Analysis of Resource Adequacy across the Eastern Interconnection

An open-source case study using GridPath

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ESIG Webinar

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Study Overview

Wide Area Resource Adequacy Study of the Eastern Interconnection

Objectives

1. Conduct a resource adequacy analysis of the Eastern Interconnection to calculate near-term (2028) loss of load risk of the system.
2. Evaluate the role of interregional transmission and market assistance on resource adequacy by evaluating regions with varying amounts of interregional transmission capability.
3. Develop a publicly available dataset and model using the GridPath open-source model that can be used by researchers and industry for future studies.

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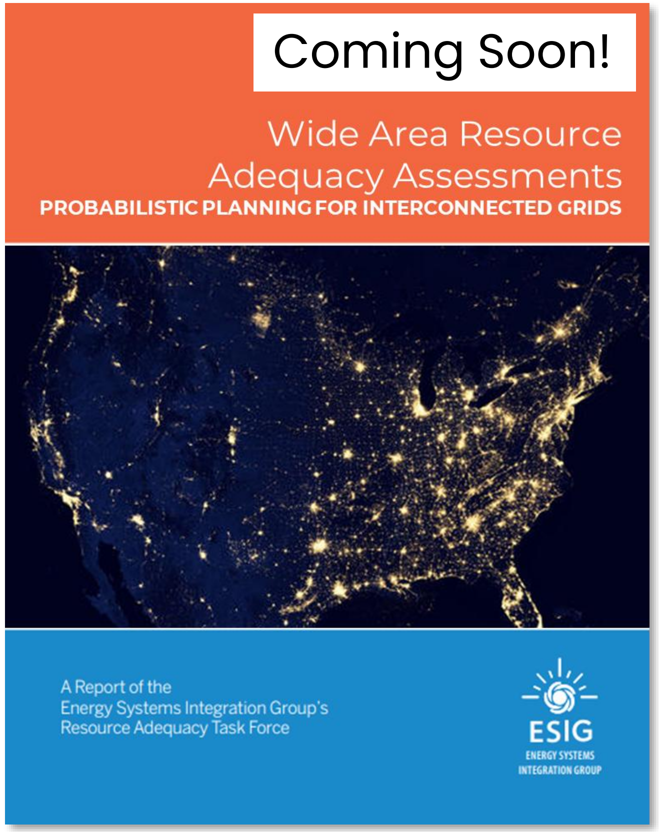
Why perform wide-area assessments?

- **Interregional Transmission Planning:** identify transfer limitations and uncover high-value opportunities for new interregional transmission
- **Scenario Consistency:** shared scenarios and assumptions that improve alignment across planning entities
- **Neighboring System Visibility:** Resource mix and load changes in adjacent regions can significantly affect local adequacy. A wide area view helps planners anticipate these shifts and plan accordingly
- **External Assistance Evaluation:** assessing regional capacity needs both with and without imports clarifies the extent to which reliability depends on neighboring systems.
- **Extreme weather event evaluation:** help identify strategies for managing risks posed by large-scale weather events that span large geographies, like polar vortexes or heat domes.
- **Methodological and metric alignment:** developing shared input data, modeling approaches, and common metrics increases transparency and comparability across regions.



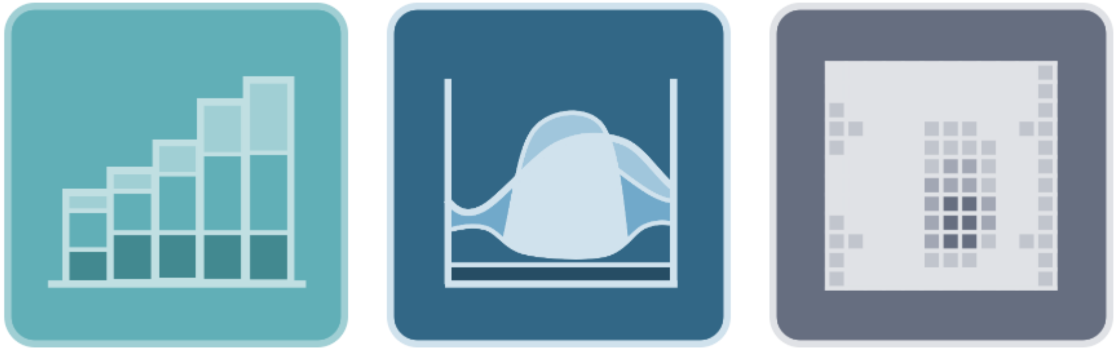
Source: Energy Systems Integration Group, Best Practices for Wide Area Assessments (Report forthcoming; fact sheet available at esig.energy)

GridPath RA Toolkit

Open-Source Modeling for Power System Planners, Researchers, and Industry

- **GridPath**, open-source power system platform developed and maintained by Sylvan Energy Analytics, which includes capacity expansion, production cost, and RA modeling: https://github.com/blue-marble/gridpath
- **Western US Dataset** which includes the load, resource, and transmission data for conducting RA assessments of the Western US in 2028: www.gridlab.org/GridPathRAToolkit
- **Eastern US Dataset** which includes models and data used to conduct this study. www.gridlab.org/GridPath_EI

Users can customize the datasets to evaluate other systems, years, or portfolios. Users can also modify the code to create new functionality in GridPath.



Capacity Expansion

- Fully customizable temporal granularity, geo-spatial granularity, and sampling methodology
- Endogenous retirements, transmission expansion, and DSM selection
- Stochastic optimization for planning under uncertainty*
- Automated integration with resource adequacy and production cost modeling via iterative optimization*

Production Cost

- Multi-stage scheduling, commitment, and dispatch optimization
- Fully customizable temporal and geo-spatial granularity
- Zonal, nodal pipe flow, and DC power flow transmission options
- Market energy and ancillary service* price-responsive dispatch

Resource Adequacy

- Time-sequential and energy-constrained dispatch simulation
- Zonal transmission constraints and path limits
- Synchronized or Monte Carlo weather treatment for loads and resource availability over wide areas
- Weather-driven Monte Carlo outages

Methodology

Evaluating chronological system operations across multiple weather years

Increase in variable renewable energy and energy limited resources requires resource adequacy to consider *chronology* and *correlation*

- Hundreds of hourly dispatch simulations, considering generating characteristics, hourly changes in load and renewable output, forced outages (randomly occurring)
- Storage scheduling and transmission flows is based on arbitraging energy margins temporally and spatially, but high value of lost load (VoLL) ensures sufficient state of charge is available during scarcity events
- No hydro sampling was performed across various weather years due to relatively low hydro resources in the Eastern Interconnect

Study Scenarios

Three transmission scenarios were conducted to evaluate benefits of interregional transmission

Increasing Transfer Capability

No Tx

No Interregional Transmission Capability

- No interregional transfers between balancing authority regions (PJM-S ✕ SERC-E)
- Intra-balancing authority region transfers subject to technical limit (PJM-S ↔ PJM-W)

RA Tx

RA Import Transmission Capability

- Interregional transfers into ISO regions limited to expected assistance modeled in local RA studies
- Simultaneous region imports limited by interface limits reported in NERC ITCS
- All regional transfers subject to technical limit

