Question text	**Answered?**
Are the stress samples common mode samples (i.e. forced outage rate/renewable availability/line ratings based on the same weather event)?	The following variables maintain weather correlation at an hourly level. Wind, solar and load. To create our stress samples we do use a daily temporal resolution for resampling new renewable and generator forced outages onto the same load day. This does break some of the correlations but we bound the resampling data by Month (for renewables) and Temperature (for thermal outages). When we resample the data we select a day with similar load conditions from the historical record and grab that days renewable profiles. We use that same day to resample all available renewable profiles for the entire US. For example, if we are creating a new sample for 1/1/2010 and we selected 1/1/2008 as a similar January load day then all our weather correlated day for 1/1/2008 would be slotted in to our new timeseries. This enables us to generate new stress samples. We chose to use a daily resolution for resampling, but you could use multi-day or weeklong periods too. This does create some discontinuities in wind power data, but we felt it worth exploring and applying the approach given wind generation can have very extreme ramps in the actual historical data.
How do you get "43 years" of grid and weather data? Is that from a more recent smaller set, e.g. 1-3 years and the rest of the years synthesized from that?	Multiple data sources were used. For the SPP data, we had 43 years of weather-based power system data they use in the Loss of Load Expectation studies. While I can't speak to all their specifics, the process they use likely similar to how many folks produce longer historical records. They take recent historical load and weather data and develop relationships between weather variables and demand. This then allows them to transform a forecasted median peak load (P50) forecast for a future year into a series of weather years that have conditions fluctuating based on the temperature-demand relationships. Similarly for renewable data they take historical renewable production profiles and match them using weather variables to historical days where renewable production did not exist. Potentially they supplement this data with some public datasources that use satellite and ground measurement data and do a reanalysis of meteorological data to produce location specific weather varibles. These are then fed into a power production model to get weather correlated production profiles for many locations of wind and solar plants. For generator outages we used daily historical outage data provided by the North American Electric Reliability Corporation and historical temperature data. The NERC data provided a sub-regional view of generator outages aggregated by fuel type (coal, single fuel gas, dual fuel gas, etc.). This data is anonymized and NERC provides it by direct request if you explain your needs. We took the historical data and binned it by temperature. So days with temperatures within a specific range have equal probability to select a historical day and have that same outage level across type of the generating fleet. We sought to preserve weather correlations using this appraoch. Due to the nature of the data there are less historical data points for extreme temperature days, but you have a probability of having some of those worst-case temperature outages maintainted. These are hard to recreate without using historical data since the probabilities of these events occuring are difficult to represent.
How do you apply or view the unserved energy events or MWh into a defined amount of support to help the system ?	We report out hourly unserved energy from the simulations and aggregate them into a unique event when reporting the data in the study. Some events are long in duration and others are short. This helps us characterize the possible shortfalls. To translate this to something that is helpful we also looked at the interchange between SPP North and South and with regions external to SPP. The availabile surplus energy and the level of imports provided by neighbors during stressful times in SPP could be interpreted as the "support level" they can offer. While we aren't explicitly assigning probabilties to support levels we are generating many stress samples per stress period identified and assessing a range of weather correlated conditions that stress the load and availability of imports. We want the method to help planners characterize the variation in possible support from neighbors during the most stressful events based on similar types of weather data.
What meteorological/other sources are being used to predict extreme weather shocks and how severe in the future (e.g. same/worse intensity, frequency,duration)?	We did not use future projections for determining the frequency of weather events. Incorporating climate change effects and future weather forecasting is an area of improvement. For our work, we only used historical weather data which does give quite a large range of weather conditions and extreme events. This is common practice in resource adequacy modeling, but incorporating effects of climate change would be beneficial.

Are you using a copper sheet approach of west and eastern interconnect showing the connection without regard of AC/DC/AC interfaces?	We are using a zonal topology of the Western and Eastern Interconnections based on the transfer capabilities reported in the NERC Interregional Transfer Capability Study. Within the zones it is copper sheet. Between each zone is a point-to-point trasnfer limit. Each zone is also limited by a simultaneous import limit.
How do you think this picture/results will change if neighbors were also represented in unit-level detail?	It might show even greater support available because we could achieve greater resolution on the outage level in the external regions. However, I think the more important improvement would be to have more granularity on the external region zonal topology. The transmission limits between regions and the ability to send power from the east coast to SPP may be more fundamental than unit level modeling. I think the NERC ITCS topology gives higher transfer interface resolution than any other dataset out there, but it could be improved while keeping the overall model complexity manageable.
