Intertie Optimization: Efficient Use of Interregional Transmission (Update)

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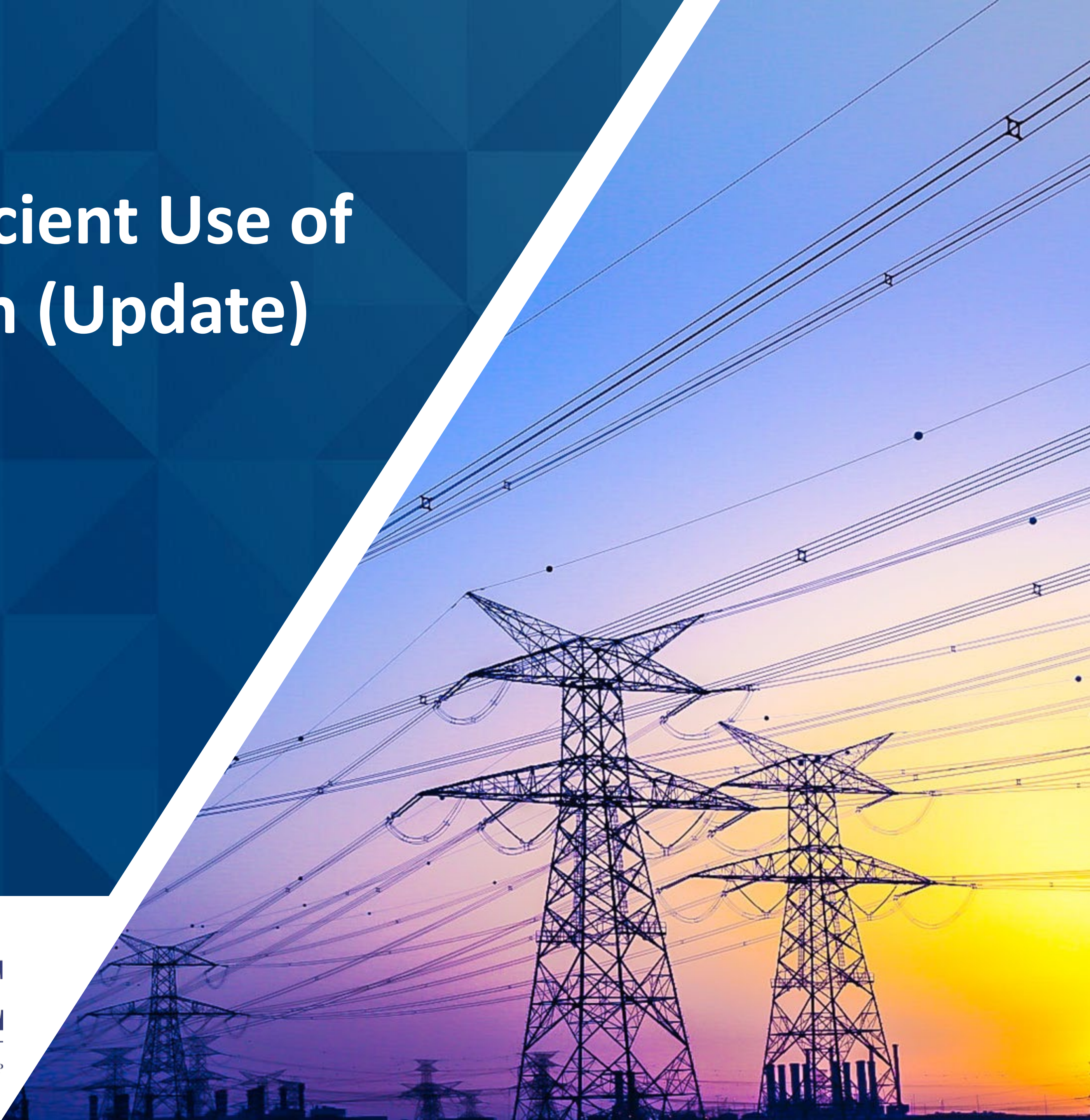


Five Sources of Inefficiencies Created by RTO Seams

Seams between RTOs will generally be more efficient than seams between non-market regions that rely entirely on bilateral trades. Nevertheless, significant seams-related inefficiencies exist between RTO markets:

1. **Interregional transmission planning** is ineffective (as discussed in the appendix slides)
2. **Generator interconnection** delays and cost uncertainty created by affected system impact studies (and effectiveness coordination through means such as the SPP-MISO JTIQ, reducing costs by 50%)
3. **Resource adequacy** value of interties (often not considered in RTO's resource adequacy evaluations) and barriers to capacity trades (often created by RTOs' restrictive capacity import requirements and incompatible resource accreditations)
4. **Loop flow management** inefficiencies through market-to-market coordinated flowgates (with shares of firm flow entitlements) under the existing JOAs
5. **Inefficient trading** across contract-path market seams and the need for intertie optimization (as discussed next)

First Step: More Efficiently Utilize Interregional Transmission

The time is ripe to consider "intertie optimization" to reduce seam-related inefficiencies!

- NYISO, ISO-NE, and Potomac Economics have called for intertie optimization in 2010-2011 to address seam-related inefficiencies, but only "coordinated transaction scheduling"(CTS) was implemented at the time
- A decade later, market monitors continue to document seams-related inefficiencies, noting that CTS has not been effective, and recommending intertie optimization
- The Western energy imbalance markets and European "market coupling" experiences have shown that intertie optimization between BAAs offers substantial benefits—reducing costs, improving reliability and renewable integration—
  - Has dramatically improved efficient utilization of interregional transmission
  - Does not require "cost allocation" for new transmission
  - Provides value of optimized transactions directly to transmission owners and their customers
  - Widely embraced; FERC approved; WEIM reduced costs by over $5 billion since inception

Coordinated Transaction Scheduling vs. Intertie Optimization

Coordinated Transaction Scheduling (CTS)

- 75+min prescheduled 15-min transactions, based on forecasts, which often results in uneconomic trades
- Based on CTS bids by traders, who need to reserve transmission (at a cost)
- Transmission charges reduce CTS efficiency
- If transmission charges are eliminated, traders capture value of transactions (free rides)
- Experience:
  - Low transaction volume due to costs and risk of inefficient trades;
  - Has not been able to improve inefficient use of interregional transmission

Intertie Optimization

- Optimized in real time every 5 min, greatly reducing the frequency of uneconomic trades
- Optimized by RTOs using transmission that remains available after bilateral markets have closed
- Hurdle-free optimization increases market efficiency
- Value of transactions shared by RTOs (i.e., their transmission owners and, ultimately, customers)
- Experience:
  - High transaction volume with substantial benefits to participating BAAs (e.g., Western EIM)
  - Can greatly reduce inefficient use of interregional transmission (e.g., European “market coupling”)

Bottom Line: CTS is not working – not for Traders, not for RTOs, not for TOs, and not for Customers

See also: Frequently Asked Questions

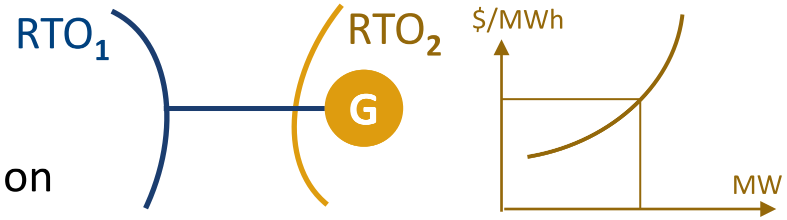
Intertie Optimization: Implementation Options

How would RTOs/ISOs determine and schedule optimal intertie transactions?

