Update on Reliability Risk Modeling

CIFP - Resource Adequacy

May 30, 2023

Purpose of this Presentation

- Provide an update on PJM's proposal for enhancing reliability risk modeling in resource adequacy studies
- Share *preliminary* results on the patterns of reliability risk observed for the RTO with the new model
- Solicit stakeholder feedback on the analysis and preliminary results and how this might inform the market design

PJM Proposal: Reliability Risk Modeling

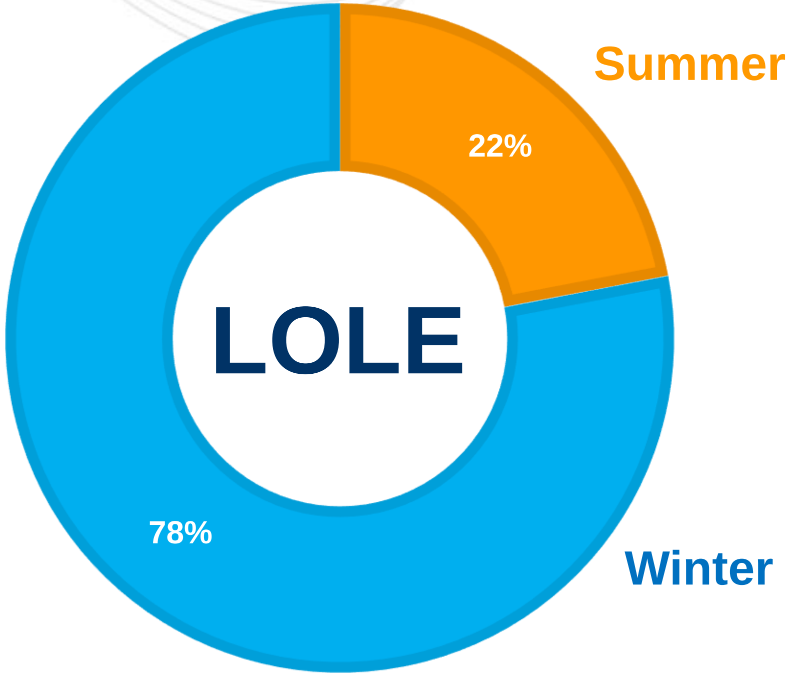
Enhance reliability risk modeling, especially that of winter risks

- Explicitly model how **forced outages and other de-rates vary with temperature** (increasing in extreme cold and hot) *and* are further **correlated across the fleet** even after accounting for unit-specific performance dependence on temperature
- **Expand weather history in reliability modeling** to 50+ years (*currently 28 years in updated model*) to better represent the full distribution of summer and winter weather outcomes
- Move to Expected Unserved Energy (EUE) as the primary reliability metric
- Move to hourly modeling in the reserve requirement studies

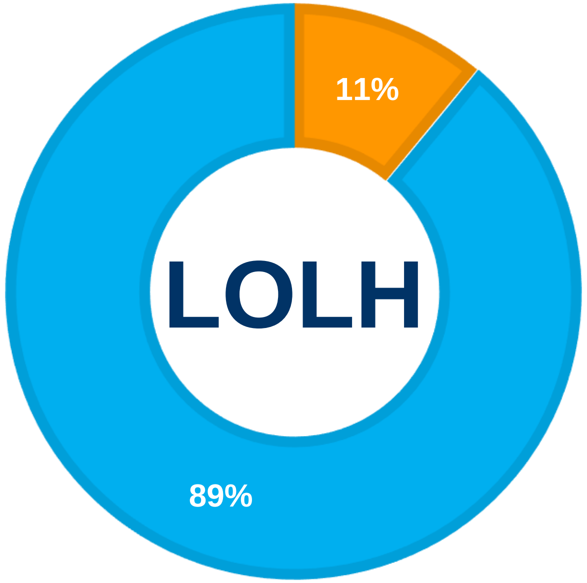
Result: reliability risk modeling that better captures the likelihood, severity, and patterns of risk

Preview of Preliminary Analysis Results

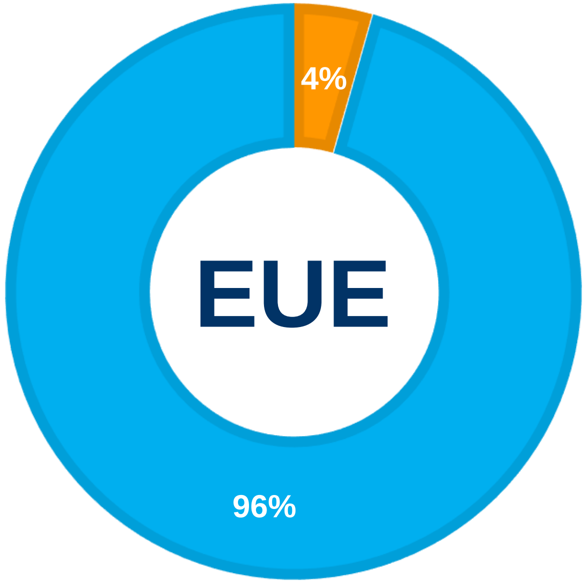
LOLE = 0.10 days



LOLH = 0.4 hours



EUE = 1,800 MWh



Methodological Overview

Weather Scenarios

Historical weather patterns observed from expanded history

- *Adjusted to capture impact of climate change on temperatures*

Load Scenarios

Hourly load profiles derived from PJM's Load Forecast model for each weather scenario

