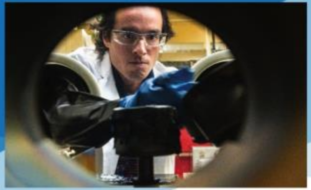
NATIONAL RENEWABLE ENERGY LABORATORY


NREL Interconnections Seam Study

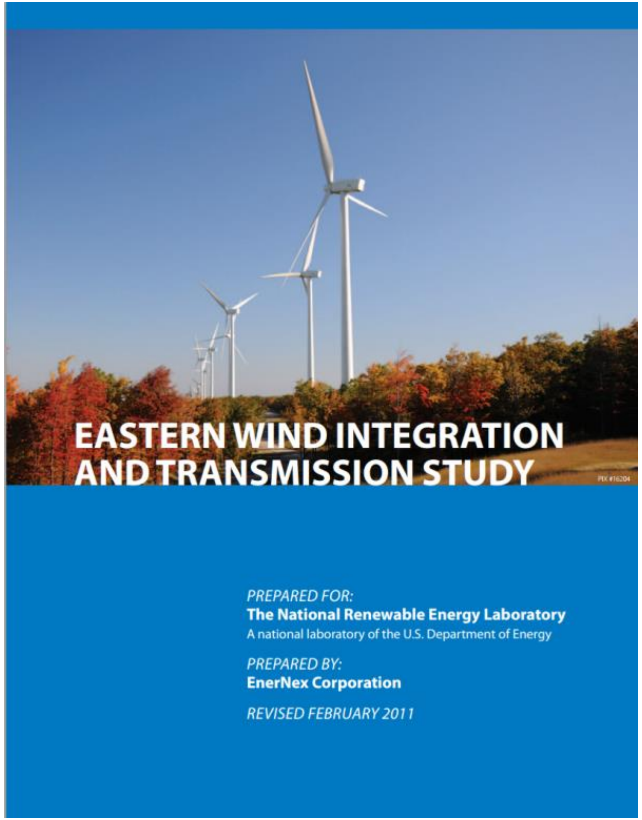
Aaron Bloom

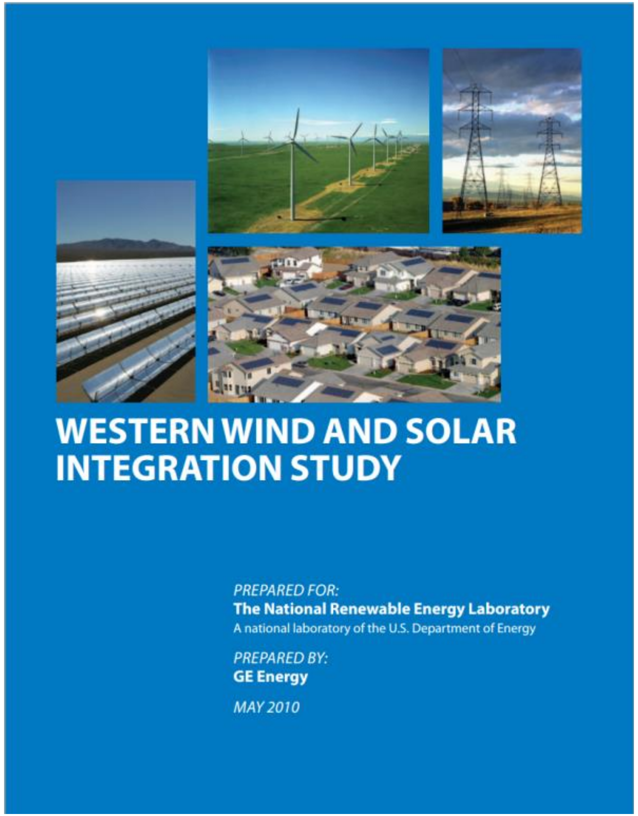
UVIG Spring Workshop, Tucson, AZ
March 2018

Multi – disciplinary Team of Engineers, Economists, and Analysts

- Special Thanks
  - Engineering: Greg Brinkman, Jennie Jorgenson, Clayton Barrows, Matt O'Connell
  - Maps: Billy Roberts
  - Visualization: Kenny Gruchalla
  - High Performance Computing Team: Wes Jones, Harry Sorenson, Kevin Regimbal

Early Integration Studies





Renewable Electricity Futures Study

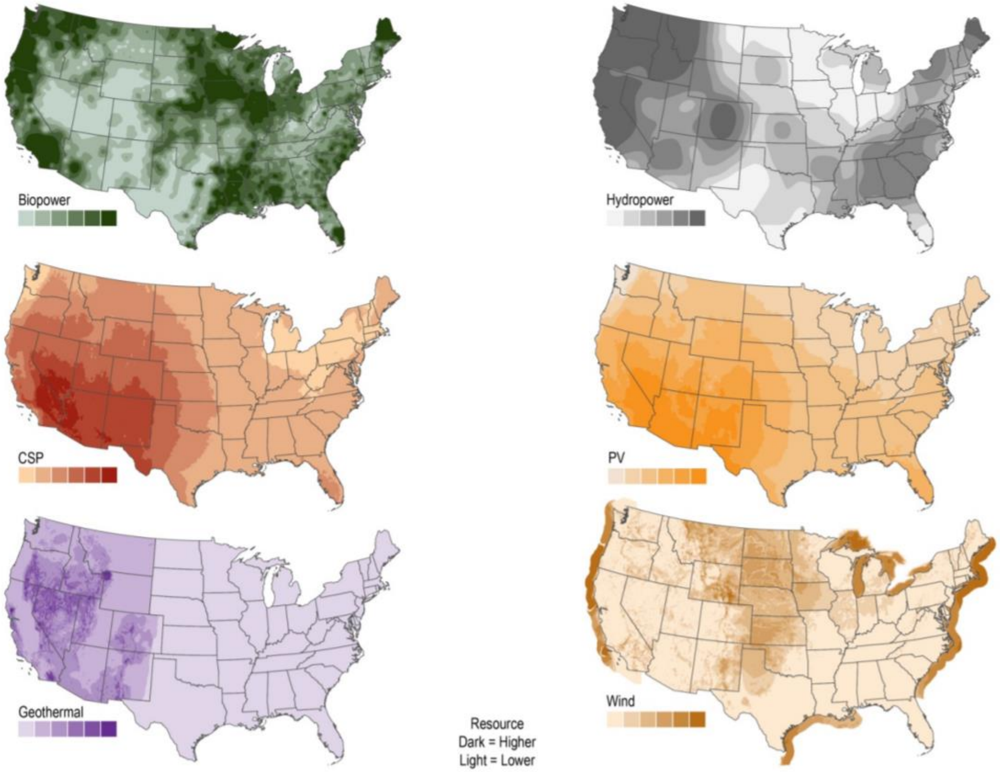
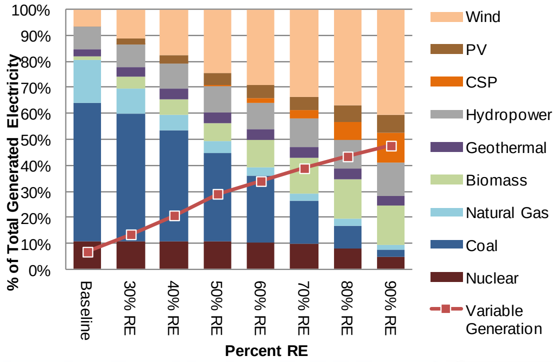


Figure ES-2. Geographic distribution of renewable resources in the contiguous United States



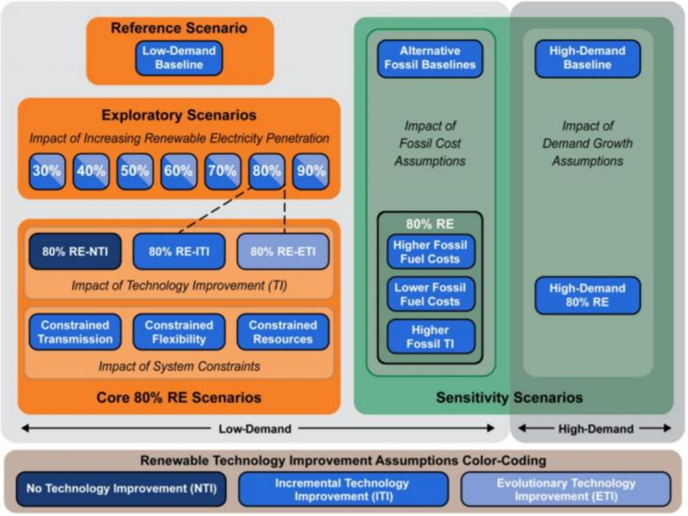
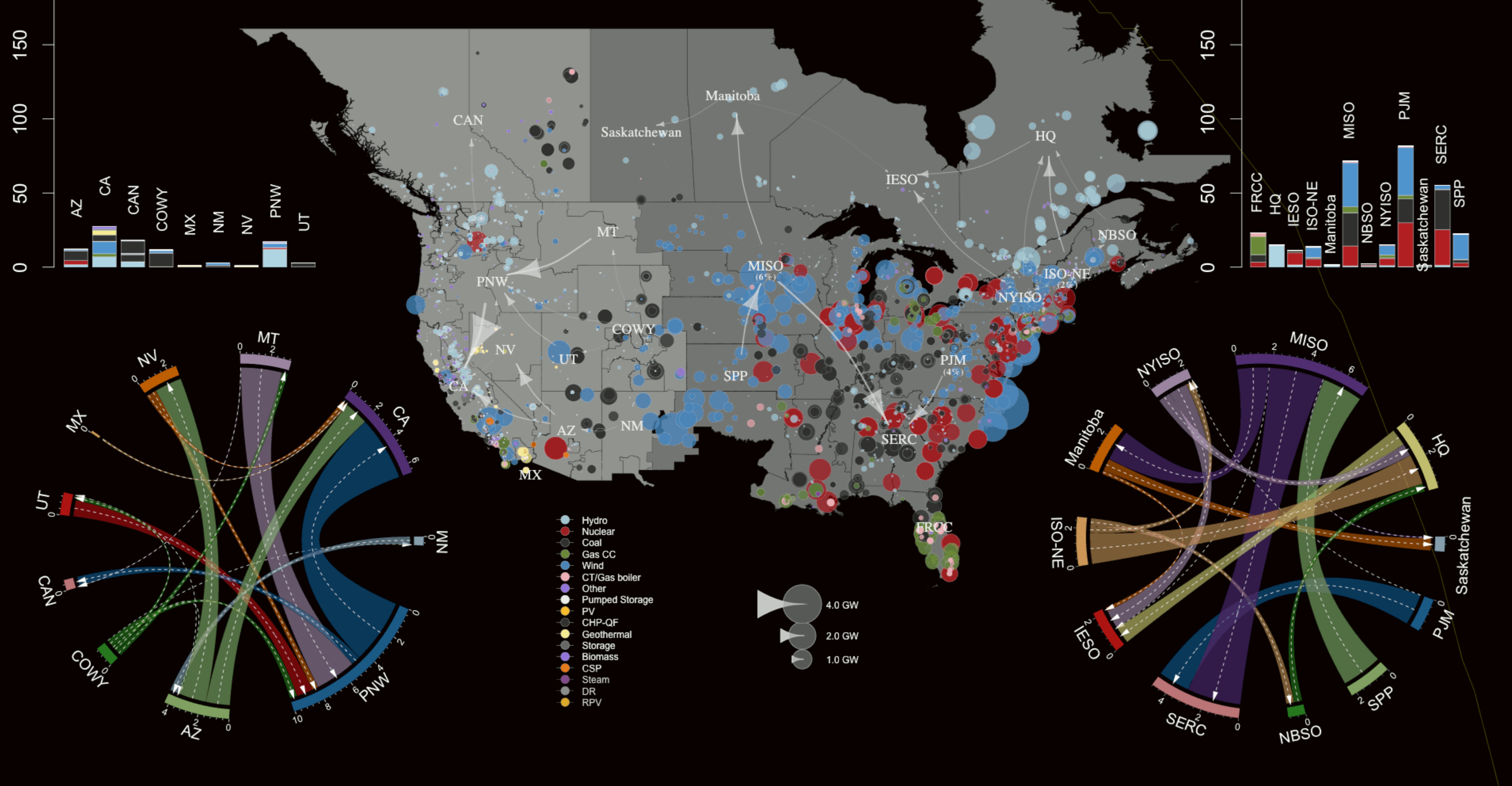


