The role of transmission in deep decarbonization

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Vibrant Clean Energy, LLC

Energy Systems Integration Group
Webinar Virtual Meeting
March 22nd, 2021

Go to Slido.com use code *ESIG22* to submit your questions!

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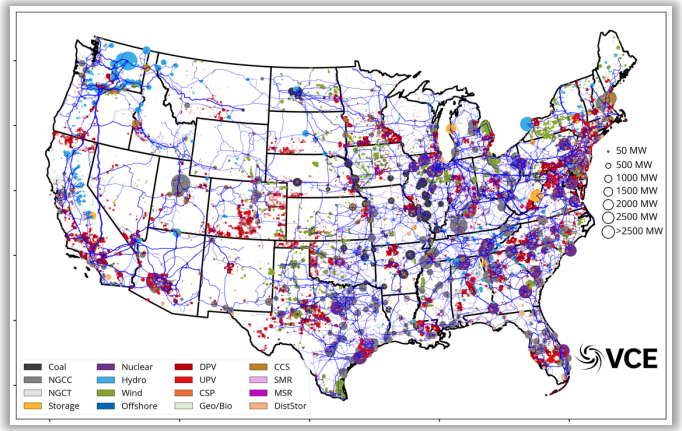

Purpose of Vibrant Clean Energy, LLC:

- Reduce the cost of electricity and help evolve economies to near zero emissions;
- Co-optimize transmission, generation, storage, and distributed resources;
- Increase the understanding of how Variable Generation impacts and alters the electricity grid and model it more accurately;
- Agnostically determine the least-cost portfolio of generation that will remove emissions from the economy;
- Determine the optimal mix of VG and other resources for efficient energy sectors;
- Help direct the transition of heating and transportation to electrification;
- ***License WIS:dom® optimization model & data and/or perform studies using the model;***
- Ensure profits for energy companies with a modernized grid;
- Assist clients unlock and understand the potential of high VRE scenarios, as well as zero emission pathways.

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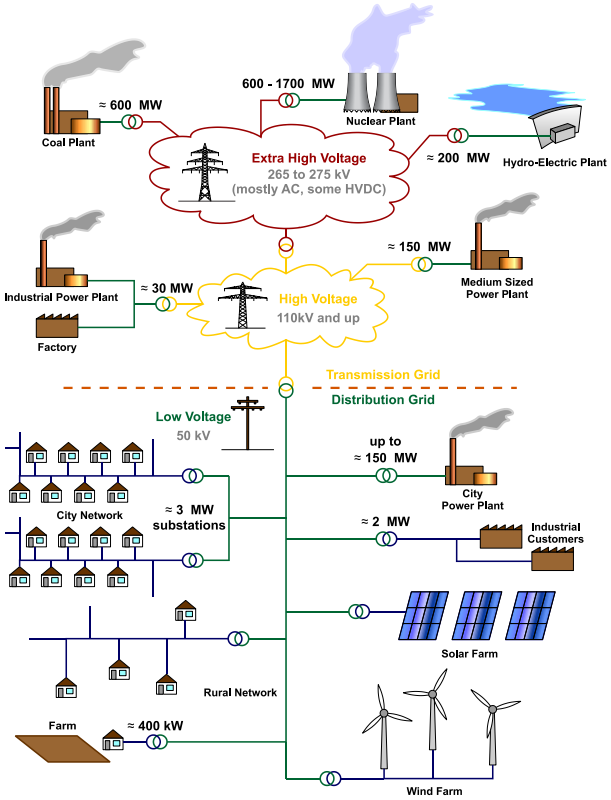
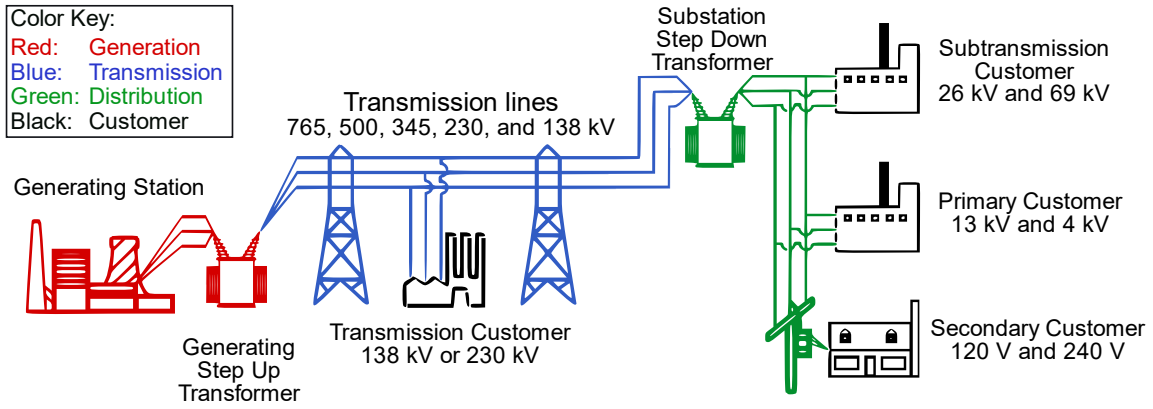
What is transmission?





Transmission is the wires that connect us all together. It moves generation around an electric grid until it is consumed.

https://en.wikipedia.org/wiki/Electrical_grid#/media/File:Electricity_Grid_Schematic_English.svg
https://www.ferc.gov/industries/electric/indus-act/reliability/blackout/ch1-3.pdf

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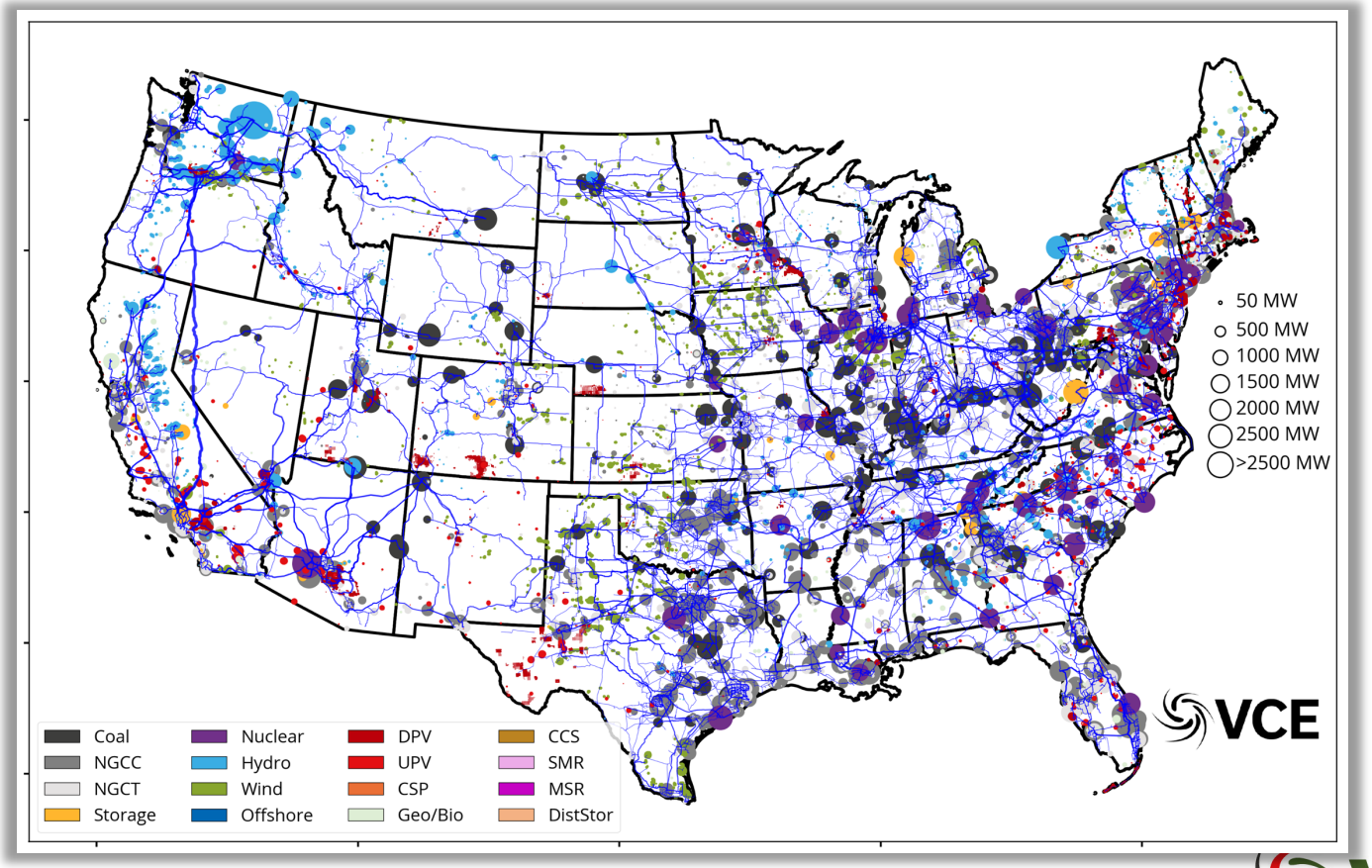
The Continental United States Electric Grid (2018)



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Available Clean Generation Are Tied To Electricity

Low-marginal Cost Electricity Production Resources (kWh)

- *Wind*
- *Solar*
- *Geothermal*
- *Nuclear*
- *Hydroelectric*

Flexibility Resources (kWh → kW → kWh)

- ***Transmission***
- *Hybrid Resources (wind+solar+storage)*
- *Storage (electricity+heat)*
- *Electrification*
- *Direct Air Capture*
- *Demand-side management*
- *Dispatchable Generation (SMR, EGS, H_2 CC, NGCC+CCS)*
- *Synthetic Fuel/Chemical Production (H_2, CH_4, NH_3)*
- *Peaking Generation (H_2 CT)*

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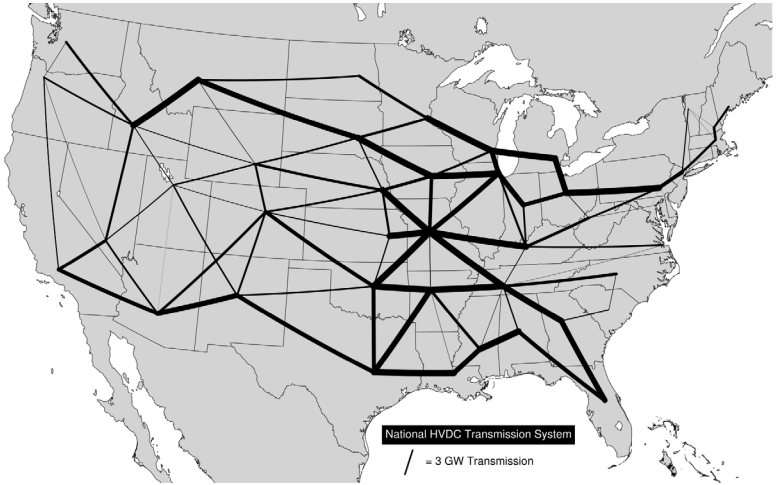
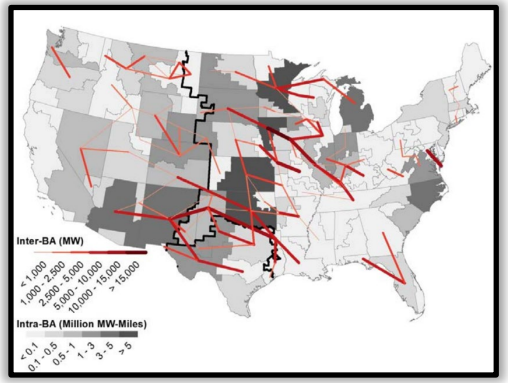
Why is transmission important?

Transmission unlocks:

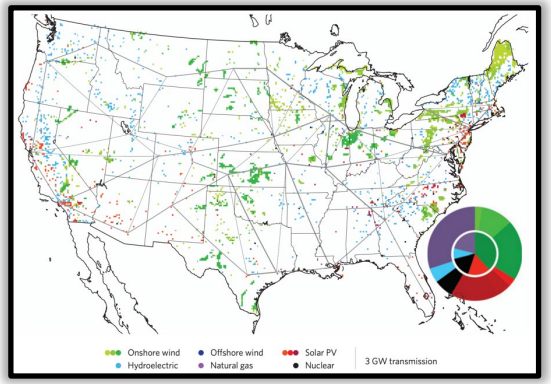
- Easier decarbonization of electricity grid;
- More efficient electrification of other sectors;
- Reduced electricity costs for all customers;
- Enhanced reliability of electricity for users;
- Reduction of curtailment of renewables;
- Increased storage and DER integration;
- Interstate markets for electricity.