- *Weather patterns shifted forward and backward to account for day of the week / holiday variables*

Resource Performance

Unit, class, & fleet historical performance (forced outages, ambient de-rates, etc.) as a function of weather for thermal and variable generation

- *Correlated outages for any reason captured in class/fleet outage rates above the "typical range"*

Resource Adequacy Analysis

Model system resource adequacy under thousands of alternative histories

- *One alternative weather history, reflecting distribution of uncertainty given 50+ years of history*
- *One alternative load history, reflecting distribution of load forecasts given weather, time/date, etc.*
- *One alternative realization of capacity resource performance, reflecting distribution of potential performance of individual resources and historically observed correlations across resources*

Patterns of Reliability Risk

LOLE vs. LOLH vs EUE metrics

- *Summer vs. winter? Morning vs. midday vs. evening? Long vs. short events? Deep vs. shallow?*

Thermal and Variable Resource Performance

Thermal Generation

Forced outages (including ambient de-rates) modeled as a function of temperature based on historically observed performance back to 2012

- *Each historical day provides an observation of hourly forced outage rates for individual units and classes*
- *Each historical day of observed generator performance is grouped into daily temperature bins (based on min daily temperature in winter and max in summer)*
  - *e.g. bin1 for winter might include all days of observed performance with min. daily temp. below 0°*
- *The Monte Carlo analysis then draws against observed performance from the appropriate temperature bin for a given day (and temperature) of the historical weather scenarios*
  - *e.g. if Jan X, '94 has a daily min temp. of -10°, the analysis will draw against all observations of performance in bin1*

Planned / maintenance outages "optimally" scheduled for a given weather scenario and load profile

Variable Resources

Performance modeled as a function of weather and historically observed performance (or back-casts) back to 2012

- *Monte Carlo analysis draws from performance data in similar manner as thermal availability / forced outage rates*

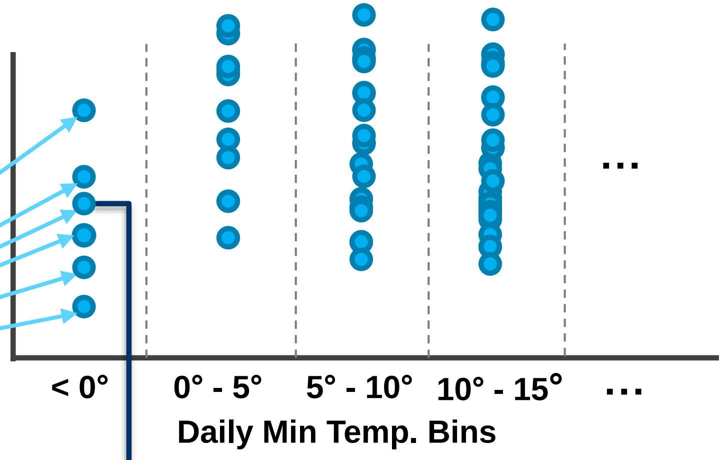
Monte Carlo Draws of Thermal and Variable Performance *(Illustrative Example)*

Weather Scenarios

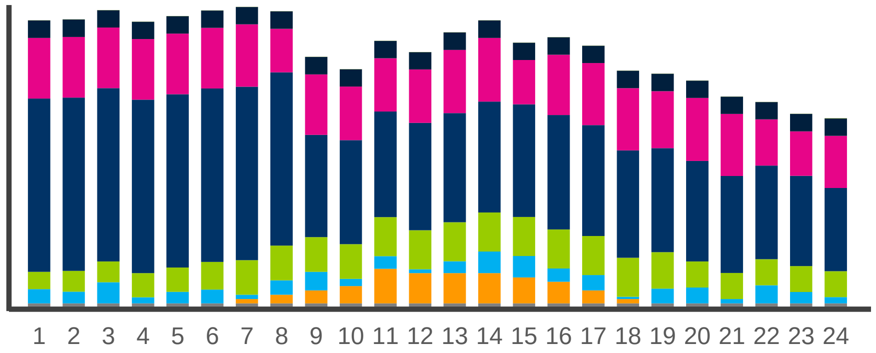
Weather Year	Date	Season	Daily Temp.
197X	Jan. 1	Winter	4° (min)
197X	Jan. 2	Winter	8° (min)
197X	Jan. 3	Winter	7° (min)
	…	…	…
1994	Jan. X	Winter	-5° (min)
	…	…	…
2012	7/15/12	Summer	92° (max)
2012	7/16/22	Summer	89° (max)
	…	…	…
2022	Dec. 31	Winter	12° (min)

