Modeling Renewable Energy, Clean Technologies and Electrification For Deep Decarbonization Future

Prepared By:

Vibrant Clean Energy, LLC

Dr Christopher T M Clack,

Dr Aditya Choukulkar, Brianna Coté, Sarah A McKee, Dr Joshua D Rhodes

Prepared For:

Colorado Public Utilities Commission

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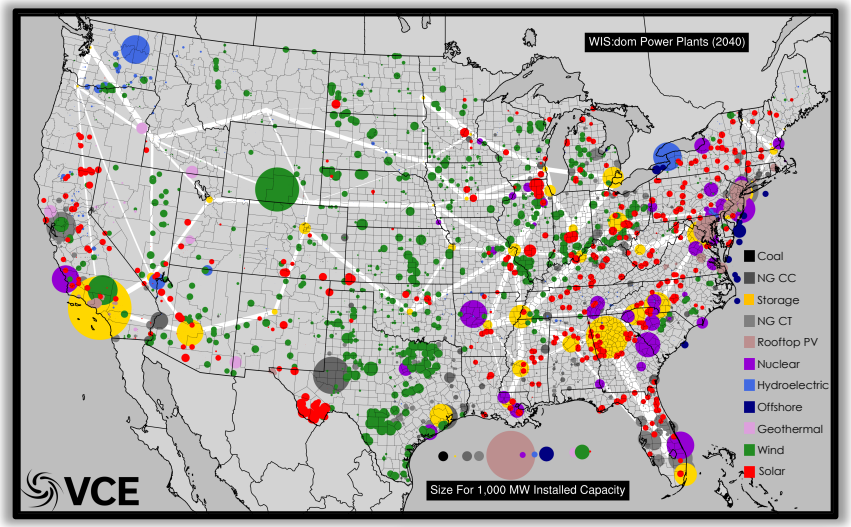
info@vibrantcleanenergy.com

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;
- Model the ***electrification*** of industry, heating & transportation;
- License ***WIS:dom® optimization modeling suite*** 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.

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Current clients include

- ✓ Large ISOs;
- ✓ Fortune 100 Companies;
- ✓ Universities (and others) purchasing weather, power and climate datasets as well as studies of microgrids for their campuses;
- ✓ Venture Capitalists & Startup companies;
- ✓ Nonprofit organizations seeking robust modeling of electricity transitions;
- ✓ Energy Developers Seeking Advantages in Deployment of New Generators;
- ✓ Philanthropists & others in need of robust energy transition modeling.

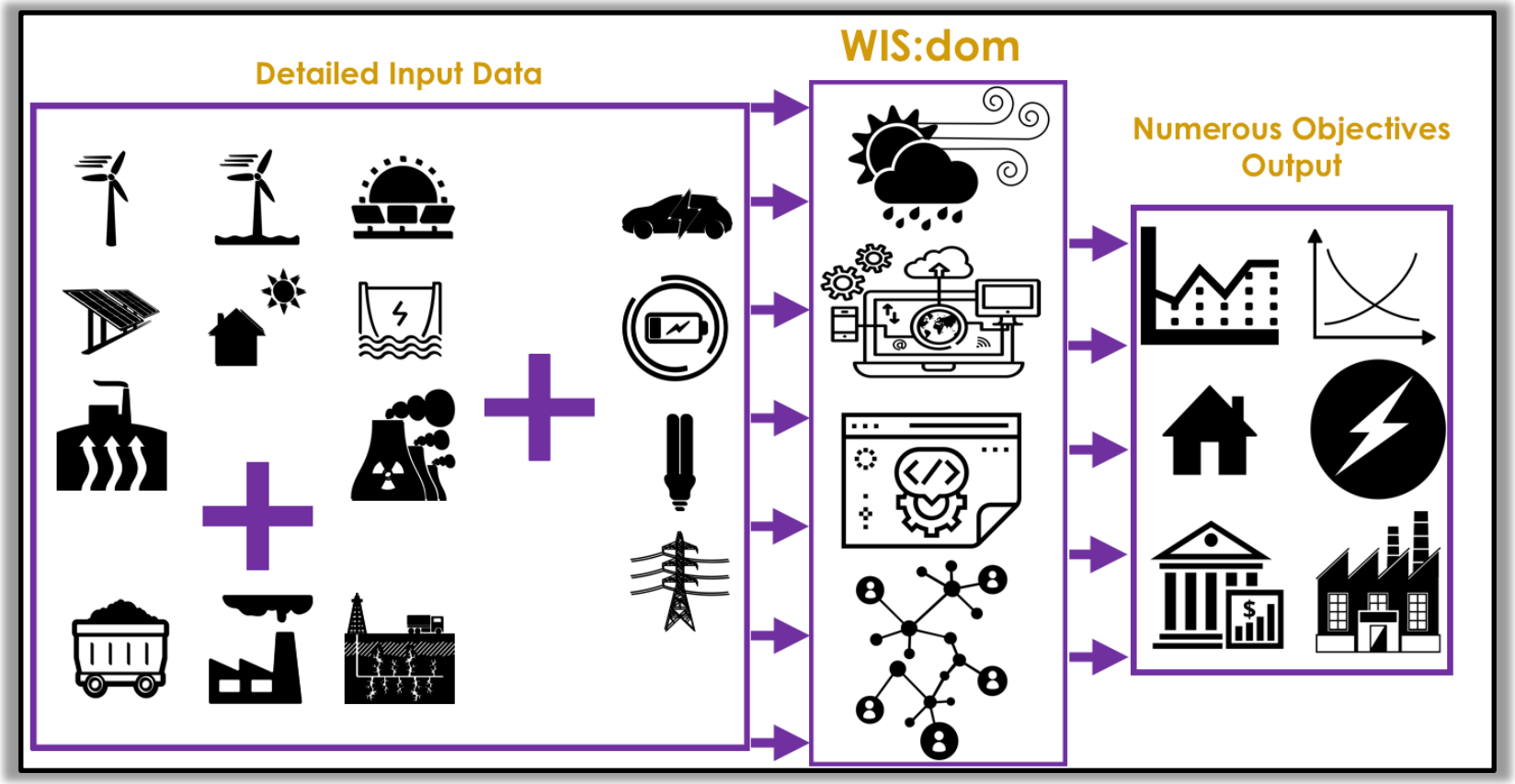
Outline of presentation

1. Tools VCE® uses and how we approach the problem of planning future scenarios;

2. General results from VCE® national studies with WIS:dom®;

3. Specific results from WIS:dom® for Colorado.

The WIS:dom® model co-optimizes generation, transmission, storage and DERS across the entire CONUS at 3-km for each chronological 5-minutes for multiple years



WIS:dom® is a synthesis model

WIS:dom is the ***only*** commercially available combined capacity expansion and production cost model. It combines:

- ✓ Continental-scale (globally capable), spatially-determined co-optimization of transmission, generation, storage, and demand-side resource expansion while simultaneously determining the dispatch of these sub systems at 3-km, 5-minutely resolution;
- ✓ Dispatch includes:
  - ➢ Individual unit commitments, start-up, shutdown profiles, and ramp constraints;
  - ➢ Transmission power flow, planning reserves, and operating reserves;
  - ➢ Detailed description of Distributed Generation Potential;
  - ➢ Weather forecasting and physics of weather engines;
  - ➢ Detailed hydro modeling;
  - ➢ High granularity for weather-dependent generation;
  - ➢ Chronological intervals for at least a full calendar year;
  - ➢ Existing generator and transmission asset attributes such as heat rates, line losses, power factor, variable costs, fixed costs, capital costs, fuel costs, etc.;
- ✓ Large spatial and temporal horizons;
- ✓ Policy and regulatory drivers such as PTC, ITC, RPS, RGGI, etc.;
- ✓ Detailed investment periods;
- ✓ Capable of including electrification of other sectors, hydrogen production, fuel price elasticity, Ammonia production, and carbon mitigation.

WIS:dom® can be defined as a blended capacity expansion & production cost model

Models	US	Trans Exp.	Gen Exp.	Gen Plan Spatially	Trans Plan Spatially	Temp Res	Spat Res (km^2)	Physics of Weather	Forecasts	W+S Tech count	Hydro Modeling	Global Capable	Disaggregate	Horizon	Invest Periods	Hardware	Elec Power Flow Realized
ReEDs	Y	Y	Y	N*	Y	17	2,472 (NA only)	N	N	3	N	N	Time slices, most T constrained	2050	25	Desktop; HPC	N
Switch	N	Y	Y	Y	Y	288	25	N	N	4-5	N	N*	WECC only and temporal splicing	2050	5	Desktop	N
GE Maps	N	Y*	Y	Y	N	760	~2500 (NA only)	N	N	3	N	N*	Only small areas	1 YR	1	Desktop LInux cluster	DC no loss
ABB Grid View	N	Y*	Y	Y	N	760	~2500 (NA only)	N	N	3	N	N*	Only small areas	1 YR	1	Desktop LInux cluster	DC no loss
Plexos	N	N	Y	N	N	8766	4 (no standard)	N	Y	3	Some	Y	Only small areas	1 YR	1	Desktop LInux cluster; HPC	DC (plus AC, but only technically)
WIS:dom®	**Y**	**Y**	**Y**	**Y**	**Y**	**8766 105,192 / yr 10 or 5 years US 1 year Global**	**9 - USA 49 - Globe**	**Y**	**Y 2, 6, 12 hr**	**Wind 35; Solar 40; Storage included**	**Detailed using weather and hydro data**	**Y**	**None: couples high granularity with large space temporal horizons**	**2050**	**6-16: blind and seer mode**	**High powered servers; Powerful Desktops; Simpler Version Laptops**	**DC with losses, Kirchhoff laws, reliability, substations and existing lines**
IAM	Y	N	Y	N	N	1-100	250,000	Y	N	3-5	Y	Y	Long time averages; low spatial res	2100	10	Desktop all the way to HPC	N

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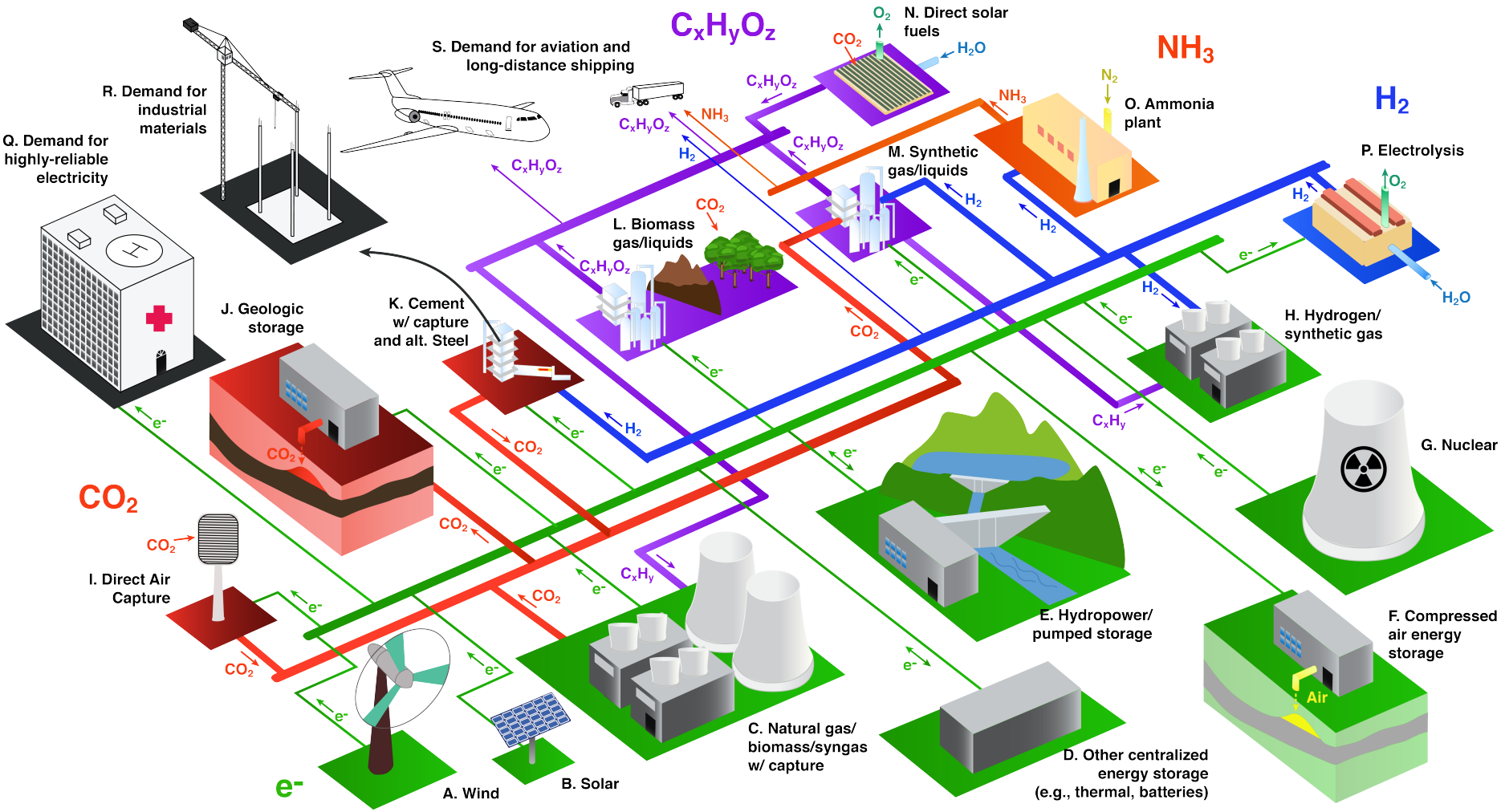
The whole economy needs energy



Davis et al. *Science*, 2018

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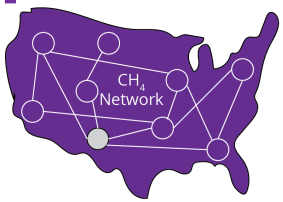
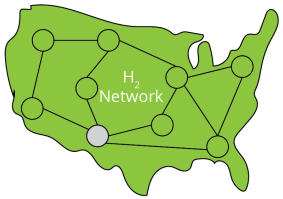
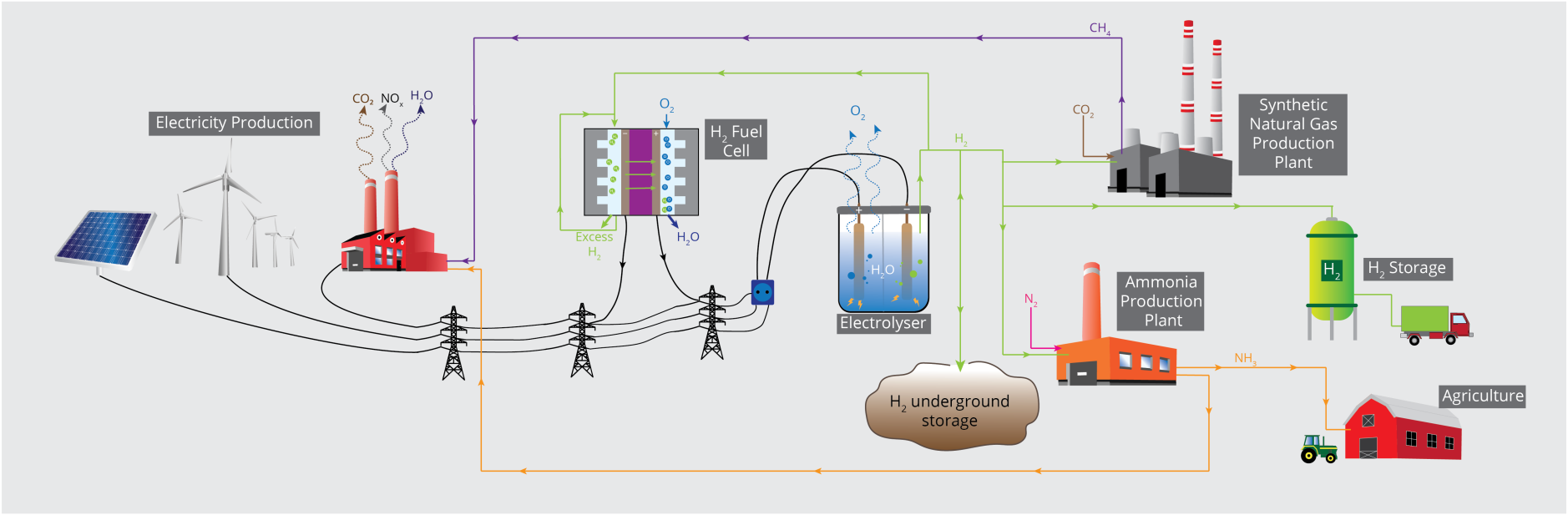
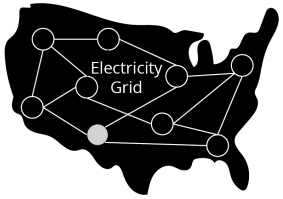
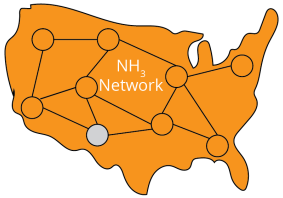
The interconnection between sectors will create possible emergent behavior











