New Study Presents a Plan for a Low Cost and Clean Grid: A Discussion of the Seams Study with Transmission Leaders

October 9, 2018

Introduction to ACEG

- Americans for a Clean Energy Grid (ACEG) has been engaged since 2008 in building broad-based awareness of the need to expand, integrate and modernize America's high-voltage transmission system.
- Read more about our coalition and policy agenda: cleanenergygrid.org

Americans for a Clean Energy Grid

Agenda

- Introductions
- Review of key findings from the Seams Study
- Moderated discussion
- Q&A with panelists

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Featuring

Jay Caspary, Panelist
Director of Research & Development, Southwest Power Pool
Co-chair of the Technical Review Committee

Michael Goggin, Panelist
Vice President, Grid Strategies LLC
Member of the Technical Review Committee

Jesse Jenkins, Panelist
Postdoctoral Fellow, Harvard Kennedy School

Rob Gramlich, Moderator
President, Grid Strategies LLC
Board Member, Americans for a Clean Energy Grid

Americans for a Clean Energy Grid


SPP Southwest Power Pool
HELPING OUR MEMBERS WORK TOGETHER
TO KEEP THE LIGHTS ON... TODAY AND IN THE FUTURE.

Interconnections Seam Study Update

October 9, 2018

Jay Caspary

Director – Research, Development & Tariff Services

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Disclaimer

- The results from the Interconnections Seam Study are preliminary. While the models and inputs have been vetted on several occasions with stakeholders, caution needs to be exercised in drawing conclusions and sharing results
- DOE NREL Interconnections Seam Study official site
  - https://www.nrel.gov/analysis/seams.html

DOE-funded, NREL-led Interconnection Seams Study

- $1.2M, 18 month EI-WECC Seams and HVDC Overlay Study approved as part of DOE's Grid Modernization Laboratory Collaborative (GMLC)
  - Strong industry support
  - Opportunity to not just replace in-kind the aging B2B HVDC Ties between EI and WECC
  - Four DC Scenarios
    - Status Quo
    - Modernized/Optimized Seam with Rightsized/Relocated B2B and/or Links
    - Macrogrid Overlay
- Promising preliminary results
- Additional analyses being discussed

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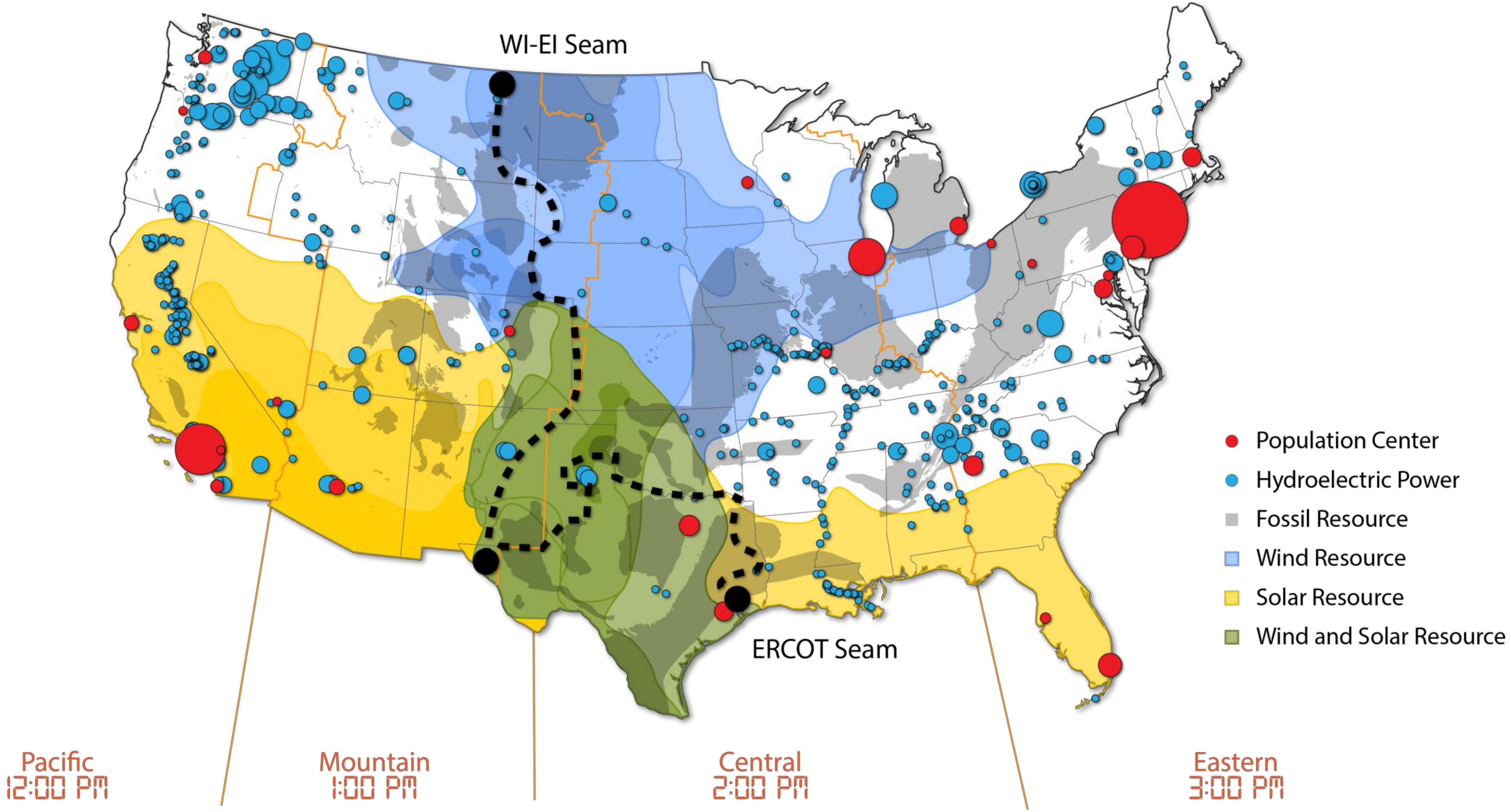
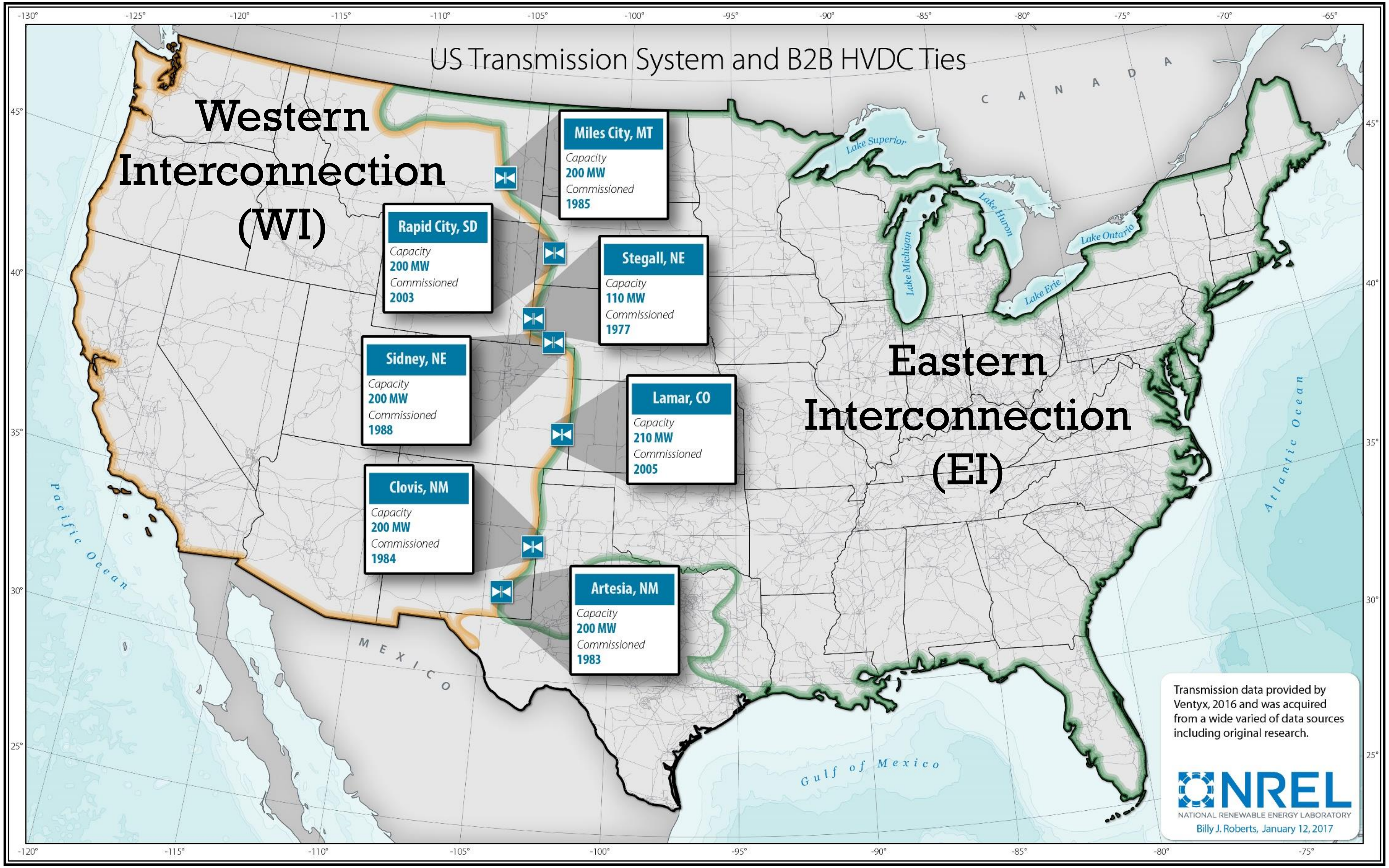
The U.S. has Diverse Resources and Demand



- GRID Modernization Laboratory Consortium U.S. DOE Interconnection Seams Study – Aaron Bloom

