On the road to dispatchable variable resources

Prepared By:

Vibrant Clean Energy, LLC

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Prepared For:

Energy Systems Integration Group Fall Workshop

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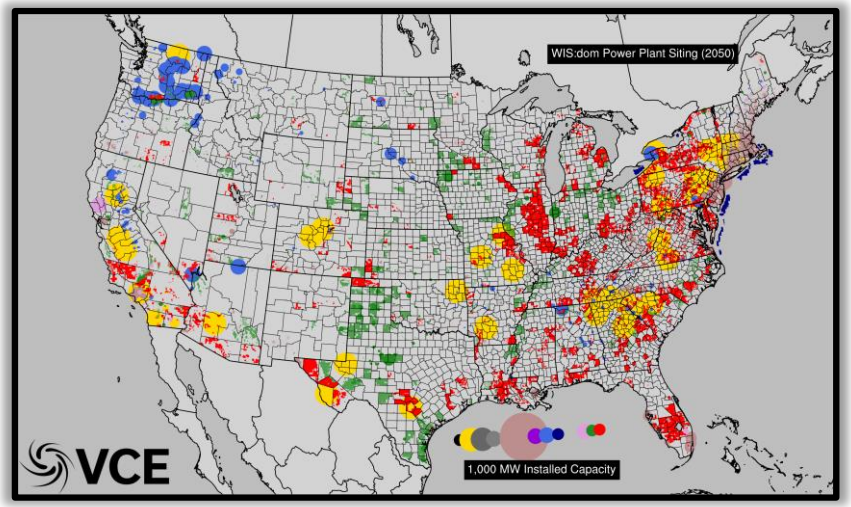
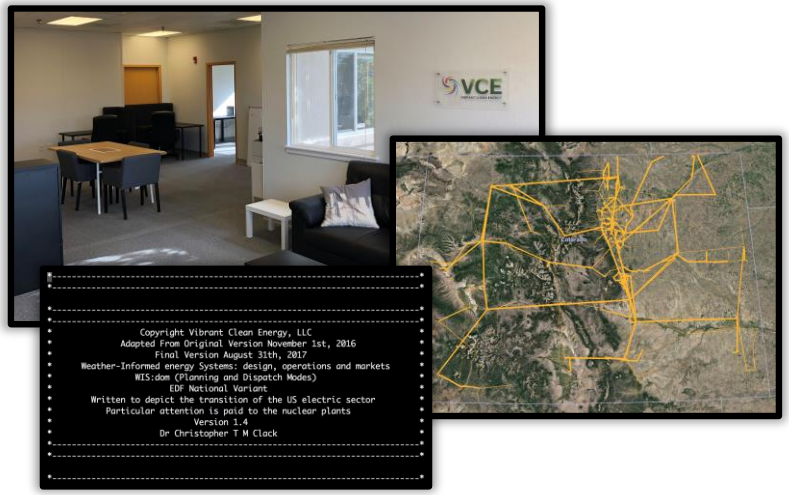
VCE

Who Are We: Vibrant Clean Energy (VCE®)



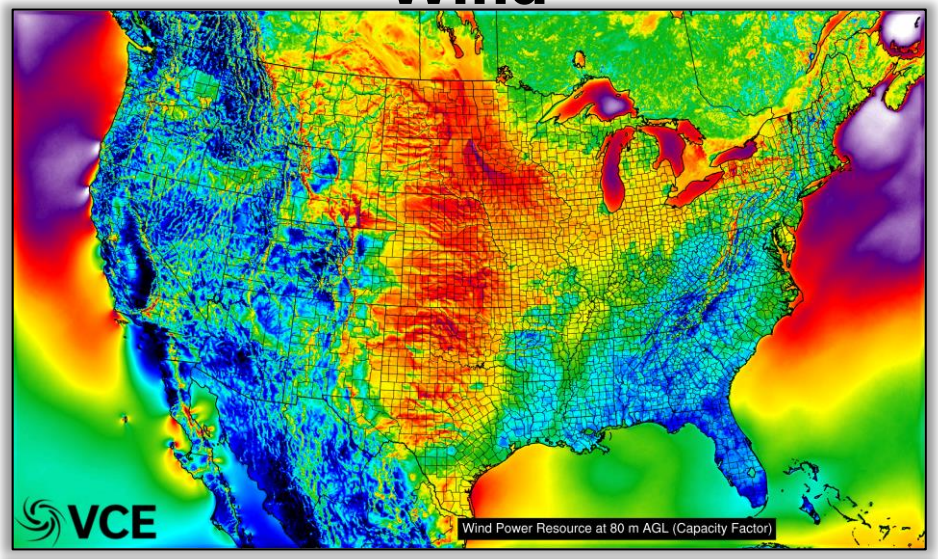


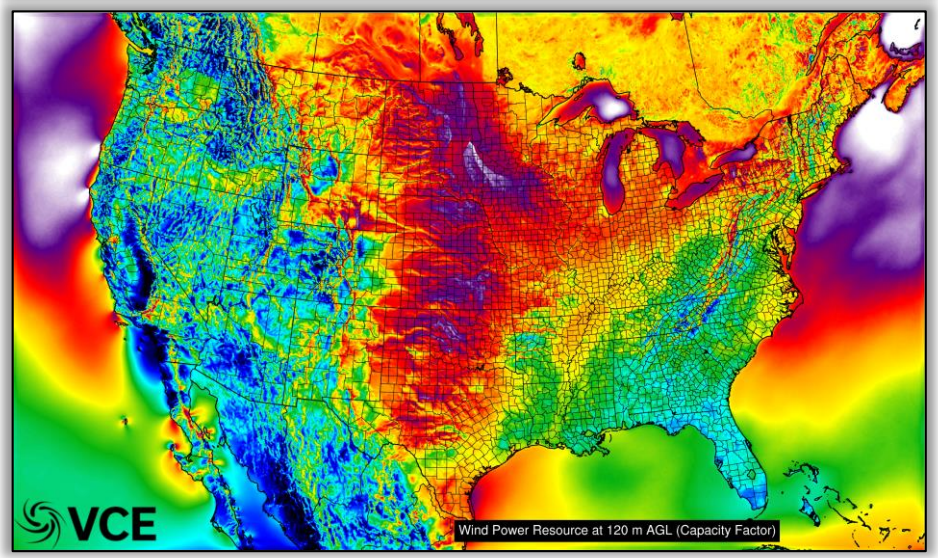
Purpose of Vibrant Clean Energy, LLC:

- 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.

