GRID DEPLOYMENT OFFICE

National Transmission Planning Study

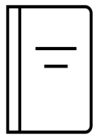
U.S. Department of Energy

October 2022

Building a Better Grid Initiative

Engagement and collaboration

- States
- Tribal nations
- Stakeholders
- Federal Agencies
- ISO/RTOs
- EROs



Enhanced transmission planning

- Transmission Needs Study
- National Transmission Planning Study
- Atlantic Offshore Wind Transmission Study

Federal financing tools ($20+B)

- Transmission Facilitation Program ($2.5B)
- Smart Grid Investment Matching Grant Program ($3B)
- Grid resilience grants for states, Tribes, and utilities ($10+B)
- Loan guarantee programs
- Transmission Facility Financing ($2B)
- Siting of interstate Electricity Transmission Lines ($760M)

Transmission permitting process

- Streamline permitting with federal agencies
- Public private partnerships
- Designation of National Corridors

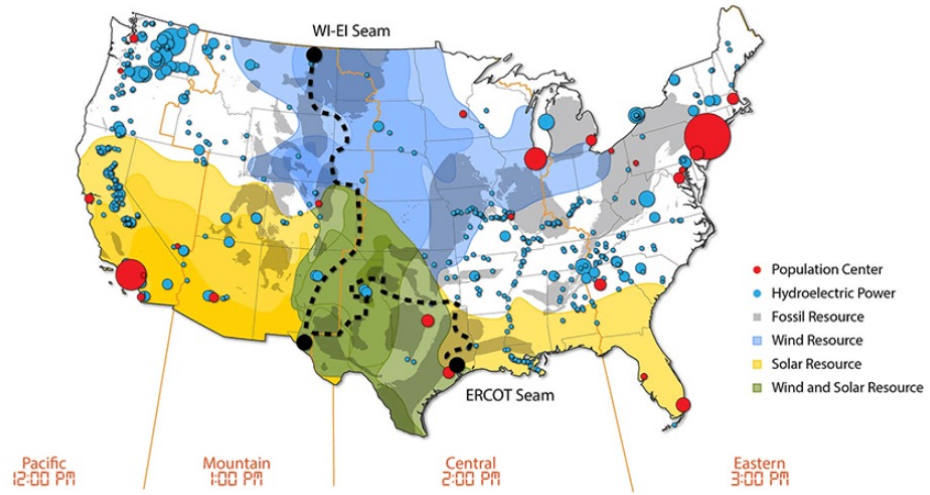
Transmission-related R&D

- "Next generation" electricity delivery technologies
- Supporting activities

One Stop Shop: the DOE Grid and Transmission Programs Conductor

Project Team

- This study is conducted by a joint National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL) project team
- This study builds on past projects and expertise at NREL and PNNL with the support and direction of DOE's Office of Electricity and Grid Deployment Office



U.S. DEPARTMENT OF ENERGY

Office of Electricity

North American Energy Resilience Model

Objectives of the study

Identify interregional and national strategies to accelerate cost-effective decarbonization while maintaining system reliability

Inform regional and interregional transmission planning processes, particularly by engaging stakeholders in dialogue

Results help prioritize future DOE funding for transmission infrastructure support

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What the Study is and is not doing

What the study will do

- Link several long-term and short-term power system models to test a number of transmission buildout scenarios
- Inform existing planning processes
- Test transmission options that lie outside current planning
- Provide a wide range of economic, reliability, and resilience indicators for each transmission scenario

What the study will not do

- Replace existing regional and utility planning processes
- Site individual transmission line routes
- Address the detailed environmental impacts of potential future transmission lines
- Provide results that are as granular as planning done by utilities
- Develop detailed plans of service

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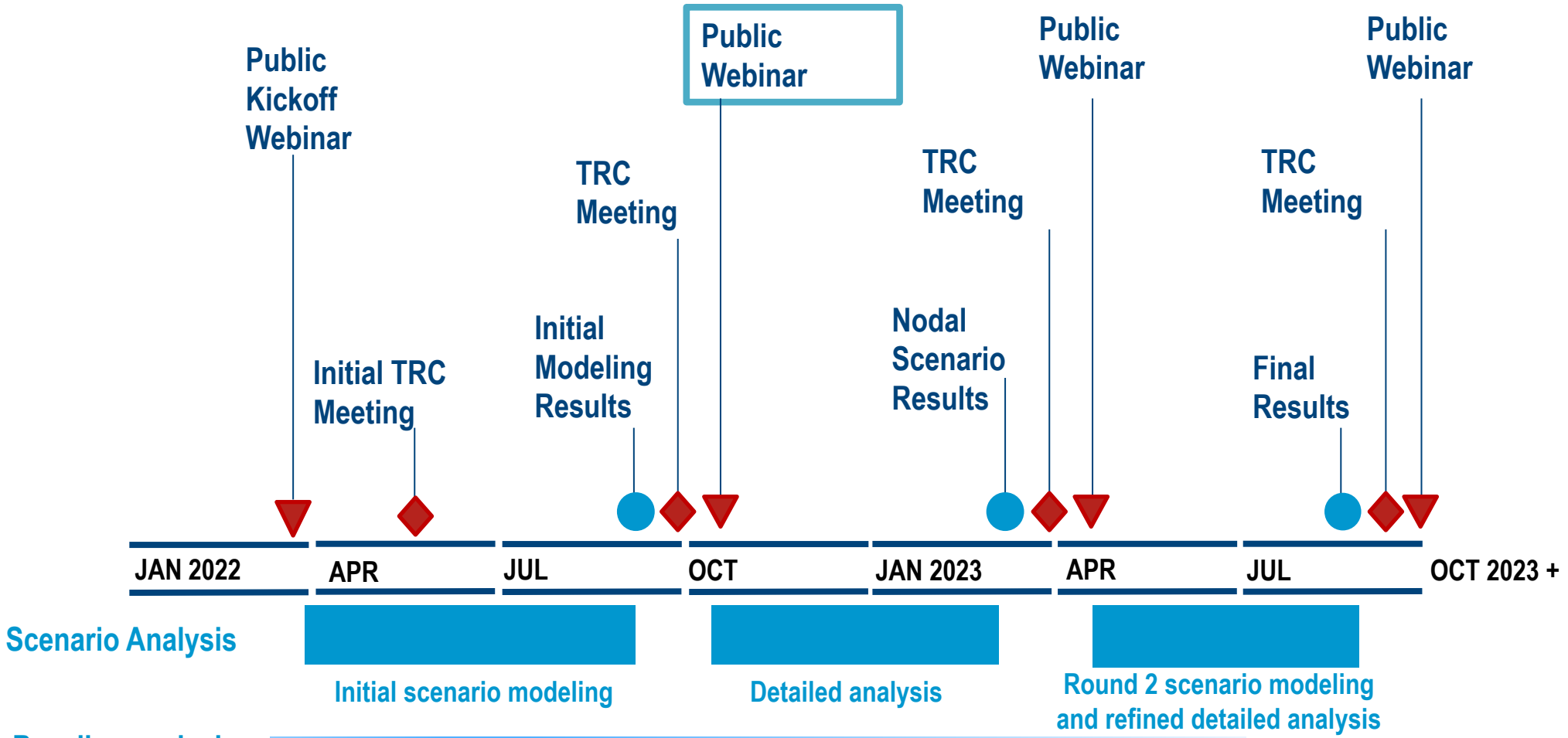
NTPS Timeline



