Transmission Planning for a Changing Generation Mix

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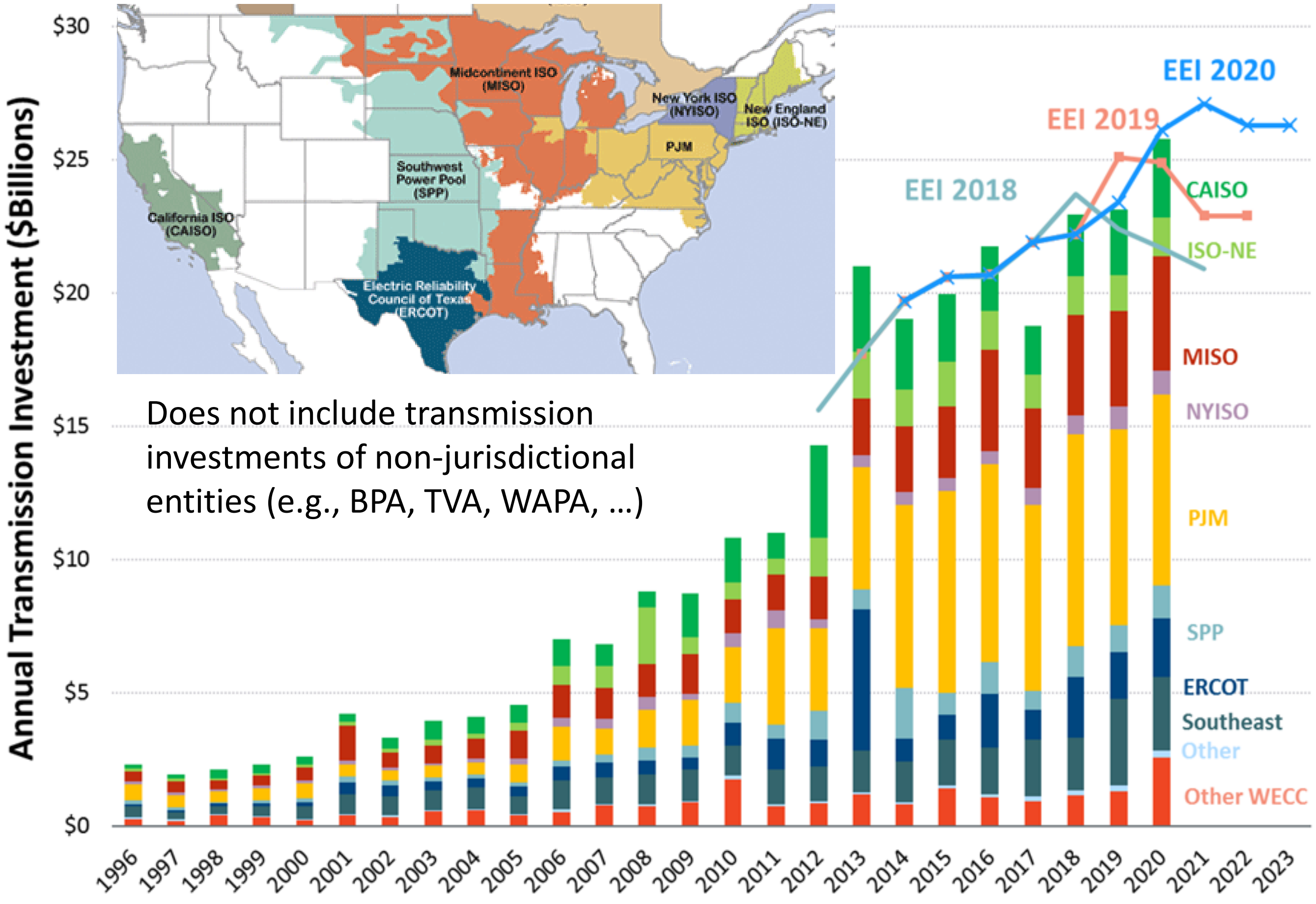
Brattle

Transmission Investment is at Historically High Levels

Annual Transmission Investment
As reported to FERC by Region (1996 – 2020)

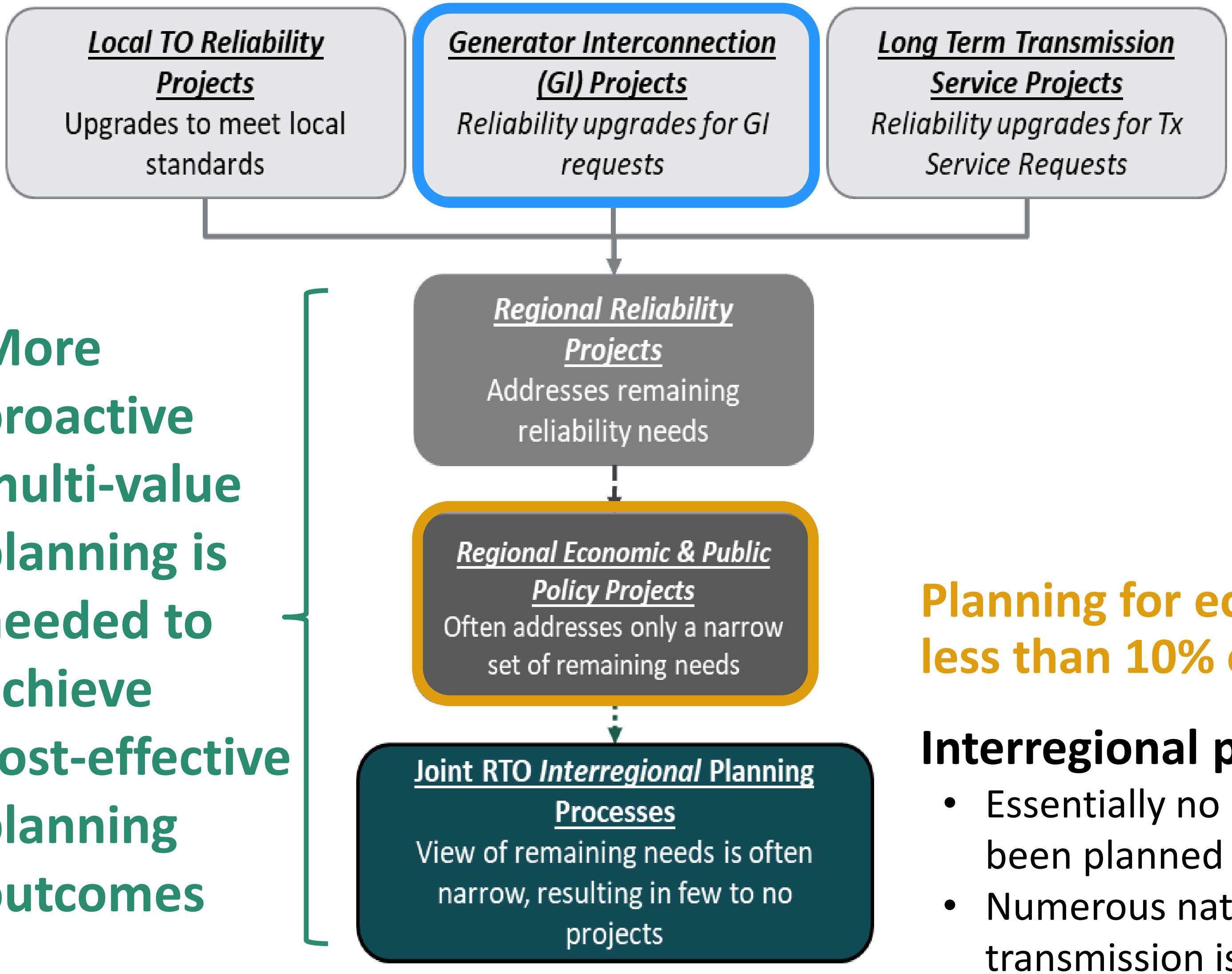


Source: FERC Form 1 Data, EEI "Historical and Projected Transmission Investment" most recent accessed here: https://www.eei.org/resourcesandmedia/Documents/Historical%20and%20Projected%20Transmission%20Investment.pdf