Sampling of Performance Observations

Daily Historical Winter Observations of Availability / Performance by Temperature Bin (since 2012)



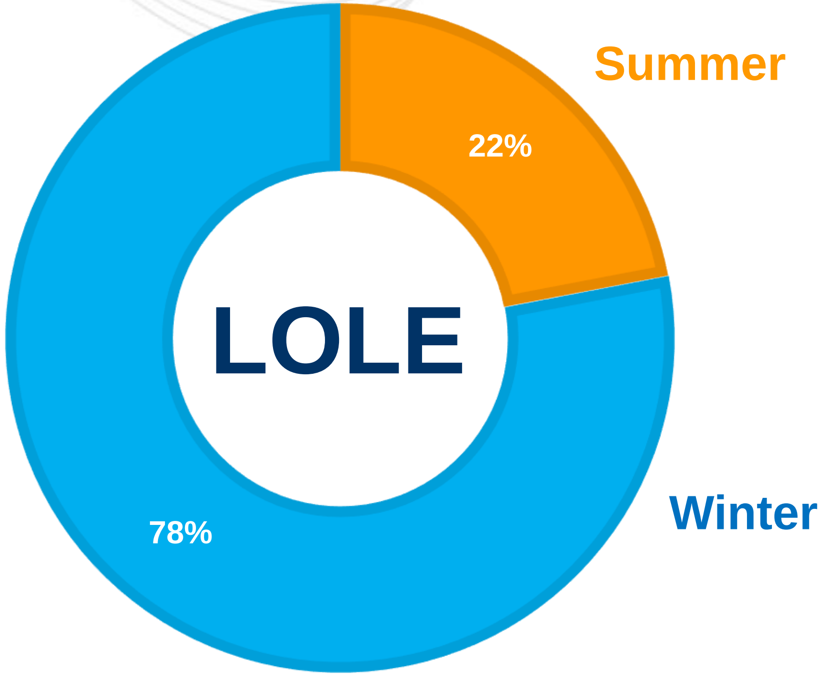
Sample Observation: Feb. X, 2015 Hourly Availability*