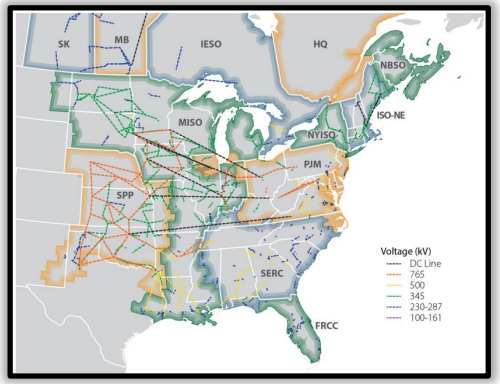
Many studies have shown the benefits of long distance transmission



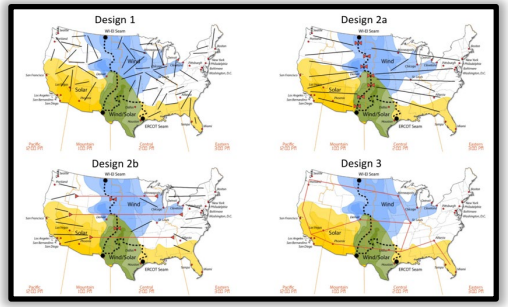
NREL REFs (2012)



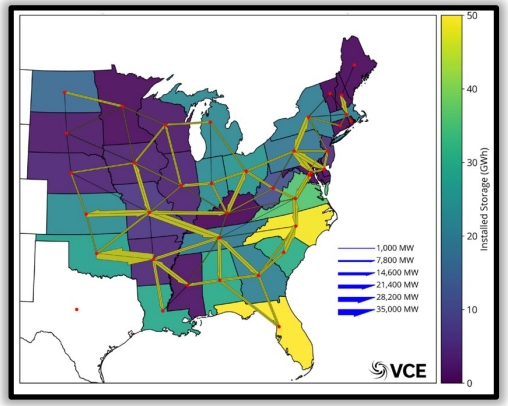
MacDonald, Clack et al. (2016)



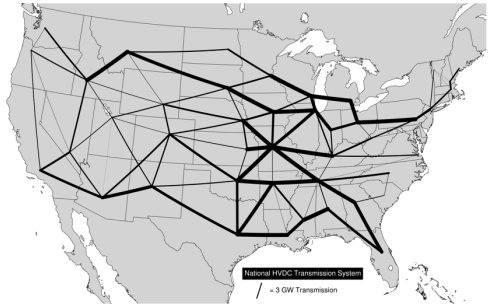
NREL ERGIS (2016)



NREL SEAMS (2018)



ACEG EI Study (2020)



VCE ZBF Study (Mar 2021)

**Note, there are many, many more!*

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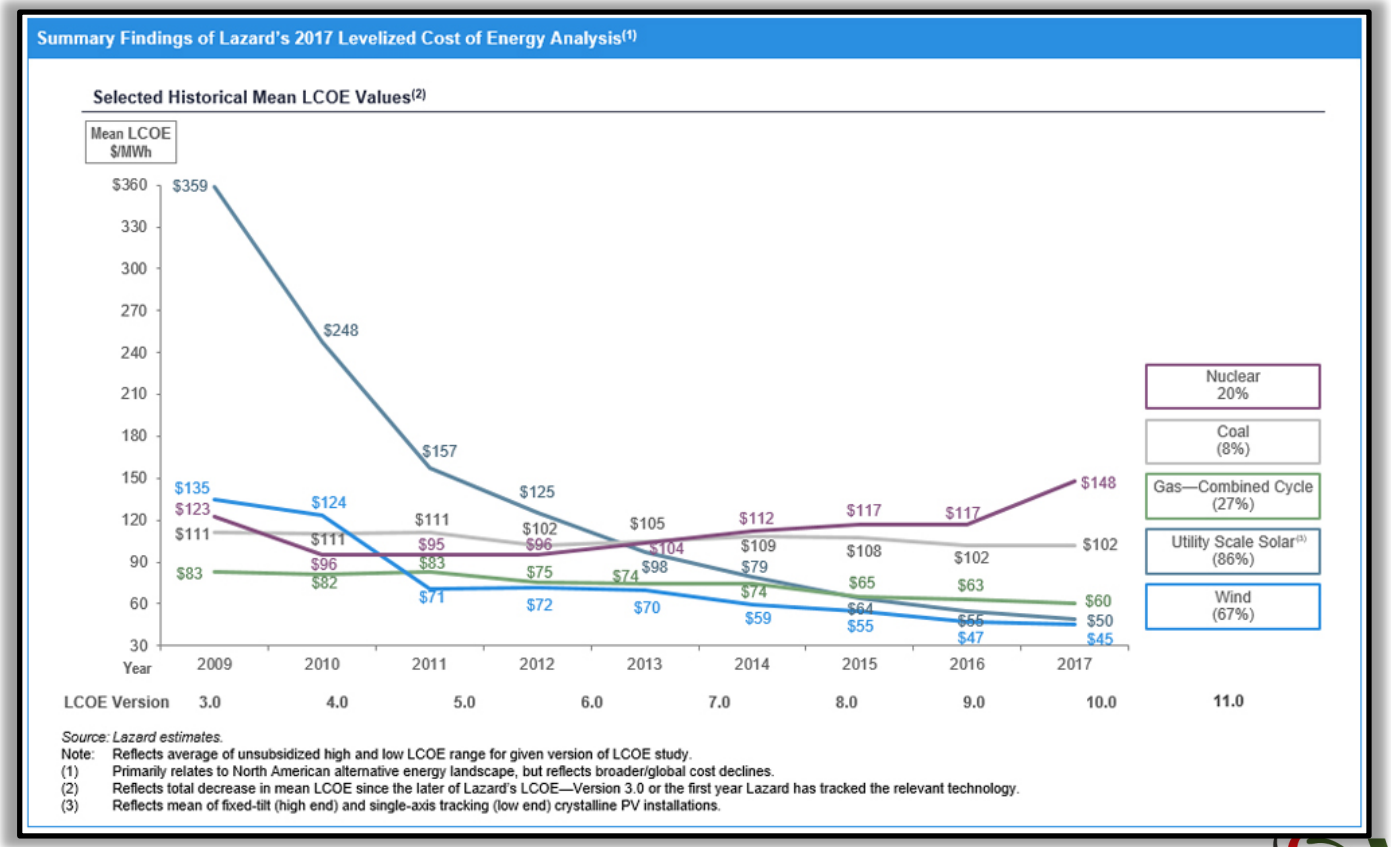
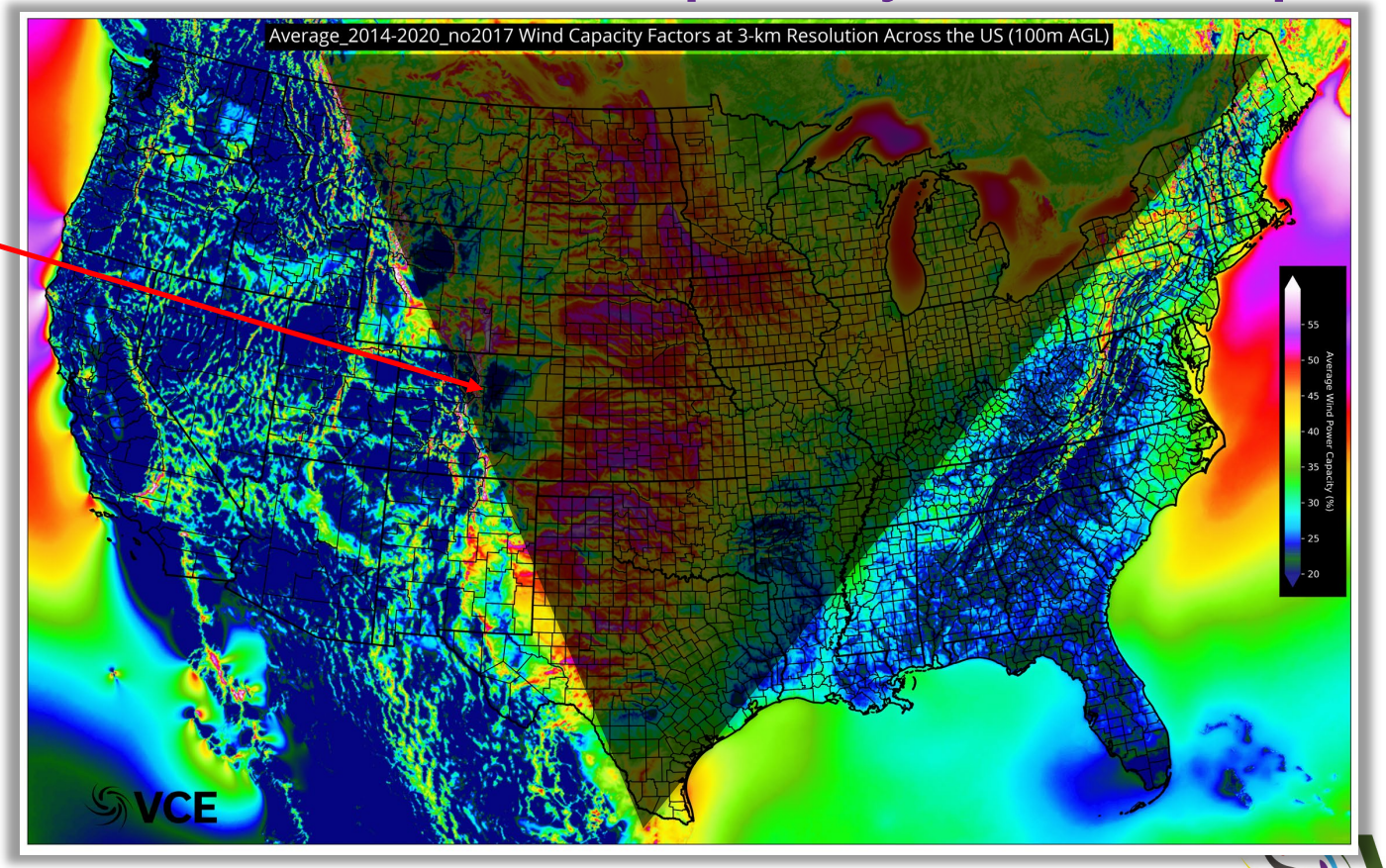
How does a transmission grid enable deep decarbonization?

Renewables are the cheapest source of electricity



Lowest cost wind is confined primarily to the central plains



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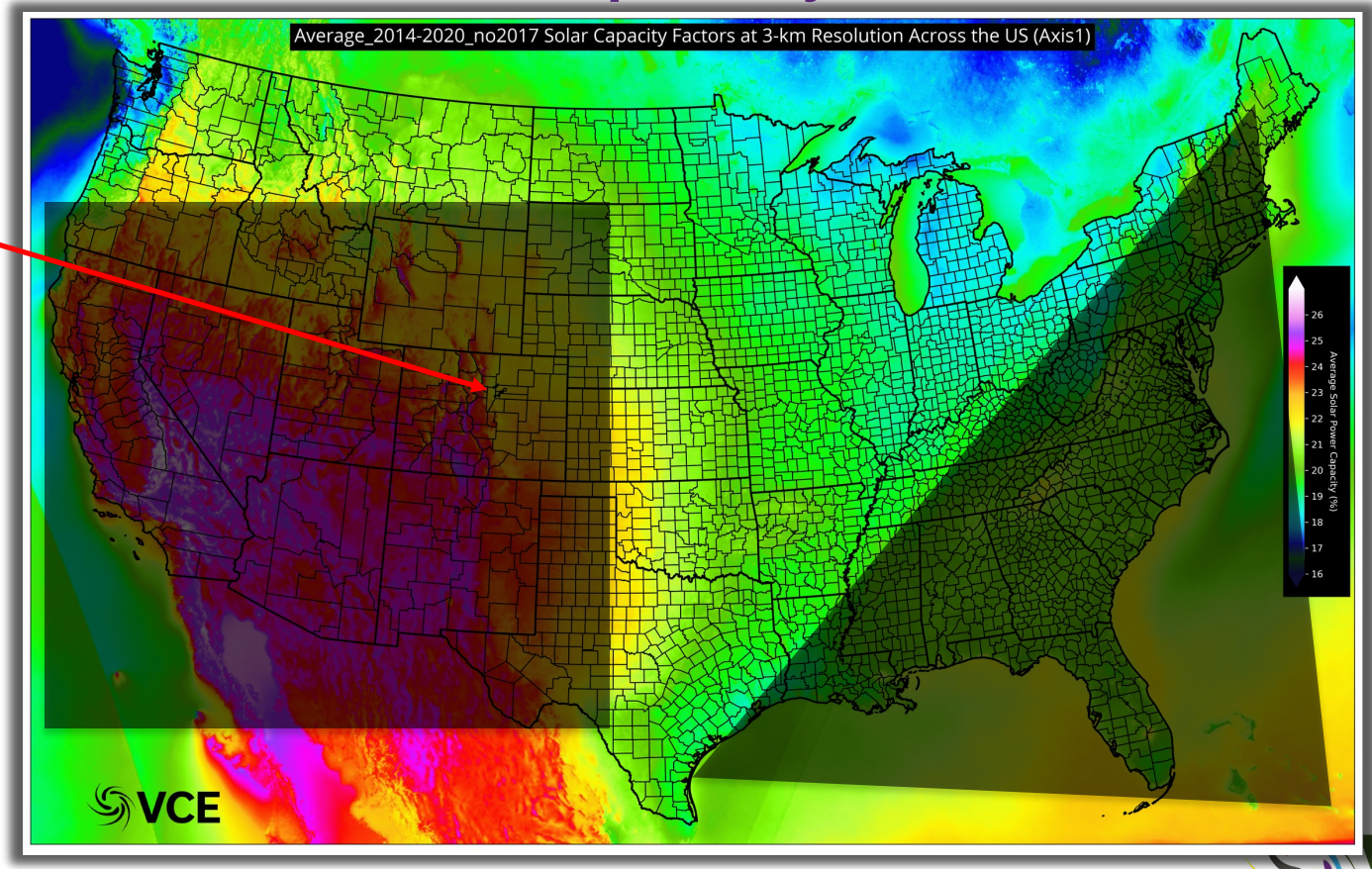
Lowest cost solar is confined primarily to the west and south east



