Transmission Planning for 100% Clean Electricity

ESIG Webinar
February 23, 2021

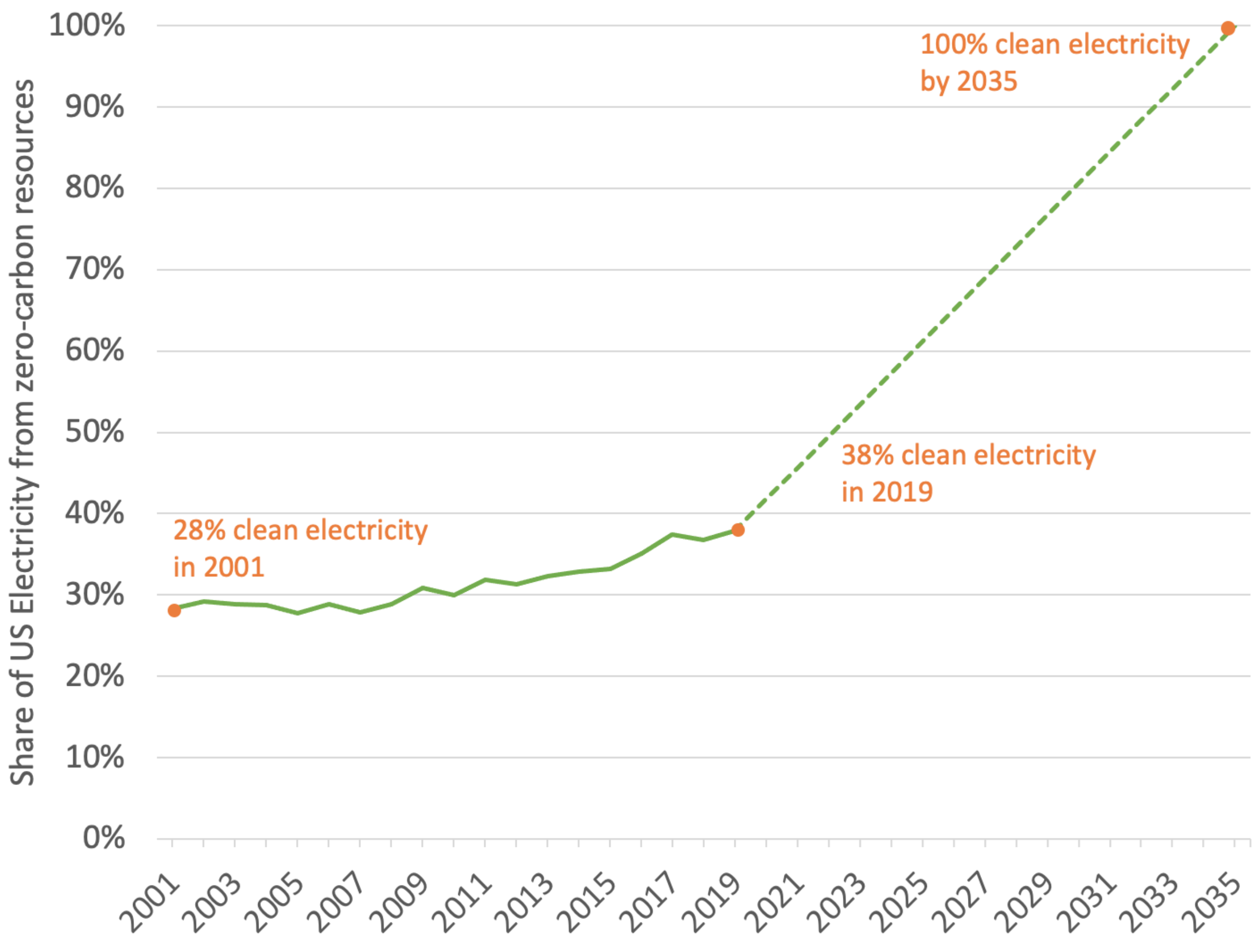
ENERGY SYSTEMS INTEGRATION GROUP

Overview

- ESIG held five transmission special sessions in Nov-Dec 2020 to convene over fifty electricity experts to examine transmission needs for 100% clean electricity goals
- Reviewed number of clean energy studies and their transmission plans
- Developed set of recommendations and macro grid concept
- https://www.esig.energy/transmission-planning-for-100-clean-electricity/

How can we get to 100% clean electricity while maintaining affordability and reliability?

Decarbonization requires action on a transformative scale



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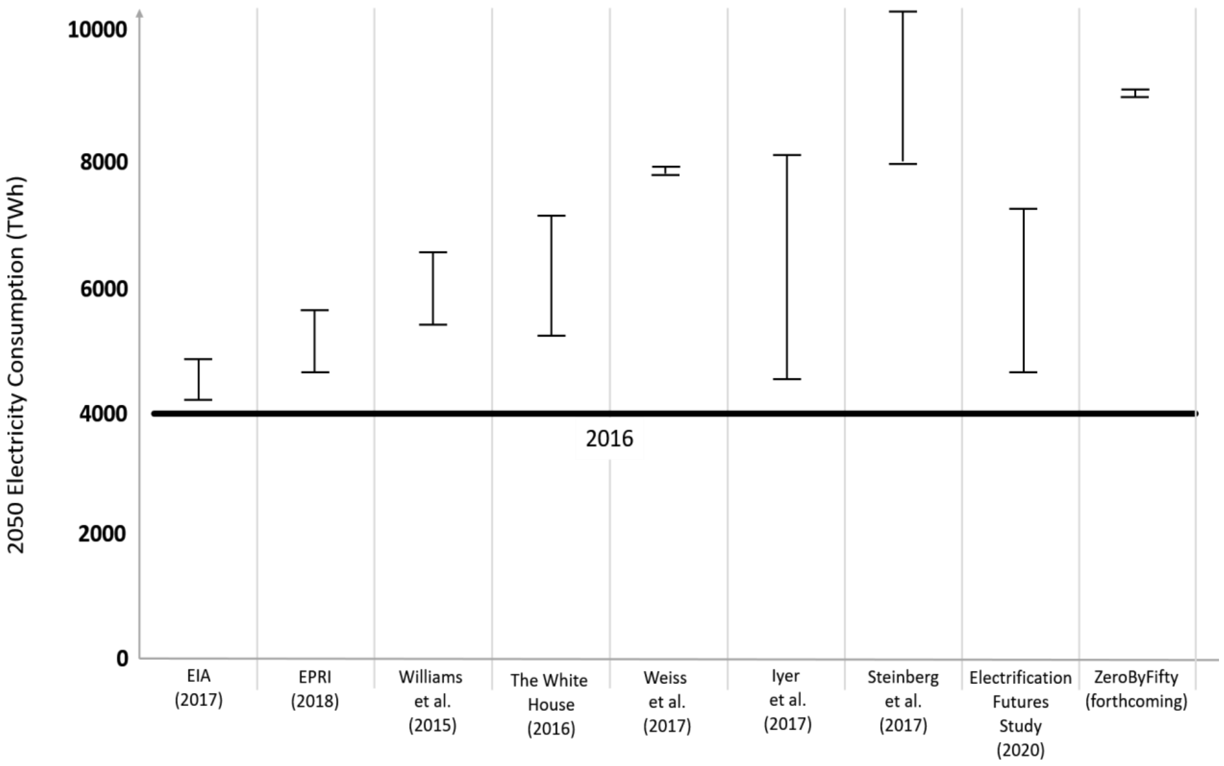
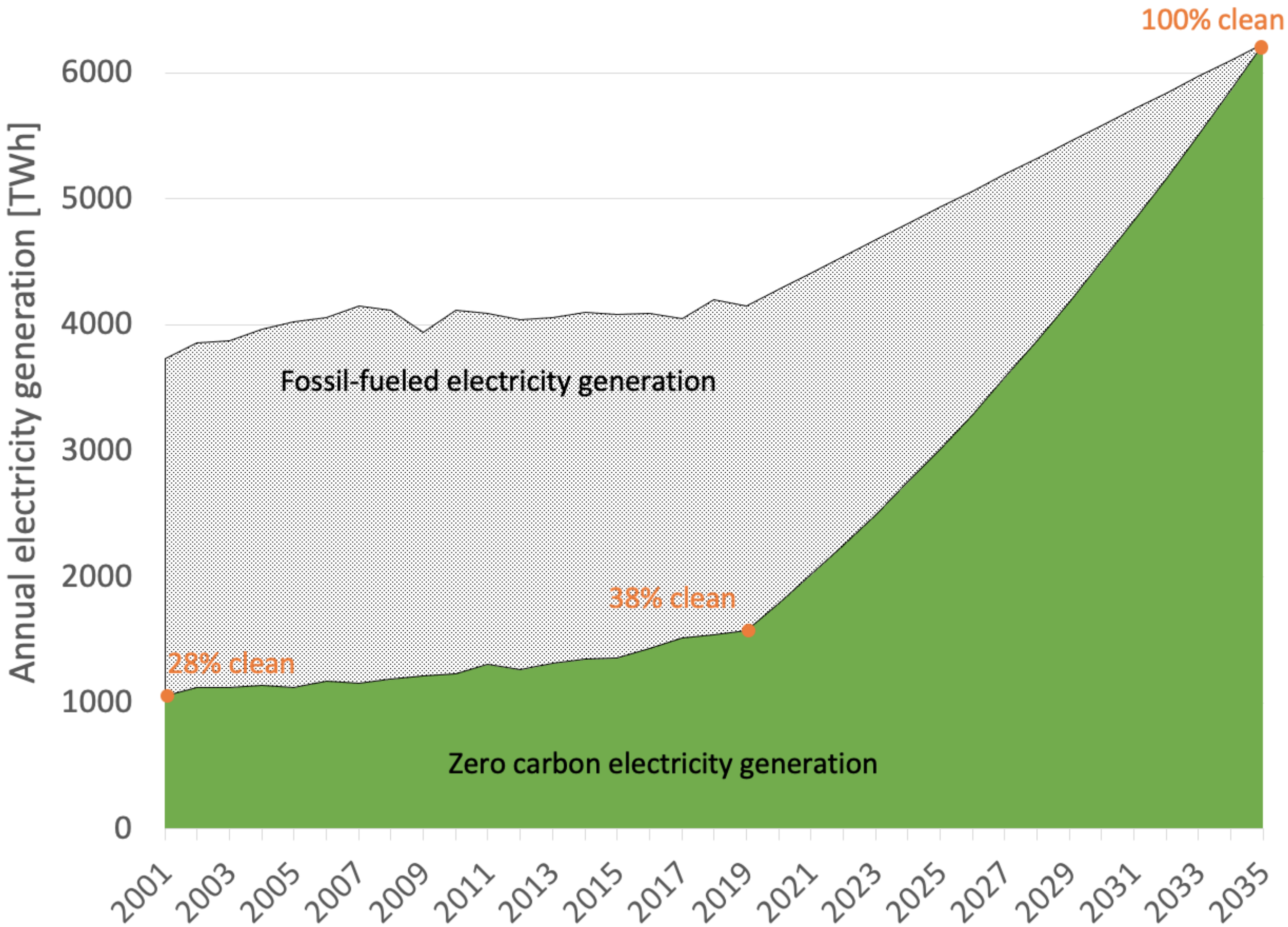
Demand will increase due to electrification