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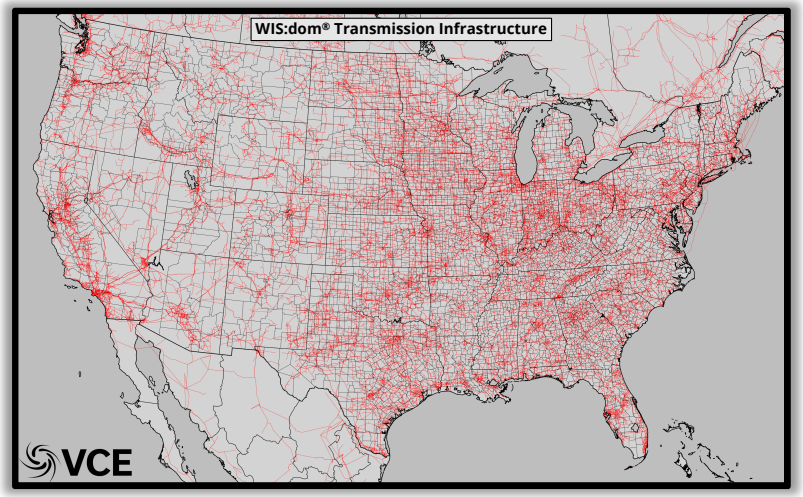
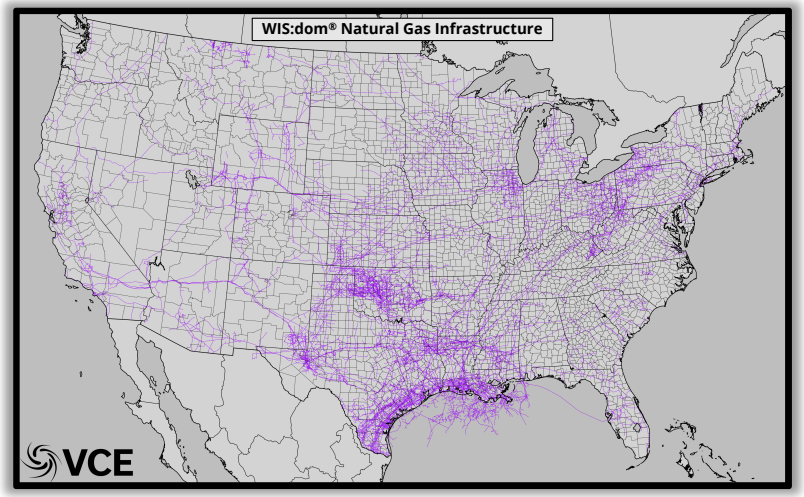
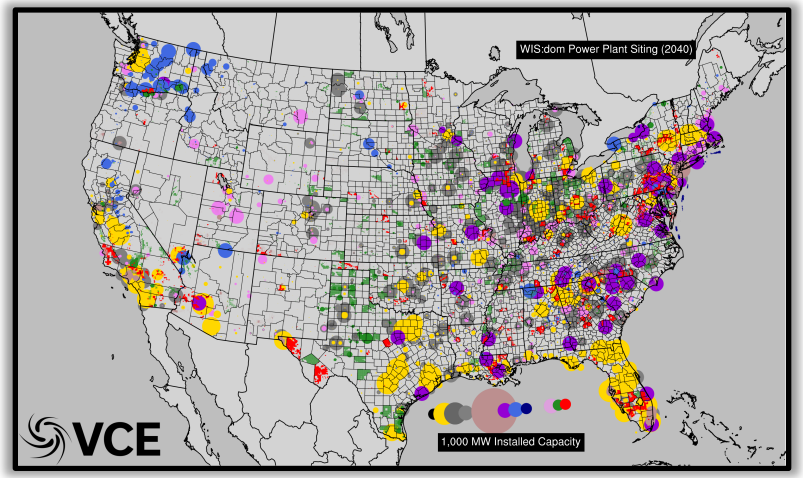
The WIS:dom® model co-optimizes across sectors that are dependent upon each other when considering economy wide decarbonization







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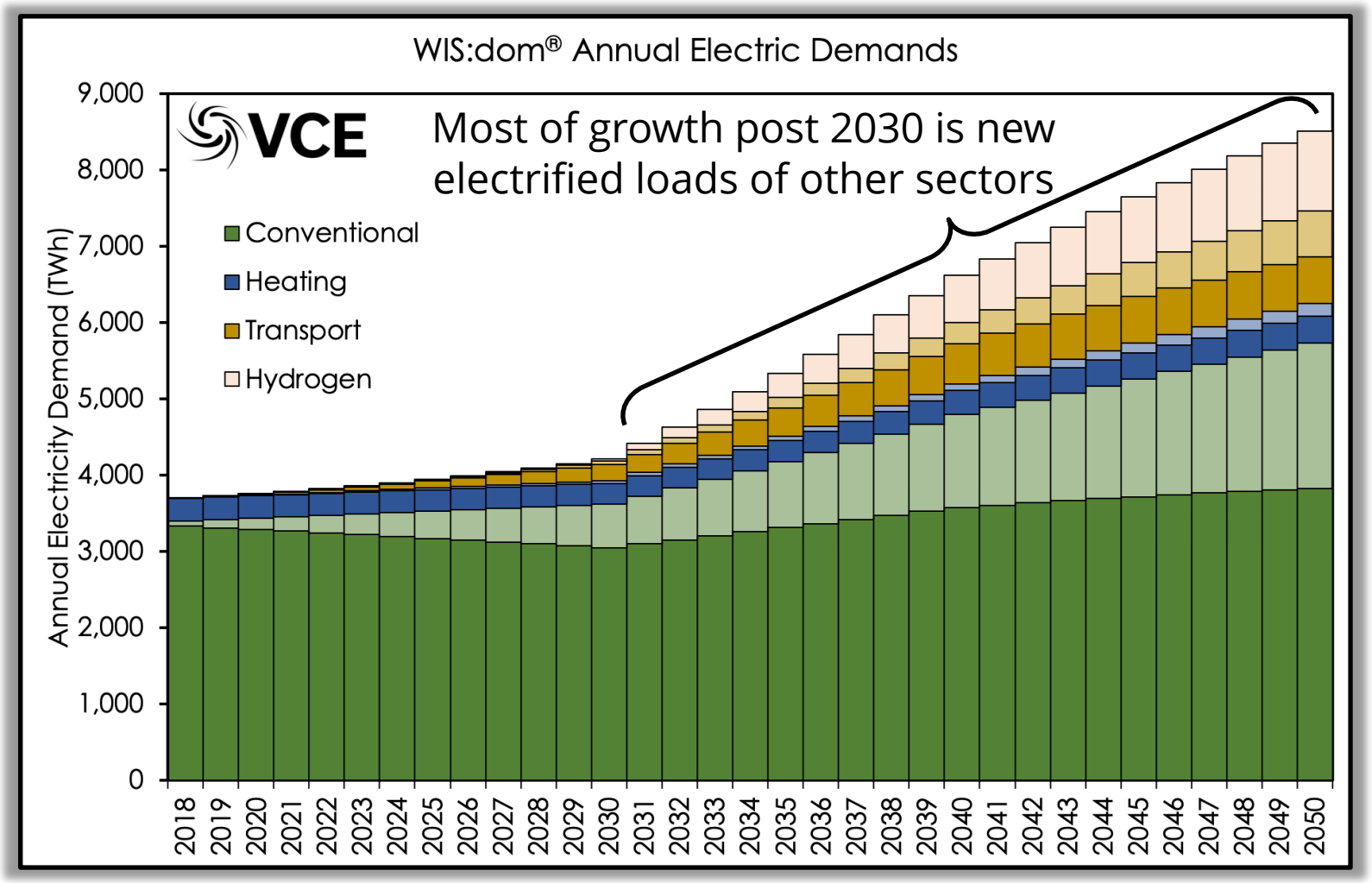
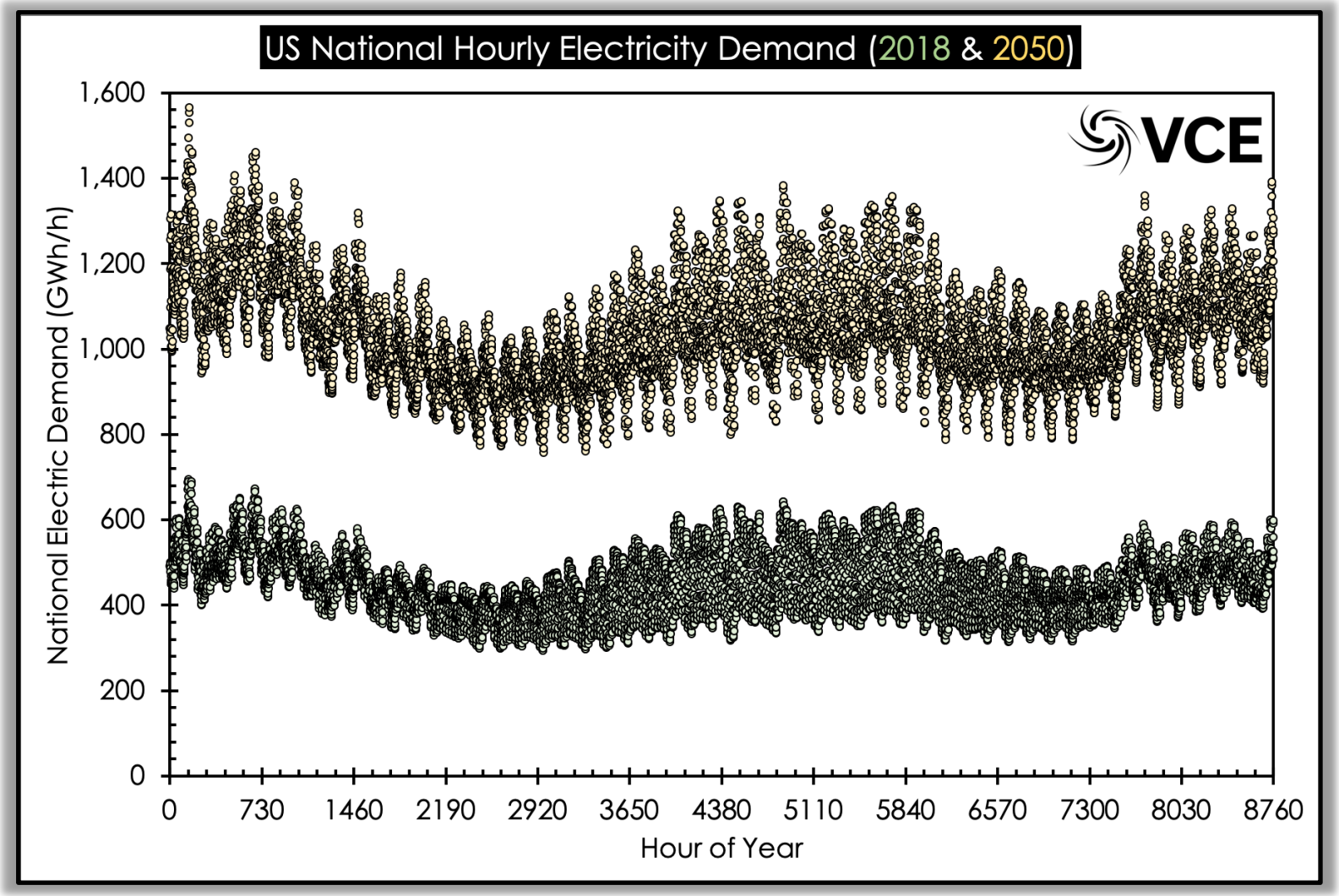
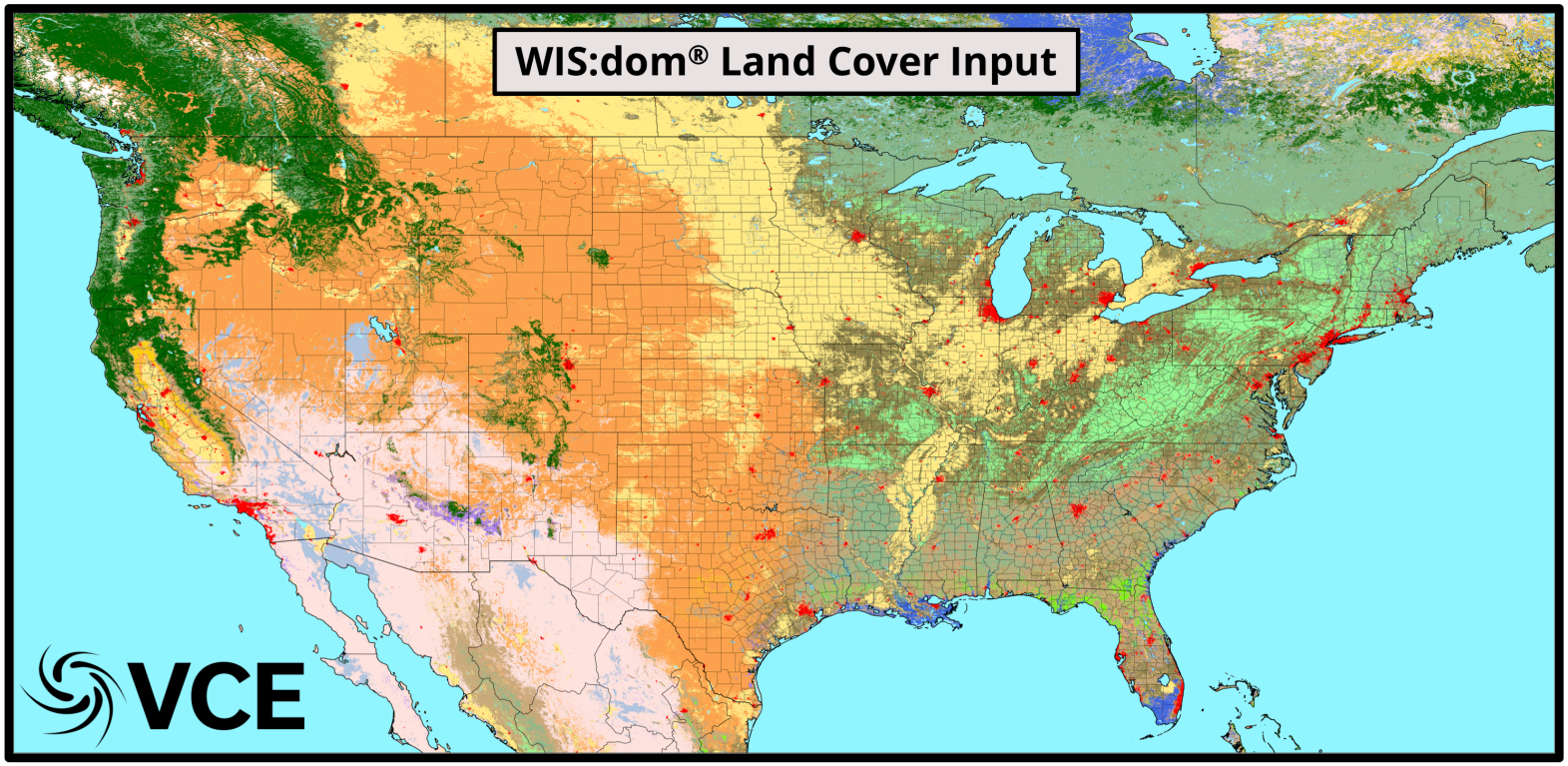
Electrification changes electricity needs



Electrification changes electricity needs everywhere

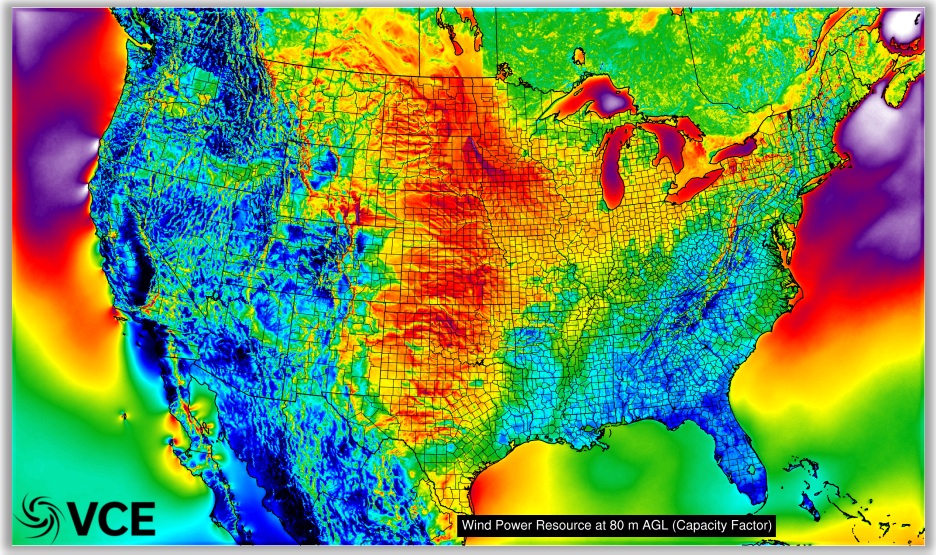


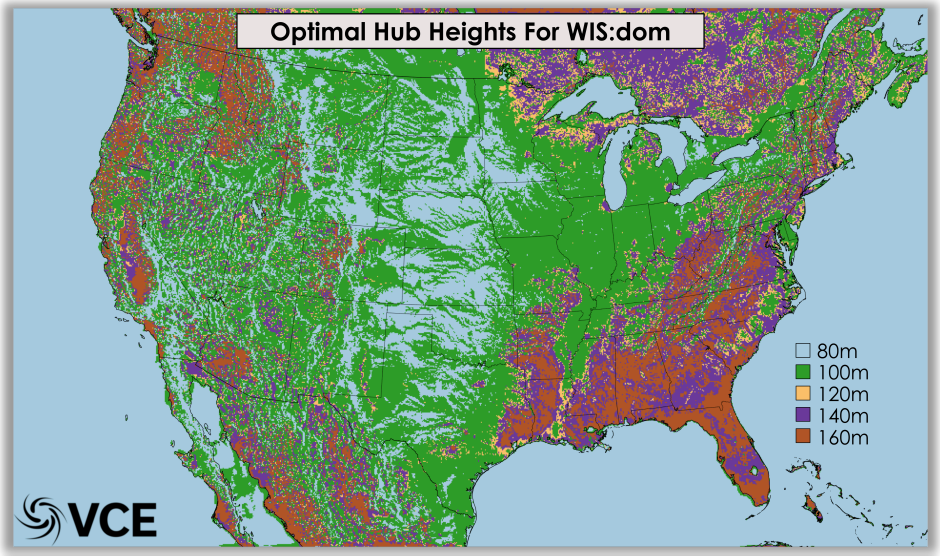
Land use-informed modeling

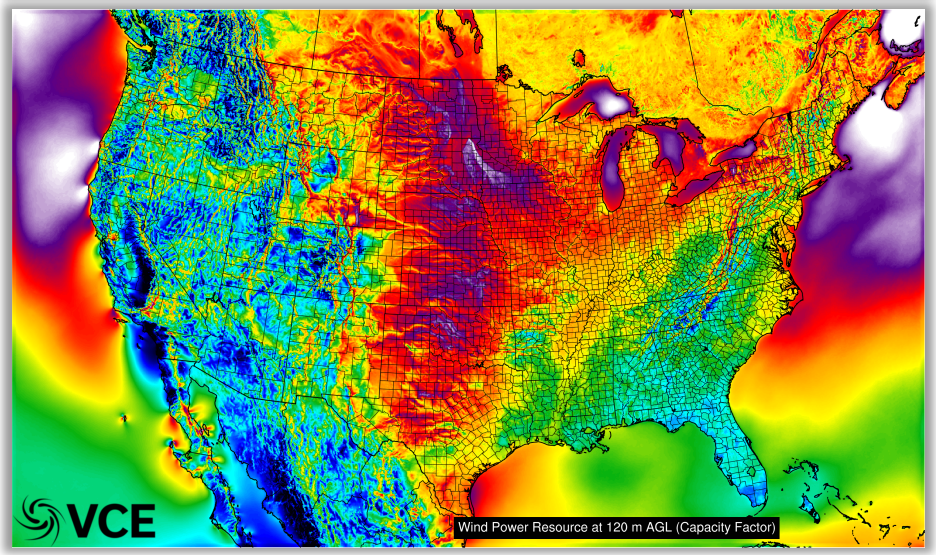


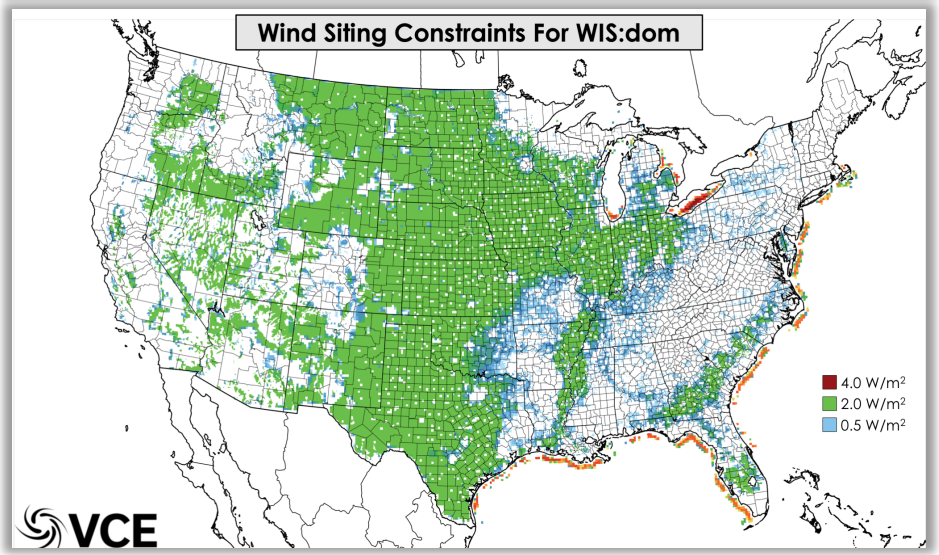
Original Data Source: *https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd12c1*

