Empirical Estimates of Transmission Value: Conditions that Lead to High Value

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Outline

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  - Transmission value geographic patterns
  - Transmission value temporal trends
  - Drivers of peak transmission value
- **Conclusion**
  - Key takeaways

Transmission can facilitate electricity sector decarbonization but faces institutional barriers to deployment

Transmission is key to limiting decarbonization costs

- “Inter-state coordination and transmission expansion **reduce the system cost** of electricity in a 100%-renewable US power system by **46%**” [1]
- The **“no new transmission”** scenario achieved 100%-renewable generation by 2050 at **5% greater cost** than the baseline [2]
- To unlock the full emissions reduction potential of the Inflation Reduction Act, the **pace of transmission expansion must more than double the rate over the last decade** to reach an average of ~2.3%/year (comparable to the long-term average rate of transmission additions from 1978-2020). [3]
- While transmission spending increased through the 2010s, **construction of new high-voltage lines slowed** [4]

Standard approaches to planning transmission are being rethought

- Regulated planning processes typically establish a need for transmission to meet **reliability or public policy directives**
- **Economically-driven transmission is uncommon** and traditionally evaluated solely based on production cost savings
- The **tendency to underestimate congestion in planning** studies has been well-documented (e.g., [5], [6], [7])
- Multi-value planning approaches suggest that **total transmission benefits can dwarf production cost savings** [8]
  - Some regions are moving in this direction, for example MISO’s multi-value project tariff
- **Merchant** development has produced **few completed projects**

[1] Brown, P. R., & Botterud, A. “The value of inter-regional coordination and transmission in decarbonizing the US electricity system.” Joule, 2021
[2] Cole, Wesley J., et al. "Quantifying the challenge of reaching a 100% renewable energy power system for the United States." Joule, 2021
[3] Jenkins, J.D., et al. “Electricity Transmission is Key to Unlock the Full Potential of the Inflation Reduction Act,” REPEAT Project, 2022.
[4] Casparty, J., et al. “Fewer New Miles: The US Transmission Grid in the 2010s.” Grid Strategies, 2022
[5] J. Pfeifenberger et al., “Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs,” Brattle Group, Oct. 2021.
[6] K. Van Horn, J. Pfeifenberger, and P. Ruiz, “The value of diversifying uncertain renewable generation through the transmission system,” Sep. 2020
[7] S. Newell et al., “Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades,” Sep. 2015
[8] D. Stenclik and R. Deyoe, “Multi-Value Transmission Planning for a Clean Energy Future,” Energy Systems Integration Group, Jun. 2022.

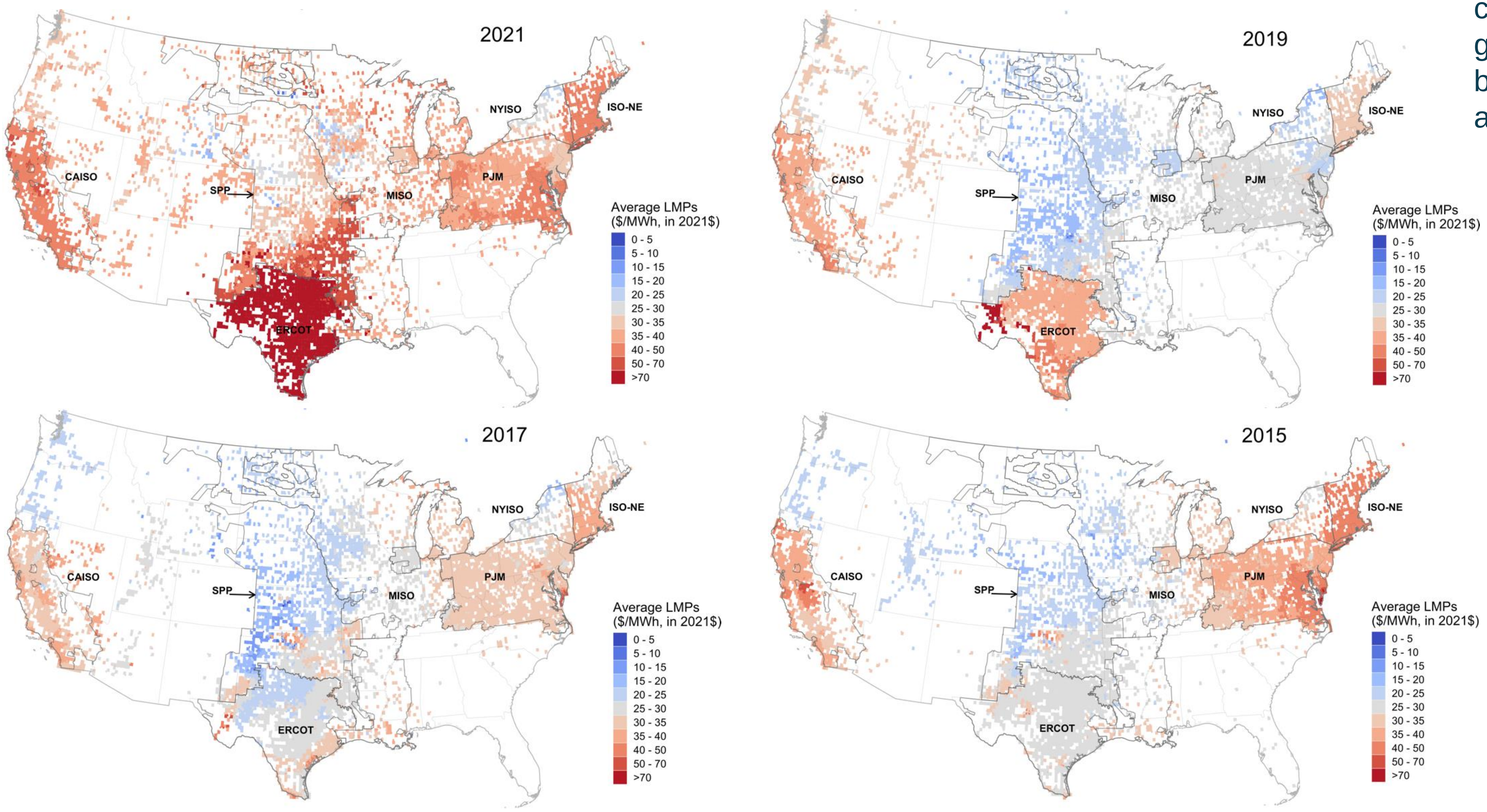
Goal: To offer unique insights into where, when, and why transmission is valuable