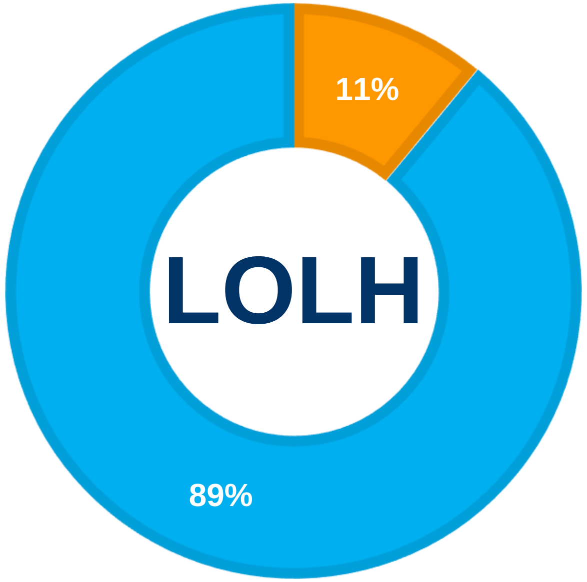
Preliminary Analysis Results

Preliminary Analysis Indicates Shifting Risks

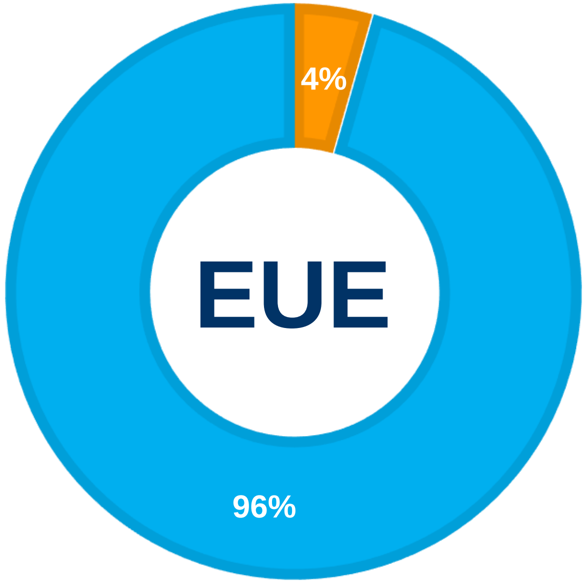
LOLE = 0.10 days



LOLH = 0.4 hours

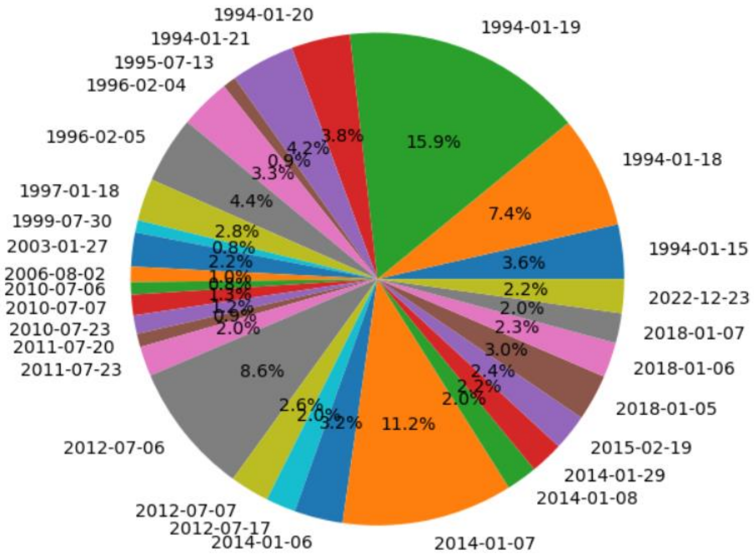


EUE = 1,800 MWh

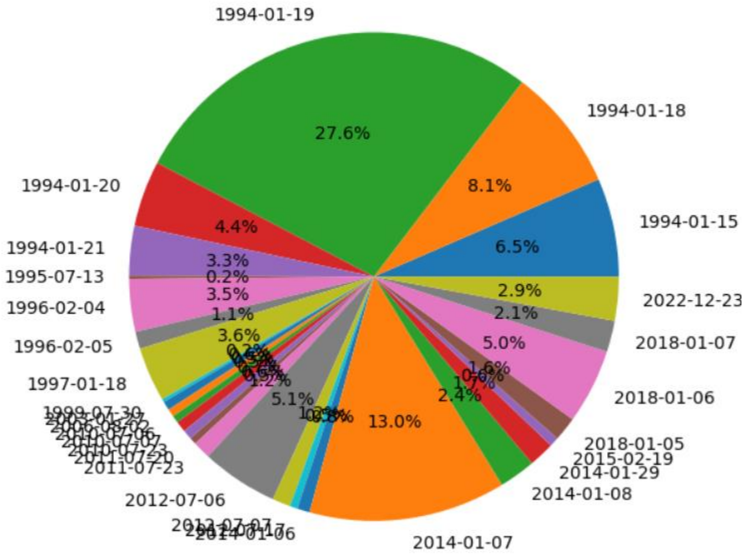


Winter Risk Driven by Extreme Weather

