Reaching the "Coal Crossover" in the Southeast

Prepared By:

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Prepared For:

Energy Foundation & Other Stakeholders

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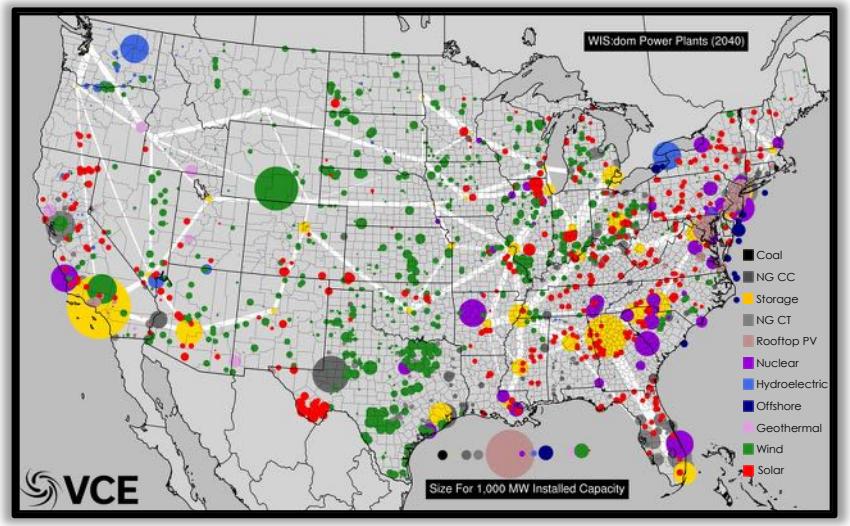
Who Are We: Vibrant Clean Energy (VCE®)



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 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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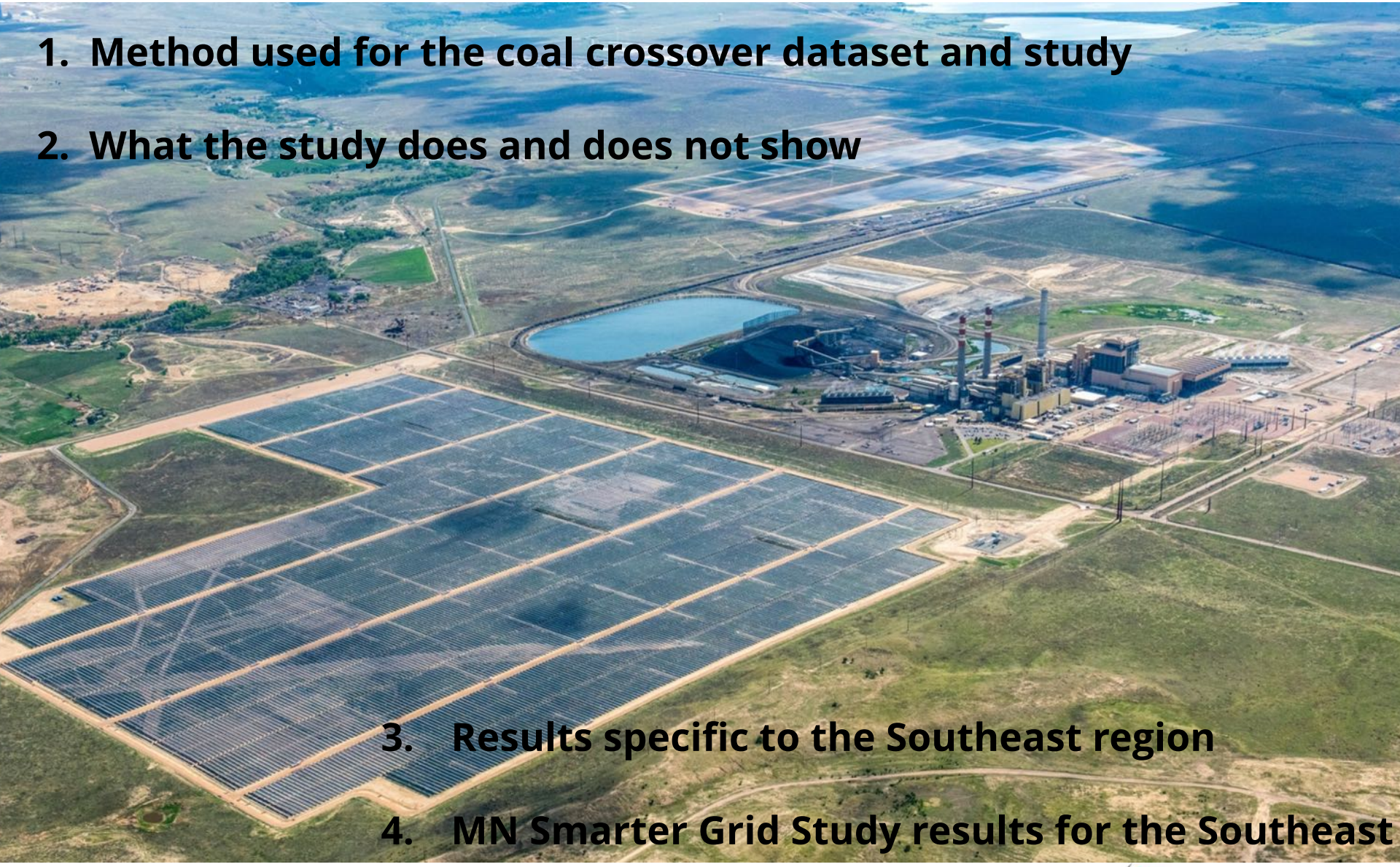
Outline



1. Method used for the coal crossover dataset and study
2. What the study does and does not show
3. Results specific to the Southeast region
4. MN Smarter Grid Study results for the Southeast

Method used for the coal crossover study

1. Create an highly granular wind and solar power dataset (3-km, 5-minute) using sophisticated methods (peer-reviewed) across all of the contiguous USA:
   - https://www.vibrantcleanenergy.com/wp-content/uploads/2016/11/Choukulkar_et_al-2016-Wind_Energy.pdf
   - https://www.vibrantcleanenergy.com/wp-content/uploads/2016/11/Demonstrating_the_effect_of_vertical_and.pdf
   - http://journals.ametsoc.org/doi/pdf/10.1175/JAMC-D-16-0175.1
   - https://www.vibrantcleanenergy.com/wp-content/uploads/2019/03/mwr-d-18-0194.1.pdf
2. The power dataset takes into account many aspects of wind and solar that others do not, for example:
   - Different tilt angles of solar panels
   - Various solar panel mounting technologies
   - Impact of temperature, wind speed and humidity on panel performance
   - Cloud brightening effects on solar panels
   - Inverter Loading Ratios changes
   - Snow cover and melting for solar power production
   - Components of irradiance for more accurate power estimation of solar PV
   - Wind sheer on turbine blades
   - Wind veer across the turbine blades
   - Turbulent kinetic energy extraction by turbine blades
   - Icing and overheating conditions for shutdown of wind turbines
   - The Coefficient of Power as a metric of wind speed, density and direction of turbines
   - Turbine wake interactions that reduce power production
3. The highly granular wind and solar power datasets are aggregated to produce annual average capacity factors for each 3-km grid cell across the contiguous USA.

Complete dataset can be downloaded from: https://vibrantcleanenergy.com/wp-content/uploads/2019/03/LCOE-Mapping/ExistingCoal_vs_NewWindSolar_17April2019.xlsb

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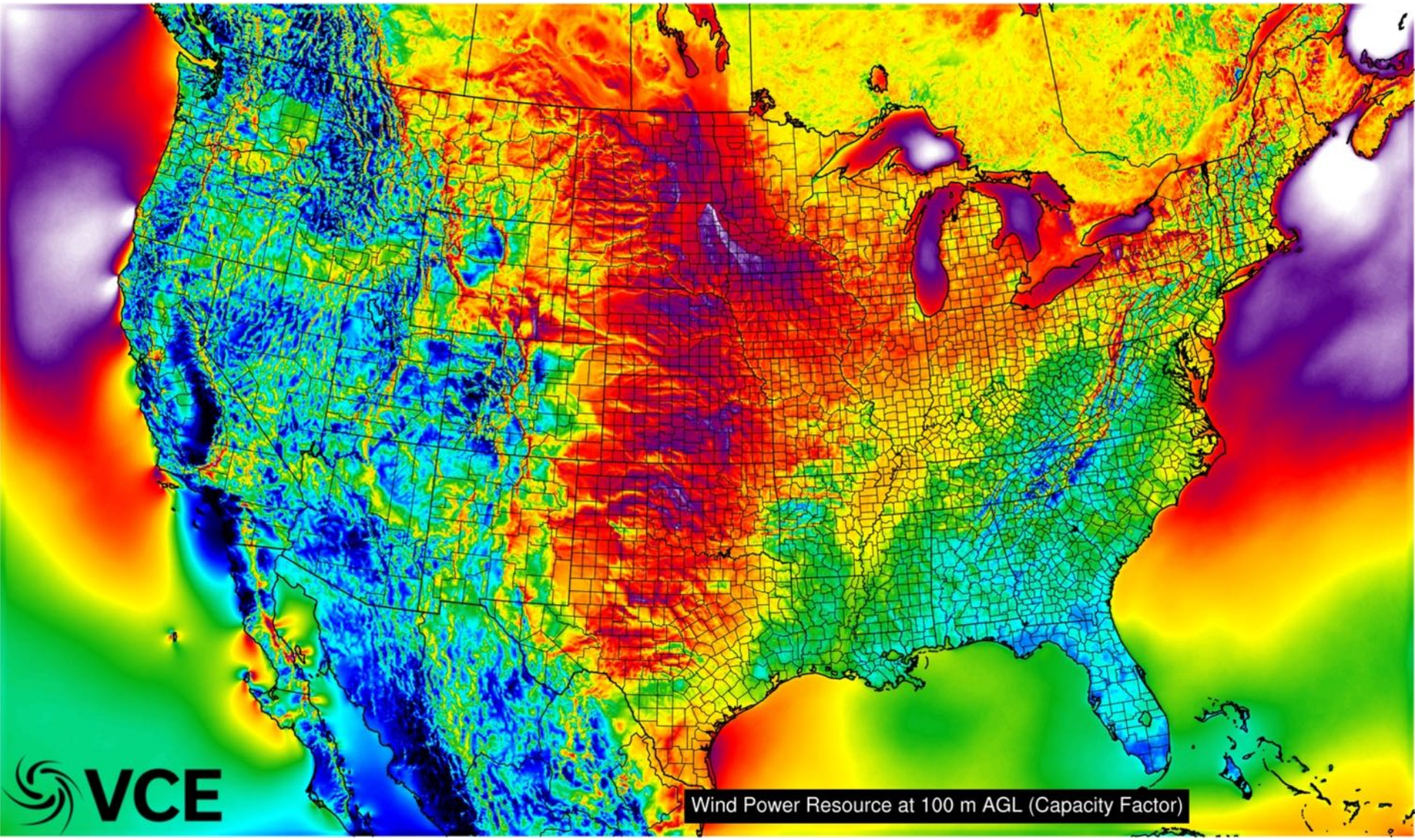
Method used for the coal crossover study