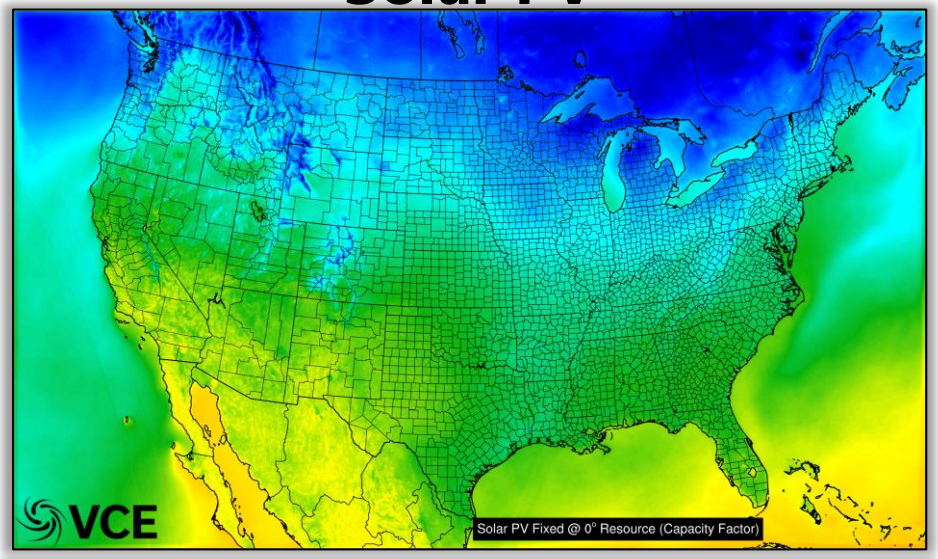
VRE Power Data Incorporated

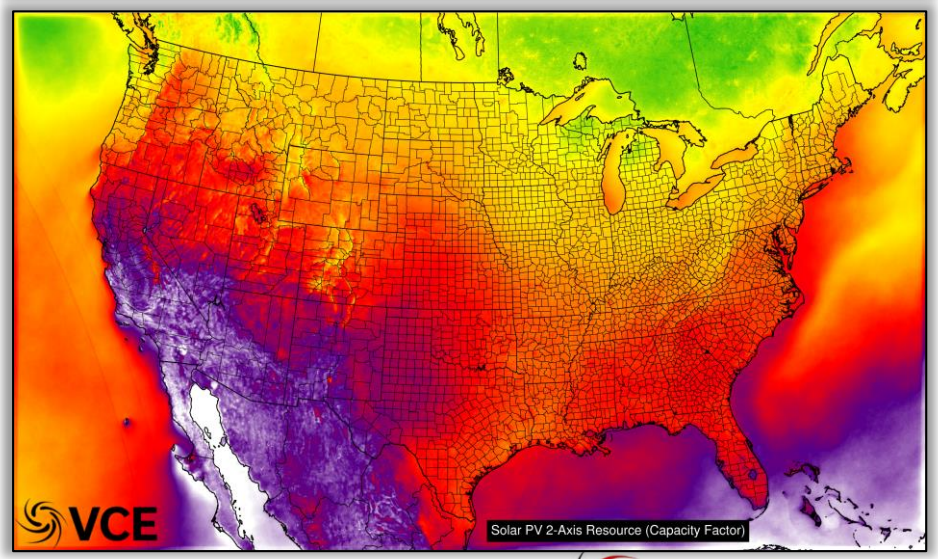
Wind





Solar PV





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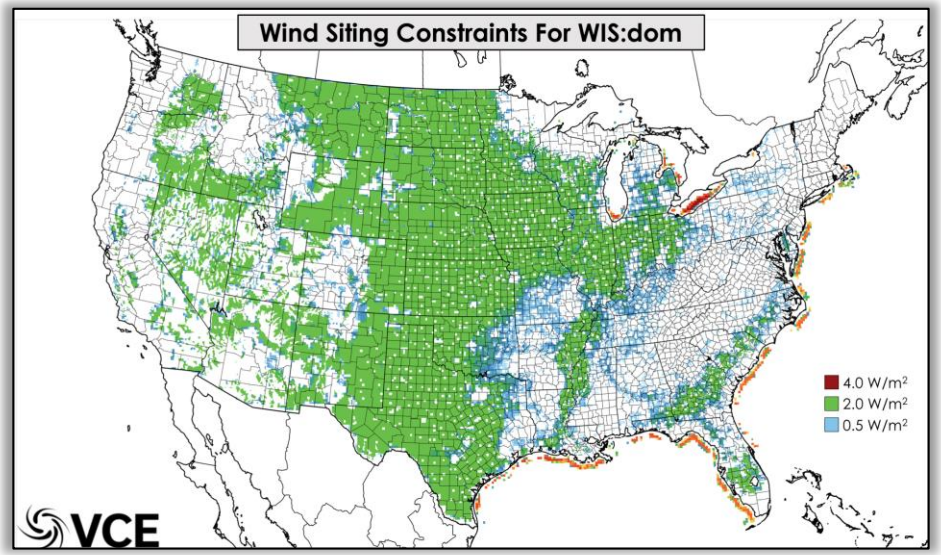
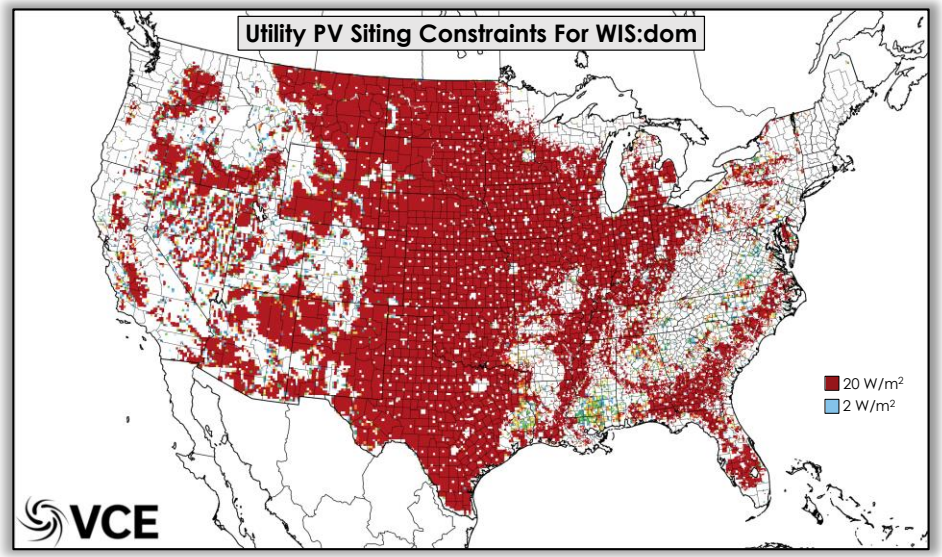
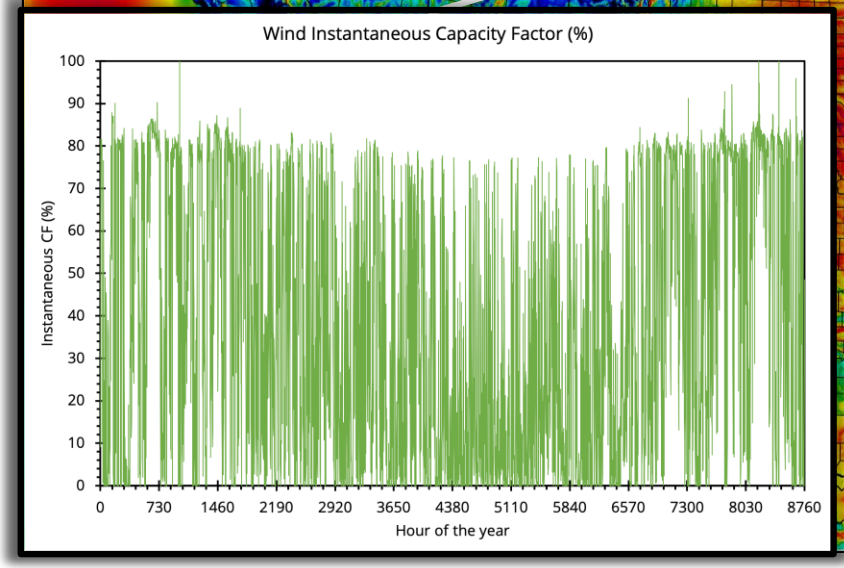
Potential Siting Screening





VRE Power Data Incorporated

Each site has **5-minute data** for **2014 through 2018**. There are ~ 1 million unique sites.



Wind Power Resource at 80 m AGL (Capacity Factor)