$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 and overall cost savings

Silo-ed, Reliability-focused U.S. Transmission Planning Cannot Identify the Most Cost-Effective Solutions



More proactive multi-value planning is needed to achieve cost-effective planning outcomes

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)

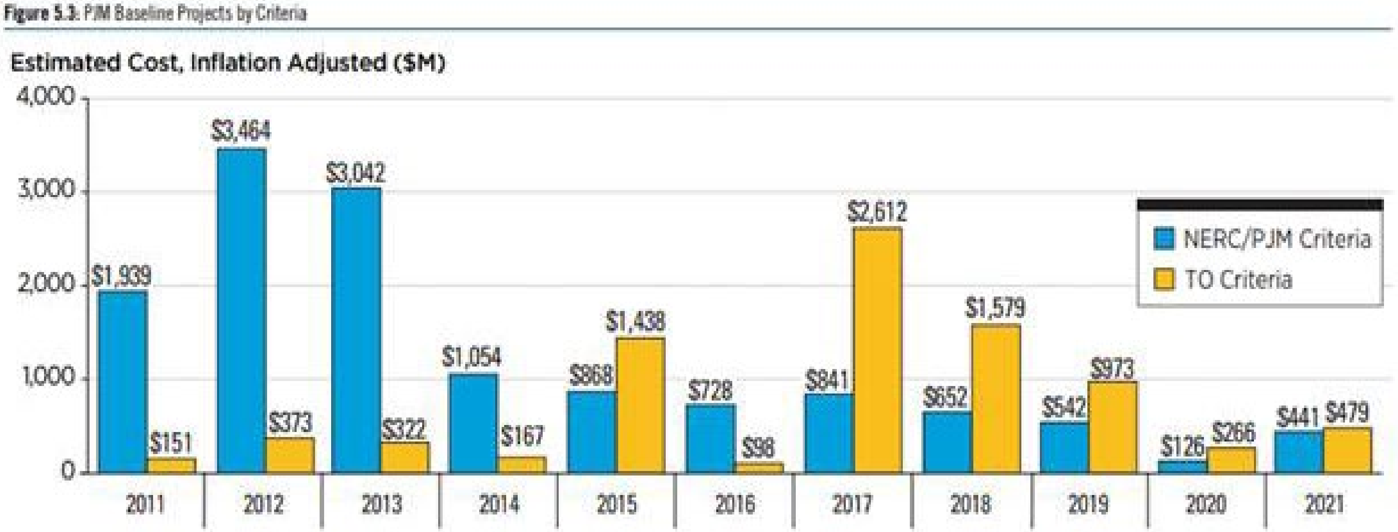
Incremental generation interconnection has become the primary tool (and efficiency barrier) to support public policy goals

Planning for economic & public-policy needs results in less than 10% of all U.S. transmission investments

Interregional planning processes are large ineffective

- Essentially no major interregional transmission projects have been planned and built in the last decade
- Numerous national studies show that more interregional transmission is needed to reduce total system costs

PJM Transmission Investments: Predominantly Reliability Driven



Source: [2021-rtep-report.ashx (pjm.com)]

"Baseline" and "Supplemental" projects account for the large majority of PJM transmission investments, with trends toward fewer Baseline projects and fewer projects triggered by NERC/PJM criteria

- This trend may be inconsistent with the large-scale, regional system needs associated with PJM states' clean-energy goals and mandates
- More proactive multi-driver planning will be necessary to cost-effectively meet regional needs
- PJM's State Agreement Approach (SAA), if used more broadly, can help but will not be a substitute for achieving most cost-effective solutions

Needed: Transmission Planning for the 21st Century*

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

1. **<u>Proactively plan</u> for future generation and load** by incorporating realistic projections of the anticipated generation mix, public policy mandates, load levels, and load profiles over the lifespan of the transmission investment
2. **Account for the <u>full range of transmission projects' benefits</u>** and **<u>use multi-value planning</u>** to comprehensively identify investments that cost-effectively address all categories of needs and benefits
3. **Address uncertainties and high-stress grid conditions explicitly through <u>scenario-based planning</u>** that takes into account a broad range of plausible long-term futures as well as real-world system conditions, including challenging and extreme events
4. **Use comprehensive transmission <u>network portfolios</u>** to address system needs and **<u>cost allocation</u>** more efficiently and less contentiously than a project-by-project approach
5. **Jointly <u>plan inter-regionally</u> 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.

Proactive Planning Can Also Streamline Generation Interconnection

Improving generation interconnection requires addressing all five elements of the GI process (with most current reform discussions focused mostly on Nos. 1 and 5):

1. **GI Process and Queue Management:** individual vs. cluster studies, type of studies and contractual agreements, readiness criteria, financial deposits, study and restudy sequences, etc.
2. **GI Scope and "Handoff" to Regional Transmission Planning:** are major ("deep") network upgrades triggered by incremental generation interconnection requests or handled through regional transmission planning?
3. **GI Study Approach and Criteria:** study assumptions, modeling approaches, and specific criteria differ significantly across regions (e.g., ERIS vs. NRIS study differences, injection levels studied, are market-based redispatch opportunities considered?)
4. **Selecting Solutions to Address the Identified Criteria Violations:** most regions select only traditional transmission upgrades to address criteria violations; grid-enhancing technologies, such as power-flow-control devices or dynamic line ratings, are not typically considered or accepted
5. **Cost Allocation:** most regions require the interconnecting generator (or group of generators) to pay for all upgrades identified, even though (a) there may be significant regional benefits to loads and other market participants and (b) more cost effective (multi-value) regional solutions may exist

Benefits of Proactive Planning: PJM's 75 GW Renewable GI Study

Generation interconnection processes, studying one generator at a time, are ineffective in determining the cost-effective transmission solutions. More pro-active GI processes are needed:

- For example: A review of PJM generation interconnection studies for 15.5 GW of individual offshore wind plants identified $6.4 billion in onshore transmission upgrades ($400/kW)
- In contrast: the recent PJM Offshore Wind Transmission Study that proactive evaluated all existing state public policy needs identified only **$3.2 billion in onshore upgrades for over 75 GW of renewable resources** (up to 17 GW of offshore wind, 14.5 GW of onshore wind, 45.6 GW of solar, and 7.2 GW of storage) ($40/kW)
- Upgrades also provide substantial PJM-wide economic benefits: reduced congestion, curtailments, emissions (App B)

State RPS Targets*

NJ: 50% by 2030**	VA: 100% by 2045/2050 (IOUs)
MD: 50% by 2030	NC: 12.5% by 2021 (IOUs)
DE: 40% by 2035	OH: 8.5% by 2026
DC: 100% by 2032	MI: 15% by 2021
PA: 18% by 2021***	IN: 10% by 2025***
IL: 25% by 2025/2026	

* RPS targets at time of study
** Includes an additional 2.5% of Class II resources each year
*** Includes non-renewable "alternative" energy resources

Table 10. Renewable Capacity in Model for Achieving State RPS Targets

State	Year	Offshore Wind (MW)	Onshore Wind (MW)	Solar (MW)	Storage (MW)
NJ	2027	2,900	-	7,111	1,475
	2035	*7,648	-	11,322	2,875
MD	2027	768	210	5,002	-
	2035	1,568	210	5,602	-
DC	2027	-	-	343	-
	2035	-	-	462	-
DE	2027	-	-	468	-
	2035	-	-	595	-
VA	2027	2,600	130	6,270	280
	2035	5,200	130	16,570	3,100
NC	2027	-	600	1,117	-
	2035	-	600	1,153	-
PA	2035	-	1,585	2,185	58
IL		-	7,329	2,406	1,080
OH		-	1,742	3,938	24
MI		-	-	356	-
IN		-	2,325	275	-
Rest of PJM KY, TN, WV *(non-RPS states)*		-	609	713	54
2035 Total		14,416 MW	14,530 MW	45,577 MW	7,191 MW

