Stress Testing the Southwest Power Pool

Evaluating the role of interregional transmission in supporting SPP resilience to extreme events

February 9, 2026 Webinar – Executive Summary

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Study Motivation & Key Findings

Motivation 1: Develop an approach for stress testing to analyze system resilience to discrete extreme events and incorporate interregional transmission.

Motivation 2: Use the stress testing approach on an actual system to evaluate interregional transmission resilience benefits.

Available Content:

1. Stress Testing Methods for Evaluating Resilience to Extreme Events
2. Stress Testing the Southwest Power Pool for the 2029/2030 System

Stress Testing Principles	SPP Stress Testing Results
• Create realistic, high impact scenarios using actual weather data.	• Modeling extreme events without correlated interregional representation typically shows greater unserved energy.
• Reflect real-world constraints and interregional resource availability.	• Extreme cold events present the most substantial risks due to correlated outages.
• Model stressors on all resource types (thermal, renewables, storage) using time-synchronized and correlated data.	• Existing interregional transfer capability can substantially mitigate SPP risk even under high load conditions.
• Set limits on maximum disruptions to create a feedback loop with capacity expansion and resource adequacy models.	• Moving beyond static transfer capability values and determining “extreme event” capabilities is a needed next step.
• Don’t limit mitigations to grid stress to capacity procurements alone. Stress testing models can serve as a testing ground to value alternatives like load flexibility, weatherization, etc.	• Modeling full transfer capability + external resource variability shows how the timing of risk matters between regions.

A four-step stress testing process turns extreme events into planning conclusions.

The method connects scenario selection, interconnected-grid representation, chronological simulation, and result interpretation for planning decisions.

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Step 1: Develop Extreme Event Scenarios	Prioritize realism and relevance in scenario design. • Stress tests should be plausible and rooted in multiple years of real-world weather correlated data to maintain credibility. Be open to future climate change scenarios. • Events should be defined clearly using magnitude, duration, frequency, and geographic scope. • Emphasize stakeholder understanding. Be transparent about what is being tested and why.
Step 2: Model the Interconnected Grid	Represent the physical and operational details of the broader system. • Models should seek to reflect real-world capabilities, grid constraints, economics, and interdependencies. • Include interregional transfers and model external resource availability. • Maintain correlation across geographic areas to represent load and resource diversity.
Step 3: Assess Grid Resilience	Evaluate the changing, time-dependent, and correlated nature of stressful events. • Simulate chronological, multi-day events that are relevant for today's grid and the grid of the future. • Analyze risks for all resources and load for how the extreme event affects their risk profiles. • Avoid “peak hour” thinking – resilience is more than capacity at the highest load hour.
Step 4: Create Actionable Plans	Use results to inform practical, forward-looking decisions. • Define risk tolerance thresholds to indicate a pass/fail for stress test results. • Consider diverse mitigation tools beyond just new capacity (transmission, weatherization, distributed resources). • Enable feedback loops between existing planning processes like resource adequacy studies.

Wide-area, multi-day screening captures interregional dependence during extreme events.

The screening criteria enforce correlated weather, coincident stressors, and sustained conditions that drive tail risk

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- Develop a list of **extreme weather and renewable risk event** candidates to select for stress testing
- Assess **region-wide** and **continent-wide** weather to include interregional resource availability
- Long history and a range of years should be considered to understand outlier events what tail-risks may look like
- Focus should be on multi-day events and NOT consider a single peak hour or day but rather over a **span of hours or days**

Integrated System Planning Opportunity

NERC TPL-008-1 standard on extreme heat and cold weather events presents a collaboration point for planners to link stress testing and transmission planning

Four event types and 100 chronological runs per event probe high-risk conditions.

The study varies outages, renewables, and load across 50 stress samples and two load levels for each event.

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4 Stress Tests

Extreme Cold Feb 2021

Extreme Heat July-Aug 2011

Wind Drought Sept 2011

Compound Event Jan-Feb 2010

50 Stress Samples

Stress Variable	Stress Testing Approach
Thermal Forced Outages	50 Random Daily Samples Correlated to Daily Temp
Renewable Generation	50 Random Daily Samples Correlated to Daily Load
Thermal Maintenance	50 Samples of Scheduled Outages
Transfer Capability Levels	50 Randomly Generated Outage Samples (DC lines) or based on published data

2 Load Levels

Reference

10% Higher

Source: Energy Systems Integration Group.

A hybrid stress test model links unit-level operations in SPP with hourly external energy margins.

This approach preserves chronology and weather correlation so transfer capability and external support are evaluated realistically.

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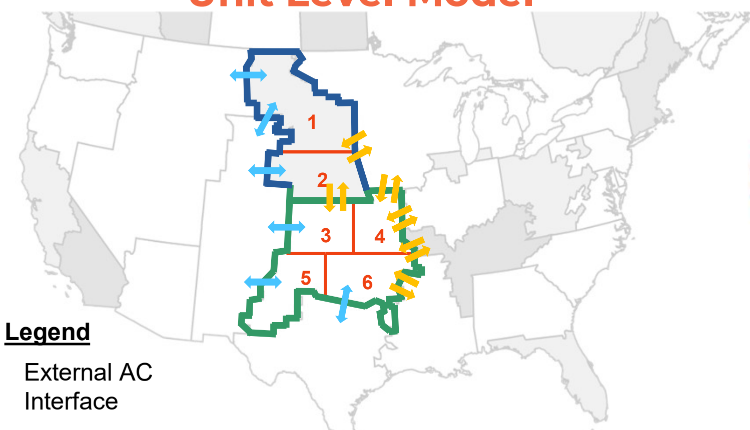
Combining unit-level modeling and hourly energy margins allows for tracking the availability of external resources and interregional transmission benefits in extreme events.

1 Detailed Sub-regional SPP Unit Level Model



Legend

- External AC Interface
- DC Interface
- SPP South
- SPP North
- SPP Subregion

*All region boundaries are approximate and do not show overlapping territory
**All internal SPP interfaces connect to a central "SPP System" node for DR and respective SPP-S and SPP-N nodes for internal transfers
***Canadian regions depicted are not included in the model

Source: Energy Systems Integration Group.

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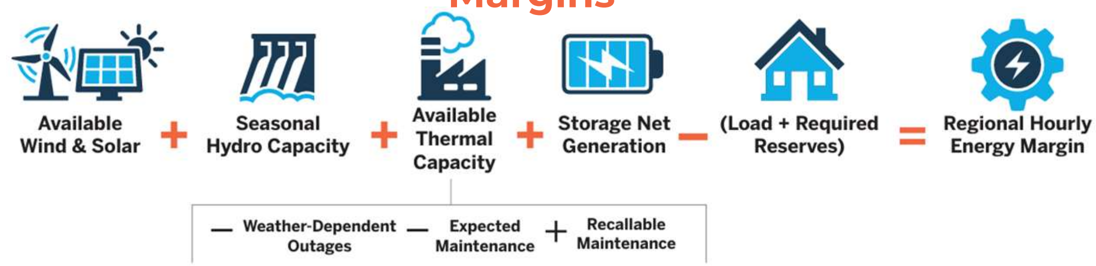
2 External Regions Modeled using Hourly Energy Margins



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Stress Testing Model

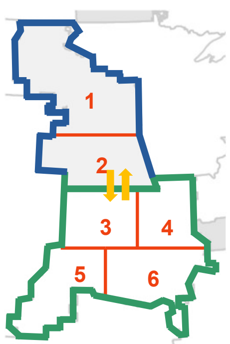
Granular zonal study regions with weather correlated & time synchronized national representation to model discrete extreme events.

Three import representations are used to assess interregional transmissions value

These cases isolate the impact of modeling decisions on stress testing results which affect the perceived resilience value of transmission.

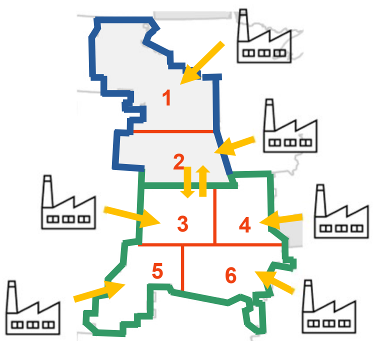
Modeling the same stress test across three import representations was done to reveal the impact that higher fidelity interregional modeling has on system risk.