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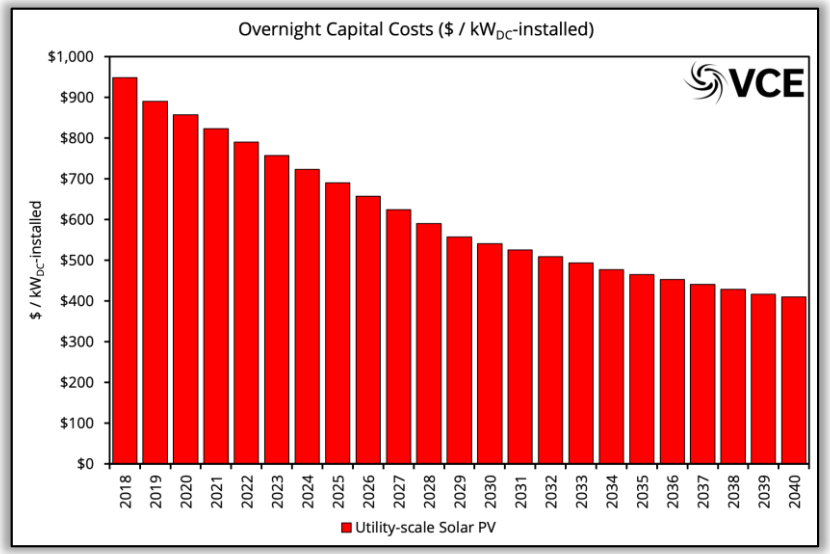
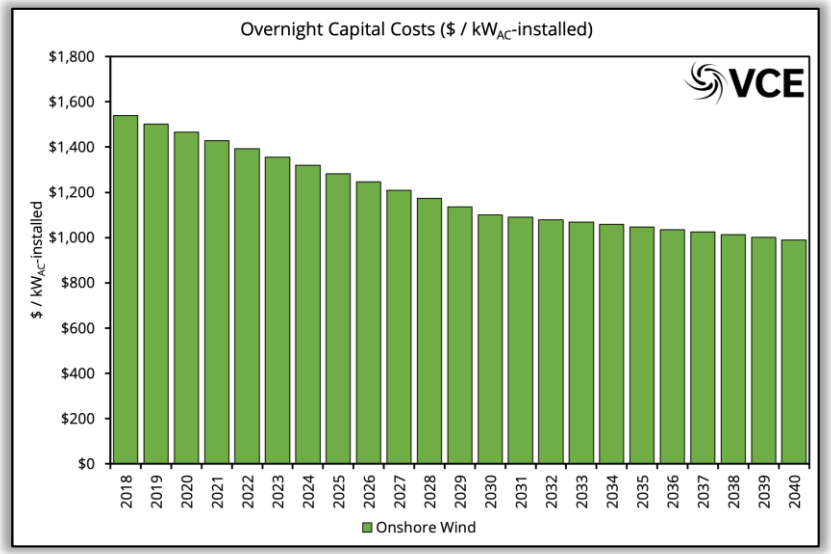
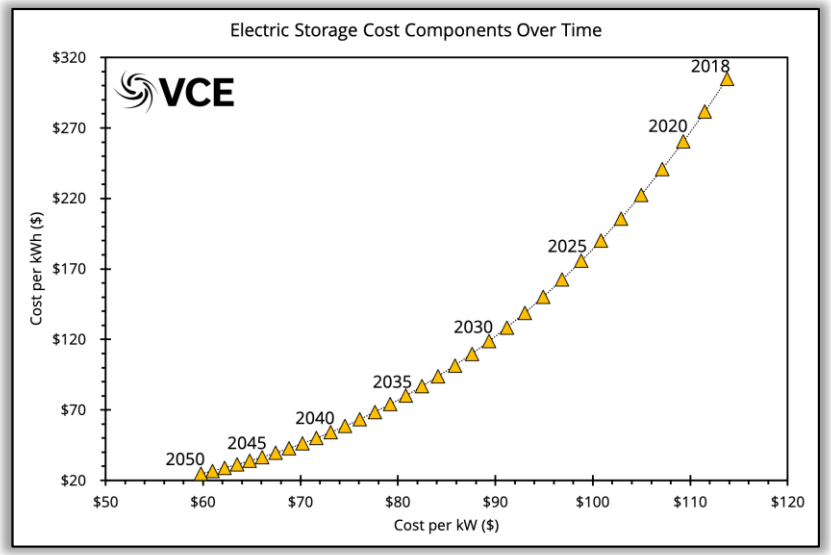
Cost Projections Used

