# Generation Interconnection and Transmission Planning


**PRESENTED BY**

Johannes Pfeifenberger


**PREPARED FOR**

ESIG Special Topic Workshop

August 9, 2022

Brattle

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

# U.S. Transmission Needs are currently identified through …

***Local TO Reliability Projects***
Upgrades to meet local standards

***Generator Interconnection (GI) Projects***
*Reliability upgrades for GI requests*

***Long Term Transmission Service Projects***
*Reliability upgrades for Tx Service Requests*

**Current RTO Regional Transmission Planning Processes**

***Regional Reliability Projects***
Addresses remaining reliability needs

***Regional Economic & Public Policy Projects***
Often addresses only a narrow set of remaining needs

**Joint RTO *Interregional* Planning Processes**
View of remaining needs is often narrow, resulting in few to no projects

**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)

**Generation interconnection processes often have become the primary tool (and barrier) to support public policy goals for clean energy**

**Planning for economic & public-policy projects 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

# Current U.S. Transmission Planning and Generation Interconnection Processes = Higher Total Costs

**Current planning processes do not yield the most valuable transmission infrastructure and result in higher overall costs to electricity customers:**

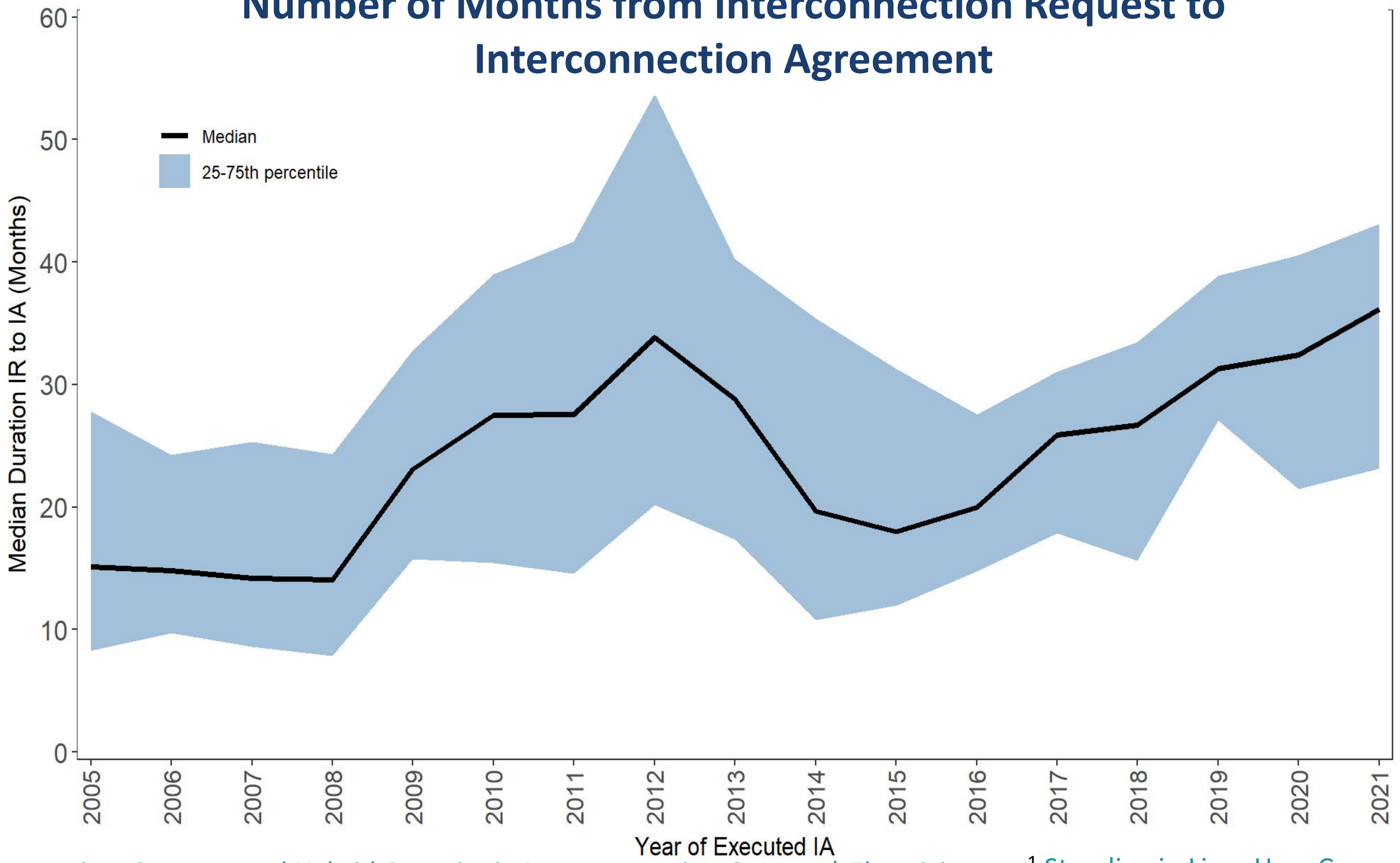
- Reactive, reliability-driven planning results in piecemeal, higher-cost transmission solutions
- Silo-ed generation interconnection, local and regional reliability planning, and public policy planning processes cannot identify most cost-effective solutions
- Failure to evaluate multiple benefits of most transmission projects: does not result in the selection of the highest-value projects that reduce system-wide costs
- Failure to evaluate the full range of plausible futures (to explicitly account for long-term uncertainties): results in higher-cost outcomes when the future deviates from base-case planning assumptions, which usually are based on "business-as-usual" or "current-trends" forecast
- Failure to consider interregional transmission solutions: result in higher-cost regional and local transmission investments