Islanded (No Imports)



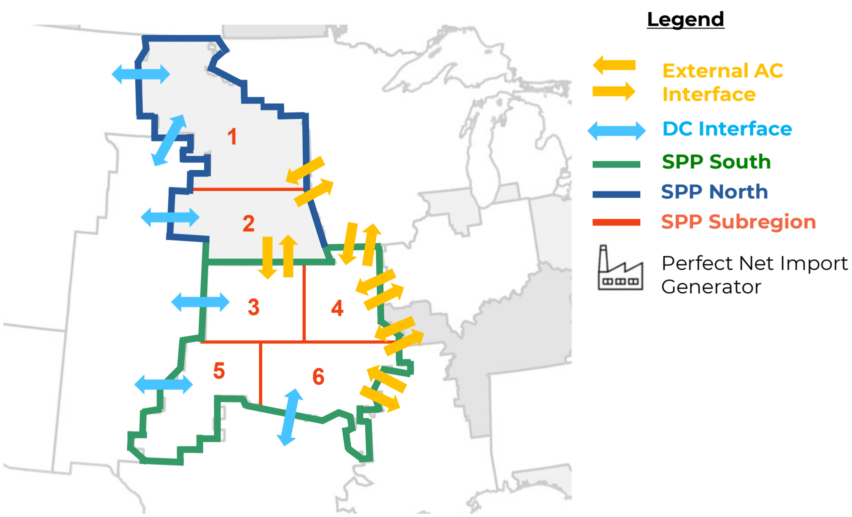
Source: Energy Systems Integration Group.

Firm Net Import Generators



*Consistent with SPP modeling

Transfer Capability + Hourly Energy Margin



There are different regulatory, risk tolerance, and methodological reasons for different modeling choices. But stress testing should seek to represent the available resources and transfer capability of the external system.

Stress Testing Results

Extreme Cold, Extreme Heat, and Wind Drought Events

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Cold event: Compounding stressors make imports decisive for limiting load shed.

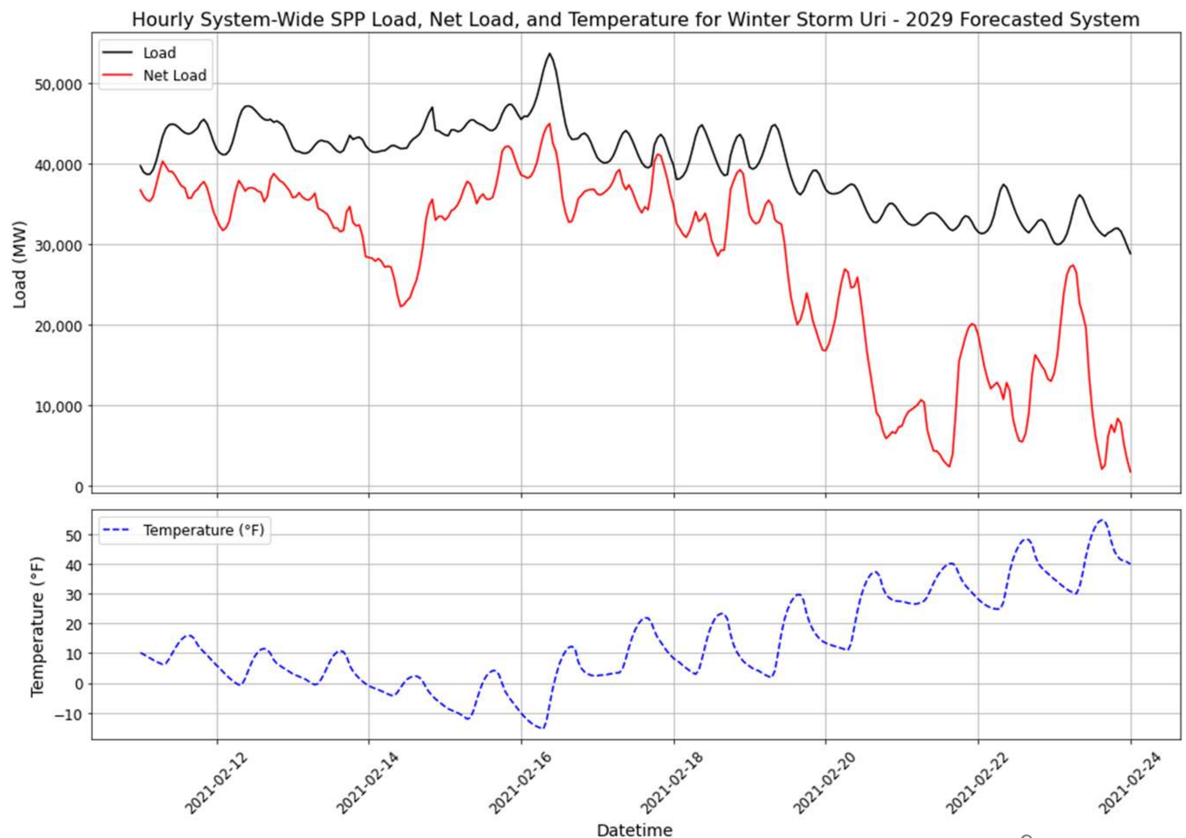
The Uri-like event aligns high load, low renewable output, and elevated outage risk over many hours.

Re-simulated Winter Storm Uri weather, applied to a future power system.

The event consists of a multi-day period with declining temperatures and high net load across SPP and neighboring regions.

Periods of high net load plus low renewable generation truly stress the system. Imports were critical to maintain reliability.

SPP shed load on February 15th and 16th during the actual Uri event.



Source: Energy Systems Integration Group; data from the Southwest Power Pool and PNNL.

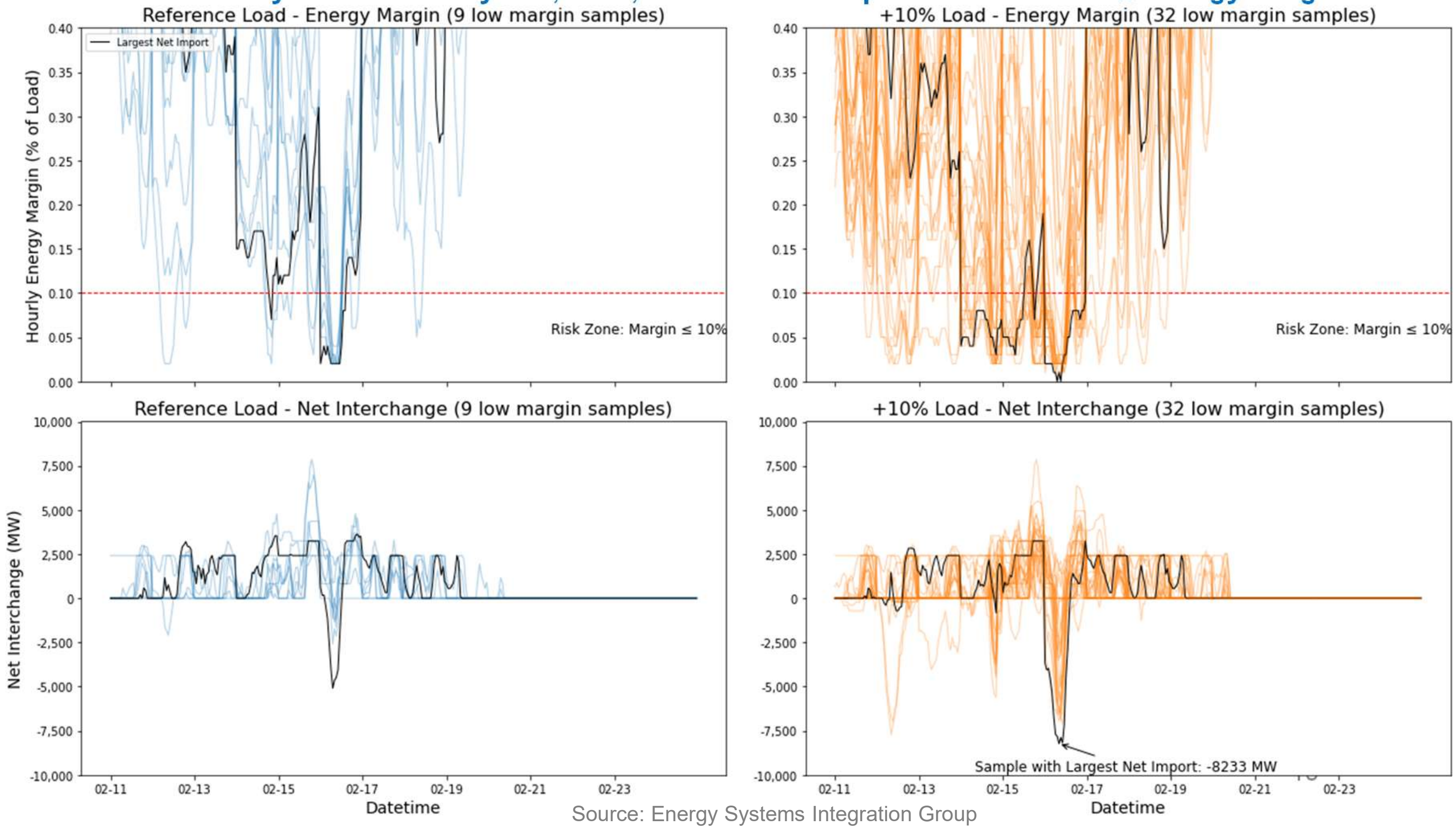
During the cold event, higher load increases scarcity hours and imports are more essential to maintaining service

Modeling neighbors shows imports rising as margins tighten, and unserved energy appears only under higher load when imports are exhausted.

