Interregional Transmission Needs & the Benefits of HVDC Transmission

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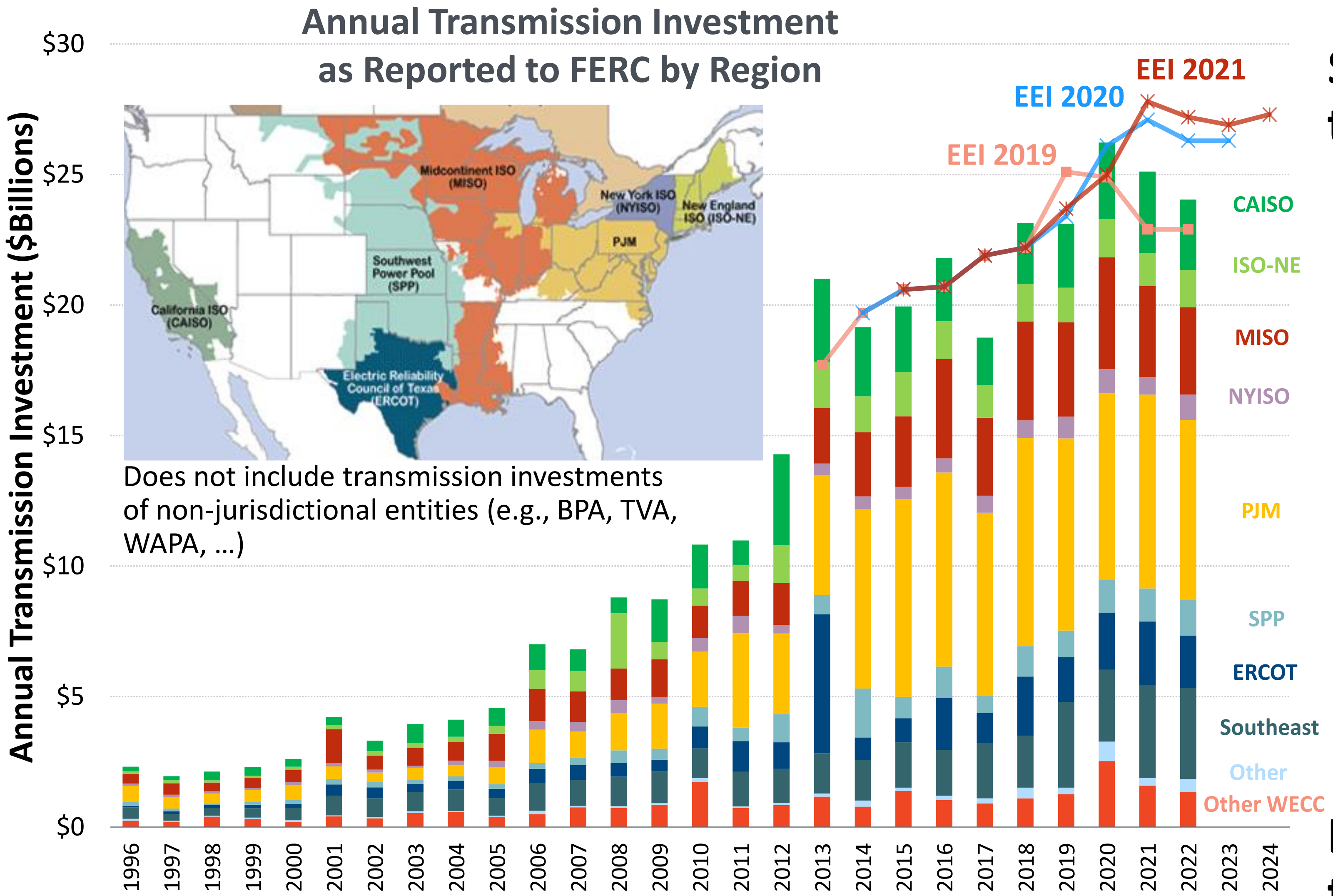
Brattle

Transmission Investments is at Historically High Levels



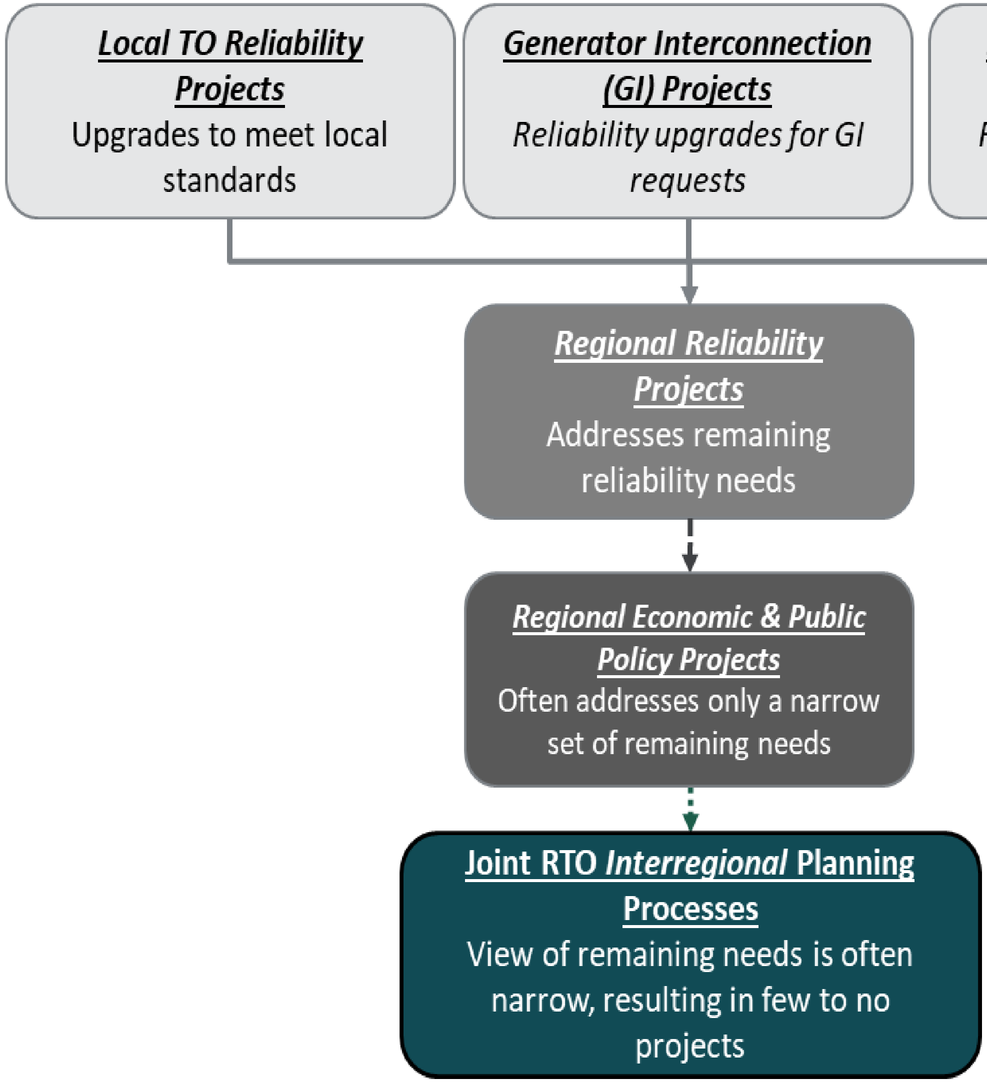
Sources: The Brattle Group analysis of FERC Form 1 Data; EEI "Historical and Projected Transmission Investment" most recent accessed here: https://www.eei.org/resourcesandmedia/Documents/Historical%20and%20Projected%20Transmission%20Investment.pdf

$20-25 billion in annual U.S. transmission investment, but:

- More than 90% of it justified solely based on reliability needs without benefit-cost analysis
  - About 50% solely based on "local" utility criteria (without going through regional planning processes)
  - The rest justified by regional reliability and generation interconnection needs
- While significant experience with transmission benefit-cost analyses exists, very few projects are justified based on economics to yield overall cost savings

Essentially no interregional transmission!

