GTS&D Co-optimization

System Expansion Modeling

ESIG Integrated Planning Workshop

Virtual

Dr Christopher T M Clack, Vice President

integrated Energy Systems Planning

November 18th, 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.

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.

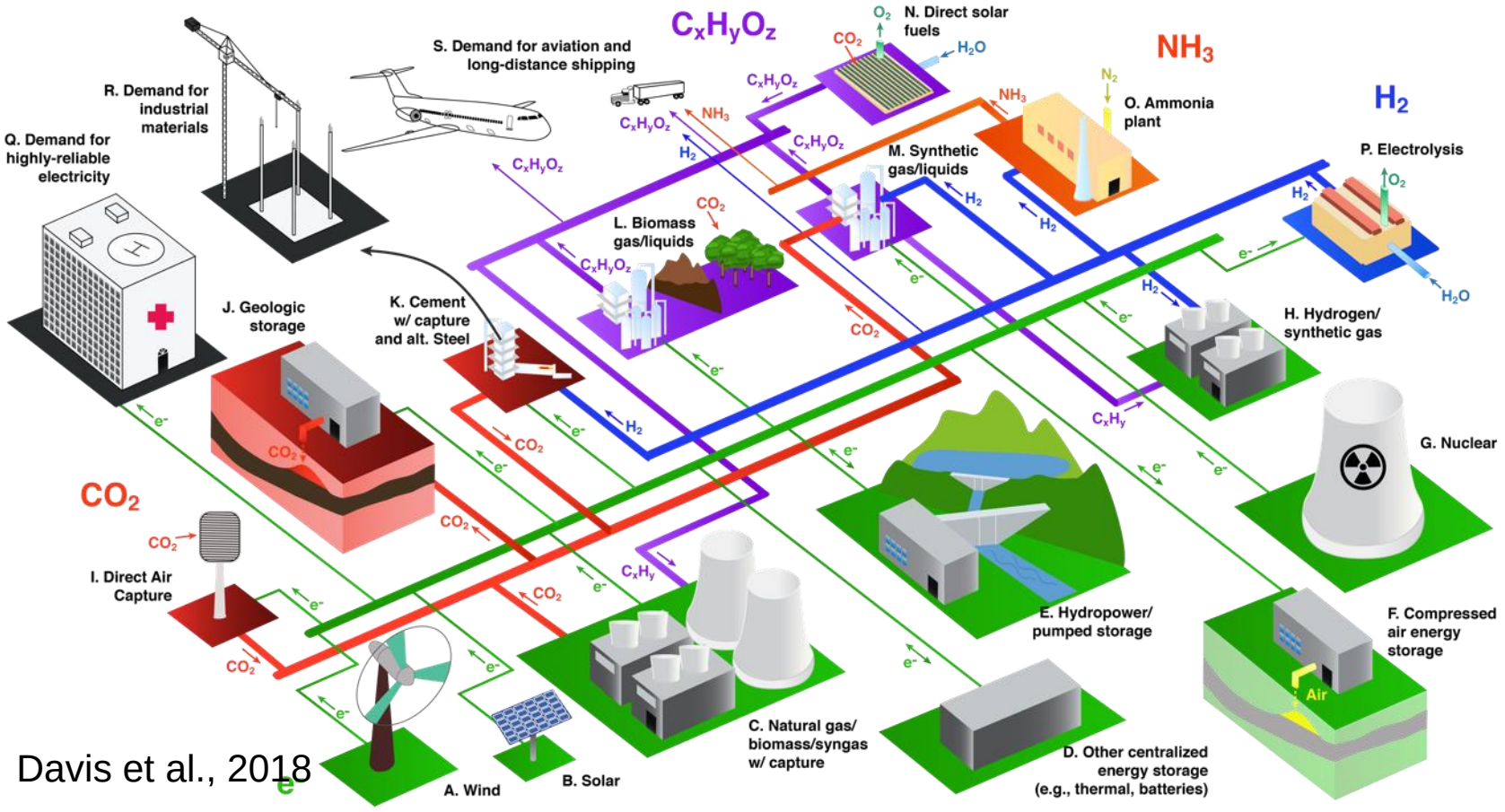
Second release in Q1 2025 will include 2014 through 2018. Annual releases while the HRRR remains operational at NOAA.

Use the QR code to get straight to the raw csv files

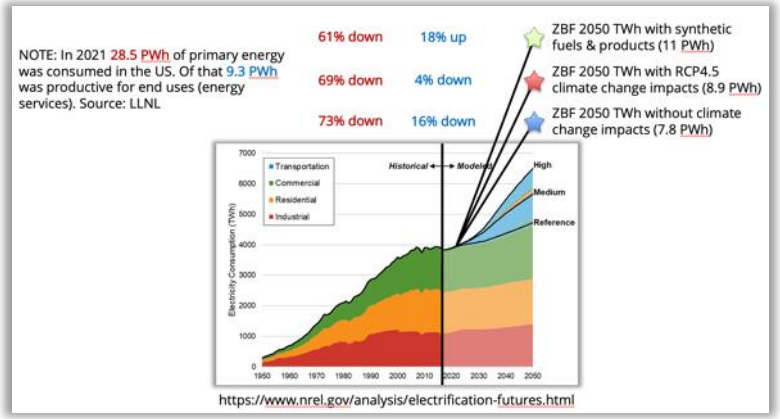
Please visit Catalyst Cooperative to download an exquisitely curated database of the data

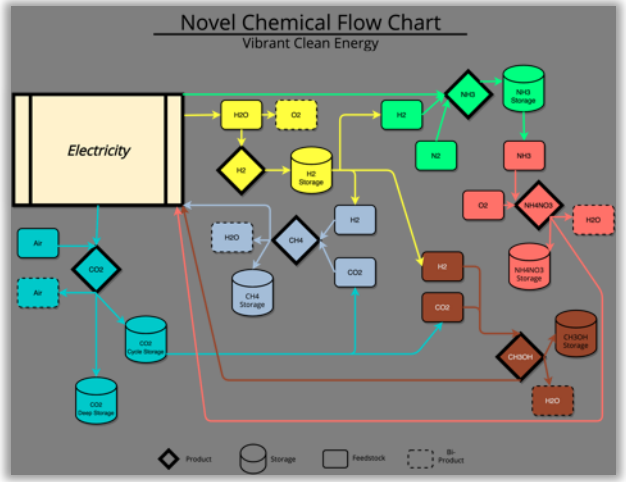
Weather-Informed energy Systems:

for design, operations & markets



Davis et al., 2018



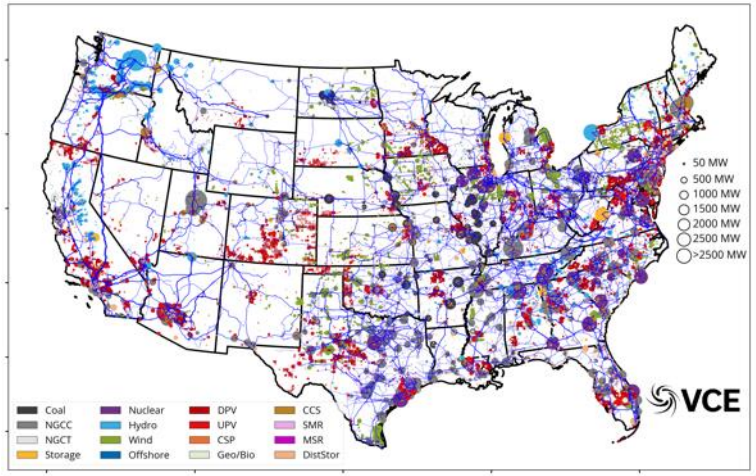


The modeling is designed to encompass as much of the energy economy as possible

WIS:dom-P (Planning)

WIS:dom®-P is a ***combined*** capacity expansion and production cost model.

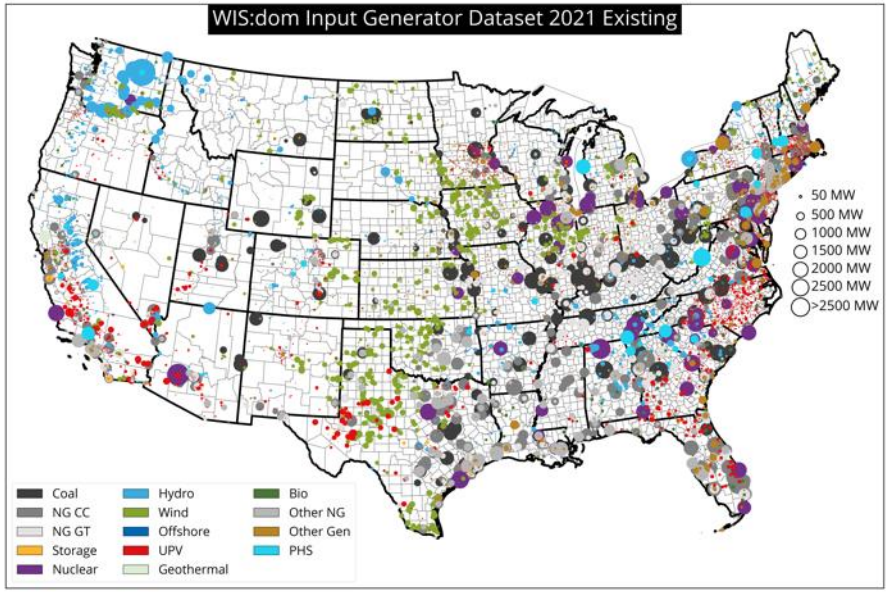
- ***Capacity expansion includes:***
  - ✓ Continental-scale & spatially-determined;
  - ✓ Co-optimization of generation, transmission, storage and distributed resources;
  - ✓ Myopically perform investment periods from 2020 through 2050 (annually);
  - ✓ Transmission can be explicitly resolved at each 69-kV substation;
  - ✓ Generation siting can be explicitly resolved at 3-km spatial resolution;
  - ✓ Existing policies, restrictions and incentives;
  - ✓ Detailed land-use screening for siting of technologies;
  - ✓ Future cost projections for technologies and fuels;
  - ✓ Detail accounting for retirement of generation assets;
  - ✓ Can includes climate change data from CMIP-5 for possible future drivers of infrastructure stress;
  - ✓ **STANDARD MODEL GRANULARITY FOR LONG TERM STUDIES IS COUNTY-LEVEL.**

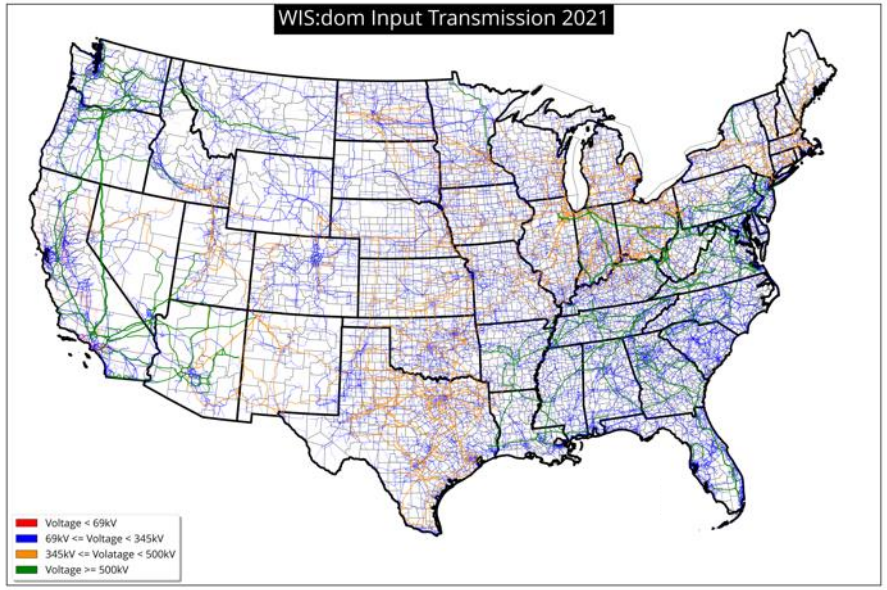


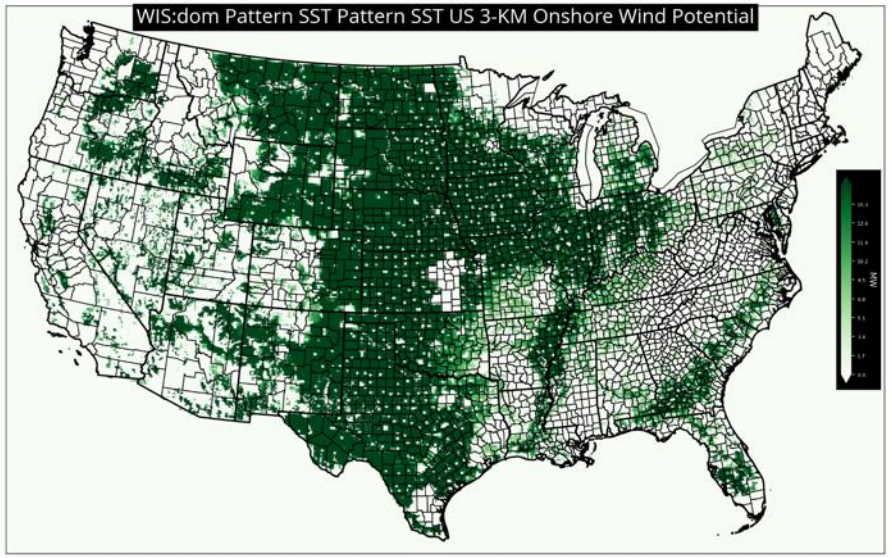
- ***Production cost includes:***
  - ✓ Unit commitment;
  - ✓ Start-up & shutdown profiles of generators;
  - ✓ Ramp constraints, minimum up and minimum down times;
  - ✓ Transmission power flow, transmission dynamic line ratings, and transmission line losses;
  - ✓ Planning reserve margins and operating reserves, with detailed VRE accounting;
  - ✓ **Distribution planning & hybrid optimization of the grid edge;**
  - ✓ Weather forecasting and physics of weather engines for resources and demands;
  - ✓ Up to 5-minutely temporal granularity (**STANDARD FOR LONG TERM STUDIES IS HOURLY-LEVEL**);
  - ✓ Zero loss of load at any time or location;
  - ✓ Detailed energy storage dispatch subroutines for arbitrage & transmission asset configurations;
  - ✓ **Demand flexibility modeling based on granular weather drivers;**
  - ✓ Novel technology inclusion and integration (SMR, MSR, EGS, CCS, DAC, H_2, NH_3, CH_4, P2X);
  - ✓ Existing generator and transmission asset characteristics.

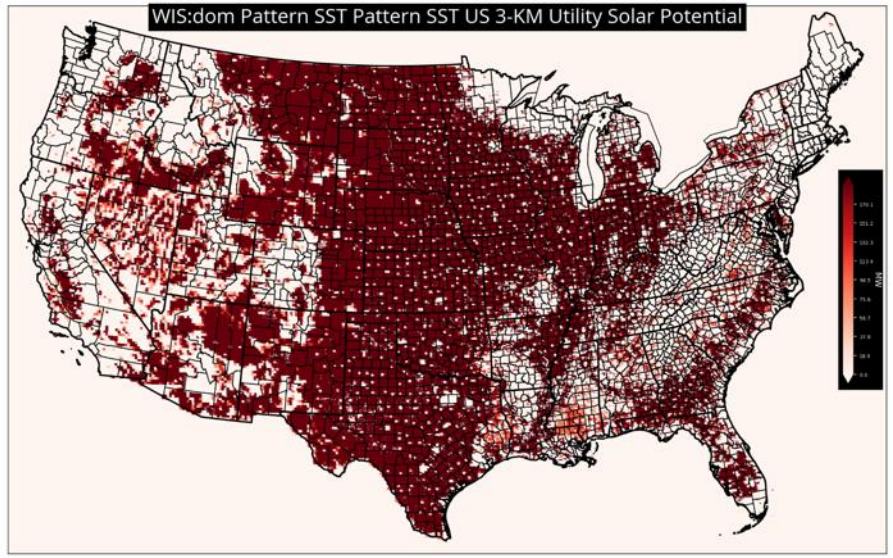
Datasets

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

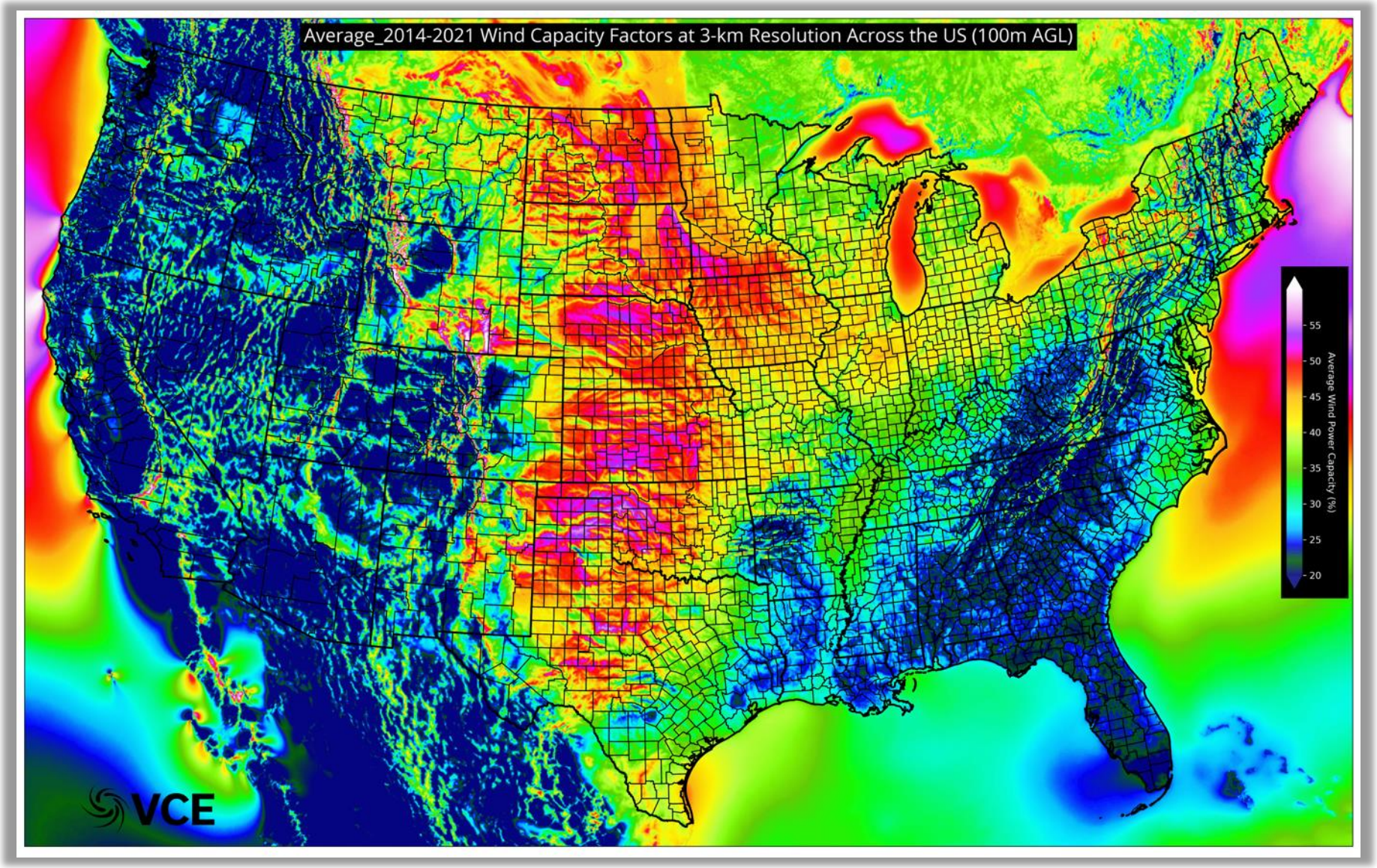




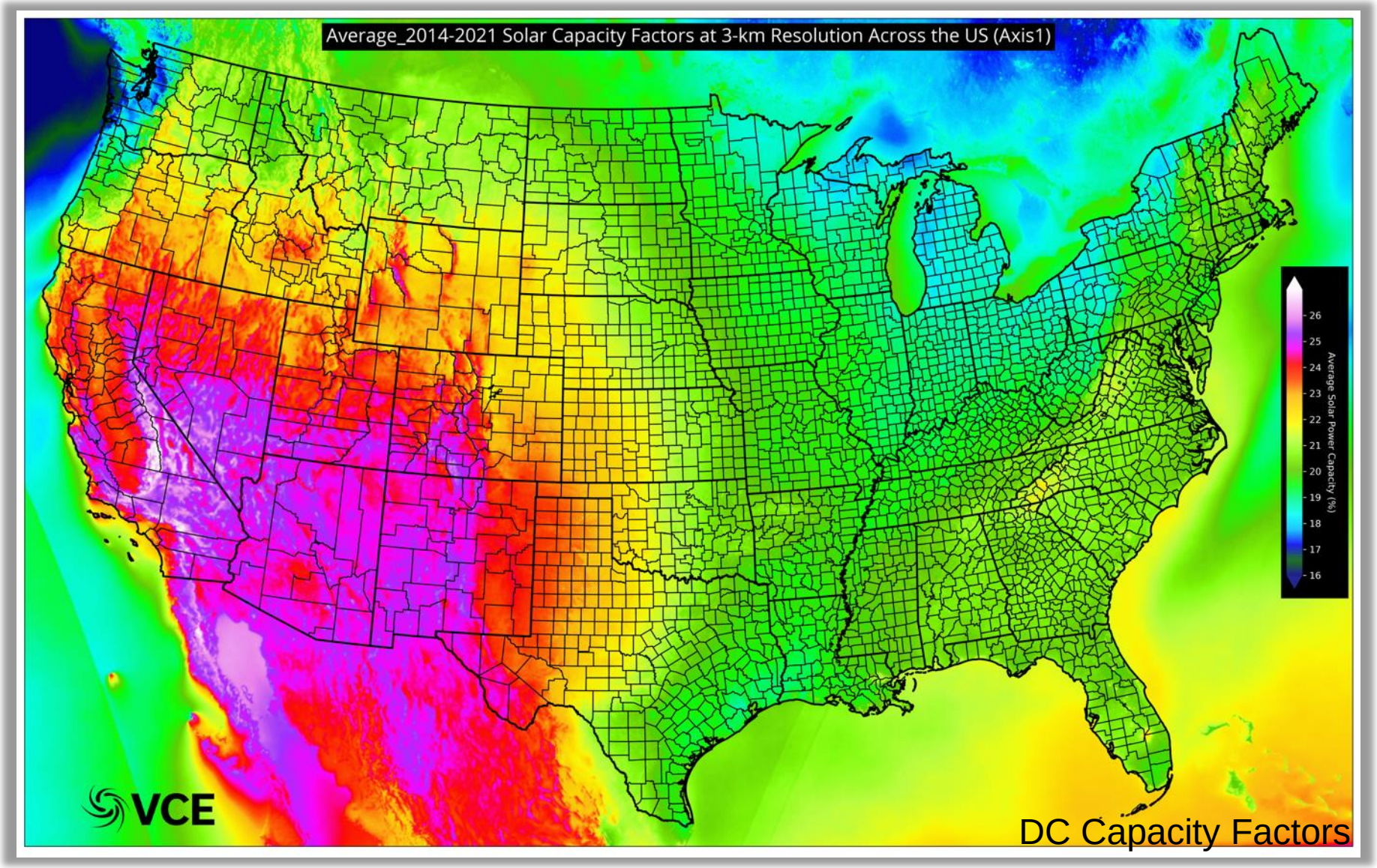




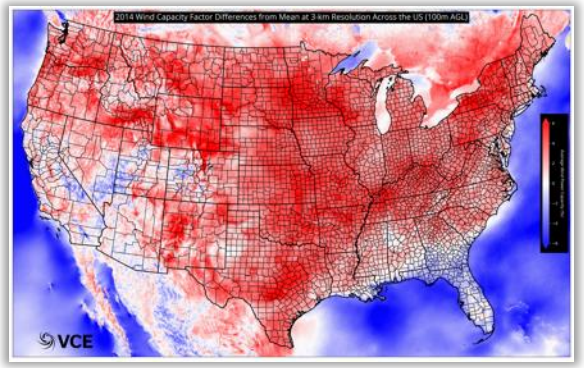
Weather will drive our electricity supply (Wind)