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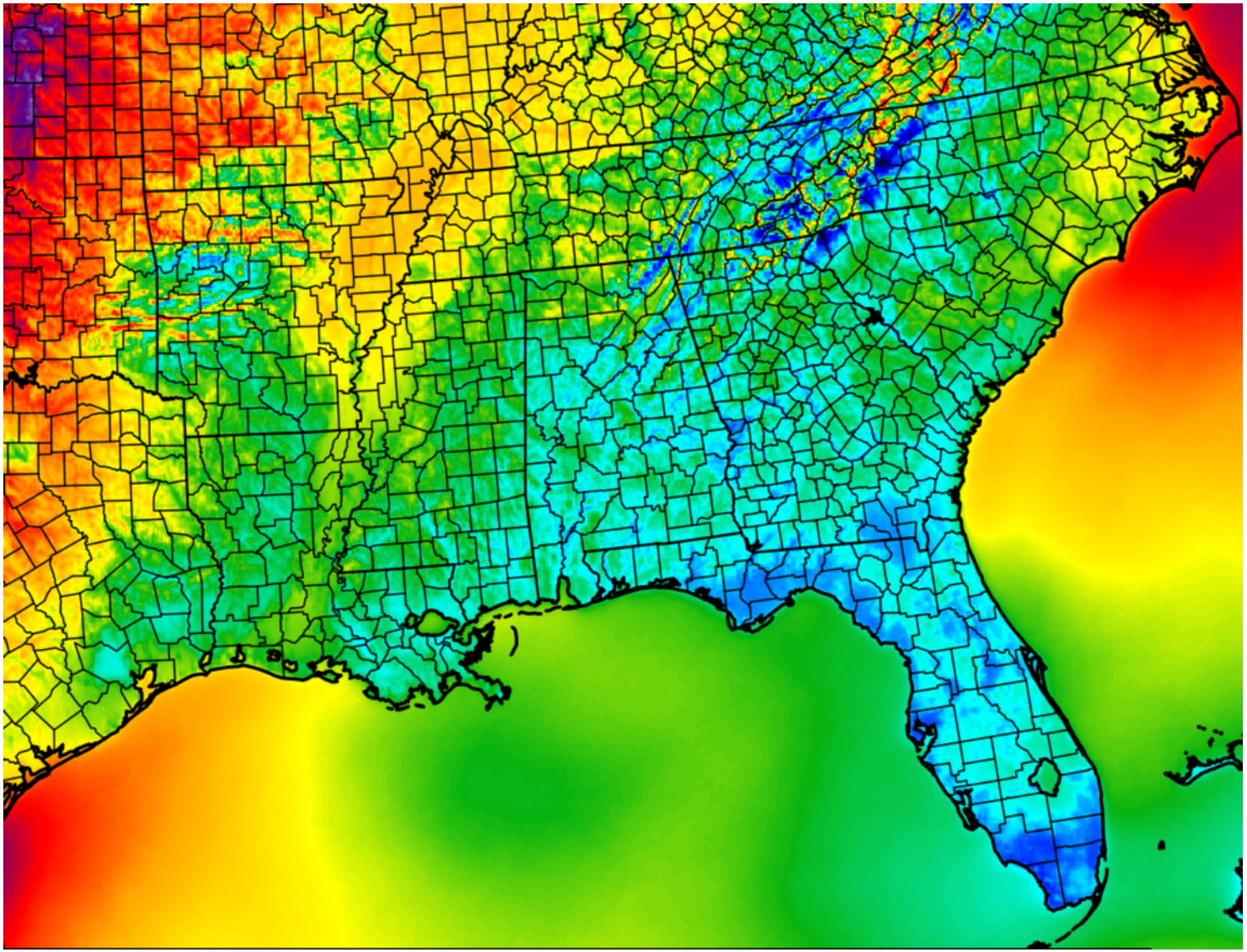

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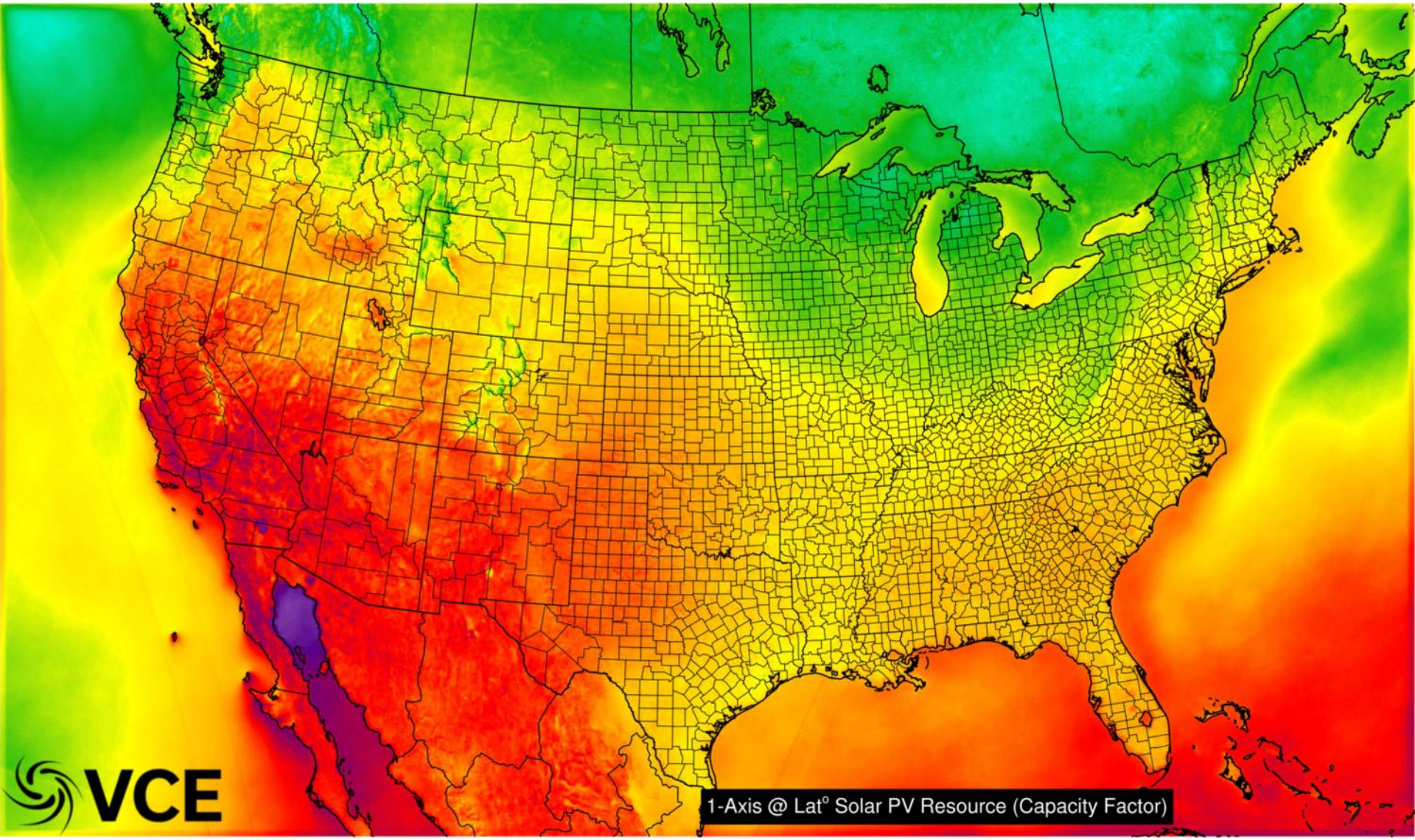

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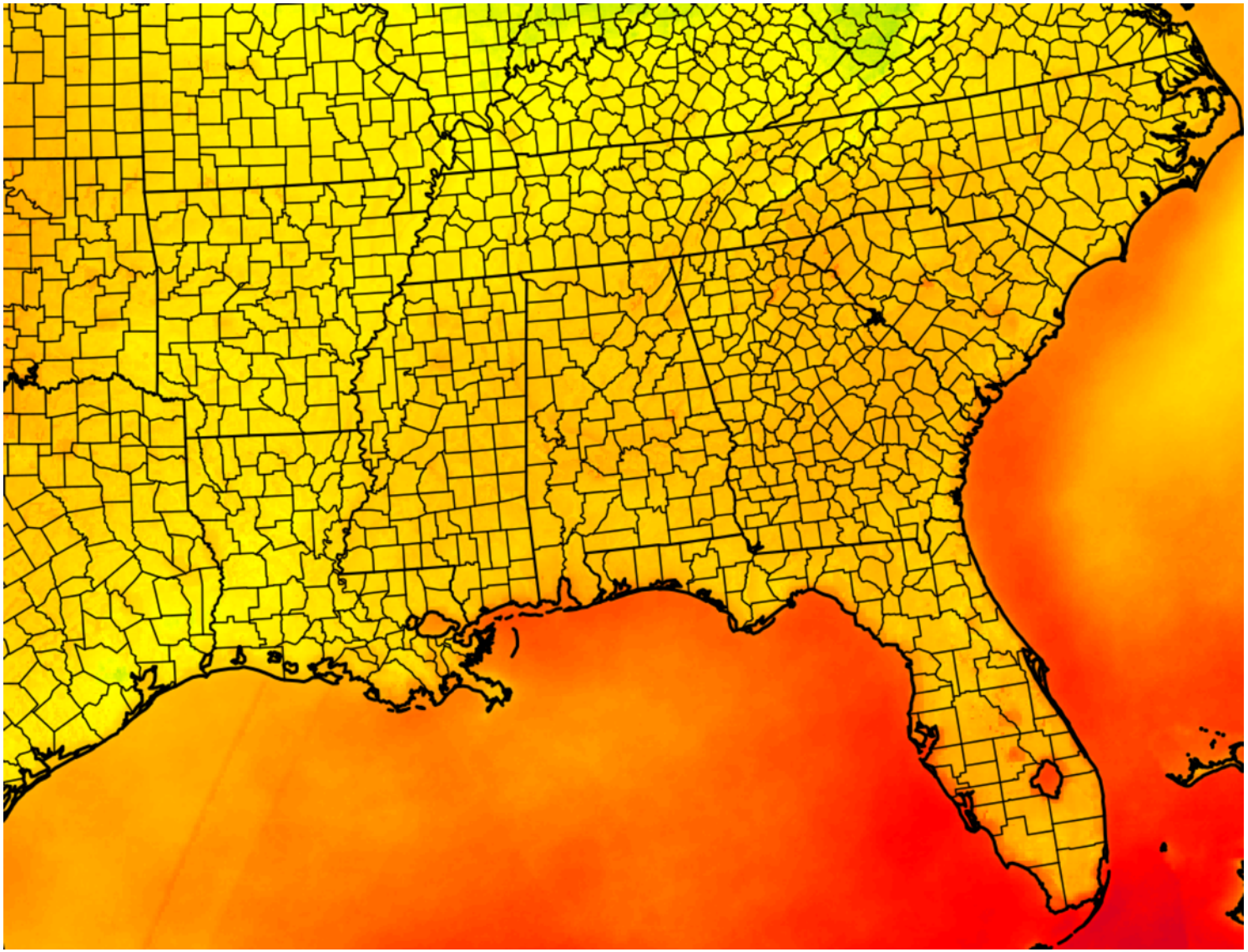

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Method used for the coal crossover study