Full Tx

Technical Transmission Capability

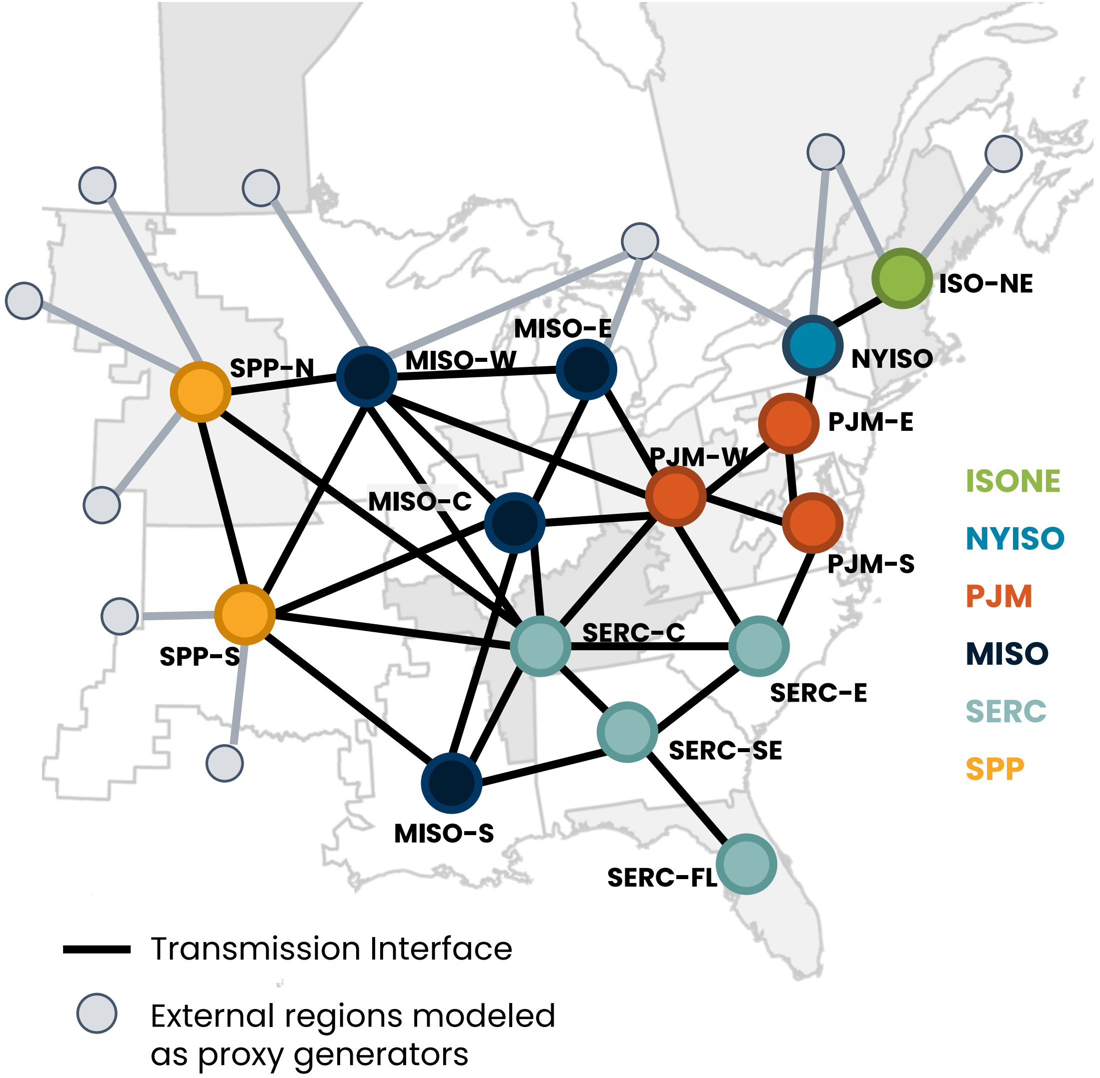
- Simultaneous region imports limited by interface limits reported in NERC ITCS
- All regional transfers subject to technical limit

Inputs & Assumptions

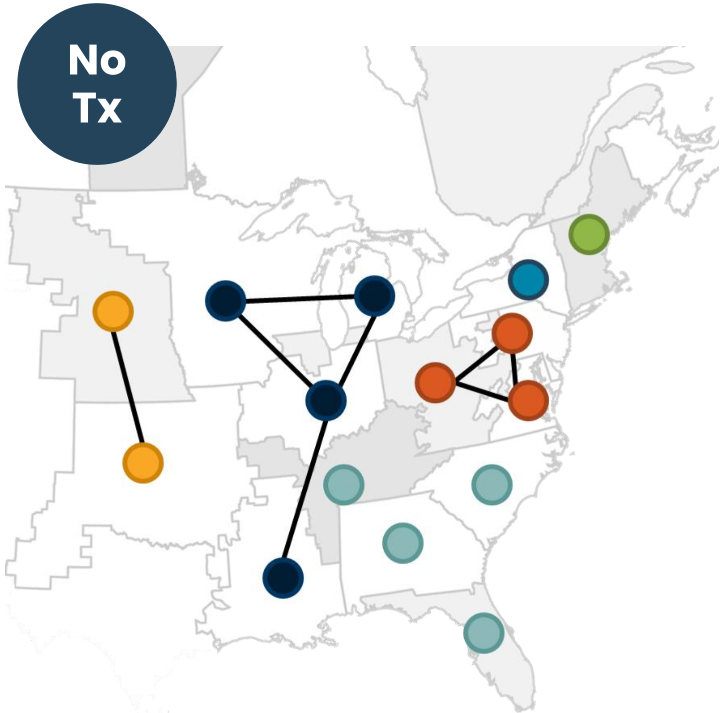
Study Topology

- Eastern Interconnect divided into Transmission planning regions aligned with NERC ITCS topology.
  - SPP, MISO, and PJM are divided into sub-regions
  - SERC regions divided into NERC Assessment Areas
- Flows across transmission interfaces limited to region-to-region technical transfer capability
- Simultaneous flows into all regions are modeled with a simultaneous import capability
  - Sub-region to sub-region flows not affected
- External interties in WECC and Canada are modeled as proxy generators with a max rating and daily energy budget

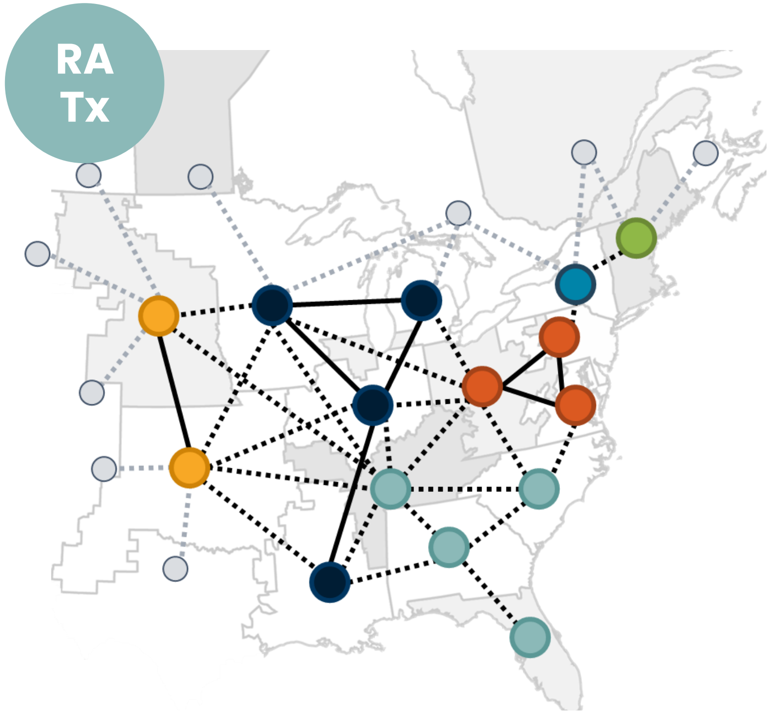
Regions are assumed to serve their own load first, imports/exports are for reliability purposes only, after exhausting local resources



Transmission Scenarios



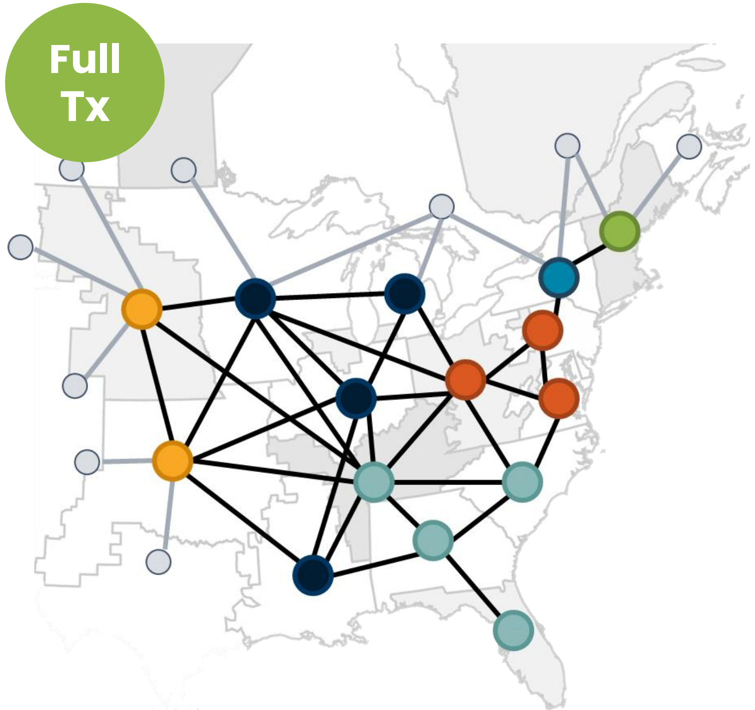
Internal transmission interfaces only, based on technical limit



Internal transmission interfaces based on technical limit

Interregional transmission limited by *Total* assumed market assistance or firm Transfers

External regions modeled as proxy generators



Internal and interregional transmission interfaces based on technical Limit

External regions modeled as proxy generators

In all cases, each region is also limited by a "total import interface" in addition to limits on individual interfaces.