Energy Systems Integration Group

Charting the Future of Energy Systems Integration and Operations

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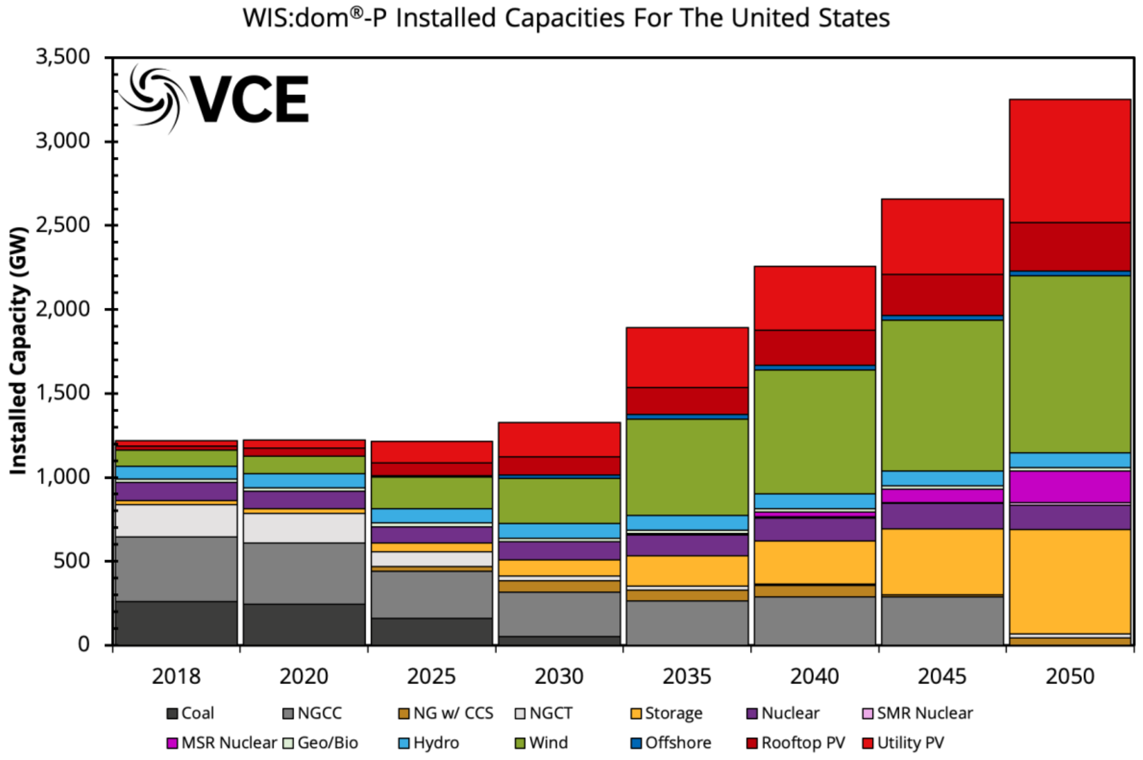
Wind and solar generation must grow exponentially

- We may need 1 TW or more of new wind and PV capacity to reach 100% clean electricity goals (that's 5x current wind/PV capacity)
- Decarbonizing the entire US energy economy may require twice that.



MISO RIIA 100% buildout [MW]			
	DPV	UPV	wind
MISO	32,190	67,975	129,647
SPP	8,139	14,700	41,750
TVA	40,174	85,275	7,300
SERC	85,119	180,825	15,250
PJM	41,174	93,100	185,600
NYISO	8,483	19,675	31,600
Total	**215,279**	**461,550**	**411,147**

Source: MISO RIIA Study, Preliminary results from VCE's ZeroByFifty Study

We evaluated a number of studies

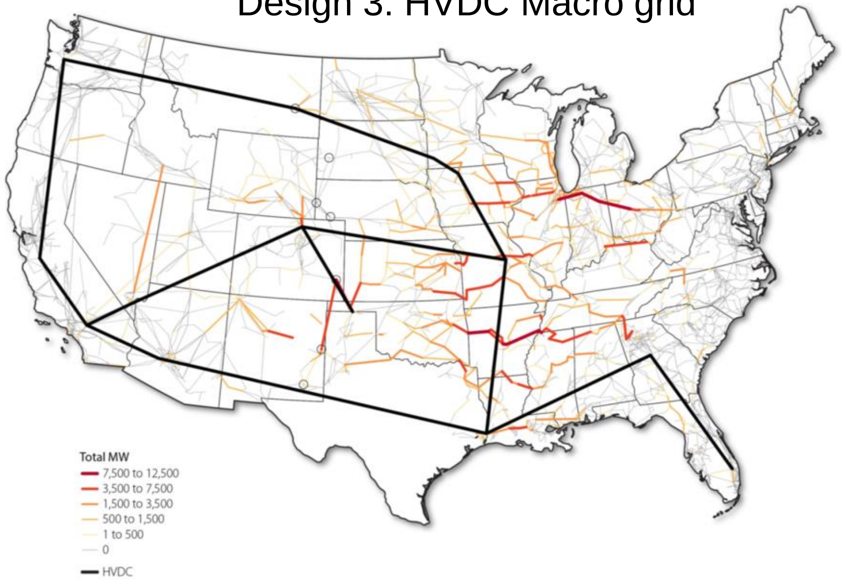
Study	Region	Renewable Capacity	Clean Energy Level(s)	Annual Electricity Demand	Target Year
The 2035 Report	United States	1,100 GW (wind and solar)	90% clean electricity	4,500 TWh	2035
Electrification Futures Study	United States and Canada	600 GW (wind) 1,000 GW (solar)	23% to 75% renewable energy	7,000 TWh	2050
Interconnections Seam Study	United States (except Texas) and Canada	600-900 GW (wind and solar)	63% to 95% carbon free electricity	4,900 TWh	2038
MIT study	United States	1,200 GW (wind) 1,100 GW (solar)	100% clean electricity	5,000 TWh	2040
Renewable Integration Impact Assessment	United States - Eastern Interconnection	411 GW (wind) 677 GW (solar)	Up to 100% clean electricity for the eastern interconnection	2018 demand	N/A
ZeroByFifty	United States	1,100 GW (wind) 1,000 GW (solar)	100% clean energy	9,000 TWh	2050

A network of cross-country transmission is critical to minimizing cost

Interconnections Seam Study

- What's the value of interconnecting the east and west?
- Crossing the seam allows you to build the solar in the west and the wind in the east and share
- 50% renewables case: macro grid adds $19B to transmission costs but saves $48B (generation capacity, O&M and emissions), for a benefit/cost ratio of 2.5
- 85% renewables case (95% clean electricity): macro grid builds 40GW transfers across seam with a benefit/cost ratio of 2.9

Design 3: HVDC Macro grid

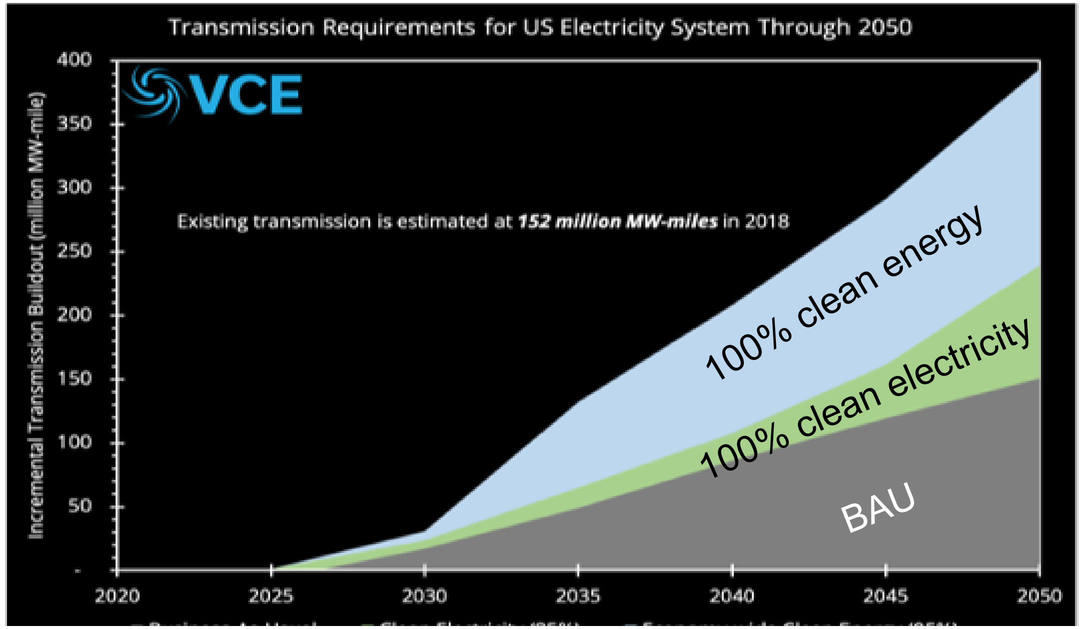


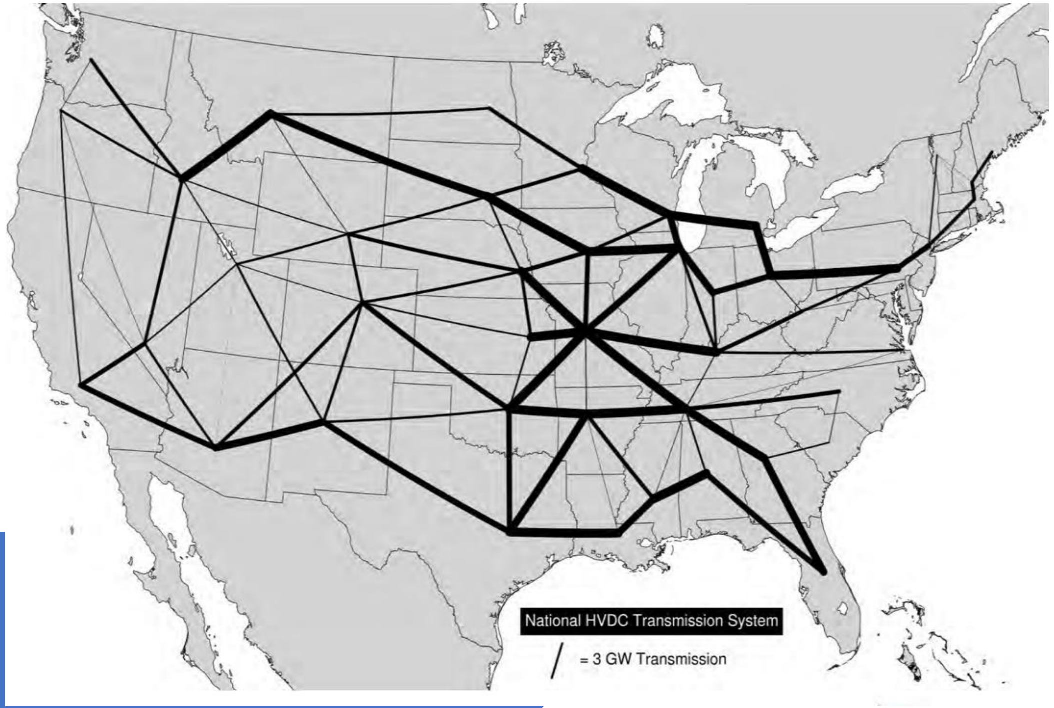
50% Renewables case	BAU across seams	HVDC Macro grid	
Objective function	**Design 1**	**Design 3**	**Delta**
Line investment (B$)	61.21	80.10	18.89
Generation investment (B$)	704.03	700.51	-3.52
Operation and maintenance (B$)	1336.36	1300.70	-35.66
Emission cost (B$)	171.10	162.50	-8.60
35-yr B/C ratio	-	-	2.52

https://www.nrel.gov/analysis/seams.html

ZeroByFifty

- What is the optimal resource and transmission expansion to decarbonize the whole energy economy including massive electrification?
- Considers widespread DERs, new nuclear, CCS, and hydrogen
- Co-optimize generation (utility-scale and distributed), storage and transmission; combines capacity expansion and production simulation
- Finds that if a macro grid is NOT built, it costs an additional $1 Trillion to get to 100% clean energy by 2050