Figure ES-1. Modeling scenario framework for RE Futures

WECC (high_solar) + ERGIS (RTx30)

05-12 03:00 EST



But that’s what we’ve done

This is What We are Doing

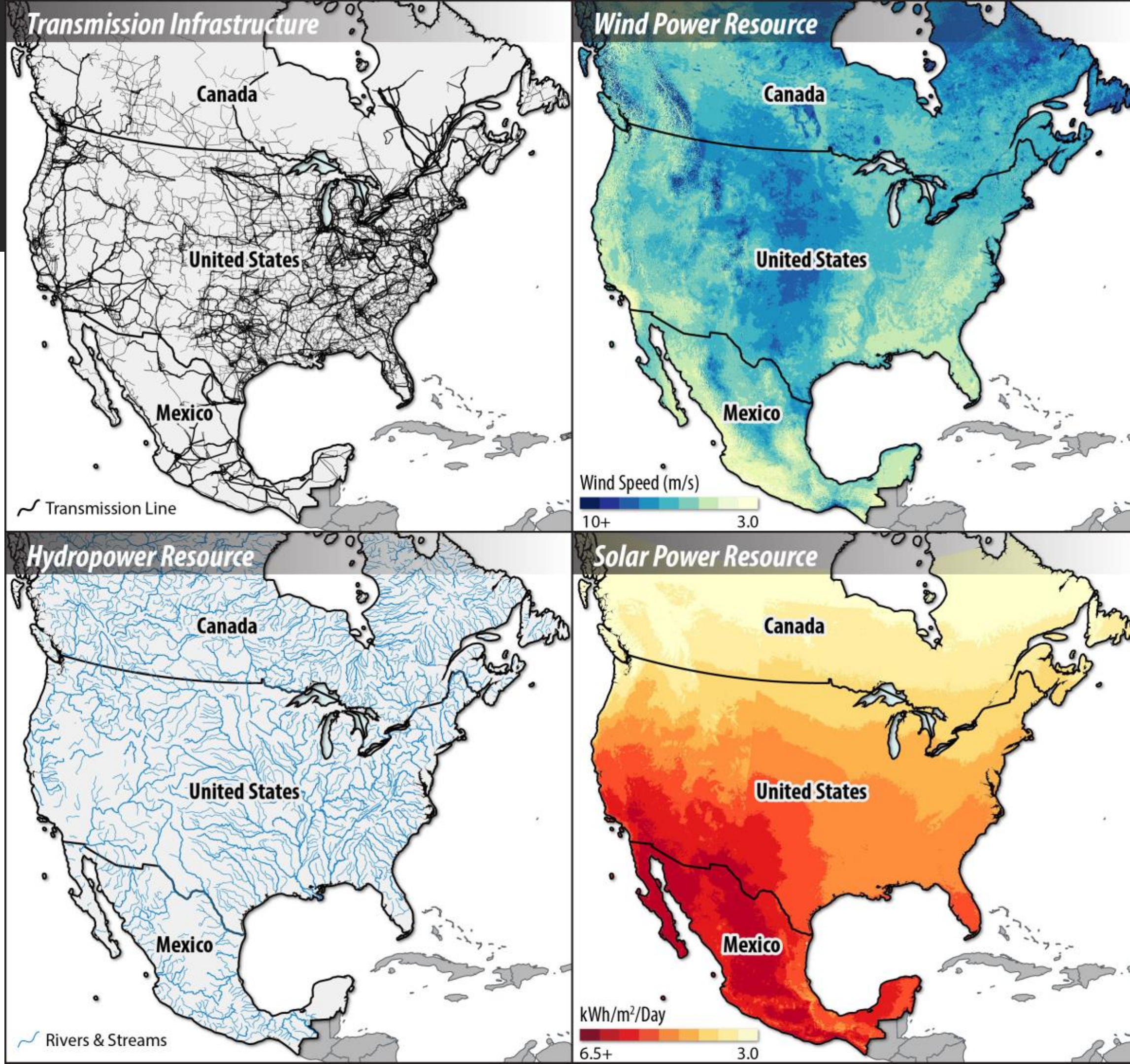
The Power System Is Changing

The Power System Is Changing

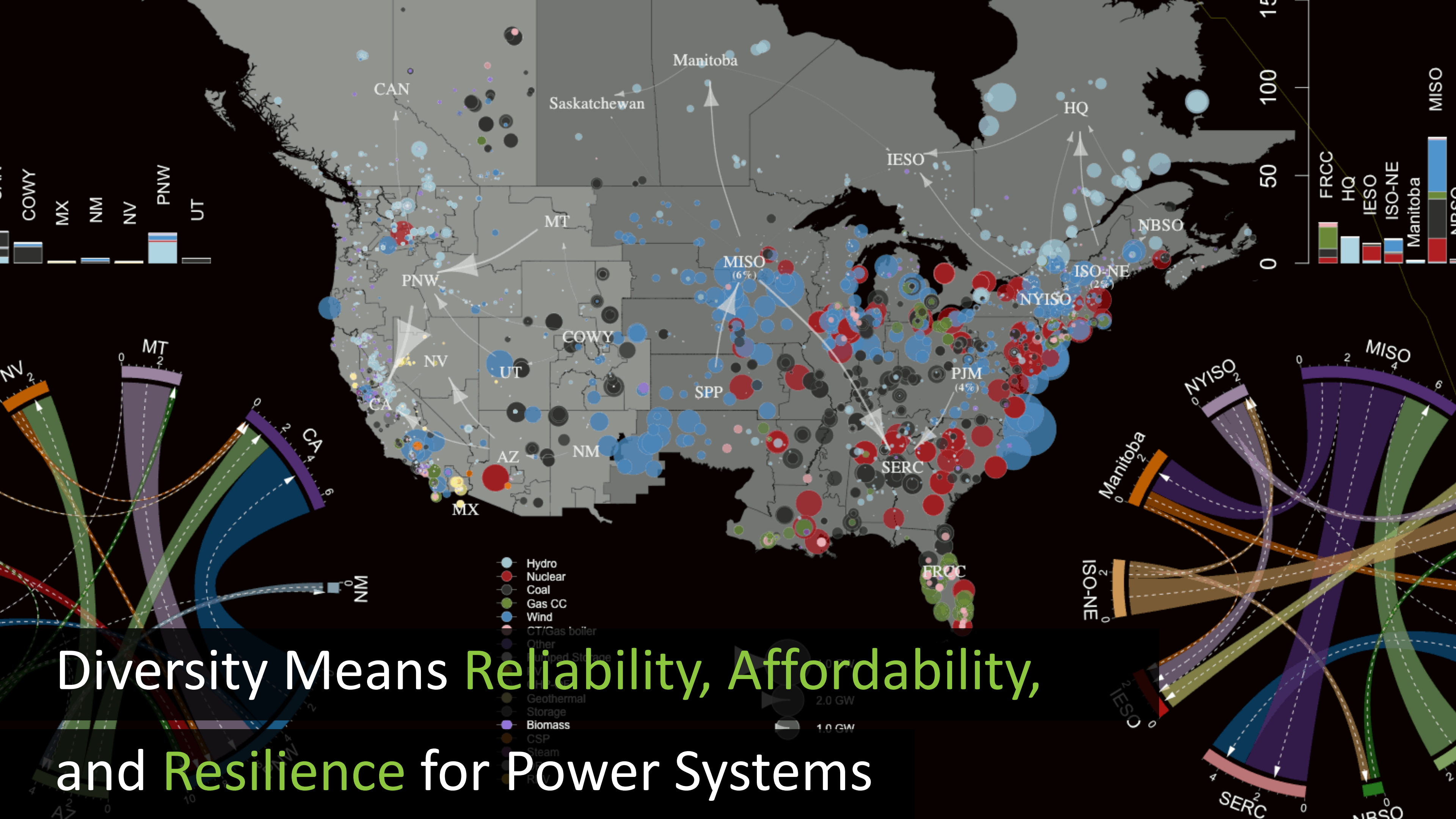
North America Is Very Diverse in Energy Resources and Load

The availability of natural resources varies widely across regions.