TRC = Technical Review Committee

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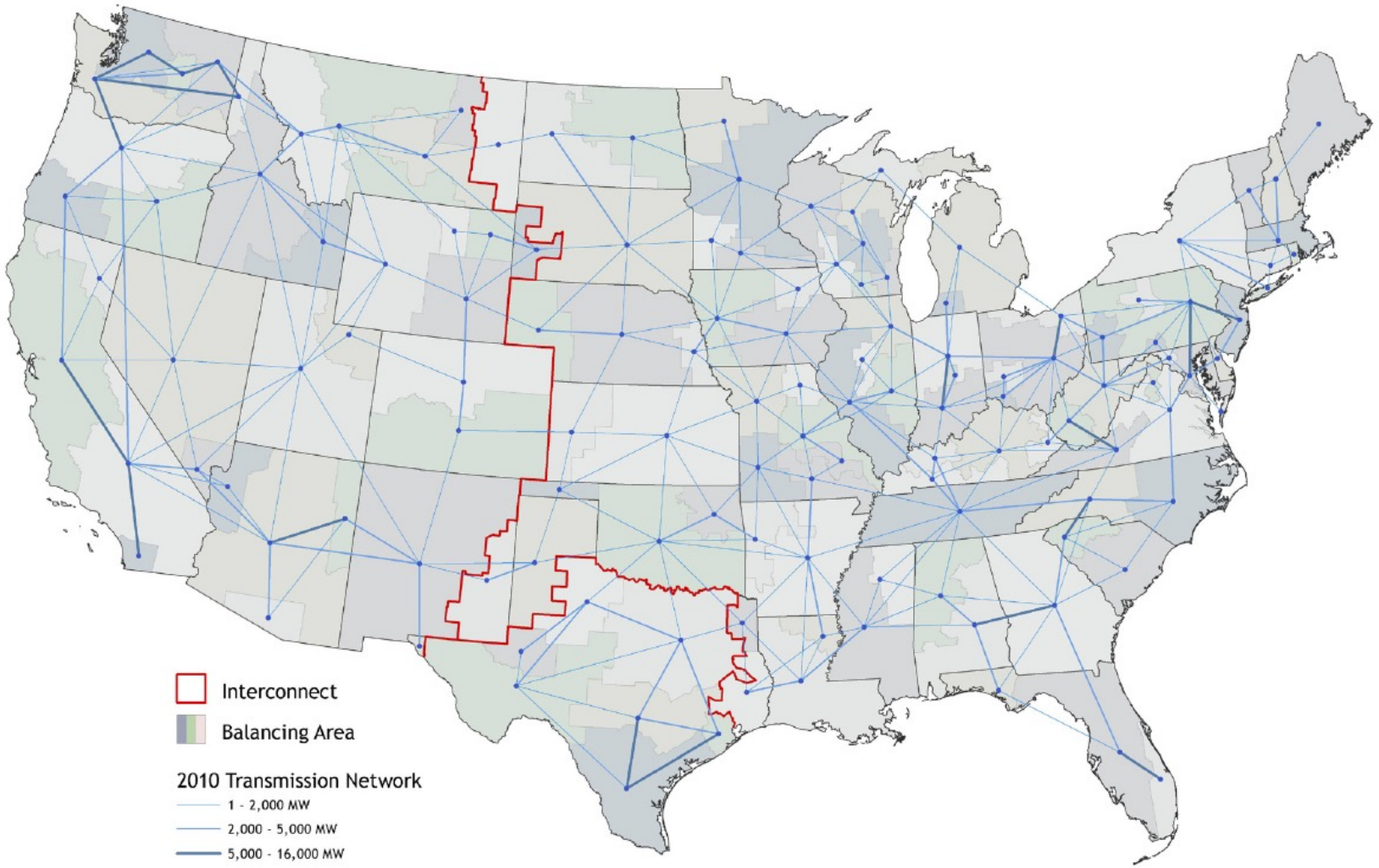
Transmission System in ReEDS



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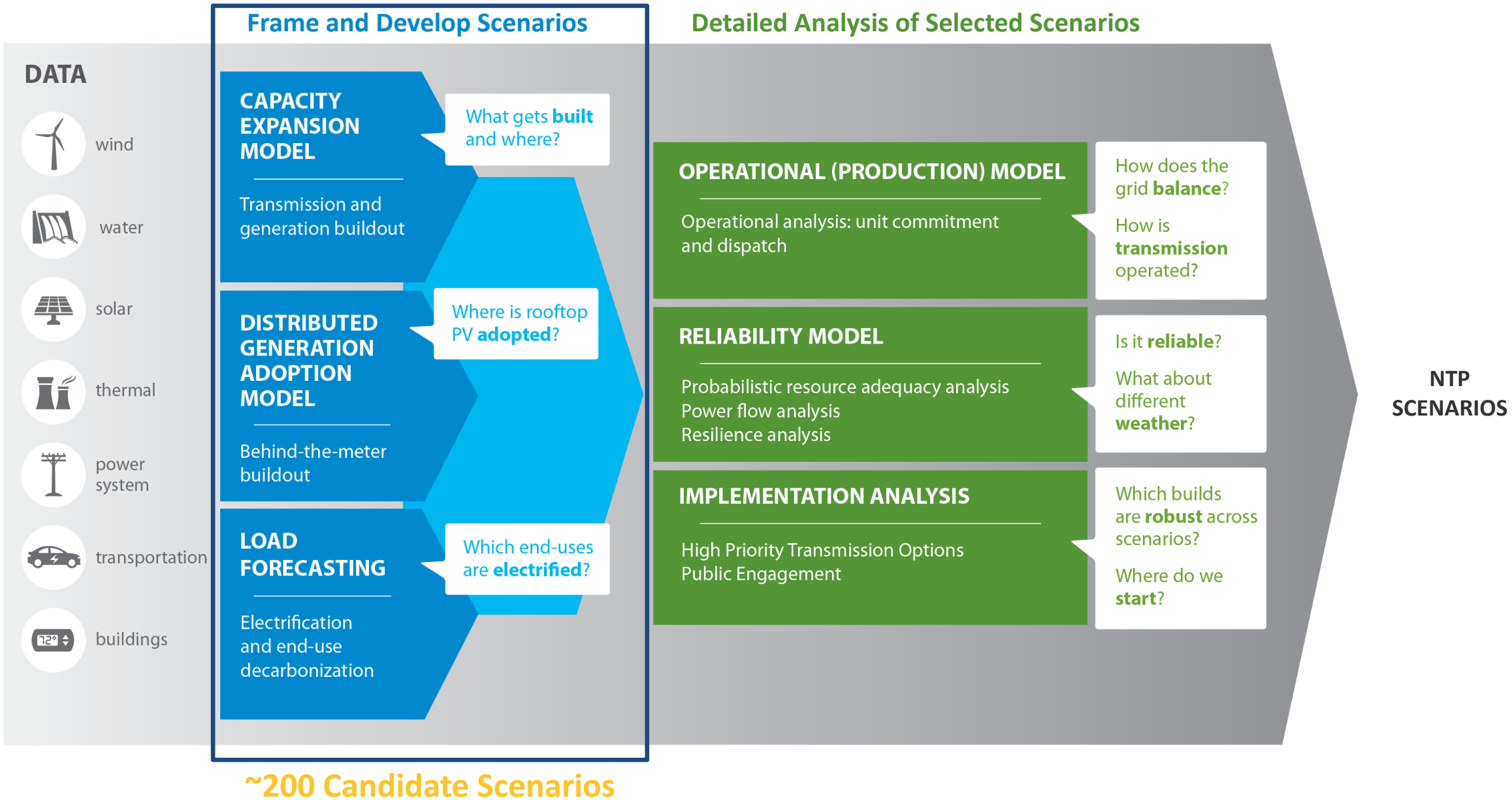
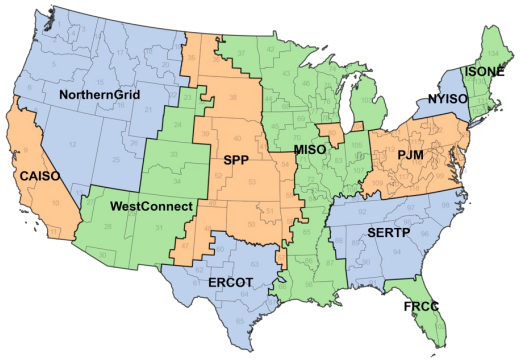
NTP Scenario Analysis Relies on Multiple Linked Modeling Exercises

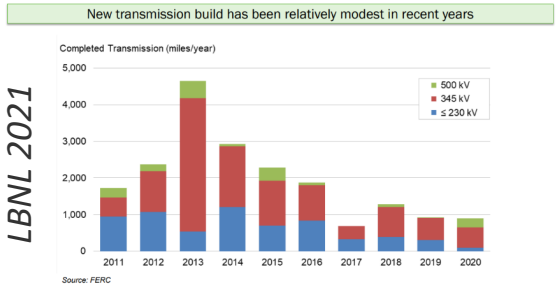


Transmission Paradigms

Limited

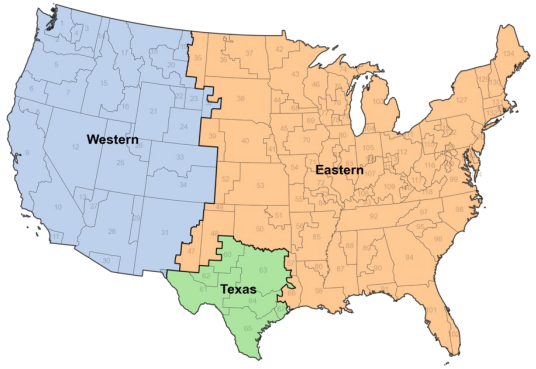


- **Intra-regional** transmission expansion within planning regions only
- Cap annual transmission builds based on recent (since 2009) average of ~1.4 TW-miles/yr.