Current U.S. Grid Planning Processes are too Siloed



These solely reliability-driven processes account for > 90% of all transmission investments

- None involve any assessments of economic benefits (i.e., cost savings offered by the new transmission)
- Which also means these investments are not made with the objective to find the most cost-effective solutions
- Will yield higher system-wide costs and electricity rates

Planning for economic and public-policy projects: less than 10% of all transmission investments

Interregional planning processes are largely ineffective

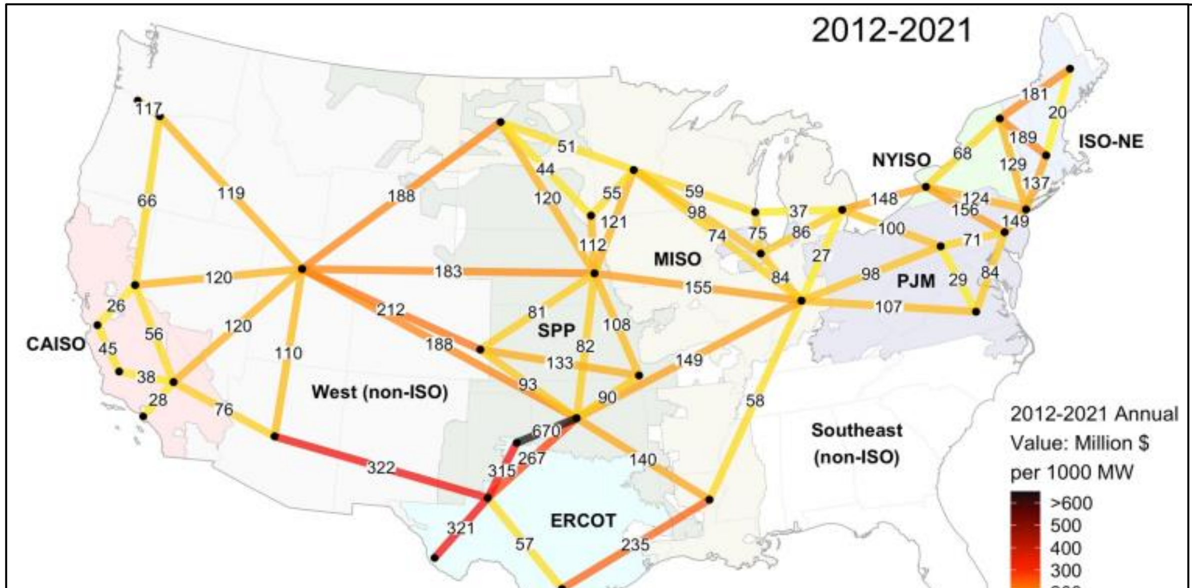
- Essentially no major interregional transmission projects have been planned by grid operators in the last decade
- Regional focus on meeting reliability needs leaves no "need" for interregional transmission, even if more cost effective

Barriers to Interregional Transmission Planning

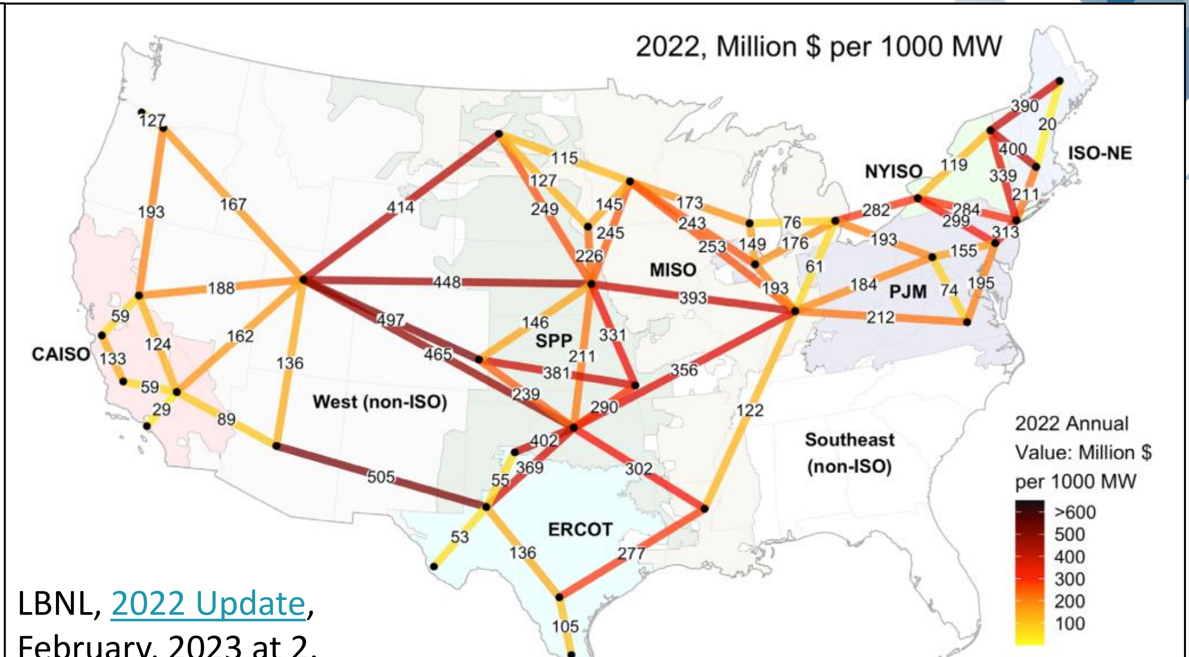
A. Leadership, Alignment and Understanding	1. Insufficient leadership from RTOs and federal & state policy makers to prioritize interregional planning 2. Limited trust amongst states, RTOs, utilities, & customers **3. Limited understanding of transmission issues, benefits & proposed solutions** 4. Misaligned interests of RTOs, TOs, generators & policymakers 5. States prioritize local interests, such as development of in-state renewables
B. Planning Process and Analytics	**6. Benefit analyses are too narrow, and often not consistent between regions** 7. Lack of proactive planning for a full range of future scenarios 8. Sequencing of local, regional, and interregional planning 9. Cost allocation (too contentious or overly formulaic)
C. Regulatory Constraints	10. Overly-prescriptive tariffs and joint operating agreements **11. State need certification, permitting, and siting**

Source: Appendix A of A Roadmap to Improved Interregional Transmission Planning, November 30, 2021. Based on interviews with 18 organizations representing state and federal policy makers, state and federal regulators, transmission planners, transmission developers, industry groups, environmental groups, and large customers.

The High Value of and Large Need for Interregional Transmission



LBNL, *Empirical Estimates of Transmission Value*, Slide 16



LBNL, 2022 Update, February, 2023 at 2.