Approach

- Empirical analysis of recent (2012-2022) system outcomes
- Market-focused
- Considers transmission across the continental US, including new pathways and between already-connected balancing areas
- Examines drivers of transmission demand beyond specific severe weather events

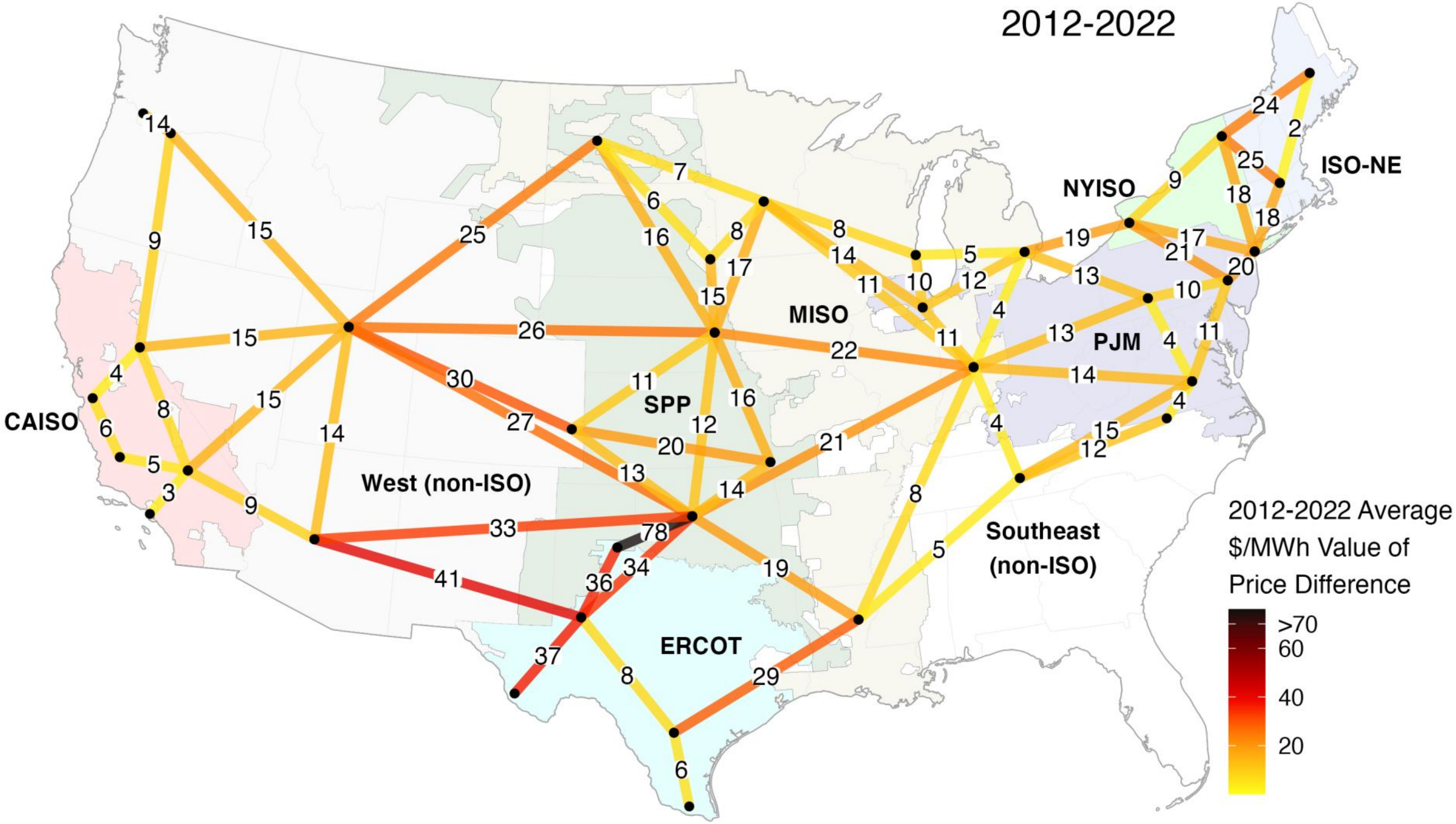
Estimating Transmission Market Value with Locational (Nodal) Market Prices (LMPs)

Context: Annual average real-time nodal wholesale electricity prices vary strongly by year and location



Beyond the clear difference in price between years, one can observe spatial gradients in prices both within regions and across regions

Historical market pricing patterns suggest that high-value transmission links are found throughout the country



2012-2022 for most, 2015-2022 for a few

Methodology: We are analyzing market signals for the value of additional transmission, according to spatial differences in observed prices

