The role of transmission in deep decarbonization

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Webinar Virtual Meeting
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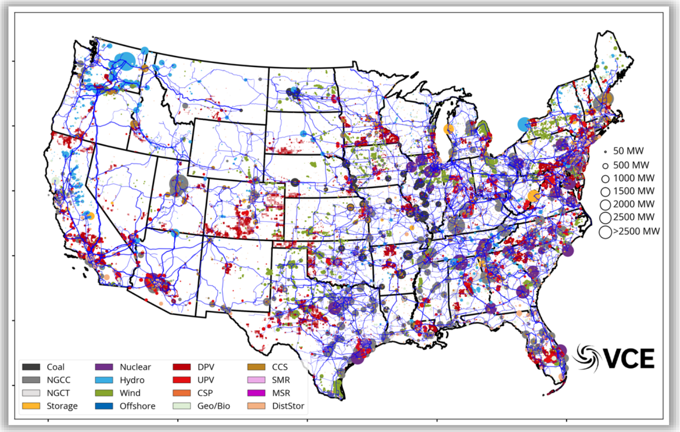

Purpose of Vibrant Clean Energy, LLC:

- 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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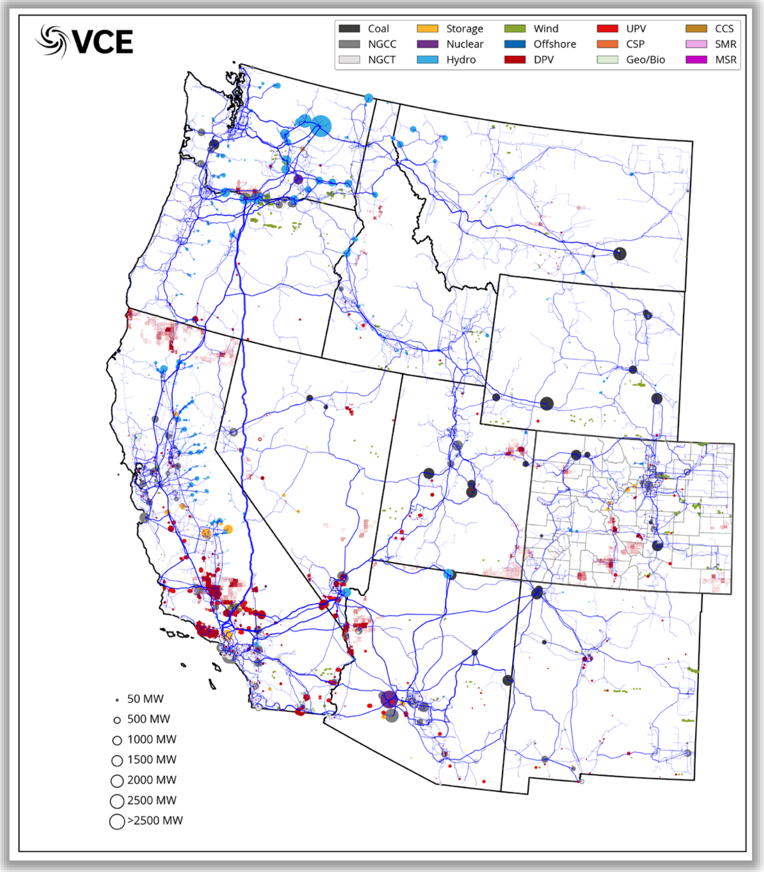
The Western United States Electric Grid (2020)



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Available Clean Generation Are Tied To Electricity

Low-marginal Cost Electricity Production Resources (kWh)

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

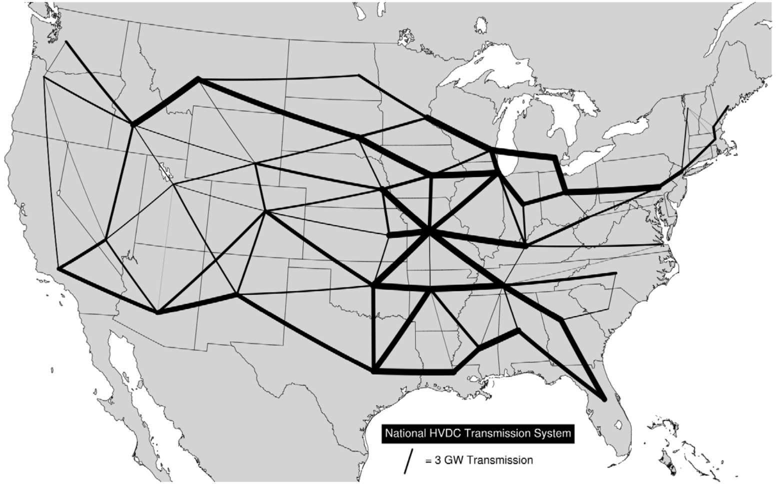
Flexibility Resources (kWh → kW → kWh)

- ***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)*

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.



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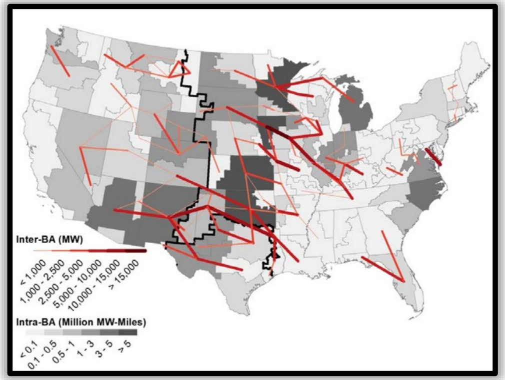
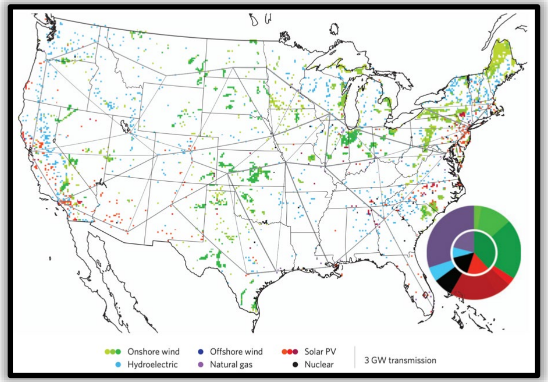
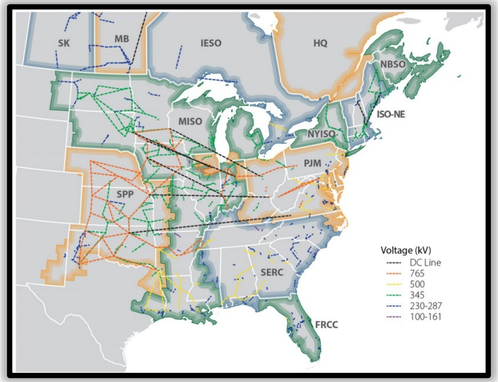
Many studies have shown the benefits of long distance transmission



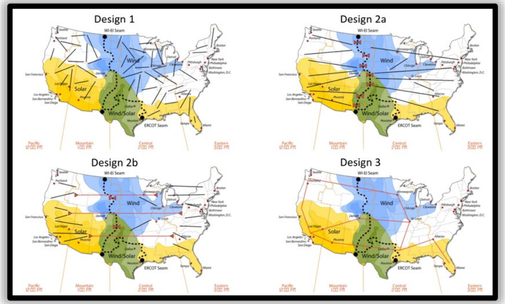
NREL REFs (2012)



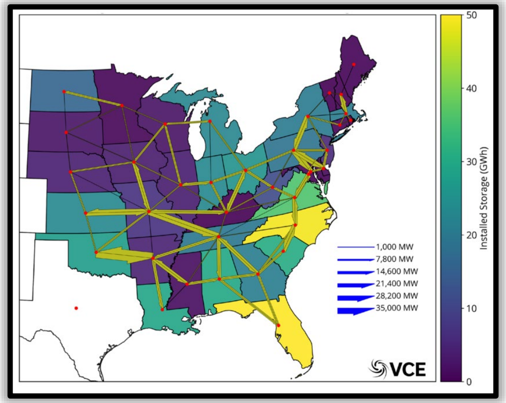
MacDonald, Clack et al. (2016)



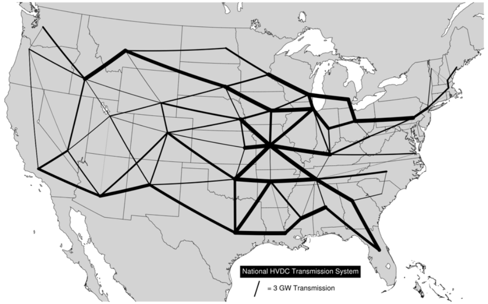
NREL ERGIS (2016)



NREL SEAMS (2018)



ACEG EI Study (2020)



VCE ZBF Study (Mar 2021)

*Note, there are many, many more!