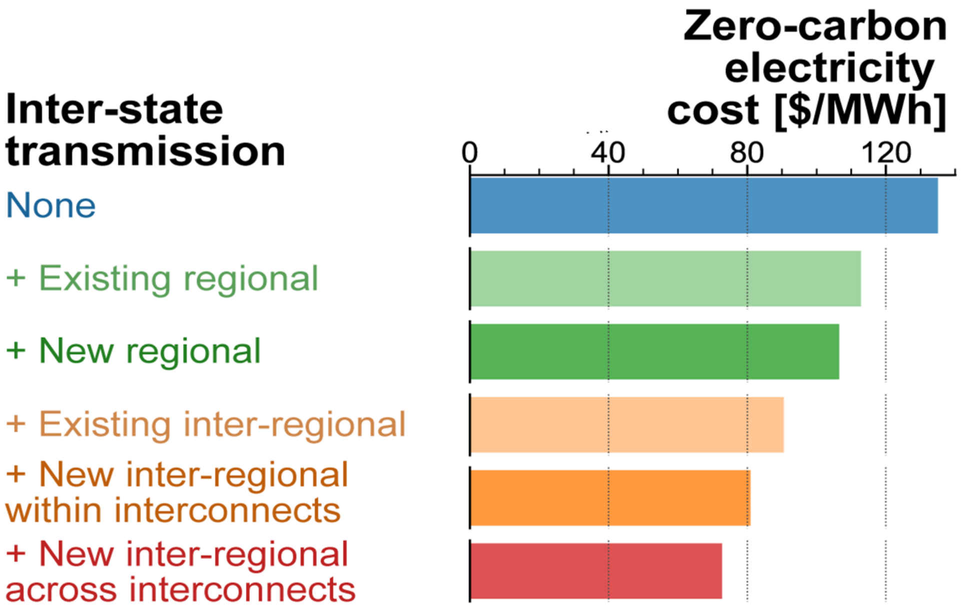


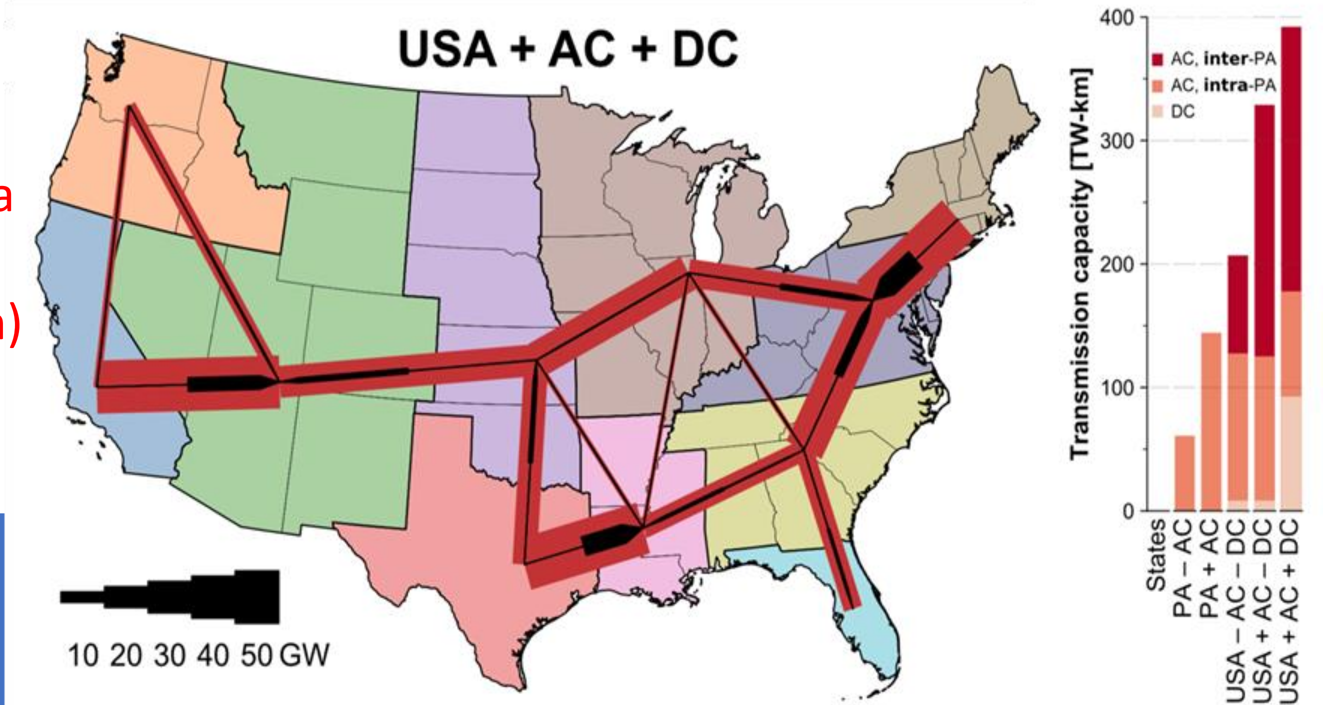


https://www.vibrantcleanenergy.com/wp-content/uploads/2020/11/ESIG_VCE_11112020.pdf

MIT Study - Value of Transmission for Decarbonization

- What is the value of coordination within regions, between regions and nationally?
- Co-optimized capacity expansion and dispatch model with 7 years of hourly weather
- Least-cost plan results in nearly double today's transmission system (in MW-miles) with 40 GW transfers between east and west and 70 GW between ERCOT and east
- Finds that an "every state for itself" approach has a levelized capital and O&M cost of $135/MWh and that this cost can be reduced by 46% (to $73/MWh) with inter-regional coordination and transmission expansion

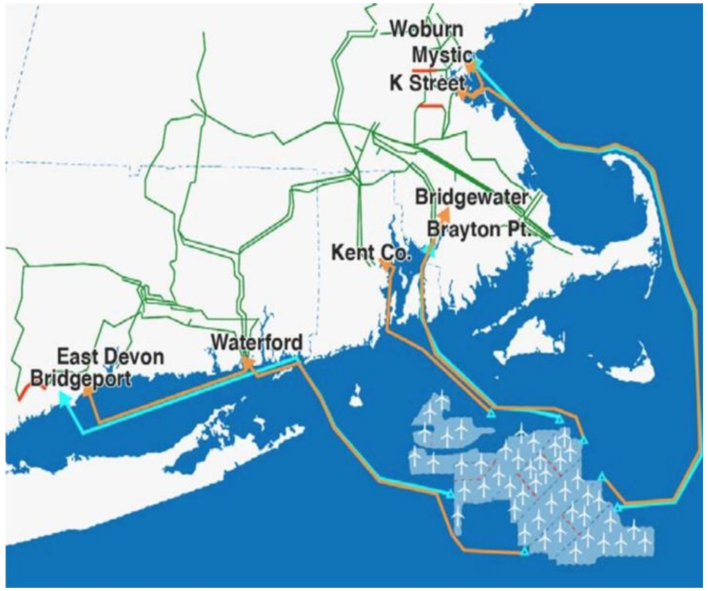




https://doi.org/10.1016/j.joule.2020.11.013

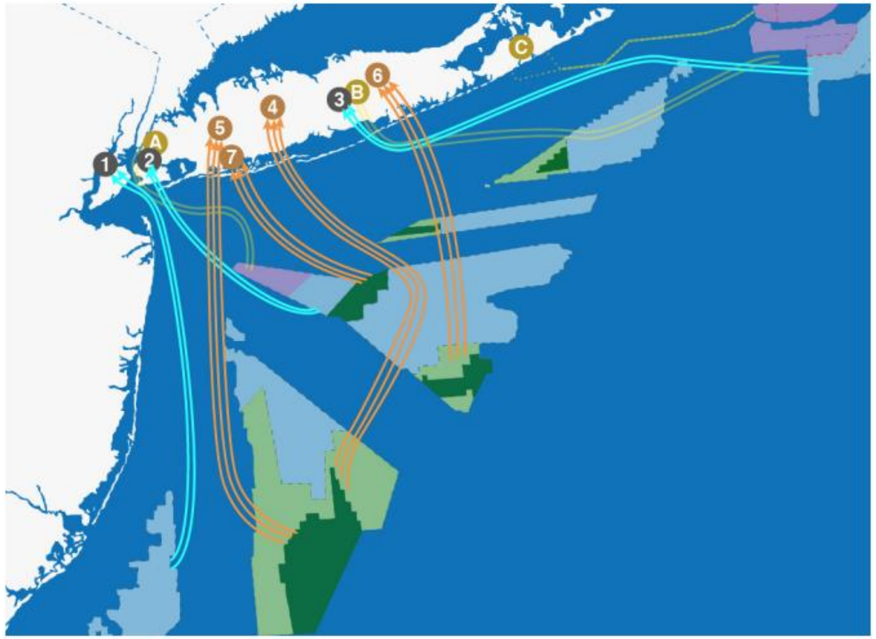
Anbaric/Brattle offshore wind studies

- ISO-NE: Proactive, planned approach saves $1B in onshore upgrades
  - HVDC grid design to enable 8.6 GW of wind without requiring major onshore grid updates
- In NYISO, it would save $500M
  - 9 GW of offshore wind

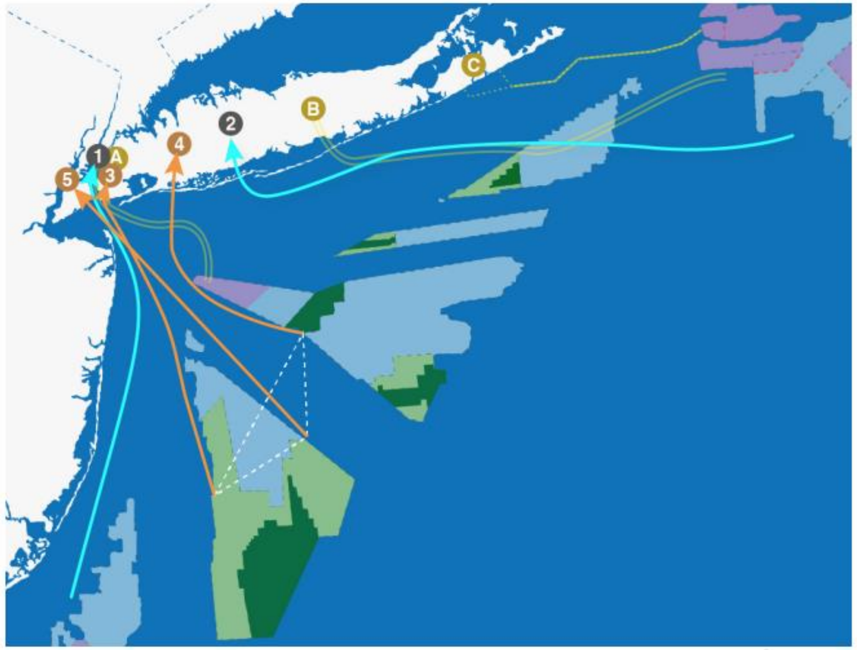


https://newengland.anbaric.com/wp-content/uploads/2020/07/Brattle_Group_Offshore_Tranmission_in_New-England_5.13.20-FULL-REPORT.pdf
http://ny.anbaric.com/wp-content/uploads/2020/08/2020-08-05-New-York-Offshore-Transmission-Final-2.pdf