LBNL 2021

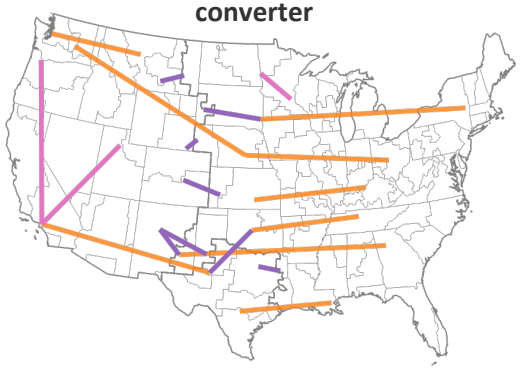
AC



- **Intra-interconnection** transmission expansion between 134 zones (no new back-back DC ties across seams)
- Transmission cost and losses based on AC transmission (500 kV).

LCC

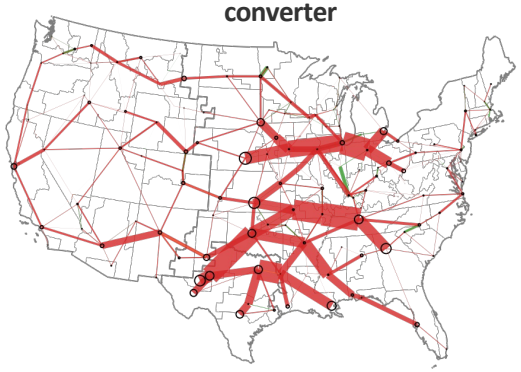
HVDC line-commutated converter



- **Inter-interconnection** transmission expansion (new back-back DC ties allowed)
- HVDC (point-to-point line-commutated converter) expansion allowed
- Available LCC connections identified based on preliminary scenarios.

VSC

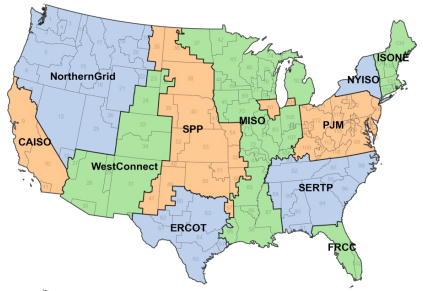
HVDC voltage-source converter



- **Macrogrid** multiterminal HVDC network designed by the model and specific to the scenario
- Transmission lines and voltage-source-converter capacities are decided separately
- VSC builds are not allowed until 2032.

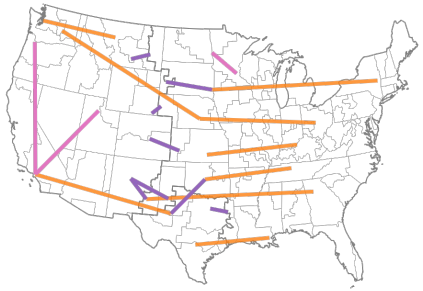
Scenario Framework: 24 Core Scenarios

4 transmission paradigms X 2 demand cases X 3 emissions targets



Limited

AC



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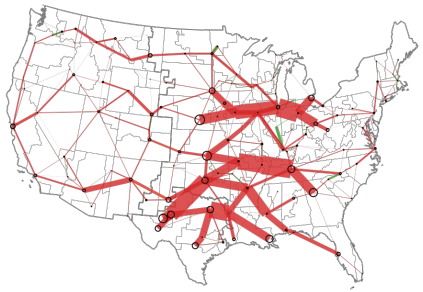
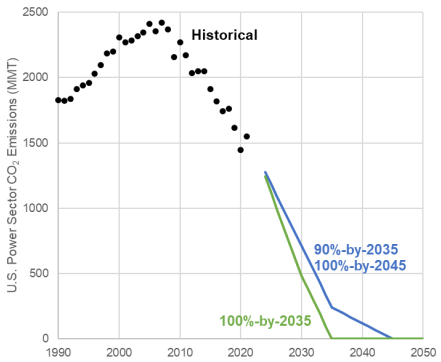


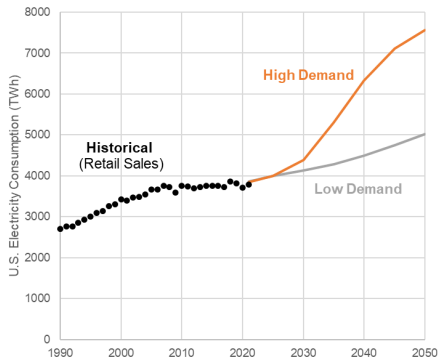
VSC

Demand Growth →

Emissions Target ↓

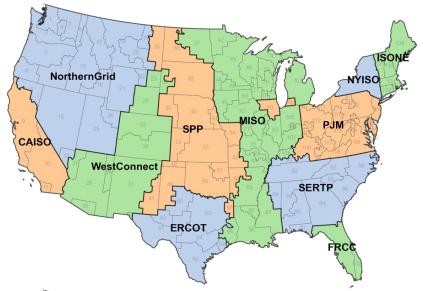
Current Policies Low Demand	**Current Policies** High Demand
90-by-2035 Low Demand	**90-by-2035** High Demand
100-by-2035 Low Demand	**100-by-2035** High Demand





Scenario Framework: 168 Sensitivities

4 transmission paradigms X 3 emissions-demand combinations X 14 sensitivities



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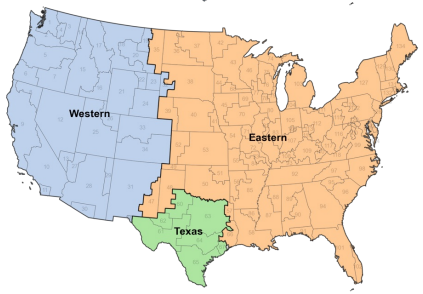

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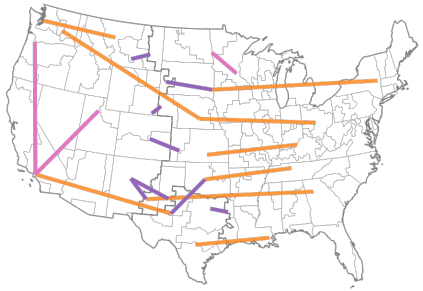

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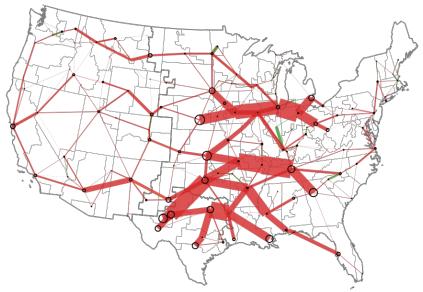

VSC

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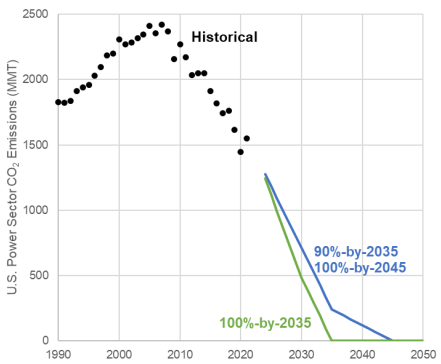

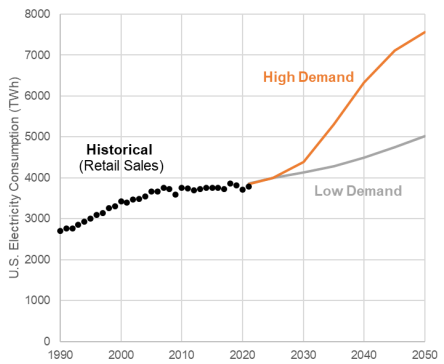

Sensitivity
Transmission 5x cost
Gas (high and low) price
PV + battery low cost
Wind low cost
Siting limited
More distributed PV
Demand peak shaving
H2 (high and low) price
+ Nuclear SMR + DAC No CCS or new nuclear
Climate
Many challenges

Scenario Framework: 168 Sensitivities

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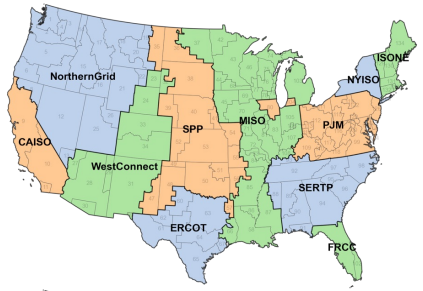
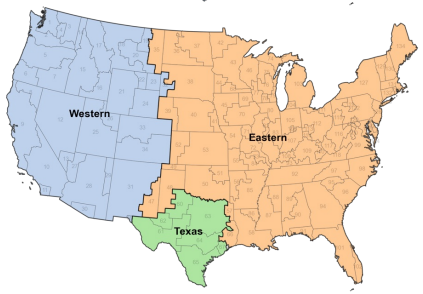