**More pro-active, multi-value, and scenario-based transmission planning and generation interconnection processes are needed**

# #1 Challenge: The Generation Interconnection Process

**89% of renewable generation developers see generation <u>interconnection time requirements and costs</u> as the single biggest barrier to achieving clean-energy goals.**[1]

## Number of Months from Interconnection Request to Interconnection Agreement




## Age of Projects Currently in GI Queues

<u>500+ Days Old</u>
MISO: 98%
SPP: 78%
PJM: 48%
CAISO: 100%
NYISO: 100%

<u>1000+ Days Old</u>
MISO: 82%
SPP: 59%
PJM: 14%
CAISO: 67%
NYISO: 82%

See: [Generation, Storage, and Hybrid Capacity in Interconnection Queues | Electricity Markets and Policy Group (lbl.gov)]

[1] [Standing in Line: How Congested Interconnection Queues Are Slowing Renewable Build-Out, LevelTen Energy, 2021]

# #1 Challenge: The Generation Interconnection Process

## GI study criteria often trigger “deep” and expensive network upgrades:

Enel example: stringent GI study criteria trigger distant reliability violations even for non-firm, energy-only interconnection requests.

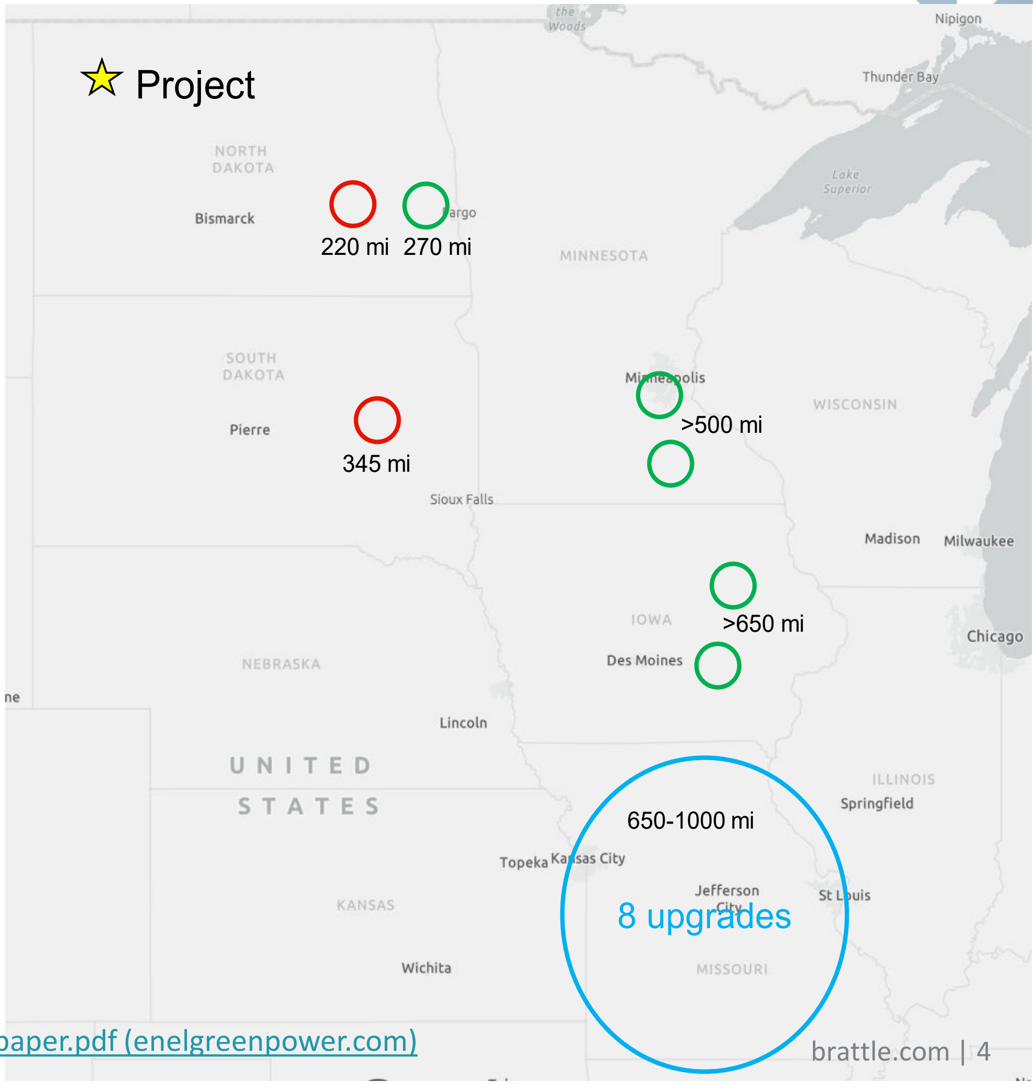
**This exponentially increases the complexity and time requirement of the interconnection process.**

Distant “violations” (if and when they might occur), can generally be “managed” more cost effectively through other means (e.g., market redispatch).