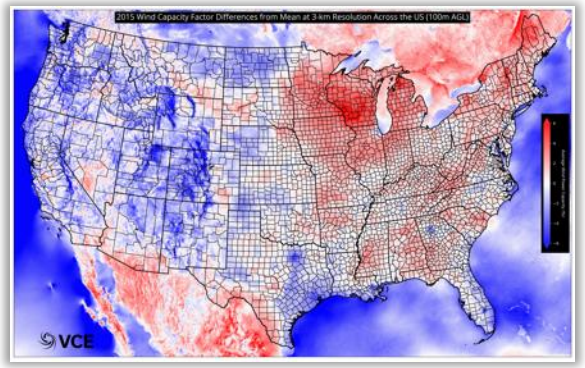


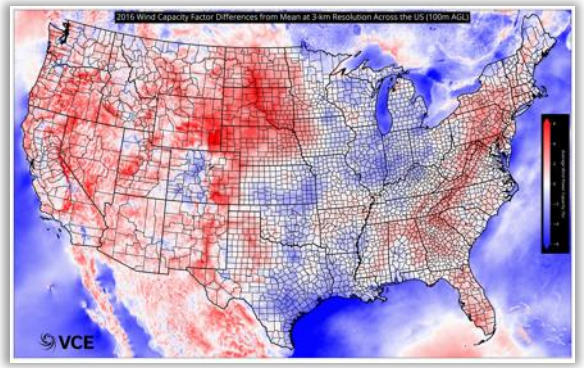
Weather will drive our electricity supply (Solar PV)

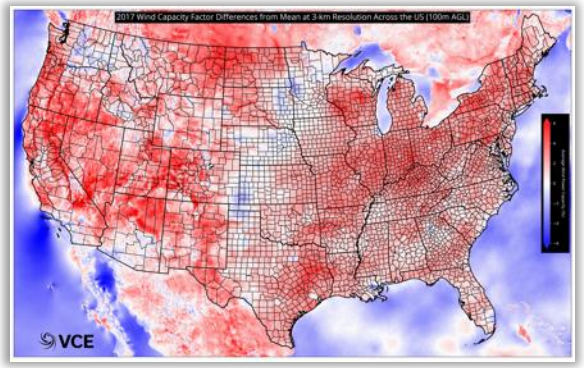


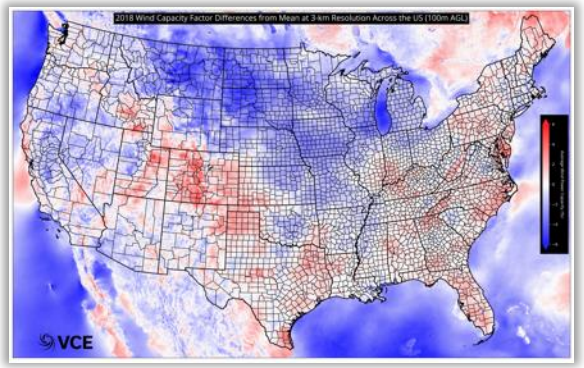
Inter-annual variability needs to be considered

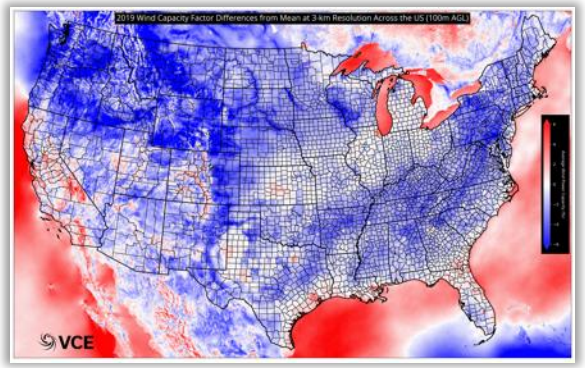


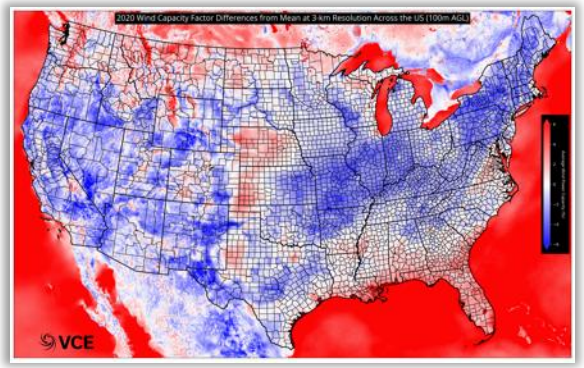


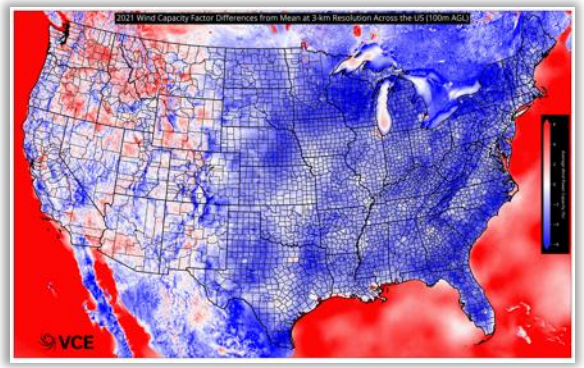




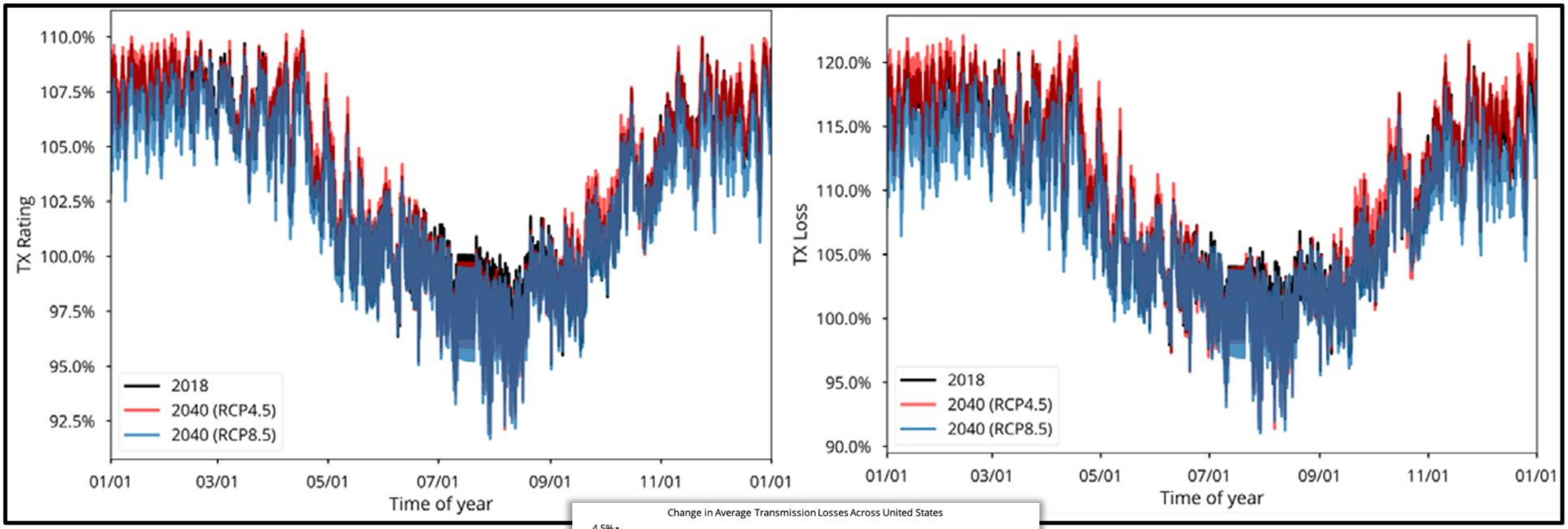






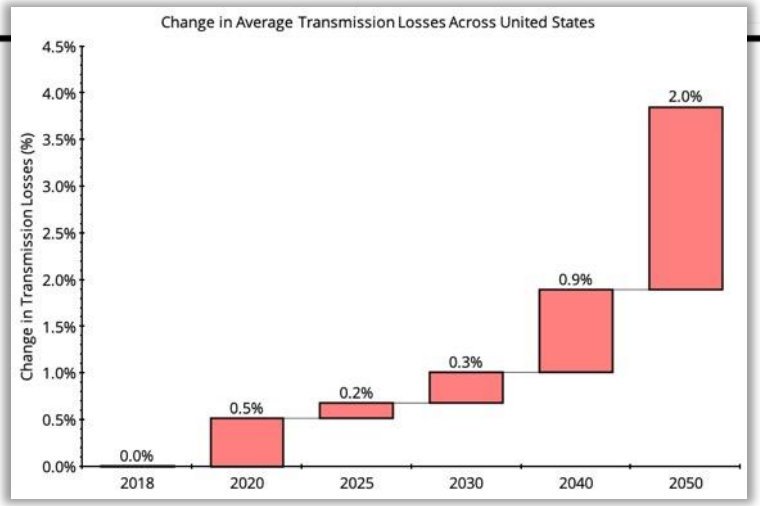


Transmission ratings & Heat rates are weather-driven



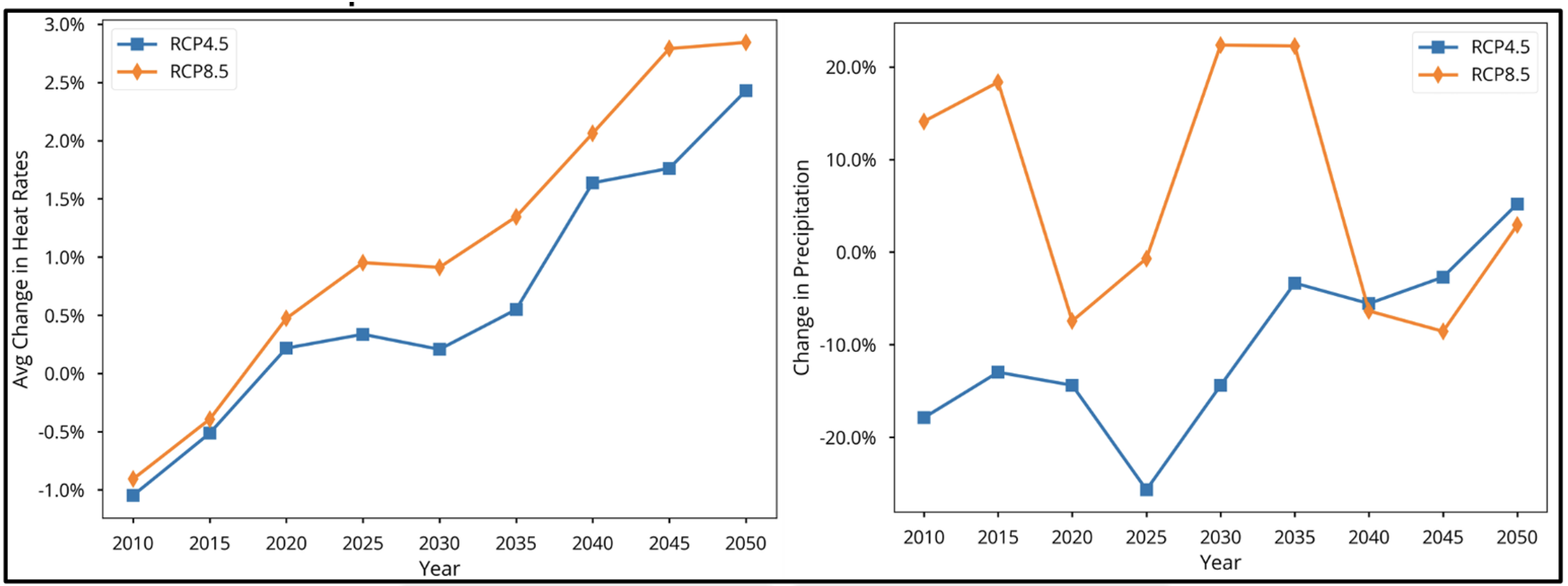
Transmission Ratings

Transmission Losses

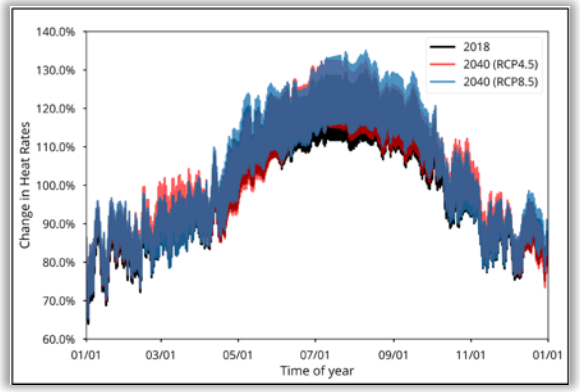


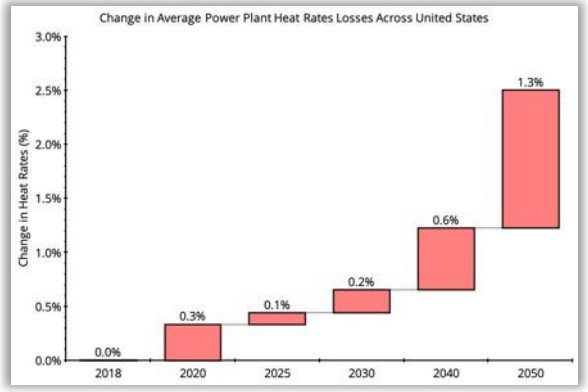
Psst… it appears that climate change makes heat rates & transmission availability worse…