Definition

Mean marginal transmission market value between nodes A and B $= \frac{1}{n}\sum_{t=1}^{n}\left|price_t^A - price_t^B\right|$

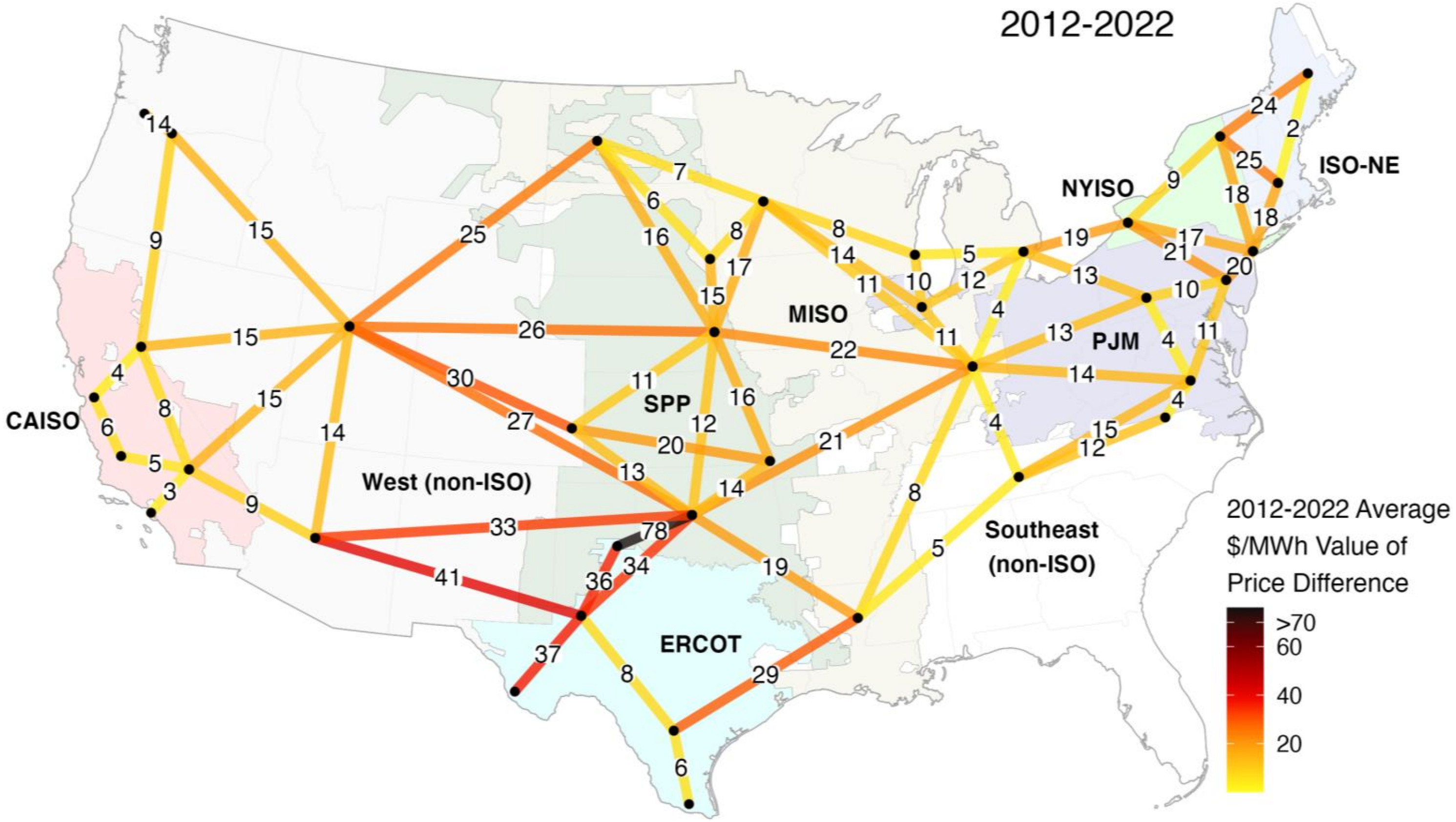
Interpretation

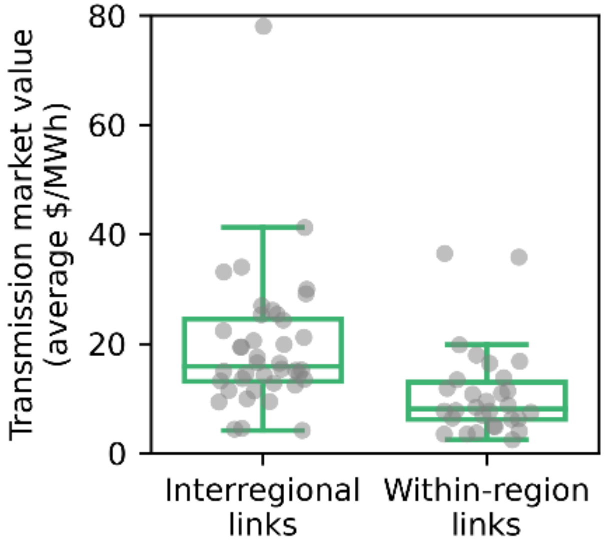
- Average "locational spot price of transmission"
- Average hourly payment from holding two financial transmission right (FTR) options of equal size: one from A to B and one from B to A.
- If the link were an existing line, the average congestion (i.e., shadow) price of the line's transmission constraint