WI & EI Back-to-Back HVDC Ties



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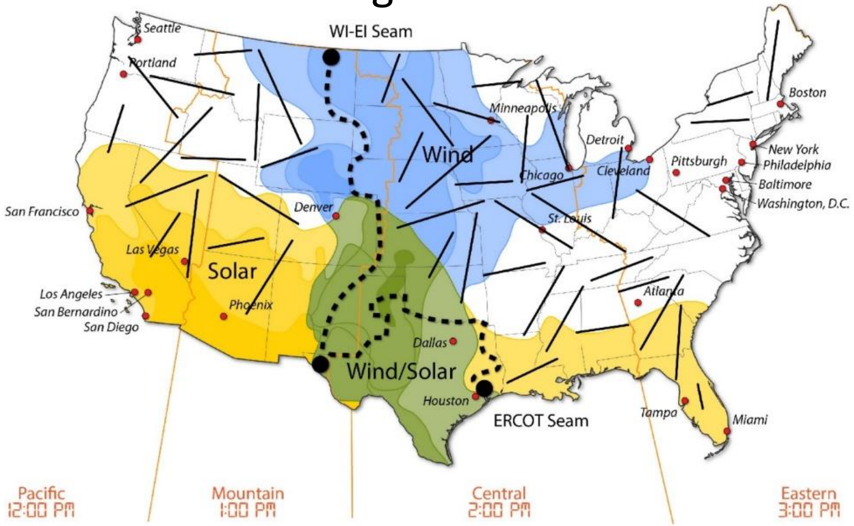
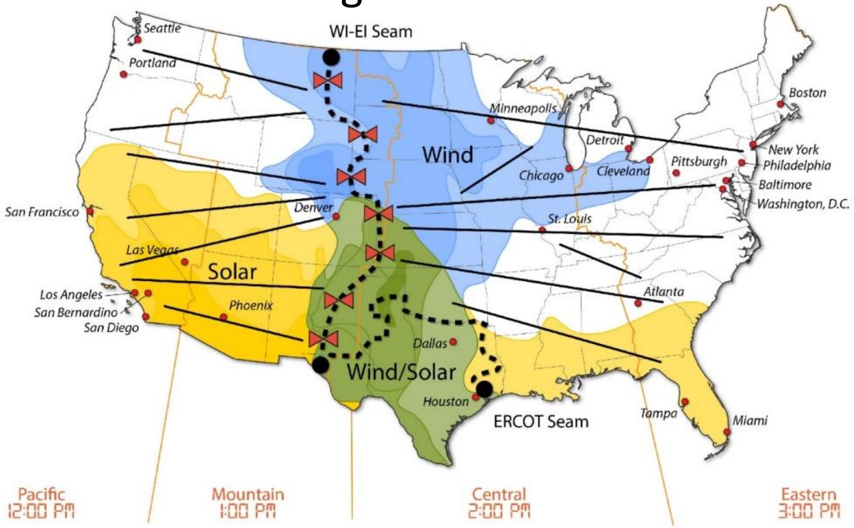
Design Concepts

Design 1



Design 2a



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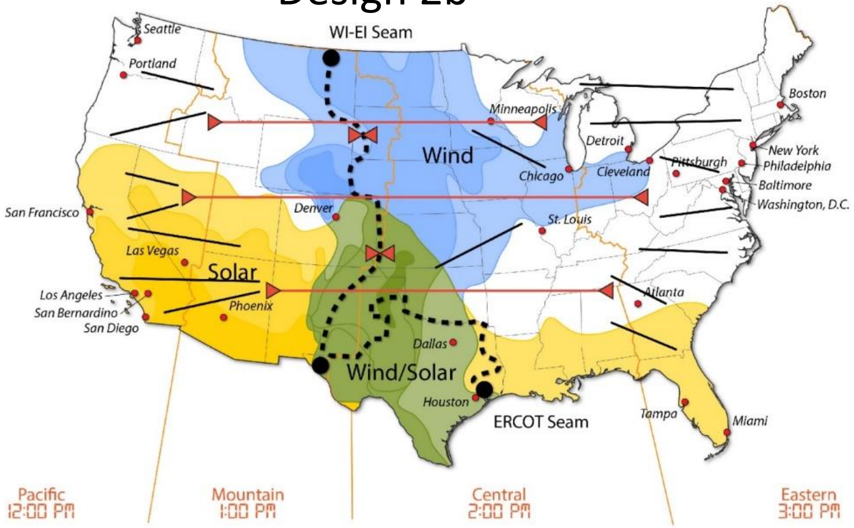
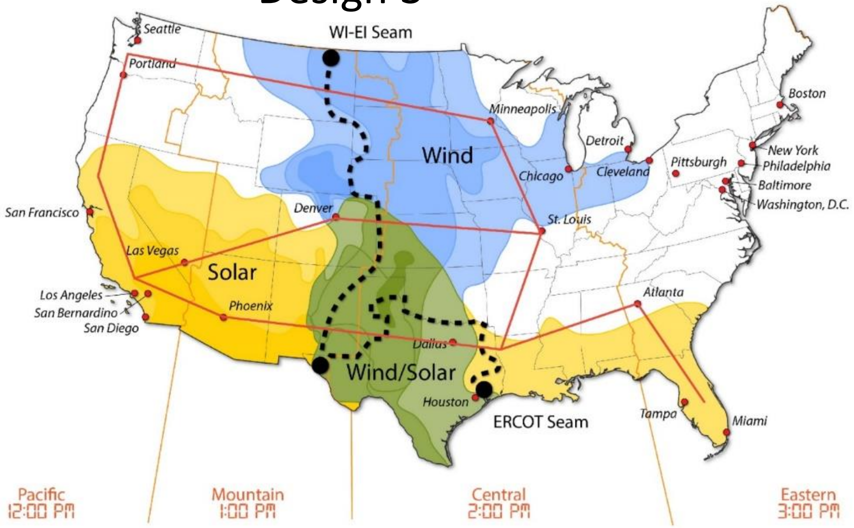
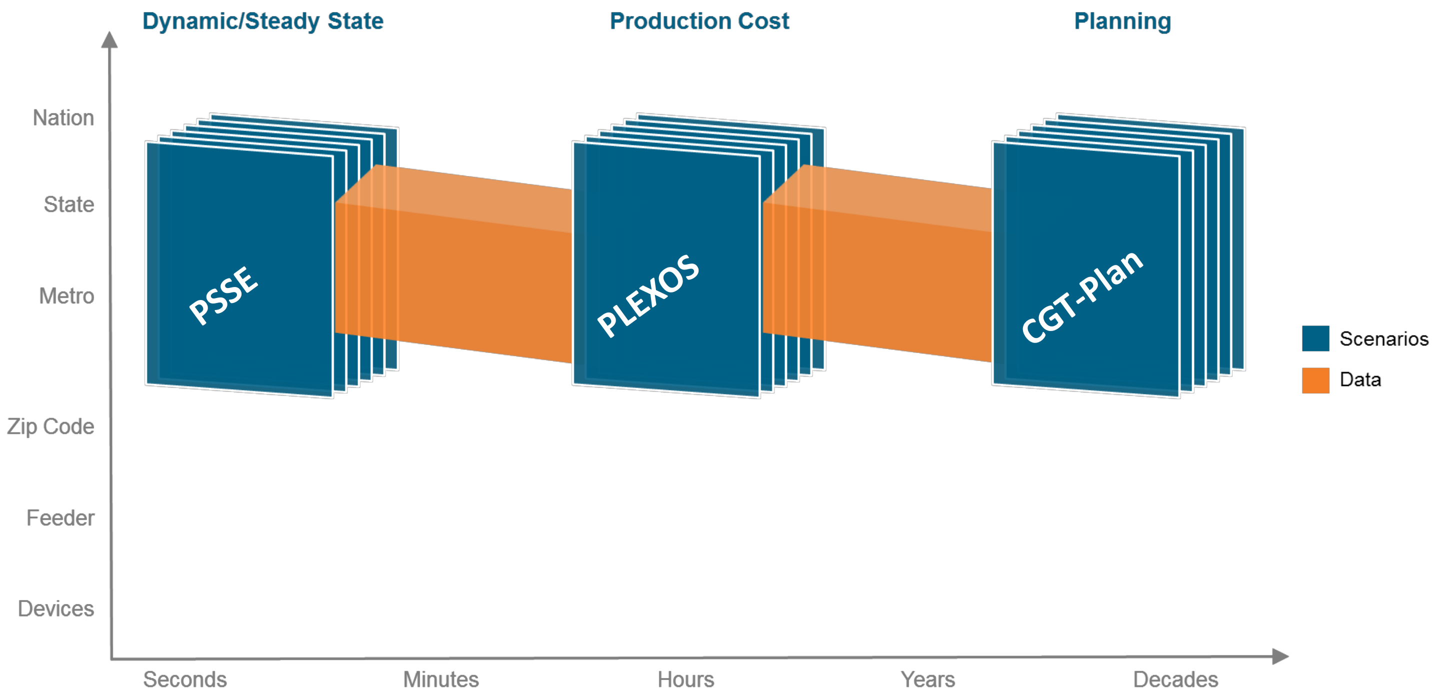


Design 3

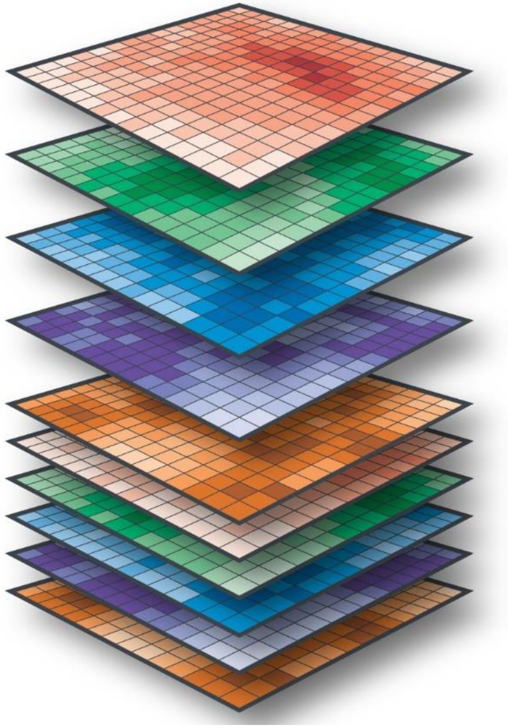


Comprehensive Economic and Reliability Analysis

- CGT-Plan
  - Iowa State University
  - Capital and operating costs 2024-2038
  - Generation and transmission system for 2038
- PLEXOS
  - NREL
  - Operating costs 2038
  - Hourly unit commitment and economic dispatch
- PSSE
  - PNNL
  - Develop a capability for future work
  - Preliminary analysis of AC power flow impacts



Integrated Data



- Consistent data between modeling domains
  - Wind
    - 2012 WIND Toolkit
    - https://www.nrel.gov/grid/wind-toolkit.html
  - Solar
    - 2012 NSRDB
    - https://nsrdb.nrel.gov/
  - Transmission and Generation
    - WECC TEPPC 2024*-Western Interconnection
    - MMWG 2026-Eastern Interconnection
  - Load
    - 2012 FERC Form 714 and RTO websites

Installed Capacity (GW)

	2024	Base Case				High VG Case			
		D1	D2a	D2b	D3	D1	D2a	D2b	D3
Coal	266	120	113	111	115	65	37	29	32
Hydro	198	198	198	198	198	198	198	198	198
Natural Gas	443	437	431	418	421	467	453	450	448
Nuclear	132	132	132	132	132	132	132	132	132
Solar	64	281	277	271	278	246	241	241	239
Wind	94	320	324	326	324	450	487	488	487

