Cloudy with a Chance of Blackouts or Full of Hot Air?

Evaluating Weather Events in Long-term Power System Planning and Resource Adequacy Analysis

G-PST/ESIG Webinar Series | June 21, 2023

TELOS ENERGY

Before we get started, a poll for the audience

2023 ESIG Redefining Resource Adequacy Task Force

Beyond One-day-in-10 new reliability criteria for modern power systems

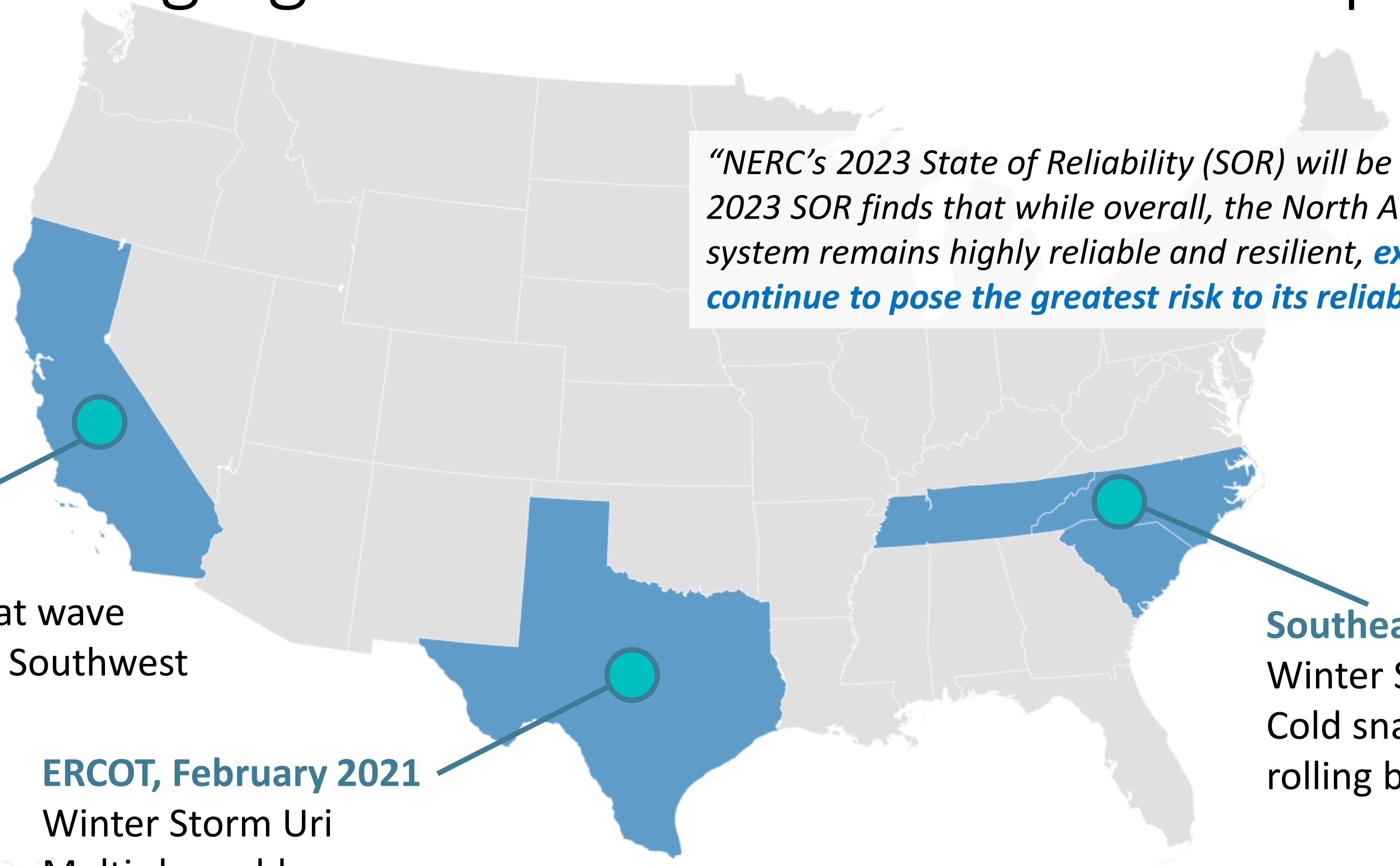
Should the industry consider (or establish) a new resource adequacy criterion?

- ❑ Yes! 0.1 days/year LOLE is arbitrary and has outlived its usefulness
- ❑ No! Don't fix it if it is not broken
- ❑ Unsure

If you had to pick one resource adequacy criterion, which would you pick?

- ❑ Planning reserve margin (% of peak load)
- ❑ Loss of Load Expectation, LOLE (days/year).
- ❑ Loss of Load Hours, LOLH (hours/year)
- ❑ Expected Unserved Energy, EUE (MWh/year), or normalized.
- ❑ An economic criterion, based on value of lost load (VoLL) or cost of new entrant (CONE)
- ❑ A multi-criteria metric combining multiple metrics
- ❑ None - use scarcity pricing to ensure reliability

Recent extreme weather causing reliability shortfalls and challenging our notions of resource adequacy



"NERC's 2023 State of Reliability (SOR) will be released June 22. The 2023 SOR finds that while overall, the North American bulk power system remains highly reliable and resilient, ***extreme weather events continue to pose the greatest risk to its reliability and stability."*** *- NERC*

CAISO, August 2020
Extreme multi-day heat wave
Heat dome across the Southwest

ERCOT, February 2021
Winter Storm Uri
Multi-day cold snap

Southeast, December 2022
Winter Storm Elliott
Cold snap leads to "first ever" rolling blackouts in some areas

Factors leading to challenging reliability conditions

Tightening reserve margins
by design – do we have the right resource adequacy criteria?

Natural gas as the primary fuel source
missing weather dependent outages and gas electric coordination

Retirements and replacements
requires more robust accreditation methods to ensure we are replacing similar amounts of effective capacity for RA

Lack of interregional transmission and planning
Each region is meeting its own reliability needs, missing opportunities in geographic diversity

Increasing weather dependency of the power system ← **Today's Focus!**
Natural gas sector, thermal outages, increased wind and solar, electrification

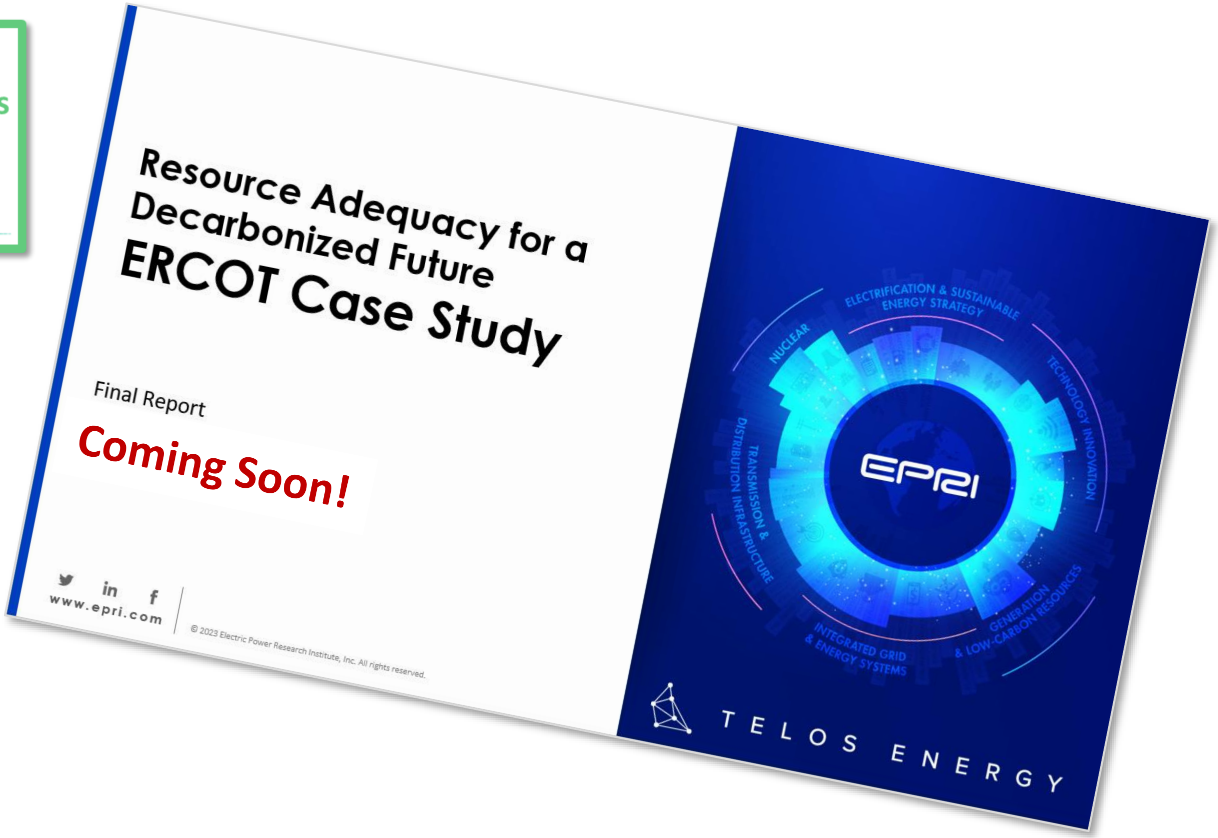
Best Practices for Modeling Extreme Weather