Assumed limit on assumed market assistance based on ISO studies or firm imports in the NERC LTRA.

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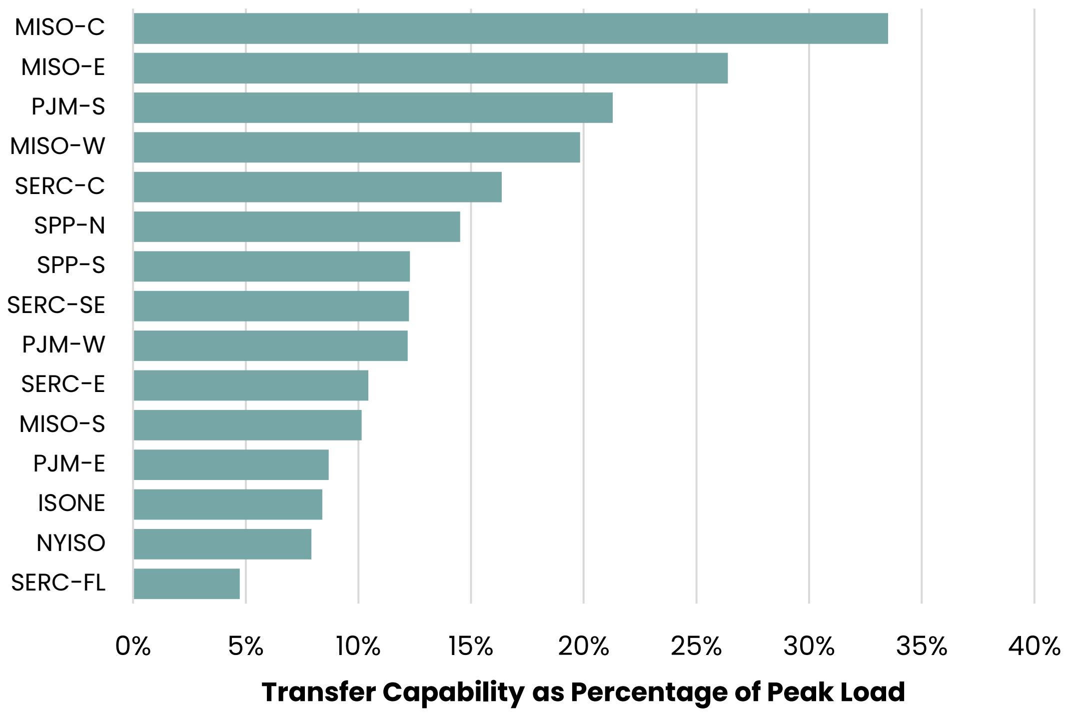
Interregional Transfer Interface Limits

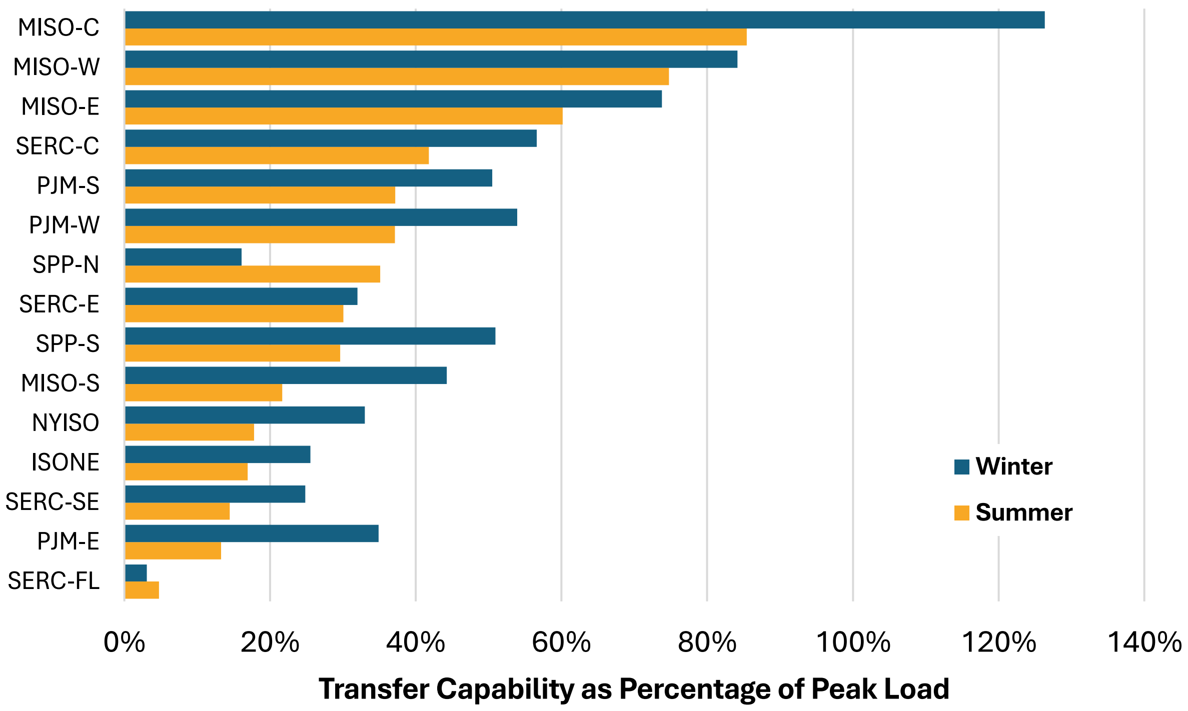
Coincident Transfer Capability

(simultaneous import capability)



Non-Coincident Transfer Capability

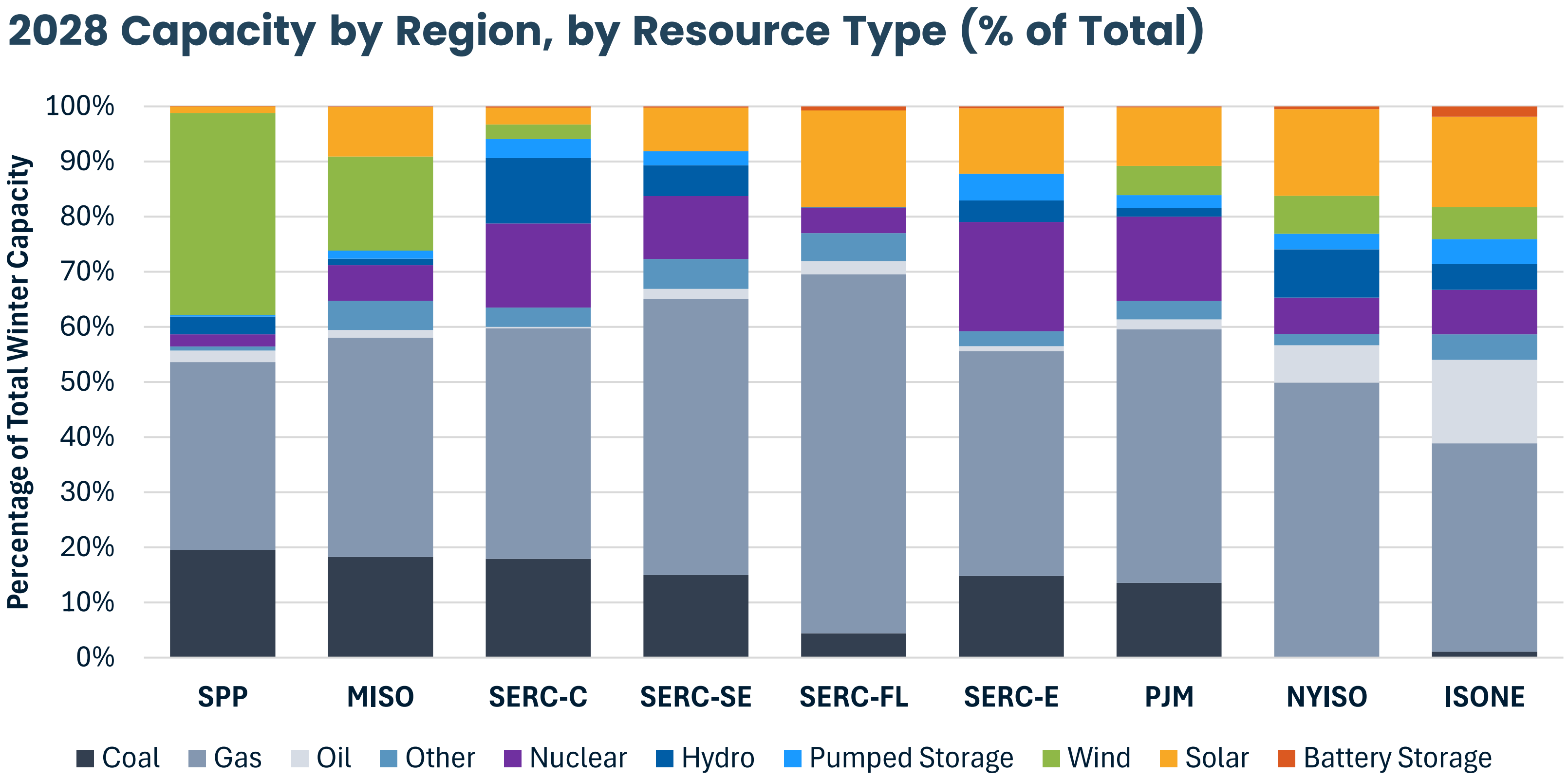
(sum of individual ties)



