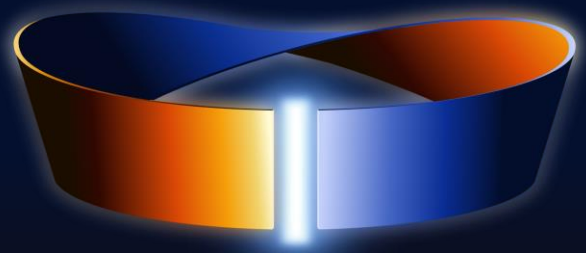

WARP to Resilience

Weather-Adapted Resource Planning

Opportunities for downscaled climate projections to support planning to the bulk grid reliability standard & role of weather extremes

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CEC C-DAWG Meeting

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Lumen ENERGY STRATEGY

The impact of extreme weather on the grid's ability to serve customers is complex

Extreme weather event ≠ **Grid failure**

When grid strains to deliver to tx load bus, not necessarily when demand peaks (combo of demand & supply & tx wires dynamics)

	Hottest Day CAISO-wide	CAISO peak demand*	Greatest threat to tx load bus delivery*	Most cust. on outage (#)
2024	**Sep 5/6** (452)	**Sep 5** 16:59 (RMO)	**Jul 24** 17:25–23:59 (watch)	*n/d*
2023	**Aug 16** (378)	**Aug 16** 17:59 (RMO)	**Jul 20** 19:30–22:00 (EEA1)	**Jan 7** (932,094)
2022	**Sep 6** (537)	**Sep 6** 16:57 (EEA3)	**Sep 6** 17:17–20:00 (EEA3)	**Sep 3** (526,607)
2021	**Jul 9** (364)	**Sep 8** 17:50 (RMO/Alert)	**Jul 9** 18:32–21:00 (EEA2)	**Jan 25** (751,218)

Timing of heat events matters; BTM solar increasingly offsetting demand peaks in early summer

No actual failures on the bulk grid in these years

But significant failures on the dx grid; & not always driven by the same stressors to bulk grid

Sources: CAISO and utility reliability reports. RMO=Restricted Maintenance Outages (relatively low level alert). tx=transmission; dx=distribution.
*Times in PDT.

- To translate weather into grid failure risks, electricity system models need:
  - Spatially-granular data, with hourly precision
  - Time series data, across planning years
  - Internally-consistent weather metrics, to understand dynamics among demand, supply, delivery

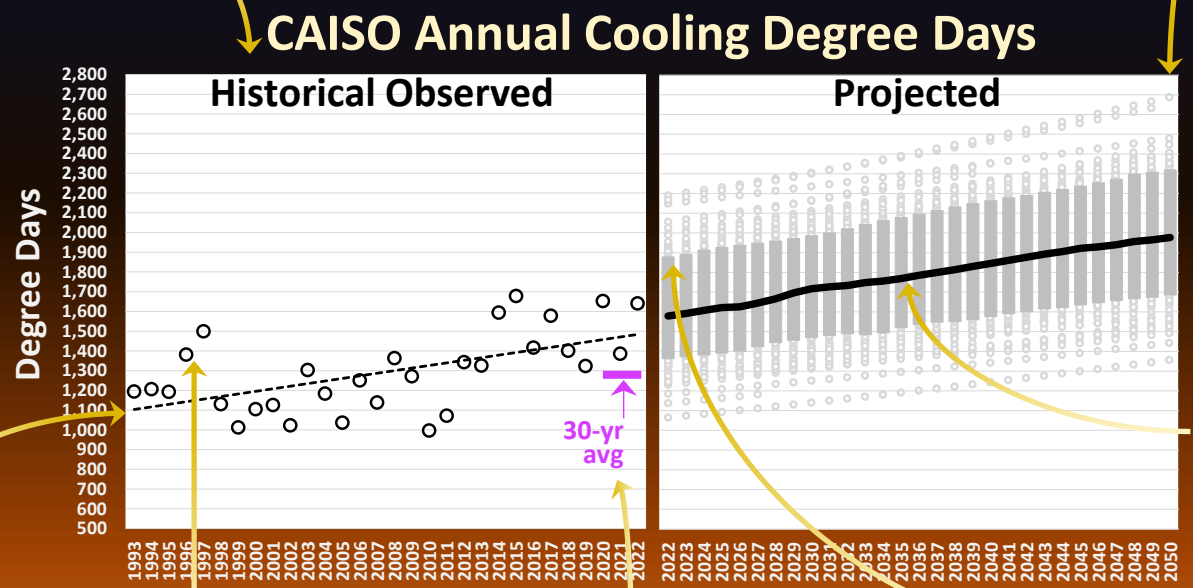
Becoming more complicated w/ variable & energy-limited resources; needed for stochastic modeling; big reason planners stick with historical data

- Planning aims to balance risks vs. costs to ratepayers
  - We don't build for worst case (but do plan for it)
  - Systematic over-mitigation, by even 1,000 MW, commits ratepayers to **$Billions** in procurements
  - Most significant impact to ratepayers is in near- and mid-term procurements

Weather extremes that cannot be well understood through actual historical outcomes and patterns are of most concern

Historical data typically 20–30 data points
One possible outcome for each year

We use downscaled climate projections to derive 204 weather variants in each future planning year



P90
Median
P10

Graph shows distribution of the 204 variants in each future planning year

Median and distribution shifts with climate signal over time
Shows extremes becoming more "normal"

LT trend entangled with annual variability & other weather cycles

How much worse would late '90s be in today's terms? More extreme than 2020 & 2022?