Margin, Imports, and Unserved Energy:

Results	Reference Load	+10% Load
Hours Margin <10%	419 (3%)	1,458 (9%)
Hours Margin <3%	66 (0.4%)	322 (2%)
Max Net Imports (MW)	5,089	8,233
Longest Duration Net Imports (hours)	10	24
Max Unserved Energy (MW)	0	1,315

February 11th – February 24th, 2021, Cold Event Samples with Hours <2% Energy Margin



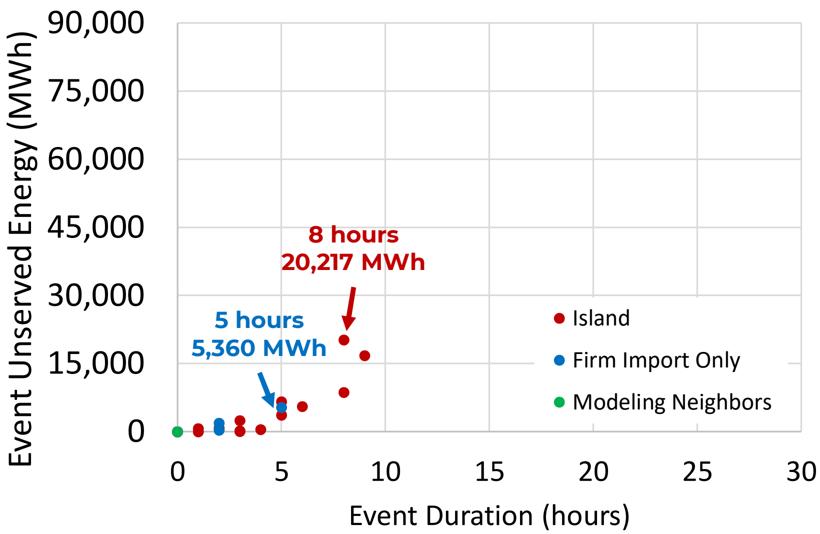
Source: Energy Systems Integration Group

Cold event: Interregional transfers limit unserved energy under high load and elevated outage risk.

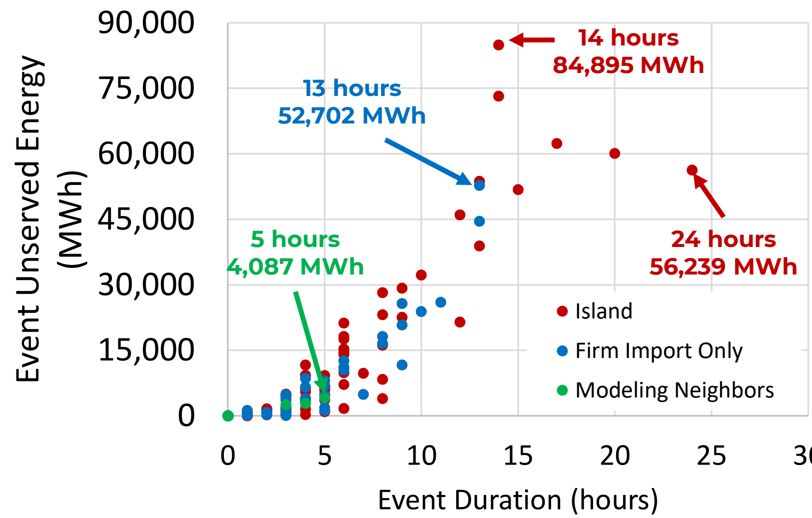
Tracking import availability using transfer capability and weather-correlated external resource availability ensures imports reflect capabilities.

- High thermal outage risks and low renewable generation coupled with high load drive unserved energy risks across all three interregional transmission topologies.
- The SPP system is shown as much more resilient to unserved energy events when modeling full interregional transfer capabilities.

USE Magnitude and Duration – Reference Load



USE Magnitude and Duration - +10% Load



Source: Energy Systems Integration Group; data from the Southwest Power Pool

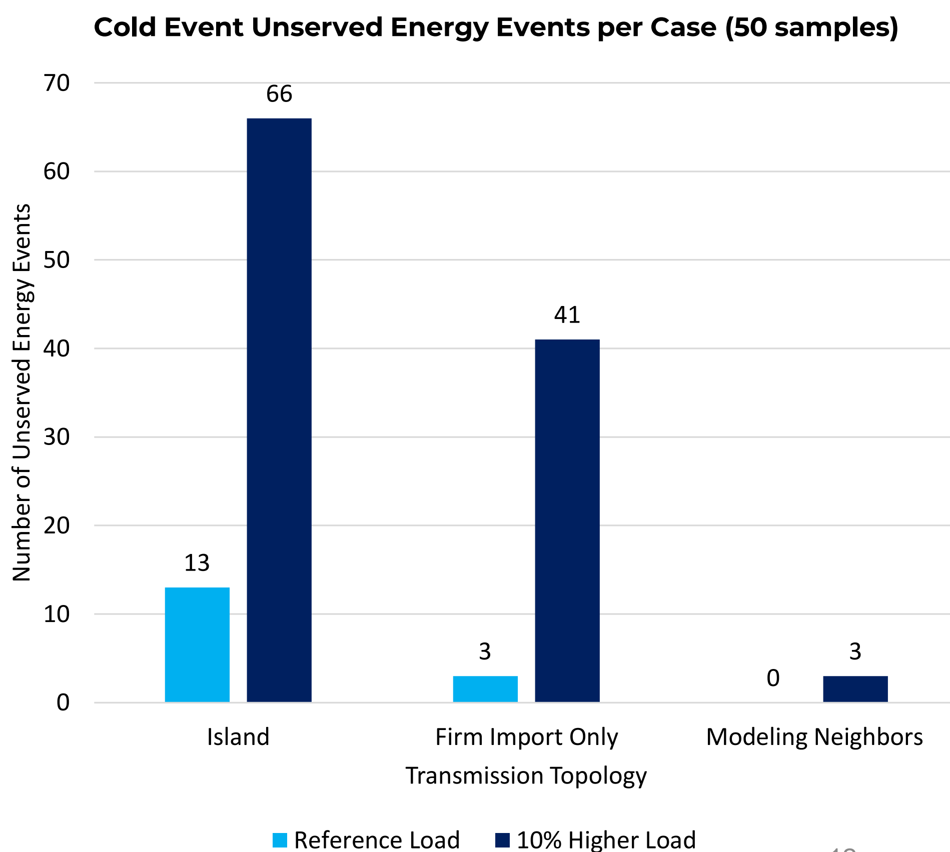
Cold event: Representing transfer limits reduces unserved energy magnitude and duration.

Comparing topologies shows reduced occurrence of shortfall events when the model represents interregional transfer capability.

Across the three system representations, modeling neighboring resource availability and existing transfer capability shows the system is resilient to the extreme cold event.

Pushing the system to high load levels for winter (59 GW) just begins to exceed interregional support.

If/how external assistance and interregional transmission is modeled has a large influence in determining how resilient a system is.



Source: Energy Systems Integration Group

Heat event: Extreme temperatures drive sustained high net load and elevate loss-of-load risk.