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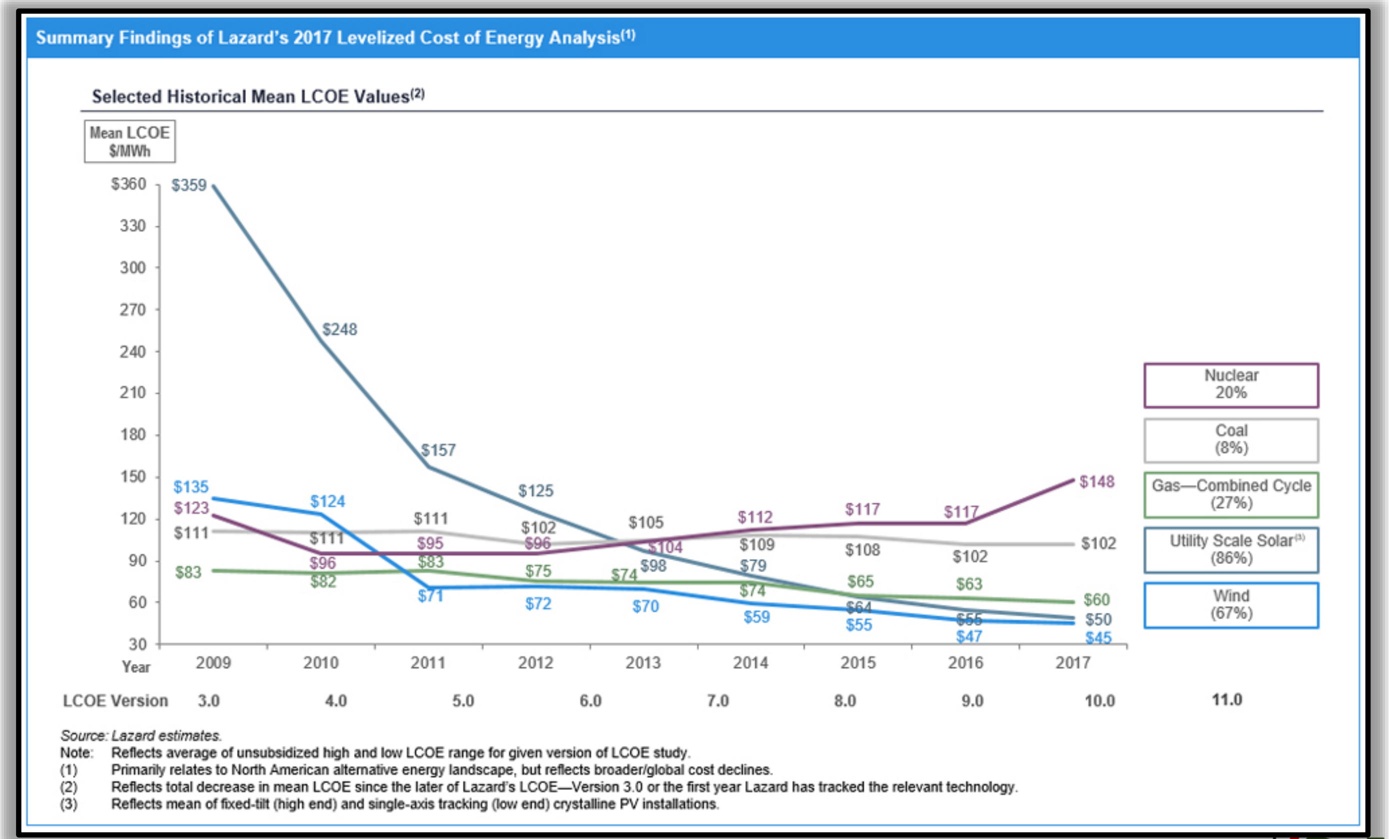
How does a transmission grid enable deep decarbonization?

Renewables are the cheapest source of electricity



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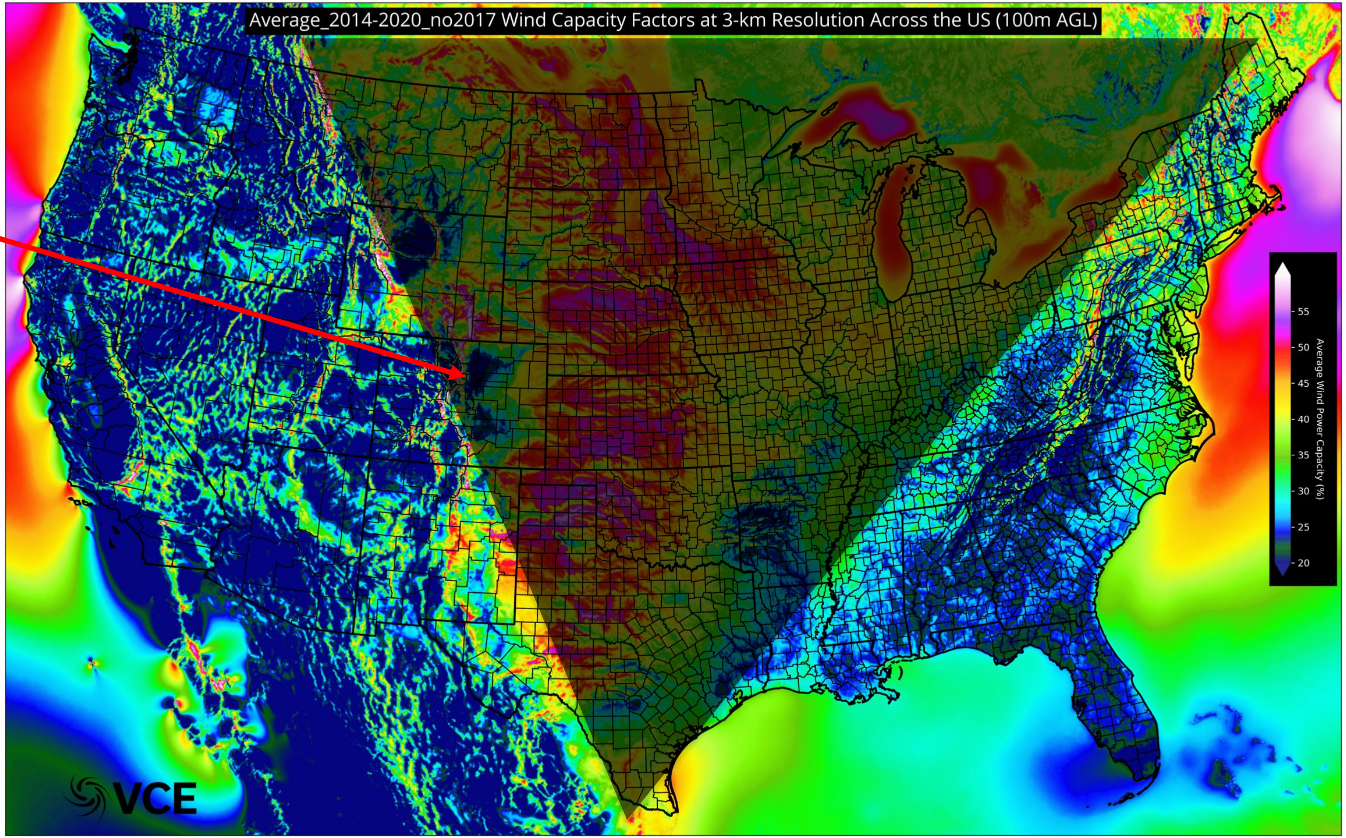
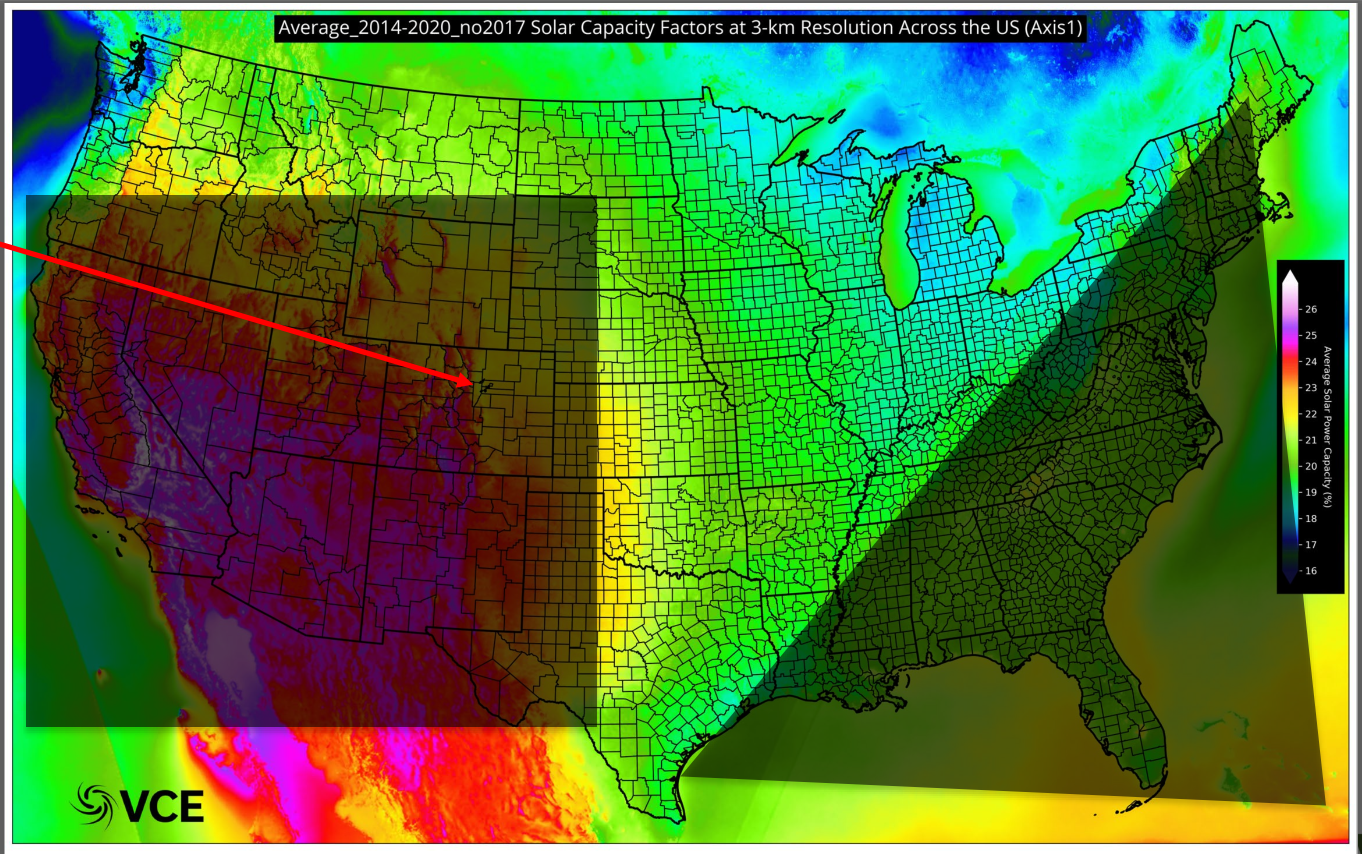
Lowest cost wind is confined primarily to the central plains