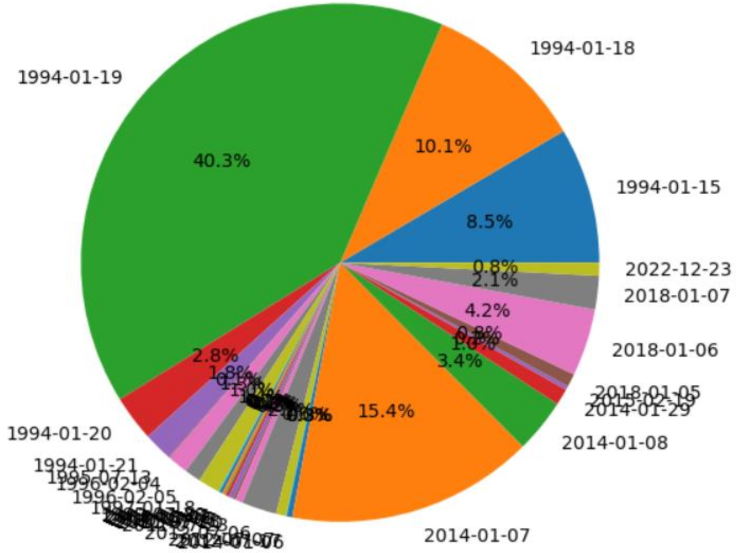
LOLE = 0.10 days



LOLH = 0.4 hours

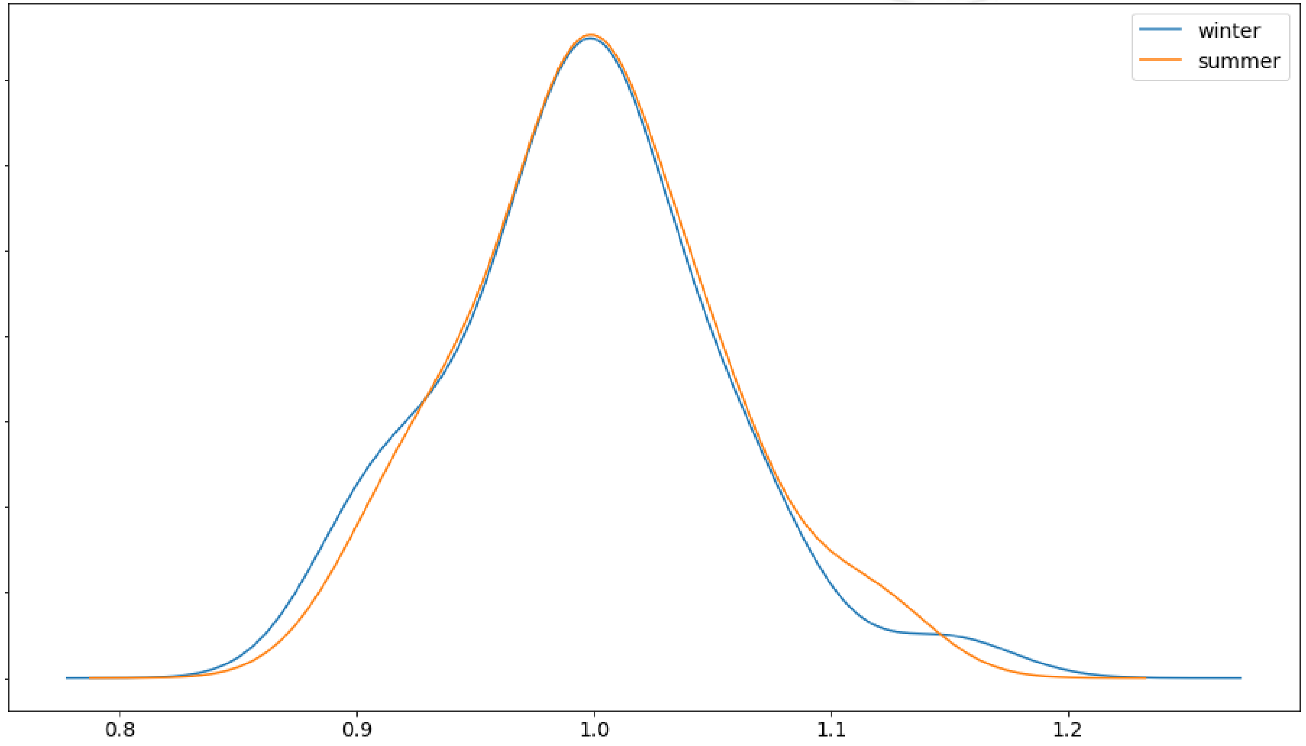


EUE = 1,800 MWh



Impact of Summer and Winter Peak Load

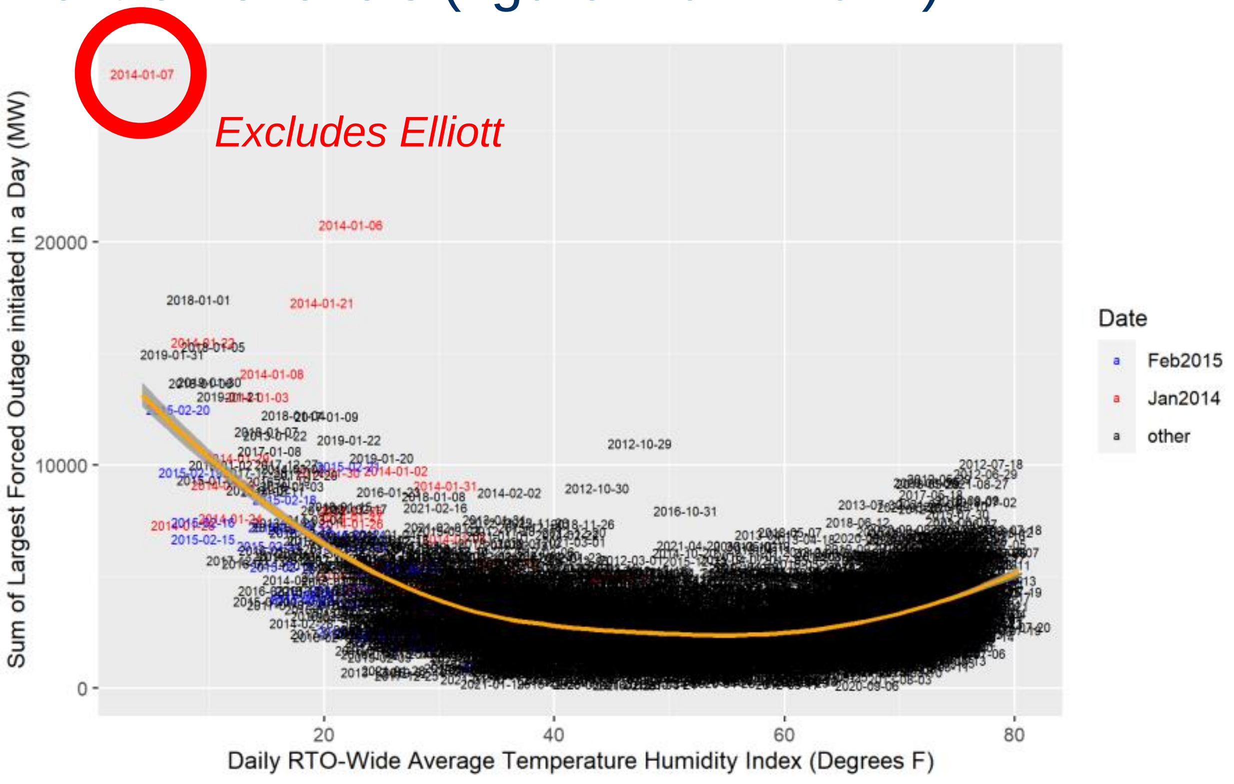
Distribution of seasonal peak load forecast
across years, relative to the respective 50/50 peak