GLL Offshore Transmission Scenario

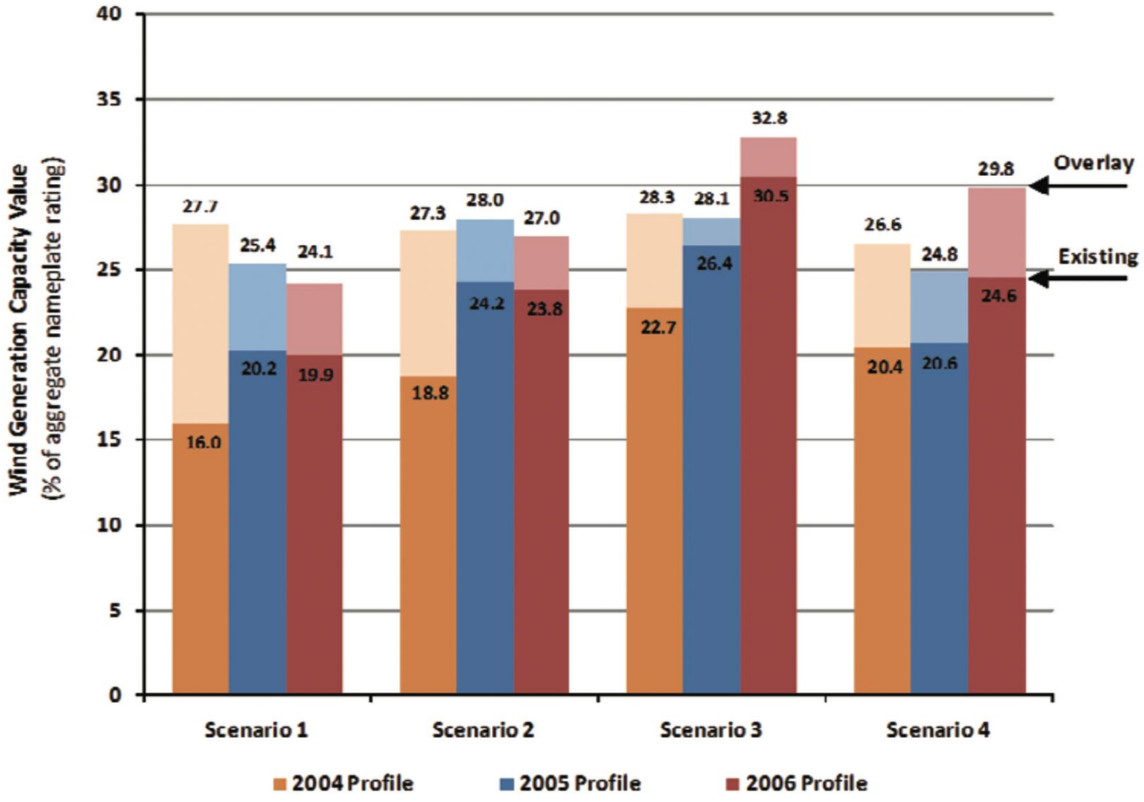


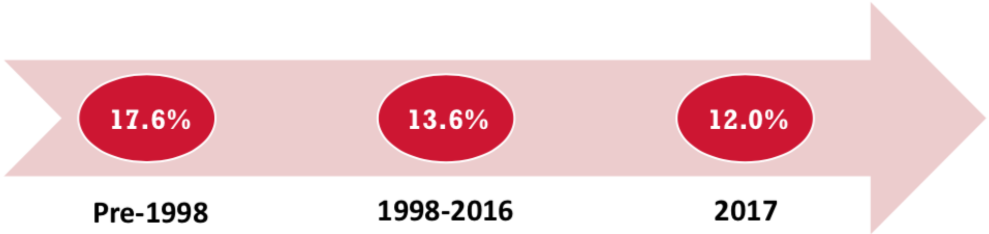
Planned Offshore Transmission Scenario

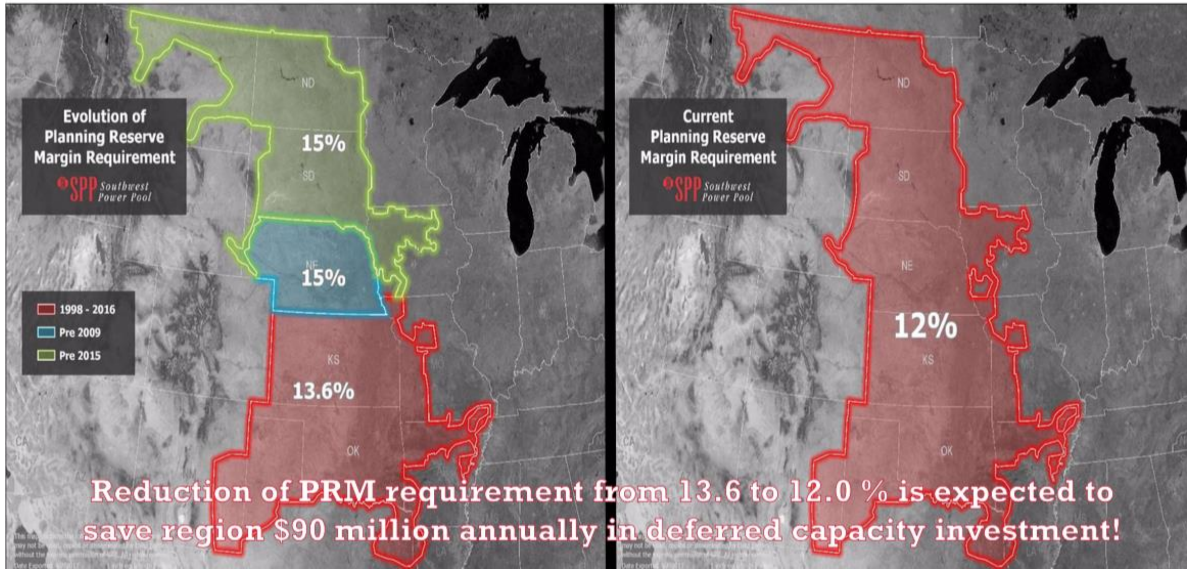


Transmission is not just about delivering resources to load

Transmission contributes to resource adequacy





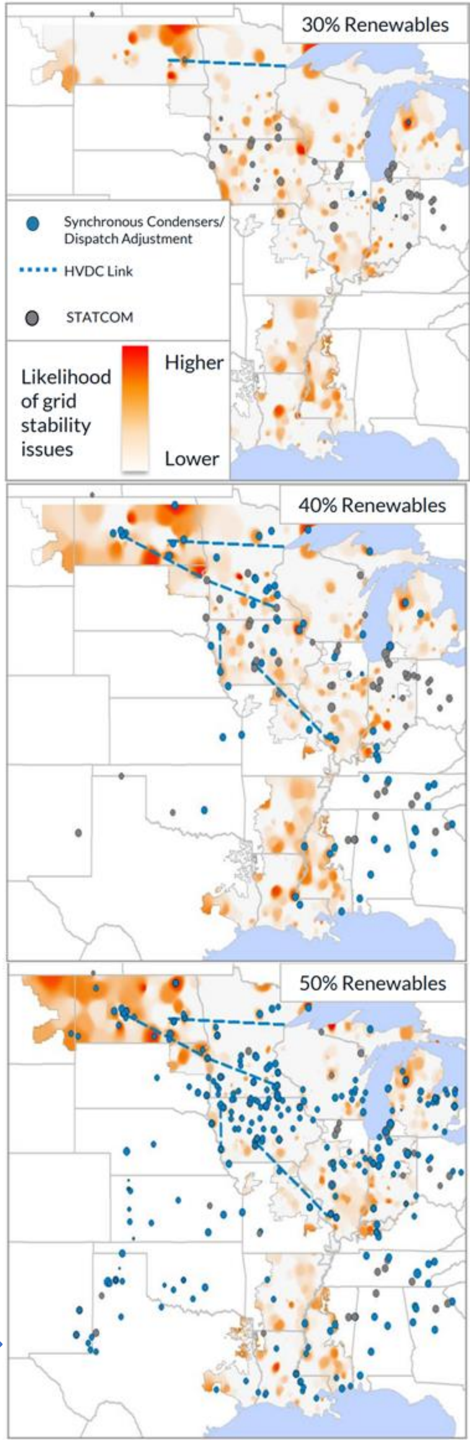


Transmission smooths all time scales of weather variability

Source: Enernex, EWITS, NREL/SR-550-47078, 2010; L. Nickell, SPP, CREPC Spring meeting, 2017

Renewable Integration Impact Assessment

- Resource and transmission expansion / Resource adequacy / System balancing / Steady-state stability / Dynamics – examines all aspects of system reliability
- Increase annual wind and PV penetration in 10% increments up to 100% for Eastern Interconnection
- At each increment, reliability issues are identified and fixed using least-cost, commercially available solutions