Transmission ratings & Heat rates are weather-driven



Heat Rates

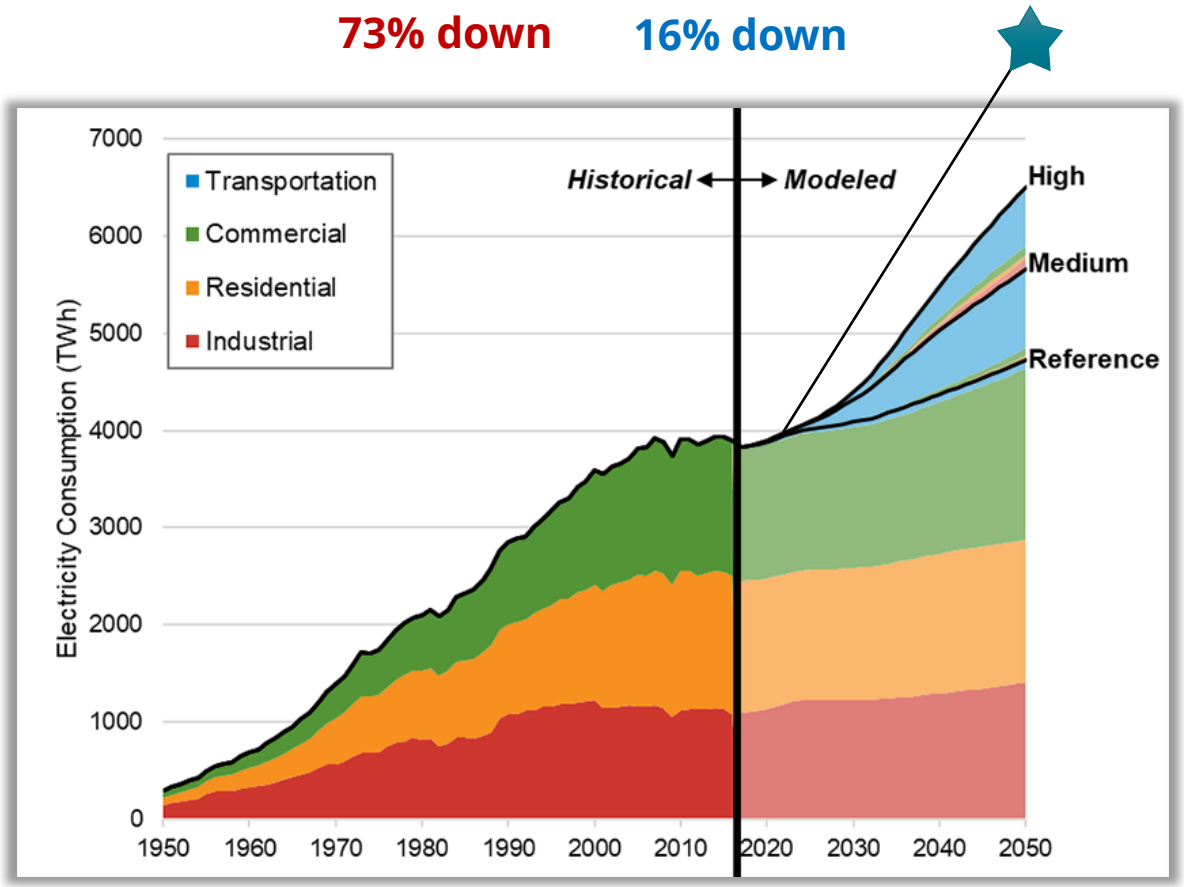




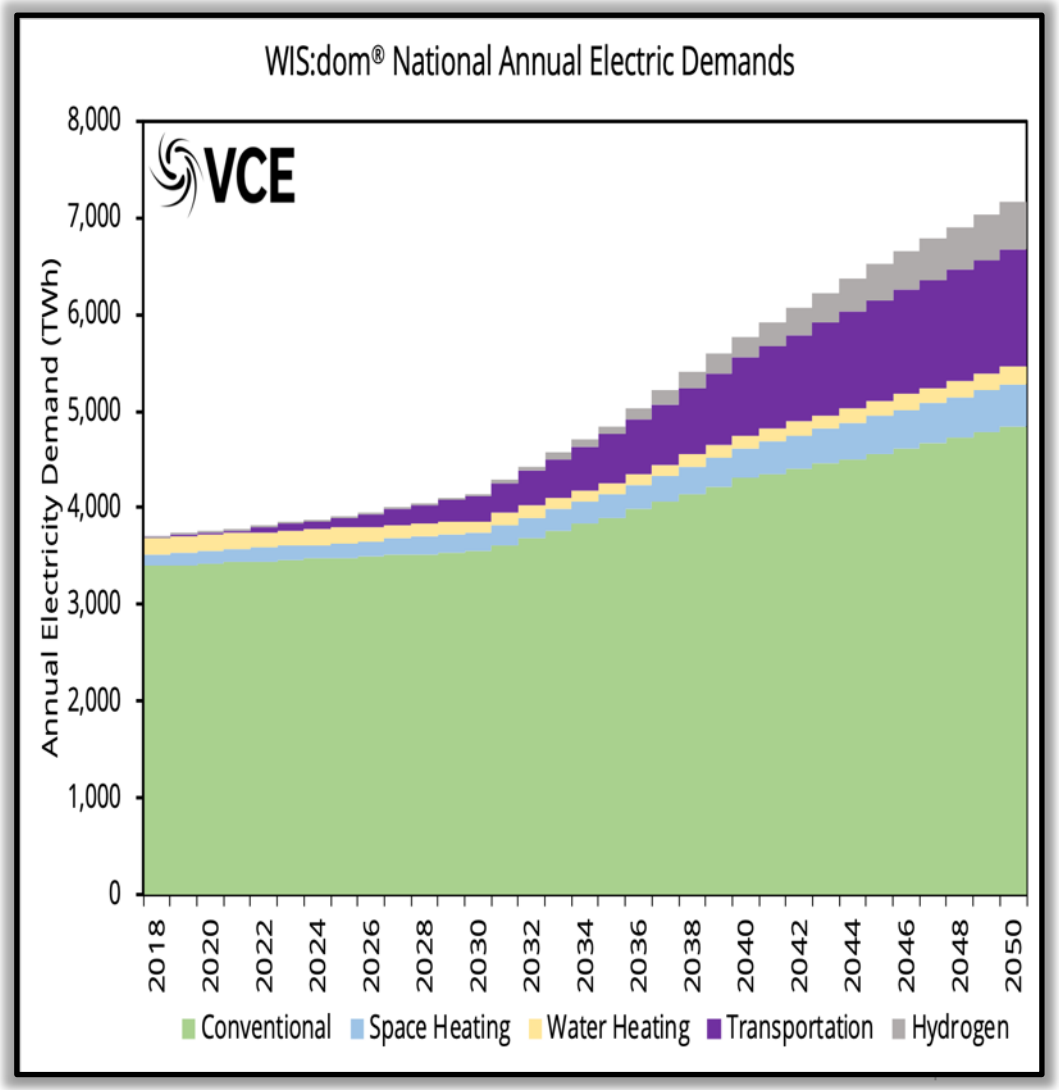
Water Availability

Electrification will drive electricity demand up

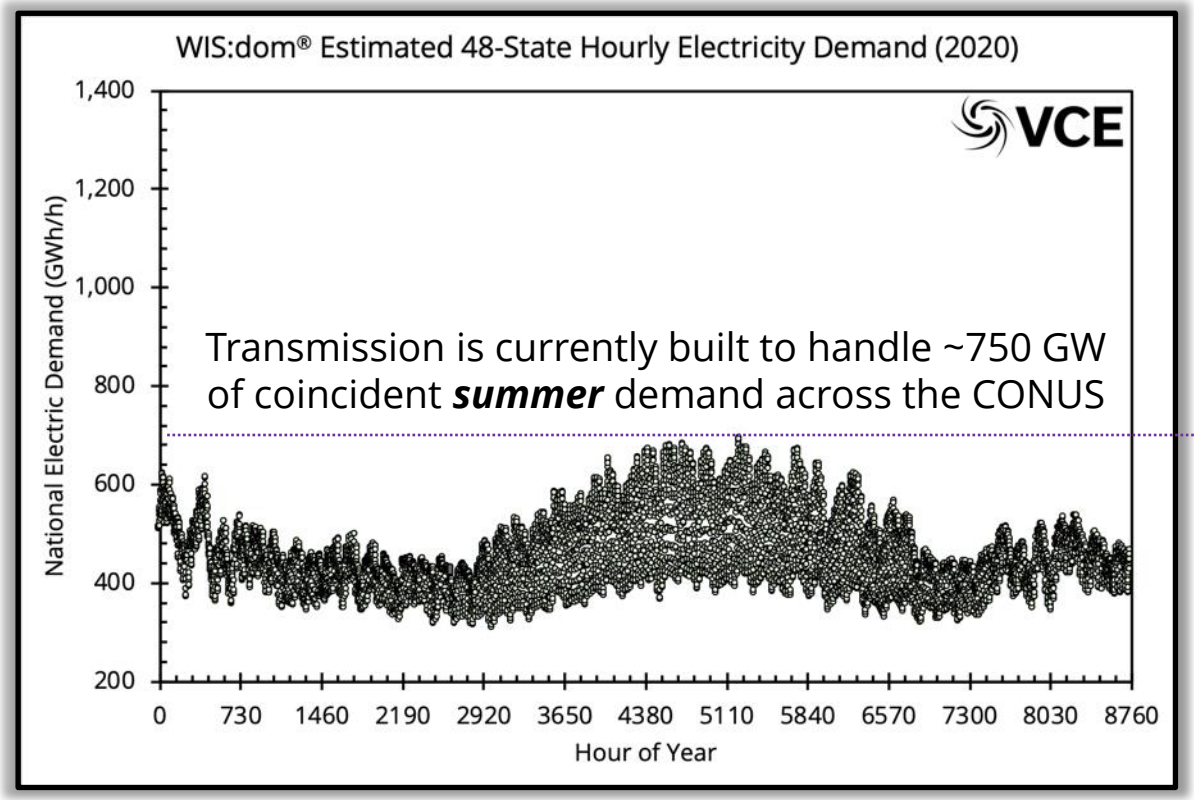
NOTE: In 2021 **28.5 PWh** of primary energy was consumed in the US. Of that **9.3 PWh** was productive for end uses (energy services).
Source: LLNL

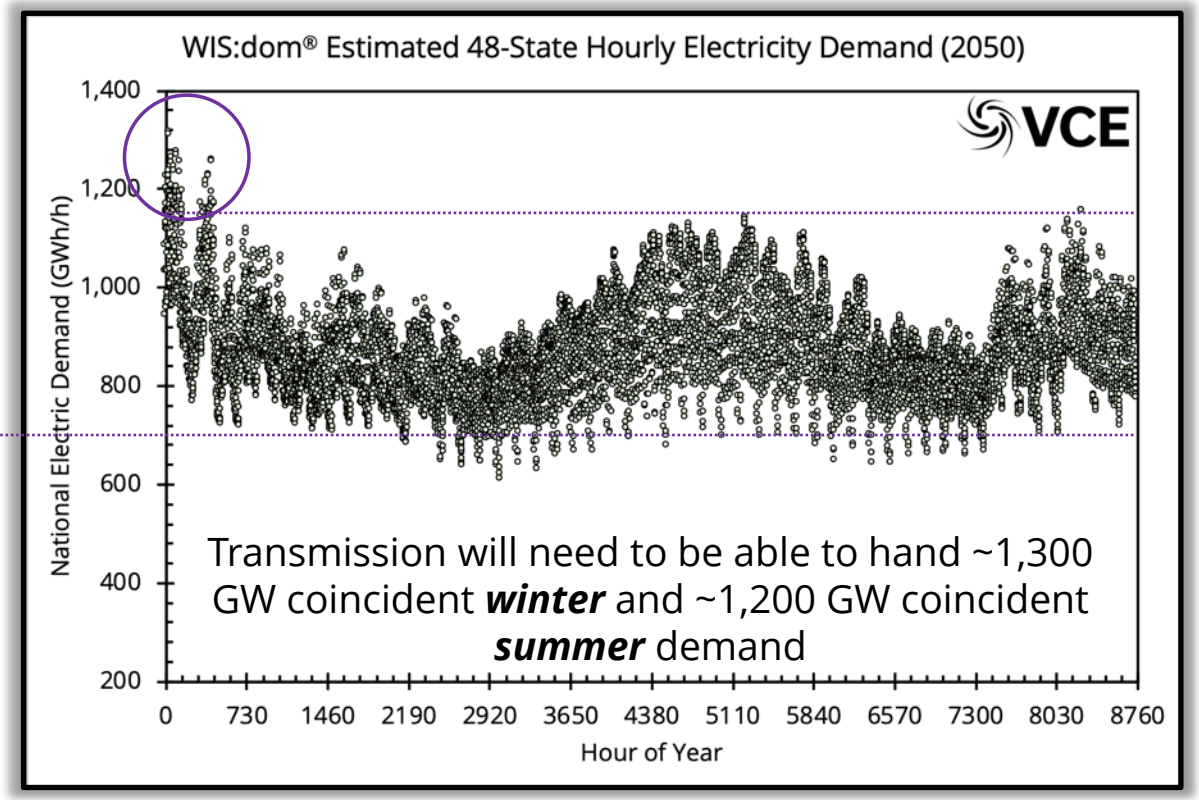


https://www.nrel.gov/analysis/electrification-futures.html



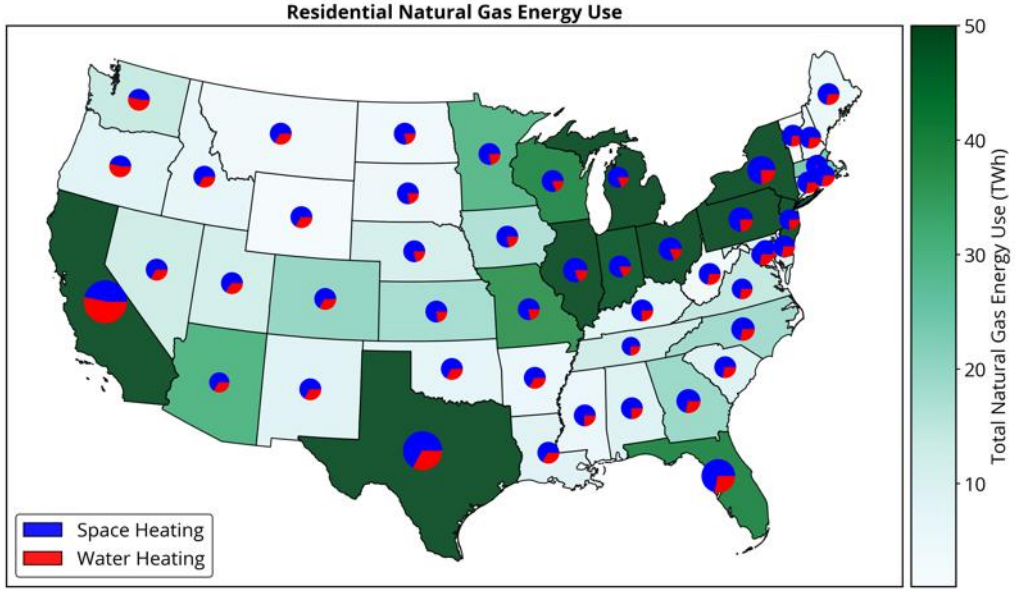
But weather will increasingly shape that demand

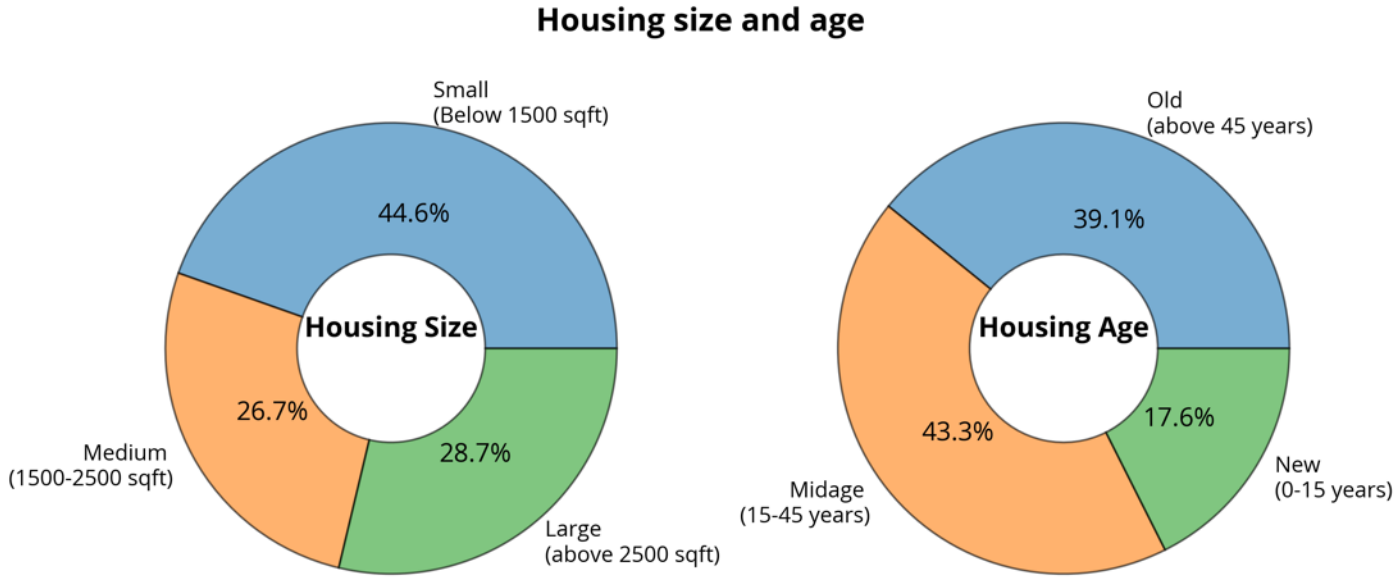


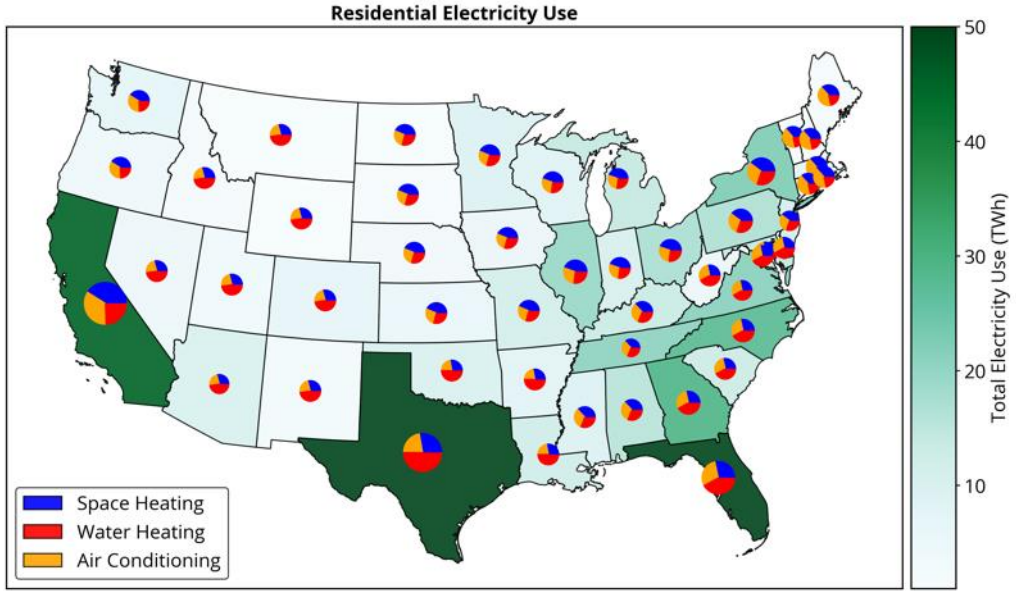


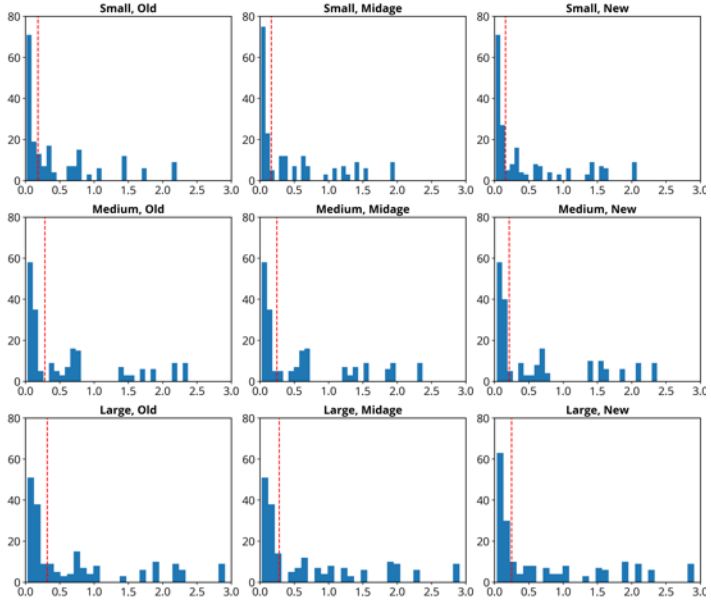
* Before considering synthetic fuel production

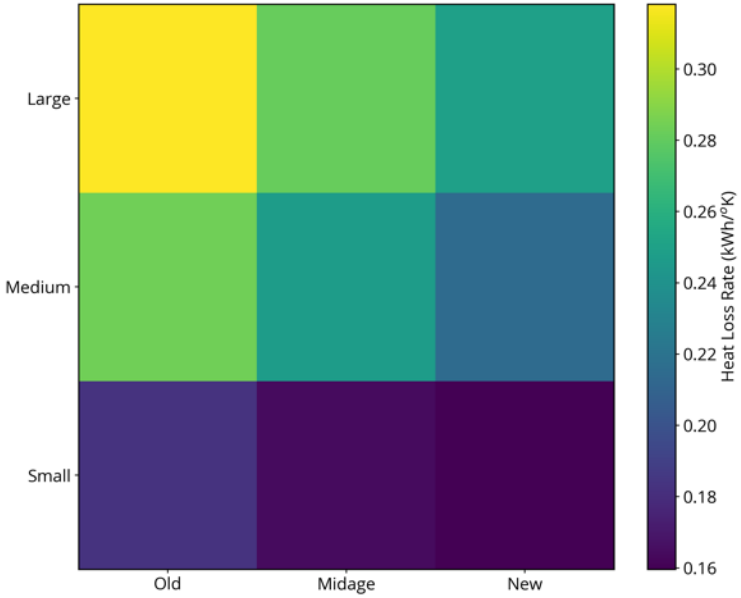
Details matter for distribution resources…