Weather-informed modeling









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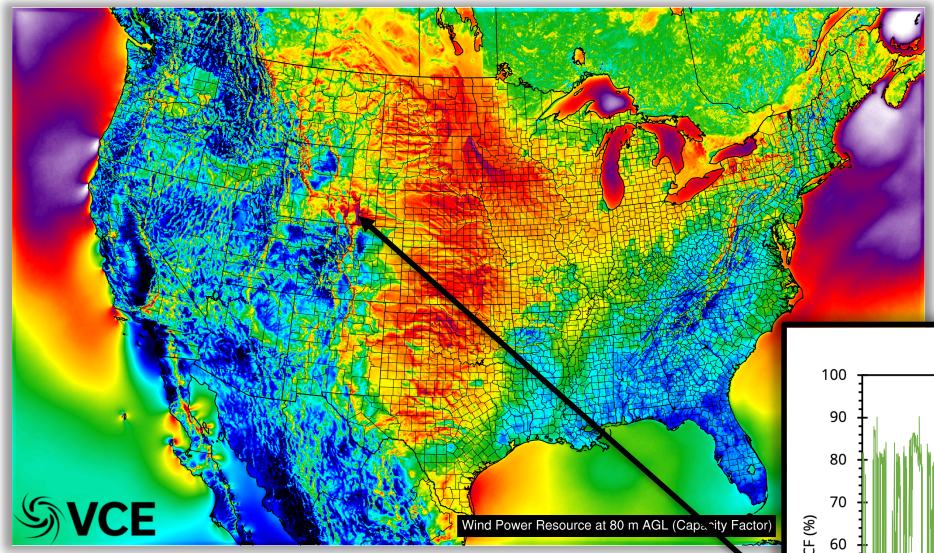
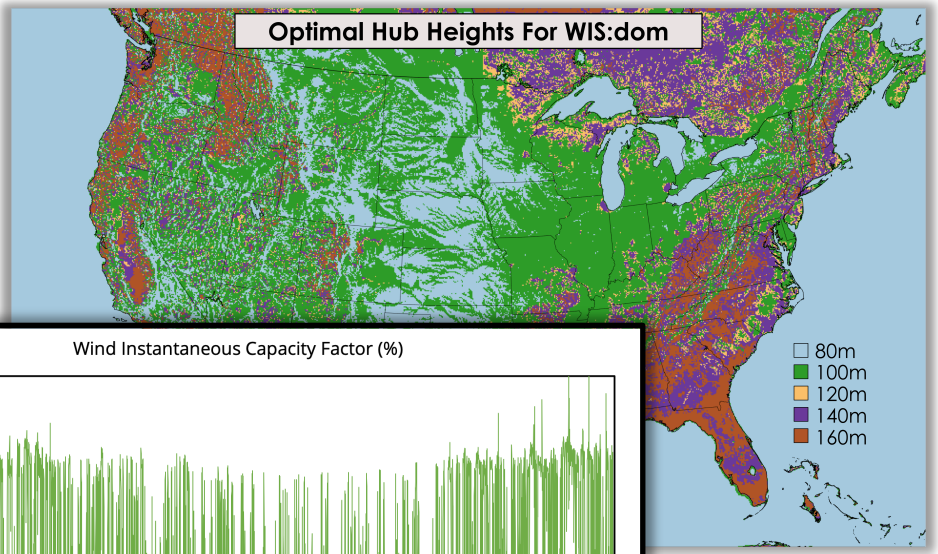
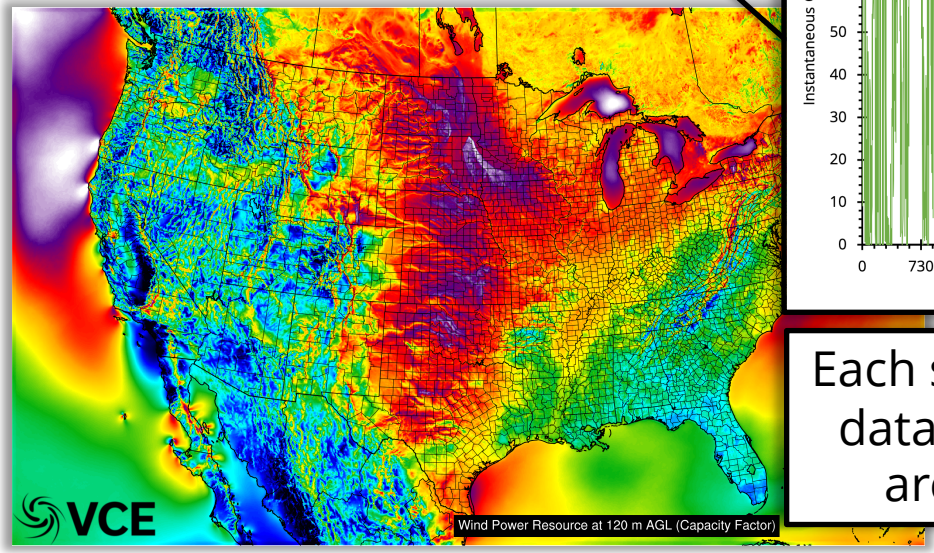
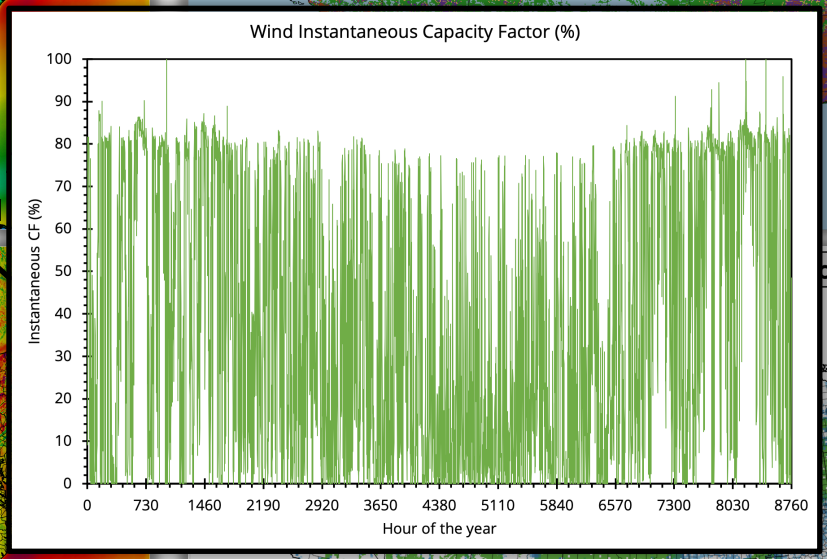
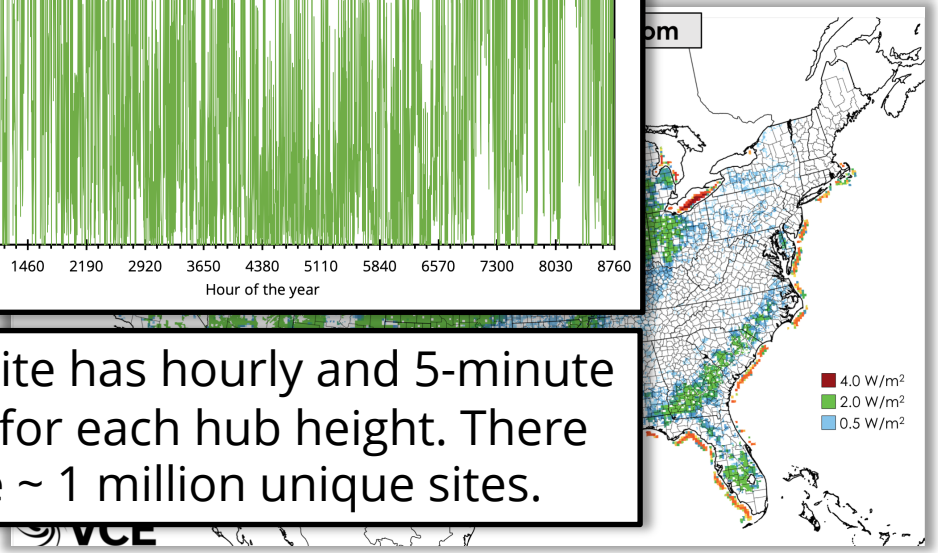
Weather-informed modeling











Each site has hourly and 5-minute data for each hub height. There are ~ 1 million unique sites.

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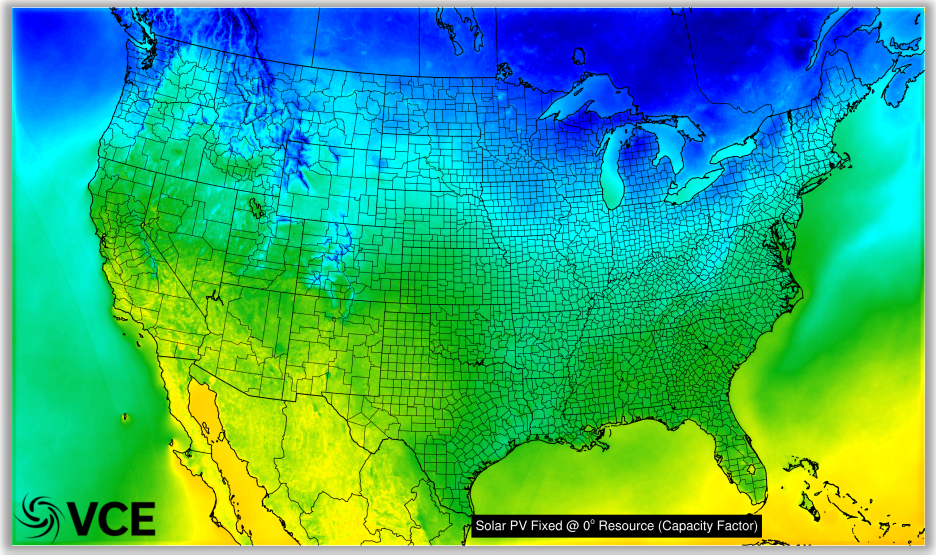
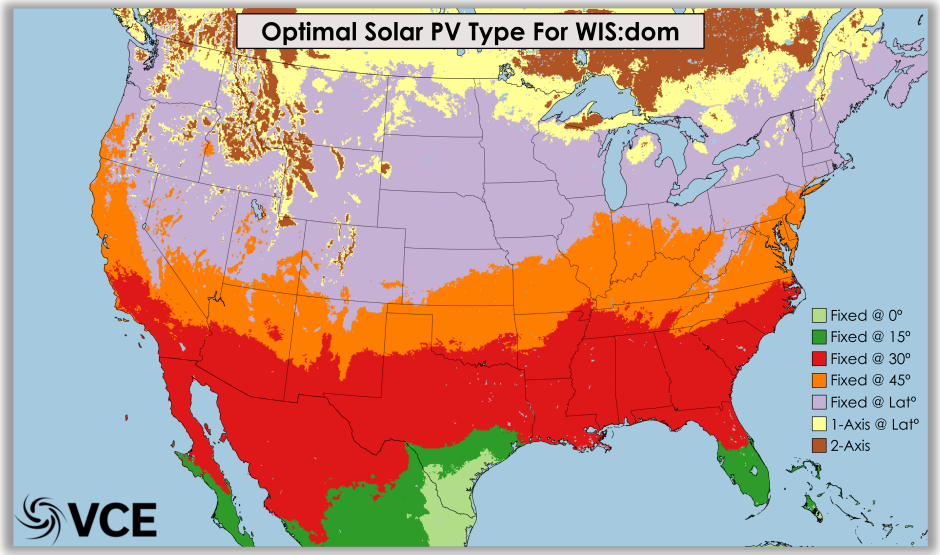
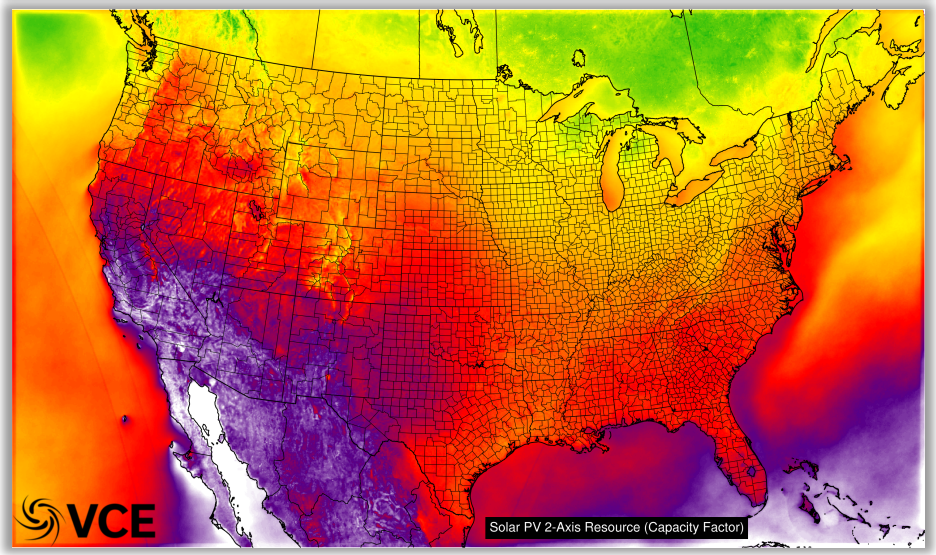
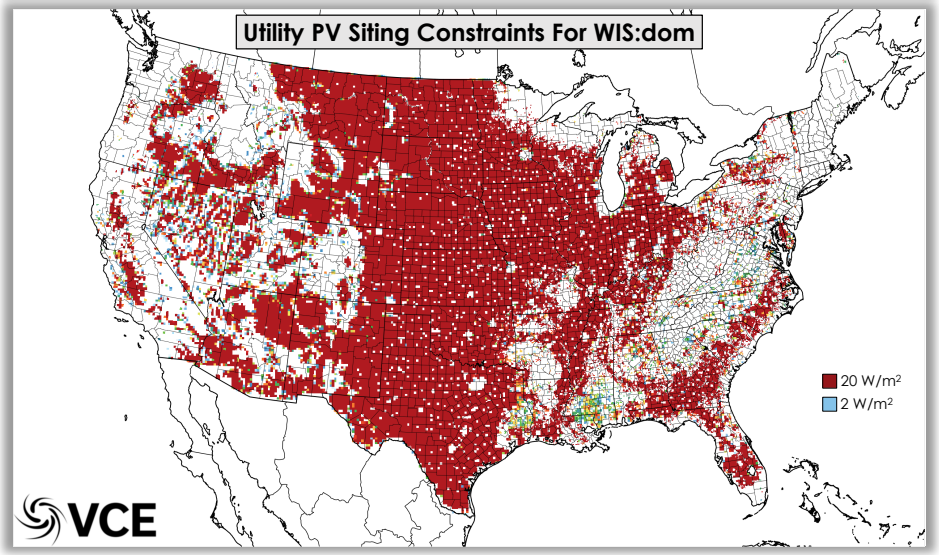
Weather-informed modeling









