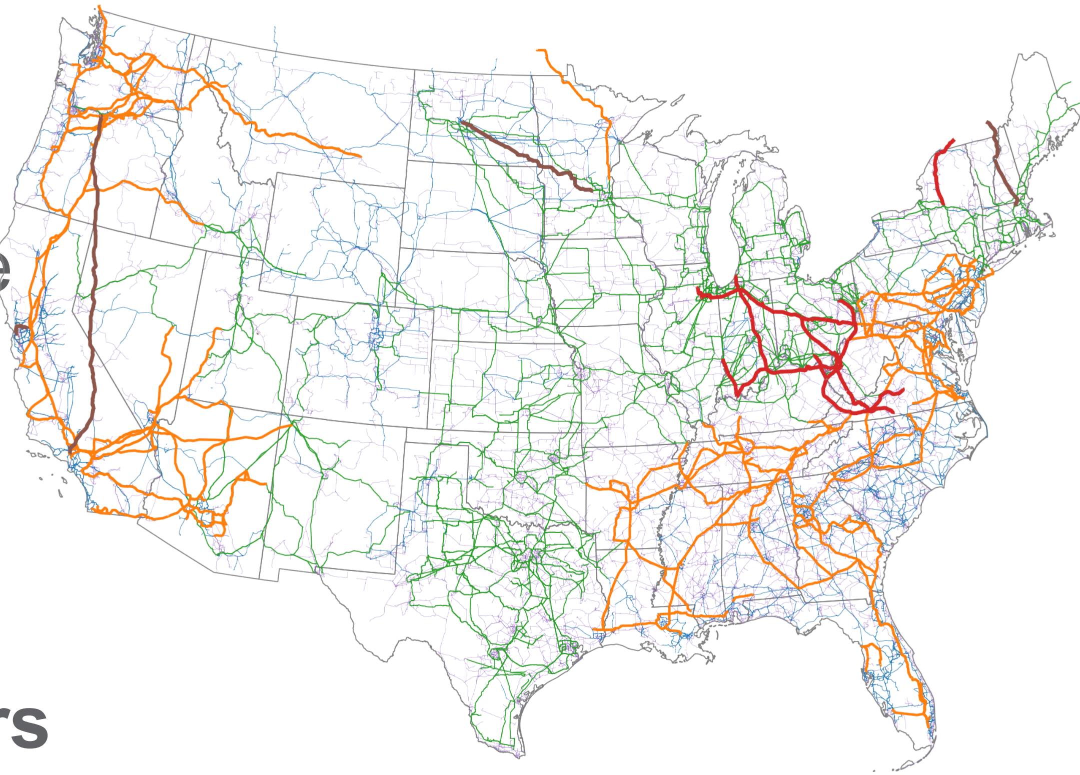
Progress on the National Transmission Planning Study

David Palchak
NREL
ESIG 2023 Spring Workshop

Objectives

- Identify **interregional and national strategies** to accelerate cost effective decarbonization



- Inform regional and interregional transmission planning processes, particularly by **engaging stakeholders**

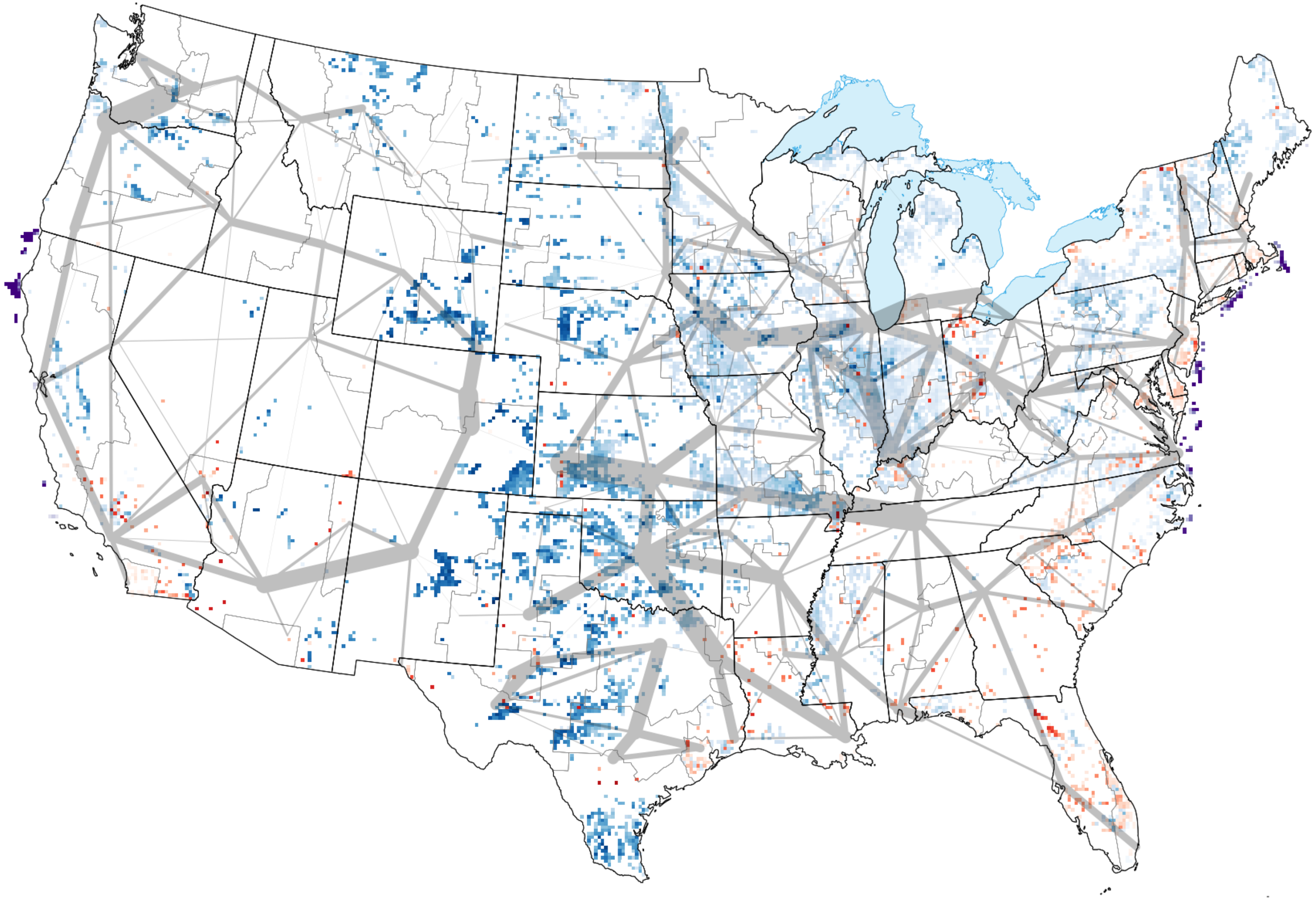
- **Identify viable and efficient transmission options that will provide broad-scale benefits**

Integrated Transmission Planning Approach

ZONAL G&T CAPACITY EXPANSION PLANNING	Technology Cost and Performance Data	Scenario Design	Capacity Expansion Modeling (CEM)
NODAL TRANSMISSION EXPANSION PLANNING	Zonal to Nodal Generation, Storage, and Demand Disaggregation	Transmission-Focused Nodal Production Cost Modeling (PCM)	DC Power & Contingency Analysis (N-0 & N-1)
SYSTEM RELIABILITY ANALYSIS	Selection of Relevant Operating Conditions	Steady-State Analysis (Power Flow and Contingency)	System Stability Analysis

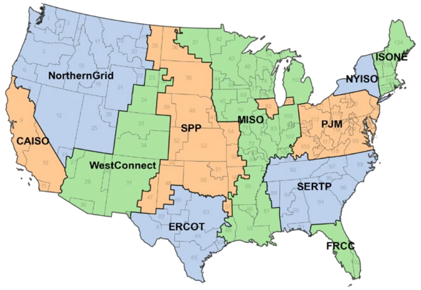
Capacity expansion scenarios

Recap from updates Patrick Brown provided in Fall 2022 workshop



Scenario Framework

4 transmission options



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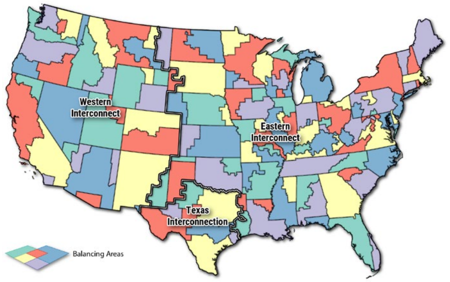

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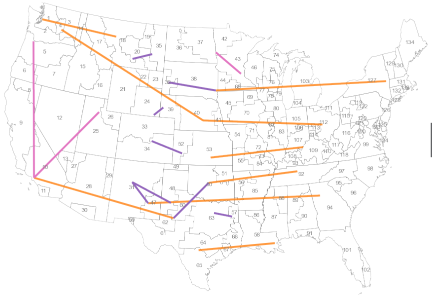
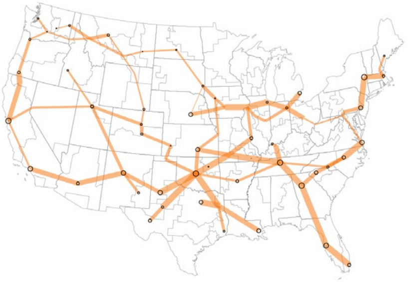


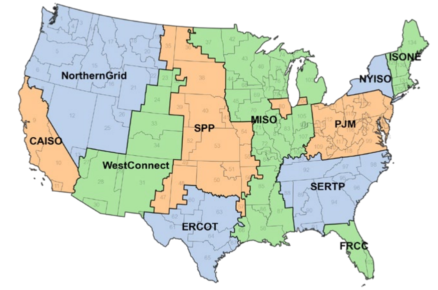
HVDC Point-to-point



HVDC Multi-terminal

Scenario Framework: 24 core scenarios

4 transmission options X 3 emissions-demand combinations



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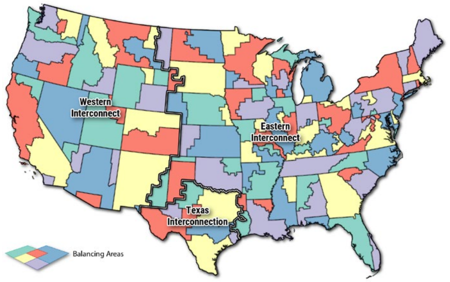