Loads during coldest temperatures are high (relative to 50/50 winter peak) but overall volatility of winter load does not appear to be primary driver of new winter risk

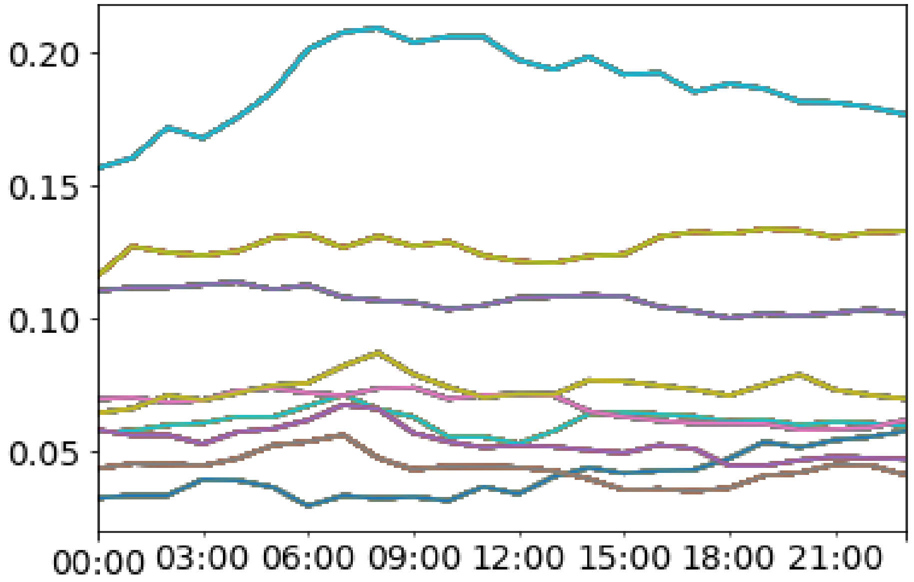
Impact of Winter Correlated Outage Risk

Historical thermal forced outages increase during colder temperatures, and can reach extreme levels (figure: 2012-2021)



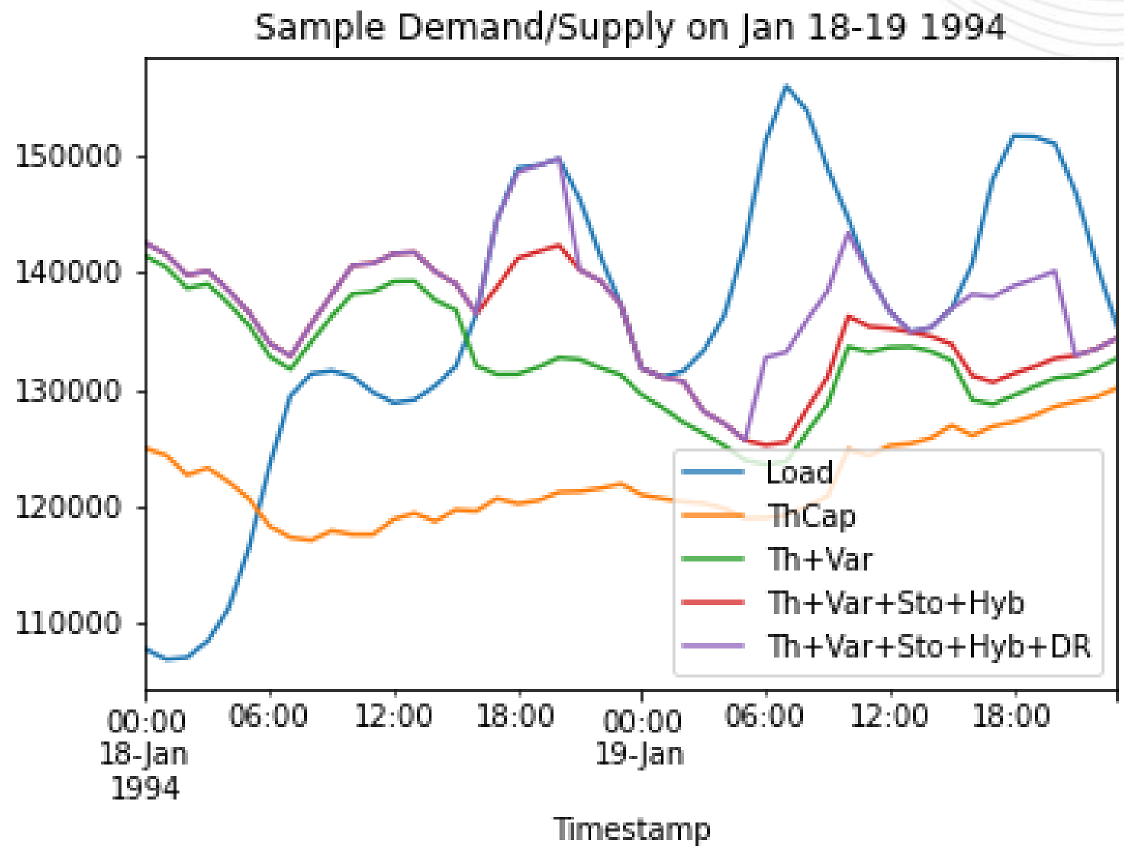
Winter risk is driven by extreme correlated outage potential