✓ NREL ATB 2019







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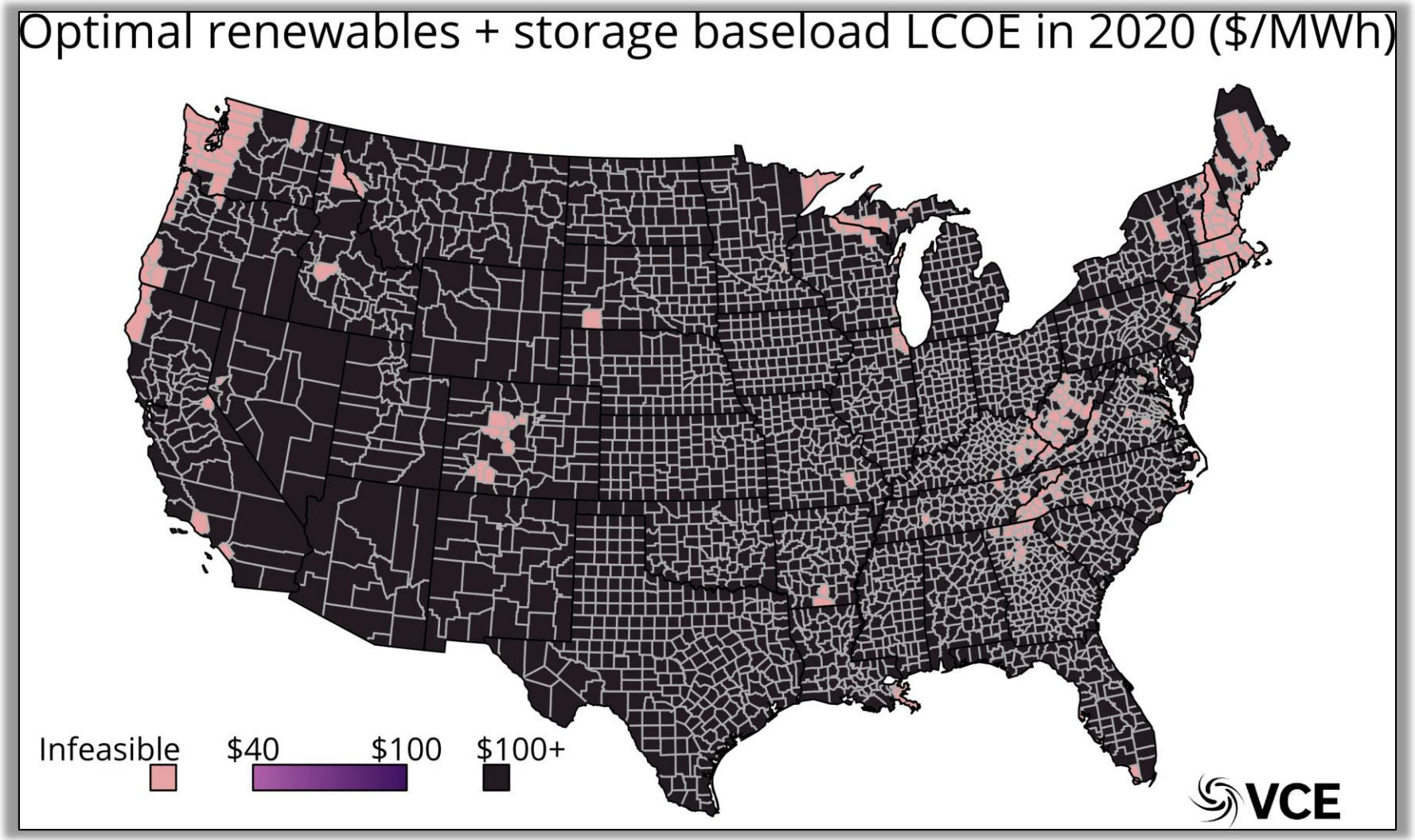
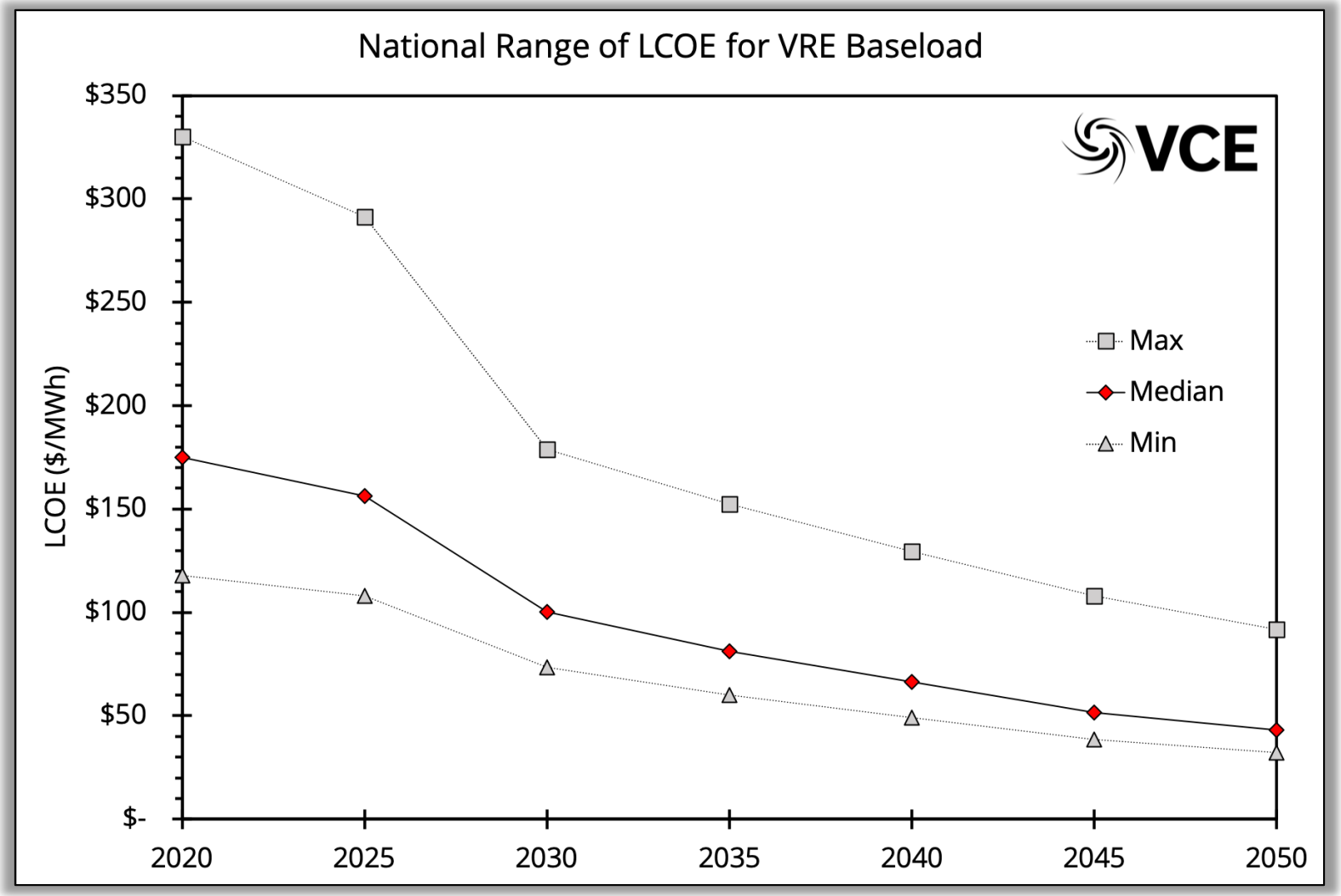
Objective & Optimization