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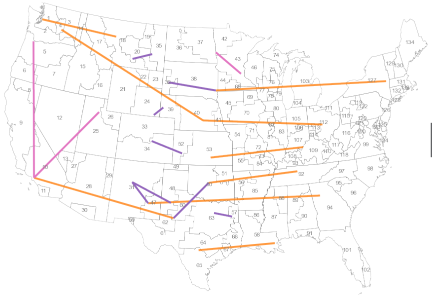
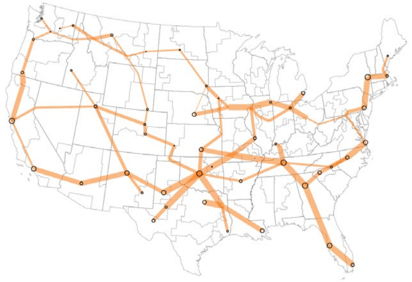


HVDC Point-to-point

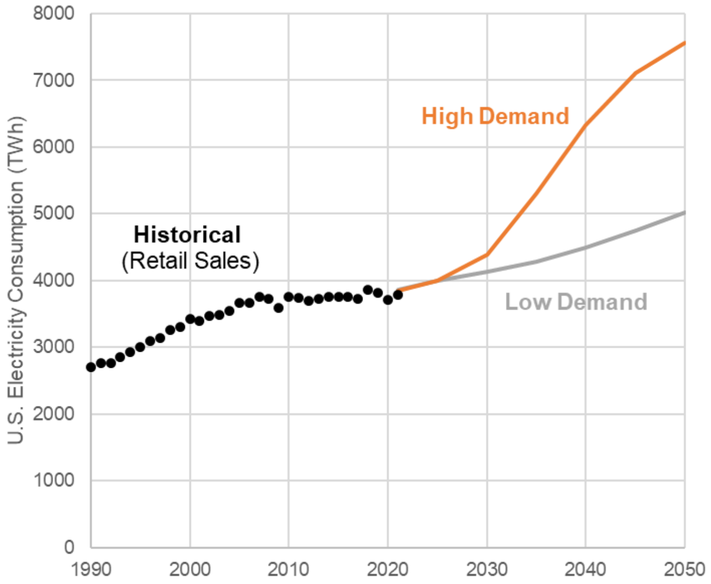


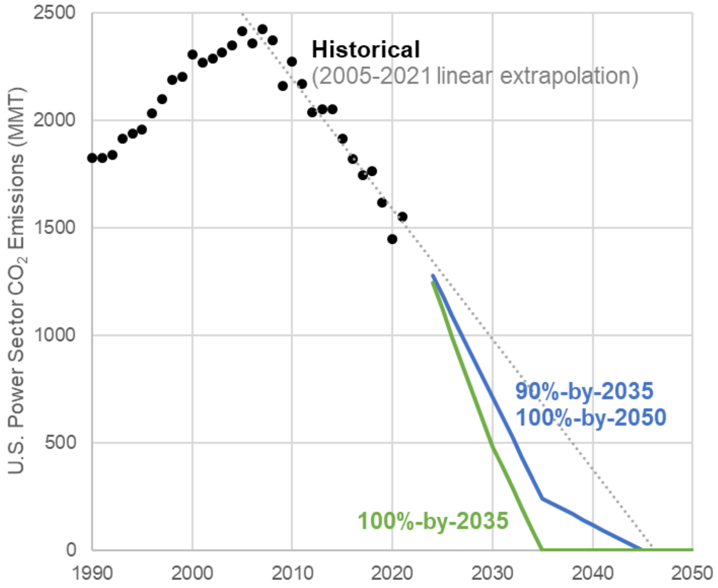
HVDC Multi-terminal

Demand Growth →

Emissions Target ↕

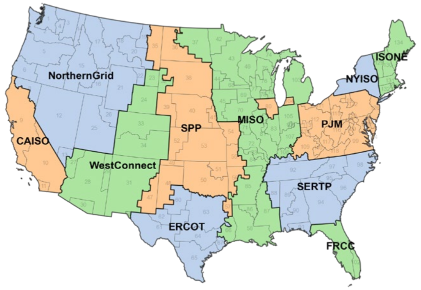
Current Policies Low Demand	**Current Policies High Demand**
90-by-2035 Low Demand	**90-by-2035 High Demand**
100-by-2035 Low Demand	**100-by-2035 High Demand**





Scenario Framework: ~200 scenarios and sensitivities

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



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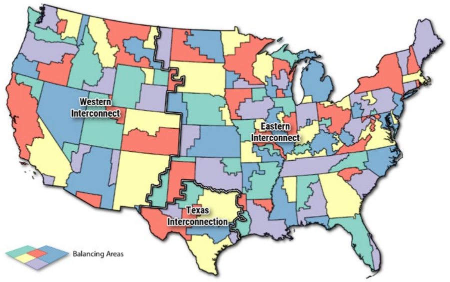

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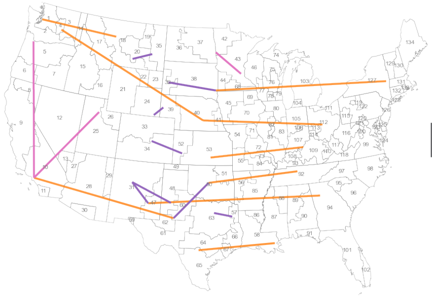

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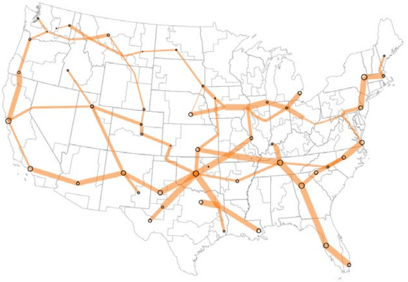
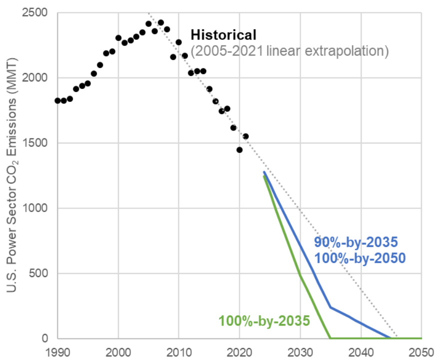
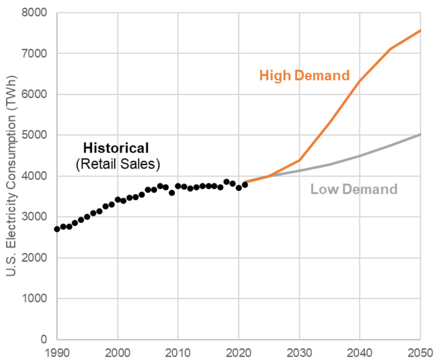


HVDC Multi-terminal

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**

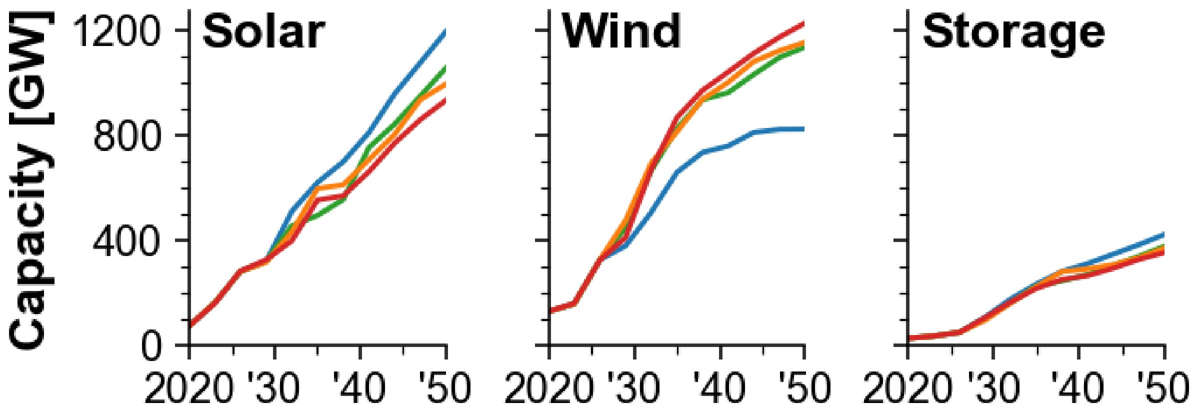


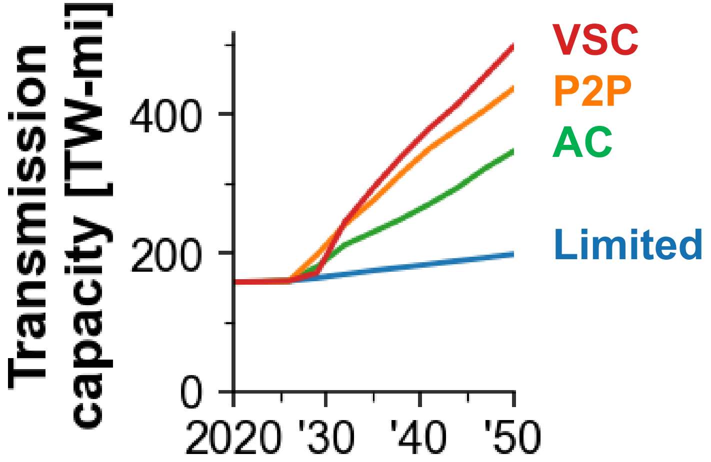


Sensitivity
Transmission costs
NG prices (higher, lower)
PV and battery costs
Wind costs
Land-based RE siting
DER adoption
Interruptible load
Clean fuel (e.g., H2) prices (higher, lower)
Technologies included (expanded, limited)
Climate change impacts
Combined pessimistic

Recap: Takeaways from capacity expansion modeling so far

Most scenarios point to RE, storage, and transmission capacities many times larger than today.