Limitations

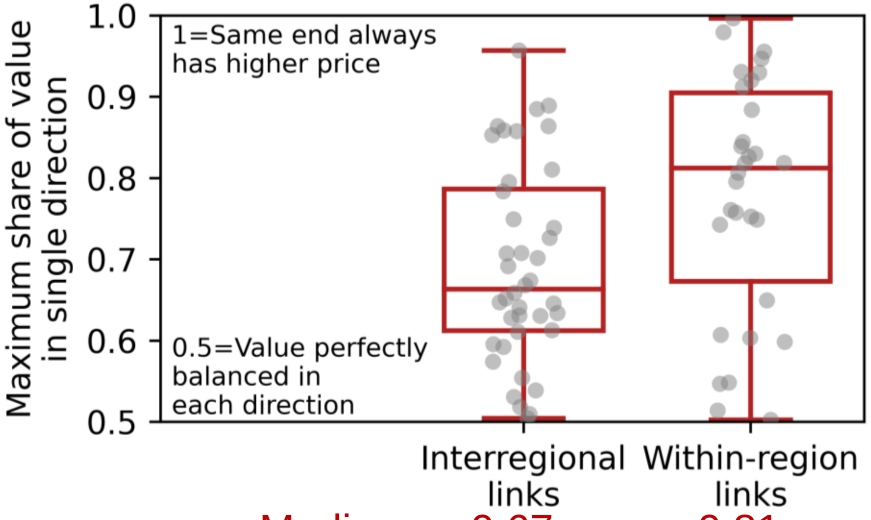
- Does not capture all benefits of transmission (e.g., reduction in un- or mis-priced emissions)
- Ignores dynamic impacts of transmission investment
- Is a marginal quantity and therefore does not reflect saturation effects that come with building substantial new transmission capacity

Interregional links are typically more valuable and directionally balanced than those contained within a single region



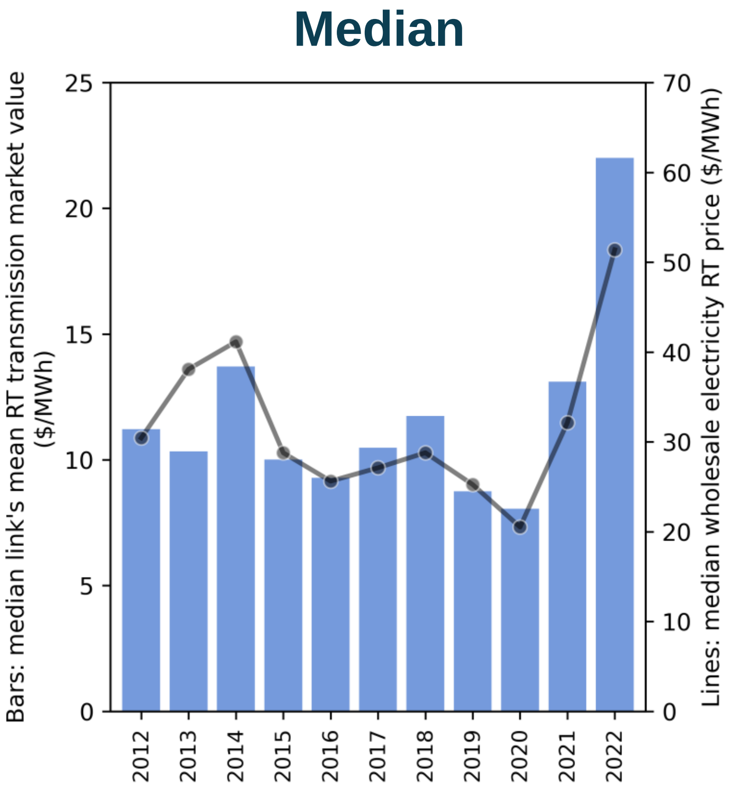


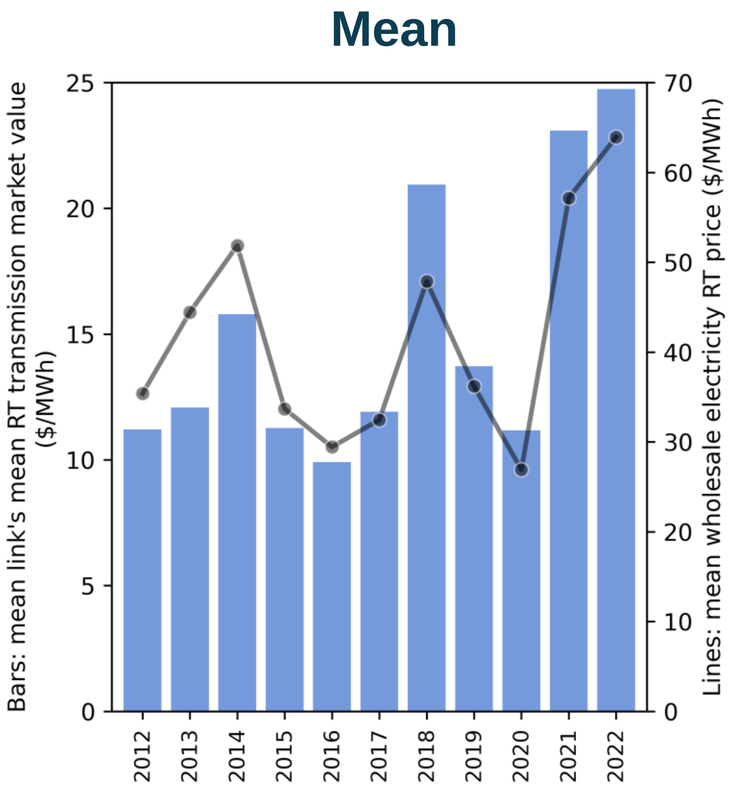
Median: $18/MWh $9/MWh



Median: 0.67 0.81

Transmission market value was greater in 2022 than during any other year in the previous decade