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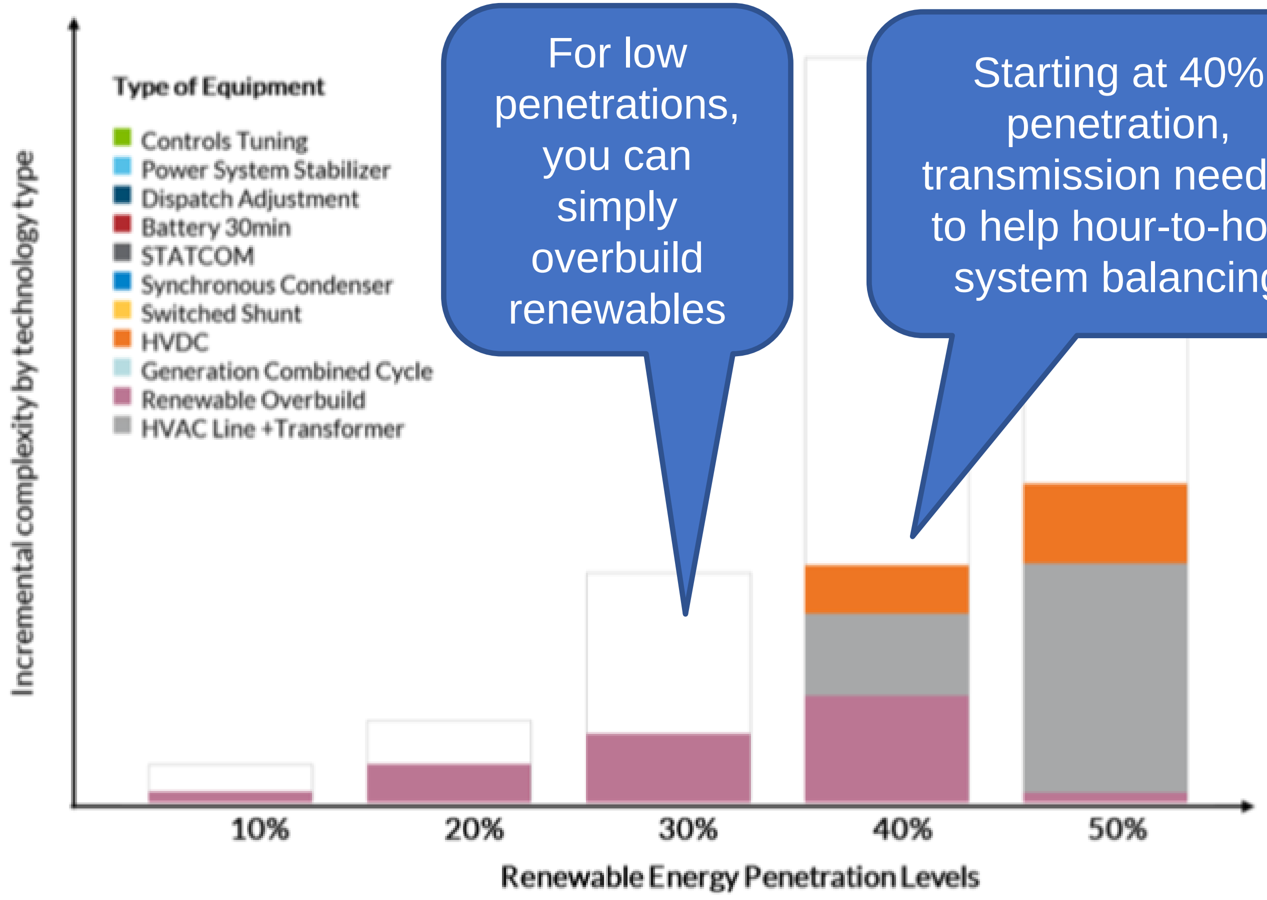
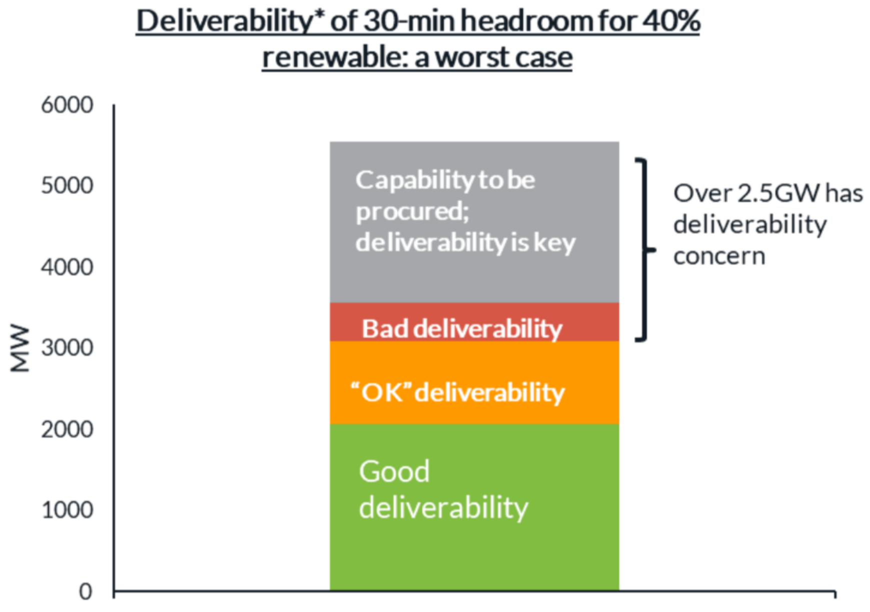
Transmission needed to help system balancing



For low penetrations, you can simply overbuild renewables

Starting at 40% penetration, transmission needed to help hour-to-hour system balancing

Transmission needed to deliver ancillary services



Transmission is critical to maximizing flexibility

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Transmission needed for steady-state reliability

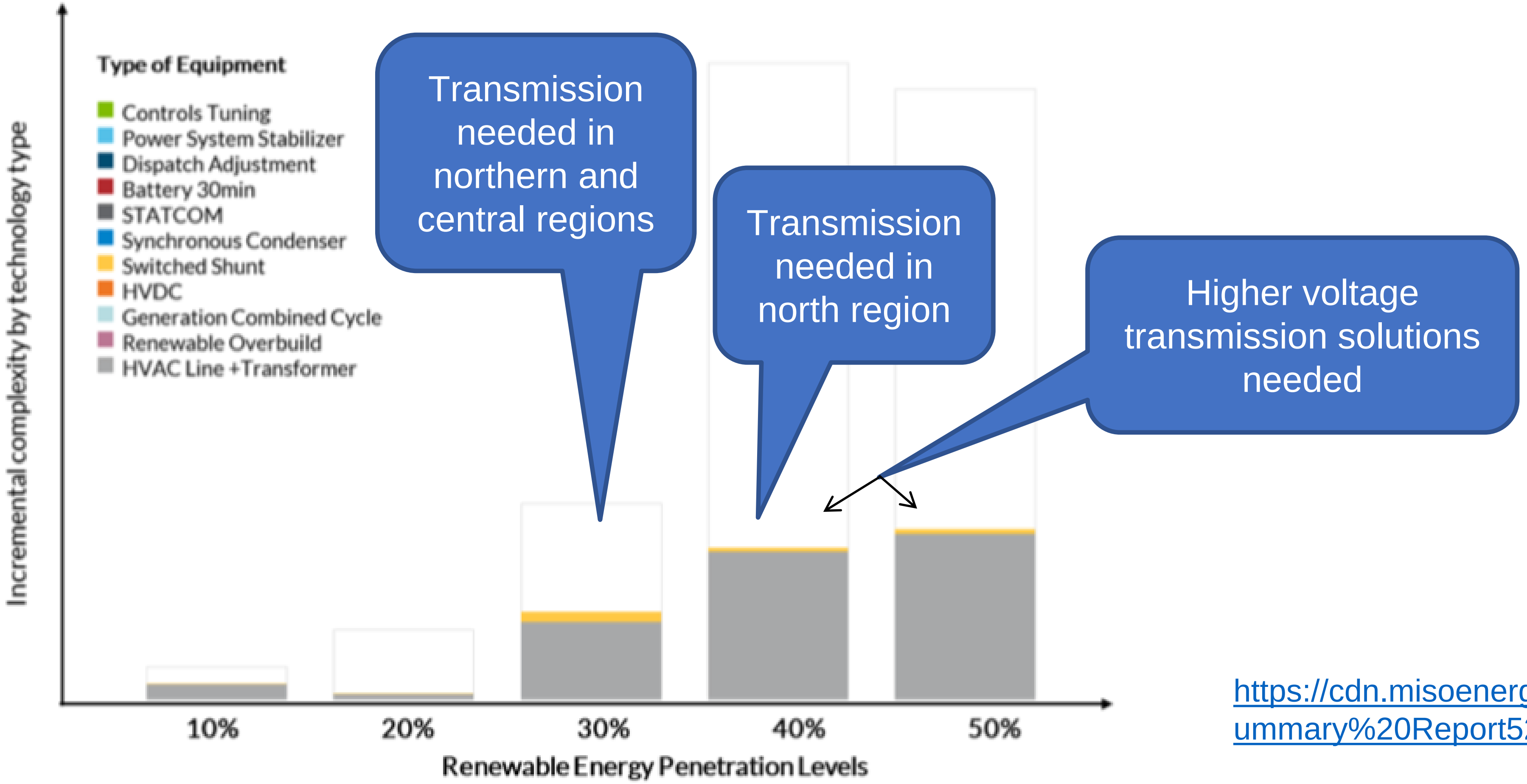

Figure UC-10: Steady state solutions - incremental complexity by technology for each renewable penetration milestone

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Transmission infrastructure needed for dynamic stability

# of equipment per milestone	MISO + Eastern Interconnect			
	30%	40%	50%	Total
Batteries (30min)	-	-	1,233	1,233
Controls Tuning	-	-	1,787	1,787
Dispatch Adjustment	-	169	60	229
HVDC	1	4	-	5
Power System Stabilizer	-	-	109	109
STATCOMs	47	31	23	101
Switched Shunts	-	-	1	1
Synchronous Condenser	5	14	248	267

HVDC to mitigate weak grid issues: transient voltage and small signal stability issues

Synchronous condensers to mitigate reduced inertia: frequency response issues

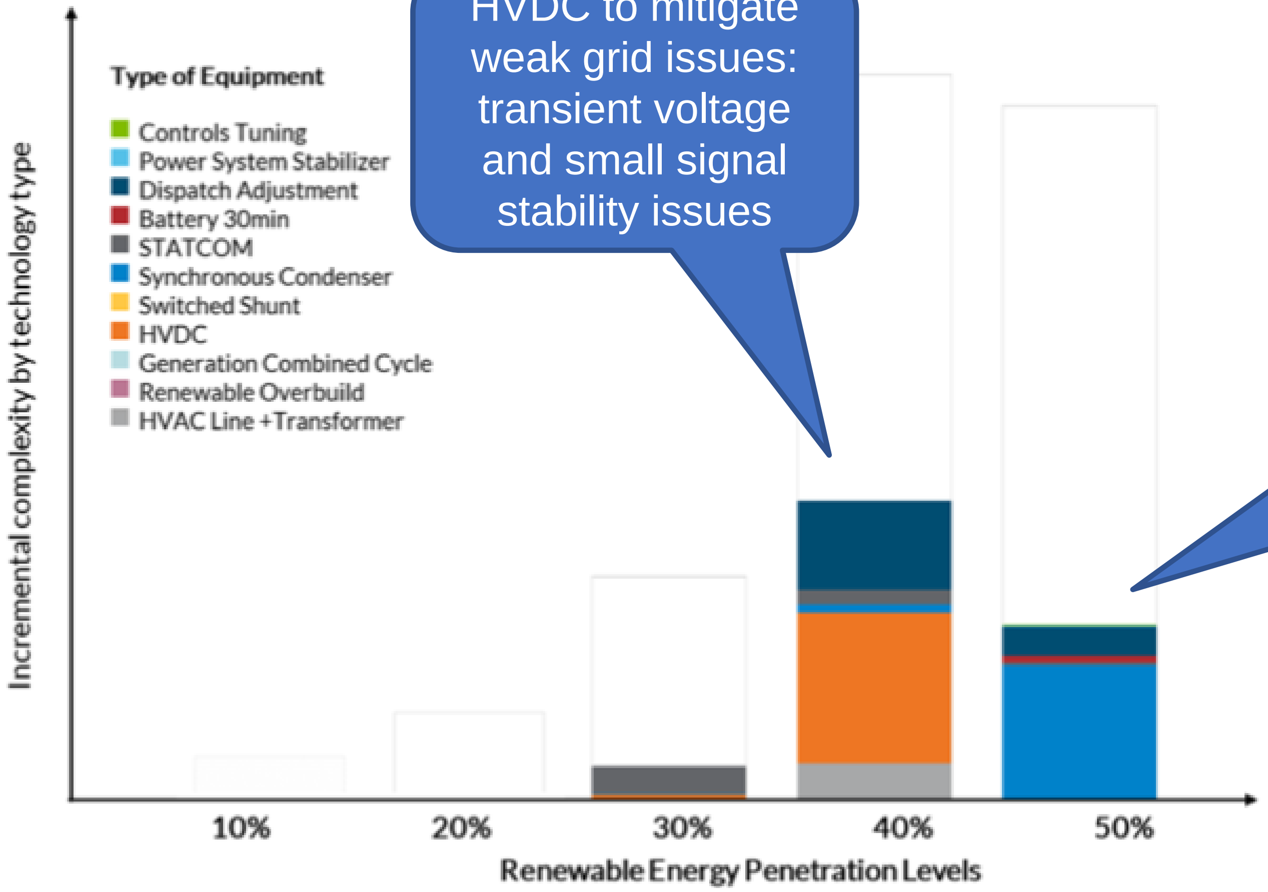

Figure UC-12: Dynamic stability solutions - incremental complexity by technology for each renewable penetration milestone