So does how and when energy is used on the grid.



Diversity Means Reliability, Affordability, and Resilience for Power Systems



How Do We Get There?

The North American Renewable Integration Study

State-of-the-art analysis of the U.S., Canada, and Mexico power systems, from planning through operations

National Resources Canada | Ressources naturelles Canada

SENER
SECRETARÍA DE ENERGÍA

WHAT WE'RE STUDYING

- Long-term pathways to a modern power system in North America
- Operational feasibility of very high-penetration scenarios
- Resilience to weather
- Value of enabling technologies: flexible hydro, thermal generation, demand response, storage, transmission
- Value of operating practices: interchange, enhanced scheduling, local generation, reserve provisions

Giving Grid Planners Answers They Need

INFORMING

grid planners, operators, market participants, and regulators of challenges and opportunities for the grid

-What are the potential reliability, clean, and affordability impacts?

- What operating practices and technologies help the most?

- Are the “solutions” robust?

- What is the benefit of inter-regional and cross-border cooperation?

ENABLING

stakeholders to deepen and extend their understanding of renewables and resiliency of modern power systems

- Creating and disseminating new data

- Pioneering and deploying new methods and computational tools

CREATING

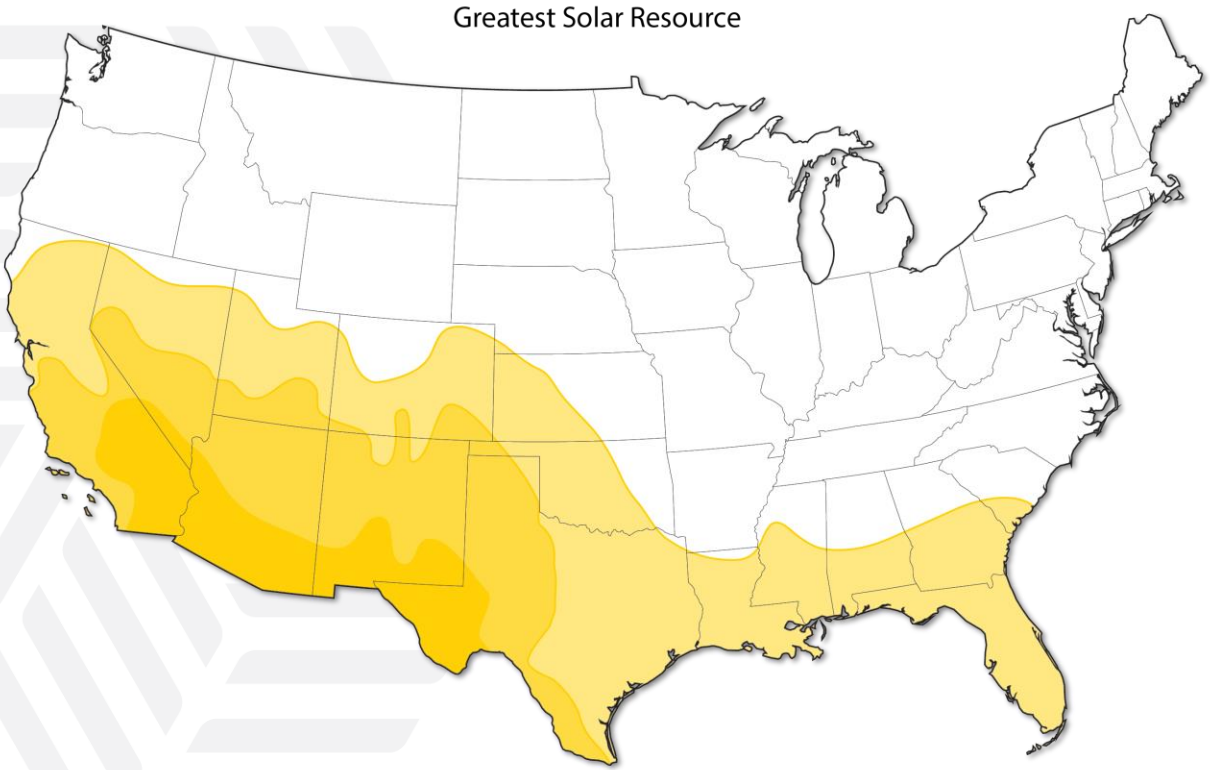
a framework for future analysis

- Stability (i.e., frequency, transient, voltage)

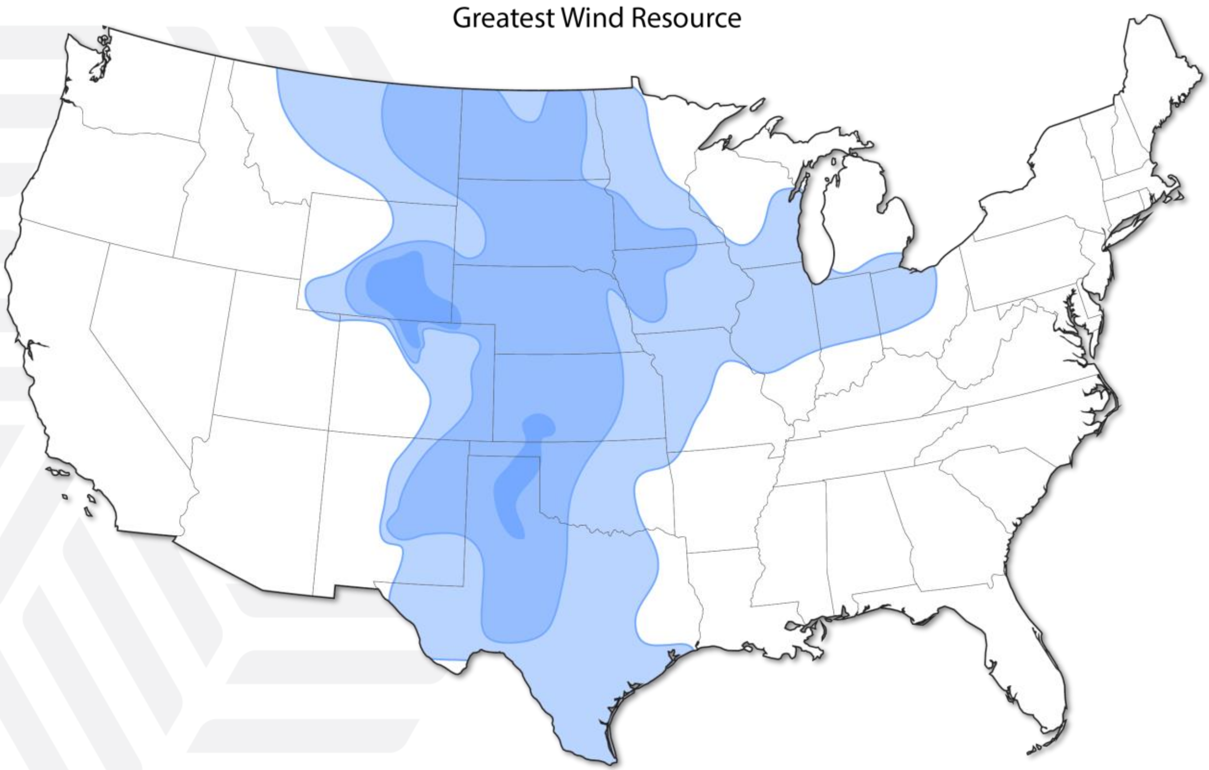
- Resilience to extreme events (e.g., weather)