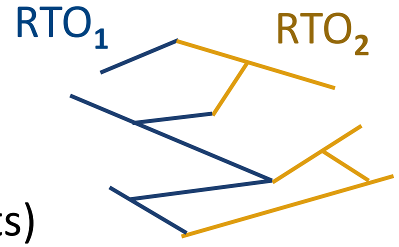
The RTOs would use their existing market optimization SCED engines to optimize intertie schedules subject to available intertie capabilities after all bilateral transactions are closed

- As the PJM IMM explains, this would: "include an optimized, but limited, joint dispatch approach that uses supply curves and treats seams between balancing authorities as constraints, similar to other constraints within an LMP market"

1. **Contract-path option**: treat the contract path across the interface like a single line with a generator (representing the neighboring region) dispatched through SCED.
   - The neighboring region would provide generation supply curve (incremental/decremental cost of importing more or less) for RT intervals
   - Simplest, will increase efficiency, but not optimally use full physical transmission



2. **Flow-based option:** represent interface physically with limiting flow gates
   - The neighboring region provides binding flow gates and marginal generators with shift factors on these flow gates (ISO-NE's 2014 IEEE "Marginal Equivalent" proposal)
   - Will use full physical capability (ISO-NE simulations achieve 99% of full optimization)



3. **Combined SCED option:** used full, multi-regional SCED (similar to Western imbalance markets)
   - Assures full optimization but likely impractical for existing market-based regions

See also: Frequently Asked Questions

FERC Has the Authority to Implement Intertie Optimization

- FERC has long recognized the inefficiencies of market seams. *See* Order No. 888 & Order No. 2000
- FERC's authority to address seams issues is clear given its duty to ensure just and reasonable rates
- There is well established precedent for FERC to address market seams:
  - Coordinated Transaction Scheduling (ISO-NE-NYISO; NYISO-PJM; and PJM-MISO)
  - Western EIM and EIS
  - FERC precedent with respect to CTS: recognizing the value of "Tie Optimization" and leaving the door open. *See NYISO*, 139 FERC ¶ 61,048 (2012) (recognizing the possibility of replacing CTS with a "different methodology for scheduling external transactions (i.e., Tie Optimization or a superior alternative), if it is determined that such changes could result in greater cost savings")
- If the RTOs/ISOs propose intertie optimization, FERC has the clear authority to accept the filing under section 205. FERC would also be able to require intertie optimization under FPA section 206

The Bottom Line

The time is ripe to consider "intertie optimization" to reduce seam-related inefficiencies and barriers to interregional transmission development, including for merchant lines that provide regional market benefits without regulated cost recovery from all customers

- NYISO, ISO-NE, and Potomac Economics have called for intertie optimization in 2010-2011 to address seam-related inefficiencies, but only CTS was implemented
- A decade later, market monitors continue to document seams-related inefficiencies, noting that CTS has not been effective, and recommending intertie optimization
- The Western energy imbalance markets and European "market coupling" experiences have shown that intertie optimization between BAAs offers substantial benefits: reducing costs, improving reliability and renewable integration—dramatically improving utilization of interregional transmission
  - The Western EDAM and Markets+ will further enhance the value of intertie optimization across BAA seams on a Day-Ahead time frame
- CAISO's new "Subscriber PTO" proposal integrates available capacity on merchant transmission projects for optimization in the regional and interregional energy markets
- FERC has the authority to approve/implement intertie optimization under either section 205 or 206 of the FPA

Thank You!

Comments and Questions?

See also: Frequently-asked Questions

Additional Slides

About the Speaker

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Johannes (Hannes) Pfeifenberger, a Principal at The Brattle Group, is an economist with a background in electrical engineering and over twenty-five years of experience in wholesale power market design, renewable energy, electricity storage, and transmission. He also is a Visiting Scholar at MIT's Center for Energy and Environmental Policy Research (CEEPR), a Senior Fellow at Boston University's Institute of Sustainable Energy (BU-ISE), a IEEE Senior Member, and currently serves as an advisor to research initiatives by the U.S. Department of Energy, the National Labs, and the Energy Systems Integration Group (ESIG).

Hannes specializes in wholesale power markets and transmission. He has analyzed transmission needs, transmission benefits and costs, transmission cost allocations, and renewable generation interconnection challenges for independent system operators, transmission companies, generation developers, public power companies, industry groups, and regulatory agencies across North America. He has worked on transmission matters in SPP, MISO, PJM, New York, New England, ERCOT, CAISO, WECC, and Canada and has analyzed offshore-wind transmission challenges in New York, New England, and New Jersey.

He received an M.A. in Economics and Finance from Brandeis University's International Business School and an M.S. and B.S. ("Diplom Ingenieur") in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.

Recall: NYISO & ISO-NE Recommended Intertie Optimization in 2011

NYISO & ISO-NE offered fully-specified, implementable designs for intertie optimization:

- Intertie Optimization: similar to the least-cost economic dispatch system used internally for each ISO's energy market, it relies on "market-based offers to determine the real-time schedule of energy interchange between their interconnected transmission networks" (see updated 2014 optimization framework*)
- Proposal was similar to PJM IMM recommendation since 2014: "The MMU recommends that PJM explore an interchange optimization solution with its neighboring balancing authorities that … would include an optimized, but limited, joint dispatch approach that uses supply curves and treats seams between balancing authorities as constraints, similar to other constraints within an LMP market"

The ISOs recommended the Intertie Optimization as their preferred solution because:

- Intertie optimization "is the more efficient solution" (and consistent with existing ISO roles of independent LMP-based market and settlement administrators)

Only CTS was implemented between NYISO and ISO-NE (and later PJM and MISO):

- It was hoped that CTS, as the less complex solution, might be almost as efficient
- Years of experience now show that CTS is not effective

* Zhao, Litvinov, and Zheng, "A Marginal Equivalent Decomposition Method and Its Application to Multi-Area Optimal Power Flow Problems," IEEE Transactions on Power Systems, Volume 29, Issue 1 (2014). (Successfully tested large-scale simulations of a "marginal equivalence" approach that works for both RTO and non-RTO seams)

2023 Update: Interregional Transmission is Poorly Utilized

2023 PJM State of the Market Report: power flows the wrong way 40-50% of the year!

- Price differences across the MISO-PJM seam exceeded $5/MWh during 3,331 hours; yet during 1,519 (43%) of these hours, market flows were inconsistent with those price differences, exporting power from the higher-priced market to the lower-priced market
- On PJM-NYISO interties, price differences exceeded $5/MWh during 4,218 hours, with inconsistent market flows during 1,641 (50%) of these hours

Potomac Economics previously observed similar intertie inefficiencies:

- On MISO's seams: "more than 40 percent of … transactions are ultimately unprofitable"
- Between NYISO and ISO-NE: the efficiency of real-time trades has been deteriorating, achieving "optimal" RT transactions during only 11% of all trading periods in 2022, down from 23% in 2018

This inefficiency is particularly pronounced and consequential in real-time markets, for which intertie optimization offers the only effective solution

- **Day-ahead**: average (absolute) value of 2023 PJM-NYISO price difference of $4.62/MWh with price differences changing signs 2.9 times per day. With absolute PJM-MISO difference = $3.72/MWh, changing sign 3.8 times/day
- **Real-time**: average (absolute) PJM-NYISO price difference of $11.04/MWh with sign changing sign 49 times each day. With absolute PJM-MISO difference = $10.21/MWh, changing sign 61 times each day

Estimated Value of Intertie Optimization: SPP, MISO and PJM

Volatility of price differences between SPP, MISO, and PJM shows that intertie optimization is needed to capture 20-30% of the total real-time transmission value

- Our analysis 2020-2022 price differences point to a high “book-end” value if interregional transfer capacity could be used more optimally for RT energy market transactions
  - **Bilateral trades** that respond to observed RT price differences with a 1-2 hour delay would typically **capture only 70-80%** of the total energy value of interties, including during reliability events
  - The value that cannot be captured by through bilateral trades consequently is roughly **20-30% of the total real-time value** (assuming a 1-2 hour delay of trades in response to observed prices)

This represents an average value of approx. $50-60 million/year for every 1,000 MW of intertie capacity

- It can only be captured by system operators through automated operational means, such as intertie optimization or an interregional energy imbalance market (similar to the Western EIM or EIS)