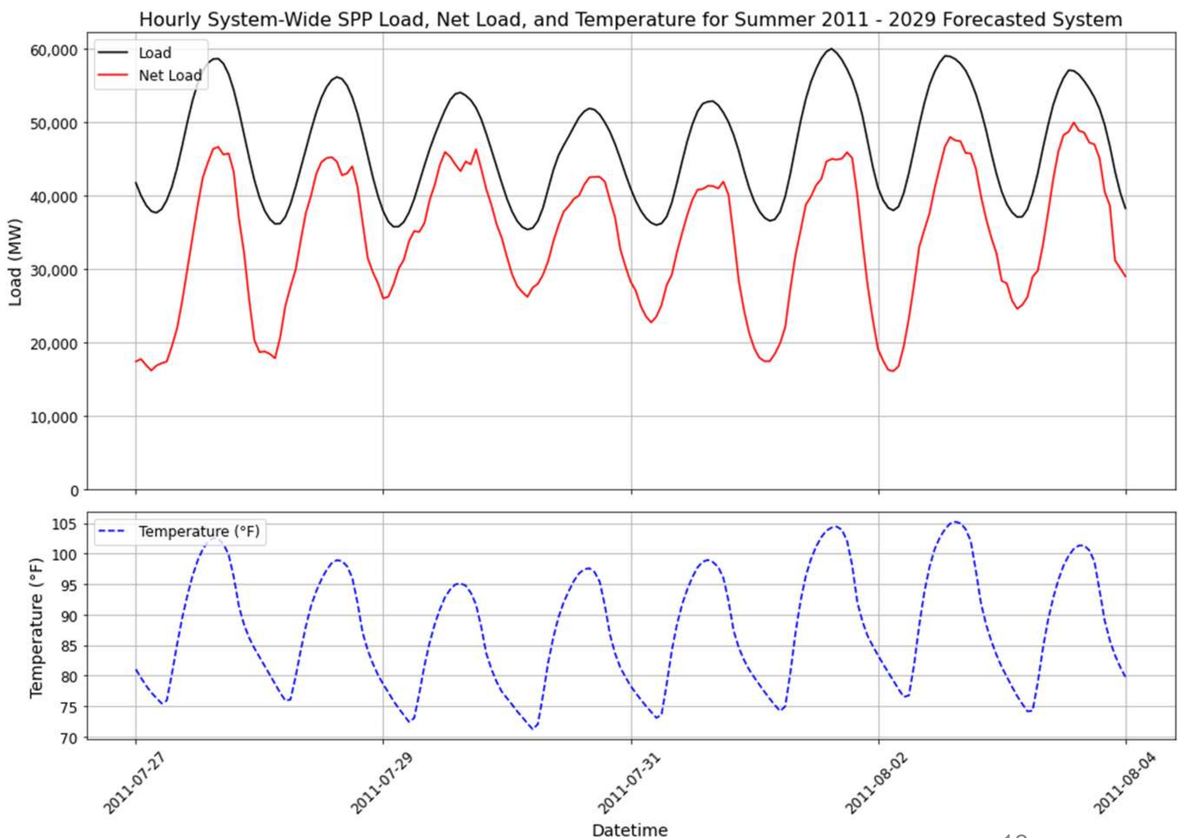
Low summer wind and uncertainty in thermal availability compound high-load conditions across multi-day heat periods

Re-simulated summer 2011 heat events across SPP. July 27 – August 4 are shown, but multiple heat events occurred.

Several days where system-wide average temperature exceeded 100 degrees F.

High load conditions due to extreme heat, low summer wind generation, and uncertainty in thermal generation contribute to high loss of load risks during this period.

The 2023 SPP LOLE Study found 41% of summer LOLE risk in 2011.



Source: Energy Systems Integration Group; data from the Southwest Power Pool and PNNL.

During the heat event, high temperatures drive high load and margins are tight.

When load is increased in the +10% scenario, SPP requires imports above net firm import levels and avoids load shedding.

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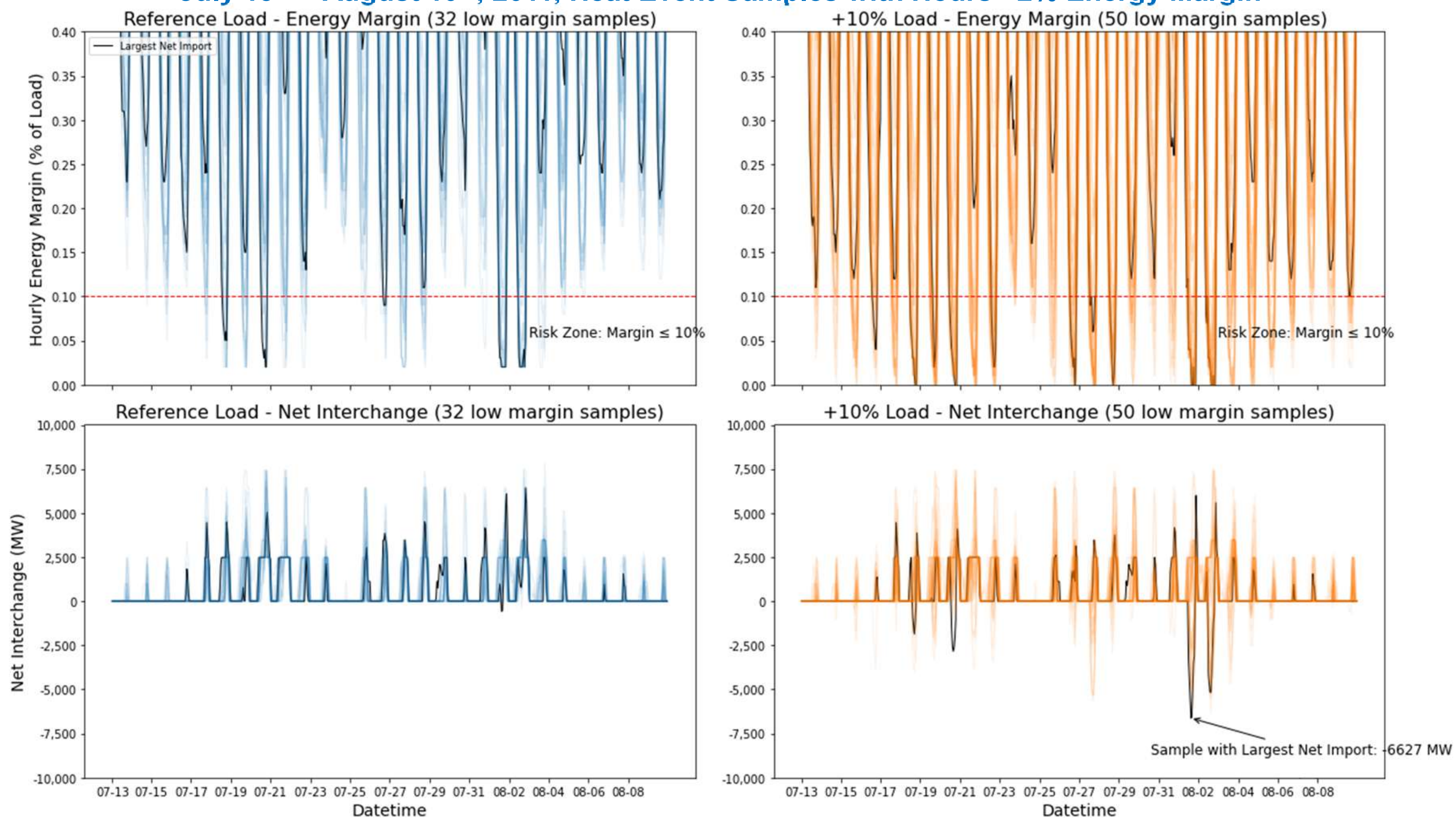
Margin, Imports, and Unserved Energy:

Results	Reference Load	+10% Load
Hours Margin <10%	991 (3%)	4236 (12%)
Hours Margin <3%	233 (0.7%)	1355 (4%)
Max Net Imports (MW)	582 MW	6,627
Longest Duration Net Imports (hours)	2	10
Max Unserved Energy (MW)	0	0

July 13th – August 10th, 2011, Heat Event Samples with Hours <2% Energy Margin



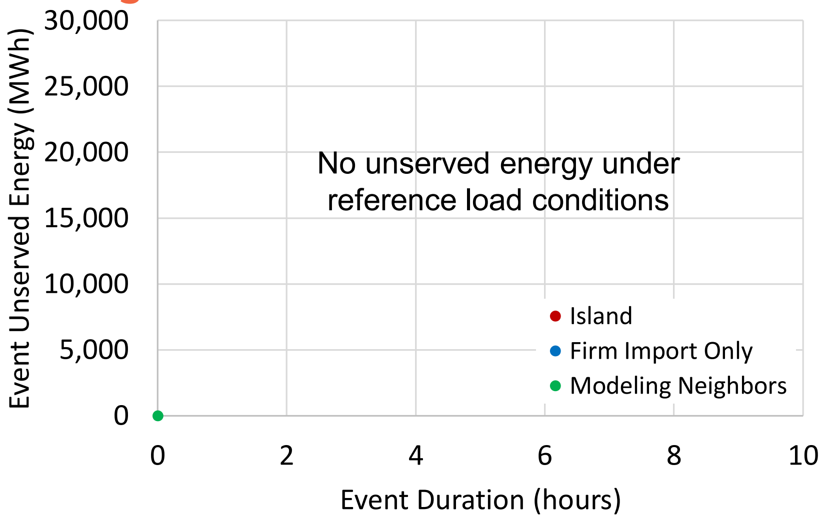
Source: Energy Systems Integration Group

Heat event: Higher load exposes how interregional transfers support reliability.