Do's	Don'ts
Consult a meteorologist Cross-disciplinary analysis is required	**Go it alone.** Power system engineers need to be cautious when bootstrapping datasets, especially for outlier events
Evaluate "Black Swan" events that include high-impact, low probability events for what-if analysis	**Try to assign a probability** or likelihood of the HILP, and incorporate it directly into the planning reserve margin
Use real weather data, based on actual meteorological conditions	**Develop a "doomsday" scenario** where worst-case contingencies occur simultaneously and arbitrarily
Consider neighboring grids, including weather, load, and system resource mix in adjacent balancing authorities	**Assume the grid is an island,** without interchange to neighboring systems (unless its an actual island)
Apply stressors to all resource types, including weather dependent outages and fuel limitations	**Assume only renewables** are affected by extreme weather

Source: Stenclik, D., "Best Practices for Modeling Extreme Weather in Power Systems Five Do's and Don'ts for Incorporating Weather in Resource Adequacy Analysis, https://www.telos.energy/post/best-practices-for-modeling-extreme-weather-in-power-systems

An ERCOT Case Study
EPRI's Resource Adequacy for a Decarbonized Future Project

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

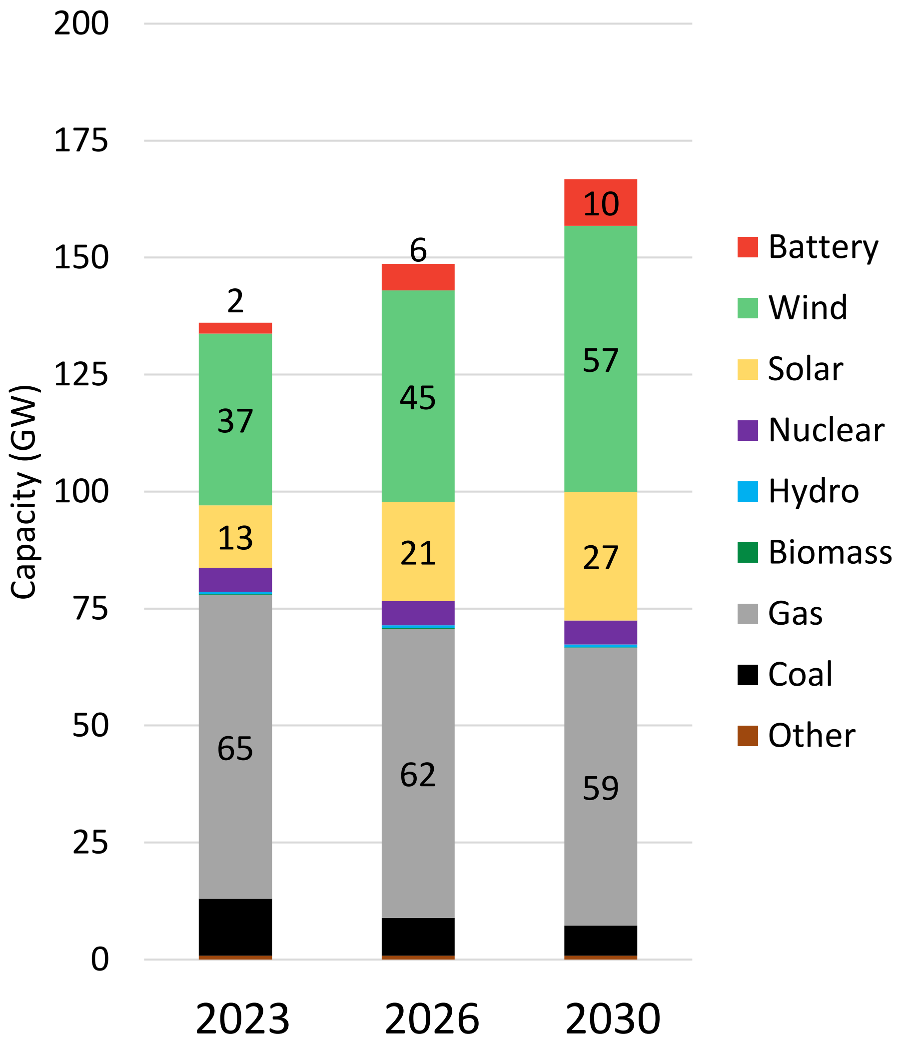


Authors Derek Stenclik, Mike Welch, Leonard Kapiloff

Special thanks to Aidan Touhy, Eamonn Lannoye, and others

More info at: https://www.epri.com/resource-adequacy

Evaluating weather impacts today and in the future



40-year load dataset

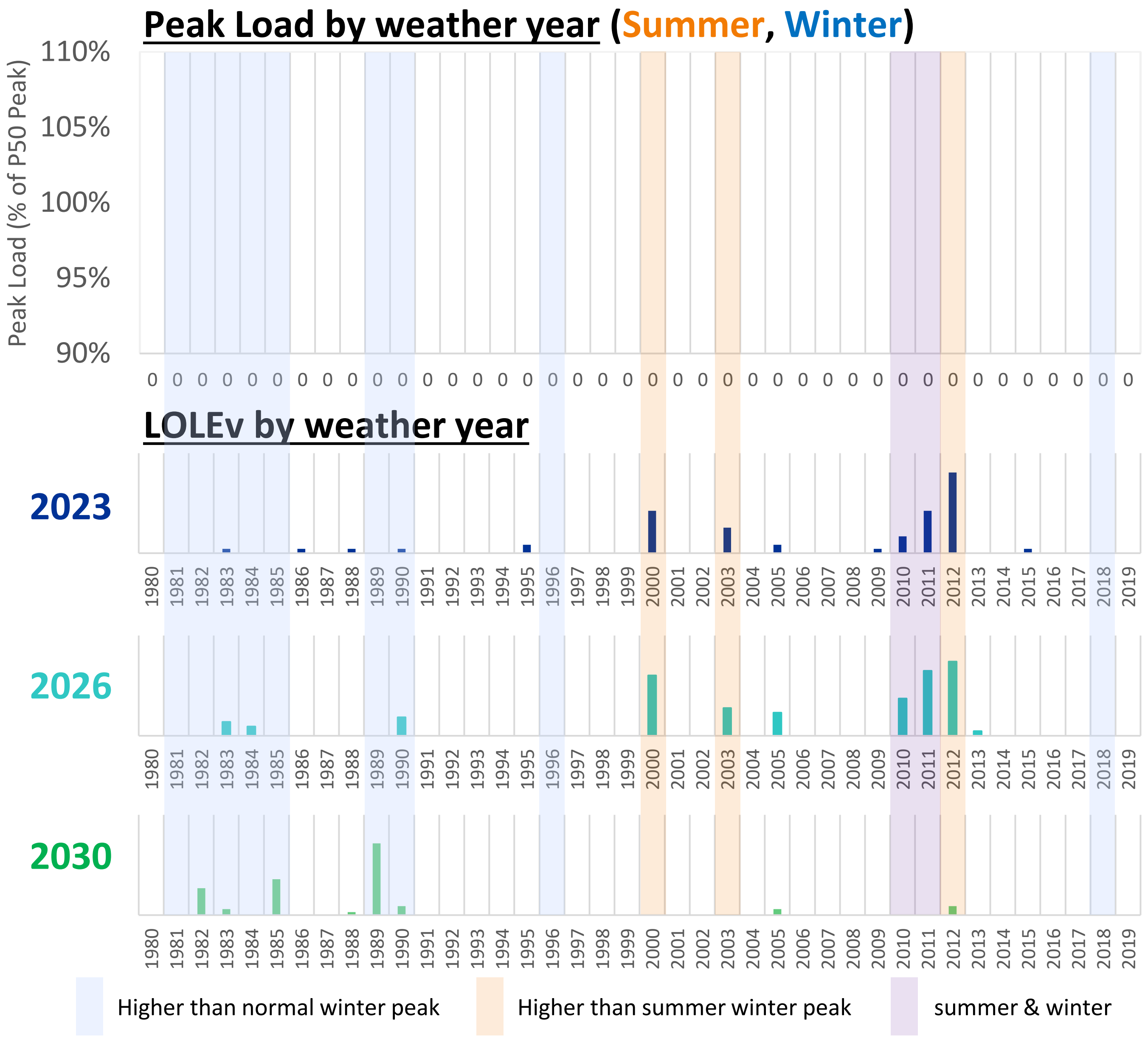
- ERCOT maintains a multi-year load dataset covering 1980-2019
- Hourly load profiles developed by ERCOT staff for the 2022 and 2024 forecast years
- Extended hourly data out to 2030 based on ERCOT peak and energy forecast assumptions

• 40-year wind & solar dataset

- UL developed site specific chronological, 8760-hour wind and solar profiles 1980 to 2019
- Covers existing and potential future plant locations
- Includes icing and cold weather impacts

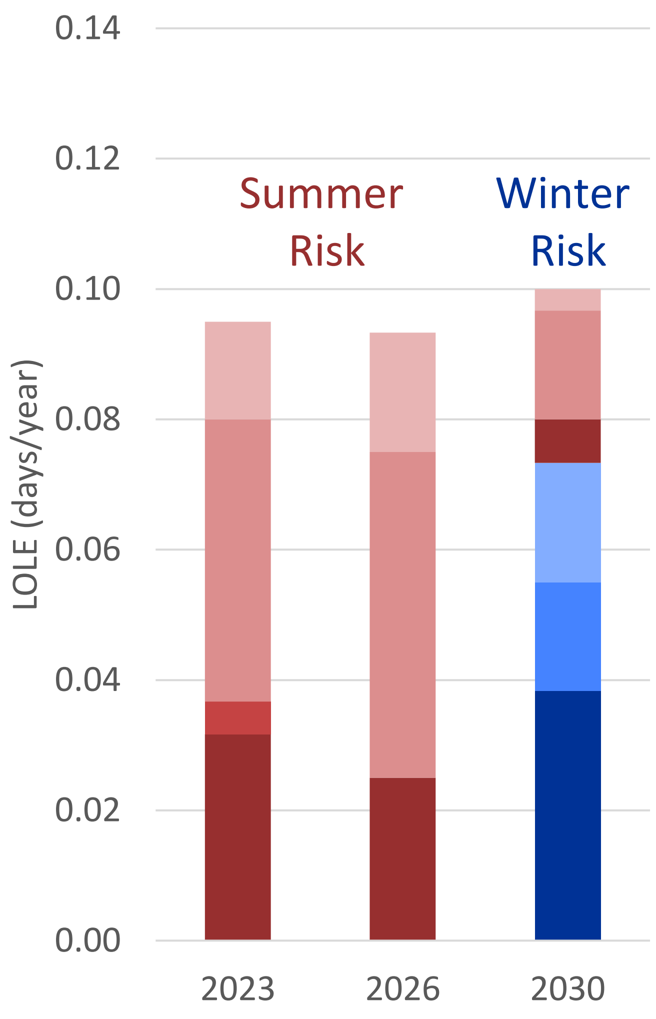
How Sensitive is the System to Weather Years?