4. Use the NREL ATB 2018 cost projections for wind and solar along with the average annual capacity factors created by VCE® to compute a Levelized Cost of Electricity (LCOE) for each site for 2018 and 2025.
   - Real WACC is assumed to be 6%
   - Economic life of wind (solar) is assumed to be 25 (30) years [except for offshore wind which is given 20 years]
   - Include the local cost multipliers for labor, equipment and taxes
5. Include the cost to build new transmission for each of the wind and solar sites if none already exists. If some already exists, pro-rate costs based upon expansion required.
6. Construct a dataset for all existing coal-fired power plants across the contiguous USA. The main sources of data for this portion of the study are the EIA-860, EIA-860M, EIA-923, FERC-1, and various PUC filings.
7. The constructed coal-fired power plant dataset contains:
   - Location of the plant
   - Name of the plant, VCE plant code, EIA plant code, and plant operator
   - Installed capacity (MW), estimated capacity factor in 2018 (%), and plant average heat rate (mmBtu/MWh)
   - Fixed costs ($), variable costs ($/MWh), and fuel costs ($/MWh)
   - Marginal Cost of Electricity (MCOE, $/MWh)

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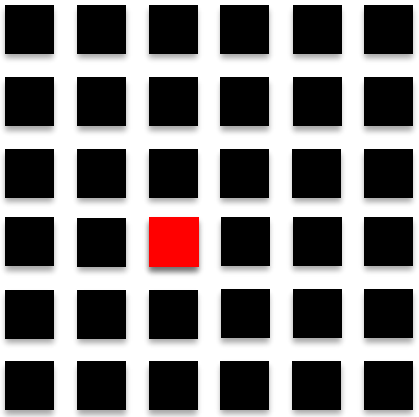
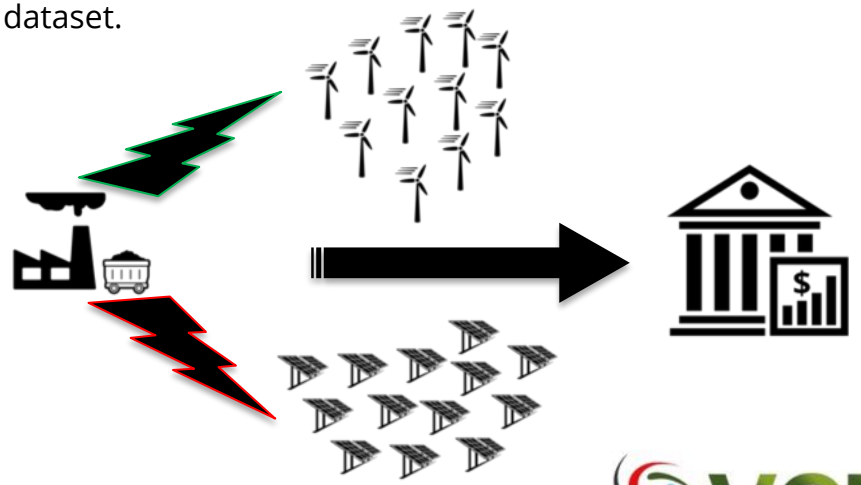
Method used for the coal crossover study

8. The comparison of the MCOE of the coal-fired power plants and the LCOE of new local wind or solar power plants is performed using a recursive algorithm:
    a. Find the closest 3-km grid cell to the coal-fired power plant and determine the wind or solar that could be constructed at that location;
    b. Does the annual generation of the wind or solar facility replace all of the generation of the coal-fired power plant? If NO, CONTINUE; ELSE GO TO END.
    c. Move to the next nearest site using the anti-clockwise spiral method (see below);
    d. Determine the wind or solar that can be constructed and then compute the total generation of the new wind and solar (including all previous construction);
    e. Does the annual generation of the wind or solar facility replace all of the generation of the coal-fired power plant? If NO, RETURN TO c., ELSE GO TO END.
    f. END: Output the LCOE of the new local wind or solar power plant and the difference to the MCOE of the existing coal replaced.
    g. REPEAT for all coal-fired power plants in the dataset.





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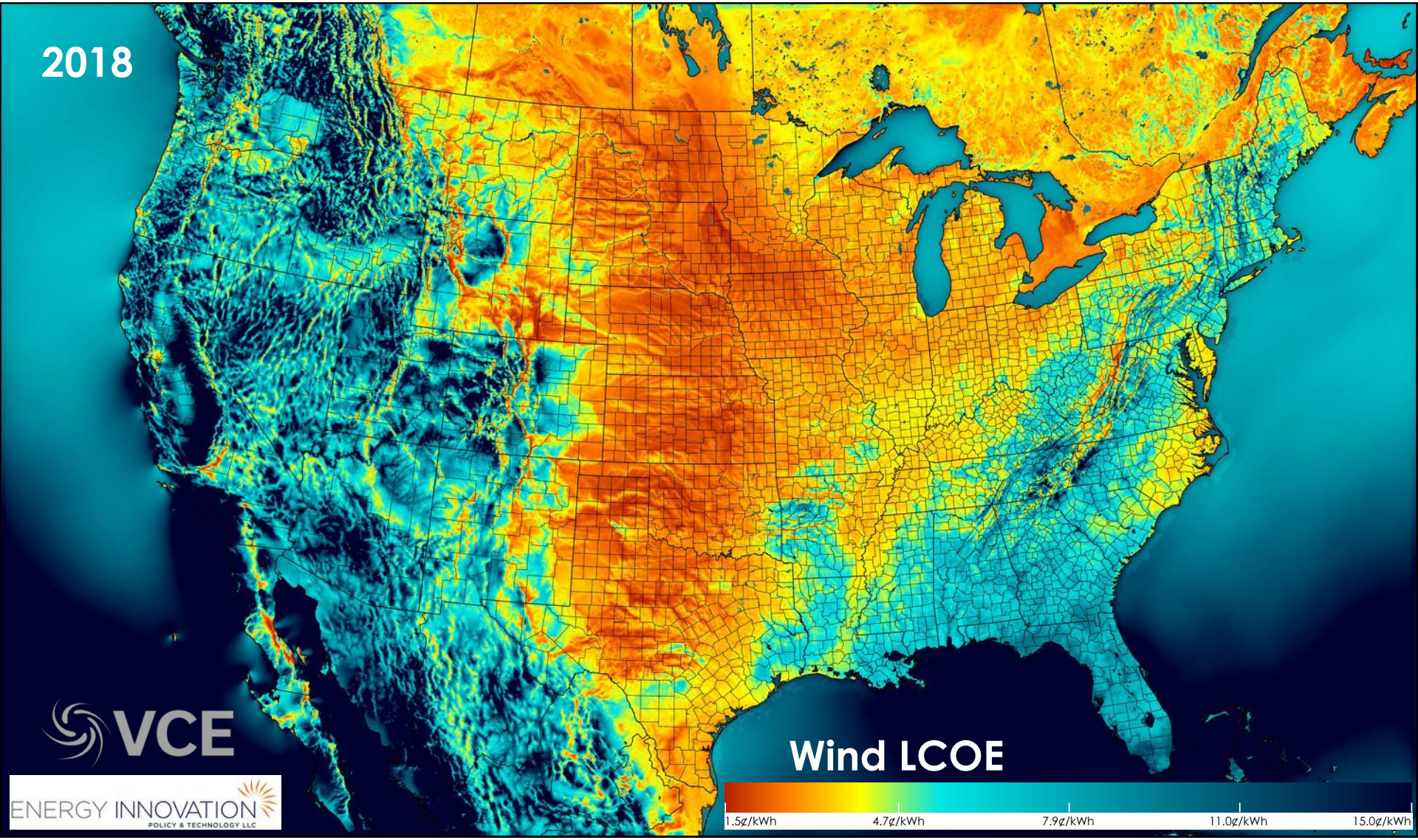

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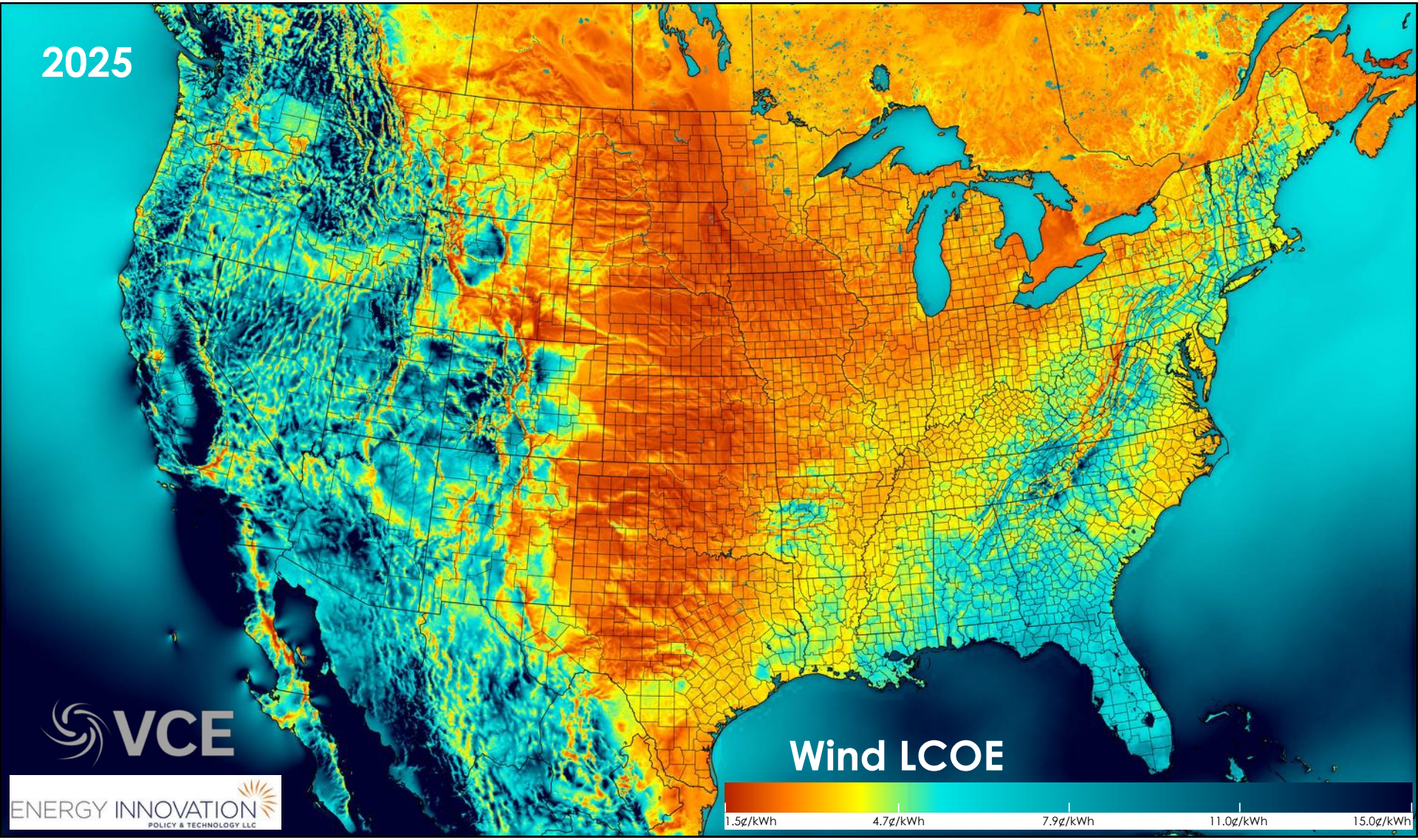