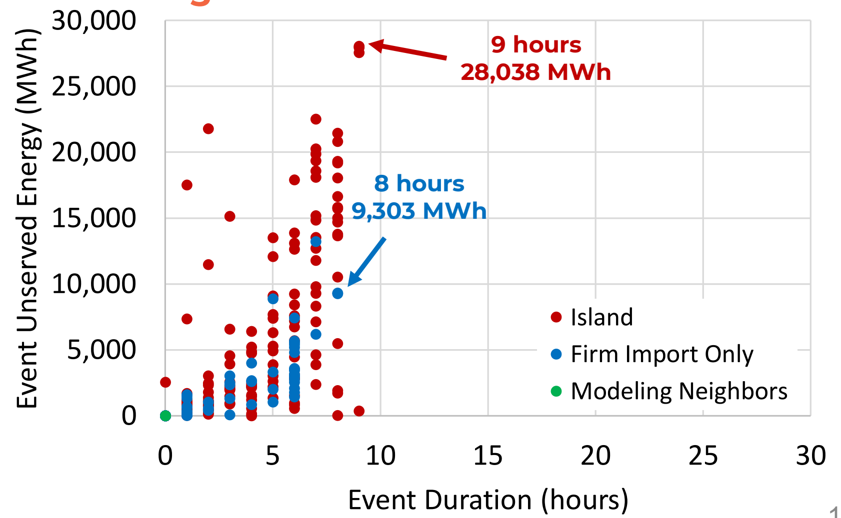
Interregional transfer capability and external resource availability can support SPP even during the most extreme +10% load case.

- Extreme heat under reference load conditions is manageable for the conditions modeled, this is driven in part by +6 GW of solar in the 2029 system relative to the 2025 system
- Modeling higher load reveals that interregional transmission provides a critical buffer to higher load conditions. The reference system shows now risk in these results, but substantial risk when load is raised and interregional transmission is not accounted for.

USE Magnitude and Duration – Reference Load



USE Magnitude and Duration – +10% Load



Source: Energy Systems Integration Group; data from the Southwest Power Pool

Heat event: Modeling neighbors reduces shortfalls identified under simplified imports.

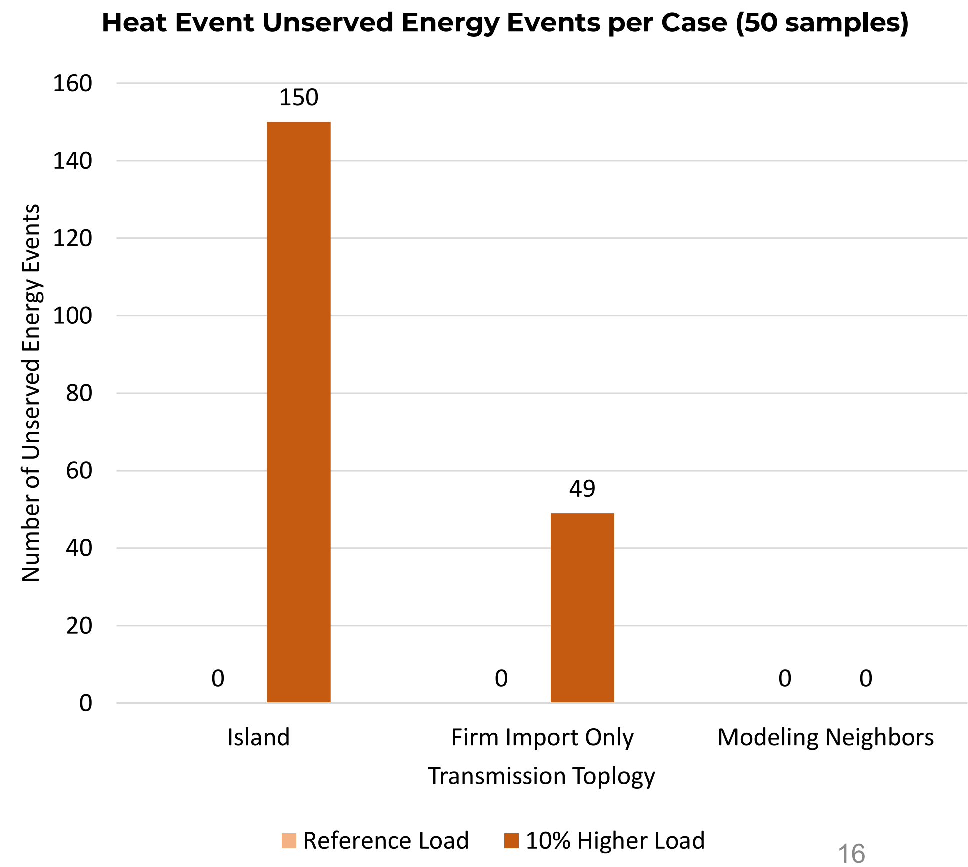
Comparing topologies shows reduced occurrence of shortfall events when the model represents interregional transfer capability.

Across the three system representations, modeling neighboring resource availability and existing transfer capability shows the system is resilient to the extreme heat event modeled.

Pushing the system to high load levels was required to see unserved energy in the limited transmission cases.

However, even for summer peak loads of 66 GW does not result in unserved energy when modeling neighbors.

The extreme heat event modeled in summer does not have as extreme of outages relative to extreme cold (minimum modeled 80% availability)



Source: Energy Systems Integration Group

Wind drought event: Prolonged low wind increases net-load stress, especially under higher load conditions.

Extended low-wind availability becomes consequential when higher demand and other stressors coincide

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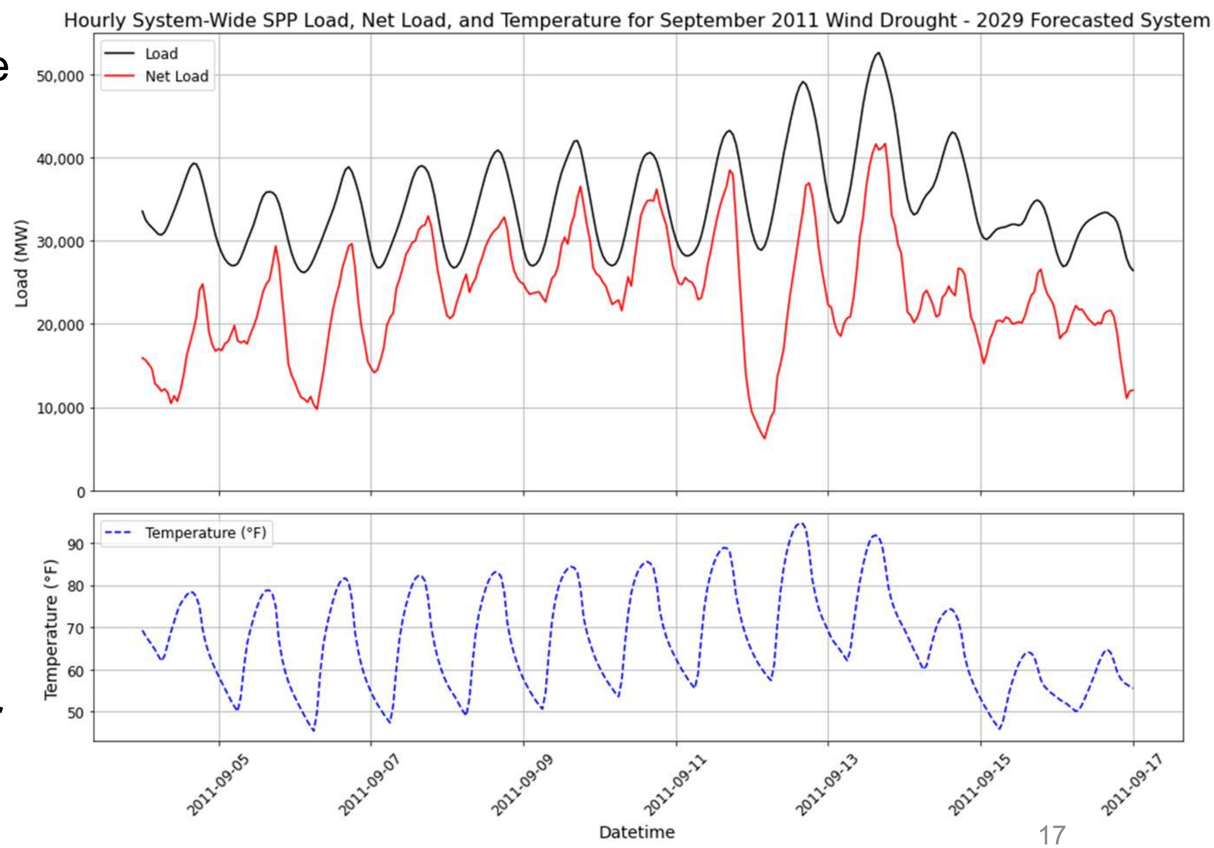
Re-simulated a five-day wind drought period across SPP. Only the Sep 4 – 17 are shown here.

Temperatures are milder in September, but low wind conditions generate periods of higher net load risk.