This is the Prelude

The U.S. has Diverse Resources and Demand

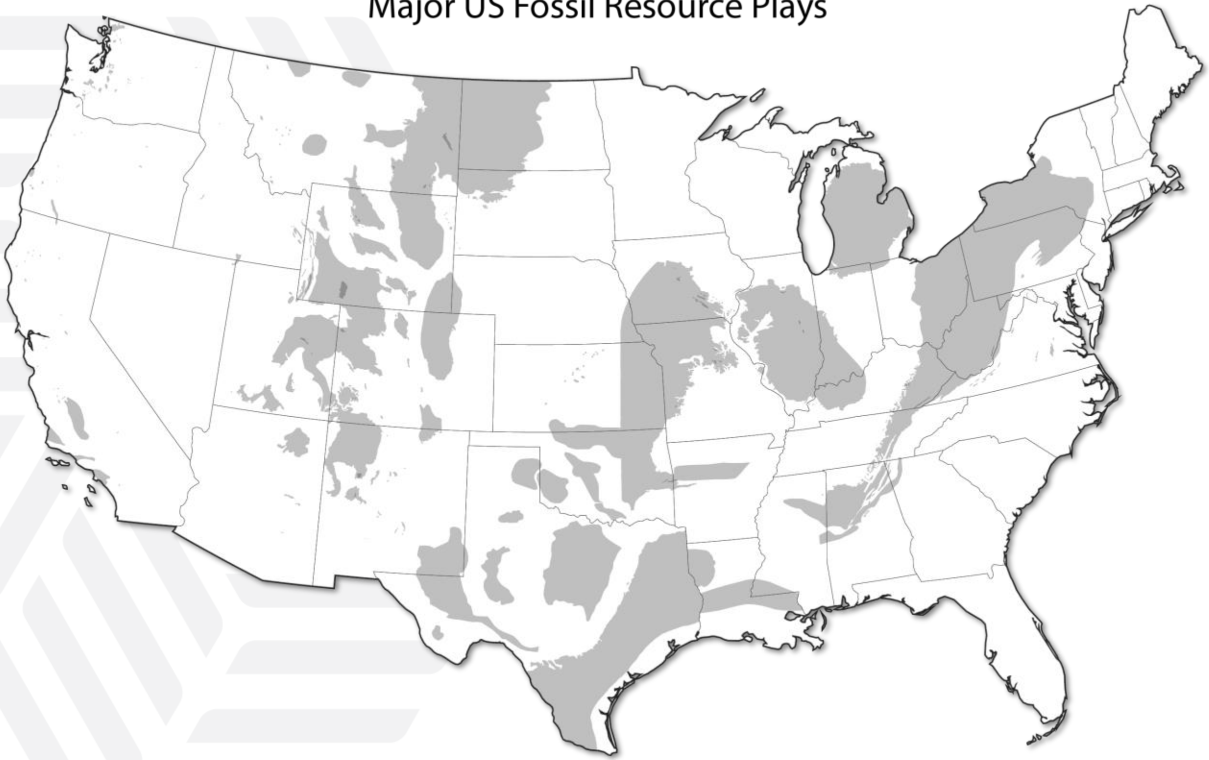


The U.S. has Diverse Resources and Demand



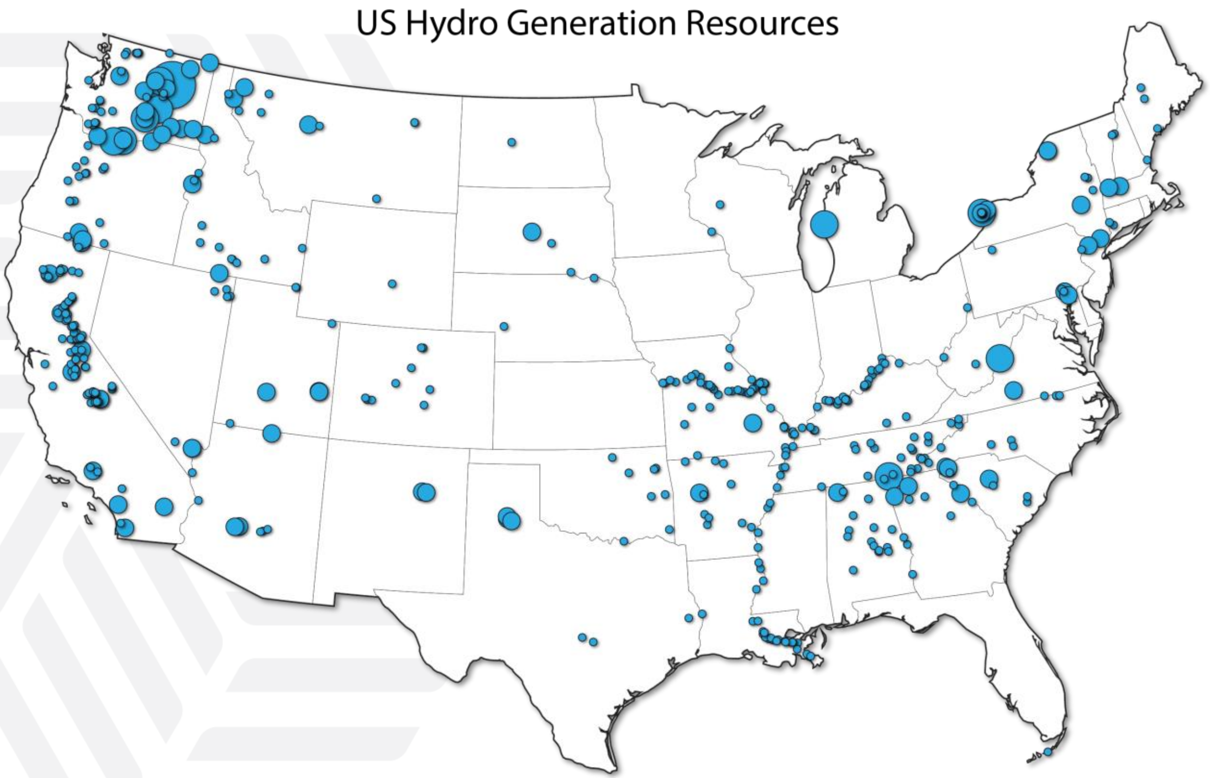
The U.S. has Diverse Resources and Demand

Major US Fossil Resource Plays

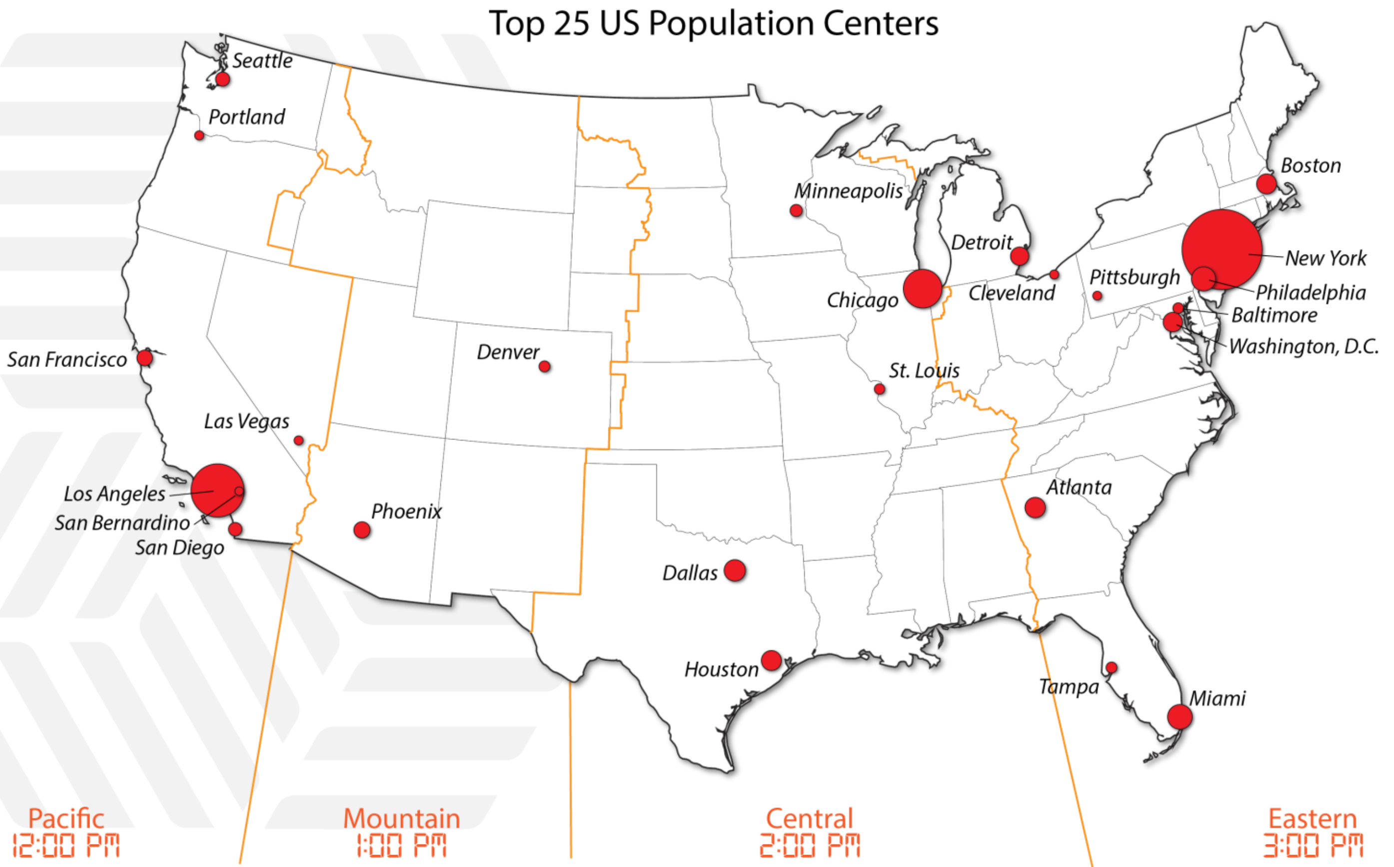


GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

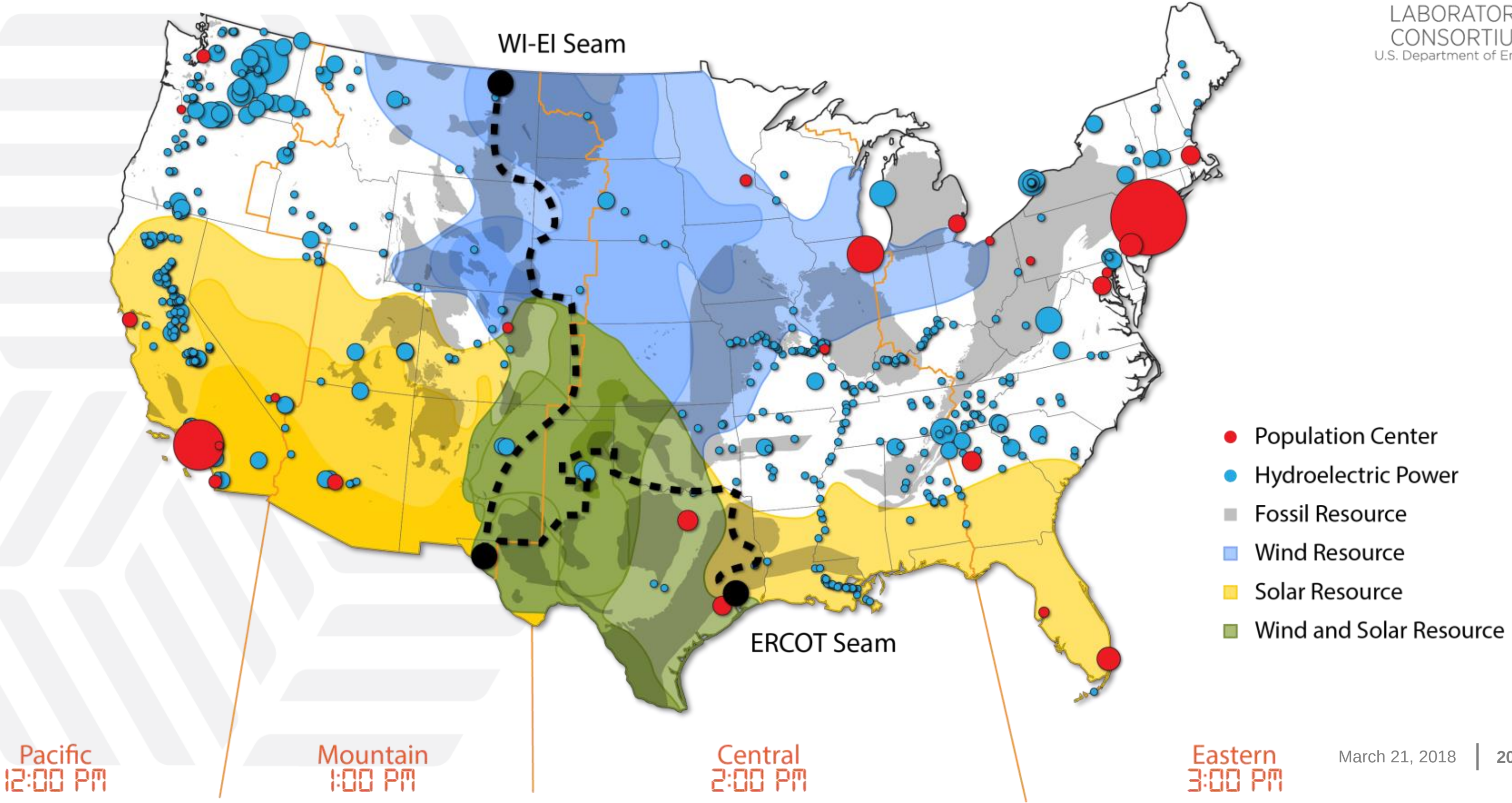
The U.S. has Diverse Resources and Demand