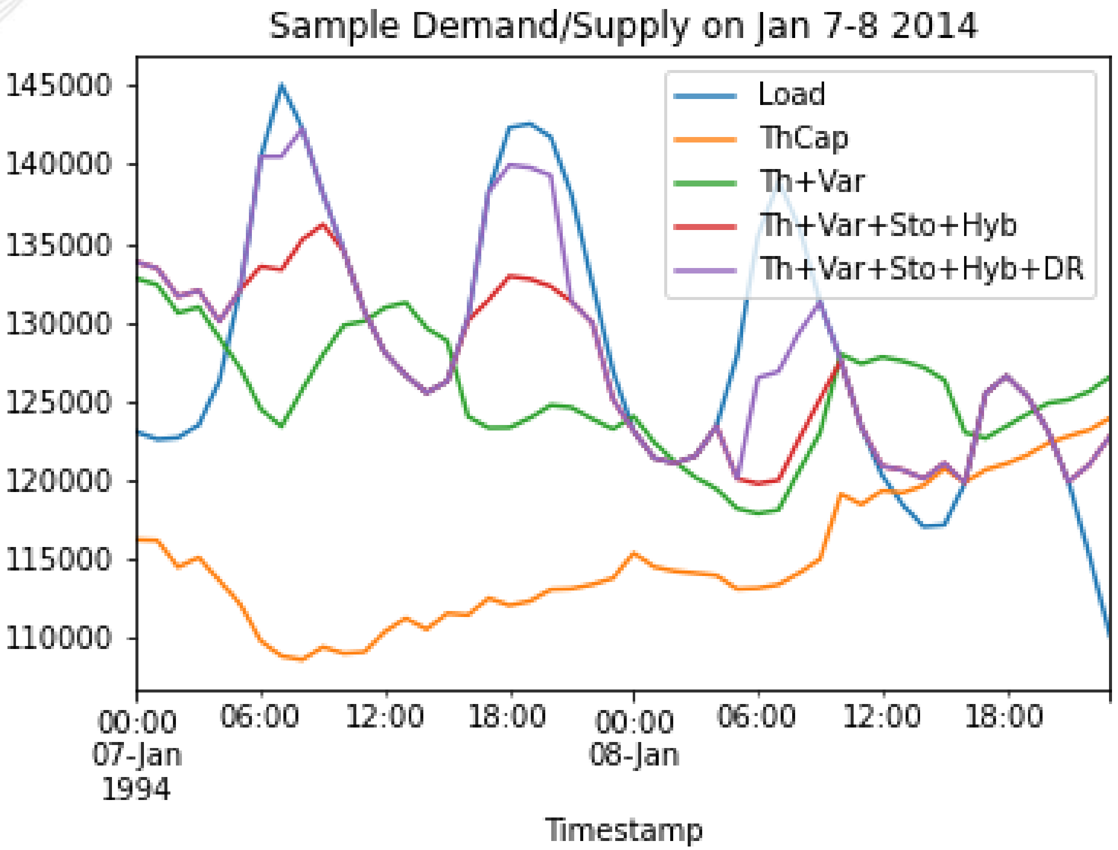
Thermal forced outage rate patterns on Jan. 19, 1994 (9 patterns)



Sample Loss of Load Events

Extreme Correlated Outage Events Driving Substantial Winter Risk





Stress Testing of Preliminary Results

Back of the envelope

- Peak load forecasts (2026/27):
  - Summer 50/50 forecast: 153 GW; 90/10: 167 GW
  - Winter 50/50 forecast: 137 GW; 90/10: 146.5 GW
- Historical supply outages:
  - Worst summers: ~15 GW (July 2012)
  - Worst winters: ~46 GW (Dec. ’22); ~40 GW (Jan. ’14)

Seasonal differences in worst-case supply outages (25+ GW) can be significantly more than differences in peak loads (15-20 GW)

Sensitivity analysis

- Inclusion/exclusion of worst historical winter (1994)
- Inclusion/exclusion of historical fuel-related outages
- Inclusion/exclusion of planned & maintenance outages during peak winter period
- Various methodologies for re-sampling from historical data

In all cases, winter risk significantly exceeded summer risk on LOLE, LOLH, and EUE basis

Implications for Market Design

- Preliminary analysis is showing a significant shift in reliability risk to the winter.