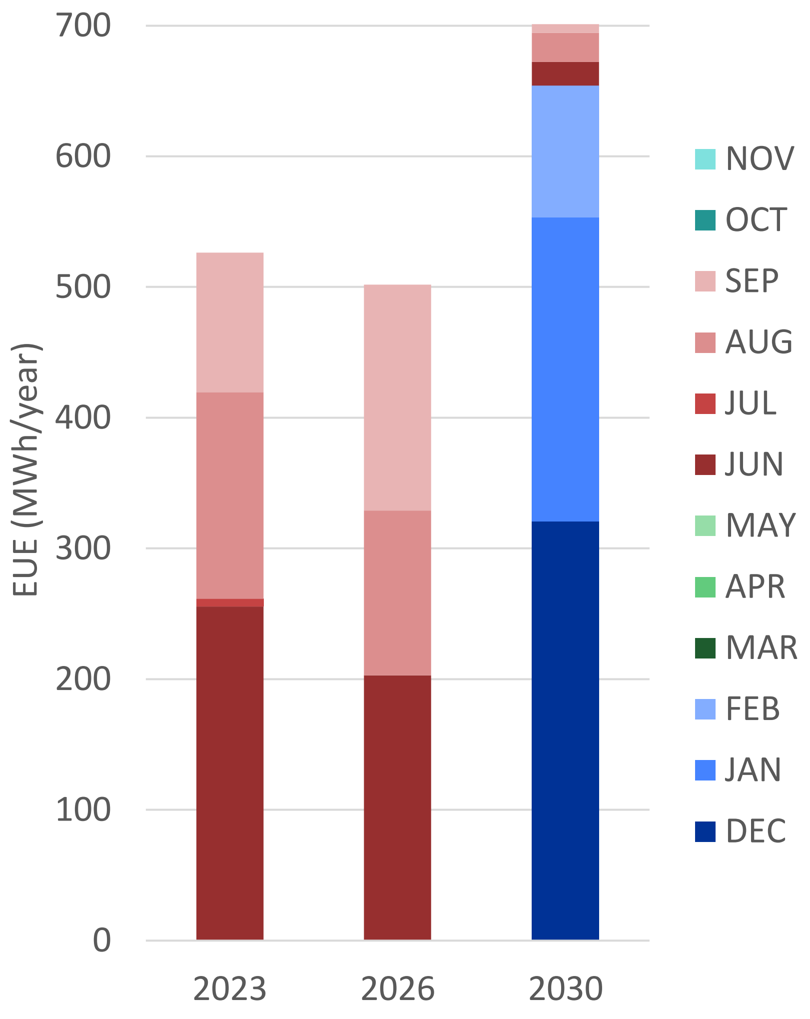
- The 2012 weather year (summer peak) has the highest number of events in 2023 portfolio… but shifts to the 1980s (winter peak) in the 2030 portfolios
- 2011 had slightly higher demand in the summer, but more wind and solar available than 2012, thus lower LOLP
- Future events are driven by combination of correlated low wind and solar availability and when load is high – shift towards early 1980s periods when extreme cold was more likely due to climate trends
- Note: the results do not include Winter Storm Uri (2021) due to data availability at the time, but similar cold events were included in the 1980s



Winter is the new Summer

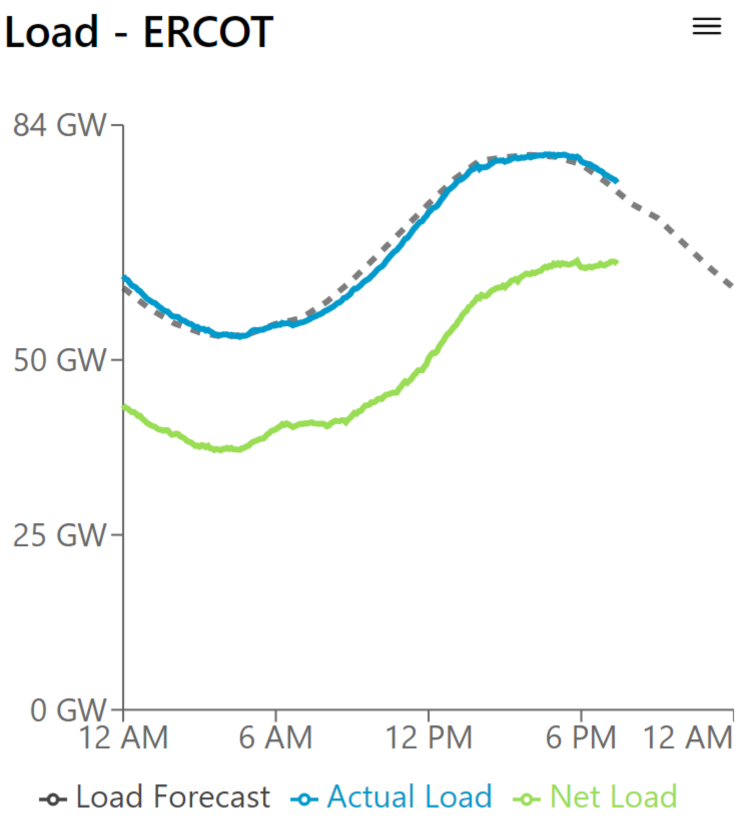
Even when not considering weather-dependent outages (coming up)

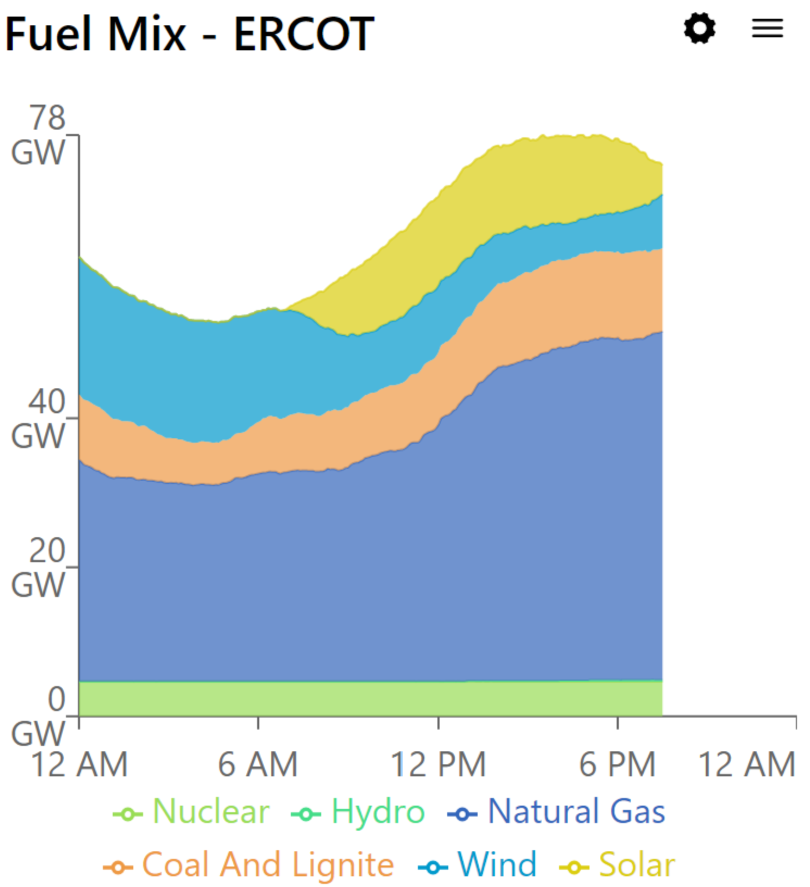


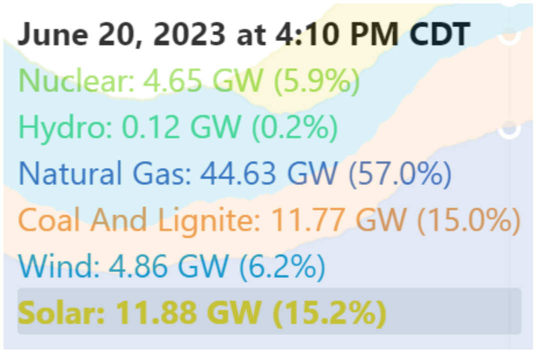


- Resource adequacy risk, measured by LOLE or EUE, is becoming more of a winter challenge as the resource mix changes
- EUE has a more pronounced change, highlighting higher impact, longer duration events in the winter
- Correlated low renewable output days with high winter loads driving risk
- Does not consider correlated generator outages (yet). There is likely winter risk embedded in 2023 and 2026, but not picked up in the model
- An additional sensitivity was evaluated in 2030, without additional renewables (replaced by firm capacity) and all risk is back into the summer season, suggesting this is driven by the resource mix change

What happened yesterday?