Generator Capacities *(continued)*

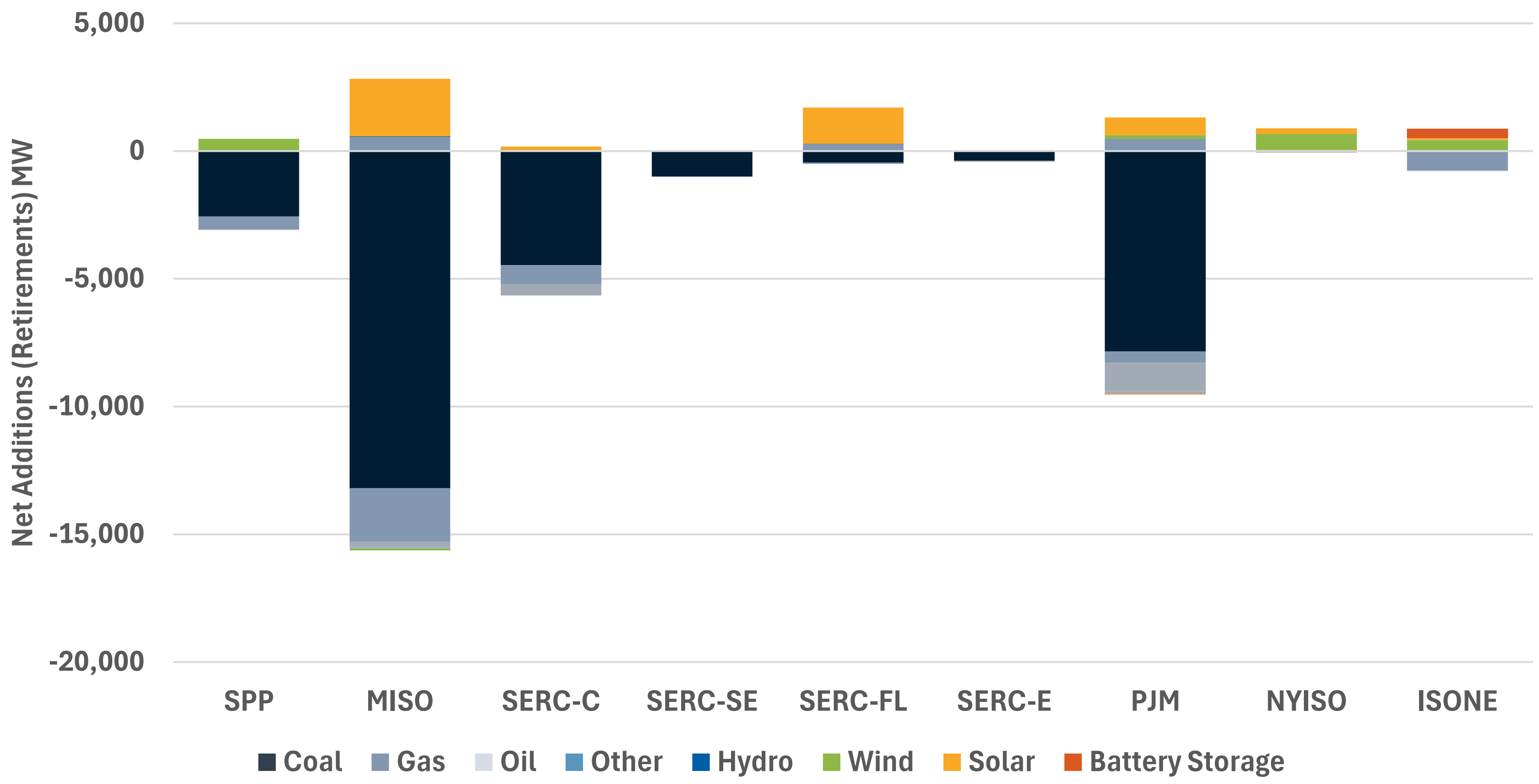
- Gathered from Operable and Proposed generators in EIA 860 2024 Data Forms
- Accounted for retirements and new installation as of 2028.
- New installations only include projects under construction or with regulatory approval
- Mapped to transmission planning regions based on state, balancing authority, or manual mapping where needed.

Data Source: EIA-860



Installations and Retirements

Net Generation Additions (+) and Retirements (-) from 2024 to 2028



- New installations predominately from wind, solar, and storage resources
- Limited new gas build, even in regions with significant retirements
- 30 GW of coal retirements, primarily in SPP (2.6 GW), MISO (13.4 GW), SERC-C (4.5 GW) and PJM (7.8 GW)
- The model is based on announced retirements and late-stage resource additions. No requirement for equal replacement

Weather Years

Approach leveraged both synthetic, modeled datasets and actual historic observed profiles.

	Modeled/Synthetic	Actuals/Historic
WEATHER YEARS	2007 · 2008 · 2009 · 2010 · 2011 · 2012 · 2013 · ...	2019 · 2020 · 2021 · 2022 · 2023
HOURLY LOAD	Hourly 8760 load profiles by weather year and region based on NREL ReEDS load profiles and Standard Scenarios. Load profiles were scaled to align with forecast year 2028 from the latest ISO forecast or NERC 2024 LTRA in non-ISO regions.	Actual load profiles derived from EIA Form-930 data. Historical load profiles were scaled up to future peak and energy targets while maintaining historical weather variation.
HOURLY WIND & SOLAR	Hourly 8760 wind and solar profiles by weather year and region based on NREL ReEDS siting and the NREL WindToolkit and NSRDB datasets. A bias correction was applied to synthetic renewable profiles to align with historic observations.	Actual wind and solar generation by region, derived from EIA Form-930 data, converted to capacity factors based on historical installed capacity.

This study assumed physically consistent weather to maintain weather correlation and consistency and did not introduce Monte Carlo sampling

Results

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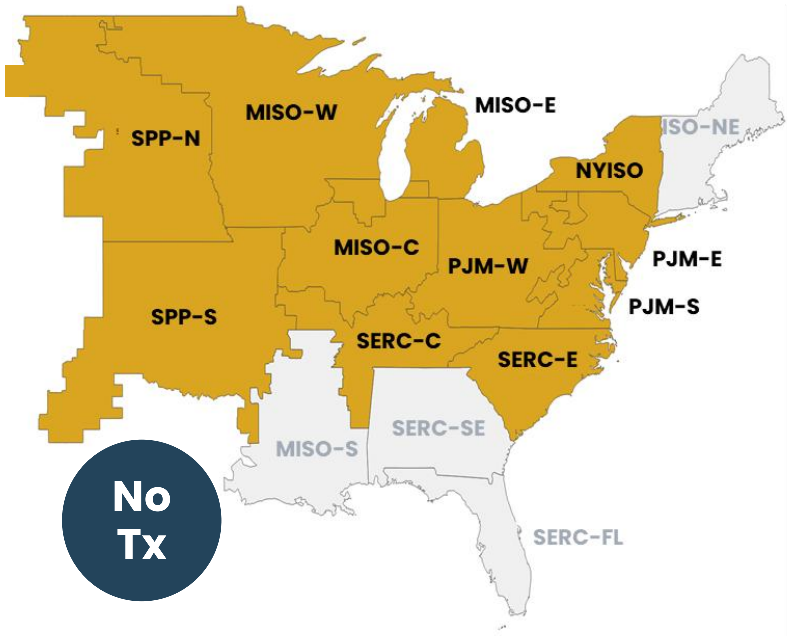
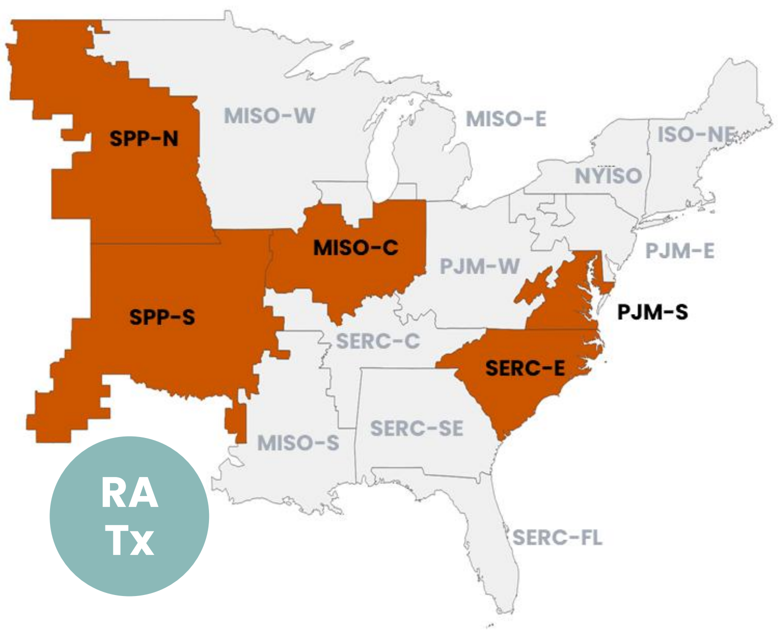
Eastern Interconnect Risk Map