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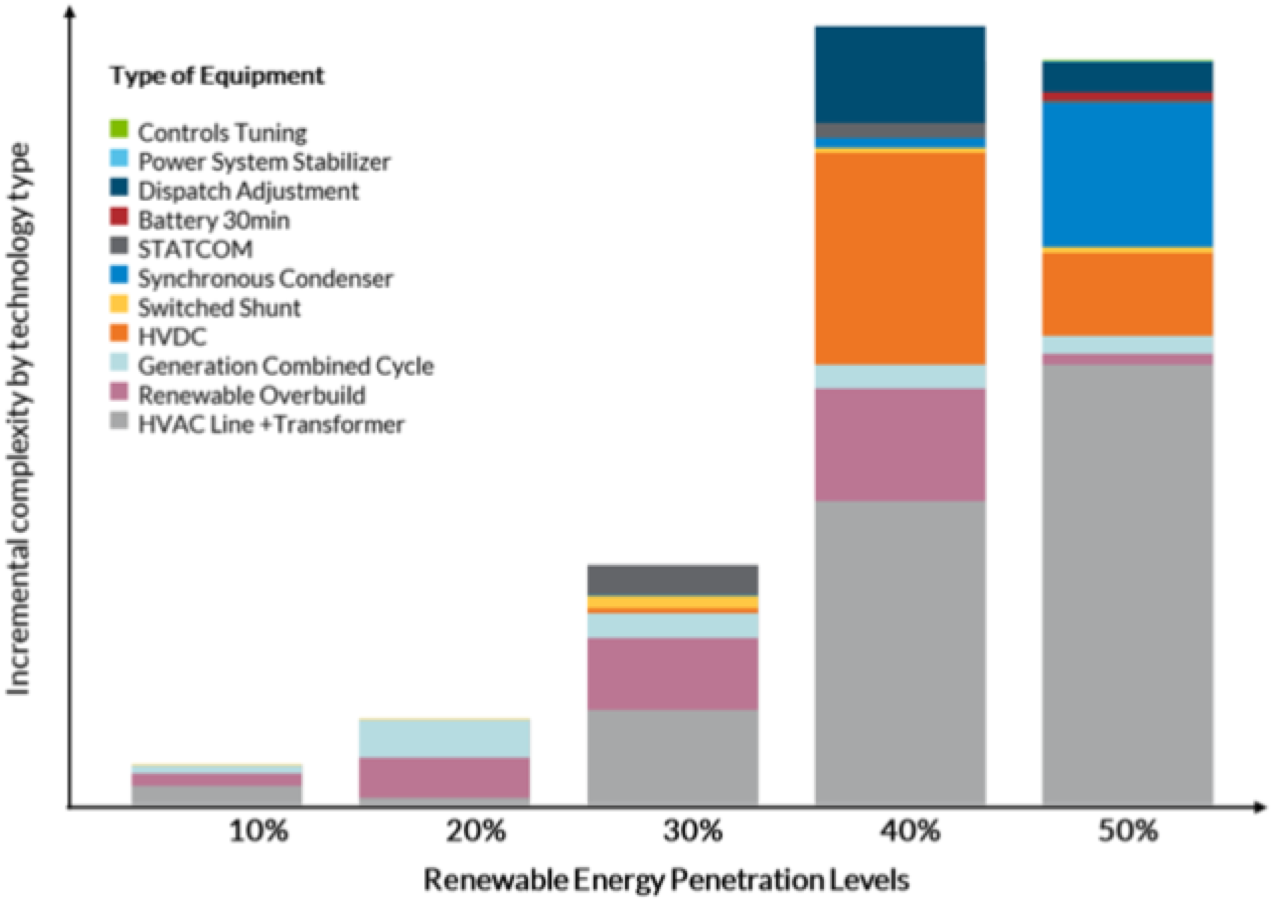
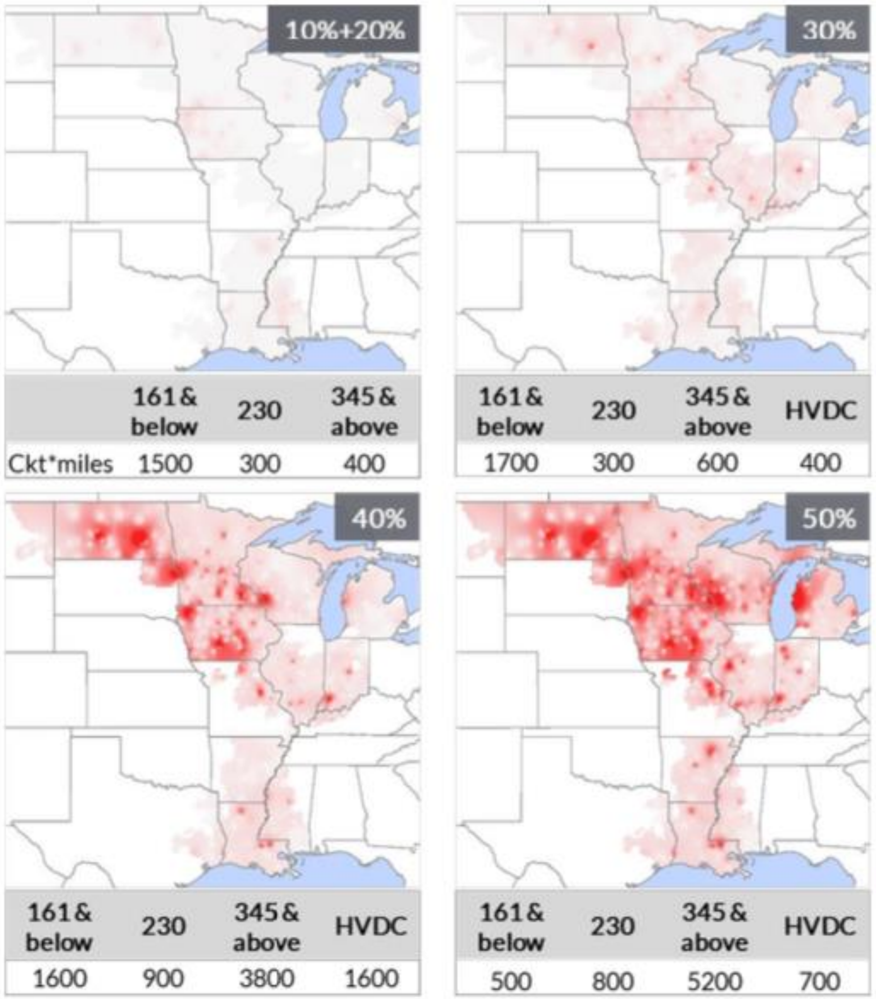
Transmission infrastructure is the biggest investment needed to make the 50% wind/PV case work





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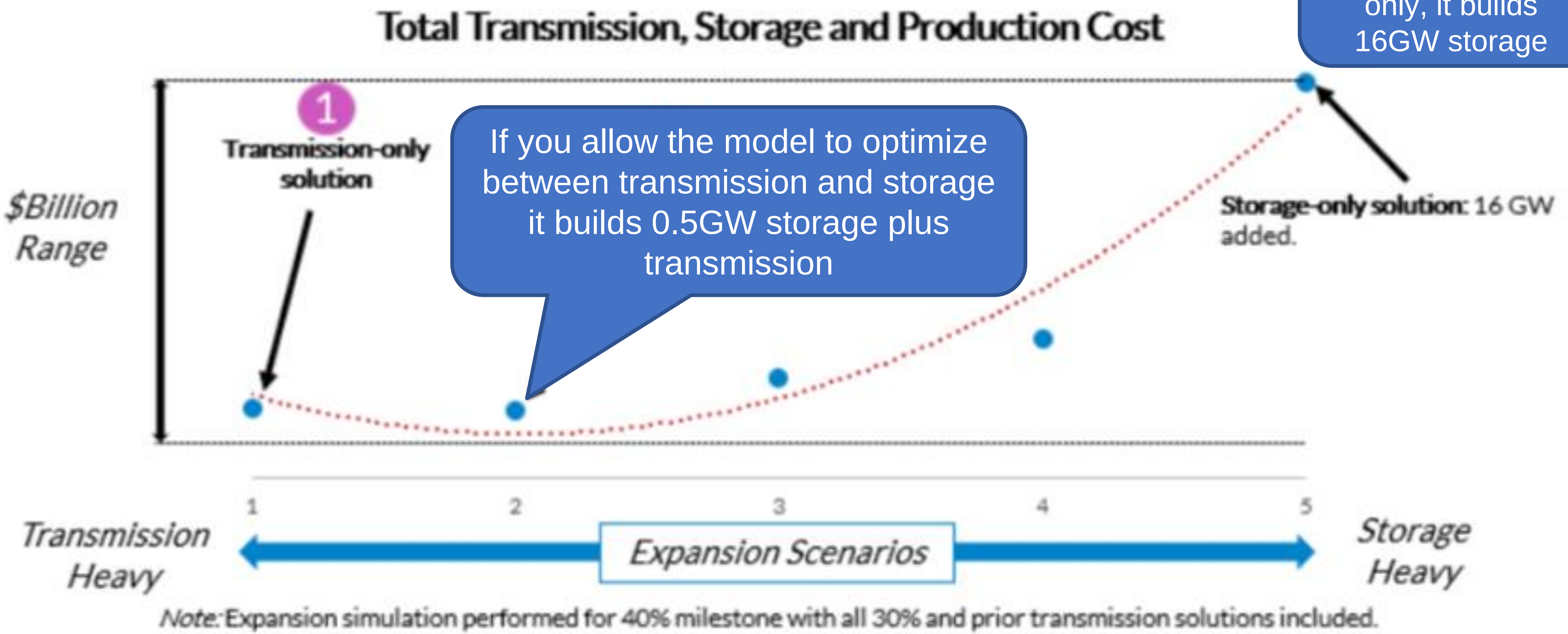
Can’t we do this with storage?
Or DERs?

