Transmission planning, operations and interactions with power markets

Future Power Markets Forum

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Johns Hopkins Environmental Health & Engineering

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The Grid of the Future

Future Power Markets Forum

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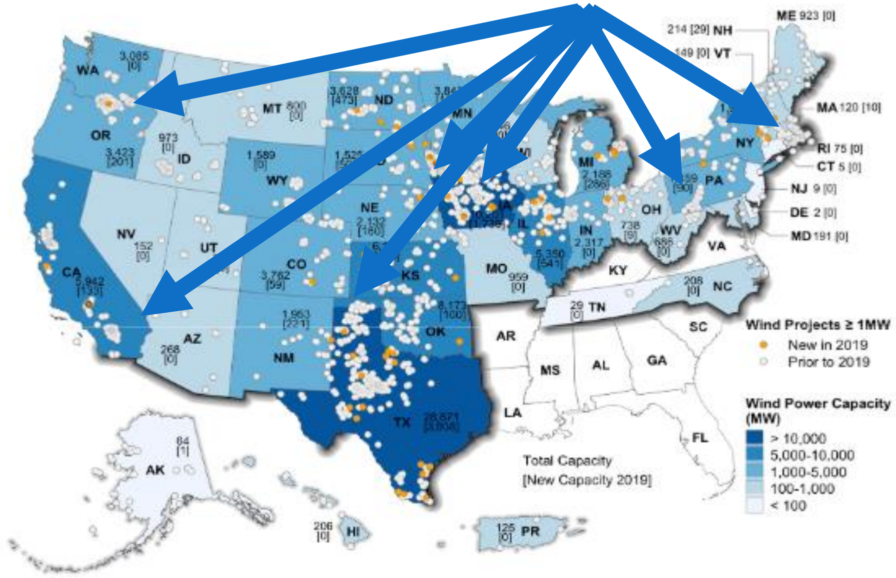
With acknowledgments to:
Debbie Lew, ESIG
Aaron Bloom, Nextera Energy, ESIG System Planning Committee

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

Generation is stuck in interconnection queues

- 734 GW of generation, 90% renewables stuck in queues, end of 2019

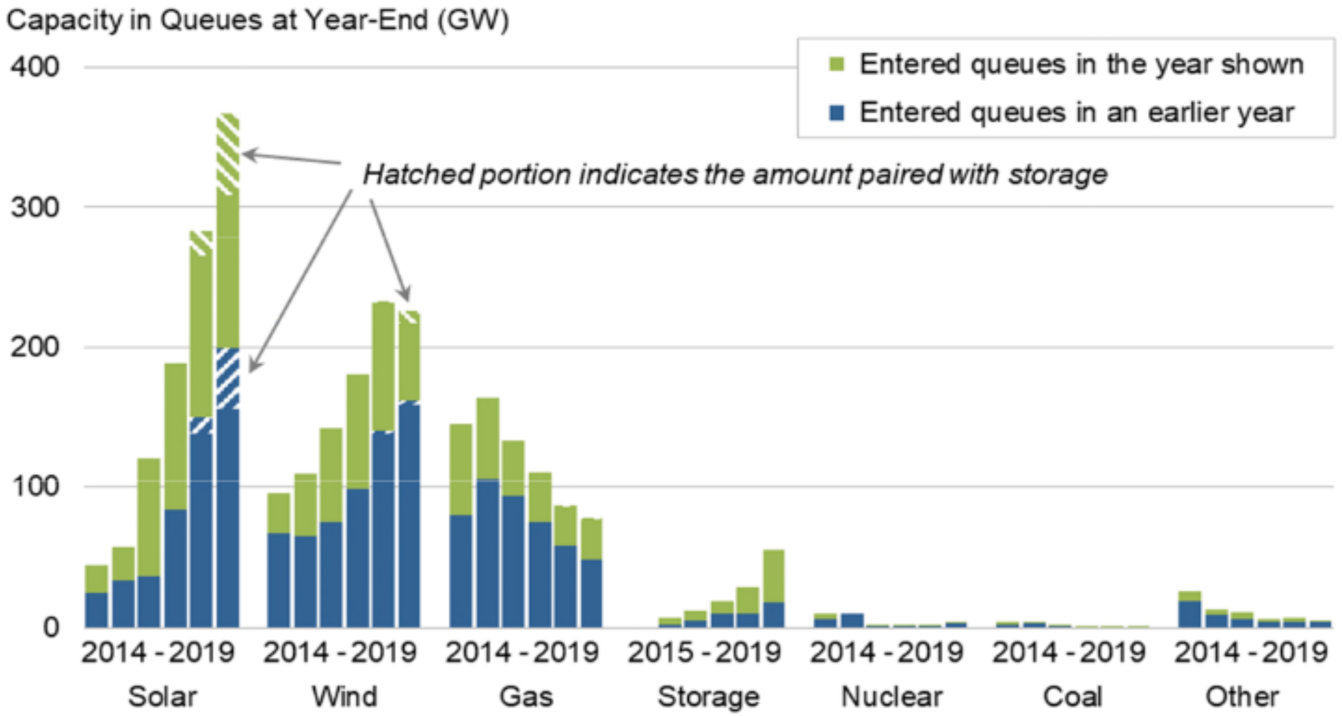
Resource Pockets



Note: Numbers within states represent MegaWatts of cumulative installed wind capacity and, in brackets, annual additions in 2019.

Source: AWEA WindIQ, Berkeley Lab

Wind Project Locations



Source: Berkeley Lab review of interconnection queues

Note: Not all of this capacity will be built

Projects Entering Interconnection Queues

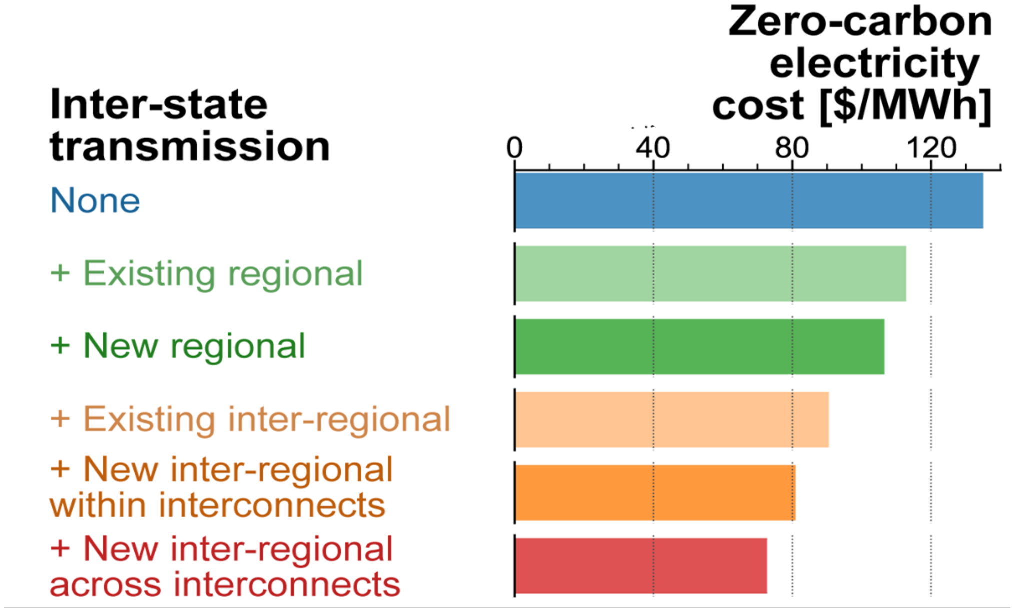
We evaluated a number of studies

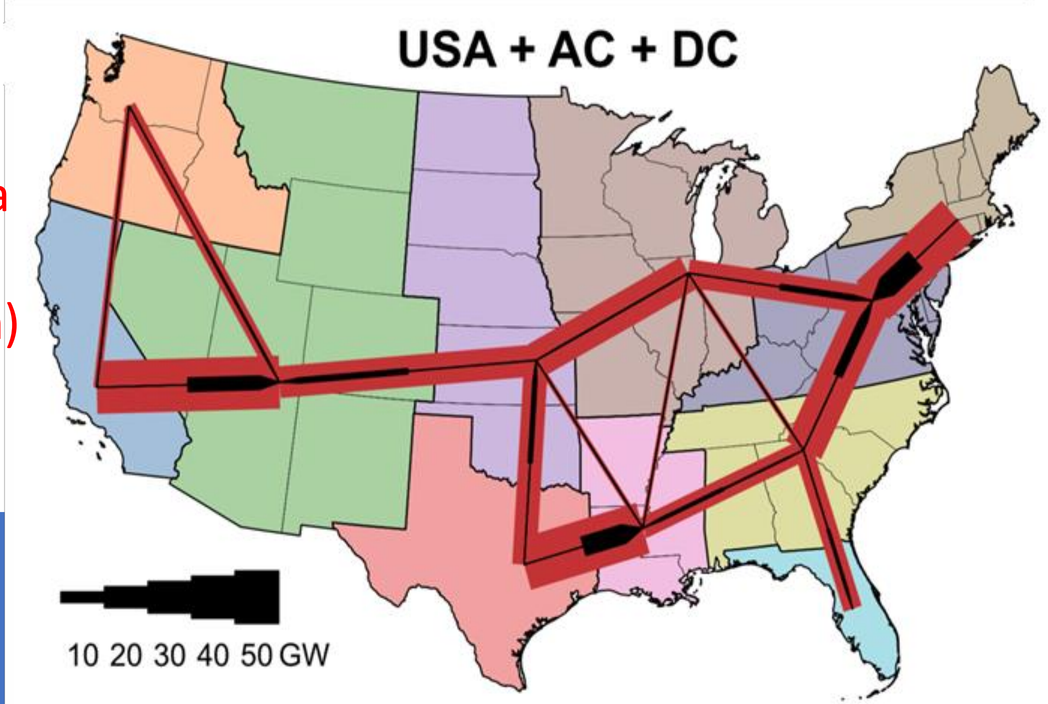
Study	Region	Renewable Capacity	Clean Energy Level(s)	Annual Electricity Demand	Target Year
The 2035 Report	United States	1,100 GW (wind and solar)	90% clean electricity	4,500 TWh	2035
Electrification Futures Study	United States and Canada	600 GW (wind) 1,000 GW (solar)	23% to 75% renewable energy	7,000 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