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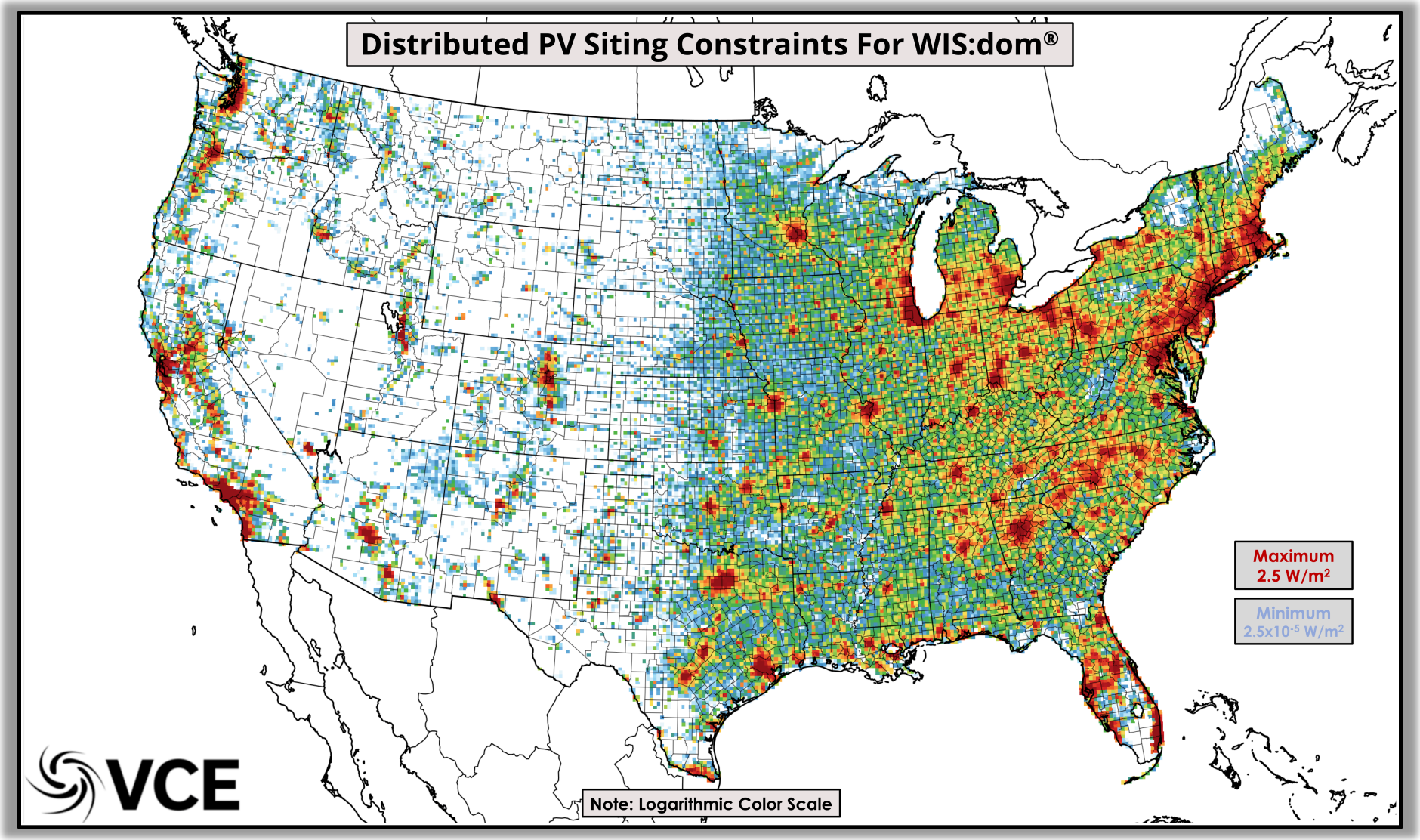
Advanced screening for distributed PV



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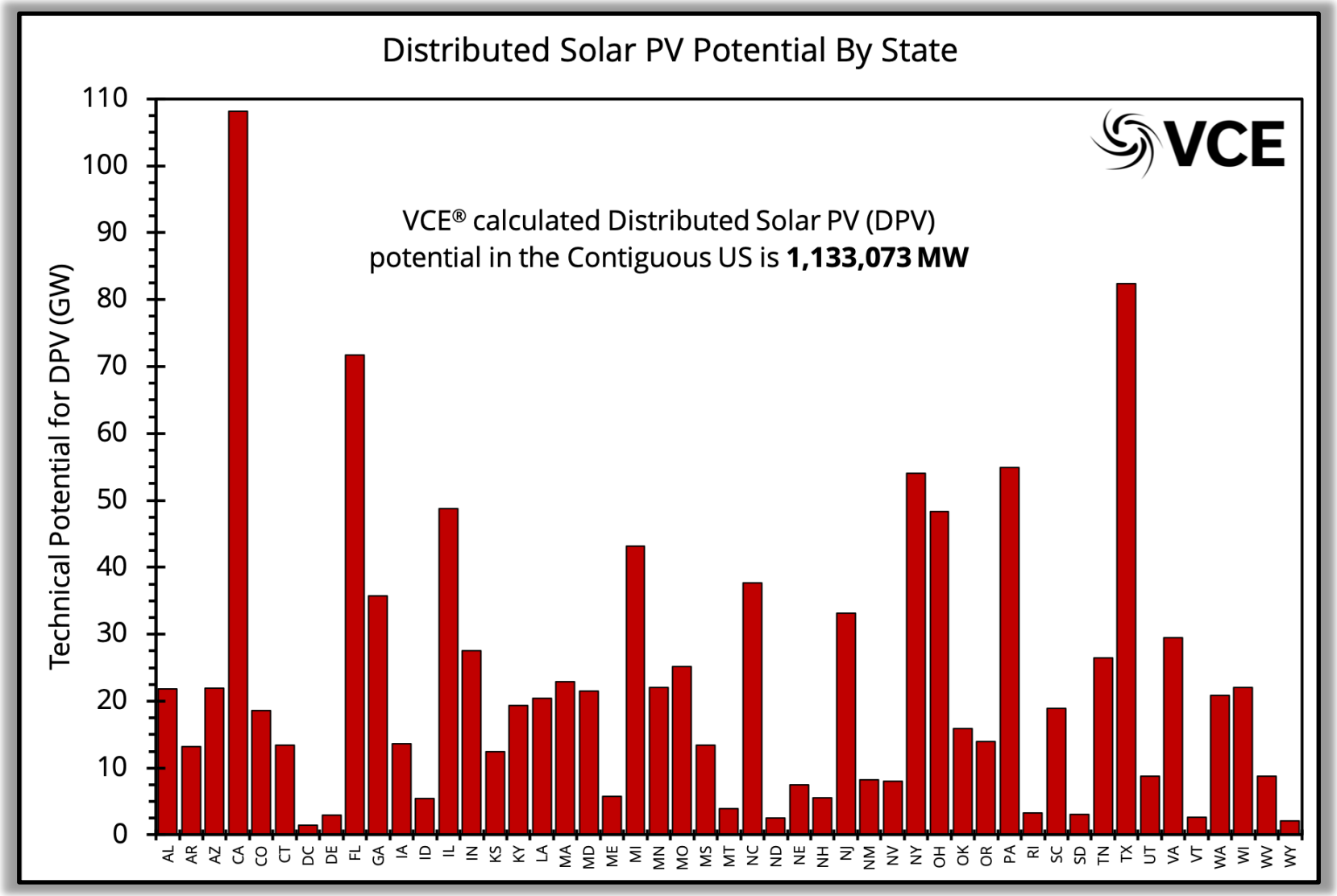
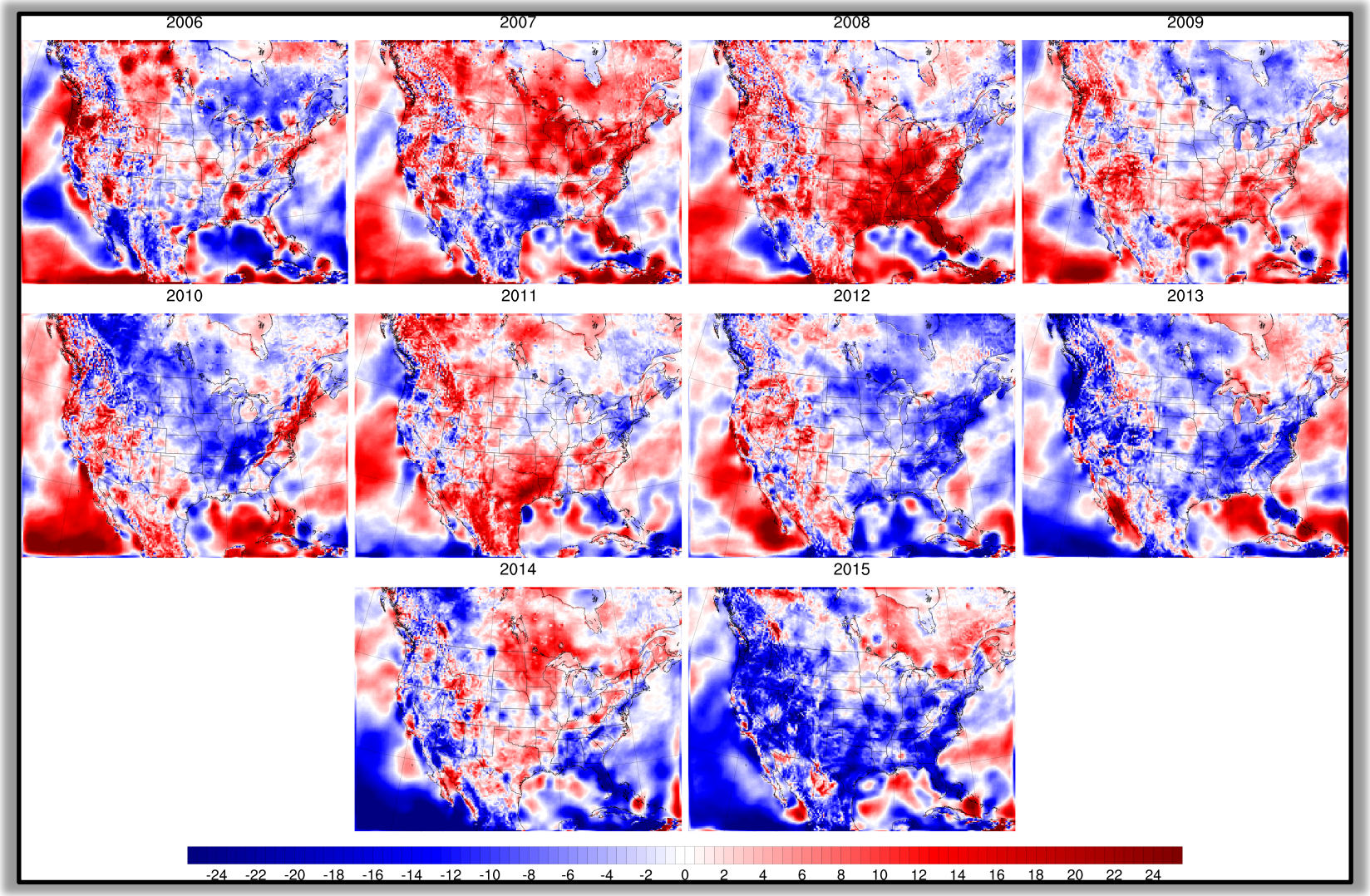


Multi-year data are necessary in WIS:dom®



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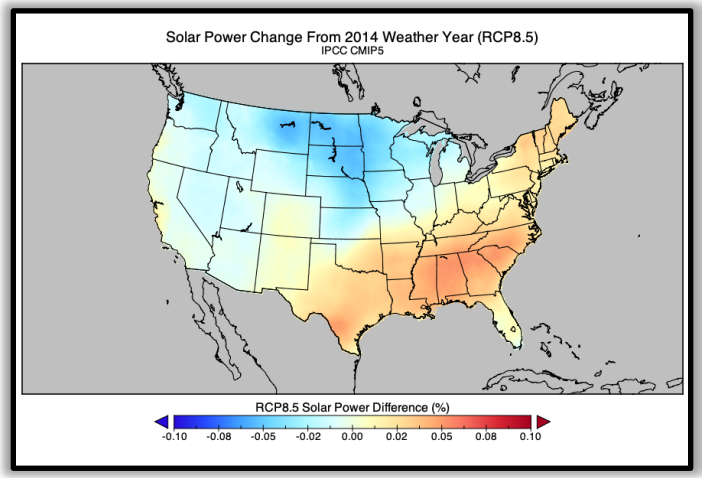
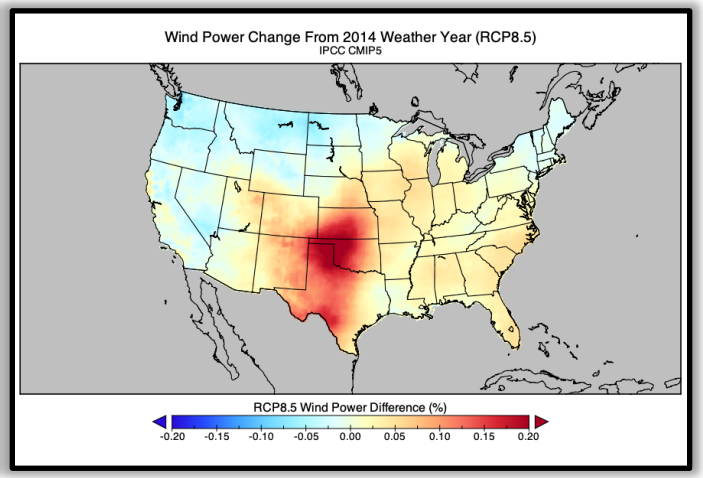
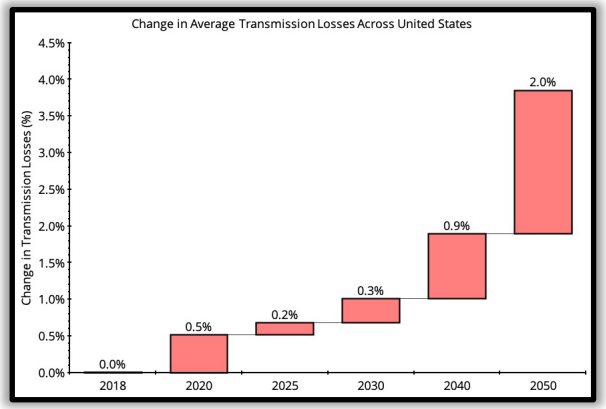
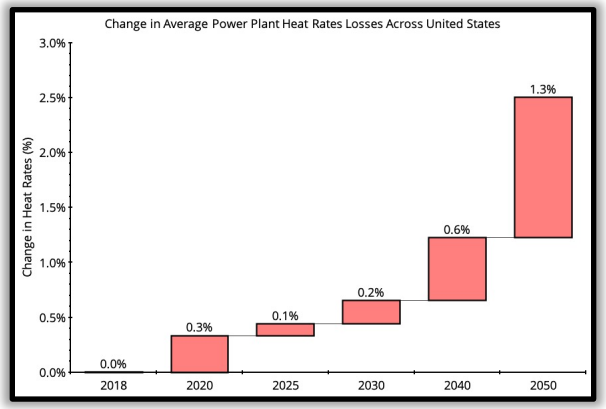
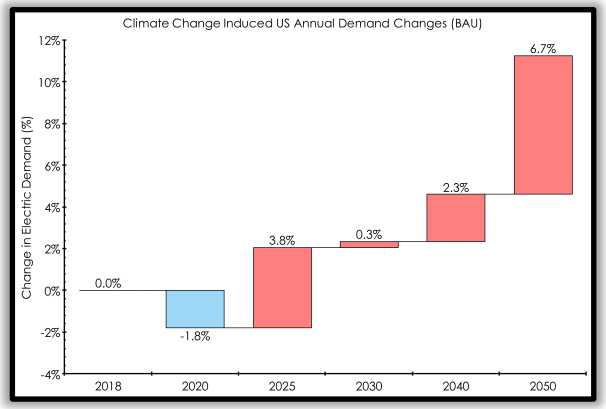
Climate change data can be included WIS:dom®











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Outline of presentation

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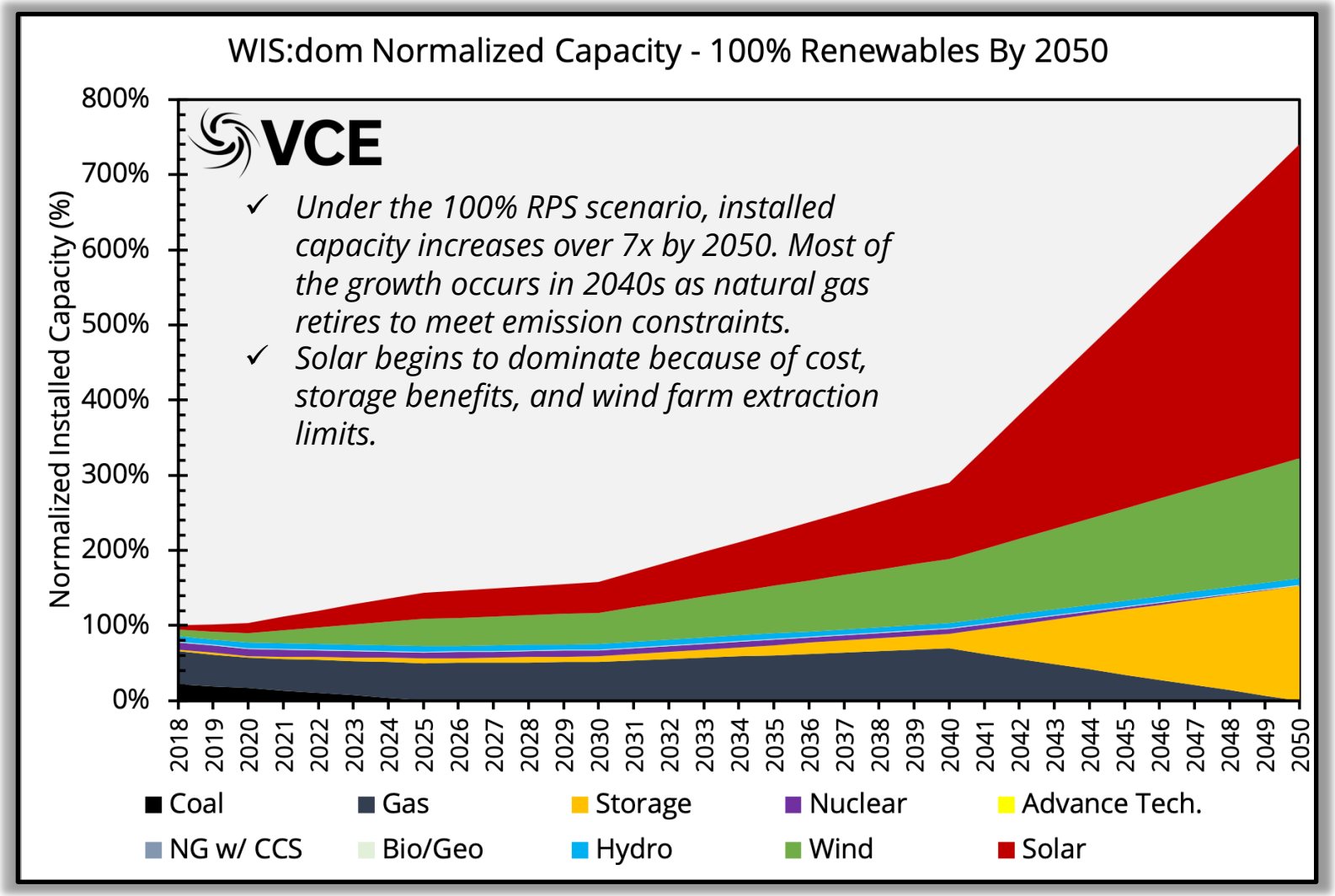
100% Renewable energy capacity for contiguous US