Storage-only solutions are more expensive and don't address all the issues

If you allow the model to optimize size of storage only, it builds 16GW storage



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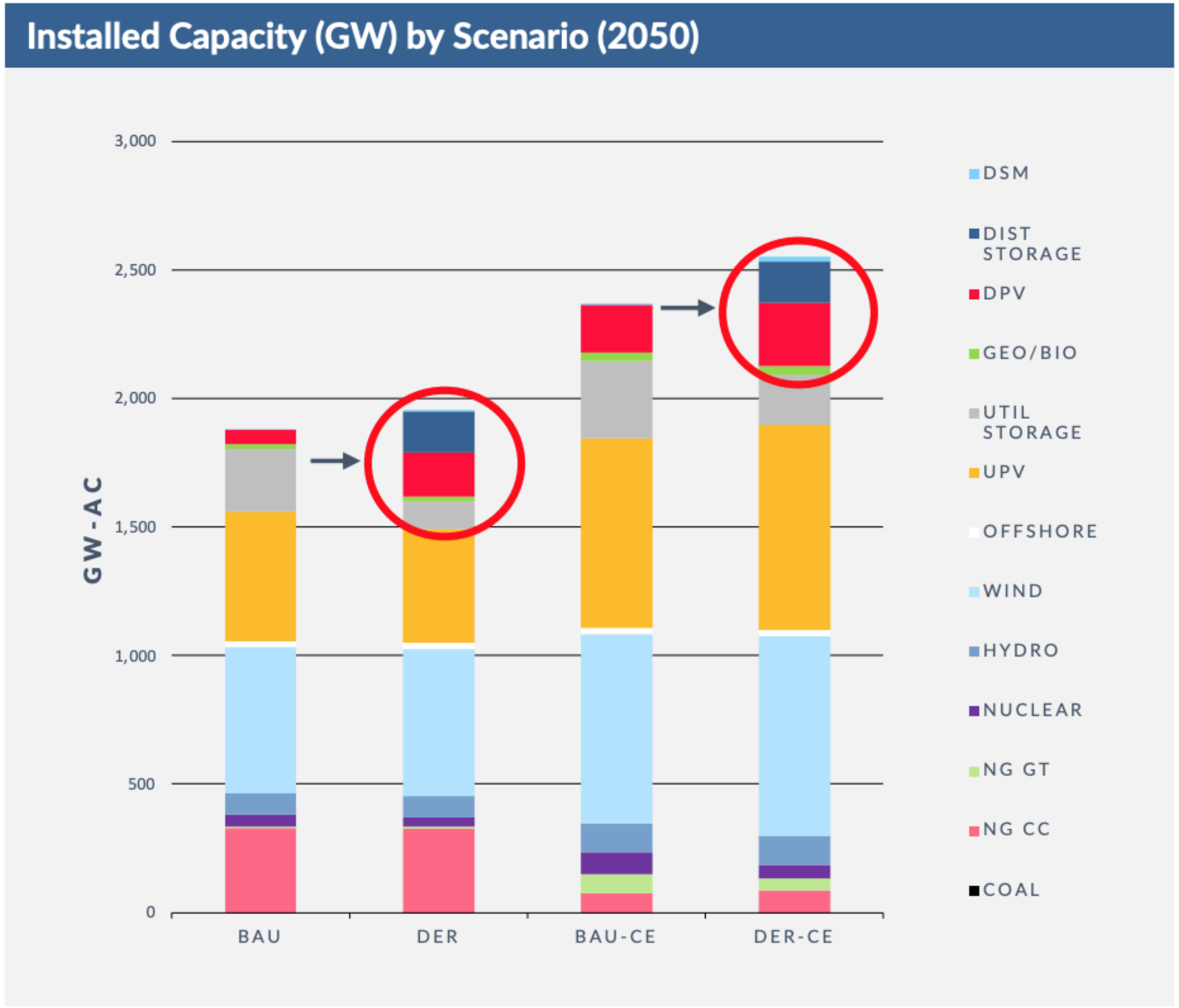
DERs are part of the solution.
We still need utility-scale wind/PV

- Optimizing G, T&D saves money vs not including distribution in optimization
- Benefits are even bigger if you have clean energy goals - save $473B by optimizing G, T&D



https://www.vibrantcleanenergy.com/wp-content/uploads/2020/12/WhyDERs_TR_Final.pdf

A National Approach to Transmission

ESIG Recommendations

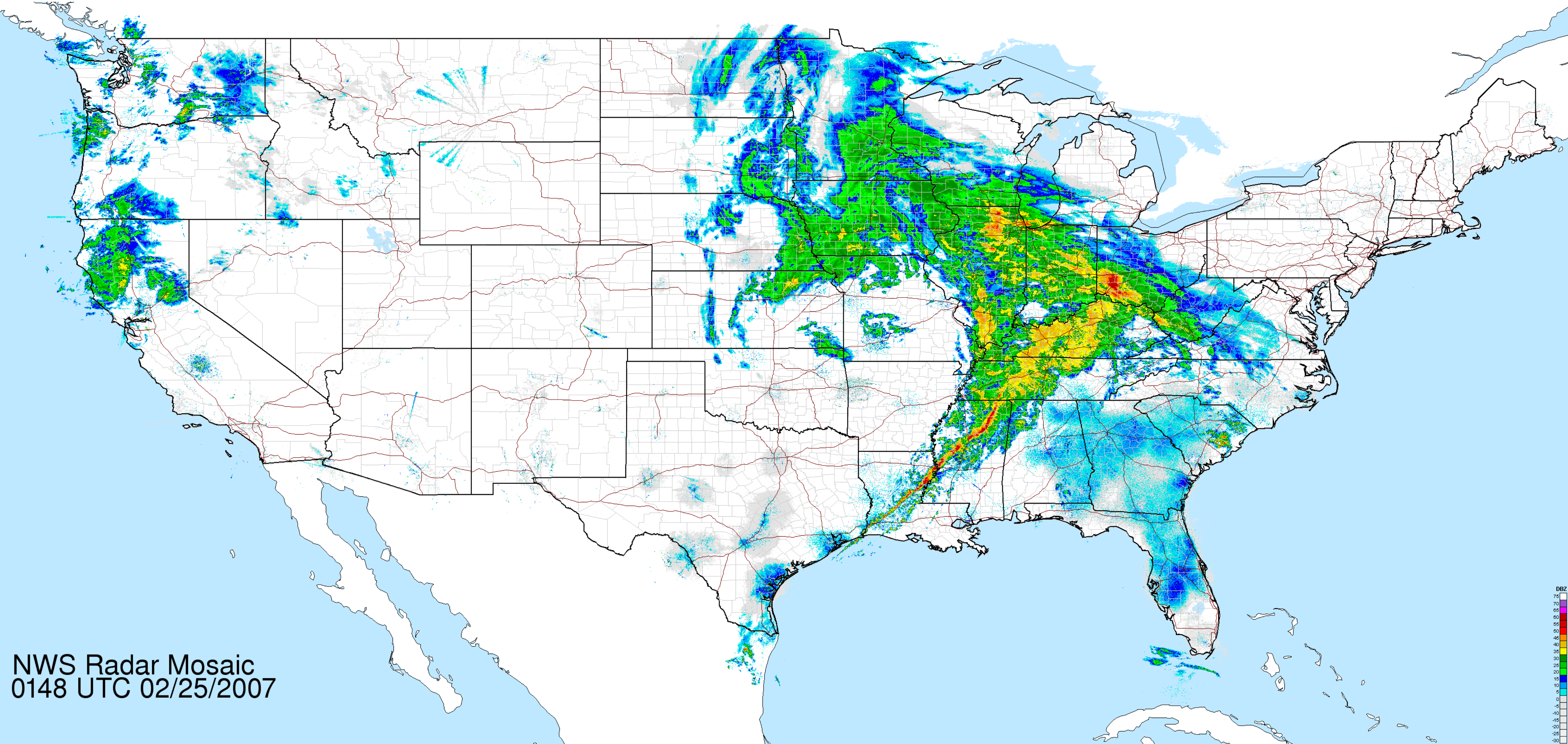
1. Create a national transmission planning authority

2. Identify renewable energy zones

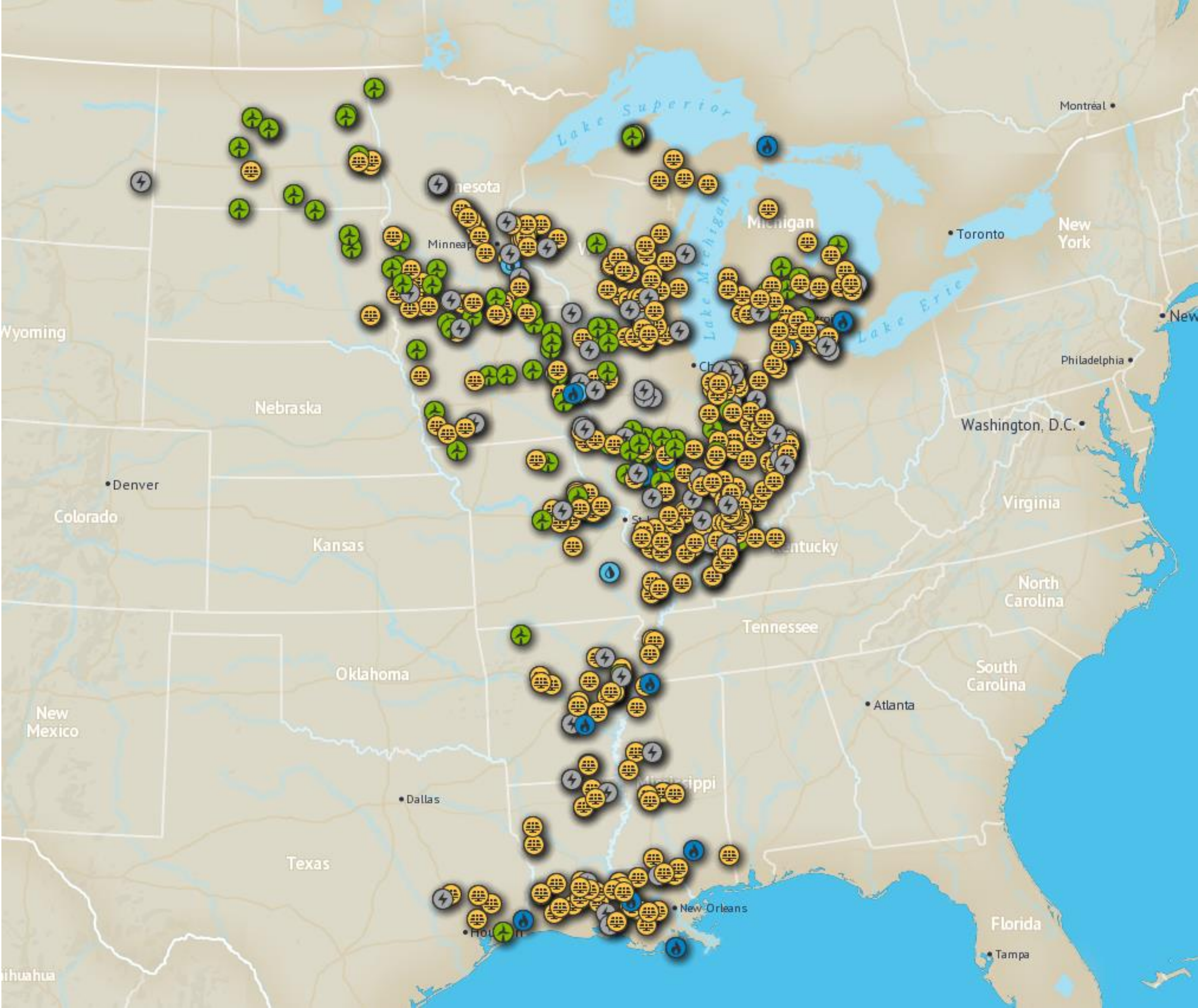
3. Design a national macro grid

If you want to go to the moon you need a space program.
If you want to decarbonize the economy you need a transmission plan.