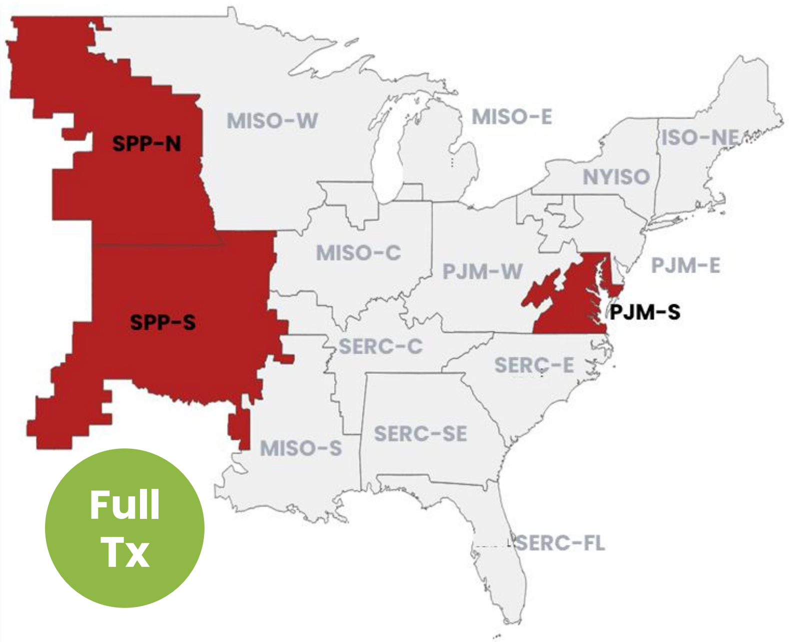
Moderate Risk
Greater than 0.1 days/year LOLE, but only without interregional transfers



Elevated Risk
Greater than 0.1 days/year LOLE when using a region's RA import levels



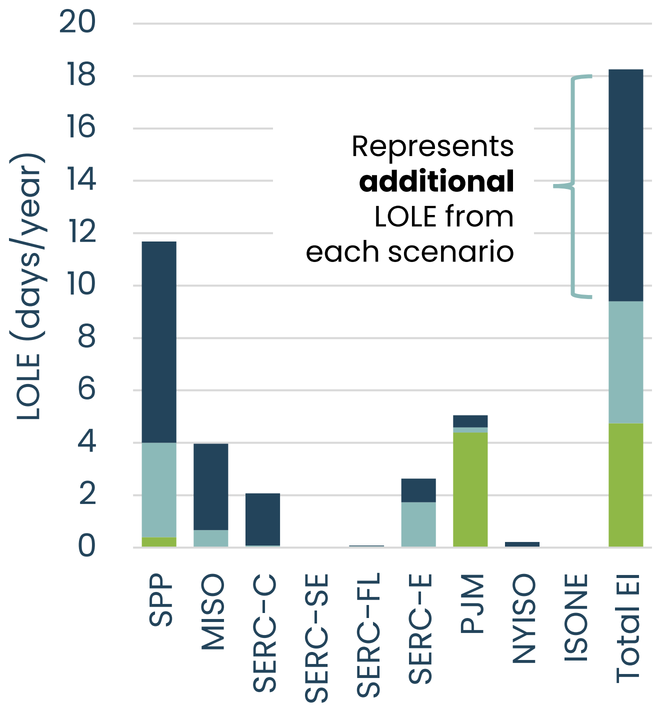
High Risk
Greater than 0.1 days/year LOLE in all scenarios, even with full transfer capability