Interim results
Do not distribute

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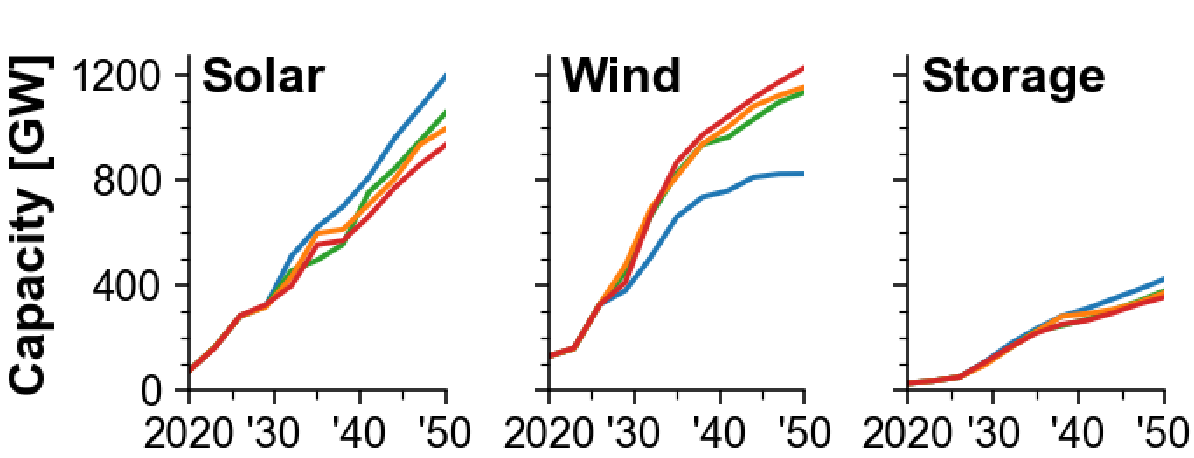
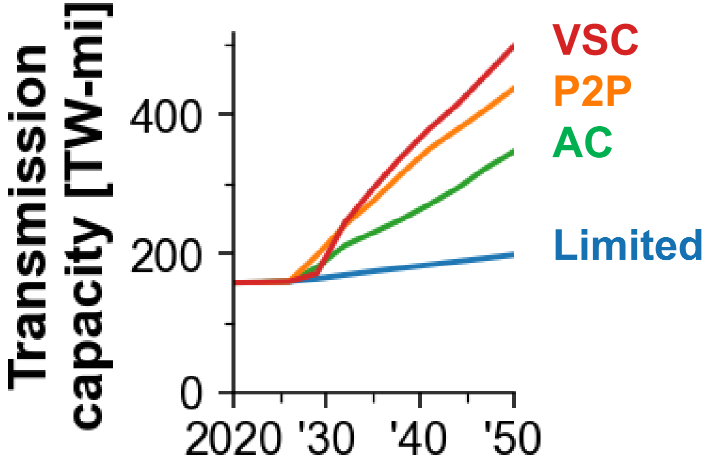
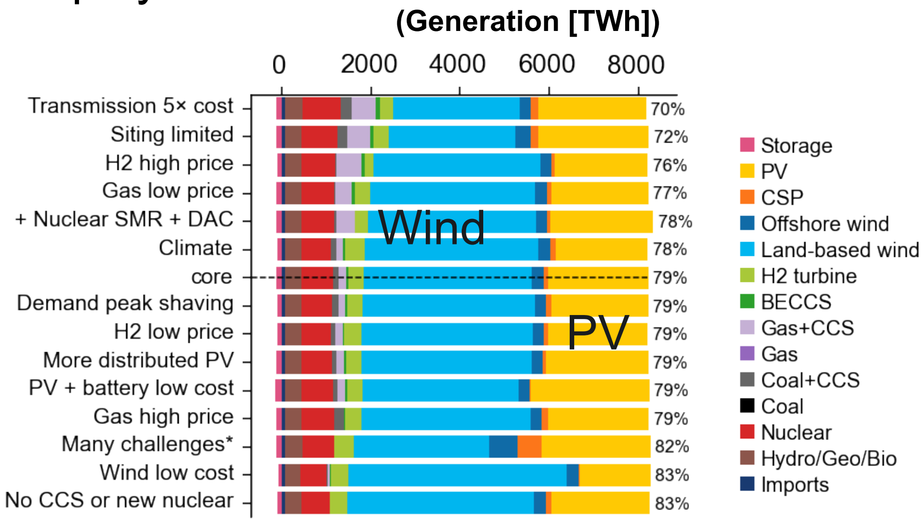




Decarbonization driven by wind and solar deployment



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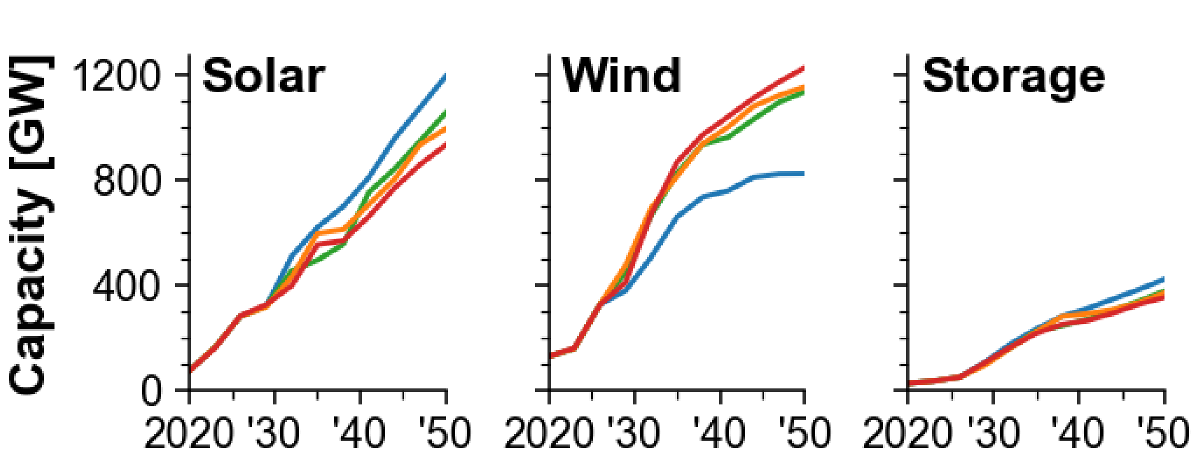

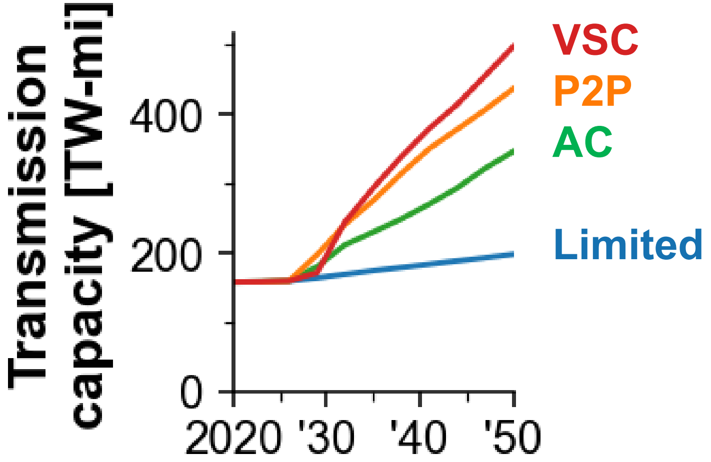

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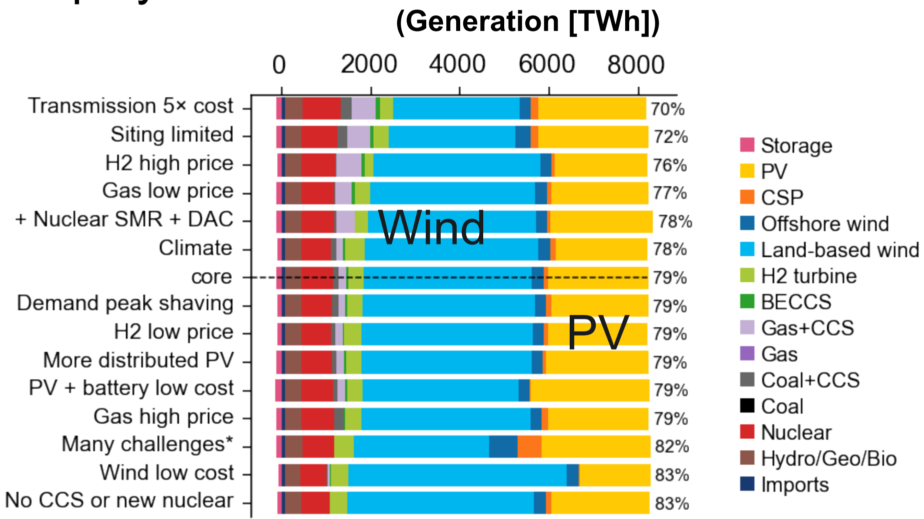
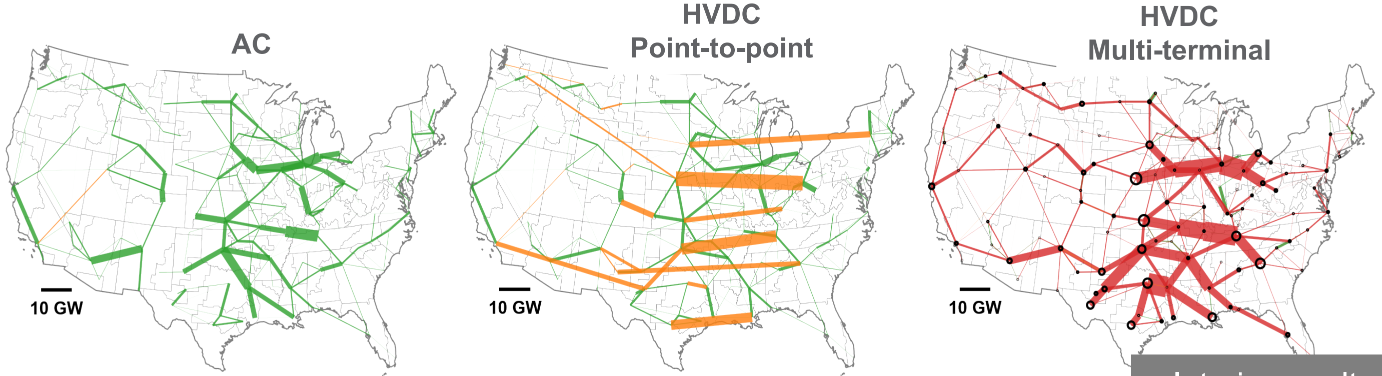


Transmission is added nationwide, but with the highest density between the wind belt and eastern interconnection demand centers.