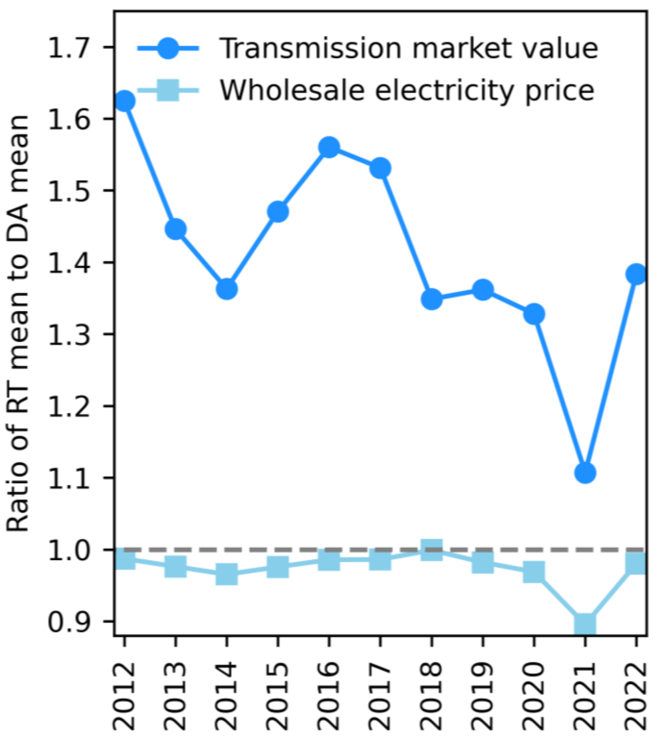




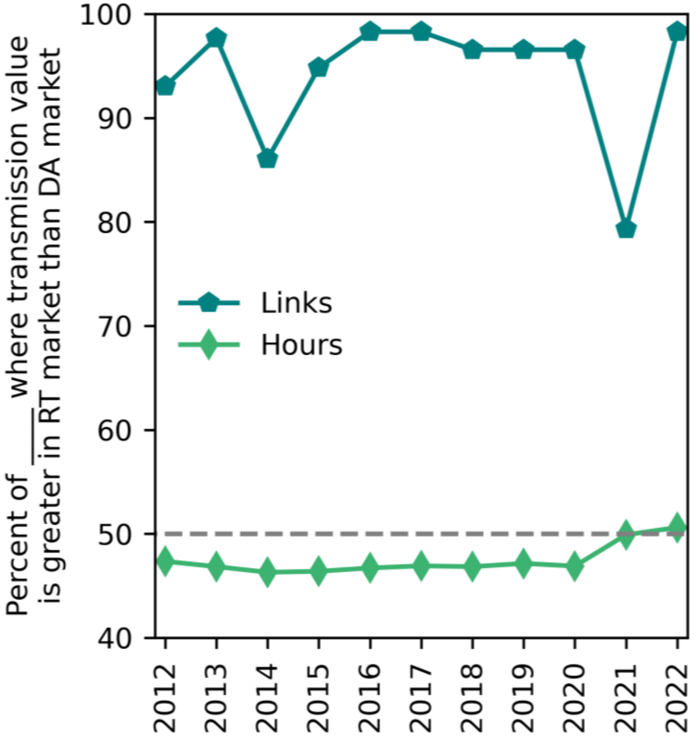
- 2018, 2021: High mean, moderate median → regional events drove extremely high values locally
- 2022: High mean and median → nationwide cause
- Value is correlated with electricity prices

Transmission value is greater in real-time markets, driven by hours with large increases in value after the day-ahead market clears

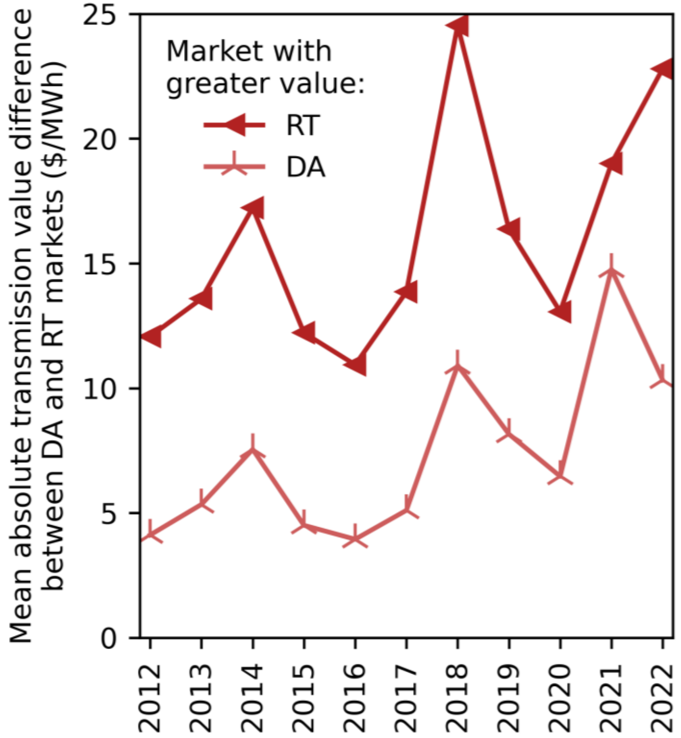
On average, transmission value is greater in RT than DA, despite lower prices.