- ✓ Minimize the total annualized costs;
- ✓ Meet the prescribed load exactly each 5-minutes for all of the five years;
- ✓ Enforce self-discharge, charging losses, discharging losses, and state of charge metrics for the electric storage;
- ✓ Compute the amount of power able to be produced by scaling by the available land for construction;
- ✓ Determine the LCOE-baseload, $/kW-baseload, reserves (hours), baseload capacity.

Levelized Cost of Electricity (Baseload)



Range of LCOE for Baseload VREs



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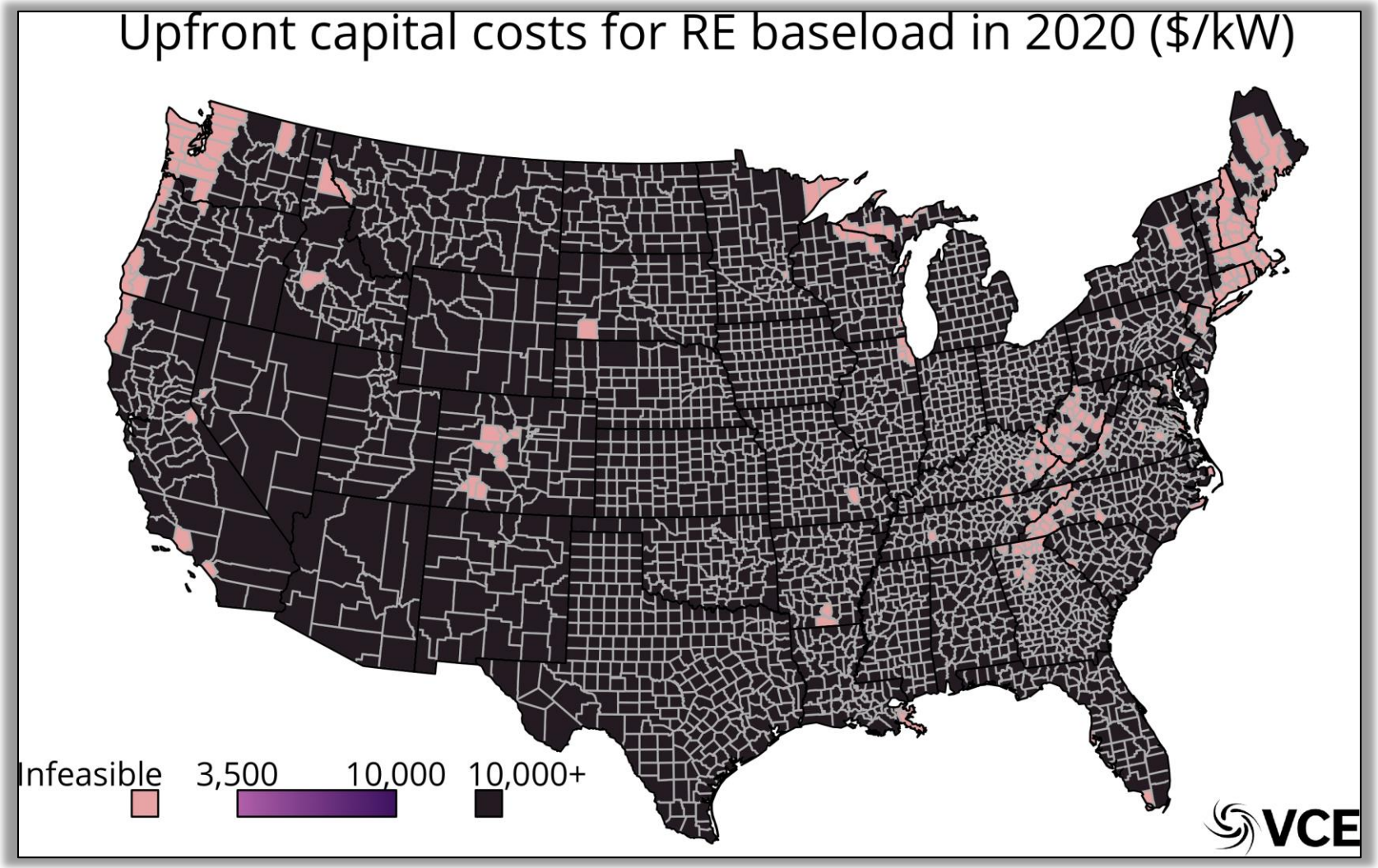
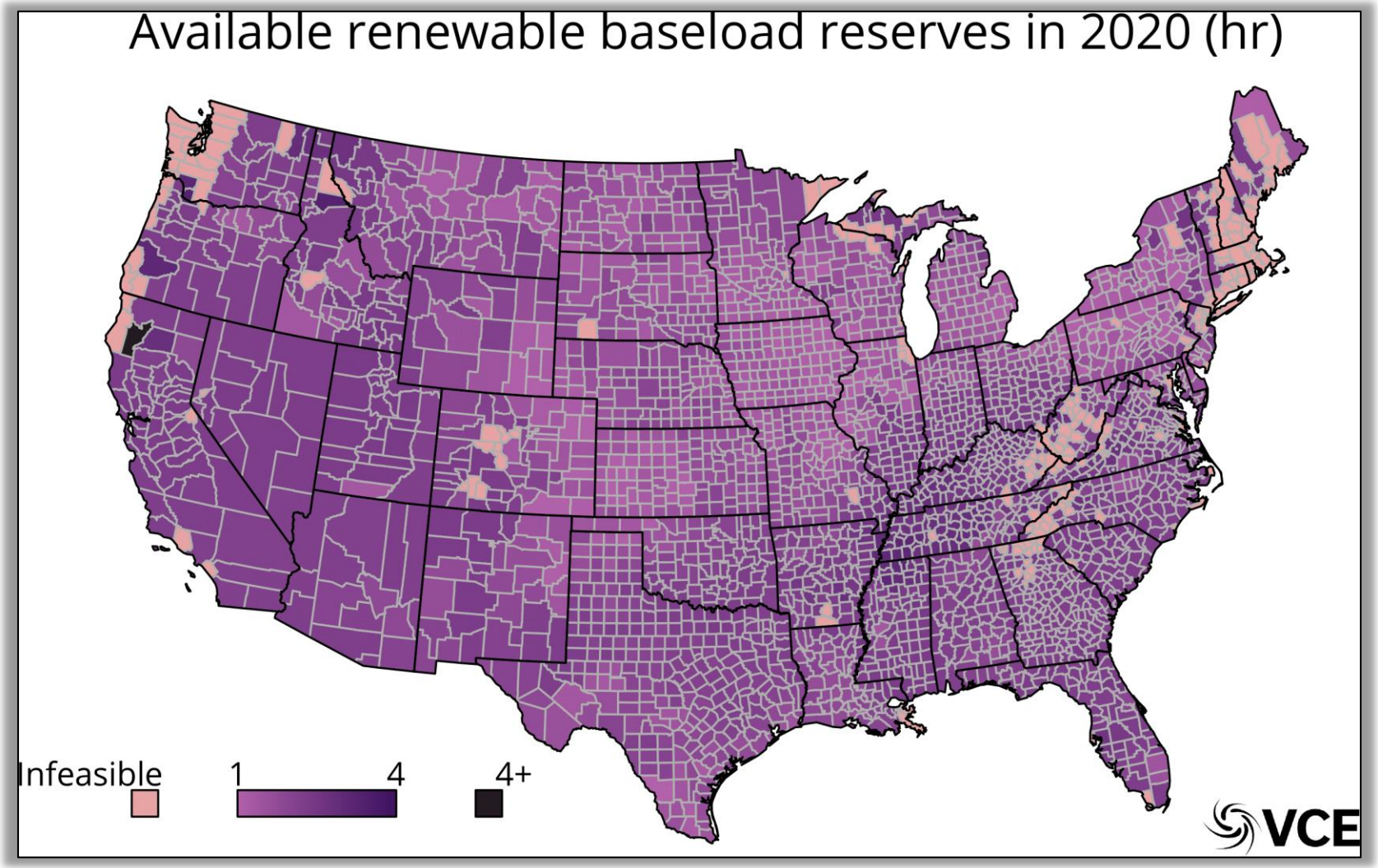
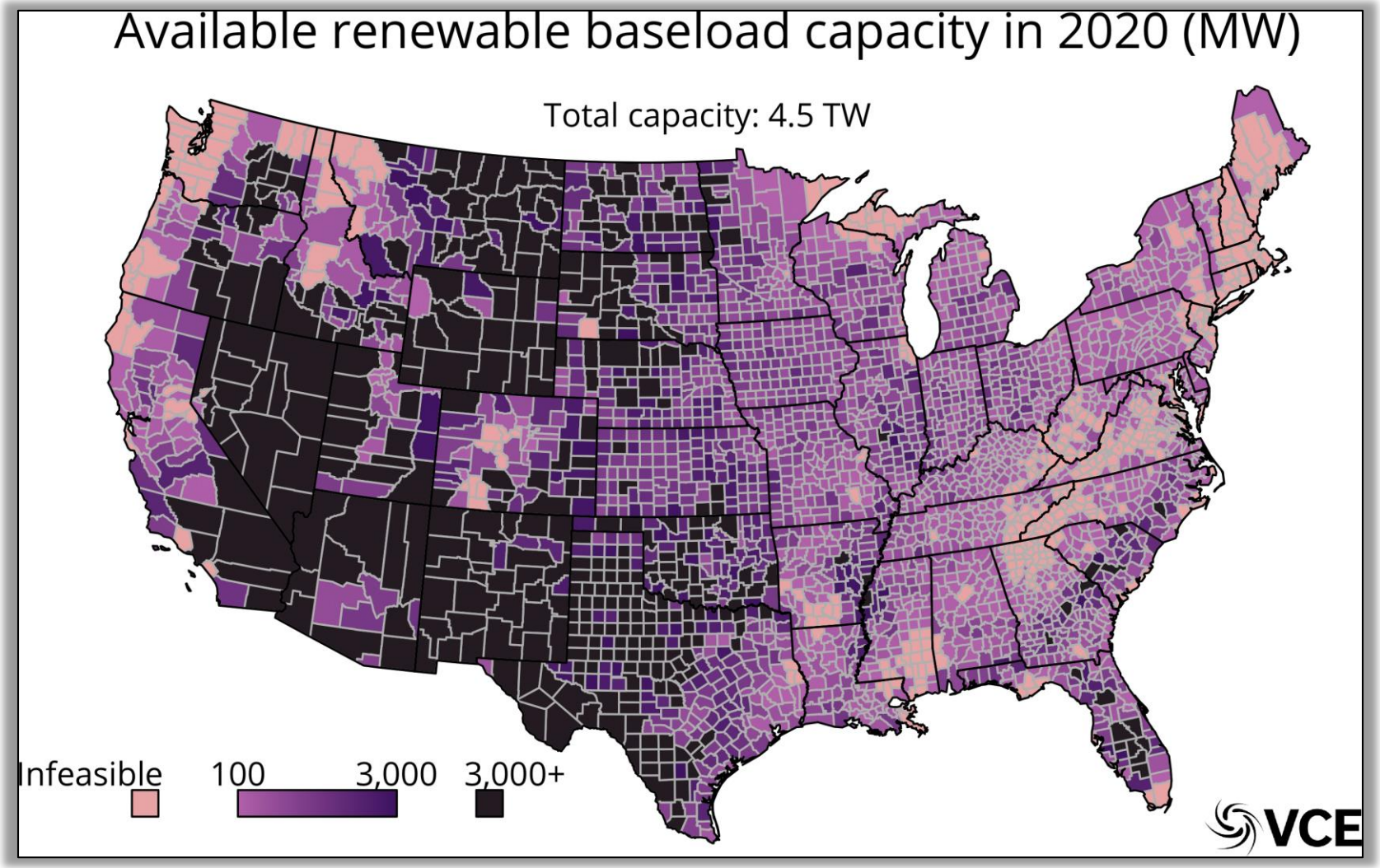
Capital Costs ($/kW-baseload)