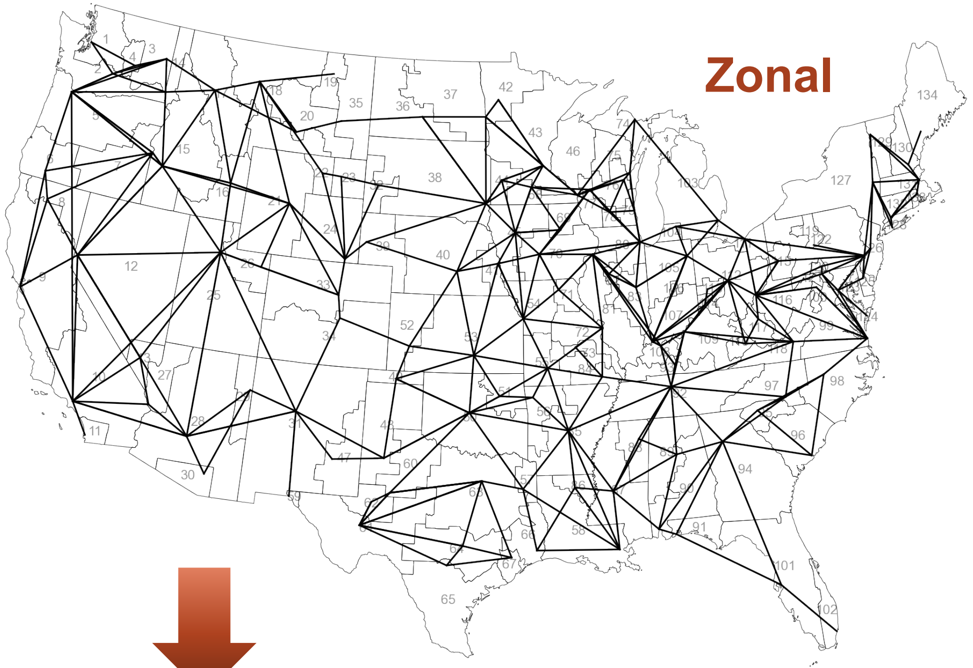


Interim results
Do not distribute

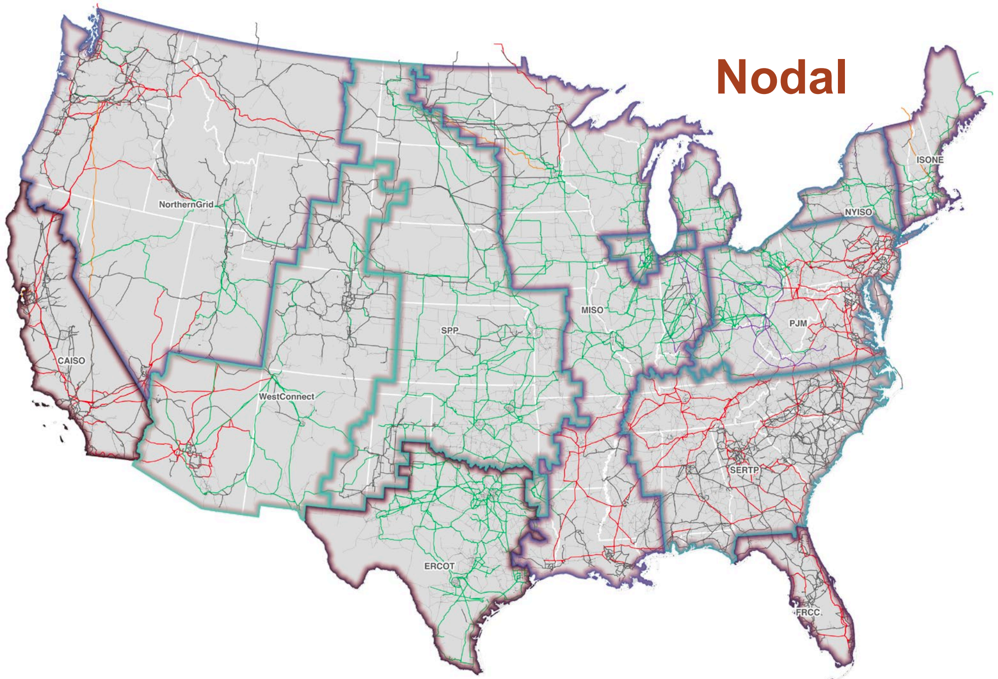
Current progress report: transitioning to nodal modeling

Jarrad Wright and **Leonardo Rese** have produced the technical work being presented

Zonal



Nodal



Scenario Framework: 168 sensitivities

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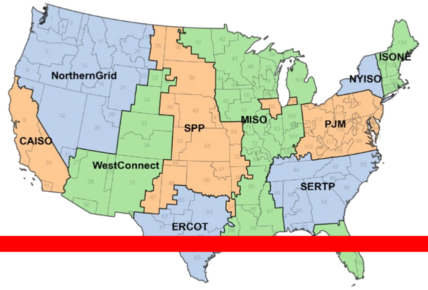
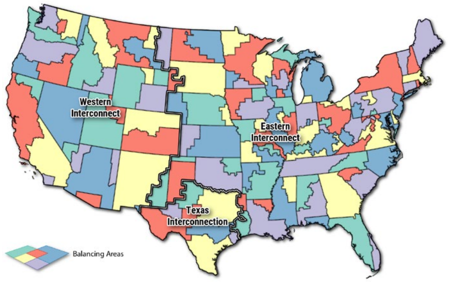


Limited



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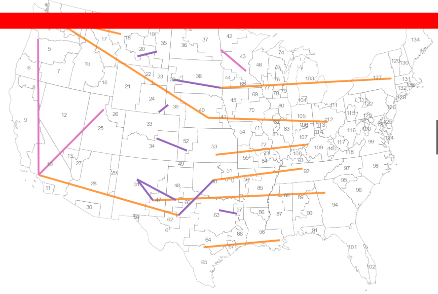
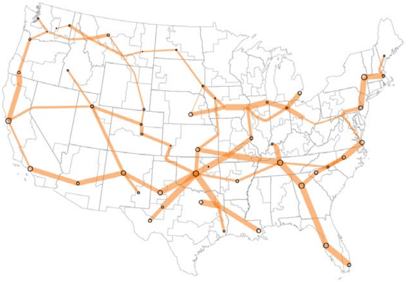


HVDC Point-to-point



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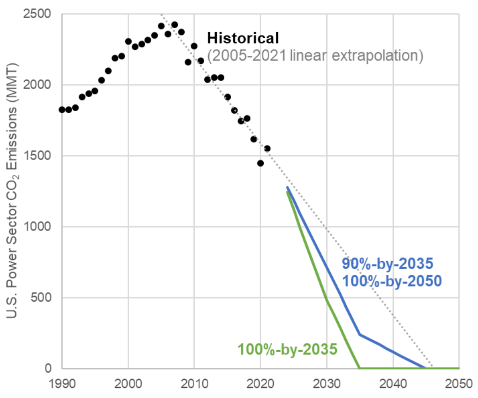

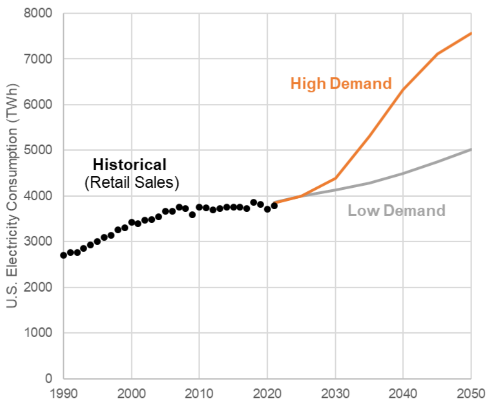

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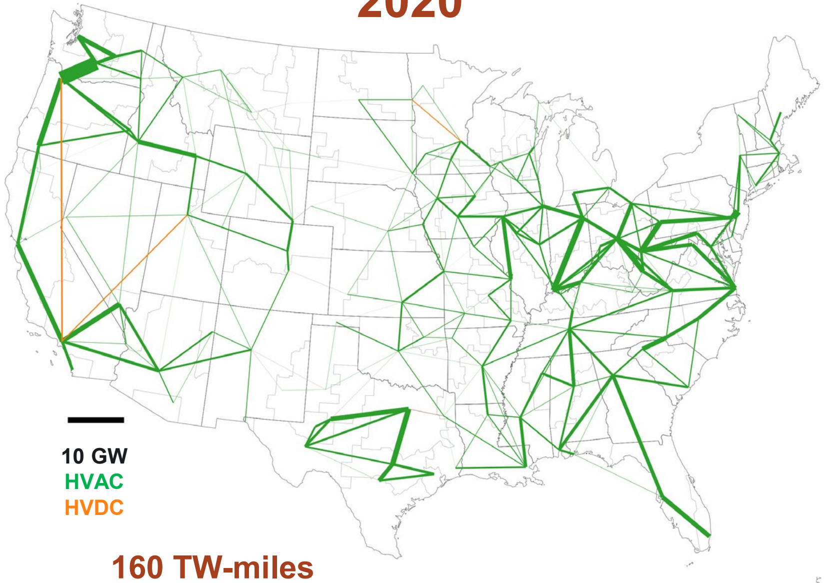
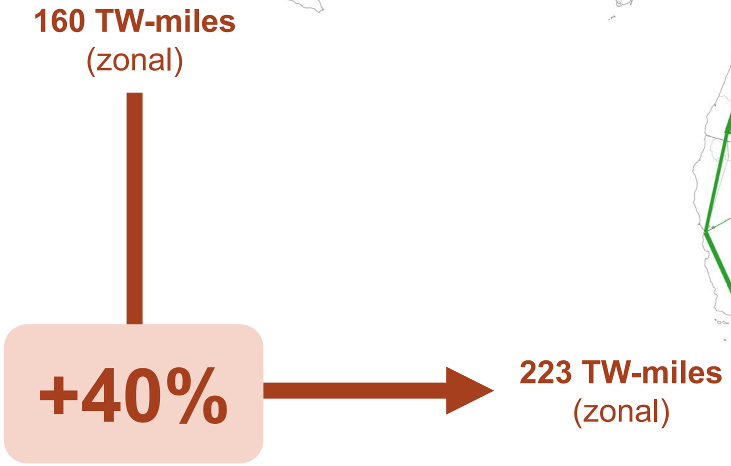
Combined pessimistic

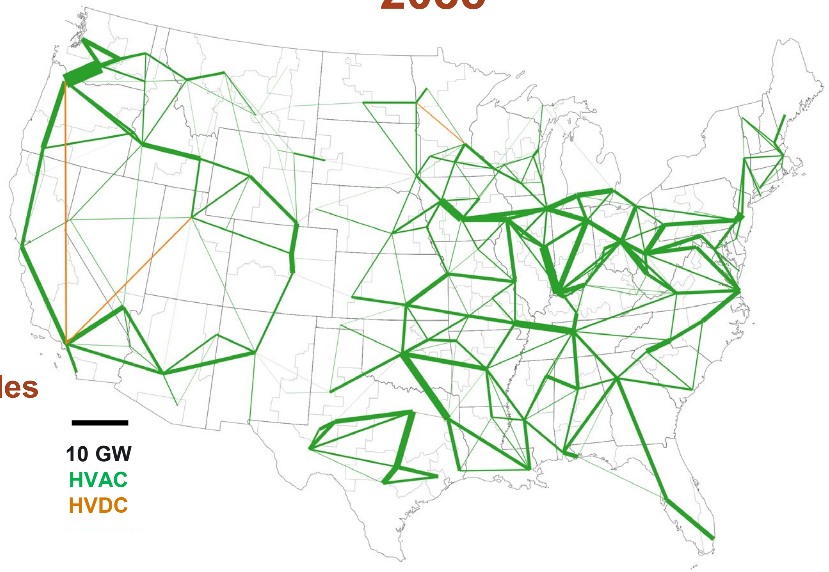
The evolution of capacity, demand, and transmission in this scenario are transformative