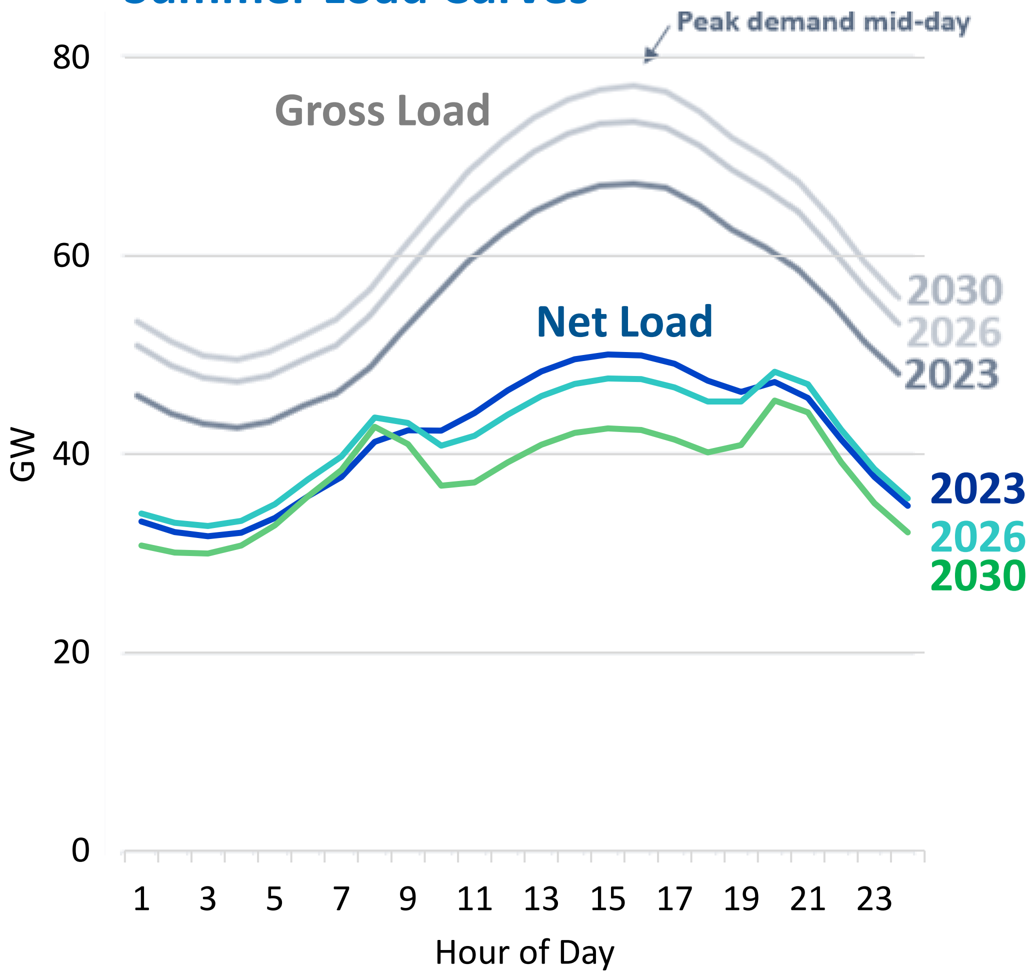




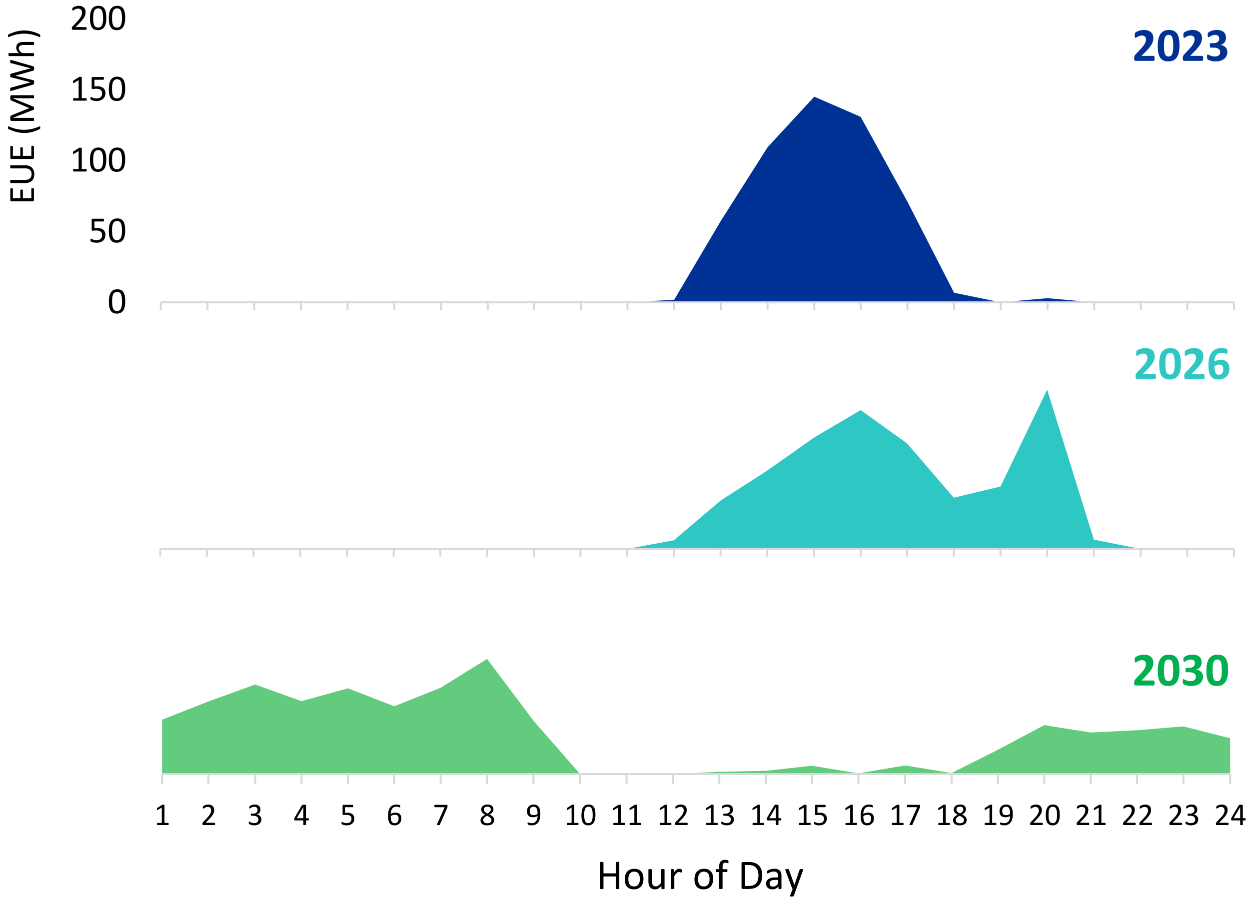
https://www.gridstatus.io/

Risk is also shifting later in the day and into the evening

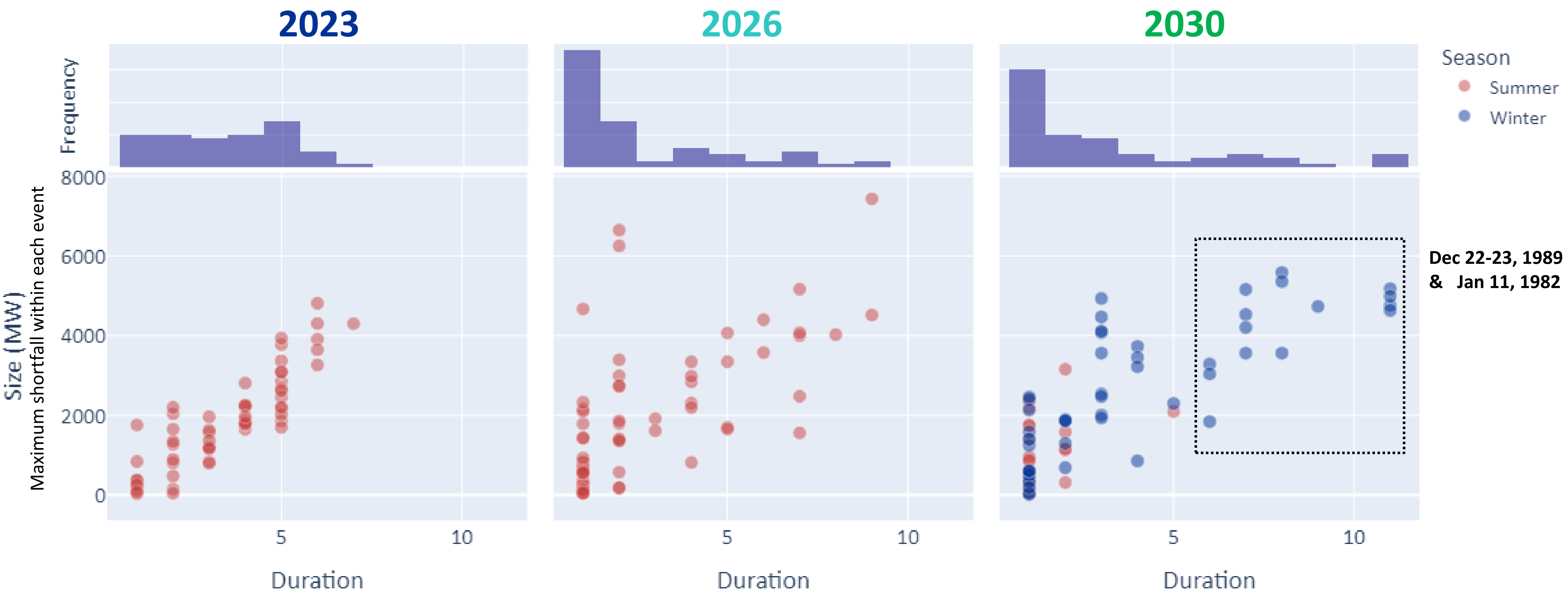
Summer Load Curves



Unserved Energy by Hour of Day



New Mitigations Require More Information on Size, Duration, and Magnitude of Shortfall Events

