

# Minnesota's Smarter Grid:

*Pathways Toward a Clean, Reliable and Affordable Transportation and Energy System*

Prepared By:

**Vibrant Clean Energy, LLC**

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Prepared For:

**ESIG Webinar Series**

*February 6<sup>th</sup>, 2019*

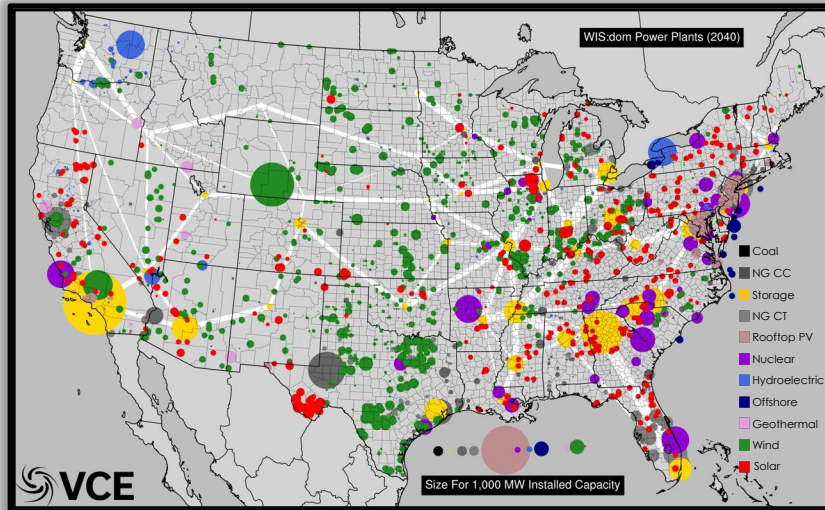
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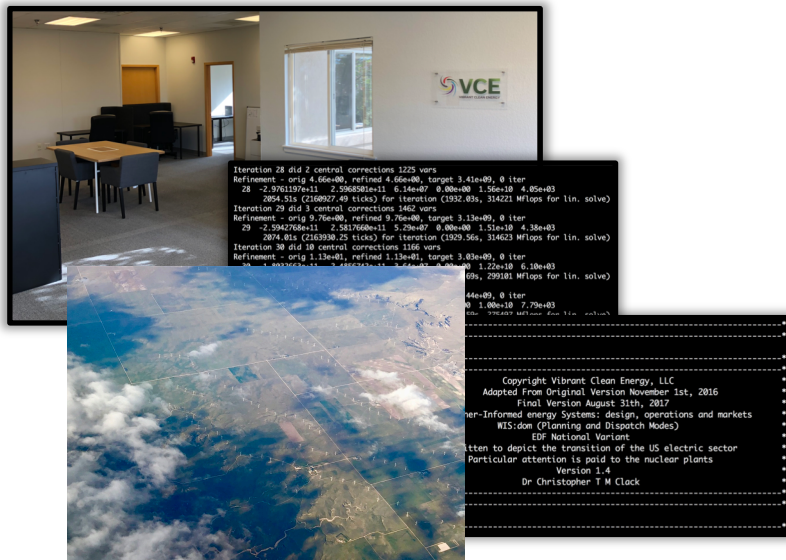
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# Vibrant Clean Energy



## 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;
- Model the **electrification** of industry, heating & transportation;
- License **WIS:dom optimization model** and/or perform studies using the model;
- Ensure **equitable compensation and costs** for energy companies within a modernized grid;
- Assist clients **unlock and understand the potential** of high VRE scenarios, as well as zero emission pathways.



# Minnesota's Smarter Grid

- Utilize the WIS:dom optimization model to investigate the pathways available to Minnesota to decarbonize the economy by 80% by 2050;
  - WIS:dom modeled the **Minnesota electricity grid (along with the MISO and wider Eastern Interconnection)** with electrification of some other sectors taken into account under baseline (BAU) and decarbonized conditions.
  - To decarbonize the economy by **80% by 2050 (meet pro-rata 2°C climate goals)**, the electricity sector must decarbonize by a minimum of **91%** (with the consideration of strong EE, electrification of space & water heating and transportation. Note these are all referenced back to **2005**.  
**Essentially, the MN electricity sector has a maximum of 4.5 mm T of CO<sub>2</sub> emissions allowed to reach goal.**
- Builds off two previous studies that VCE has performed in the MISO footprint:
  1. A MISO commissioned study “High penetration renewable energy study for MISO” found here: [https://www.misoenergy.org/\\_layouts/MISO/ECM/Redirect.aspx?ID=223249](https://www.misoenergy.org/_layouts/MISO/ECM/Redirect.aspx?ID=223249)
  2. An Energy Foundation funded project in collaboration with UMN and Strategen consulting “Modernizing Minnesota’s Grid” found here: <http://energytransition.umn.edu/wp-content/uploads/2017/07/Workshop-Report-Final.pdf>

# Electrification is Key To Low-Cost Decarbonization

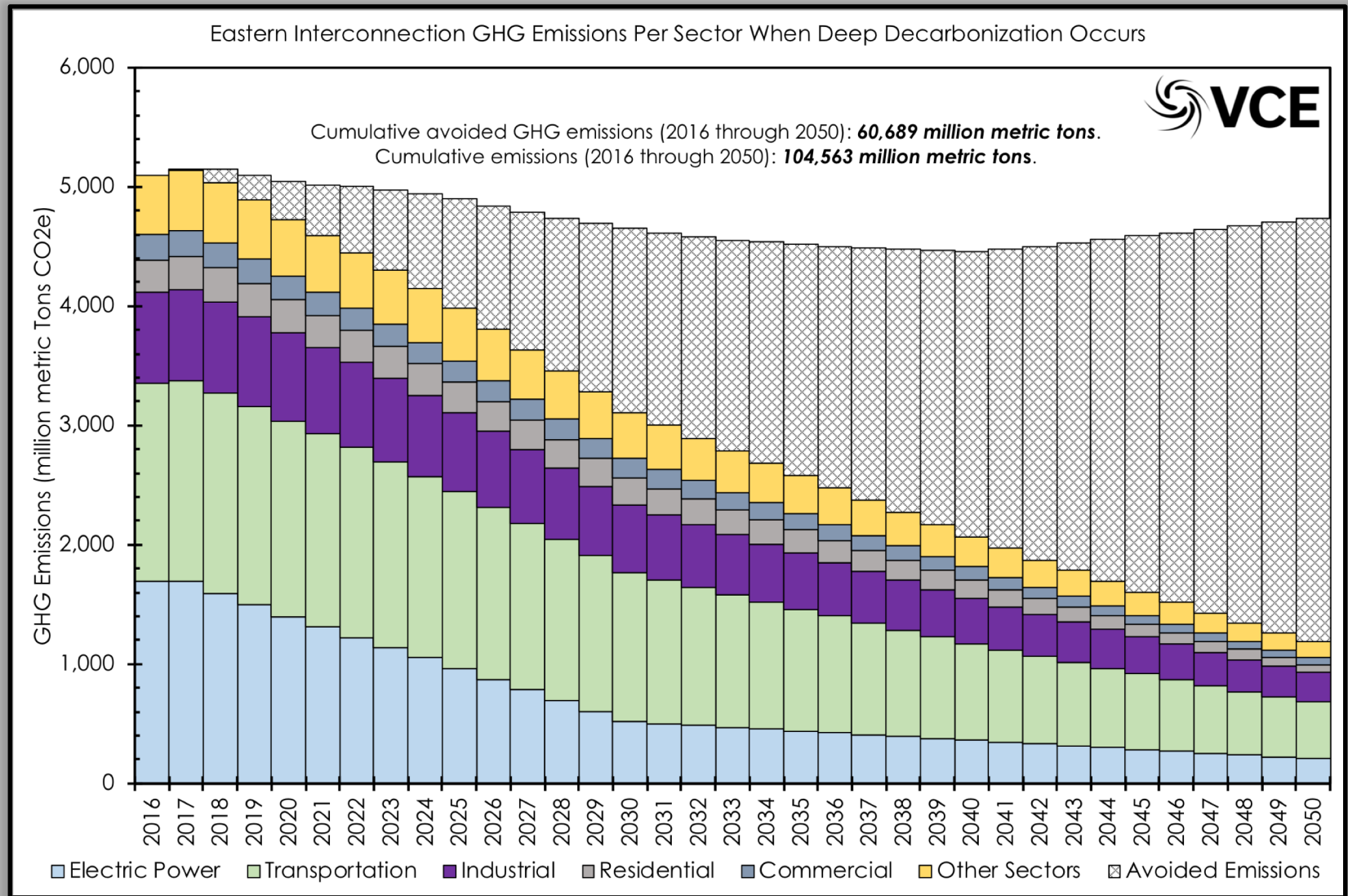
- ✓ ***Electrification and decarbonization can be achieved in Minnesota (along with the Eastern Interconnection) to provide a low-cost, low-emissions economy.***
- ✓ The electrification and decarbonization for Minnesota could save each household up to \$1,200 per year in direct costs.
- ✓ ***Electrification provides flexibility to the electricity sector that reduces the impact of resource variability (but does not eliminate it completely).***
- ✓ The electrification and decarbonization mitigates over 80% of the GHG emissions from the Minnesotan economy. It also reduces the exposure risk of the economy to volatility of the price of natural gas fuel.
- ✓ ***Without electrification, more transmission is required, and decarbonization becomes much more difficult.***



# Major Conclusions

- ✓ Minnesota has the potential to **reduce the cost of electricity for customers regardless of decarbonization portfolio**. The cost reduction **can be up to 2.8 ¢ / kWh** compared with 2017 average retail costs. If Minnesota chooses to fully decarbonize the electricity sector and perform heavy electrification the cost reduction compared with 2017 would be 1.4 ¢ / kWh. **The average decarbonization and electrification cost reduction is 2.3 ¢ / kWh.**
- ✓ Minnesota can completely decarbonize. Doing so along with the rest of the Eastern Interconnection raises the difficulty; however, Minnesota can still achieve its goals. The further integration into MISO **with expanded transmission** is essential in reducing costs for deep decarbonization – even though electrification reduces the burden on the transmission capacity required.
- ✓ Without action **emission reductions would cease by 2030**. Further, the asset choices would keep emissions high, or would be stranded if emission targets were enacted at a later date.
- ✓ The jobs within the electricity sector in Minnesota is robust under all scenarios. In particular, **with decarbonization and electrification jobs in the electricity sector rise dramatically.**
- ✓ If natural gas costs rise, and decarbonization is not chosen Minnesotans could face a cumulative **additional spend on electricity of approximately \$15.6 billion by 2050**. Alternatively, decarbonization and electrification **could save Minnesotans a cumulative \$15.9 to \$51.4 billion by 2050**. That equates to an average household saving of \$600 - \$1,200 per year in energy costs.

# Avoided Emissions For Eastern Interconnection



# Scenarios Condensed

Scenarios Completed									
ID	Scenario	Transmission Expansion	Emission Target†	Electrification	MN Flexibility Level	El Flexibility Level	NG Cost	Nuclear Retirement	DERs
A	Background	Interstate & Intrastate Allowed	Current Policies	El Minimal	0% to 2.1% by 2050	0% to 2.1% by 2050	NREL ATB - Low	Follow License Schedule	No Lower Limit
		Intrastate Allowed Only							
B	MN Deep Decarbonization	Interstate & Intrastate Allowed	MN 80% Economy Reduction	MN Extensive	0% to 20.8% by 2050	0% to 2.1% by 2050	NREL ATB - Low	Follow License Schedule	No Lower Limit
		Intrastate Allowed Only							
C	High NG Cost	Interstate & Intrastate Allowed	Current Policies	El Minimal	0% to 2.1% by 2050	0% to 2.1% by 2050	AEO 2018 - High	Follow License Schedule	No Lower Limit
			MN 80% Economy Reduction	MN Extensive	0% to 20.8% by 2050				
D	Zero Emission Electricity MN	Interstate & Intrastate Allowed	MN 84% Economy Reduction	MN Extensive	0% to 20.8% by 2050	0% to 2.1% by 2050	NREL ATB - Low	Follow License Schedule	No Lower Limit
		Intrastate Allowed Only							
E	El Decarbonizes with MN	Interstate & Intrastate Allowed	El 80% Economy Reduction	El Extensive	0% to 20.8% by 2050	0% to 20.8% by 2050	NREL ATB - Low	Follow License Schedule	No Lower Limit
F	MN Deep Decarb. with Dominant DERs	Interstate & Intrastate Allowed	MN 80% Economy Reduction	MN Extensive	0% to 32.3% by 2050	0% to 2.1% by 2050	NREL ATB - Low	Follow License Schedule	50% from DERs
G	MN Deep Decarb. with less Flexibility	Interstate & Intrastate Allowed	MN 80% Economy Reduction	MN Extensive	0% to 5.2% by 2050	0% to 2.1% by 2050	NREL ATB - Low	Follow License Schedule	No Lower Limit
H	MN Deep Decarb. Nuclear Sensitivity	Interstate & Intrastate Allowed	MN 80% Economy Reduction	MN Extensive	0% to 20.8% by 2050	0% to 2.1% by 2050	NREL ATB - Low	Allow Early Retirement	No Lower Limit
								Keep Online Through 2050	