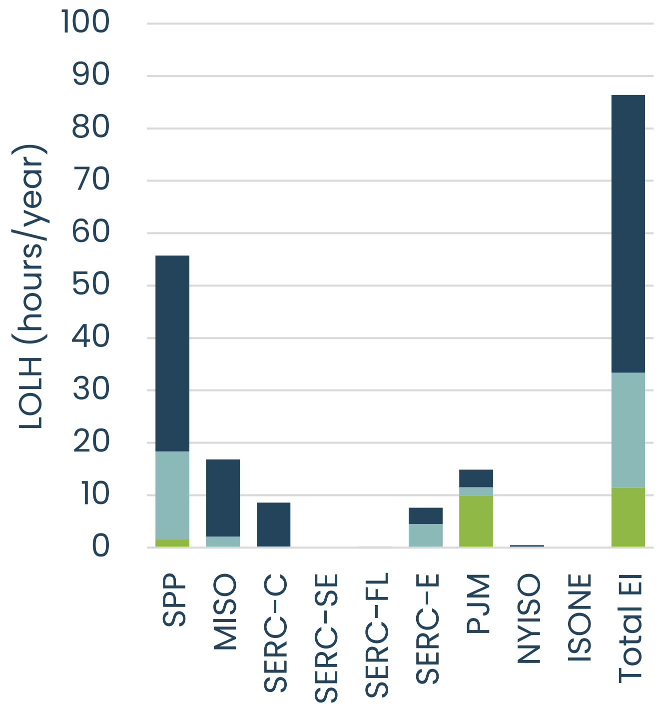
RA Summary Statistics

by Region and Scenario

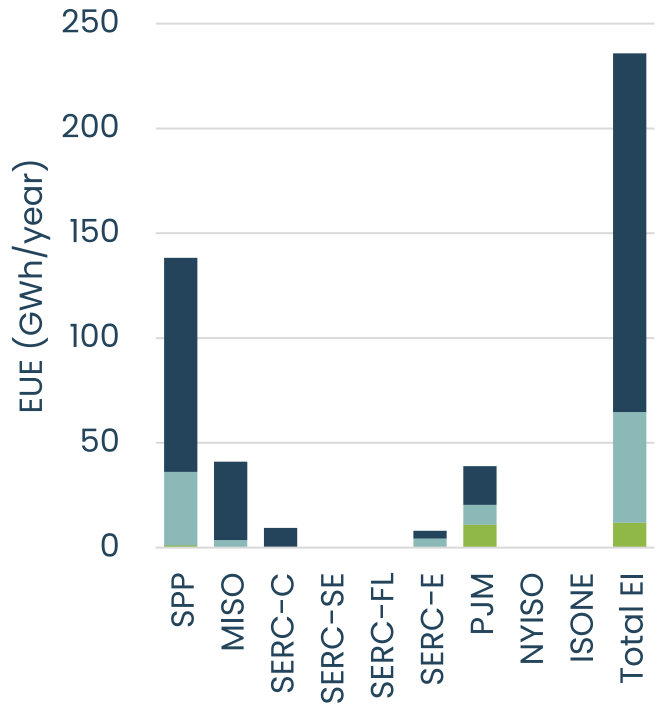
Loss of Load Expectation



Loss of Load Hours

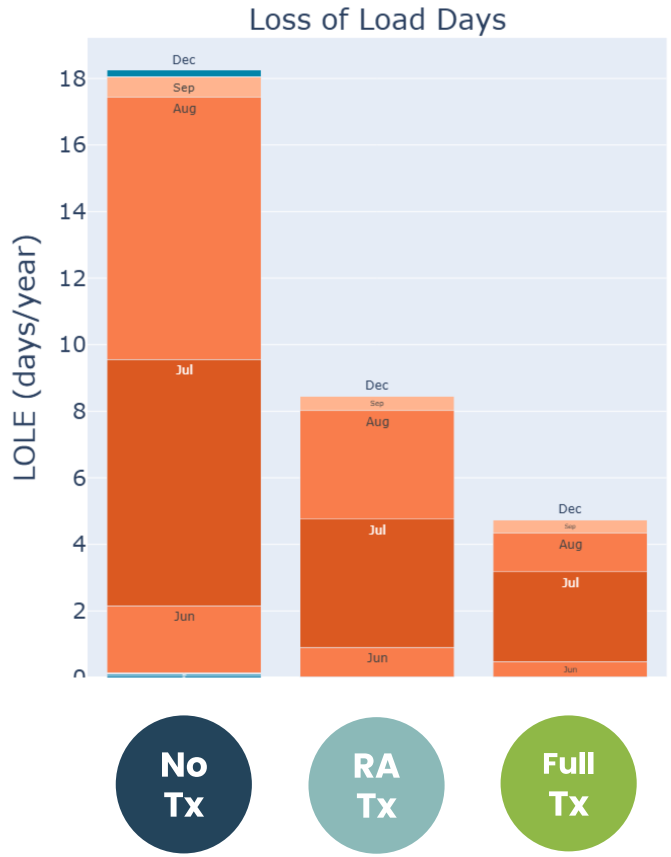


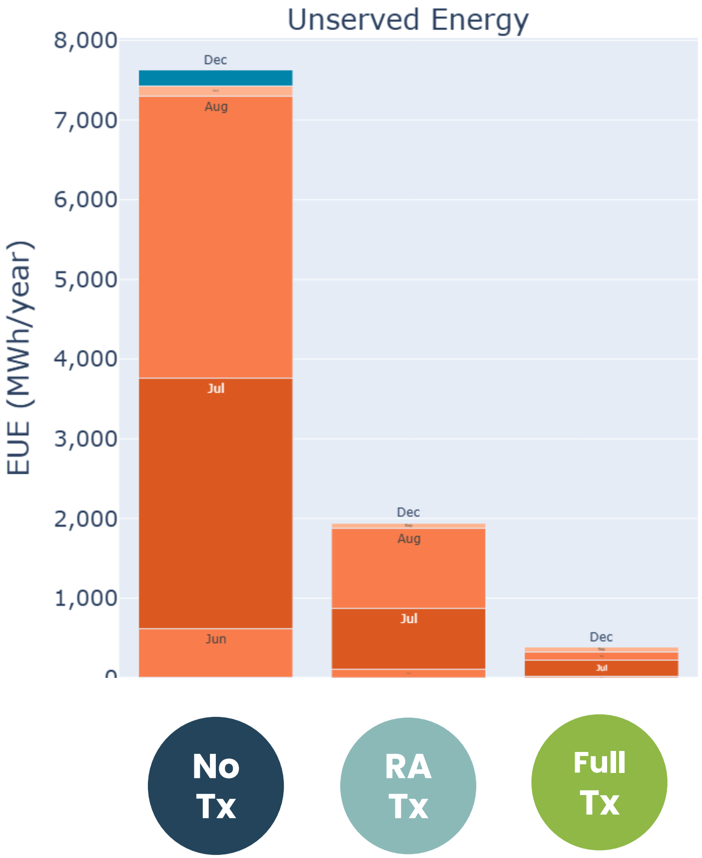
Expected Unserved Energy



No Tx (+ RA Tx + Full Tx) RA Tx (+ Full Tx) Full Tx

Loss of Load Expectation by Month

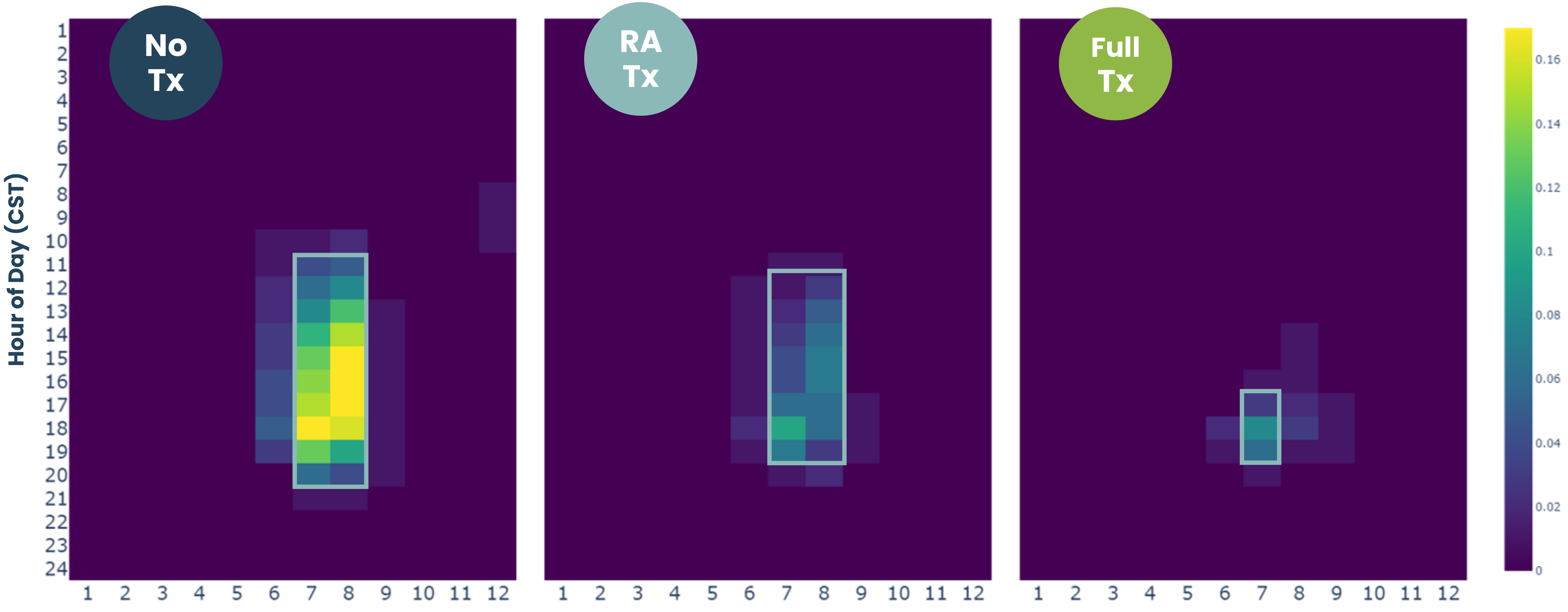




- For the wide area assessment, a loss of load event occurs if there is unserved energy anywhere in the Eastern Interconnect
- One region with one loss of load hour on a day, counts as an unserved energy event for the entire EI.
- Loss of load expectation concentrated in peak summer demand months
- Limited/no unserved energy in winter demand periods because correlated outages and fuel supply disruptions are not included at this point.