Does this work consider market impact, e.g., there is transfer capability, but no import offers due to strained supply for neighbors?	Imports and exports in the model are constrained by the relative capacity available in each region. We enforced a minimum 3% of hourly load reserve level for each region. If their available capacity is at 3% they cannot export. In addition, if they have available capacity reaching 3% they will have higher prices and this incentivizes transfers between regions. The 3% limit could be readily changed. It bascially acts as a throttle for how much they are willing to send internal resources to neighbors.
Are the weather data inputs all connected/from the same atmospheric model? (ie does the solar profile for the day match the temperature profile for today)	We combined several datasets and merged them based on timestamps. These datasets are: Historical temperature data from PNNL (https://data.msdlive.org/records/cnsy6-0y610). They provided us data through 2023 based on county and balancing authority resoutions. Wind and solar and load data for SPP is based on their LOLE model data. Weather data for wind and solar and load for 2007 - 2013 were based on public NREL datasets using NSRDB, WindToolKit, and their ReEDS load proejctions. We adjusted these datasets to match historical capacity factors for wind and also scaled the load to match the future load projections at the time of the study (2023 vintages).
And are the regions all modeled with consistent weather (ie capturing a storm like Uri reducing available imports from Texas)	Yes all regions are modeled with consistent weather conditions and had the same correlated forced outages based on temperature bin sampling. So the winter storm uri event has Uri-level outages for some events, but not for all events. This is important because not every severe winter storm has severe Uri-level outages even if they may be elevated. The underlying resource mix also changed in the model. So while weather conditions are preserved in some samples, the risk profile is different from 2021.
Are the potential ties all made at the same time or a select tie or ties all at the same time ?	I'm unsure how to answer this question. But all the transfer capabilities are modeled as fully available as long as resources are available. Transfer capabilties are based on NERC ITCS results. We do model the individual DC ties in SPP using independent outage assumptions and maintenance assumptions. These ties can be out of service independnetly of each other.
Could you kindly provide more clarification on how you are quantifying resilience?	While we didn't specify how one should quantify resilience, we used the capabilitiy to remove or reduce unserved energy events as an indicator of greater resilience for the SPP system.
Slide 17: Is that ambient temperature or system temperature?	Population weighted ambient temperature
Comments on when Distributed Energy Resources (gen & demand response including V2G with EV batteries) will become significant enough to be worth including?	We included representation of rooftop and distributed solar in our model and aggregated it at a zonal level. This could be done for distributed BESS or Evs too. But you would need assumptions on coordination and controls.
Did you factor in operational actions, e.g. committing all resources (off economics), canceling maintenance, filling reservoirs/fully charging batteries, etc.?	If a resoruce was available (not on outage) or maintenance it would be dispatched to it's available capacity rating. There is a one-day lookahead for the event so batteries and pumped storage would be fully charged if resoruces are available to charge them. Maintenance could not be recalled for the SPP model, but we adjusted historical maintenance levels in the external regions based on assuming some maintenance could be recalled during an extreme event. For SPP, maintenance was scheduled for a full year based on load. So the model had some foresight to not schedule maintenance during high load periods so overall maintenance was minimized.

What outputs are most decision-relevant for planners: unserved energy, scarcity hours, reliance on imports, exposure hours, or something else?	I would say unserved energy and comparing it before and after interregional transmission is considered. Scarcity hours are also relevant (say hours where reserves are getting low) since these are inherently fragile grid hours. You should be careful about scarctiy hours though since how you set up the model may increase the number of scarctiy hours that occurs due to exports. That's why setting a minimum reserve level is important. Planners don't want to assume a region exports itself into a shortfall.
Does the SPP portfolio pass an internal level of resource adequacy for this time period and portfolio?	We did not calculate resource adequacy metrics for the SPP system using this method. We do show only a handful of load shed events occur when using the Firm Import only setup. This is similar to SPPs current LOLE study assumptions. Load shed would be expected in some of the extreme events we modeled. We do show however that load can be substantiall higher (66 GW in summer 2029) and interregional transmission can mitigate summer events. It also helps to a signficiant degree in winter events. This study is different from a resource adequacy study but it does show the future system (2029/2030) is resilient.
Can you talk a bit more about how the firm imports are calculated? Are they procured though market modeling or are they based on historic imports?	SPP publishes their net firm import amount by SPP sub-region. We used these values directly and I can't speak to them more than that.
Comparing costs of additional dispatchable resources locally vs transmission build ?	We did not look at costs, just looked at how the existing capabiliteis of the grid provide substantial benefits that may be omitted in stress testing practices. We wanted to highlight that these benefits are signficiant and should not be ignored. We also provided methods for quantifying the level of benefit in MW or MWh terms.
