

Reliable, Efficient & Low-Carbon Resource Portfolios:

Insights from WIS:dom[®] Modeling

Prepared By:

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Dr Christopher T M Clack

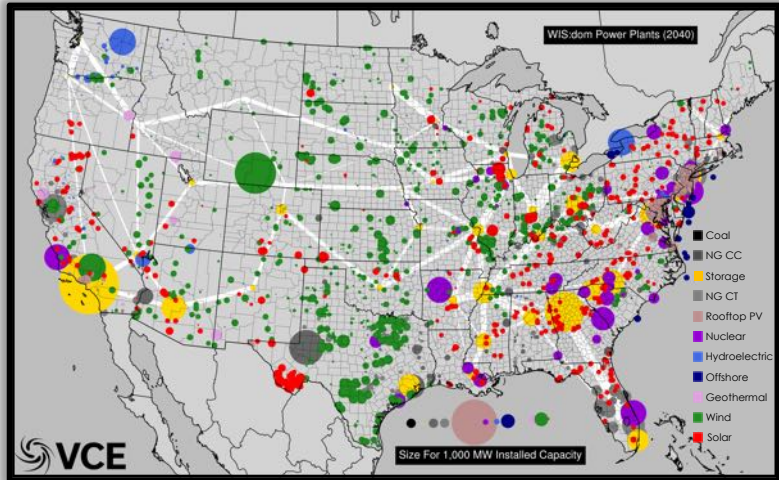
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Vibrant Clean Energy



Purpose of Vibrant Clean Energy, LLC:

- **Reduce the cost of electricity** & help evolve economies to near zero emissions;
- **Co-optimize** transmission, generation, storage, & distributed resources;
- Increase the understanding of **how Variable Generation impacts & alters the electricity grid** and model it more accurately;
- **Agnostically determine the least-cost portfolio** of generation that will remove emissions from the economy;
- Model the **electrification** of industry, heating & transportation;
- License WIS:dom® optimization model and/or perform studies using the model;
- Assist clients **unlock and understand the potential** of high VRE scenarios, as well as zero emission pathways.