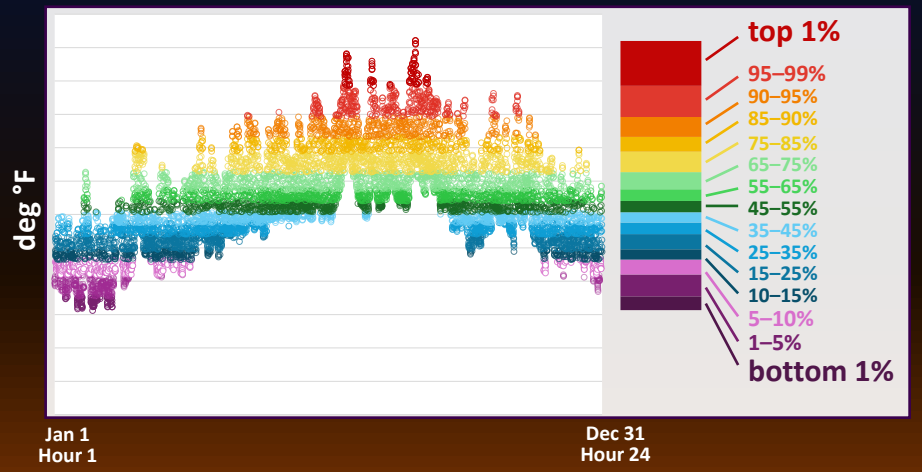
Not enough data points to determine 1-in-x, even with de-trending

Additionally, underlying data include novel temperature levels and patterns not historically observed

De-trending enables downscaled climate projections to inform a trajectory of potential weather outcomes across grid planning years

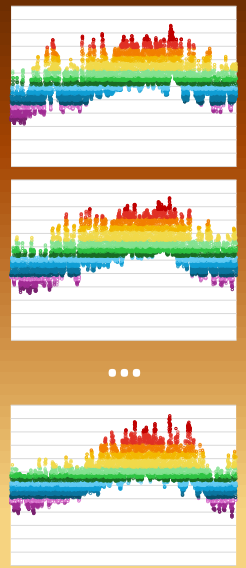
Temperature Time Series & Quantiles

Example: 1 station, 1 year, hourly, from 1 WRF run



–Starts with hourly WRF outputs, localized and bias-corrected to weather stations

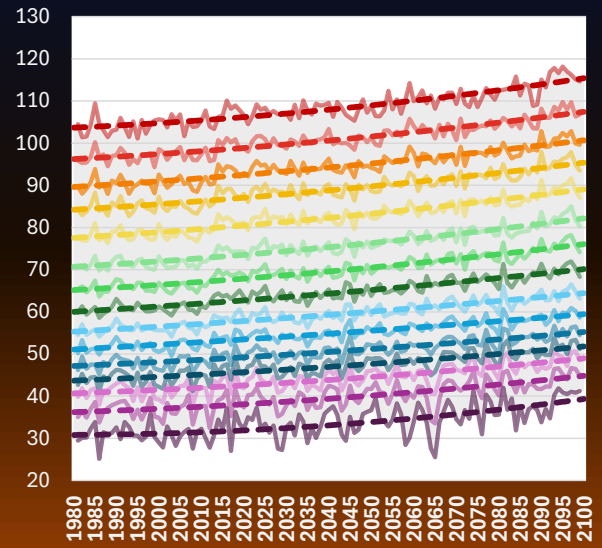
–15 quantile bins defined for each GCM run year (shown above)



Compile data for each GCM & modeled year 1981-2100

Define the LT Trend & De-Trend

Example: 1 station, hourly, 1 WRF run

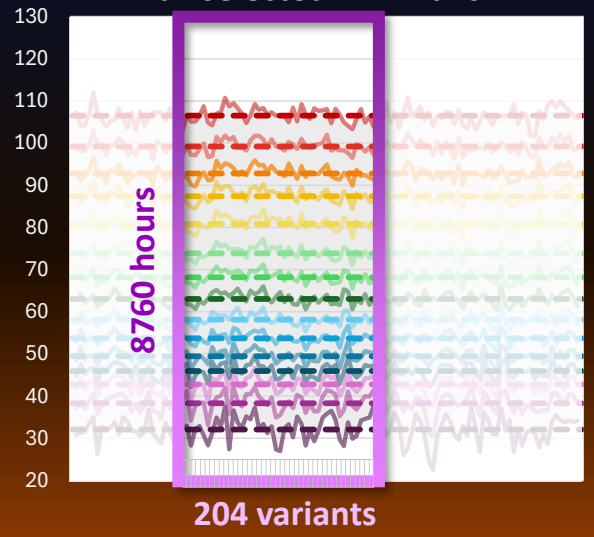


–Trend defined by GCM run, weather station, and quantile; looking across all GCM run years