Risks from lower renewable generation or higher outages could make this event stressful.

Multi-day wind droughts may be a source of increased SPP risk in a higher RE system.



Source: Energy Systems Integration Group; data from the Southwest Power Pool and PNNL.

During the wind drought event, a period of high demand requires imports when stressed.

When load is increased in the +10% scenario, SPP requires imports above net firm import levels and avoids load shedding.

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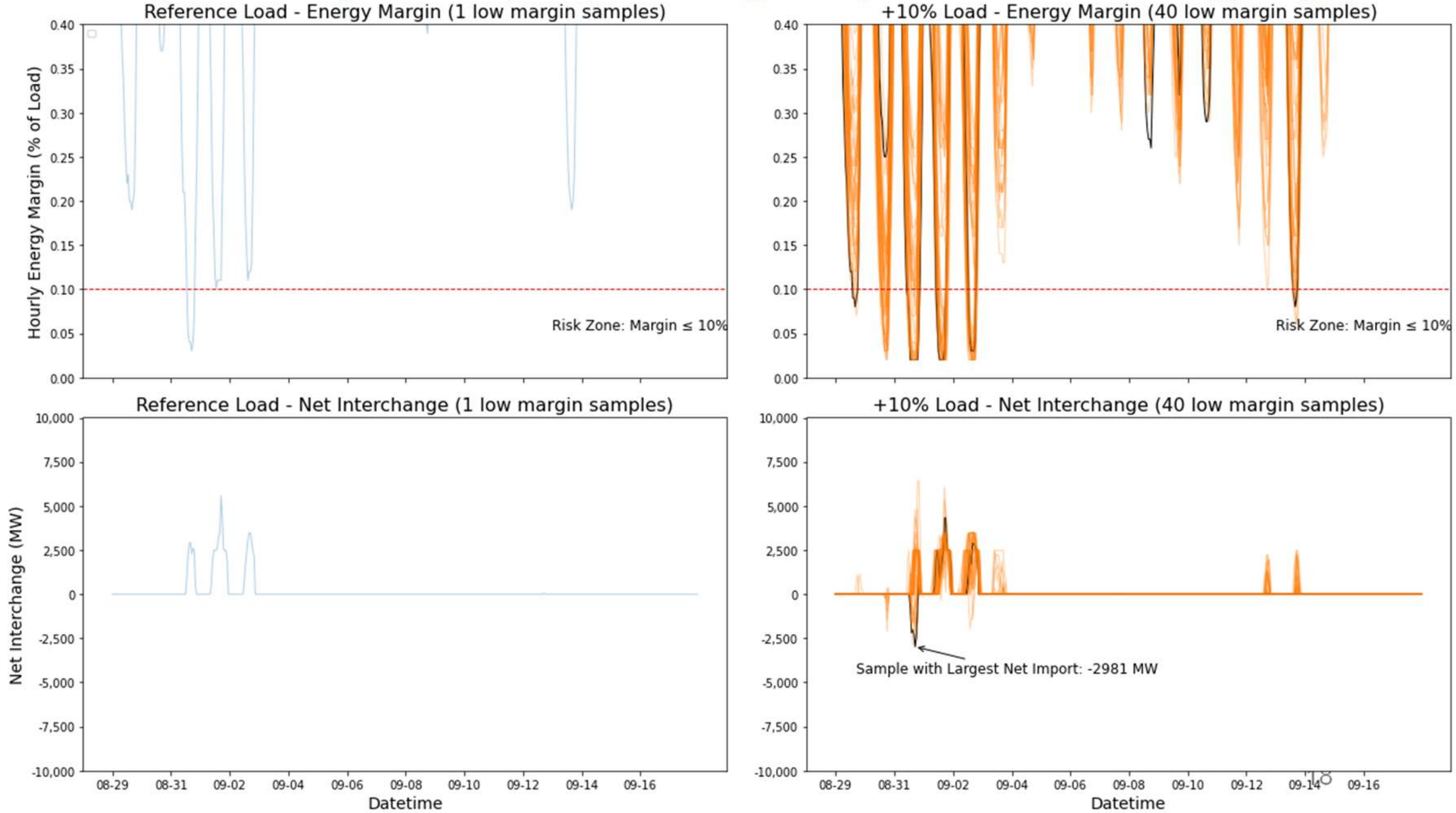
Margin, Imports, and Unserved Energy:

Results	Reference Load	+10% Load
Hours Margin <10%	114 (0.5%)	1,458 (6%)
Hours Margin <3%	1	322 (1%)
Max Net Imports (MW)	118	2,981
Longest Duration Net Imports (hours)	1	7
Max Unserved Energy (MW)	0	0

August 29th – September 18th, 2011, Wind Drought Samples with Hours <3% Energy Margin

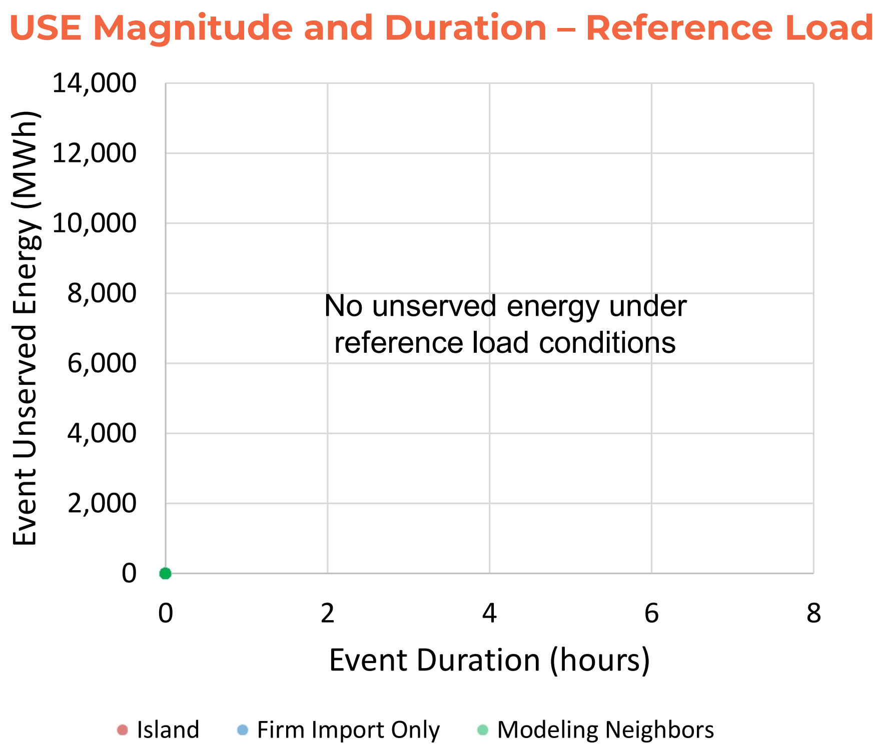


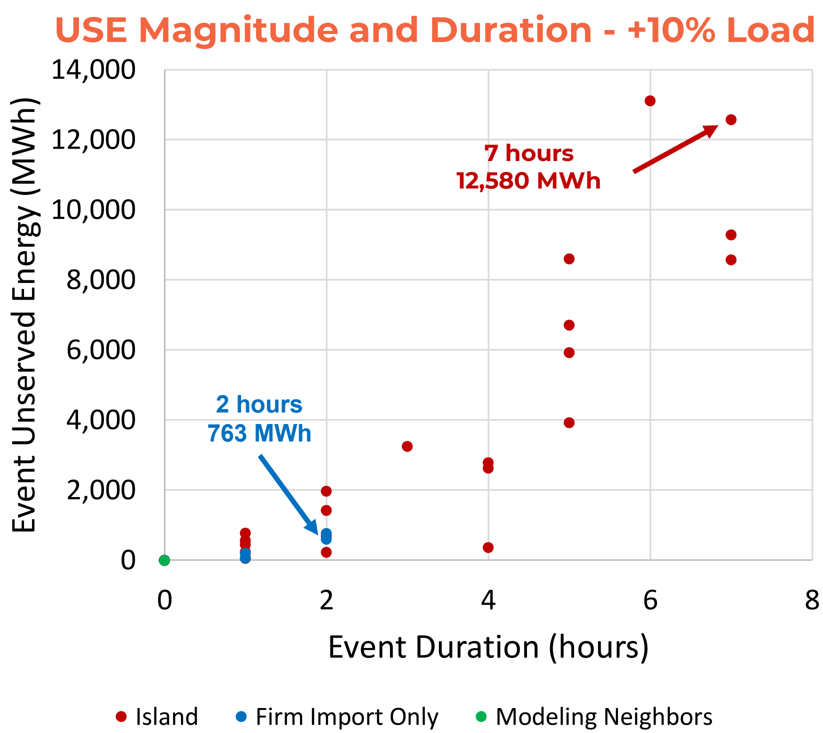
Source: Energy Systems Integration Group

Wind drought event: Reference load conditions show no unserved energy; higher load produces modest shortfalls.