Denver

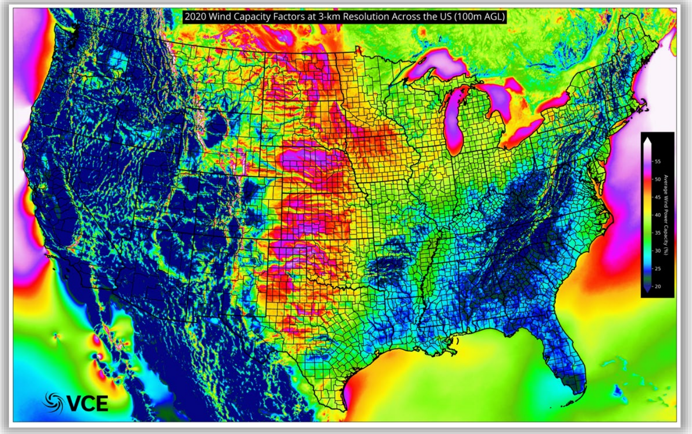


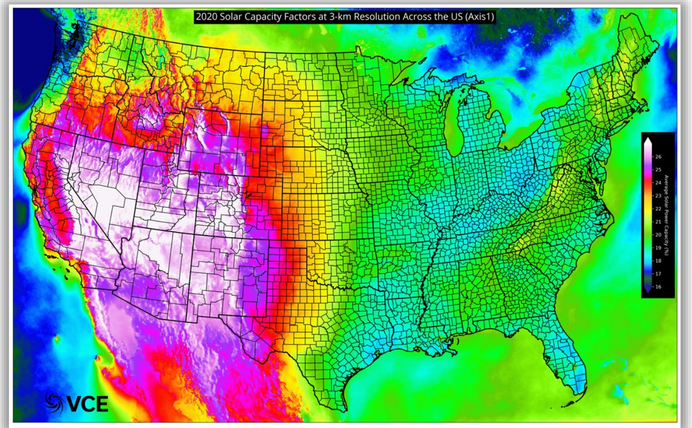
Lowest cost solar is confined primarily to the west and south east

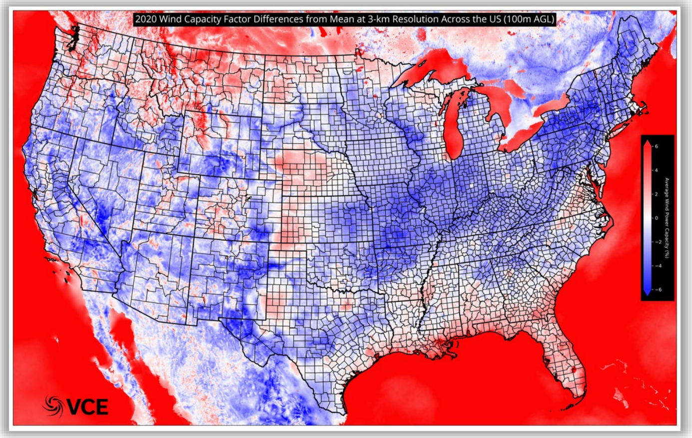
Denver

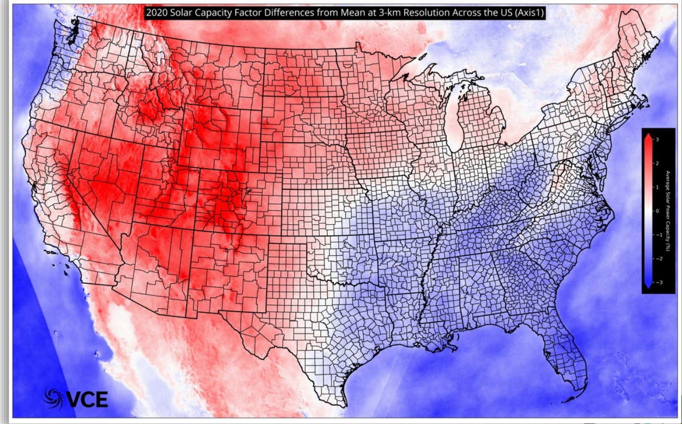


Interannual variability of VREs can be harnessed









Global Heat Transfer Drives Wind & Solar Constantly

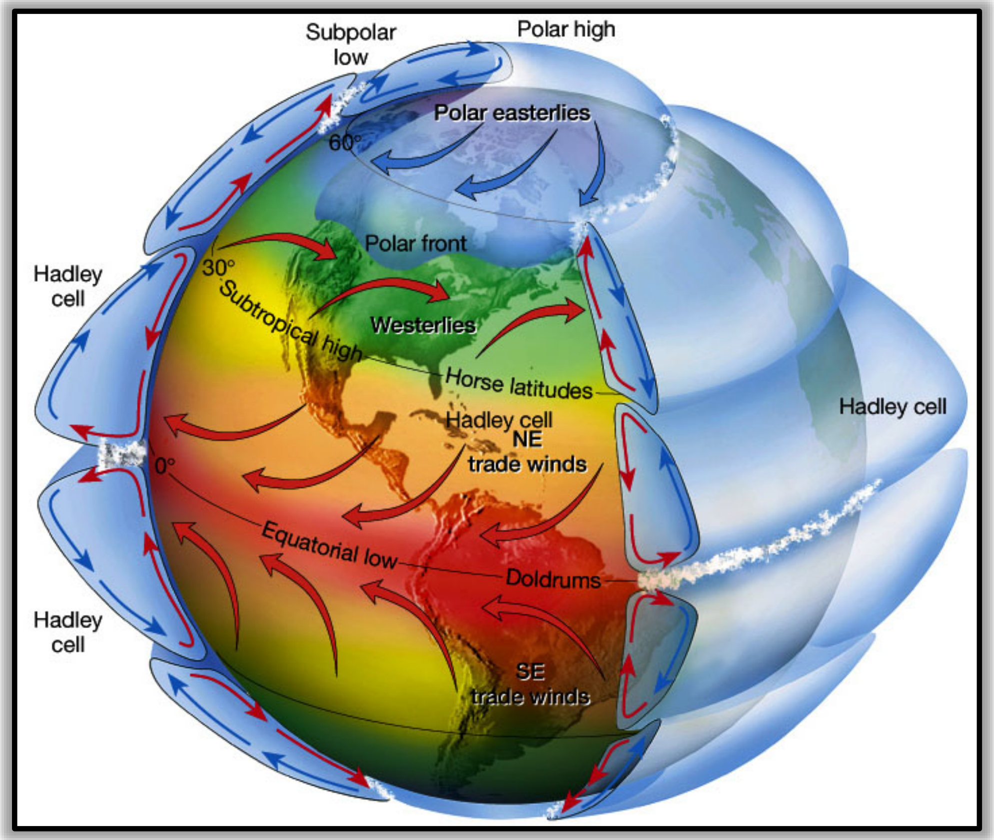


Image Credit: Figure 7.5 in *The Atmosphere, 8th edition*, Lutgens and Tarbuck, 8th edition, 2001

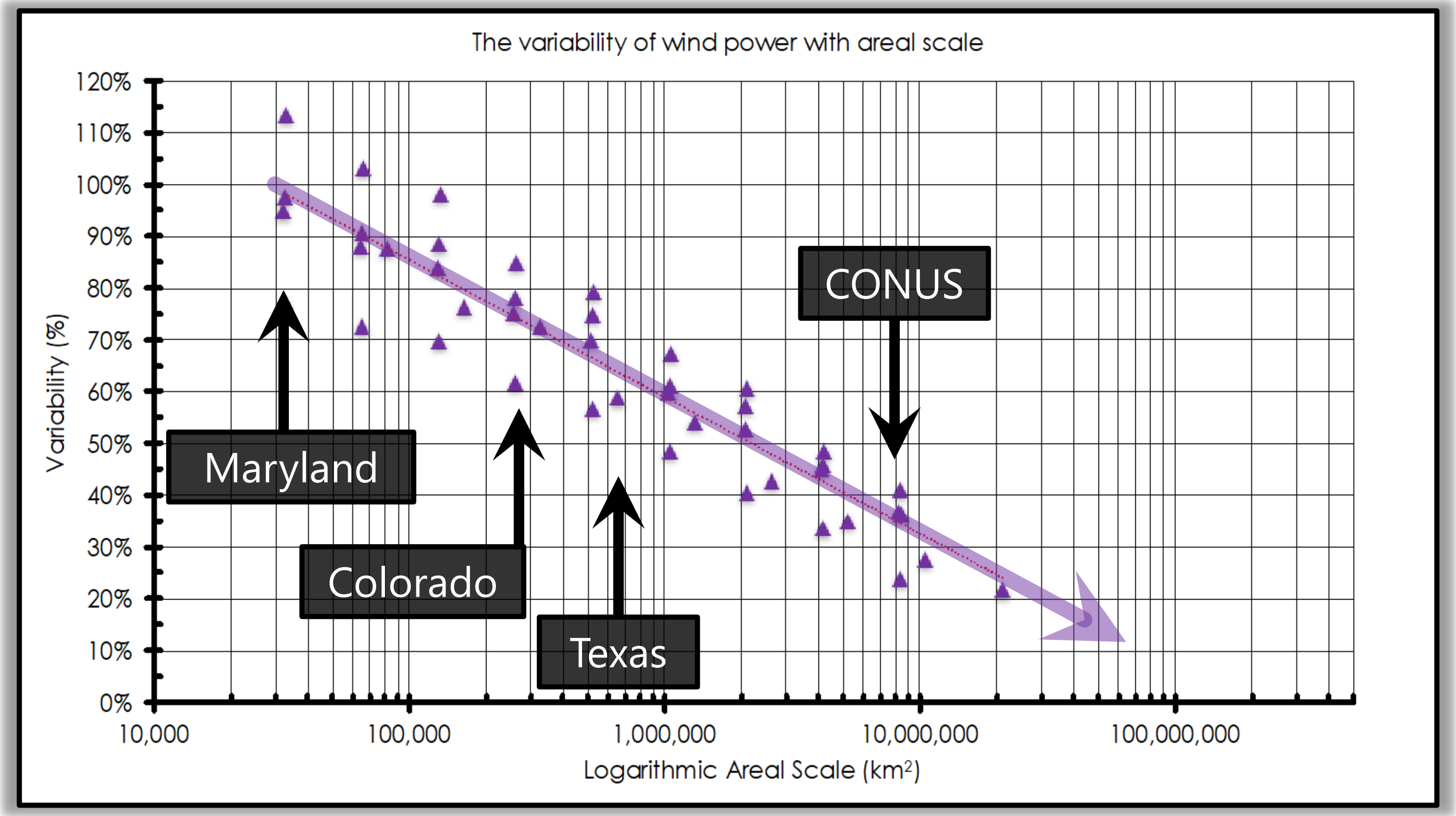
This global heat engine runs **constantly** driving wind and cloud patterns.