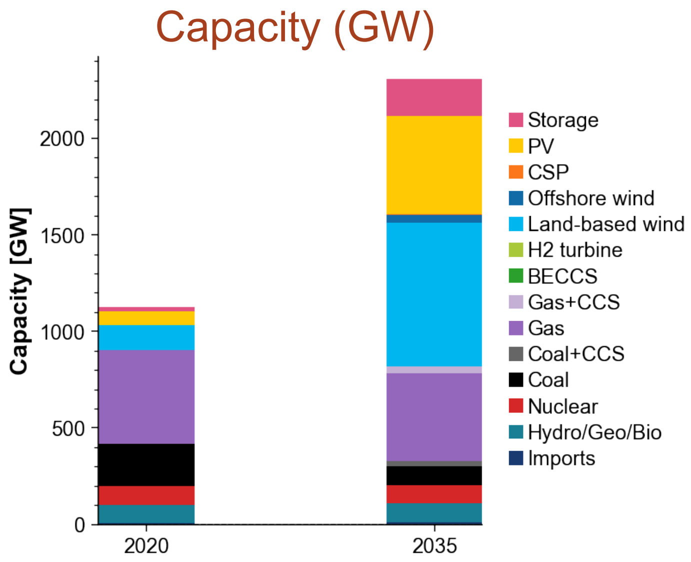
2020

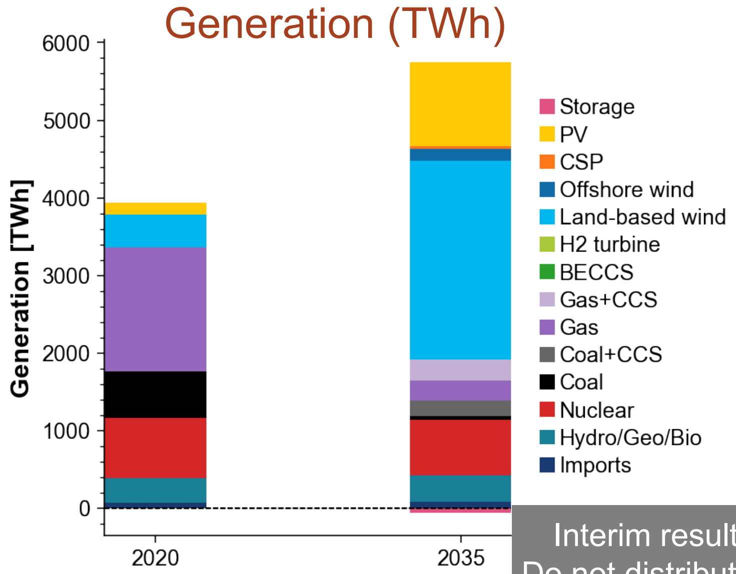




2035





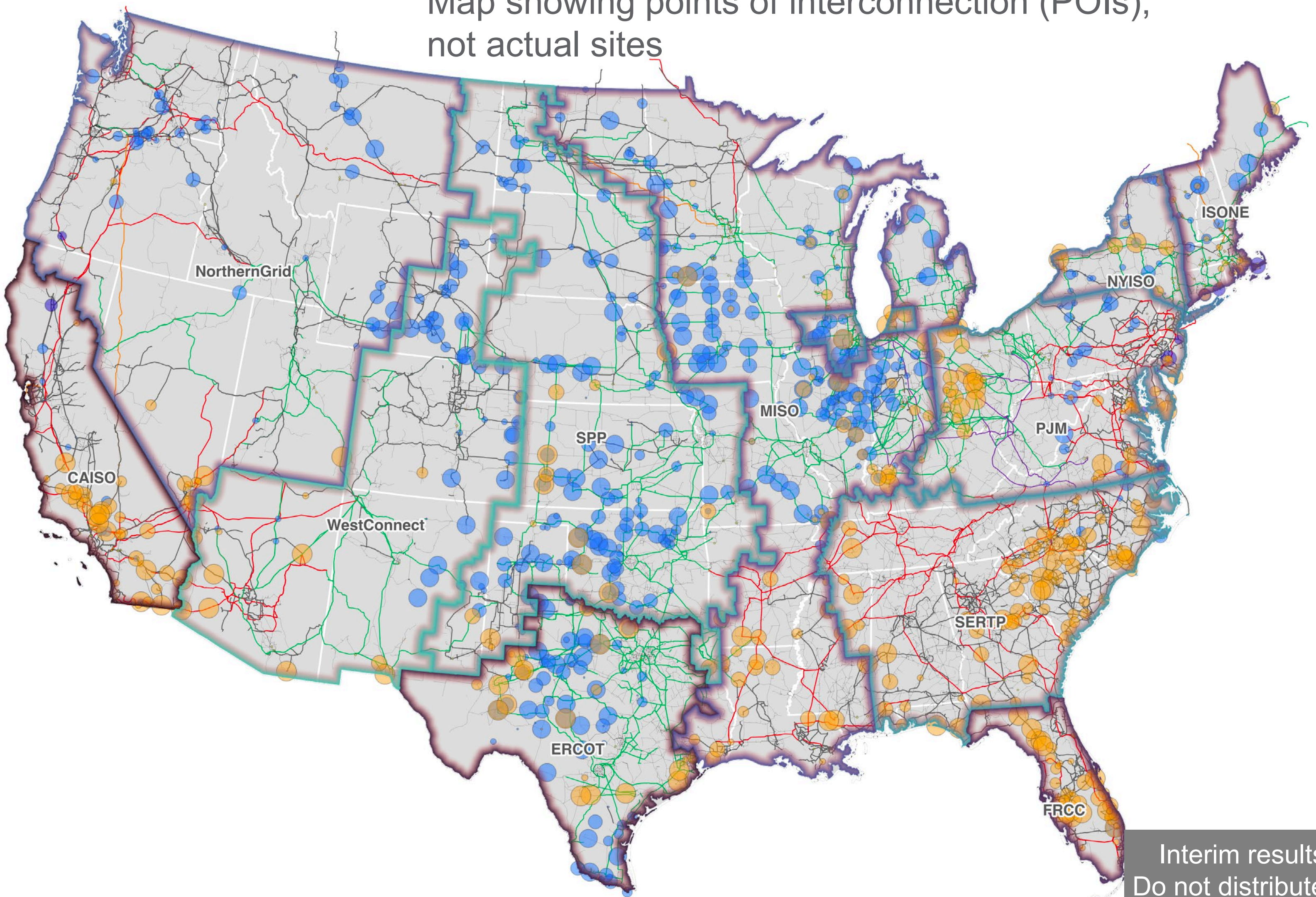


Interim results
Do not distribute

New wind and solar PV capacity disaggregation

Scenario 1 (2035)	Number of POIs	2035 Capacity
Utility-scale solar	715	718 GW
Land-based wind	634	590 GW
Offshore Wind	16	42 GW

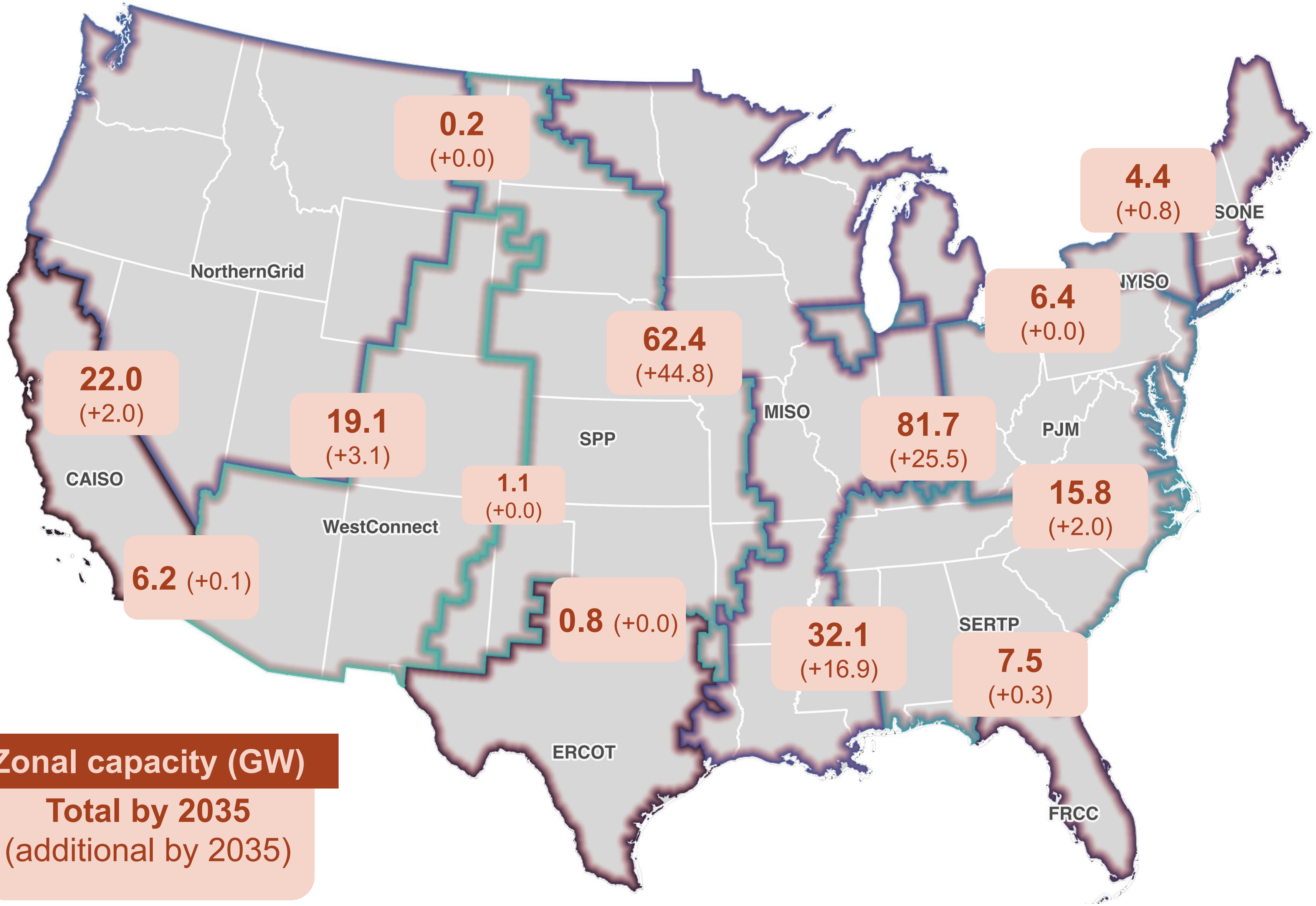
Map showing points of interconnection (POIs), not actual sites



Installed capacity (2022):
Solar PV ~140 GW (solar PV),
Land-based wind ~135 GW
Offshore wind ~0.04 GW