### Real Life Example

300 MW ERIS SPP Interconnection

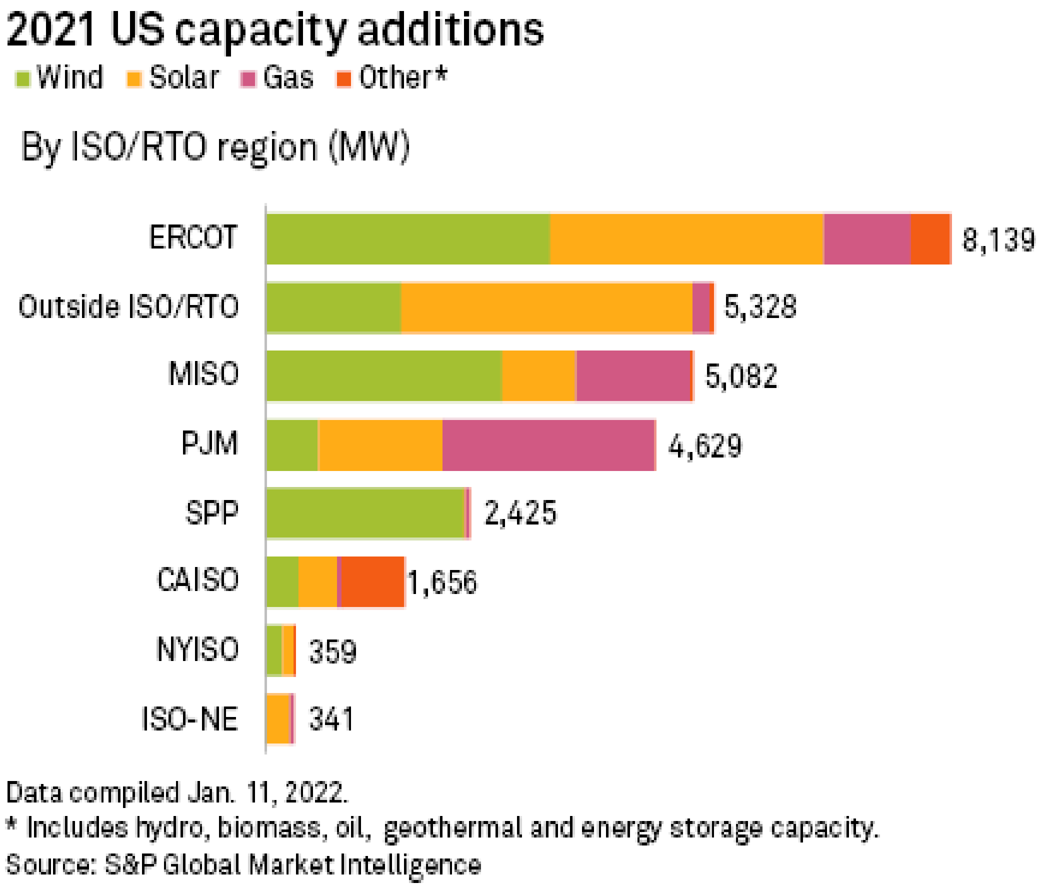
- Shared upgrades with 14 projects
- 4 SPP, 5 MISO, 3 AECI studies so far
- Upgrade criteria and distance
  - SPP
    - >3% TDF under N-0
    - 2% voltage change (group)
    - Transformer and capacitor
  - MISO
    - 1% voltage change (group)
    - Capacitors/statcoms
  - AECI
    - 3% of facility rating (group)
    - 8 69 kV lines and transformers




Source: Aaron Vander Vorst and Enel working-paper.pdf (enelgreenpower.com)

# Significant Differences in Generation Interconnection Processes

**Some RTOs are able to interconnect disproportionately more generation, and have been able to do so more quickly.**




| RTO Size | Capacity in Queue |
|---|---|
| 80 GW | 135 GW |
| 200 GW | 330 GW |
| 150 GW | 155 GW |
| 180 GW | 245 GW |
| 95 GW | 100 GW |
| 52 GW | 160 GW |
| 42 GW | 75 GW |
| 32 GW | 30 GW |

Planning regions with the most ambitious state clean energy standards (i.e., east and west coast states) are lagging behind regions such as Texas and the Midwest:

- ERCOT: added 10% of system capacity in 2021
- NYISO and ISO-NE: only 1%
- All others: 2-4%

See also: [Generation, Storage, and Hybrid Capacity in Interconnection Queues | Electricity Markets and Policy Group (lbl.gov)]

# Five Elements of Generation Interconnection Need to be Addressed

Improving generation interconnection requires addressing all five elements of the GI process. Current discussions focused mostly on Nos. 1 and 5 (NOPR on Nos. 1 and 4)

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

# Option for Improving the Generation Interconnection Process

Reducing the scope of upgrades triggered by generation interconnection processes likely will be necessary to 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 Enel 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 if:**

- Near-term needs are quickly addressed through multi-value planning (beyond reliability)
- Long-term needs are proactively addressed through scenario-based long-term planning

# Proactive Multi-Value Transmission Planning

**Available experience points to <u>proven planning practices</u> that reduce total costs and mitigate risks by proactively addressing both near-term and long-term needs:**

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 cost allocation 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.