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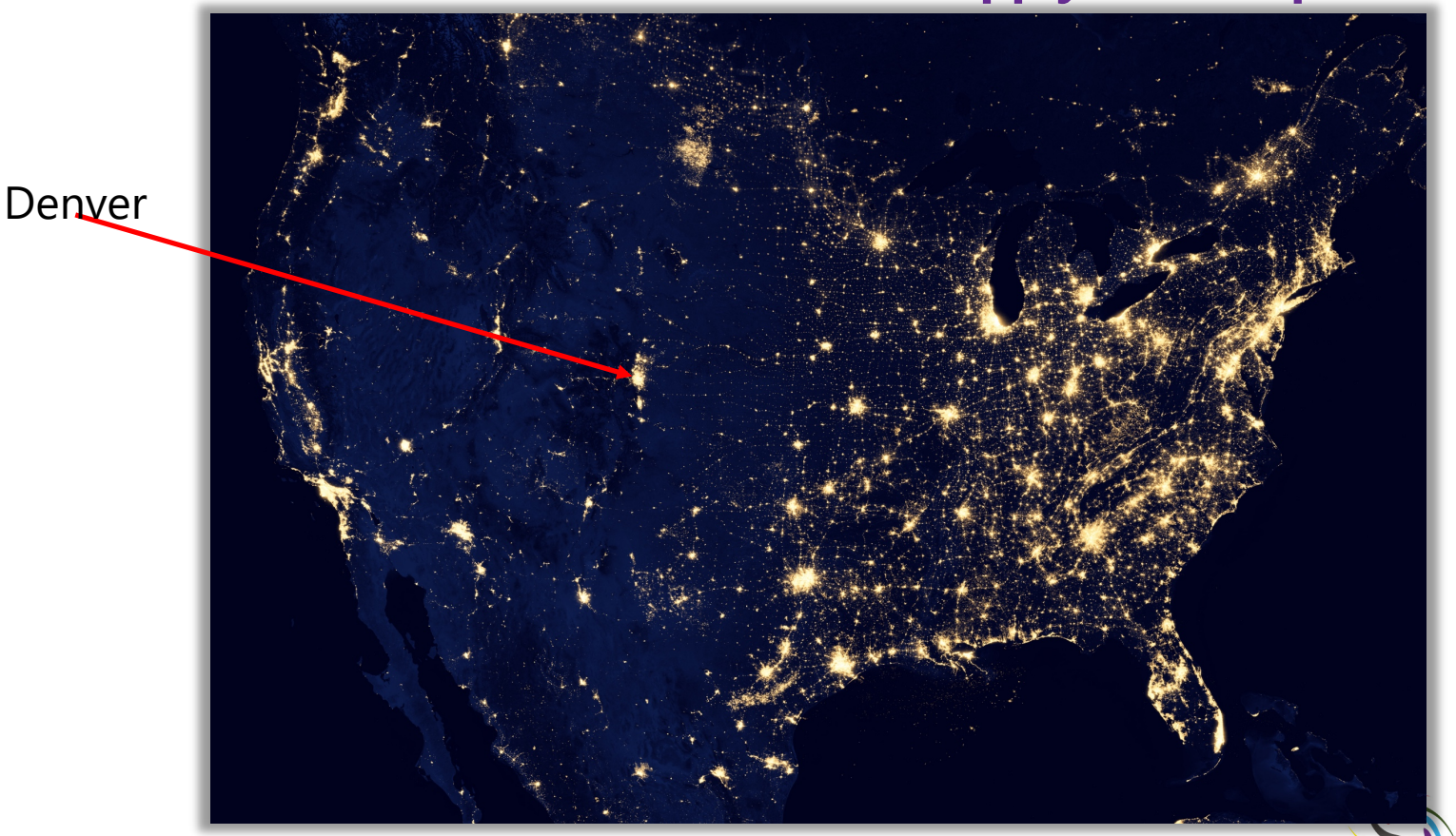
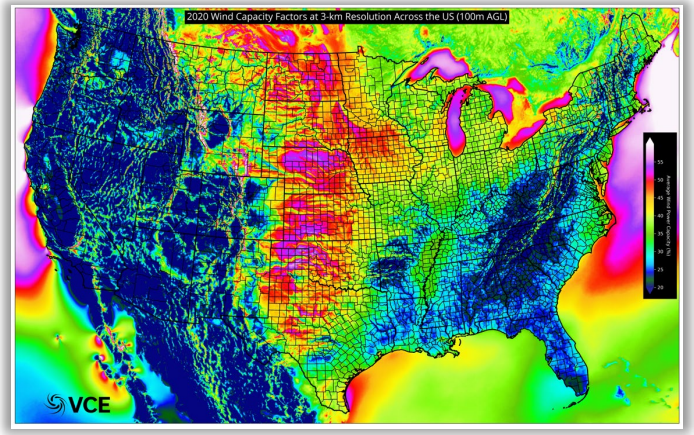
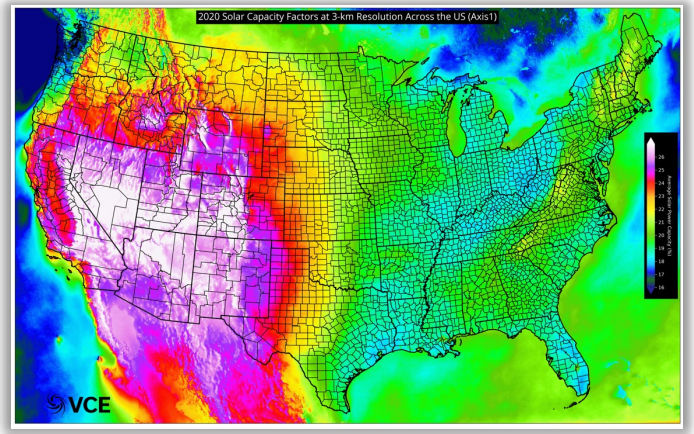
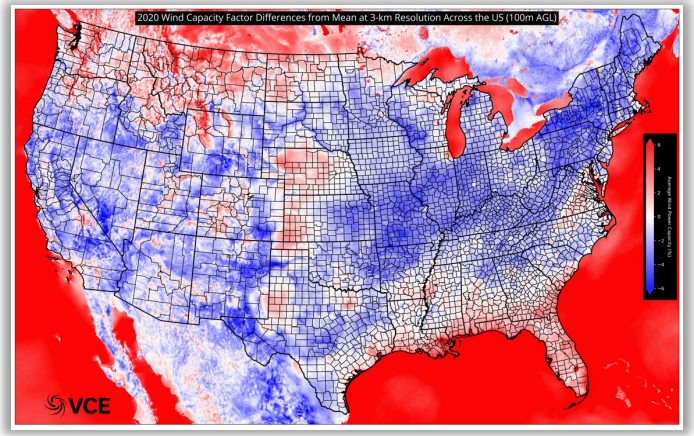
Demands are concentrated & supply will be sparse

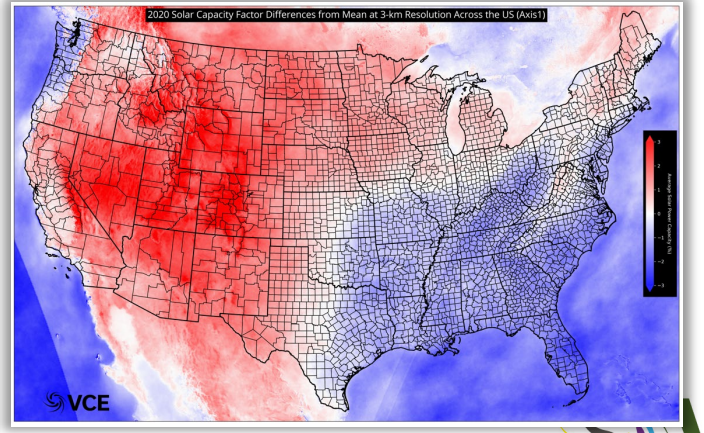


Interannual variability of VREs can be harnessed









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Global Heat Transfer Drives Wind & Solar Constantly

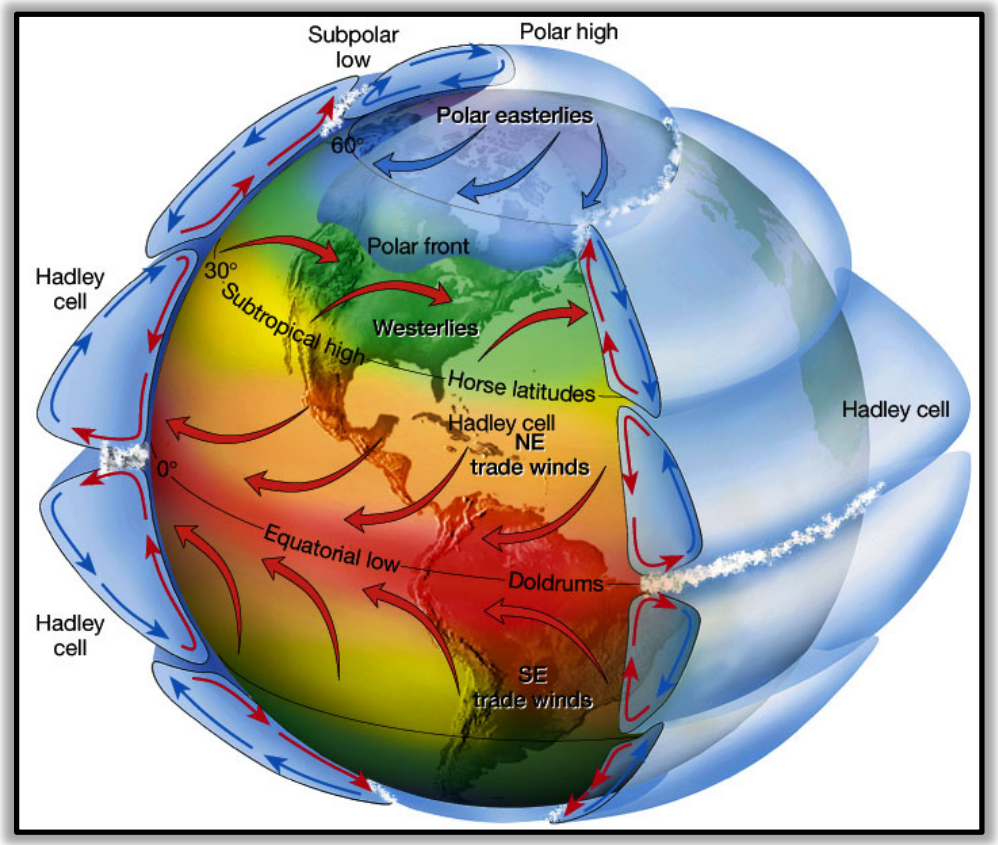

Image Credit: Figure 7.5 in *The Atmosphere, 8th edition*, Lutgens and Tarbuck, 8th edition, 2001

This global heat engine runs **constantly** driving wind and cloud patterns.

Processes ***are well understood***.

Driven By Solar Irradiance & Earth-Sun Distance.

Therefore "variability" is a **local effect**.

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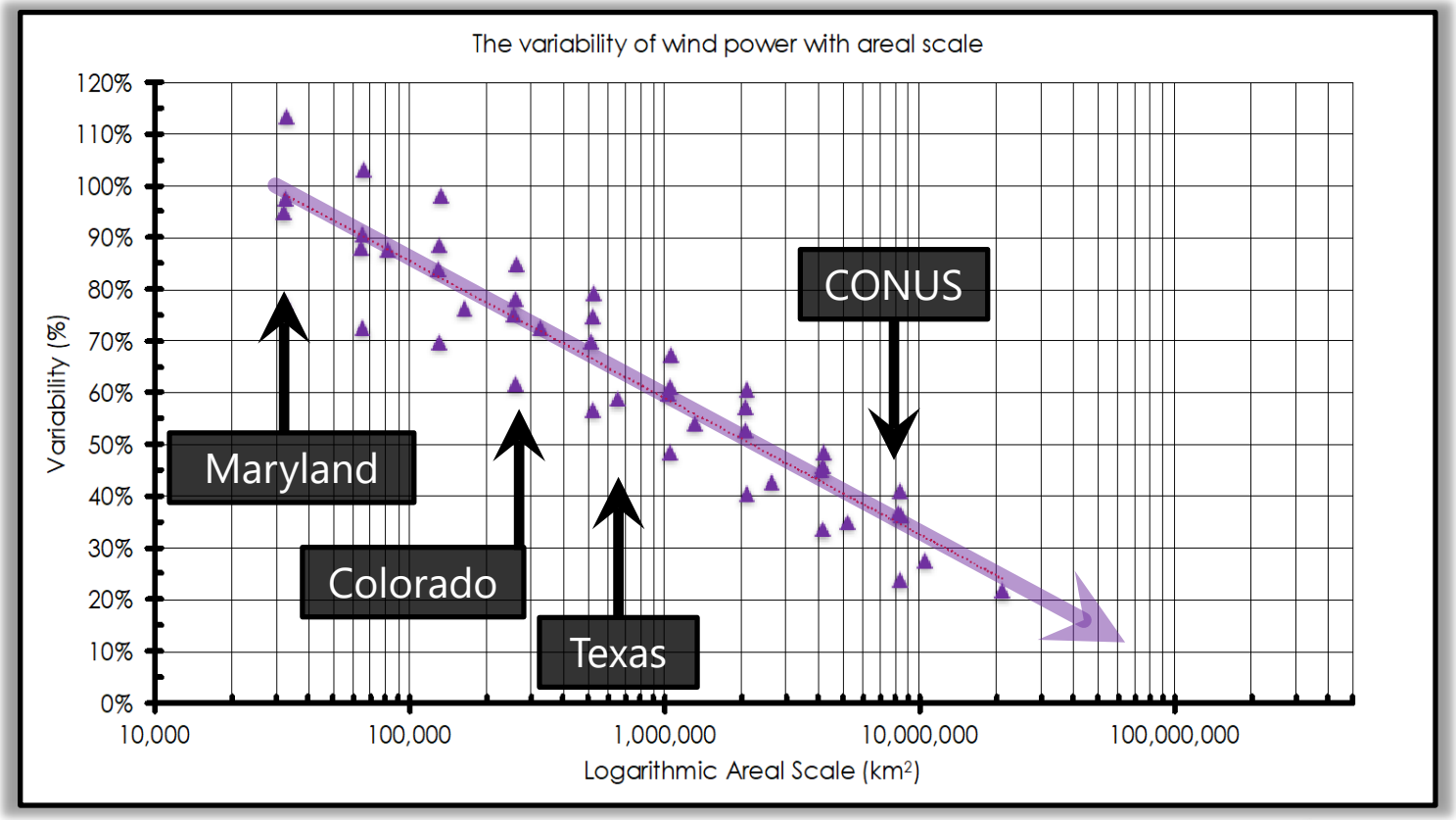
Variability Of Wind & Solar Shrinks With Larger Areas