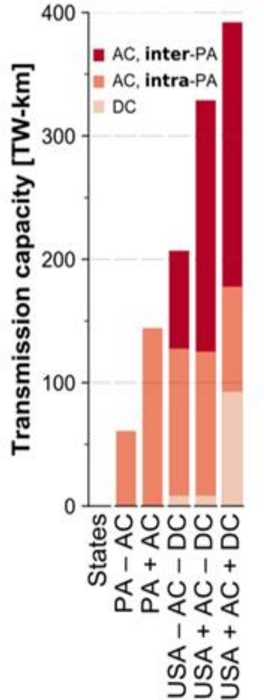
A network of cross-country transmission is critical to minimizing cost

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



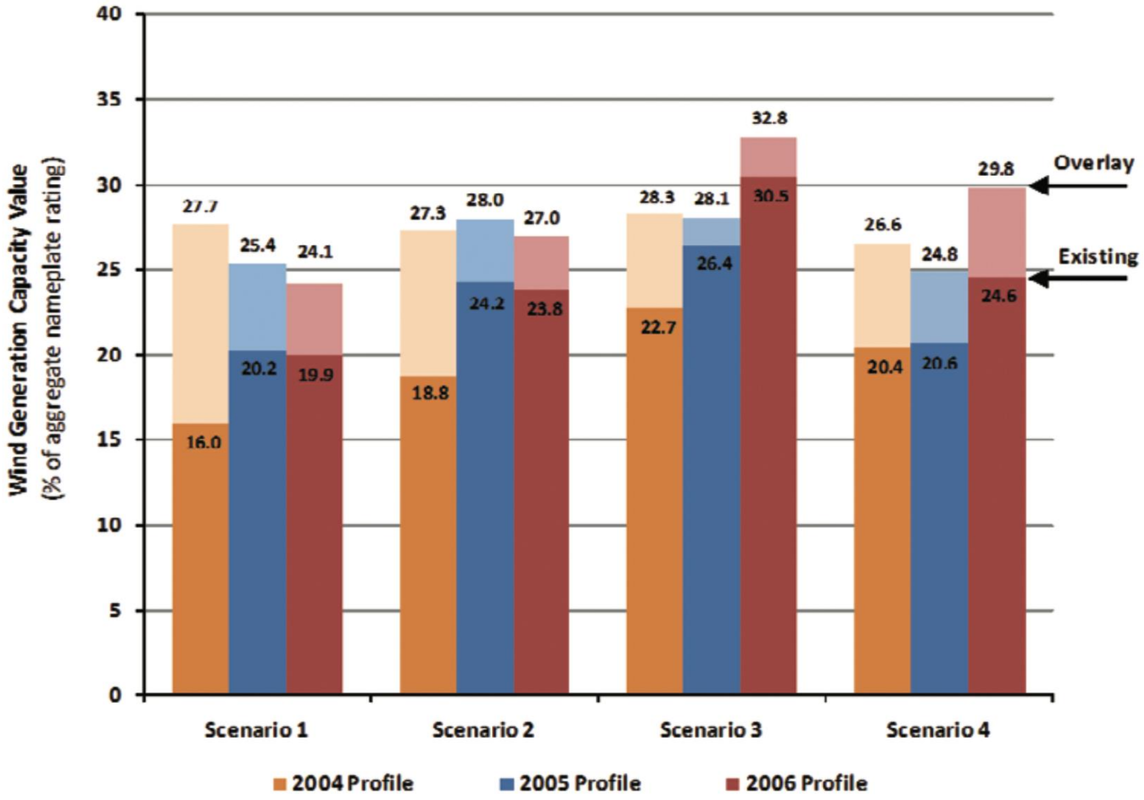


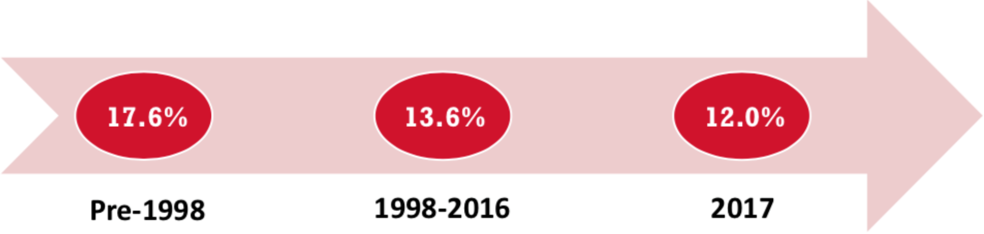


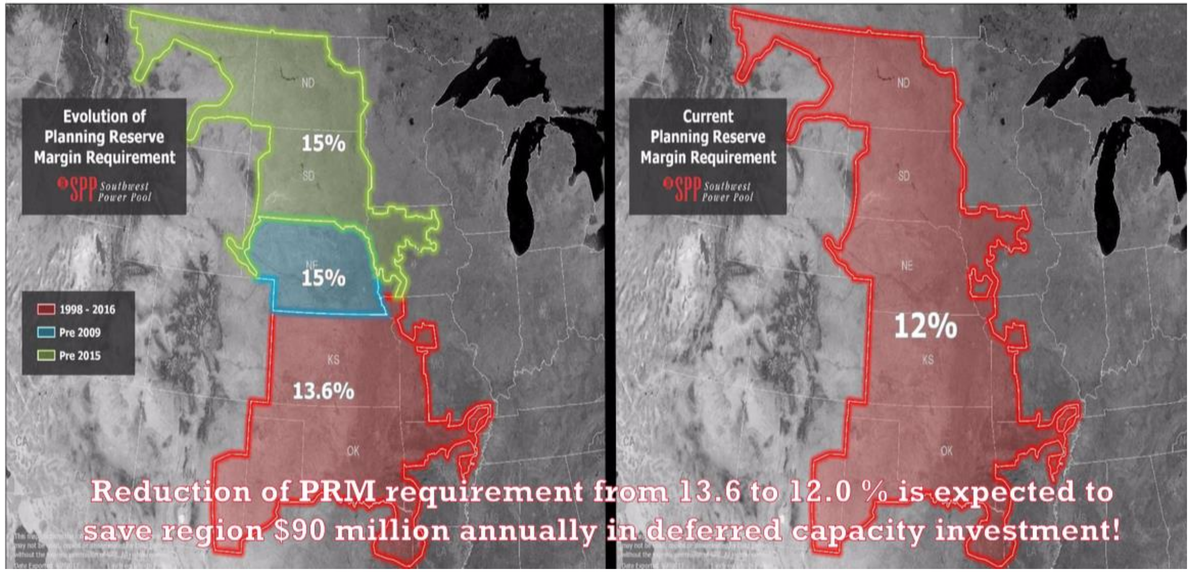
https://doi.org/10.1016/j.joule.2020.11.013