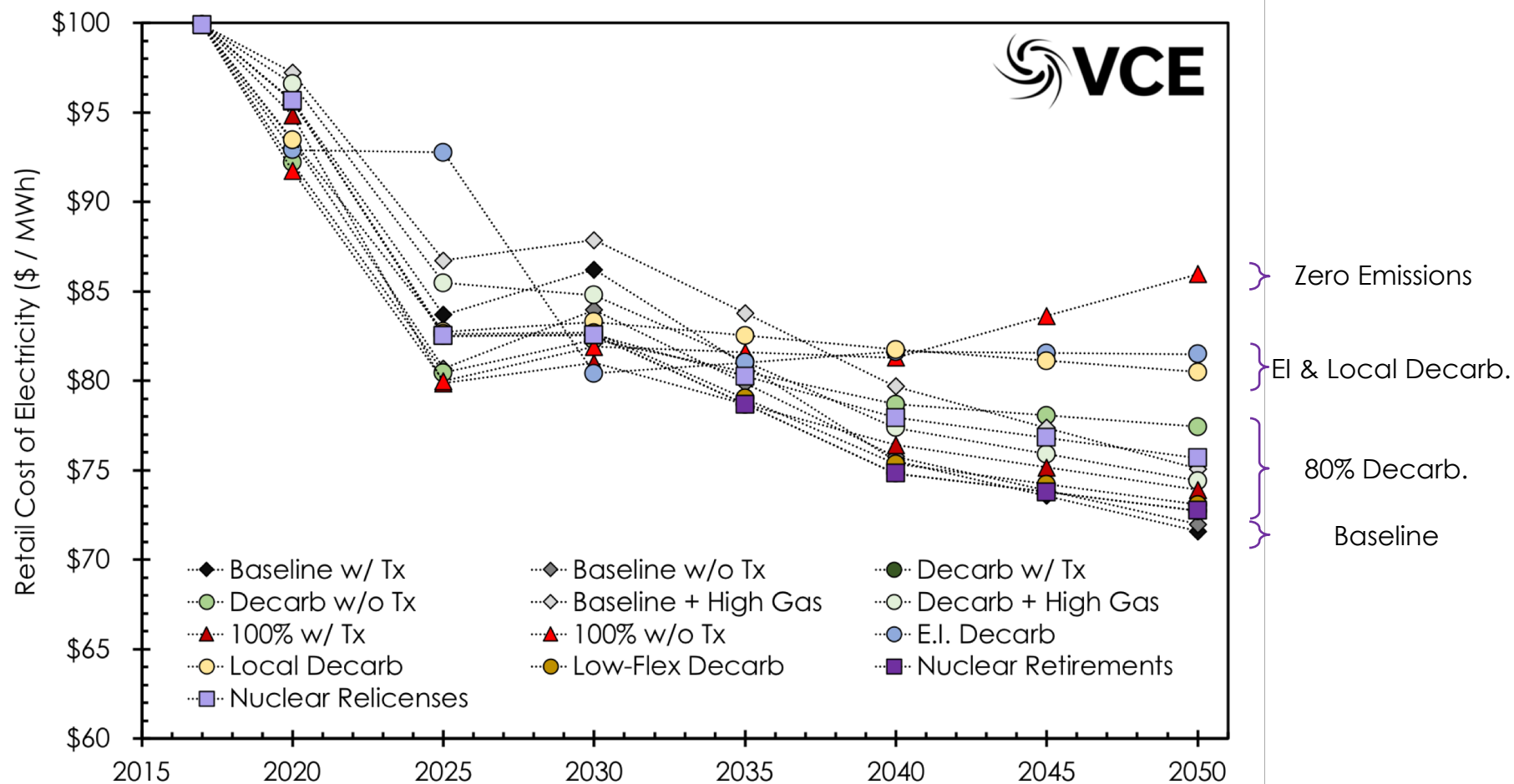
**3 Scenarios do not decarbonize or electrify**

8 Scenarios achieve 80% emissions reductions by 2050 compared with 2005

**2 Scenarios completely decarbonize electricity sector**

# MN Retail Cost of Electricity By Scenario

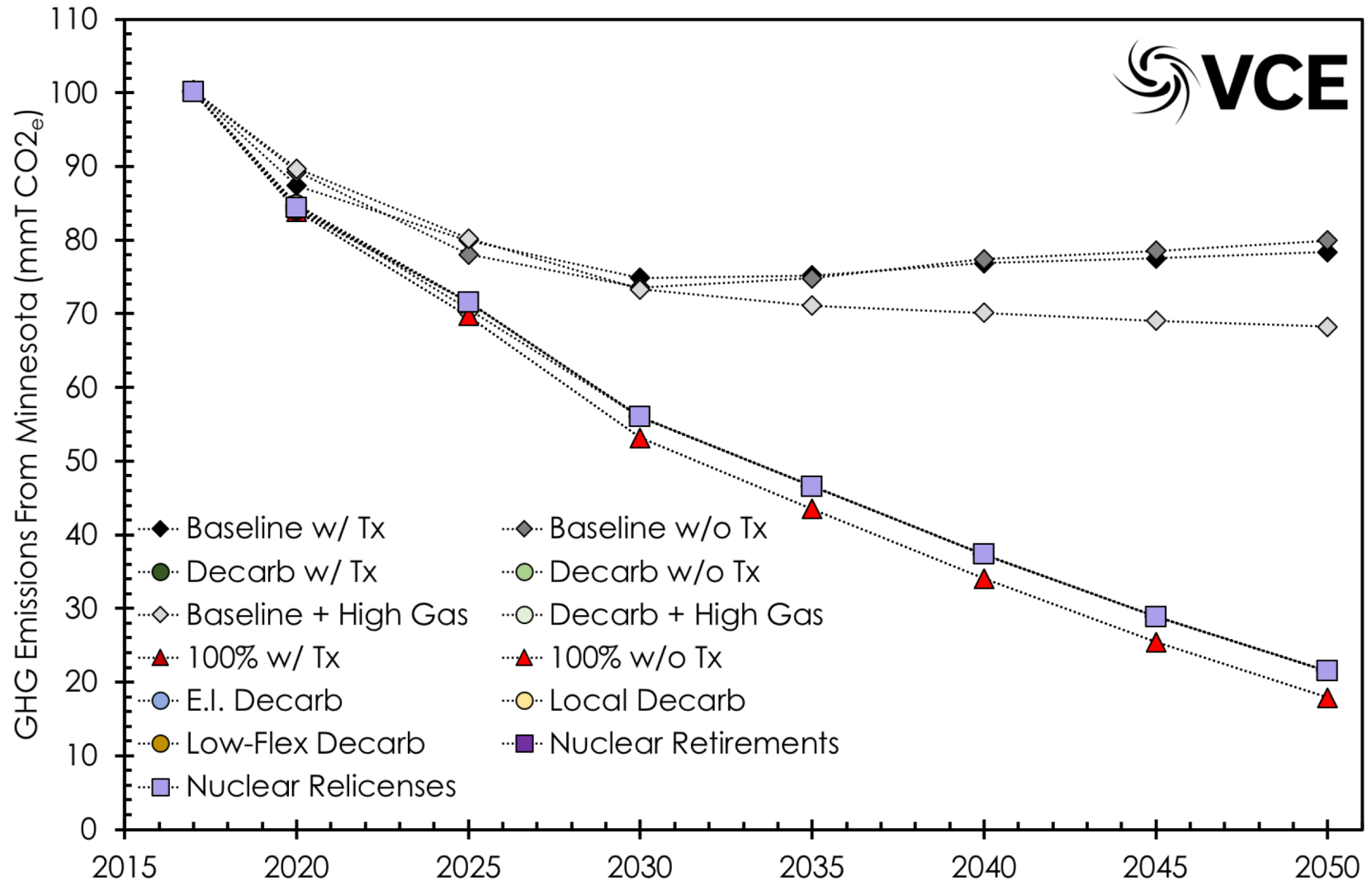
WIS:dom Estimated Retail Cost of Electricity in Minnesota