Wind & solar ***can back each other up*** using their nature

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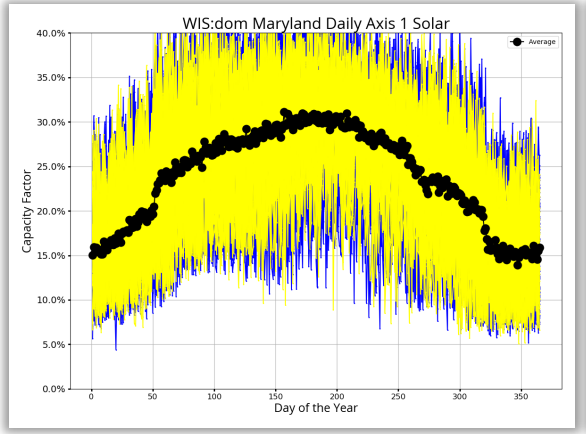
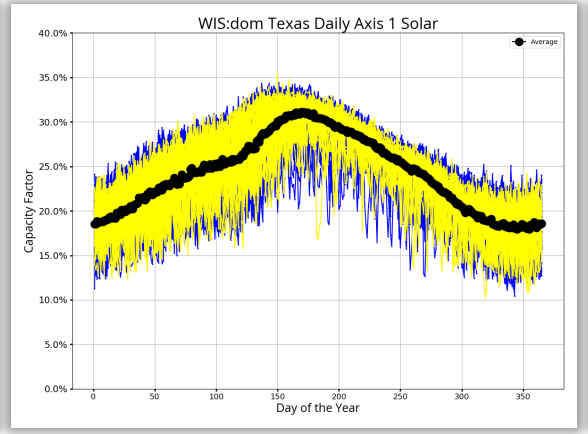
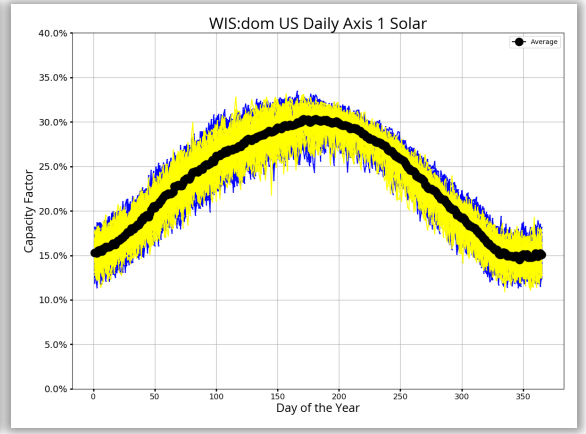
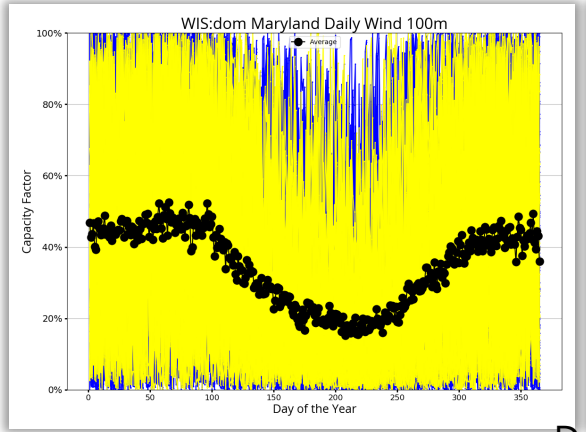
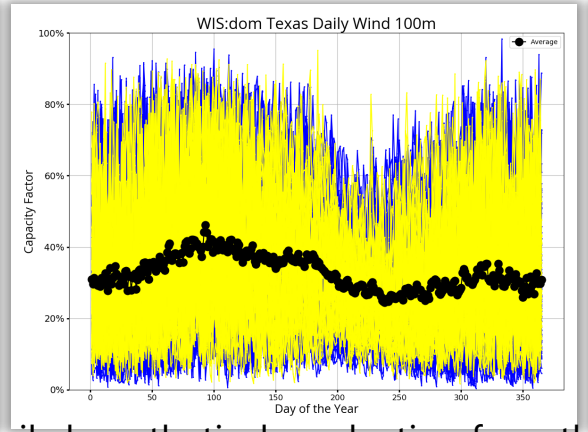
Variability Of Wind & Solar Shrinks With Larger Areas

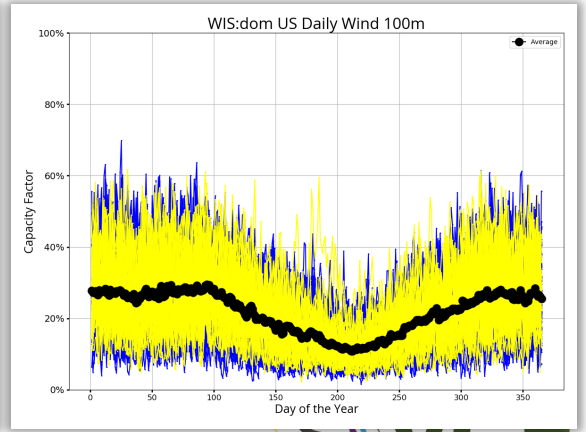












Daily hypothetical production from the VCE long-term dataset (1900-2015)

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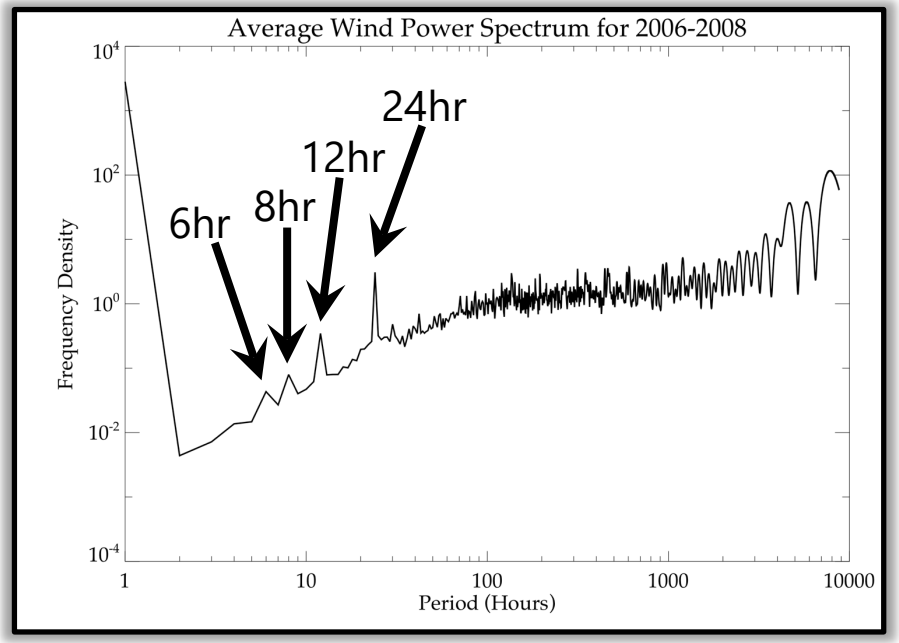
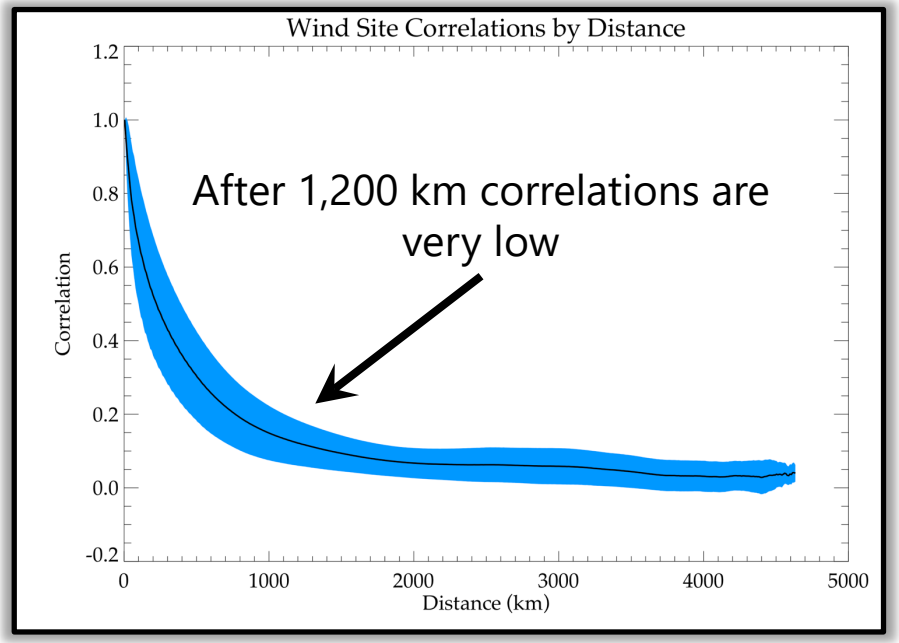
Wind & Solar Are Created By Chaotic Not Random Processes

Therefore, patterns emerge that can be taken advantage of!





Energy Density Accumulates At Predictable Times & Sites Decorrelate Rapidly

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Demand For Electricity Will Necessarily Grow

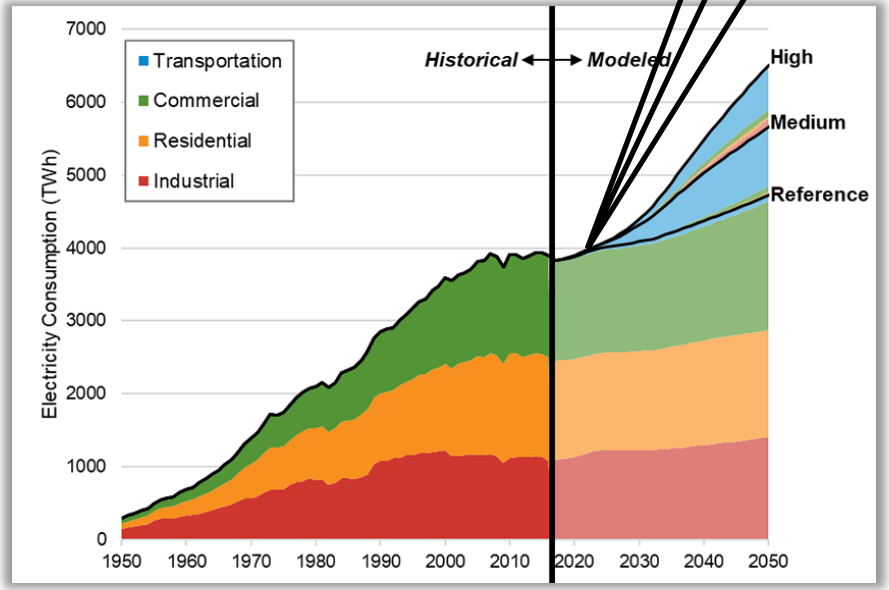
NOTE: In 2019 **29.4 PWh** of primary energy was consumed in the US. Of that **9.6 PWh** was productive for end uses (energy services).
Source: LLNL

63% down	**15% up**
70% down	**7% down**
73% down	**19% down**

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

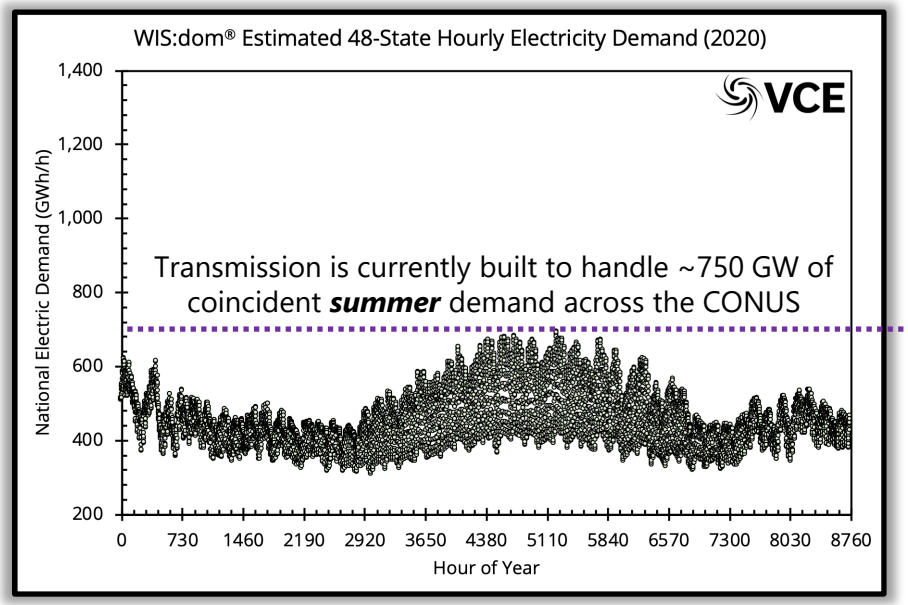
ZBF 2050 TWh with RCP4.5 climate change impacts (8.9 PWh)

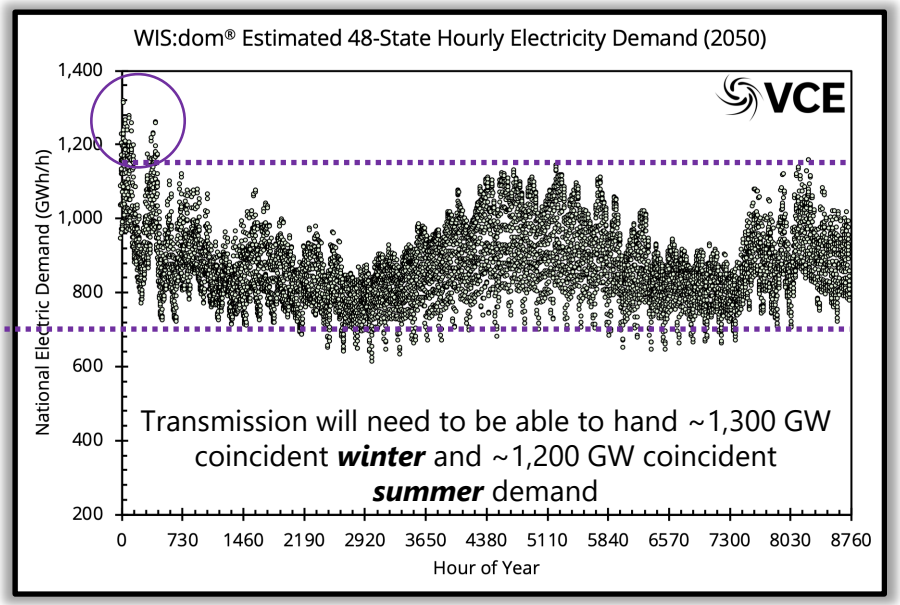
ZBF 2050 TWh without climate change impacts (7.8 PWh)