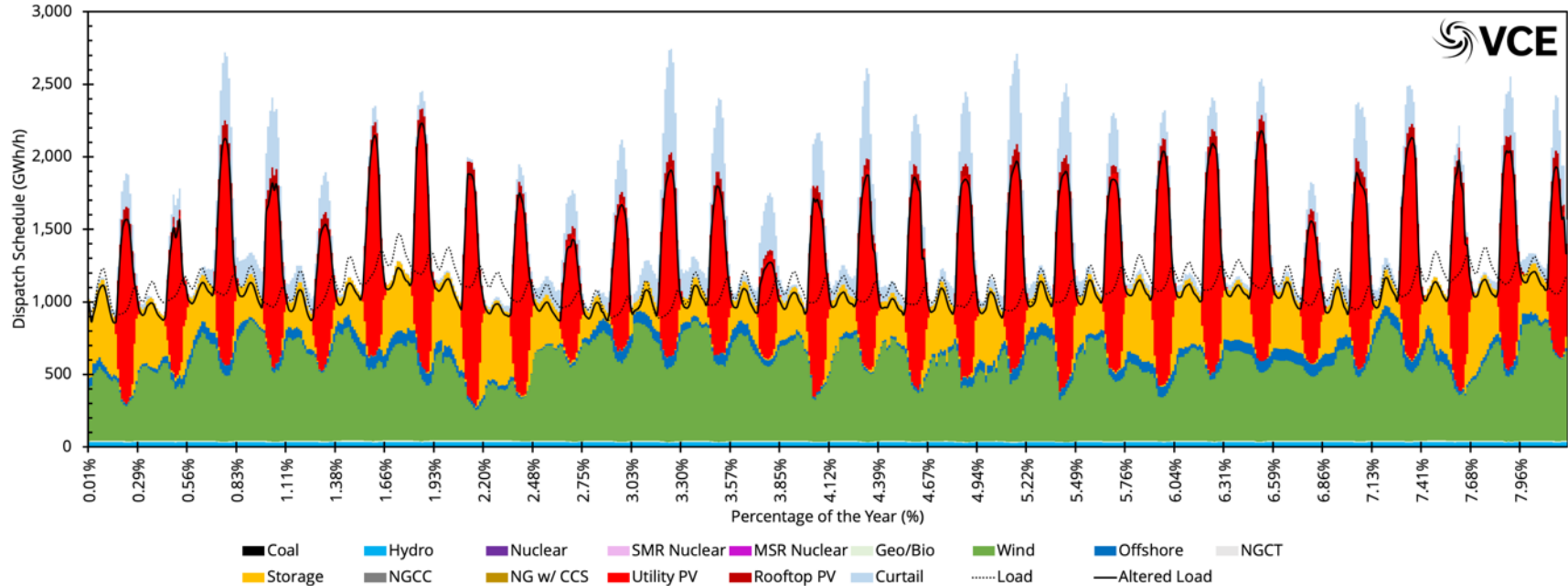
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Iteration 29 did 2 control corrections (2205 vhrs)
Refinement: orig 4.61e+08, refined 4.61e+08, target 3.41e+08, 0 iter
29 -1.270127e+11 2.206205e+11 9.16e+07 8.80e+06 1.35e+10 4.80e+03
2854.53s (2205007.49 vhrs) for iteration (1007.83s, 334223 vhrs for lin, solve)
Iteration 29 did 4 control corrections (260 vhrs)
Refinement: orig 9.76e+08, refined 9.76e+08, target 3.13e+08, 0 iter
29 -1.236274e+11 2.207705e+11 9.20e+07 8.80e+06 1.35e+10 4.80e+03
2874.85s (2205008.25 vhrs) for iteration (1007.50s, 334623 vhrs for lin, solve)
Iteration 30 did 18 control corrections (100 vhrs)
Refinement: orig 1.13e+09, refined
30 -1.801064e+11 2.206705e+11
2264.42s (2276230.36 vhrs)
Iteration 31 did 18 control corrections
Refinement: orig 4.87e+08, refined
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Iteration 32 did 18 control corrections
Refinement: orig 4.87e+08, refined
32 -1.225506e+11 2.206705e+11
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Iteration 33 did 18 control corrections
Refinement: orig 3.50e+08, refined
33 -1.813437e+11 2.206705e+11
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Iteration 34 did 4 control corrections
Refinement: orig 6.30e+08, refined
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2283.84s (2281230.34 vhrs)
Iteration 35 did 18 control corrections
Refinement: orig 2.13e+09, refined
35 -2.876687e+09 2.236642e+11
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Adapted From Original Version November 1st, 2016
Final Version August 31th, 2017
Weather-Informed energy Systems: design, operations and markets
WIS:dom (Planning and Dispatch Modes)
ESP: National Variant
Written to depict the transition of the US electric sector
Particular attention is paid to the nuclear plants
Version 2.4
Dr Christopher T M Clock
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Technologies Do Work Together (Clean Energy)

With limited generation technologies, the system will need more flexibility from other assets

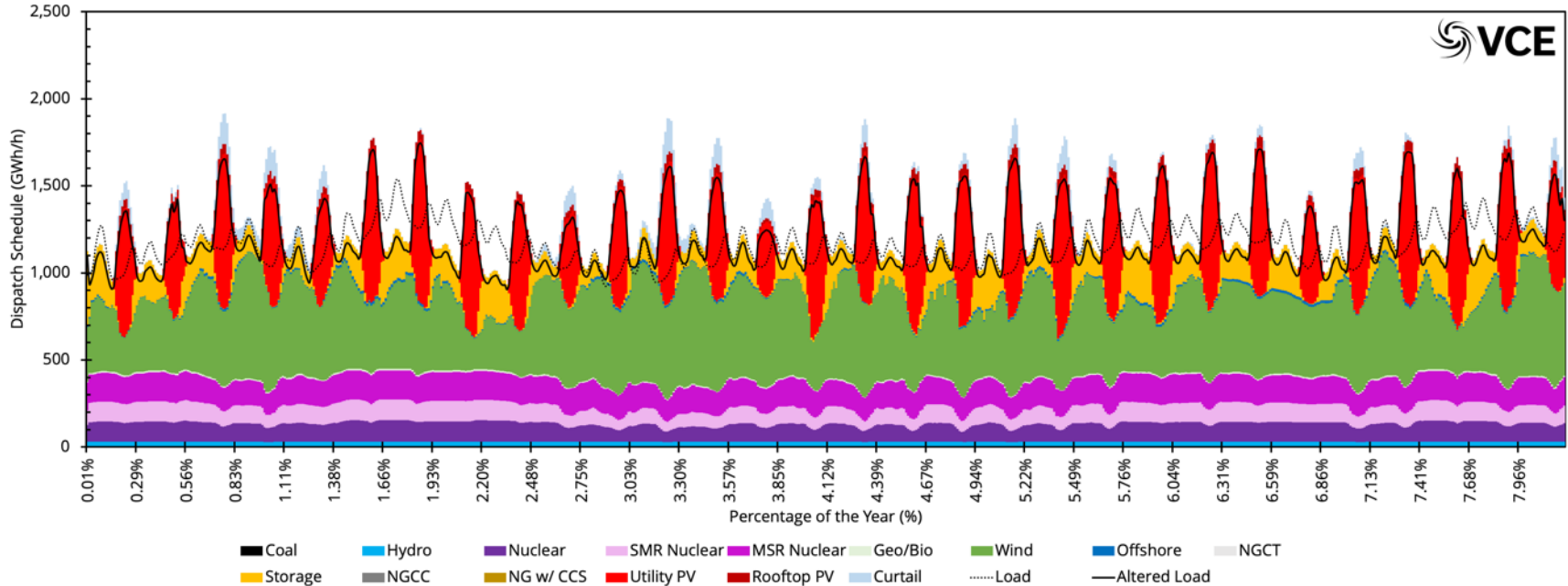
Example US Winter Economic Dispatch (2050)