Limited



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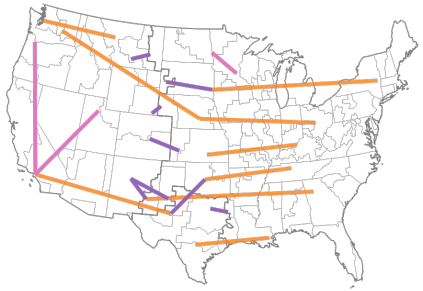
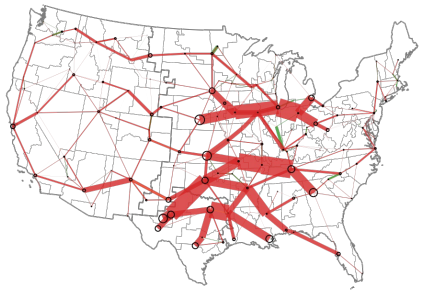


LCC



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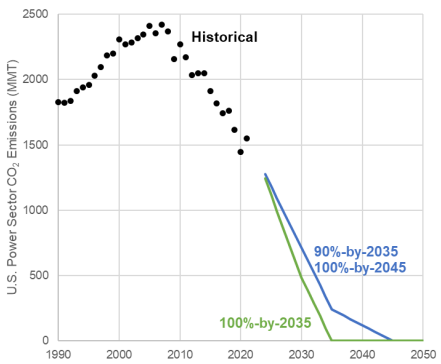

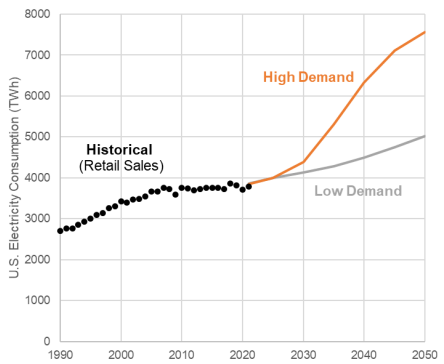

Sensitivity
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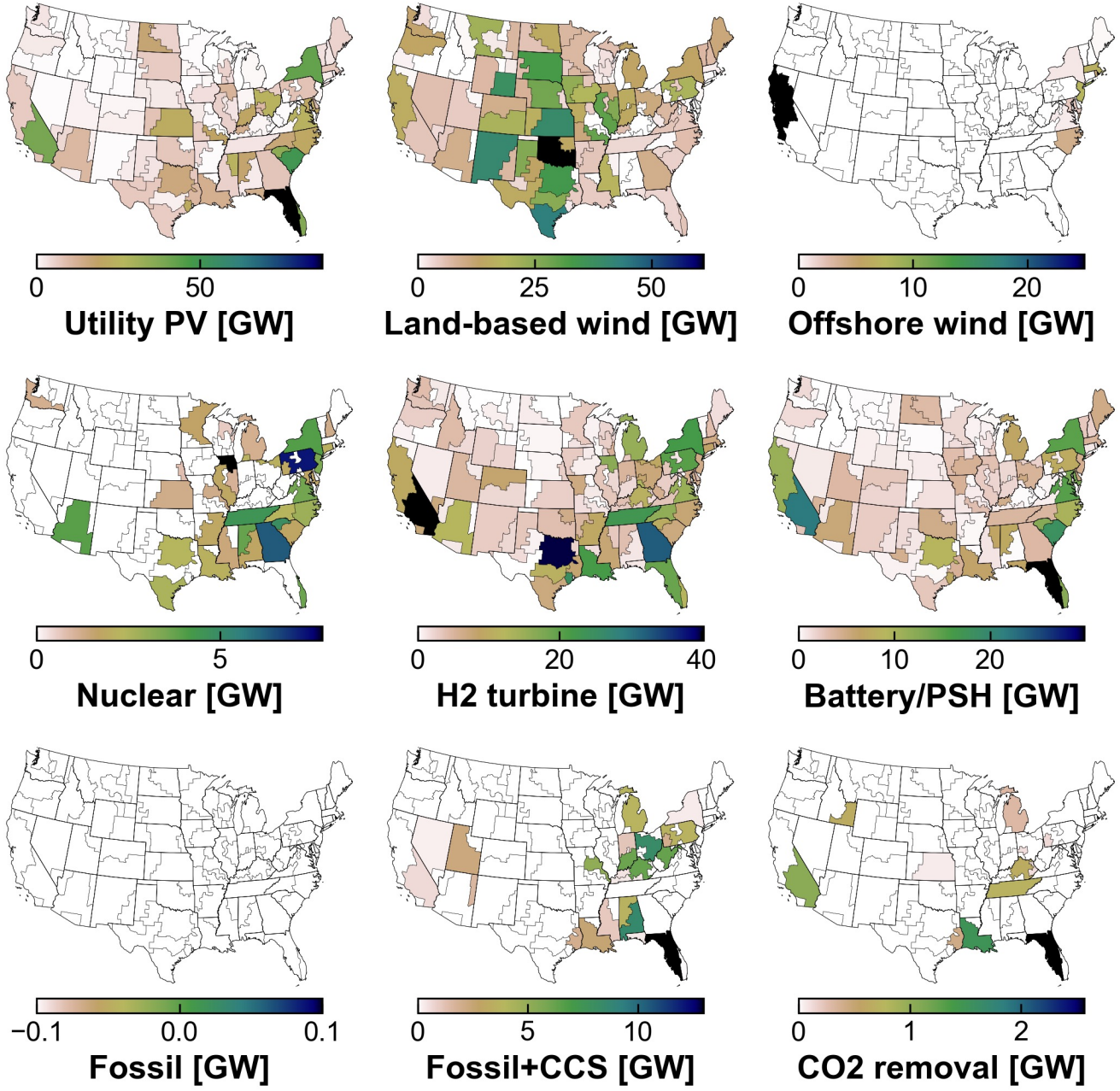
PV + battery low cost
Wind low cost
→ Siting limited
More distributed PV
Demand peak shaving
→ H2 (high and low) price
+ Nuclear SMR + DAC → No CCS or new nuclear
→ Climate
Many challenges

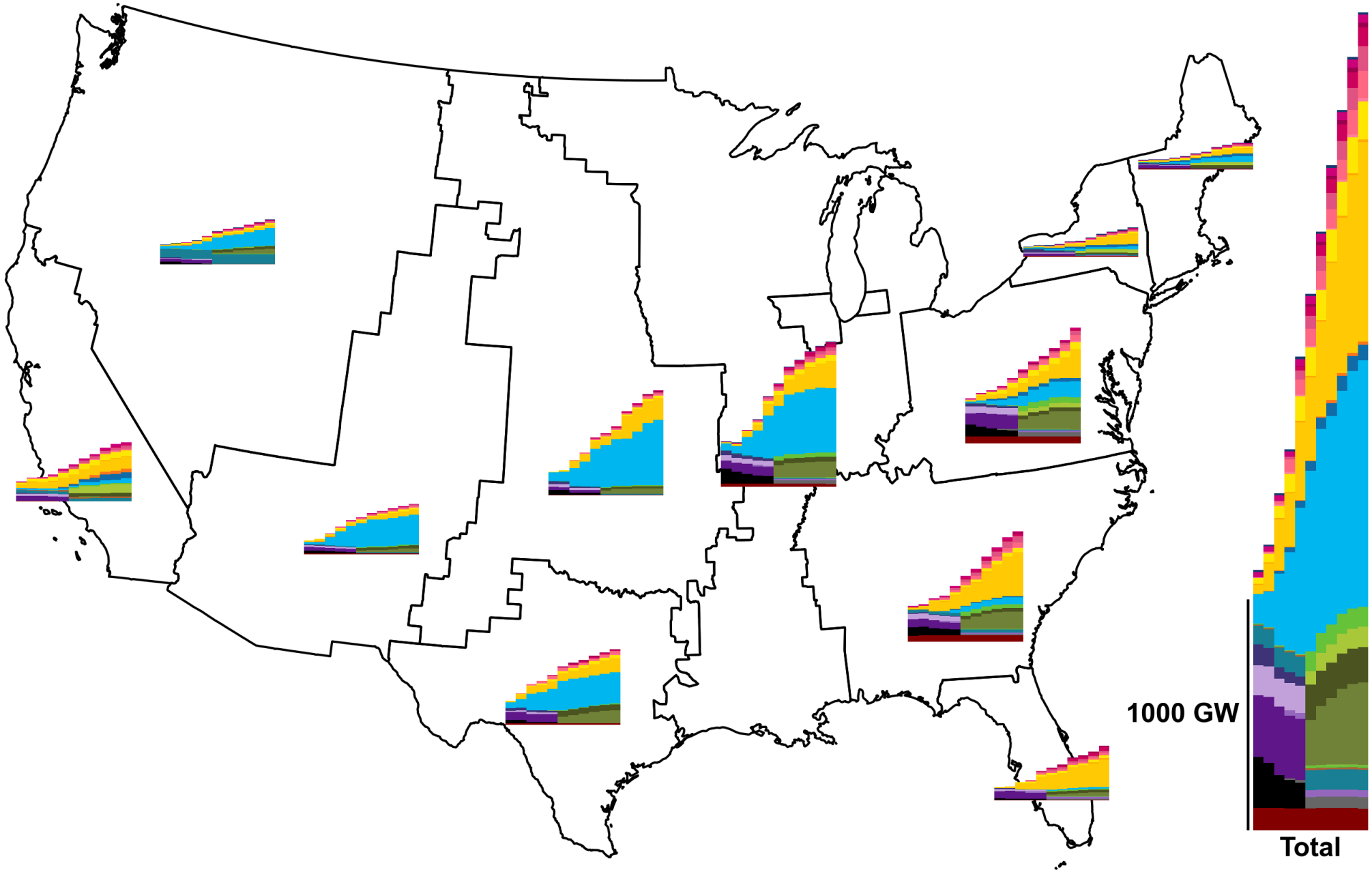
Wide-Ranging Sensitivities to Assess Robustness of Findings