DOE's National Transmission Needs Study identified significant interregional transmission needs based on 3 groups of scenarios:

1. **Mod/Mod** = status-quo with moderate load and clean-energy shares
2. **Mod/High** = moderate load growth but high clean-energy shares
3. **High/High** = high load and clean-energy shares

"Need" = optimal regional and interregional transmission expansion that minimize total system-wide costs

- Based on six recent national studies, 26 scenarios, and numerous sensitivities

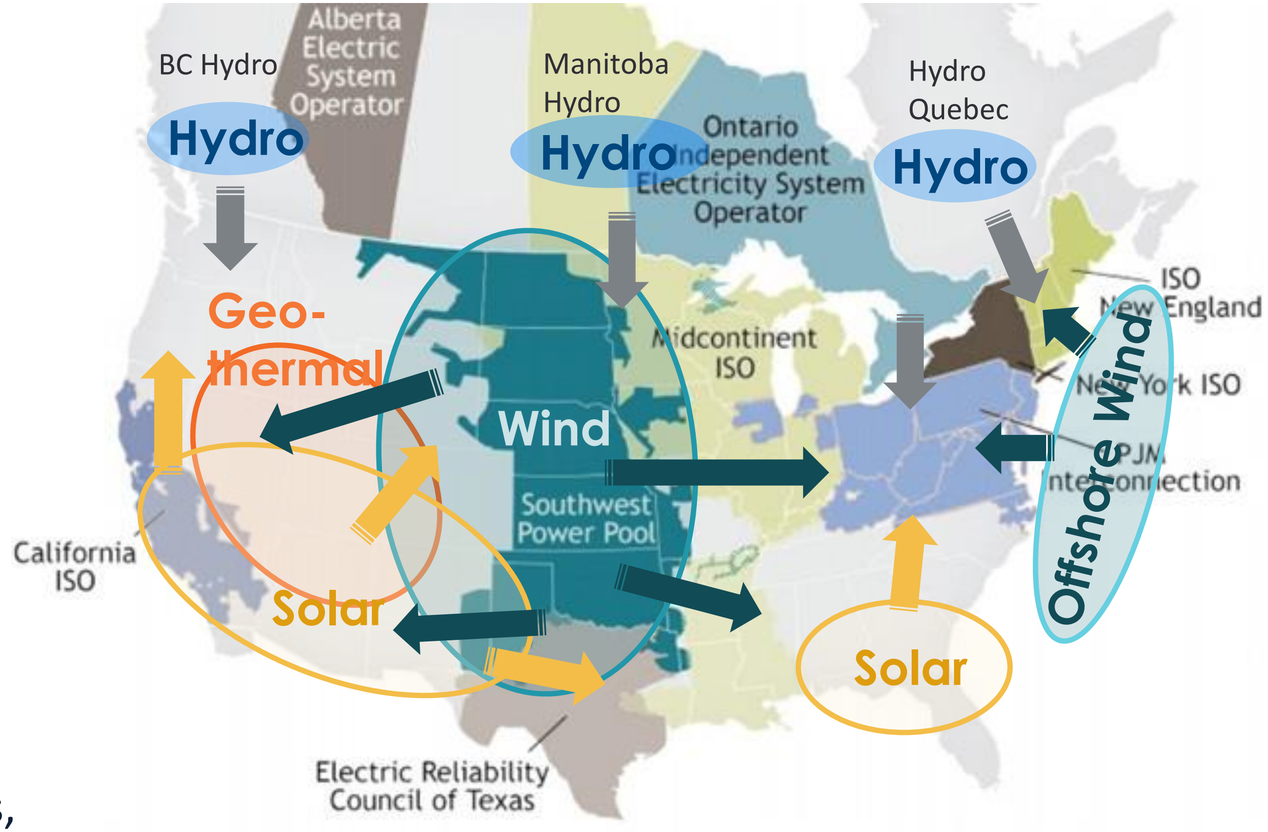
Long-Term Need: Accessing and integrating low-carbon resources

Resource quality varies by region:

- **Onshore Wind**: Interior, TX
- **Offshore Wind**: East coast, TX
- **Solar**: Southwest, TX, FL
- **Geothermal**: CA, NV
- **Hydro**: Western states, imports

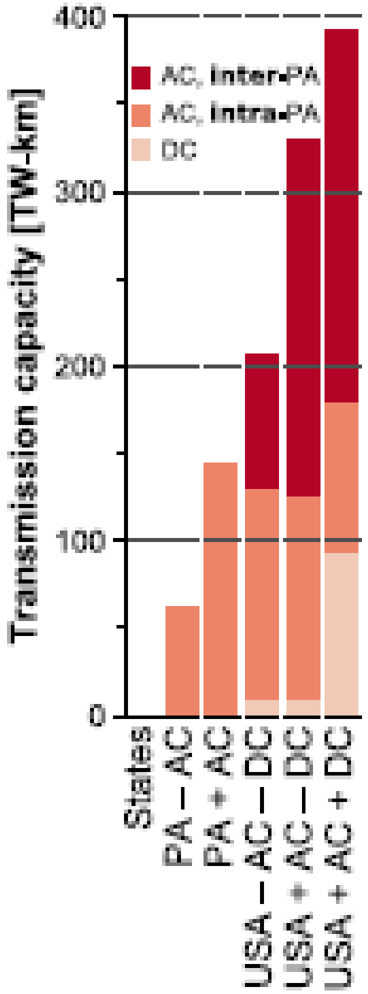
Essential to diversify renewables by expanding the grid

- Reduces generation investment and balancing costs
- Transmission will compete with other approaches to integrating renewables, including storage, distributed resources, and market expansion

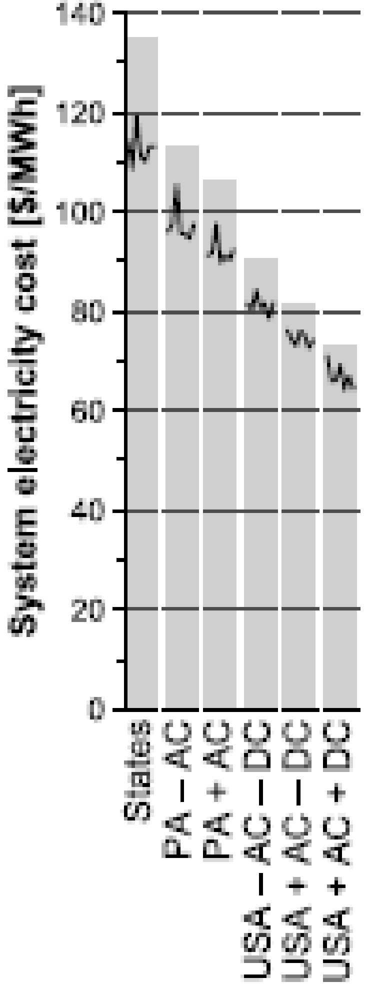


MIT Study: Cost Reductions Enabled by Interregional Transmission

TRANSMISSION ↑

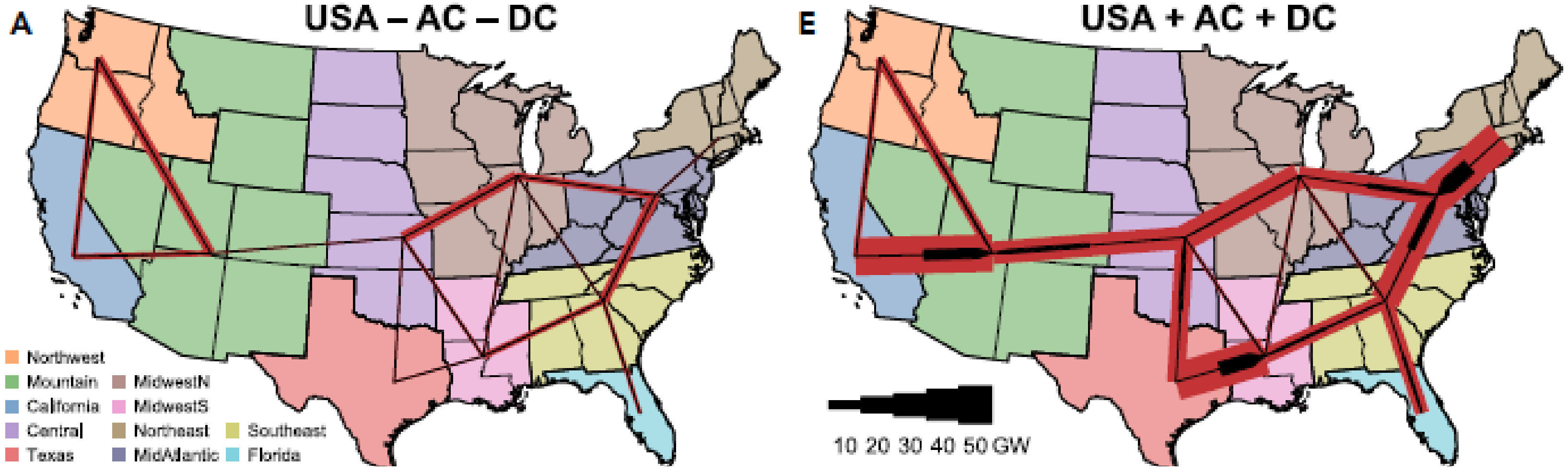


TOTAL COST ↓



Key Result: A more robust national grid would reduce the total cost of decarbonizing the grid … but (higher-cost) regional and more local solutions may also be feasible