For merchant transmission lines, intertie optimization revenues would need to accrue to either the transmission owner or its subscribers

- See CAISO Subscriber PTO proposal

Experience with Intertie Optimization: WECC and Europe

The Western EIM and Western EIS have been created to optimize in real-time the available transmission across the interregional seams between multiple Balancing Areas in the WECC

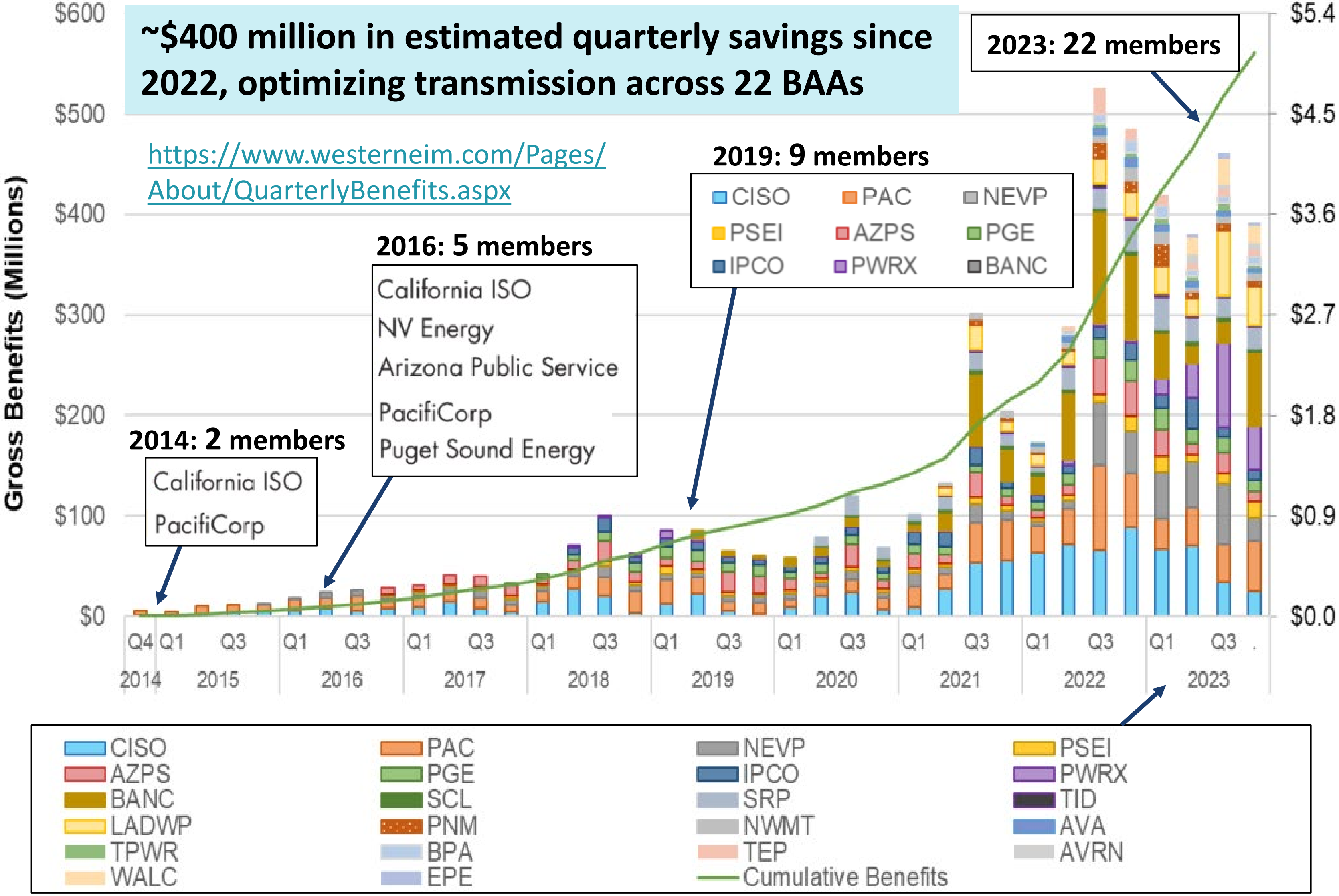
- Depancaked WEIM and WEIS transactions are scheduled on a 15-minute/ 5-minute basis after all bilateral trading has closed (approximately 20 minutes before each real-time operating period), using transmission that remains available and otherwise would go unutilized
- $5 billion in savings now accrued to the neighboring BAAs and other entities that contribute available transmission
- Real-time optimization of interregional transmission now expanded to day-ahead markets (EDAM)
- CAISO's Subscriber PTO framework: integrate unutilized capacity on merchant transmission lines into regional and interregional DA and RT energy markets

Flow-based "Market Coupling" in central and western Europe (for transmission left available after bilateral day-ahead and intra-day trading closes) is currently expanded to Scandinavia

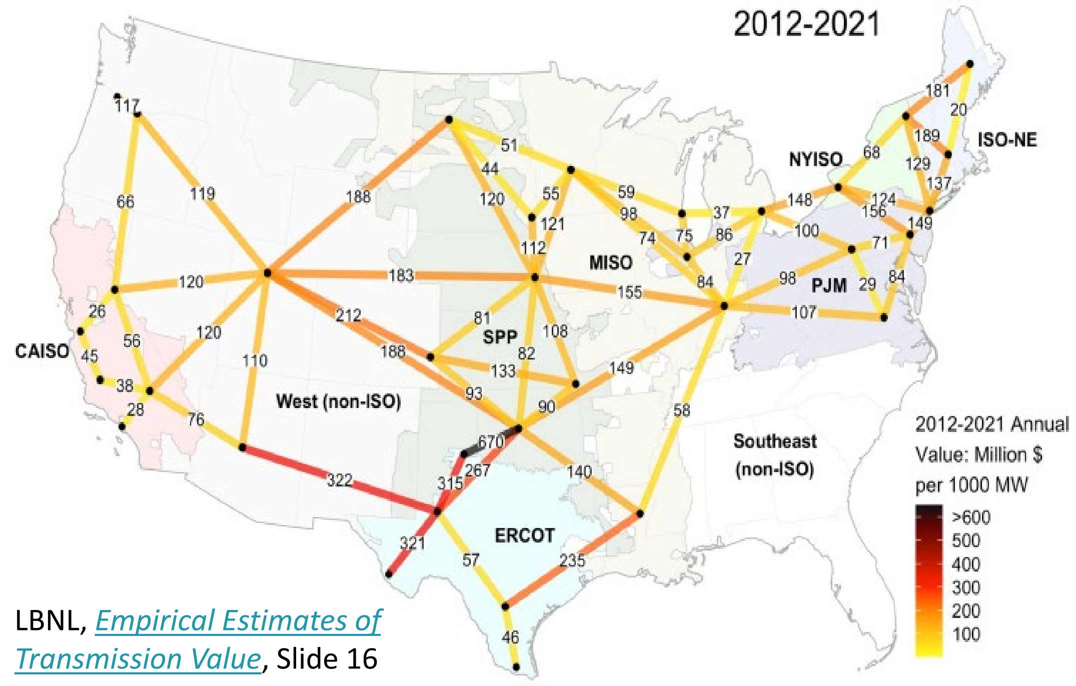
2023 WEIM Update: $5 billion savings from transmission optimization across multiple BAs in RT energy markets

~$400 million in estimated quarterly savings since 2022, optimizing transmission across 22 BAAs