Interim results
Do not distribute

Interregional (Zonal) Transmission Capacity Expansion



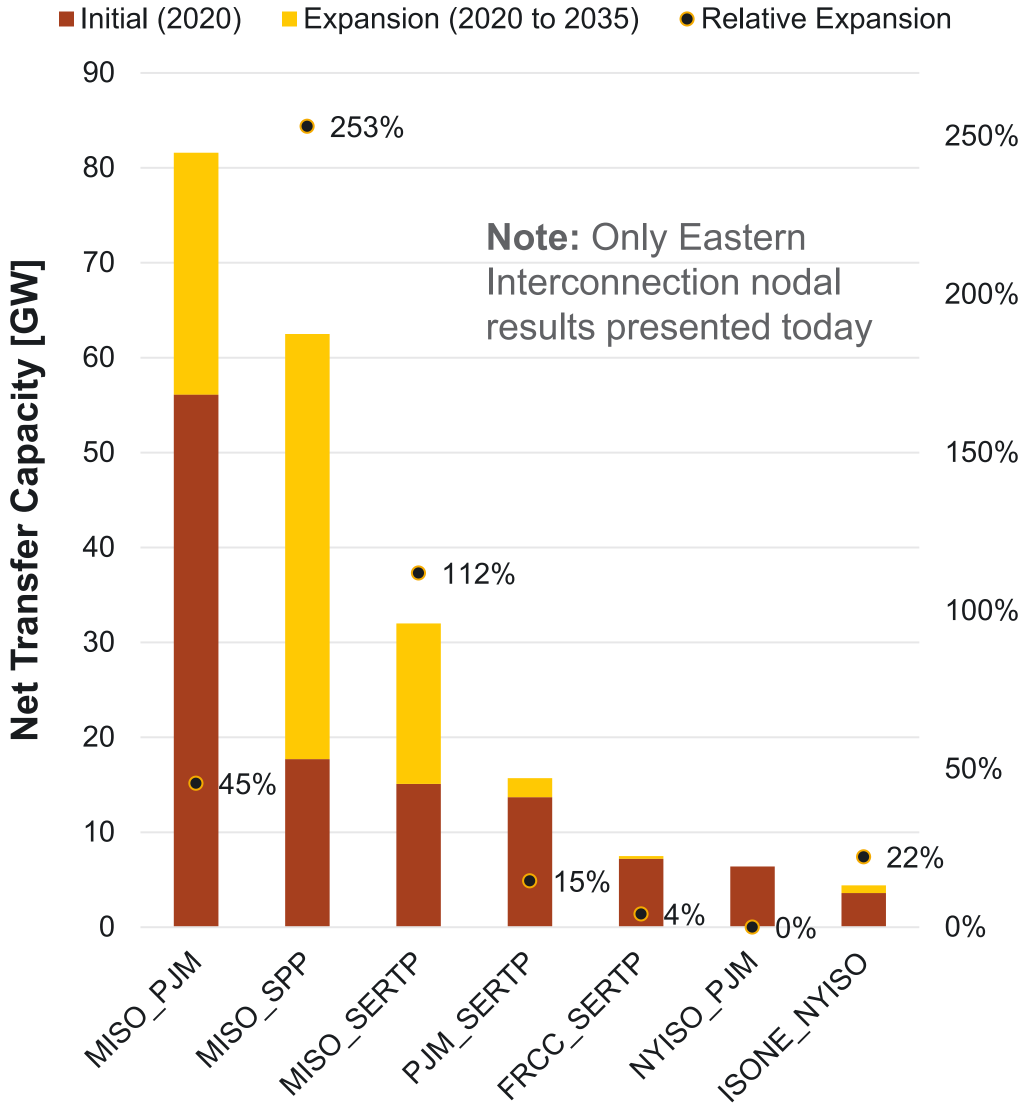
Zonal capacity (GW)

Total by 2035

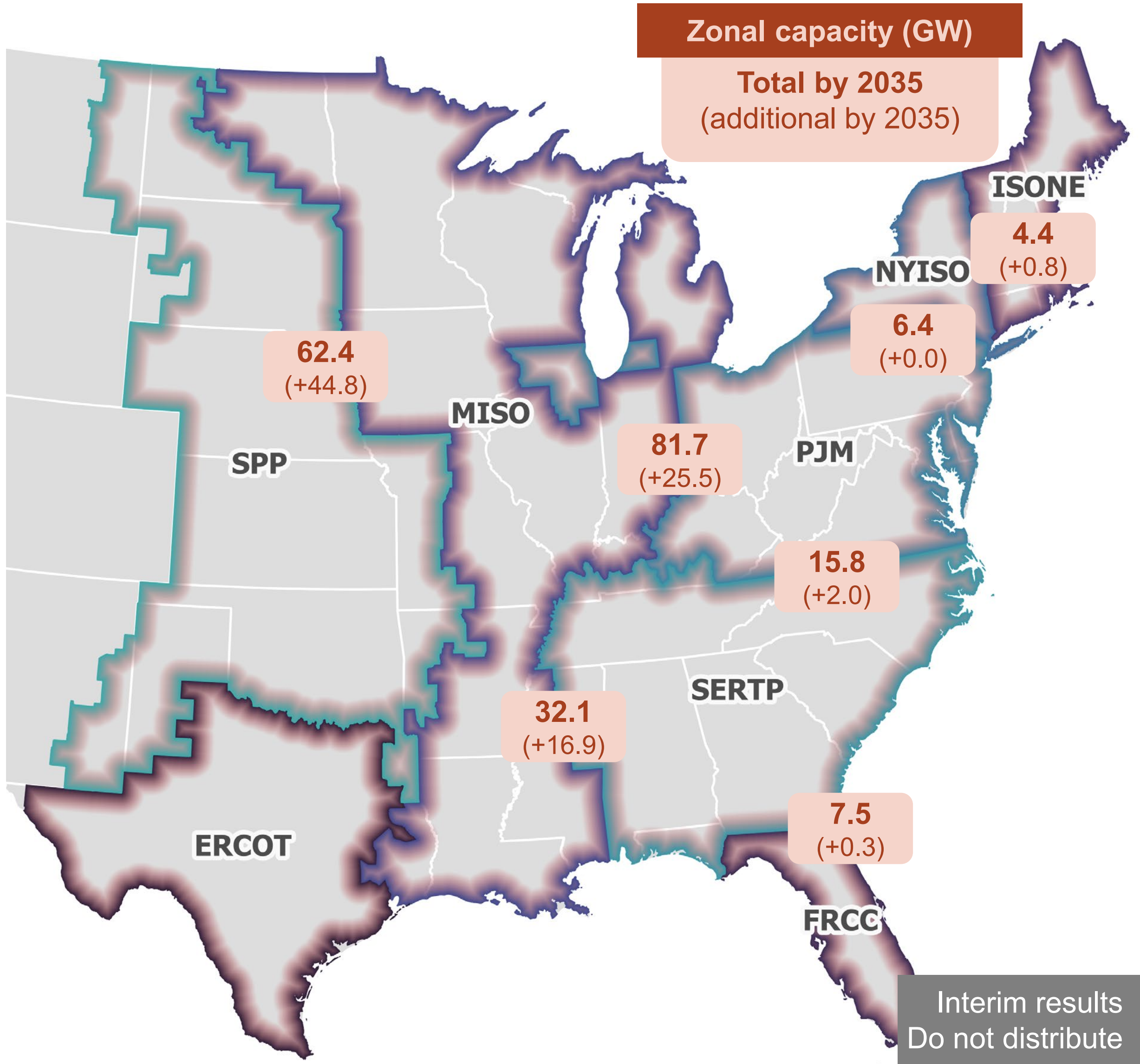
(additional by 2035)

Interregional (Zonal) Transmission Capacity Expansion needs

Scenario 1 - 2020 to 2035



Note: Only Eastern Interconnection nodal results presented today



Interim results
Do not distribute

DCPF – DC powerflow
CEM – capacity expansion model
PCM – production cost model

Transmission expansion methods summarized

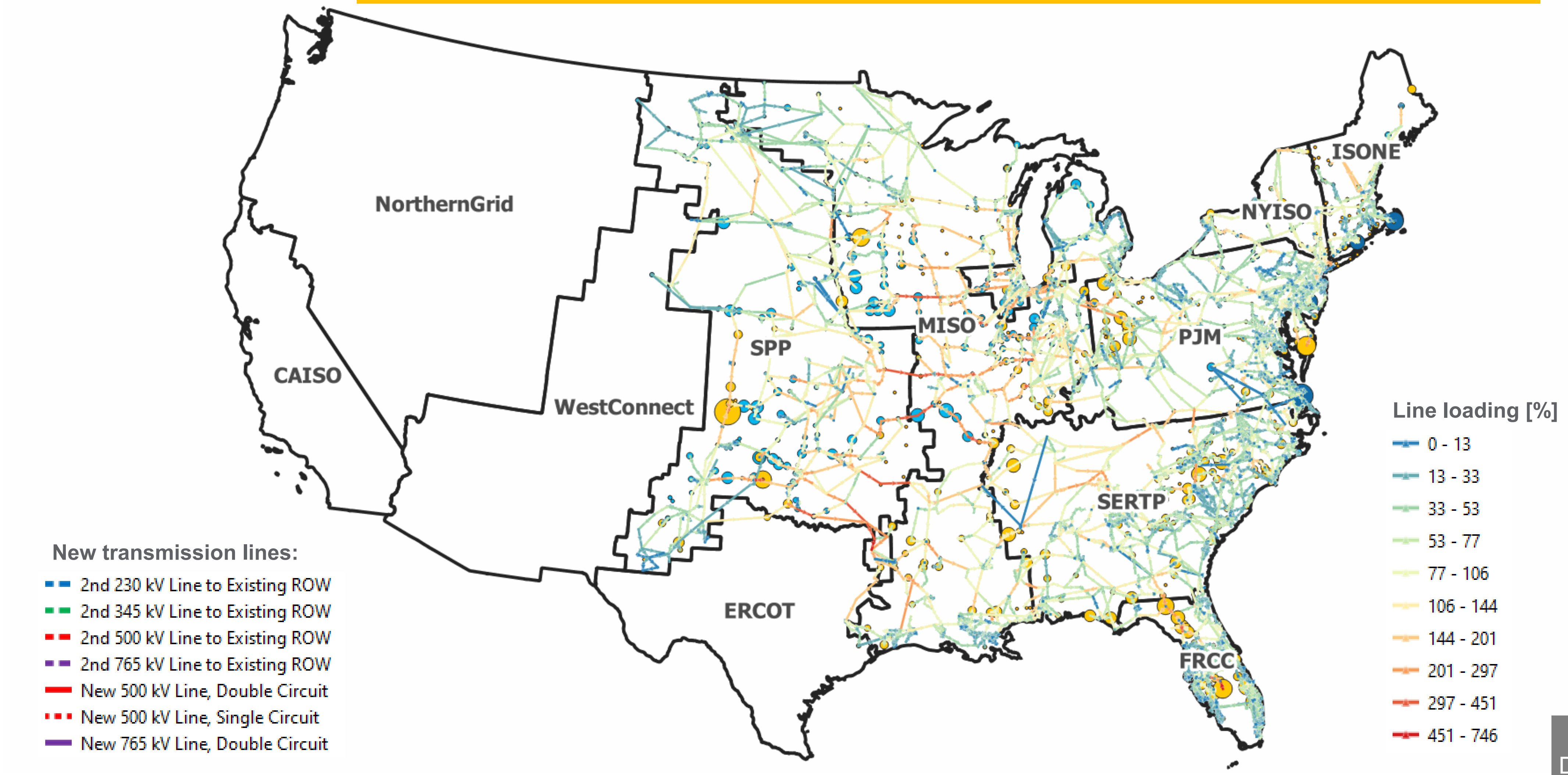
1. Disaggregate generation/storage capacity and demand based on CEM
2. Start running nodal PCM:
   - Unbounded (allow transmission overloads)
   - Semi-bounded (interface limits in selected locations)
   - Constrained (enforce everything at HV)
3. Transfer results to DCPF (snapshots):
   - Iterative transmission expansion with representative snapshots aimed at reducing overloading (with an interregional focus)
   - Use CEM transmission expansion as a guide for scale and general location
4. When overloading is greatly reduced, re-run fully constrained PCM for feasibility and to check if results are reasonable