- These results suggest improved alignment between the reliability risk analysis and the empirical observations of cold weather operational events seen during Winter Storm Elliott, Uri, and others.

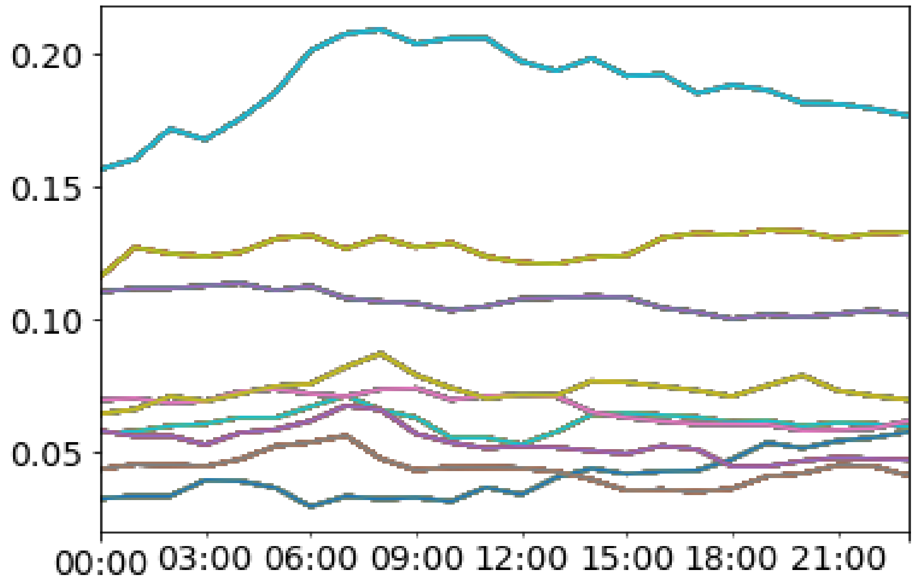
- This supports a move away from the traditional industry assumption that risk aligns solely with peak load.

- A shift in the reliability risk profile for the RTO may require associated changes to the capacity market to ensure it remains effective.

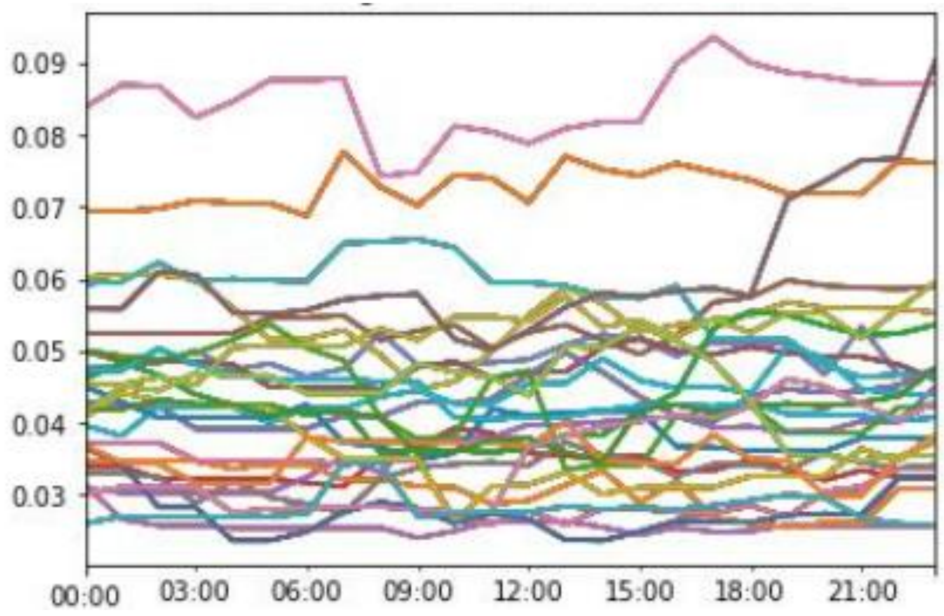
Appendix

Summer vs. Winter Forced Outage Patterns

Forced Outage Patterns under Most Extreme Winter Temperatures



Forced Outage Patterns under Most Extreme Summer Temperatures



Assumptions / Inputs used in the *Preliminary* Analysis

- **Delivery Year of Analysis:** 2026/2027
- **Weather Scenarios:**
  - Currently goes back to 1994 in this analysis
  - No adjustment for climate change applied in this analysis
- **Load Profiles:**
  - Based on 2023 Load Forecast model
  - Day of the week shifting not applied in this analysis
- **Resource Performance History:**
  - 2012 – 2022 (*includes WSE availability data*)