Transmission is not just about delivering resources to load

Transmission contributes to resource adequacy







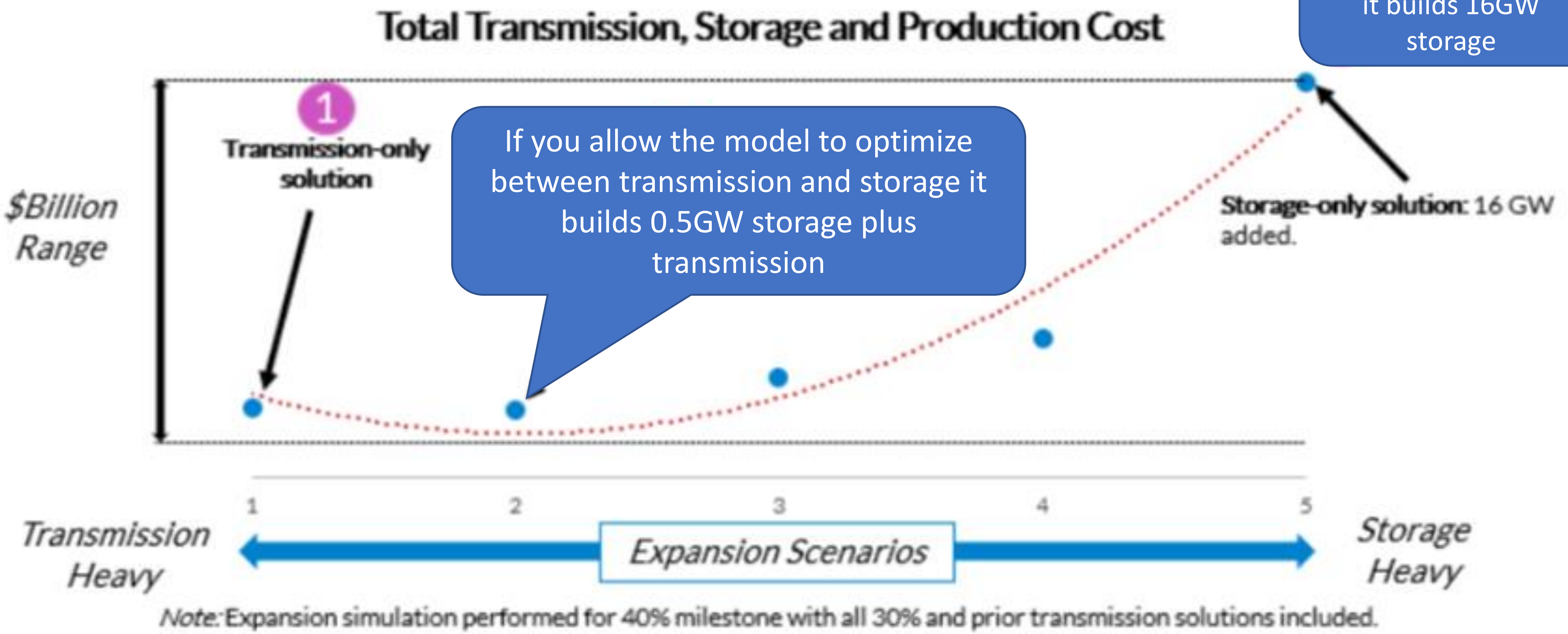
Transmission smooths all time scales of weather variability

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

Can’t we do this with storage?

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



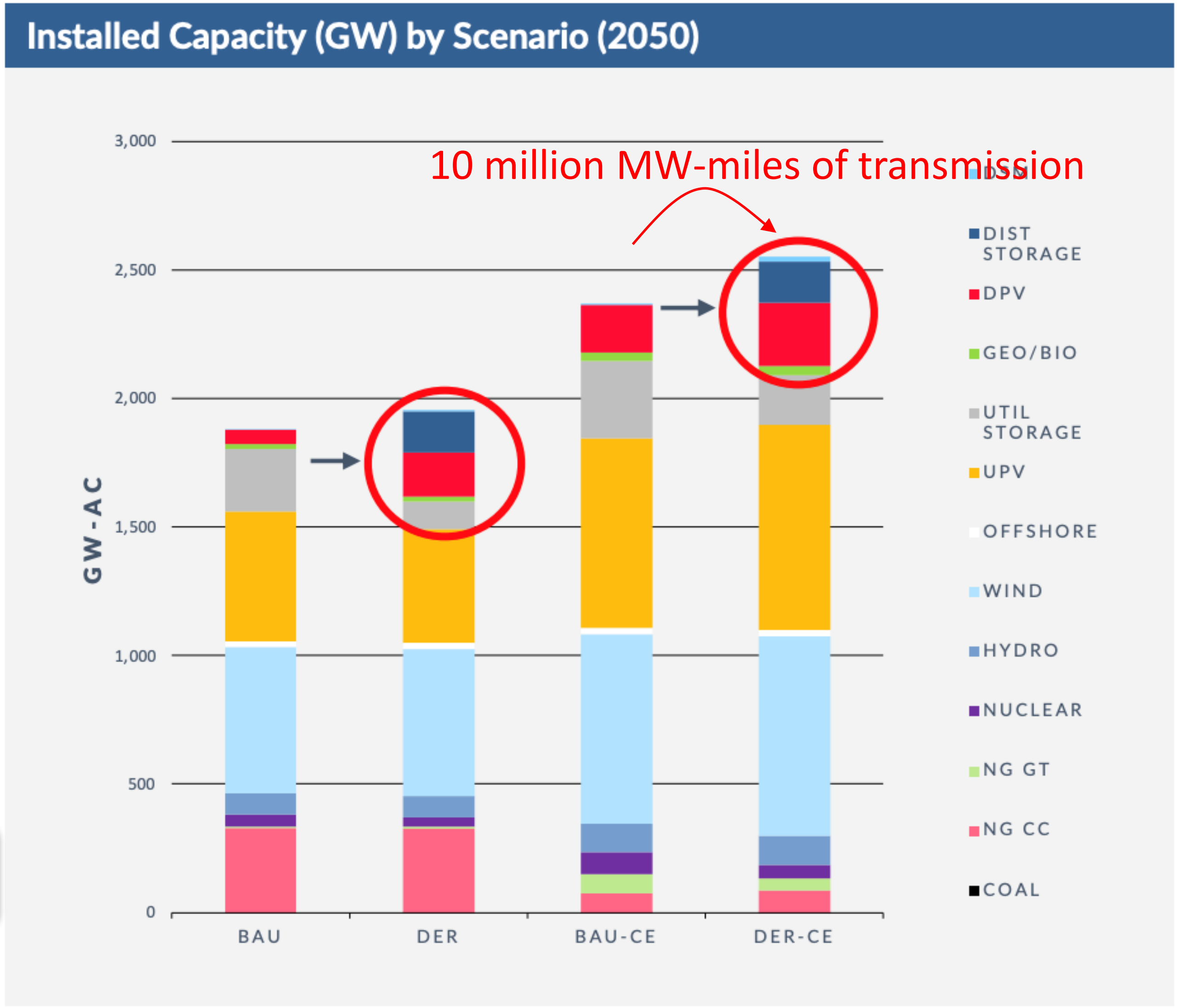
https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf

Can’t we do this with DERs?

You need transmission even with high levels of DERs

- 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
- Optimizing G, T&D builds more DERs and also builds more transmission

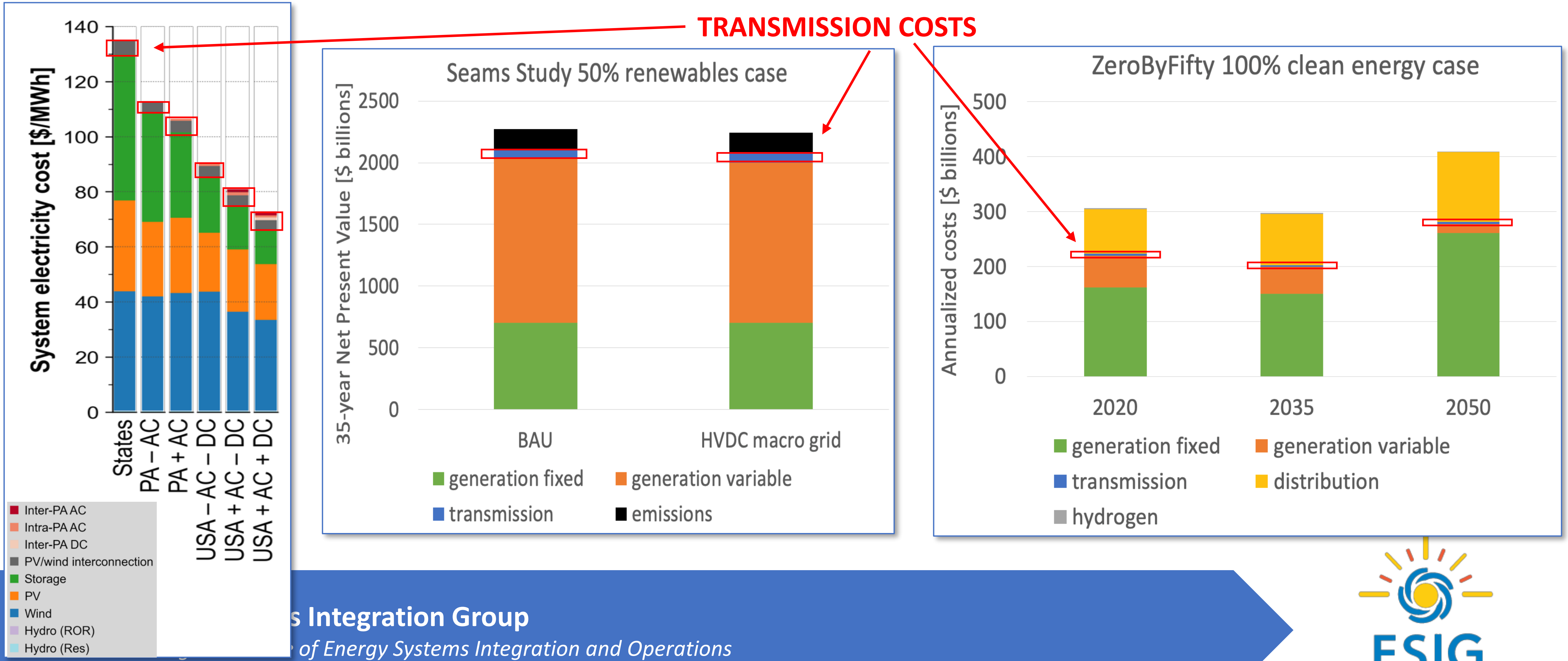
https://www.vibrantcleanenergy.com/wp-content/uploads/2020/12/WhyDERs_TR_Final.pdf