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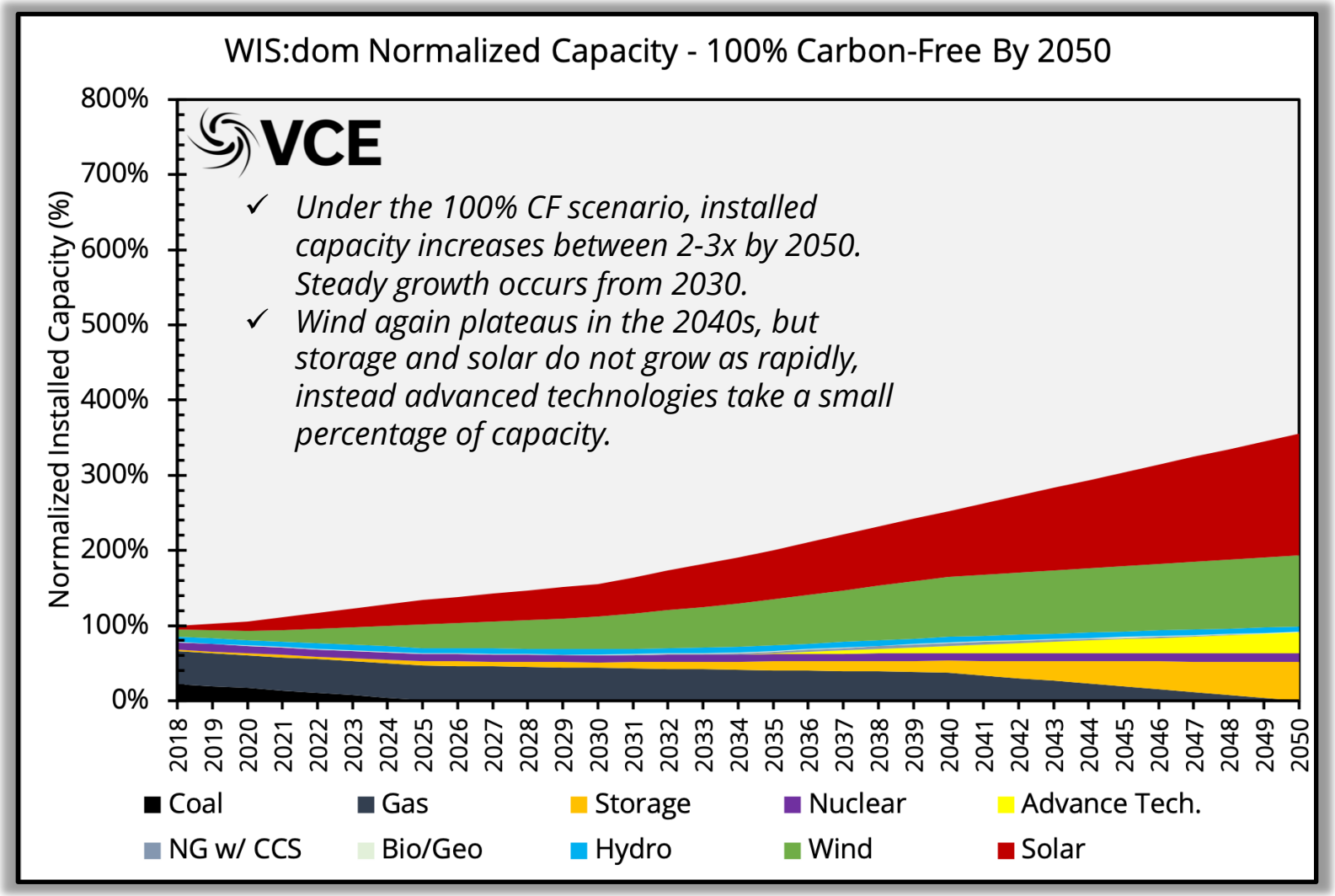
100% clean energy capacity for contiguous US



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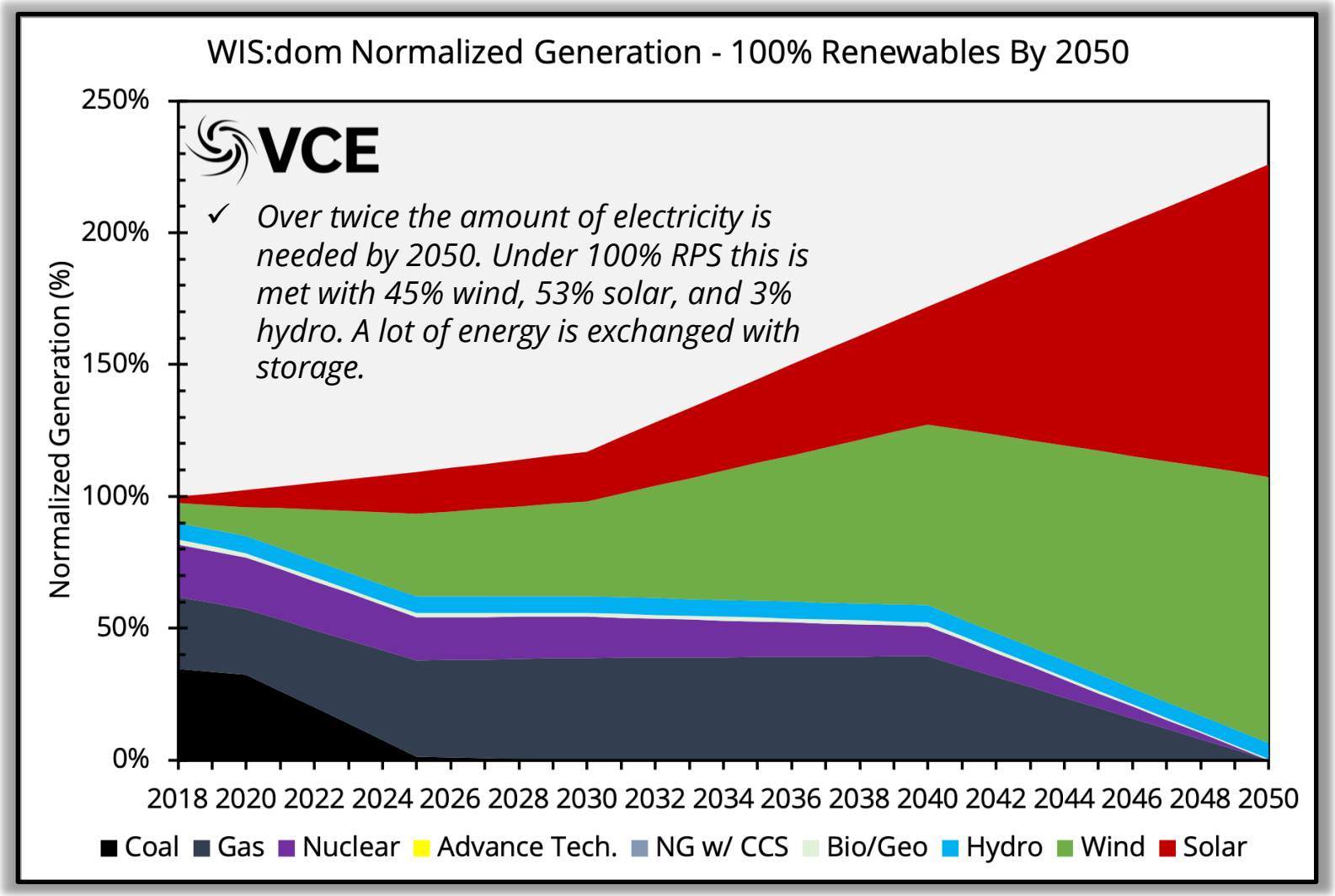
100% renewable energy generation for contiguous US



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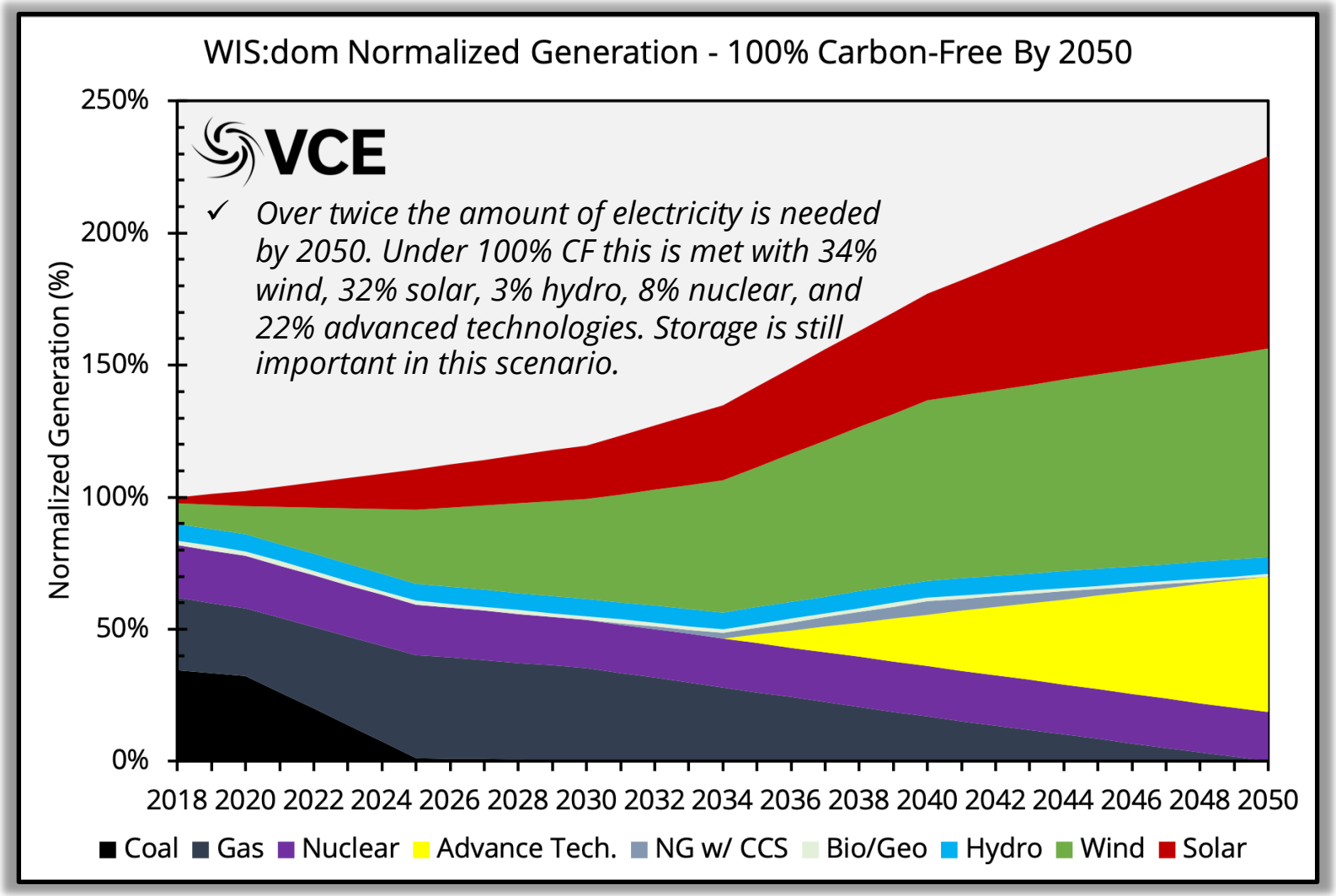
100% clean energy generation for contiguous US



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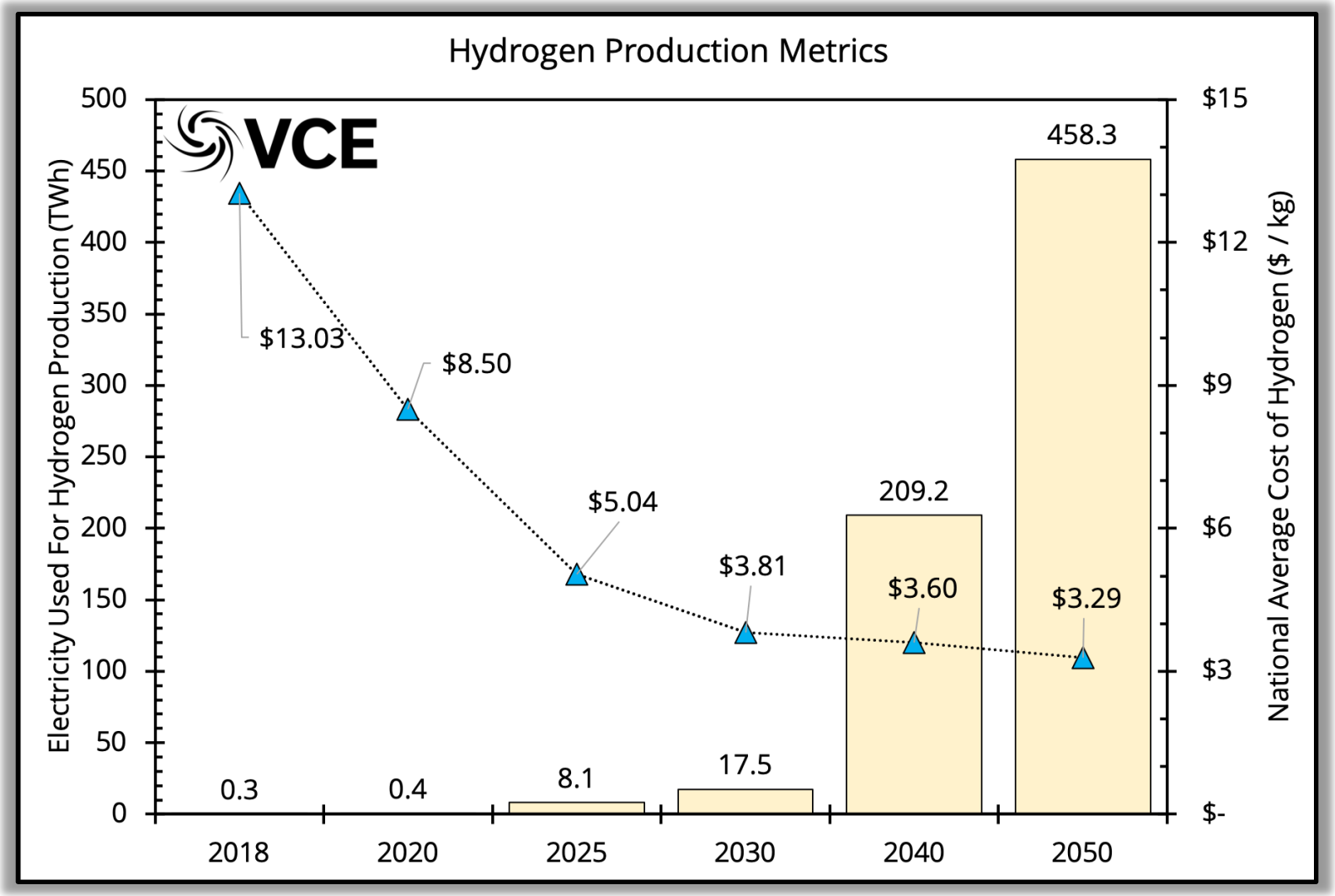
100% renewable energy for contiguous US



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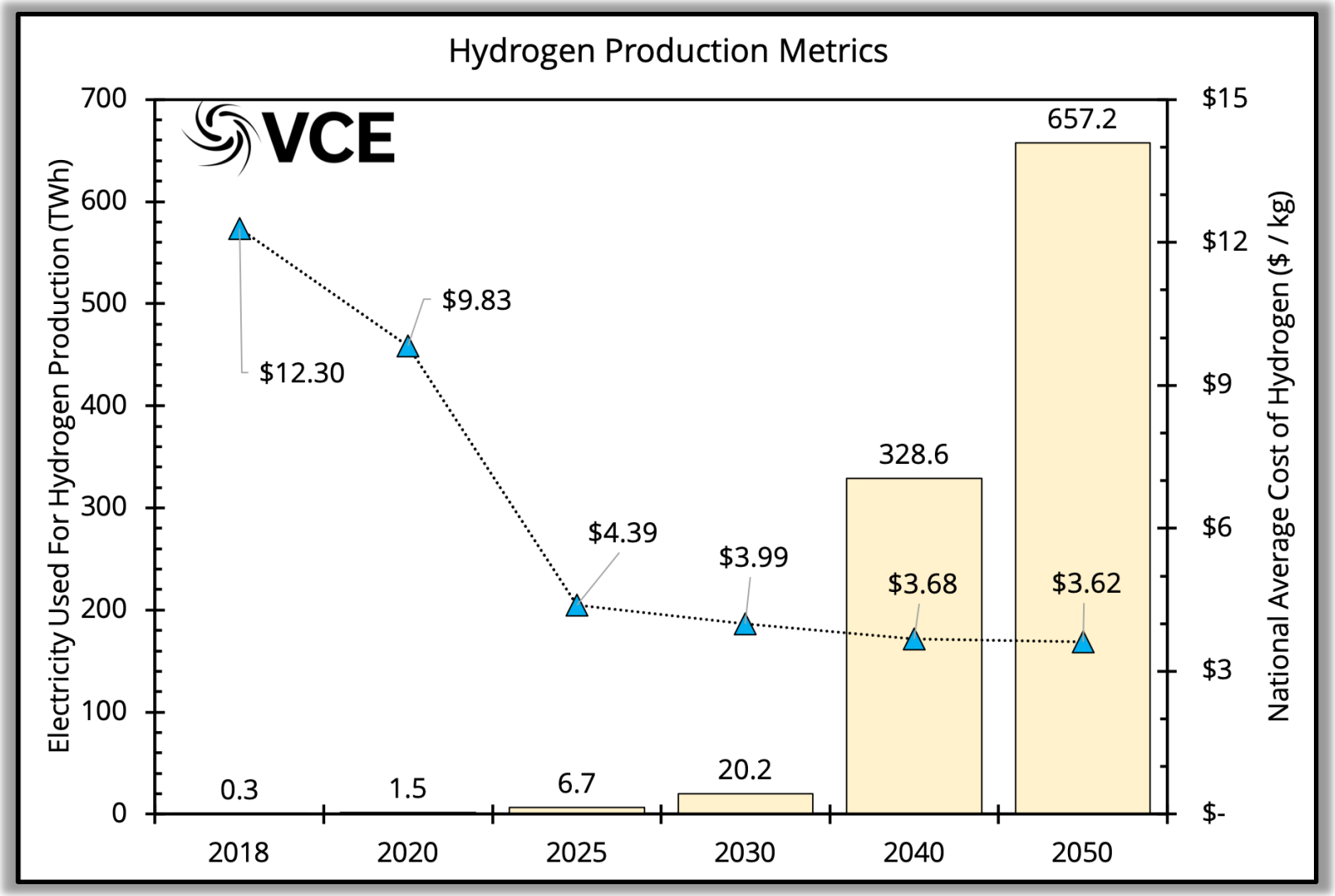
100% clean energy for contiguous US