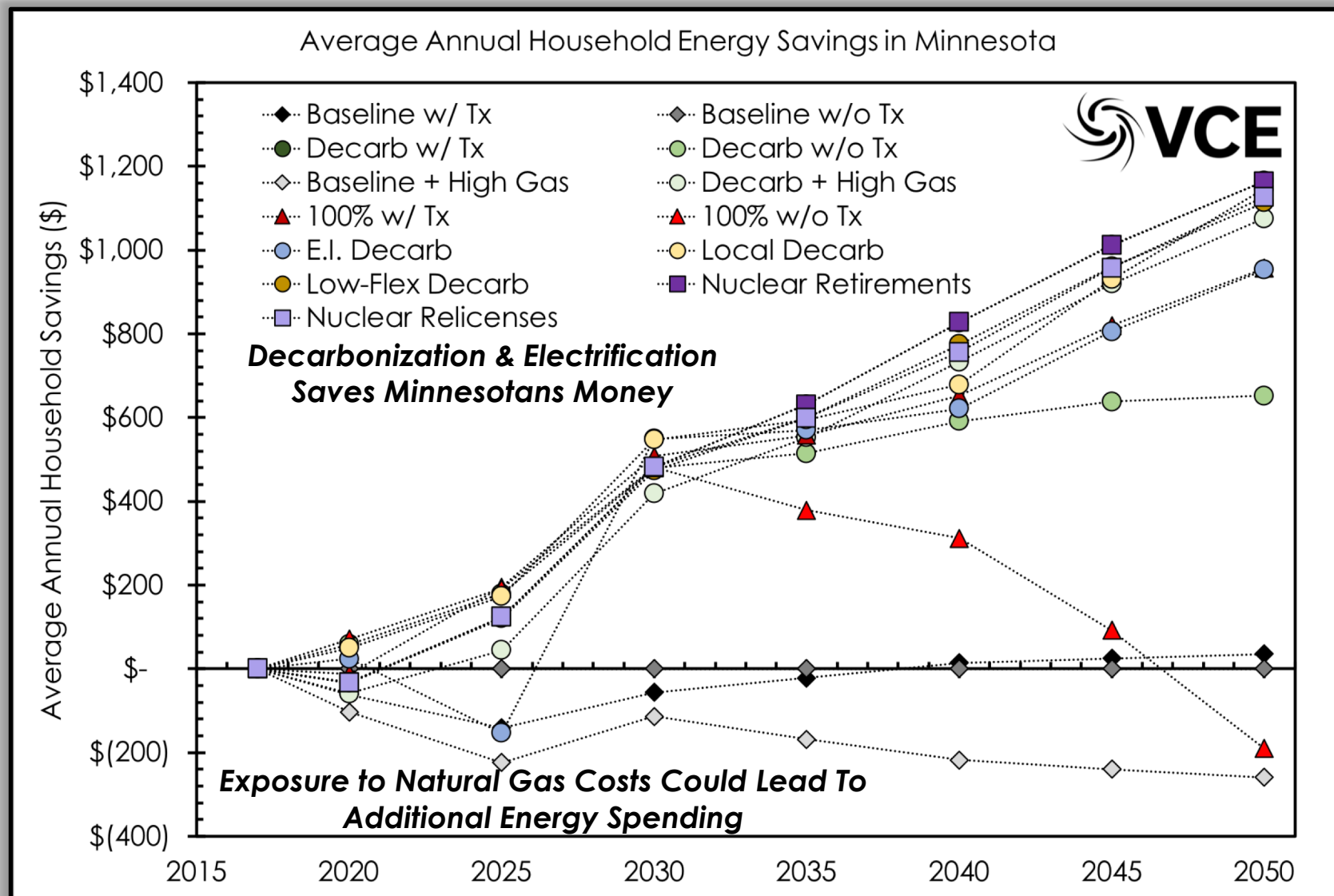


# MN Decarbonization Becomes Clear After 2020

WIS:dom Estimated GHG Emissions By Scenario For Minnesota Economy

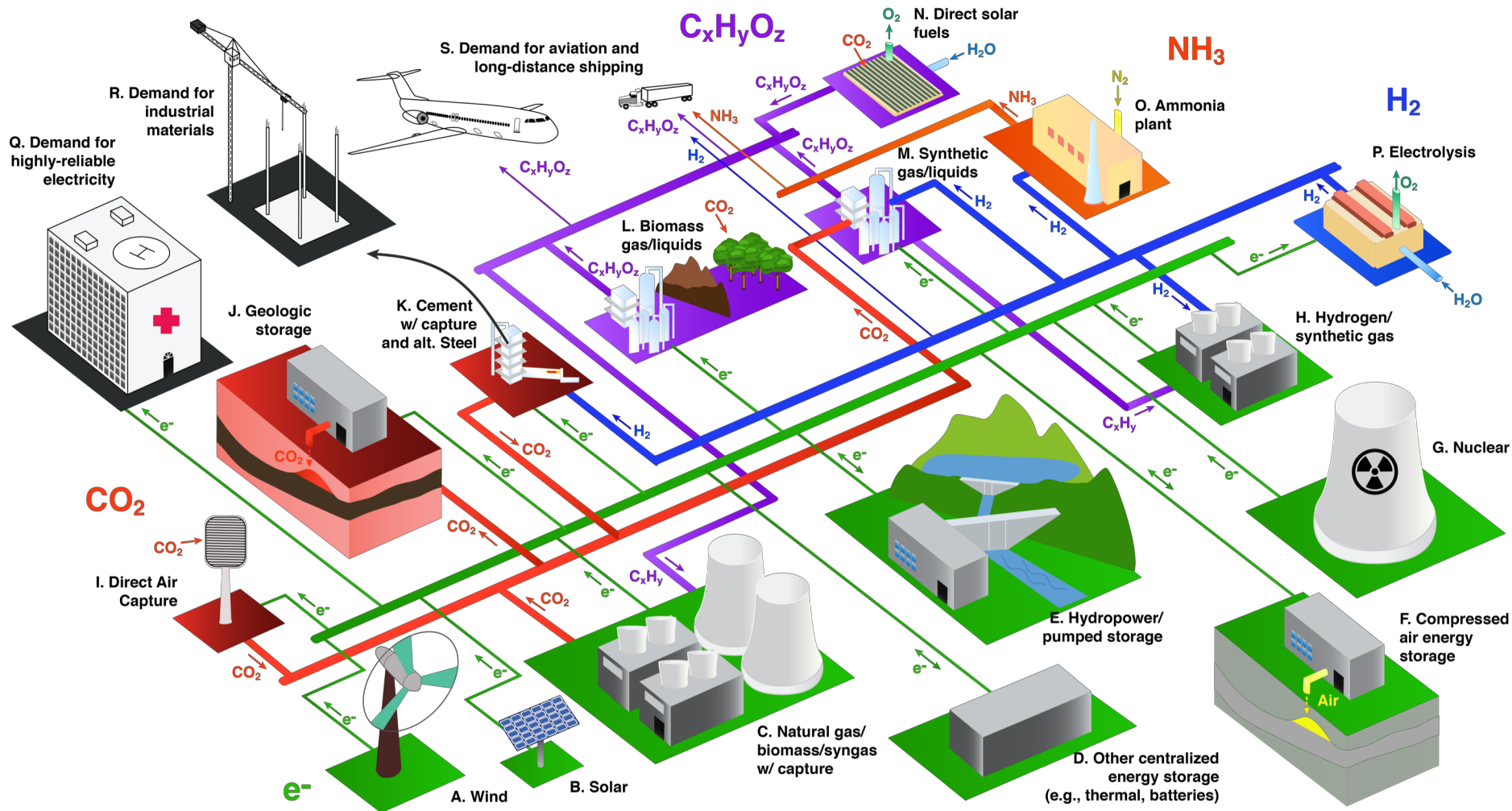


# MN Average Annual Household Savings



# Our Approach With WIS:dom

# The Whole Economy Needs Energy



Davis et al. Science, 2018



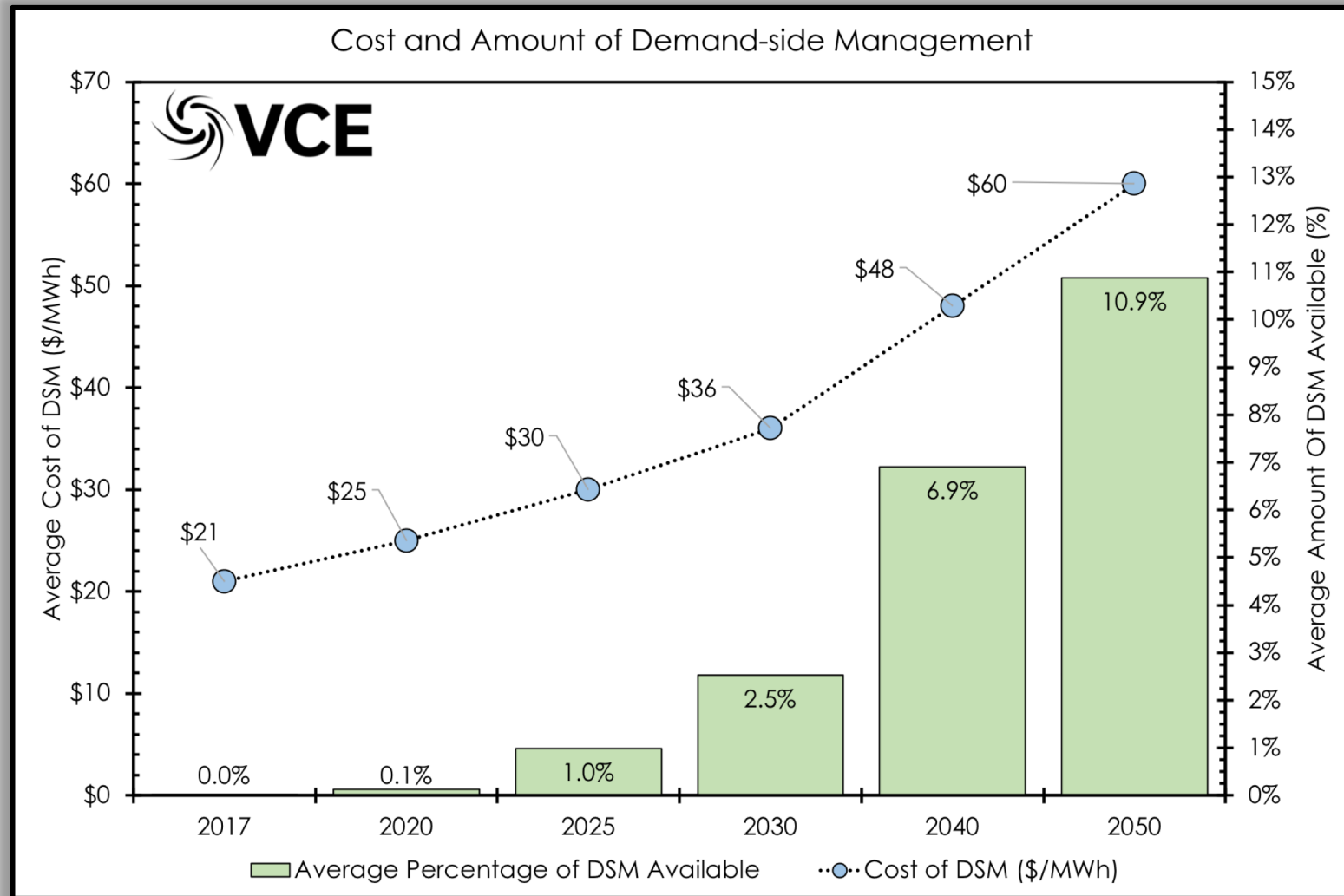


# Electrification That WIS:dom Considers

The WIS:dom optimization model considers ***electrification through:***

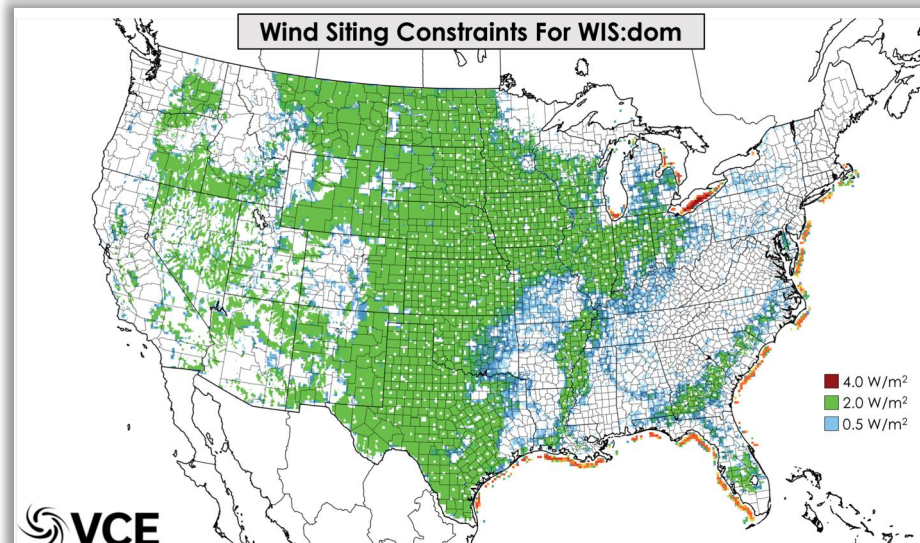
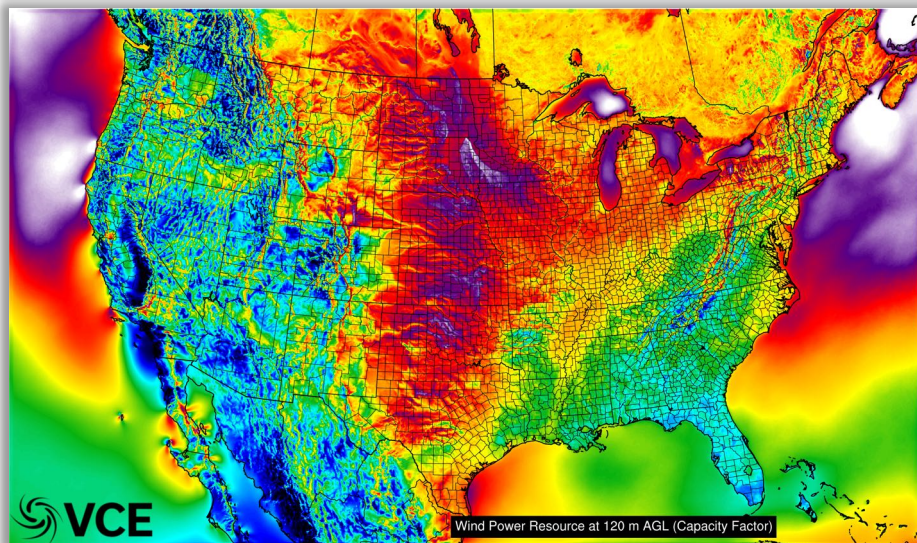
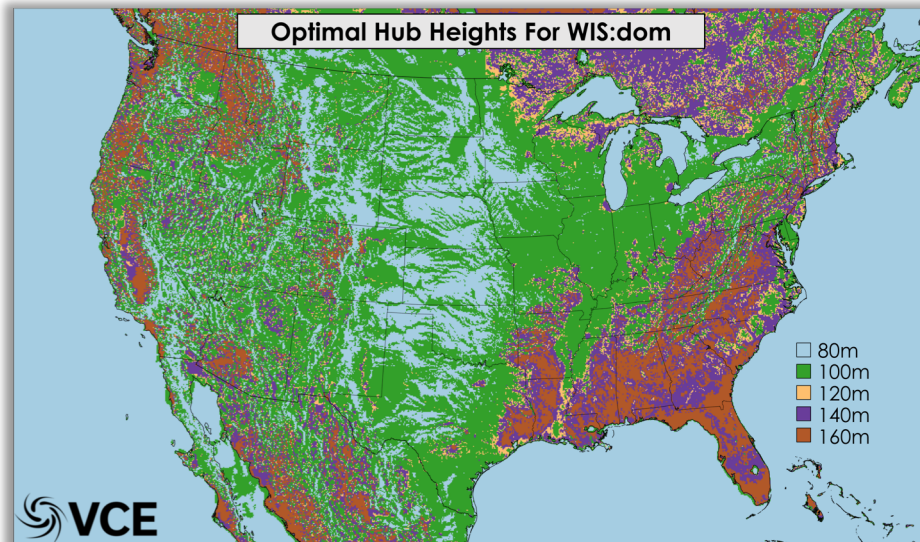
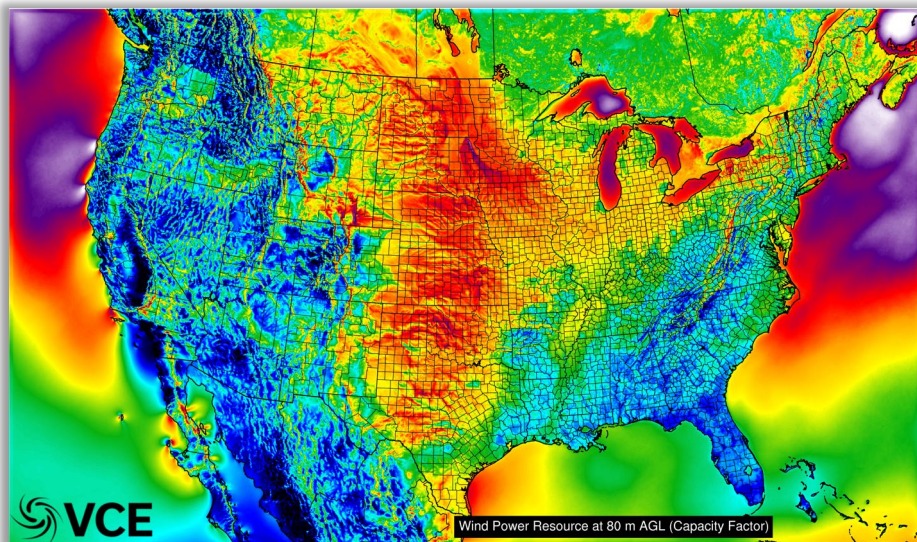
1. Light Duty Vehicles,
2. Heat pump Water Heaters (residential and commercial),
3. Heat pump space heating (residential and commercial),
4. Light Duty Trucks,
5. H2 production for:
  - *Medium / Heavy Duty Trucking,*
  - *Industrial Demands,*
  - *Space heating (residential and commercial),*
  - *Other transportation (Sabatier to Fischer-Tropsch Processes).*

# Demand-side Resources Create Flexibility



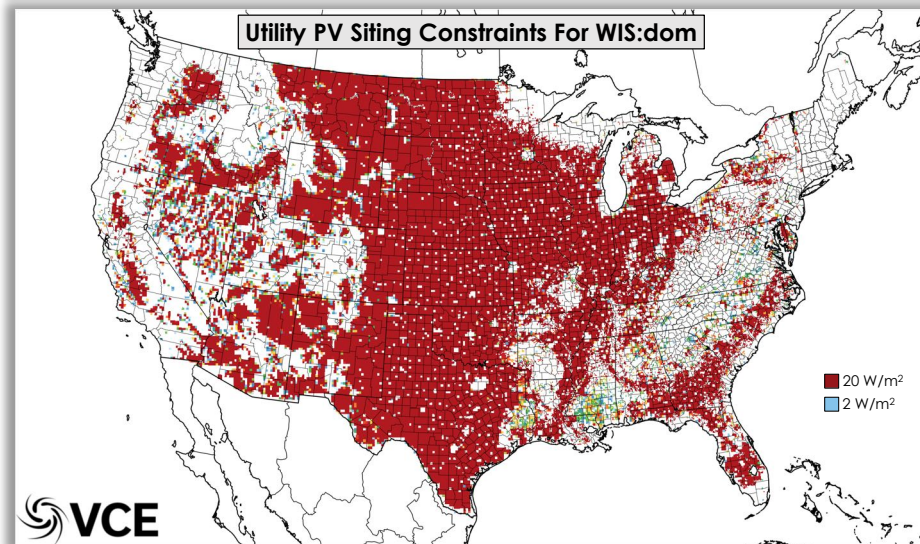
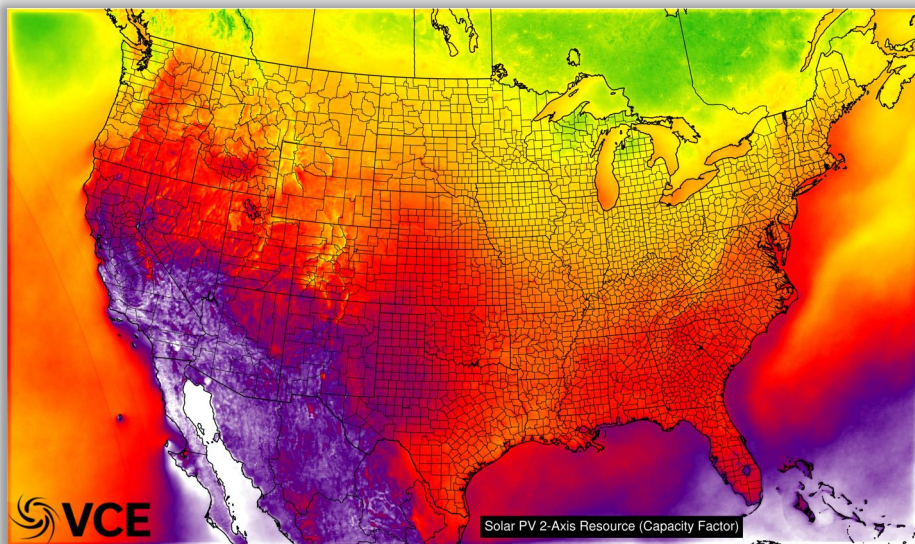
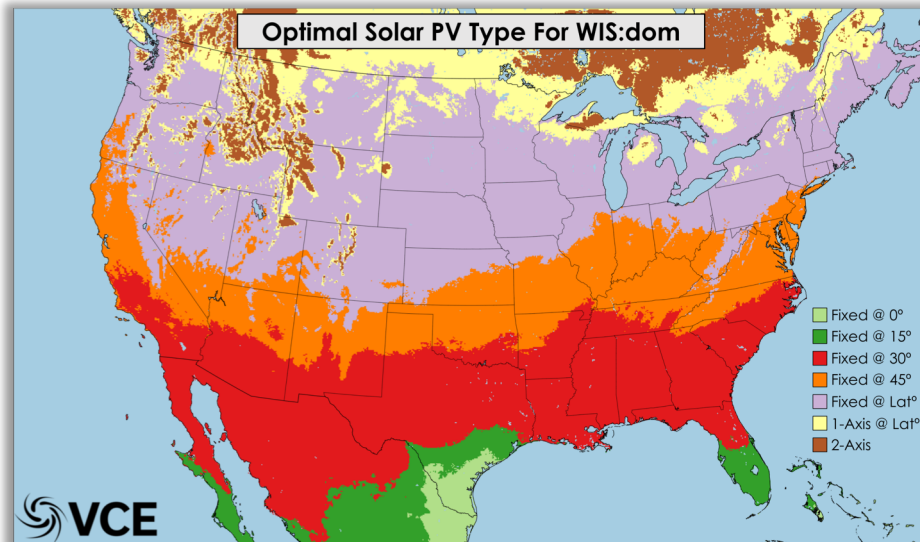
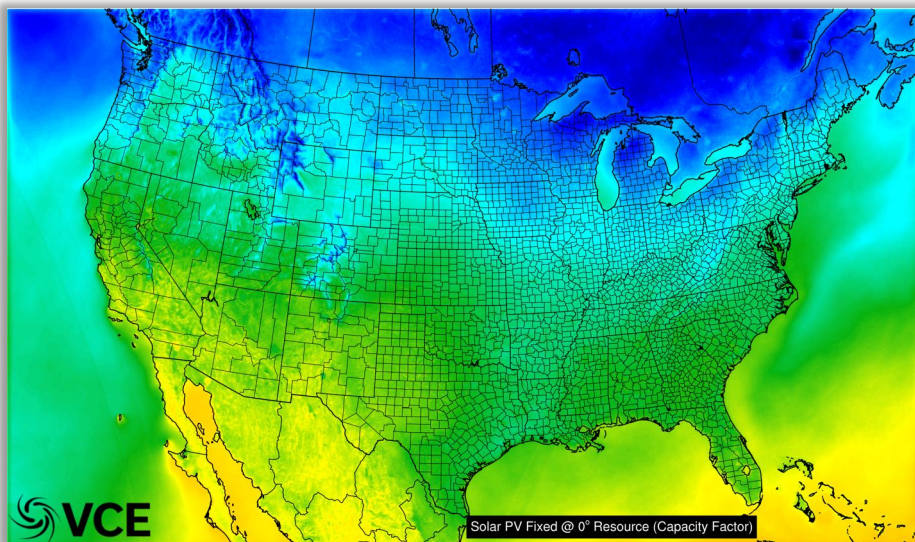