Table 7. Scenario 4 Results

	<230 kV	230 & 345 kV	500 kV	Transformer	Upgrade Cost ($M)
Atlantic City Electric	$11.30	$27.60		$11.34	**$50.24**
American Electric Power	$33.50			$9.00	**$42.50**
Allegheny Power Systems (FirstEnergy)	$37.20				**$37.20**
Baltimore Gas & Electric	$27.60	$27.25	$173.50		**$228.35**
ComEd	$15.10	$38.40			**$53.50**
Dominion	$135.00	$557.40	$995.30	$191.00	**$1,878.70**
Delmarva Power	$35.20	$18.50			**$53.70**
Jersey Central Power & Light	$13.80	$15.90			**$29.70**
Met-Ed	$9.20	$5.20			**$14.40**
PECO		$75.60	$303.50	$50.00	**$429.10**
Penelec				$50.00	**$50.00**
Pepco		$0.70			**$0.70**
PPL		$12.15			**$12.15**
PSE&G		$332.90			**$332.90**
Total ($M)	$317.80	$1,111.60	$1,472.30	$311.34	**$3,213.14**

Experience with Proactive Long-tern Planning Processes

Although still rarely used, significant experience exists with successful proactive, multi-benefit, portfolio-based transmission planning efforts:

	Proactive Planning	Multi-Benefit	Scenario-Based	Portfolio-Based	Interregional Transmission
CAISO TEAM (2004)[146]	✓	✓	✓		
ATC Paddock-Rockdale (2007)[147]	✓	✓	✓		
ERCOT CREZ (2008)[148]	✓			✓	
MISO RGOS (2010)[149]	✓	✓		✓	
EIPC (2010-2013)[150]	✓		✓	✓	✓
PJM renewable integration study (2014)[151]	✓		✓	✓	
NYISO PPTPP (2019)[152]	✓	✓	✓	✓	
ERCOT LTSA (2020)[153]	✓		✓		
SPP ITP Process (2020)[154]		✓		✓	
PJM Offshore Tx Study (2021)[155]	✓		✓	✓	
MISO RIIA (2021)[156]	✓	✓	✓	✓	
Australian Examples:					
- AEMO ISP (2020)[157]	✓	✓	✓	✓	✓
- Transgrid Energy Vision (2021)[158]	✓	✓	✓	✓	✓

Source: Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs (brattle.com)

Understanding Transmission-Related Cost Savings and Other Benefits

The wide-spread nature of transmission benefits creates challenges in estimating benefits (and <u>overall cost savings</u>) and how they accrue to different users

Broad in scope, providing many <u>different types</u> of benefits	• Increased reliability and operational flexibility • Reduced congestion, dispatch costs, and losses • Lower capacity needs and generation costs • Increased competition and market liquidity • Renewables integration and environmental benefits • Insurance and risk mitigation benefits • Diversification benefits (e.g., reduced uncertainty and variability) • Economic development from G&T investments
<u>Wide-spread</u> geographically	• Multiple transmissions service areas • **<u>Multiple states</u>** or regions
<u>Diverse</u> in their effects on market participants	• **<u>Customers</u>**, **<u>generators</u>**, **<u>transmission owners</u>** in regulated and/or deregulated markets • Individual market participants may capture one set of benefits but not others
Occur and <u>change</u> over long periods of time	• Several decades (50+ years), typically increasing over time • Changing with system conditions and future generation and transmission additions • Individual market participants may capture different types of benefits at different times

Examples: Scenario-based Multi-Value Transmission Planning

SPP 2016 RCAR, 2013 MTF

Quantified

1. **production cost savings***
   - value of reduced emissions
   - reduced ancillary service costs
2. avoided transmission project costs
3. reduced transmission losses*
   - capacity benefit
   - energy cost benefit
4. lower transmission outage costs
5. value of reliability projects
6. value of mtg public policy goals
7. Increased wheeling revenues

Not quantified

8. reduced cost of extreme events
9. reduced reserve margin
10. reduced loss of load probability
11. increased competition/liquidity
12. improved congestion hedging
13. mitigation of uncertainty
14. reduced plant cycling costs
15. societal economic benefits

(SPP Regional Cost Allocation Review Report for RCAR II, July 11, 2016. SPP Metrics Task Force, *Benefits for the 2013 Regional Cost Allocation Review*, July, 5 2012.)

MISO MVP Analysis

Quantified

1. **production cost savings** *
2. reduced operating reserves
3. reduced planning reserves
4. reduced transmission losses*
5. reduced renewable generation investment costs
6. reduced future transmission investment costs

Not quantified

7. enhanced generation policy flexibility
8. increased system robustness
9. decreased natural gas price risk
10. decreased CO_2 emissions output
11. decreased wind generation volatility
12. increased local investment and job creation

(Proposed Multi Value Project Portfolio, Technical Study Task Force and Business Case Workshop August 22, 2011)

CAISO TEAM Analysis

(DPV2 example)

Quantified

1. **production cost savings*** and reduced energy prices from both a societal and customer perspective
2. mitigation of market power
3. insurance value for high-impact low-probability events
4. capacity benefits due to reduced generation investment costs
5. operational benefits (RMR)
6. reduced transmission losses*
7. emissions benefit

Not quantified

8. facilitation of the retirement of aging power plants
9. encouraging fuel diversity
10. improved reserve sharing
11. increased voltage support

(CPUC Decision 07-01-040, January 25, 2007, Opinion Granting a Certificate of Public Convenience and Necessity)

NYISO PPTN Analysis

(AC Upgrades)

Quantified

1. **production cost savings*** (includes savings not captured by normalized simulations)
2. capacity resource cost savings
3. reduced refurbishment costs for aging transmission
4. reduced costs of achieving renewable and climate policy goals

Not quantified

5. protection against extreme market conditions
6. increased competition and liquidity
7. storm hardening and resilience
8. expandability benefits

(Newell, et al., Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades, September 15, 2015)

* Fairly consistent across RTOs

What is Proactive, Scenario-Based, Long-Term Planning?

Scenario-based planning is a process first developed in the 1940s and 1950s as a tool for integrating uncertainties into long-term strategic planning:

- Used by Shell with great success since the 1970s for long-term planning under large uncertainties
- **Assists planners to think, in advance, about the many ways the future may unfold and how to respond effectively and flexibly as the future becomes reality**
- Ranks among the top-ten management tools in the world today
- Scenario = one fully-defined, plausible view of what the future may look like

Scenario-based planning is a multi-step process:

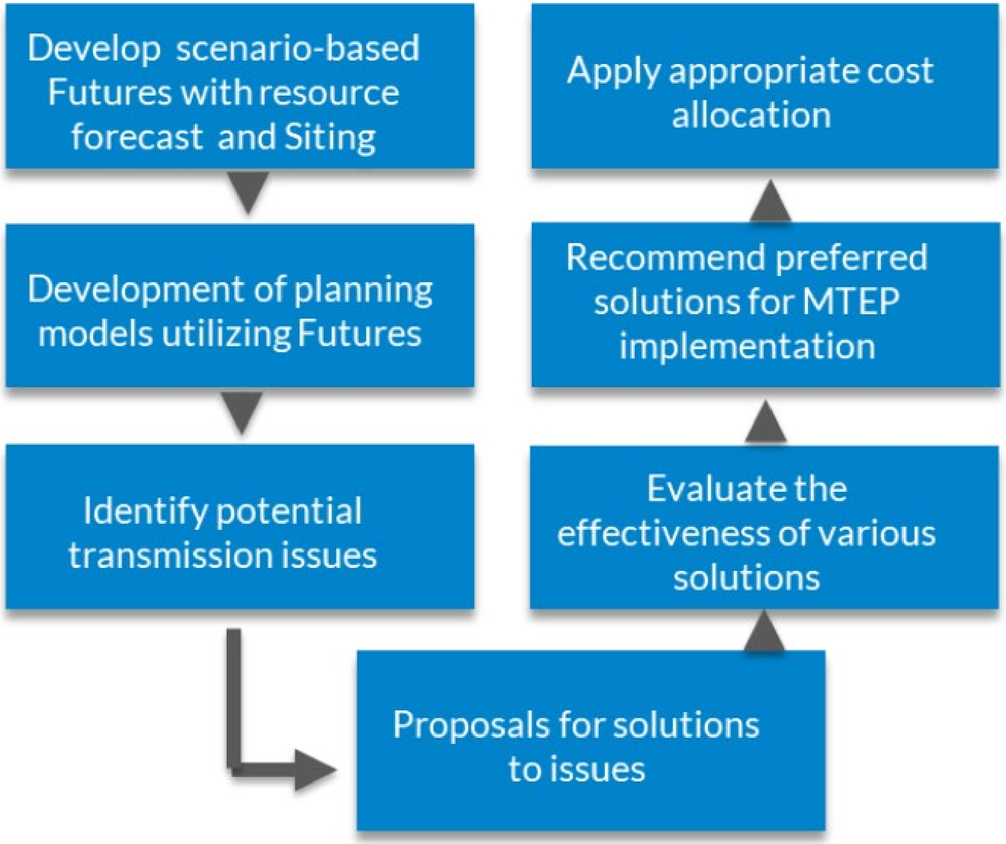
1. Define scenarios of plausible futures by scanning the current reality, trends and forecasts, uncertainties, and important internal and external drivers
2. Develop a series of plans (initiatives, projects, policies, tactics) that support a certain scenario, work well in multiple scenarios, or are flexible and robust across all scenarios
3. Implement preferred plan and define indicators to alert planners that a certain future is likely to occur, so they can take action (e.g., change course to address the new developments)