Technologies Do Work Together (Clean Energy)

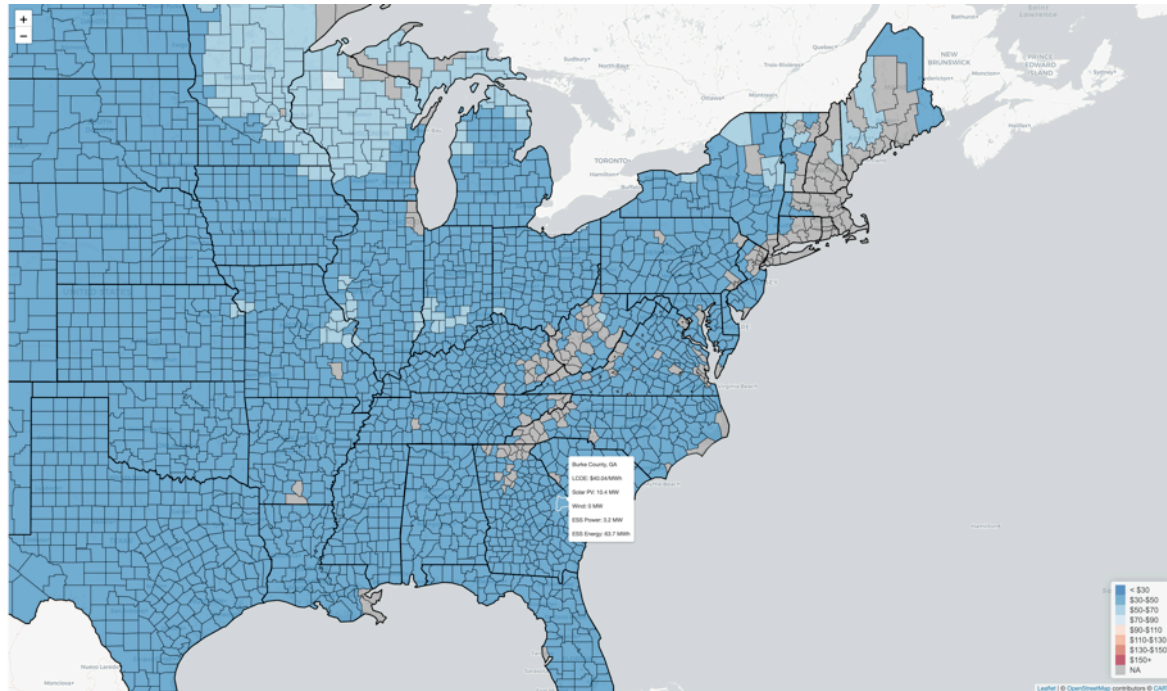
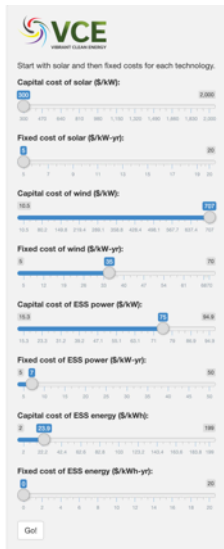
Even with all generation technology types, the system still relies on them all to provide flexibility