# WIS:dom Contains Detailed Weather and Siting Datasets





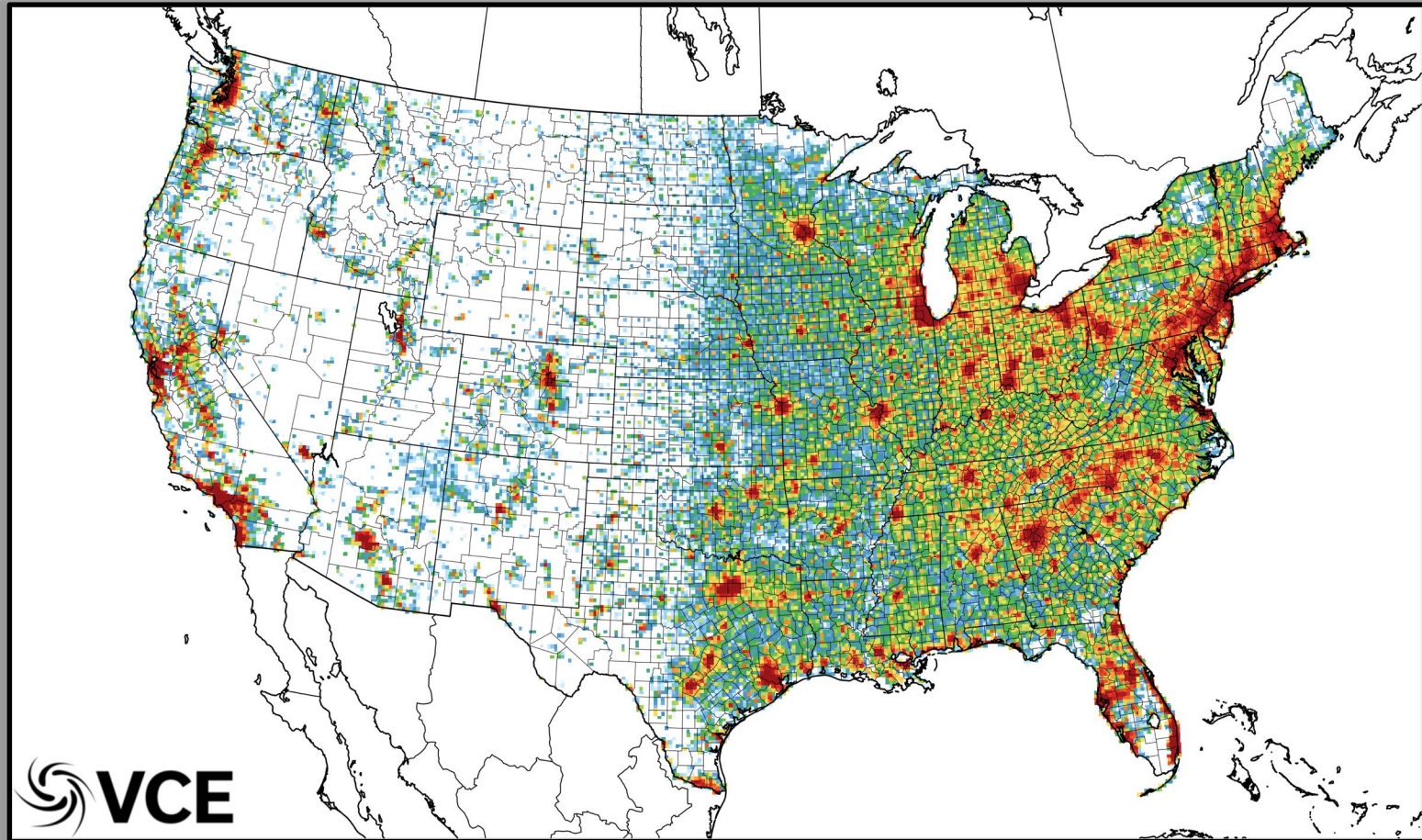
# WIS:dom Contains Detailed Weather and Siting Datasets





# Advanced Screening For Rooftop PV

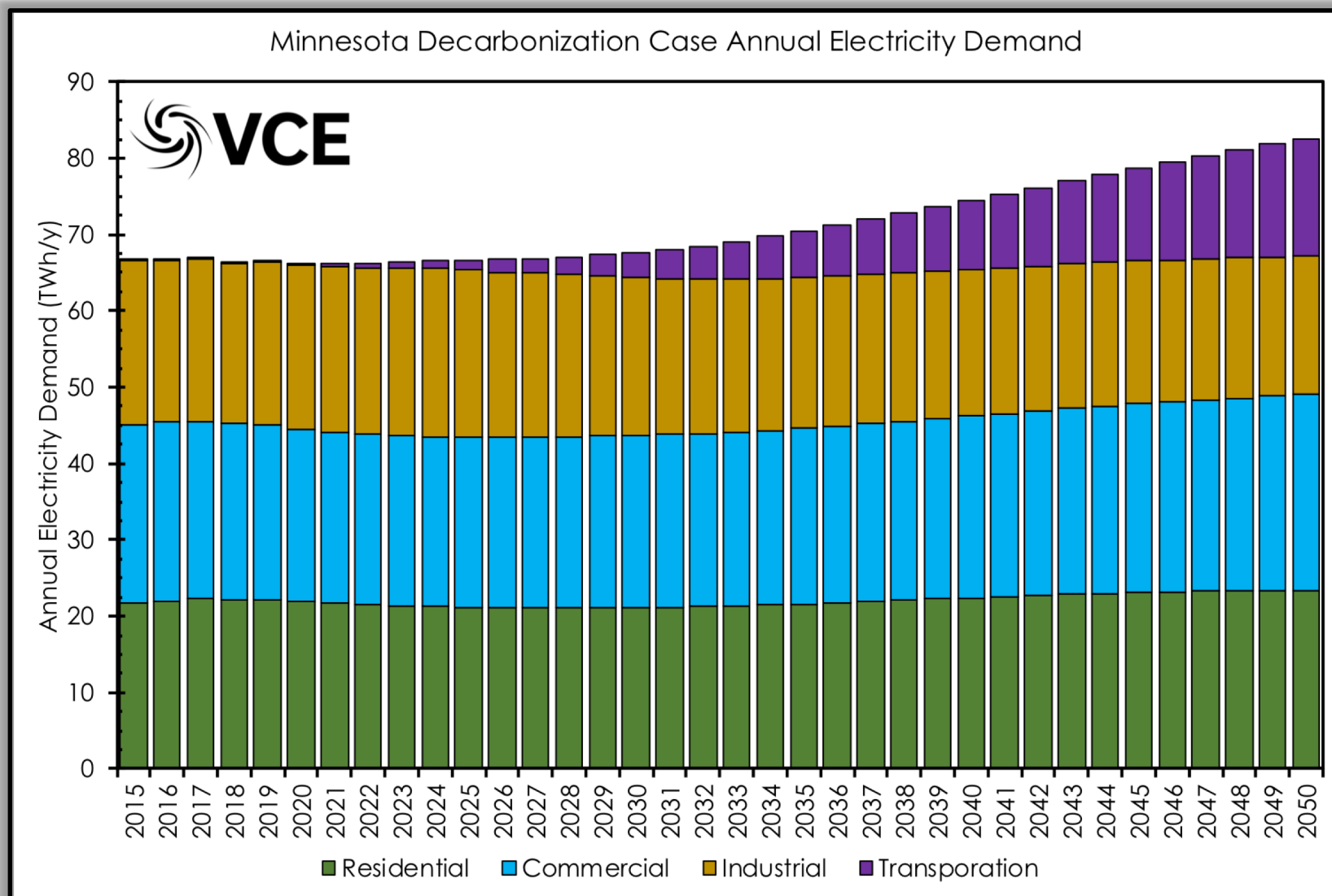
Note: Logarithmic Color Scale



**Maximum**  
**2.5 W/m<sup>2</sup>**

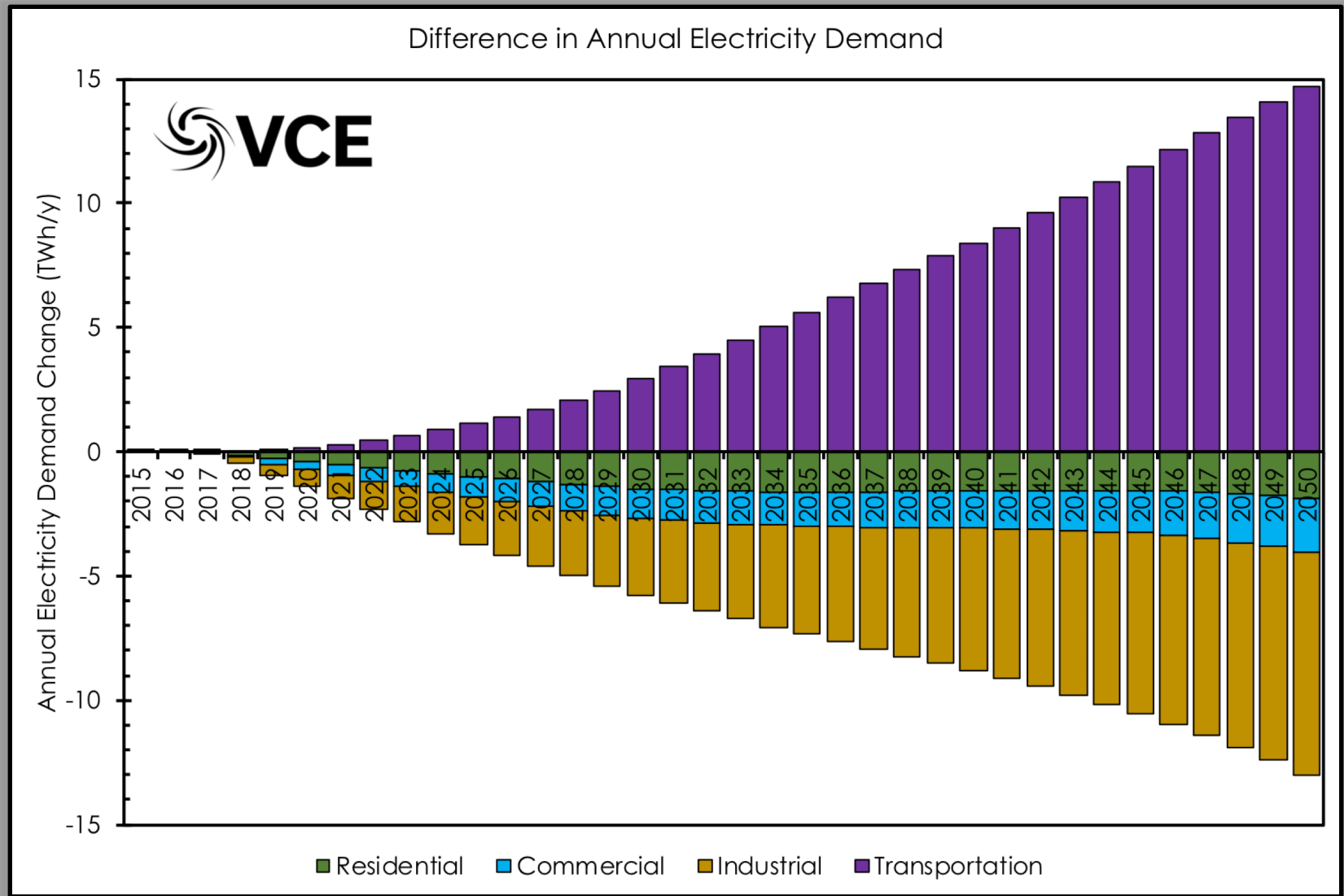
**Minimum**  
**2.5x10<sup>-5</sup> W/m<sup>2</sup>**