Managing distribution will be critical as we electrify

Charting the Future of Energy Systems Integration and Operations

Transmission costs are tiny compared to other clean resources/infrastructure



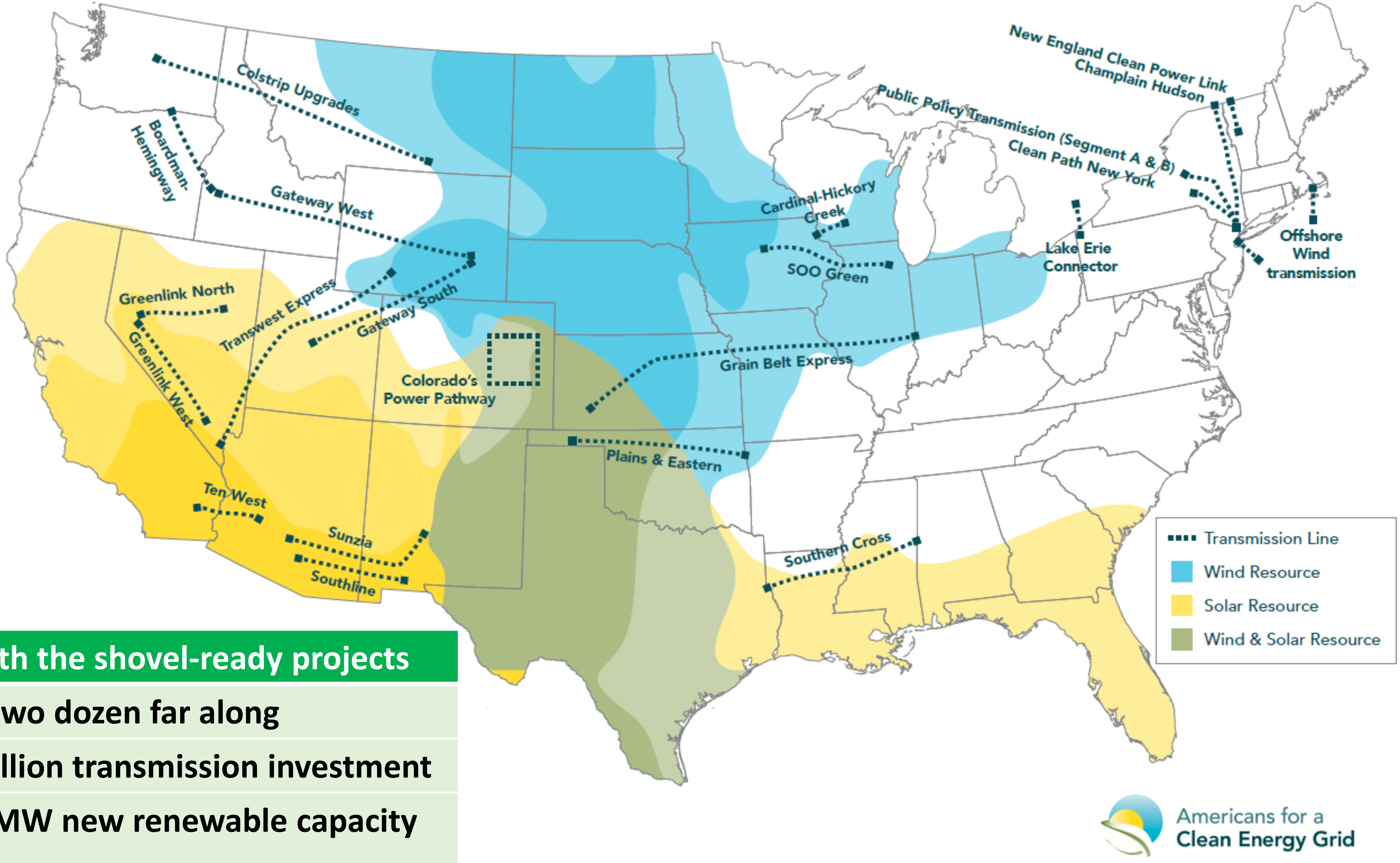
Brown and Botterud, 2020; NREL Interconnection Seams study; Preliminary results from VCE's ZeroBy

A National Approach to Transmission

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.