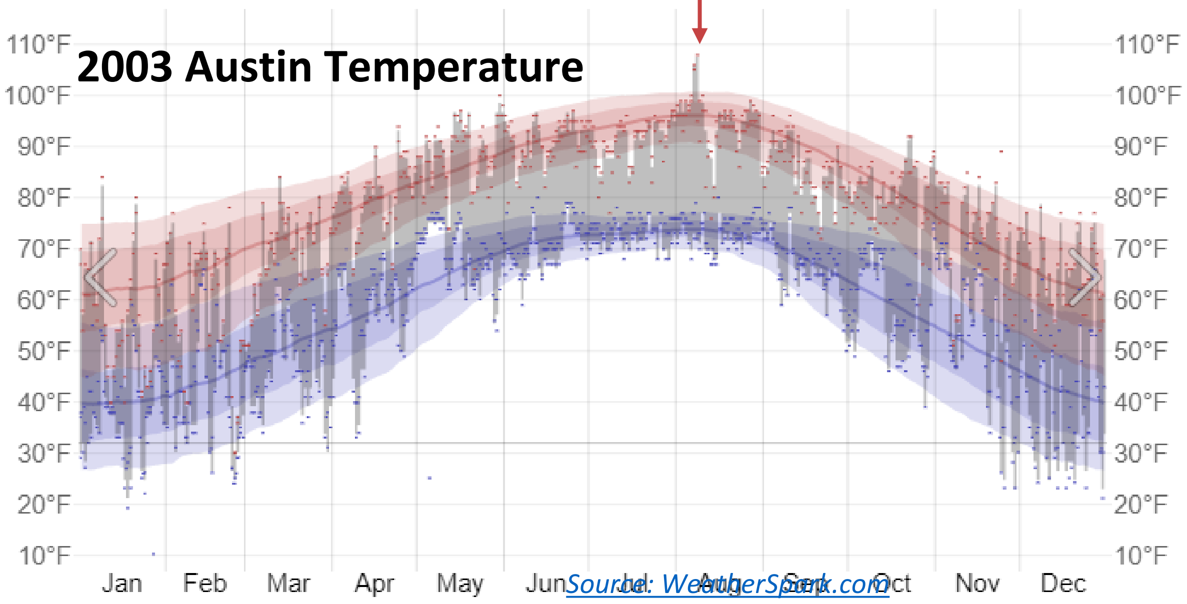


30% of events occur on June 25-26, Weather Year 2012

47% of events occur on Dec 22-23, Weather Year 1989 & Jan 11, Weather Year 1982

Top 5 LOLP Days - 2023 Portfolio

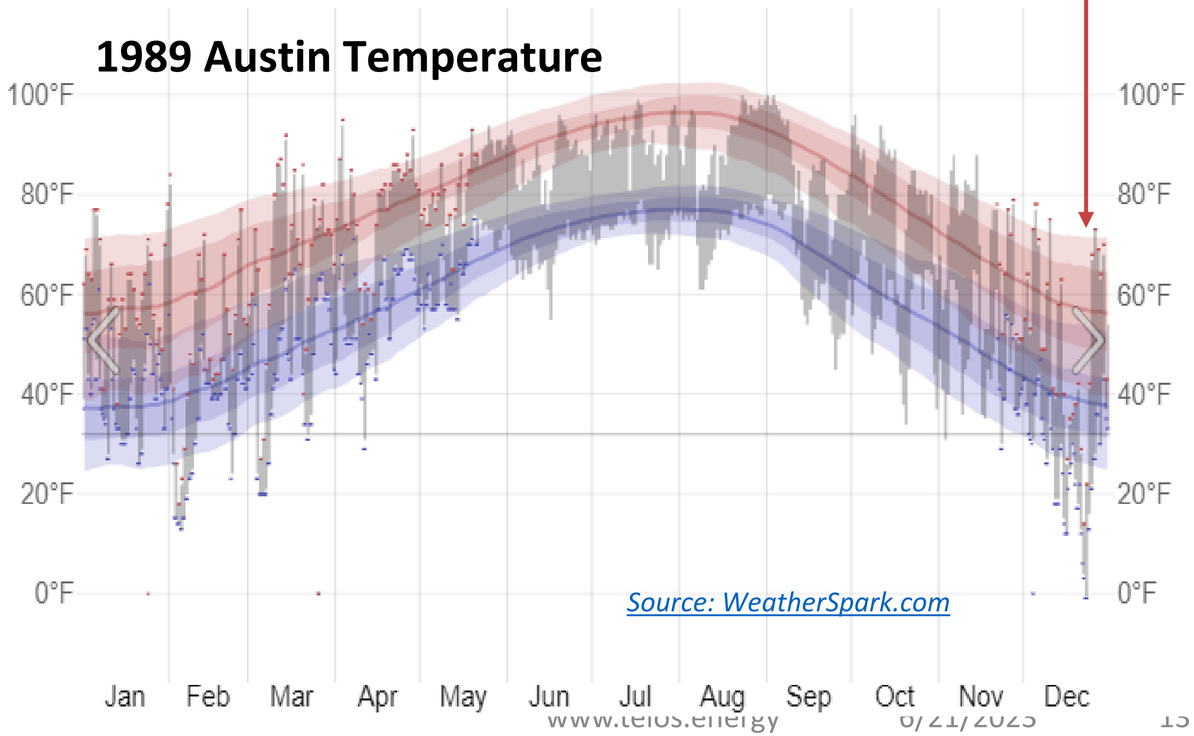
Weather Year	Date	LOLP (% of days)	Daily Min/Max Temp (Austin)	Wind and Solar Availability (based on monthly average)
2012	June 26	80%	79 / 107°F	36% below avg
2012	June 25	40%	75 / 105°F	46% below avg
2003	August 7	40%	67 / 110°F	28% below avg
2000	Sept 4	33%	71 / 110°F	20% below avg
2011	August 27	33%	72 / 107°F	43% below avg



Source: WeatherSpark.com

Top 5 LOLP Days - 2030 Portfolio

Weather Year	Date	LOLP (% of days)	Daily Min/Max Temp (Austin)	Wind and Solar Availability (based on monthly average)
1982	Jan 11	67%	11 / 30°F	46% below avg
1989	Dec 22	67%	12 / 23°F	23% above avg
1989	Dec 23	47%	4 / 29°F	1% below avg
1985	Feb 2	33%	14 / 30°F	23% below avg
1985	Feb 1	27%	19 / 23°F	26% below avg