See: Brattle and GridStrategies, Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs, October 2021.

# Example of Proactive GI Process: MISO-SPP JTIQ

**MISO's and SPP's Joint Targeted Interconnection Queue (JTIQ) Study shows that proactively studying a larger set of generation interconnection requests offers substantial cost savings**

- Goal: Identify more comprehensive, cost-effective and efficient network upgrades than could be found through the RTO's individual sequential interconnection queue and affected system coordination processes
  - Pooled GI requests for 5 (and 10) years both regions near seam
- Result: Seven-project, **$1.65 billion JTIQ Portfolio** expected to fully address the transmission needs along the MISO-SPP seam previously identified in MISO and SPP individual generation interconnection studies
  - Able to support 9 GW of existing generator interconnection requests and enable an additional 20 GW of projects near the SPP-MISO seam
  - Additionally yields estimated production cost savings of $724 million in MISO and $247 million in SPP
  - Generation interconnection costs: $58/kW with 100% participant funding; and $28/kW if production cost savings benefit to regional loads are netted
- Individual GI process costs average $100-130/kW across study years


See: MISO-SPP Joint Targeted Interconnection Queue Study (misoenergy.org), April 15, 2022 PowerPoint Presentation (misoenergy.org), and Tsuchida ESIG Case Study of MISO and SPP (August 2022, forthcoming)

# Example of Proactive GI Analysis: 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 |

# Better: Integrated Scenario-based Long-Term Transmission 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 (to better plan for the next decades):

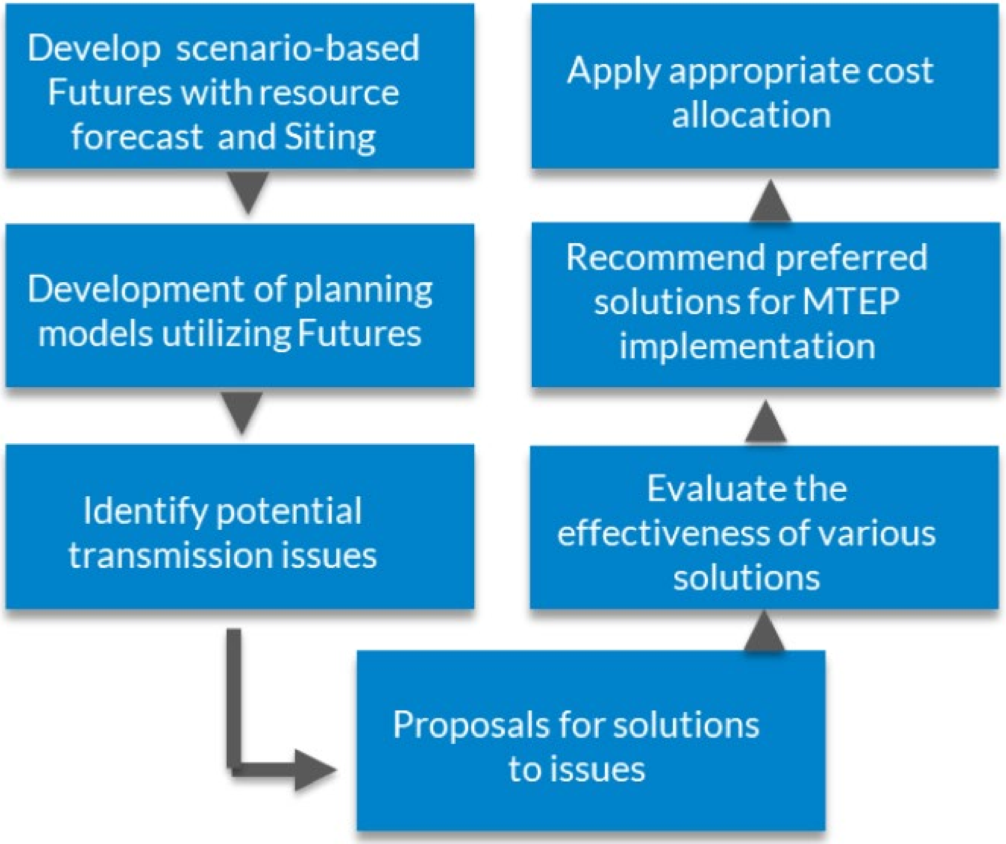
1. Define scenarios of plausible futures by scanning the current reality, trends and forecasts, uncertainties, and important internal and external drivers
2. Develop a series of plans (initiatives, projects, policies, tactics) that support a certain scenario, work well in multiple scenarios, or are flexible 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, e.g., Living in the Futures (hbr.org), Scenario Planning-A Review of the Literature.PDF (mit.edu)