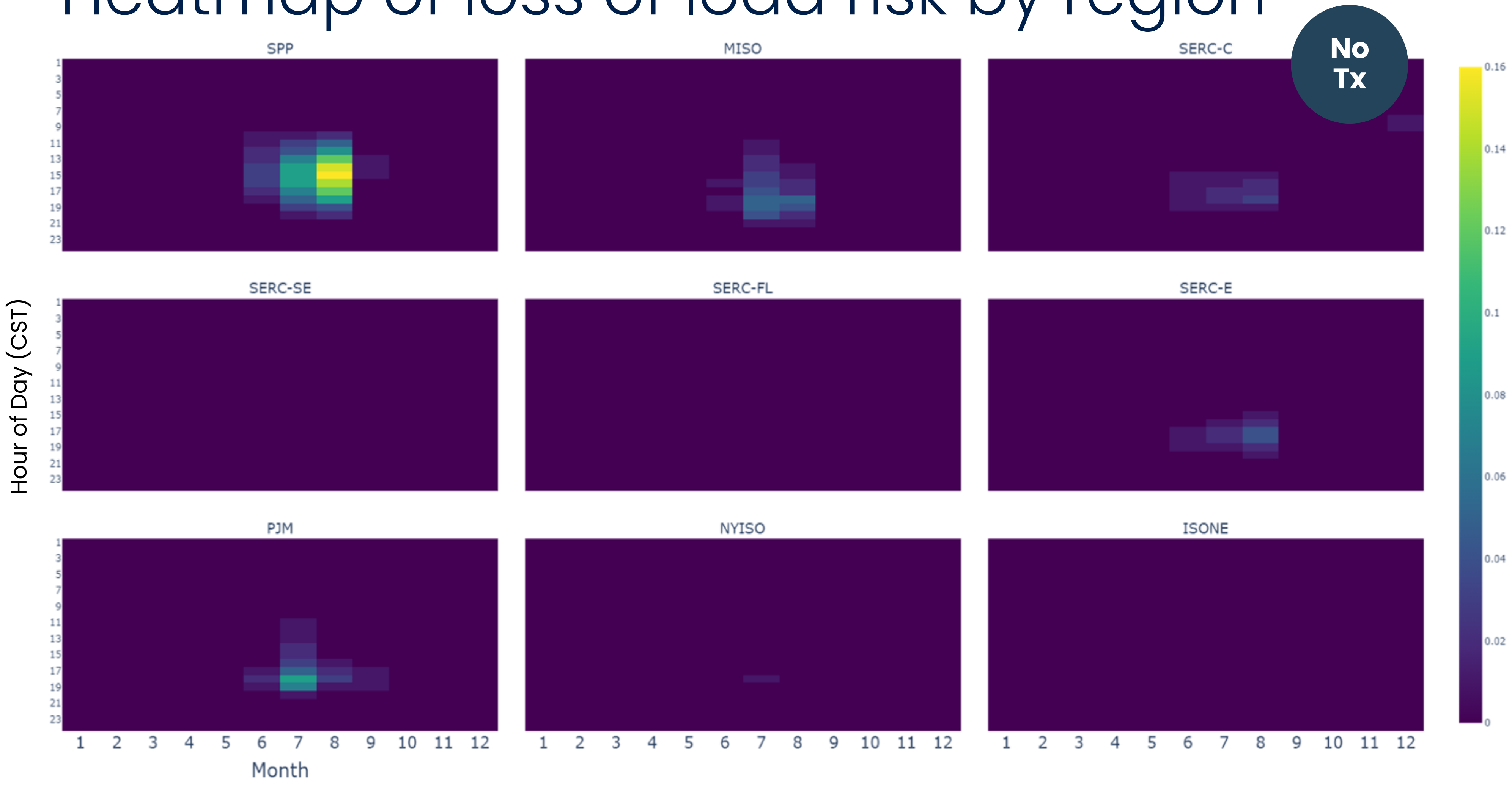
Heatmap of loss of load risk

Loss of load probability by month and hour, % of all hours



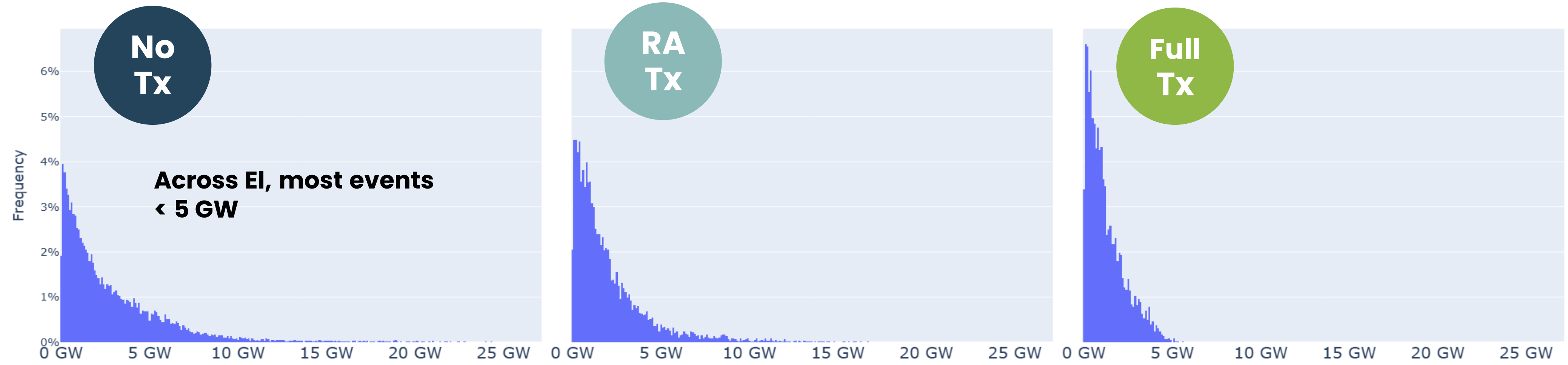
- Loss of load risk window occurs in summer evenings, primarily HE 14-20, July and August
- Interregional transmission shortens risk window, further enabling storage resources for RA

Heatmap of loss of load risk by region

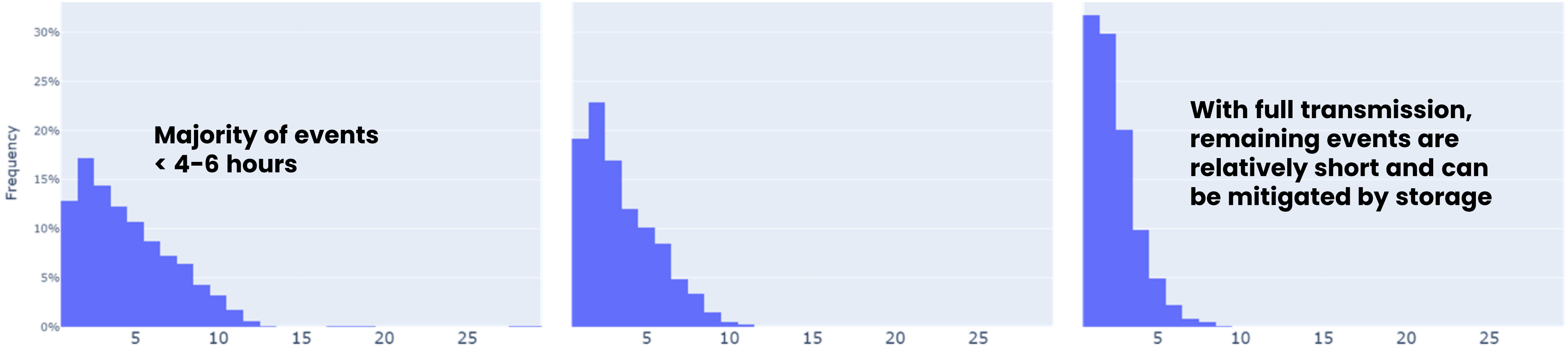


- SPP and PJM demonstrate highest risk among all load zones
- Both load zones' LOL occurs in summer months.
- SPP events concentrated in HE 13-19, PJM events concentrated in HE 17-19