RT value is greater for most links, yet hourly values increase and decrease from DA to RT with similar frequency



DA to RT increases in transmission value are larger than DA to RT decreases.



Greater transmission value variation in RT (σ=42) than DA (σ=16)

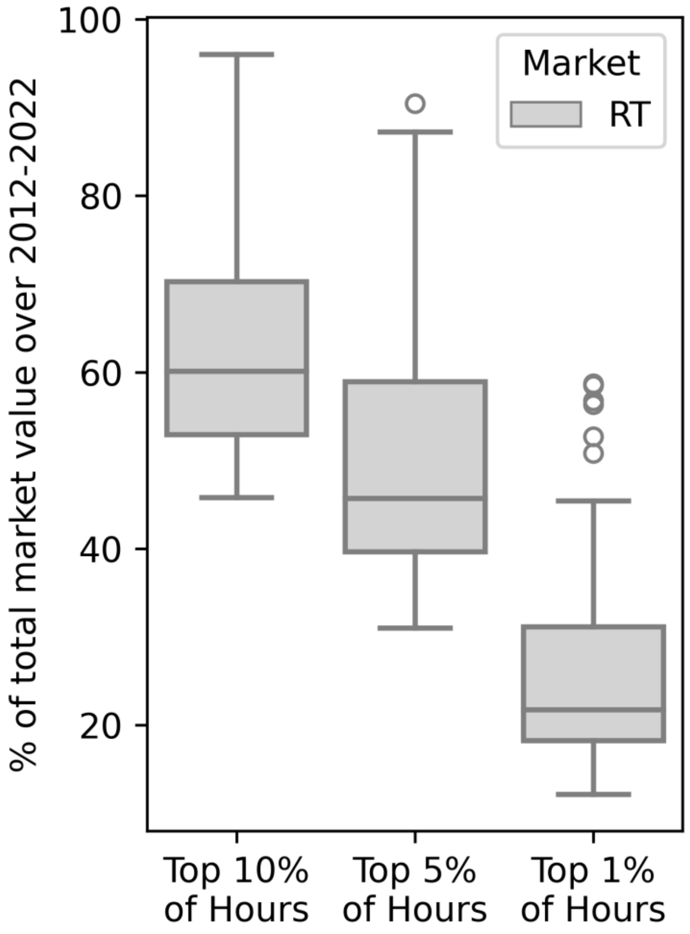
Transmission value is concentrated in time, presenting modeling challenges

Findings in the real-time market

- All links: ≥45% of value is in **10%** of hours
- Majority of links: ≥45% of value is in **5%** of hours

Implications

- It is challenging to capture conditions that happen ≤5% of the time in models
- Transmission analyses should capture a significant time horizon, since some years won't include a top 1% or even top 5% transmission value
- This pattern is similar to storage, at least in some markets[1], but is different from most generation



[1]"Annual ERCOT Storage Report 2022," Gridmatic, May 2023

Drivers of peak transmission value

Analysis of 52 links between or within ISO/RTO footprints

Understanding what drives transmission value is key to reducing barriers to deployment

PRELIMINARY

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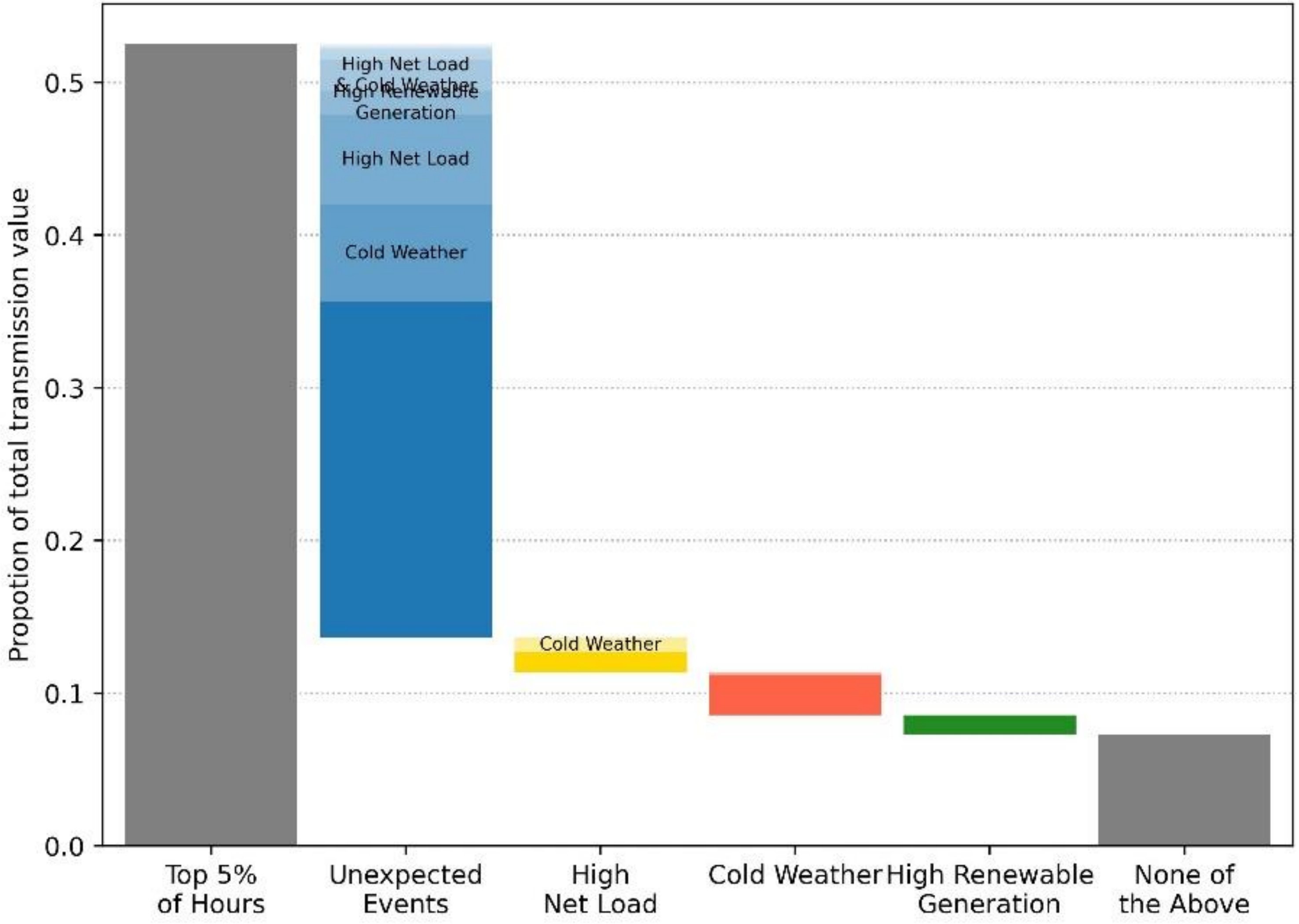
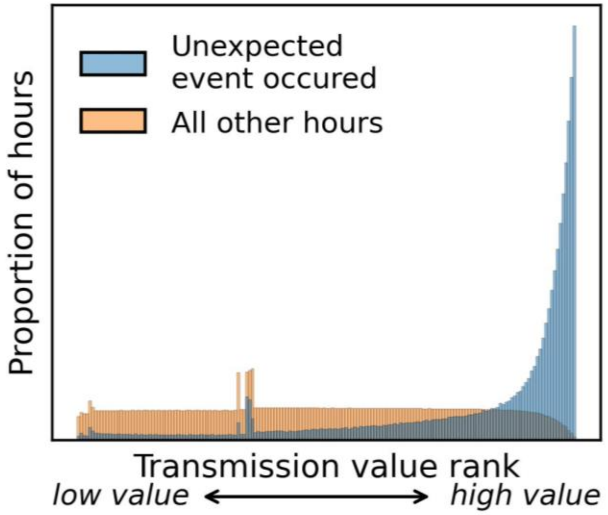