Optimal Transmission Build:
With and Without National Transmission Coordination



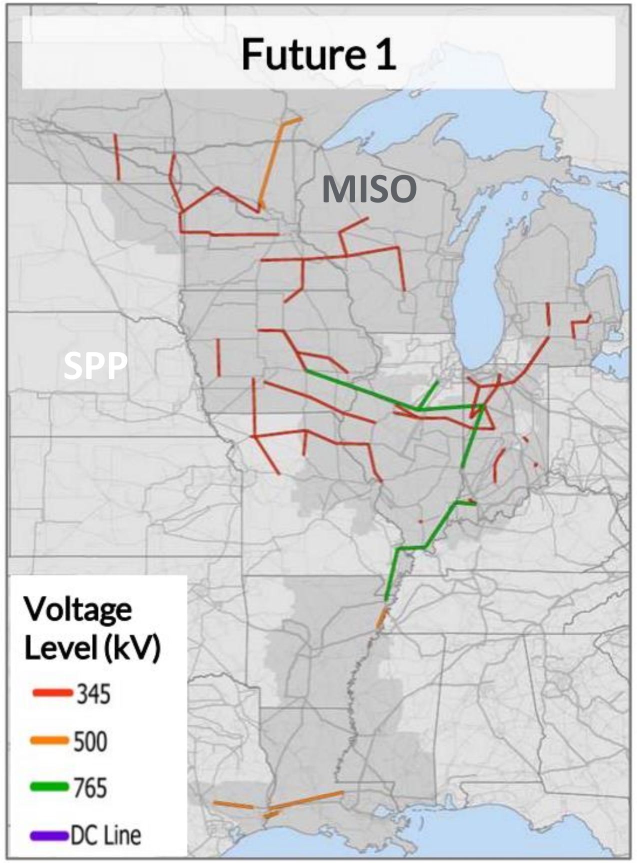
P. R. Brown and A. Botterud, *The Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electricity System*, Joule, December 11, 2020.

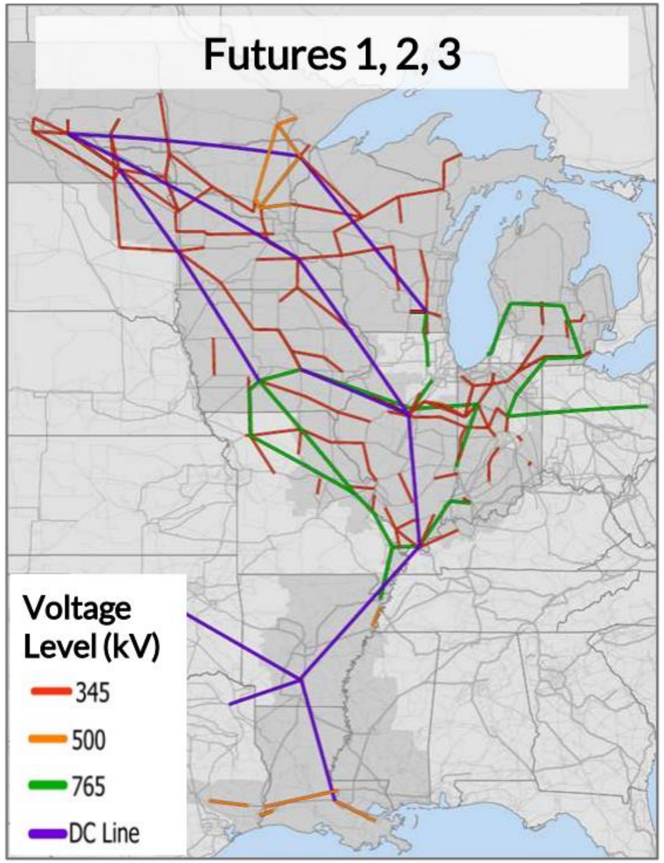
Example: Prioritizing Regional over Interregional Solutions

- MISO's new Renewable Integration Impact Assessment (RIIA) improves on many other planning studies by:
  - Establishing the need to study both policy goals and reliability goals simultaneously
  - Considering diverse future scenarios
  - Recommends a "least-regret" transmission plan (but one that does not address possibility of regret from inadequate T)
- By design, **the scope of study does not address any interregional opportunities:**
  - Despite modeling five regions in addition to MISO, the study mostly did not consider interregional transmission (see figures)
  - Even if "optimal" for MISO, it likely preempts more cost-effective interregional solutions

How would SPP-MISO-PJM wide planning results differ?

MISO's projected scope of transmission expansion needs





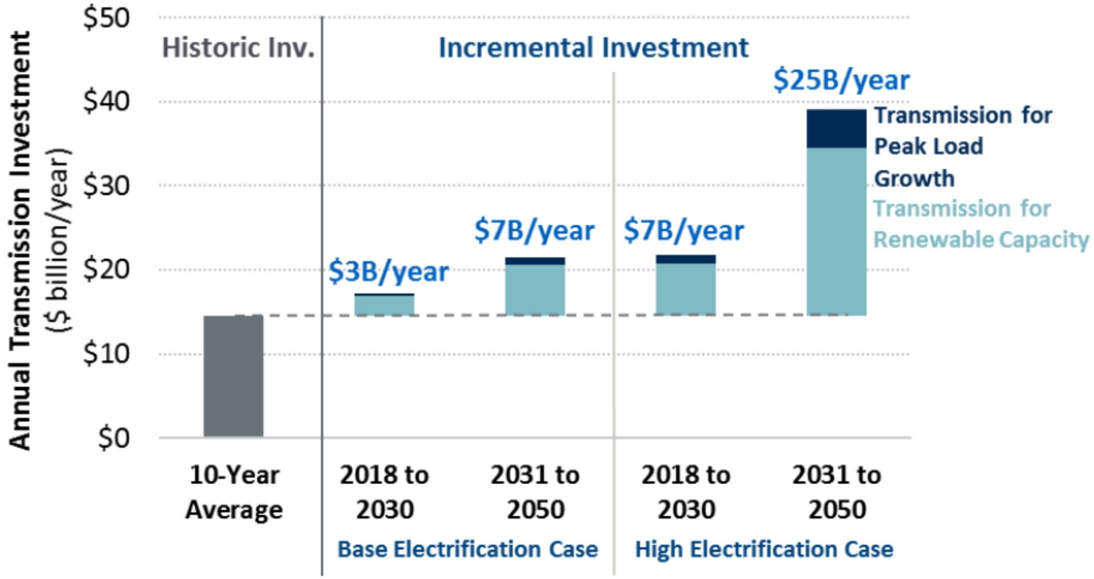
Source: MISO LRTP Roadmap March 2021

US Transmission Investment Driven by Electrification

Brattle study found that electrification will drive $3 billion/year of incremental transmission investment over the next decade