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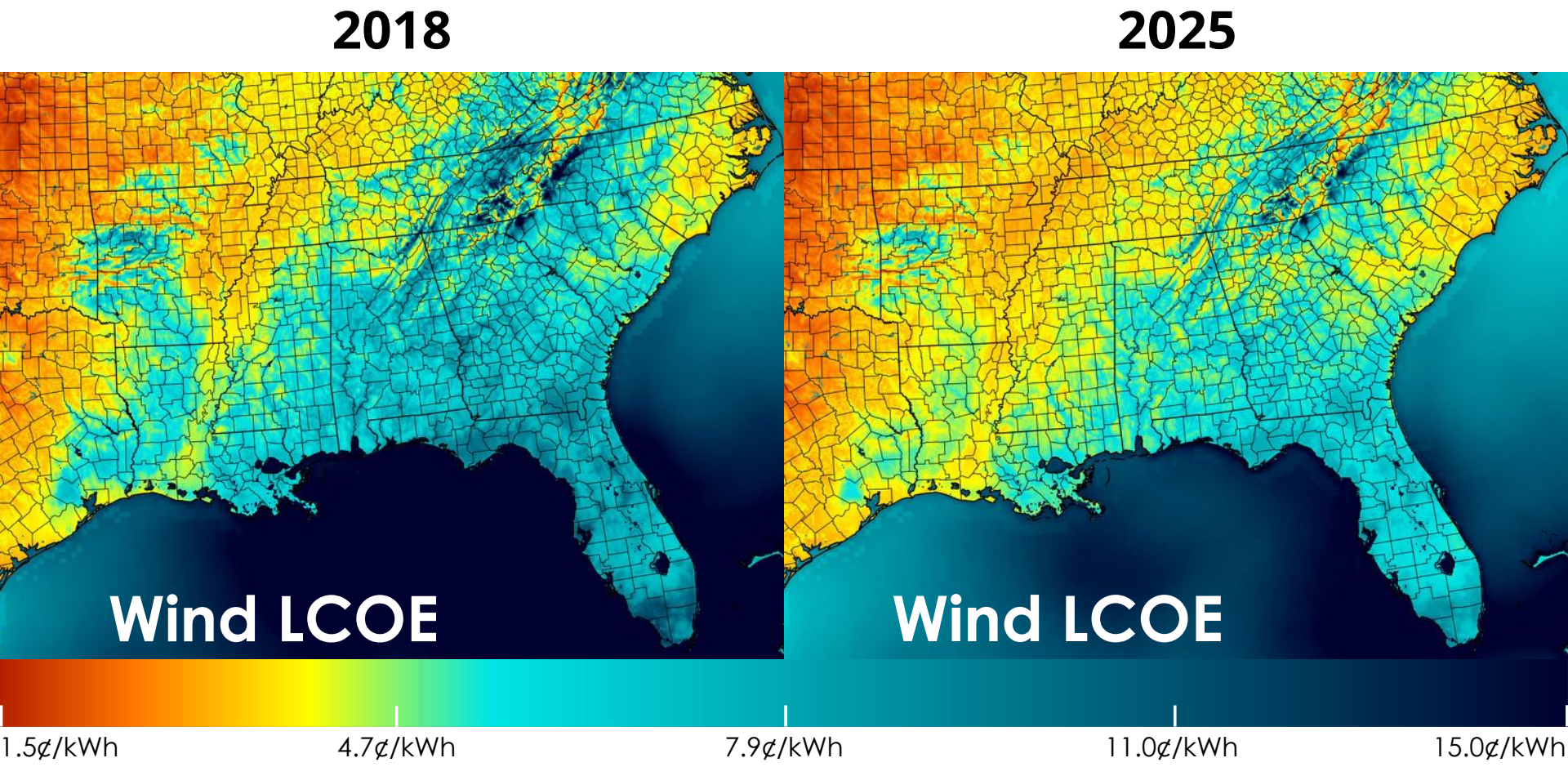

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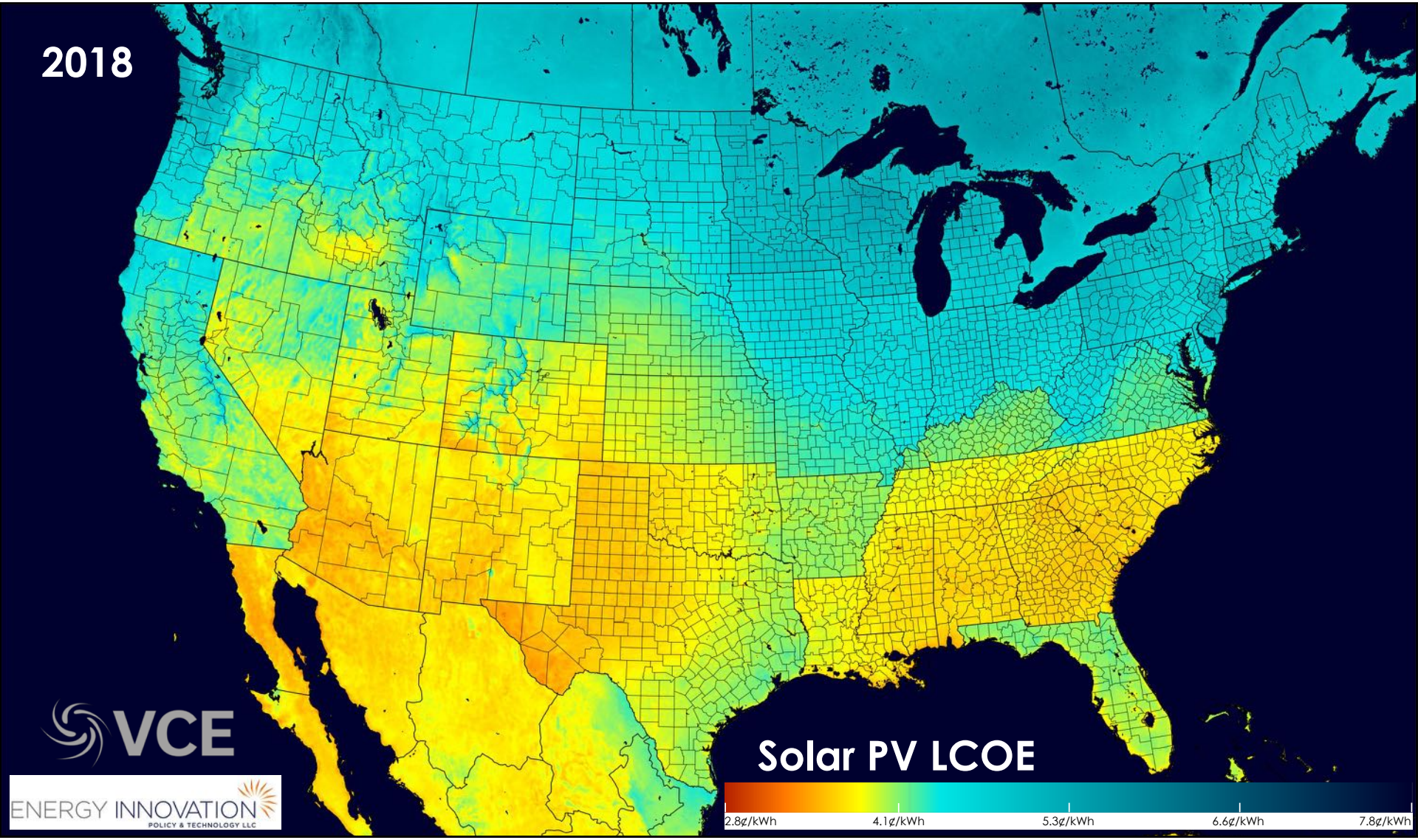

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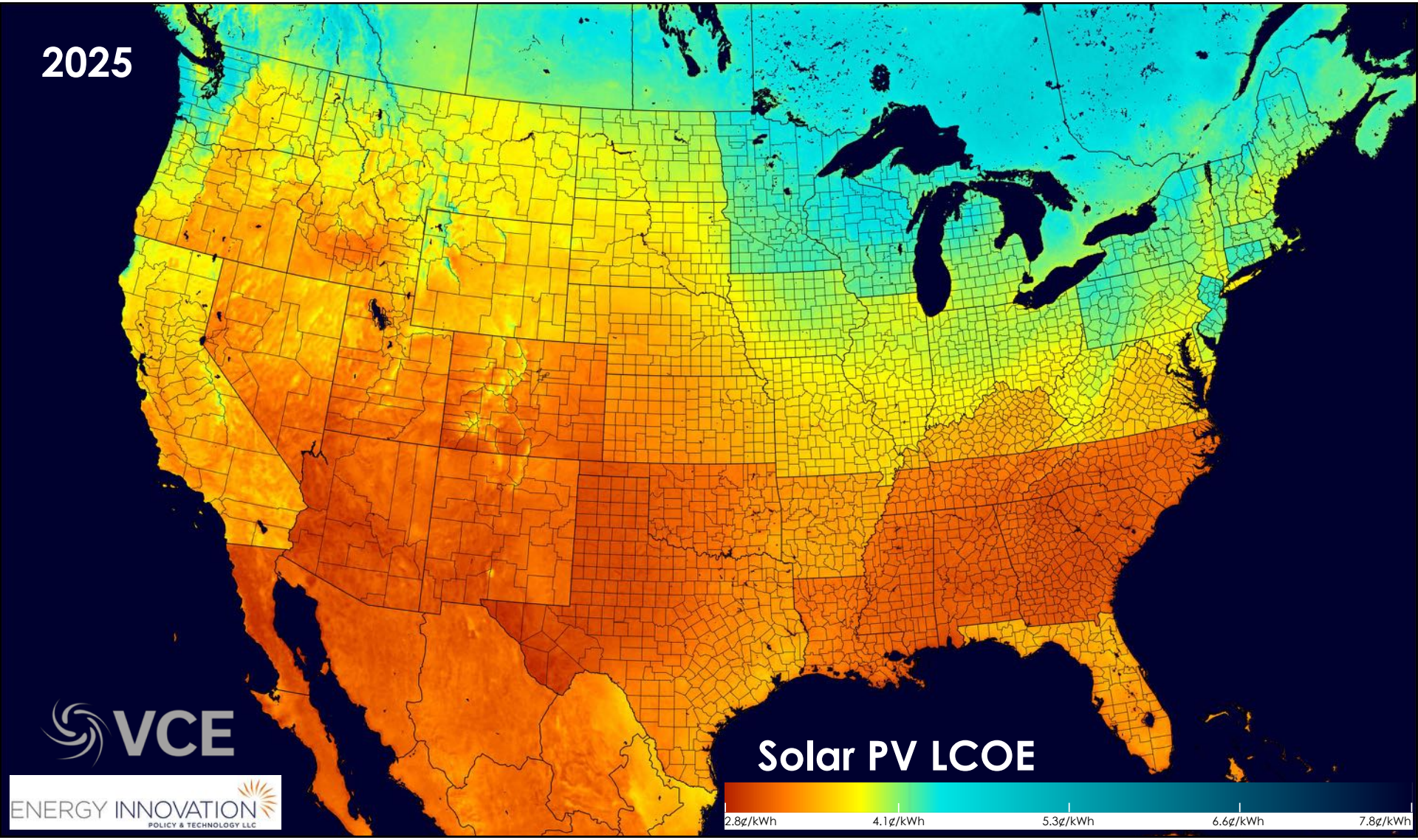