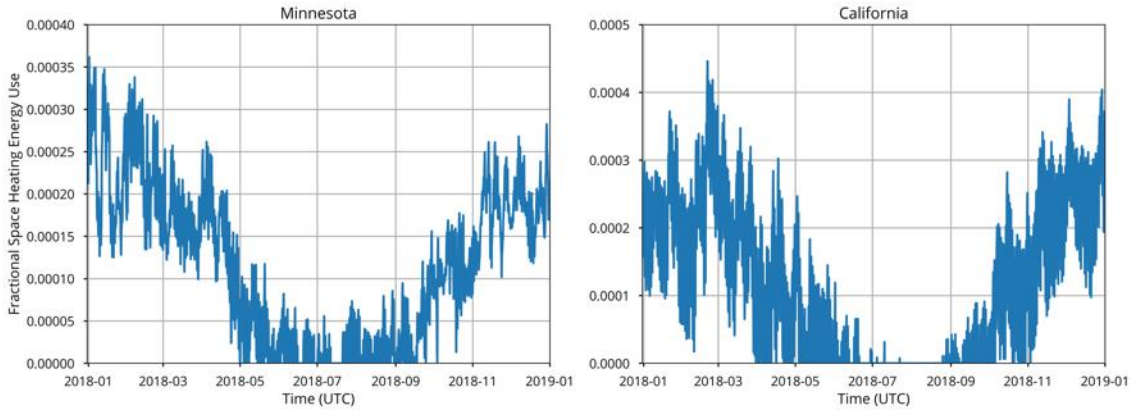




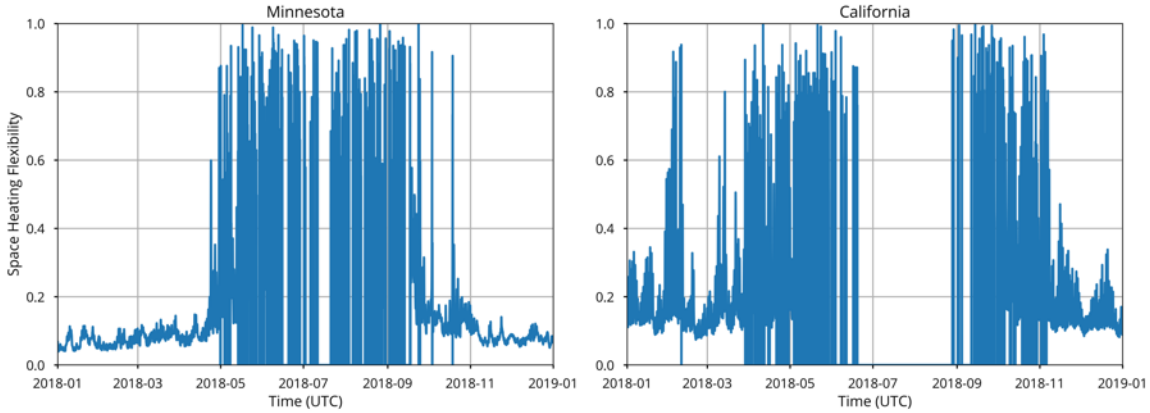


Details matter for distribution resources…

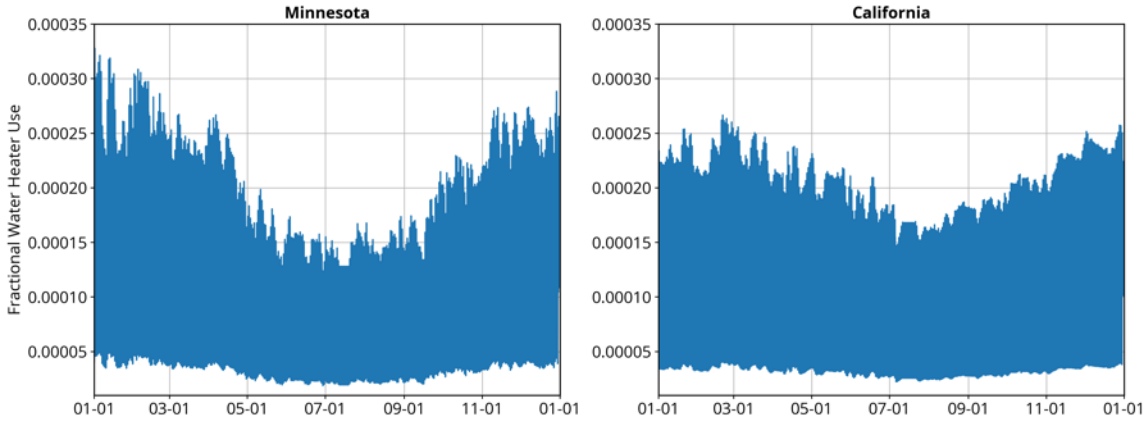
Space Heating Profiles



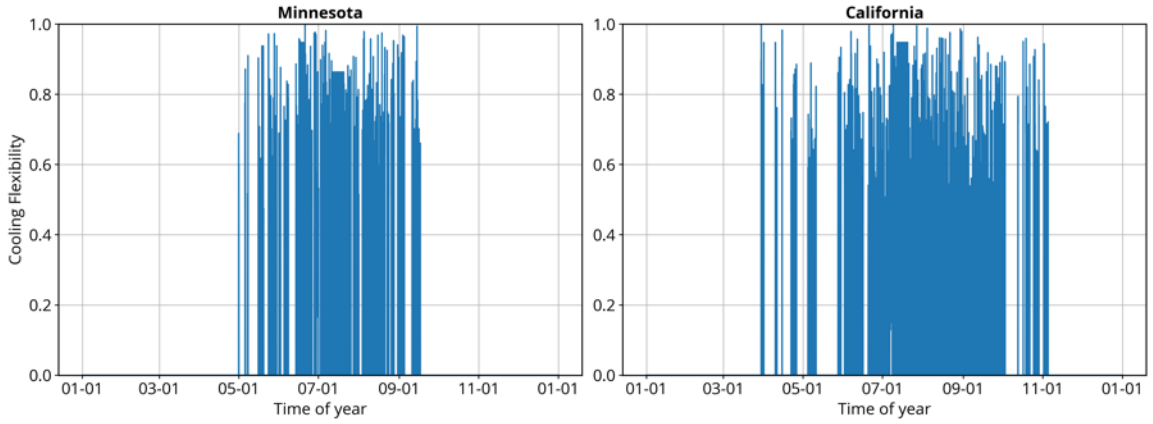
Space Heating Flexibility Profiles



Water Heating Profiles



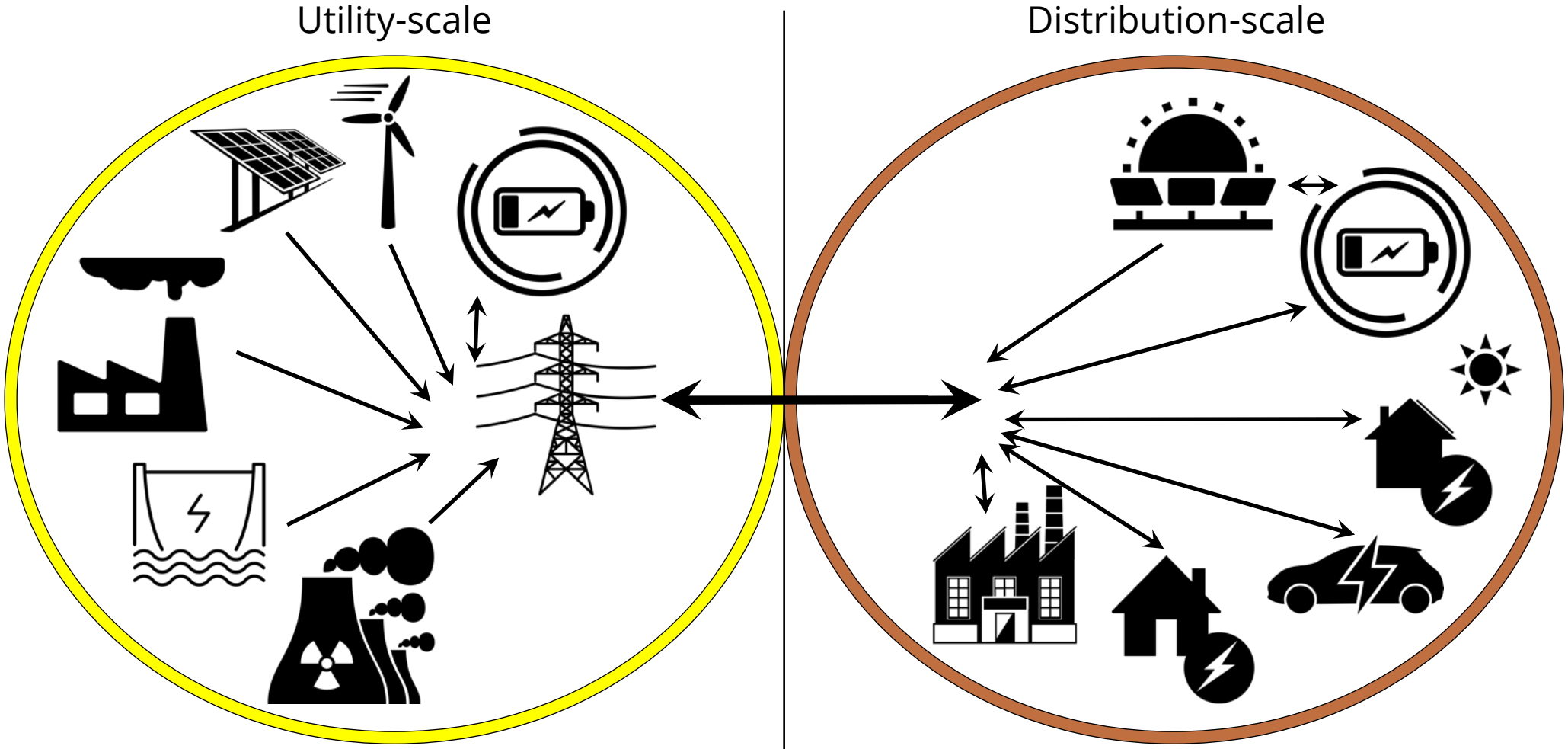
Airconditioning Flexibility Profiles



We have to do the same for electric transport, conventional demands, industrial/commercial demands, and other resources that can be flexible in the distribution grid. Note, we must model any payback time for the electricity if it's modeled as demand-side management.

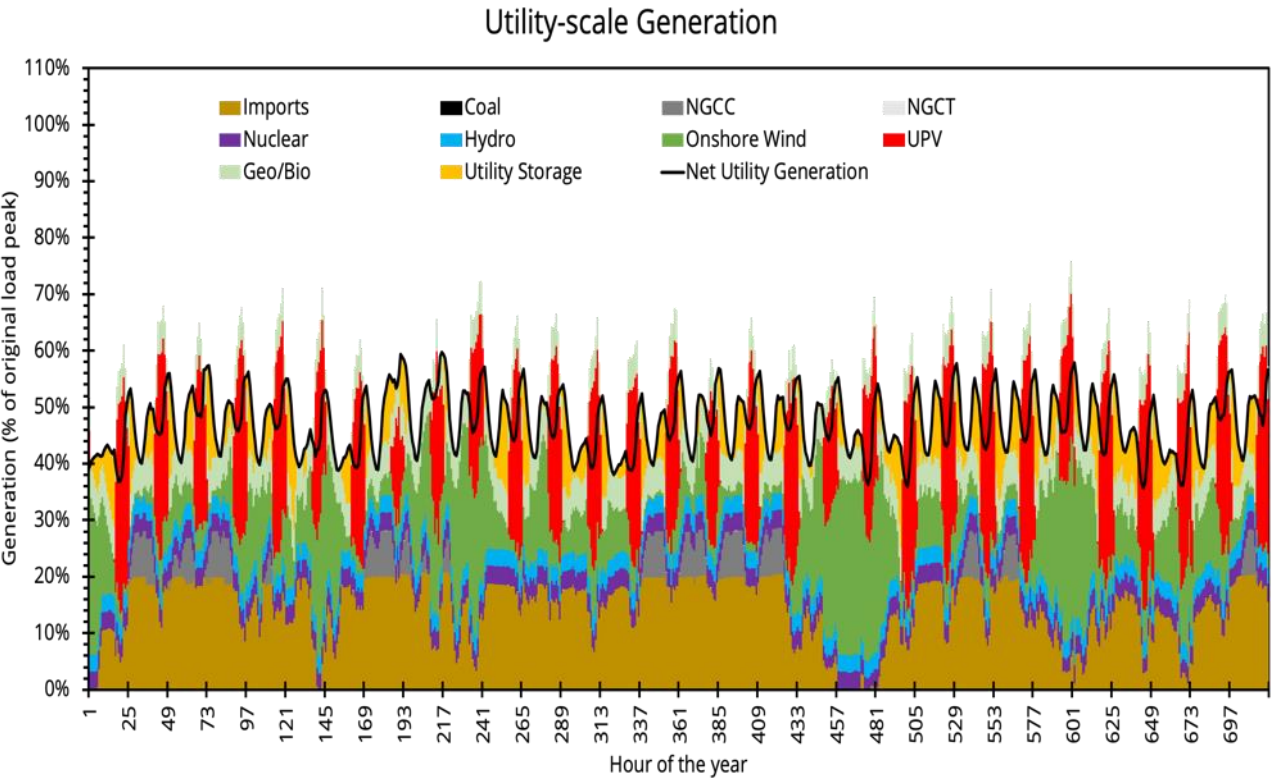
WIS:dom-P (w/o Distribution Subroutine)

The original WIS:dom® model supplies electricity to the 69-kV electricity buses only. No consideration of distribution costs were included. It did model DERs, but in direct competition with utility-scale assets purely via economics of the transmission system. There is no cost to distributed resources over-generating and pushing back on the transmission grid.

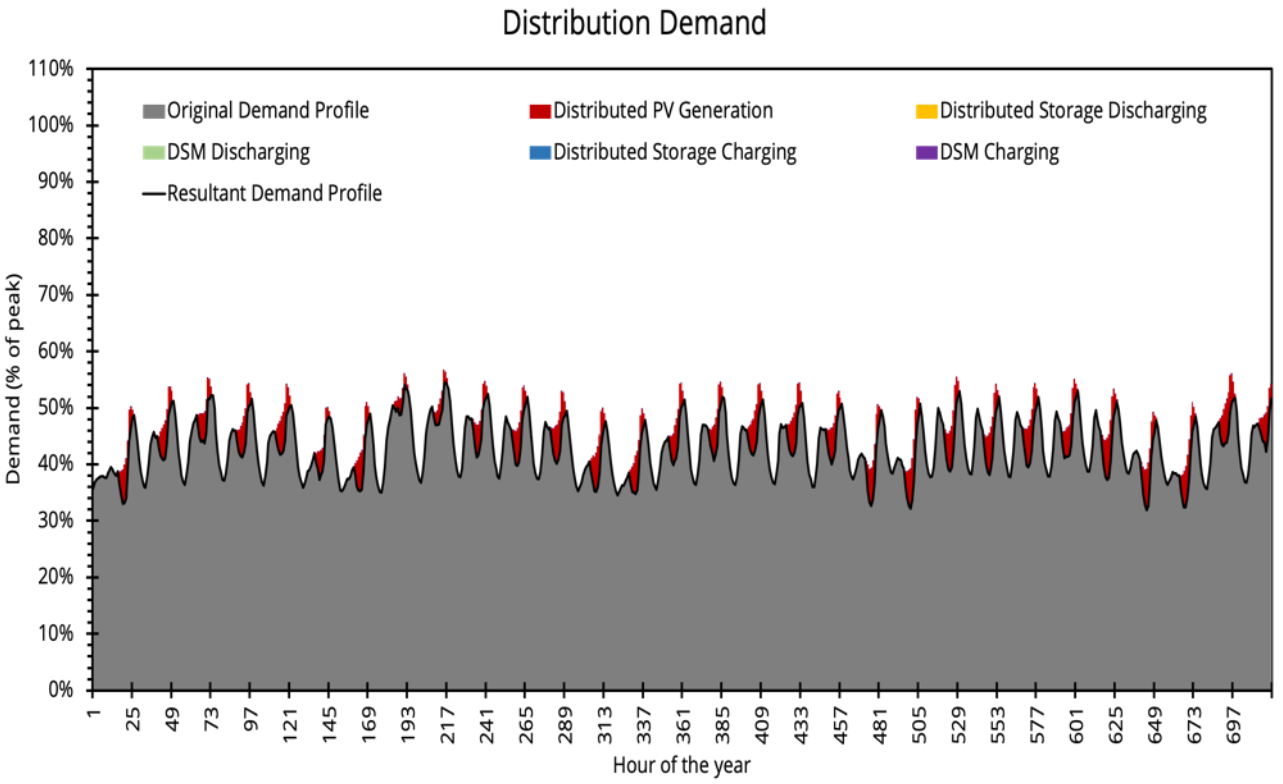


WIS:dom-P (w/o Distribution Subroutine)

The original WIS:dom® model supplies electricity to the 69-kV electricity buses only. No consideration of distribution costs were included. It did model DERs, but in direct competition with utility-scale assets purely via economics of the transmission system. There is no cost to distributed resources over-generating and pushing back on the transmission grid.



Above 69-kV Transmission

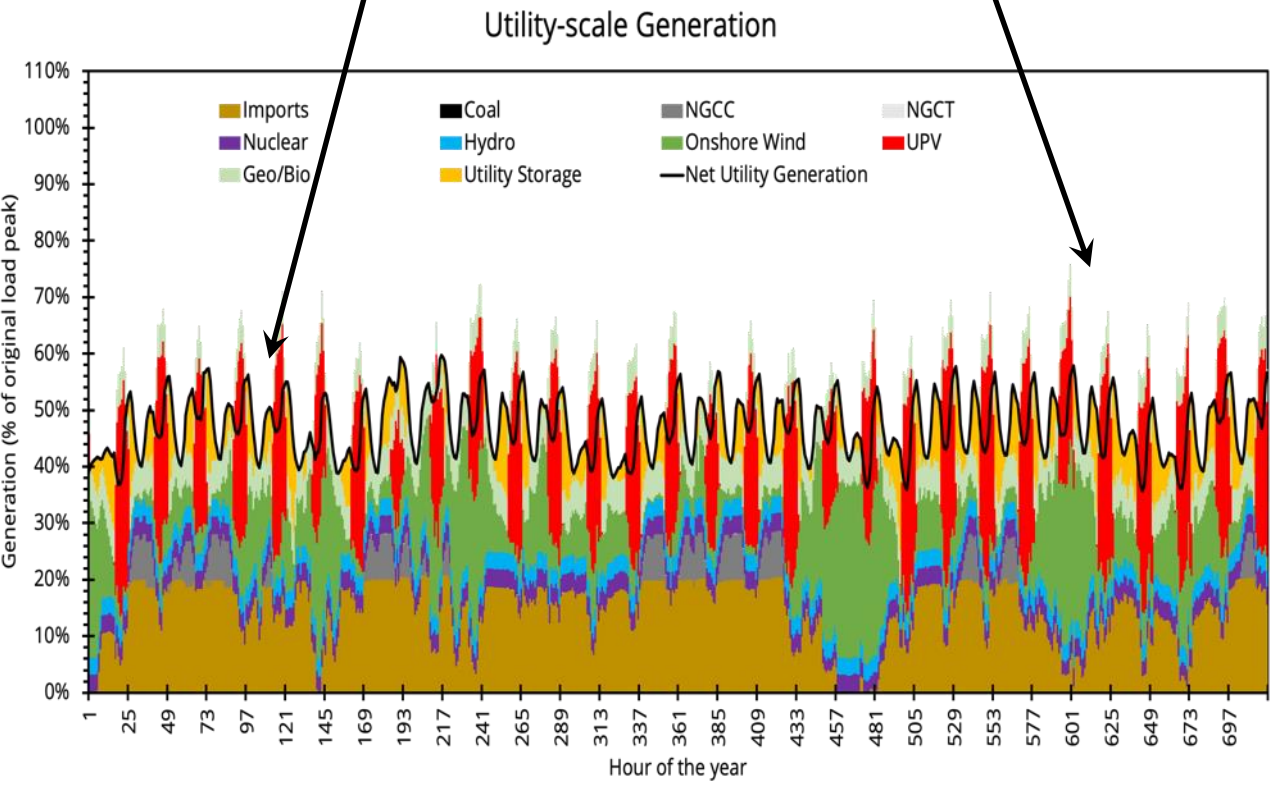


Below 69-kV Transmission

WIS:dom-P (w/o Distribution Subroutine)

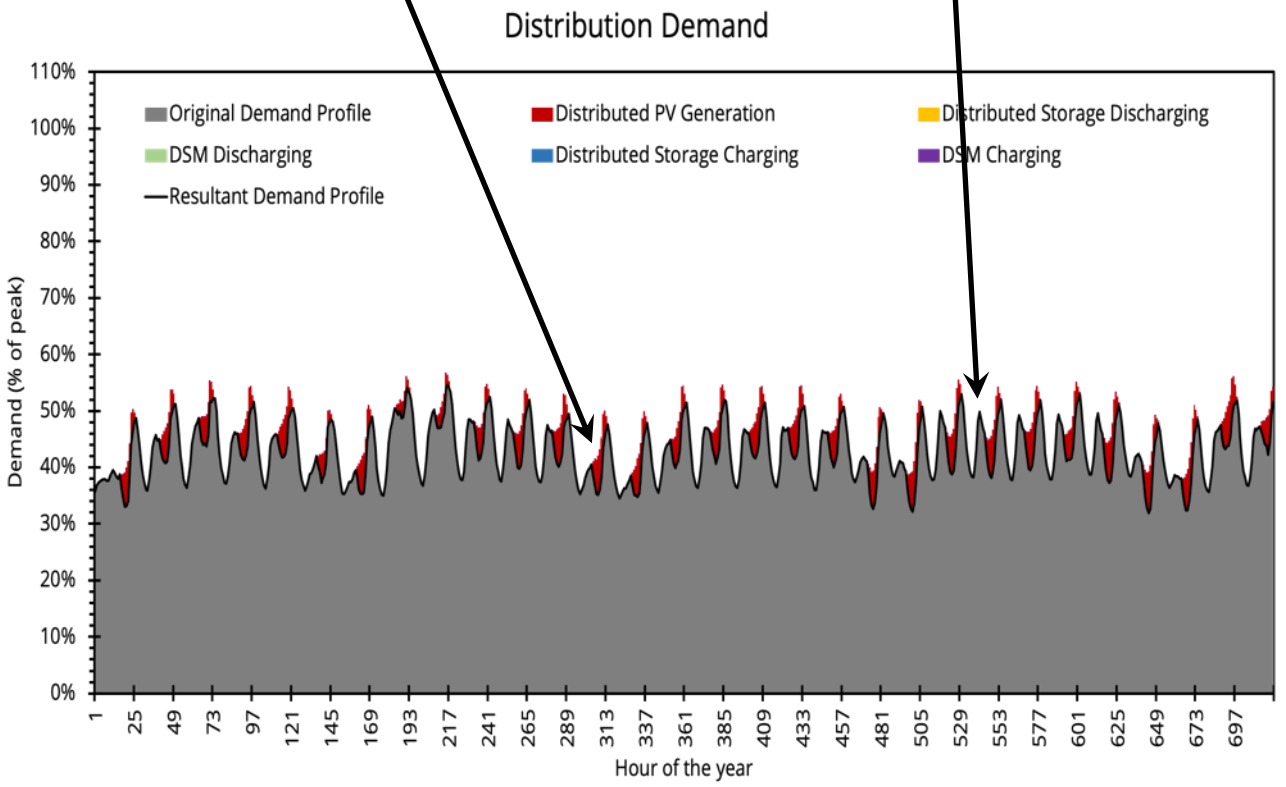
Black line is net utility generation to serve demand (includes electric losses contribution)

Above the black line is utility-scale storage charging & exports



Black line is the net demand remaining to be served by utility-scale generation

Demand is slightly compressed below peak due to DER contributions (”duck curve”)

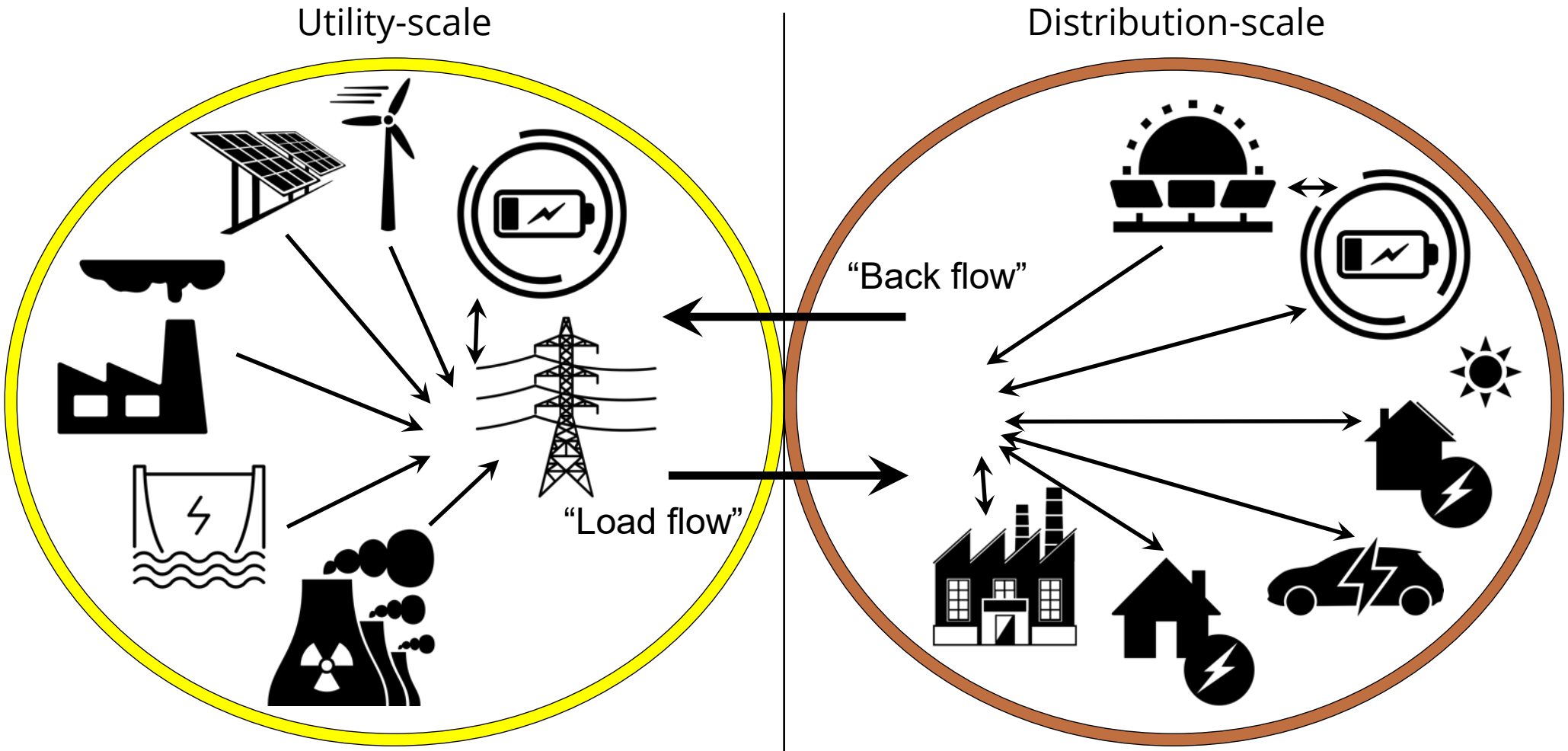


Above 69-kV Transmission

Below 69-kV Transmission

WIS:dom-P (w/ Distribution Subroutine)

The updated version of WIS:dom® considers an estimated cost of distribution infrastructure. The addition of these costs allows the model to further differentiate the distribution portion of the grid.