Processes ***are well understood***.

Driven By Solar Irradiance & Earth-Sun Distance.

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

Variability Of Wind & Solar Shrinks With Larger Areas



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

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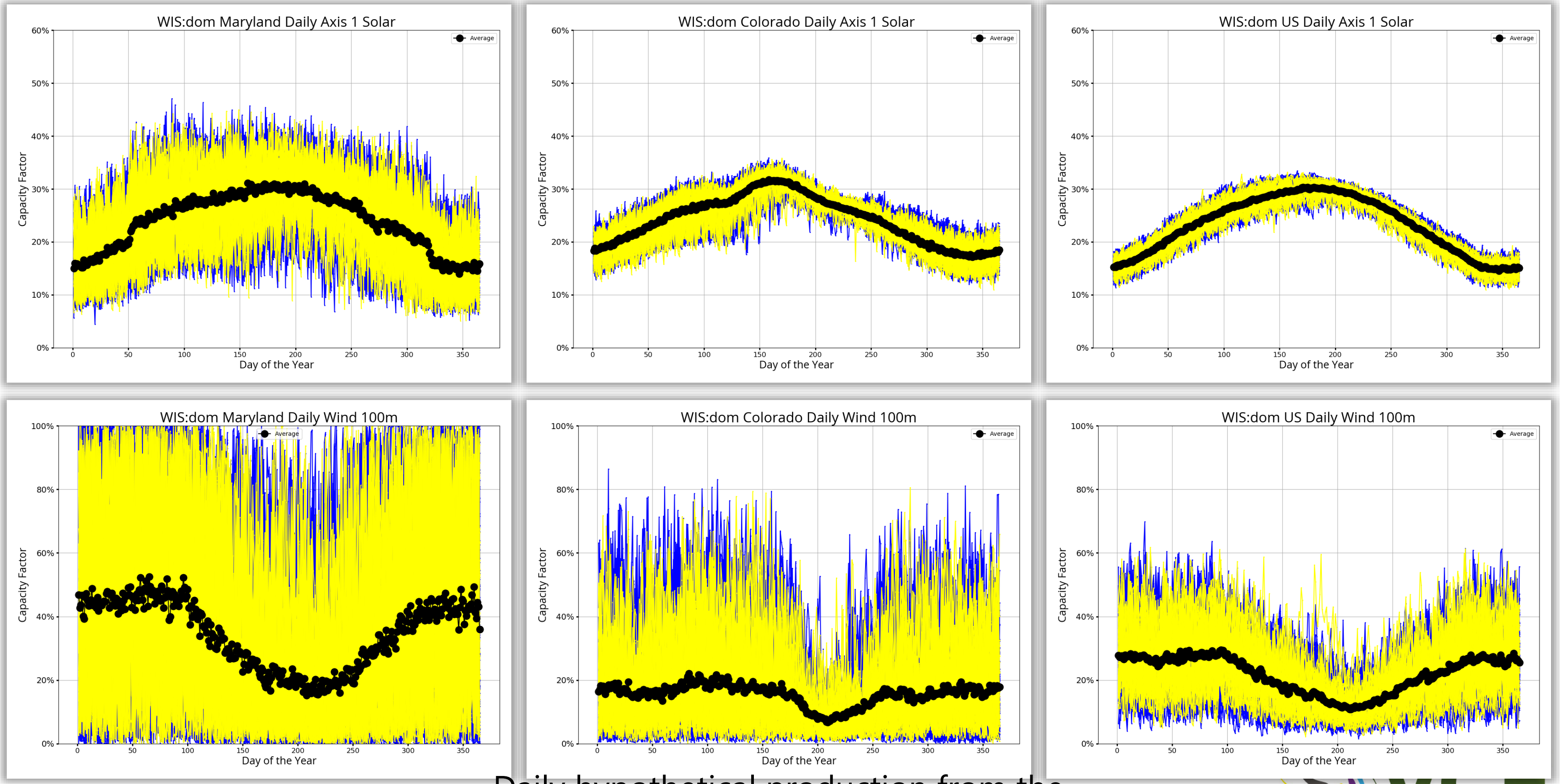
Variability Of Wind & Solar Shrinks With Larger Areas



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

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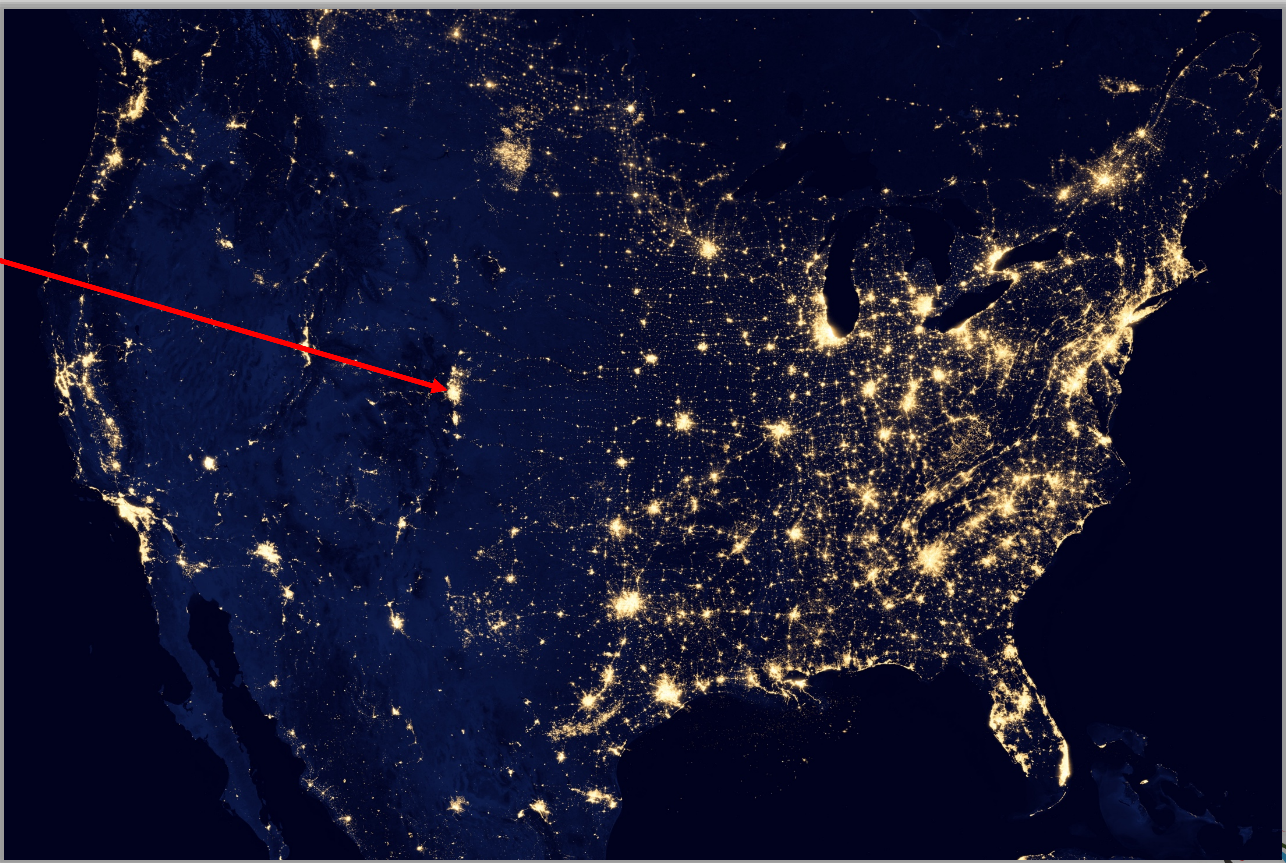
Demands are concentrated & supply will be sparse