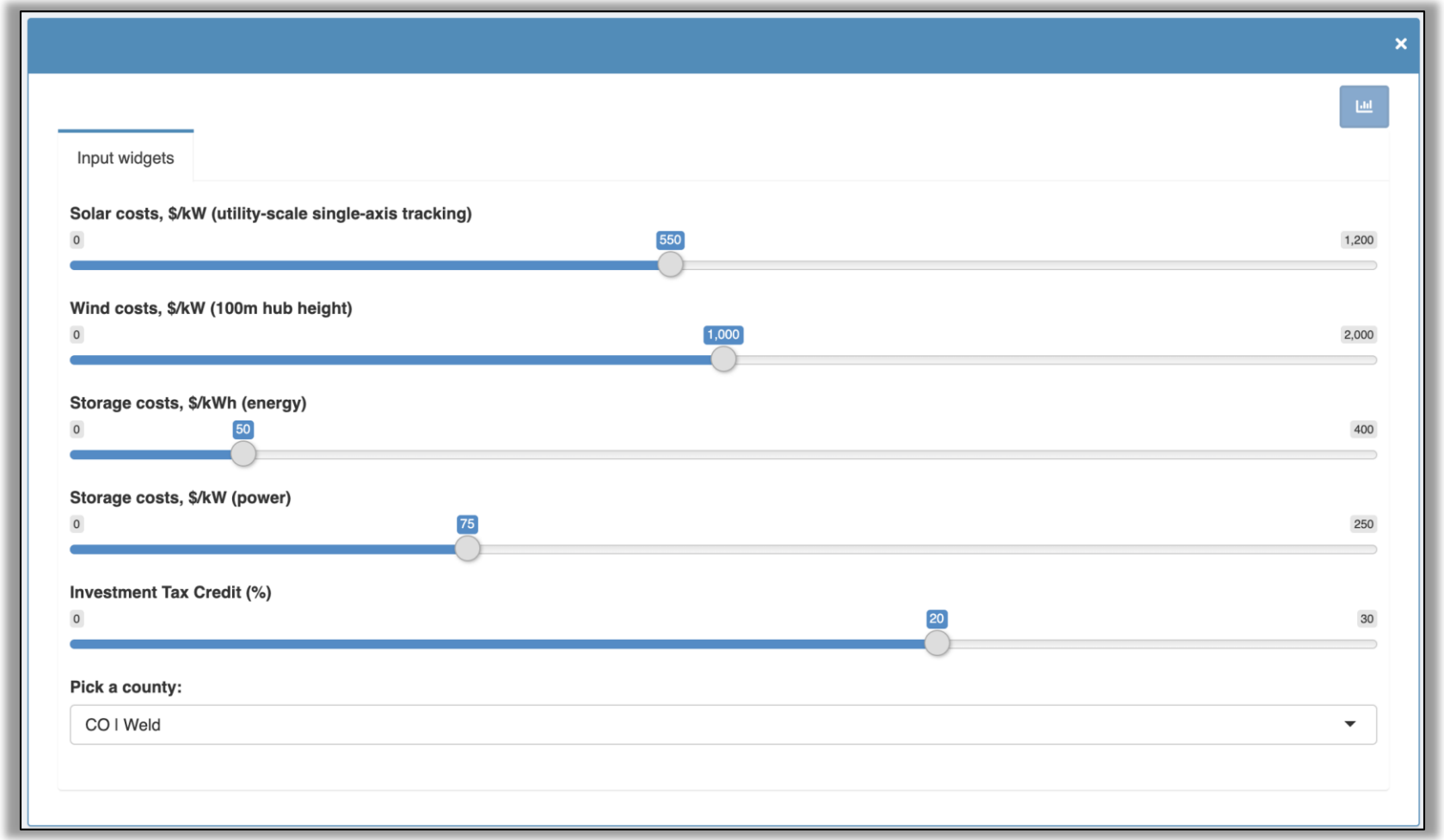
Reserves Available (hours)



Baseload Generation Capacity (MW)



WIS:dom®-B Example (CO | Weld)



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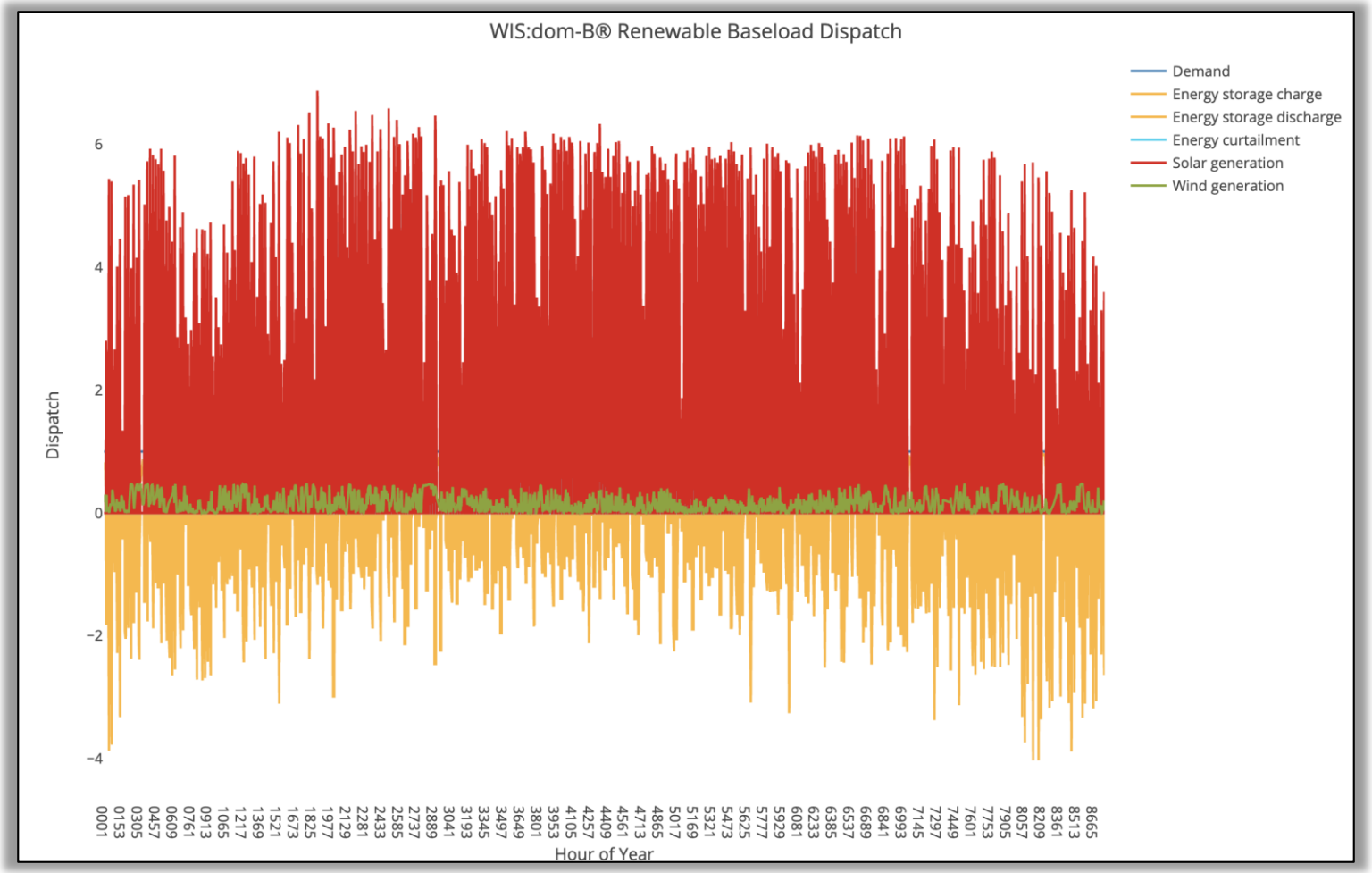