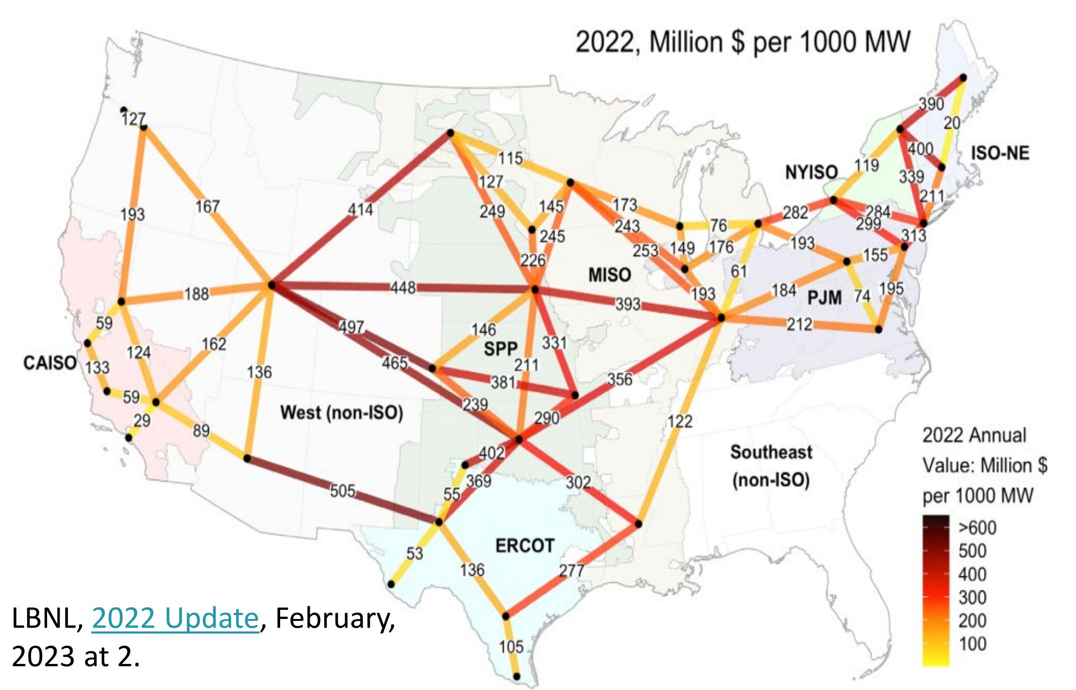
https://www.westerneim.com/Pages/About/QuarterlyBenefits.aspx



LBNL Empirical Estimates of the Value of Interregional Transmission



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



LBNL, 2022 Update, February, 2023 at 2.

Sources: LBNL, Empirical Estimates of Tx. Value (Aug 2022), Slide 16; The Latest Market Data Show that the Potential Savings of New Electric Transmission was Higher Last Year than at Any Point in the Last Decade, Fact Sheet, LBNL (Feb 2023) at 2.

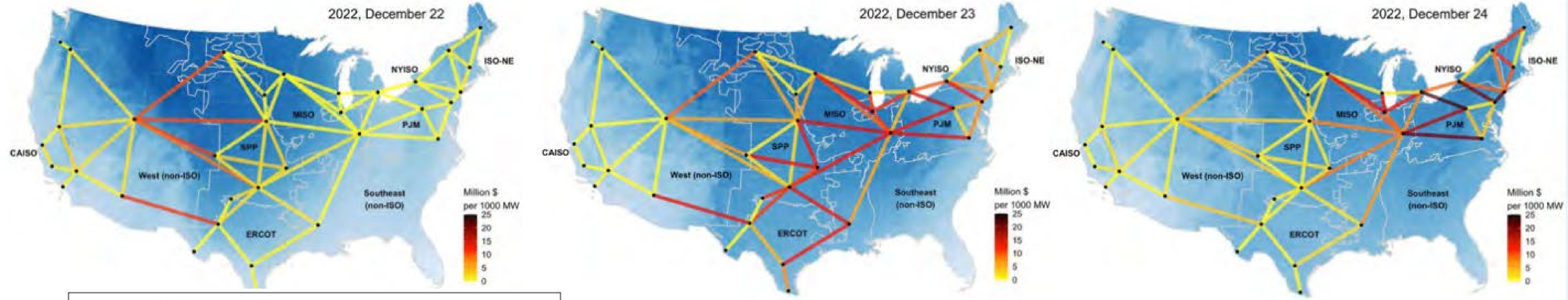
Methodology: Transmission value based on historical real-time price difference between regional nodes

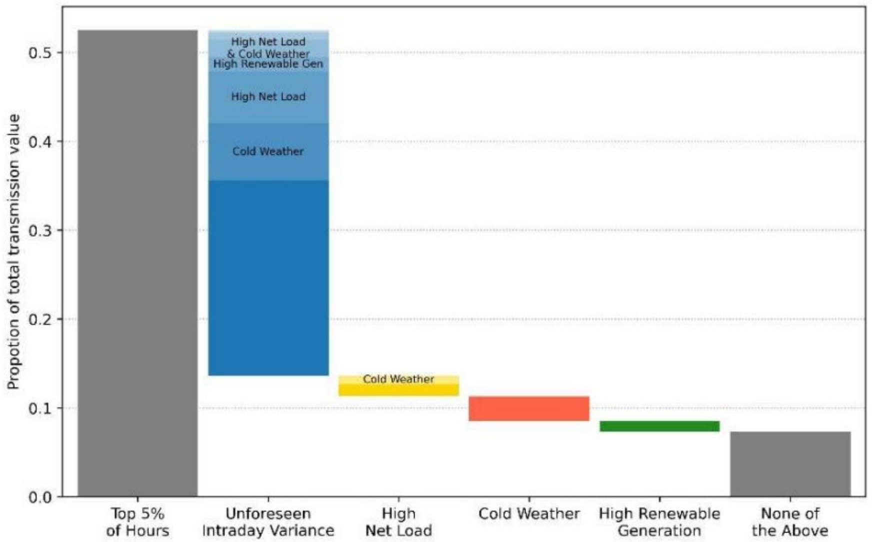
Study Findings:

- Interregional links have greater value than regional links
- **40-80% of transmission's congestion value is from 5% of hours due to extreme conditions,** 20-30% from top 1% of hours reflecting the high impact of challenging system conditions
- The value in some of the recent years (e.g., 2021, 2022) is double the 10-year average

Value of Transmission is Concentrated in Few Unpredictable Hours

Highest transmission congestion is concentrated in relatively few hours of the year and during extreme events. Example: Winterstorm Elliot (2022)





Findings:

- Real-time values (reflecting actual conditions) are higher than DA values
- On average, about half of the value is concentrated in top 5% of all hours
- Most of that value is due to real-time market conditions that are not foreseeable on a day-ahead basis
- Estimated benefits exceed estimated costs for all interregional projects

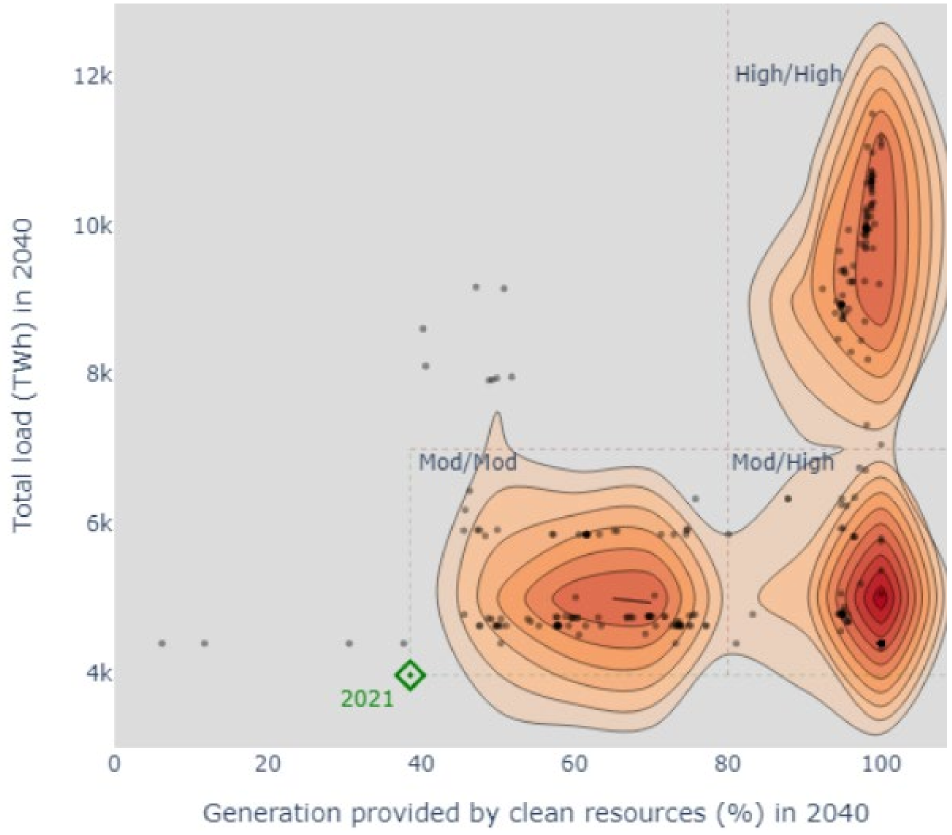
Sources: LBNL, Transmission Value Manuscript NatureEnergy (March 29, 2024); Department of Energy's 2023 National Transmission Needs Study (Oct 2023)