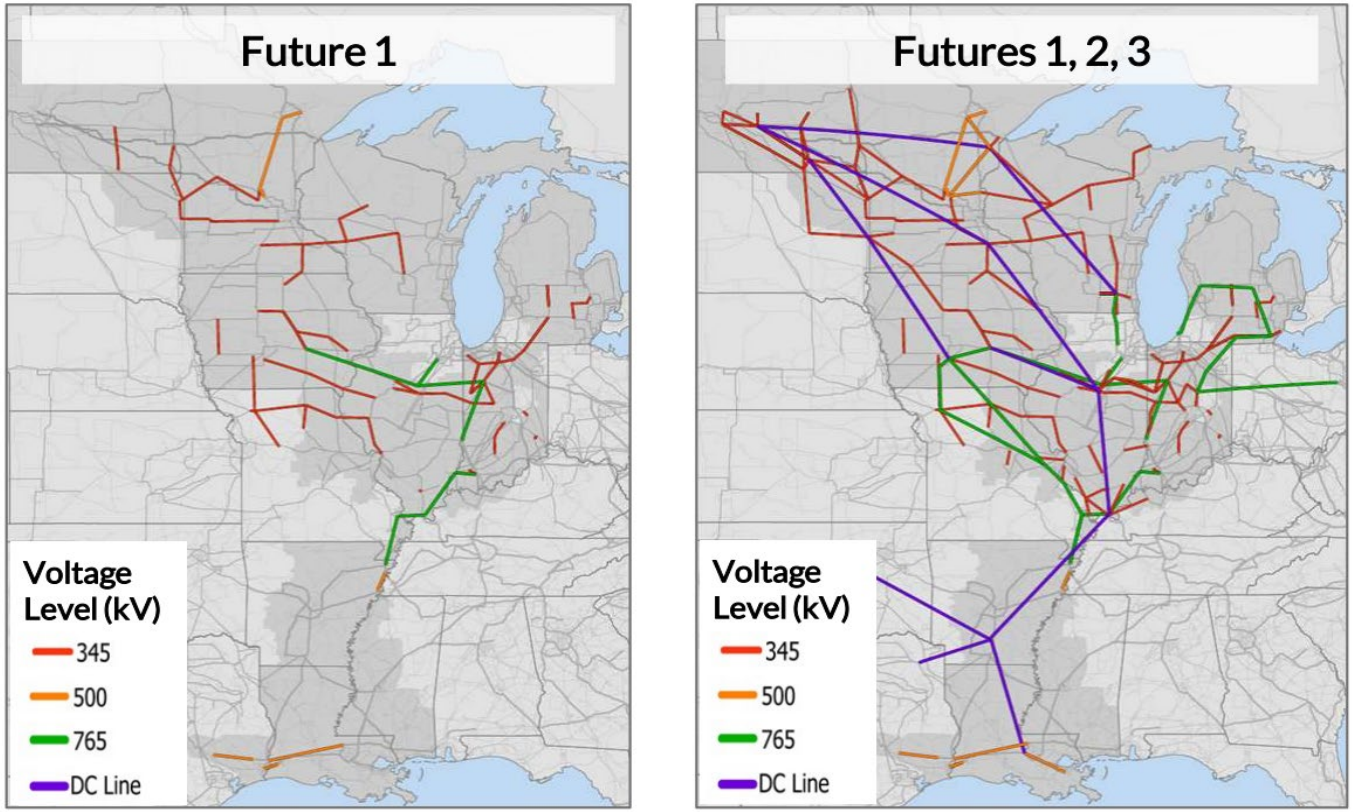
# Example: MISO Long-Term Transmission Planning (LRTP)