See also, e.g., Living in the Futures (hbr.org), Scenario Planning-A Review of the Literature.PDF (mit.edu)

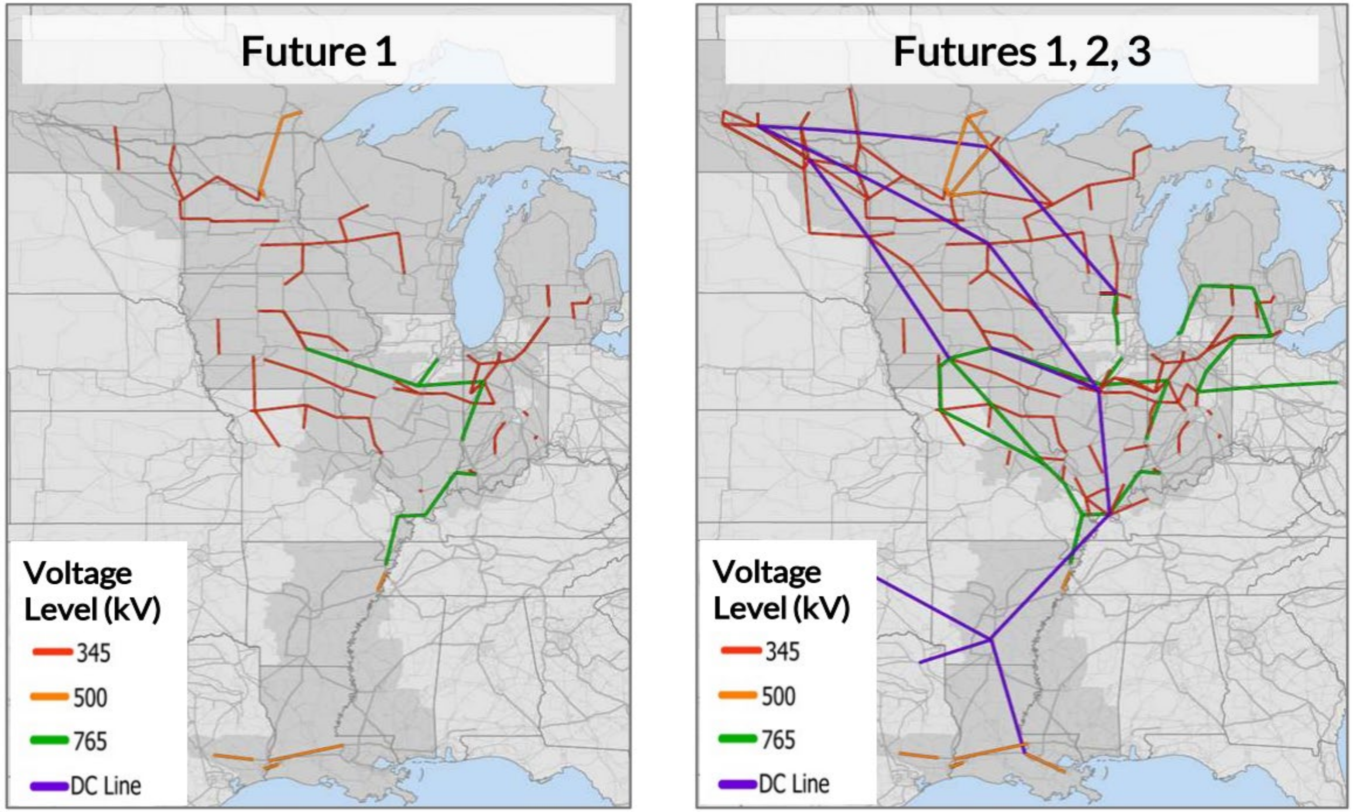
Example: MISO Long-Term Transmission Planning (LRTP)

MISO's LRTP effort simultaneously evaluated 20-year reliability, economic, and public policy needs for a diverse set of plausible "Futures" (scenarios)

MISO's 2022 LRTP Process



MISO's Identified Long-Term Transmission Needs



Source: MISO LRTP Roadmap March 2021

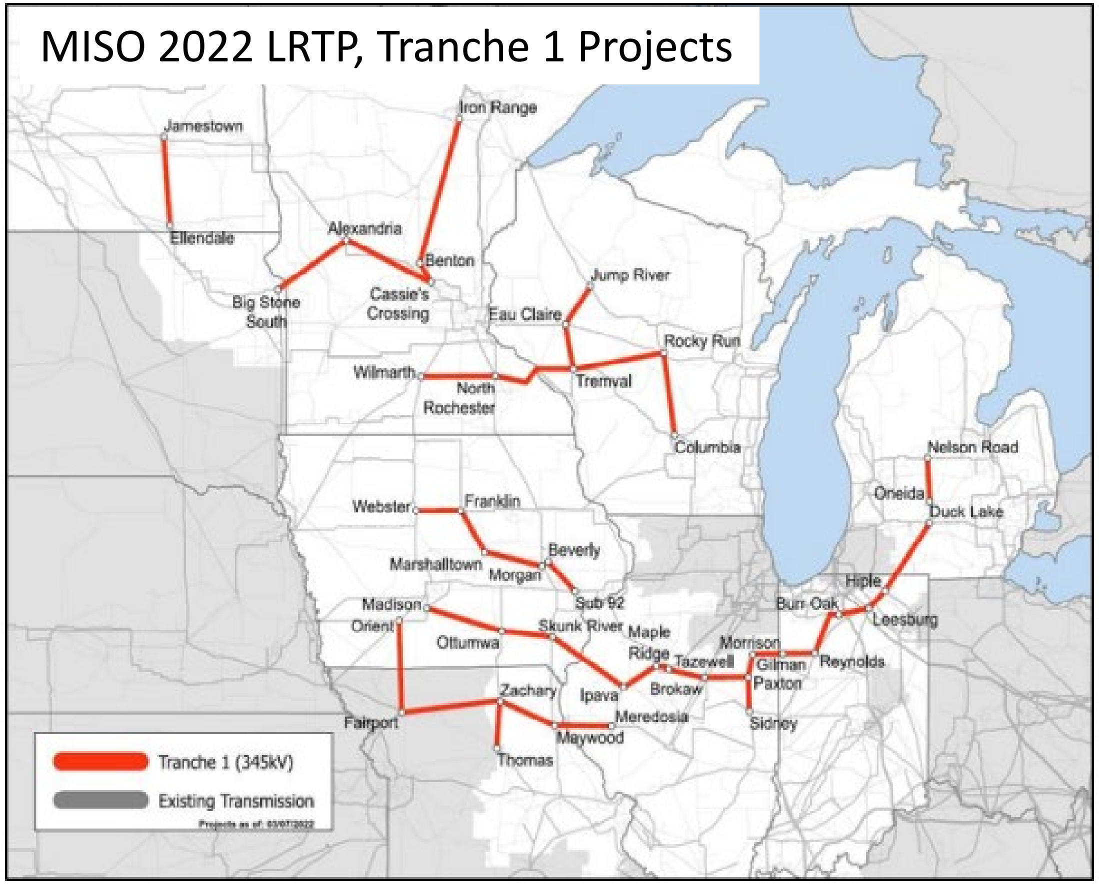
Example: MISO Long-Term Transmission Planning (LRTP)