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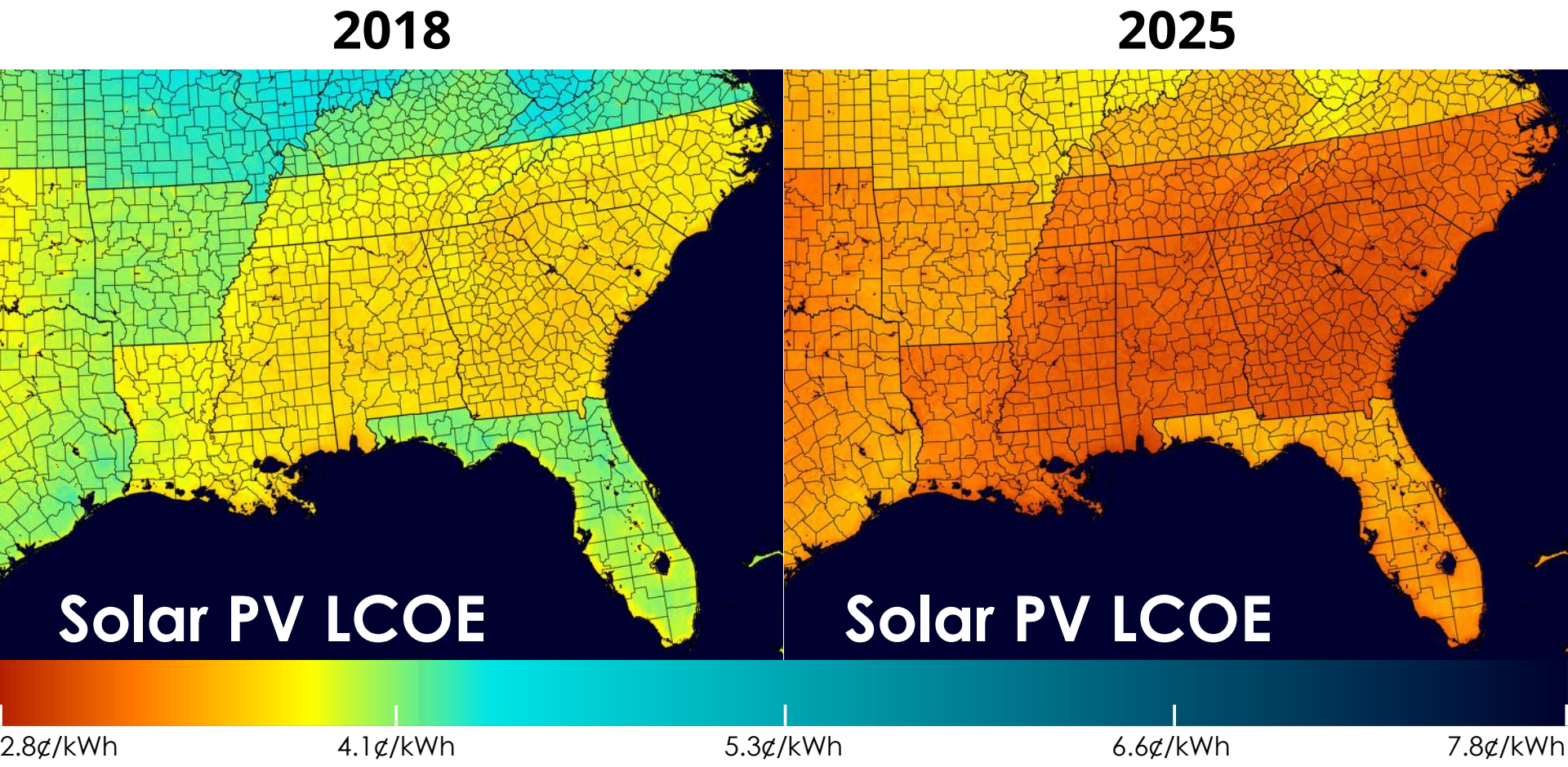

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What the study does and does not show

- **DISCLAIMER**: The study does not attempt to replace all the generation from the coal-fired power plants temporally. This means that the study does not show that the local wind or solar can replace the coal-fired power plants with respect to reliability or dispatch.

- It does show that where local new wind or solar can replace the existing coal on a total annual generation basis at a cost lower than MCOE there should be careful consideration of that existing coal-fired power plant's future.

- The study does not consider remote wind or solar that could be imported at a much lower cost than the new local facilities.

- The study does consider the interconnection of the wind or solar (transmission costs).

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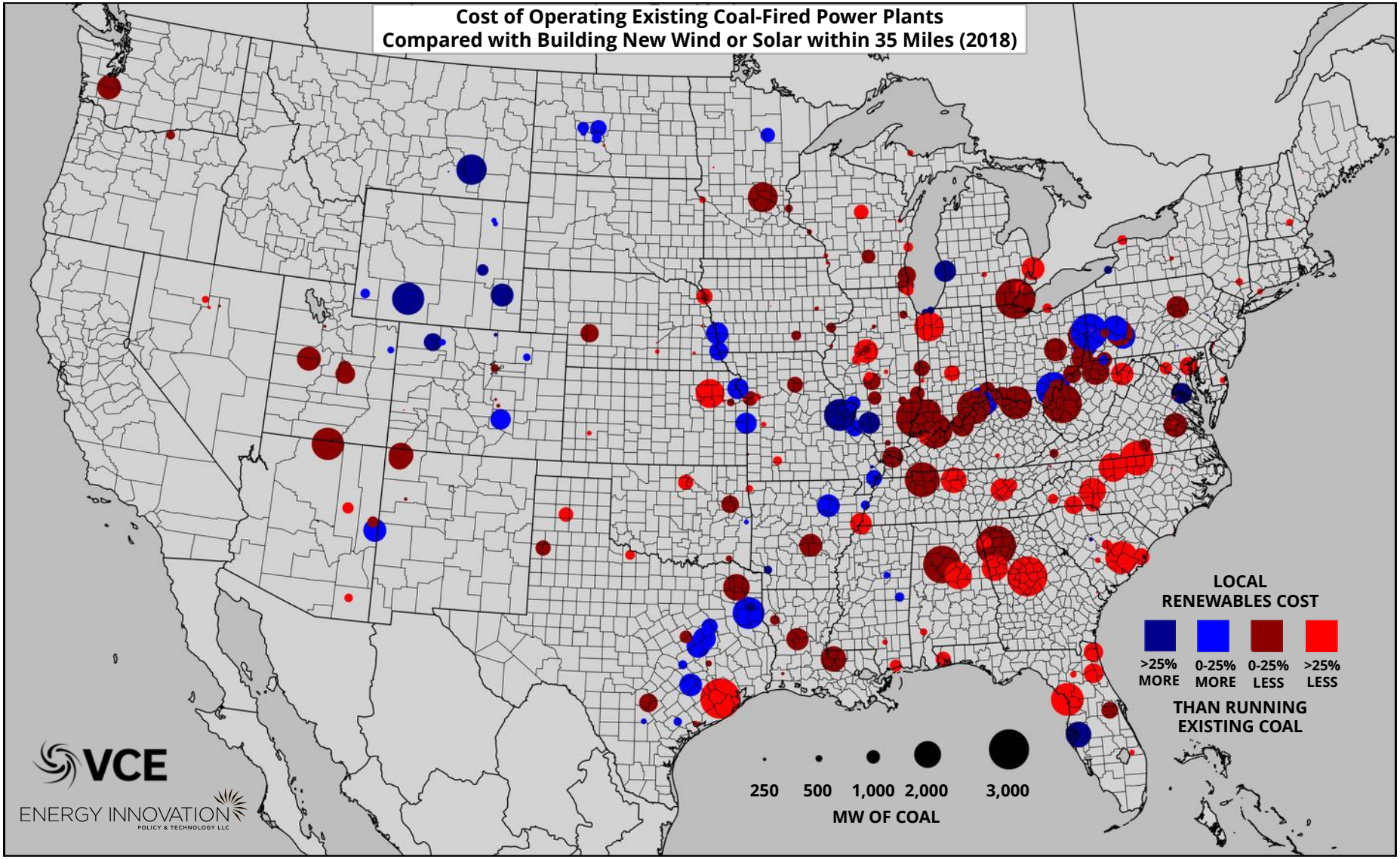
Results Specific to the Southeast



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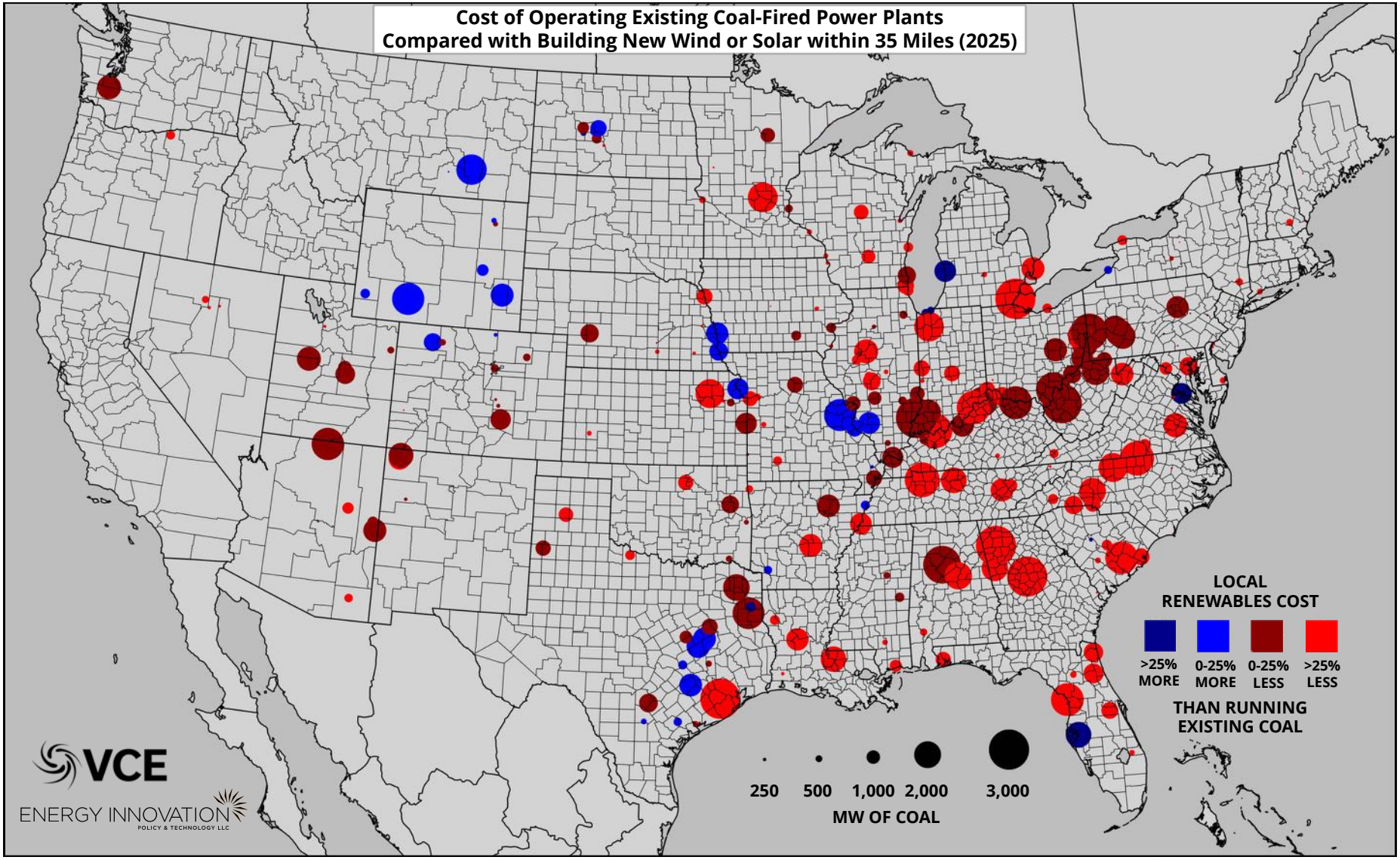