Regional planning isn't setup for big storms



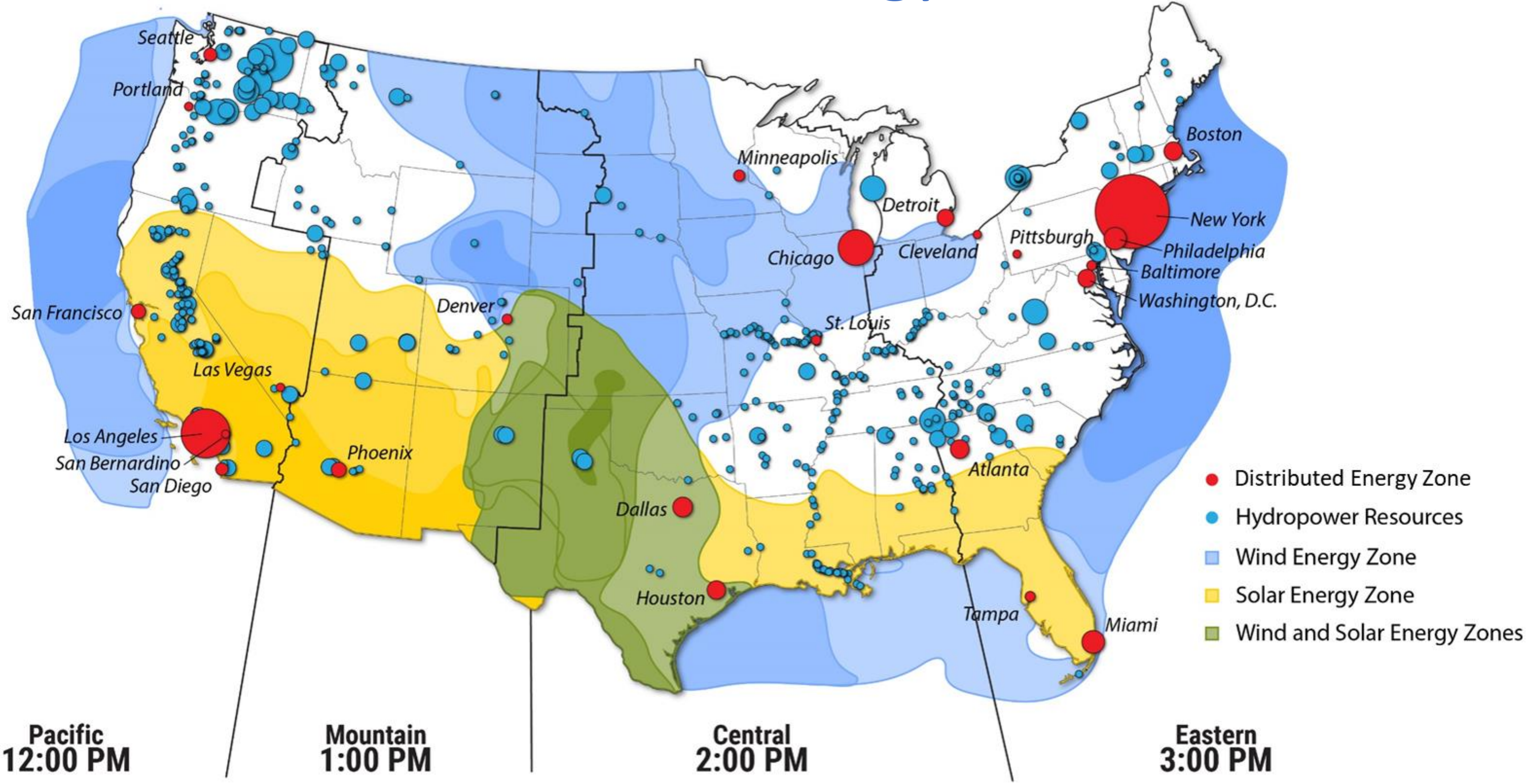
Regional queues are overloaded with national demand



National Planning Process

- Conduct regular, on-going planning activities
- Include comprehensive engineering and economic analysis
- Leverage national and regional capabilities
- Include regional planners, utilities, and governments
- Result in the construction of multi-regional transmission

Renewable Energy Zones

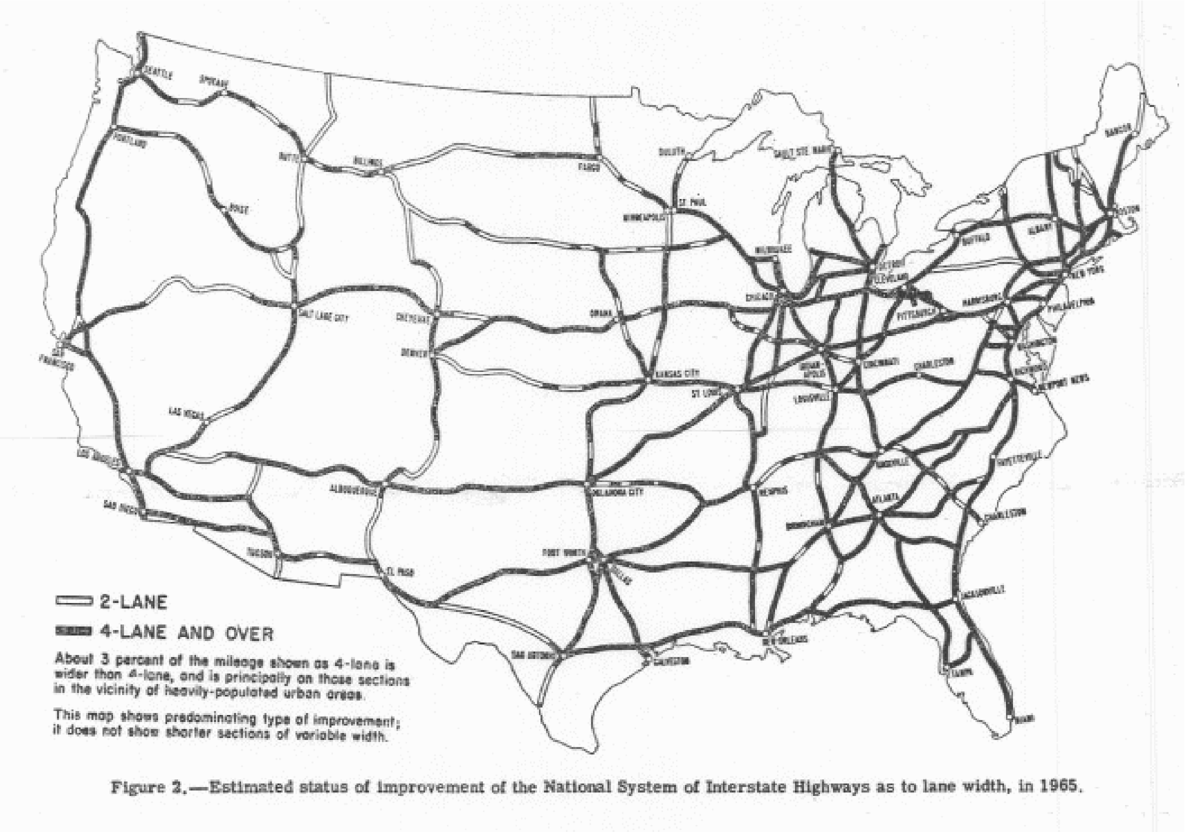


Principles of a Macro Grid

- Connect regions with diverse load and generation profiles
- Have the smallest cost and footprint possible
- Take advantage of existing surplus transmission capability
- Be tightly integrated yet able to separate safely when necessary
- Have a network of transmission lines to minimize risk of failure
- Be built out in several stages

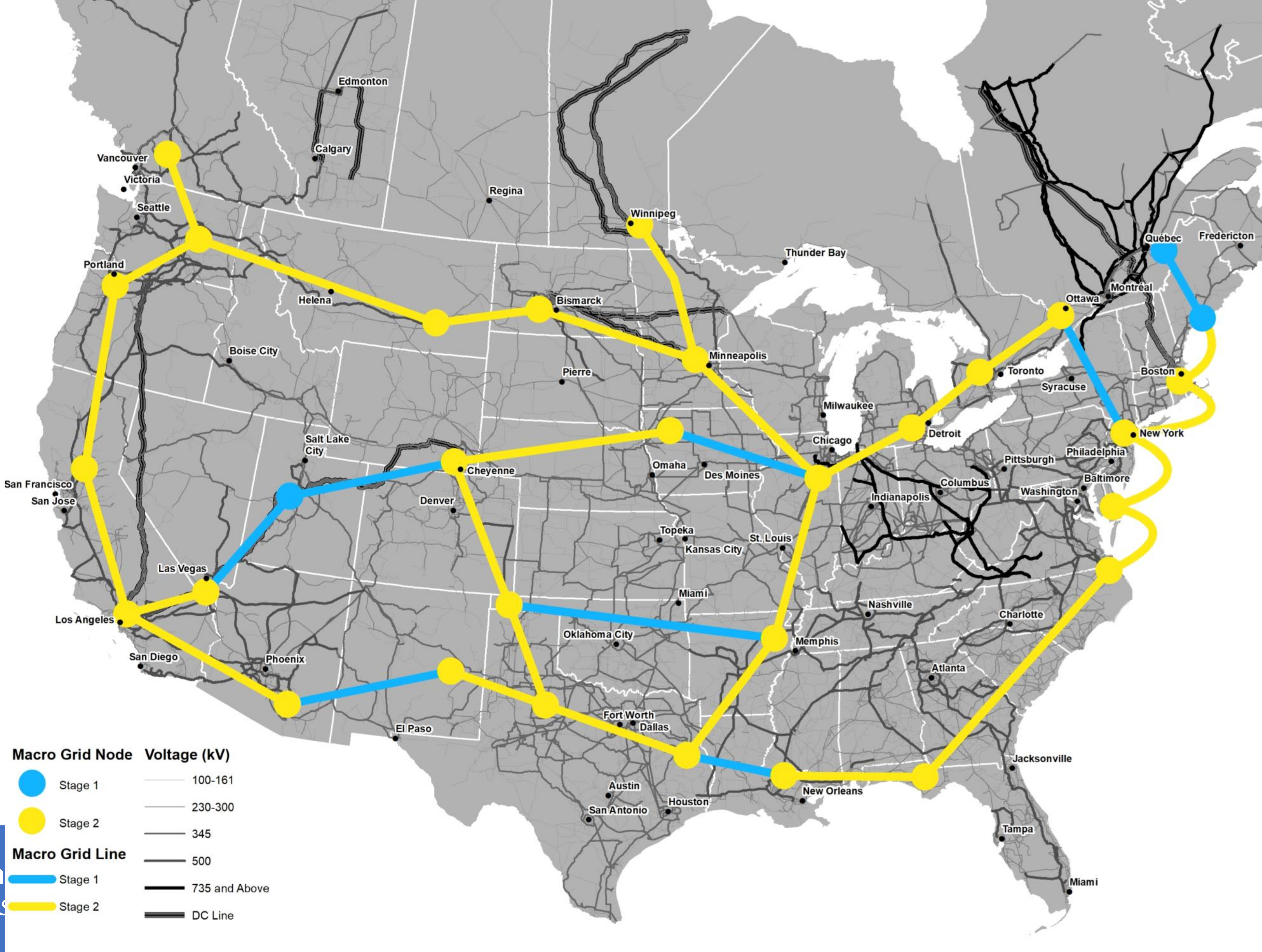
Stages of a Macro Grid

- Stage 1: Start with shovel ready projects that can grow
- Stage 2: Build reliable loops and collector systems
- Stage 3: Review, update, expand



Original US Highway Map

We can't build a macro grid overnight but that doesn't mean we shouldn't start today



Next Steps

- Start immediately
- Articulate the decarbonization vision and convene the major players
- Designate and authority
- Leverage national capabilities and industry expertise
- Provide seed funding for new transmission planning and financing