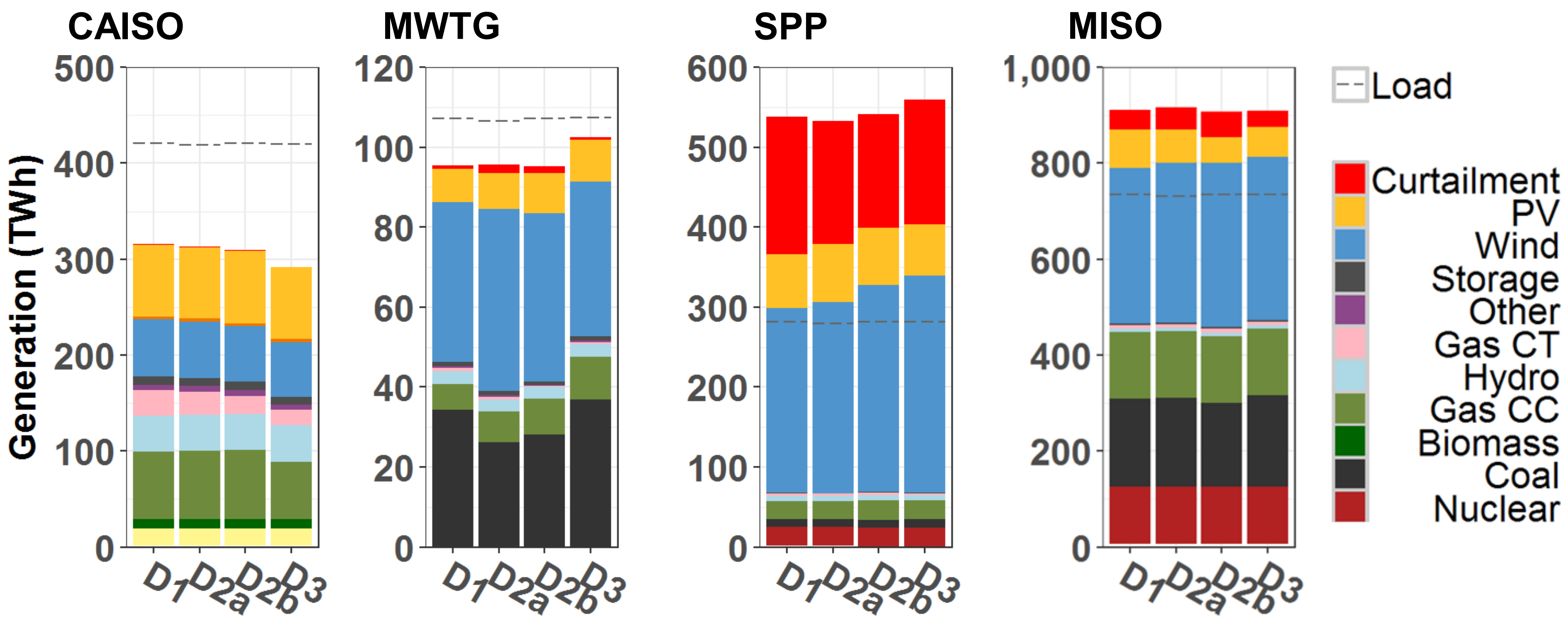
Transmission Capacity Additions (GW)

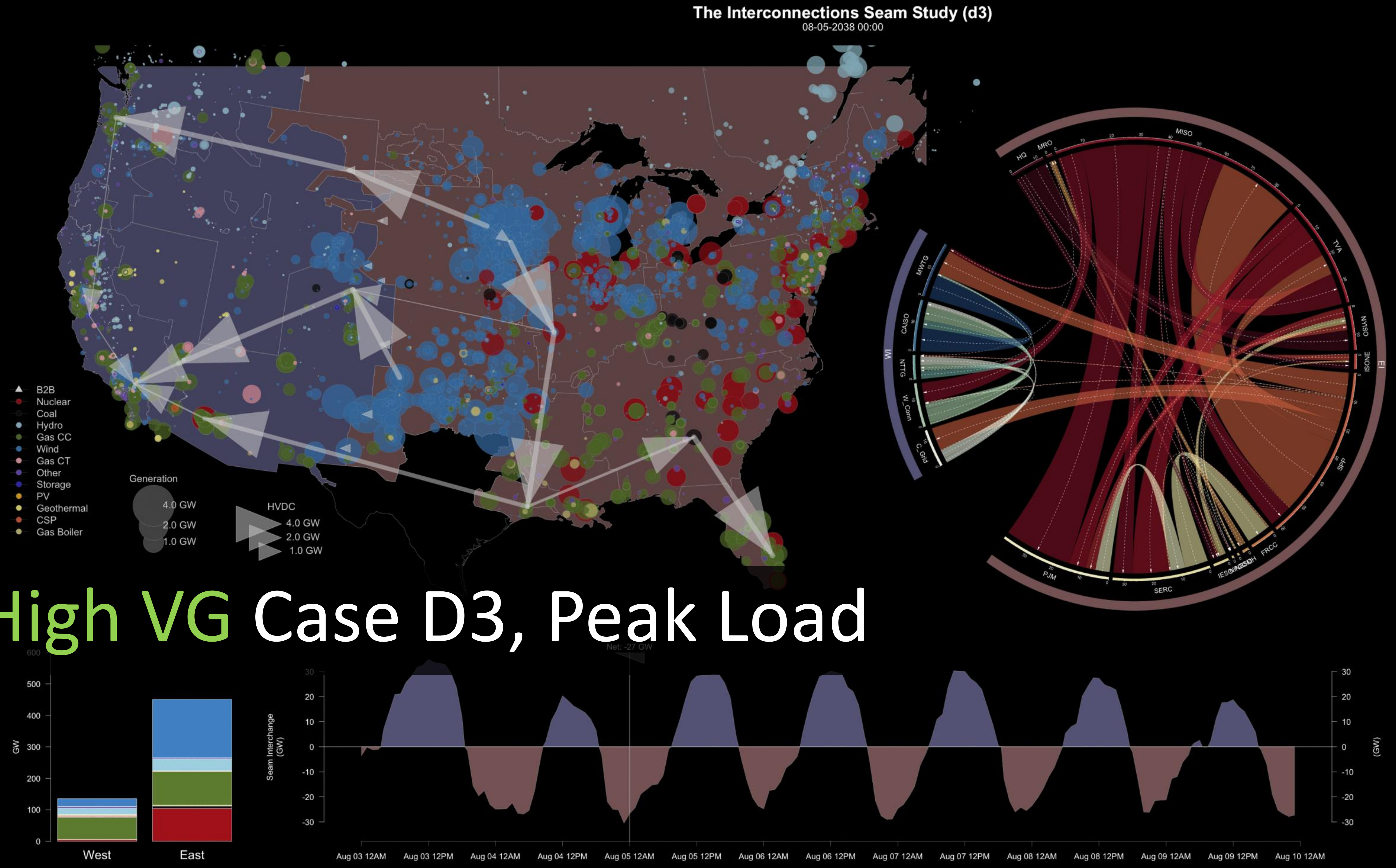
	Base Case				High VG Case			
	D1	D2a	D2b	D3	D1	D2a	D2b	D3
AC Transmission	92	95	89	84	228	251	235	195
HVDC Transmission	0	7	20	58	0	26	36	126

Expansion Overview

- All cases imagine a future where it is feasible to build multi-region transmission
- Design 1 is the only case without new HVDC and without new transmission across the Seam
- The generation mix changes substantially in all cases
- Results are known to be imperfect, yet informative
- Substantial AC transmission is added in all cases
- All cases meet the same Resource Adequacy target (15% planning reserve margin). Details here: https://lib.dr.iastate.edu/etd/16128/

Regional Generation Base Case





High VG Case D3, Peak Load

Total Costs 2024-2038 (NPV $B)

BCR = $\frac{\text{Change in Total non-Transmission Costs}}{\text{Change in Transmission Investment Costs}}$

Example, D1 vs D2a Current Policy: 4.01/3.19= 1.26

	Base Case							High VG Case						
ECONOMICS, NPV $B	**D1**	**D2a**	**Delta**	**D2b**	**Delta**	**D3**	**Delta**	**D1**	**D2a**	**Delta**	**D2b**	**Delta**	**D3**	**Delta**
Line Investment Cost	23.5	26.69	3.19	31.5	8	37.7	14.2	61.21	73.89	12.68	74.88	13.67	80.1	18.89
Generation Investment Cost	493.6	494.7	1.1	492.5	-1.1	494.2	0.6	704.03	703.32	-0.71	696.99	-7.04	700.51	-3.52
Fuel Cost	855.1	852.7	-2.4	851.2	-3.9	845.6	-9.5	753.8	738.98	-14.82	737.3	-16.5	736.12	-17.68
Fixed O&M Cost	416.4	415.6	-0.8	413.7	-2.7	413.8	-2.6	455.6	450.2	-5.4	448.95	-6.65	450.23	-5.37
Variable O&M Cost	81	81.1	0.1	81.2	0.2	81.2	0.2	64.5	63.9	-0.6	64.27	-0.23	64.39	-0.11
Carbon Cost	0	0	0	0	0	0	0	171.1	164.2	-6.9	162.6	-8.5	162.5	-8.6
Regulation-Up Cost	31.6	30.97	-0.63	31.13	-0.47	30.02	-1.58	33.29	31.63	-1.66	29.96	-3.33	26.63	-6.66
Regulation-Down Cost	45.1	44.2	-0.9	44.42	-0.68	42.85	-2.26	4.76	4.52	-0.24	4.29	-0.47	3.81	-0.95
Contingency Cost	23.9	23.42	-0.48	23.54	-0.36	22.71	-1.2	24.41	23.19	-1.22	21.97	-2.44	19.52	-4.89
Total Non-transmission Cost (Orange)	1,947.00	1,943.00	-4.01	1,937.70	-9.01	1,930.00	-16.34	2,211.49	2,179.94	-31.55	2,166.33	-45.16	2,163.71	-47.78
15-yr B/C Ratio (Orange/Green)			1.26		1.13		1.15			2.48		3.3		2.52

2038 Production Costs

	Base Case				High VG Case			
Design	D1	ΔD2a	ΔD2b	ΔD3	D1	ΔD2a	ΔD2b	ΔD3
Emissions	0	0	0	0	24.3	-1.5	-1.6	-1.1
Fuel	98.3	-0.4	-0.9	-3.2	83.0	-2.3	-2	-0.1
Start & Shutdown	2.8	-0.1	-0.1	-0.3	3.1	-0.4	-0.6	-0.5
VO&M	6.5	-0.1	-0.1	-0.1	4.9	-0.1	-0.1	-0.1
Total	107.6	-0.6	-1.2	-3.6	115.2	-4.2	-4.1	-1.8

Benefits

- All designs produce benefits that exceed costs.
- Results should be viewed directionally, not definitively.
- Comparisons are made to D1, which includes significant AC expansion, but no cross seam expansion.
- Full asset life is assumed to be 35 years, over the long run, the benefit may be significantly higher.
- Not appropriate to assume 2038 savings will stay the same until retirement, they may increase or decrease depending on the rest of the system.

	Benefit-to-Cost Ratio 2024-2038	
	Base Case	High VG Case
D1	-	-
D2a	1.26	2.48
D2b	1.13	3.3
D3	1.15	2.52

	Production Cost Savings 2038 ($B)	
	Base Case	High VG Case
D1	-	-
D2a	-0.6	-4.2
D2b	-1.2	-4.1
D3	-3.6	-1.8

Areas for Improvement

- Refine multi-model integration to remove modeling seams, e.g. capacity and network translation, and retirements.
- Study more designs: no new transmission, synchronize systems, all of North America
- Analyze multiple weather years of simulation to inform resilience to weather.
- Conduct comprehensive stability and contingency analysis

Findings

- Is there value to increasing the transmission between the Eastern and Western Interconnections?
  - Yes, there is substantial value to increasing the transfer capability between the Eastern and Western Interconnections, status quo on the existing B2Bs is the least desirable.