Scenario-based LRTP ➔ First tranche of a new "least regrets" portfolio of multi-value transmission projects (MVPs)

MISO 2022 LRTP results

- Tranche 1: $10 billion portfolio of proposed new 345 kV projects for its Midwestern footprint
- **Supports interconnection of 53,000 MW of renewable resources**
- **Reduces other costs by $37-70 billion**
- Portfolio of beneficial projects designed to benefit each zone within MISO's Midwest Subregion
- Postage-stamp cost allocation within MISO's Midwest Subregion

MISO 2022 LRTP, Tranche 1 Projects



Source: 3-29-22 LRTP Presentation (misoenergy.org)

Addressing Short- and Long-term Uncertainties through Scenario-based Transmission Planning

Most transmission planning efforts do not adequately account for short- and long-term risks and uncertainties affecting power markets

- **Short-Term Risks:** transmission planning generally evaluates only "normal" system conditions
  - Planning process typically ignores the high cost of **short-term challenges and extreme market conditions** triggered by high-impact-low-probability ("HILP") events due to weather, transmission outages, fuel supply disruption, or unexpected load changes associated with economic booms/busts
  - Can be addressed through modeling assumptions and **sensitivities** that capture these short-term challenges
- **Long-Term Risks:** Planning does not adequately consider the full range of long-term scenarios
  - Does not capture the extent to which a less robust and flexible transmission infrastructure will help reduce the **risk of high-costs incurred under different (long-term) future market fundamentals**
  - Can be addressed through improved **scenario planning** that covers the full range of plausible futures

A more flexible and robust grid provides "**insurance value**" by reducing the risk of high-cost (short- and long-term) outcomes due to inadequate transmission

- Costs of inadequate infrastructure (typically are not quantified) can be much greater than the costs of the transmission investment
- Project may not quite be cost effective in "base case" future but be highly beneficial in 3 out of 5 futures

Risk Mitigation Through "Least-Regrets" Transmission Planning

Additional considerations regarding the risk mitigation and insurance value of transmission infrastructure:

- Given that it can take a decade to develop new transmission, delaying investment can easily **limit future options** and result in a **higher-cost, higher-risk** overall outcomes
  - "Wait and see" approaches limit options, so can be costly in the long term
  - The industry needs to plan for both short- and long-term uncertainties more proactively – and develop "anticipatory planning" processes
- However **"least regrets" planning** too often only focuses on identifying those projects that are <u>beneficial under most circumstances</u>
  - Does not consider the many potentially "regrettable circumstances" that could result in very high-cost outcomes
  - Focuses too much on the cost of insurance without considering the cost of not having insurance when it is needed
- **Probabilistic weighting assumes risk neutrality** and does not distinguish between investment options with very different risk distributions

Risk Mitigation Example: ATC's Scenario-based Planning

In evaluating the Paddock-Rockdale Project, ATC evaluated scenarios of seven plausible futures, spanning the range of identified long-term uncertainties

- The 40-year PV of customer benefits fell short of the $136 million PV of the project's revenue requirement in the "Slow Growth" future, but exceeded the costs in all other futures
- The net benefits in the other six futures ranged from:
  - $100 million (above cost) under the "High Environmental" future
  - to approx. $400 million under the "Robust Economy" and "High Wisconsin Growth" futures
  - reaching up to approx. $700 million under the "Fuel Supply Disruption" and "High Plant Retirements" futures

The B-C analyses of multiple scenarios of plausible futures showed:

- The estimated benefits can range widely across sets of plausible futures
- The project is beneficial in most (but not all) futures
- Risk Mitigation: Not investing in the $136m project could have left customers $400-700m worse off in four of seven plausible futures

Advanced Grid Technologies: Fast and Cost Effective Solutions

Advanced, grid-enhancing transmission (GET) technologies can significantly and quickly increase the capability of the existing grid, offer low-cost solutions to address near-term reliability needs, and also make new transmission more valuable and cost effective in the long-term

- Increasingly well-tested and commercially-applied technologies include: dynamic line rating, smart wires and flow control devices, grid-optimized storage, and topology optimization
- Can be deployed quickly to integrate renewables on the existing grid (see Chapter III of NY Power Grid Study)
- Brattle case study in SPP: DLR, topology optimization, and advanced power-flow controls can integrate 2,670 MW of renewable generation for $90 million
- Value proposition: more visibility of actual grid capability; shift flows to underutilized portions of the grid

Consideration of GETs needs to be expanded beyond addressing operational and seam-related reliability and congestion needs – GETs should be part of the standard set of available solutions to address generation interconnection and both short- and long-term transmission planning needs

- As low-cost solutions to address reliability needs identified in generation interconnection and near-term planning
- In long-term multi-value planning to make new transmission more cost effective and valuable, reducing system-wide costs
- Consider European experience: NOVA-Principle and CurrENT's new analysis

Summary and Recommendations

Benefit-cost analyses and cost allocations for proactive long-term planning can be improved to offer more cost-effective and less controversial outcomes:

- Simultaneously consider <u>broad range of reliability, economic, and public-policy benefits</u>, including experience gained over the last decade by others:
  - MISO, NYISO, SPP, CAISO, ERCOT examples of long-term, scenario-based, multi-value planning processes
- Reduce divisiveness of <u>cost allocation</u> through multi-value planning and portfolio-based allocations
  - Recognize broad range of benefits → more likely to be evenly distributed and exceed costs
  - Focus on larger portfolios of transmission projects → more uniform distribution of benefits
  - Broad range of benefits for a portfolio will also be more stable over time
  - Use cost allocations that are “roughly commensurate” rather than strictly a function of benefits

Focus less on local, near-term reliability and generation-interconnection needs, but proactively on infrastructure that provides <u>greater flexibility and higher long-term value at lower system-wide cost</u>

- Recognize that the most cost-effective transmission projects will tend to address multiple needs
- Lowest-cost transmission is not “least cost” from an overall customer-cost perspective

Ideally: Co-optimize generation interconnection, system operations, near-term planning, and long-term planning for local, regional, and interregional projects

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 transmission-related renewable generation 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.

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.