Example US Winter Economic Dispatch (2050)



Local VREs Can Work Together to Provide Energy & Capacity

Combining wind, solar and storage (and possible synthetic fuels) allows for cheap, clean electricity & flexibility to ensure reliability



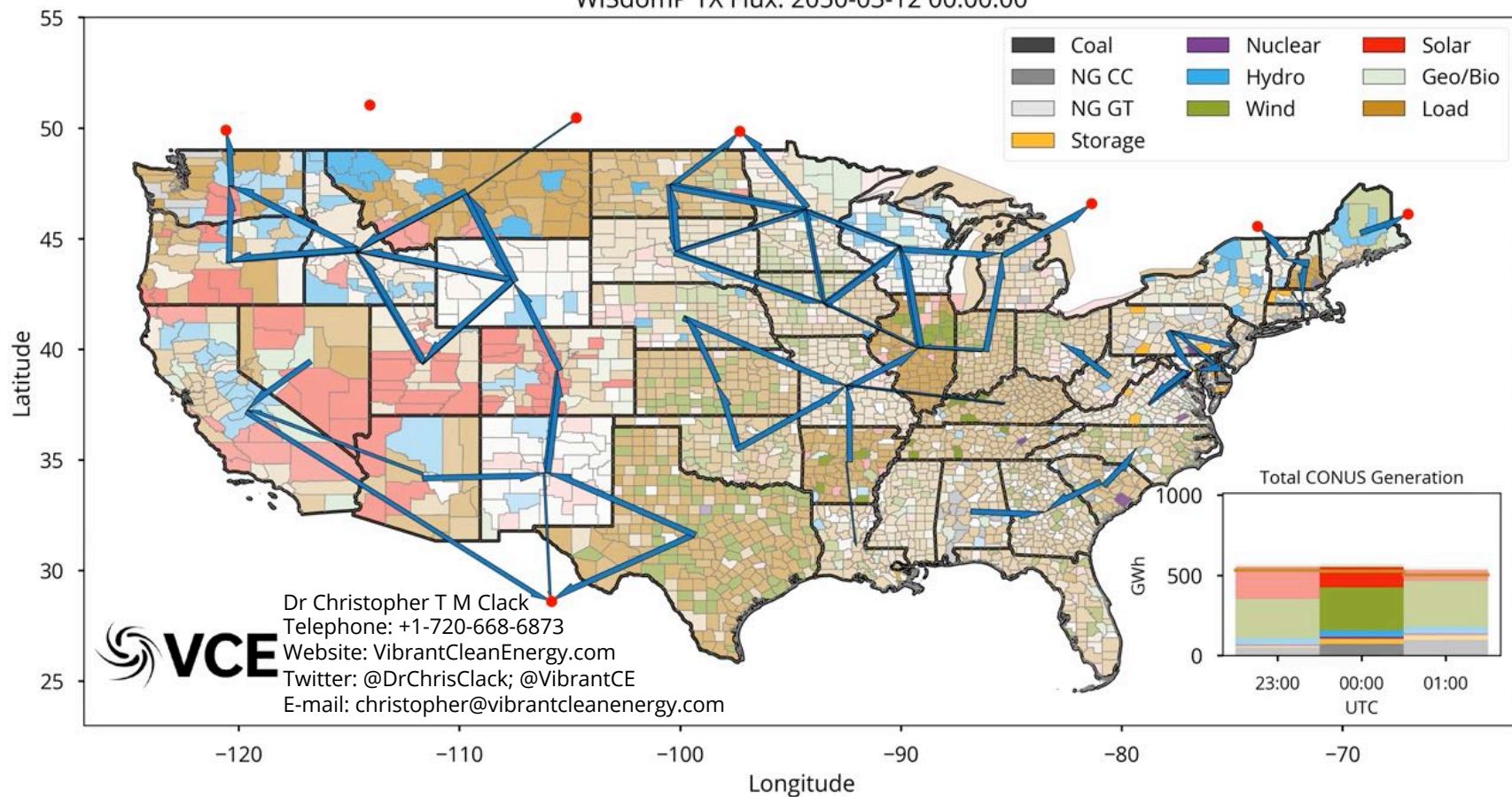
There are Only Two Key Portfolio Components

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, H₂ CC, NGCC+CCS)*
- *Synthetic Fuel/Chemical Production (H₂, CH₄, NH₃)*
- *Peaking Generation (H₂ CT)*



Thank You!