DOE's 2023 Transmission Needs Study: Review of National Analyses

DOE's National Transmission Needs Study documented high historical value of interregional transmission and summarized numerous results from six national studies into 3 groups of scenarios:

1. **Mod/Mod** = status-quo: moderate load growth and 40-70% clean-energy shares
2. **Mod/High** = moderate load growth but high (90+%) clean-energy shares
3. **High/High** = high electrification load growth and high clean-energy shares

"Need" = optimal regional/interregional transmission expansion that minimizes total system-wide costs
("Expansion" = enhancing the existing grid & existing ROW plus new transmission lines)



DOE's 2023 Transmission Needs Study: Interregional Needs

Example: Existing and cost-effective additional interregional transmission capacity between SPP, MISO-N, PJM, and NYISO:

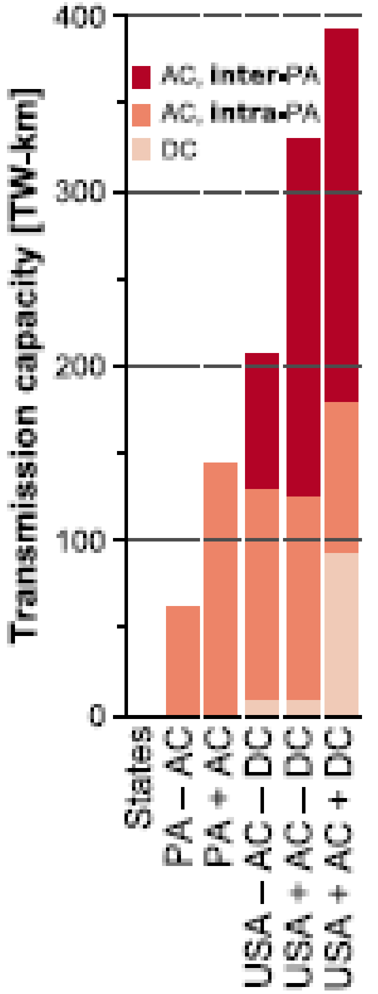
Table VI-4. Median regional transfer capacity results for each scenario group in 2030, 2035, and 2040. Both new transfer capacity in GW and percent growth from 2020 system are shown.

Regional Pair	2020 GW	Scenario Group	New in 2030		New in 2035		New in 2040	
			GW	% Growth	GW	% Growth	GW	% Growth
Midwest – Plains	12.1	Mod/Mod	1.35	11.2%	3.14	26.0%	3.62	30.1%
Midwest – Plains	12.1	Mod/High	7.99	66.3%	21.1	175%	23.0	191%
Midwest – Plains	12.1	High/High	24.6	204%	88.0	731%	98.7	819%
Mid-Atlantic – Midwest	21.7	Mod/Mod	1.10	5.1%	2.39	11.0%	2.65	12.2%
Mid-Atlantic – Midwest	21.7	Mod/High	9.87	45.5%	33.8	156%	21.9	101%
Mid-Atlantic – Midwest	21.7	High/High	42.4	196%	103	475%	119	550%
Mid-Atlantic – New York	2.00	Mod/Mod	0.00	0.0%	0.29	14.7%	0.81	40.6%
Mid-Atlantic – New York	2.00	Mod/High	0.00	0.0%	2.43	122%	14.8	742%
Mid-Atlantic – New York	2.00	High/High	2.03	102%	8.24	412%	12.7	634%

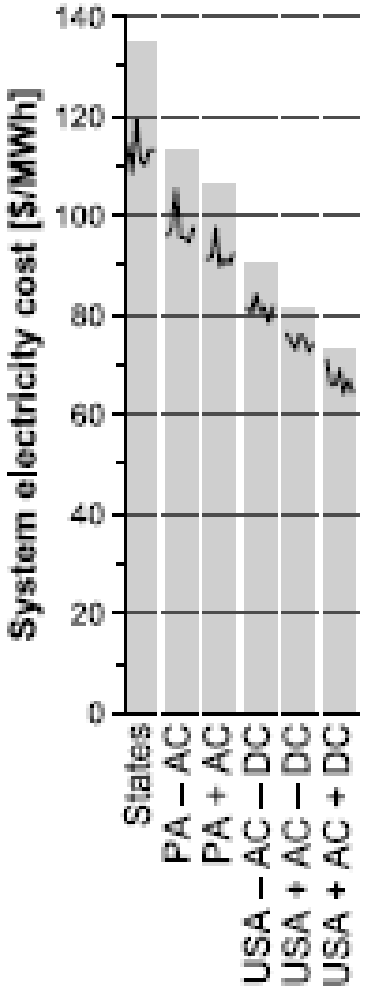
Source: DOE, National Transmission Needs Study, October 2023, Table VI-4, p. 131-133