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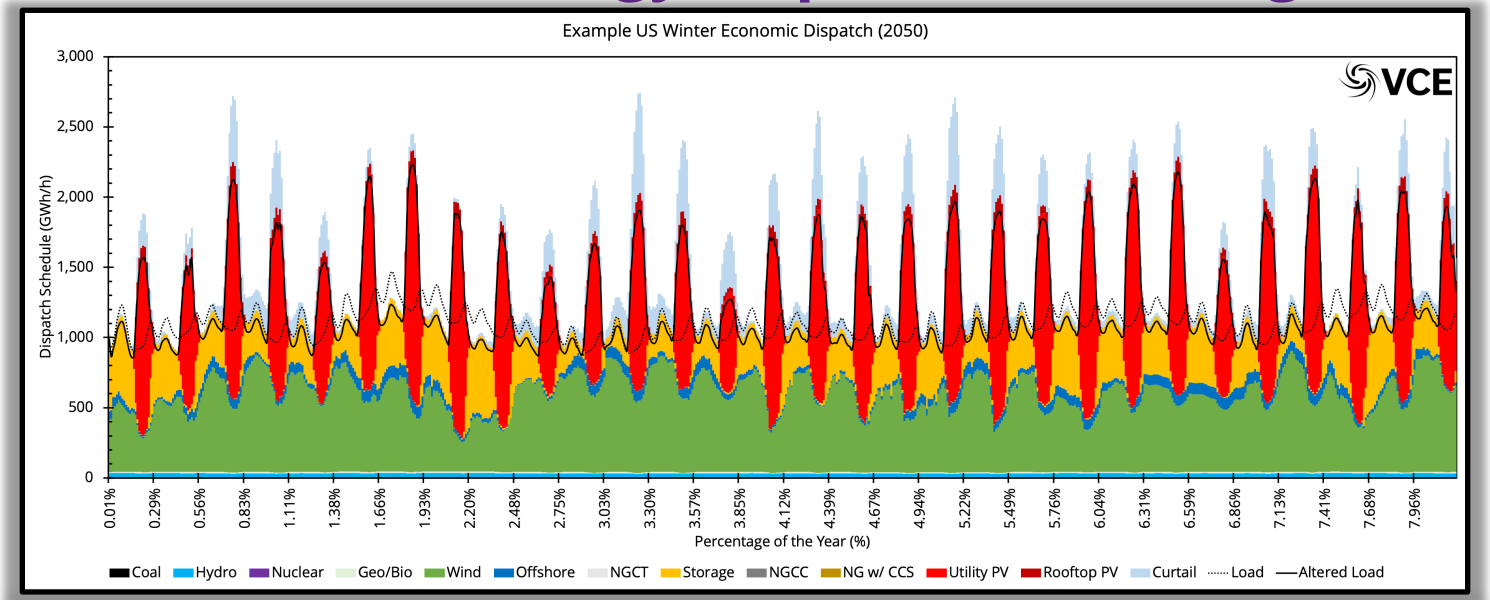
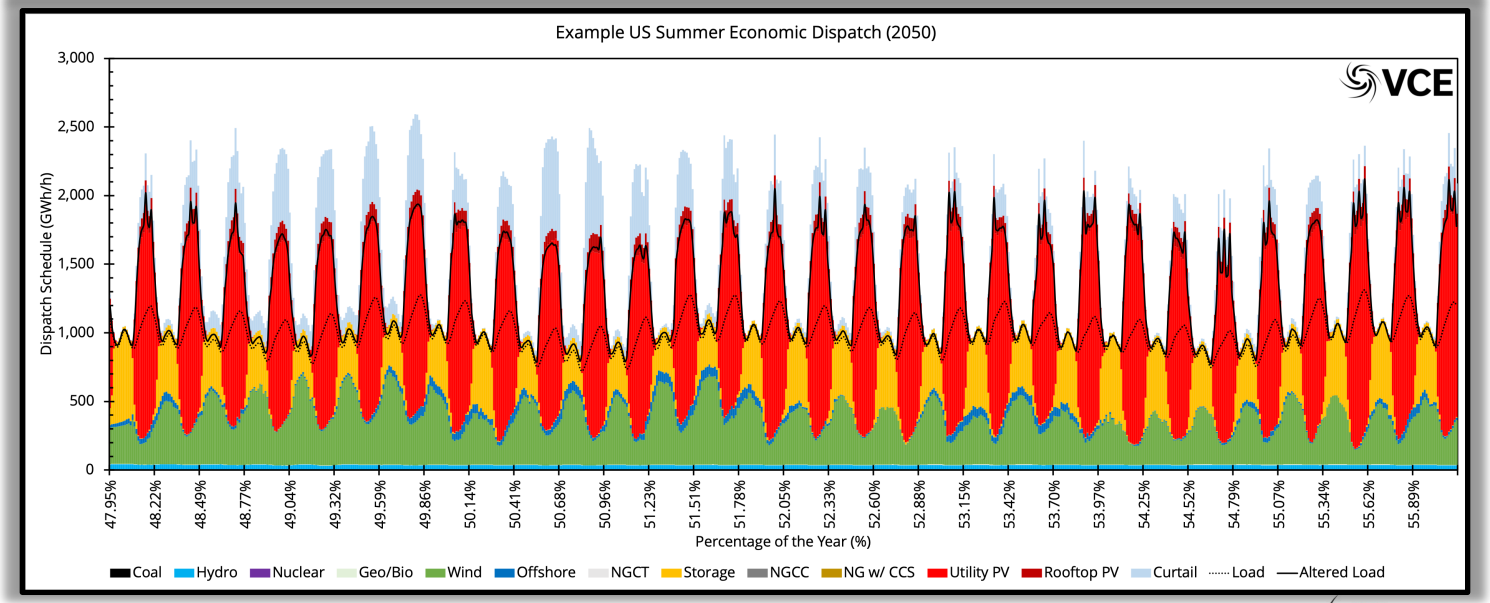
100% renewable energy dispatch for contiguous US





✓ *Annual curtailment by 2050 is 15% of generation – this is the most economic it could be (the model includes storage, HVDC, H2 production, reserves from curtailment, etc.)*

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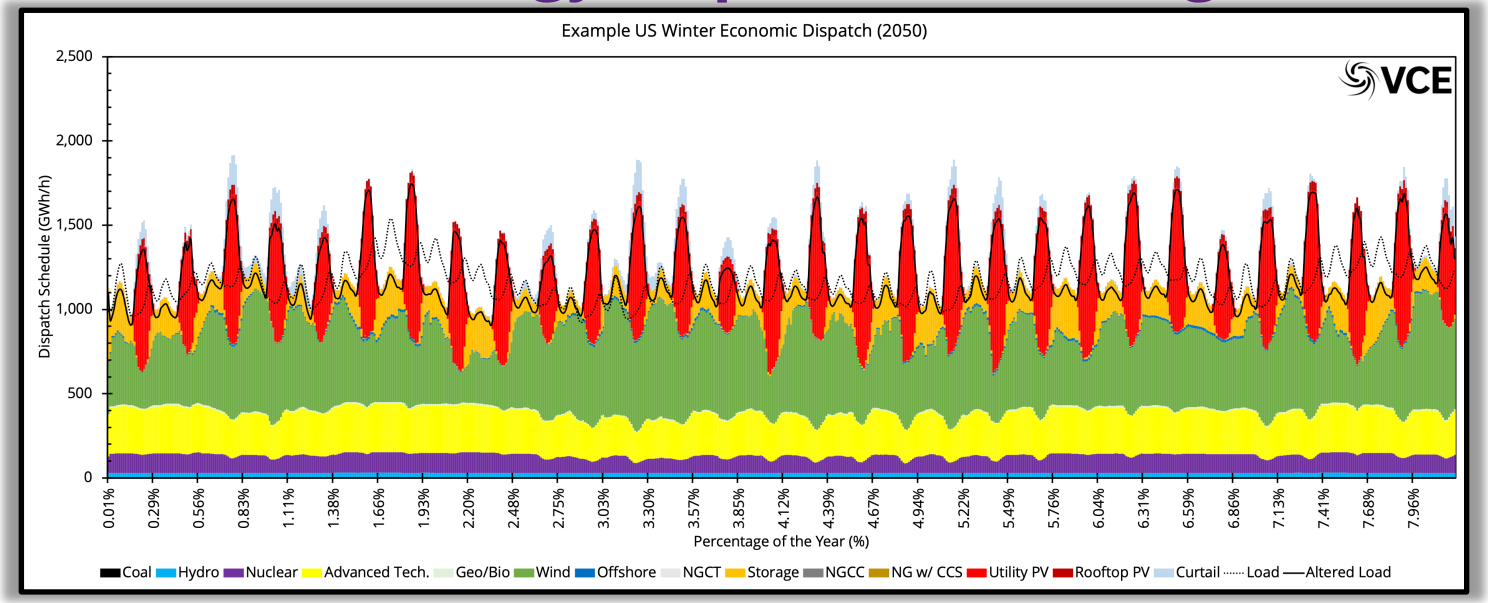
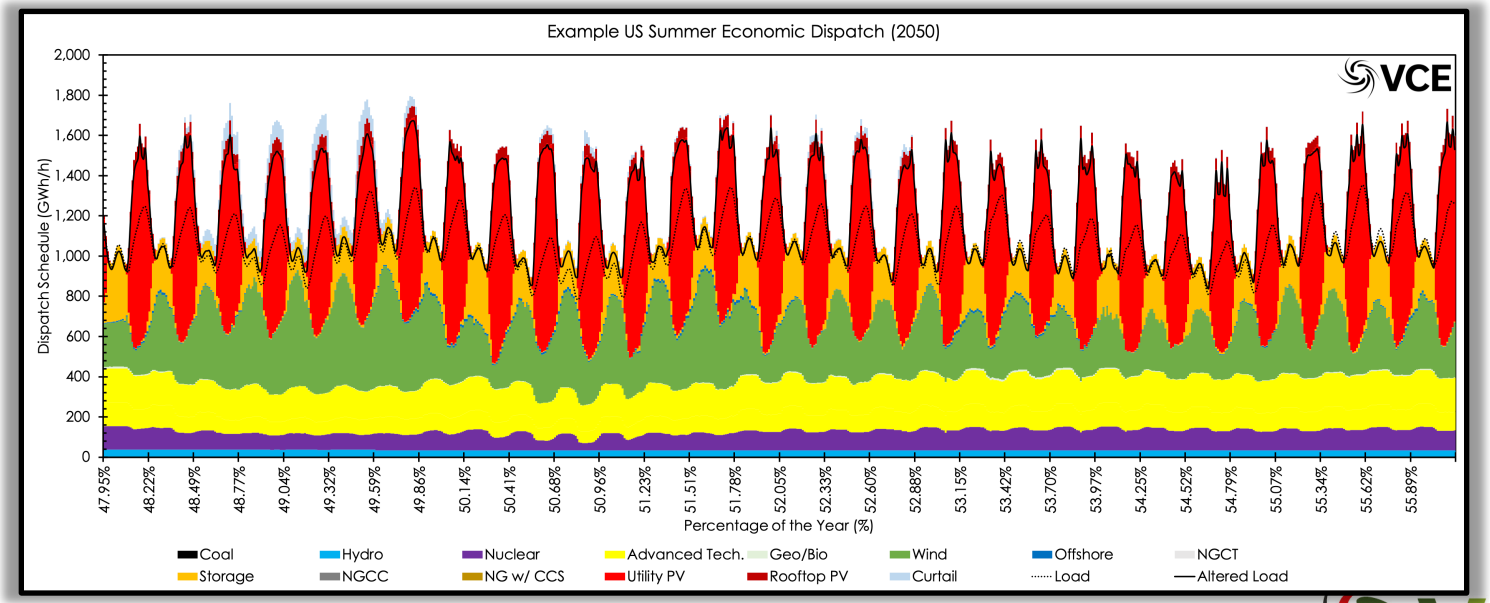
100% clean energy dispatch for contiguous US





✓ *Annual curtailment by 2050 is 4% of generation – Much less wasted energy.*

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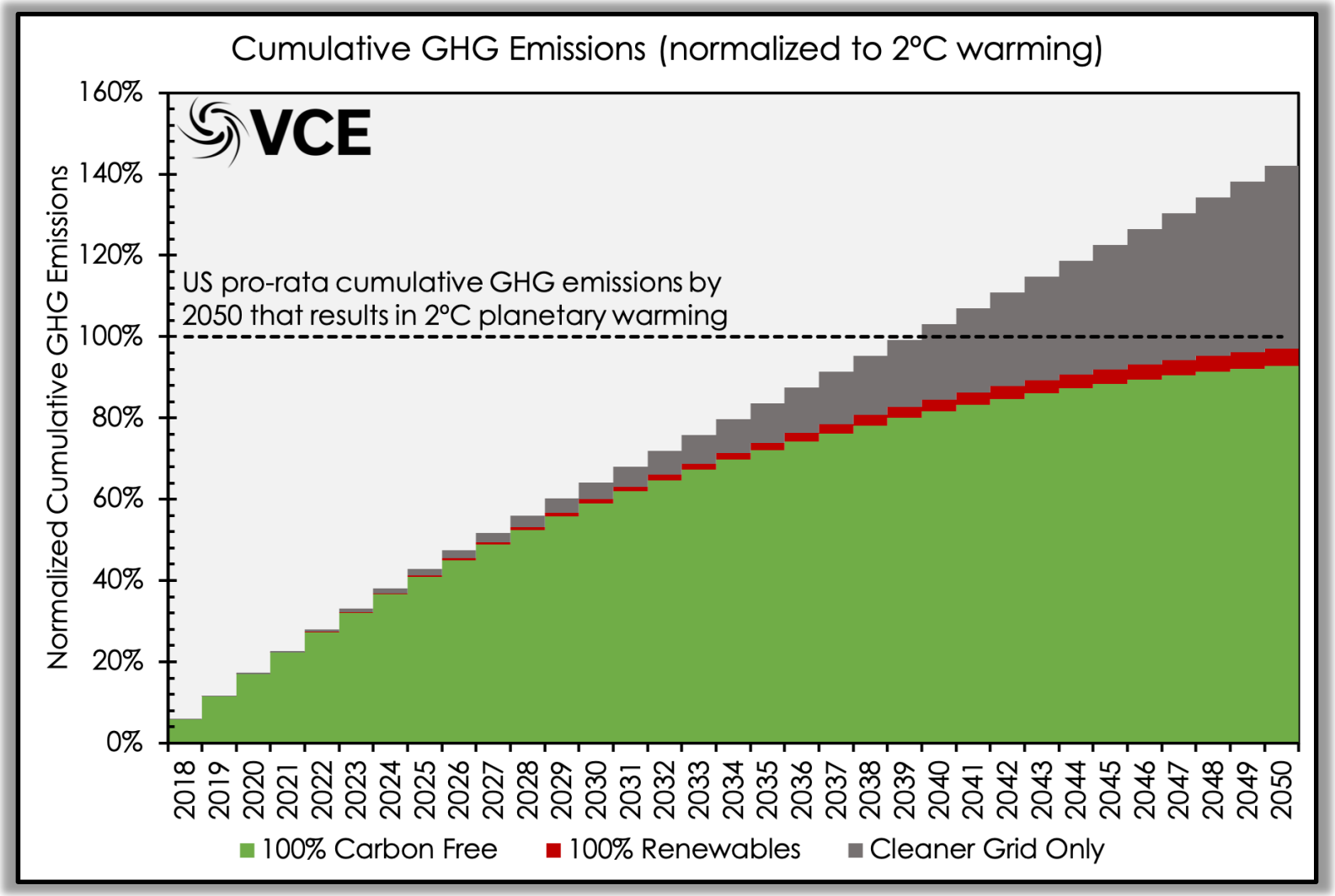
GHG emissions for contiguous US



✓ *Both 100% RPS and 100% CF reach 80% GHG emission reductions from 1990 levels by 2050 across the whole economy. The electricity system is zero emissions.*