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

Demand Profiles & Stress Periods Will Change Over Time





* Before synthetic fuel production

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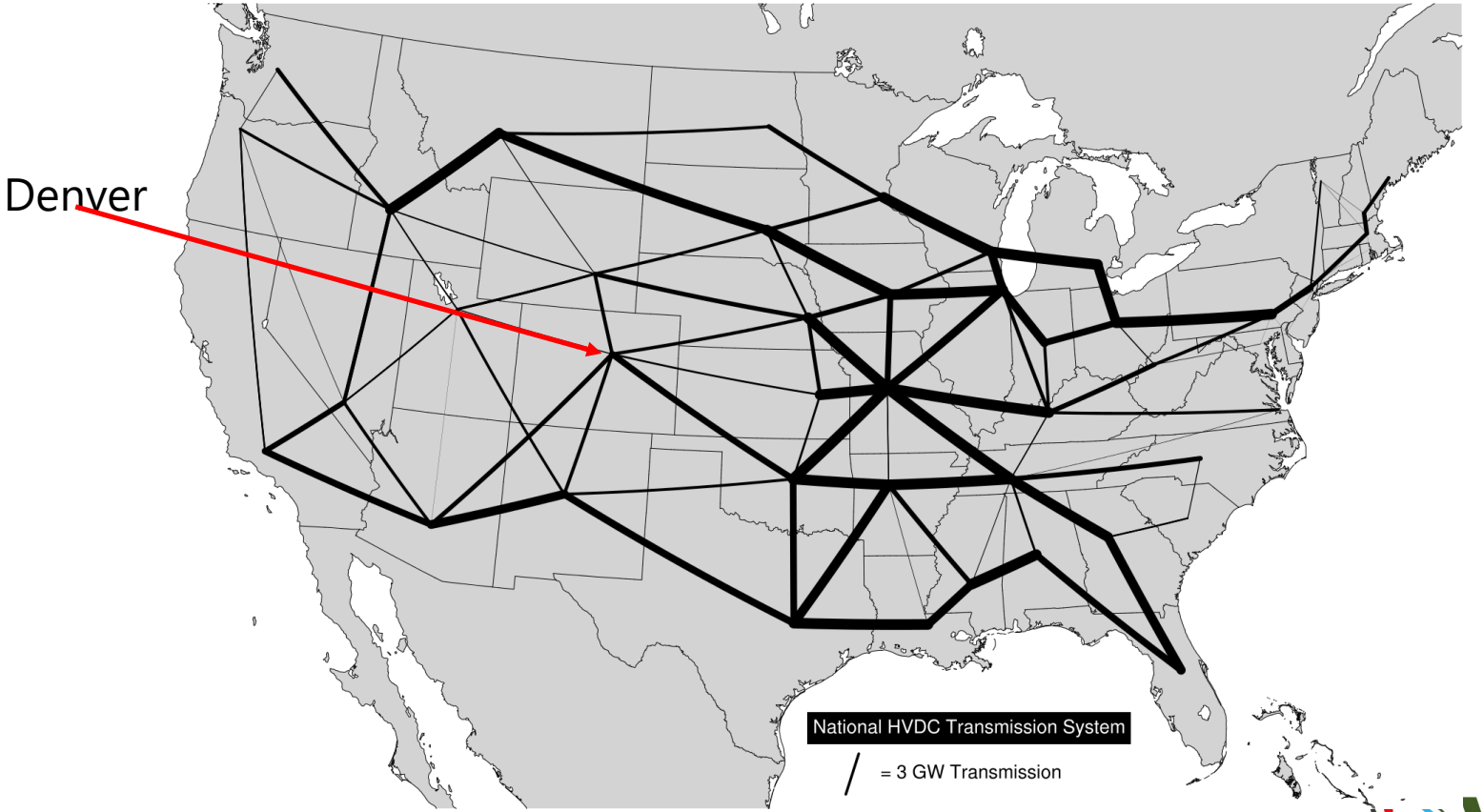
Could a continental transmission grid help deep decarbonization?



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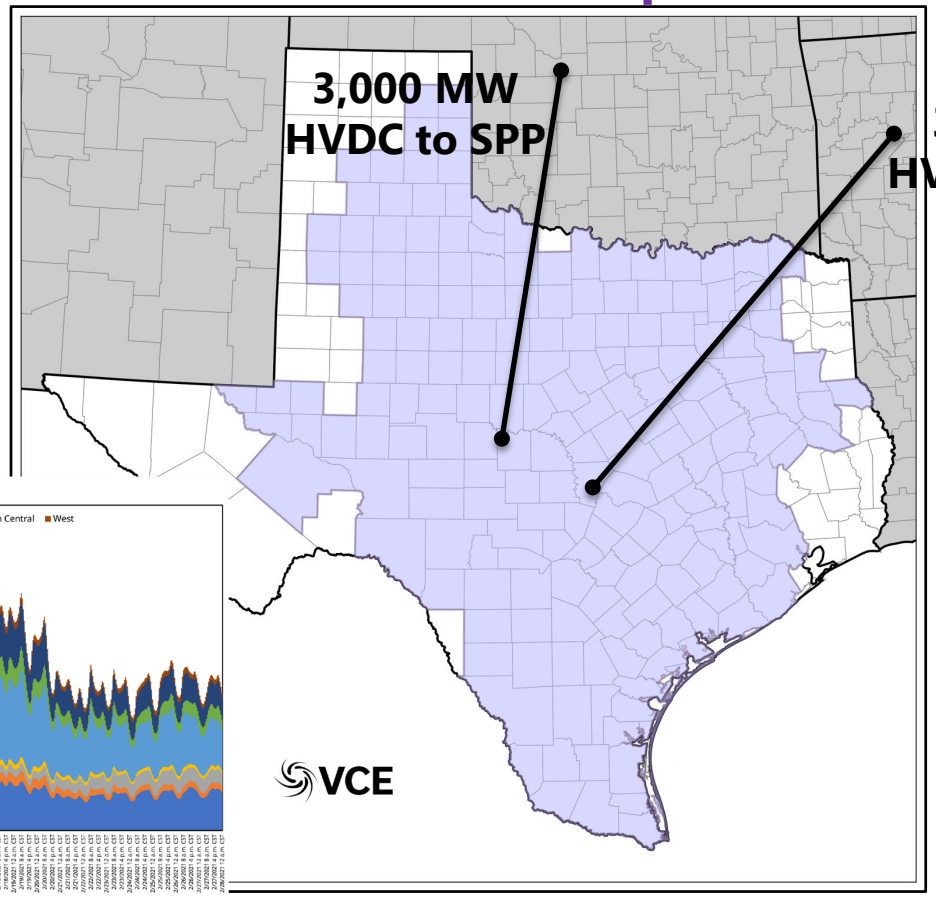
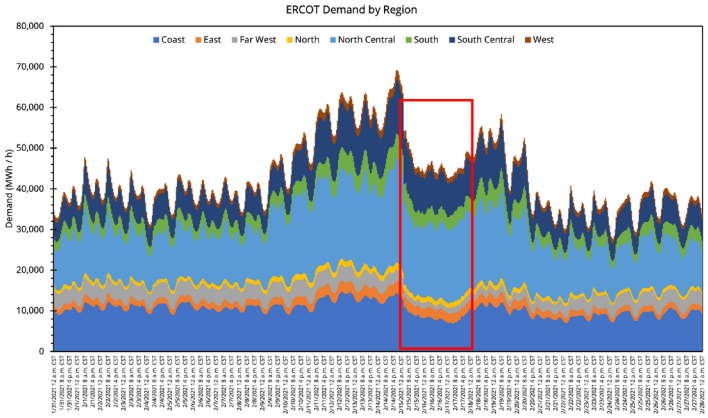
How could a transmission grid handle extreme events?

Could have transmission for ERCOT helped for Storm Uri? [YES!]





NB: Each HVDC transmission line would cost ~$1.2 billion

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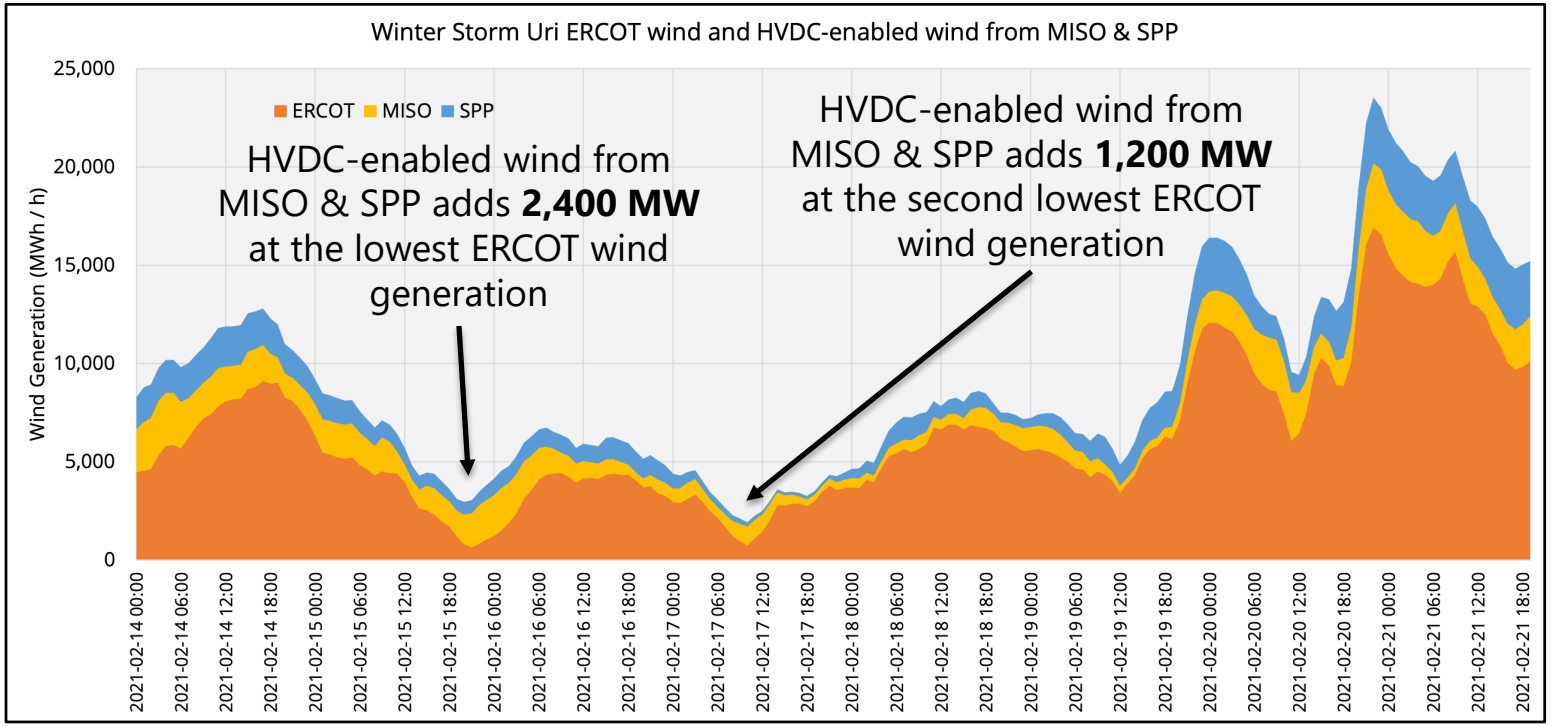
Could have transmission for ERCOT helped for Storm Uri? [YES!]



Over the blackout period HVDC-enabled wind from MISO & SPP could have provided ***515 GWh*** of clean generation

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NB: We assume additional wind is built for these transmission lines, which will provide generation all year; but our focus is this extreme event.

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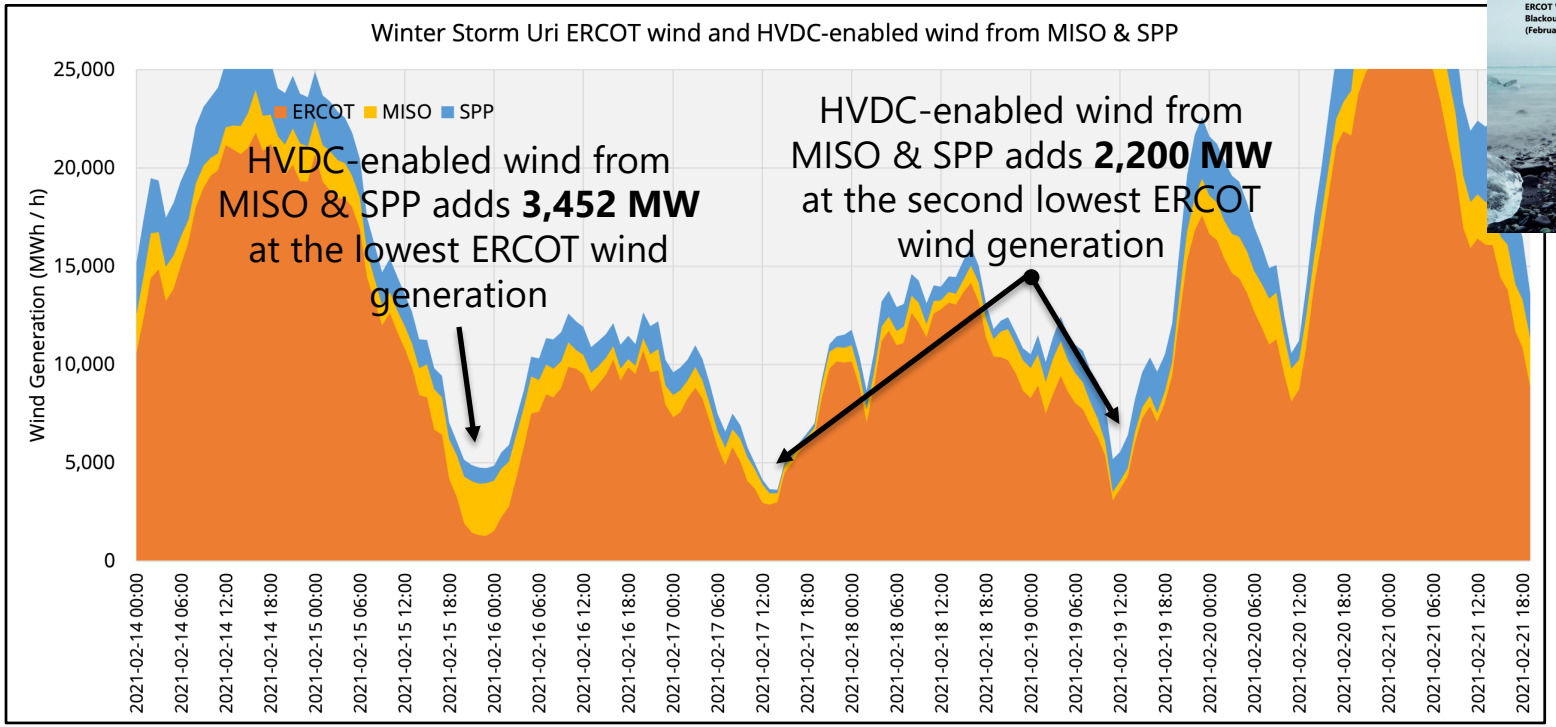
Could have transmission for ERCOT helped for Storm Uri? [YES!]