MIT Study: Cost Reductions Enabled by Interregional Transmission

TRANSMISSION ↑

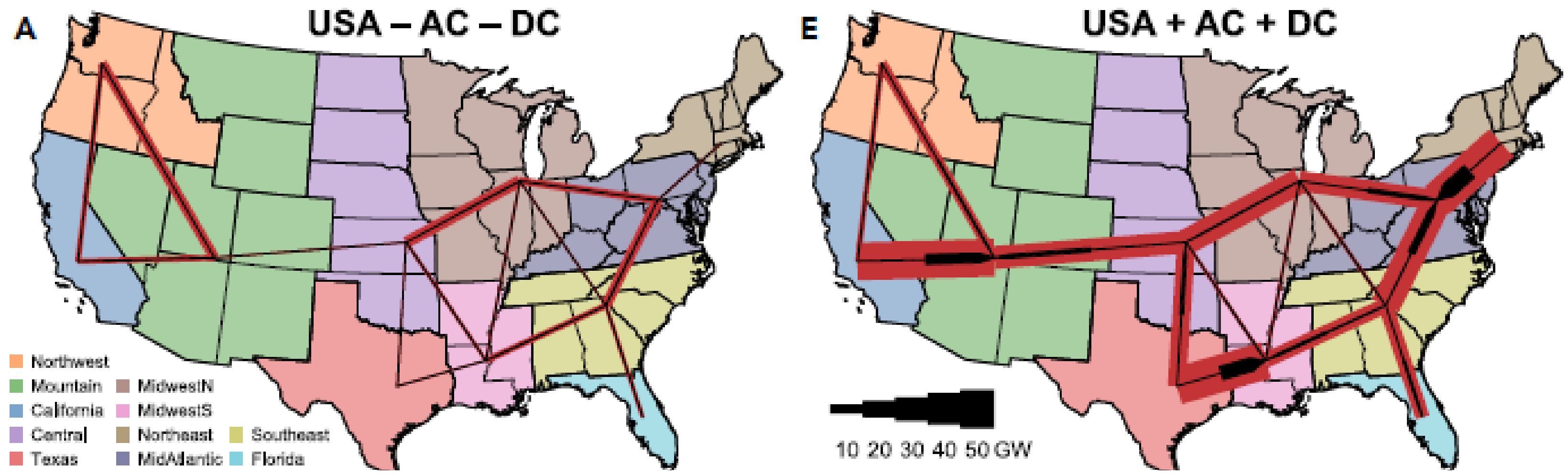


TOTAL COST ↓



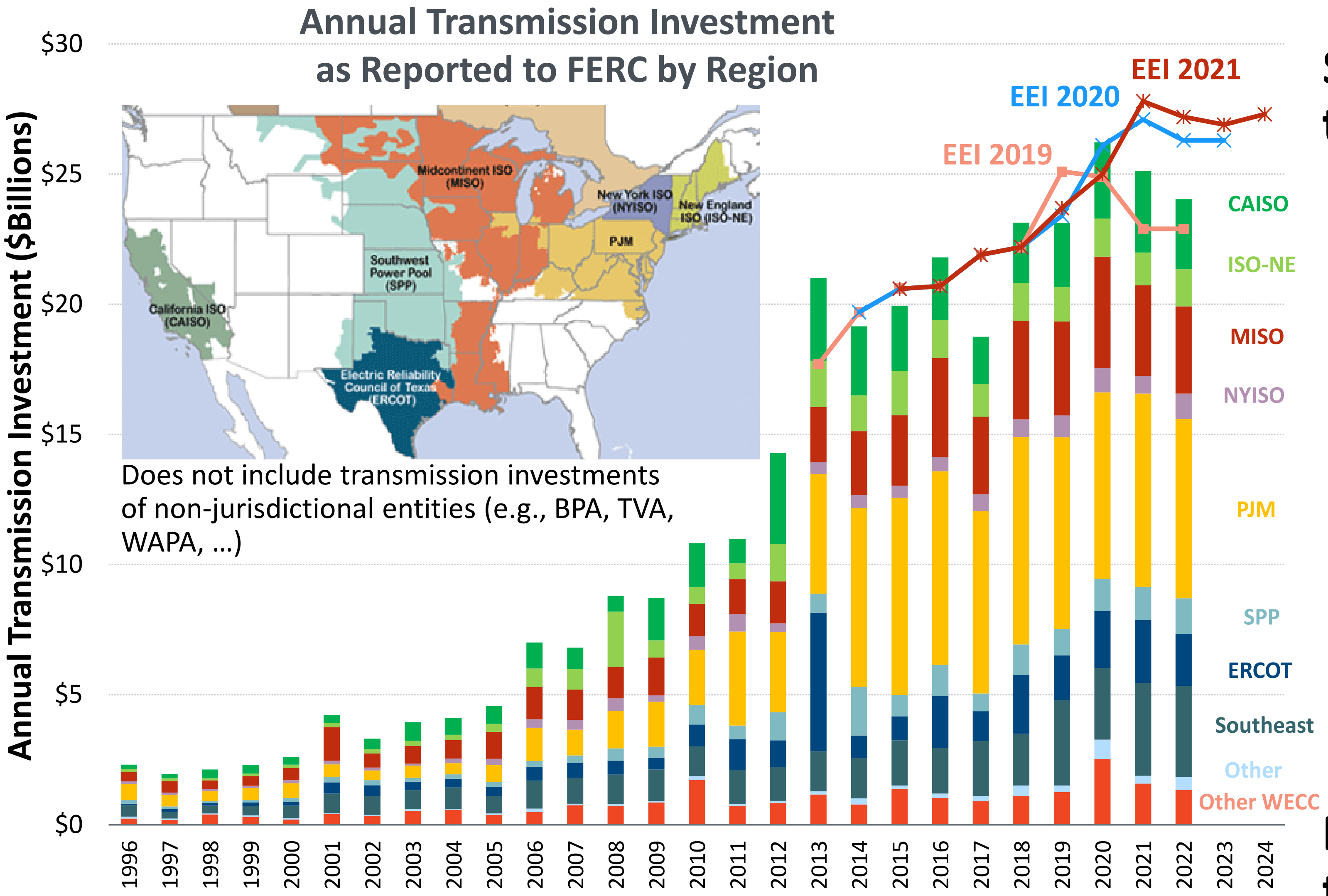
Key Result: A more robust national grid would reduce the total cost of decarbonizing the grid … but (higher-cost) regional and more local solutions may also be feasible

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.

Transmission Investment is at Historically High Levels



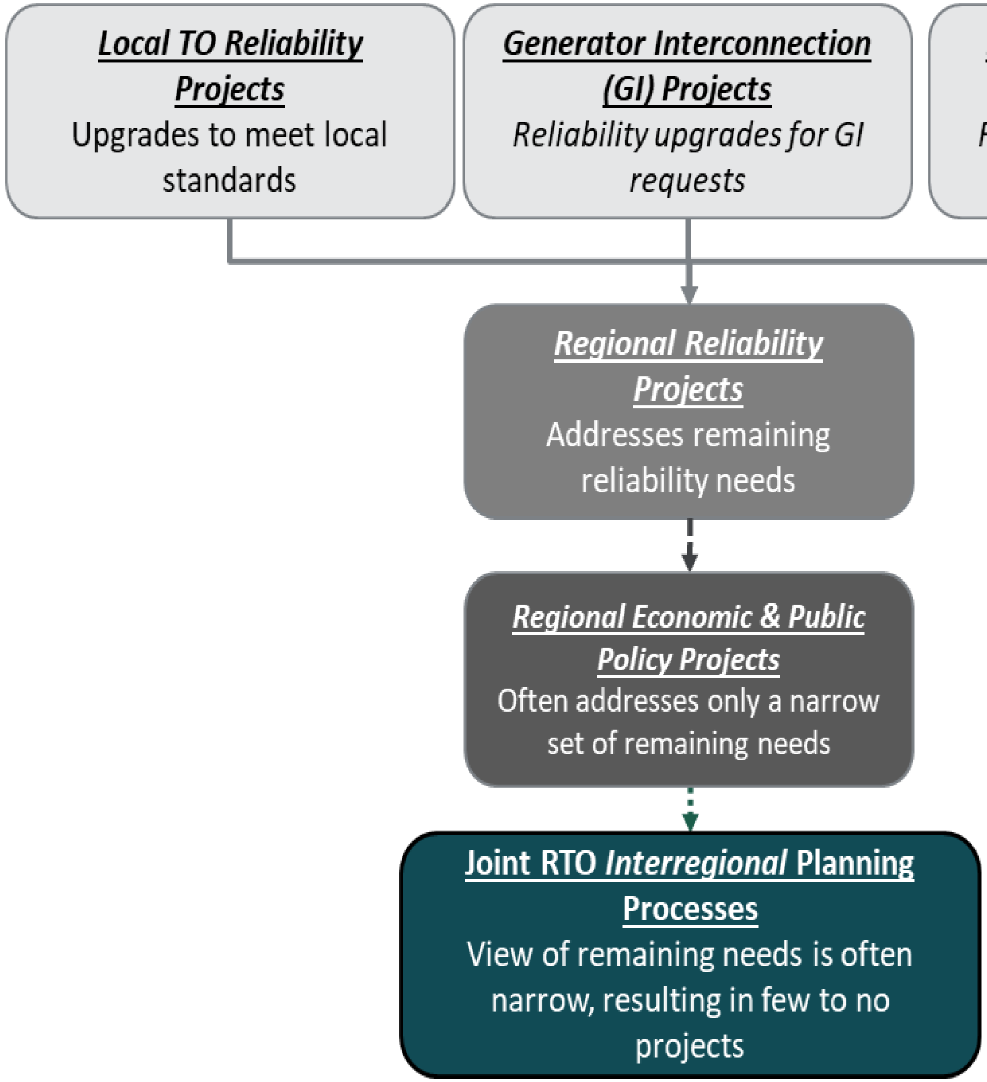
Sources: The Brattle Group analysis of FERC Form 1 Data; EEI "Historical and Projected Transmission Investment" most recent accessed here: https://www.eei.org/resourcesandmedia/Documents/Historical%20and%20Projected%20Transmission%20Investment.pdf