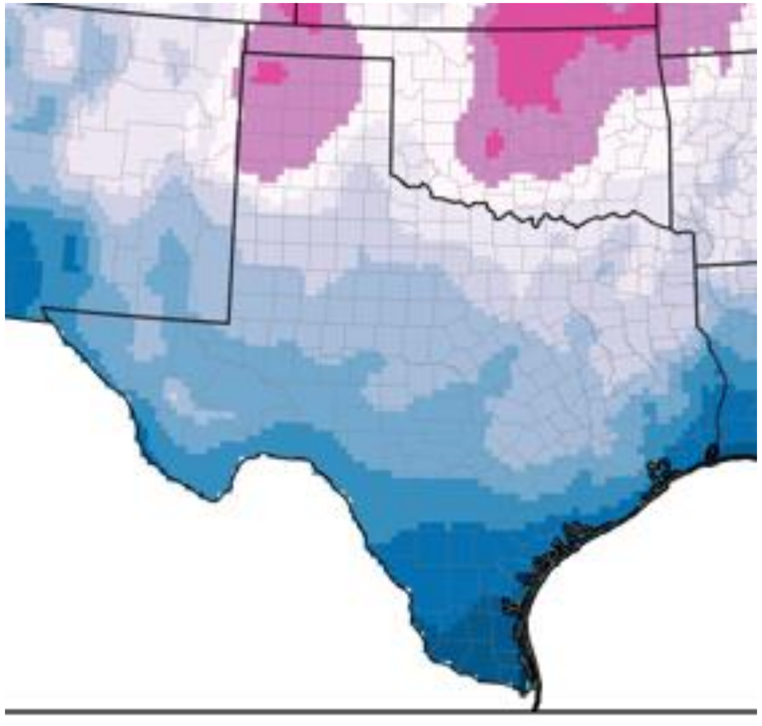


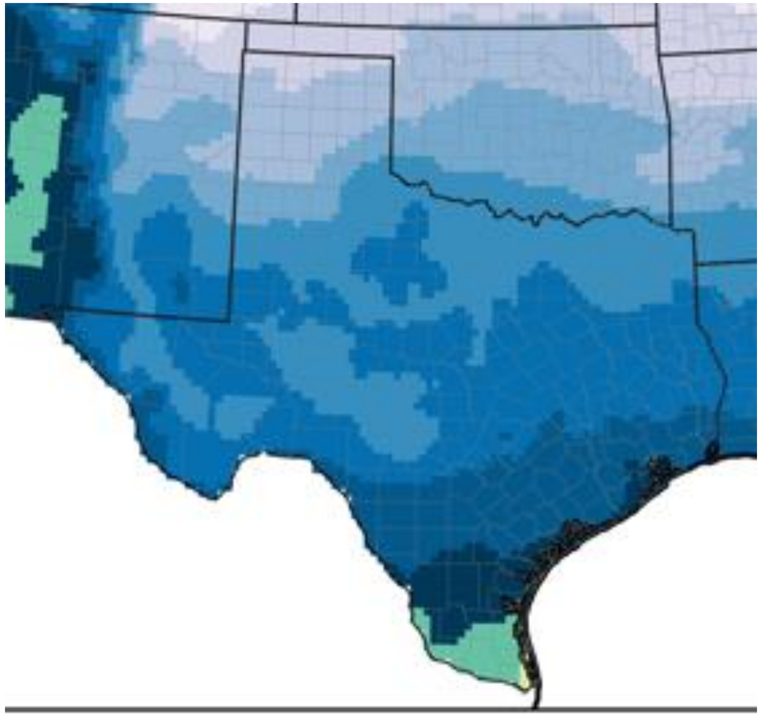
Source: WeatherSpark.com

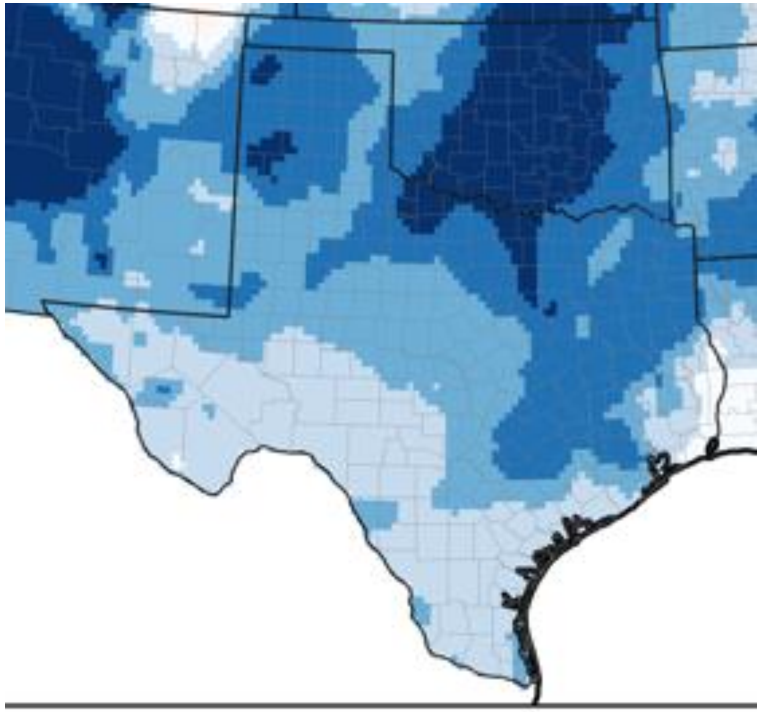
Weather maps of Winter Storms Uri and Elliott

Daily minimum temperature comparison

Winter Storm Uri Feb 15, 2021	Winter Storm Elliott Dec 23, 2022	How much colder was Uri?



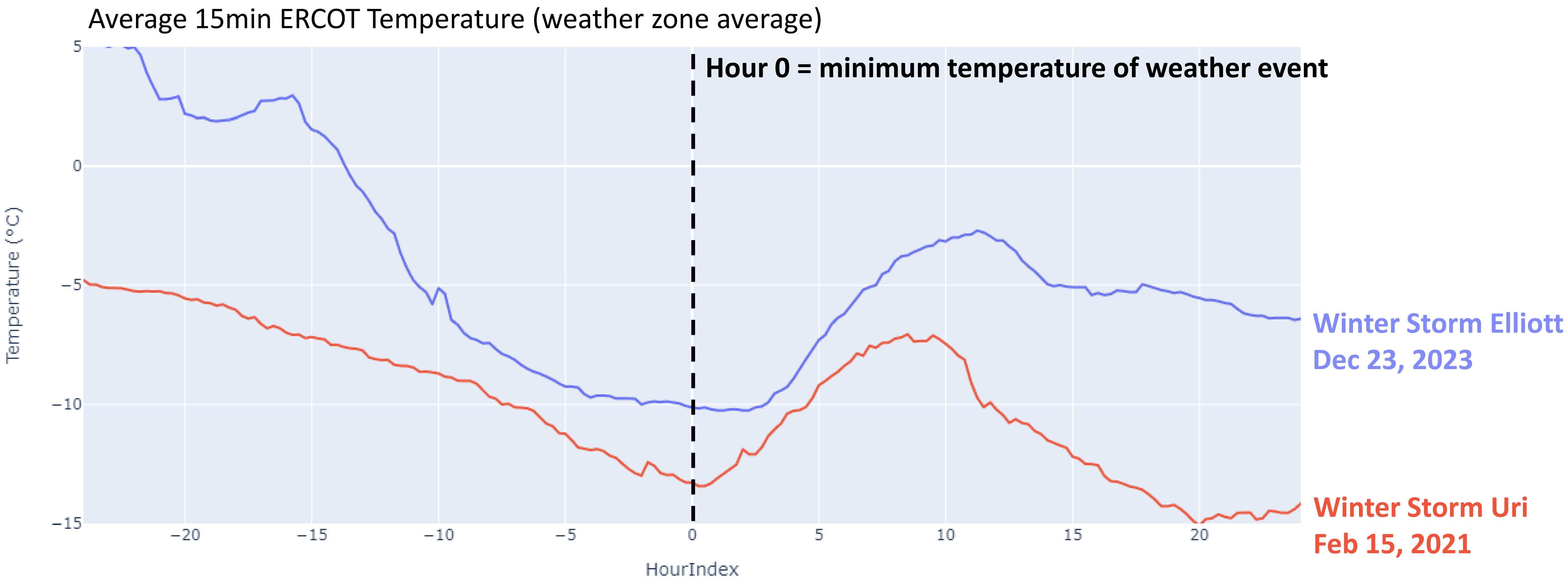




Source: EPRI, Erik Smith, Linkedin post Dec 2022

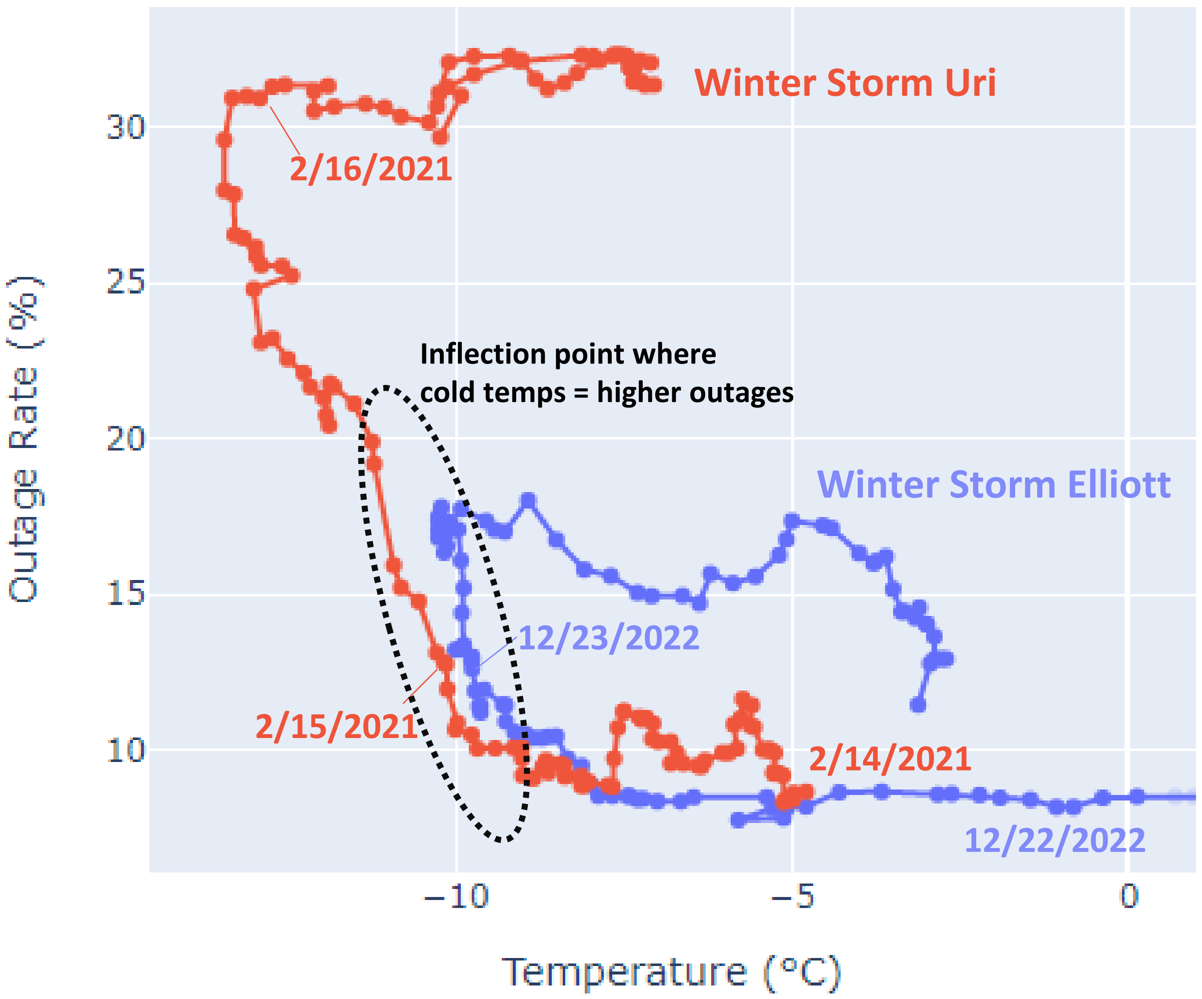
Uri saw colder temperatures and went further south in Texas, affected gas generation in Houston