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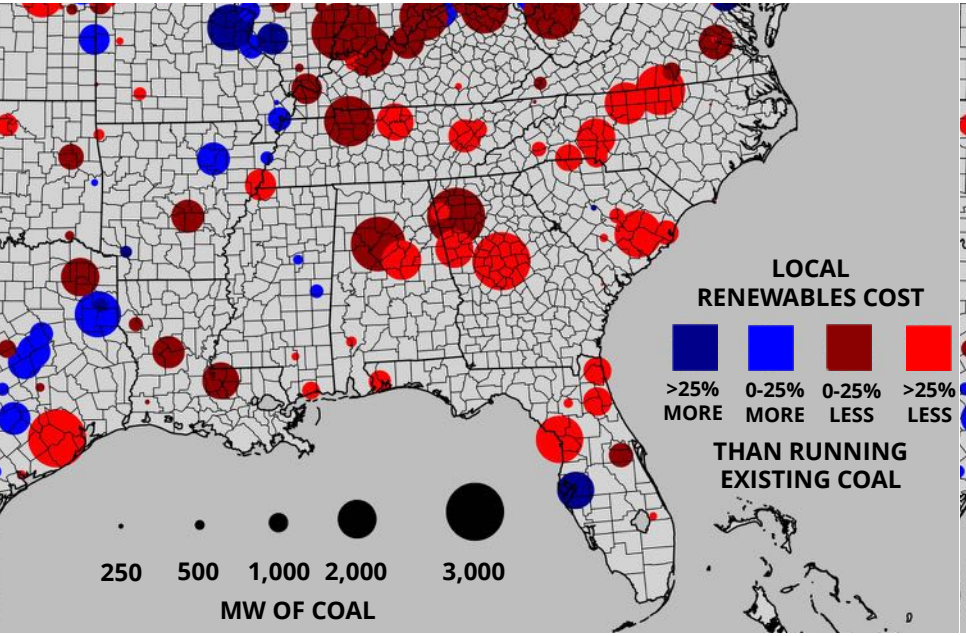
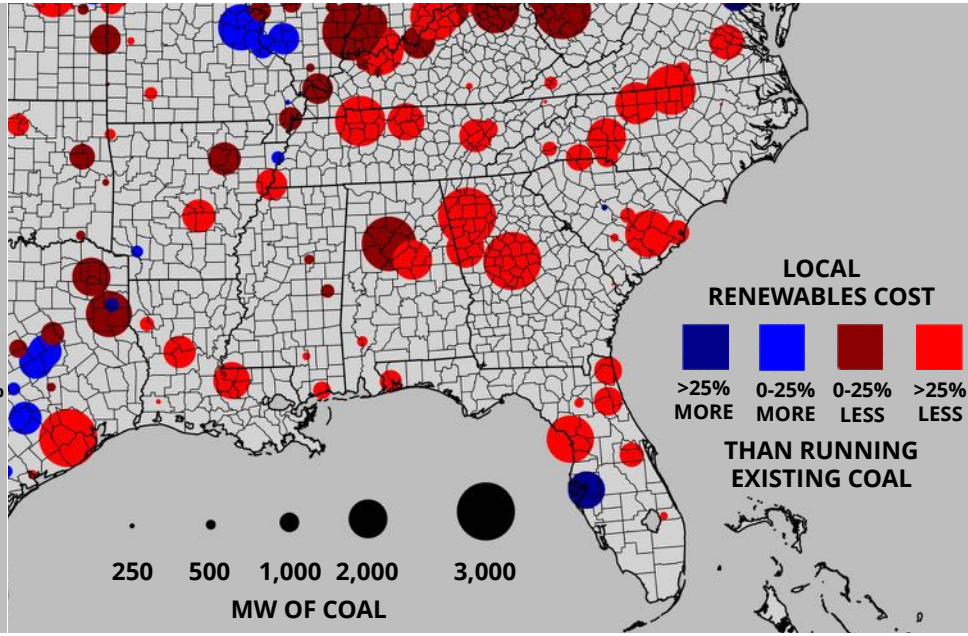
Results Specific to the Southeast

2018



2025



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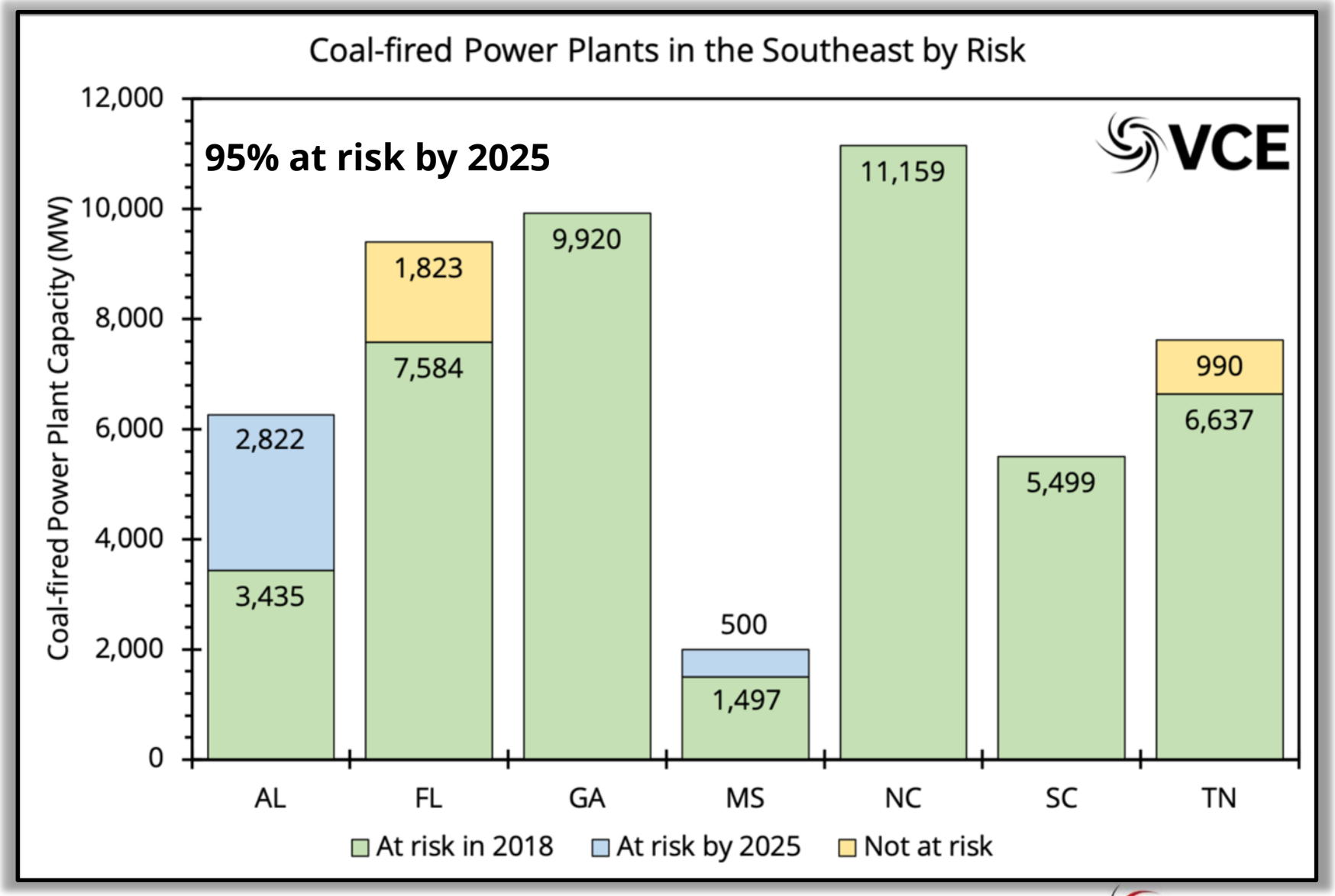

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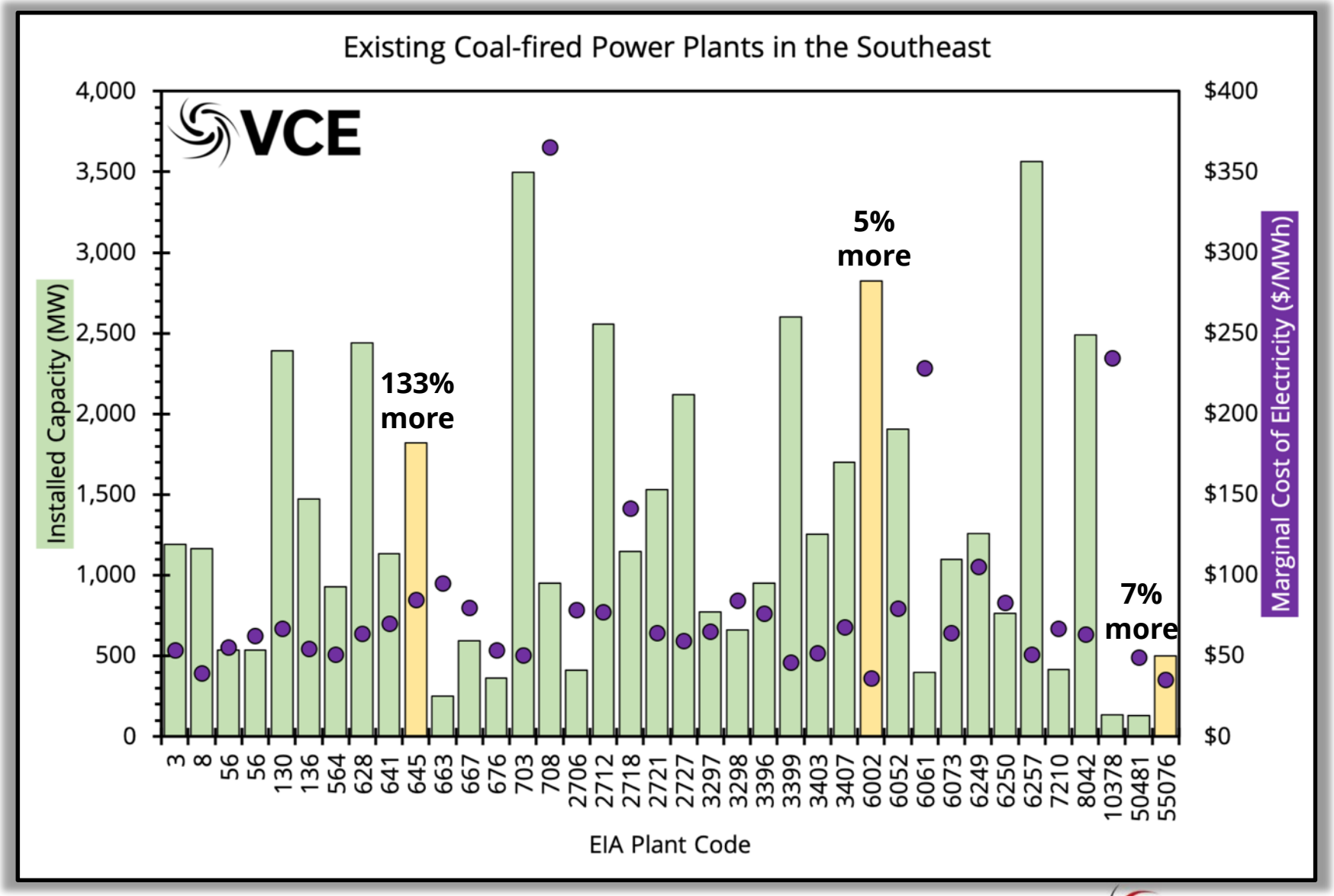

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MN Smarter Grid Results for the Southeast

- The MN Smarter Grid Study investigated the electrification and decarbonization of Minnesota and the surrounding Eastern Interconnection. The modeling included 5-minute dispatch (at 3-km) for all resources in the Eastern Interconnection as well as modeling transmission, capacity expansion, storage, and demand-side flexibility.
- The results show that (under a decarbonization scenario) the Southeast will have no coal by 2040 and the Eastern Interconnection will only have 3% generation from coal as many areas transition to renewables.
- The cost of the system is much lower than the system is today.
- The results from the scenario shown finalize with 80x50 for the entire economy of the Eastern Interconnection.
- Jobs, tax revenues, emissions and all other metrics are positive (beneficial) in this scenario.