- Increases to $7 billion/year between 2030 and 2050
- High electrification sensitivity finds $7 billion/year in near term; $25 billion/year from 2030 to 2050

Incremental Transmission Investment Driven by Electrification



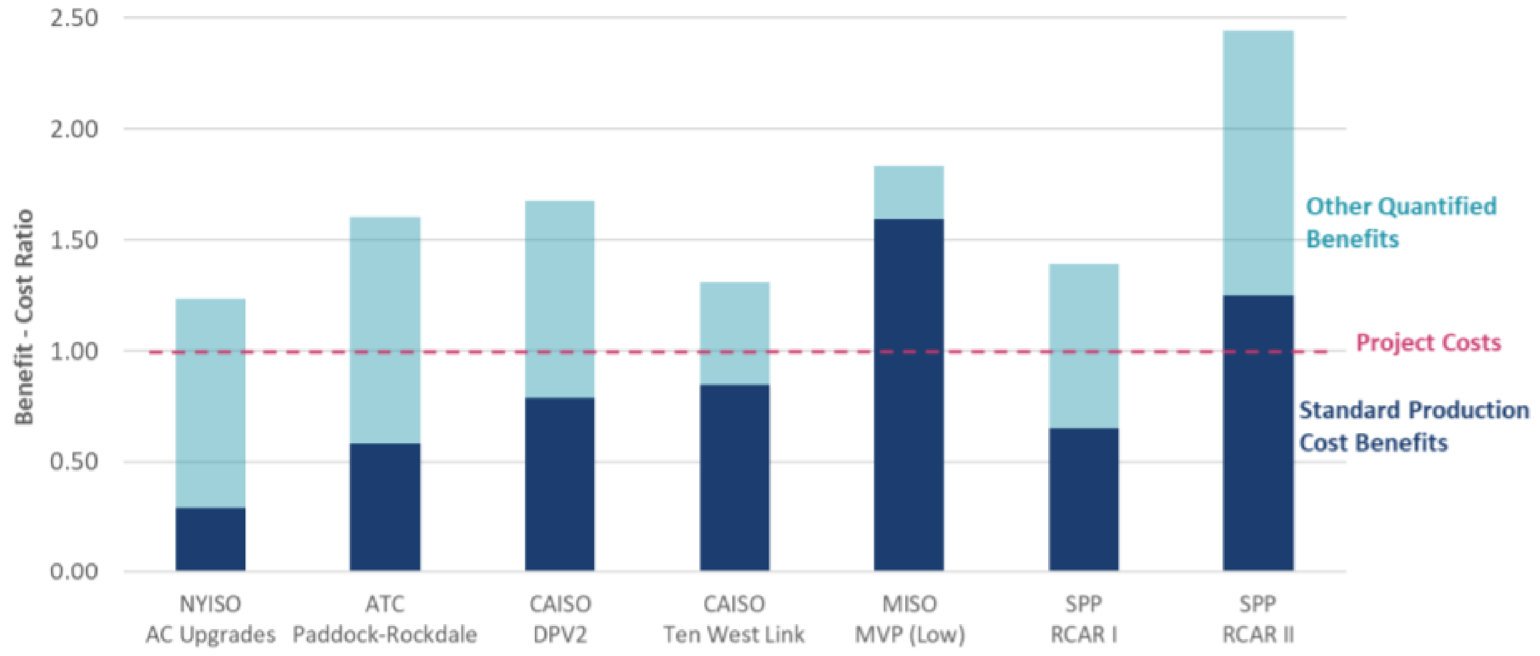
Notes: The historical average reflects transmission investments from 2006 to 2016 based on transmission capital expenditures reported on FERC Form 1.

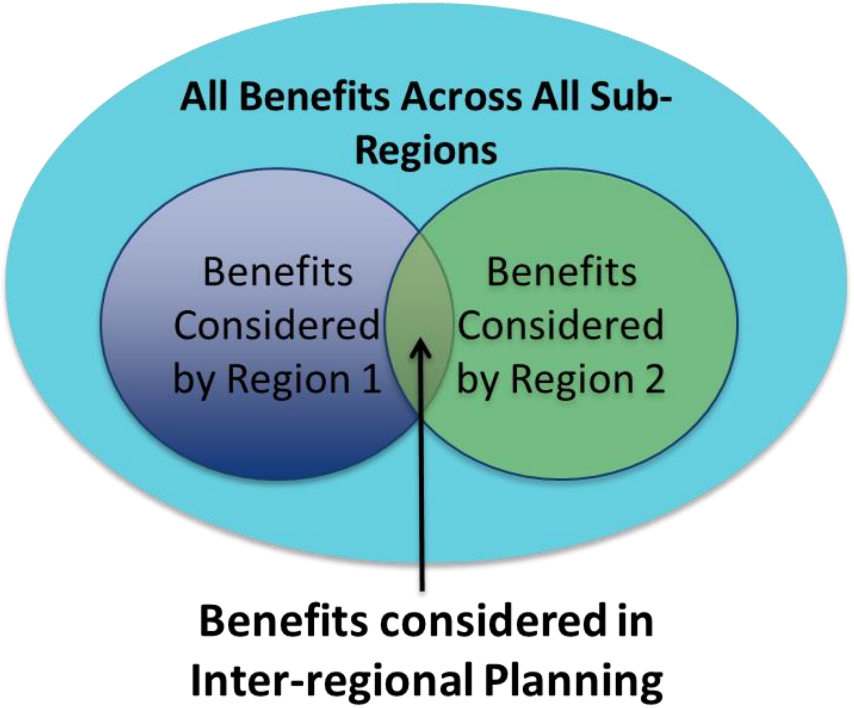
Source: Weiss et. al., The Coming Electrification of the North American Economy, WIRES, March 2019.

Quantifying Benefits Beyond "Production Cost" Savings

Relying solely on traditionally-quantified Adjusted Production Cost (APC) Savings results in the rejection of beneficial transmission projects – particularly for interregional planning efforts that consider an even smaller subset of benefits

FIGURE 5. BENEFIT-COST RATIOS OF TRANSMISSION PROJECTS WITH AND WITHOUT A BROAD SCOPE OF BENEFITS





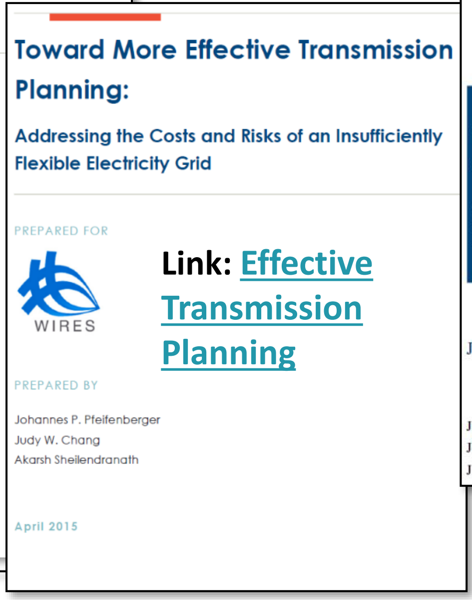
Source: Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs
A Roadmap to Improved Interregional Transmission Planning.