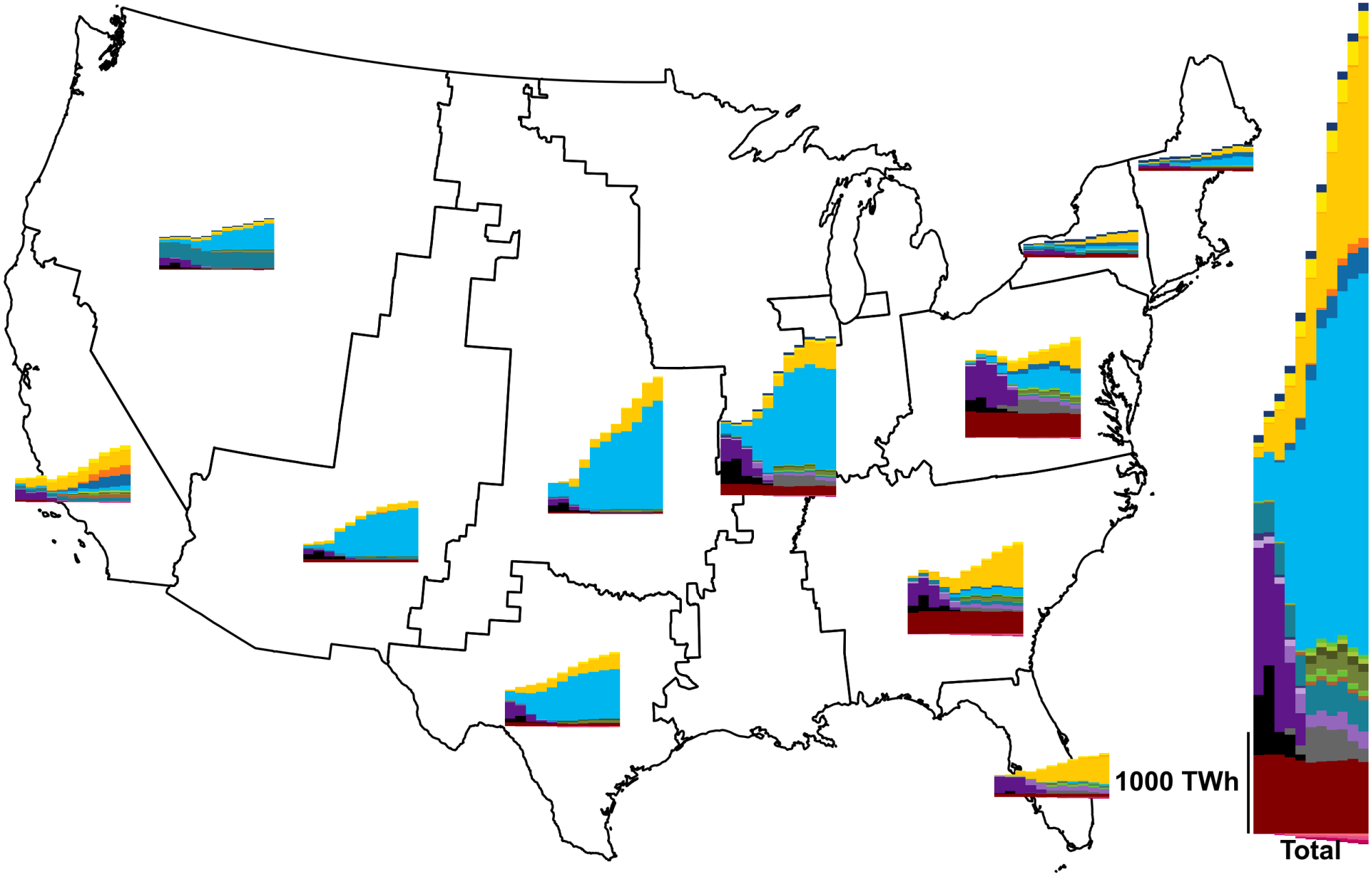
Sensitivity	Variation	Default
Transmission 5x cost	5x higher	Varied sources, regional variations
Gas (high and low) price	Higher (AEO LOGR) Lower (AEO HOGR)	AEO Reference
PV + battery low cost	ATB Advanced	ATB Moderate
Wind low cost	ATB Advanced	ATB Moderate
Siting limited	Limited Access	Reference Access
More distributed PV	190 GW by 2035, 363 GW by 2050	134 GW by 2035, 181 GW by 2050
Demand peak shaving	Top 80 hrs per half-year clipped	Top 40 hrs per half-year
H2 (high and low) price	Higher ($40/MMBtu) Lower ($10/MMBtu)	$20/MMBtu
+ Nuclear SMR + DAC **No CCS or new nuclear**	Expanded (DAC, nuclear-SMR) Limited (no CCS, no new nuclear)	All except DAC, nuclear-SMR
Climate	Hydro availability from RCP8.5; reduced hydro capacity credit (80%), thermal summer capacity (85%), and transmission summer capacity (95%).	Historical performance
Many challenges	Limited access siting, no CCS and no new nuclear, high H2 costs, climate impacts	See above

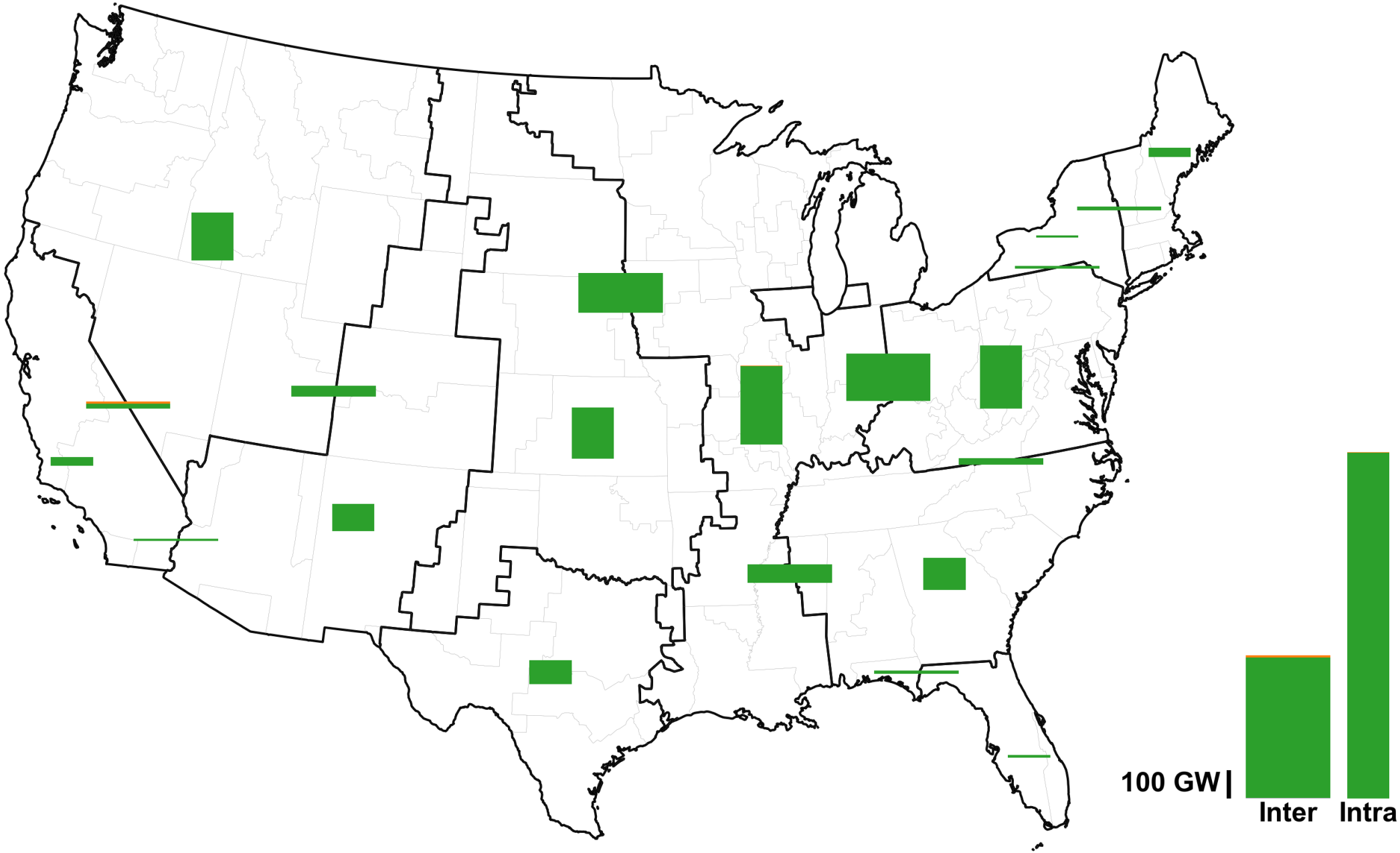
Example CEM Outputs for individual scenarios

v20220929_PTDFh0_AC_DemHi_100by2035EarlyPhaseout__core (2050)