# Decarbonization Electricity Demand in MN



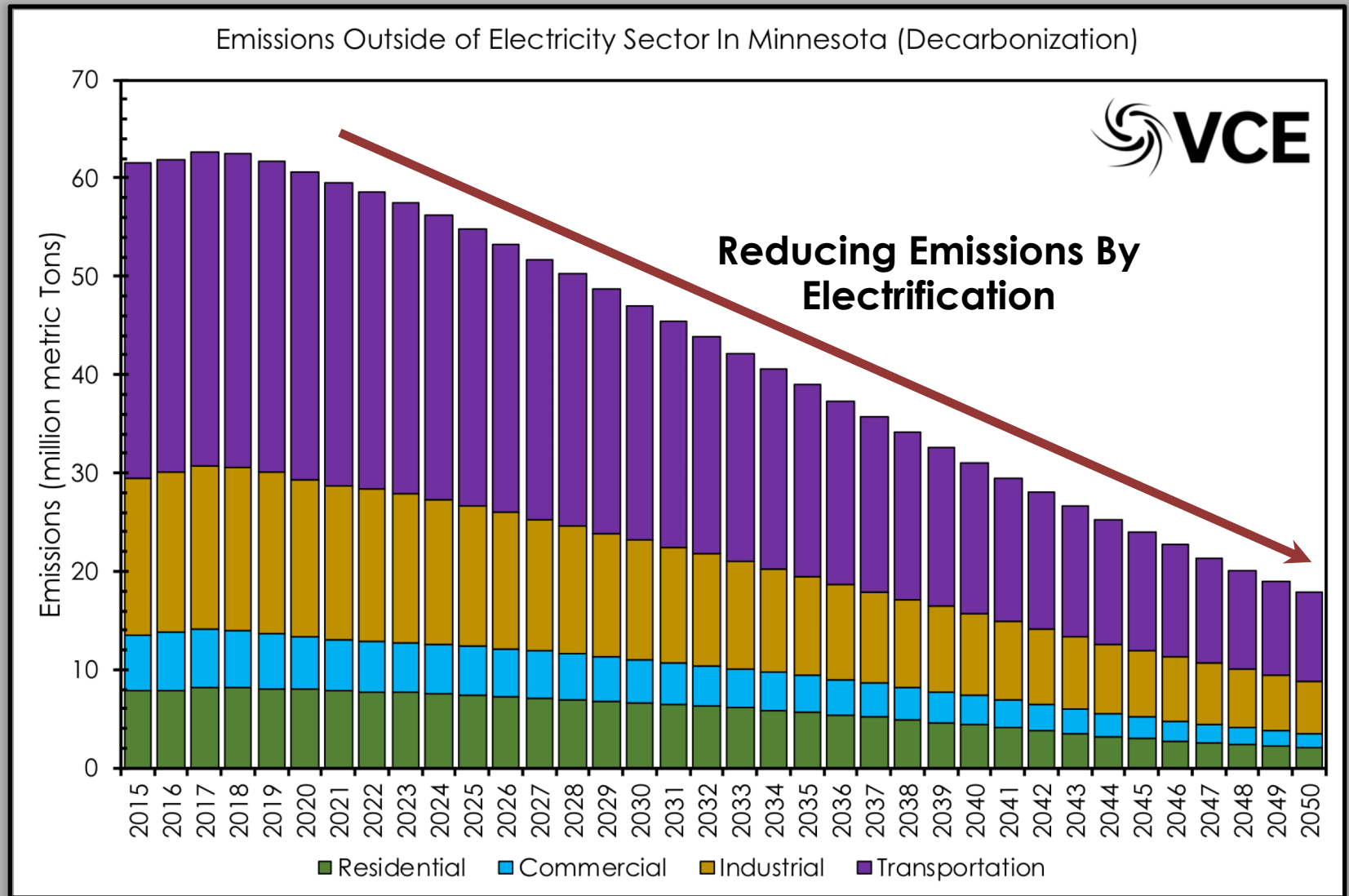
Data provided by **Synapse**

# Electricity Demand Change For Decarbonization



Data provided by **Synapse**

# Emissions From Outside Electricity in MN

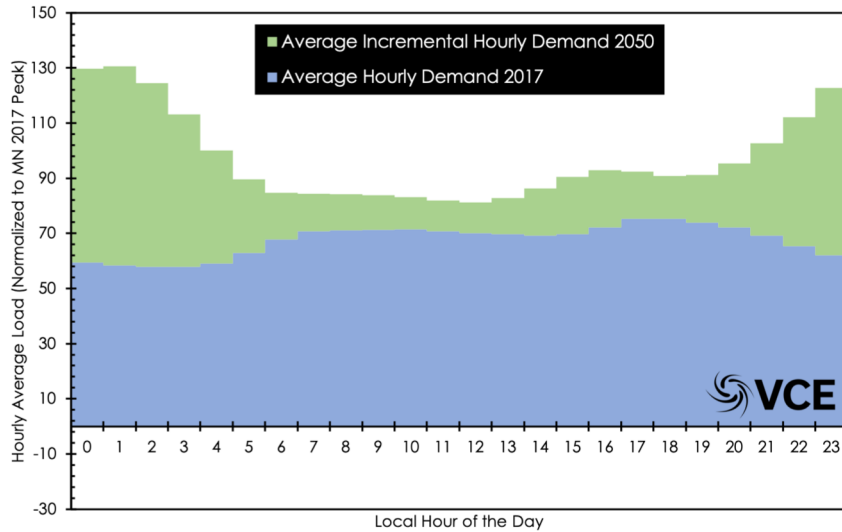


Data provided by **Synapse**

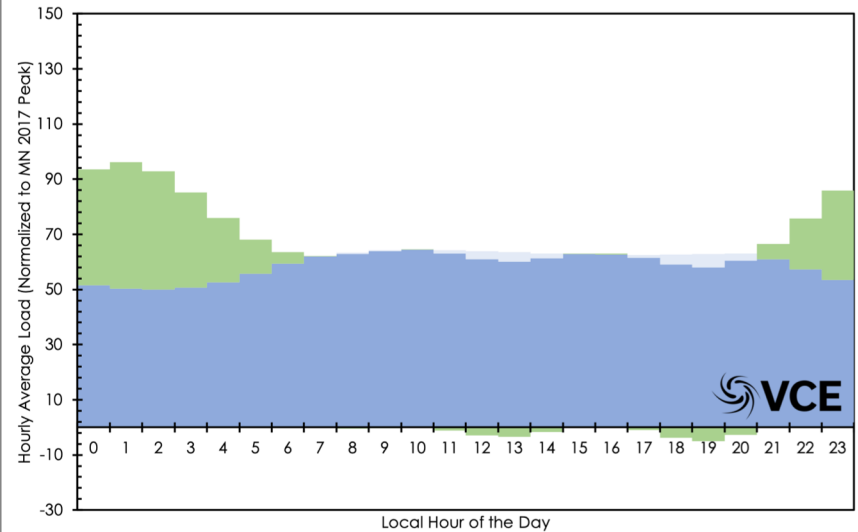


# Change in Hourly MN Demand Profiles

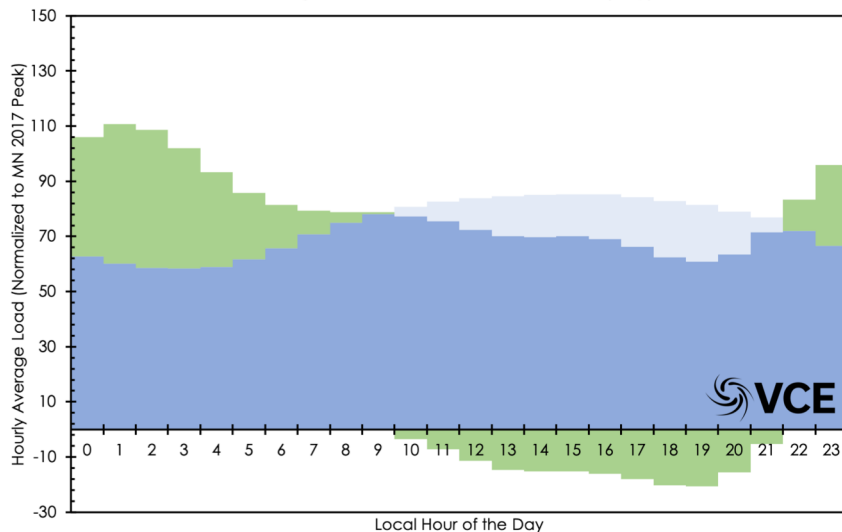
The Evolving Electric Demand of Minnesota (January)



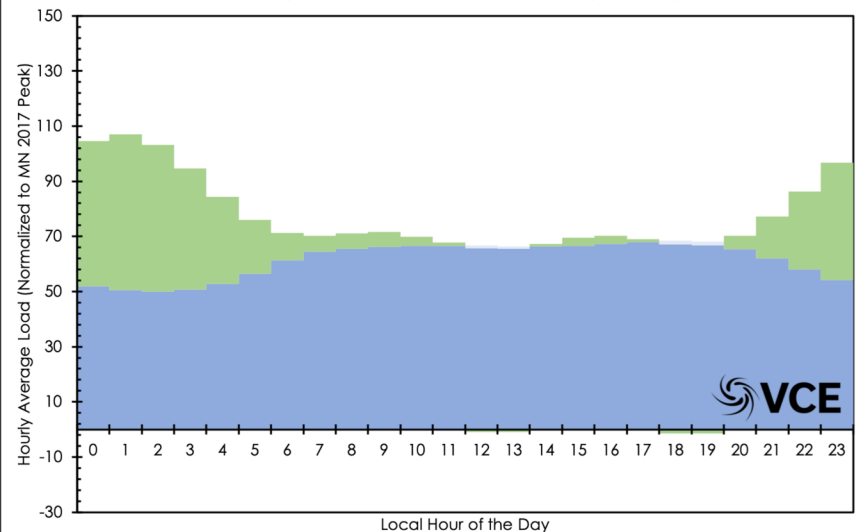
The Evolving Electric Demand of Minnesota (April)



The Evolving Electric Demand of Minnesota (July)

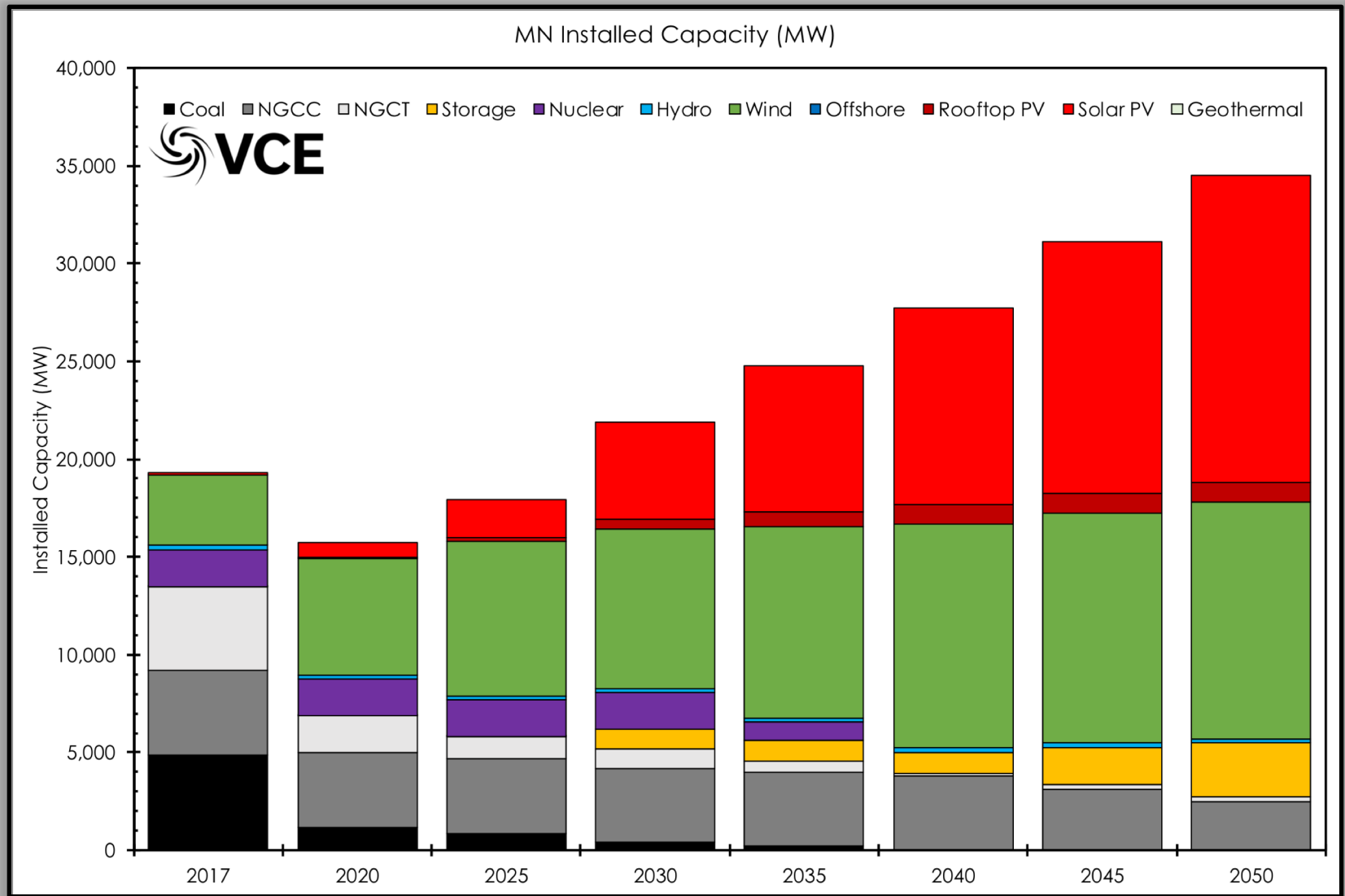


The Evolving Electric Demand of Minnesota (October)