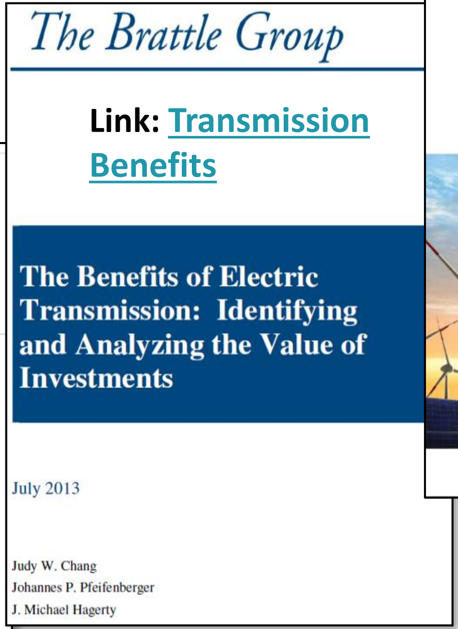
Value Consideration for Interregional Transmission

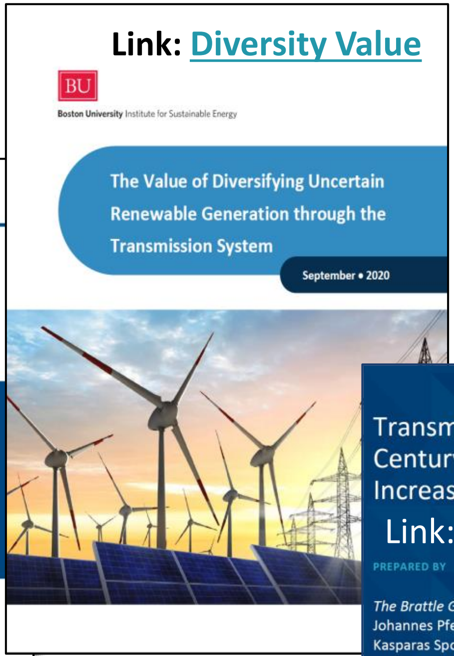
Planning interregional transmission that reduces costs and improves reliability compared to regional or local solutions, the following changes are needed:

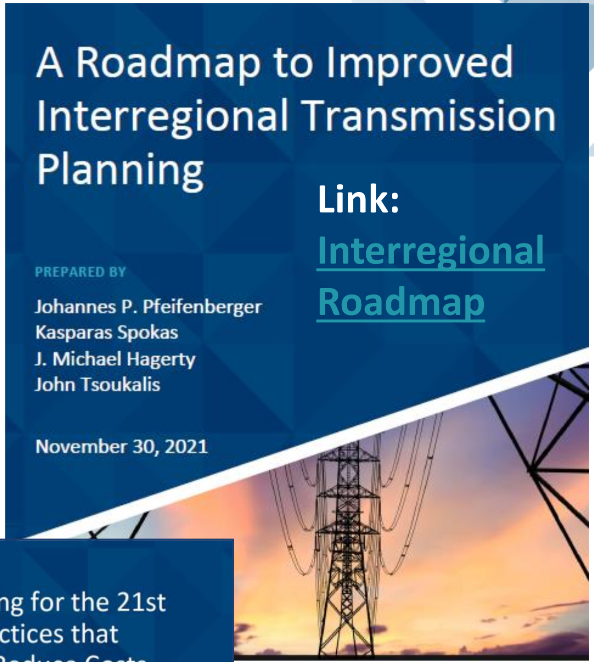
- Fully and efficiently **utilize interregional transmission** in energy markets and for resource adequacy
- **Improve planning models**:
  - Improve representation of neighboring regions in model footprint to capture diversity
  - Capture impacts of challenging conditions and extreme events, such as heat waves or cold snaps
    - Simultaneous spikes in loads, fuel prices, generation and transmission outages, resilience challenges
    - LBNL study: 40-80% of annual transmission value is concentrated in top 5% of all hours
  - Integrate/combine all benefit metrics of neighboring regions in economic analyses
  - Recognize the full resource adequacy value of interregional transfer capability (even if non-firm or not committed to capacity imports) to reflect load and resource diversity
- Proactively **evaluate whether interregional solutions are more cost effective** than regional or local solutions in regional planning processes
  - Recognize regional/interregional benefits, including avoided cost of regional/local solutions

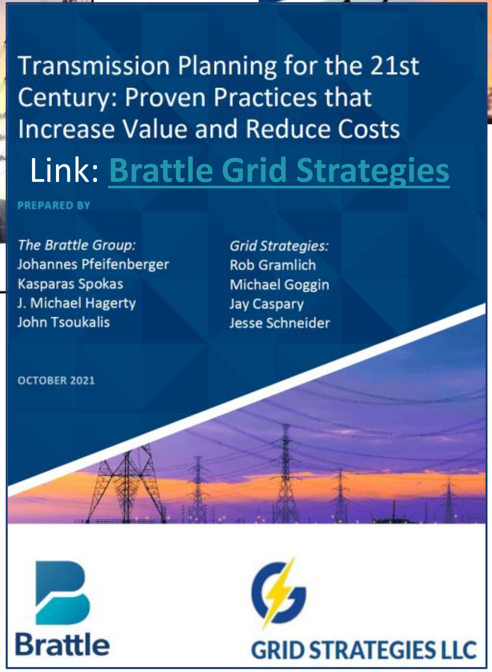
Examples of Brattle Reports on Regional and Interregional Transmission Planning and Benefit-Cost Analyses











Summarizes proven approaches to quantifying various benefits

Key Takeaways on HVDC Technology

HVDC transmission technology has evolved dramatically over the last 5-10 years

- HVDC offers higher-capacity, longer-distance, lower-loss transmission on a smaller footprint than AC
- The development of voltage-sourced converter (VSC) technology has also offered dramatic improvements in HVDC capabilities
- These VSC-based capabilities are increasingly needed to enhance the existing AC grid

Internationally, approximately 50 GW of VSC-HVDC transmission projects are in operation today and approx. 130 GW planned or under development through the end of the decade

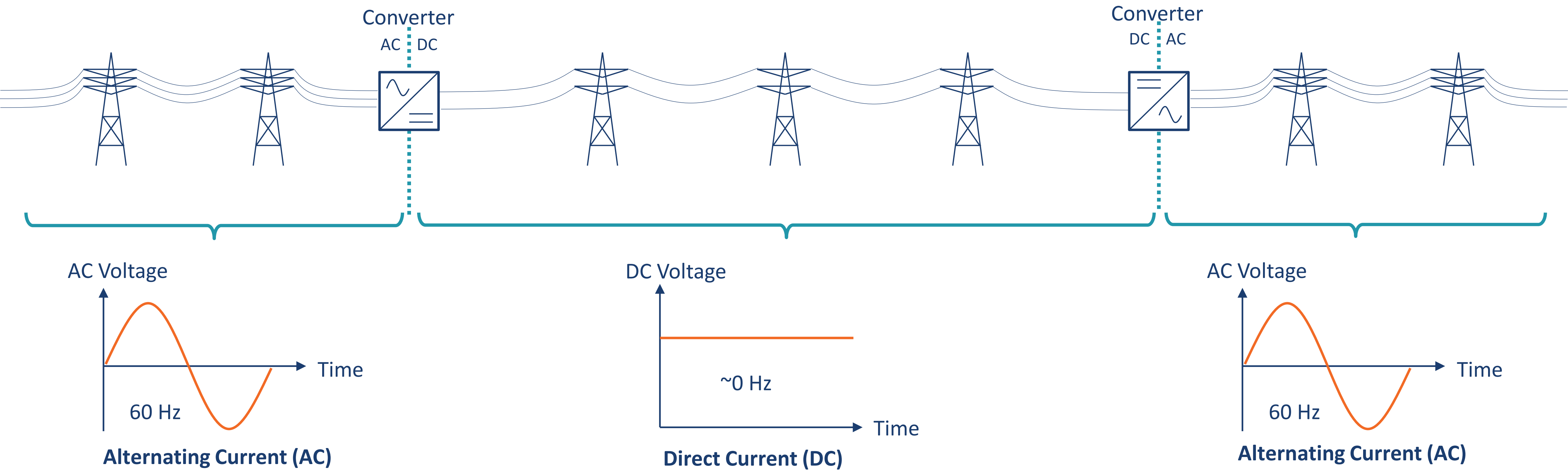
- North America accounts for only 3% of all VSC systems in operation worldwide and (almost exclusively due to merchant developers) for approx. 30% of planned and proposed VSC systems