** VCE white paper on ERCOT coming by tomorrow morning*



Strong winterization would increase HVDC-enabled wind to ***643 GWh*** & ERCOT could have removed second lowest generation substantially

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NB: We assume additional wind is built for these transmission lines, which will provide generation all year; but our focus is this extreme event.

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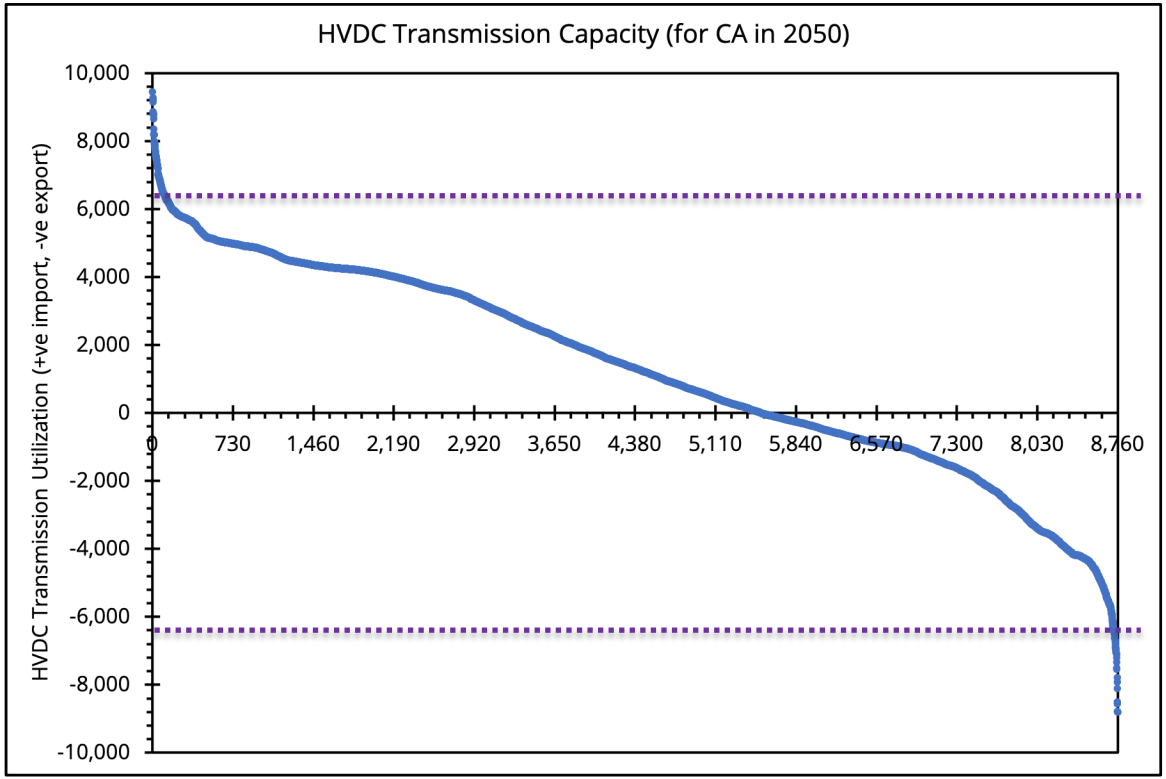
How could a transmission grid be deferred or avoided? What are the alternatives?

An Example for California



Reduce HVDC by ***3,000 MW*** (a large single line)

This is a simplified example!

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An Example for California (today's alternatives)

California example			Assume 500 miles
2025 (current trends)	Natural Gas	Storage	Transmission (HVDC)
Capital ($/kW)	**$ 887.00**	**$ 139.00**	**$ 401.60**
Capital ($/kWh)	$ -	**$ 160.00**	$ -
Fixed ($/kW-yr)	$ 11.40	$ 8.10	$ 0.53
Variable ($/MWh)	**$ 4.50**	**$ 26.30**	**$ 25.00**
Fuel ($/MMBTU)	**$ 2.90**	**$ -**	**$ -**
Capacity Factor (%)	0.368%	0.368%	0.468%
Size (MW)	3,000	3,000	3,000
WACC	5.87%	5.87%	5.87%
Term	30	10	40
LCOE ($/MWh)	**$2,327**	**$16,934**	**$653**

This is a simplified example!

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An Example for California (must reach alternatives)

California example			Assume 500 miles
Cost to match HVDC	Natural Gas	Storage	Transmission (HVDC)
Capital ($/kW)	**$ 135.00**	**$ 85.00**	**$ 401.60**
Capital ($/kWh)	$ -	**$ 1.00**	$ -
Fixed ($/kW-yr)	$ 11.40	$ 6.50	$ 0.53
Variable ($/MWh)	**$ 4.50**	**$ 1.30**	**$ 25.00**
Fuel ($/MMBTU)	**$ -**	**$ -**	**$ -**
Capacity Factor (%)	0.368%	0.368%	0.468%
Size (MW)	3,000	3,000	3,000
WACC	5.87%	5.87%	5.87%
Term	30	10	40
LCOE ($/MWh)	**$654**	**$659**	**$653**

This is a simplified example!

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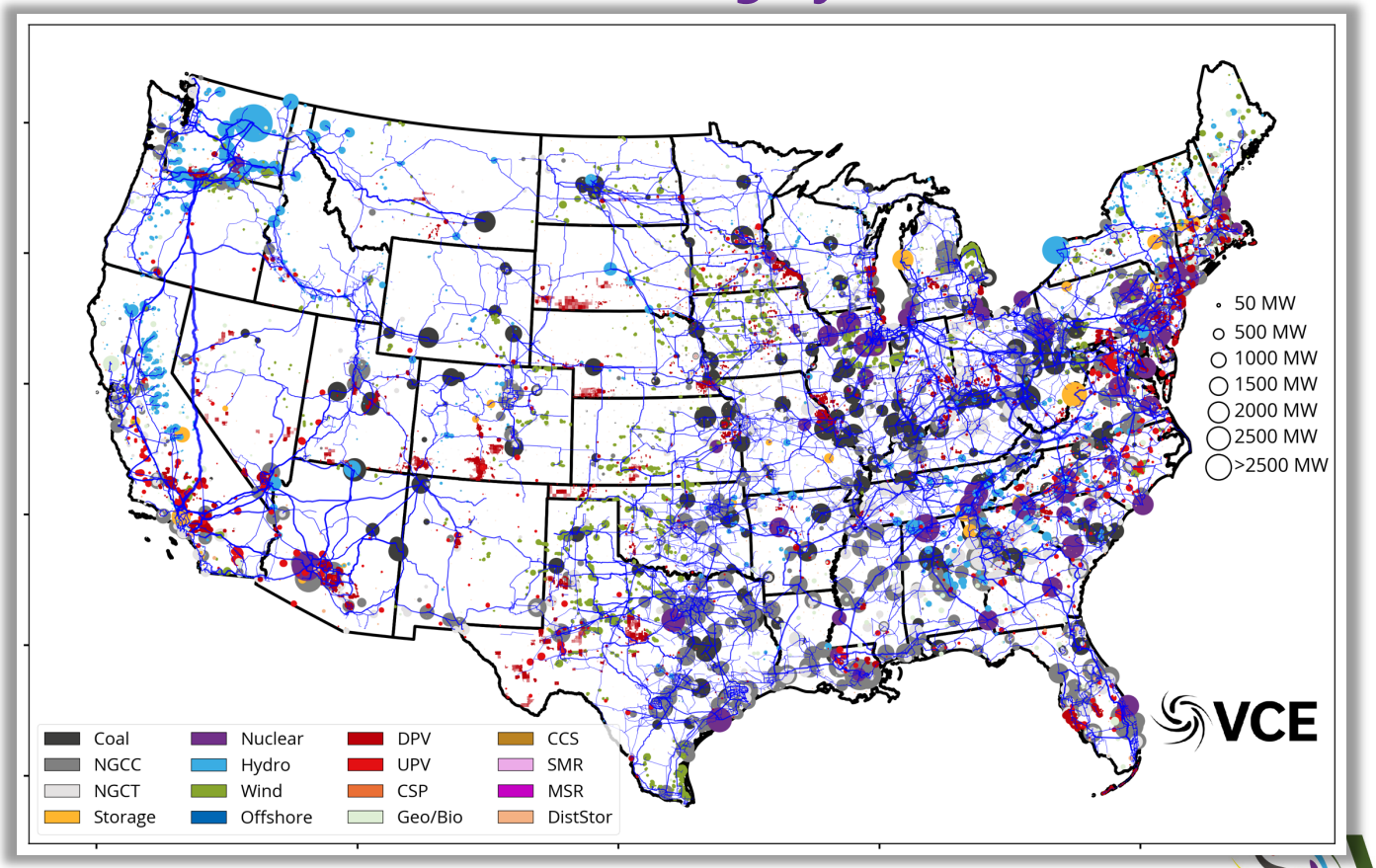
Results from Zero By Fifty (ZBF)

Resource Siting by 2020



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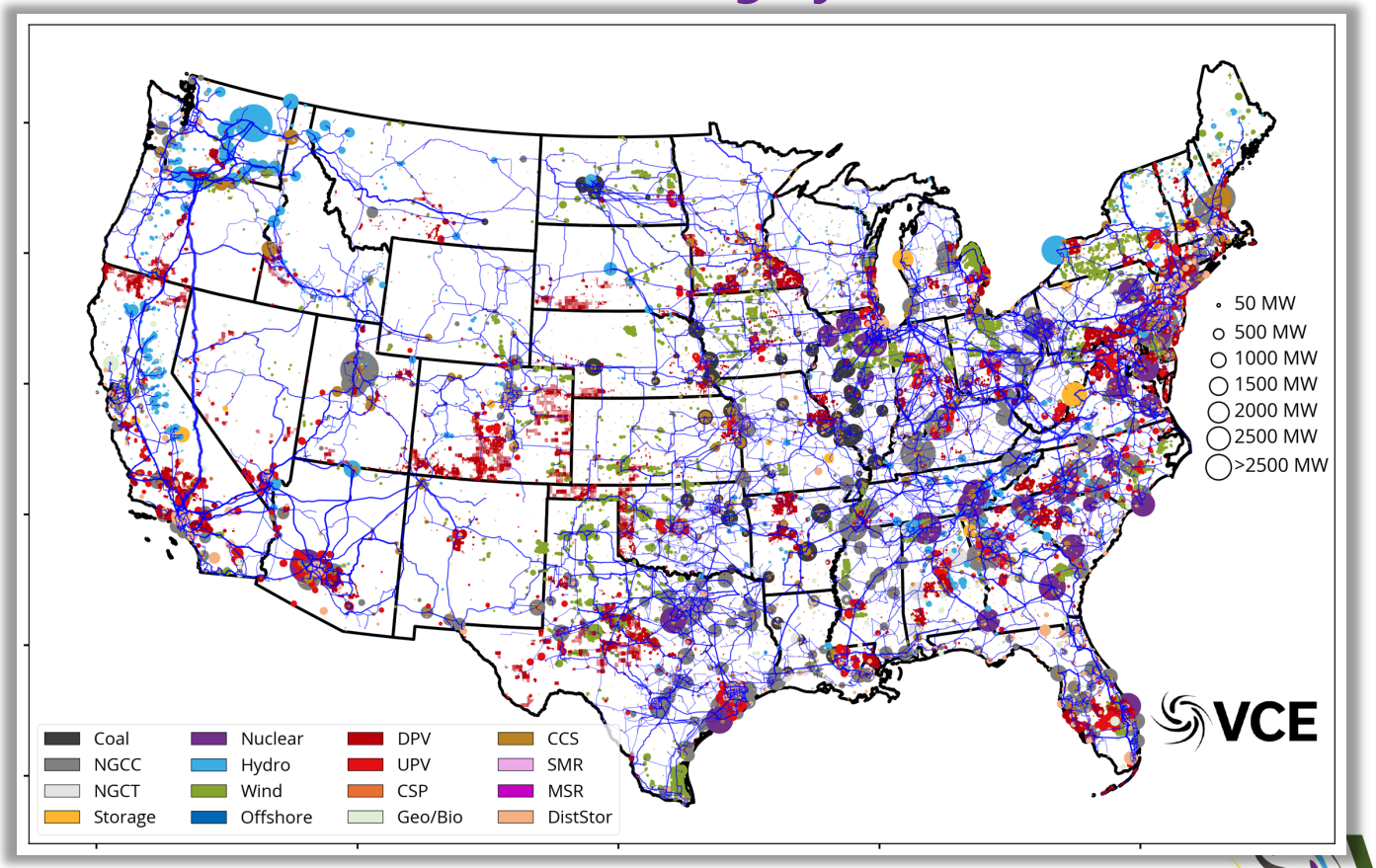
Resource Siting by 2035