$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

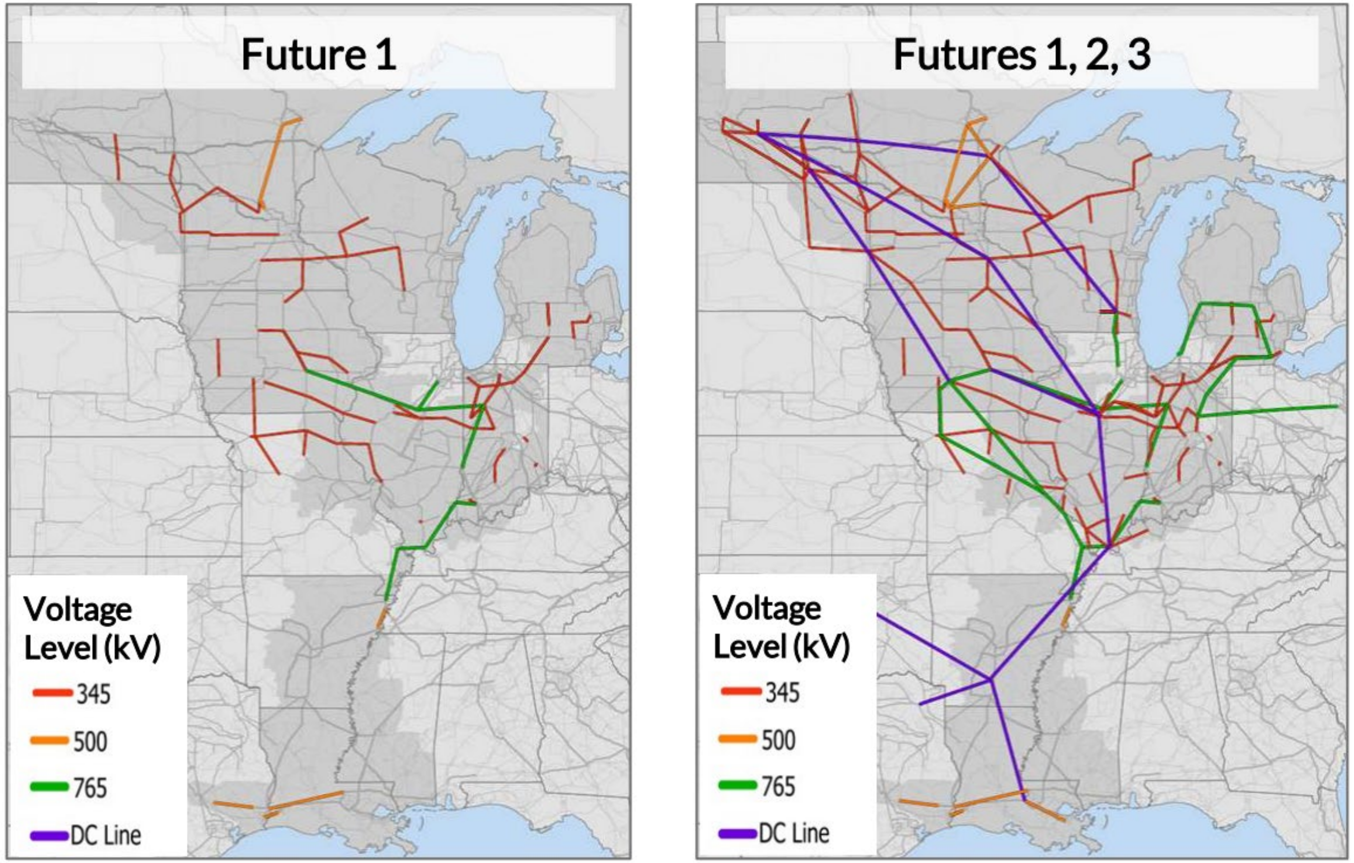
- Essentially no major interregional transmission projects have been planned by grid operators in the last decade
- Regional focus on meeting reliability needs leaves no “need” for interregional transmission, even if more cost effective

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

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 Need for and Value Proposition of Interregional Transmission

Existing studies highlight how interregional transmission can provide significant benefits as the grid transitions to clean resources

- **The value proposition (increased reliability, reduced costs, risk mitigation) of interregional transmission defines the "need" for the approval these projects**
- In the last ten years, numerous studies have looked at a wide range of grid transition scenarios—including a "continuation of recent trend" view in which coal is gradually being replaced by renewables to reduce emissions
  - In all instances, **building new interregional transmission reduces overall system costs and reduces emissions** while reducing risk and helping to maintain or increase reliability
- The **need for interregional transmission has evolved** as renewable costs have declined and state clean-energy and decarbonization policies have become more ambitious. It has shifted from transporting (mostly) low-cost wind to load centers to include a broader set of benefits: **interregional transmission improves reliability and protects customers from high-cost outcomes**
- While there is some substitutability between solar, storage, and transmission, the **declining cost of solar and storage has not changed the conclusion that interregional transmission reduces costs**
- The development of **interregional transmission and lower electricity rates also create jobs**; potentially more than many local-only renewables policies
- Particularly as shares of weather-correlated renewable generation increases, **robust interregional transmission** is needed to ensure that the geographic scale of the grid exceeds **the size of typical weather systems**

Considerations for Planning New Interregional Transmission

To be able to plan interregional transmission that reduces costs and improves reliability compared to regional or local solutions requires that we:

- 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 (including in regional planning processes) if interregional solutions exist that are more effective than regional or local solutions
  - Recognize regional/interregional benefits, including avoided cost of regional/local solutions

Limitations of National Studies

Although existing studies demonstrate the benefits of interregional transmission, they have not been successful in motivating improved interregional planning or actual transmission project developments. The reasons include some or all of the following:

- Many studies **tend to analyze aspirational clean energy targets (e.g., 90% by 2035 or 100% by 2050)** not the actual policies and mandates applicable for the next 10-15 years
  - By not modeling actual state or federal policies, clean-energy mandates, and renewable technology preferences, the studies cannot demonstrate a compelling "need" to policy makers, regulators, and permitting agencies
- The studies are **not transmission planning studies** that produce specific transmission projects that can be developed to deliver the identified benefits and they **do not support an actionable need for specific projects**
  - The results of these studies do not connect with RTO planning processes and needs identification
- Studies **do not to identify how benefits and costs are distributed** across utility service areas, states, or RTO/ISO under different scenarios, as would be necessary to gain support and develop feasible cost recovery options
  - The studies typically do not consider or propose how to recover ("allocate") transmission costs
- There has not been **an analysis of the state-by-state economic impact and job creation** from interregional transmission development, reduced electricity prices, and shifts in the locations of clean-energy investment
- Most studies do not **propose actionable solutions** to address the many barriers to planning processes and to the development of new interregional transmission projects

National Studies are Not a Substitute for Transmission Planning

While national studies indicate the economic benefits of new regional and interregional transmission, they do not analyze the transmission grid in sufficient detail to yield actionable interregional transmission plans (and cannot substitute for interregional transmission planning)

- Various "macro grid" studies show how much transmission capacity might be cost effective between certain regions, but they fail to:
  - Consider existing **transmission planning criteria** (e.g., reliability, stability, size of largest contingencies)
  - Pinpoint **specific locations on the power system** where transmission projects could interconnect to achieve cost reductions (studies typically only indicate which regions would benefit from more transfer capacity)
  - **Identify a list of actionable individual transmission projects (or manageable portfolios of projects)** and quantify project-specific benefits needed by regional planning authorities and transmission developers to obtain approvals for individual projects
  - **"Connect" to RTO/ISO and TO planning processes** that can approve actual projects for development
  - **Consider actual project costs and cost allocations** (including the costs of necessary local upgrades)