Condition	Definition
Unexpected Event	Large price change (↑ or ↓) between DA and RT for either side • ≥50% and $40/MWh
High Net Load	≥95th percentile net load hour for either side • ISO/RTO-level
Cold Weather	≥95th percentile heating degree day for either side • Regional
High Renewable Generation	≥95th percentile wind + solar hour for either side • ISO/RTO-level

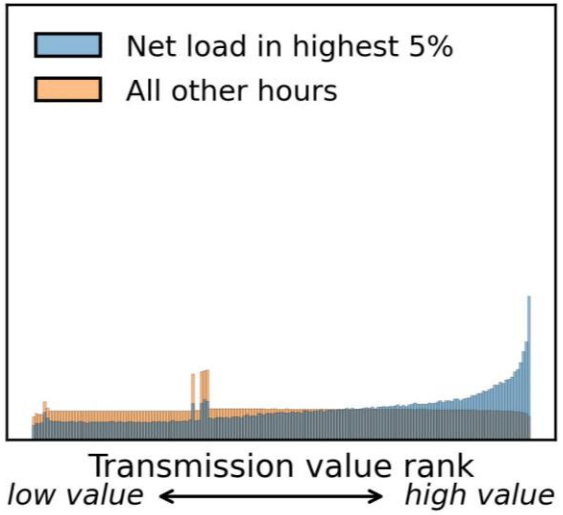
- Severe storms' impacts are captured by the conditions above
- Hot weather had less impact on peak value and overlapped almost entirely with other 4 conditions

Evidence for causality: Not only are these conditions important to peak value, but they are less common during times of low transmission value