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



Start with the shovel-ready projects

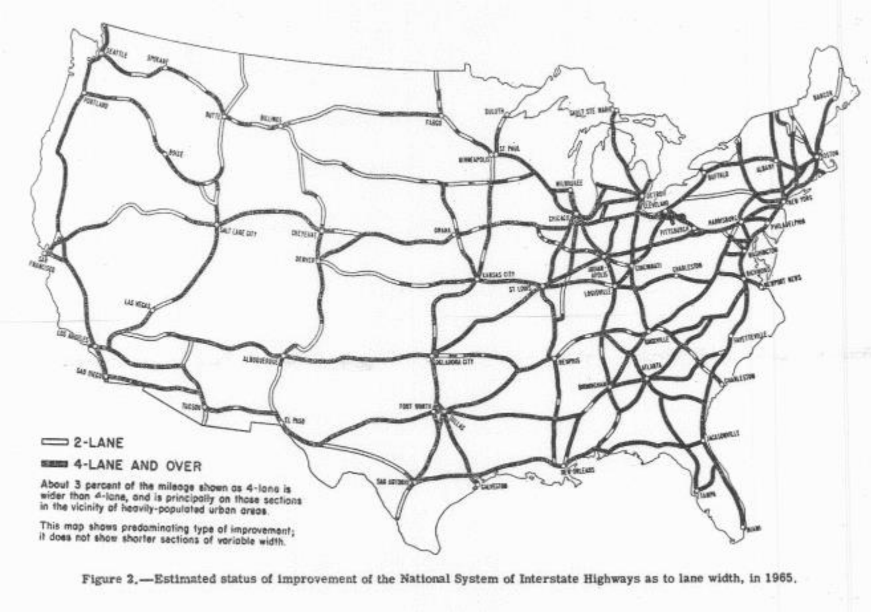
Nearly two dozen far along

$33.3 billion transmission investment

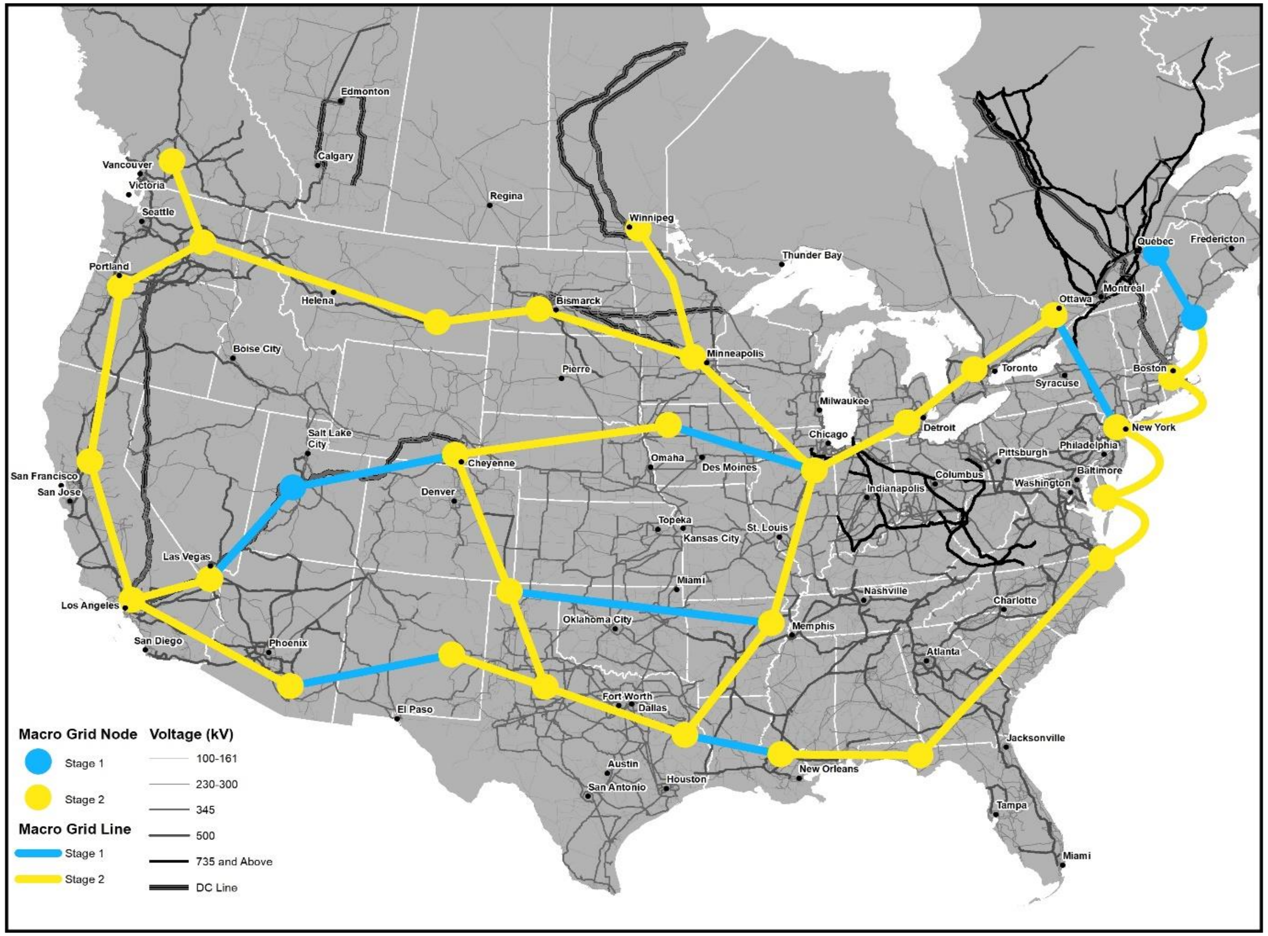
60,000 MW new renewable capacity

Design a national macro grid

Build in stages and start planning now



Original US Highway Map

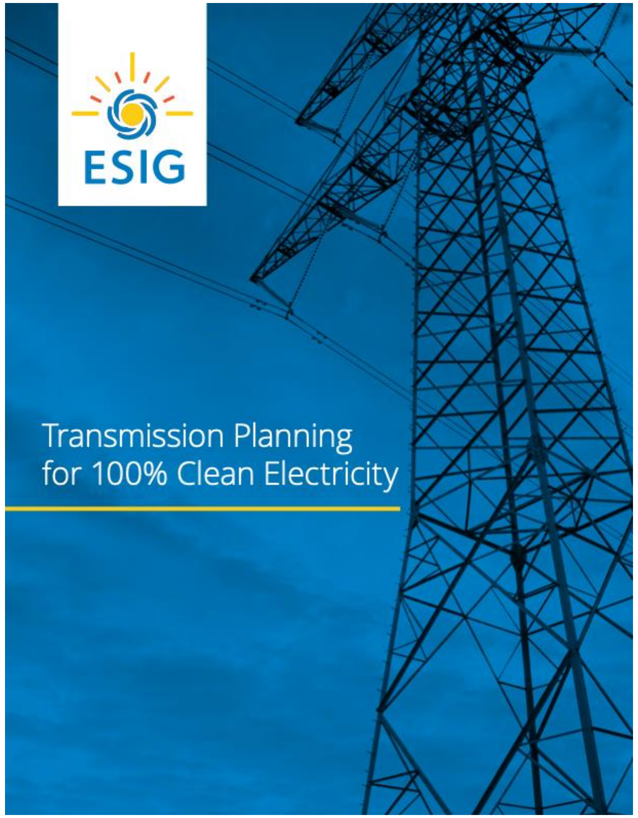


ESIG Recommendations

1. Create a national transmission planning authority that conducts ongoing national transmission planning
2. Identify renewable energy zones
3. Design a national macro grid

The Sooner the Better!

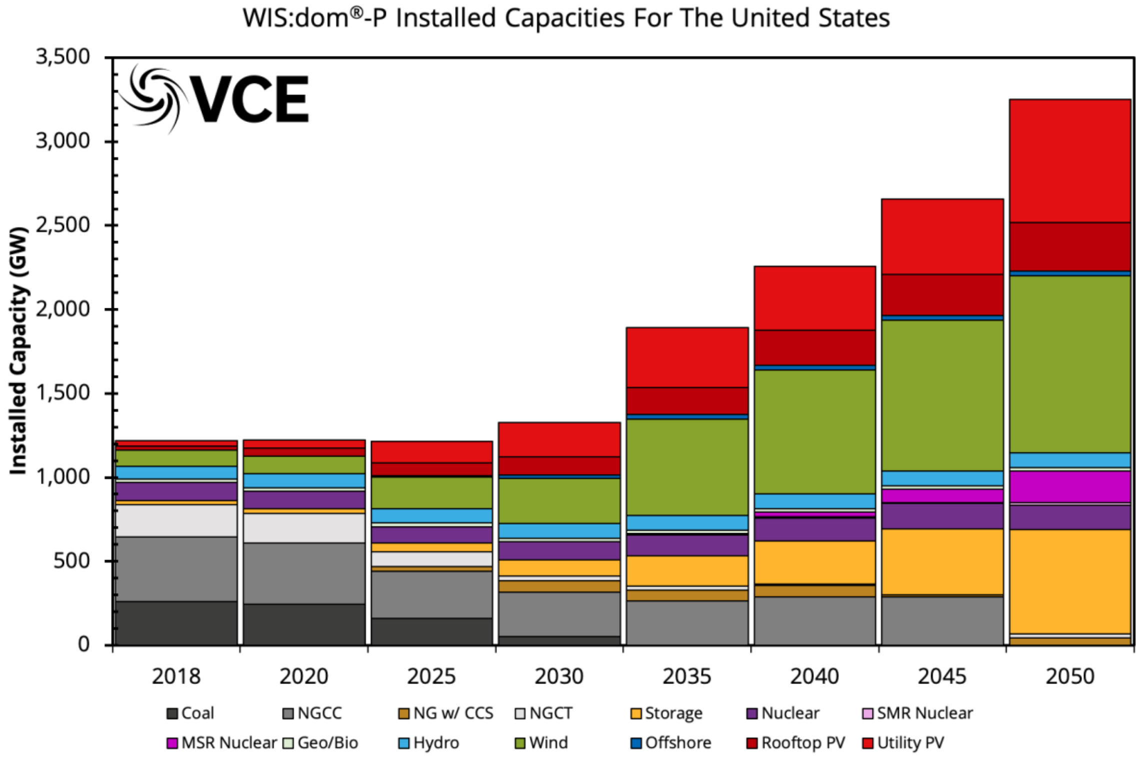
https://www.esig.energy/transmission-planning-for-100-clean-electricity/



Additional Slides

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.



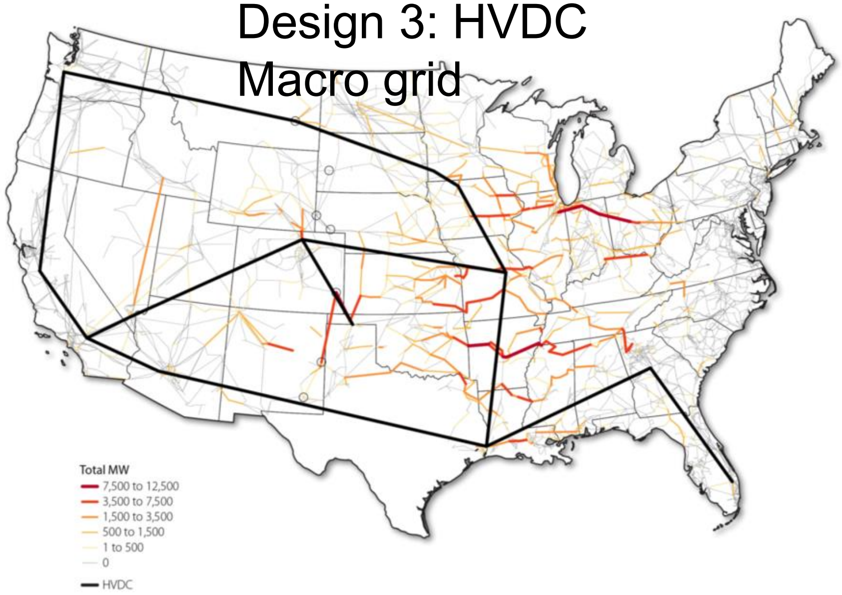
MISO RIIA 100% buildout [MW]			
	DPV	UPV	wind
MISO	32,190	67,975	129,647
SPP	8,139	14,700	41,750
TVA	40,174	85,275	7,300
SERC	85,119	180,825	15,250
PJM	41,174	93,100	185,600
NYISO	8,483	19,675	31,600
Total	**215,279**	**461,550**	**411,147**

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

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



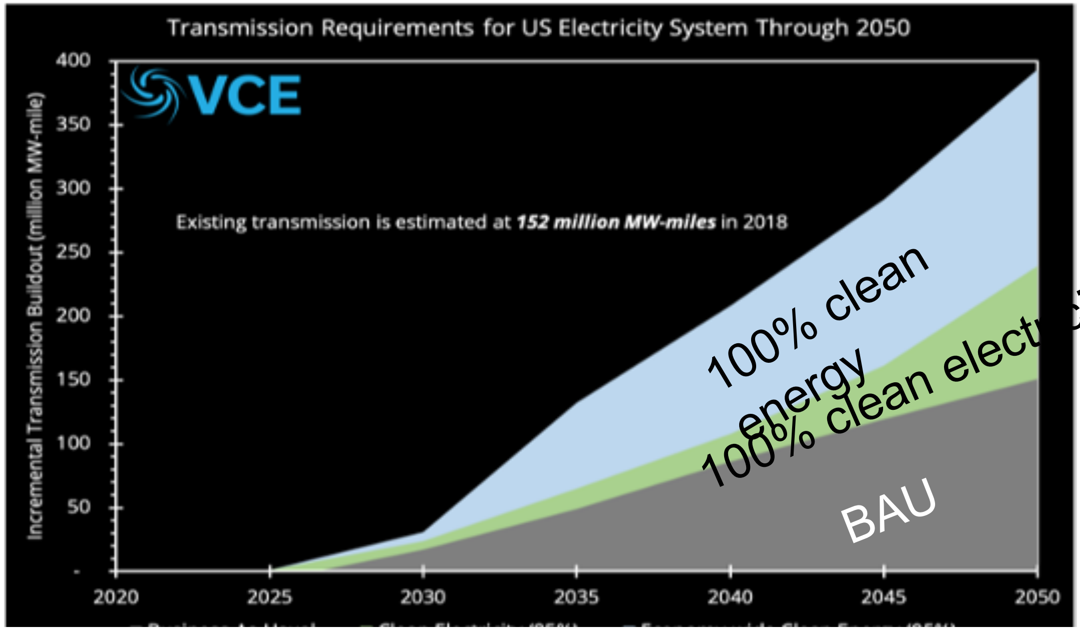
50% Renewables case	BAU across seams	HVDC Macro grid	
Objective function	**Design 1**	**Design 3**	**Delta**
Line investment (B$)	61.21	80.10	18.89
Generation investment (B$)	704.03	700.51	-3.52
Operation and maintenance (B$)	1336.36	1300.70	-35.66
Emission cost (B$)	171.10	162.50	-8.60
35-yr B/C ratio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