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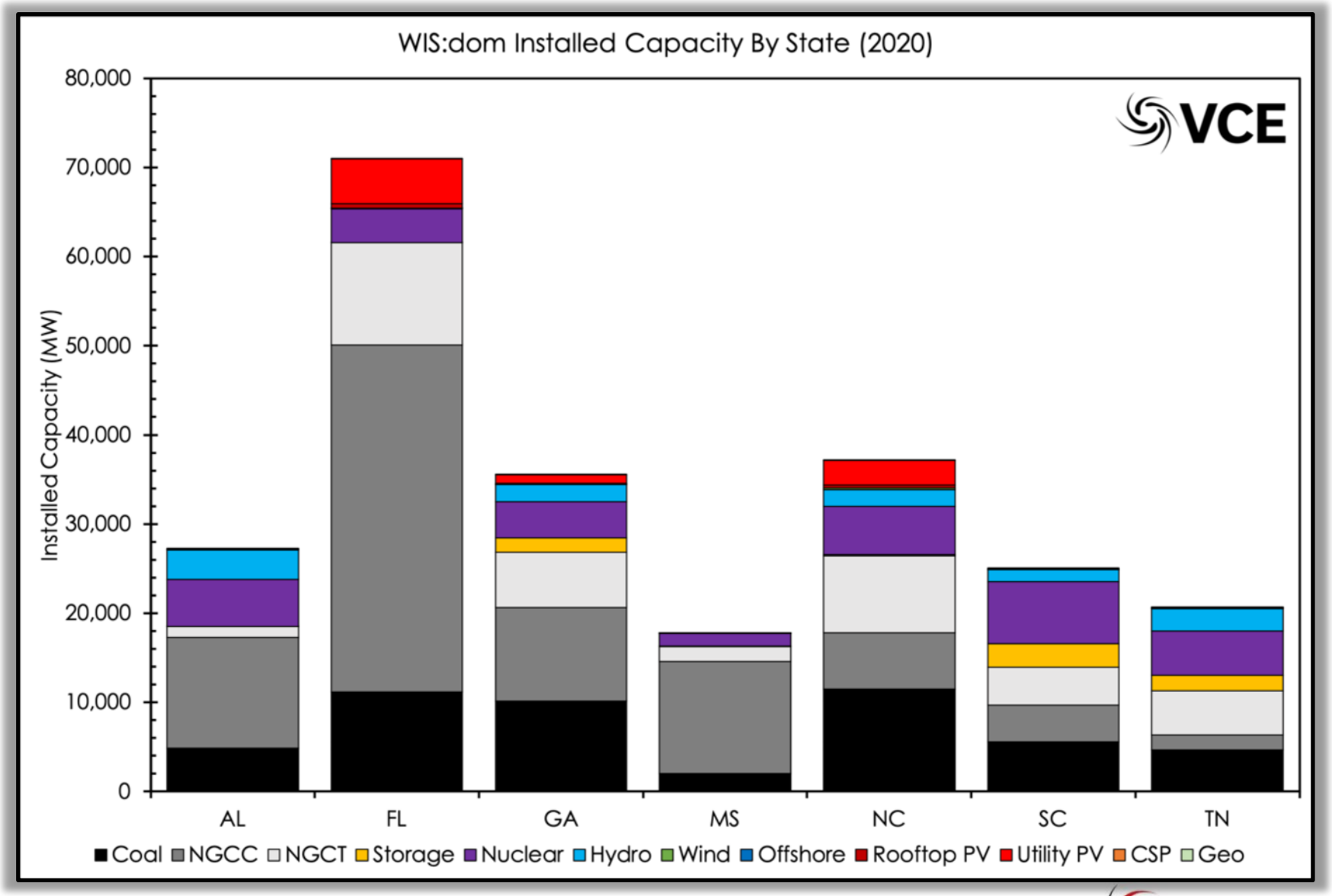

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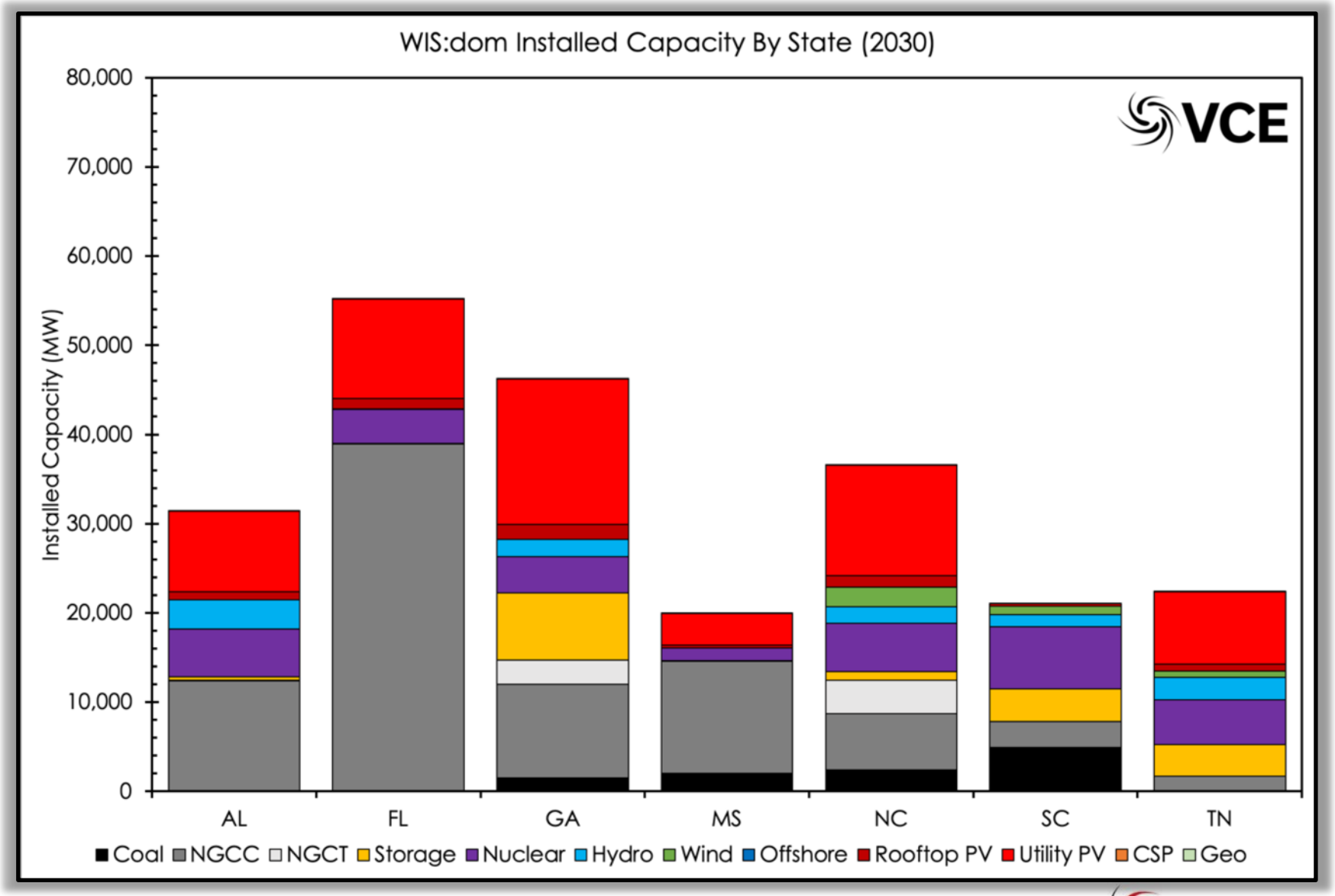

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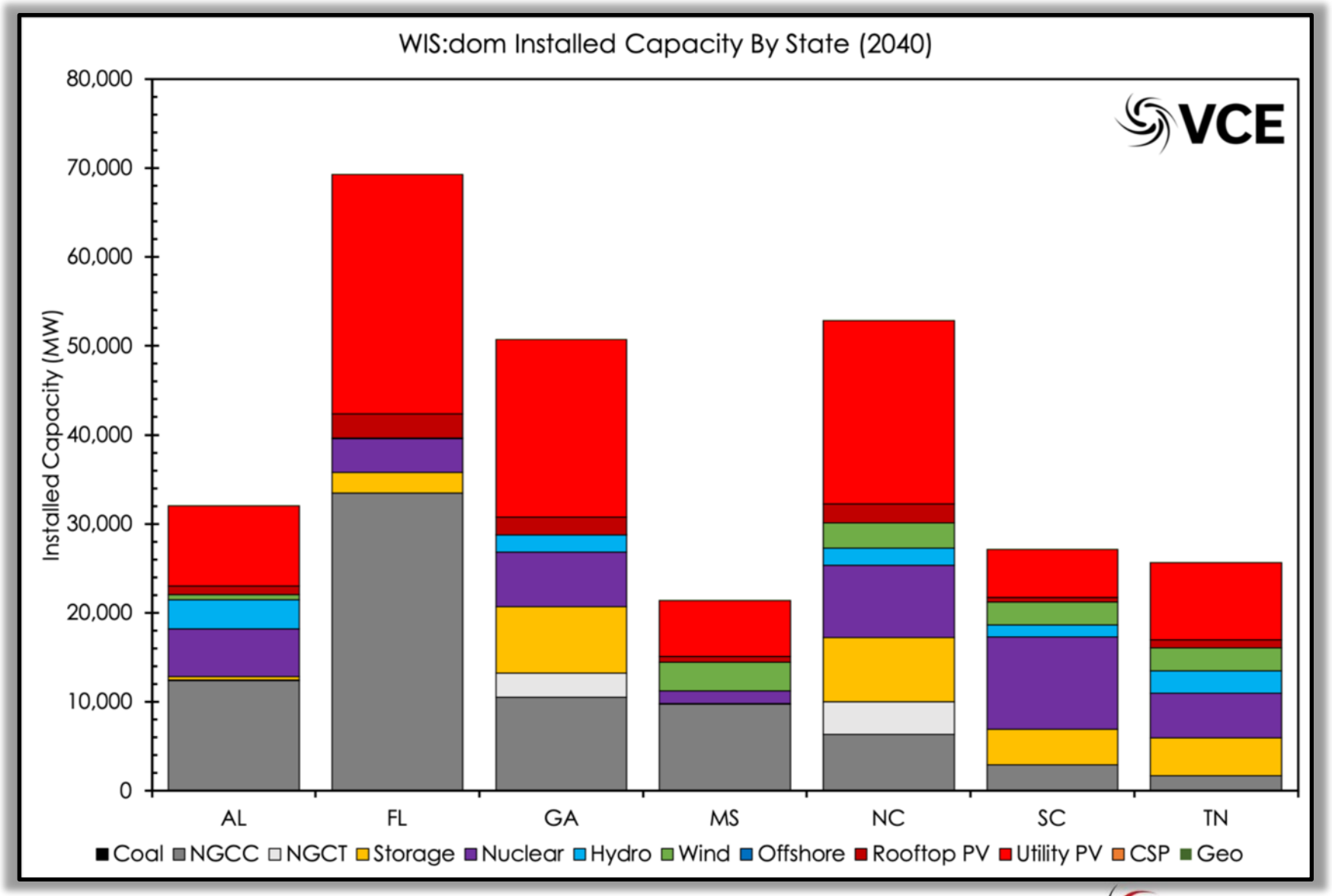