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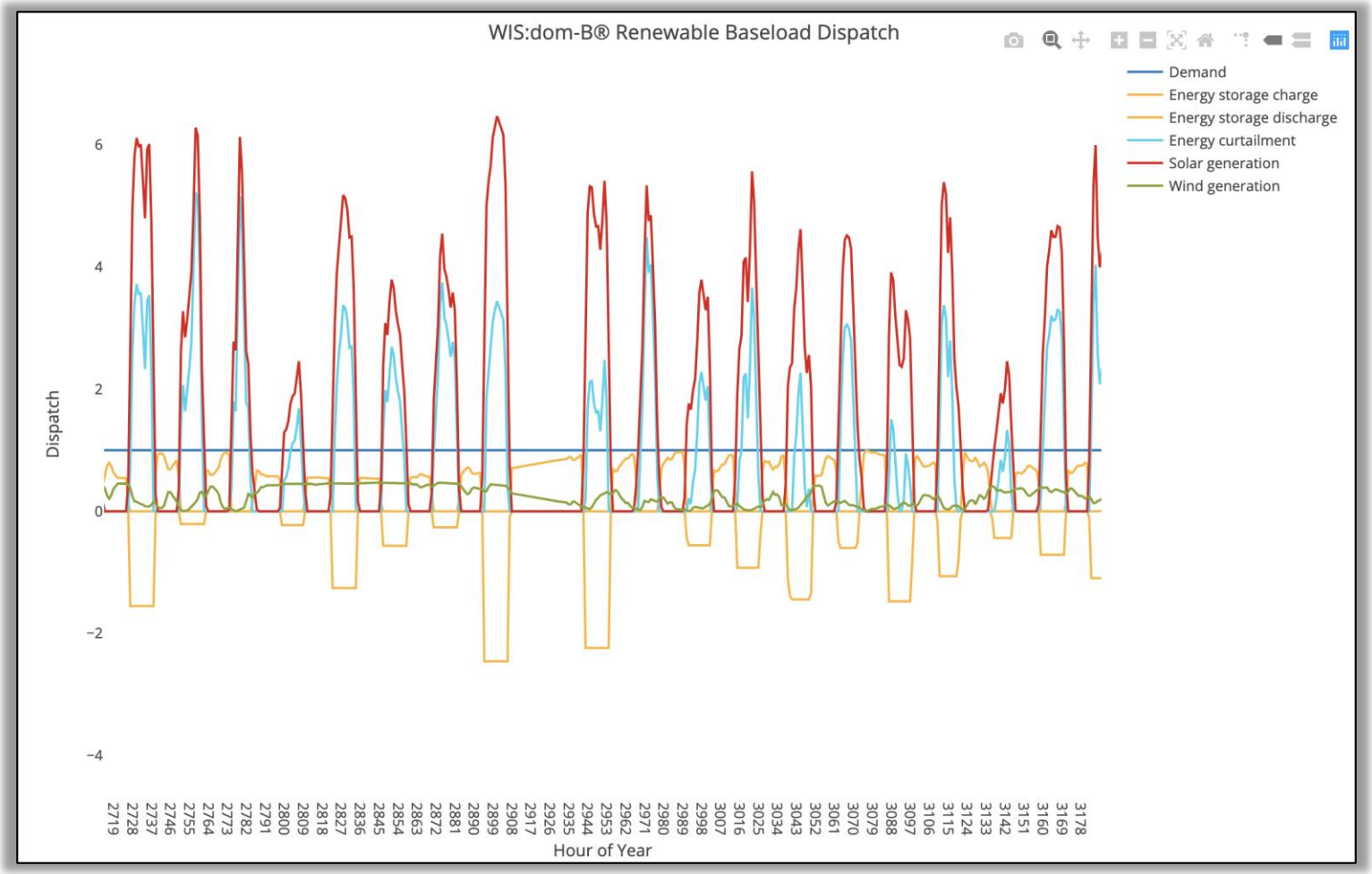

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WIS:dom®-B Example (CO | Weld)

Release Timeline

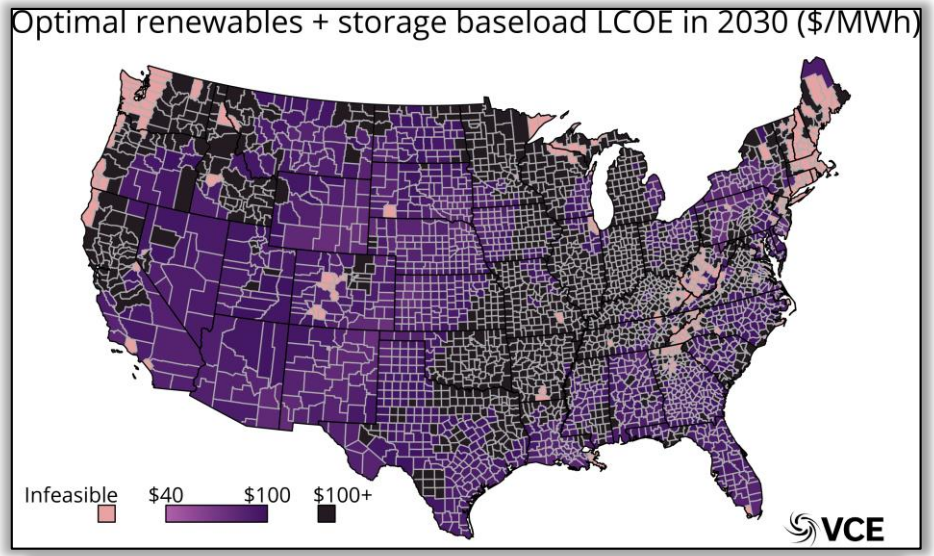
1. The WIS:dom®-B results will be released and open source with all accompanying data (county-level).

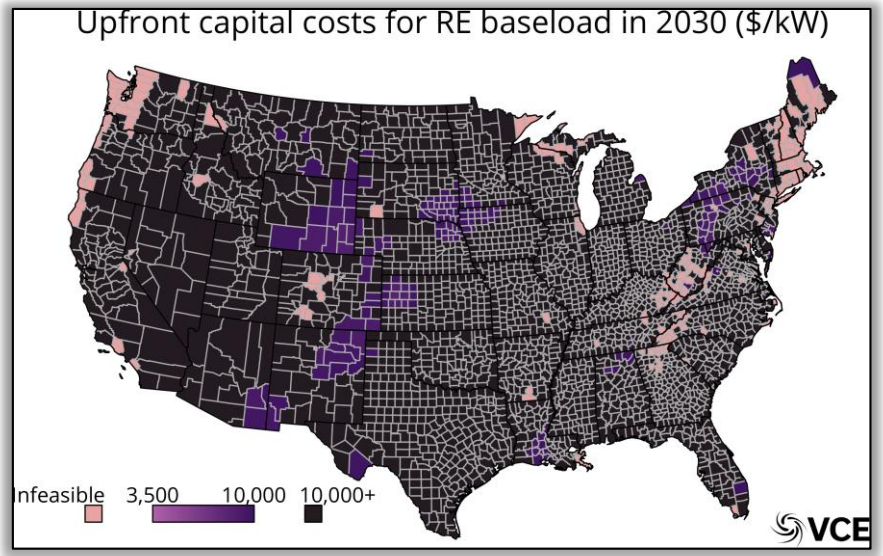
2. VCE® will be writing a report based on the results.

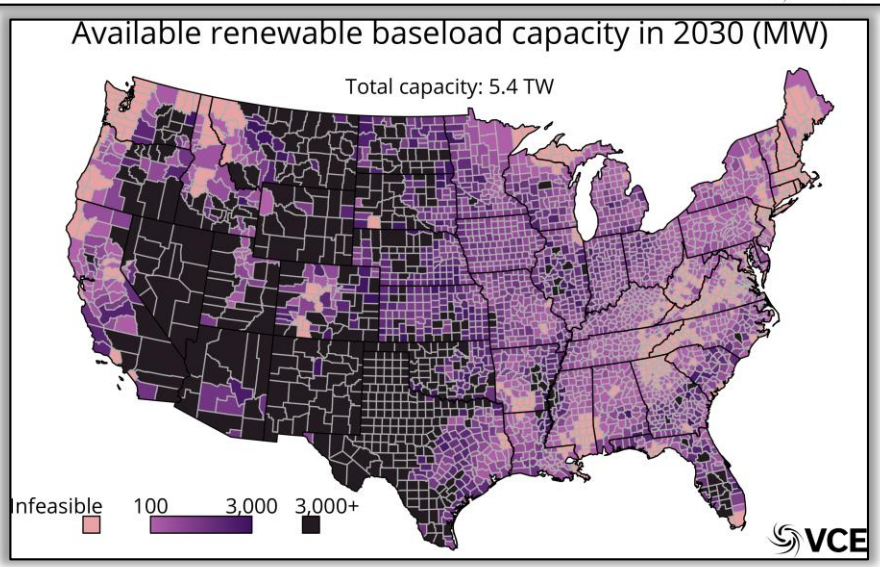
3. The WIS:dom®-B will match any input load profile shapes.