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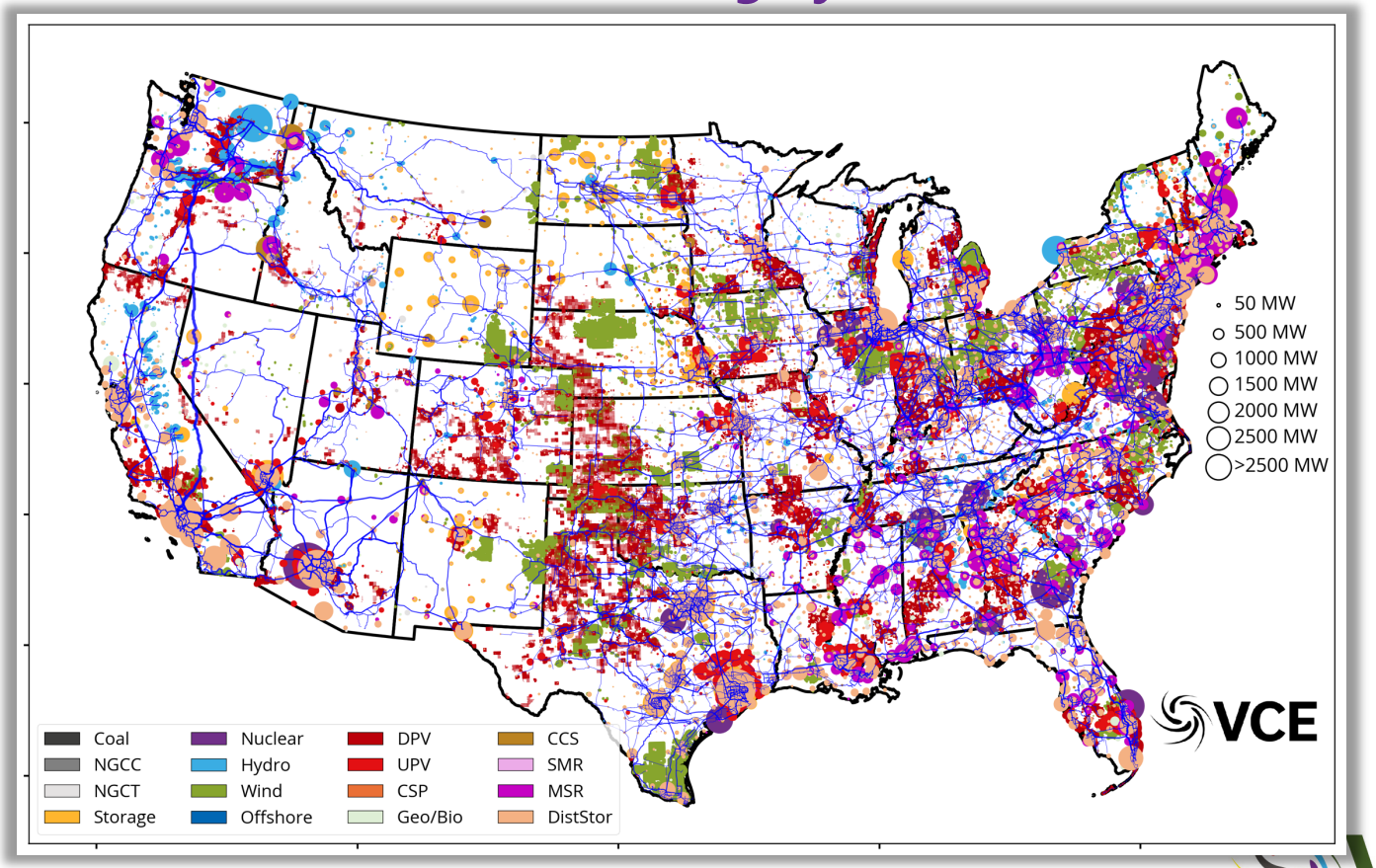
Resource Siting by 2050



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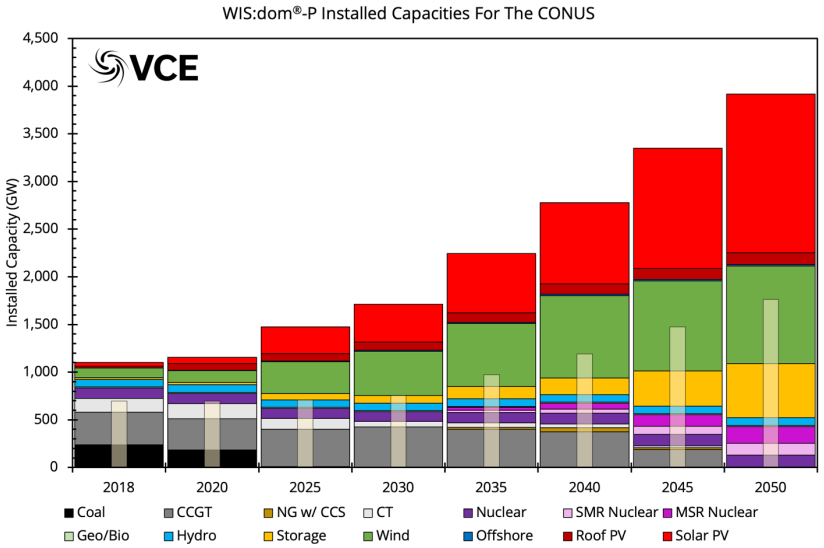
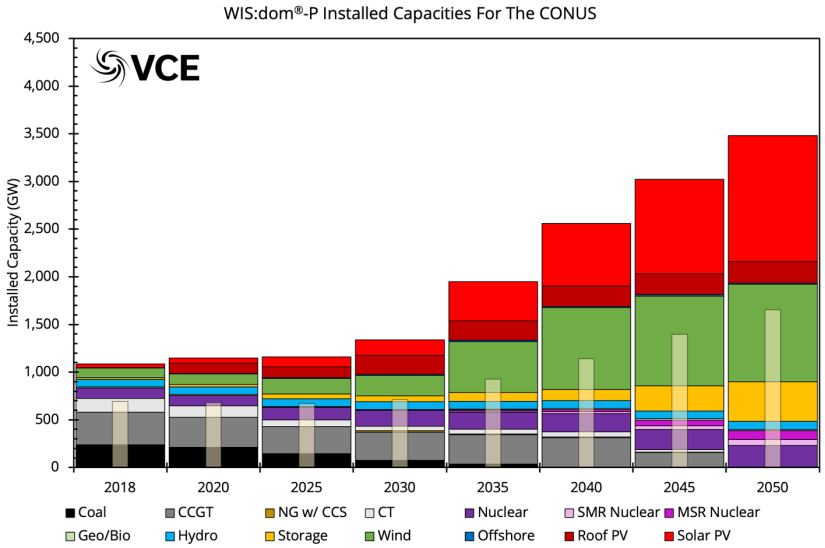
Installed Capacities



Without HVDC



With HVDC

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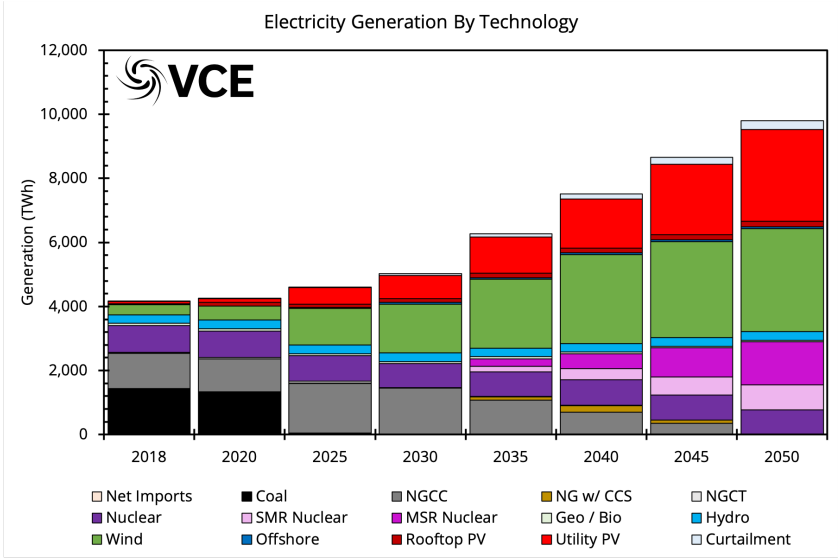
Generation Stack



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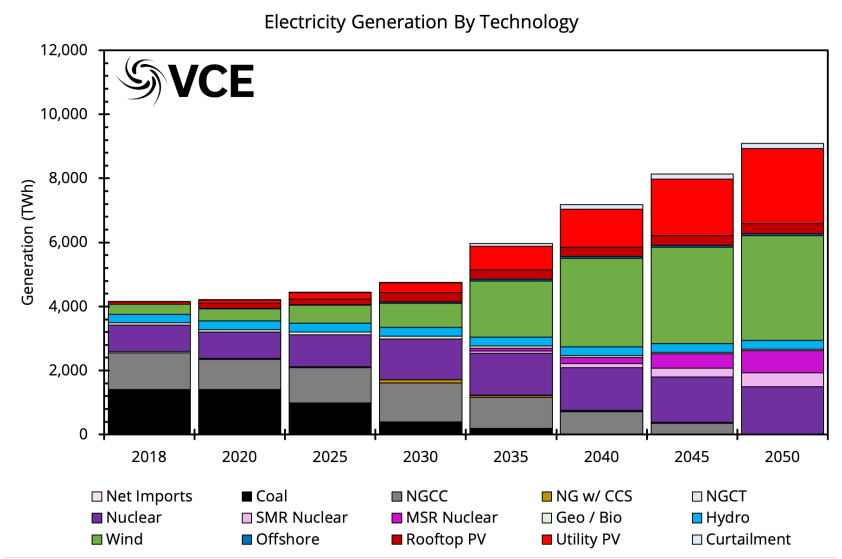

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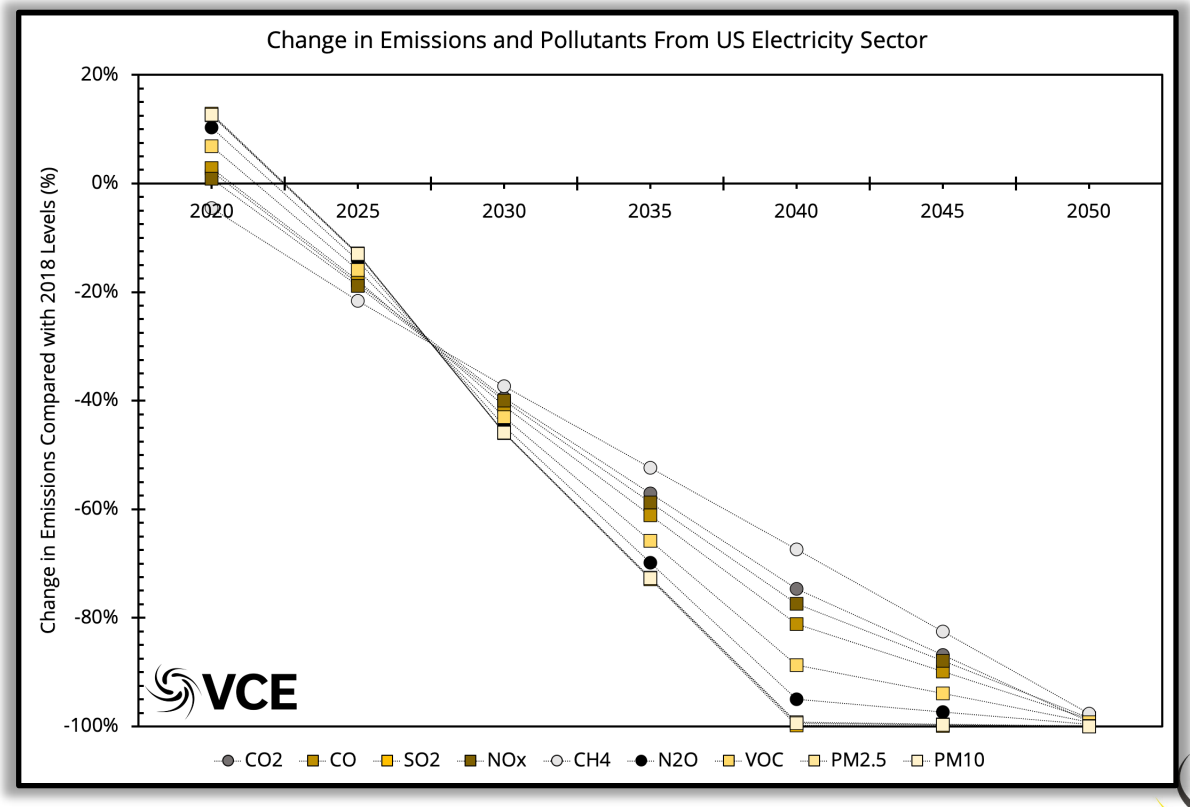
Pollution and GHG Emissions



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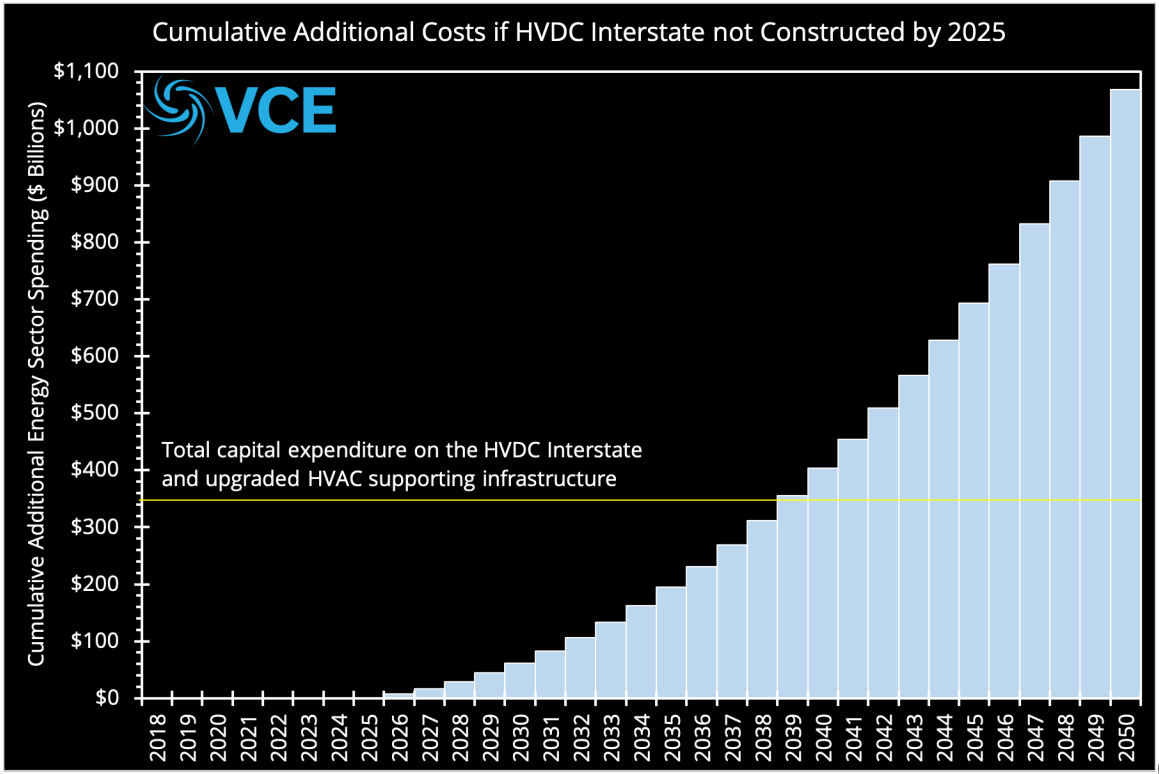
Not building an HVDC grid adds $1 trillion in energy costs by 2050