- What are the options for replacing existing “seams” facilities?
  - There are several options for replacing existing seams facilities and these options impact the location, size, and type of generation.

- What are the opportunities for new cross country transmission?
  - There are many options for cross-seam transmission and each option enables substantial energy & operating reserve sharing on diurnal and seasonal basis.

- How might transmission needs change with the generation mix?
  - Transmission benefits appear robust under a variety of generation futures.

- Are there other potential benefits?
  - Yes, there may be substantial additional benefits (and costs) may exist, i.e. frequency response and resilience to extreme events.

Observations

- ► Further analyses are warranted since status quo appears to be least desirable scenario among HVDC alternative futures
- ► Significant AC expansion is needed 2024-2038 absent any changes to EI-WECC Seams facilities.
- ► EHV/UHV voltages for backbone AC facilities need further analysis and consideration given preliminary results
- ► Transmission expansion costs are understated since they are based on equivalized EHV models and don’t consider substations as well as integration to underlying existing AC systems. Significant system reconfiguration would be required for any of these futures.
- ► Harmonized models and datasets are an important and valuable step in shaping future dialogue and assessments

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Next Steps

- ► Finalize NREL report
- ► Need to investigate relocated B2B ties and HVDC terminals, as well as potential AC and Hybrid Seam scenarios
- ► Need to scope supplemental analyses to inform regional planning and shape dialogue about next steps:
  - DOE's North American Resiliency Model initiative
  - Shared vision to provide a roadmap to address aging infrastructure

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Questions?

Please submit any questions through the GoToWebinar panel on the right side of your screen, and we will answer as many as possible during Q&A.

Americans for a Clean Energy Grid

Discussion with Panelists

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Thank you

To learn more about ACEG, visit cleanenergygrid.org

Additional questions? Email: info@cleanenergygrid.org

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Appendix

Partners are Everything

SPP Southwest Power Pool

MISO

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

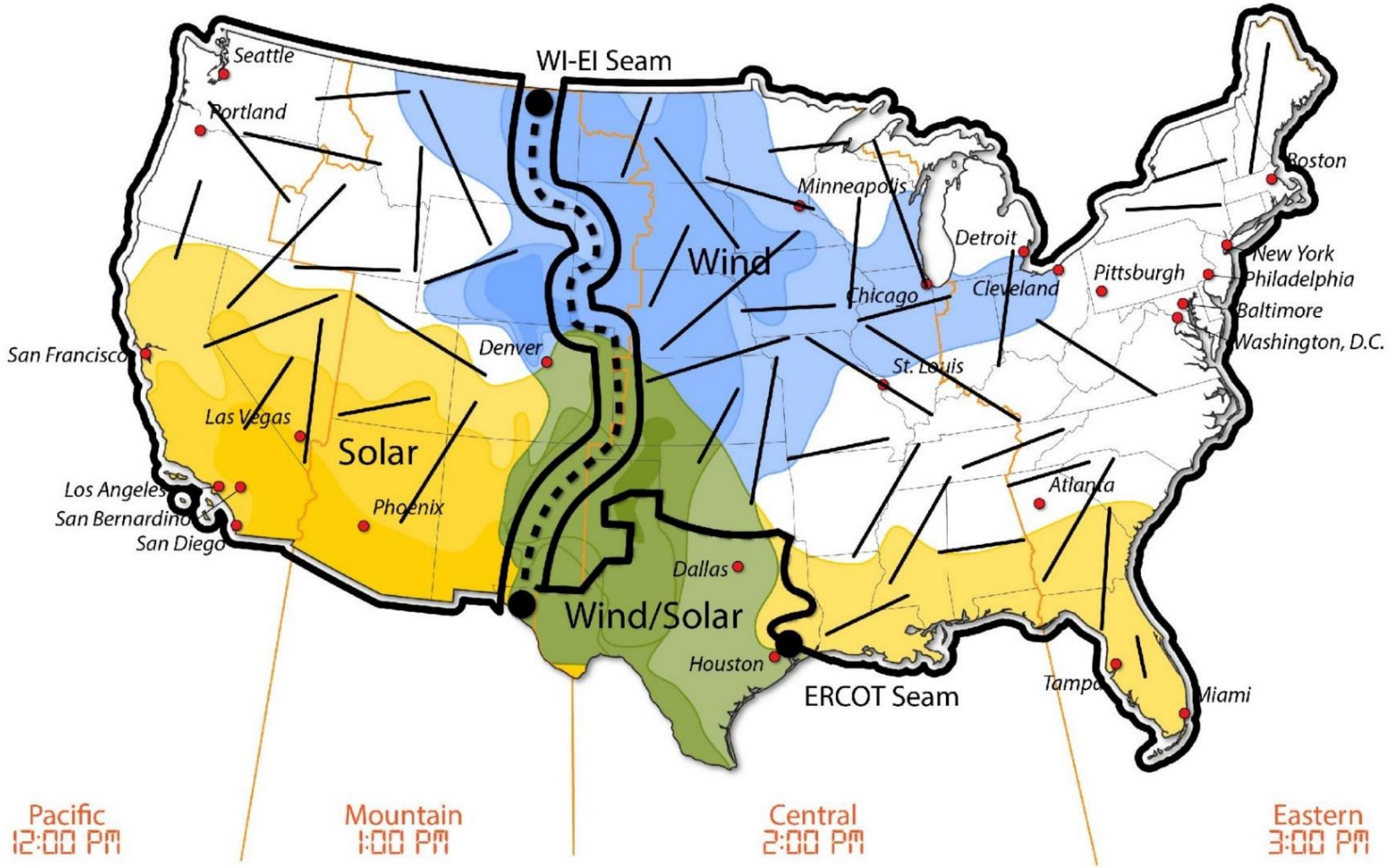
Western Area Power Administration

IOWA STATE UNIVERSITY

Pacific Northwest
NATIONAL LABORATORY

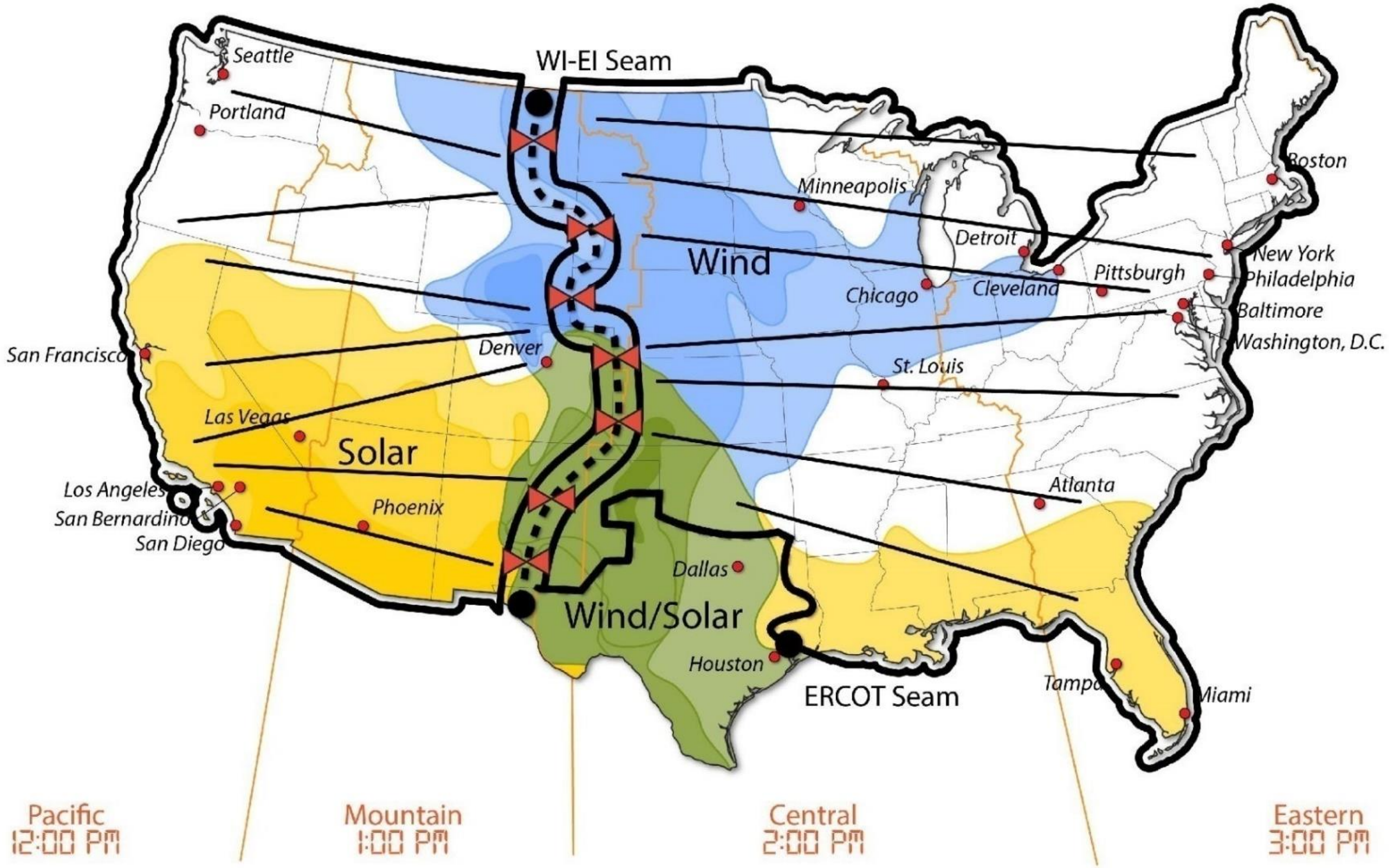
Technical Review Committee

- Alberta Independent System Operator
- American Wind Energy Association
- Basin Electric Power Company
- Black Hills Energy
- Energy Exemplar
- El Paso Electric
- Electric Power Research Institute
- Electric Reliability Council of Texas
- Great River Energy
- Grid Strategies
- Hydro Quebec
- LS Power
- Manitoba Hydro
- Minnesota Power
- National Grid
- North American Electric Reliability Corporation
- National Rural Electric Cooperative Association
- NB Power
- NextEra
- NS Power
- Power from the Prairie
- Public Service Company of New Mexico
- SaskPower
- SDG&E
- Soo Green Rail Transmission
- Solar Energy Industry Association
- TransCanyon
- Tri-State Generation and Transmission
- Energy Systems Integration Group
- Western Electricity Coordinating Council
- Xcel Energy