Unserved energy results are sensitive both to load levels and whether or not interregional transmission is represented in the model.

Under the reference load case, there are no unserved energy events occurring. Substantially increasing load levels results in small unmitigated unserved energy unless modeling neighbors.





Source: Energy Systems Integration Group; data from the Southwest Power Pool

Wind drought event: Capping imports amplifies the shortfall risk under higher load conditions.

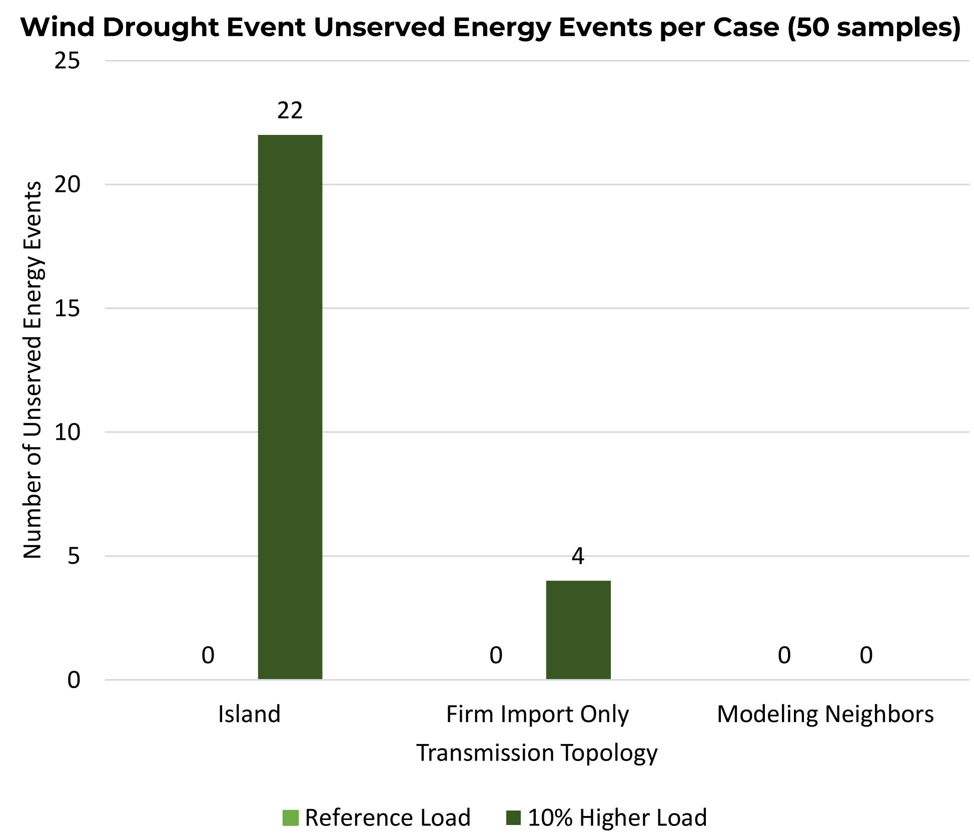
Comparing topologies shows reduced occurrence of shortfall events when the model represents interregional transfer capability.

Across the three system representations, modeling neighboring resource availability and existing transfer capability shows the system is resilient to risk.

Pushing the system to high load levels was required to see unserved energy.

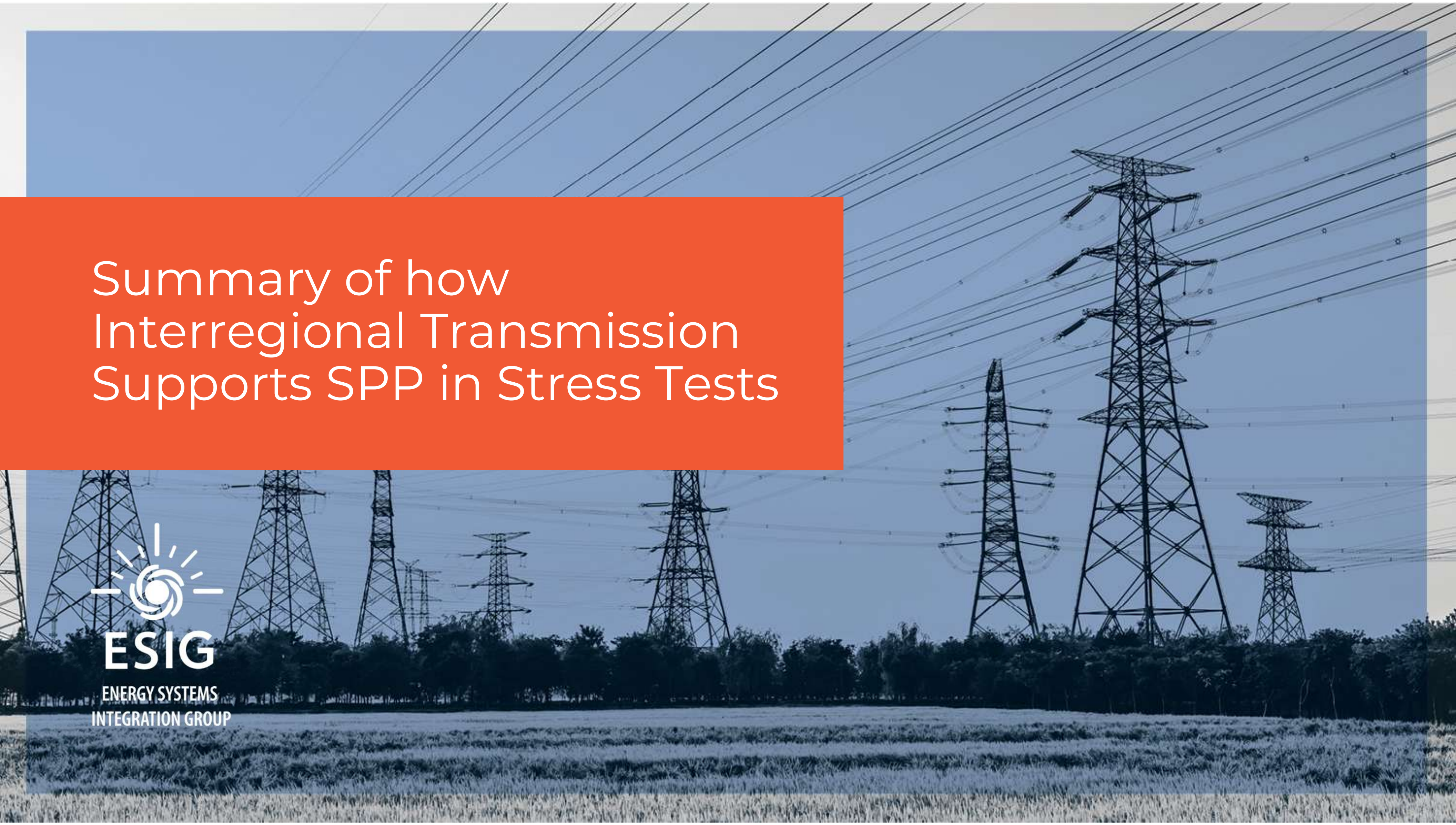
The availability of thermal resources and interregional transmission offsets the periods of high temperature and low wind production.

Constraining import capabilities shows increased risk under high load scenarios.