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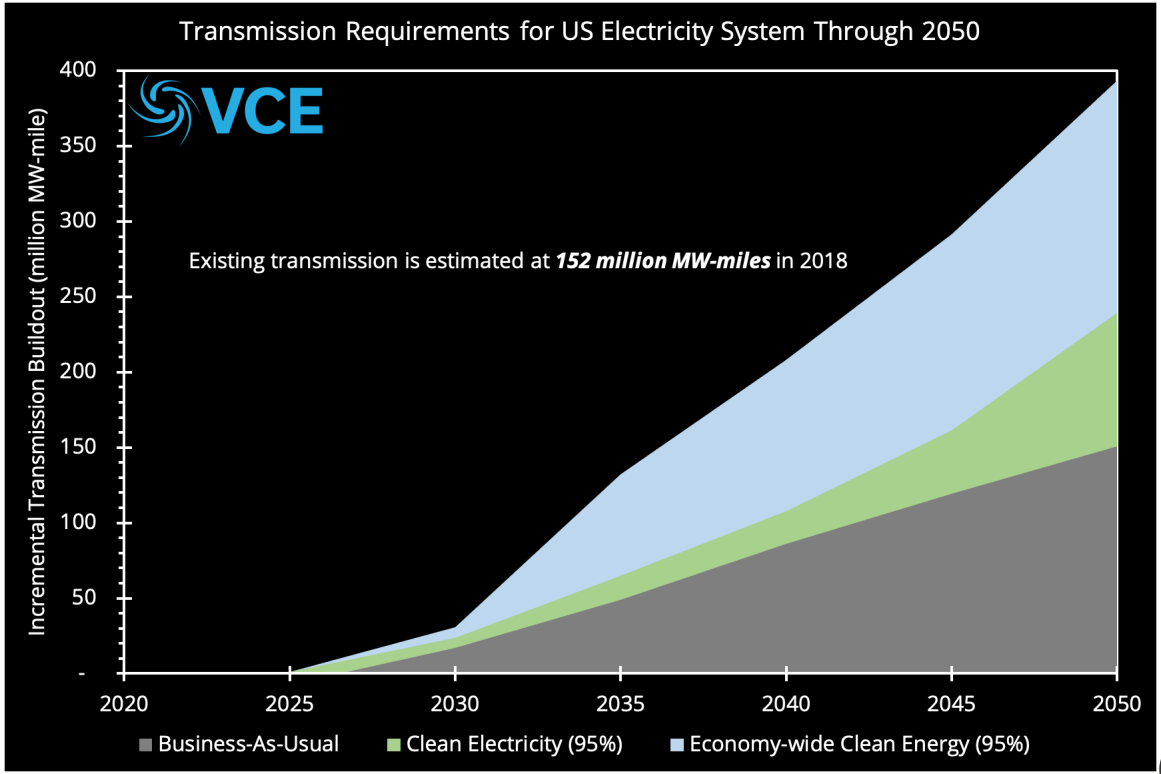
The United States needs a lot of new transmission to meet its goals



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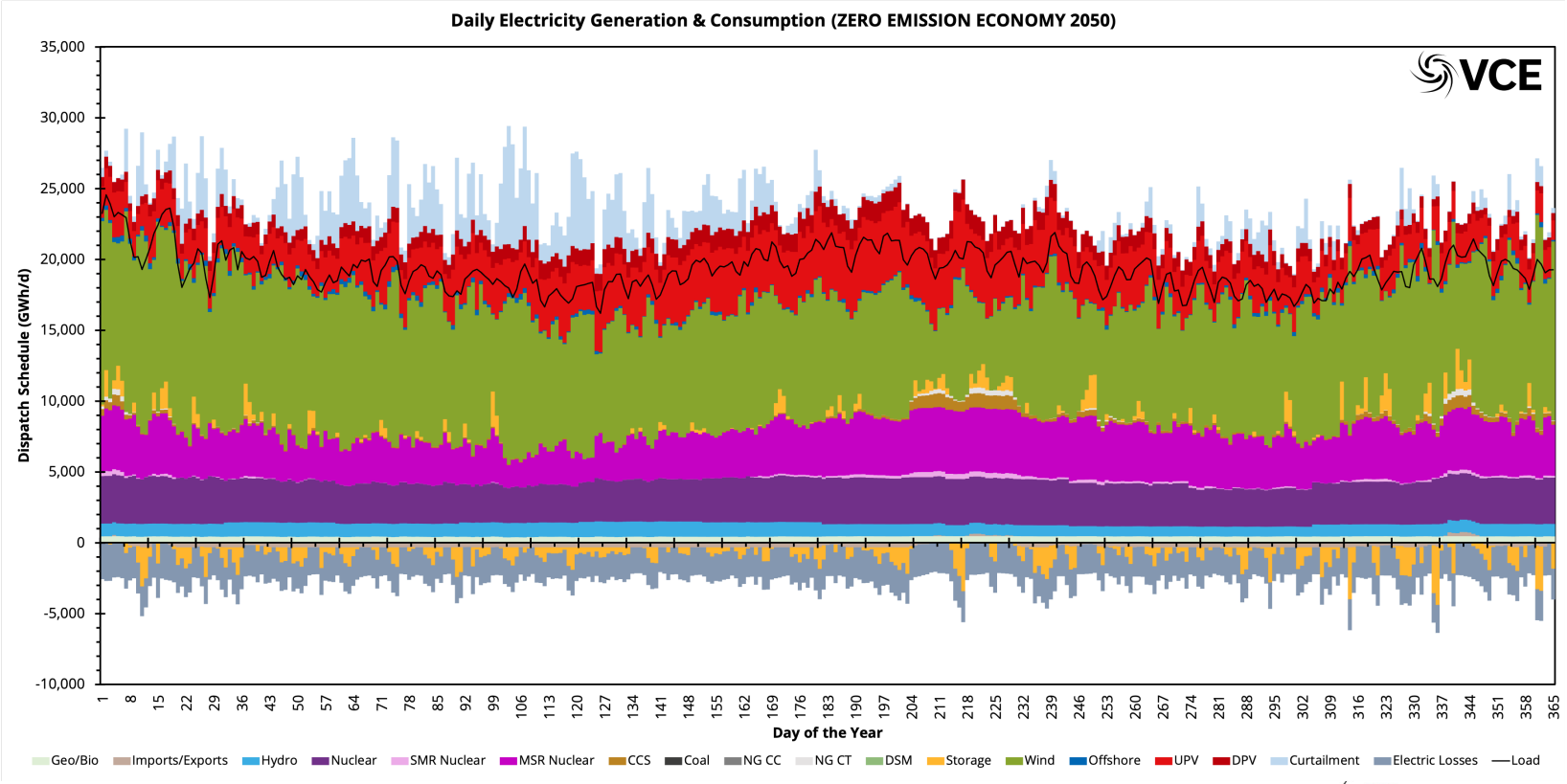
Operations of a CONUS-wide system



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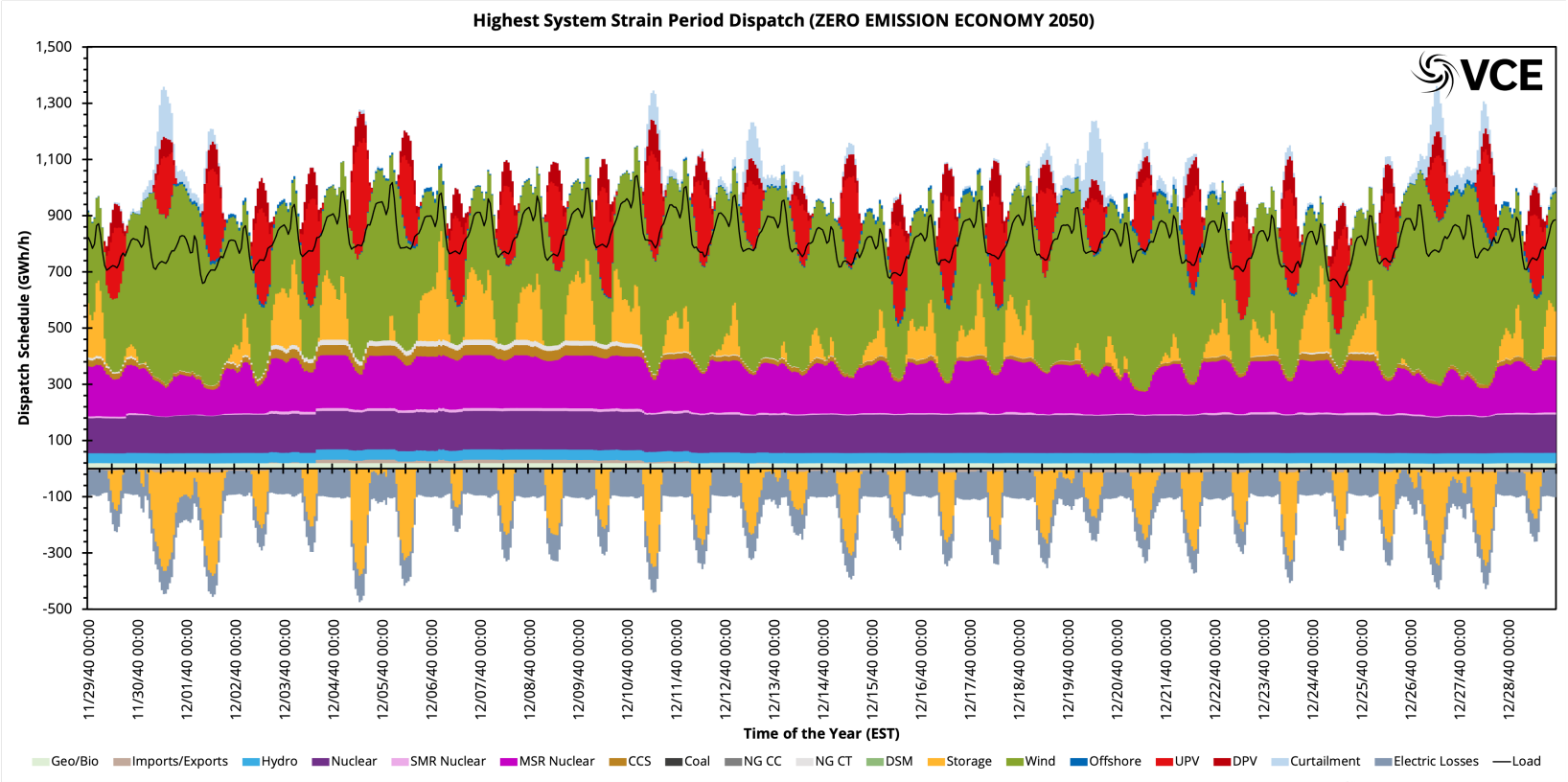
Operations of a CONUS-wide system



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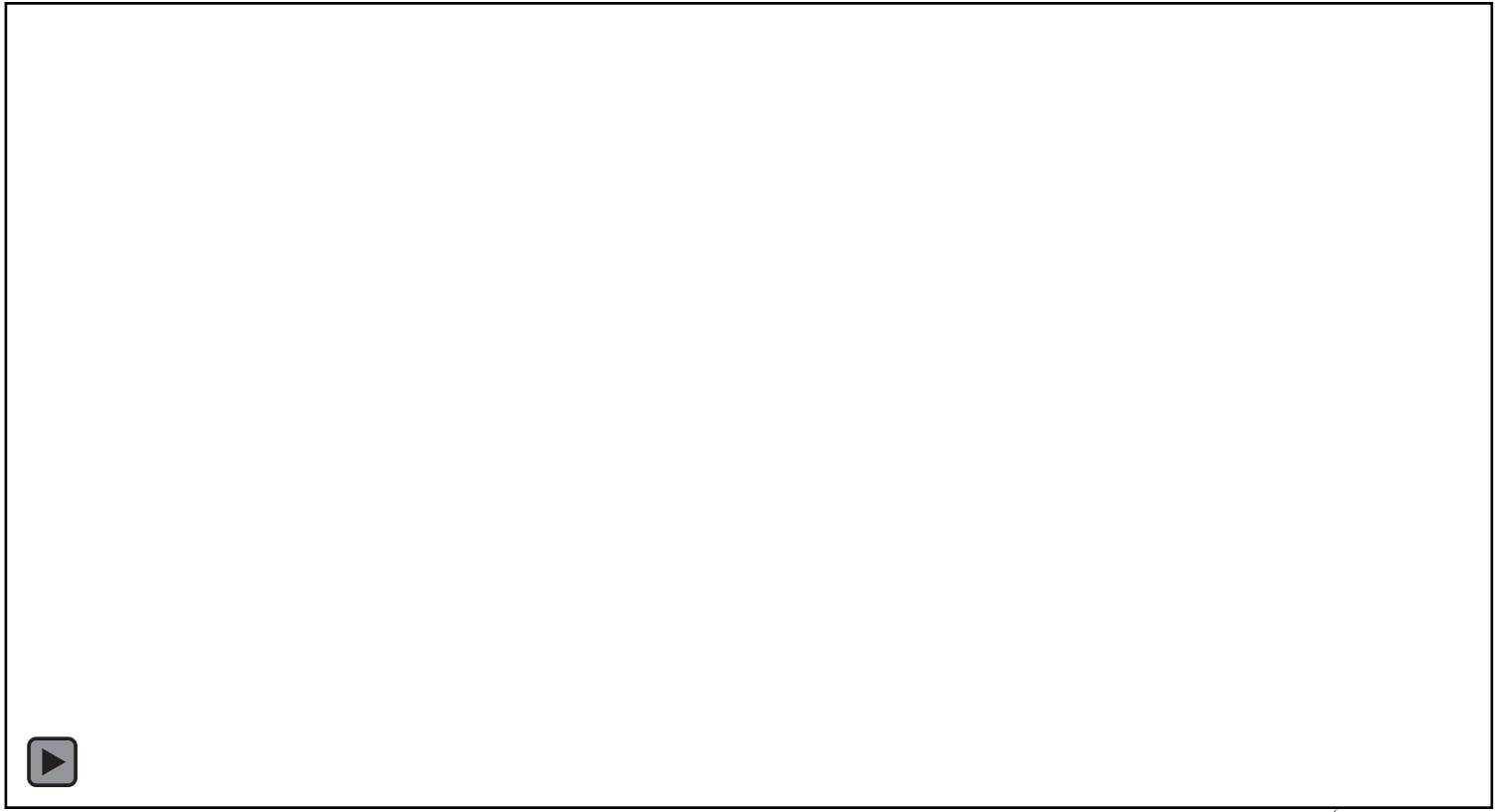
Example system running across CONUS



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Thank You

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