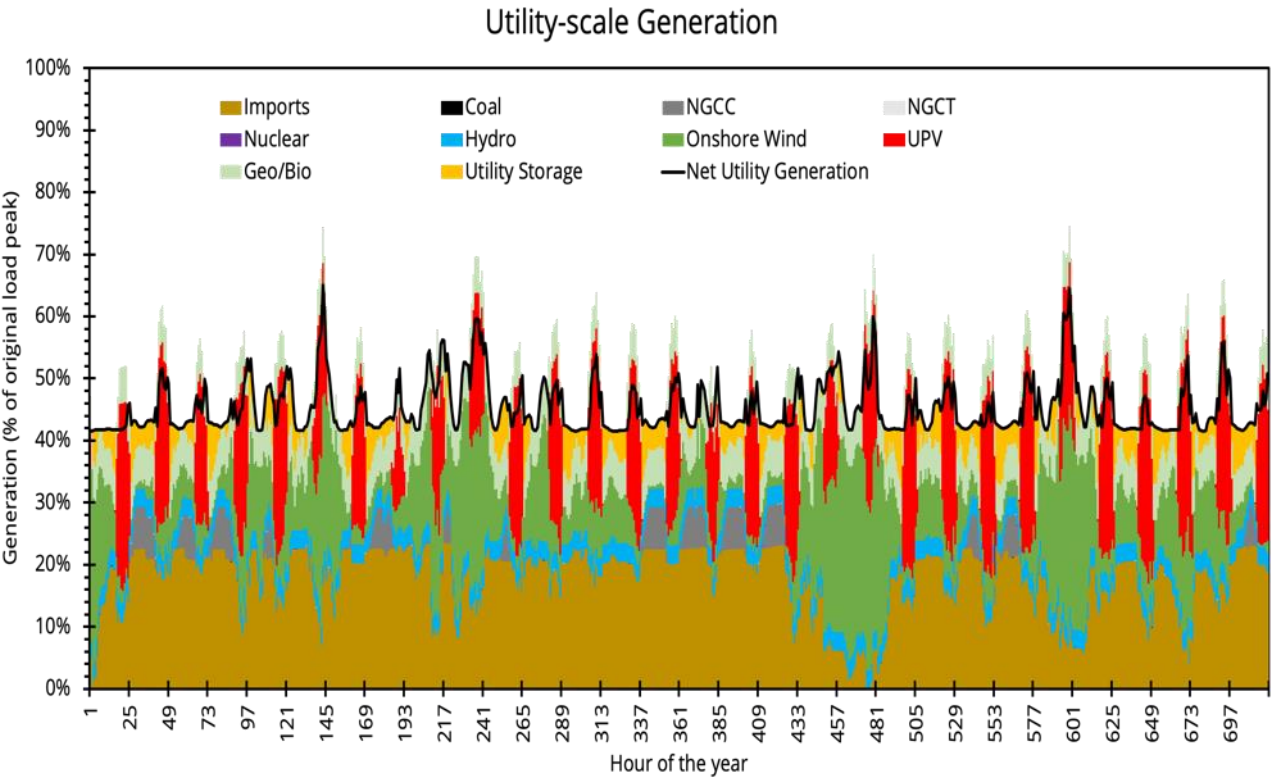


Above 69-kV Transmission

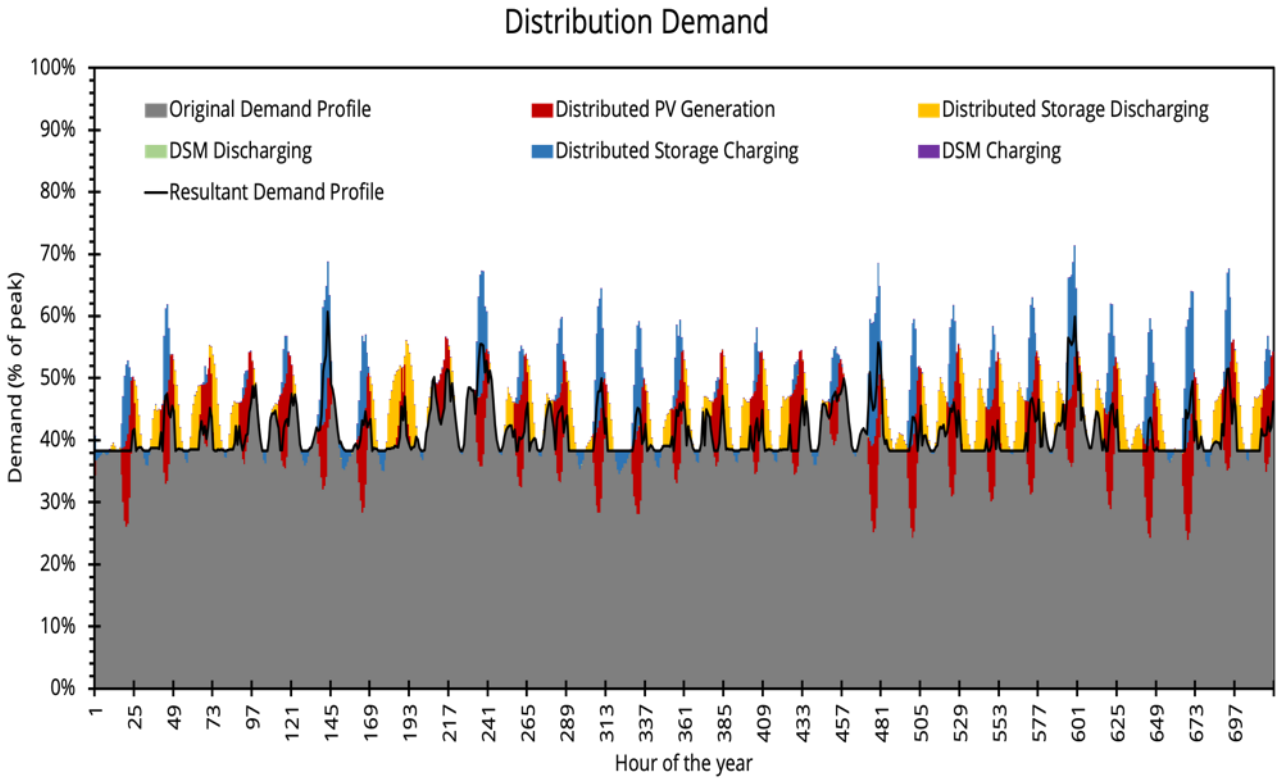
Below 69-kV Transmission

WIS:dom-P (w/ Distribution Subroutine)

The updated version of WIS:dom® considers an estimated cost of distribution infrastructure. The addition of these costs allows the model to further differentiate the distribution portion of the grid.

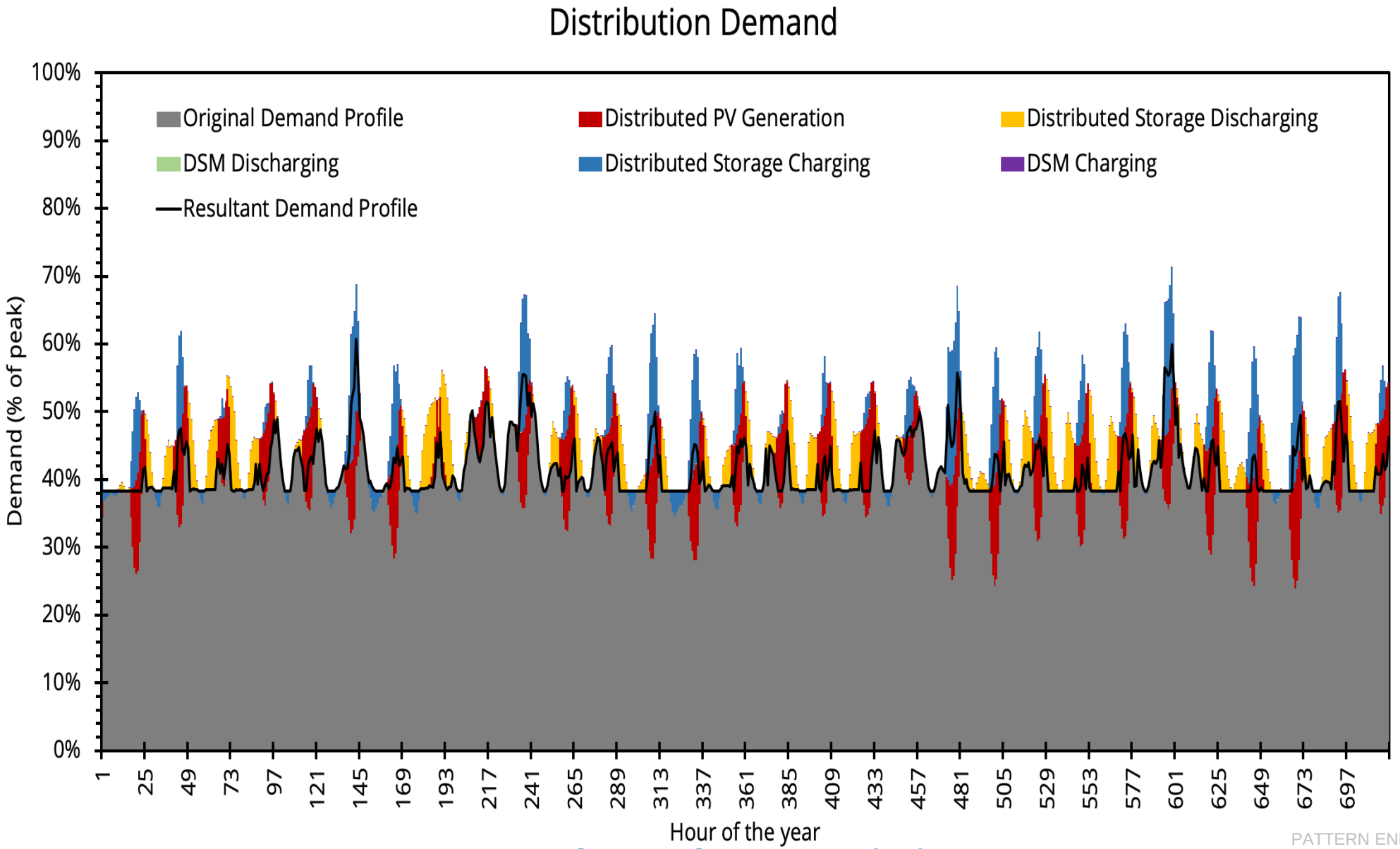


Above 69-kV Transmission

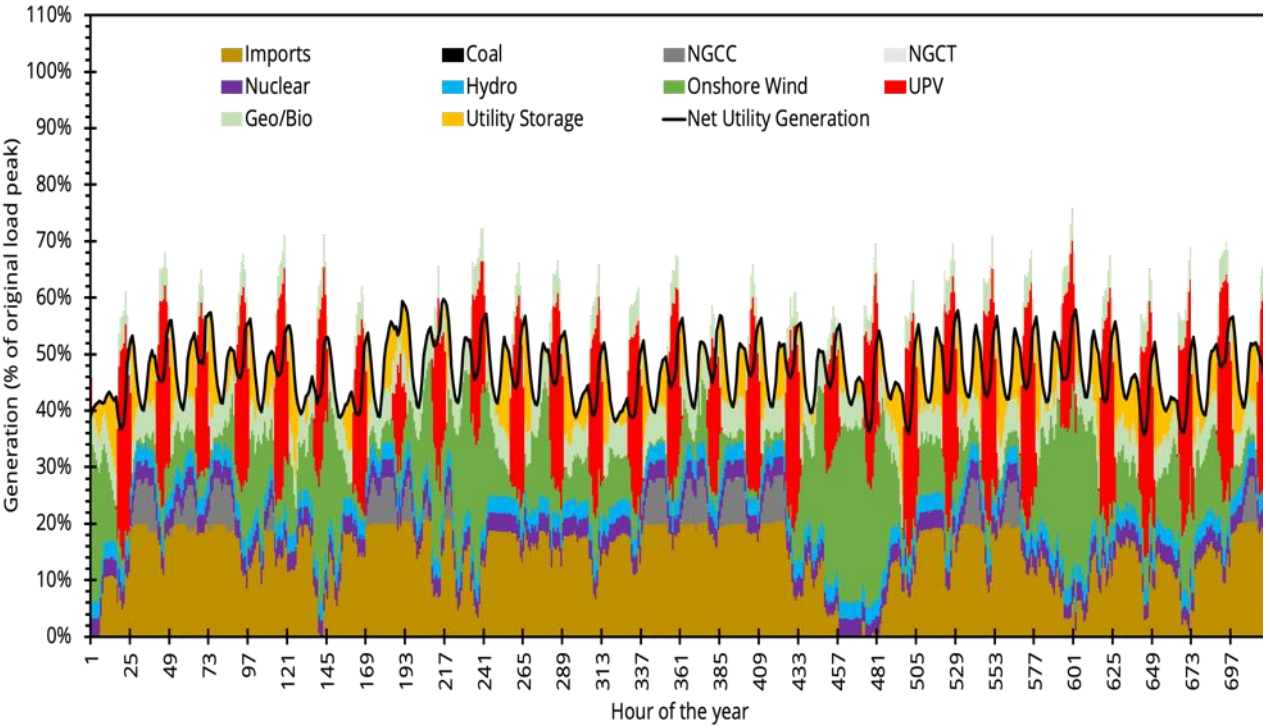


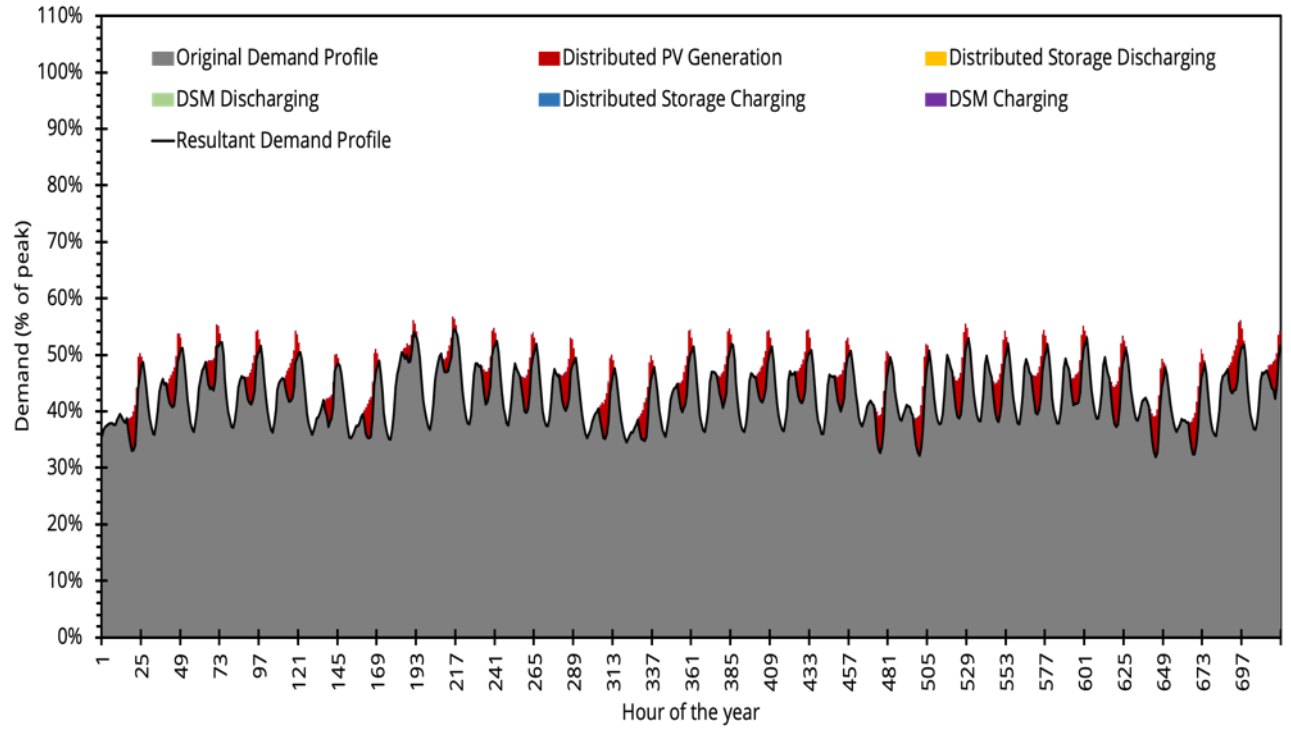
Below 69-kV Transmission

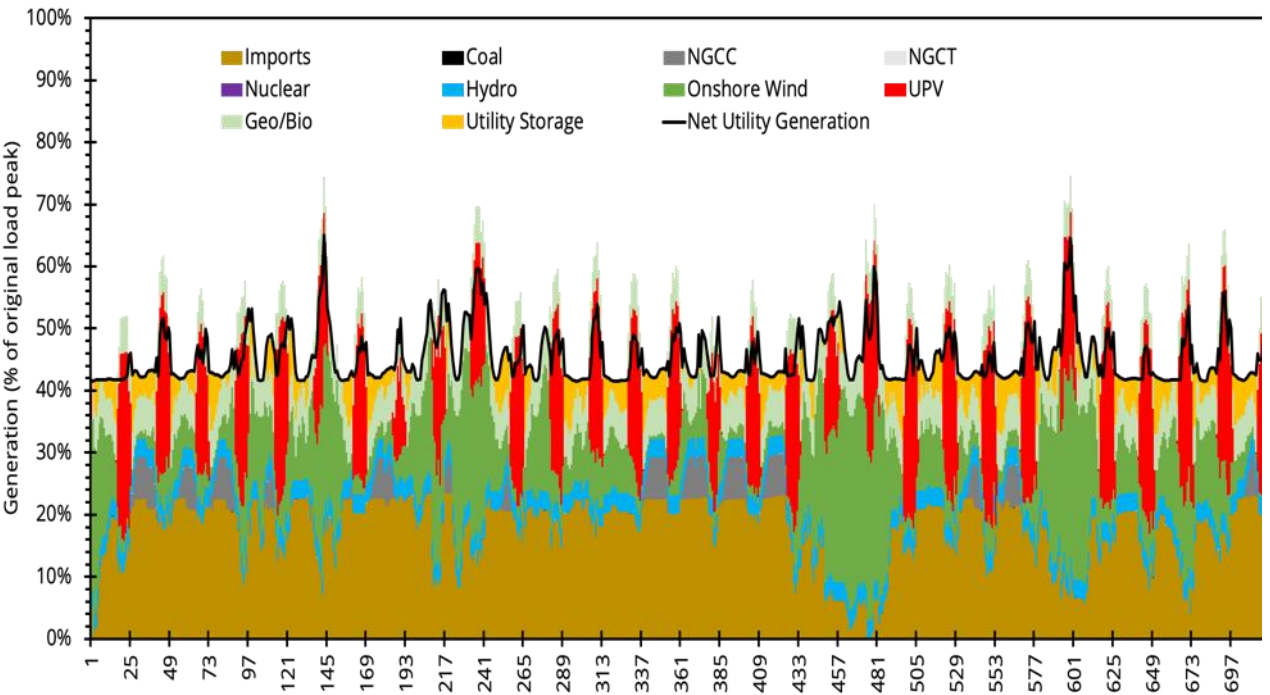
WIS:dom-P (w/ Distribution Subroutine)