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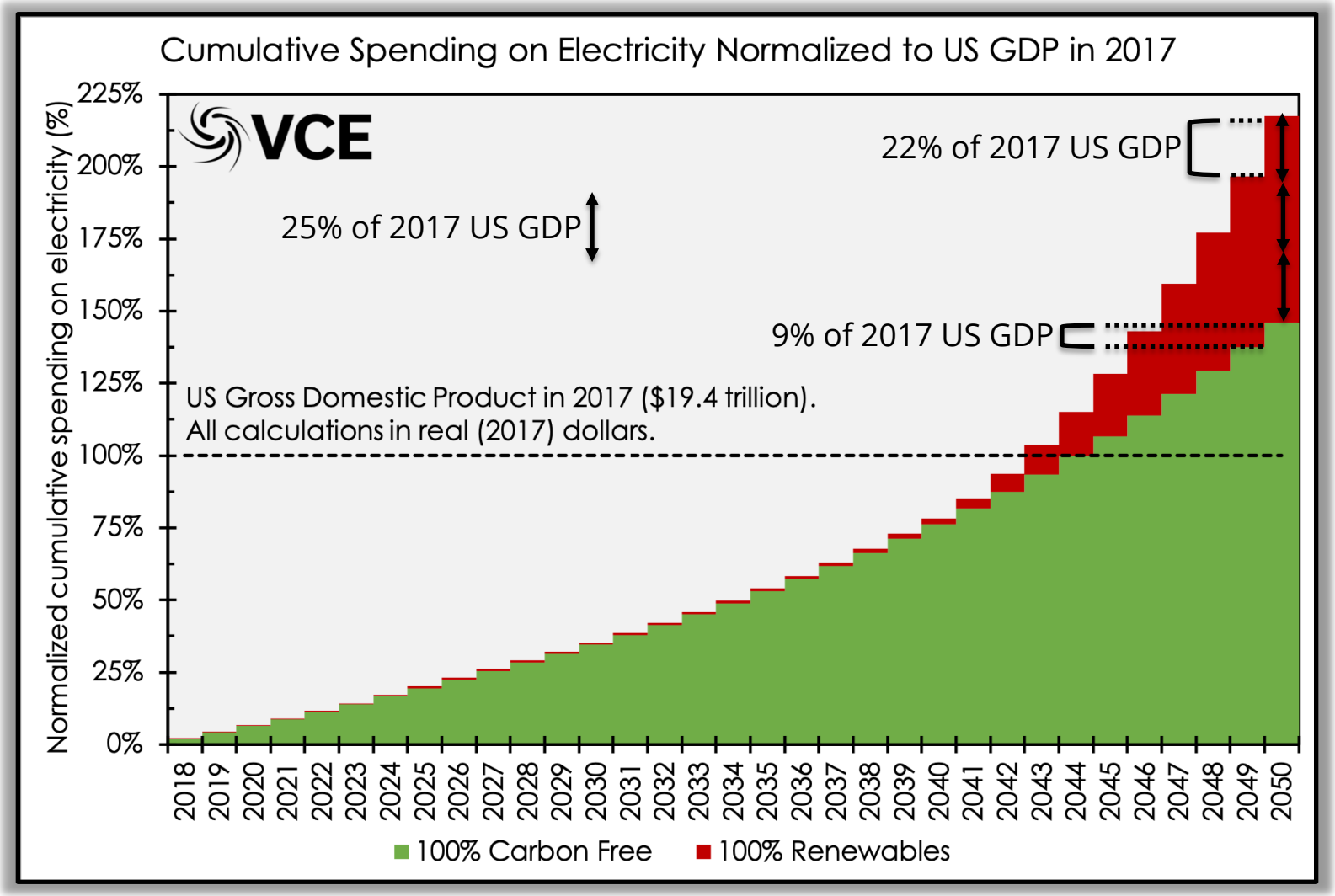
Cumulative electricity costs for contiguous US



- ✓ *By 2050, the average cost of electricity in the 100% RPS Scenario is **$155 / MWh***
- ✓ *By 2050, the average cost of electricity in the 100% CF Scenario is **$95 / MWh***

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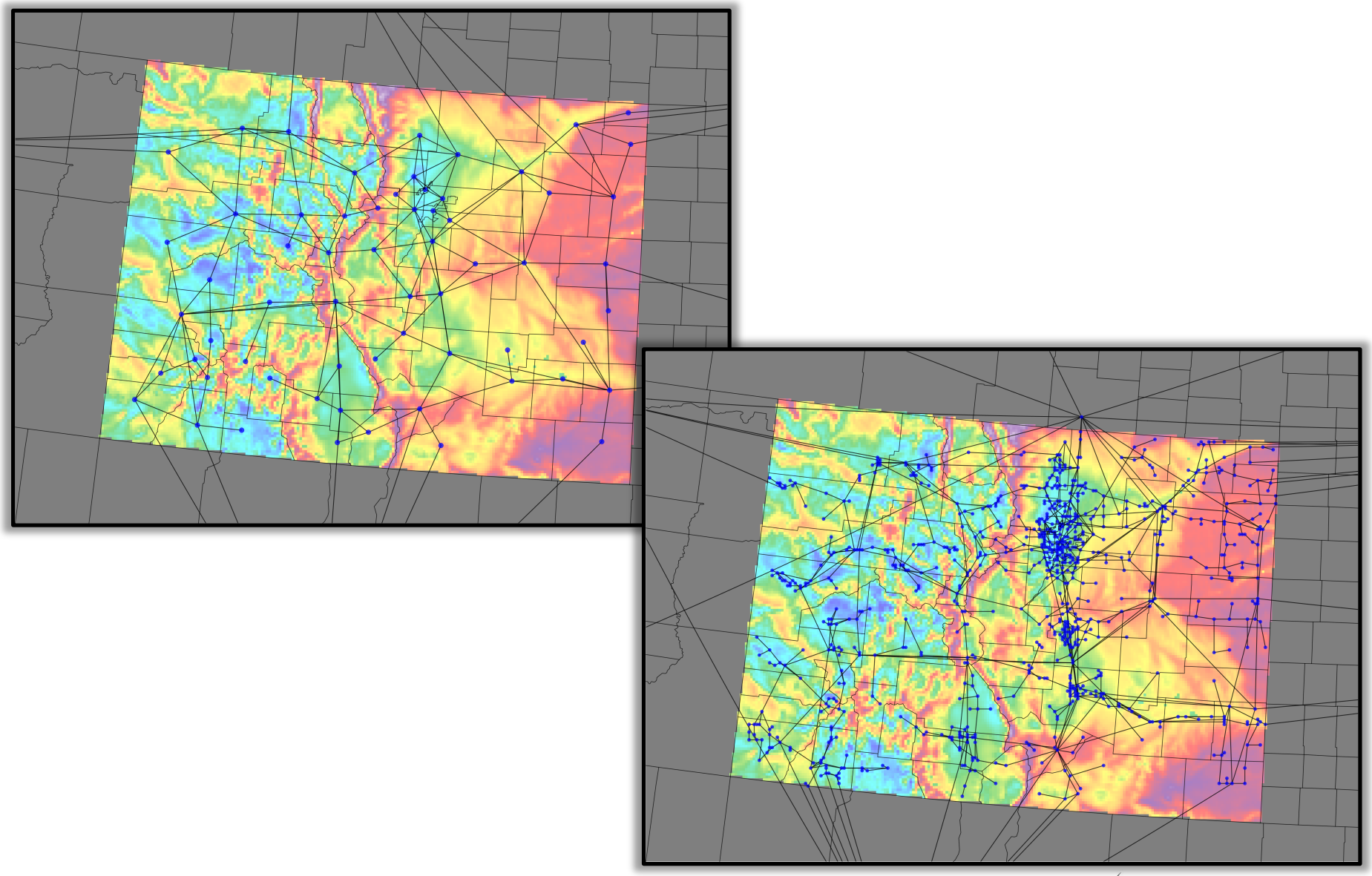
Outline of presentation

1. Tools VCE® uses and how we approach the problem of planning future scenarios;

2. General results from VCE® national studies with WIS:dom®;

3. Specific results from WIS:dom® for Colorado.

Colorado transmission modeling in WIS:dom®



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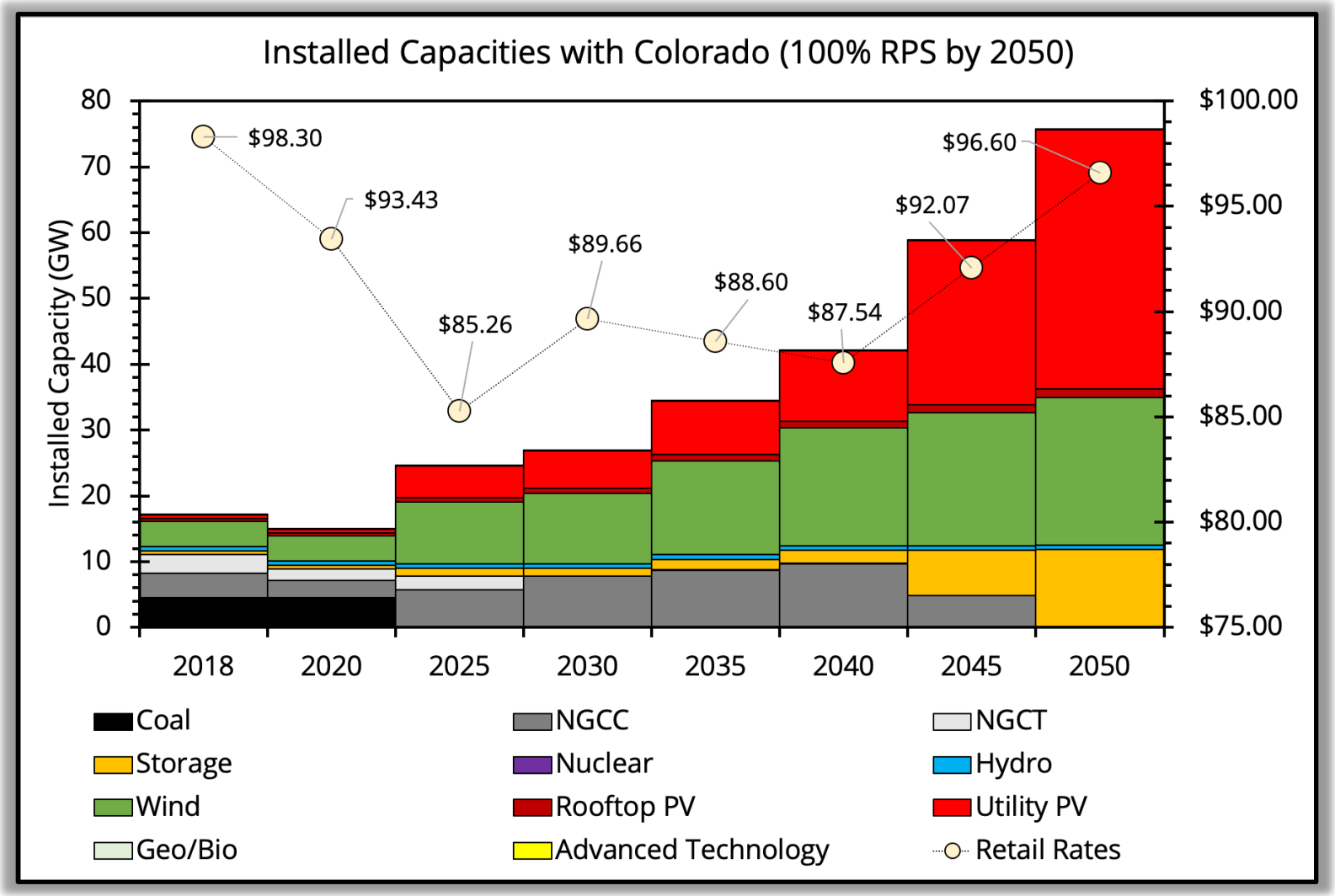
Result of 100% RPS vs 100% clean by 2050 in CO



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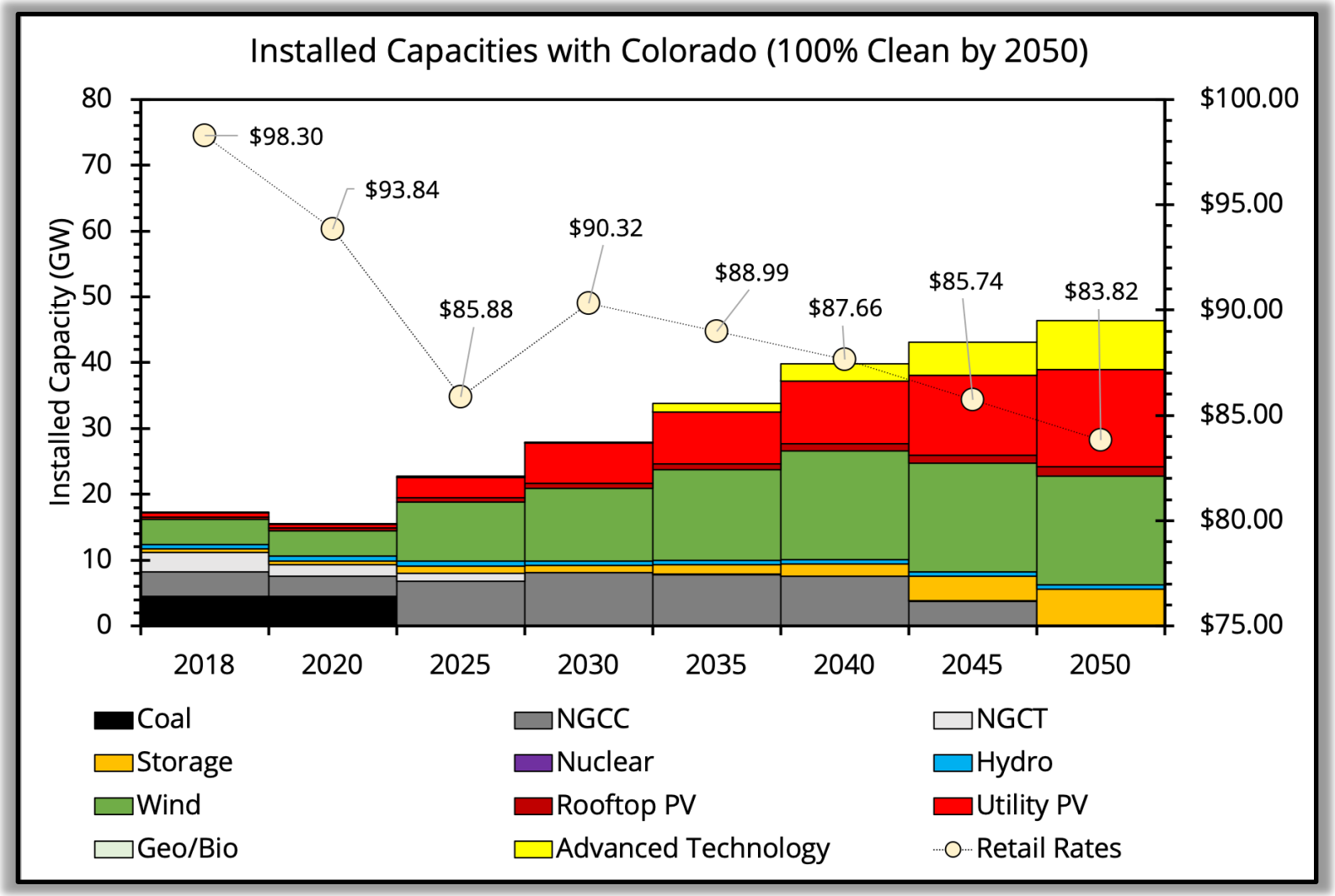
Result of 100% RPS vs 100% clean by 2050 in CO



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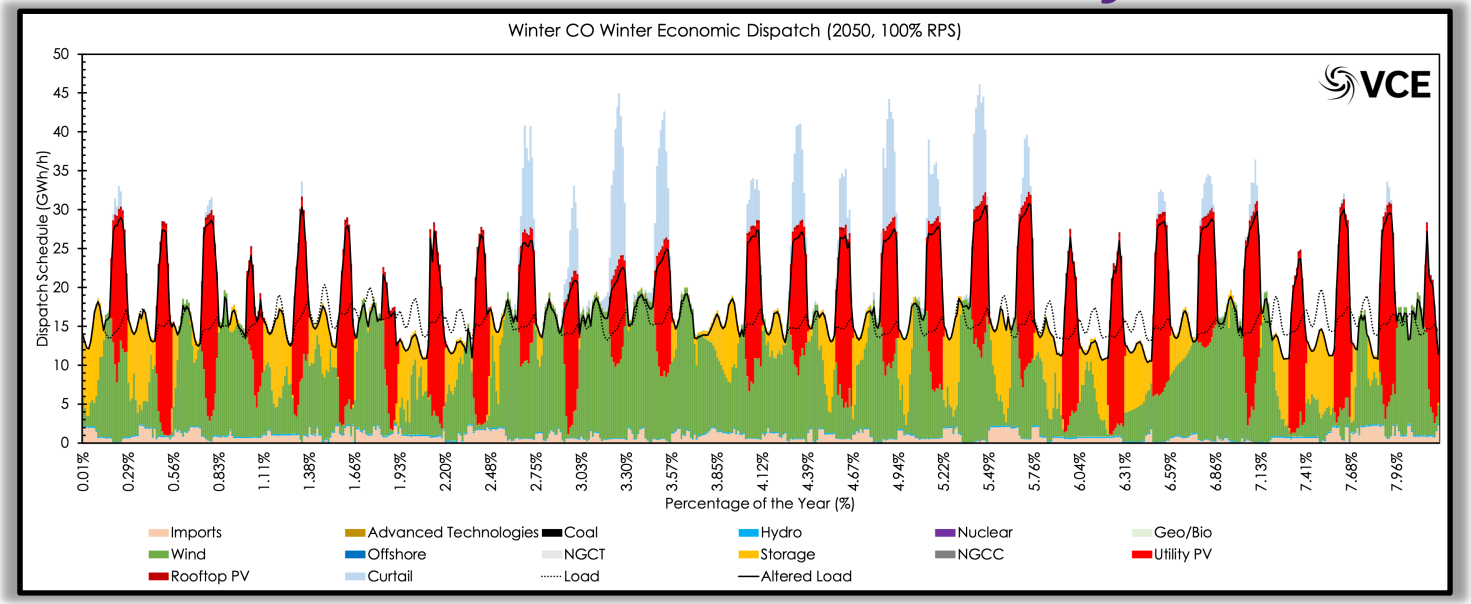
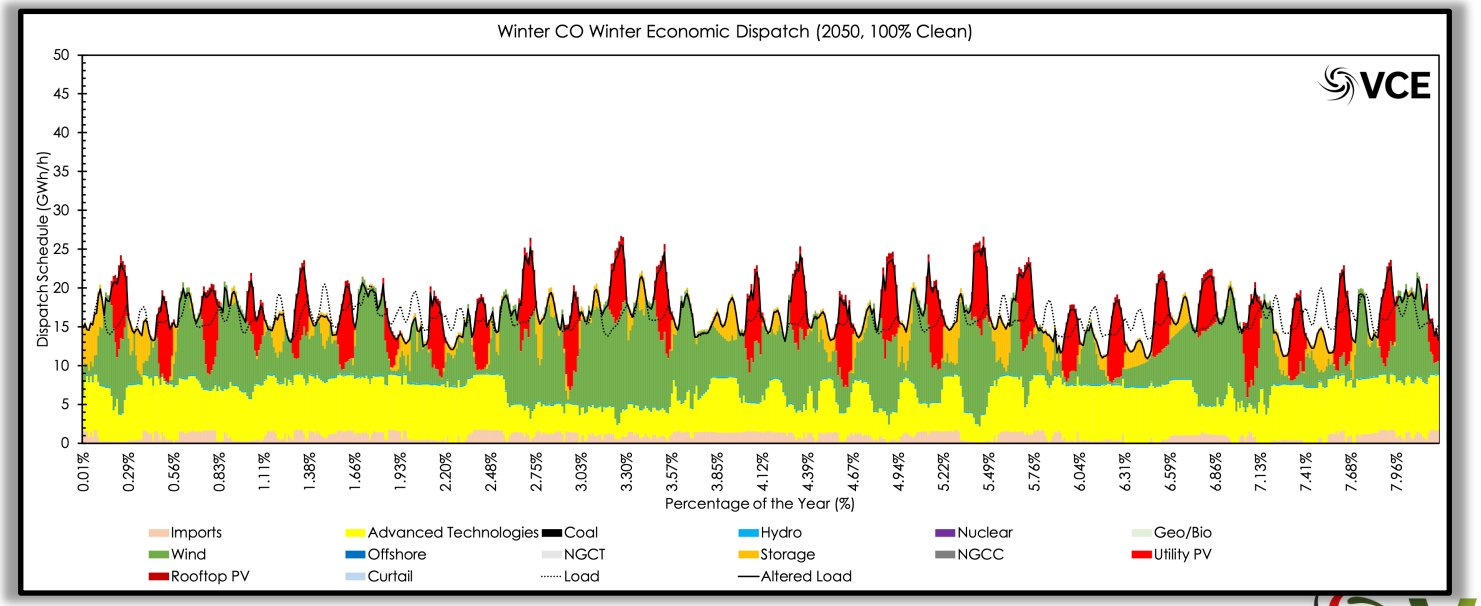
Result of 100% RPS vs 100% clean by 2050 in CO