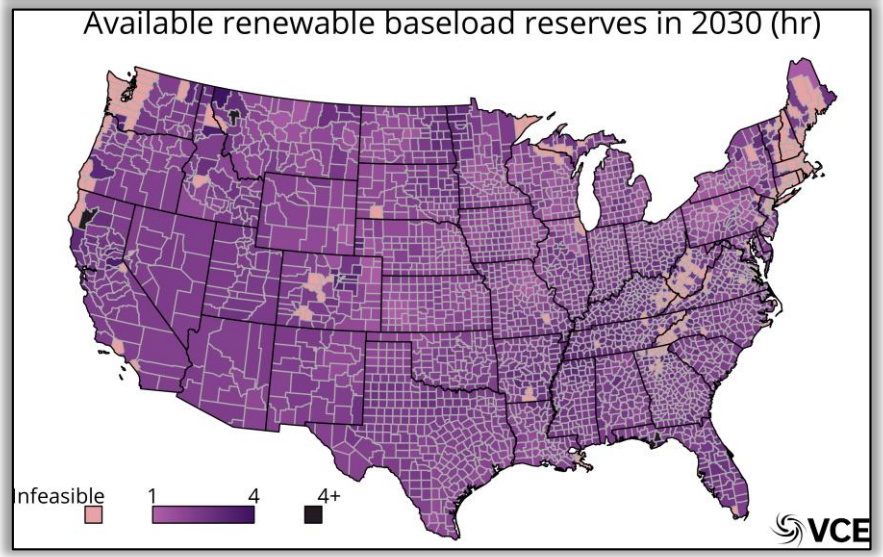
4. The timeline is early 2020 (Q1 or Q2).

Overview (2030)









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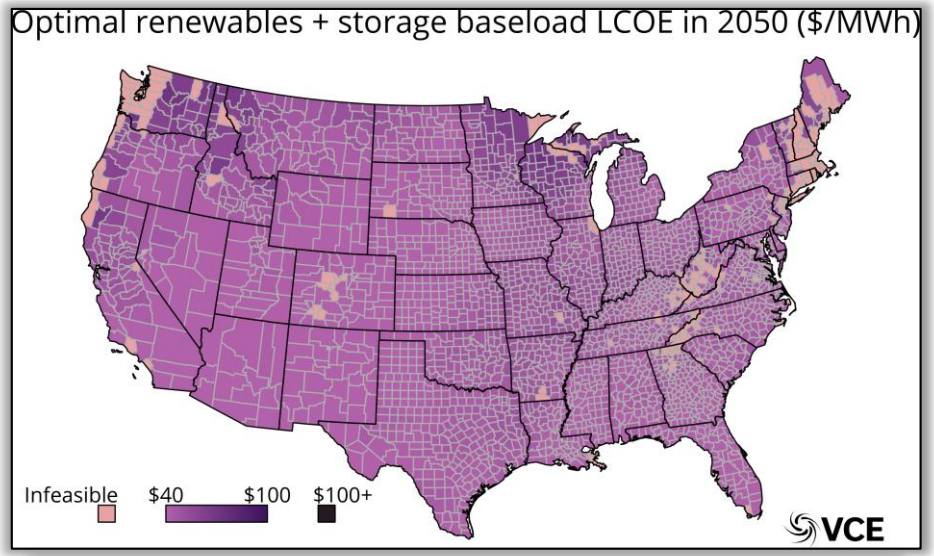
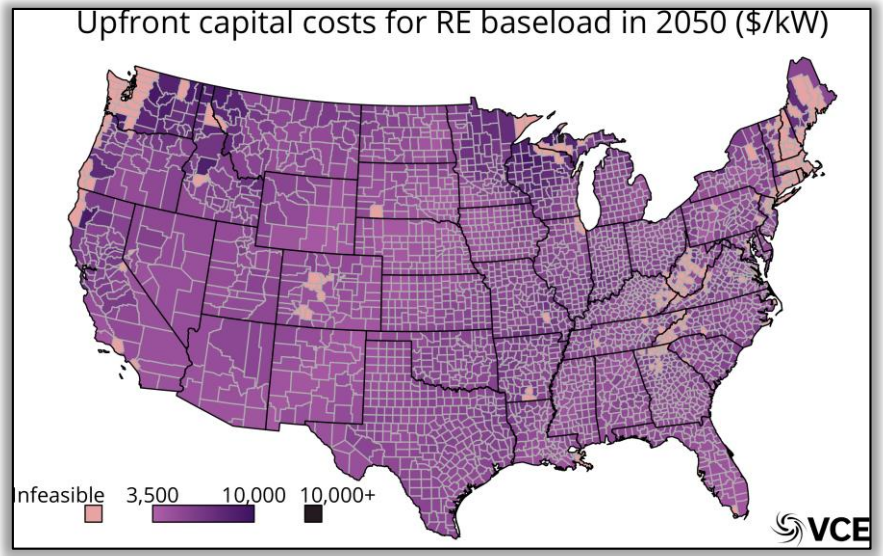
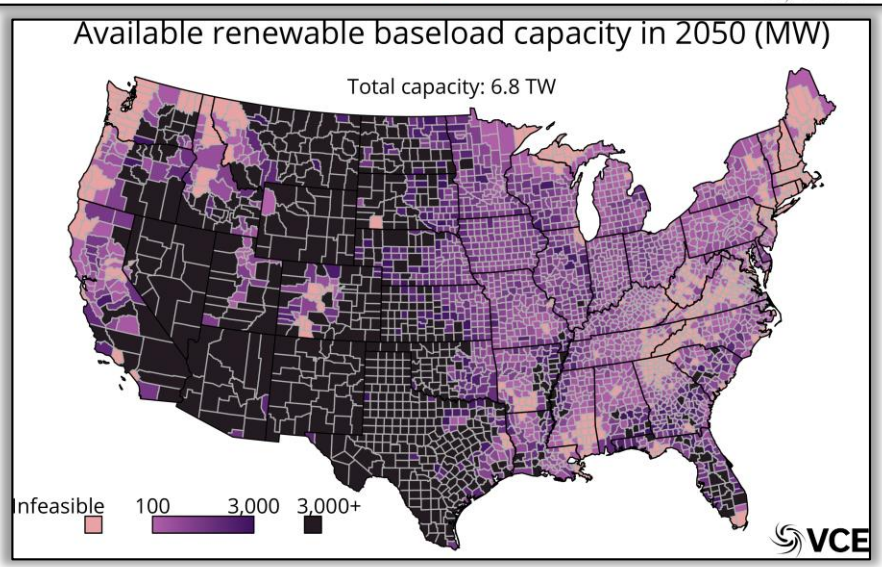
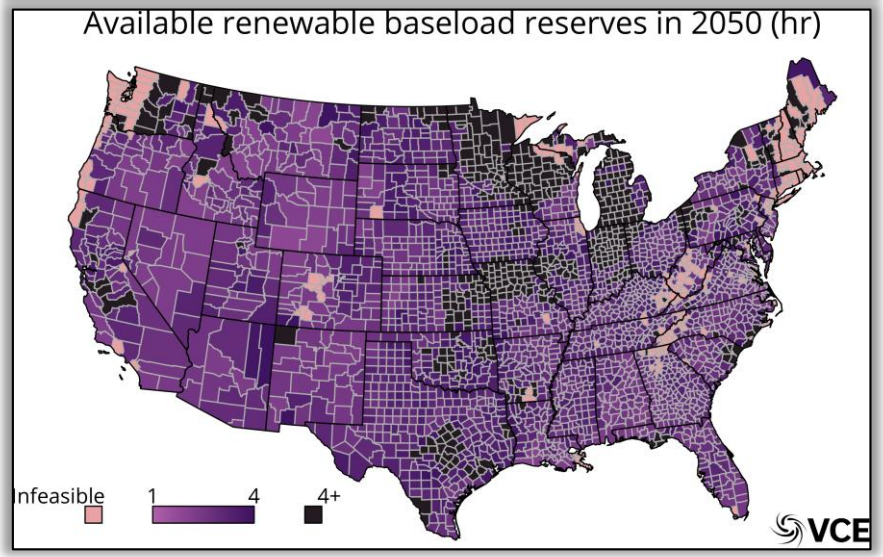
Overview (2050)









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Conclusions

1. VRE hybrid systems coming down in cost, soon will be cheaper than anything else;

2. They will be more reliable than baseload generation from thermal because of the ability to hold "reserves" at all times;

3. The places with greatest resource do not have the demand to use it;

4. HVDC transmission (underground) in a super grid is likely most economically efficient means to move the low-cost electricity over the continent;

5. These systems can become energy centers to produce e^-, H_2, CH_4, NH_3, CO_2 capture.

6. As our electricity needs grow, there will be a greater acceptance that we should use all the energy we can with fewest resources, that is reduce curtailment via other technologies.

Thank You

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