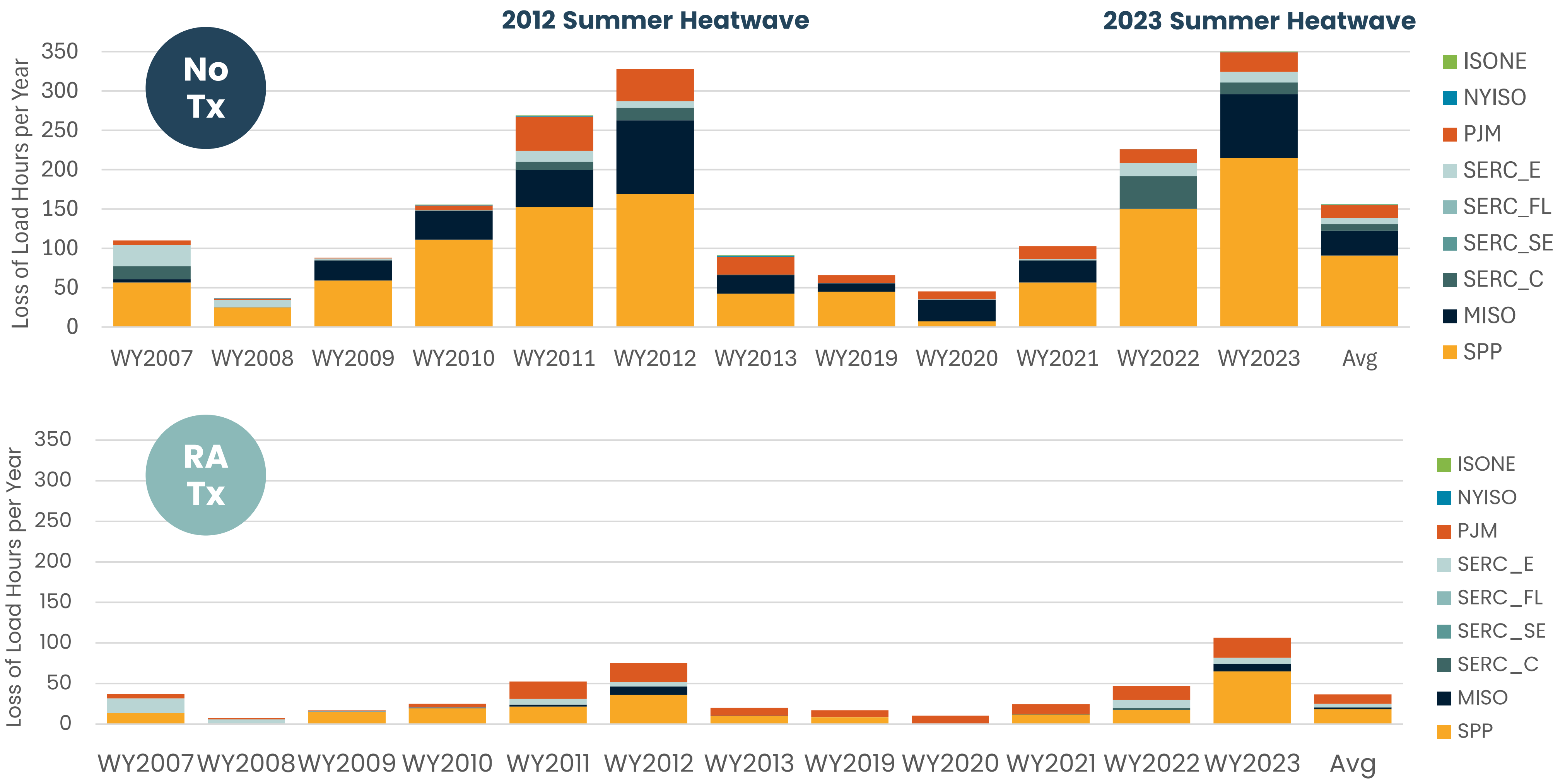
Event Histograms – Max Unserved Energy



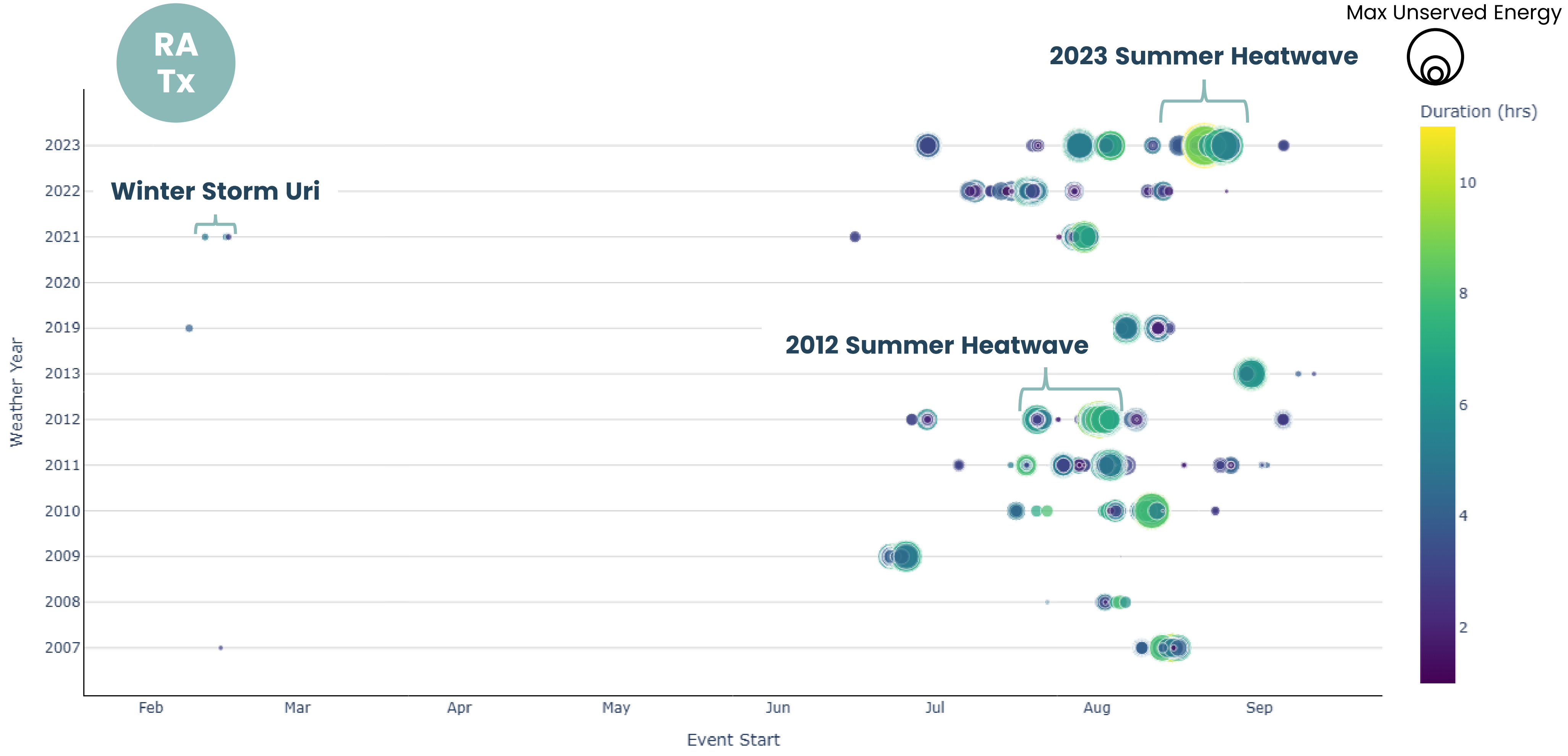
Event Histograms – Duration (Hours)



Regional LOL Hours – By Weather Year



Event Duration and Magnitude Timelines



PJM-S Sensitivity Analysis

Three sensitivities to address PJM-S risk

A. Capacity Additions

- +4 GW Battery Storage (33% of Queue)
- +1 GW of OSW (40% of Queue)
- +3 GW of Solar (25% of Queue)

B. Import TX Additions

- 4 GW increase to PJM-S Total Import Limit, but still below the non-coincident transfer capability of individual interfaces [9,580 MW → 13,580 MW]

C. Half of Capacity and Import TX Values

Significant decrease in loss of load risk

PJM-S	LOLE days/yr	LOLH hrs/yr	EUE MWh/yr
Base Case [No Tx]	5.05	14.85	36,836
A. Resources	0.05	0.06	25
B. Transmission	0.12	0.14	107
C. Resources + Tx	0.06	0.07	40

**based on 300 samples instead of 900*

PJM-S can meet its resource adequacy needs with either new clean energy resources or new transmission using less than a third of the proposed interconnection queue resources and no new gas.

Key Findings and Future Research

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Key Findings

In 2028, with assumed load growth, generator retirements, and limited new resources:

- Most regions in EI have moderate to high loss of load risk if interregional transfers are not included. SERC-SE, SERC-FL, ISONE have sufficient resources to meet load without imports
- Regional diversity in load, wind and solar generation, and loss of load risk shows that capacity can be transferred between regions, even when each region in isolation is inadequate.
- With interregional transfer levels assumed by the regions (RA Tx) most regions have sufficient resources when regions are evaluated together.
- PJM and SPP show high LOLE risk without new additions, even when allowing imports from neighbors. PJM-S is import constrained, leading to high RA risk even with surplus capacity in PJM-E and PJM-W.
- Remaining resource adequacy risk can be mitigated with a portfolio of clean energy (including demand response , given durations of the events) or interregional transmission resources

Future Research and Data Improvements

Future Clean Energy Portfolios

While this study evaluated announced retirements and additions of wind, solar, and storage deployment, future studies that evaluate higher levels of retirements and new resource additions can quantify resource needs.

Increased Transmission Scenarios

In tandem with generation scenarios, increased inter- and intra-regional transmission can address regional energy shortfalls.

Additional Load Years

This study used 12-years of consistent and correlated weather data for wind, solar, and load. Additional study years, notably for load, would increase statistical power.

Transmission Accreditation

Wide area assessments can be used to calculate capacity contributions for new interregional transmission, compare accreditation to resource options and prioritize new development.

Weather Dependent Outage Rates

Additional data on thermal resource reliability, including cold weather forced outages and fuel supply constraints, is required. Sector coupling between the natural gas system and power system is also necessary.

Weather and Climate Data

Power system reliability is becoming increasingly driven by the weather. Improved data for correlated wind, solar, load, and temperature is needed, with and without climate change trends.

Thank you!

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