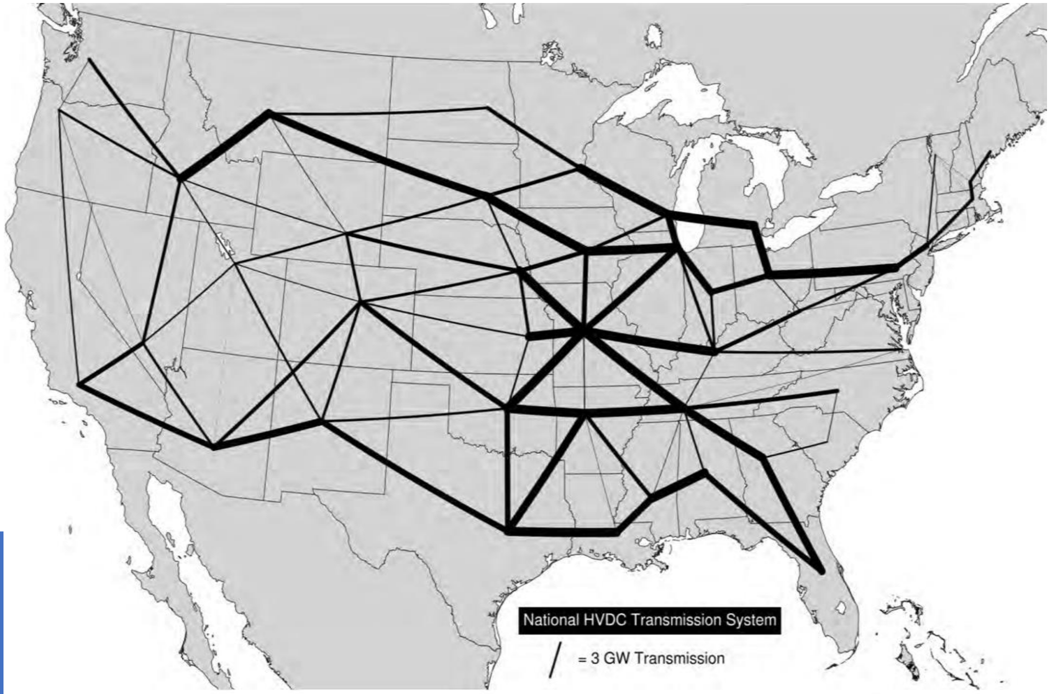
https://www.nrel.gov/analysis/seams.html

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



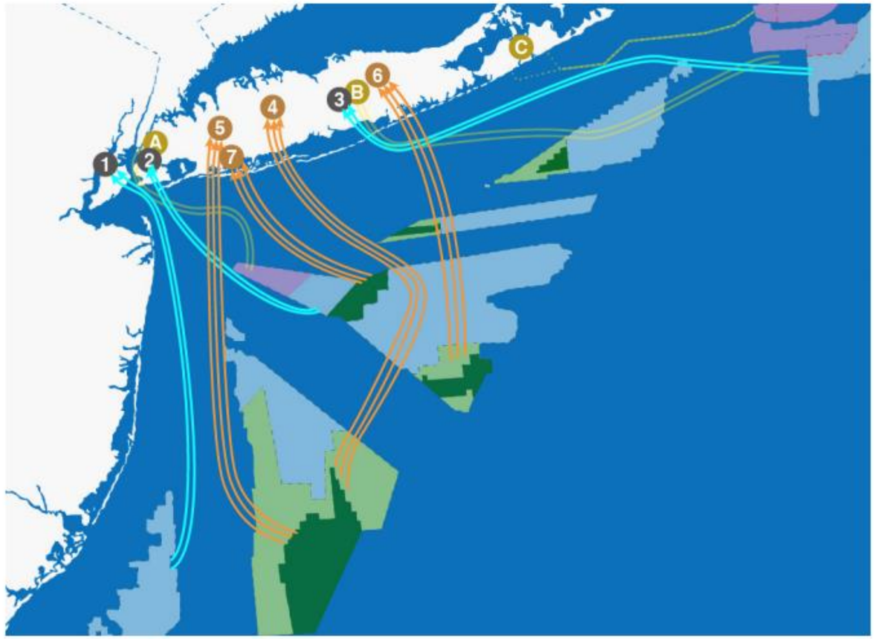


Anbaric/Brattle offshore wind studies

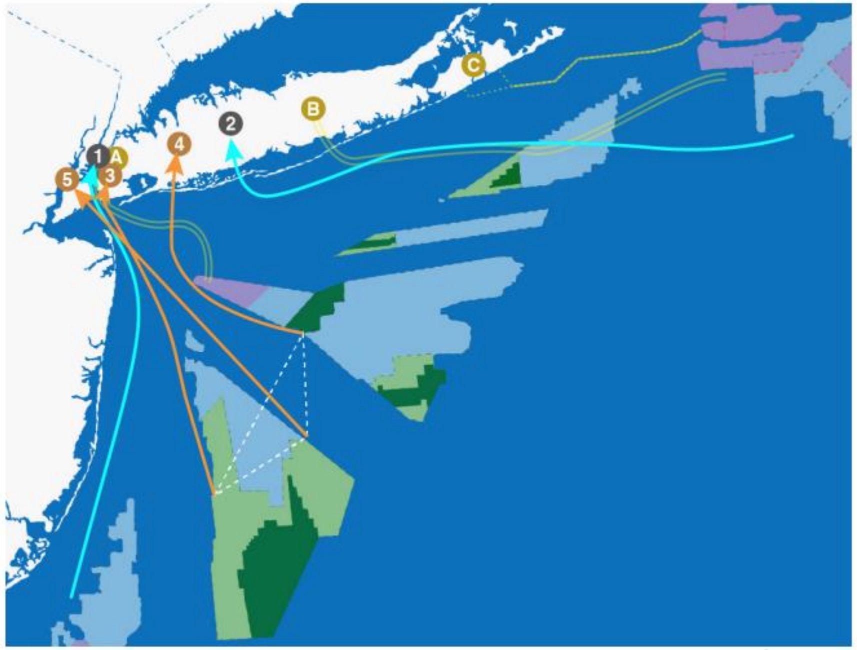
- ISO-NE: Proactive, planned approach saves $1B in onshore upgrades
  - HVDC grid design to enable 8.6 GW of wind without requiring major onshore grid updates
- In NYISO, it would save $500M
  - 9 GW of offshore wind