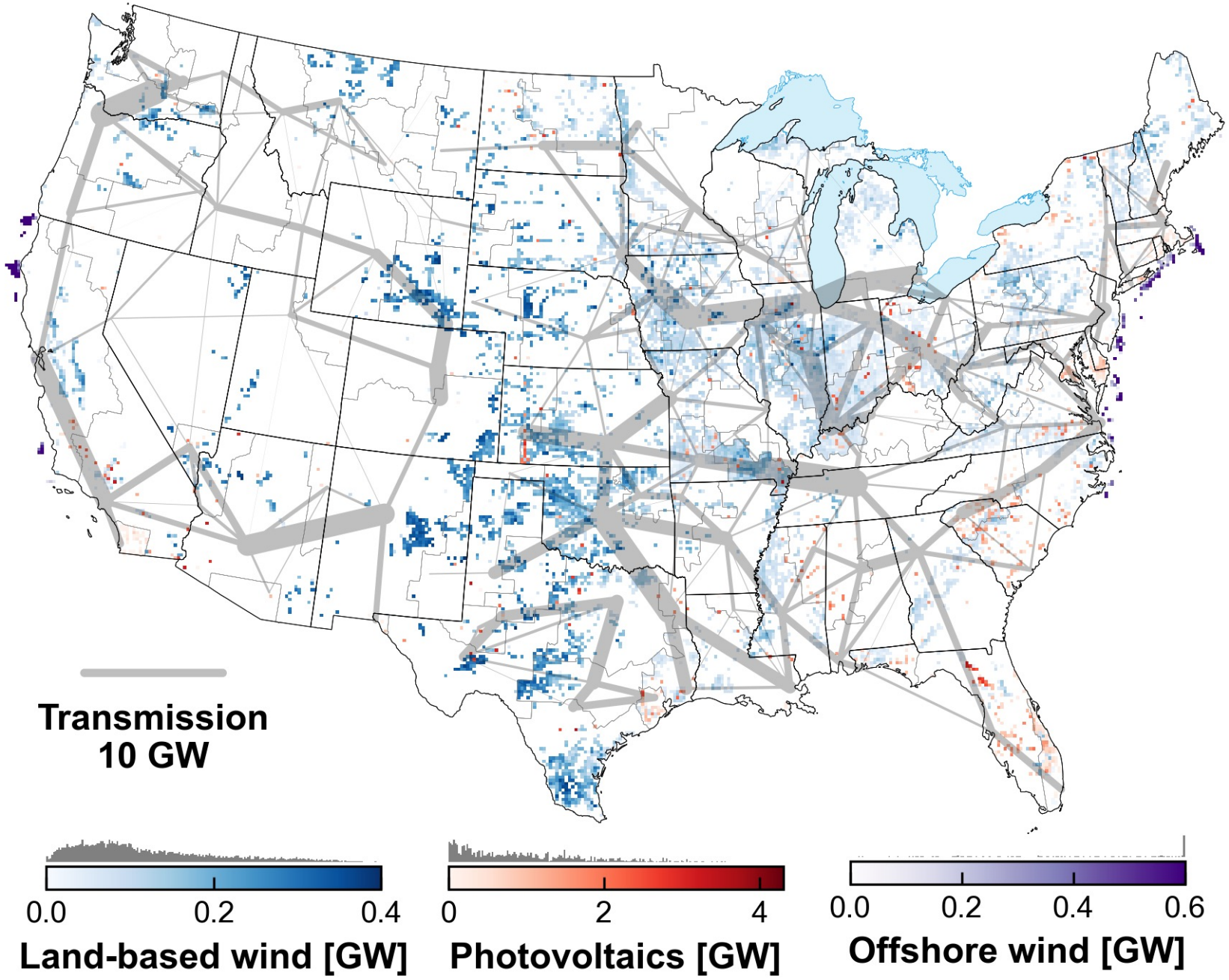



1000 GW
Total


1000 TWh
Total


100 GW
Inter
Intra

v20220929_PTDFh0_AC_DemHi_100by2035EarlyPhaseout__core (2050)



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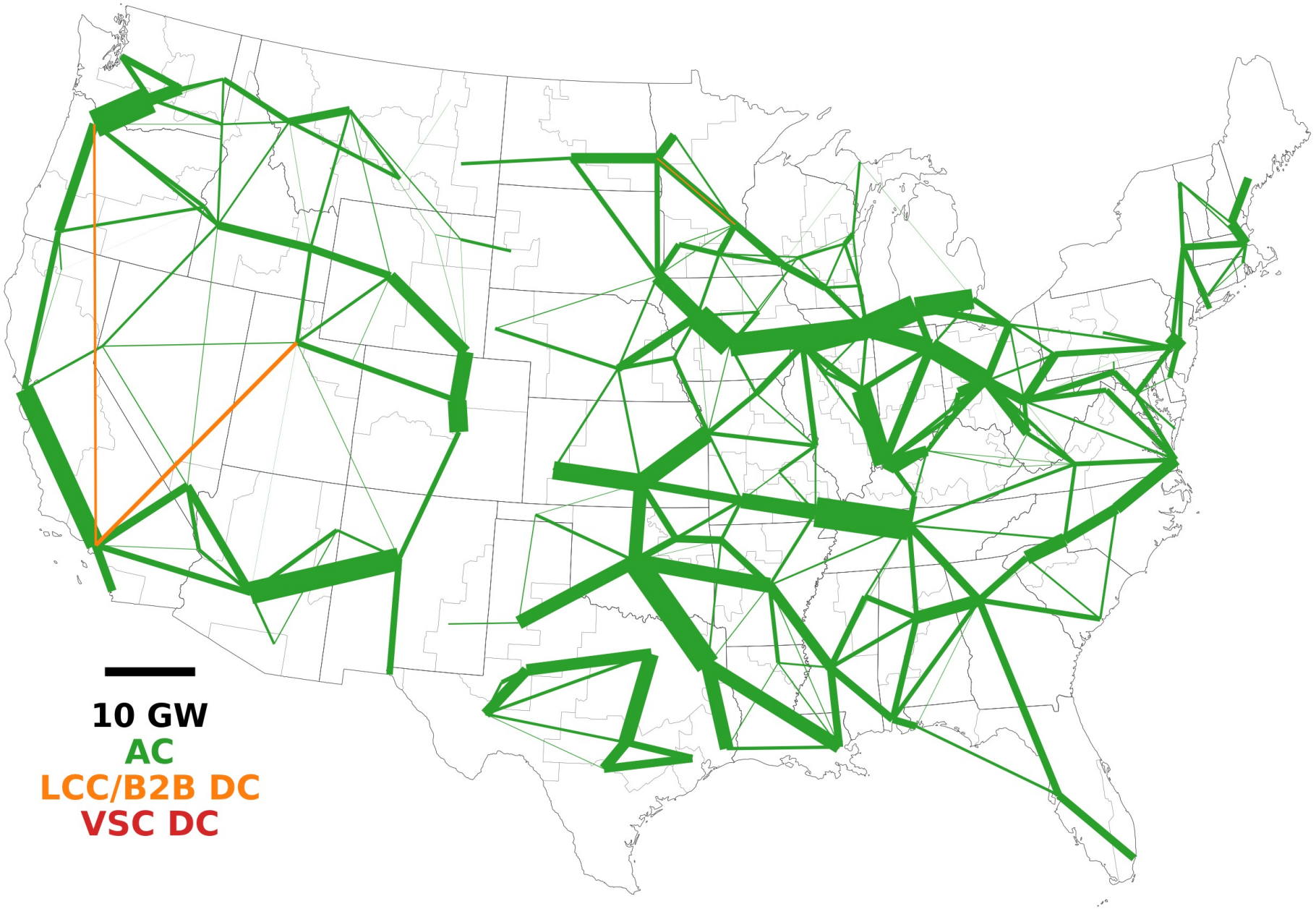
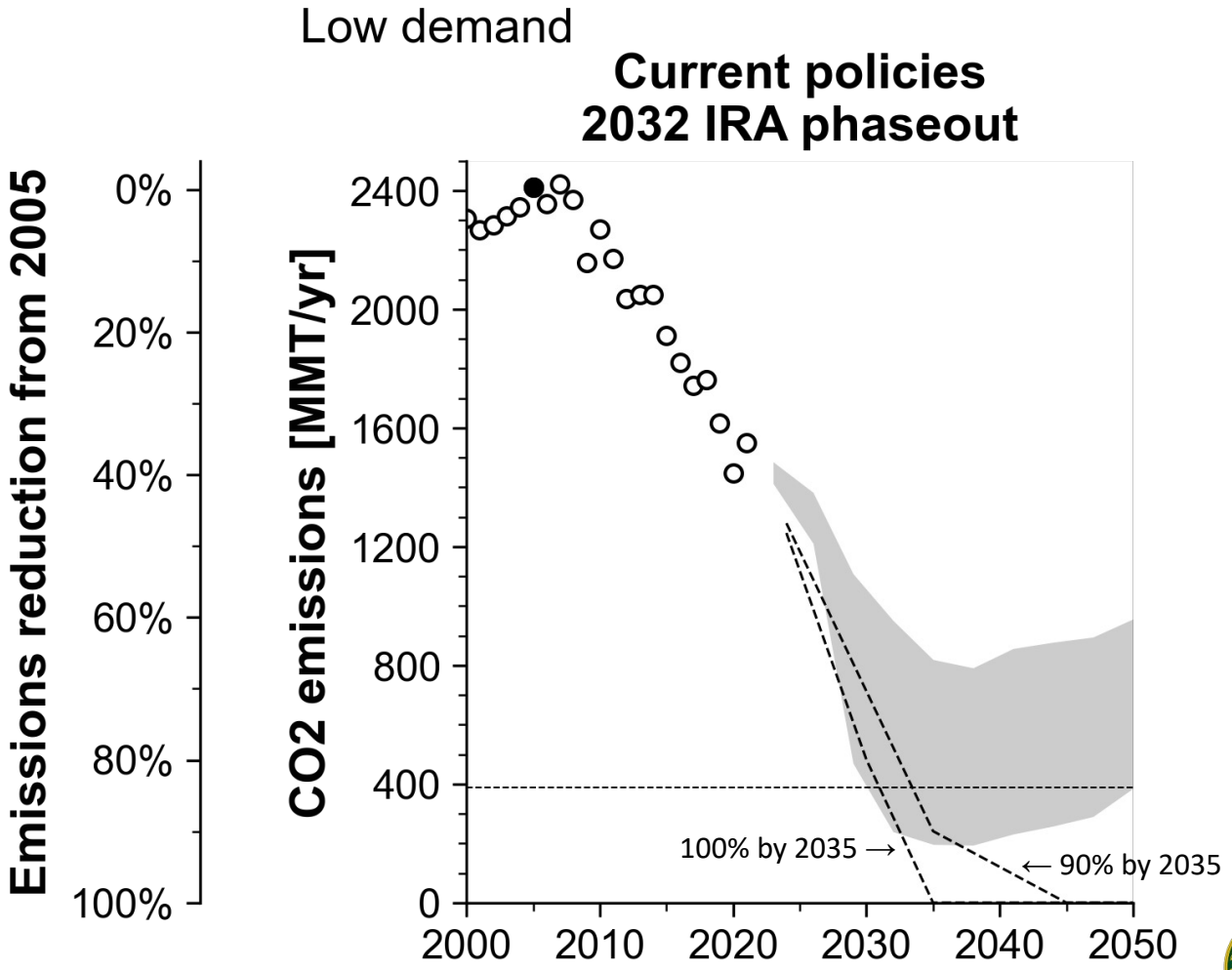