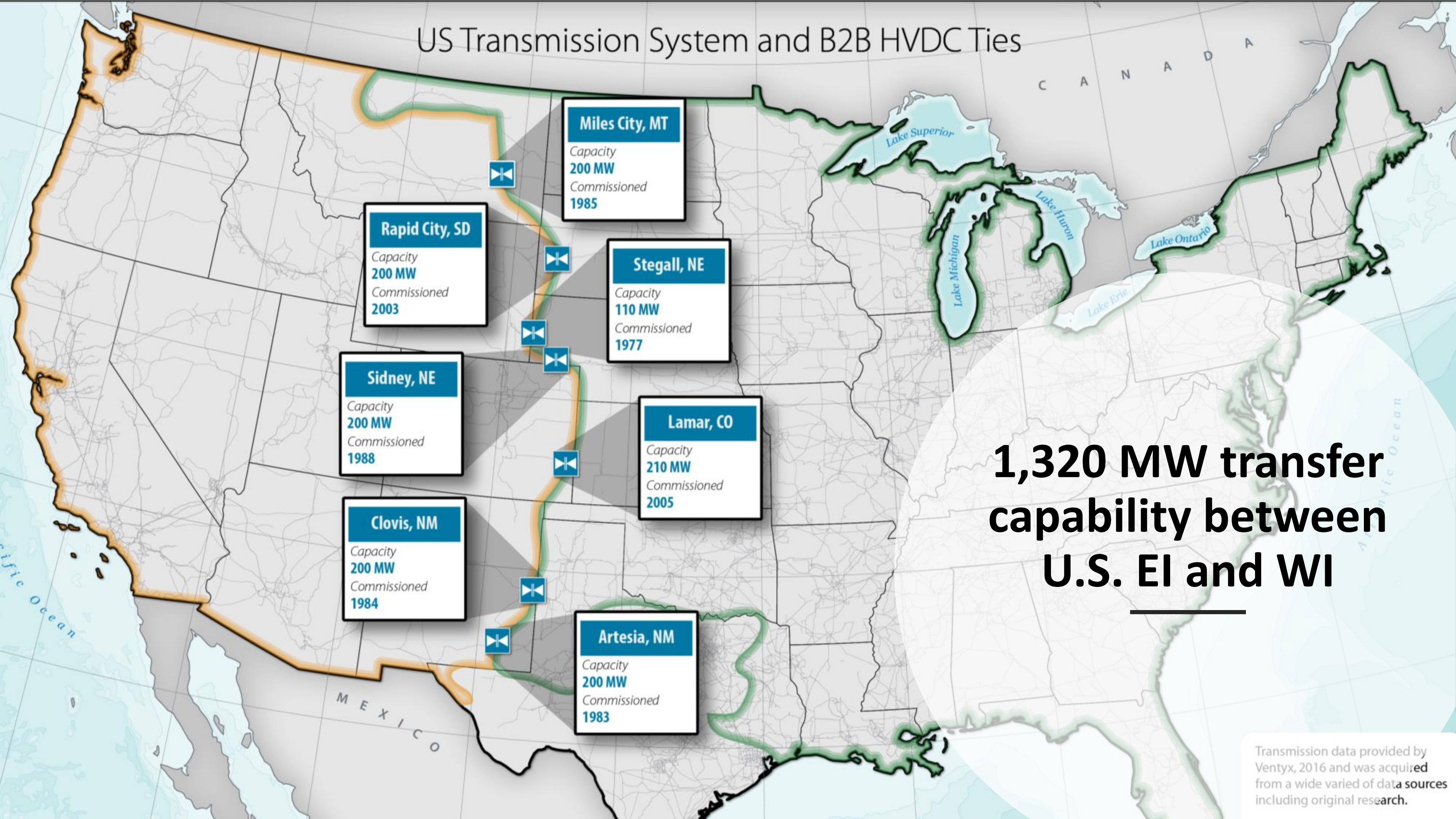


The U.S. has Diverse Resources and Demand



The Interconnections Seam Study





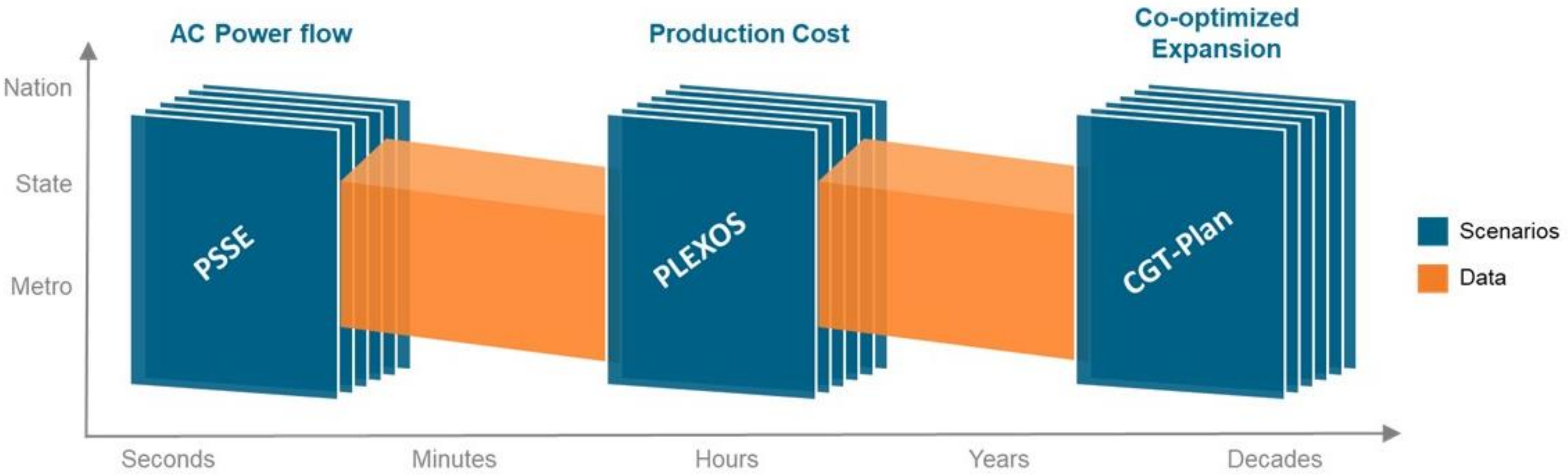
1,320 MW transfer capability between U.S. EI and WI

Partners are Everything

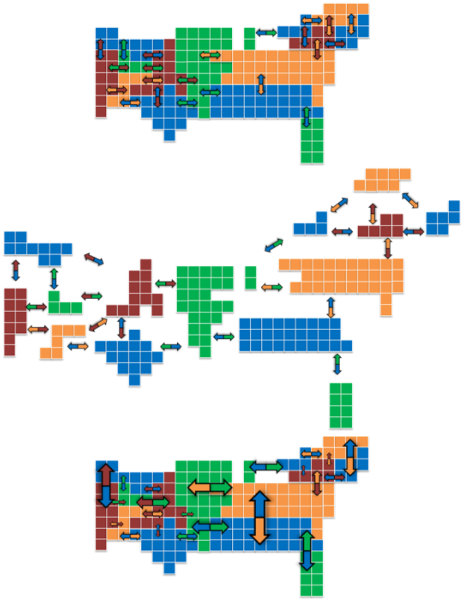
- SPP Southwest Power Pool
- MISO
- NREL National Renewable Energy Laboratory
- Western Area Power Administration
- Iowa State University
- Pacific Northwest National Laboratory