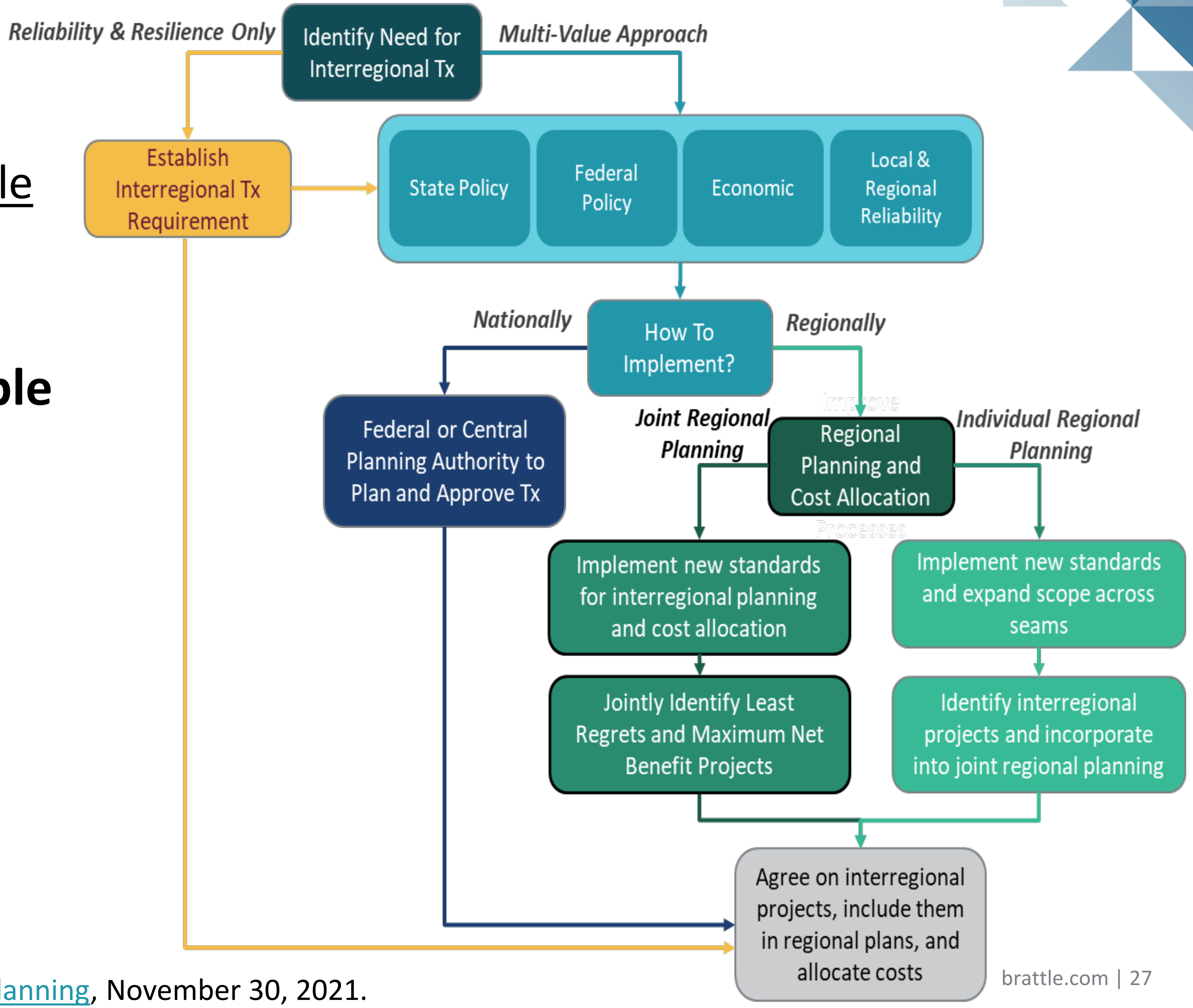
Detailed interregional transmission studies that include RTOs/ISOs are needed to identify specific projects that meet all planning criteria and are cost-effective overall and to the individual regions

Options for Improving Interregional Planning Processes

While national studies show there are benefits of interregional transmission, these studies do not create an actionable "need" for approving projects

Four paths can be pursued simultaneously, identifying actionable transmission needs through:

1. **New Interregional Tx requirements?**
2. **New Federal planning?**
3. **Improve joint RTO planning**
4. **Expand planning by individual RTOs**



Source: A Roadmap to Improved Interregional Transmission Planning, November 30, 2021.

Framework for More Proactive Transmission Planning*

FERC NOPR efforts and available experience point to proven planning practices that can reduce total system costs and risks, but are rarely used today:

1. **Proactively and holistically plan for future generation and load** by incorporating realistic projections of all needs: the anticipated generation mix, public policy mandates, load levels, and load profiles over the lifespan of the transmission investments. Avoid siloed, incremental planning processes.
2. **Account for the full range of transmission needs** and **use multi-value planning** to comprehensively identify investments that cost-effectively address all categories of needs and benefits
3. **Address uncertainties and high-stress grid conditions explicitly through scenario-based planning** that takes into account all transmission needs for a broad range of plausible long-term futures as well as real-world system conditions, including challenging and extreme events
4. **Use comprehensive transmission network portfolios** to address system needs and **cost allocation** more efficiently and less contentiously than a project-by-project approach
5. **Jointly plan inter-regionally across neighboring systems** to recognize regional interdependence, increase system resilience, and take full advantage of interregional scale economics and geographic diversification benefits

* Brattle & Grid Strategies Report: Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs, October 2021.

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

Well-Planned Electric Transmission Saves Customer Costs:
Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future

PREPARED FOR
WIRES

Link: Well-Planned Transmission

PREPARED BY
Judy W. Chang
Johannes P. Pfeifenberger

May 2016

THE Brattle GROUP

Toward More Effective Transmission Planning:
Addressing the Costs and Risks of an Insufficiently Flexible Electricity Grid

PREPARED FOR
WIRES

Link: Effective Transmission Planning

PREPARED BY
Johannes P. Pfeifenberger
Judy W. Chang
Akarsh Sheilendranath

April 2015

The Brattle Group

Link: Transmission Benefits

The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments

July 2013

Judy W. Chang
Johannes P. Pfeifenberger
J. Michael Hagerty

Link: Diversity Value

BU
Boston University Institute for Sustainable Energy

The Value of Diversifying Uncertain Renewable Generation through the Transmission System

September • 2020

A Roadmap to Improved Interregional Transmission Planning

Link: Interregional Roadmap

PREPARED BY
Johannes P. Pfeifenberger
Kasparas Spokas
J. Michael Hagerty
John Tsoukalis

November 30, 2021

Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs

Link: Brattle Grid Strategies

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Grid Strategies:
Rob Gramlich
Michael Goggin
Jay Caspary
Jesse Schneider

OCTOBER 2021

Brattle
GRID STRATEGIES LLC

Summarizes proven approaches to quantifying various benefits

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Brattle Group Practices and Industries

ENERGY & UTILITIES

- Competition & Market Manipulation
- Distributed Energy Resources
- Electric Transmission
- Electricity Market Modeling & Resource Planning
- Electrification & Growth Opportunities
- Energy Litigation
- Energy Storage
- Environmental Policy, Planning and Compliance
- Finance and Ratemaking
- Gas/Electric Coordination
- Market Design
- Natural Gas & Petroleum
- Nuclear
- Renewable & Alternative Energy

LITIGATION

- Accounting
- Analysis of Market Manipulation
- Antitrust/Competition
- Bankruptcy & Restructuring
- Big Data & Document Analytics
- Commercial Damages
- Environmental Litigation & Regulation
- Intellectual Property
- International Arbitration
- International Trade
- Labor & Employment
- Mergers & Acquisitions Litigation
- Product Liability
- Securities & Finance
- Tax Controversy & Transfer Pricing
- Valuation
- White Collar Investigations & Litigation

INDUSTRIES

- Electric Power
- Financial Institutions
- Infrastructure
- Natural Gas & Petroleum
- Pharmaceuticals & Medical Devices
- Telecommunications, Internet, and Media
- Transportation
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