Denver



National 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**

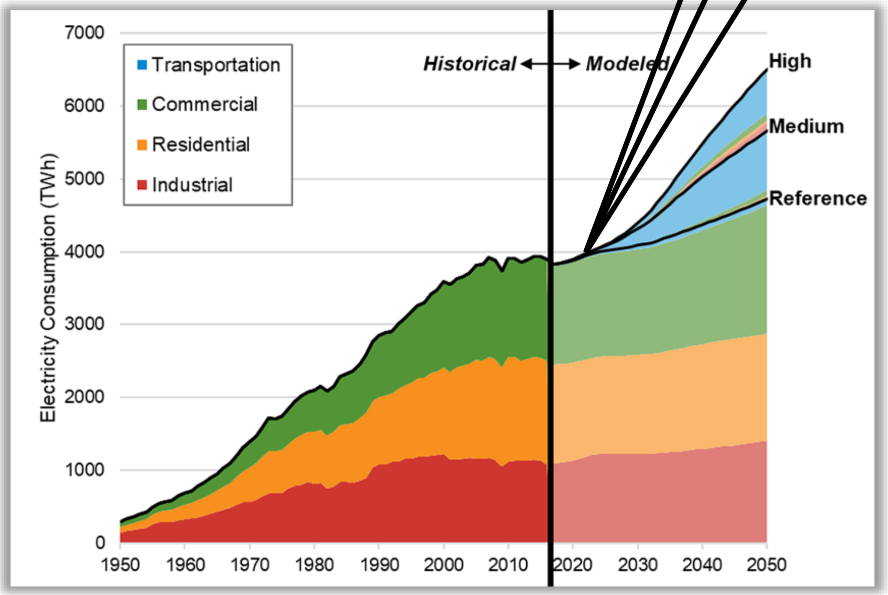
70% down **7% down**

73% down **19% down**

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

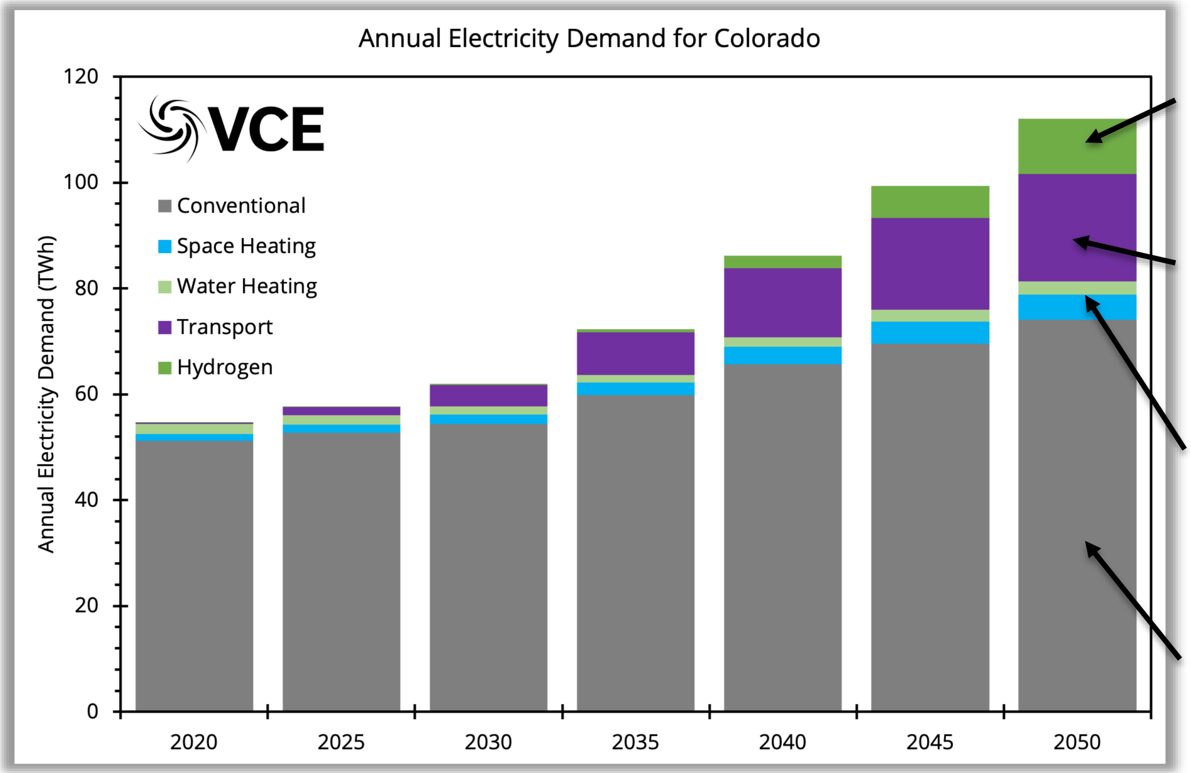
ZBF 2050 TWh with RCP4.5 climate change impacts (8.9 PWh)

ZBF 2050 TWh without climate change impacts (7.8 PWh)



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

Colorado Demand For Electricity Will Necessarily Grow



Hydrogen for agriculture, transport & industry grows rapidly after 2035

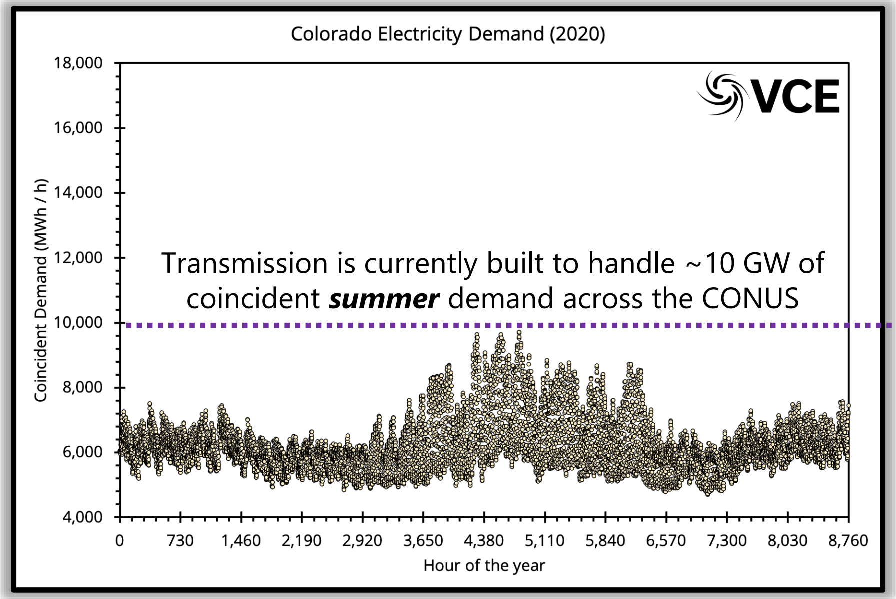
Transportation electrification is fastest growing demand

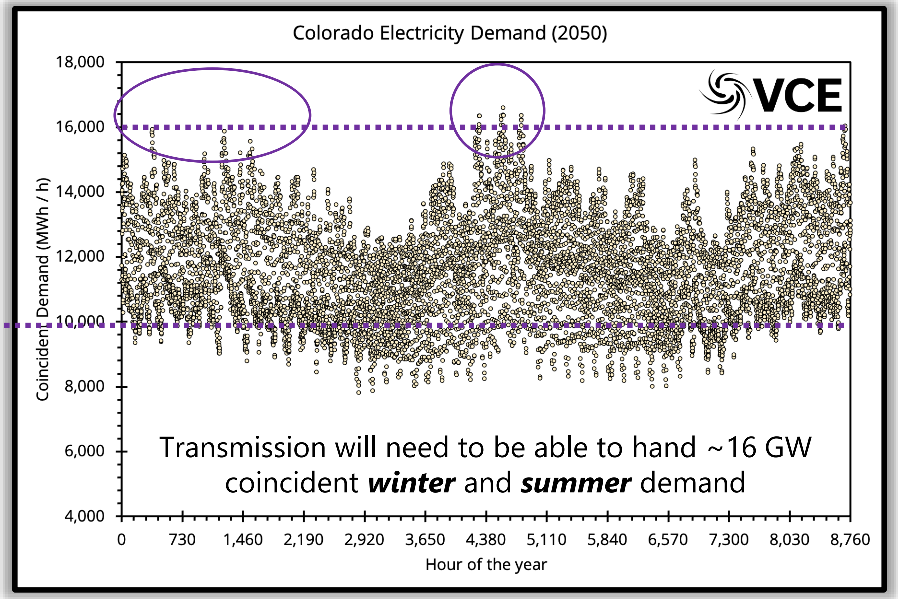
Building electrification does not add large electric demand, but shifts timing of peaks dramatically

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

55 TWh	62 TWh	86 TWh	112 TWh

Demand Profiles & Stress Periods Will Change Over Time

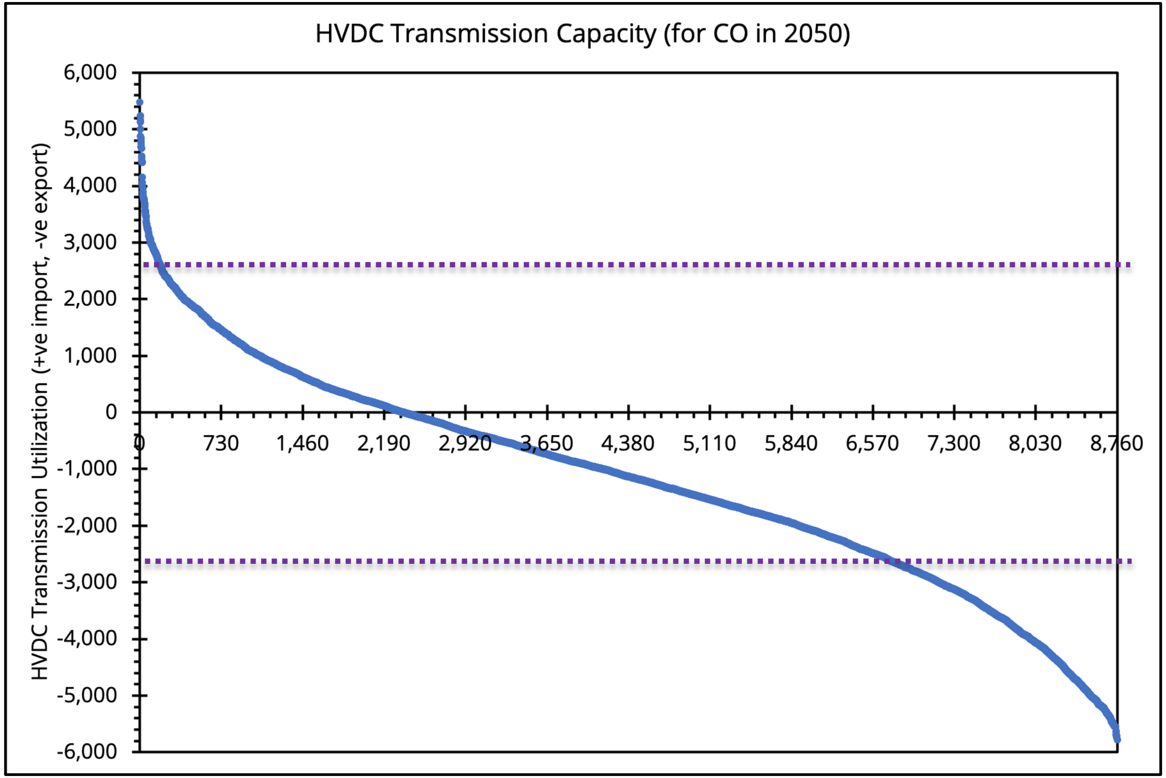




* Before synthetic fuel production

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

An Example for Colorado (from ZBF results)



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

This is a simplified example!

An Example for Colorado (2025 alternatives)

Colorado 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 (%)	1.130%	1.130%	19.349%
Size (MW)	3,000	3,000	3,000
WACC	5.87%	5.87%	5.87%
Term	30	10	40
LCOE ($/MWh)	**$757.03**	**$2,017.29**	**$15.81**

Natural gas is ***50x*** more expensive and storage is ***126x*** more expensive!