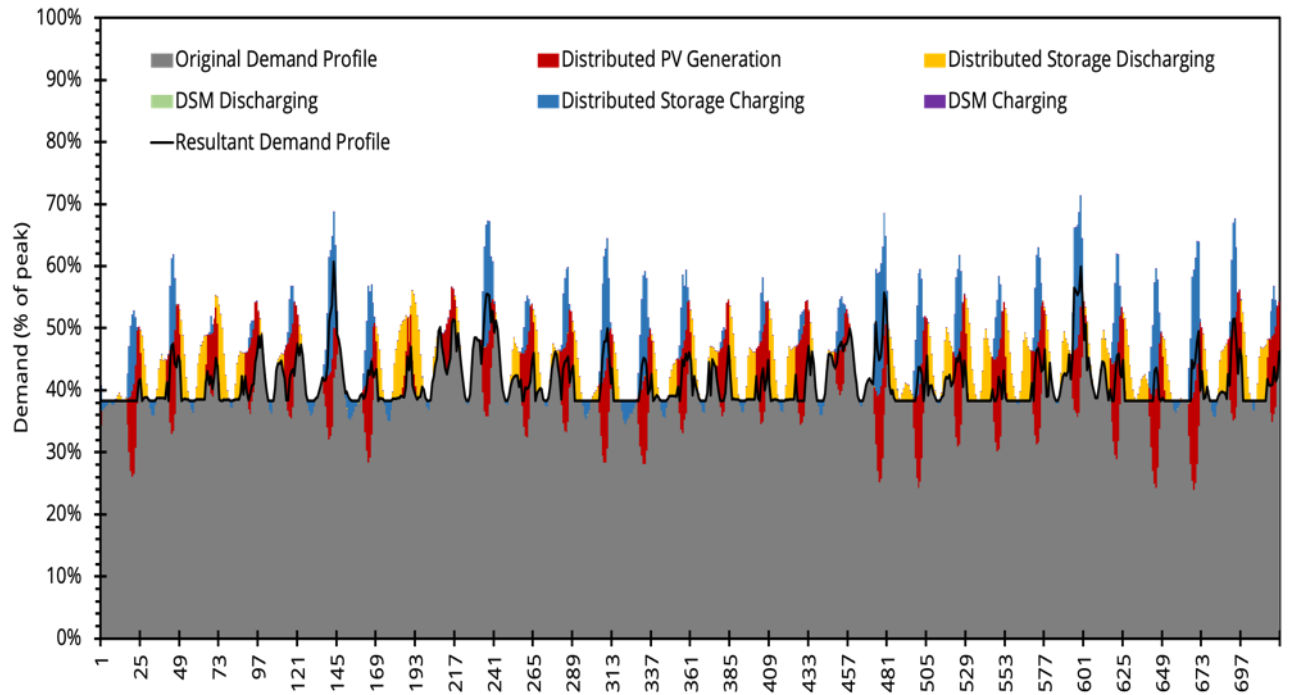


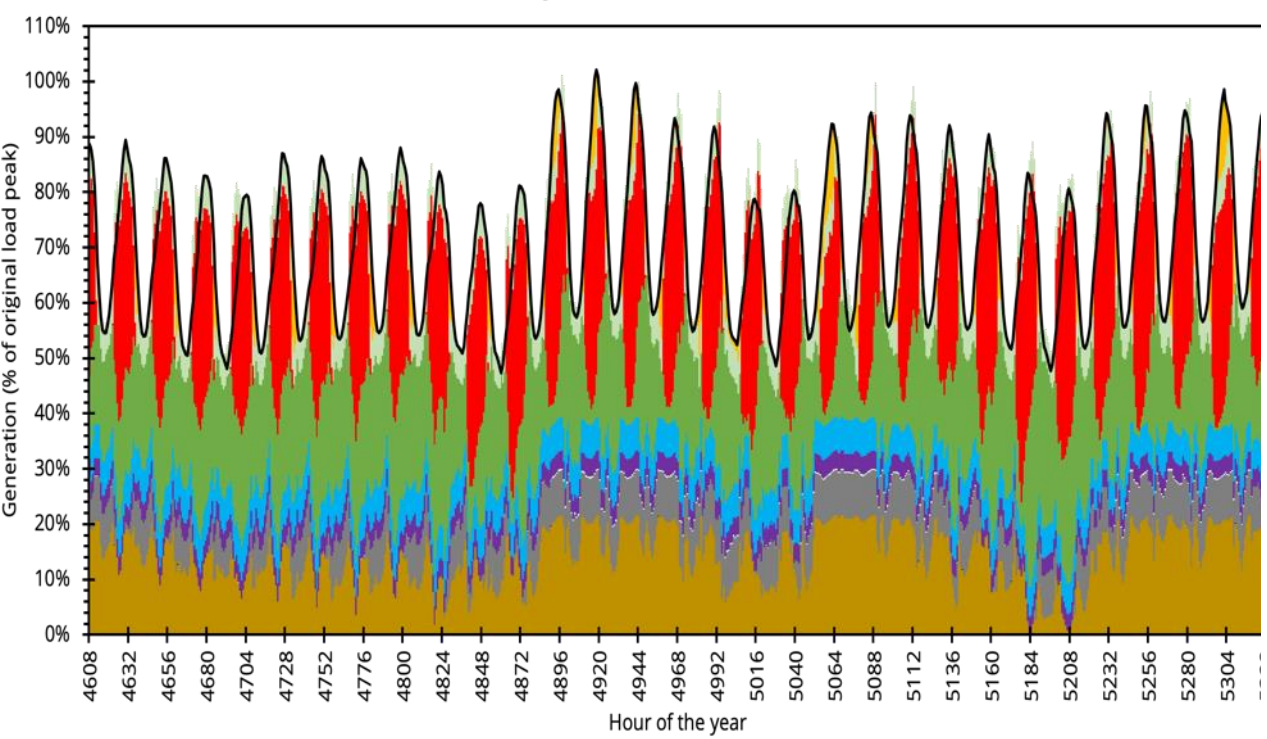
Below 69-kV Transmission

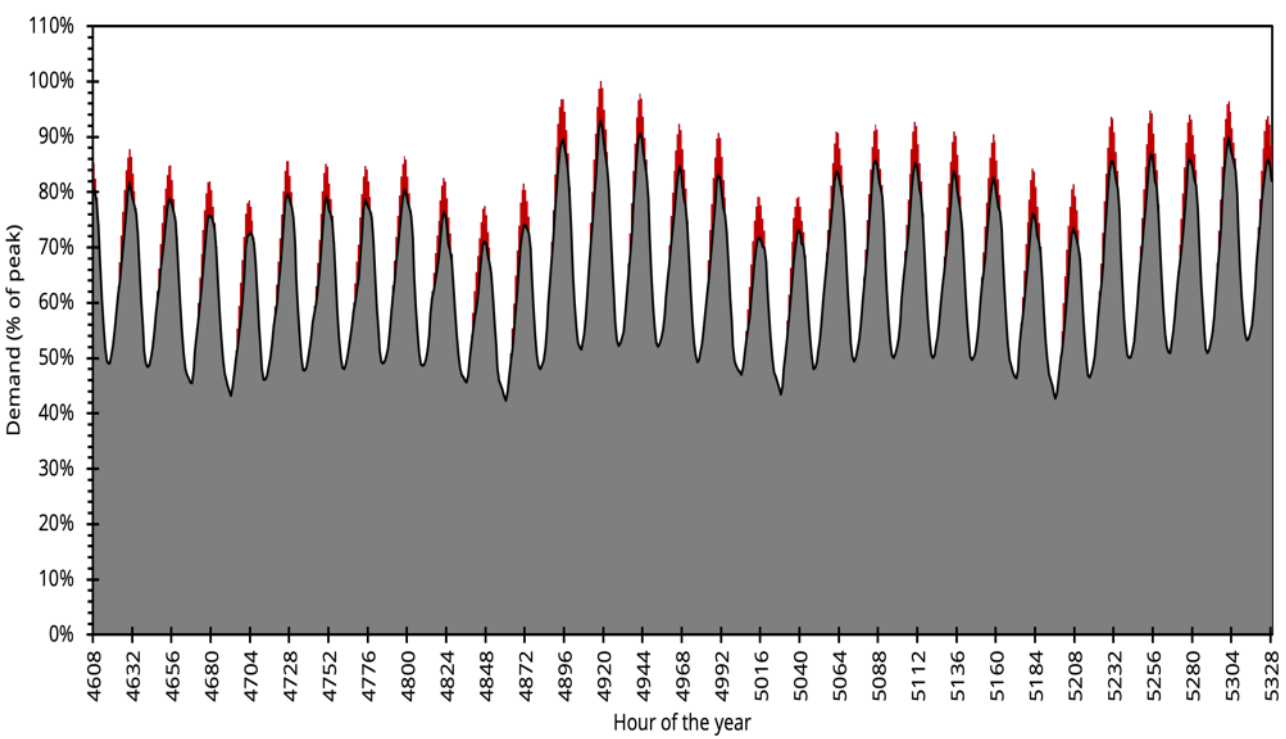

Imports
Coal
NGCC
NGCT
Nuclear
Hydro
Onshore Wind
UPV
Geo/Bio
Utility Storage
Net Utility Generation
Generation (% of original load peak)
Hour of the year

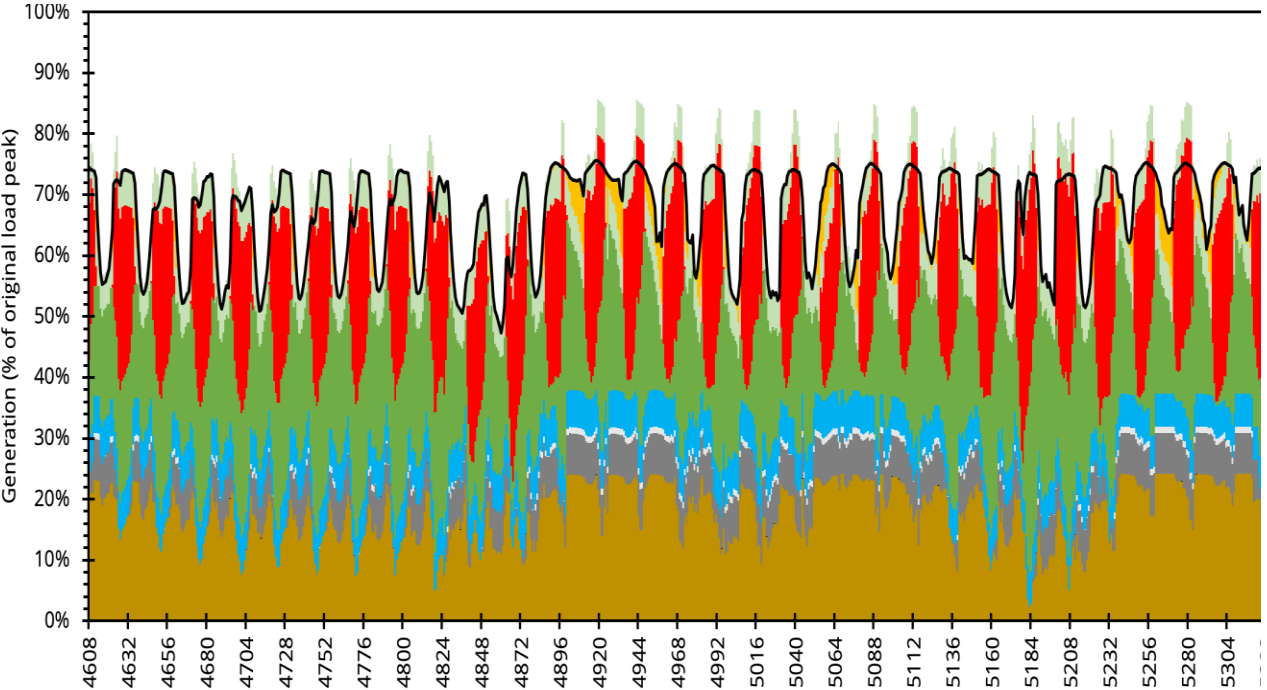

Original Demand Profile
Distributed PV Generation
Distributed Storage Discharging
DSM Discharging
Distributed Storage Charging
DSM Charging
Resultant Demand Profile
Demand (% of peak)
Hour of the year

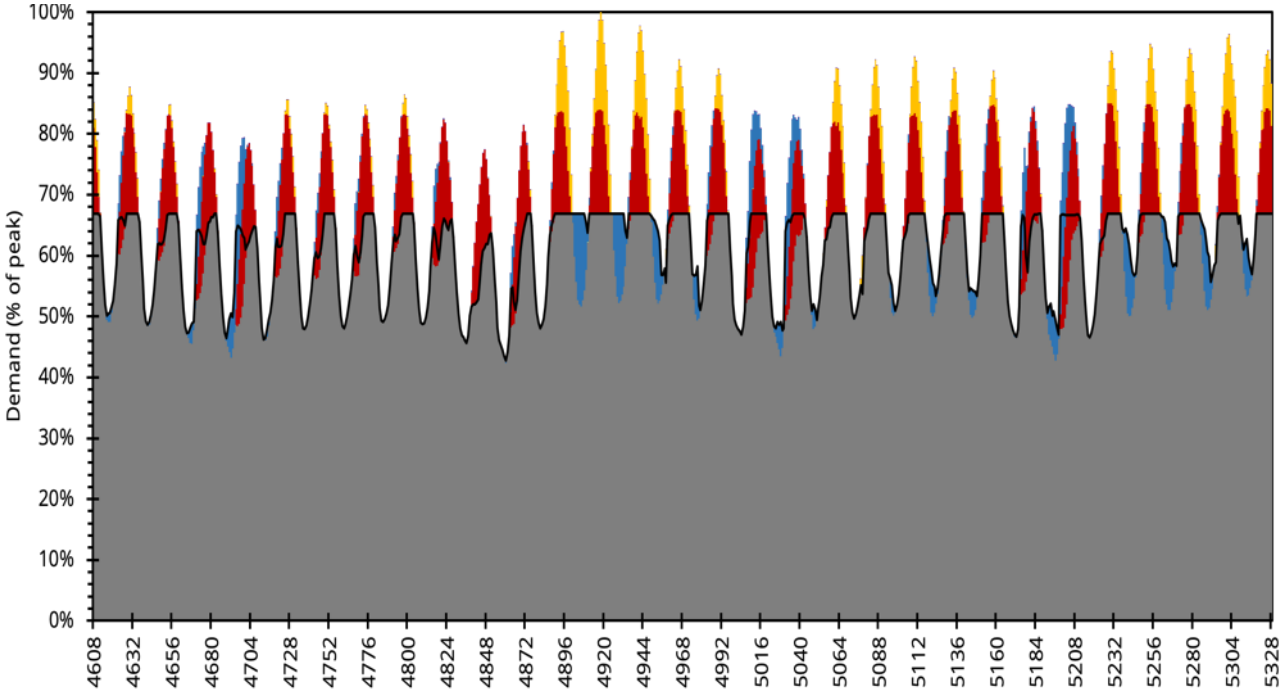

Imports
Coal
NGCC
NGCT
Nuclear
Hydro
Onshore Wind
UPV
Geo/Bio
Utility Storage
Net Utility Generation
Generation (% of original load peak)


Original Demand Profile
Distributed PV Generation
Distributed Storage Discharging
DSM Discharging
Distributed Storage Charging
DSM Charging
Resultant Demand Profile
Demand (% of peak)

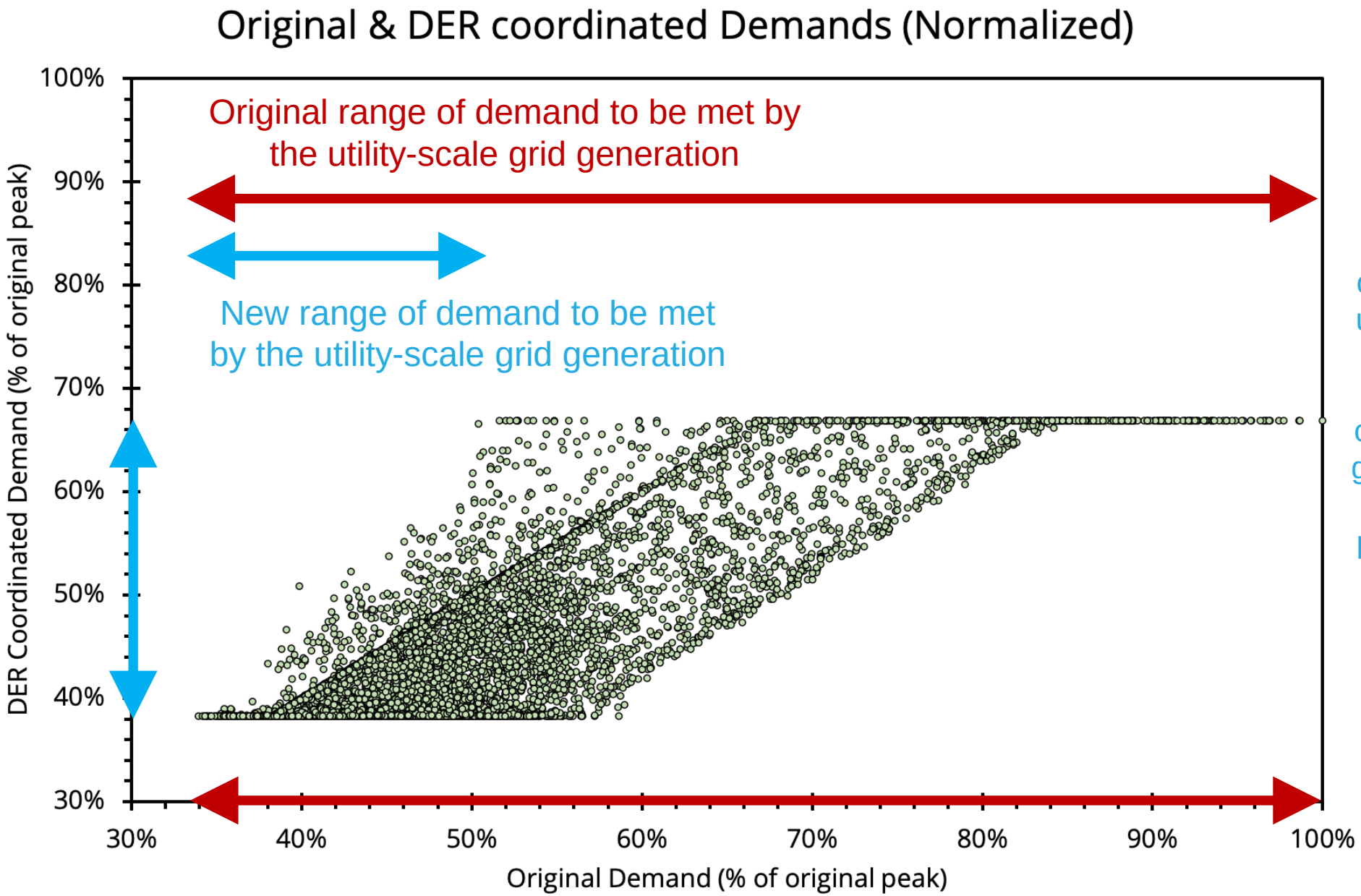

Generation (% of original load peak)
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
4608 4632 4656 4680 4704 4728 4752 4776 4800 4824 4848 4872 4896 4920 4944 4968 4992 5016 5040 5064 5088 5112 5136 5160 5184 5208 5232 5256 5280 5304
Hour of the year


Demand (% of peak)
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
4608 4632 4656 4680 4704 4728 4752 4776 4800 4824 4848 4872 4896 4920 4944 4968 4992 5016 5040 5064 5088 5112 5136 5160 5184 5208 5232 5256 5280 5304 5328
Hour of the year


Generation (% of original load peak)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
4608 4632 4656 4680 4704 4728 4752 4776 4800 4824 4848 4872 4896 4920 4944 4968 4992 5016 5040 5064 5088 5112 5136 5160 5184 5208 5232 5256 5280 5304

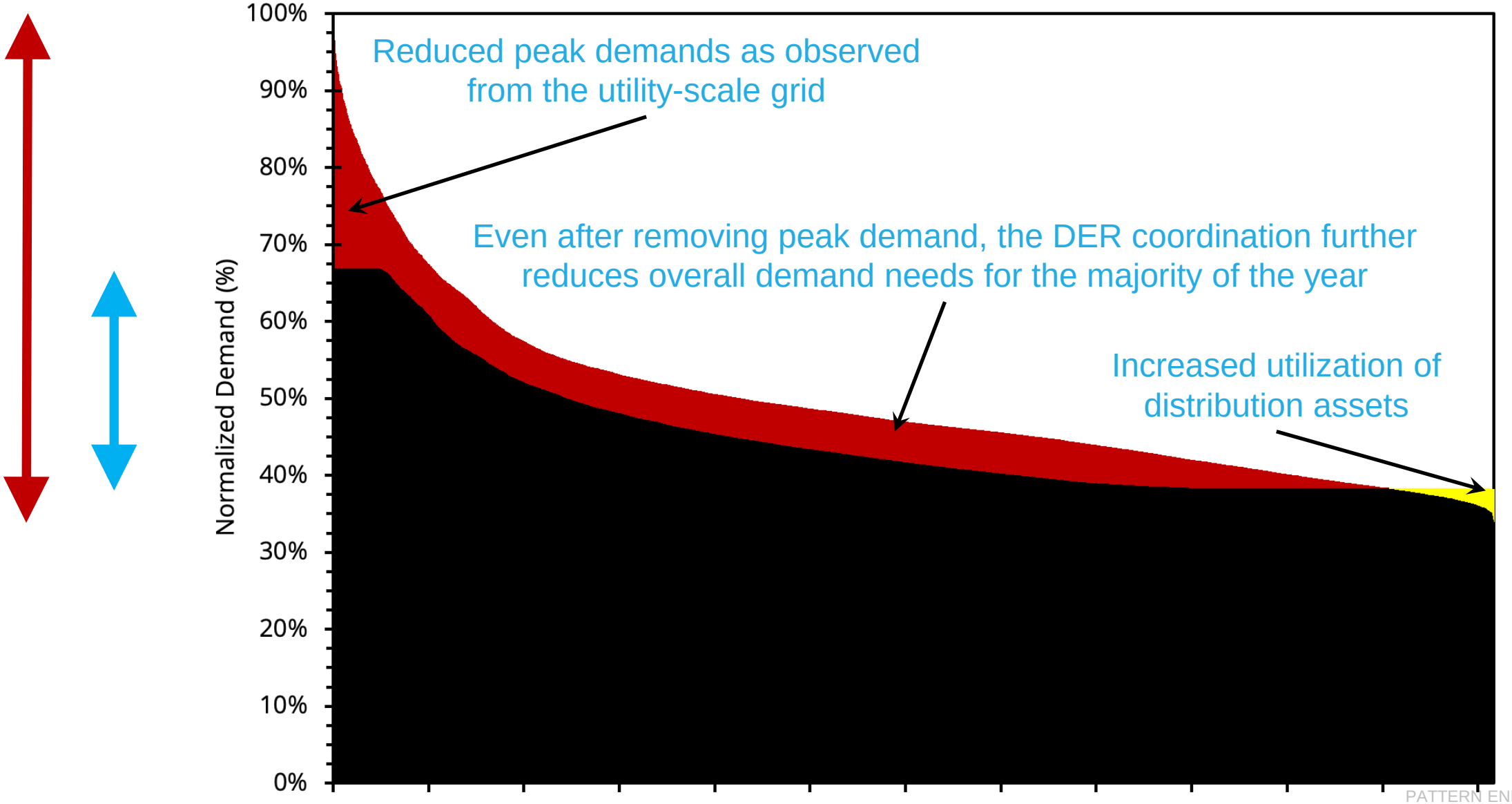

Demand (% of peak)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
4608 4632 4656 4680 4704 4728 4752 4776 4800 4824 4848 4872 4896 4920 4944 4968 4992 5016 5040 5064 5088 5112 5136 5160 5184 5208 5232 5256 5280 5304 5328

WIS:dom-P (w/ Distribution Subroutine)