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



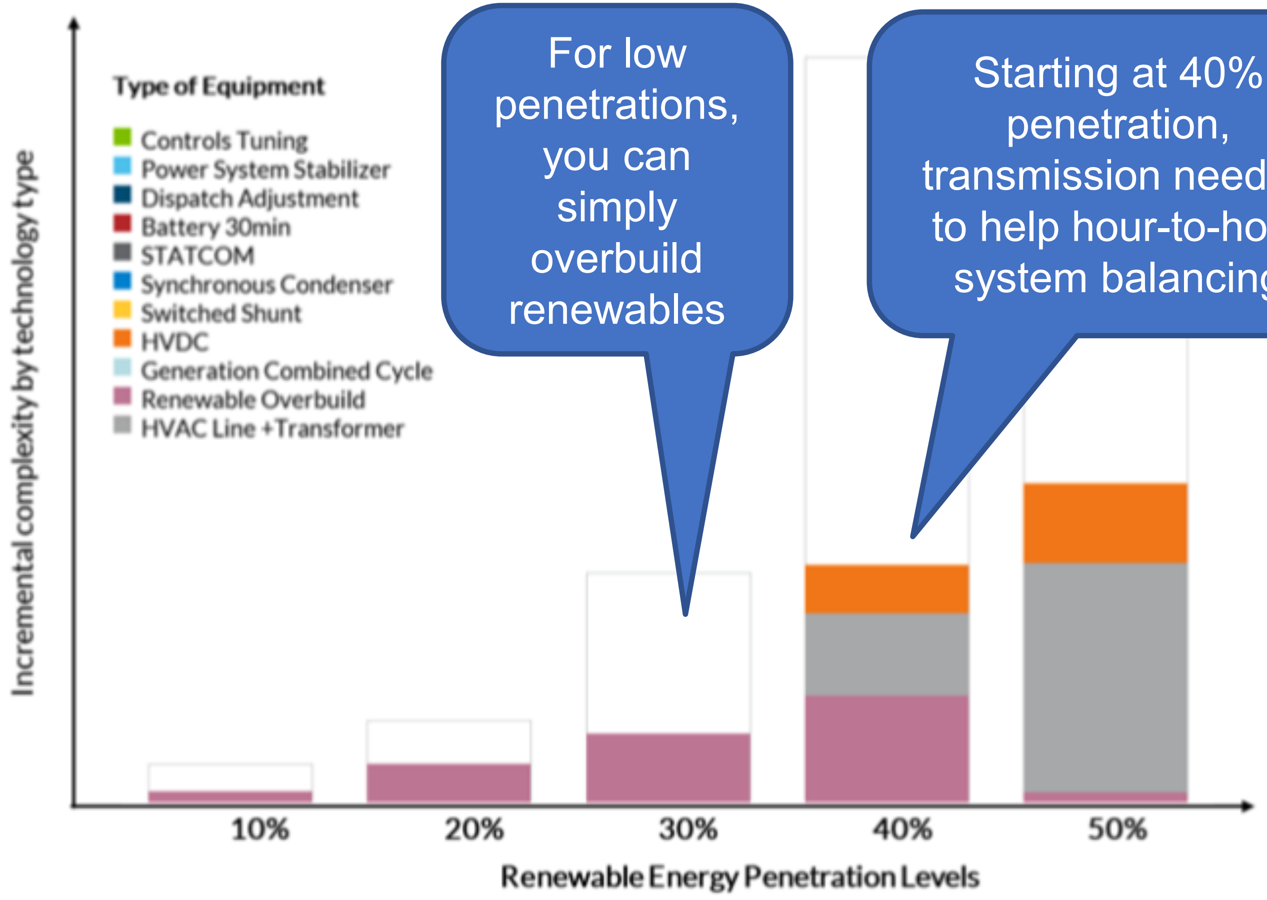
Planned Offshore Transmission Scenario



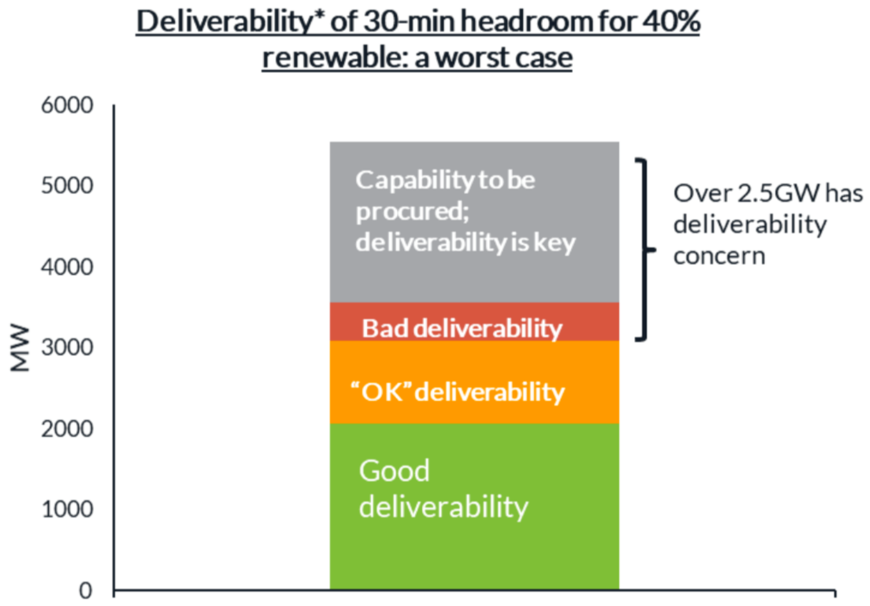
Transmission needed to help system balancing

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



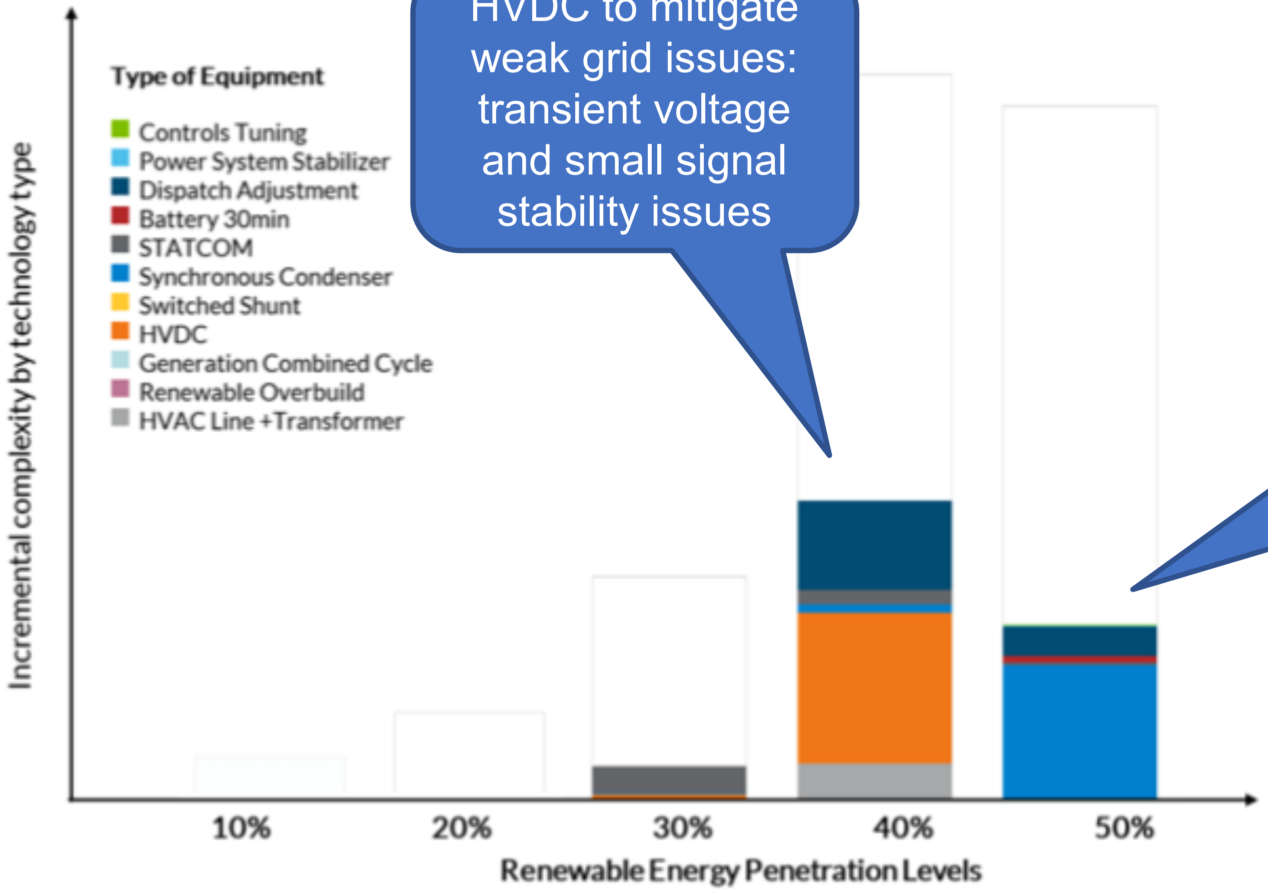
Transmission is critical to maximizing flexibility