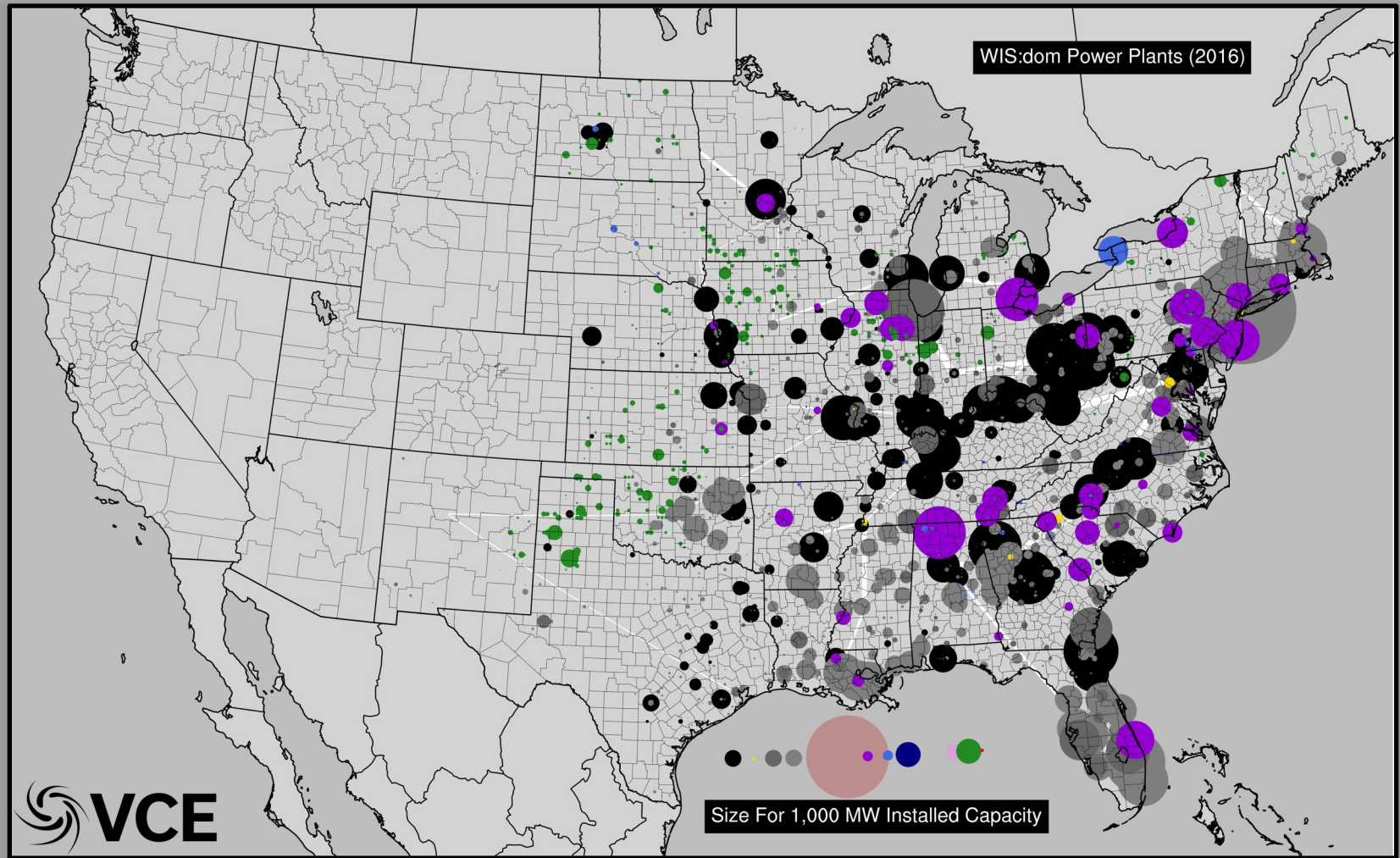


# Deeper Dive: *MN Decarbonization*

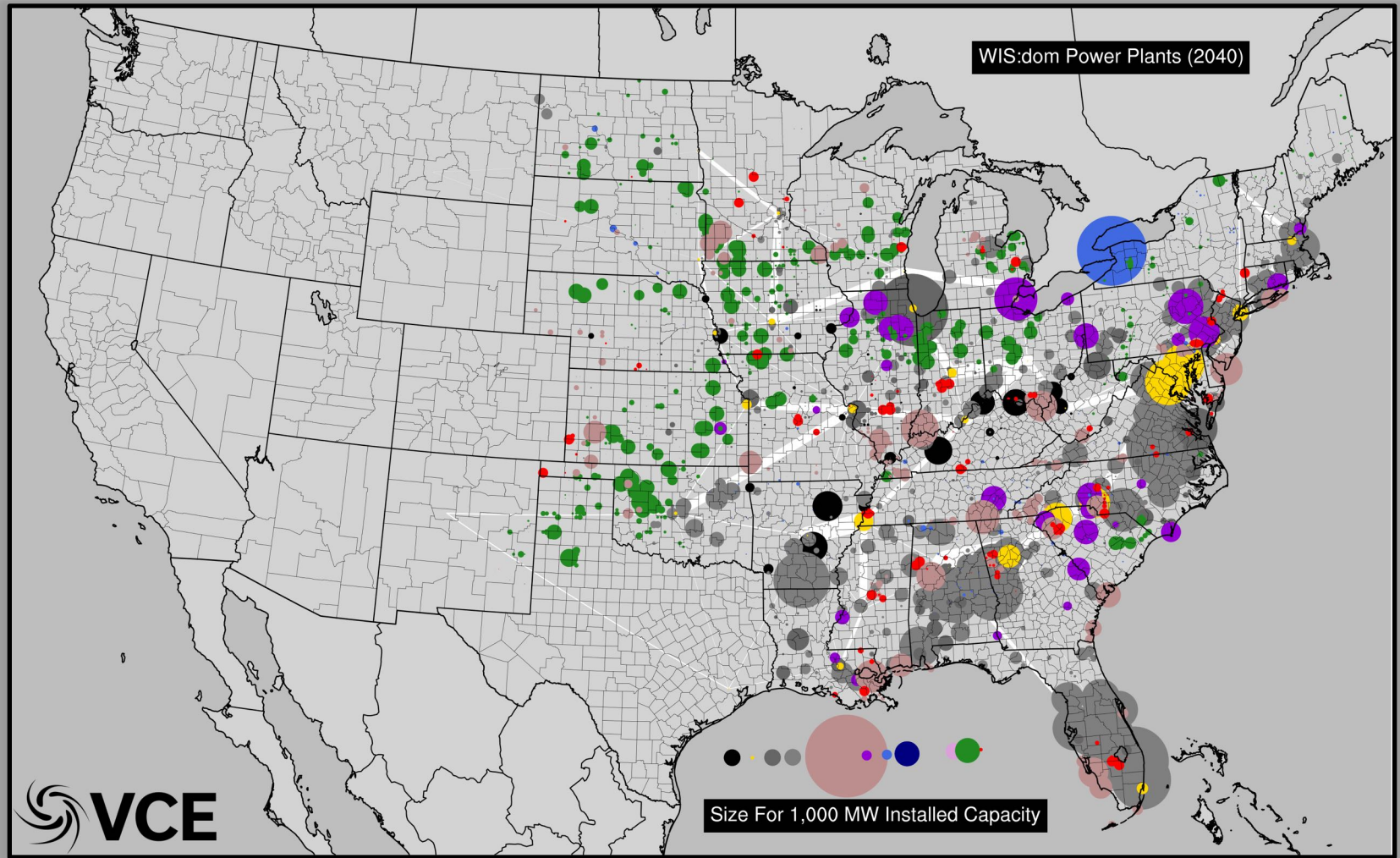
# Minnesota Installed Capacity



# Installed Capacity (Geographic)

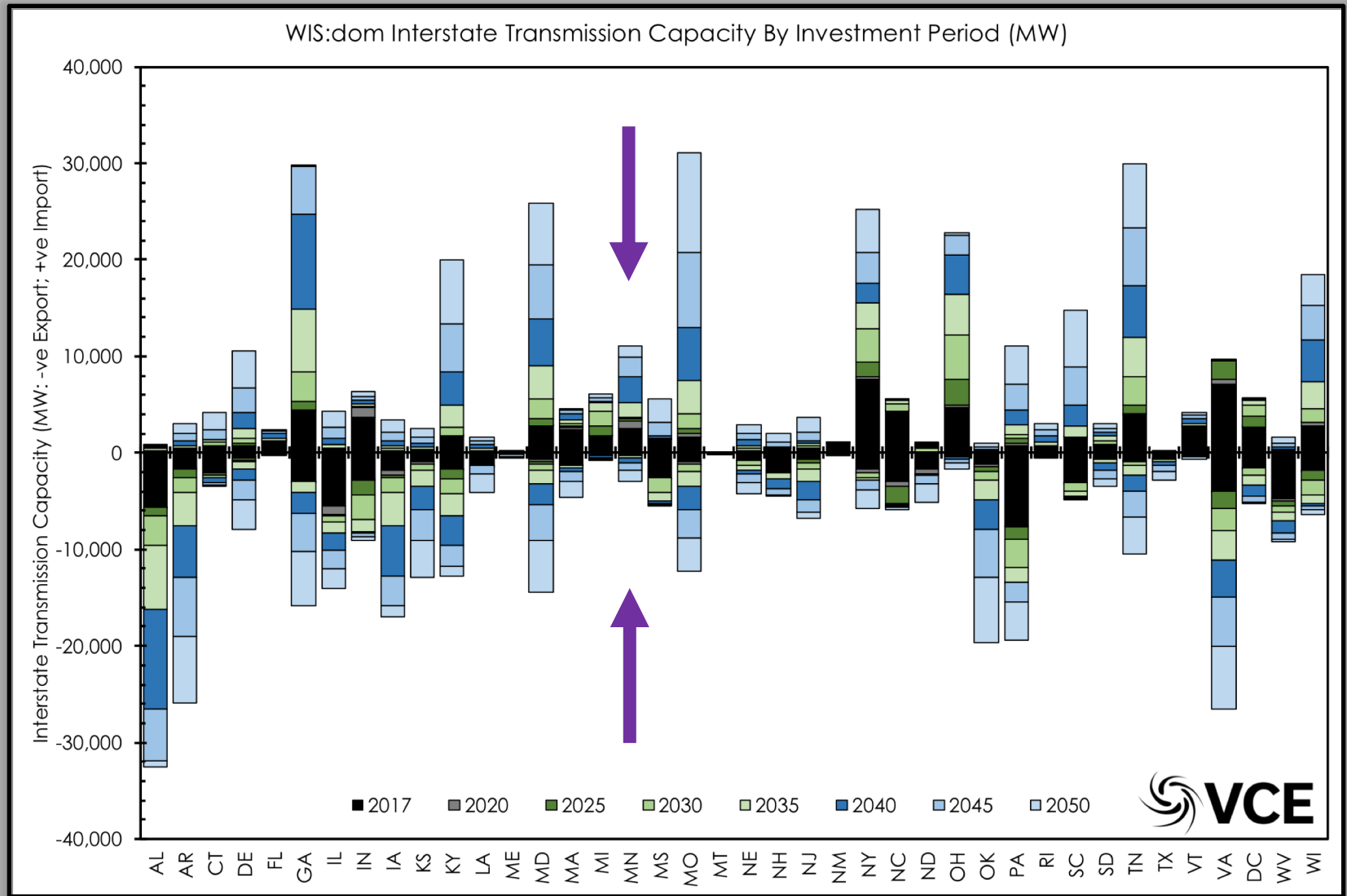


# Installed Capacity (Geographic)

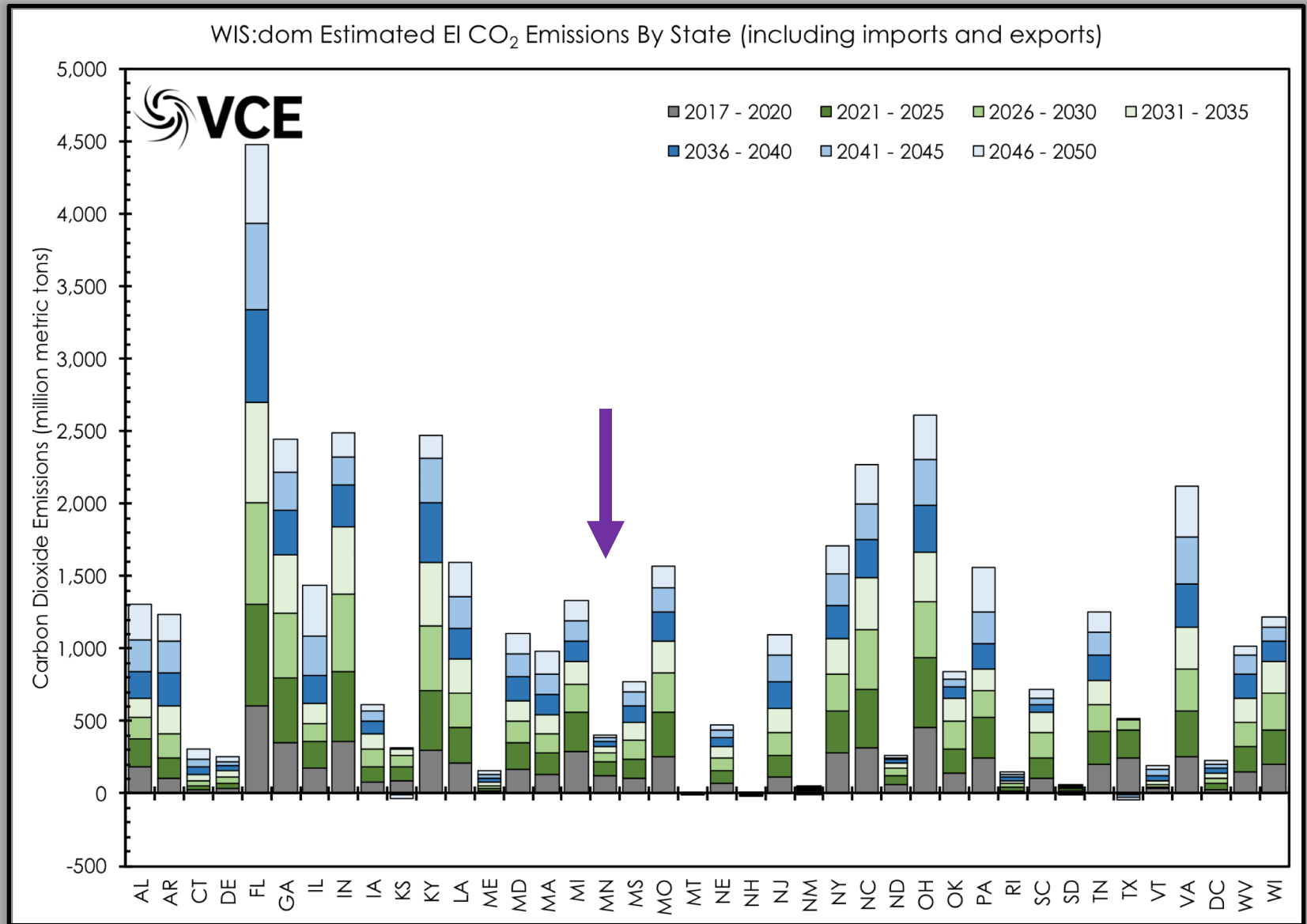




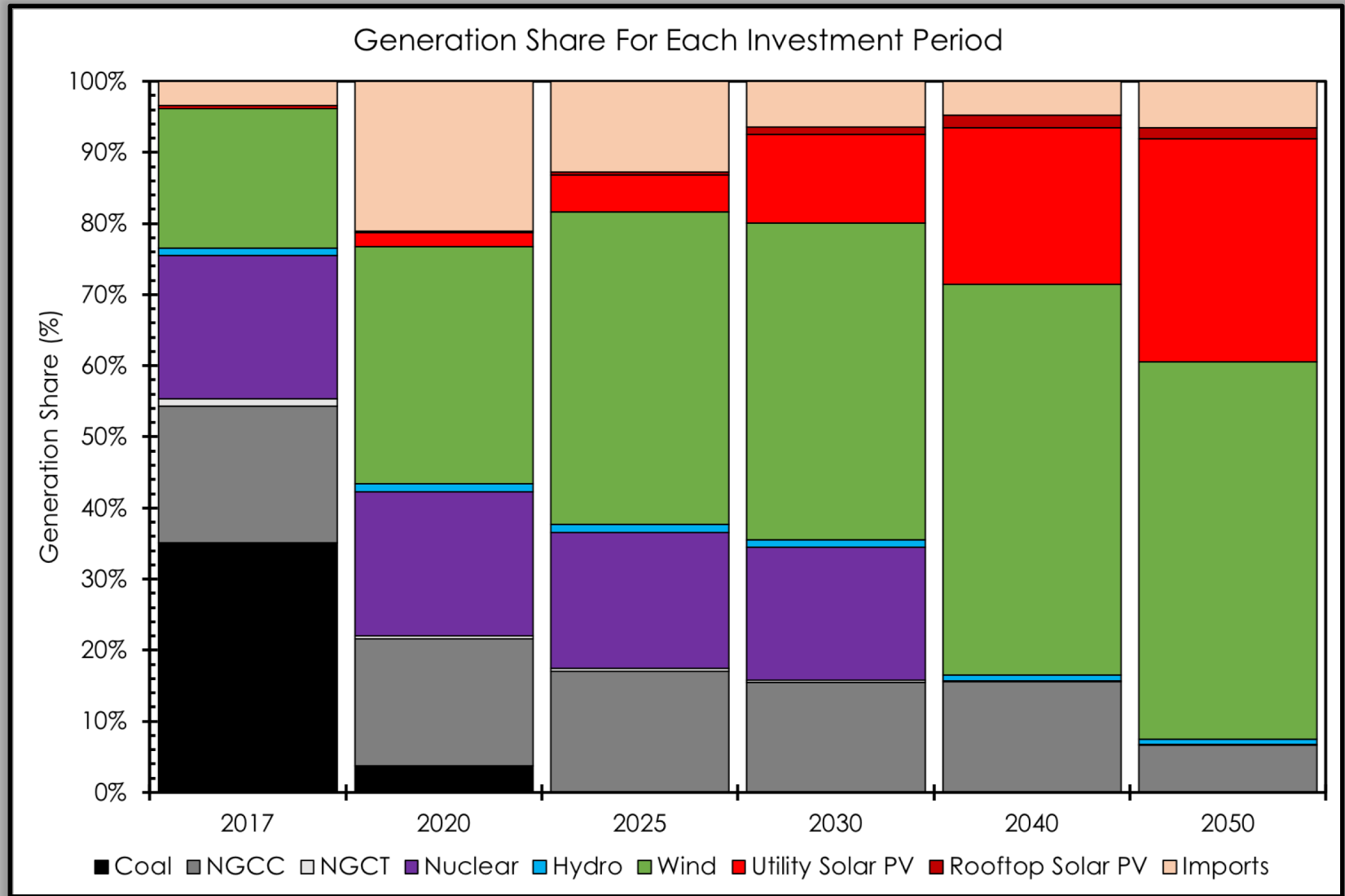
# Installed Interstate Transmission Capacity