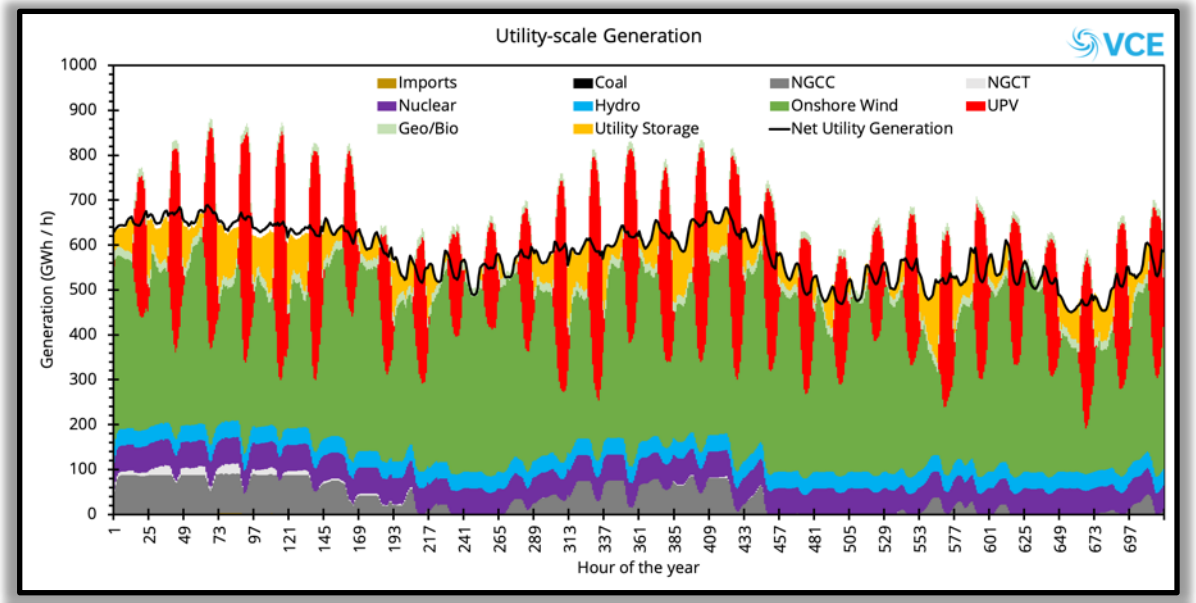


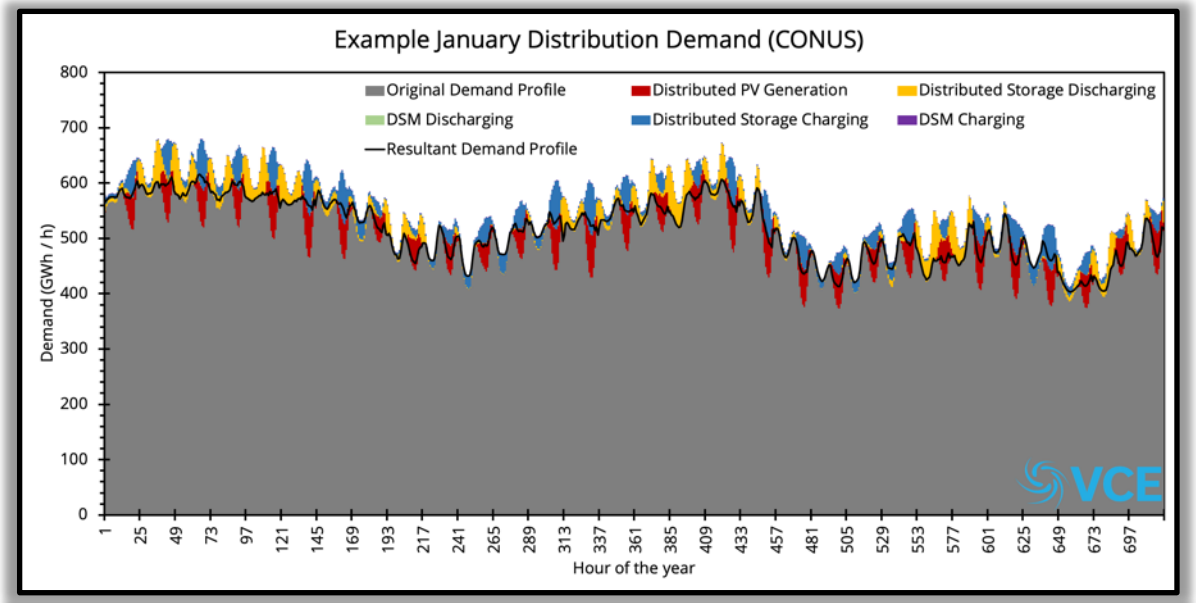
One consequence of co-optimizing and coordinating utility-scale with distributed-scale is the reduction of volatility in the demand as observed by the utility-scale grid. A second consequence is a dramatic drop in the peak demand requirements as observed by the utility-scale grid.

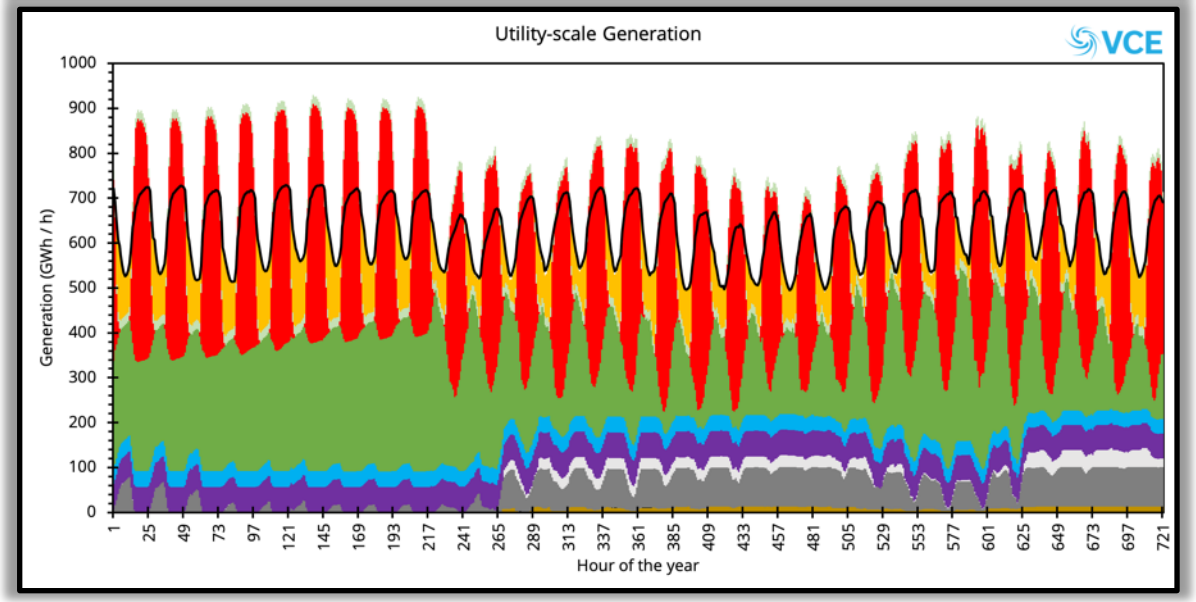
WIS:dom-P (w/ Distribution Subroutine)

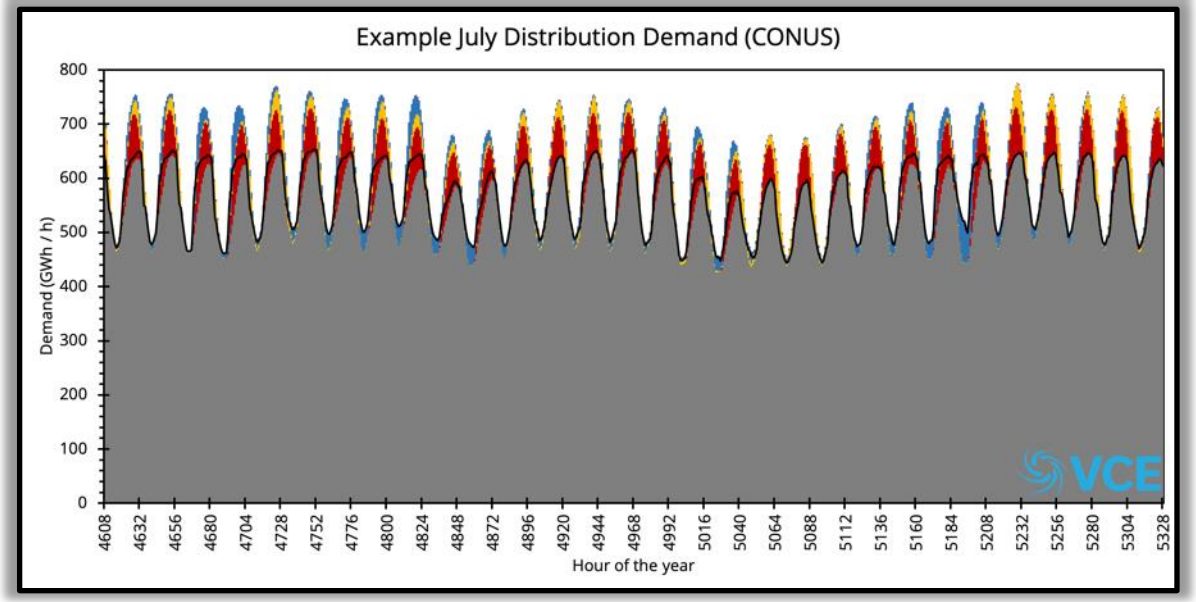


How does this manifest at CONUS-level (2050)?

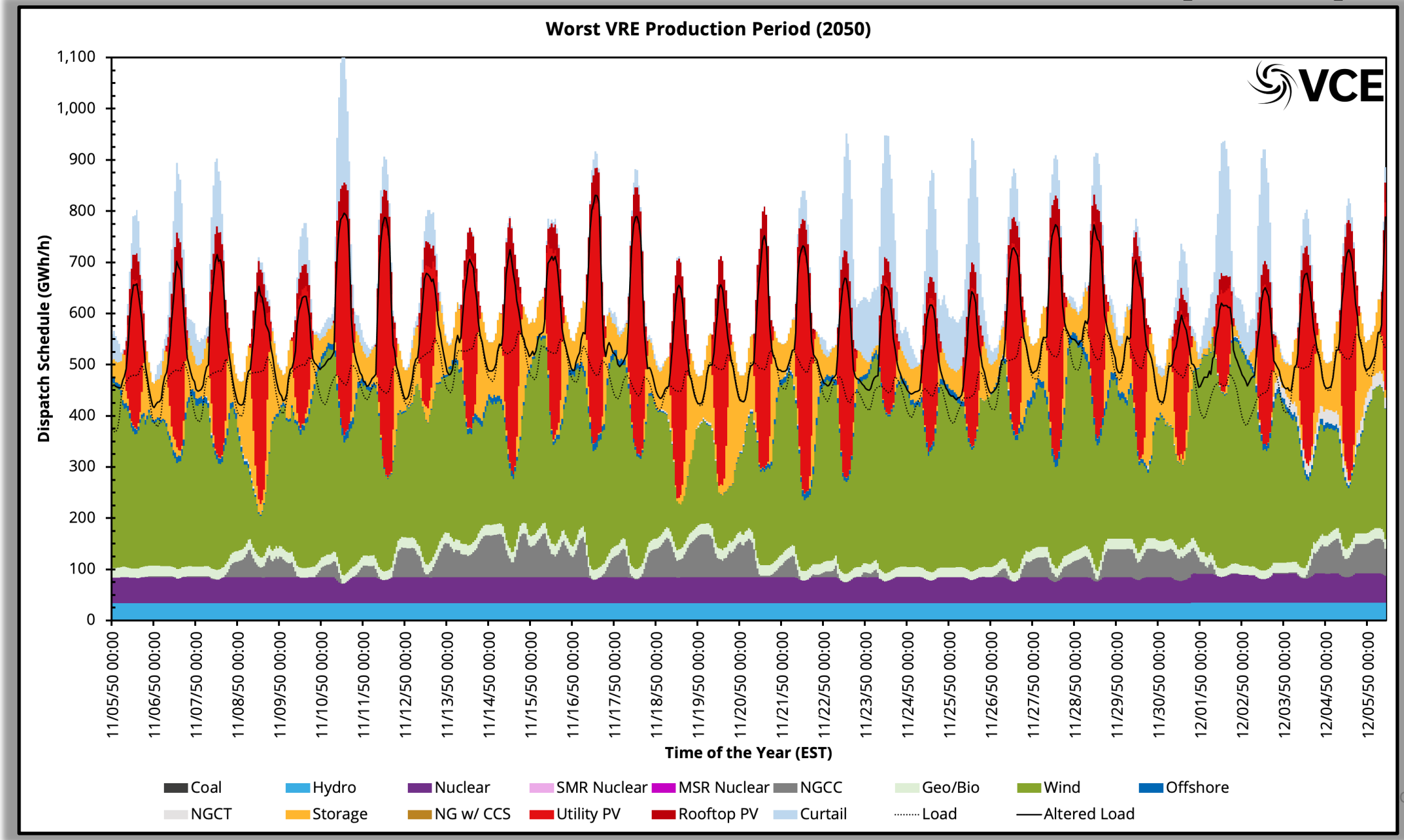




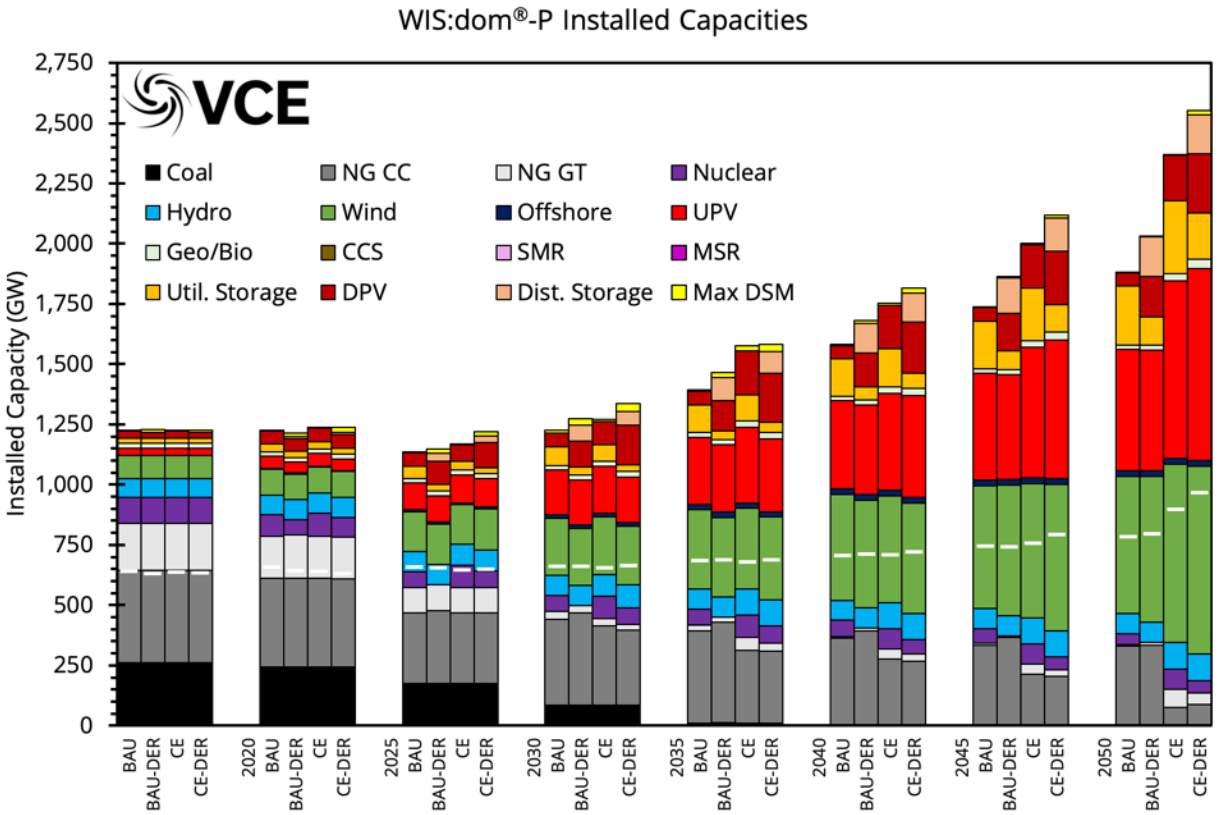


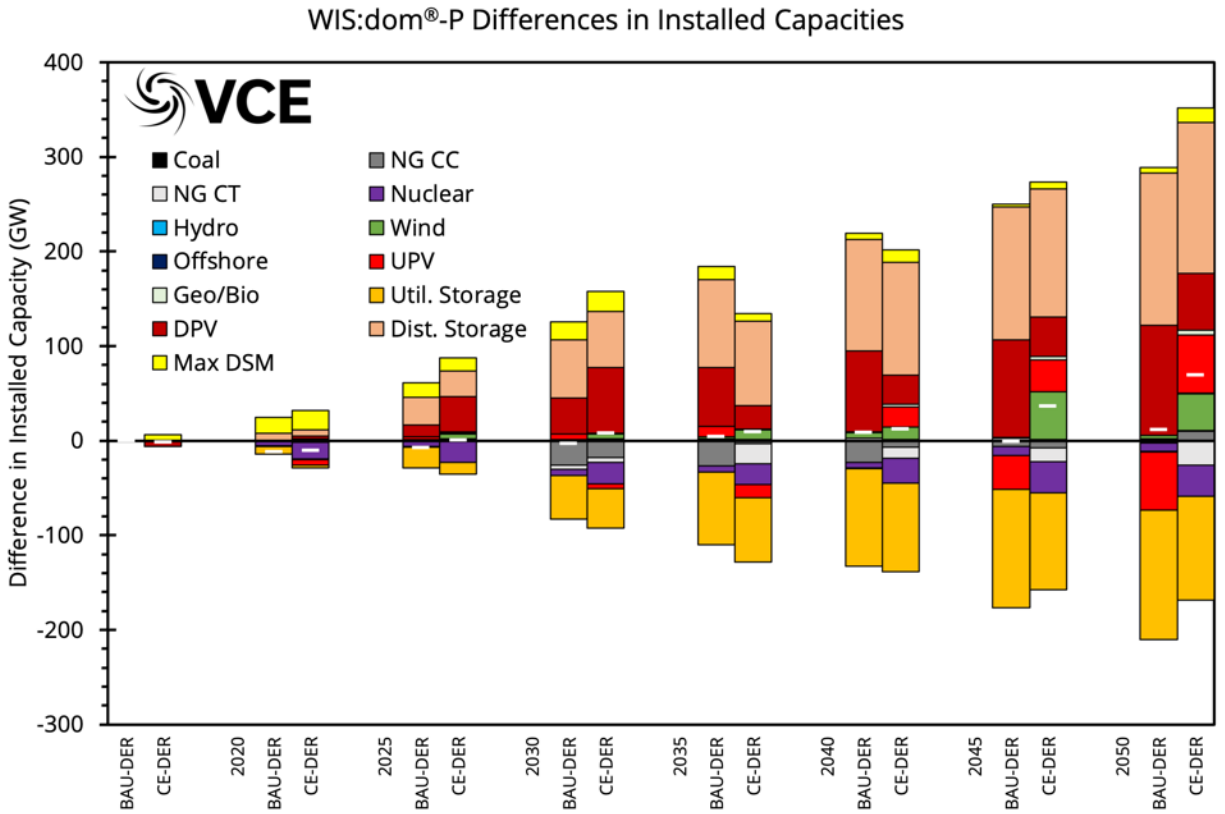


How does this manifest at CONUS-level (2050)?

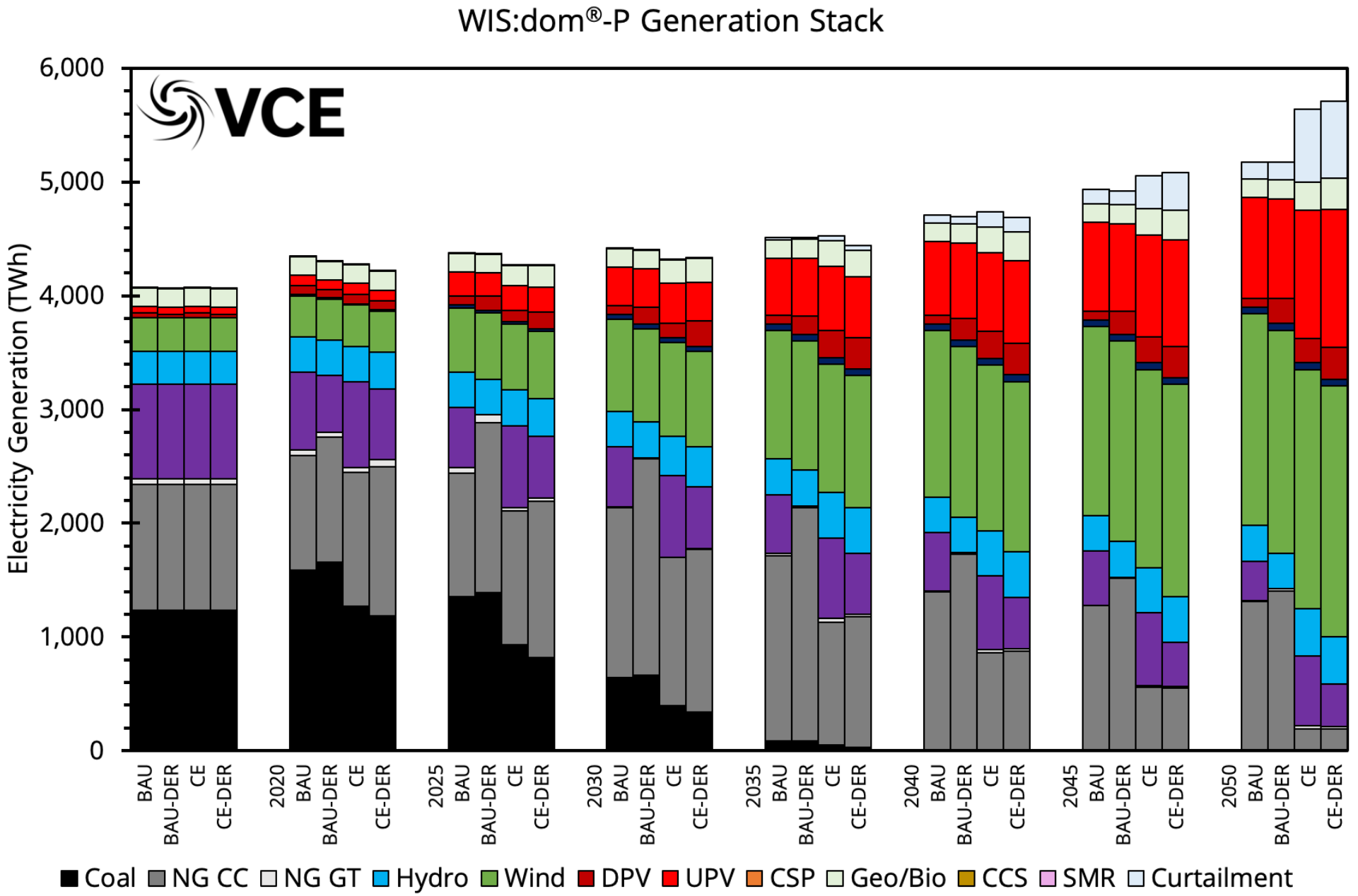


How does Distribution co-opt change installed capacity?