An Example for Colorado (must reach alternatives)

Colorado example			Assume 500 miles
Cost to match HVDC	Natural Gas	Storage	Transmission (HVDC)
Capital ($/kW)	**$ 8.87**	**$ 1.39**	**$ 401.60**
Capital ($/kWh)	$ -	**$ 1.60**	$ -
Fixed ($/kW-yr)	$ 0.11	$ 0.08	$ 0.53
Variable ($/MWh)	**$ 0.05**	**$ 0.26**	**$ 25.00**
Fuel ($/MMBTU)	**$ 0.03**	**$ -**	**$ -**
Capacity Factor (%)	1.130%	1.130%	19.349%
Size (MW)	3,000	3,000	3,000
WACC	5.87%	5.87%	5.87%
Term	30	10	40
LCOE ($/MWh)	**$ 7.57**	**$ 20.17**	**$ 15.81**

To get close to matching HVDC, natural gas and storage need to fall by ***100x***!

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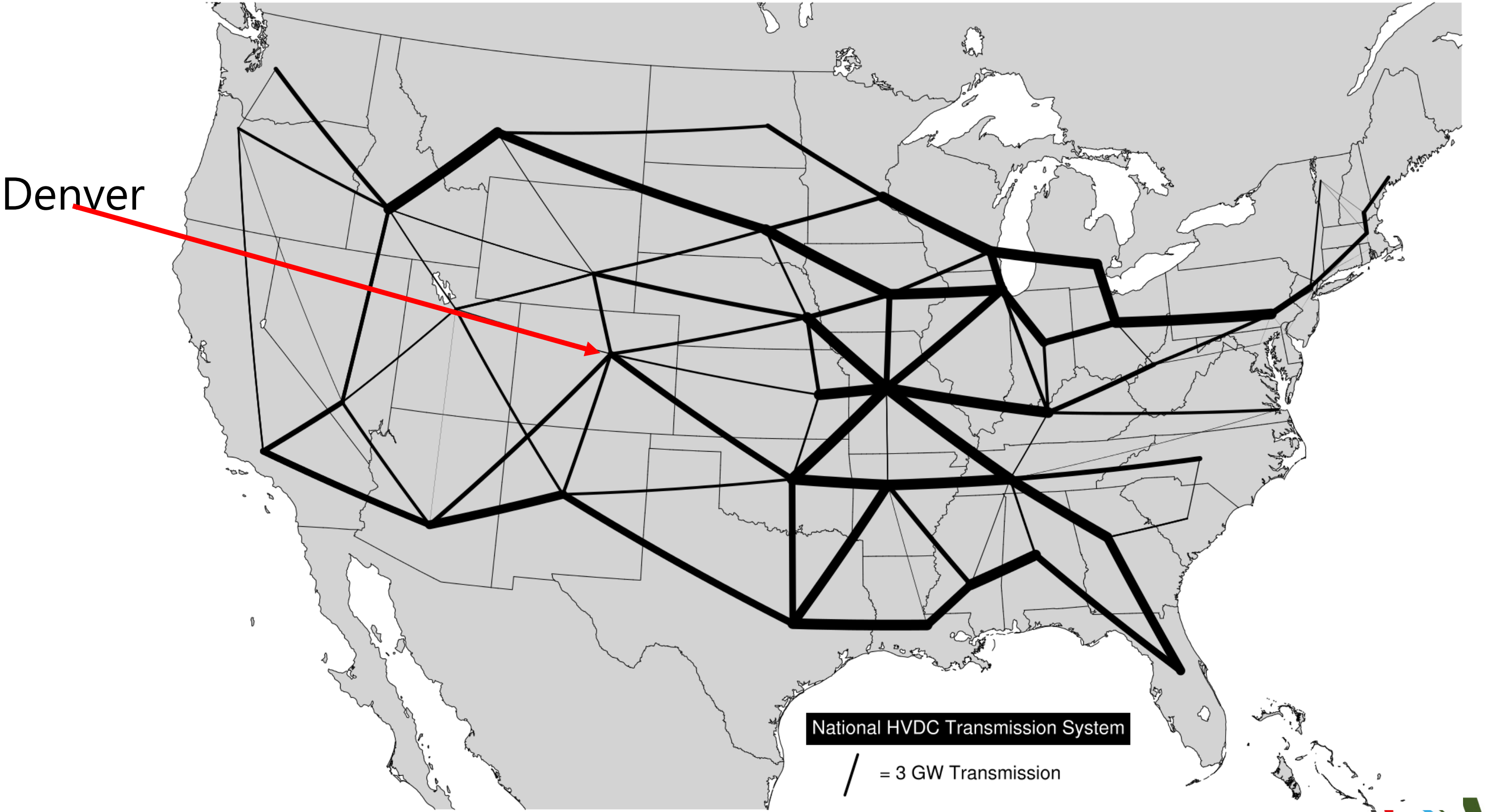
Results from Zero By Fifty (ZBF)

Could a continental transmission grid help deep decarbonization?



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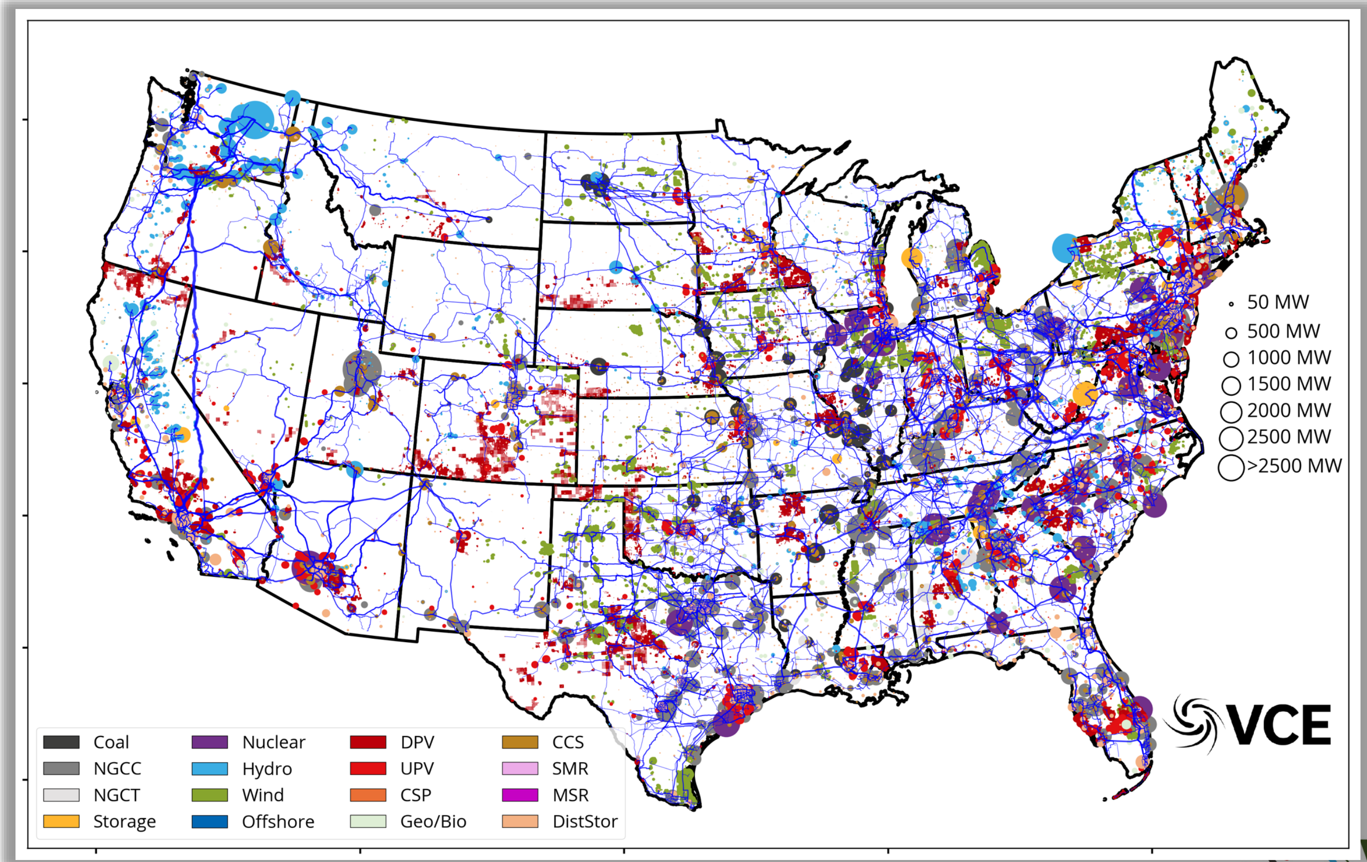
Resource Siting by 2035