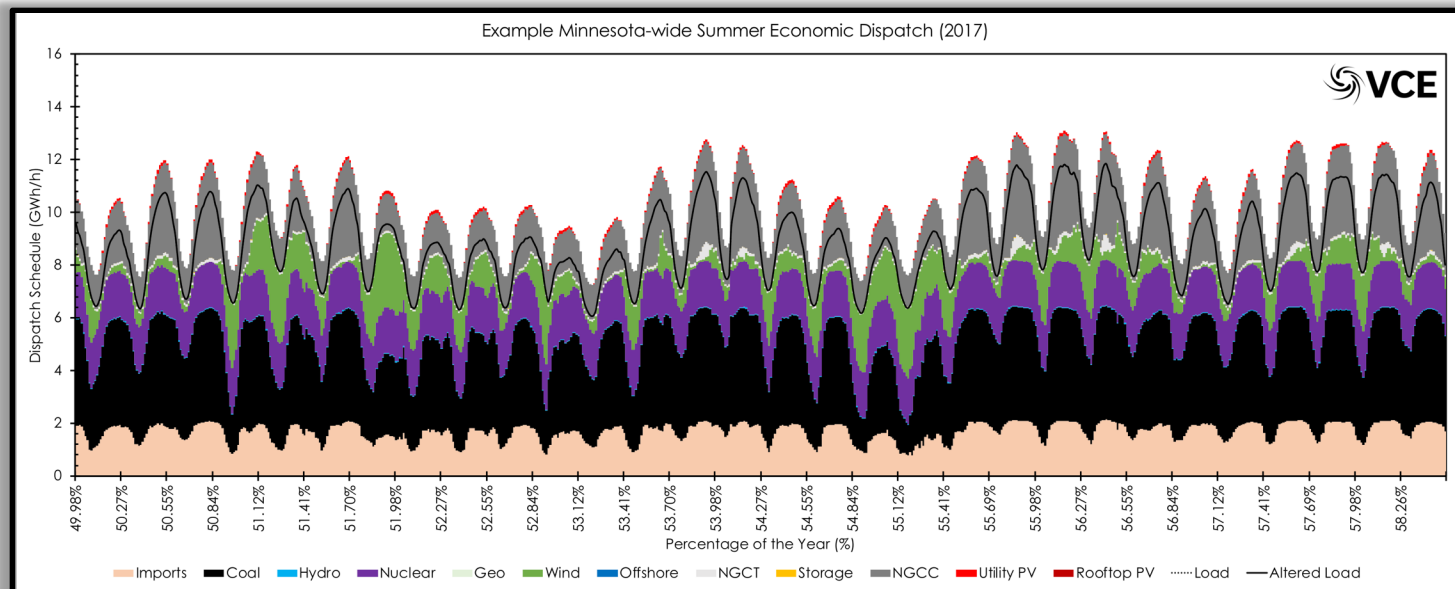
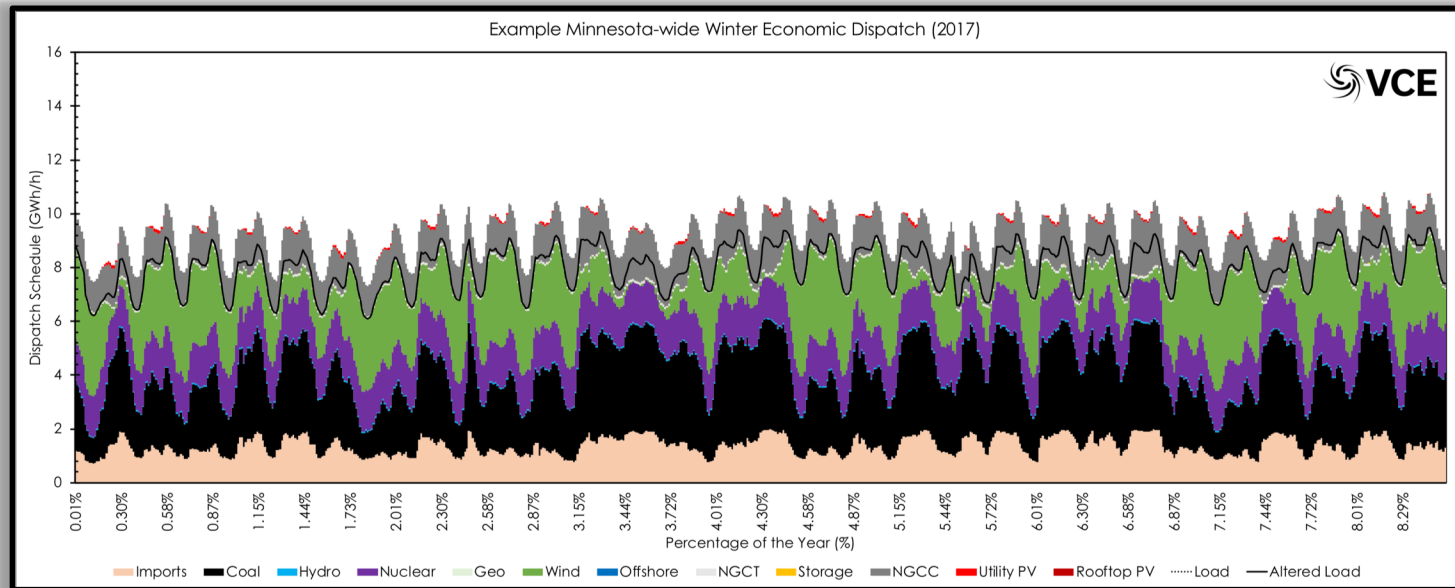
# Cumulative Emissions By State



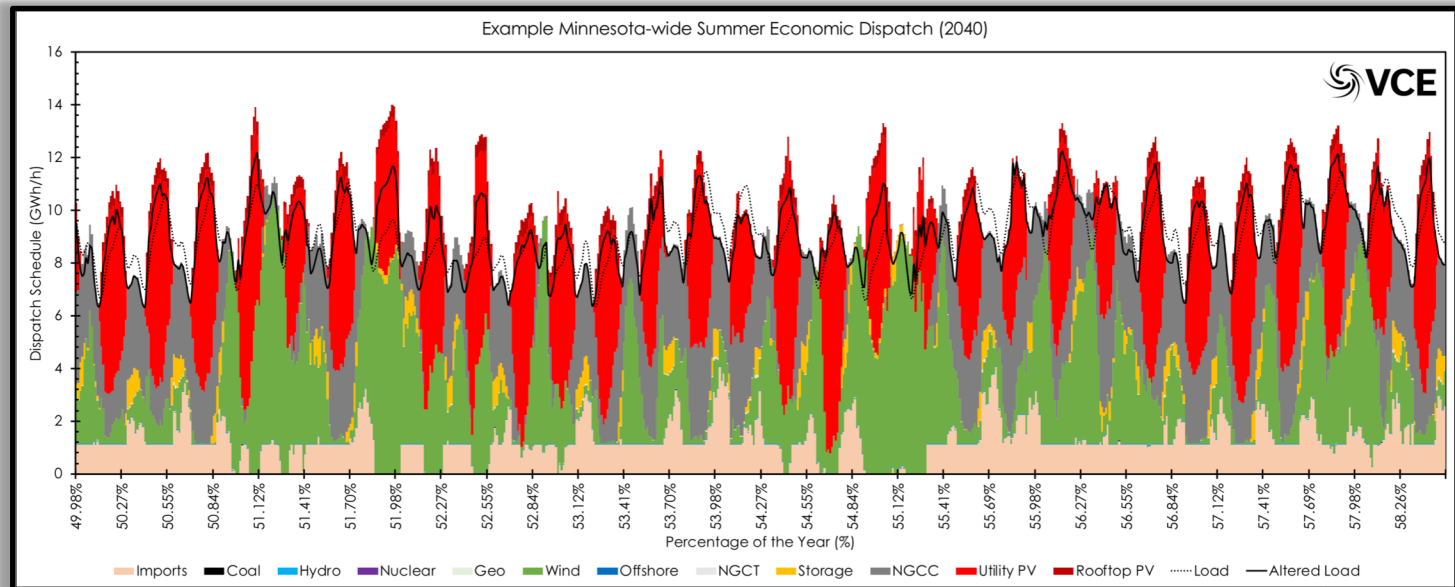
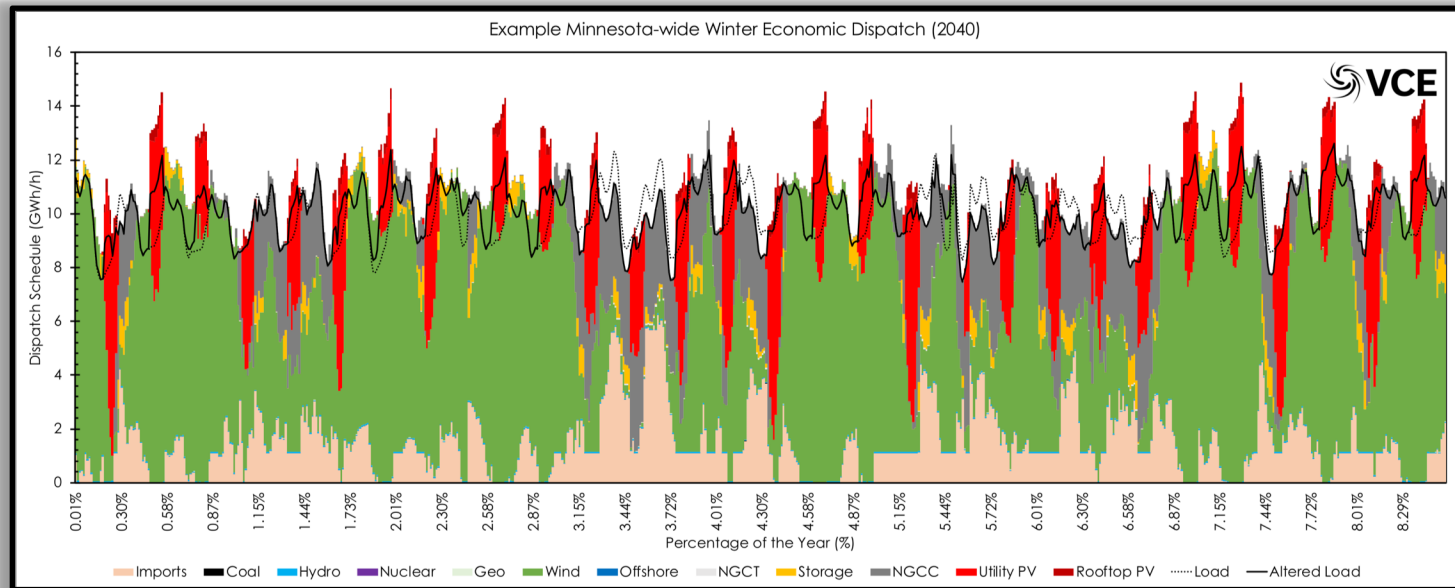
# Generation Share For Minnesota (Decarb)