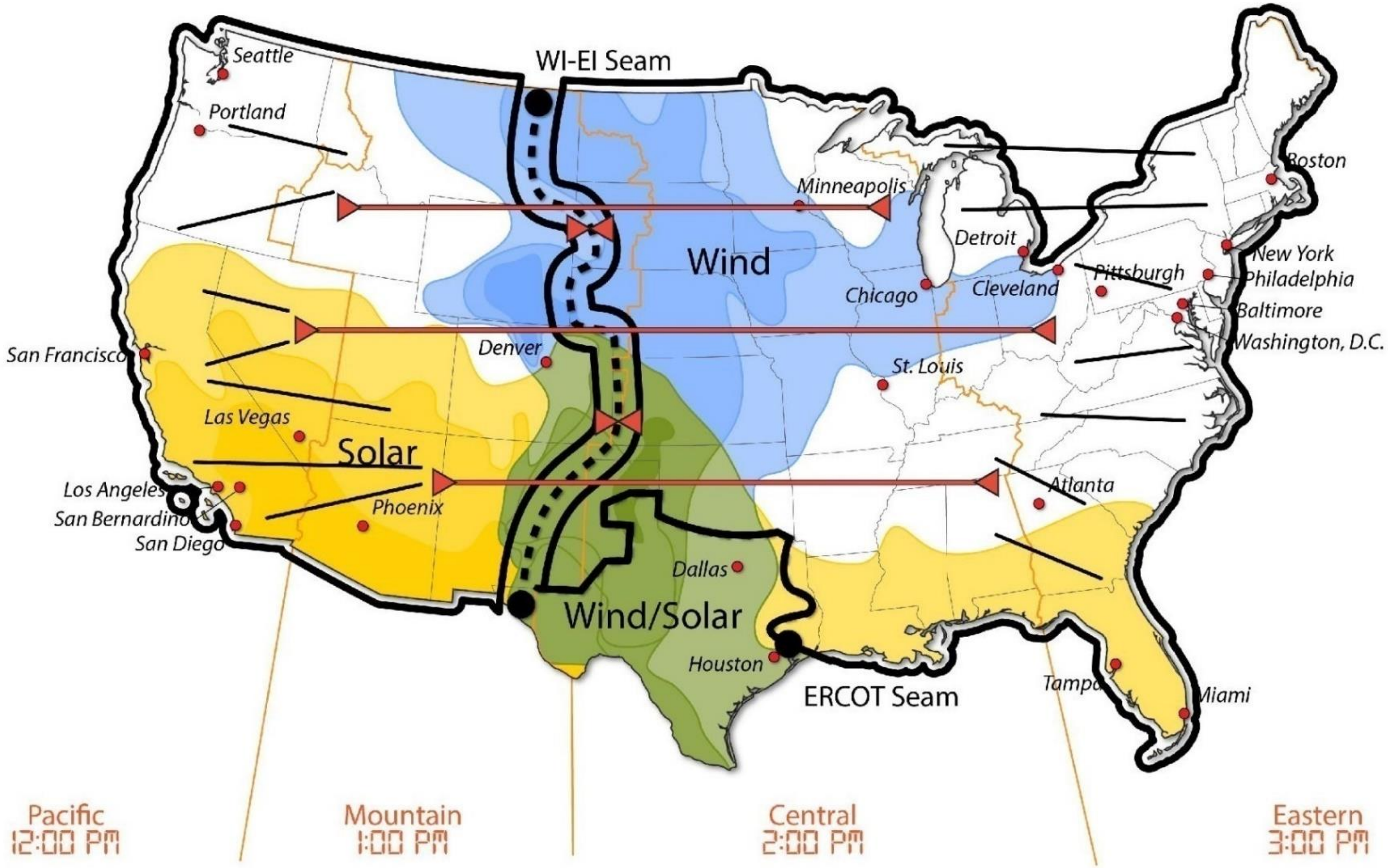
Design 1

Existing B2B facilities are replaced at their current (2017) capacity level and new AC transmission and generation are co-optimized to minimize system wide costs.



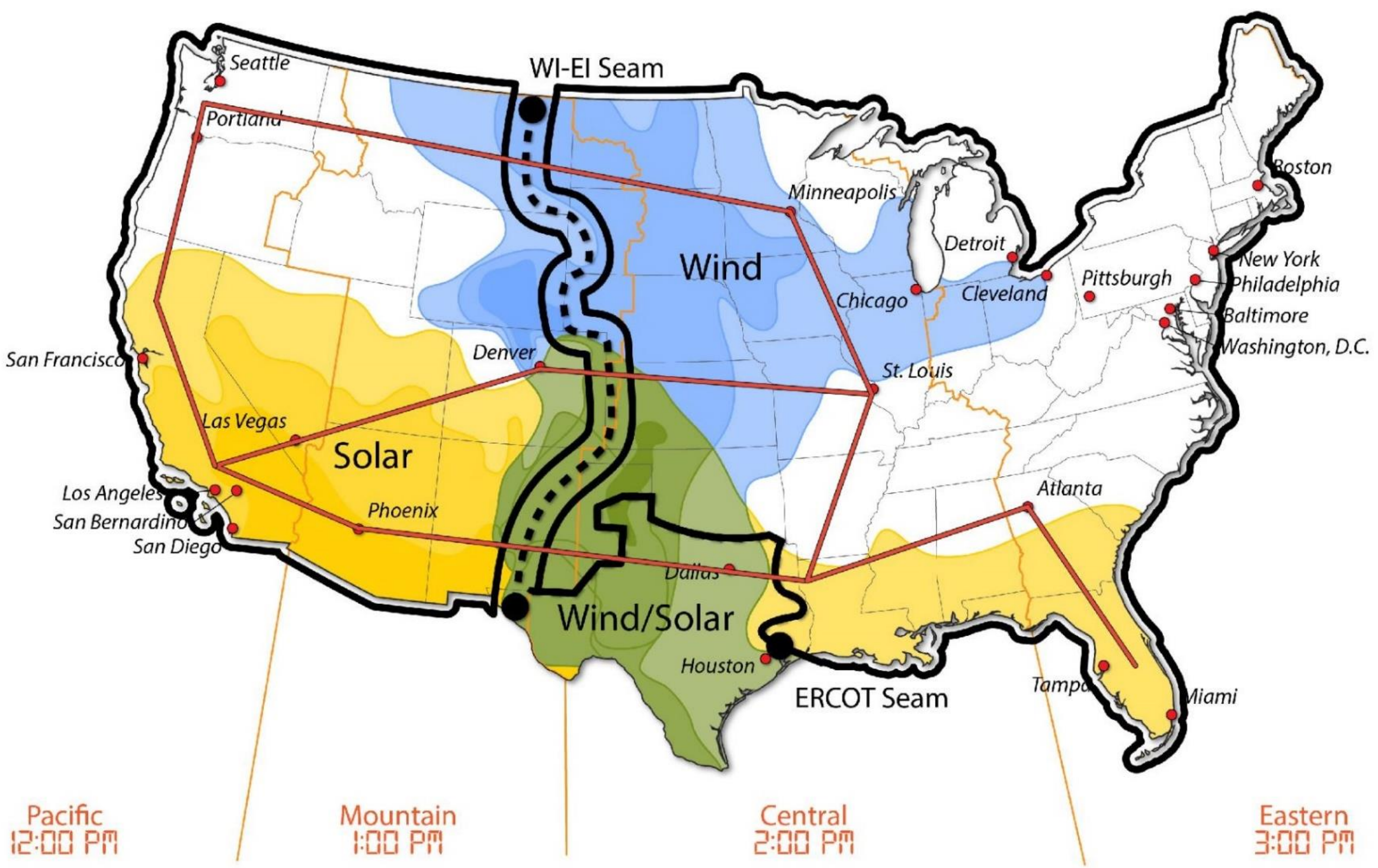
Design 2a

Existing B2B facilities are replaced at a capacity rating that is co-optimized along with other investments in AC transmission and generation.



Design 2b

Three HVDC transmission segments are built between the Eastern and Western Interconnections and existing B2B facilities are co-optimized with other investments in AC transmission and generation.



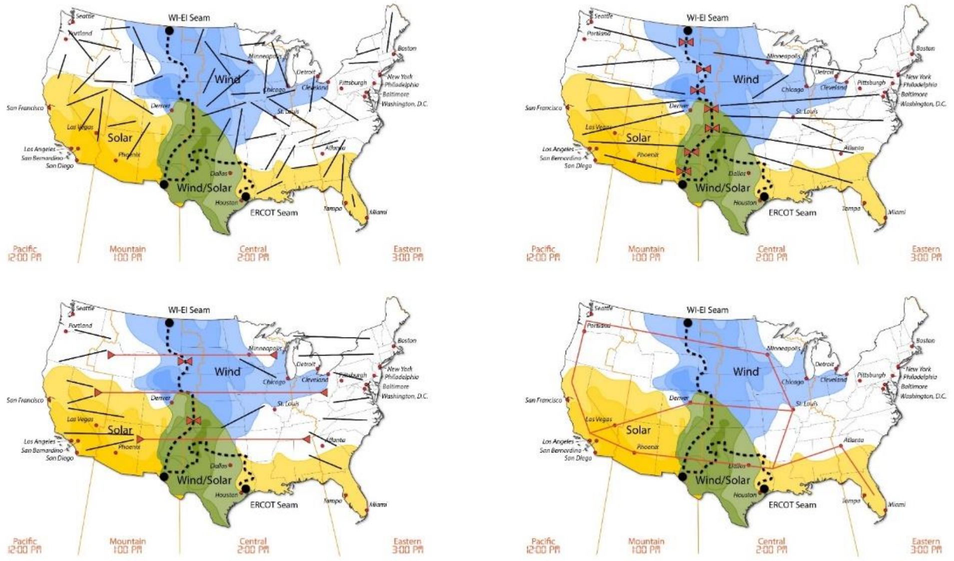
Design 3

A national scale HVDC transmission network, Macro Grid, is built and other investments in AC transmission and generation.

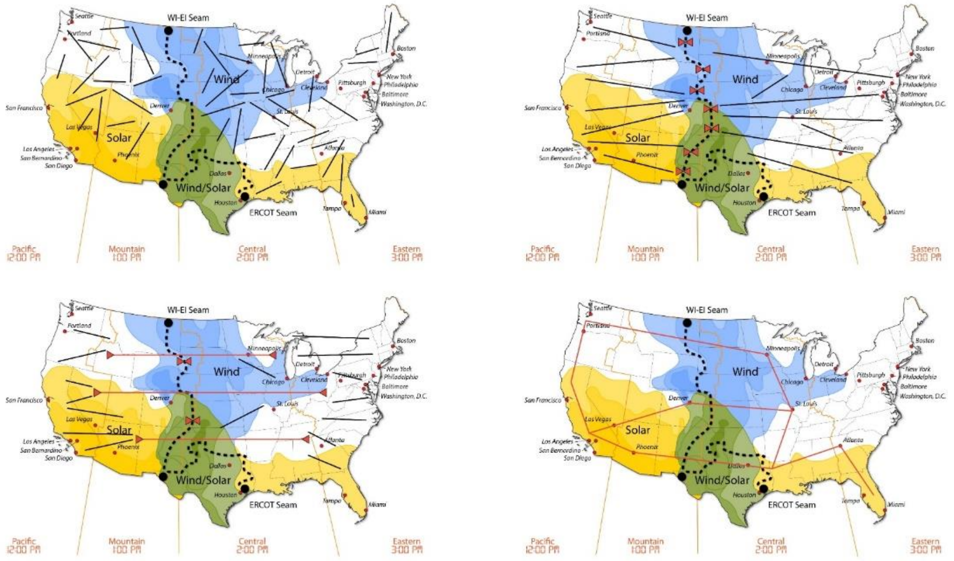
Research Environments

The four conceptual transmission designs were studied under two different system conditions