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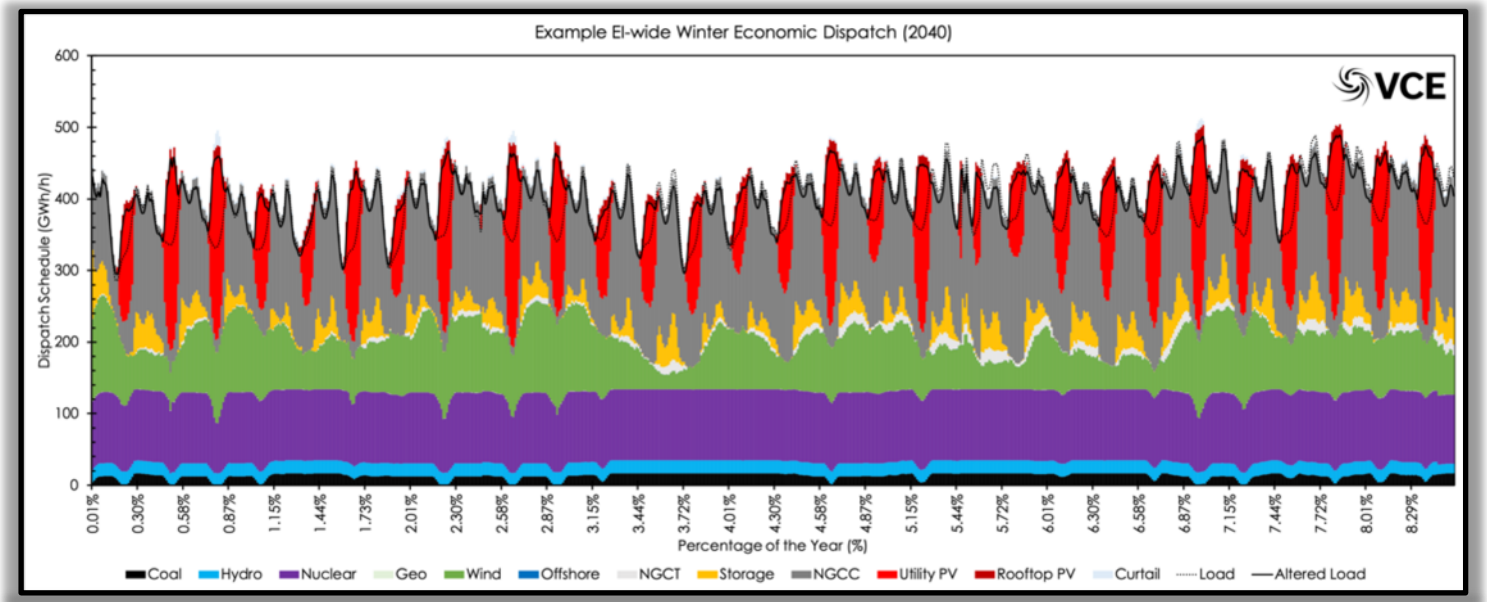

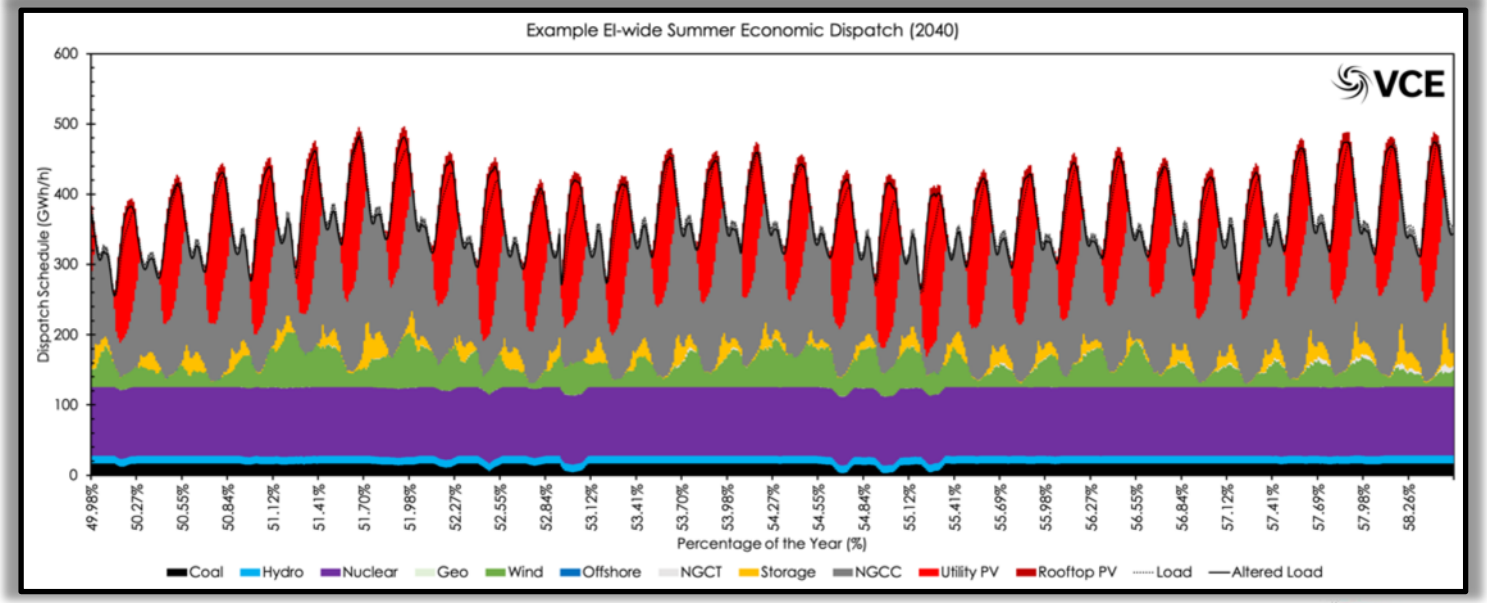

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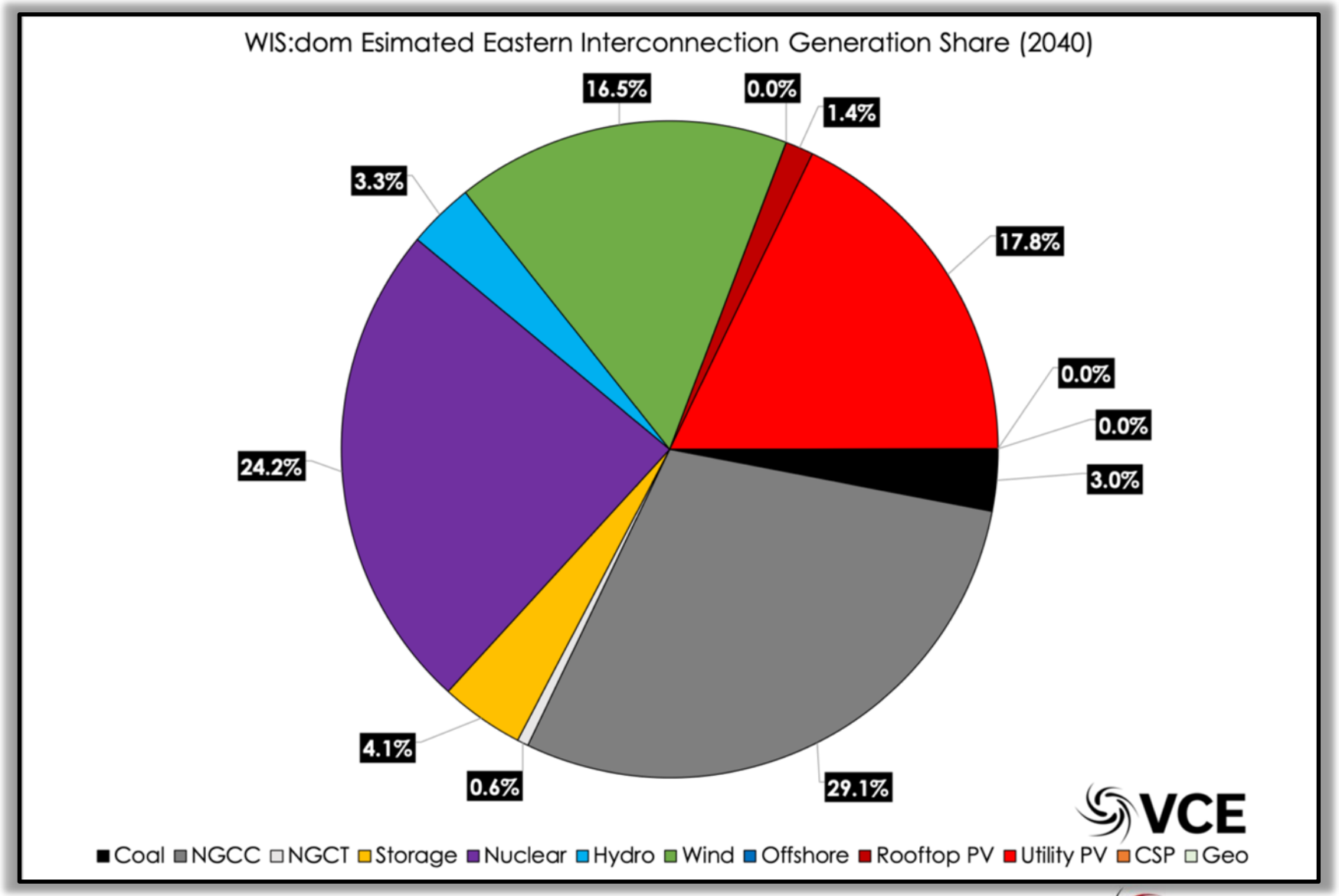

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Thank You

Full report found here:
https://www.vibrantcleanenergy.com/media/reports/

Full Coal-fired Power Plant Dataset here:
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