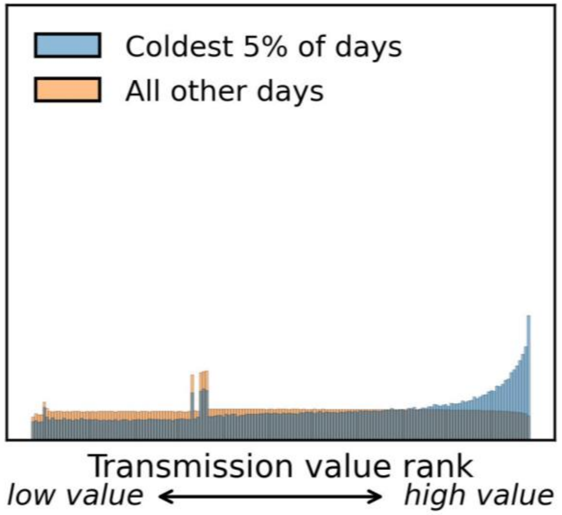
Unexpected events



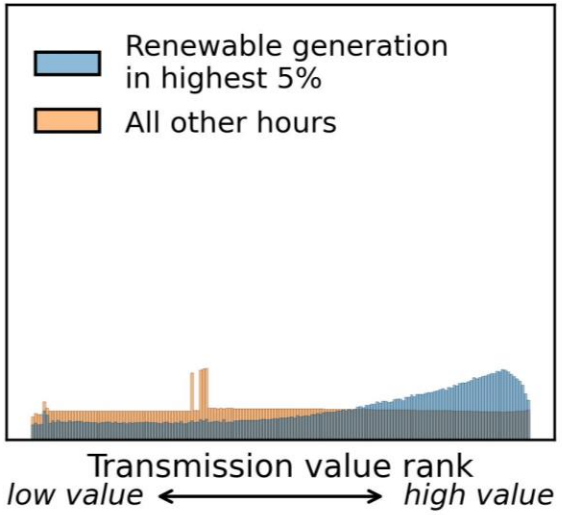
High net load



Cold weather



High renewable generation



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Conclusion

Key take-aways from transmission market value trends and drivers

- There are numerous links with high transmission market value, yet few completed merchant projects
  - ➡ Significant barriers to entry
- Links connecting different regions have the greatest potential and see symmetry in the benefits
  - ➡ Importance of interregional planning
  - ➡ Relevant to recent policy proposals to set interregional transfer minimums
- The market value of transmission is highly influenced by a small portion of time during which transmission is extremely valuable
  - ➡ Challenge for planning models to capture infrequent conditions
- Transmission value is greater and especially concentrated in the real-time market
  - ➡ Planning processes should consider real-time conditions, not just day-ahead
- Peak transmission value is primarily driven by events that are unforeseen a day or two in advance, though high net load, cold weather, and high levels of wind and solar generation also contribute
  - ➡ Relationships between renewables development and congestion are important for decarbonization

Contact and acknowledgements

Contact: Julie Kemp (jmulvaneykemp@lbl.gov)

Report: https://emp.lbl.gov/publications/empirical-estimates-transmission

More Information: https://emp.lbl.gov

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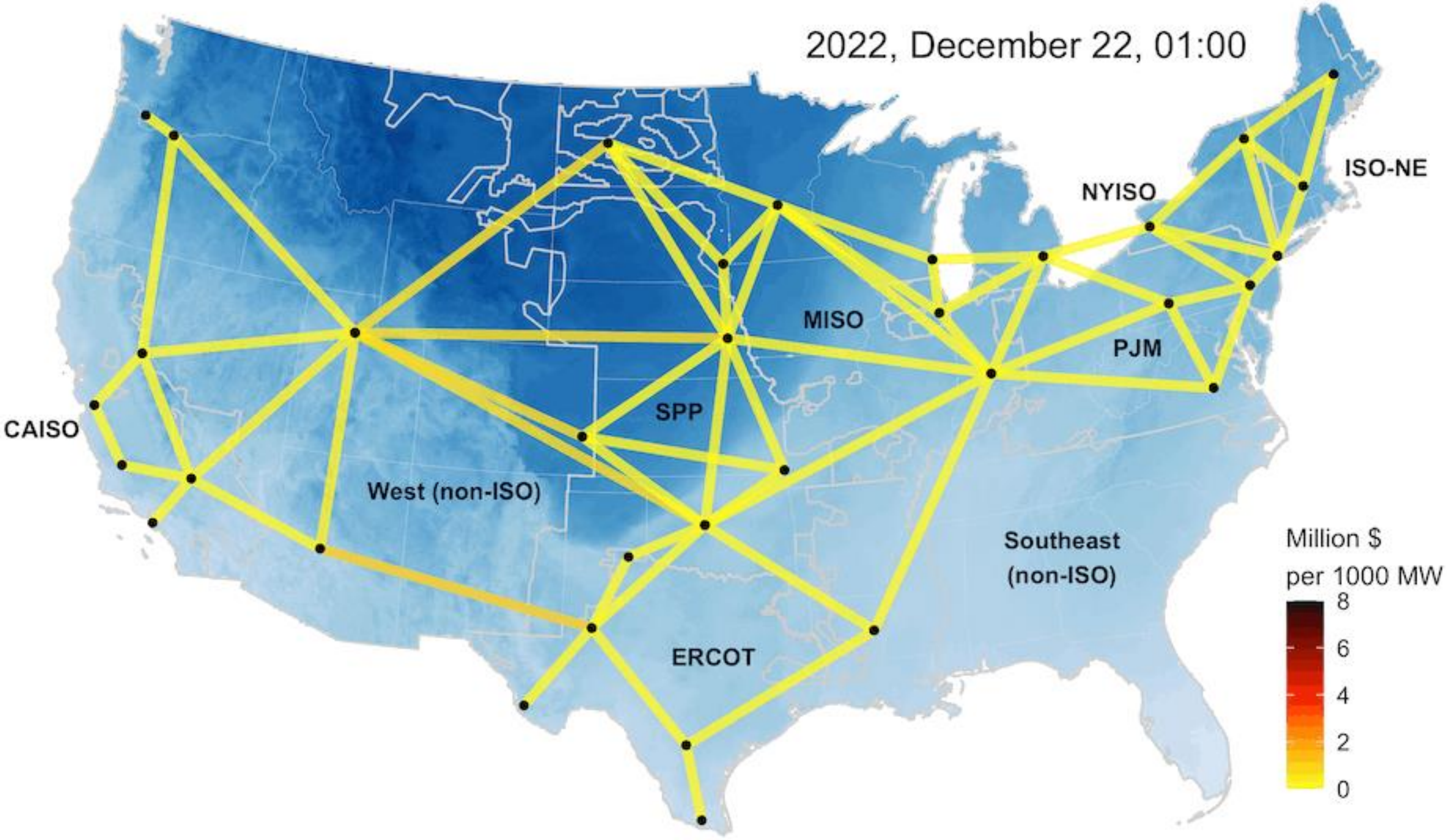
Appendix

Transmission value followed Winter Storm Elliott as it moved from west to east



Winter Storm Elliott provided a substantial portion of total 2022 transmission value in some regions of the country