What implications do your results have for SPP's RTO West (going live April 1 this year) and potential upgrades to East-West Interconnection DC ties?	I believe this is great news for reliability and resilience to the SPP system as a whole. Upgrades to the DC ties, additional new ties, and greater coordination between the Eastern, Western, and Texas interconnections would be beneficial for cost, resilience, and reliability.
How these methods could be replicated for a distribution system?	Weather data from NREL and the data we used is typically at a 2km resolution. Other weather data is at county level. This might help for distiribution modeling but I think getting more granular data would be preferred.
How is there confidence on the portfolio operations and flows from adjacent regions?	The availability of resources is based on historical performance and historical weather data so it does reflect historical resource capability to a degree. However it doesn't capture nodal detail which means congestion isn't fully represented. Transfer capability is represented between regions based on AC power flow analysis from NERC ITCS. While the approach doen't reflect opertaional level detail, it does reflect the weather correlated availability of capacity, energy, and demand. The intent is to provide a way to track that availabiltiy to a reasonable degree for simulating external regions.
Can you share on any methods and algorithms used to come up with your events and the various (many!) mixes assessed?	For the event screening we used an Energy Drought characterization method detailed in https://www.sciencedirect.com/science/article/pii/S0960148123014659. We adapted this method to also include thermal fleet availabiltiy risks when screening for events. We used the standardized indices to select high ranking (high risk) events for single and multi-factor events. There were many events to choose from and refinement of event selection could be improved.
Did you model any risk of transmission connections (within SPP or with external neighbors) going down due to extreme weather conditions?	Transfer capabilities for SPP used their assumtptions for zonal transfers in their latest LOLE study. NERC ITCS transfers were based on N-1 conditions. DC intertie transfers capability fluctuated based on randomized forced and maintenance outages. No specific changes to transfer capabilities were modeled due to extreme weather.
Was the import distribution across the NERC regions for the stress testing scenarios done under existing interregional transfer capacity or optimal?	We modeled existing transfer capabilities only.

How does this stress affect the market economy? Could you provide insights on wildfires and strategies for managing congestion in such situations?	We aren't looking at market operations but rather the availability and relative scarcity of resources across regions. Greater interregional transmission and coordination on interchanges could benefit markets by enabling lower cost production and also enhancing hedges against extreme events.
What approaches can be used to integrate this framework into resilience assessment of power grids in wildfire-prone regions?	I would say the framework is adaptable to other extreme events like wildfires. This could be another layer of weather data that is brought into the sampling method and causes a change in transmission capabilities (due to shutoffs) or generating capabilities (like smoke and solar). The idea is to have a consistent and correlated dataset of weather and grid conditions and then layer in additional stressors as that data is available.
Might it be better to define stresses based on their impact on the system, not on their placement in the tail of the input conditions?	For this effort we focused on weather-based stresses. These naturally fall in the tail of their data distributions. Other stressors might be better characterized based on their impact rather than their existence on the tail event. Regardless, a stress event is by nature at the tail of grid conditions. I think reviewing historical events like we did gives insight into the conditions that might be most impactful. But it is not an exhaustive list.
Any framework models you can speak to (or a paper) on integrating Plexos (or xyz software) with the actual grid simulations?	These methods could be integrated into a more detailed (nodal) model of the grid and onto a model that represents day ahead and real-time conditions. The models have the capabilities to do this or at least pre-compute the effect of weather on model elements and then feed that into reproduce the effects such as outage probabiliteis or fuel price increases etc.
Future stress results from the new load shape, and peak demand, climate... have you reviewed other work on scenario generation on projections of these inputs?	We did not look to using climate change informed future weather data. But this is an important area for expanding the stress test assessments.
how can stress tests align with regulation focused on riskiness not robustness? Does low probability cancel out the value of stress-tested plans?	The low probability of these types of events makes the investment case challenging. I would expect monetization based on probabiliteis to produce low values. However, I expect the actual path forward will see some sort of threshold or cap that triggers resilience investement. By their nature, controlling for the tail-risk is challenging. That is why a different hedging approach such as a risk magnitude or duration threshold can be helpful. This forces evaluating the most economic solutions to mitigate the extreme tail risks.
How would you determinate a capacity accreditation for an HVDC tie between two regions? What ballpark range do you think would be reasonable for accreditation?	It is hard to speculate what the ballpark range would be. But it should be calculated. But the further away a region is the greater weather diversity and increased chance for a higher accreditation.
how sensitive are stress-tested investments to the VOLL?	If you monetize a stress test investment based on VOLL or avoided cost of capacity the monetization would be extremely sensitive to it.