Brattle Reports on Transmission Planning

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
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November 30, 2021

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

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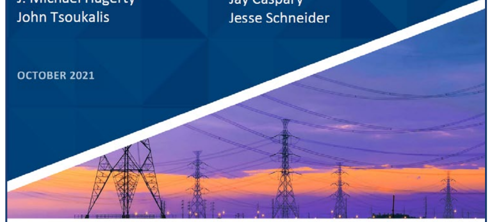

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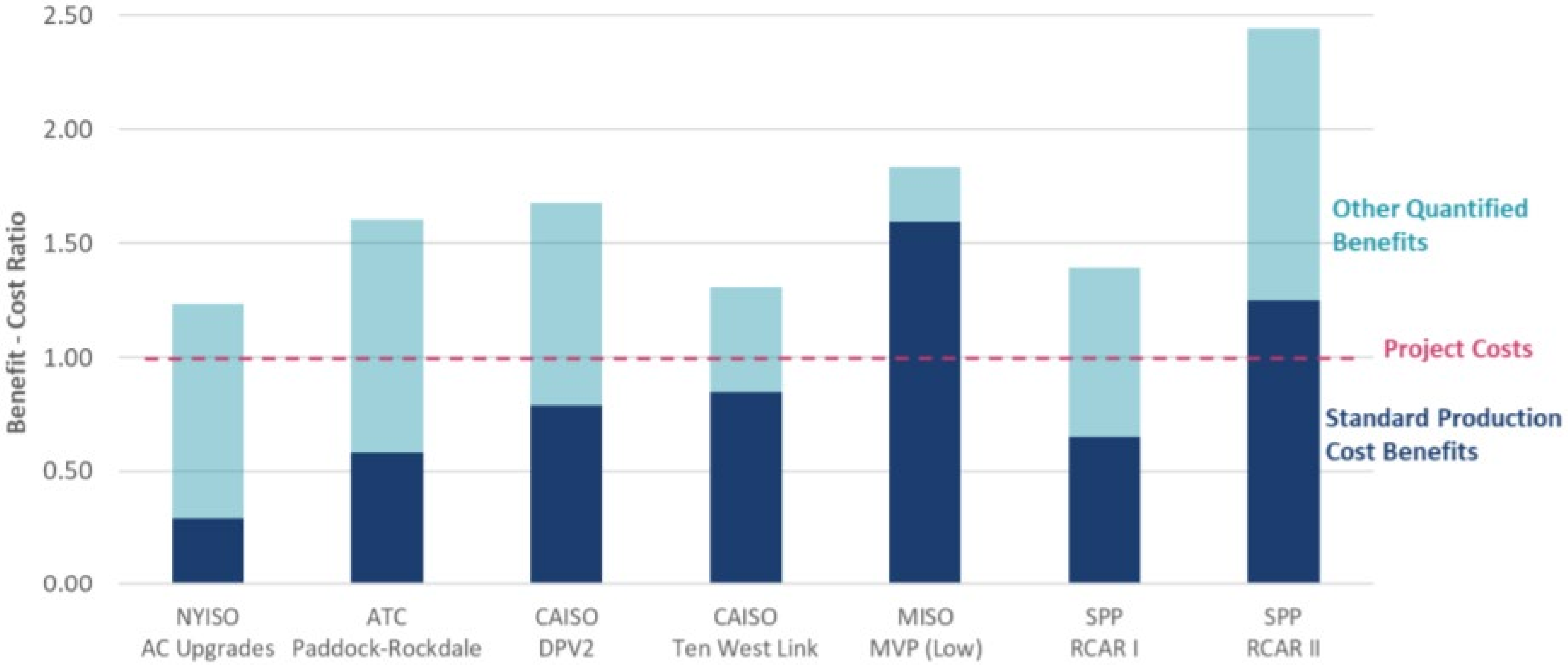
GRID STRATEGIES LLC

Summarizes proven approaches to quantifying various benefits

Quantifying Benefits Beyond Production Cost Savings

Relying on solely on traditionally-quantified <u>Adjusted Production Cost</u> (APC) results in the rejection of beneficial transmission projects:

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



Savings based on Load LMPs (as used by PJM) will be similarly understated (but can overstate benefits relative to APC)

Source: [Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs (brattle.com)]

"Checklist" of Transmission Benefits With Proven Practices for Quantifying Them

We have documented in our recent report (filed with ANOPR comments), available proven practices:

1. Consider for each project (or synergistic portfolio of projects) the full set of benefits transmission can provide (*see* table)
2. Identify the benefits that plausibly exist and may be significant for that particular project or portfolio; then
3. Focus on quantifying those benefits

(See our recent report with Grid Strategies for a summary of quantification practices)

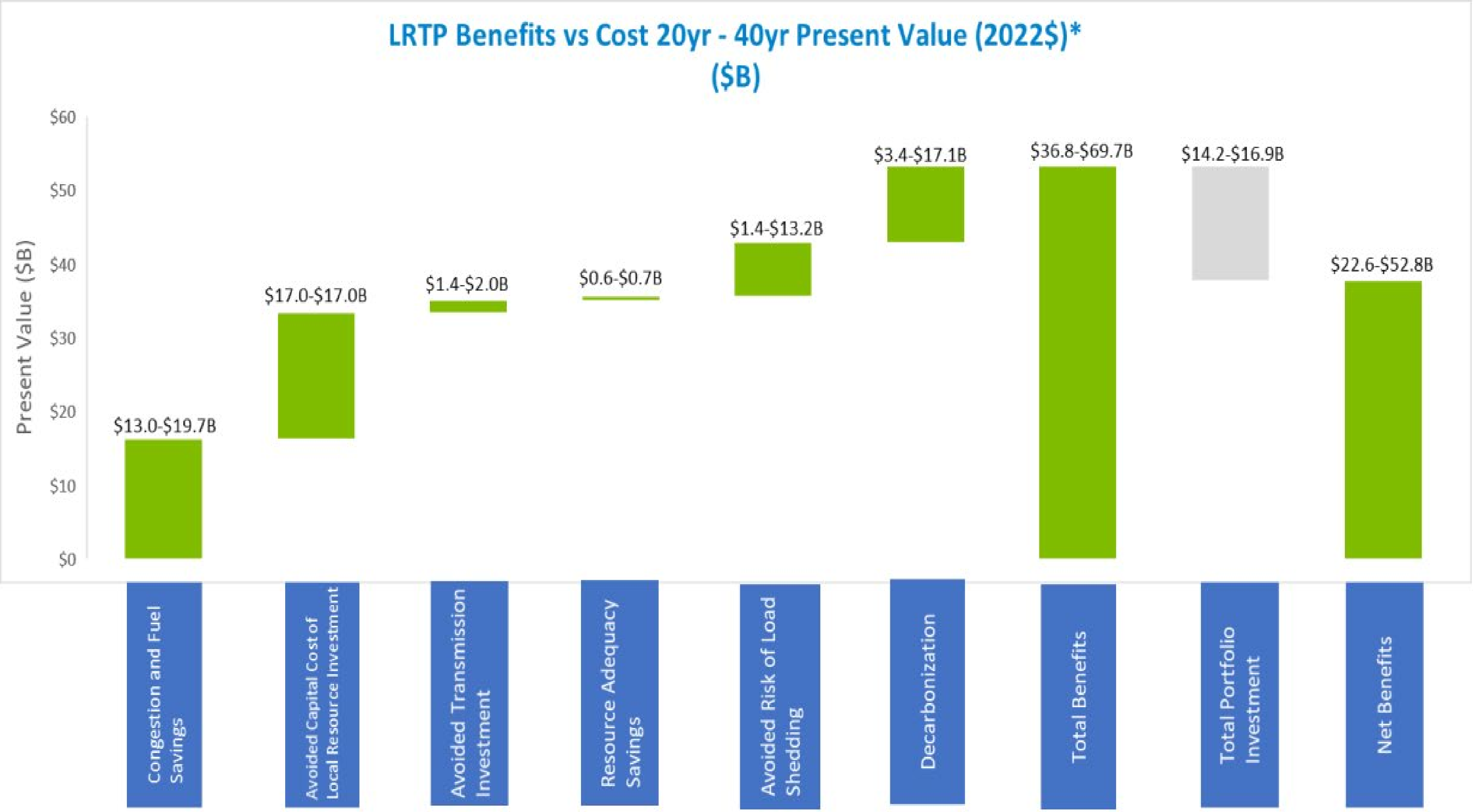
Benefit Category	Transmission Benefit
1. Traditional Production Cost Savings	Adjusted Production Cost (APC) savings as currently estimated in most planning processes
2. Additional Production Cost Savings	i. Impact of generation outages and A/S unit designations
	ii. Reduced transmission energy losses
	iii. Reduced congestion due to transmission outages
	iv. Reduced production cost during extreme events and system contingencies
	v. Mitigation of typical weather and load uncertainty, including the geographic diversification of uncertain renewable generation variability
	vi. Reduced cost due to imperfect foresight of real-time system conditions, including renewable forecasting errors and intra-hour variability
	vii. Reduced cost of cycling power plants
	viii. Reduced amounts and costs of operating reserves and other ancillary services
	ix. Mitigation of reliability-must-run (RMR) conditions
	x. More realistic "Day 1" market representation
3. Reliability and Resource Adequacy Benefits	i. Avoided/deferred cost of reliability projects (including aging infrastructure replacements) otherwise necessary
	ii. (a) Reduced loss of load probability or (b) reduced planning reserve margin
4. Generation Capacity Cost Savings	i. Capacity cost benefits from reduced peak energy losses
	ii. Deferred generation capacity investments
	iii. Access to lower-cost generation resources
5. Market Facilitation Benefits	i. Increased competition
	ii. Increased market liquidity
6. Environmental Benefits	i. Reduced expected cost of potential future emissions regulations
	ii. Improved utilization of transmission corridors
7. Public Policy Benefits	Reduced cost of meeting public policy goals
8. Other Project-Specific Benefits	Examples: increased storm hardening and wild-fire resilience, increased fuel diversity and system flexibility, reduced cost of future transmission needs, increased wheeling revenues, HVDC operational benefits