Example Outputs for Comparing Scenarios

Carbon Emissions



Interim results
Do not cite

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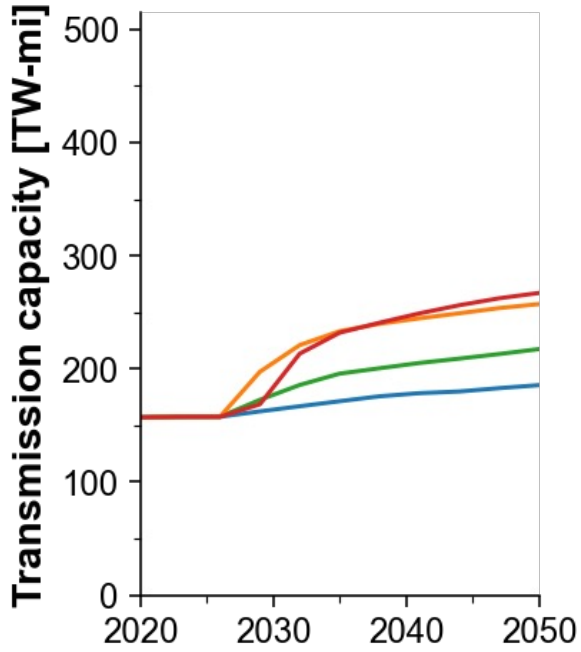
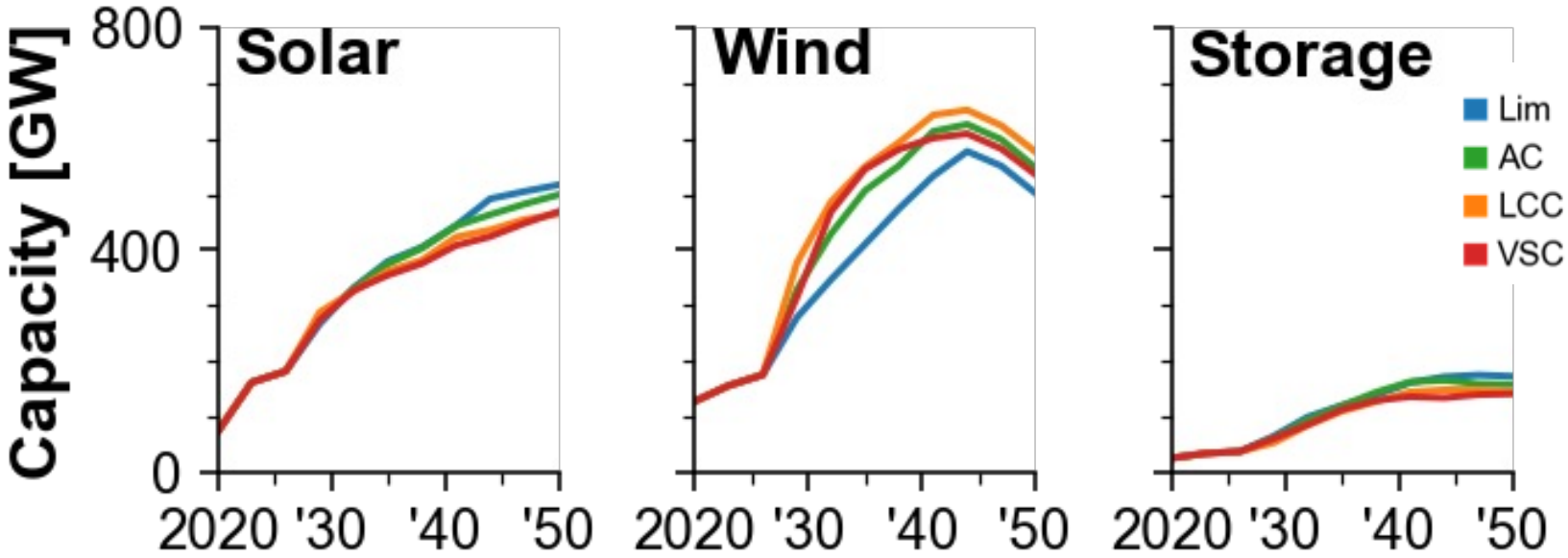
Transmission and Resource capacities by type