–Separates portion of temperature variability due to climate signal from variability due to shorter-term weather cycles

De-trended Variants

+/- 25 yrs around planning year
× all selected WRF runs



–204 variants for each planning year, at hourly & spatial detail (weather station)

–Reflects a trend-adjusted range of potential weather outcomes in a given planning year

–Retains original hourly chronological order, annual and spatial relationships, GCM run climate signal across planning years

THANK YOU

LEARN MORE ABOUT *WARP TO RESILIENCE* AND JOIN OUR MAILING LIST FOR STUDY UPDATES

www.lumenenergystrategy.com/resilience

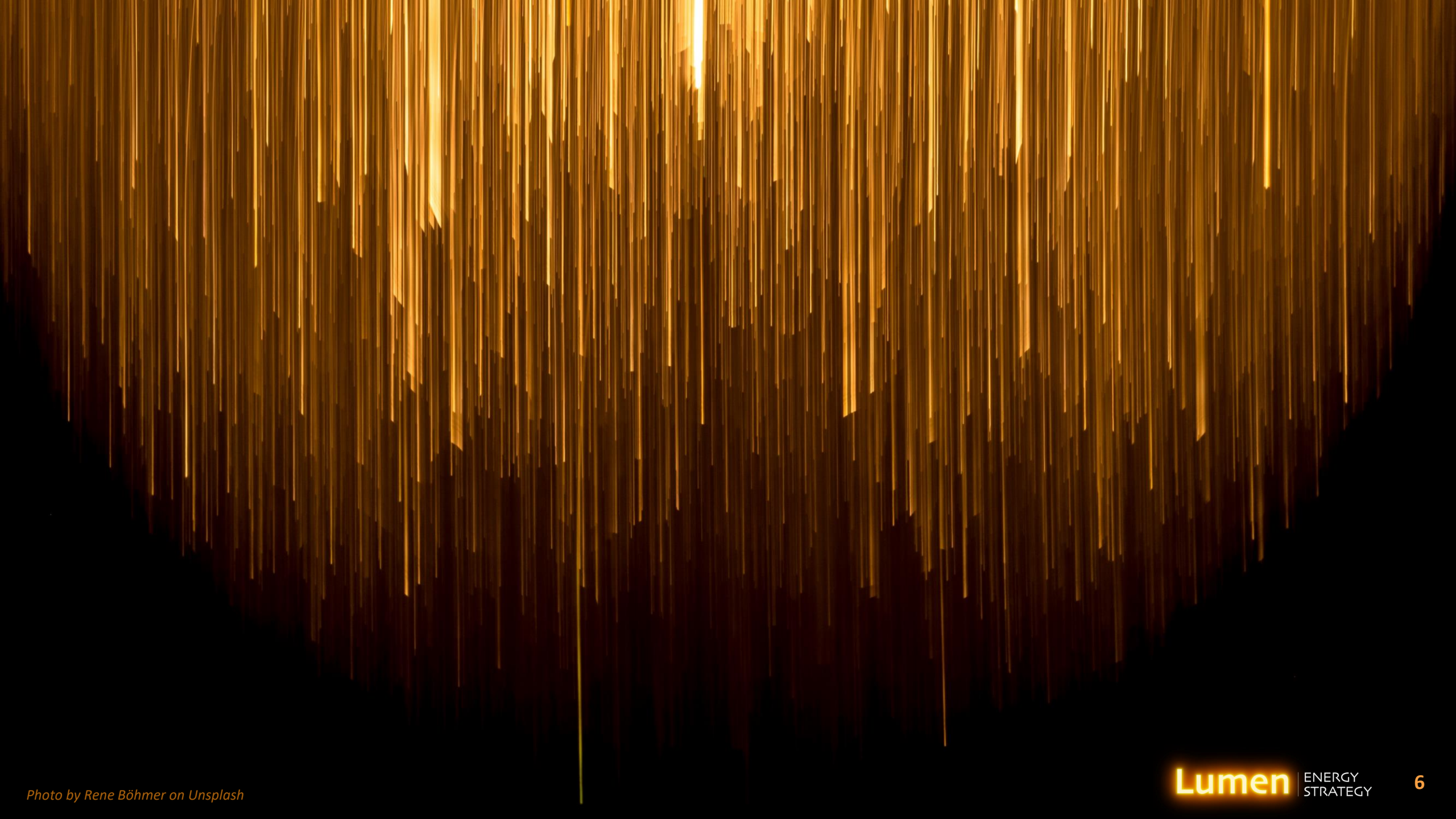


Photo by Rene Böhmer on Unsplash

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