DC power flow-aided transmission expansion

Priority is addressing interregional

Round 0

Between rounds, decrease overloading on the underlying system and utilize the new transmission

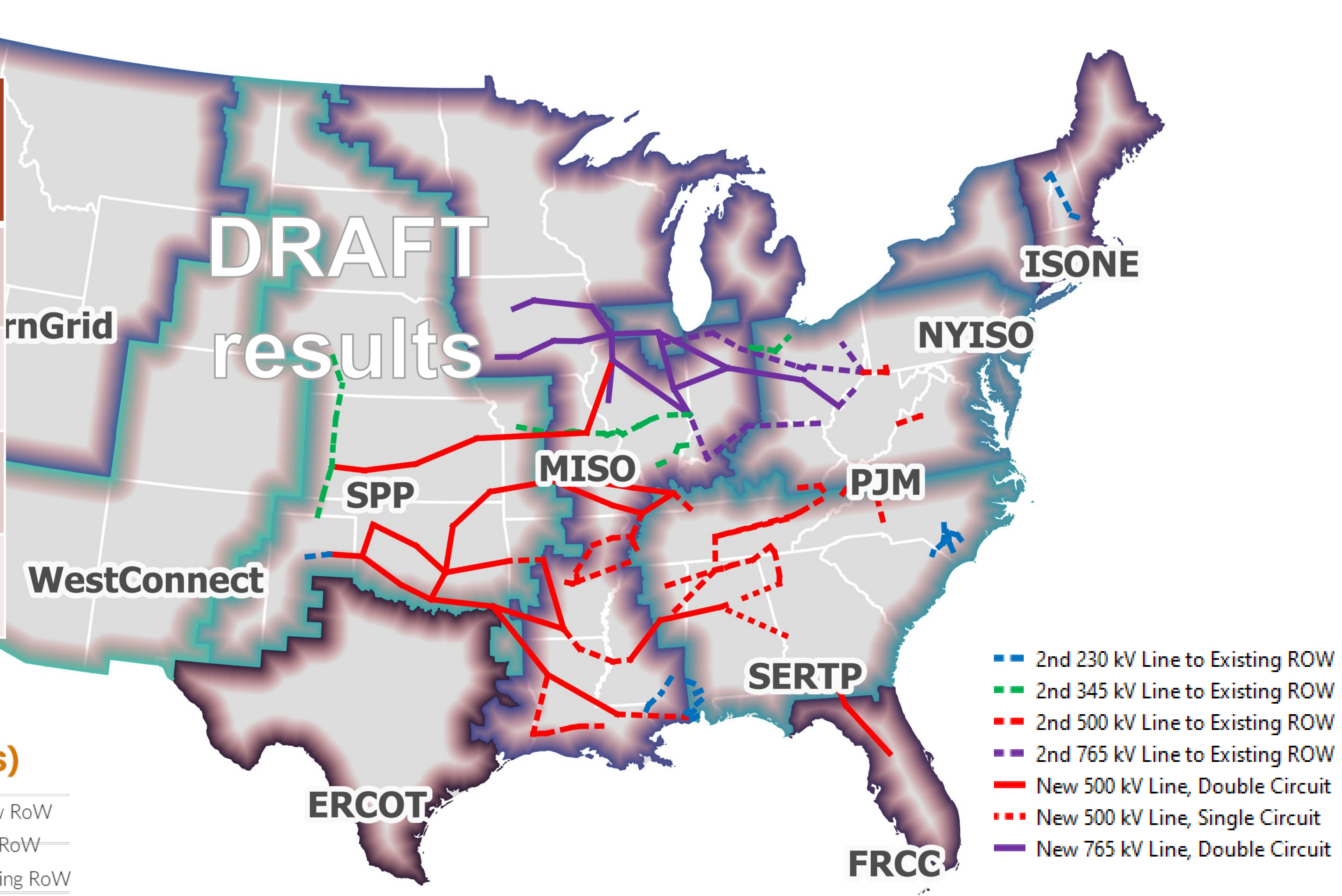


Interim results
Do not distribute

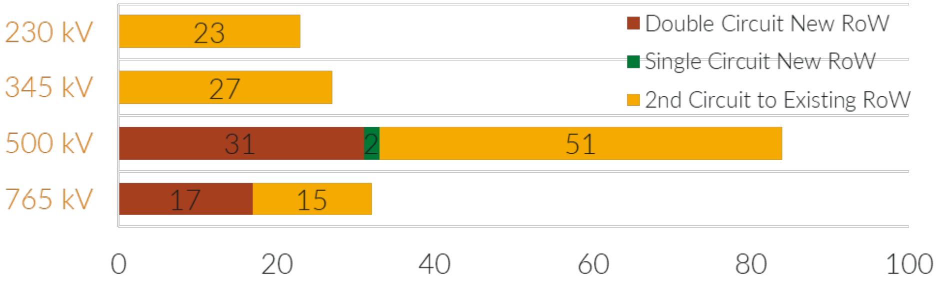
Transmission expansion configuration after iterative DCPF
(Scenario 1 – EI)

Does the new transmission result in:

- ❑ Reduced VRE curtailment?
- ❑ Decreased production cost?
- ❑ Adequately used networks?
- ❑ Etc.



TRANSMISSION EXPANSION (NUMBER OF NEW LINES)

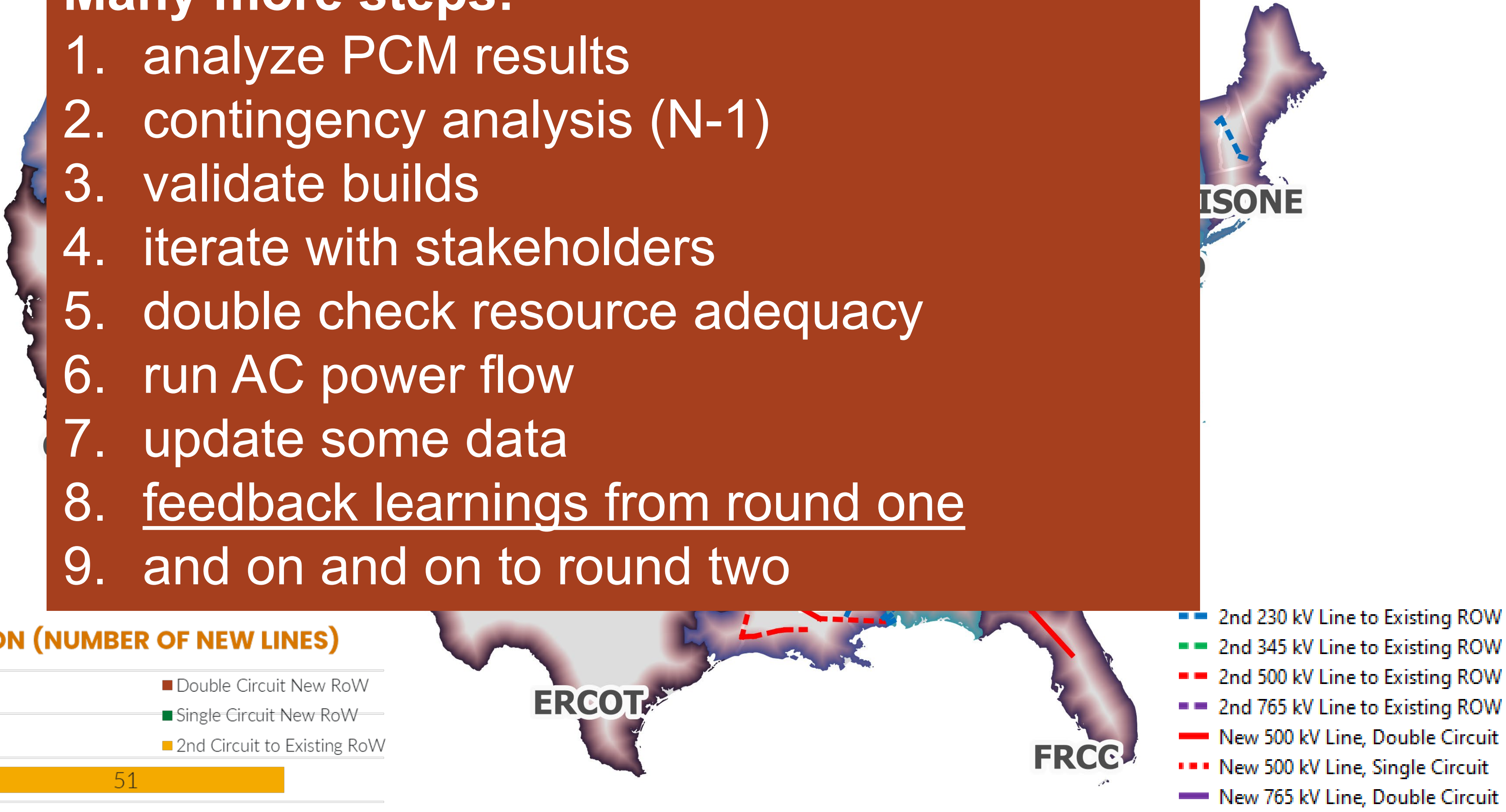


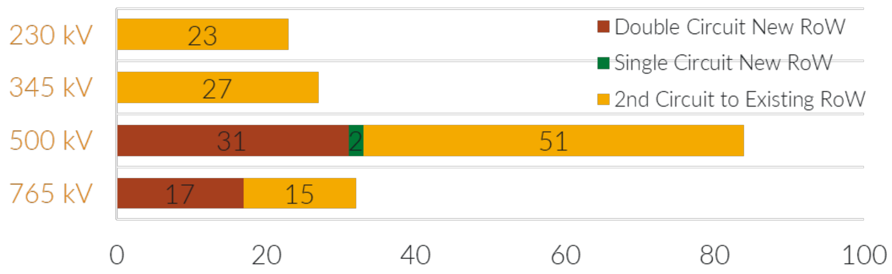
Interim results
Do not distribute

Transmission expansion configuration after iterative DCPF
(Scenario 1 – EI)

Many more steps:

1. analyze PCM results
2. contingency analysis (N-1)
3. validate builds
4. iterate with stakeholders
5. double check resource adequacy
6. run AC power flow
7. update some data
8. <u>feedback learnings from round one</u>
9. and on and on to round two





Key Takeaways

- Solving inter-regional transmission as a highest priority addresses a lot of the transmission buildout needs, but not all.

