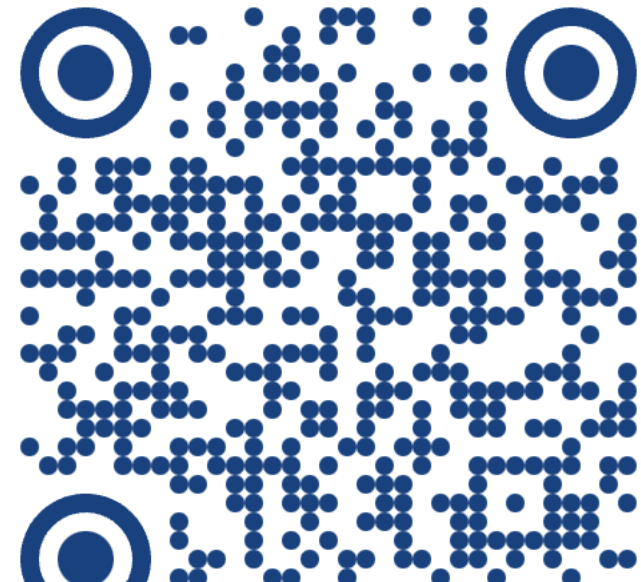
Thank You

Dr Christopher T M Clack
Vice President, integrated Energy Systems Planning,
Fundamentals & New Markets, Pattern Energy
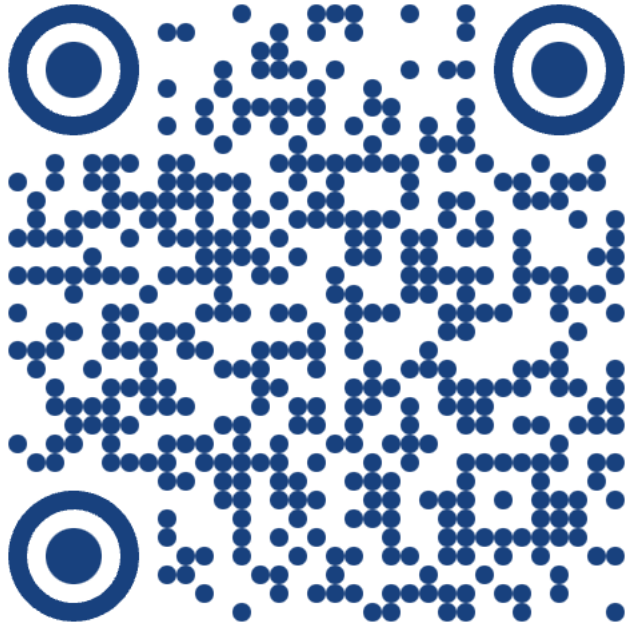
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Twitter: @DrChrisClack

More Download Options for the RARE Power Dataset

The Resource Adequacy Renewable Energy (**RARE**) Power Dataset

- Zenodo archive of the input data (CSVs)
  https://doi.org/10.5281/zenodo.13937522
- Zenodo archive of PUDL v2024.10.0, the first release containing VCE RARE (as Parquet):
  https://doi.org/10.5281/zenodo.13957372
- Jupyter notebook on Kaggle with some examples of accessing the Parquet data:
  https://www.kaggle.com/code/catalystcooperative/04-renewable-generation-profiles
- VCE RARE data source documentation page in the PUDL docs:
  https://catalystcoop-pudl.readthedocs.io/en/nightly/data_sources/vcerare.html
- General PUDL data access instructions:
  https://catalystcoop-pudl.readthedocs.io/en/nightly/data_access.html
- Direct HTTPS download link for the (1.5GB) VCE RARE Parquet output:
  https://s3.us-west-2.amazonaws.com/pudl.catalyst.coop/v2024.10.0/out_vcerare__hourly_available_capacity_factor.parquet
- PUDL in the AWS Open Data Registry, for those comfortable with cloud storage:
  https://registry.opendata.aws/catalyst-cooperative-pudl/