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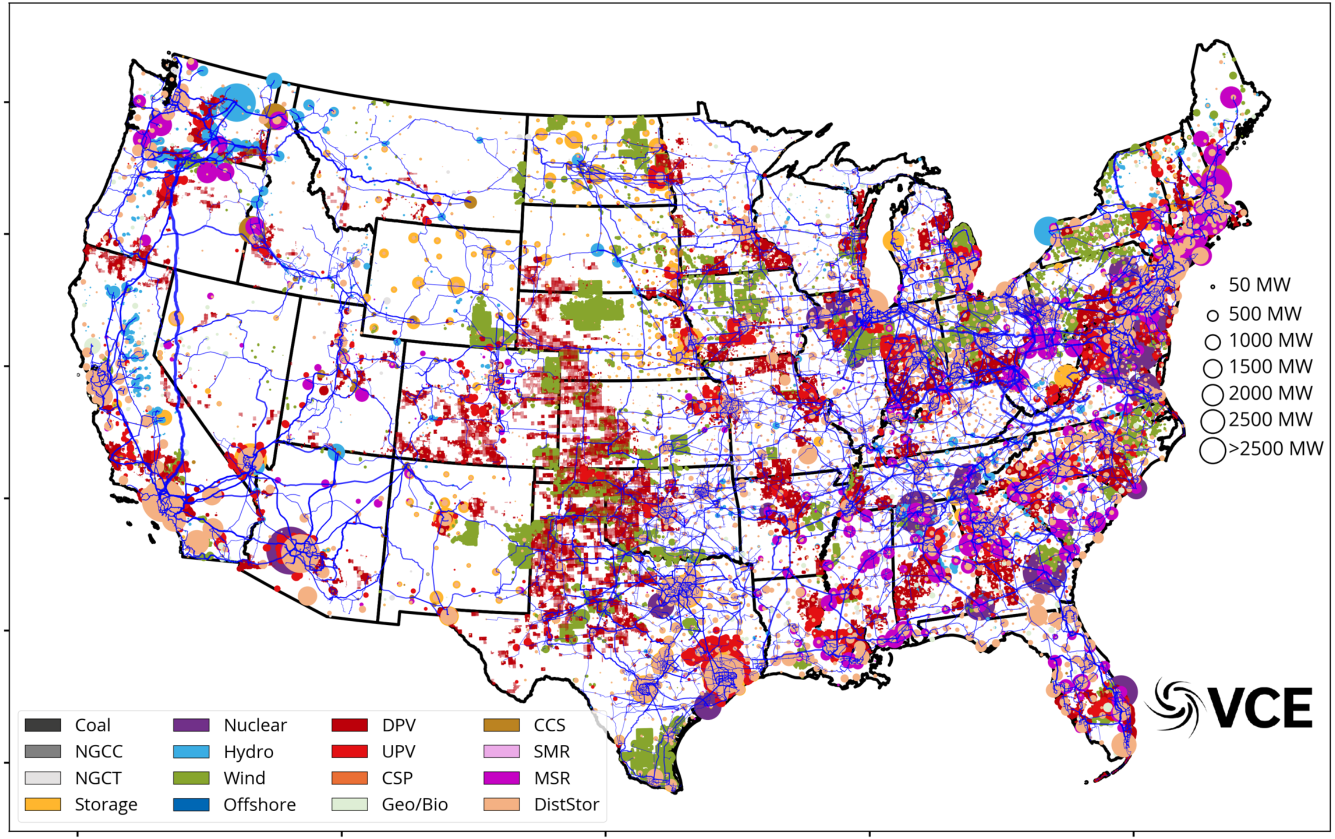
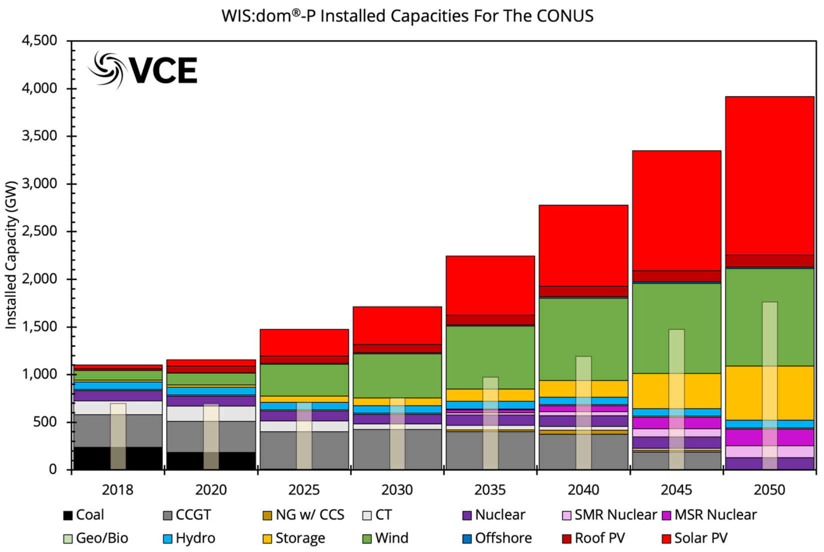
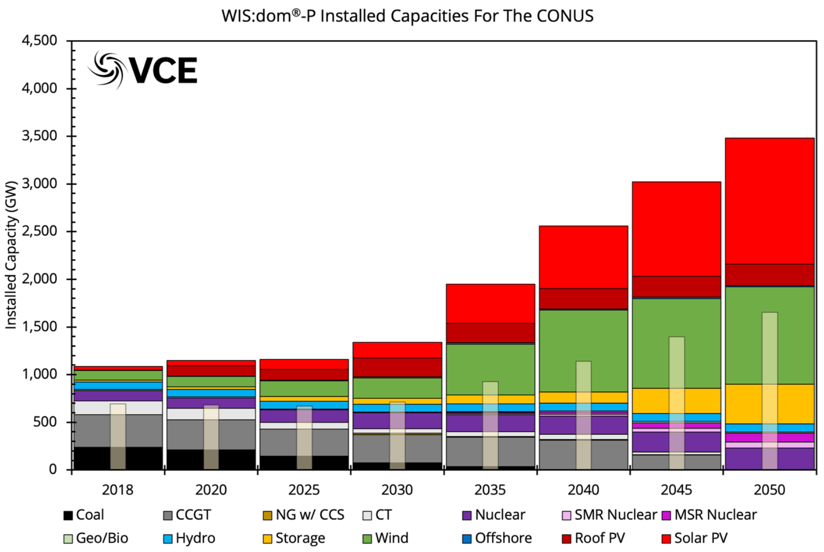
Resource Siting by 2050