**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](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 GW of renewable resources**
- **Reduces other costs by $37-70 billion** (based on estimates for 7 benefit metrics)
- 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)]

# 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 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 also be part of the standard set of available solutions to address both generation interconnection and 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

# The Bottom Line

**Integrating generation interconnection into more proactive transmission planning processes offers substantial advantages**

- More cost-effective, holistic solutions can be identified to address the wide range of future needs
- The costs and time required to interconnect the large number of resources necessary to meet clean-energy goals can be reduced dramatically

**The benefits of proactive planning increase for planning processes that:**

1. Consider generation <u>needs over longer time frames</u> (i.e., a decade of already known resource needs, as opposed to one resource or one class year at a time)
2. Reduce the scope of network upgrades triggered by generation interconnection through more <u>integrated, proactive transmission planning</u> that simultaneously considers <u>multiple needs</u> (generation interconnection, local and regional reliability, economic benefits, and public policy needs)
3. Use proactive multi-value planning processes to address <u>both urgent near-term</u> needs <u>and long-term</u> needs
4. Look <u>beyond regional seams</u> to identify more cost-effective <u>interregional</u> solutions to the range of identified transmission needs (and minimize the scope of and uncertainties associated with “affected system studies”)
5. Rely on <u>advanced transmission technologies</u> to address identified needs
6. Improve and standardize <u>study criteria</u>
7. Utilize <u>pragmatic cost allocations</u> that are roughly commensurate with benefits received

# About the Speaker


Johannes P. Pfeifenberger

**PRINCIPAL**
**BOSTON**

Hannes.pfeifenberger@brattle.com

+1.617.234.5624


**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
Kasparas Spokas
J. Michael Hagerty
John Tsoukalis

November 30, 2021

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

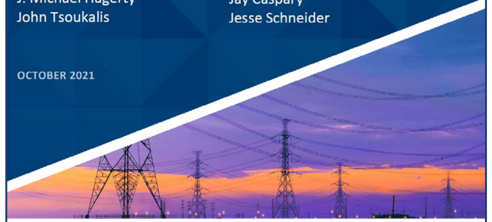
Link: [Brattle Grid Strategies]

PREPARED BY

*The Brattle Group:*
Johannes Pfeifenberger
Kasparas Spokas
J. Michael Hagerty
John Tsoukalis

*Grid Strategies:*
Rob Gramlich
Michael Goggin
Jay Caspary
Jesse Schneider

OCTOBER 2021



Brattle

GRID STRATEGIES LLC

Summarizes proven approaches to quantifying various benefits

# Additional Reading on Transmission


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.

Pfeifenberger, Ruiz, Van Horn, "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. "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

## INDUSTRIES

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

# Our Offices


BOSTON


BRUSSELS


CHICAGO


LONDON


MADRID


NEW YORK


ROME


SAN FRANCISCO


SYDNEY


TORONTO


WASHINGTON, DC