Base Case



High Variable Generation

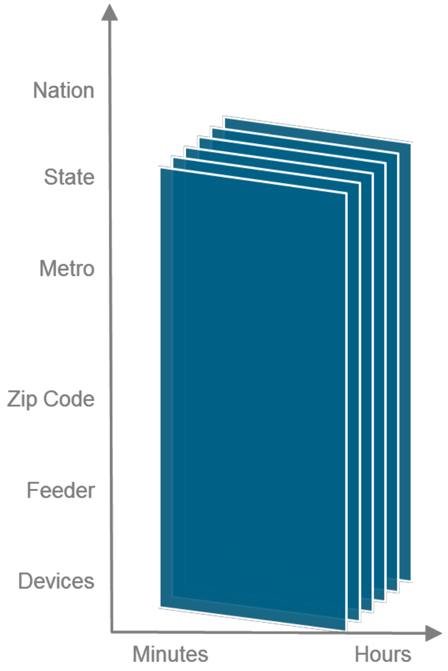


TRC Driven Assumptions

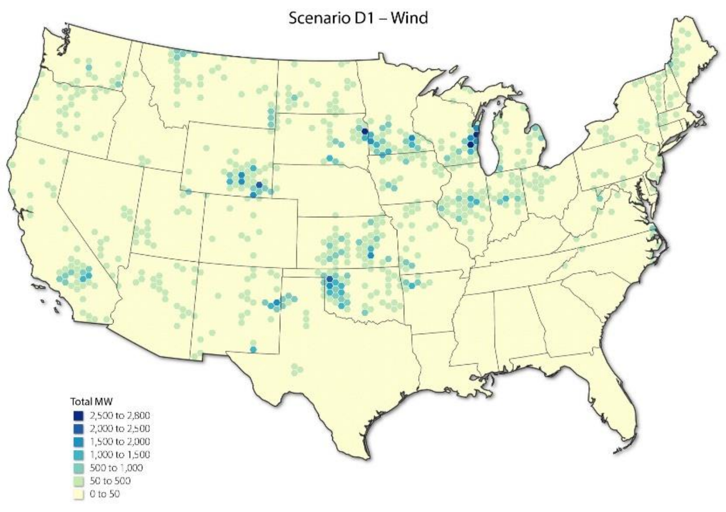
- North American Eastern and Western Interconnections
- Retire generation based on economic performance
- Run for 15 years, with 7 investment periods
- Fuel cost forecasts according to AEO 2017 (med-gas)
- Gen investment base costs & maturation rates from NREL ATB 2016
- Transmission base costs according to EIPC/B&V
- Gen & trans regional cost multipliers from EIPC/WECC
- Use of 169 bus model (68 EI, 101 WI)
- 4 regions: West, Northwest, Midwest, East
- Wind uses 100-m tower CFs ~ 0.45-0.50
- Gen capacity investment limited to 40GW/yr
- Demand growth per NEEM & WI (E3) per state
- DG growth per AEO 2016, 3% per yr
- New nuclear, offshore wind, geothermal, concentrating solar power, and carbon capture technologies were not studied

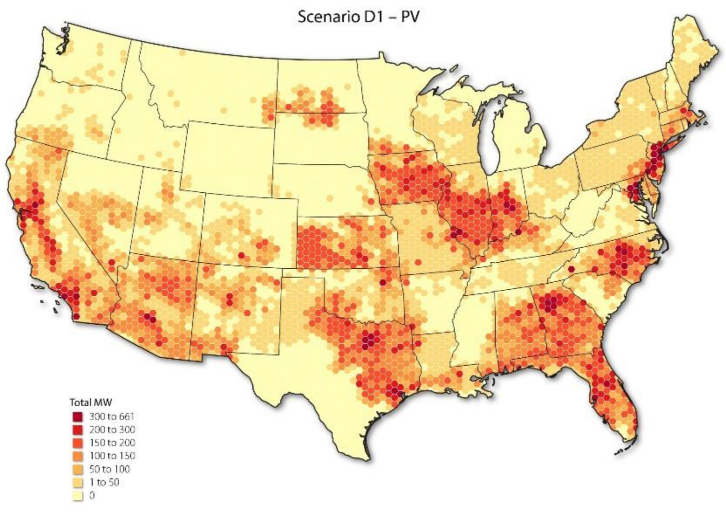
Production Cost Models

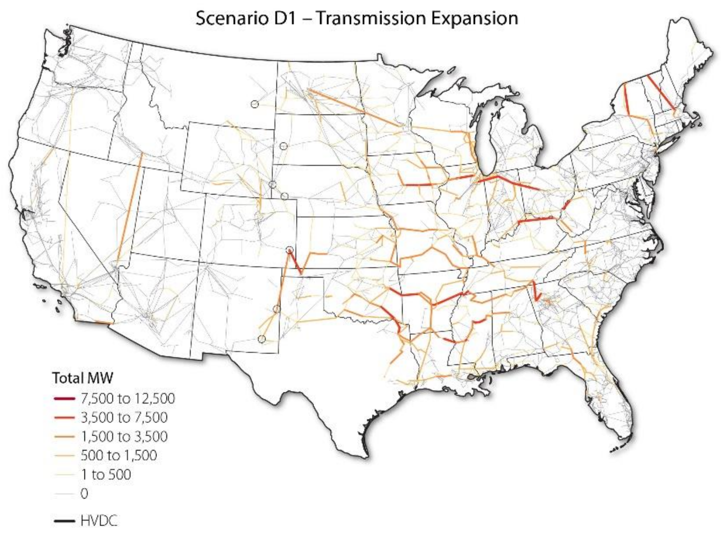
Production Cost



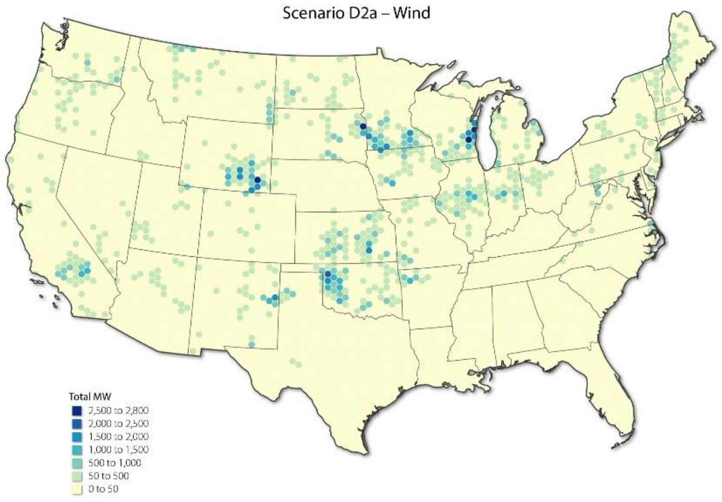
- Simulate the unit commitment and economic dispatch of a power system
- Approximate the daily operations of an IOU or RTO/ISO (Day ahead and Real Time)
- Used to simulate an entire year of hourly operations
- Calculates the cost of producing electricity
- Linearized DC Power flow