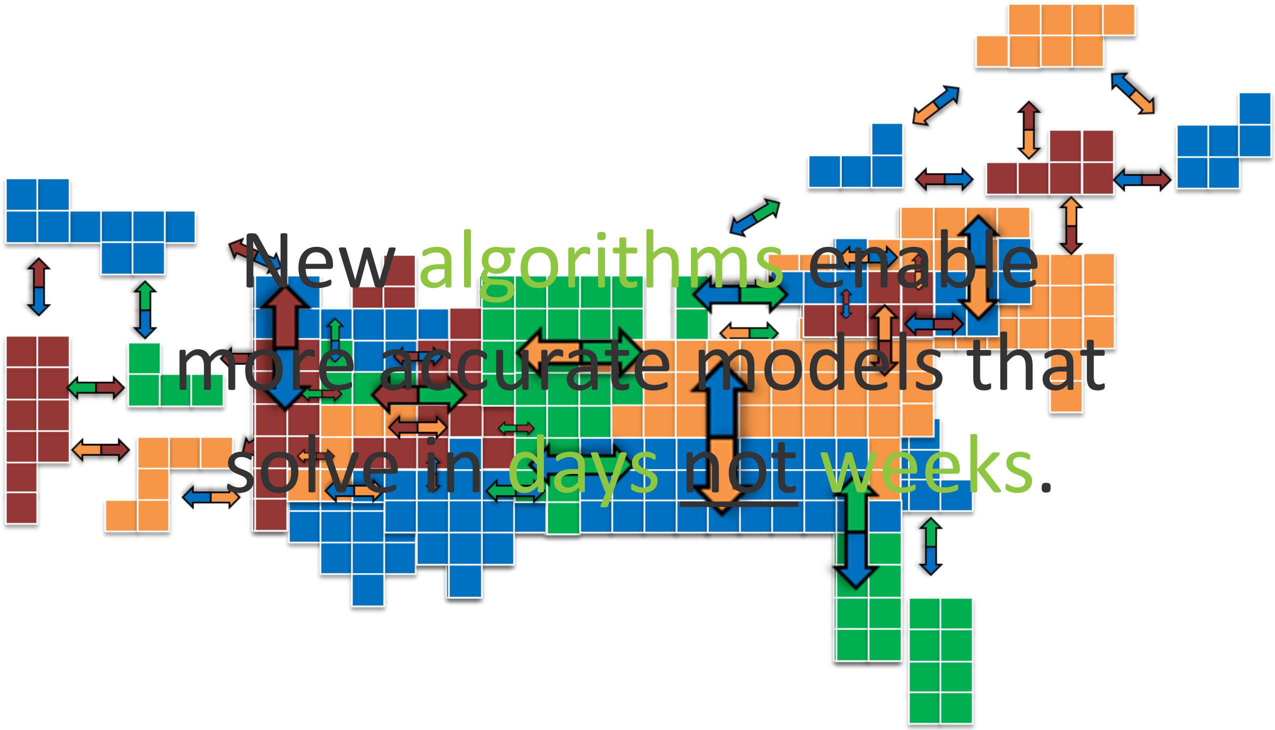
More Data, Better Resolution

- 1,000 times more wind and solar data, from GBs to TBs
- Transmission models have moved from 10s of nodes to nearly 100,000
- Every generator in North America, and many more around the world
- It’s not just the data, it’s the tools to use the data: ReV (above)



Integrated Power System Models and Data

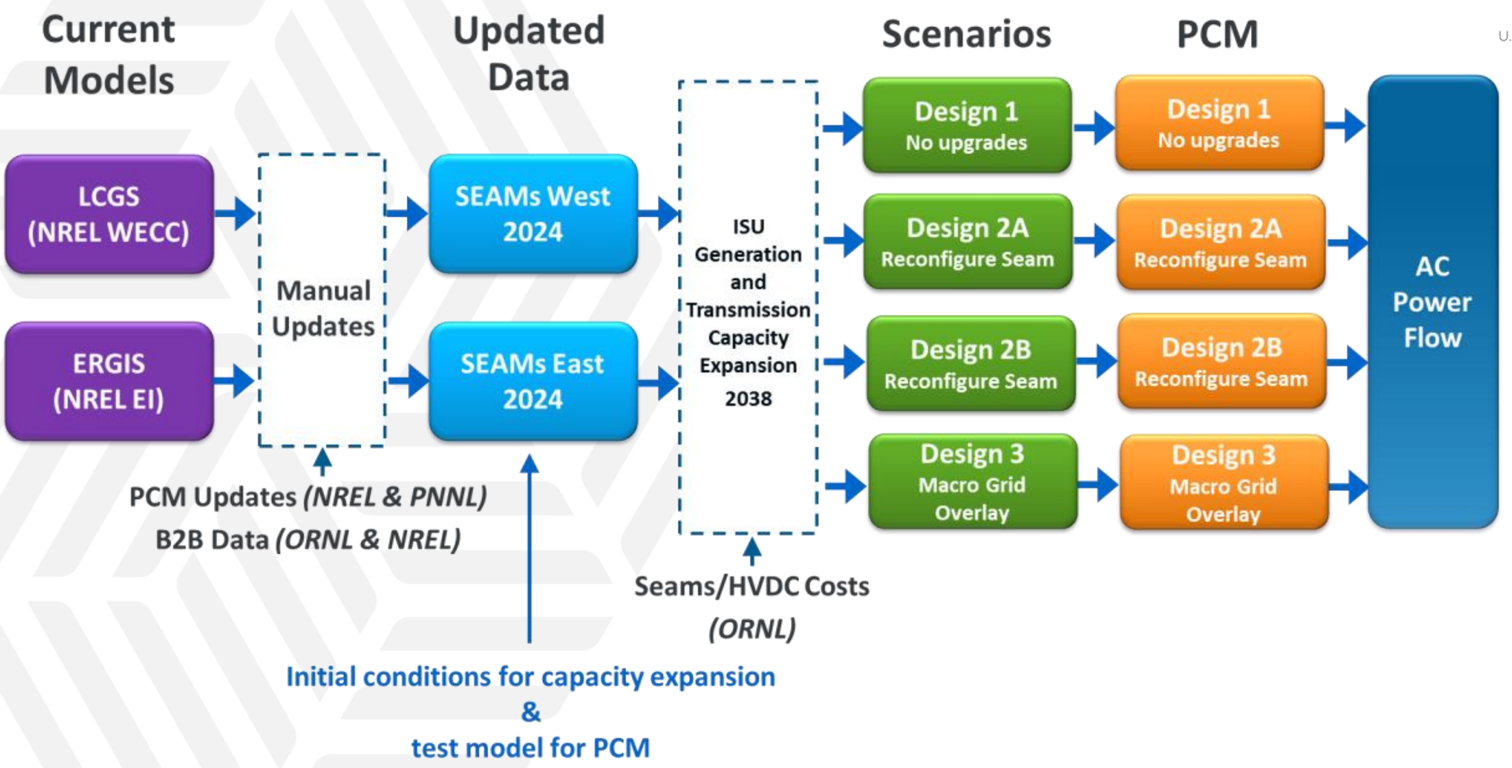




New algorithms enable more accurate models that solve in days not weeks.