# Dispatch For Minnesota



# Dispatch For Minnesota

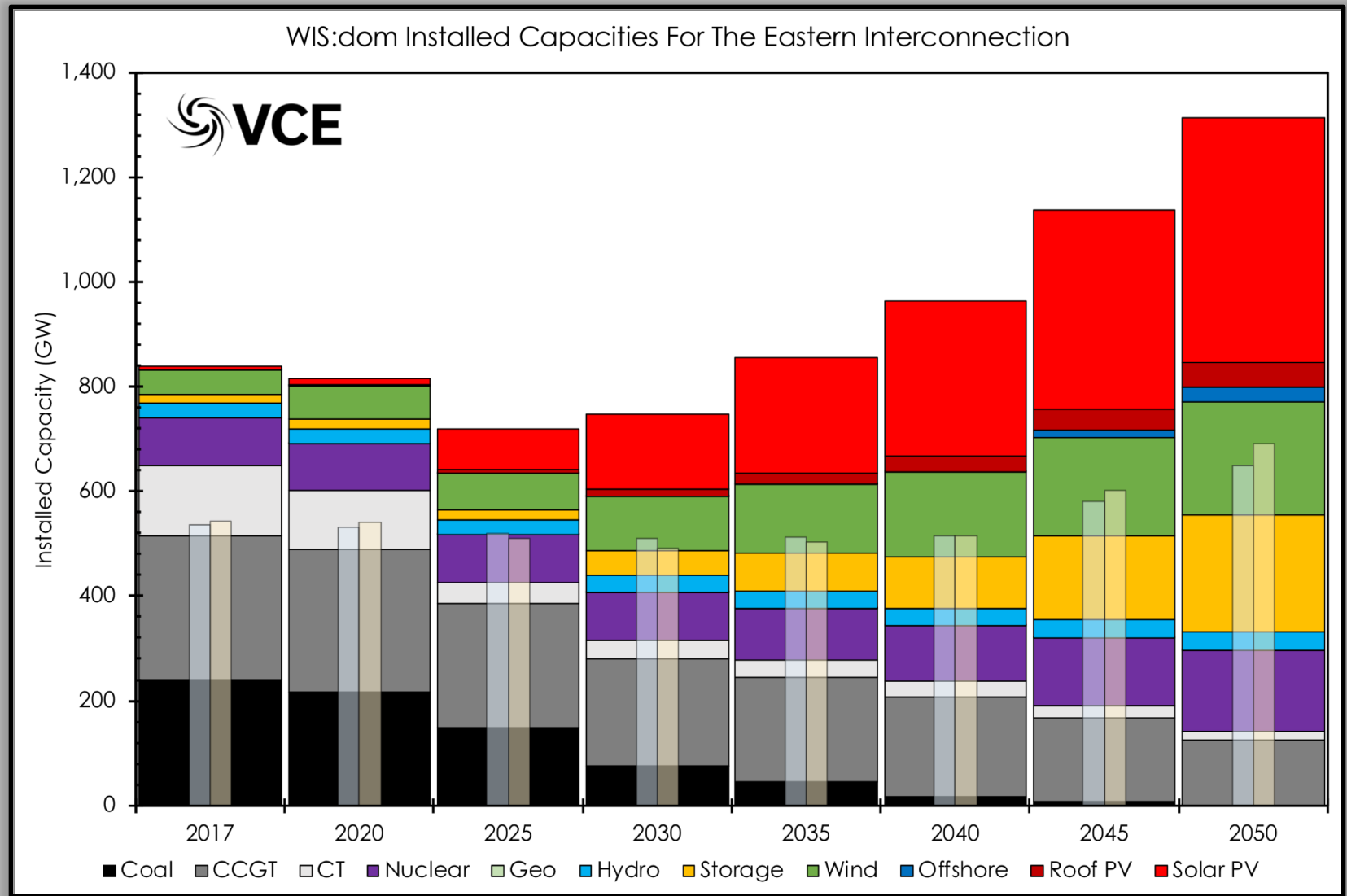




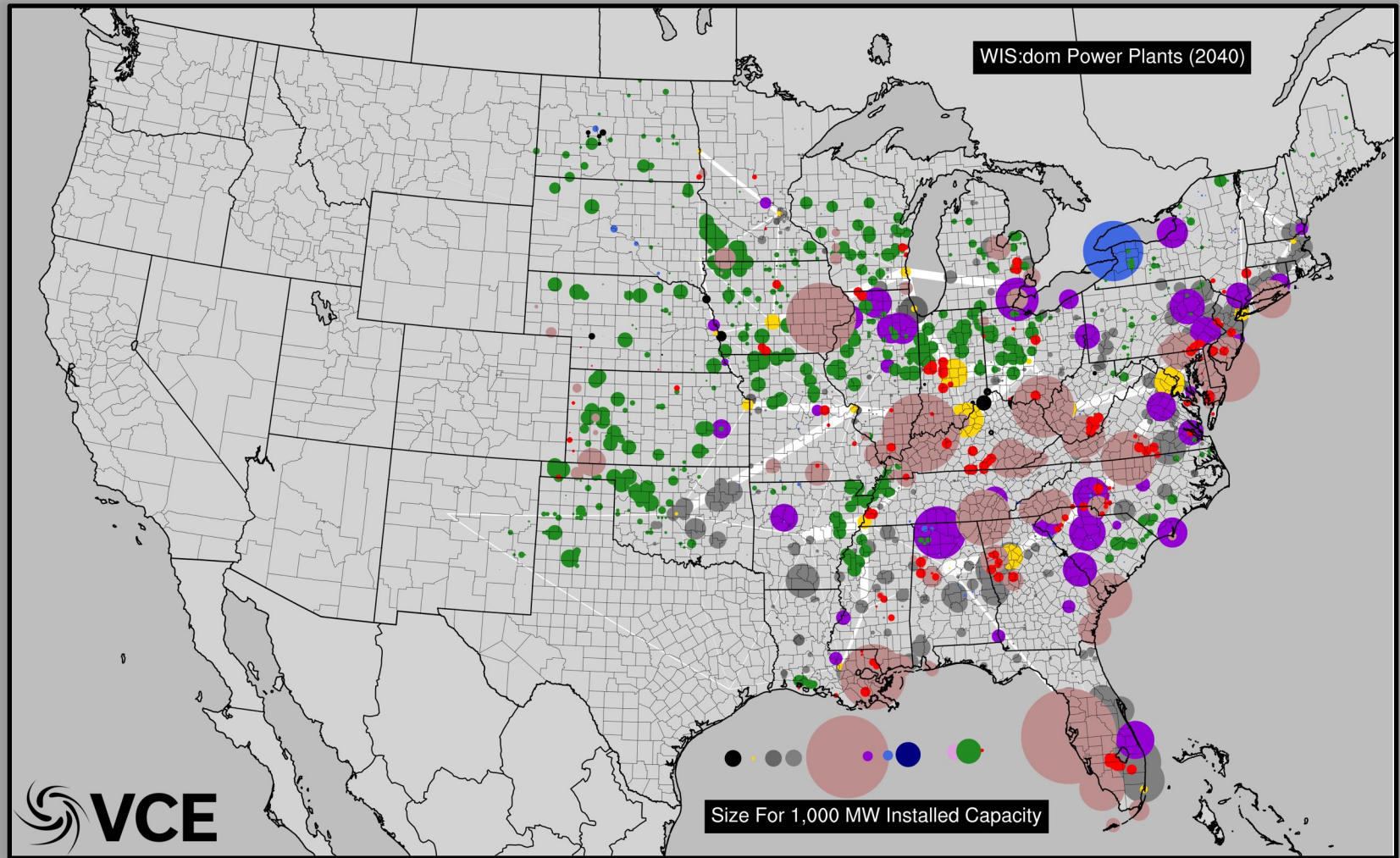
# Deeper Dive:

## *El Decarbonization*

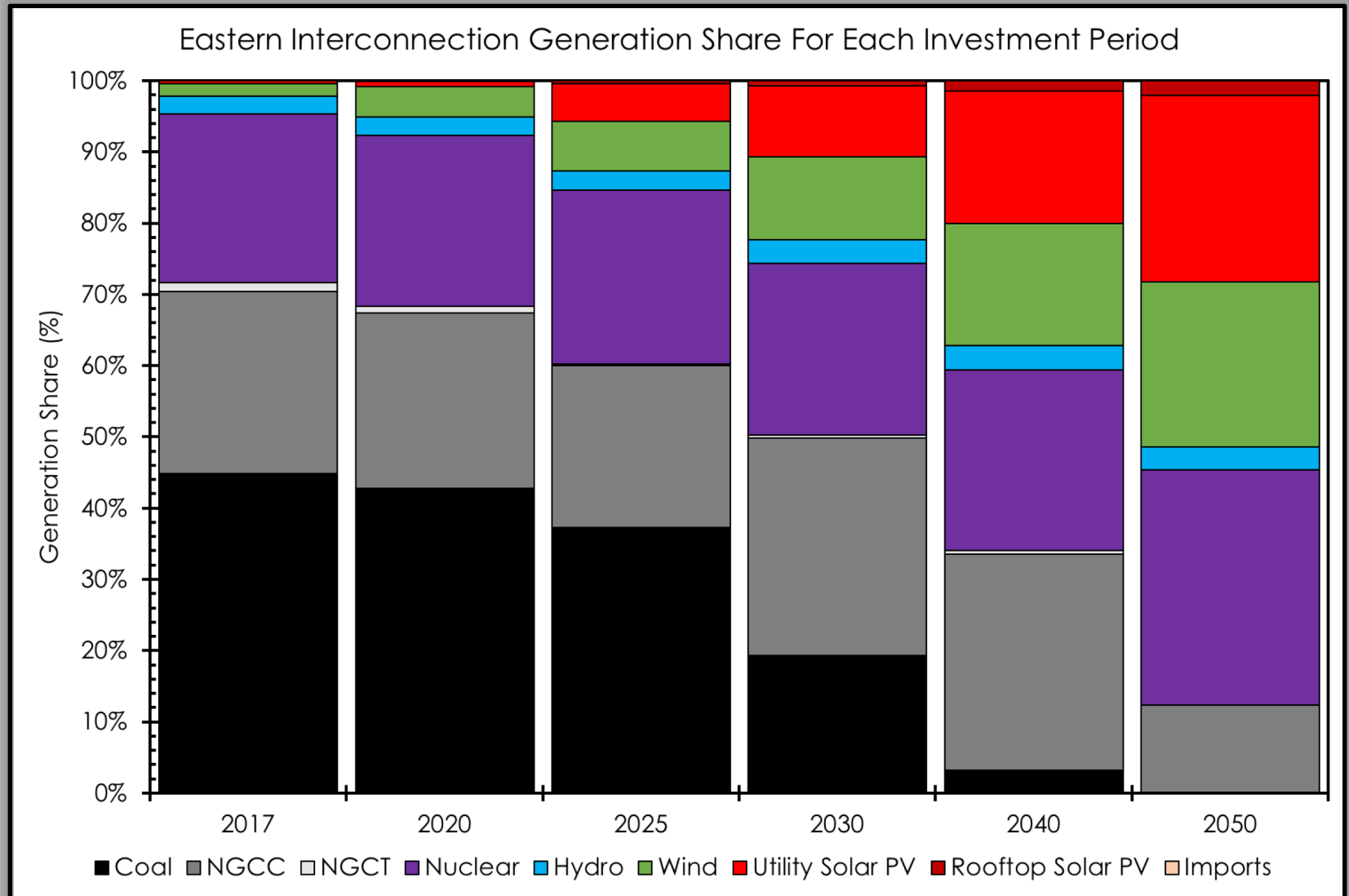
# Eastern Interconnection Installed Capacity



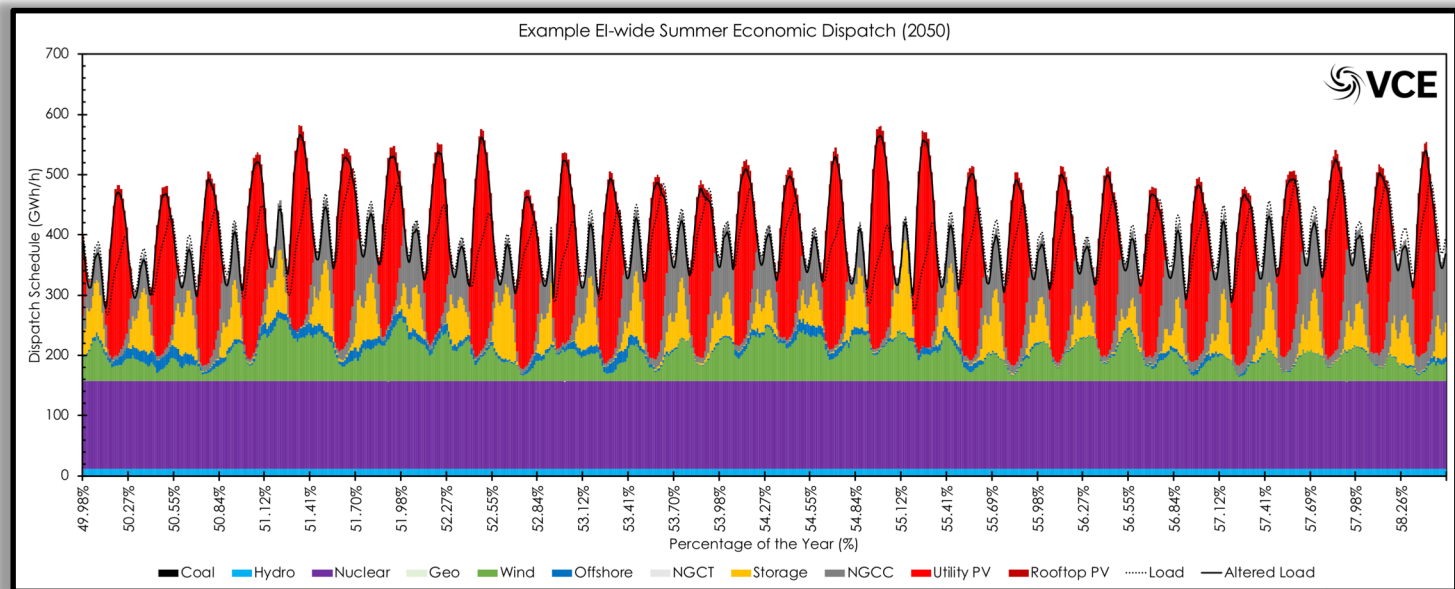
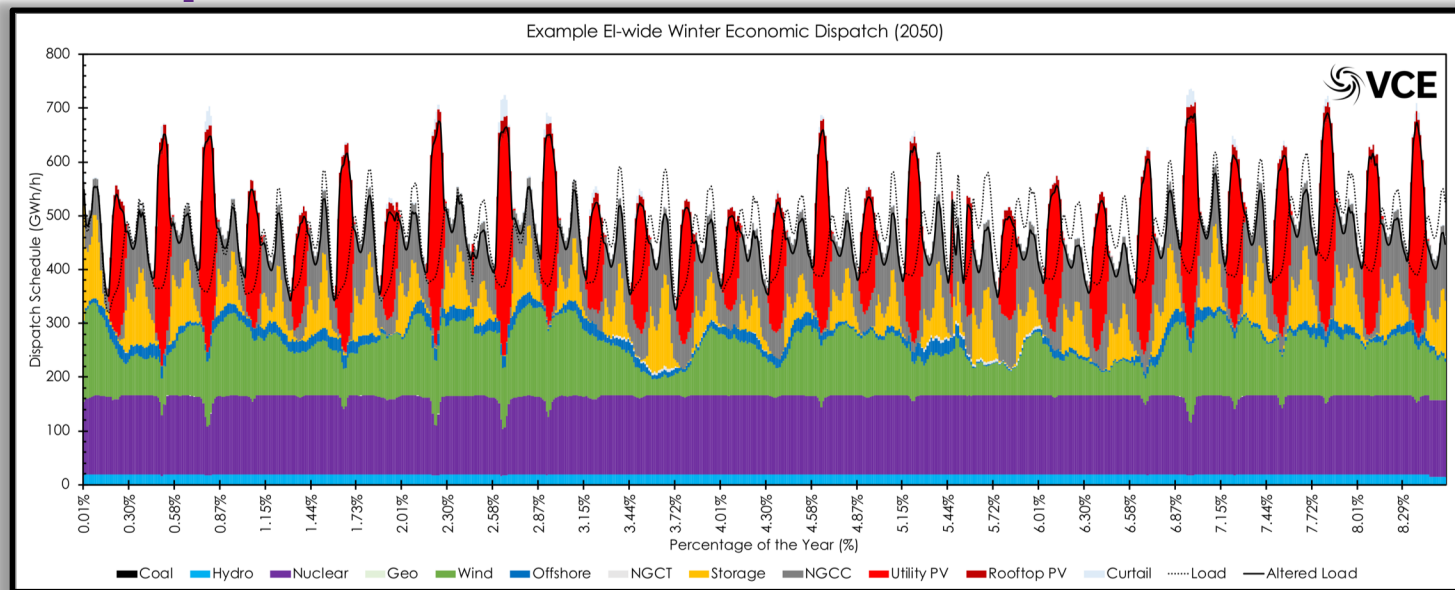
# Installed Capacity (Geographic)



# Generation Share For Eastern Interconnection



# Dispatch For Eastern Interconnection





# Recap: Electrification is Key To Low-Cost Decarbonization

- ✓ ***Electrification and decarbonization can be achieved in Minnesota (along with the Eastern Interconnection) to provide a low-cost, low-emissions economy.***
- ✓ The electrification and decarbonization for Minnesota could save each household up to \$1,200 per year in direct costs.
- ✓ ***Electrification provides flexibility to the electricity sector that reduces the impact of resource variability (but does not eliminate it completely).***
- ✓ The electrification and decarbonization mitigates over 80% of the GHG emissions from the Minnesotan economy. It also reduces the exposure risk of the economy to volatility of the price of natural gas fuel.
- ✓ ***Without electrification, more transmission is required, and decarbonization becomes much more difficult.***

# Thank You Questions?

*Full report found here:*

*<http://www.vibrantcleanenergy.com/media/reports/>*

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