Interim results
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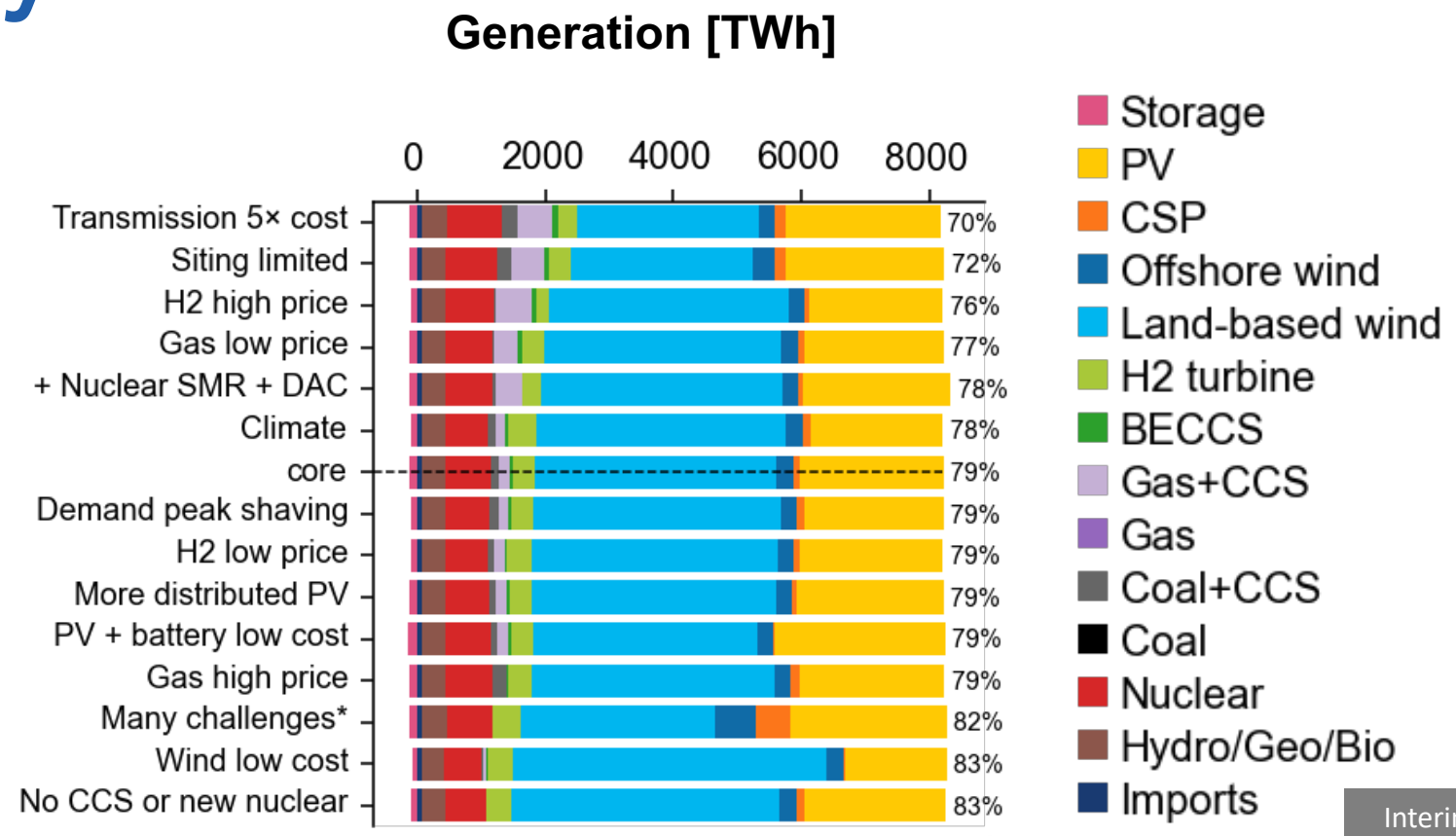
Annual Energy mixes



Percent wind+solar energy

Interim results
Do not cite

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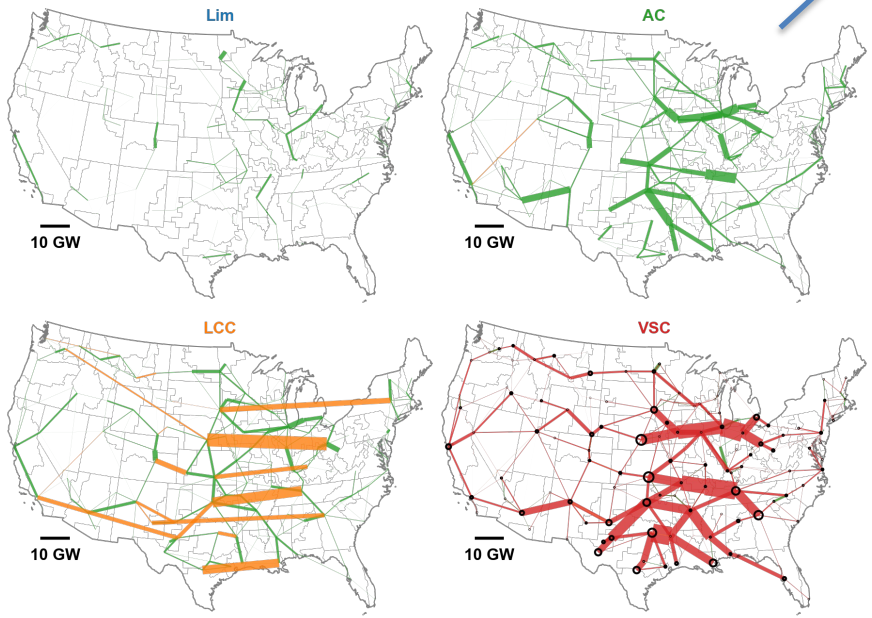
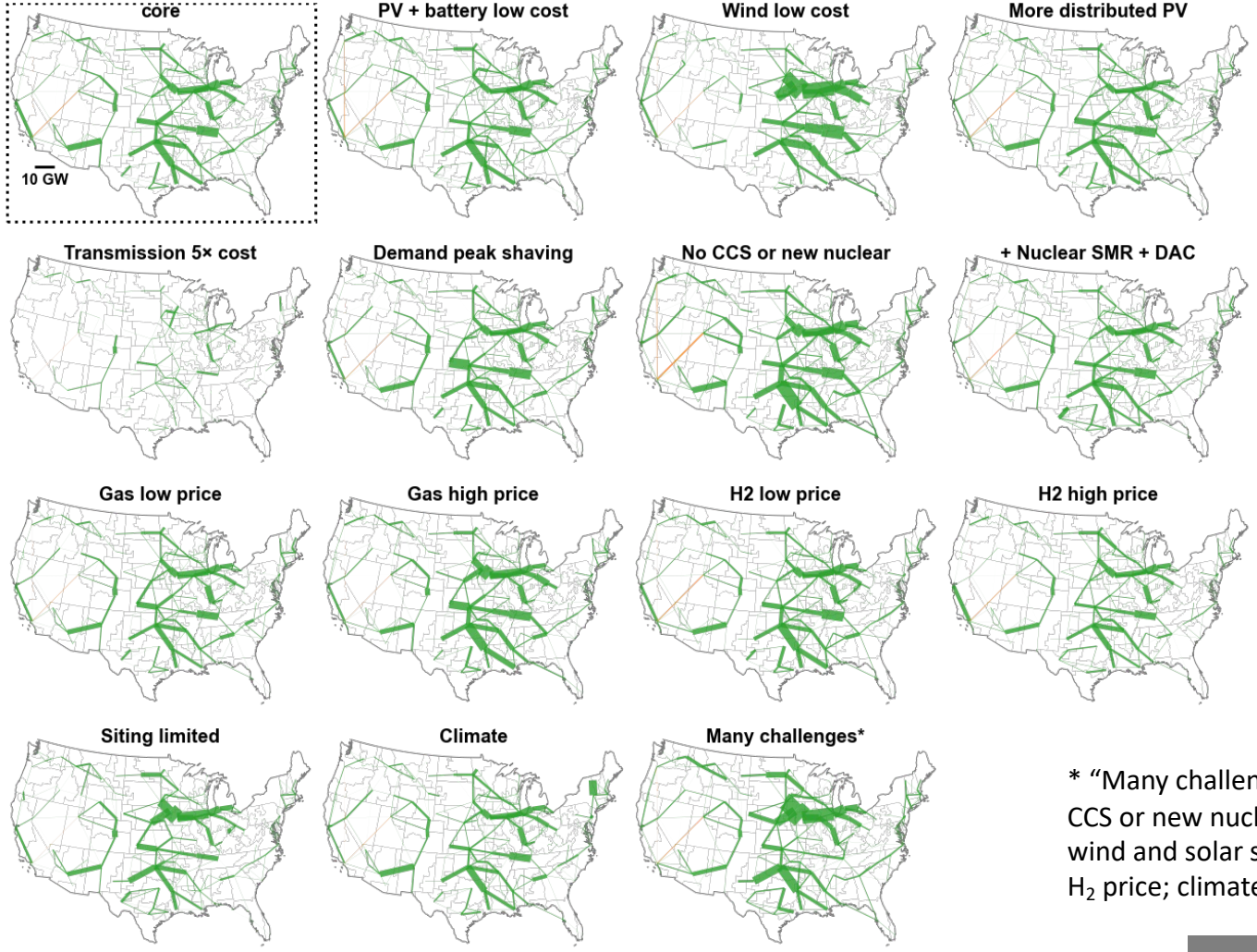
Geographic Representation of TX Expansion





* "Many challenges" = No CCS or new nuclear; limited wind and solar siting; high H_2 price; climate