https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf

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

https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf

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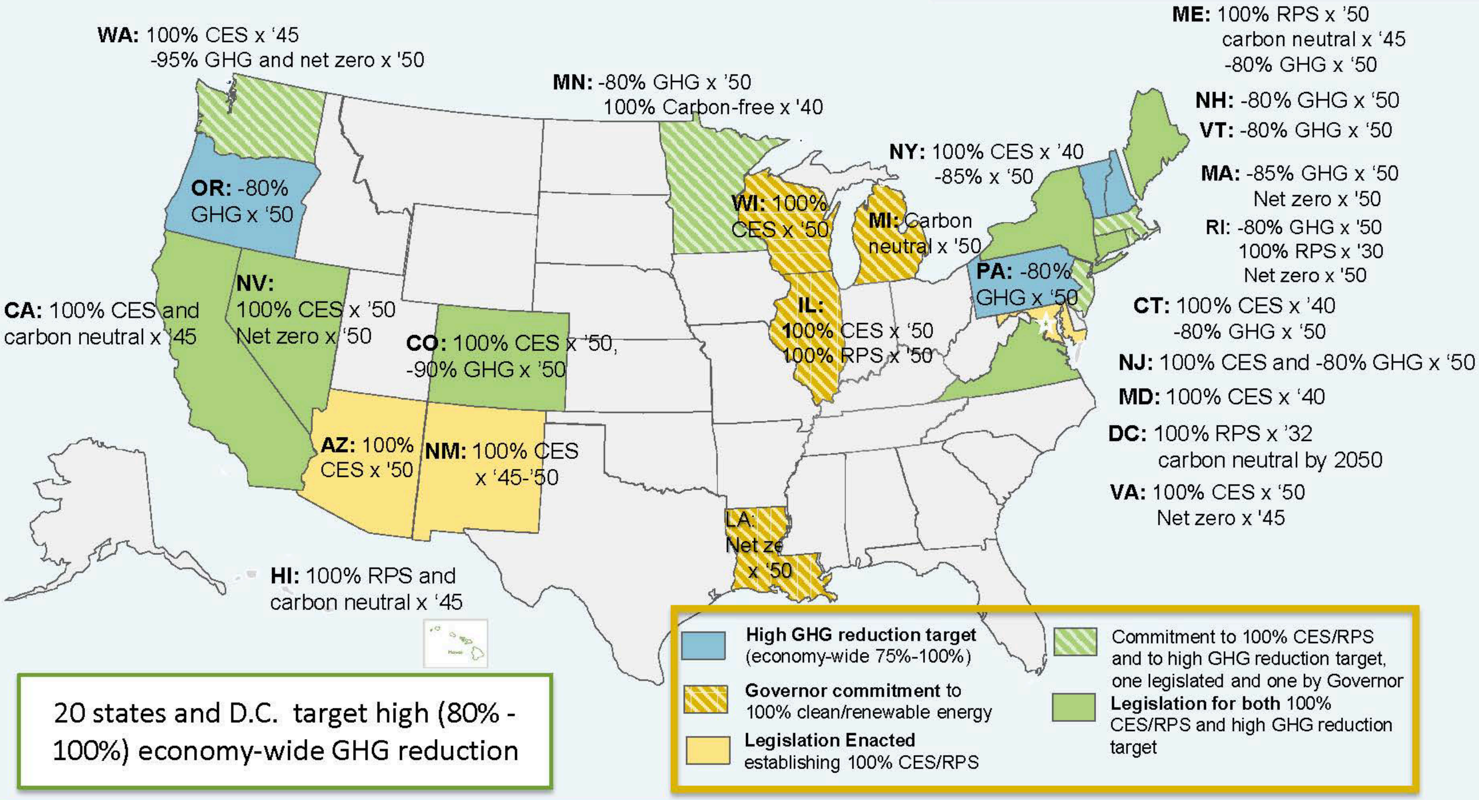
Principles of a Macro Grid

- Connect regions with diverse load and generation profiles
- Have the lowest cost and smallest 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

Transmission Planning for the Future

100% Clean Electricity Standards,100% RPS, or High GHG Reduction Targets

17 states and the District of Columbia have legislation enacted or Governor commitment to target 100% clean electricity (14) or 100% RPS (3+D.C.)



20 states and D.C. target high (80% - 100%) economy-wide GHG reduction

24 states and the District of Columbia have 100% clean electricity targets, deep GHG reduction targets, or both, encompassing 53% of US residential electricity customers.

Rev. August 16, 2021

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What Needs Are We Planning to Meet Today?

- Main objective of regional transmission planning processes:
  - Ensure system reliability throughout the planning horizon based on historical usage and conservative future assumptions.
  - Transmission owners discouraged from proactively planning for the future because it involves a degree of risk that the future will be different than expected.
- While Order No. 1000 required regions to consider transmission needs driven by public policy requirements, few regions have been able to reach sufficient consensus to adopt criteria to fully integrate any real public policy drivers.
- Load forecasts do not fully reflect expected electrification trends or the potential for electric storage to change usage patterns.

The transmission planning process can only meet the needs that we ask it to address, and the assumptions and planning criteria that underlie today's regional transmission planning processes primarily focus on maintaining reliability and reducing delivered power costs given the existing resource mix and load forecasts.

Why Aren't Regions Identifying More Regional Transmission Projects?

The lack of regional transmission projects since the issuance of Order No. 1000 is driven by several factors:

Limited load growth

- Load growth has slowed or been nonexistent since the Great Recession, in part due to expanded energy efficiency efforts.
- Load growth has been largely limited to new customer interconnections (e.g., data centers), which do not result in the NERC Reliability Standard violations that would drive a regional need.

Modest congestion

- Due to reduced load growth, low natural gas prices, and an increase in zero marginal cost resources on the system, congestion has fallen as well, limiting the opportunities to identify regional economic projects.

Reliance on the generator interconnection process to integrate new resources

- Generator interconnection processes identify needed network upgrades outside of the regional transmission planning processes.
- As a result, even when large-scale network upgrades are necessary to integrate new resources, they are not categorized as regional transmission projects.

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The Problem: Lack of Proactive Planning to Integrate Clean Energy Resources

Today, the transmission infrastructure needed to integrate new clean energy resources is identified primarily through the generator-by-generator interconnection process.

- Individual generators submit requests for interconnection service.
- The transmission owner/provider studies the network upgrades necessary to accommodate those requests on a request-by-request basis.
- Generators are driven to find the lowest-cost network upgrades needed to interconnect.

Relying on individual interconnection processes to integrate clean energy resources is inefficient for both generator interconnection customers *and* transmission owners/providers.

- Given current backlogs in the interconnection queue, generators often submit multiple interconnection requests for a single project to determine which location has the lowest network upgrade costs.
- The transmission owner/provider must study each request (no matter how speculative) to identify the associated network upgrades.
- With this information, the generator typically withdraws one or more of its requests, necessitating restudies for resources further behind in the queue.
- Only the minimum infrastructure needed to reliably interconnect the generator is funded.

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A Solution: Robust Scenario-based Integrated with Deterministic Regional Planning

Scenario-based Regional Planning

- Plans over the longer-term (i.e., 10 years+)
- Uses proactive assumptions and planning criteria
- Identifies a regional high-voltage transmission overlay to integrate clean energy zones

Deterministic Regional Planning

- Plans for nearer-term needs
- Uses more conservative assumptions and criteria
- Addresses residual needs not met by the regional high-voltage transmission overlay

Closing Thoughts

- Order No. 1000 provides a strong foundation for more proactive regional transmission planning; with limited revisions to the regional transmission planning and developer requirements, we can better facilitate the clean energy transition.

- Proactive, scenario-based planning will not replace the need for deterministic regional or local transmission planning, although it will help to ensure that those processes focus on addressing residual needs.

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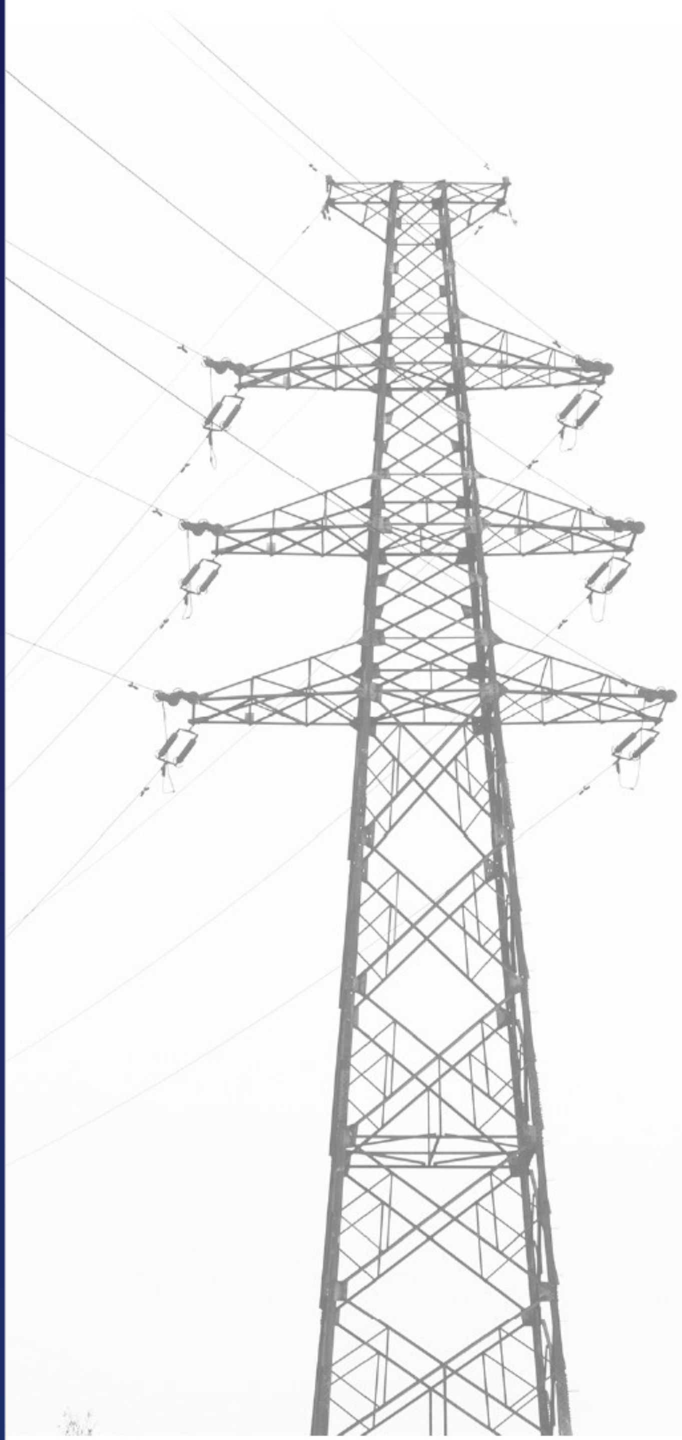

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