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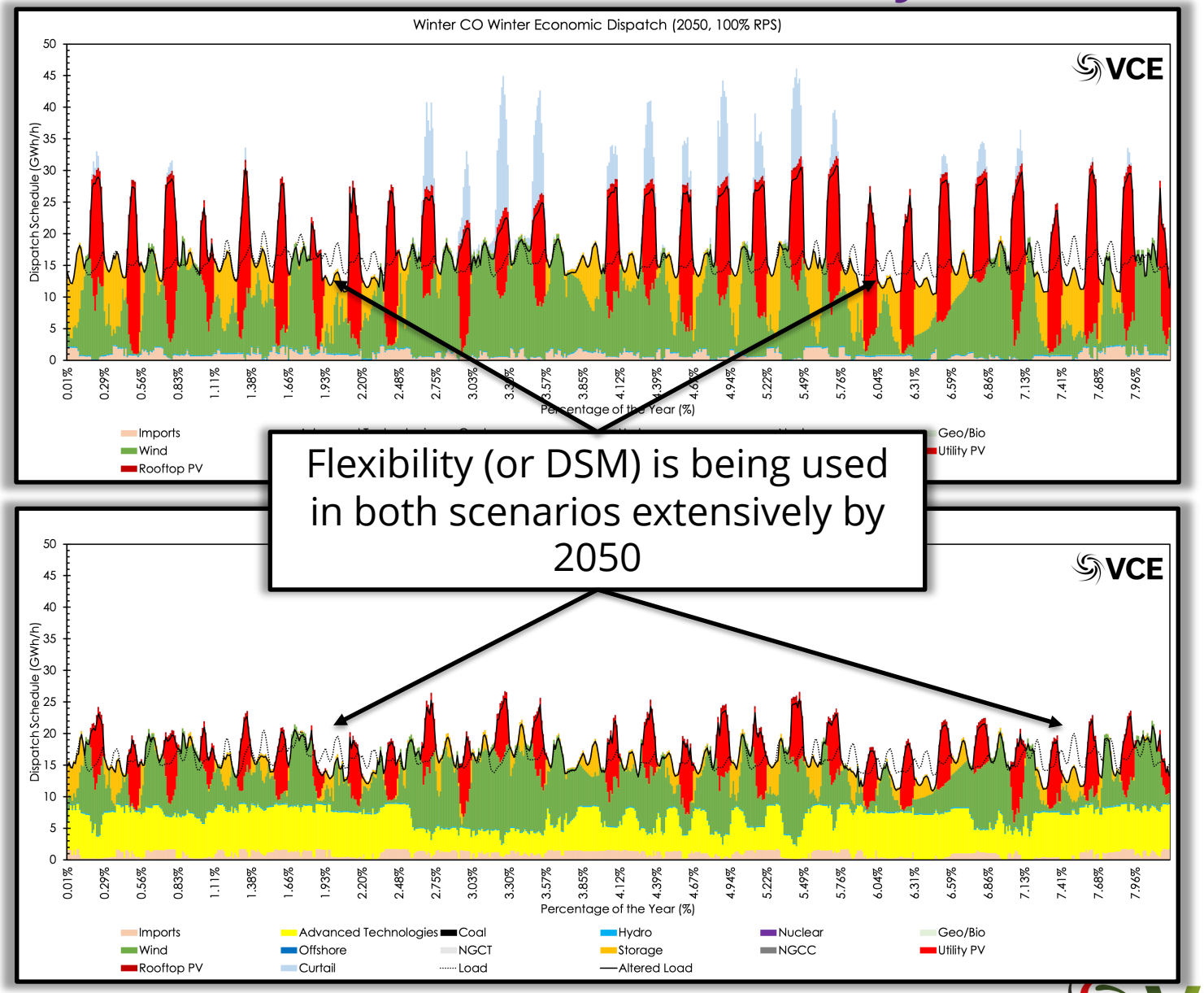
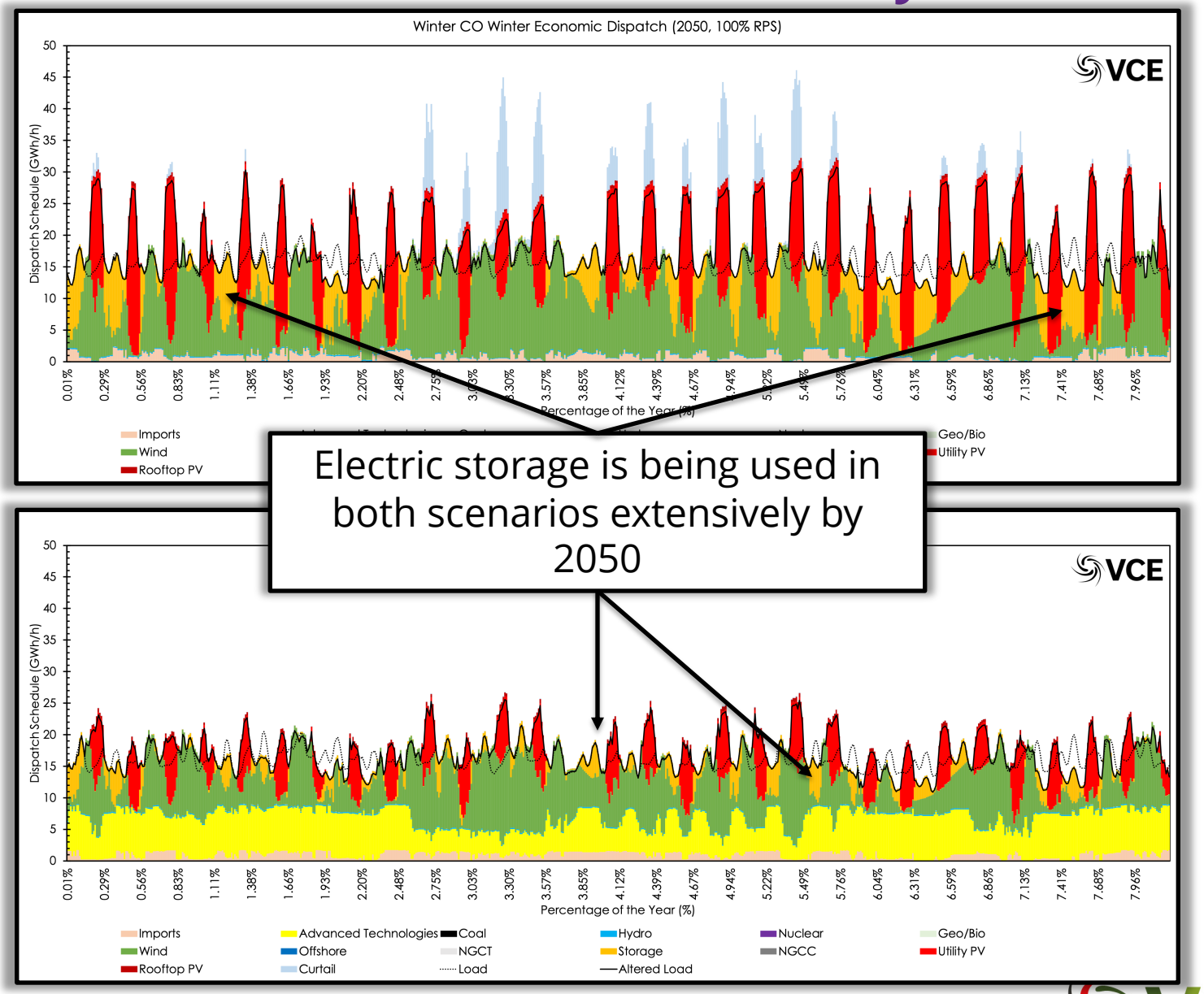
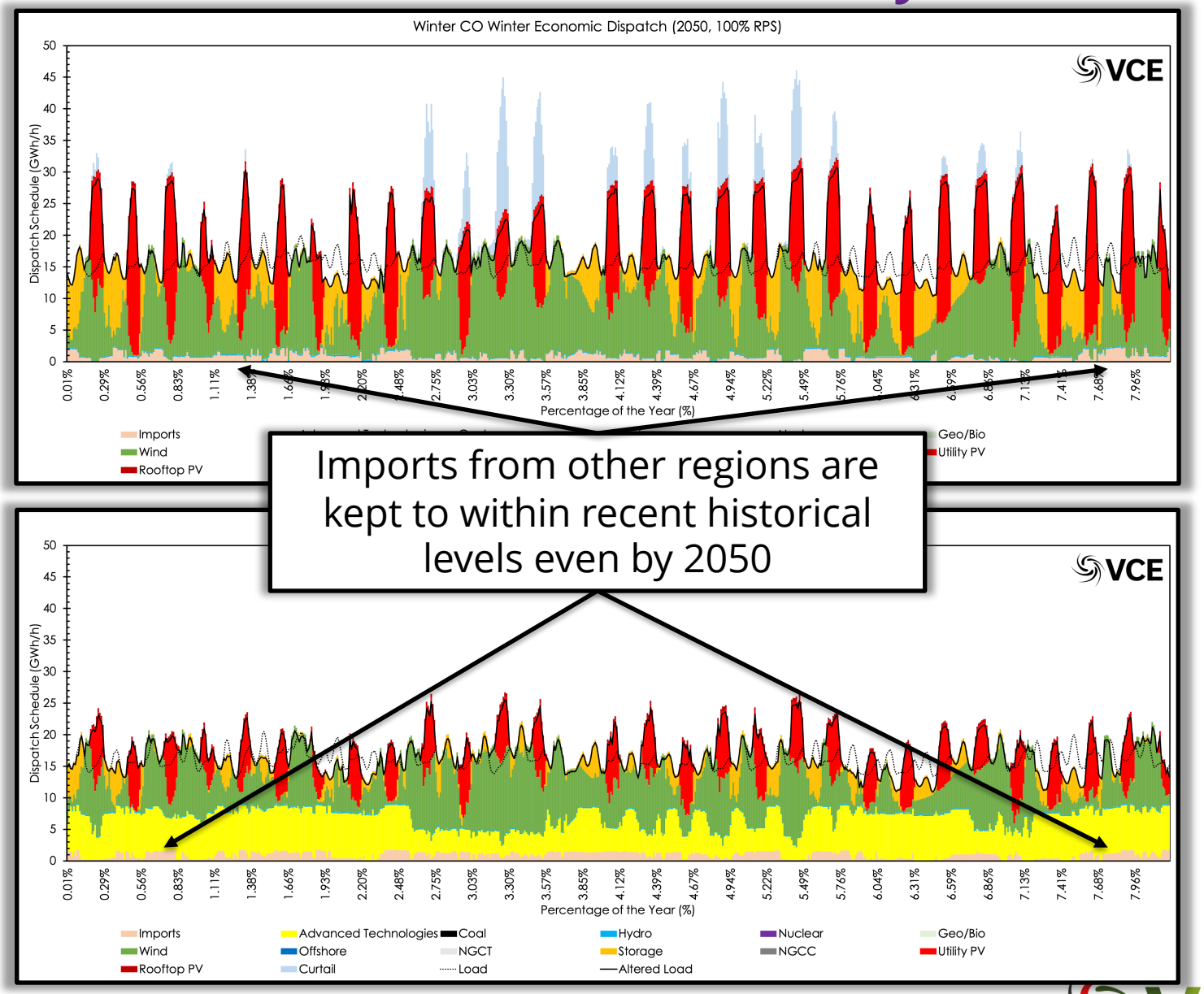
Result of 100% RPS vs 100% clean by 2050 in CO



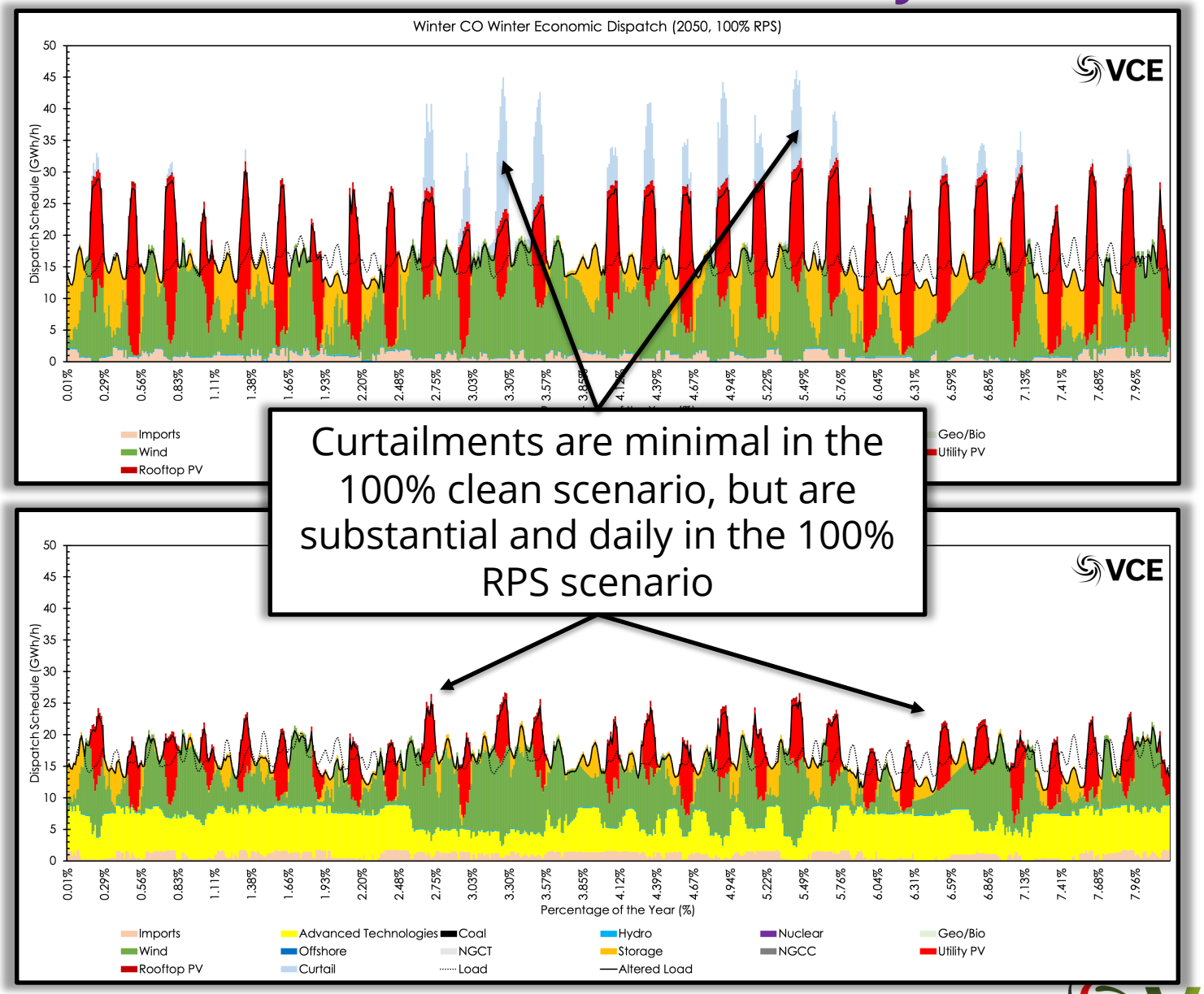
Result of 100% RPS vs 100% clean by 2050 in CO



Result of 100% RPS vs 100% clean by 2050 in CO



Result of 100% RPS vs 100% clean by 2050 in CO



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Thank You

Questions?

Dr Christopher T M Clack
CEO Vibrant Clean Energy, LLC

Twitter: @VibrantCE & @DrChrisClack
Telephone: +1-720-668-6873
E-mail: christopher@vibrantcleanenergy.com
Website: VibrantCleanEnergy.com

Outline of presentation

1. Tools VCE® uses and how we approach the problem of planning future scenarios;

2. General results from VCE® national studies with WIS:dom®;

3. Specific results from WIS:dom® for Colorado.

4. One more thing… (demonstration of WIS:dom®-K)