Installed Capacities

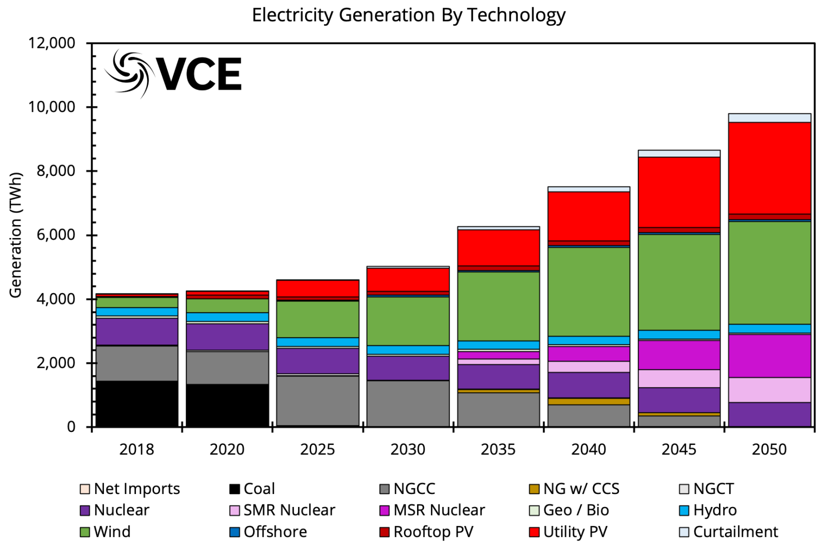


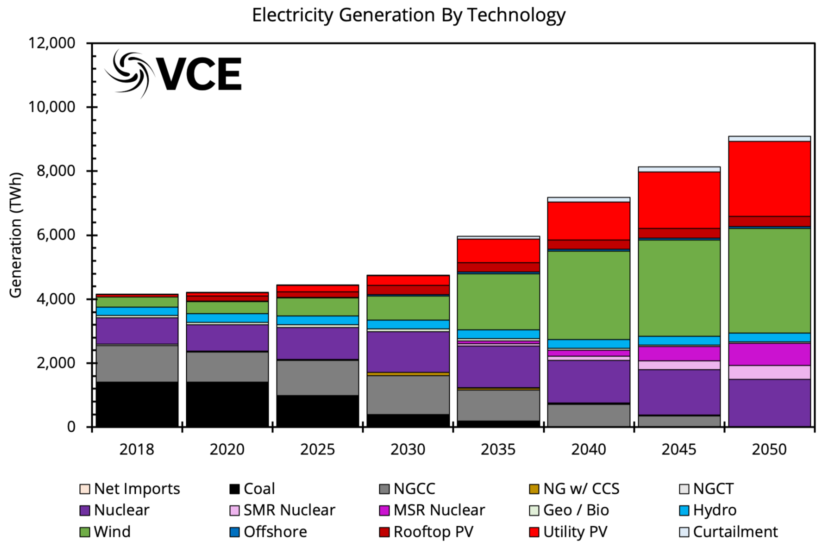
Without HVDC



With HVDC

Generation Stack

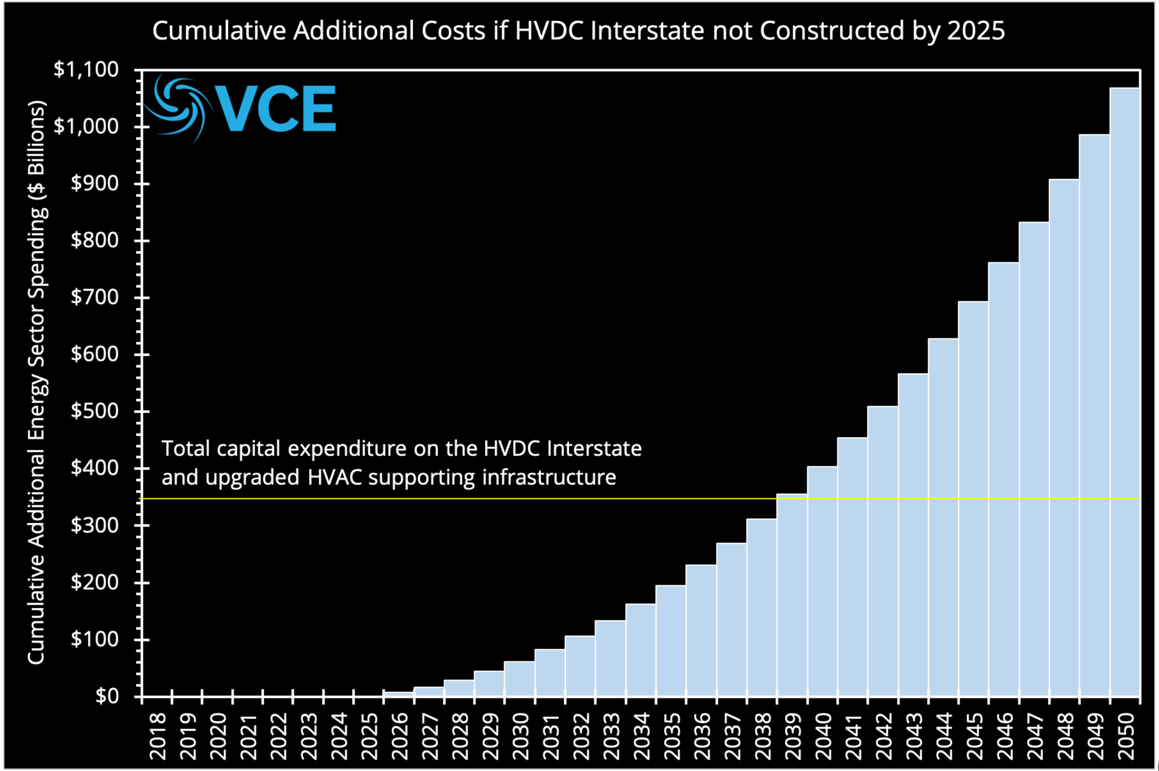




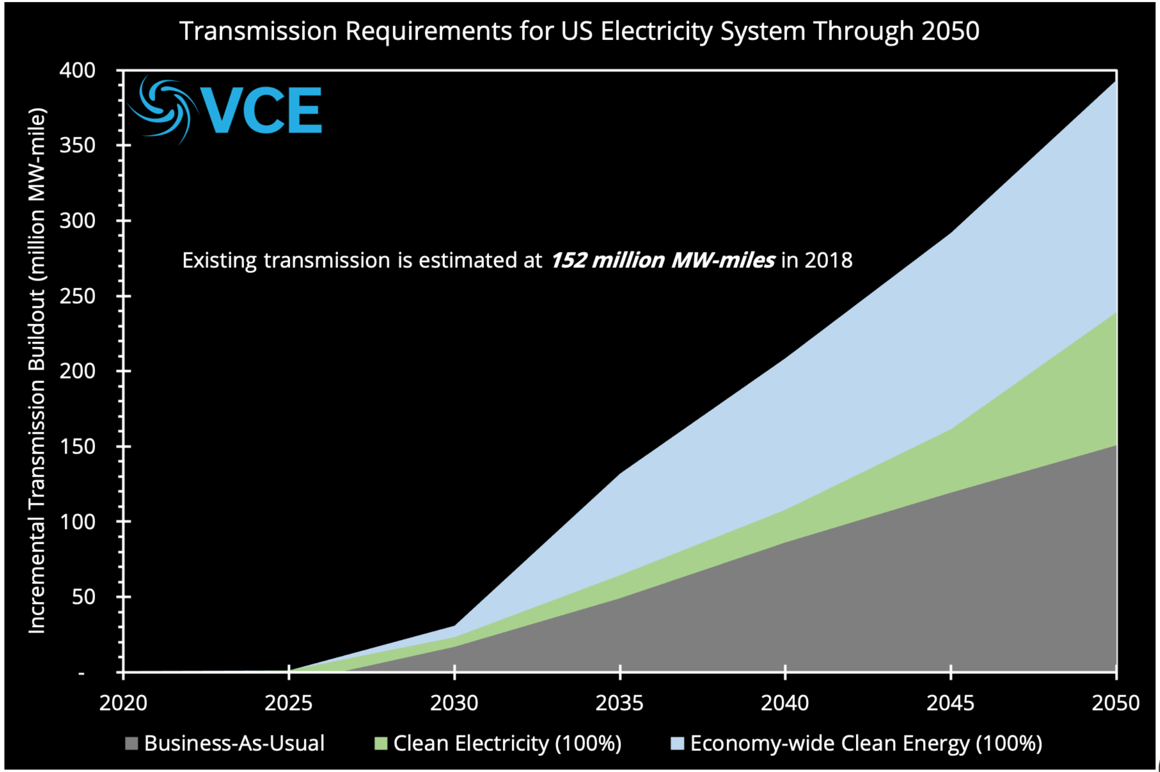
Without HVDC

With HVDC

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



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



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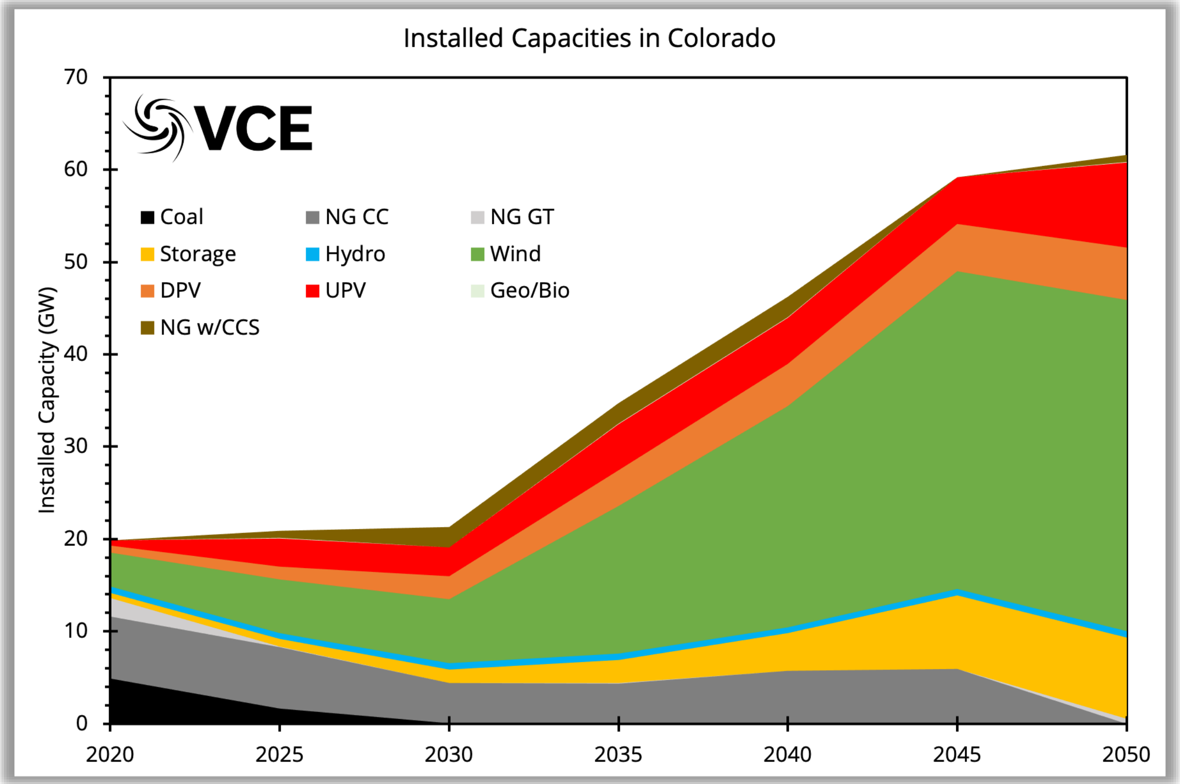
Colorado gains at the seams of an interconnect



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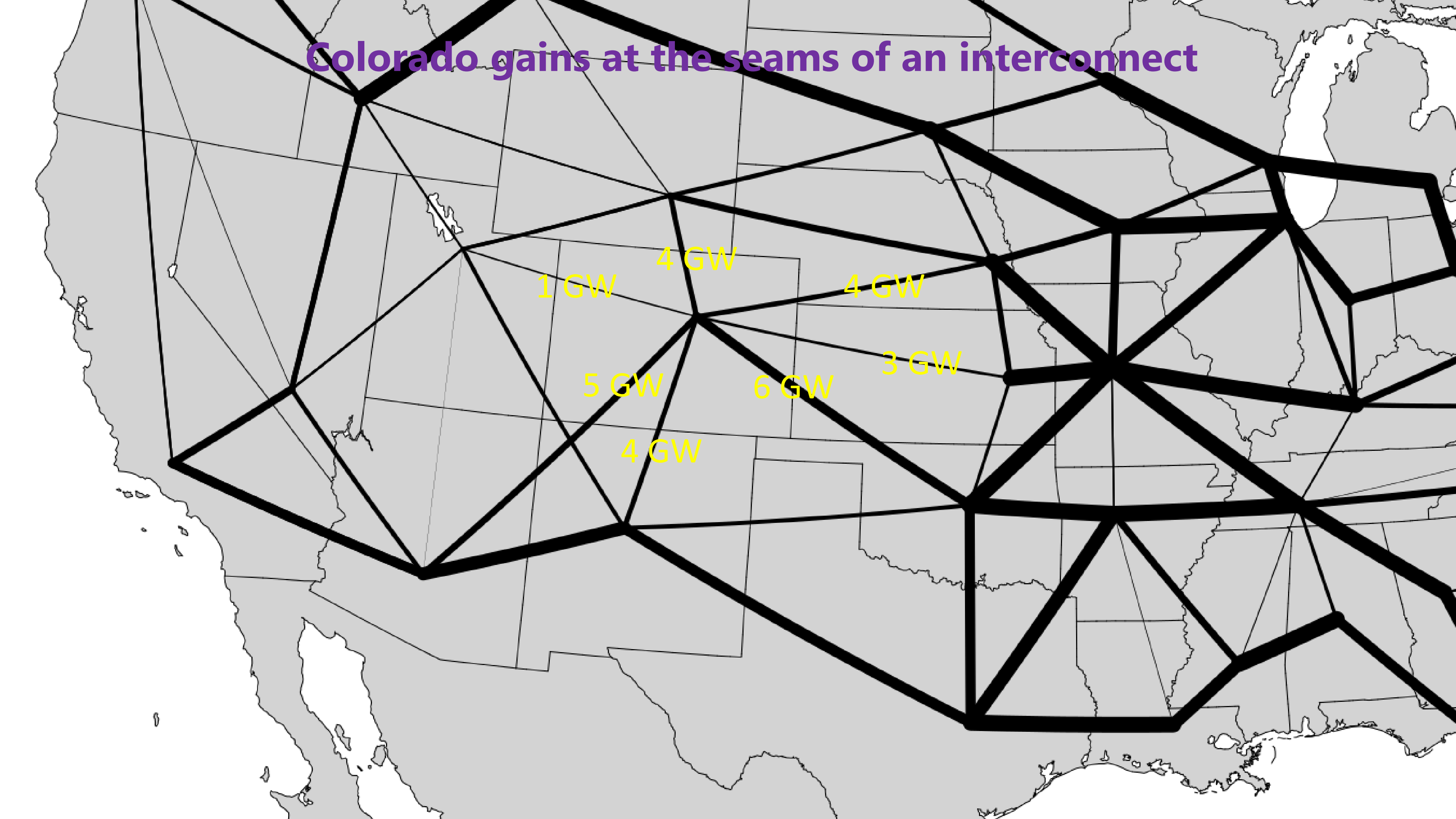
Colorado gains at the seams of an interconnect



Thank You

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