Comparing Winter Storms Uri and Elliott in ERCOT



Weather Dependent Outages

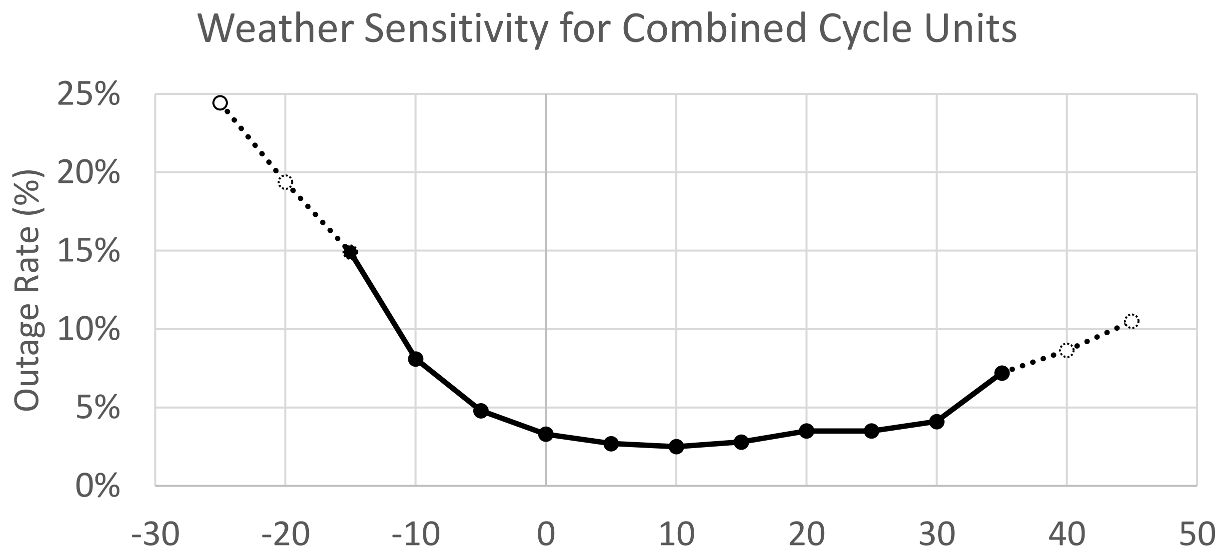
Natural Gas Capacity During Winter Storm Uri



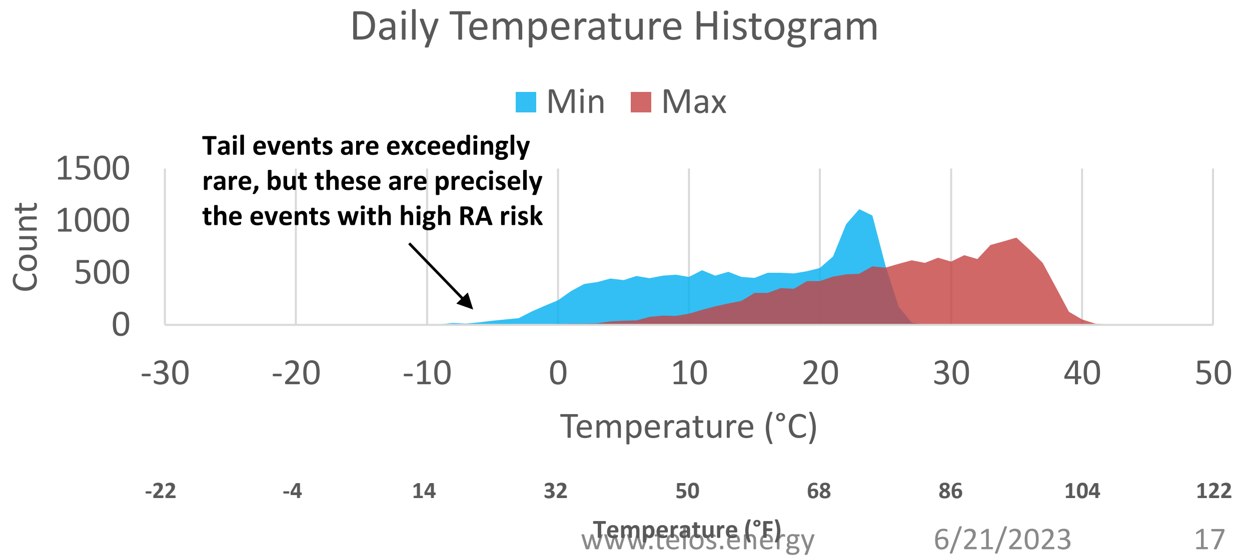
- <u>**Inflection point in outage rates at -7 to -10ºC**</u> (14-19ºF)
- Data limitation on temporal and location-specific outage rates
- Tough to disaggregate forced outages and fuel supply disruptions
- **Data Need:** critical data need for long historical record of generator outages relative to temperature
  - Extreme temperatures are rare, we likely do not have enough data to for accurate modeling
  - Stress testing is necessary to understand risk

Method to Incorporate Weather Dependent Outages

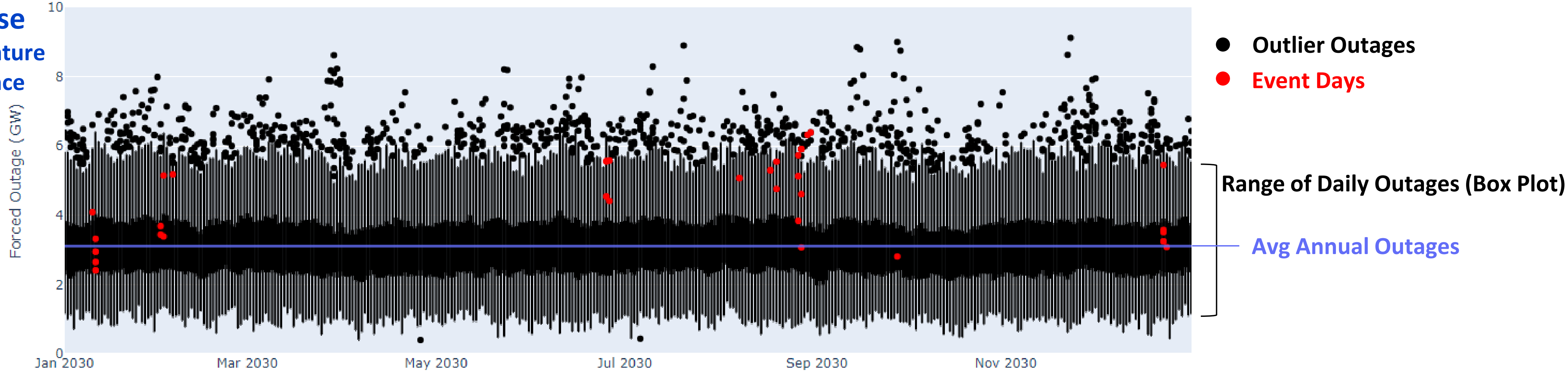
- Outage rates based on Murphy, et al. (but based on PJM data)
- Based on observations, ERCOT generators perform better at high temperatures and worse at low temperatures than the PJM dataset
- For better calibration, the outages rate curves are shifted 5°C to the right, which
  - Increases outage rate at colder temps
  - Lowers outage rate at higher temps
- Each generator was assigned ***a daily outage rate*** based on the historical temperature in the respective ERCOT weather zone (8-statewide)