Example: MISO Long-Term Transmission Planning (LRTP)

20-40-year PV of benefits ($37-$70b) substantially exceeds PV of TRR ($14-17b)

B-C analysis based on multiple benefit metrics:

1. Congestion and fuel savings
2. Avoided capital costs of local resource investments
3. Avoided transmission investment
4. Reduced resource adequacy requirements
5. Avoided risk of load shedding
6. Decarbonization value
7. Reliability issues addressed by LRTP
8. Other qualitative and indirect benefits

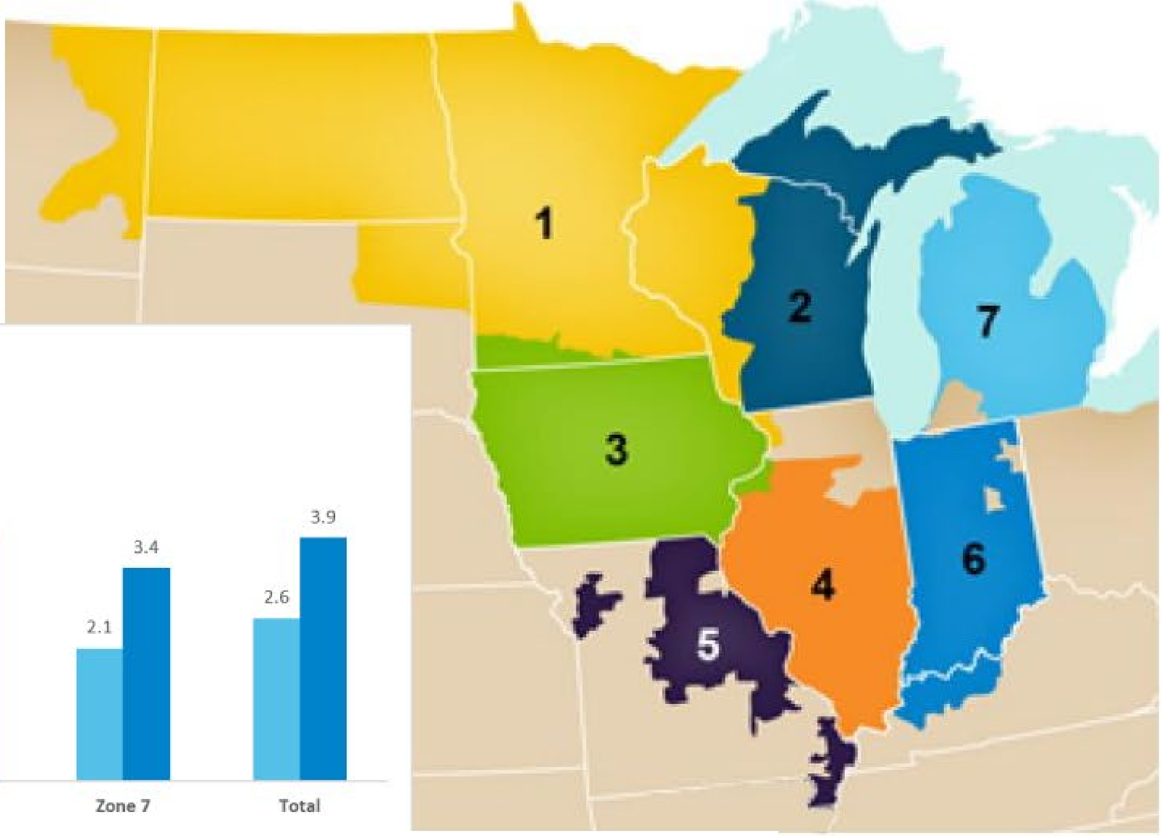


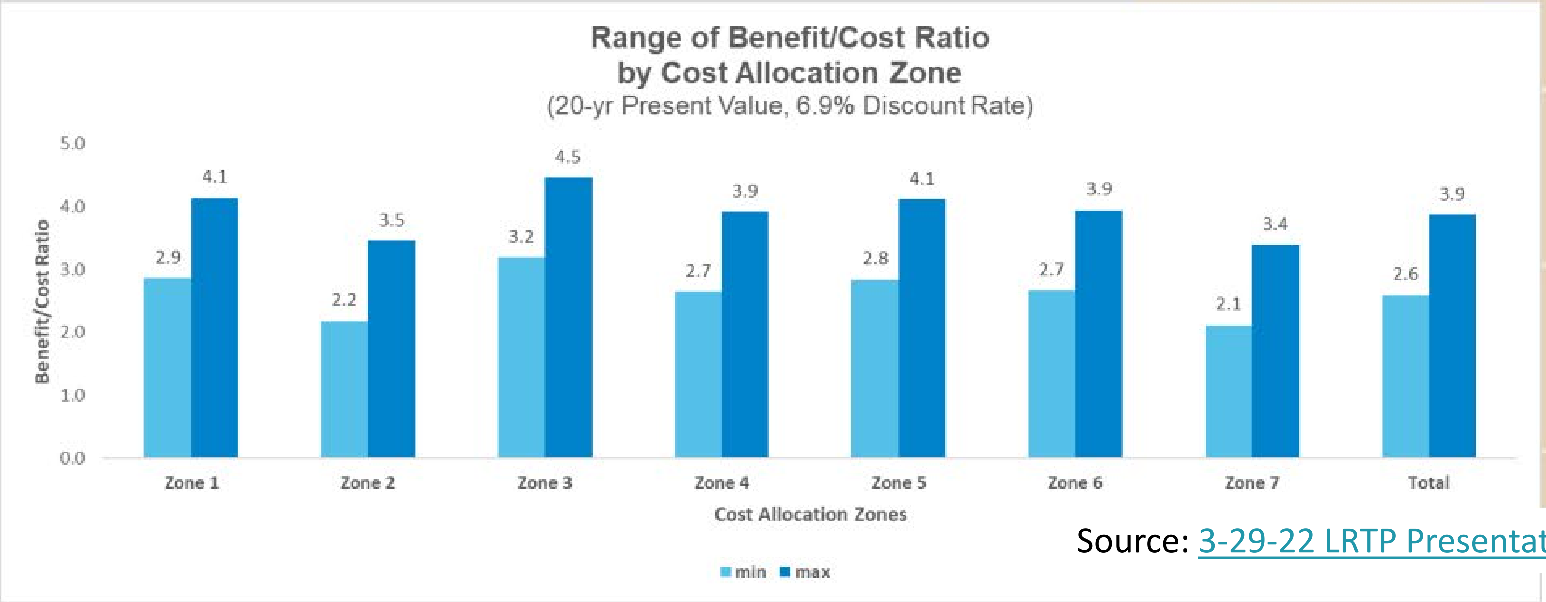
Source: 3-29-22 LRTP Presentation (misoenergy.org)

Example: MISO Long-Term Transmission Planning (LRTP)

Postage-stamp within MISO's Midwest Subregion results in allocated costs that are roughly commensurate with benefits received:

- Each Zone's benefits are at least 2.1-3.4 times higher than allocated costs
- B-C ratios vary across zones, scenarios, and study assumptions
- No costs allocated to MISO's South Subregion due to disproportionately small benefits received

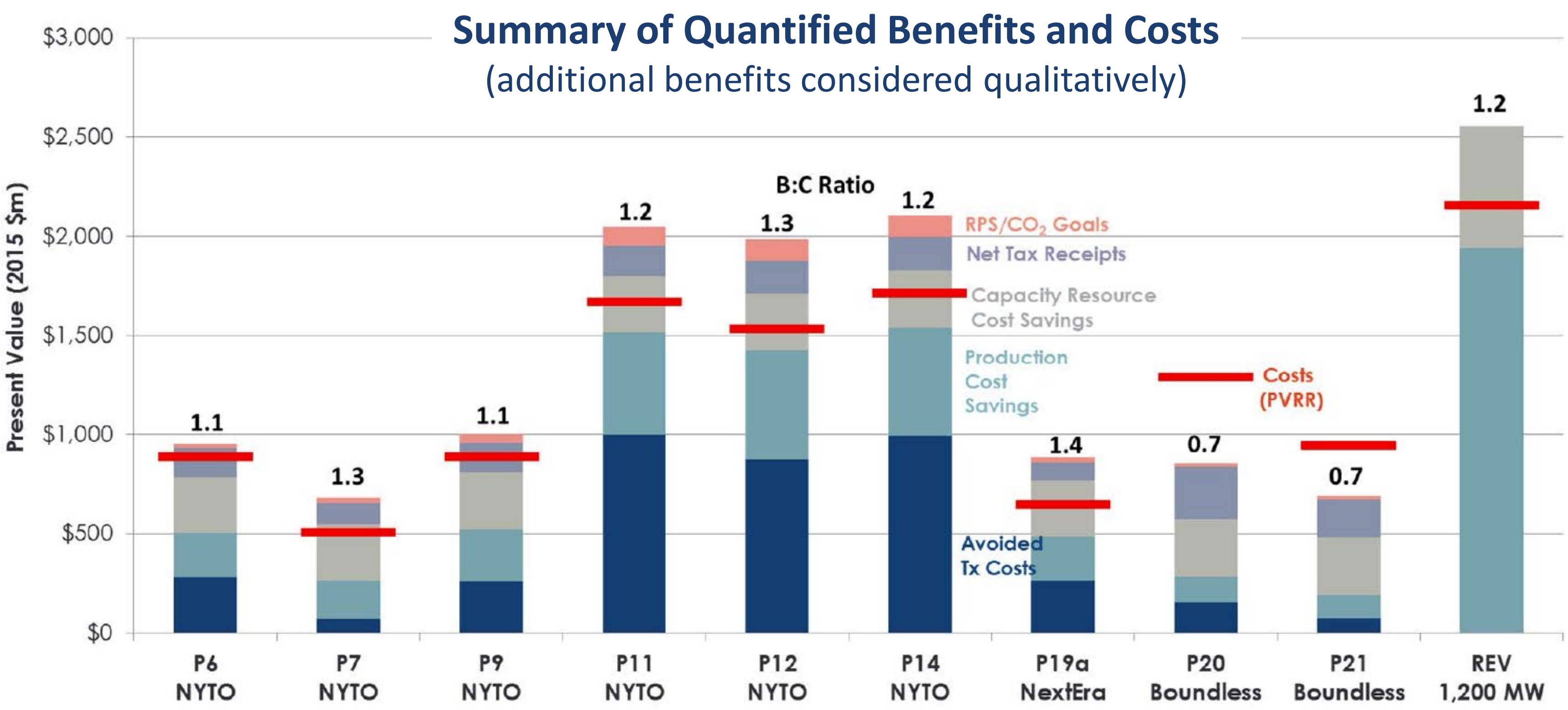




Source: [3-29-22 LRTP Presentation (misoenergy.org)]

Example: New York's (Multi-Value) "Public Policy" Transmission Planning Process (2015)

With PSC support, NYISO developed its "public policy transmission planning process" (PPTPP) that quantifies multiple transmission benefits for a number of long-term scenarios. Resulted in approval and competitive solicitation of several major upgrades to the New York transmission infrastructure providing.



Source: "Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades," September 15, 2015.

See also: AC Transmission Public Policy Transmission Plan (nyiso.com)

Further Improvements to the Generation Interconnection Process

Reducing the scope of upgrades triggered by generation interconnection processes likely would both accelerate and lower the cost of renewable interconnection:

- Attractive: UK "Connect and Manage" (replaced prior "Invest and Connect")
  - Similar to ERCOT; reduced lead times by 5 years; network constraints addressed later (e.g., with congestion management) https://www.gov.uk/guidance/electricity-network-delivery-and-access#connect-and-manage
- ERCOT's generation interconnection process is perhaps most effective in the U.S.
  - Efficient handoff of study roles by ERCOT and Transmission Owners limits restudy needs
  - Projects can be developed and interconnected within 2-3 years; in other regions, the interconnection study process itself may take longer than that
  - Upgrades focused only on local interconnection needs and are recovered through postage stamp
  - Network constraints managed through market dispatch – which imposes high congestion and curtailment risks on interconnecting generators … in part due to ERCOT's insufficiently proactive multi-value grid planning
  - See working-paper.pdf (enelgreenpower.com) [Note: Brattle was not involved]

Generation interconnection based on "connect and manage" when combined with proactive transmission planning offers more timely and cost-effective solutions

Additional Reading on Transmission

Pfeifenberger, Promoting Efficient Investment in Offshore Wind Transmission, DOE-BOEM Atlantic Offshore Wind Transmission Economics & Policy Workshop, August 16, 2022.

Pfeifenberger, Generation Interconnection and Transmission Planning, ESIG Joint Generation Interconnection Workshop, August 9, 2022.

Pfeifenberger, Proactive, Scenario-Based, Multi-Value Transmission Planning, Presented at PJM Long-Term Transmission Planning Workshop, June 7, 2022.

Pfeifenberger, Planning for Generation Interconnection, Presented at ESIG Special Topic Webinar: Interconnection Study Criteria, May 31, 2022.

RENEW Northeast, A Transmission Blueprint for New England, Prepared with Borea and The Brattle Group, May 25, 2022.

Pfeifenberger, New York State and Regional Transmission Planning for Offshore Wind Generation, NYSERDA Offshore Wind Webinar, March 30, 2022.

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

Pfeifenberger, 21st Century Transmission Planning: Benefits Quantification and Cost Allocation, Prepared for the NARUC members of the Joint Federal-State Task Force on Electric Transmission, January 19, 2022.

Pfeifenberger, Spokas, Hagerty, Tsoukalis, A Roadmap to Improved Interregional Transmission Planning, November 30, 2021.

Pfeifenberger, Tsoukalis, Newell, "The Benefit and Cost of Preserving the Option to Create a Meshed Offshore Grid for New York," Prepared for NYSERDA with Siemens and Hatch, November 9, 2022.

Pfeifenberger, Transmission–The Great Enabler: Recognizing Multiple Benefits in Transmission Planning, ESIG, October 28, 2021.

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

Pfeifenberger et al., Initial Report on the New York Power Grid Study, prepared for NYPSC, January 19, 2021.

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.

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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. "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 and Pfeifenberger, "Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future," WIRES and The Brattle Group, 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 The Brattle Group, April 2015.

Chang, Pfeifenberger, Hagerty, "The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments," on behalf of WIRES, July 2013.

Chang, Pfeifenberger, Newell, Tsuchida, Hagerty, "Recommendations for Enhancing ERCOT's Long-Term Transmission Planning Process," October 2013.

Pfeifenberger and Hou, "Seams Cost Allocation: A Flexible Framework to Support Interregional Transmission Planning," on behalf of SPP, April 2012.

Pfeifenberger, Hou, "Employment and Economic Benefits of Transmission Infrastructure Investment in the U.S. and Canada," on behalf of WIRES, May 2011.

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

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