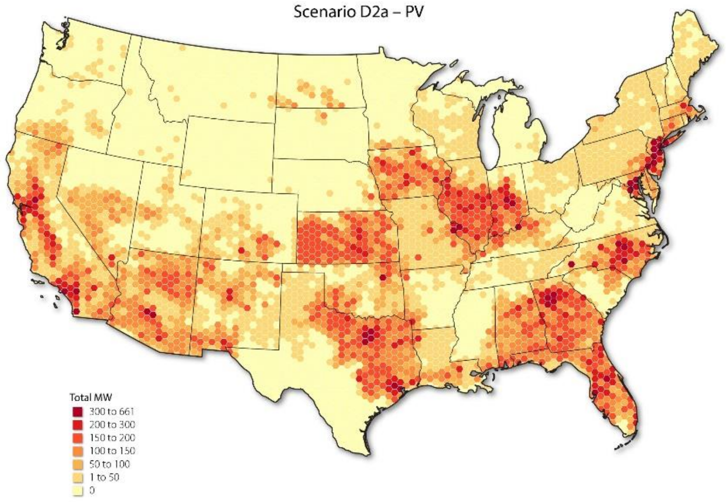


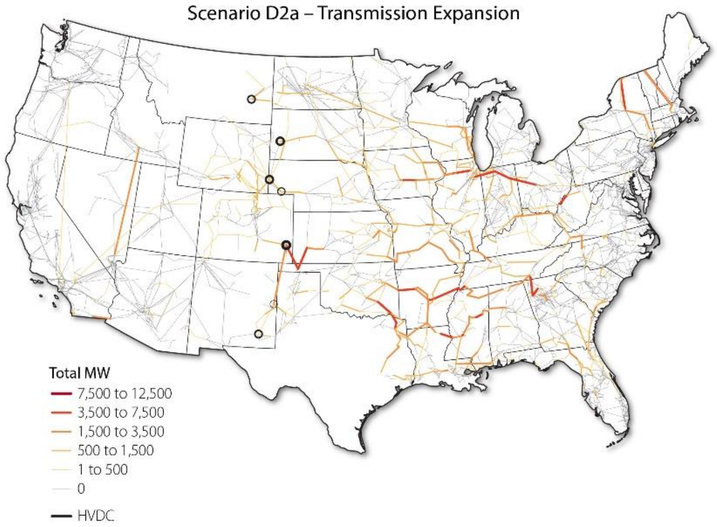




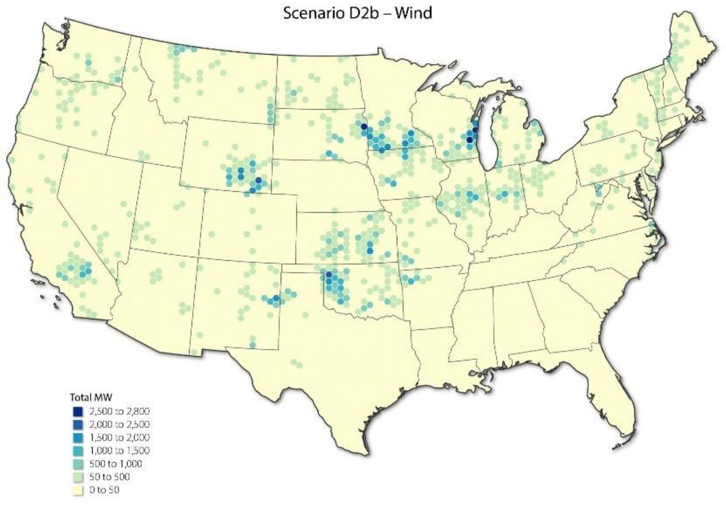
Design 1
Base Case

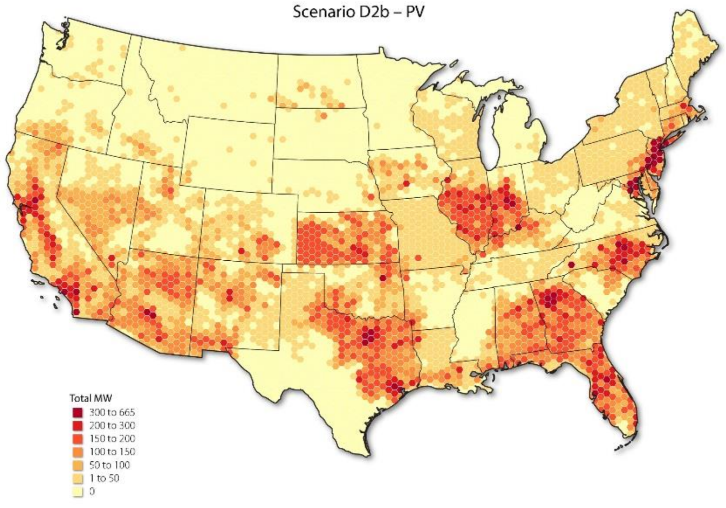


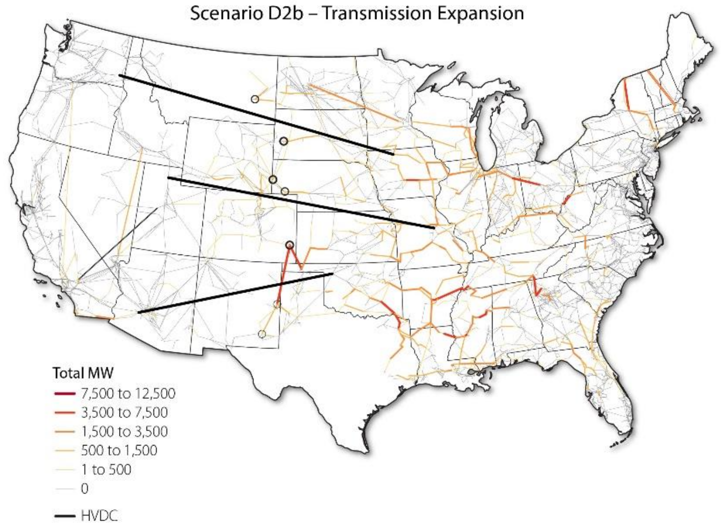




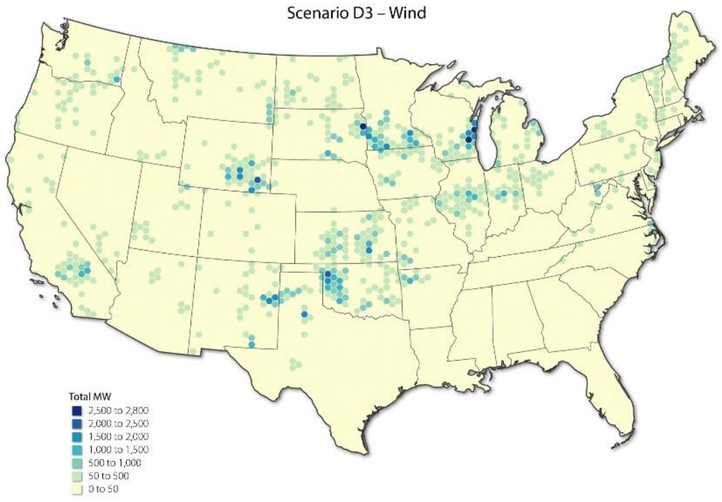
Design 2a
Base Case

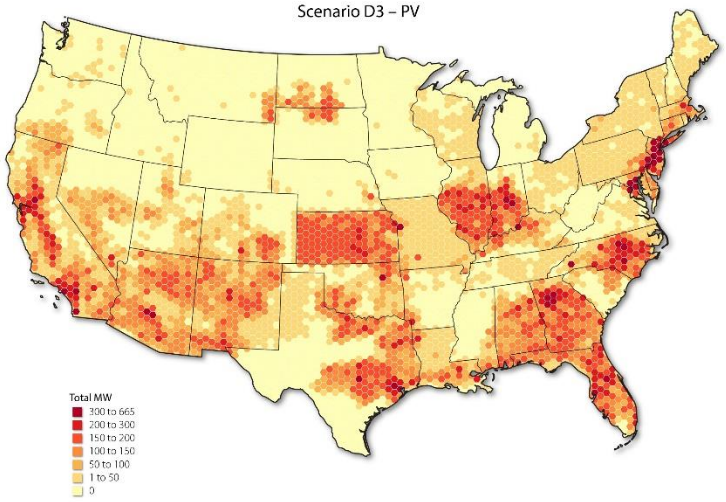


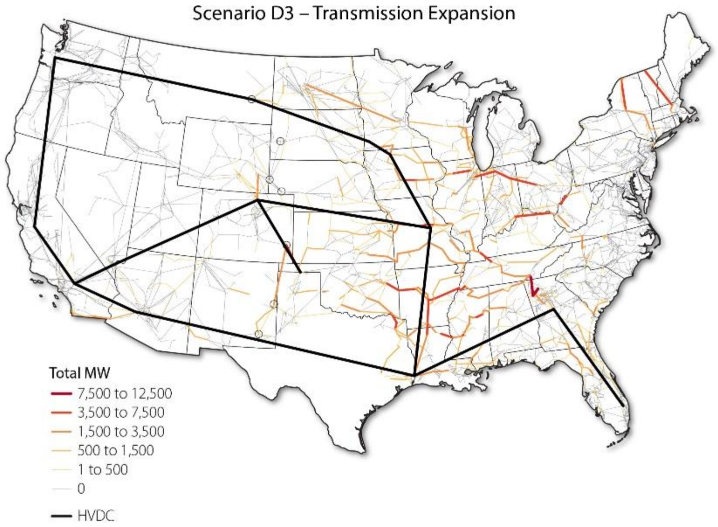




Design 2b
Base Case

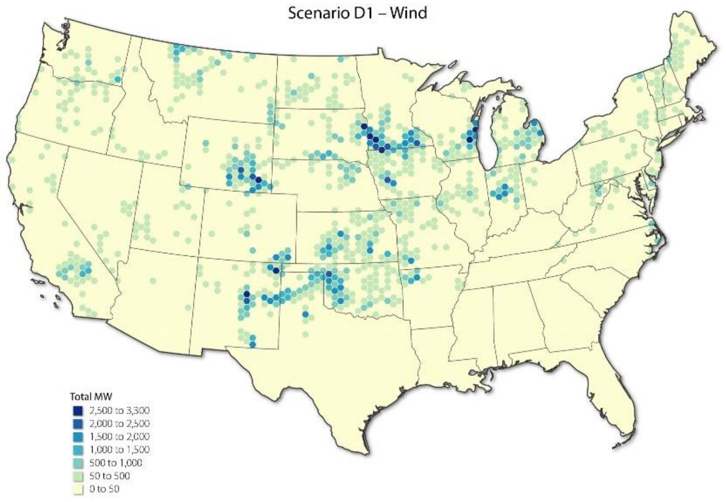


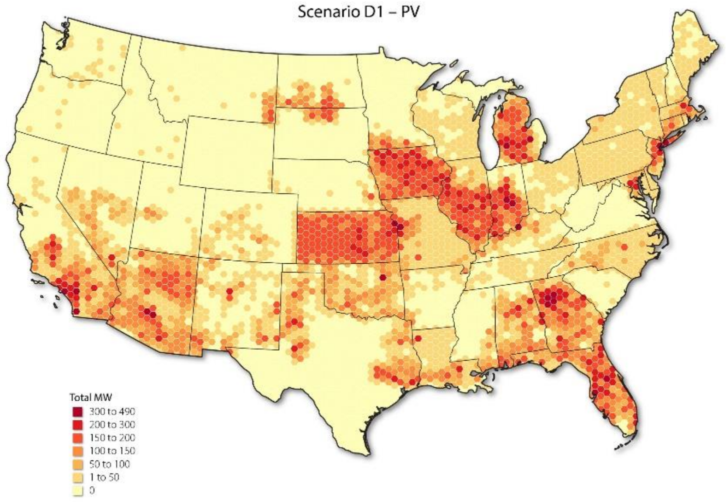


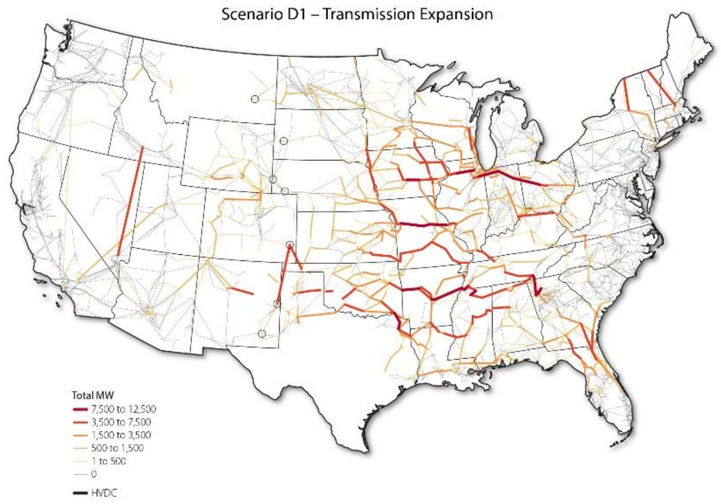


Design 3