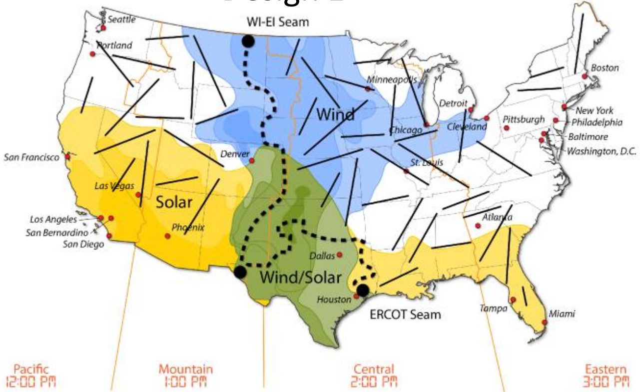
Advanced Computational Methods

Modeling Approach

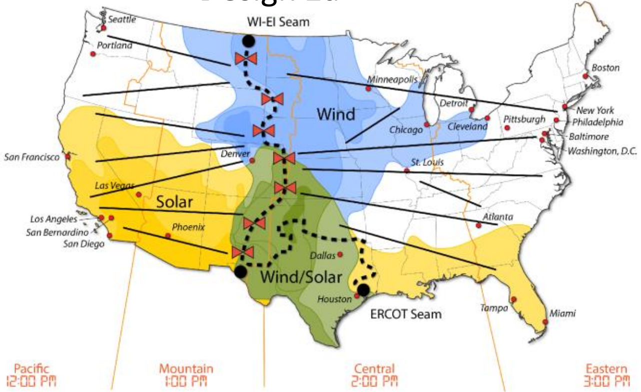


Conceptual Scenario Design

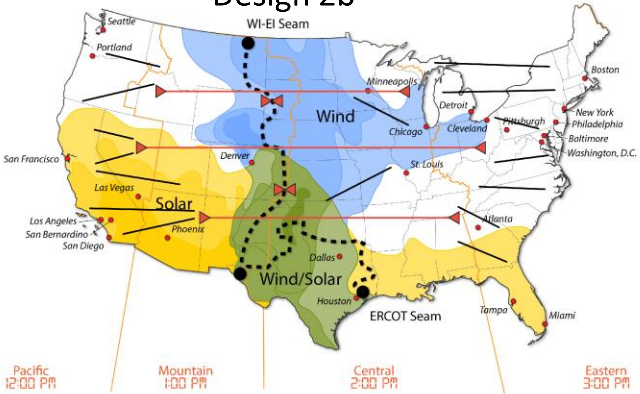
Design 1



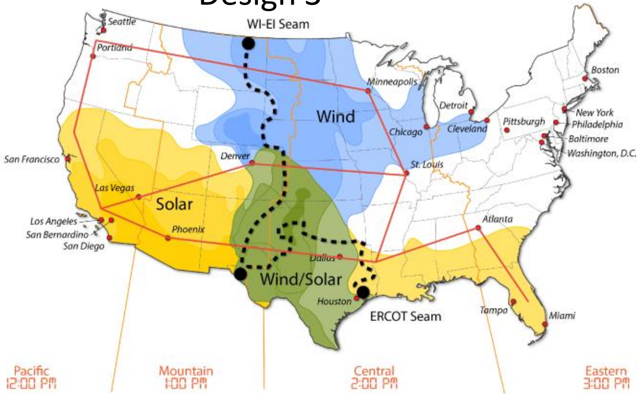
Design 2a



Design 2b



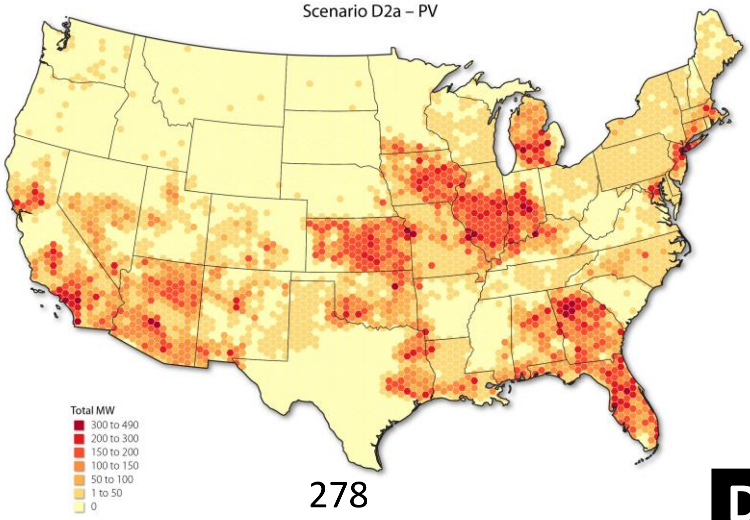
Design 3



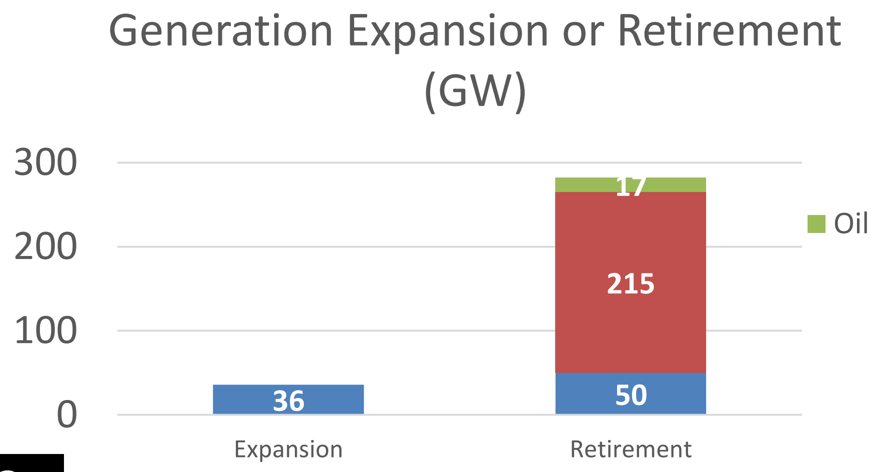
Results Summary:
Benefits: 15 B/C Ratio + Perpetuity Value

ECONOMICS, NPV $B	Design 1	Design 2a	Delta	Design 2b	Delta	Design 3	Delta
15-yr B/C Ratio	-	-	2.48	-	3.30	-	2.52
Perpetuity (Annualized 20-yr) Cost	83.71	82.35	-1.37	81.20	-2.51	79.53	-4.19

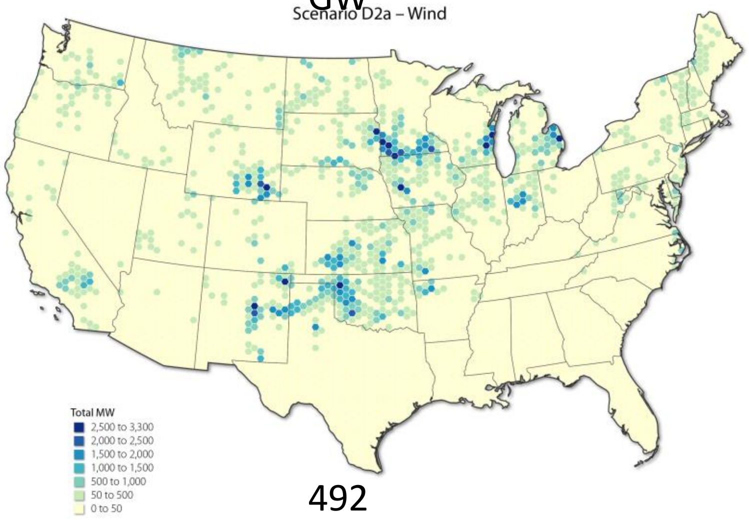
The above "Perpetuity Cost" row provides annualized (over 20 yrs) perpetuity cost for the base designs. Interpretation is that base designs 2a, 2b, & 3 will see the above 15-year B/C plus a savings each year over 20 years equal to the annualized perpetuity value in yellow.