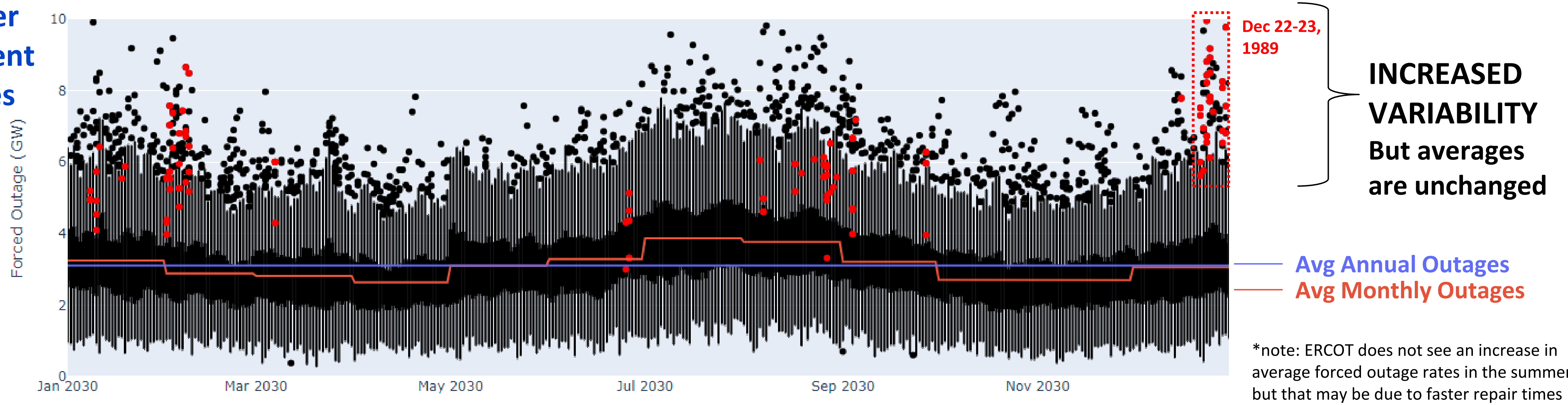
Source: Murphy, et al., 2020



Base Case
No Temperature Dependence



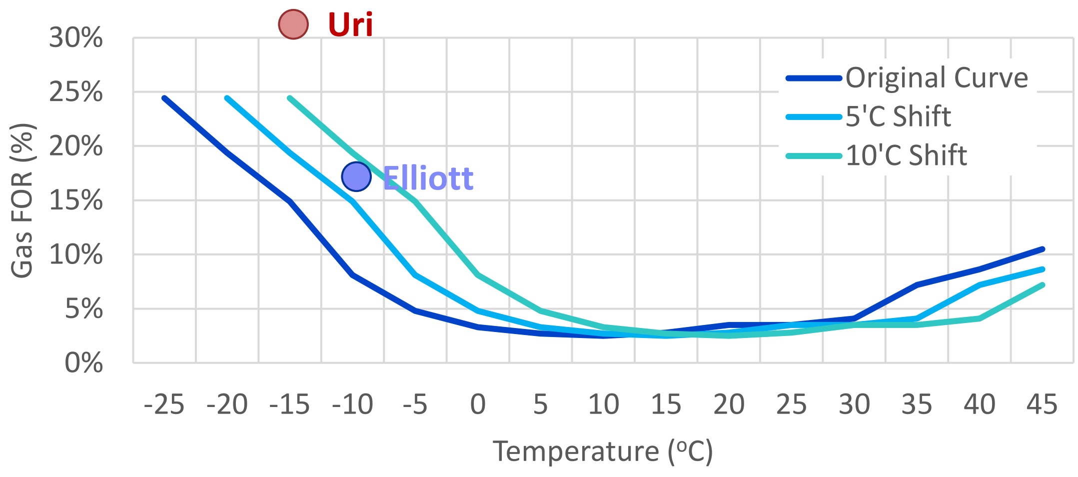
Weather Dependent Outages

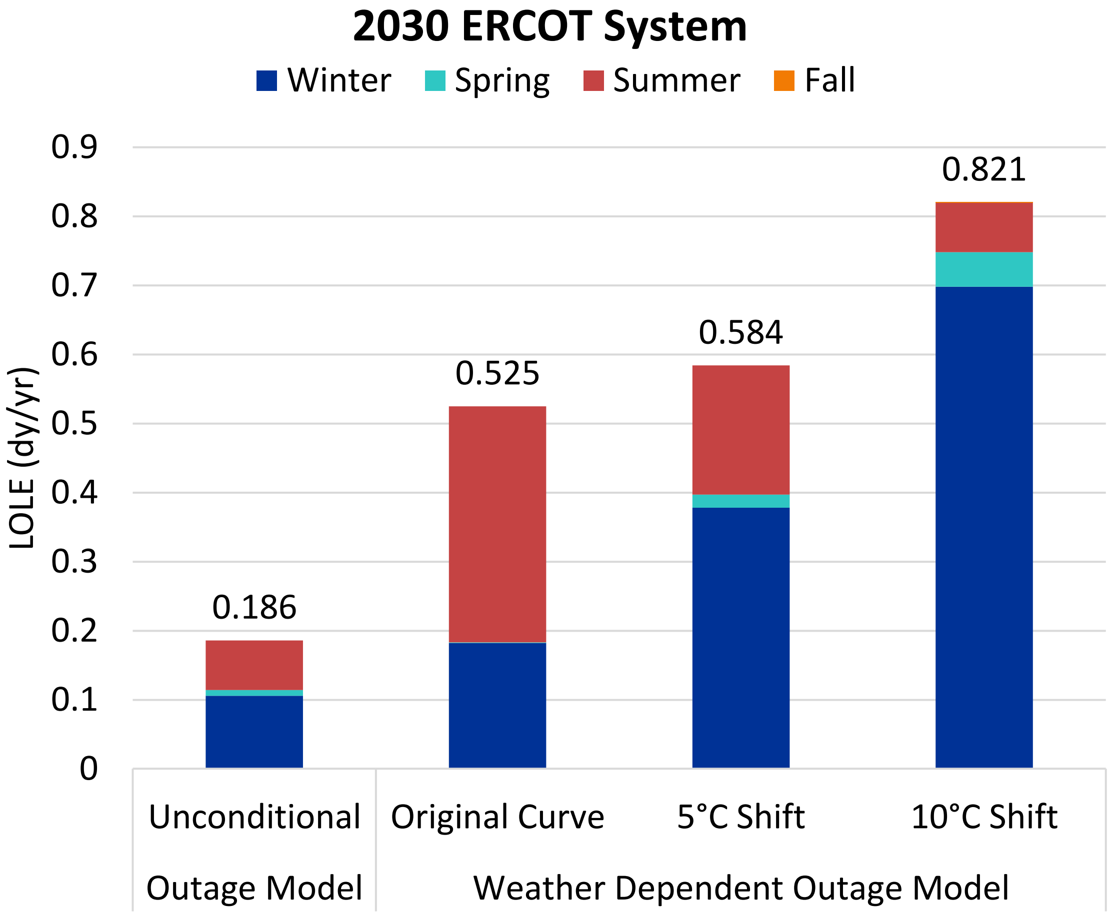


*note: ERCOT does not see an increase in average forced outage rates in the summer, but that may be due to faster repair times

Source: ERCOT Annual Reports 2012-2020

Weather dependent outages increase LOLE significantly





- Introducing WDO causes a significant increase in observed loss of load events, even when the *average* outage rate is the same
- This risk is not captured in many of today's resource adequacy analyses
- **Loss of load probability approaches 100% on extreme cold days when weather dependent outages are included.**

NOTE: The "Unconditional Outage Model" uses a higher annual outage rate such that the *average* outage rate between the unconditional outage model and the weather dependent outage models are consistent. than the Base Case of the ERCOT Case Study

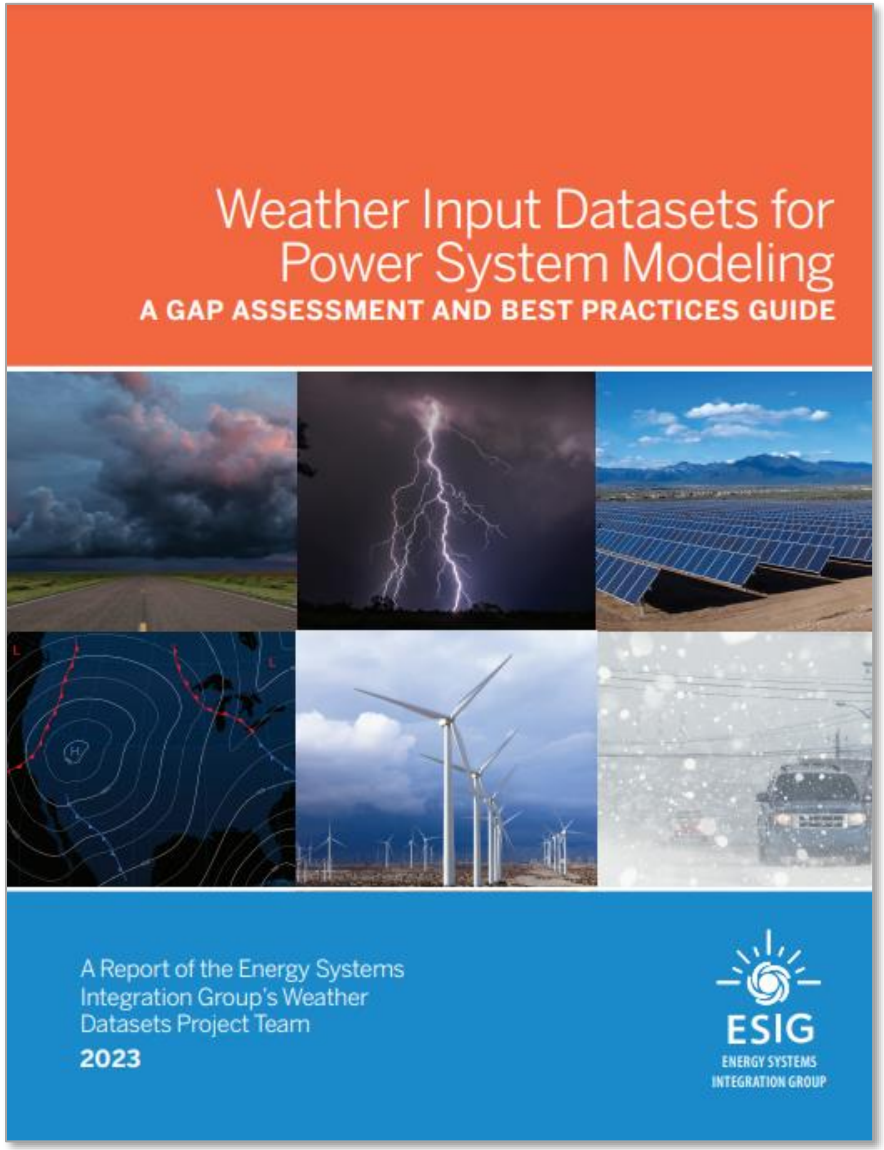
New ESIG Report!

The ideal dataset: time-synchronized weather dataset covering solar, wind, load, and temperature data across electric sector that includes electrification and climate trends

Filling the Gaps: what do we do when we don't have data? Wide spectrum of approaches to fill the gaps. (bootstrapping, repeating data, guessing…)

Next Steps: we need a broad, national-scale weather dataset from a **consistent source** on *wind/solar/load/temperature*

Cross-disciplinary, inter-regional research and development is necessary



Thank You!

Questions?

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