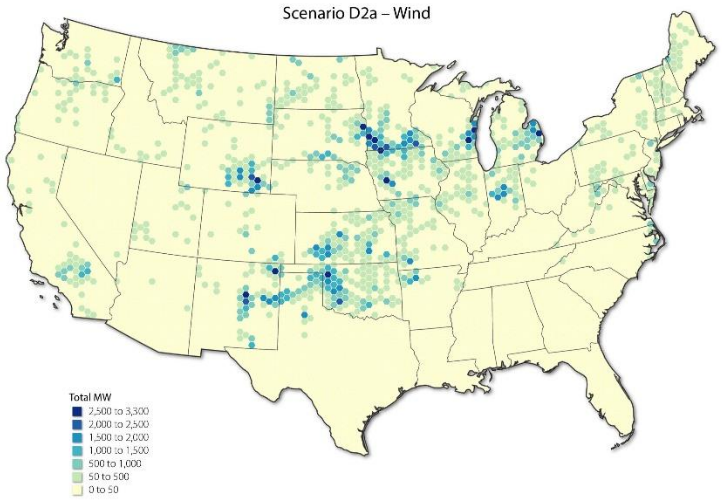
Base Case

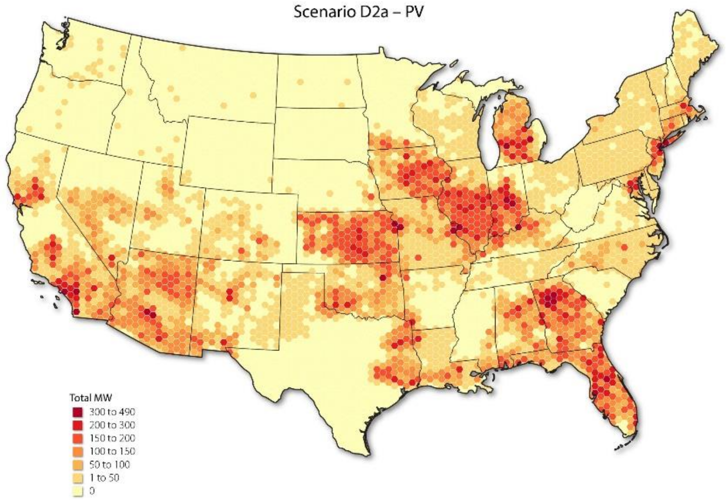


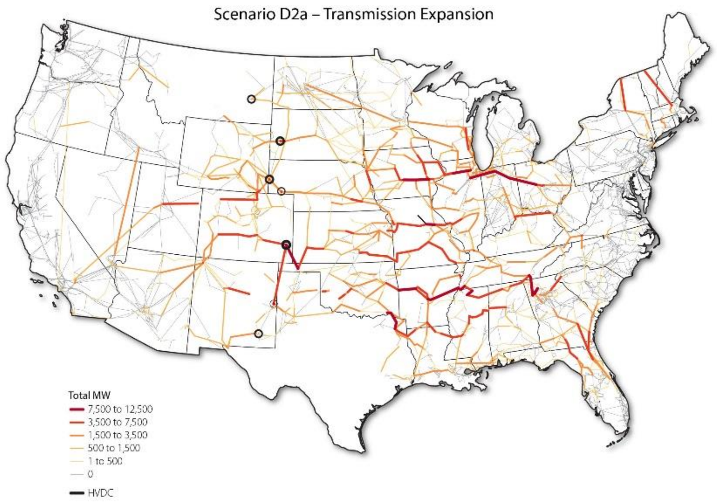




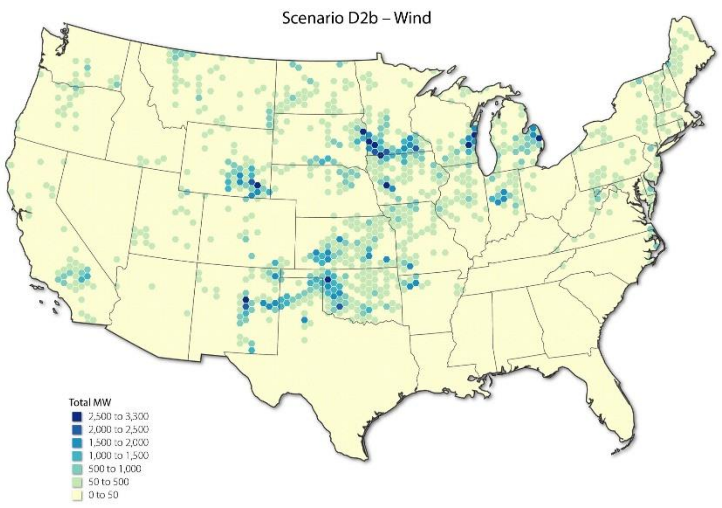
Design 1
High VG Case

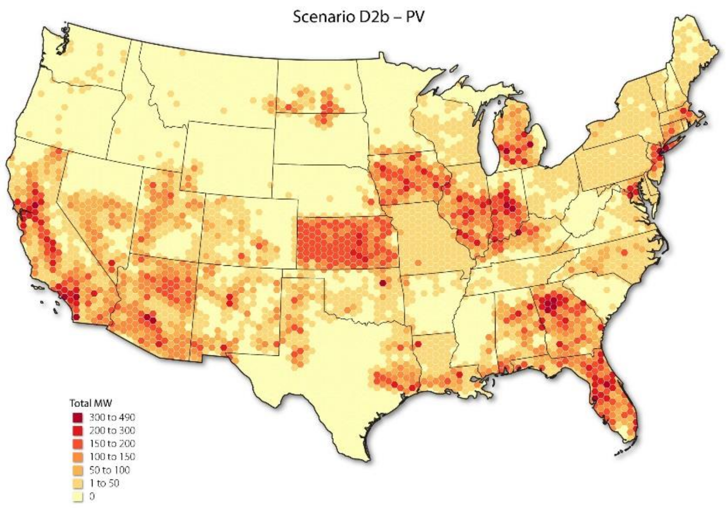


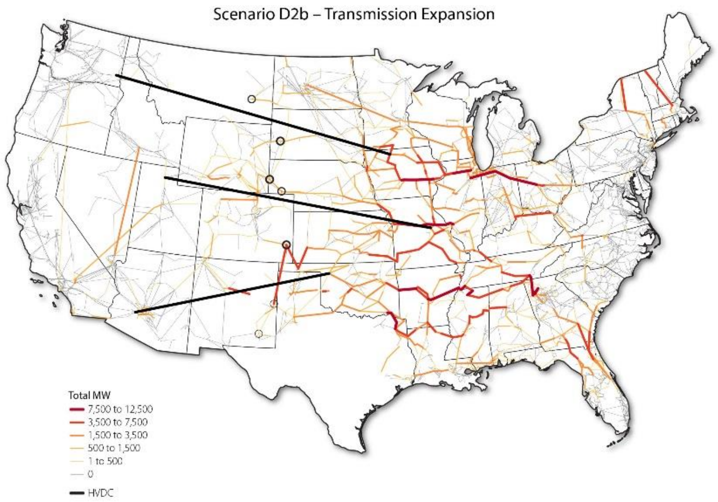




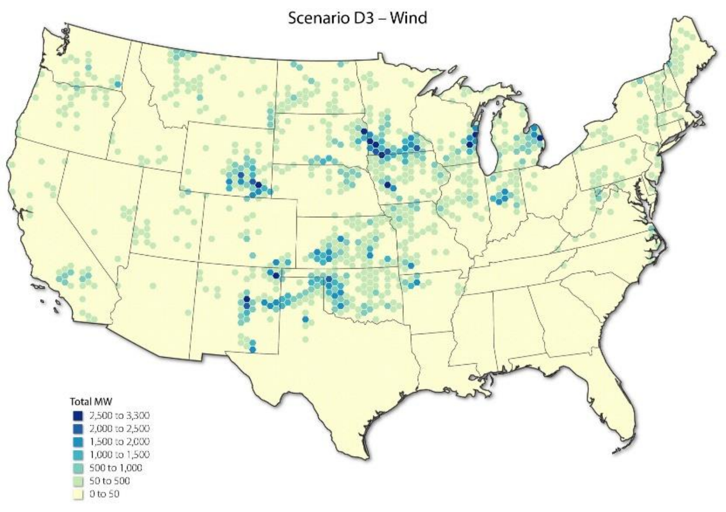
Design 2a
High VG Case

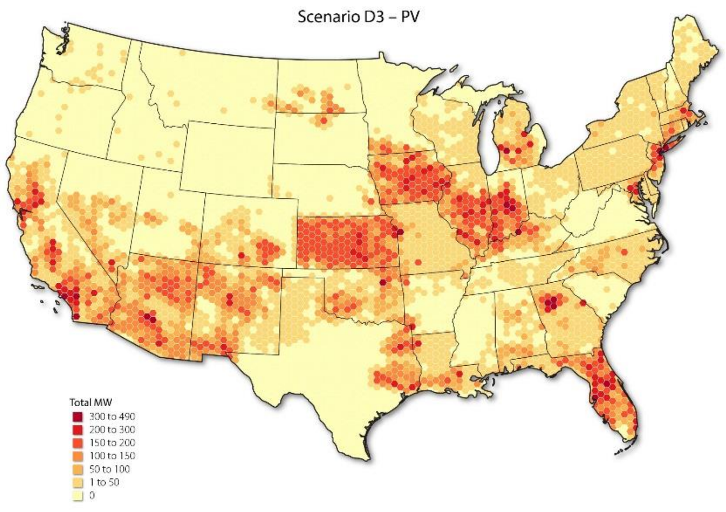


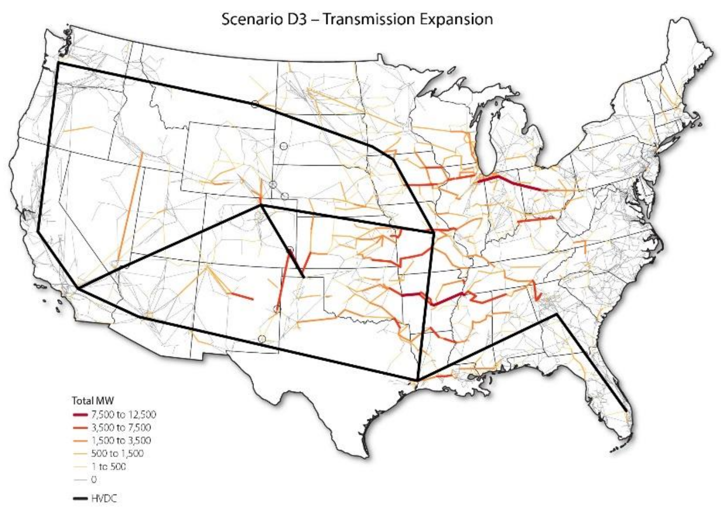




Design 2b
High VG Case



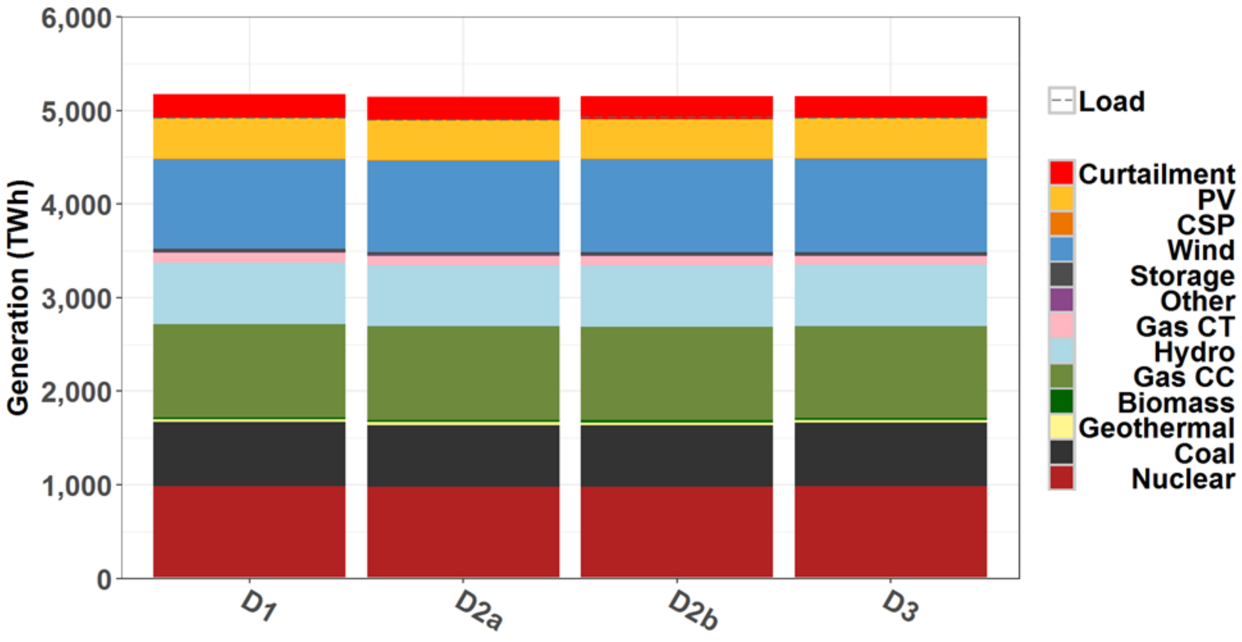




Design 3
High VG Case

Annual Generation

- Base Case



- High VG Case