Source: Energy Systems Integration Group

Summary of how Interregional Transmission Supports SPP in Stress Tests



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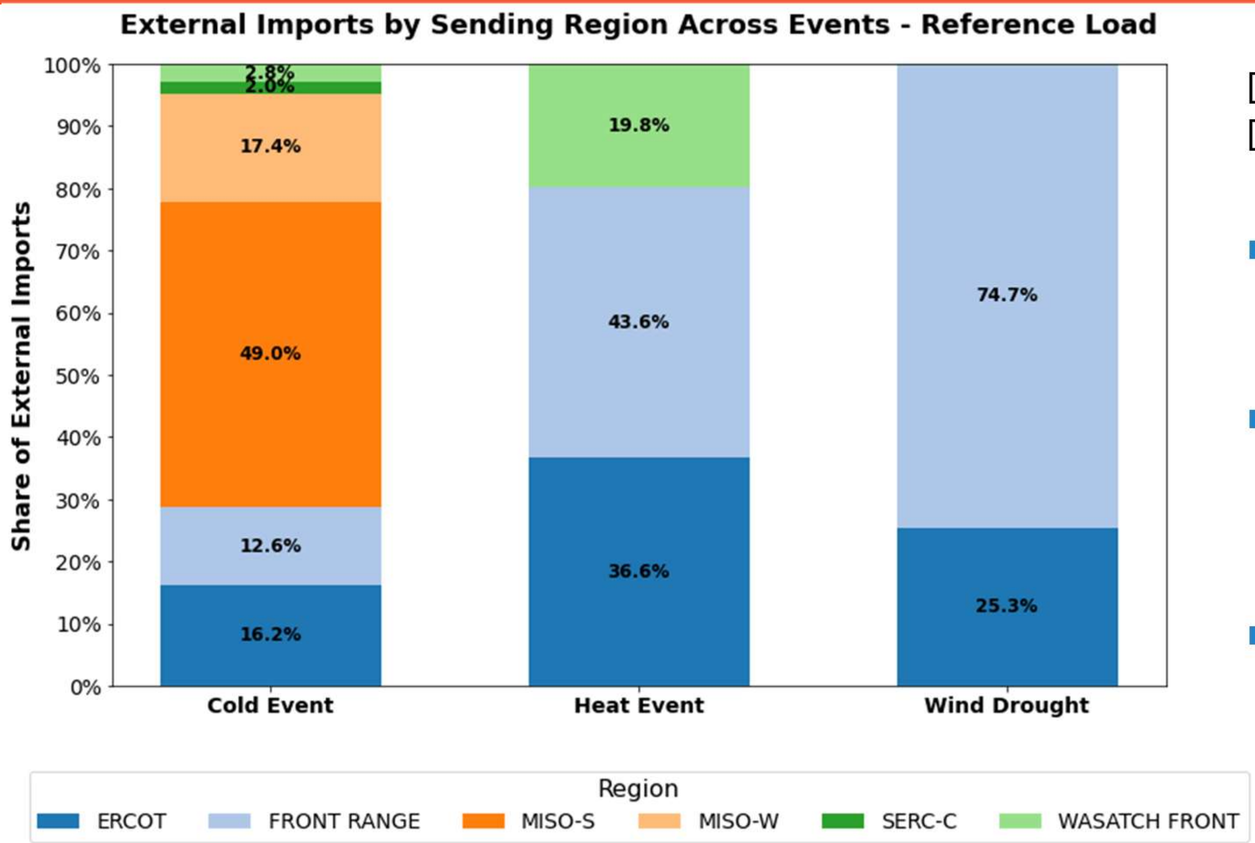
Under reference load, different events shift which neighbors supply the most support.

Import shares change across cold, heat, and wind drought conditions, indicating event-specific neighbor effectiveness.



Source: Energy Systems Integration Group

Different Stress Events Reveal Different Key Supporting Regions:

- **Cold Event Support**: MISO-W and MISO-S (67% of imports)
- **Heat Event Support:** Separate Interconnections via ERCOT and WECC Regions
- **Wind Drought:** Separate Interconnections via ERCOT and WECC Regions

*Data for the Compound Event is not shown due to identified dates not resulting in high stress for the 2030 SPP system, therefore no imports occurred.

Under higher load, a broader set of interfaces contributes meaningful support.

As stress increases, more paths contribute and different interfaces or surplus resource availability constrain imports by event and hour

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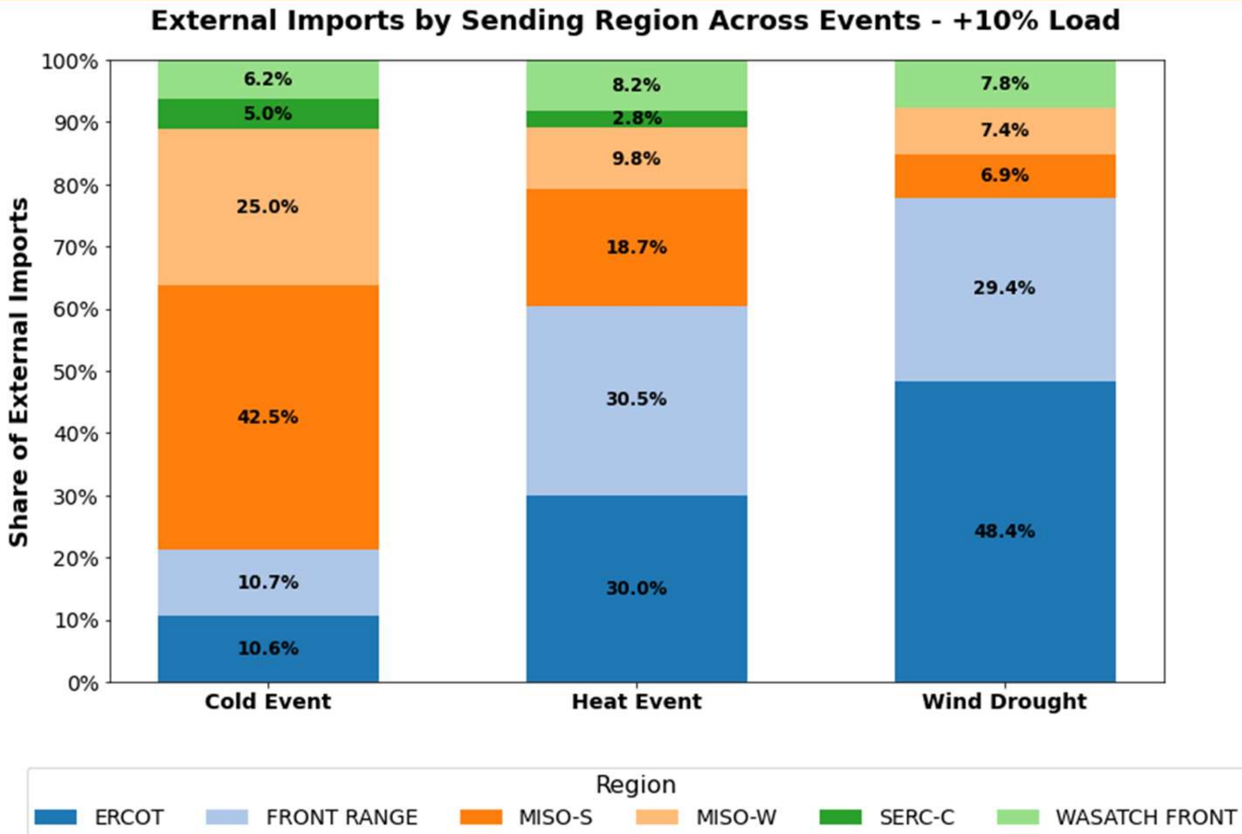

Proportion of support diversifies under even higher load conditions:

- **Cold Event Support**: SERC-C and Wasatch Front support grows
- **Heat Event Support:** MISO and SERC regions get involved
- **Wind Drought:** MISO and Wasatch Front regions get involved

Source: Energy Systems Integration Group

*Data for the Compound Event is not shown due to identified dates not resulting in high stress for the 2030 SPP system, therefore no imports occurred.

Key Findings from SPP Stress Testing

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External Assistance and interregional transmission is important for modeling stress events

- When coupled with interregional transmission, the future SPP resource mix is resilient to the modeled events, although some unserved energy remains in the high load scenario.
- External regions can offer substantial support, even during periods of extreme weather or renewable droughts that can occur in external regions coincident with the study region.

Stress testing offers a method to evaluate outlier events in more detail

- Difficulties assigning probabilities for events and gaining consensus on those probabilities can be avoided by modeling them discretely in stress testing.
- Digging deeper into events that drive reserve margin levels and capacity needs is warranted. This includes evaluating the importance of existing and future interregional transmission for system resilience and to minimize costs.

Evaluating different renewable profiles for specific events can expand risk analysis

- Limited weather data for national datasets can benefit from resampling renewable profiles for similar load days to extend stress testing analysis to new combinations of load and renewables.
- More historical and synthetic weather correlated load and renewables data is becoming available which can further enhance this process.

Future Stress Testing Work

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Improve How External Assistance and Interregional Transfer Capabilities are Modeled

- Incorporate more power flow modeling, potentially nodal or hybrid nodal details.
- Perform transfer analysis on multiple load and weather dispatch conditions
- Use stress testing periods in power flow analyses to inform how capabilities change under different weather conditions
- Refine transfer capability to capture existing firm exports/import contracts

Improve how Stress Events are Developed

- Evaluate more stress events beyond those shown here and including additional extreme event variables such as precipitation, wind chill, gas production declines, tornadoes, hurricanes (not SPP specific), etc.
- Use a longer historical correlated national weather dataset to improve stress sample creation
- Leverage synthetic datasets and/or climate change datasets like Sup3rCC

Use Stress Testing to Evaluate Multiple Types of Risk Mitigation Solutions

- Use stress testing as a sandbox to evaluate risk mitigation beyond adding capacity resources (which is typically the result of RA analysis)
- Consider the outsized effect of low average event benefit, but high extreme event benefit mitigation options (e.g., winterization, demand response, VPPs)

THANK YOU

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