U.S. system operators less familiar with HVDC can benefit from the experience gained overseas (particularly in Europe) … but significant planning, supply chain, operational, and regulatory challenges need to be addressed

- The report provides a primer on HVDC technology, documents available capabilities and experience, addresses misconceptions, and offers recommendations to collaboratively address the identified challenges

High Voltage Direct Current (HVDC) technology

A reliable and effective electrical power transmission solution since the late 1890s

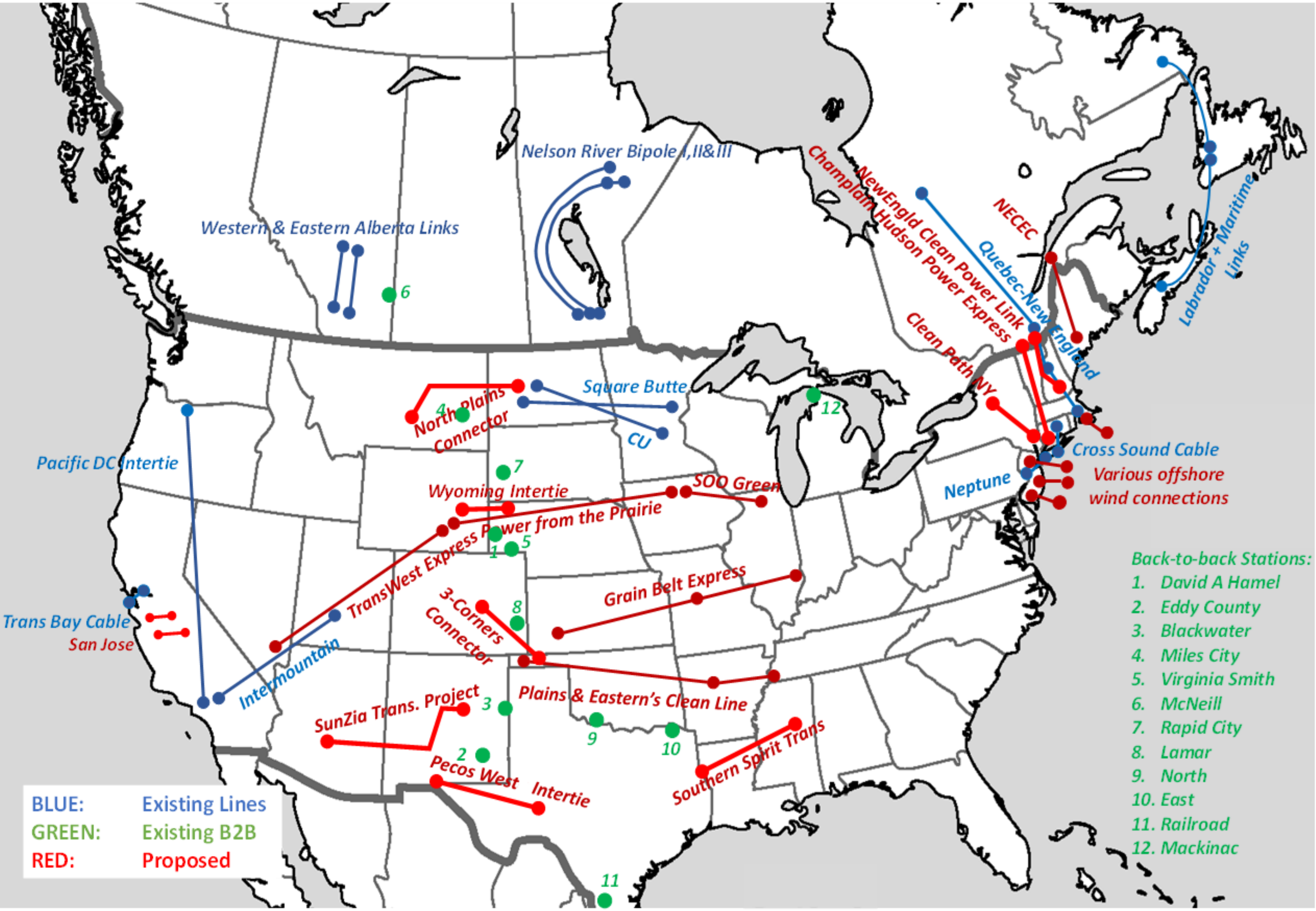


No reactive power → Long distance transmission
Overhead or underground
No skin effect → Optimal use of conductors
Converters → Power flow control / grid services

Less right of way = Smaller environmental and community impacts

Experience with HVDC transmission in North America

North American HVDC Projects (Existing and Planned/Proposed)



Source: Jim McCalley, Iowa State University

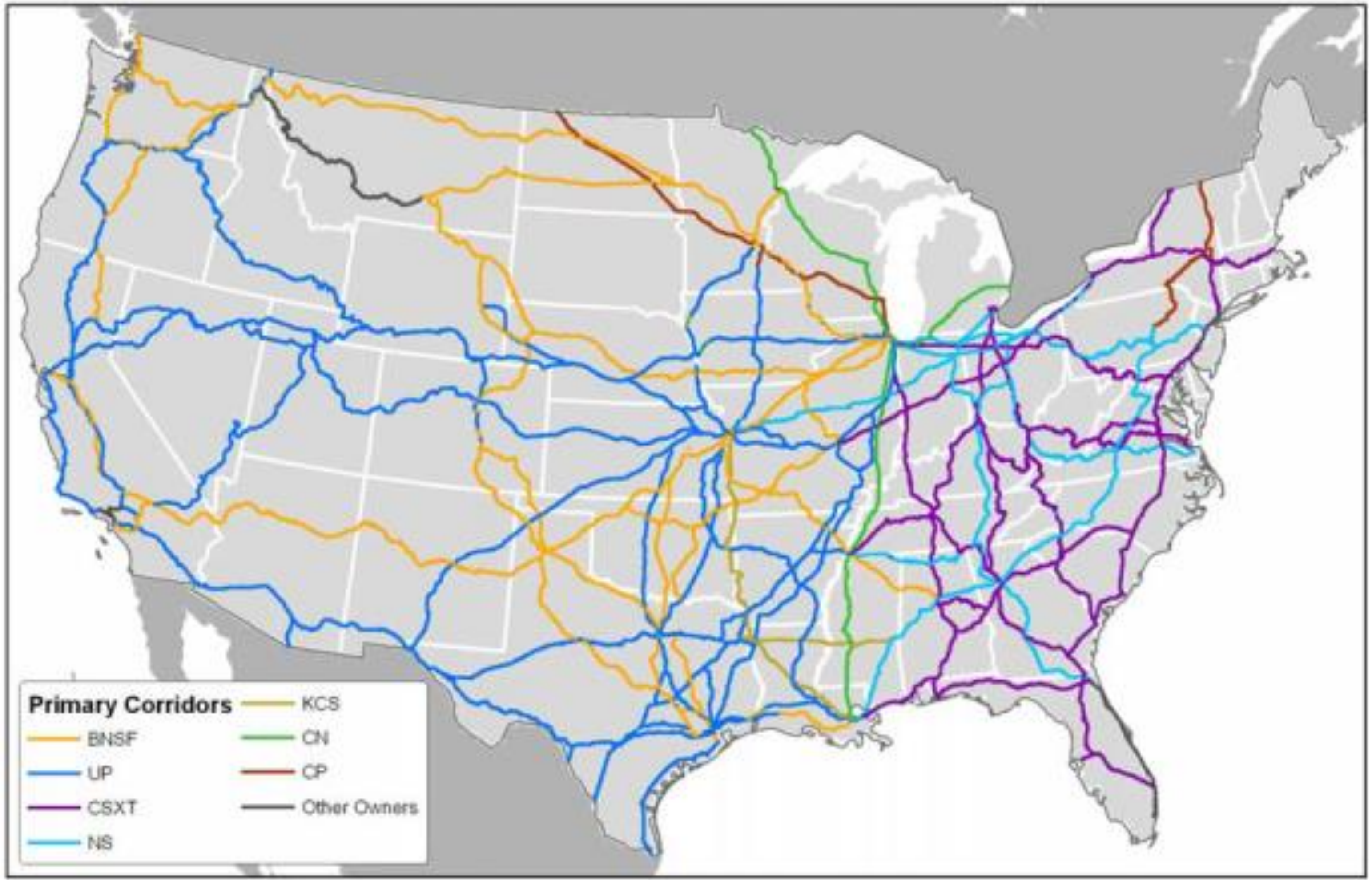
CAISO leads the U.S. in planning and utilizing HVDC transmission:

- First VSC-MMC HVDC line (TransBay, 2013)
- 10 VSC-HVDC systems evaluated in transmission planning; 2 approved
- Full co-optimization of HVDC transmission with generation in day-ahead and real-time markets since 2017
- Interregional optimization in WEIM
- Subscriber PTO proposal (merchant lines)

Most U.S. HVDC transmission projects proposed by merchant and OSW developers (not system operators)

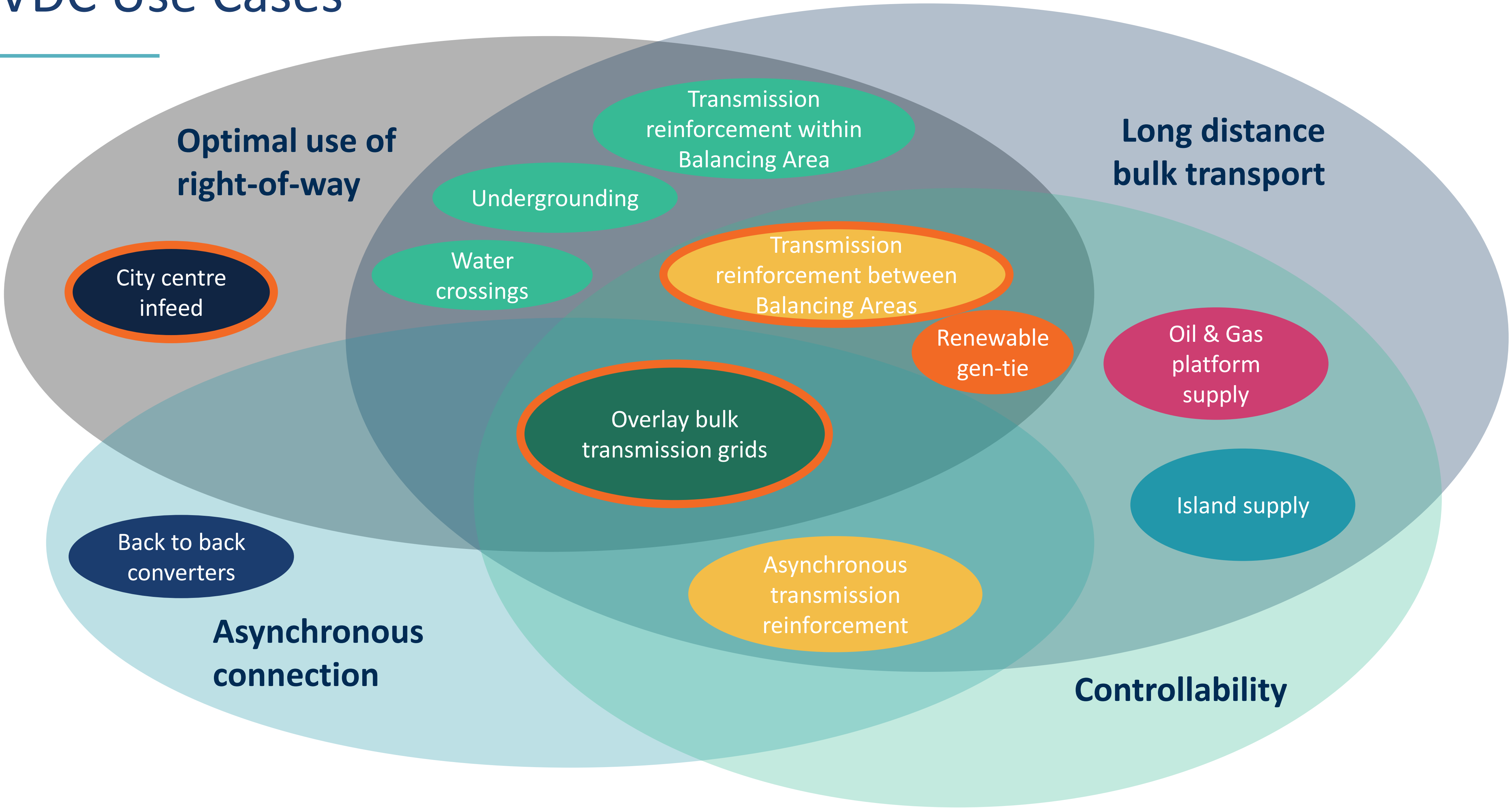
Railroad Right-of-Ways Cover Needed Transmission Corridors

National Network of Class I Railroads



Source: Cambridge Systematics, Inc., National Rail Freight Infrastructure Capacity and Investment Study, September 2007.

HVDC Use Cases



Thank You!

Comments and Questions?

Additional Slides

Additional Reading on Transmission

Pfeifenberger, Plet, et al., The Operational and Market Benefits of HVDC to System Operators, for GridLab, ACORE, Clean Grid Alliance, Grid United, Pattern Energy, and Allete, September 2023.

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Pfeifenberger et al., New Jersey State Agreement Approach for Offshore Wind Transmission: Evaluation Report, October 26, 2022.

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Pfeifenberger, The Benefits of Interregional Transmission: Grid Planning for the 21st Century, US DOE National Transmission Planning Study Webinar, March 15, 2022.

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Pfeifenberger et al., Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs, Brattle-Grid Strategies, October 2021.

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Van Horn, Pfeifenberger, Ruiz, "The Value of Diversifying Uncertain Renewable Generation through the Transmission System," BU-ISE, October 14, 2020.

Pfeifenberger, Newell, Graf and Spokas, "Offshore Wind Transmission: An Analysis of Options for New York", prepared for Anbaric, August 2020.

Pfeifenberger, Newell, and Graf, "Offshore Transmission in New England: The Benefits of a Better-Planned Grid," prepared for Anbaric, May 2020.

Tsuchida and Ruiz, "Innovation in Transmission Operation with Advanced Technologies," T&D World, December 19, 2019.

Pfeifenberger, "Cost Savings Offered by Competition in Electric Transmission," Power Markets Today Webinar, December 11, 2019.

Chang, Pfeifenberger, Sheilendranath, Hagerty, Levin, and Jiang, "Cost Savings Offered by Competition in Electric Transmission: Experience to Date and the Potential for Additional Customer Value," April 2019 and "Response to Concentric Energy Advisors' Report on Competitive Transmission," August 2019.

Ruiz, "Transmission Topology Optimization: Application in Operations, Markets, and Planning Decision Making," May 2019.

Chang, Pfeifenberger, "Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future," WIRES&Brattle, June 2016.

Newell et al. "Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades," on behalf of NYISO and DPS Staff, September 15, 2015.

Pfeifenberger, Chang, and Sheilendranath, "Toward More Effective Transmission Planning: Addressing the Costs and Risks of an Insufficiently Flexible Electricity Grid," WIRES and Brattle, April 2015.

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Brattle Group Practices and Industries

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