- Good alignment on transmission capacities between capacity expansion and production cost model
  - I.e., the investment decisions being made with zonal granularity hold up with detailed modeling

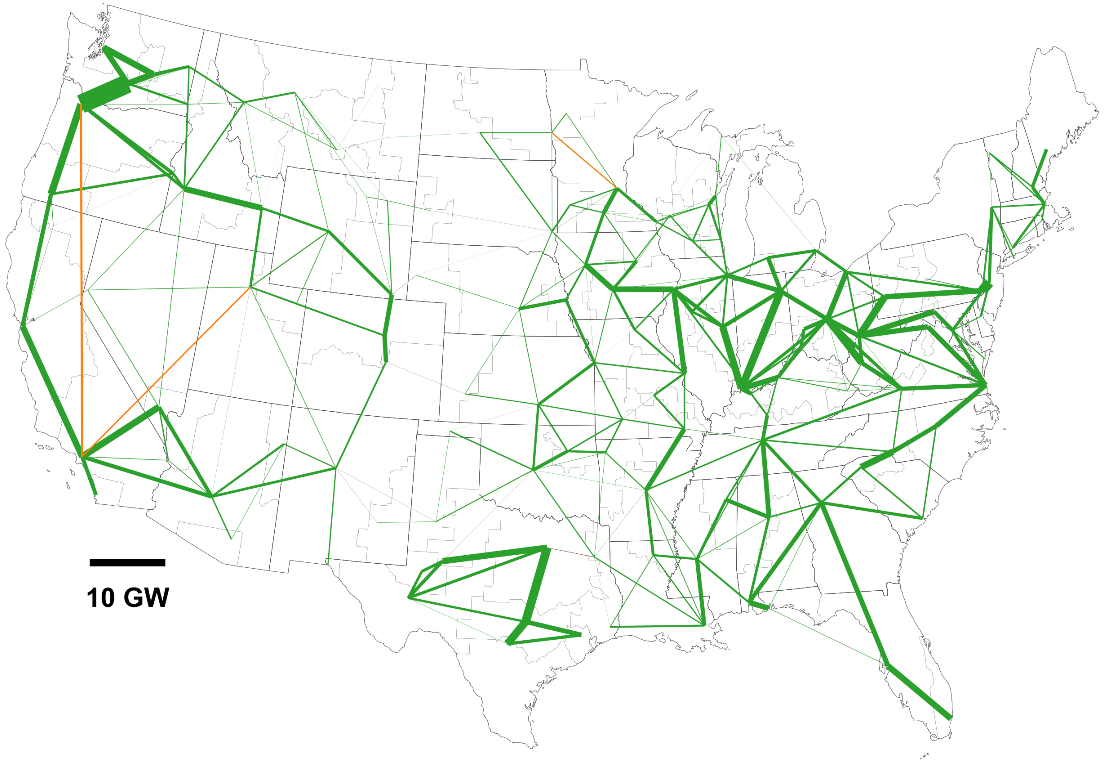
- Expecting wide variation between nodal scenarios – similarities will help with inter-regional priorities

Next steps

Next up in zonal to nodal

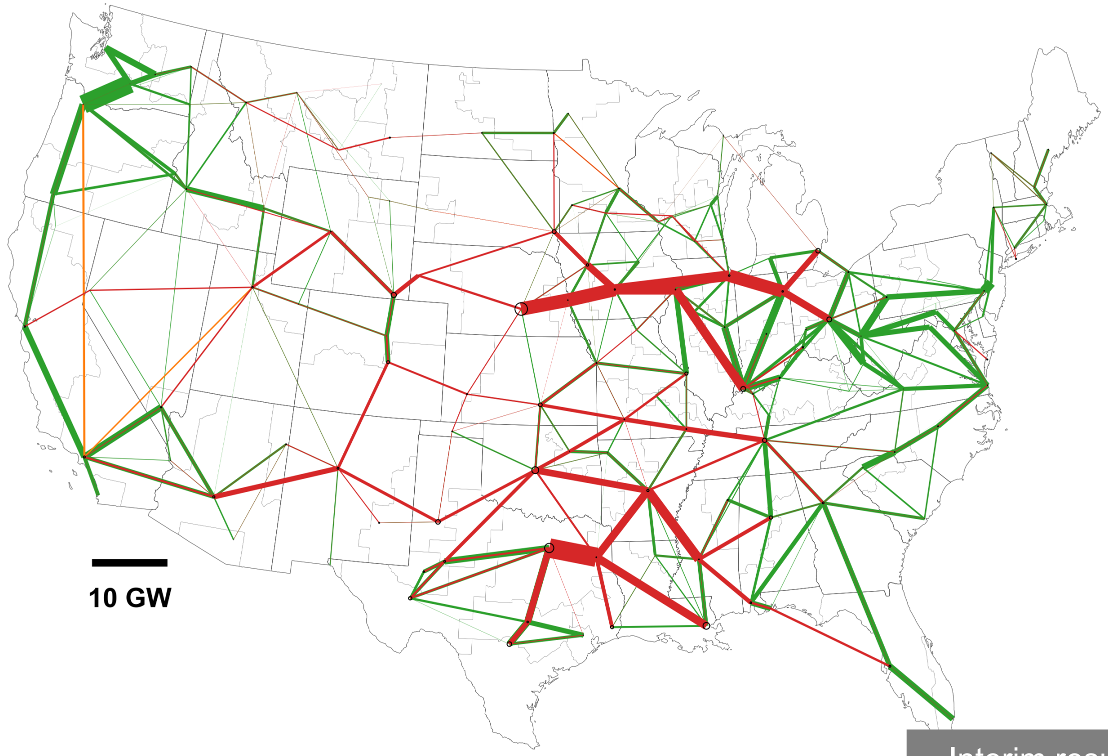
Scenario 2

- Limited AC expansion
- Year: 2035
- High demand
- 90% decarbonization by 2035



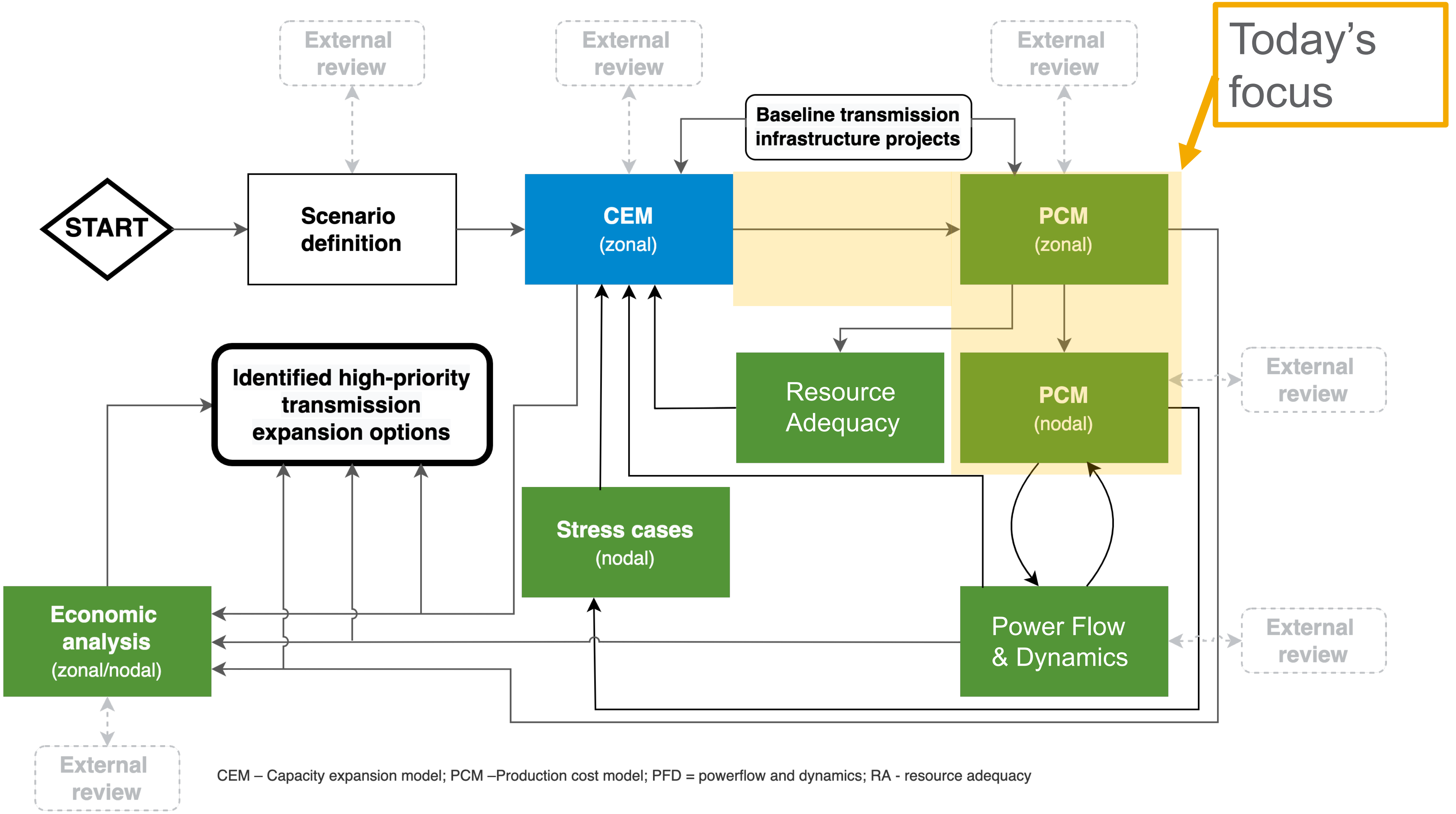
Scenario 3

- HVDC
- Year: 2035
- High demand
- 90% decarbonization by 2035



Interim results
Do not distribute

Additional analyses underway



CEM – Capacity expansion model; PCM –Production cost model; PFD = powerflow and dynamics; RA - resource adequacy

Thank you

David.Palchak@nrel.gov