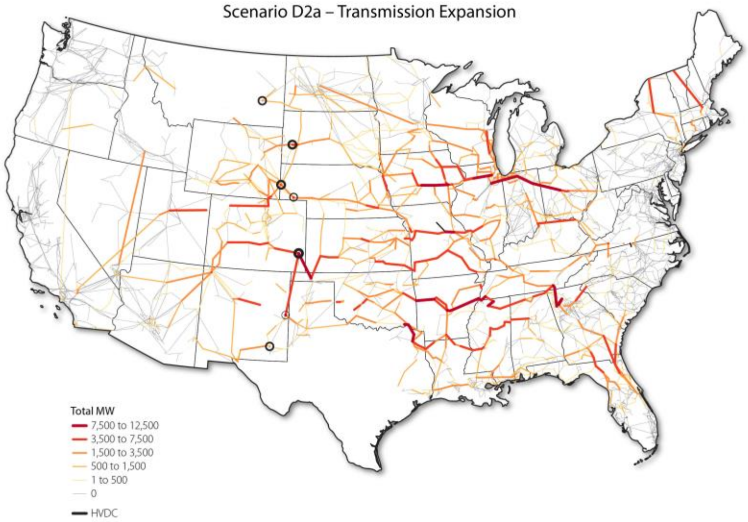
278 GW

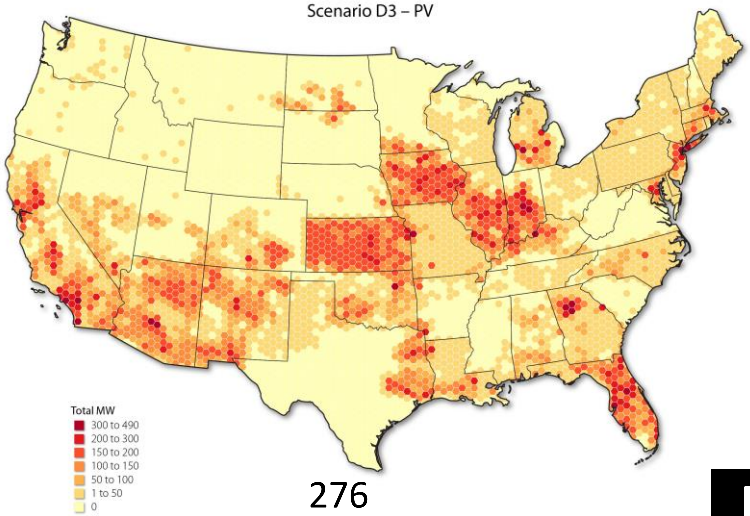


Design 2a

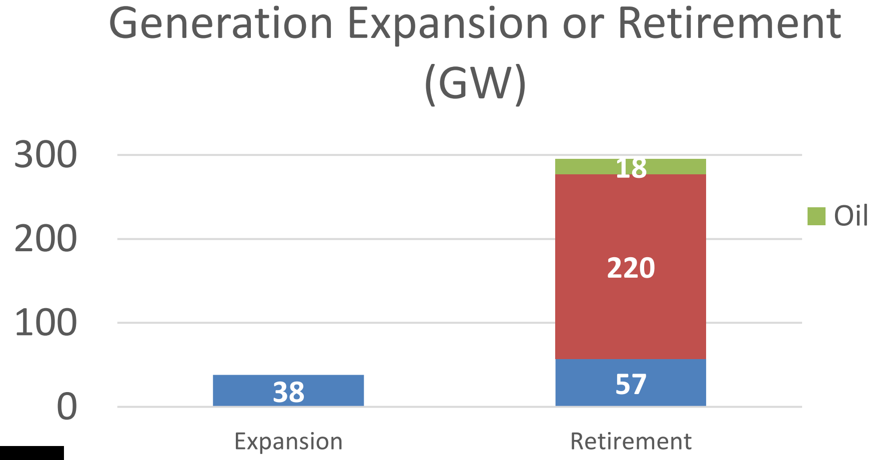


492

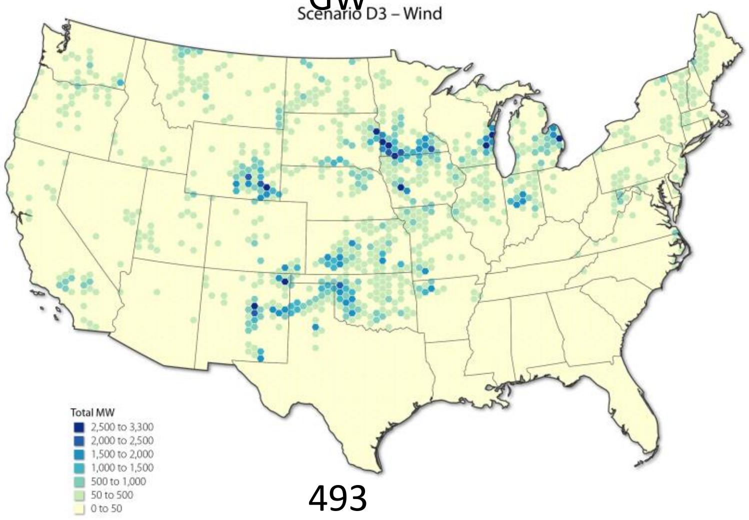




276 GW



Design 3



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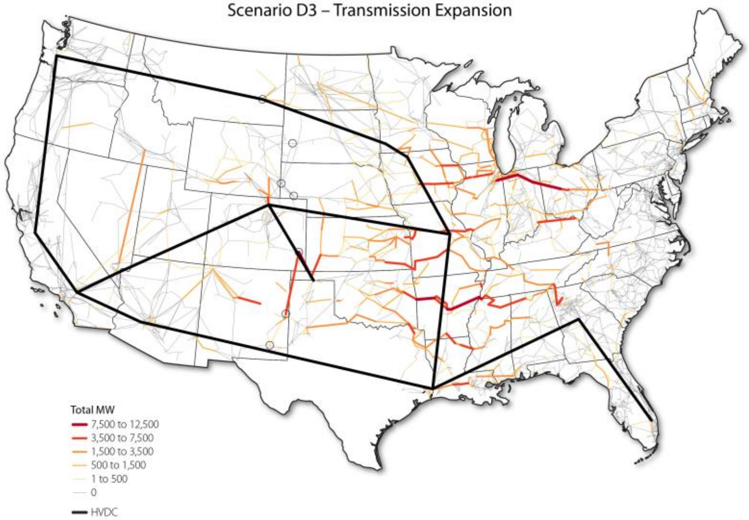
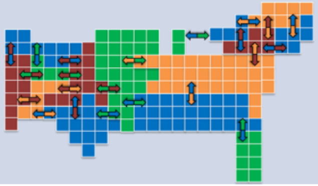
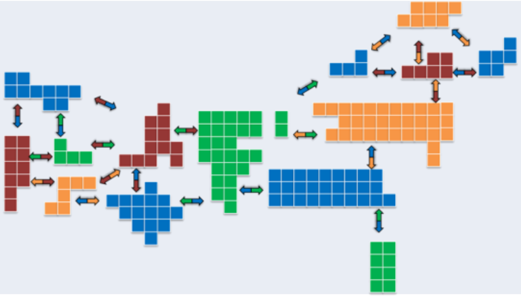
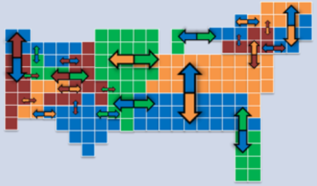
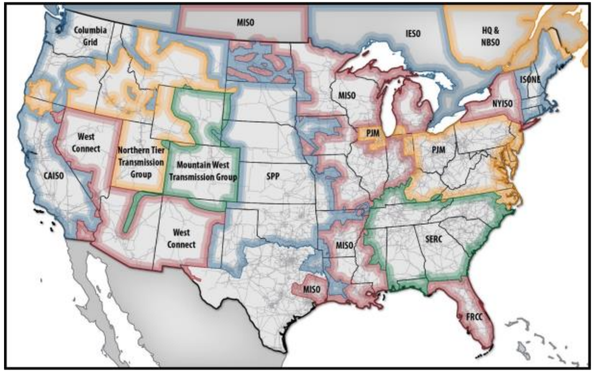


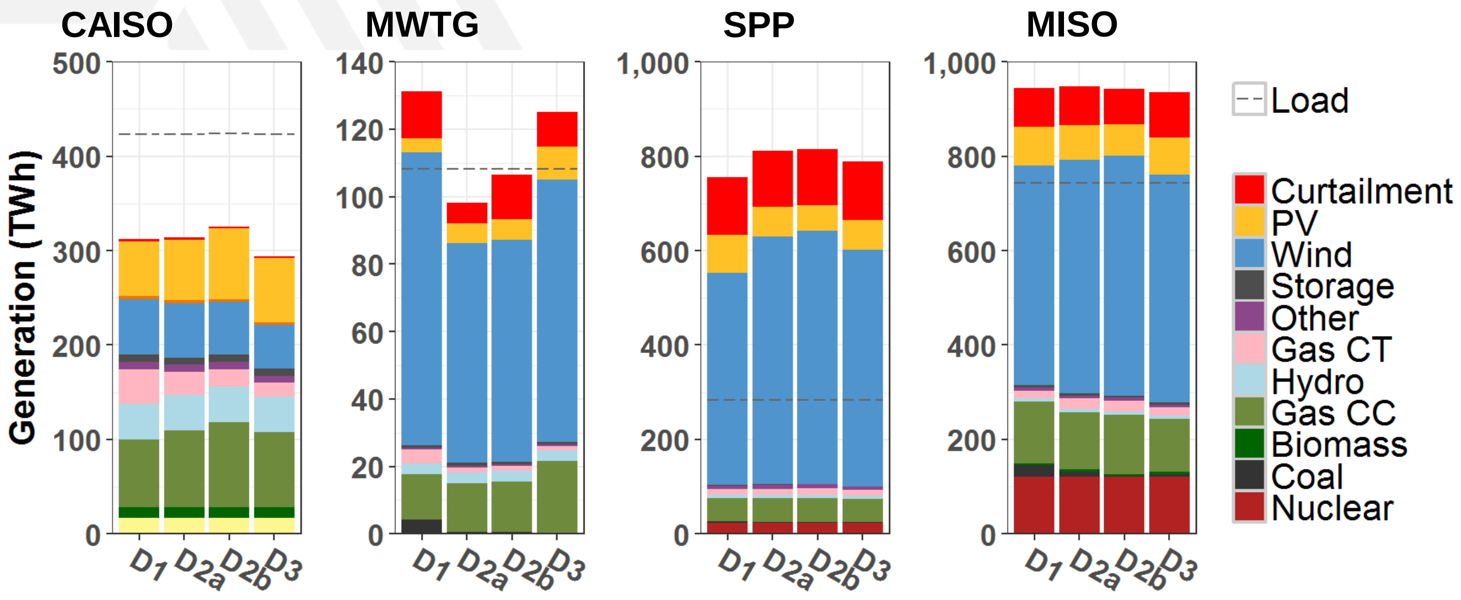
Geographic Decomposition

Model Phase		Solve Time
Stage A: Transmission Flow Forecast		8 hrs/ simulation week
Stage B: Decomposed UC		8 hrs/ simulation week **Over 700 parallel simulations!**
Stage C: Real-Time		10 hrs/simulation week



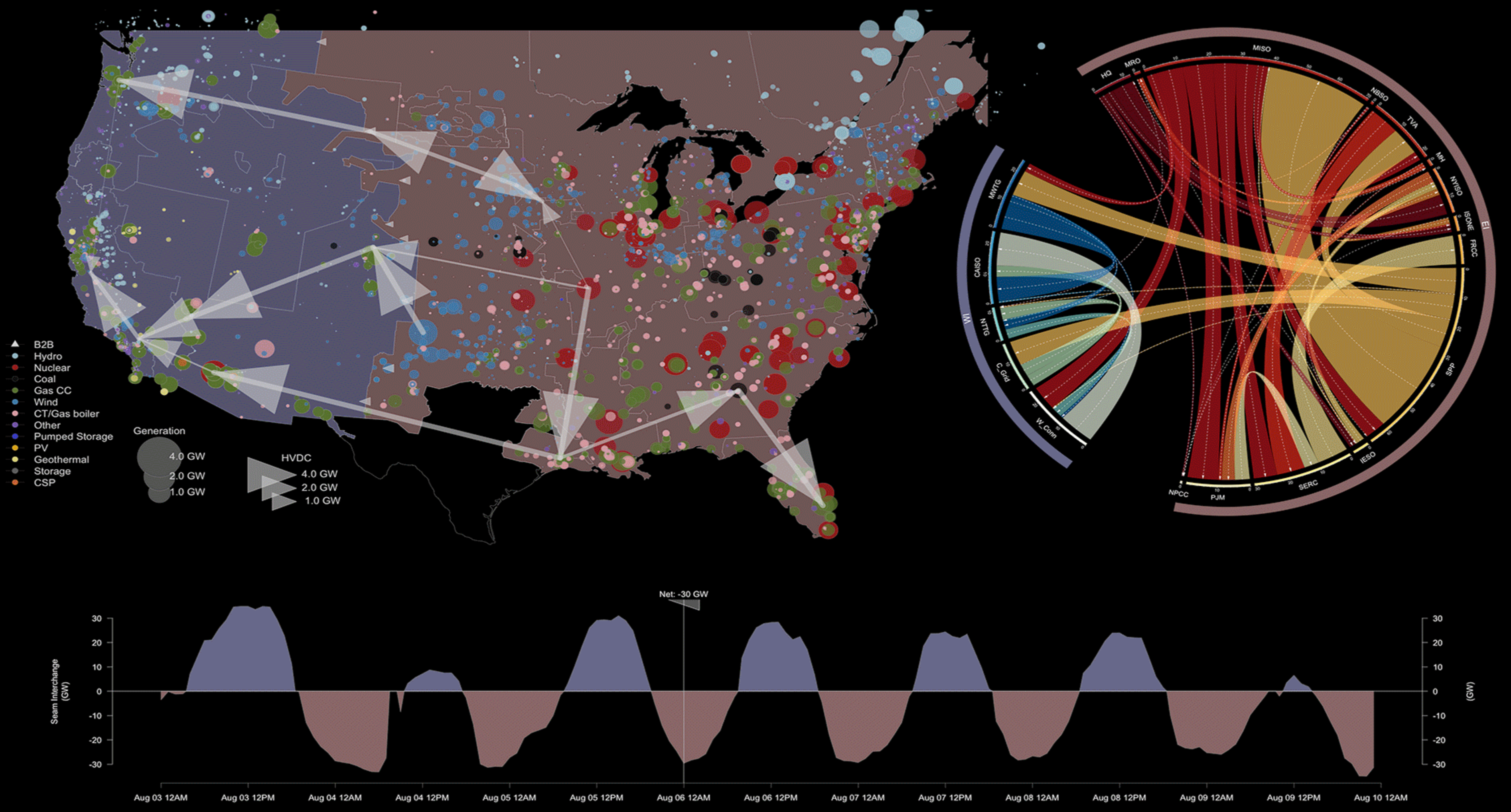
- Decomposed Regions shown in map
- Executing without geographic decomposition would have been challenging. ERGIS (EI) took 20 days
- Seams simulation year with temporal and geographic decomposition takes **20-30 hours from 20-30 days!**

Regional Generation (note scale)



The Interconnections Seam Study (d3)

08-06-2038 00:00



Takeaways

- Analysis indicates there is substantial value to increasing the transfer capability between the interconnections, status quo on the existing B2Bs is the least desirable.
- Cross seam transmission has a substantial impact on the location, size, and type of wind and solar.
  - The “best” wind (Eastern Interconnection) and “best” solar (Western Interconnection).
- Cross-seam transmission enables substantial energy & op-reserve sharing on diurnal basis.
- Need to investigate relocated B2B ties and HVDC links / marcogrid overlay terminals, potential UHV AC solutions, as well as Hybrid Seam scenarios
- Non-Quantified Benefits of HVDC could be significant: dynamic, resilience, adaptability.
  - D2a requires no DC lines but may provide less NQBs; D2b is highest B/C but not self-contingent; D3 is self-contingent and may maximize NQBs.
- Additional engineering analysis is needed to complement the economic analysis.

Next Steps

- Create a platform for actually building new facilities and doing additional analysis.
- Need to scope supplemental analyses to inform regional planning and shape dialogue about next steps.
- More analysis is critical to provide a vision for the continental infrastructure upgrades to take advantage of our diversity and build in resilience for the future grid.