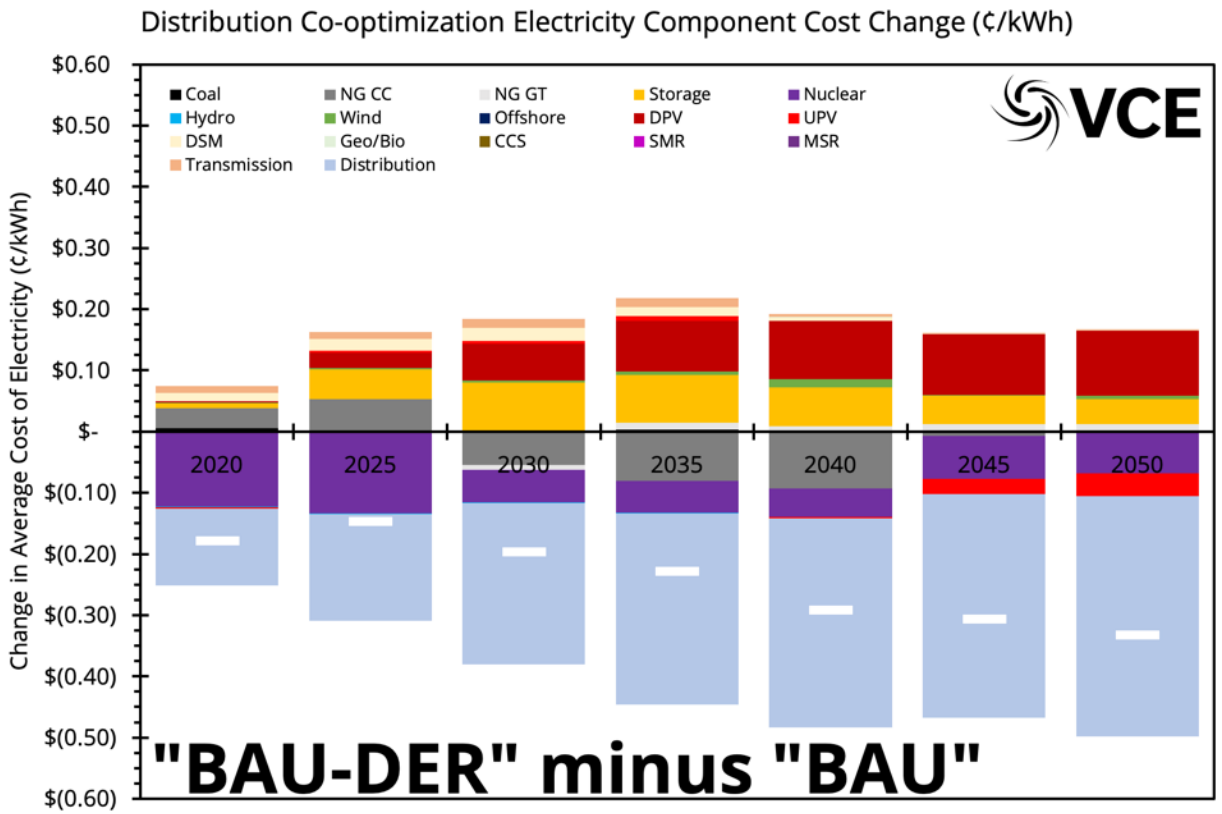


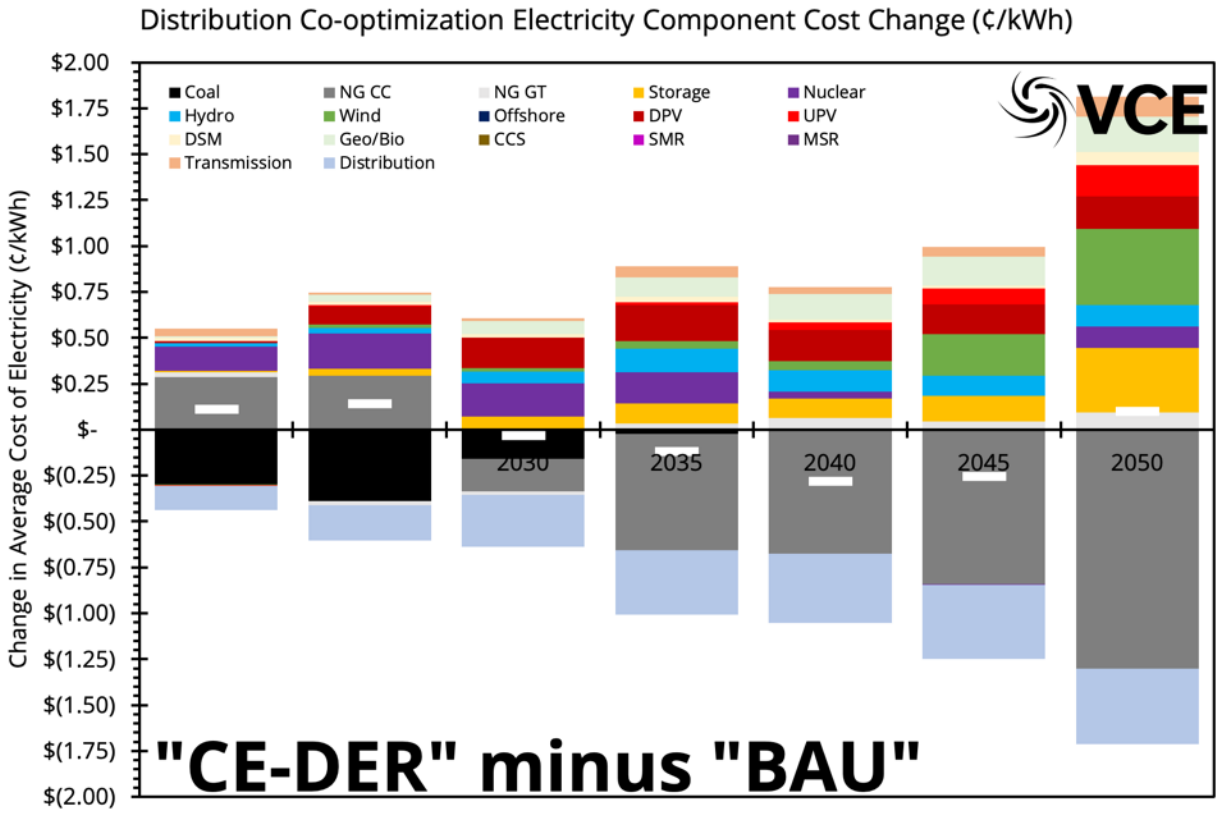


How does Distribution co-opt change generation?

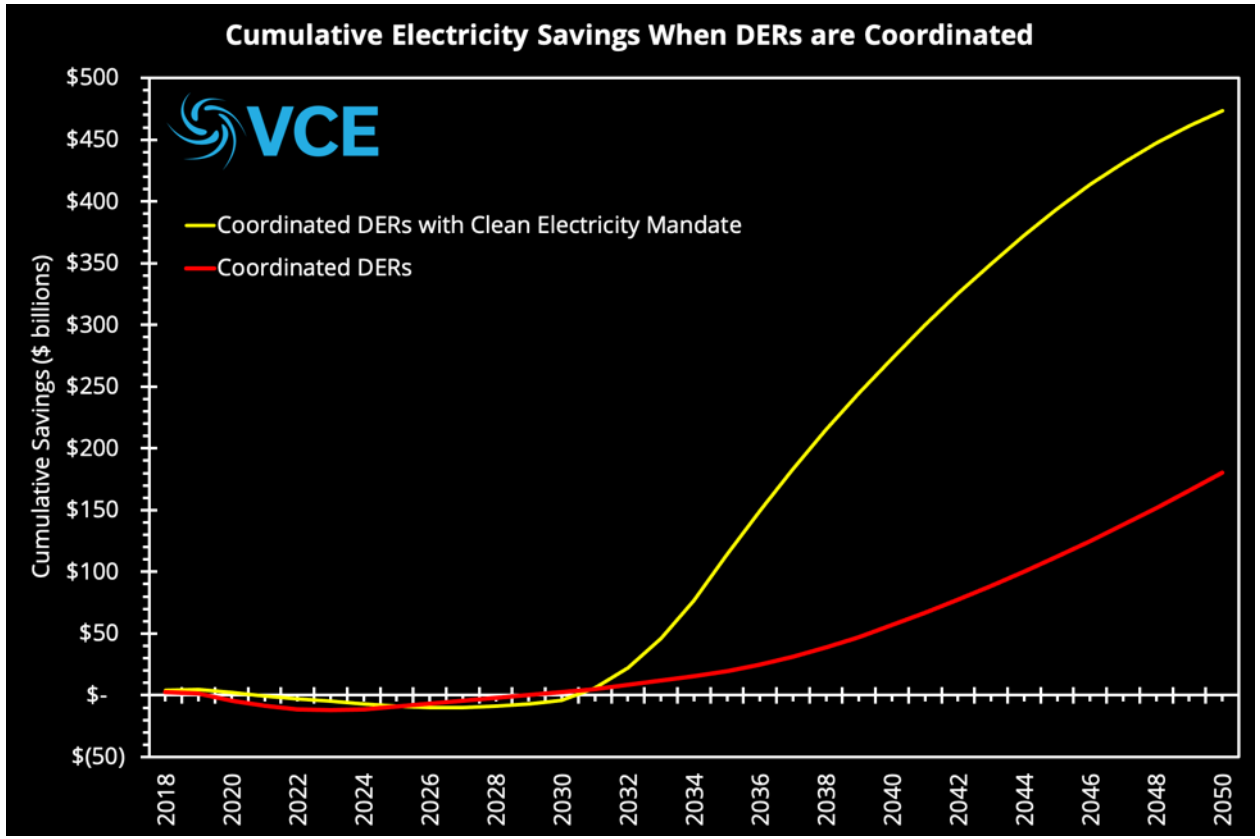


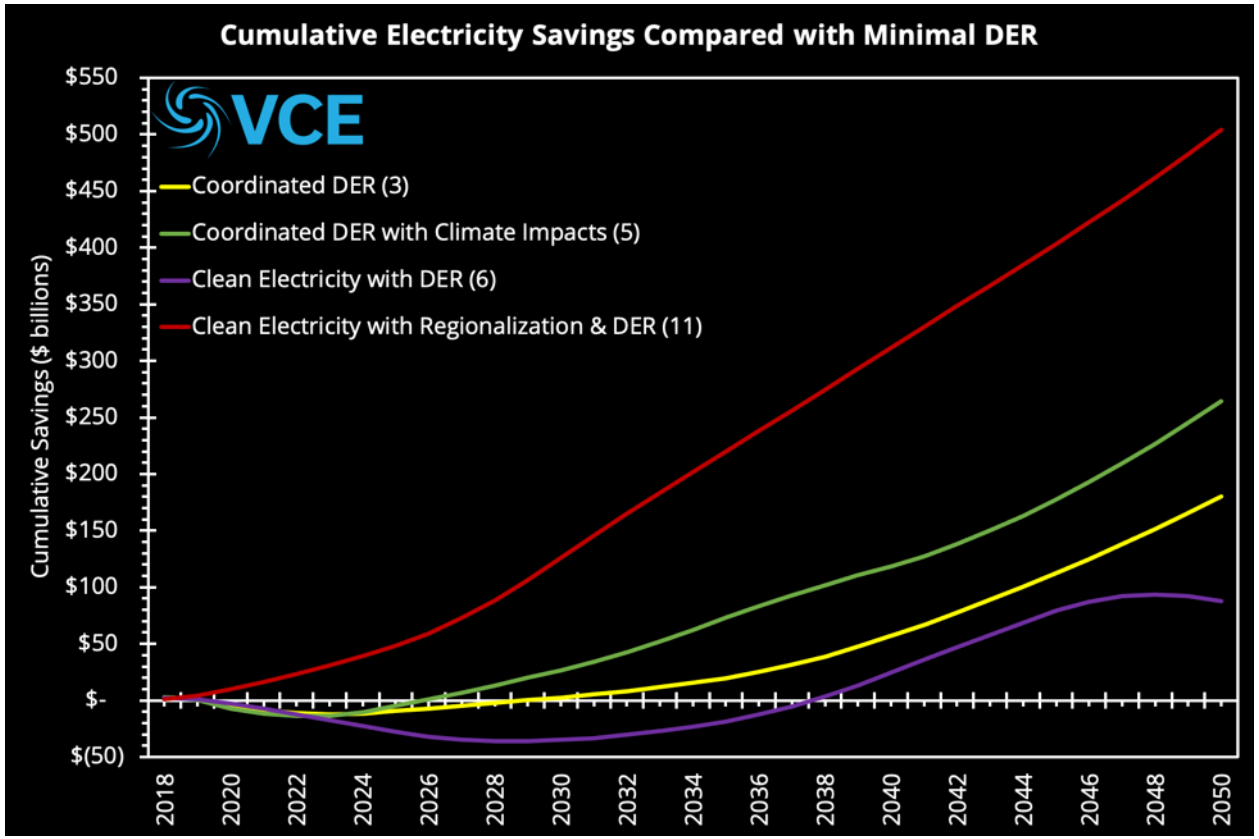
How does Distribution co-opt change the costs?



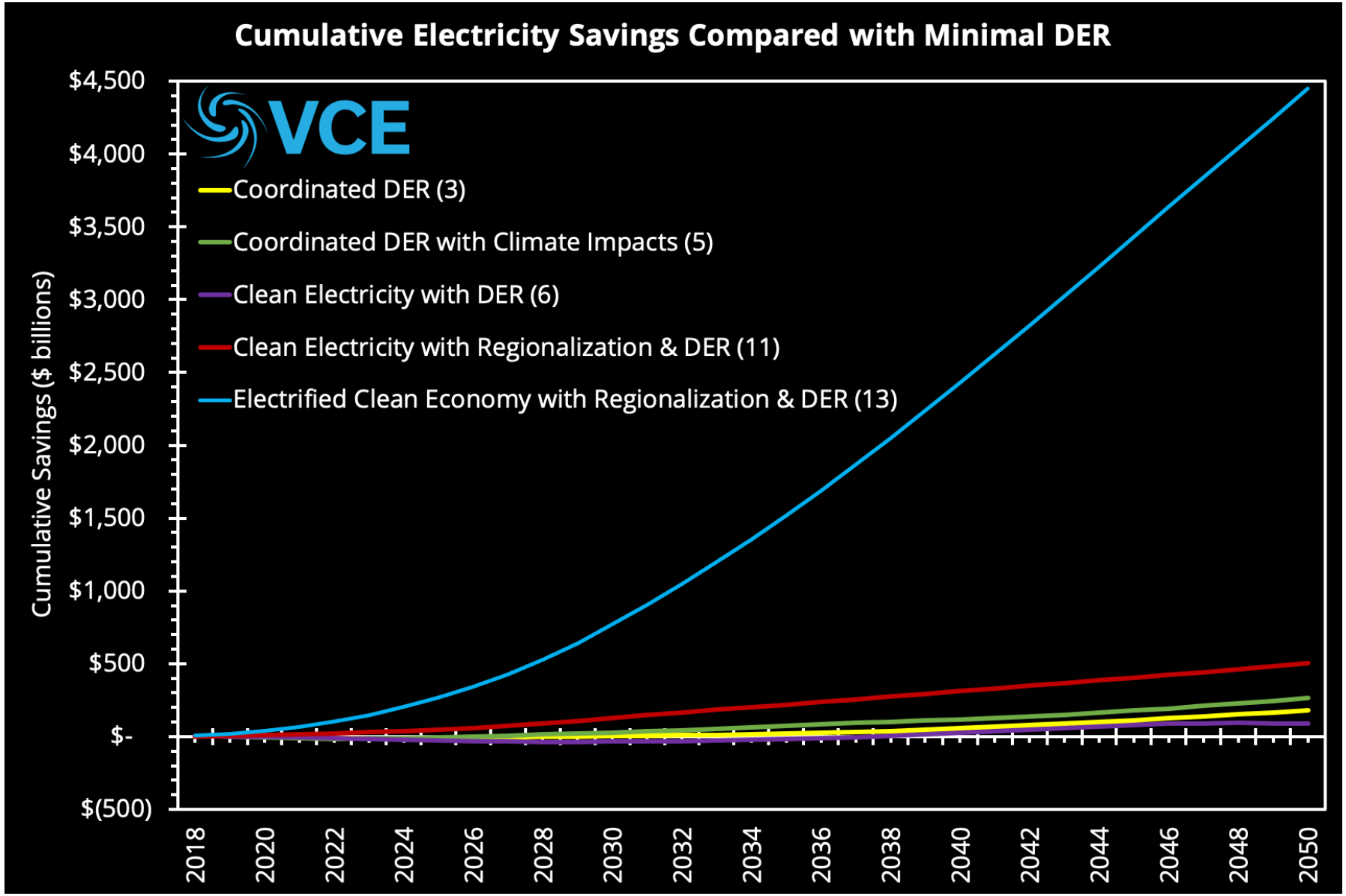


How does Distribution co-opt change the costs?

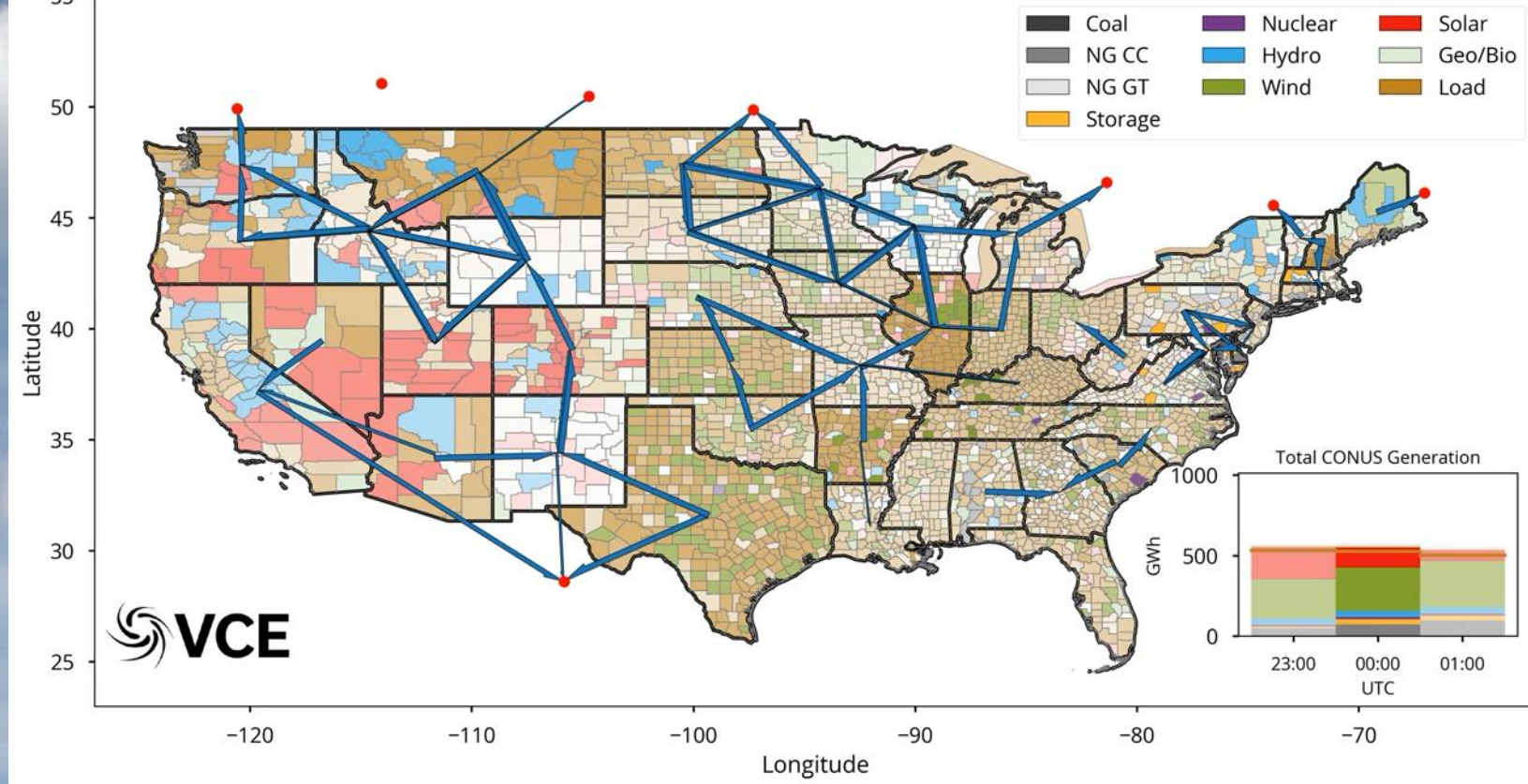




How does Distribution co-opt change the costs?



Thank You



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

Telephone: +1-720-668-6873
E-mail: chris.clack@patternenergy.com
Twitter: @DrChrisClack