Meteorological vs Power System Extremes

Insights into EPRI Research and Overview of EPRI's Risk Screening Tool

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IEA Workshop: Forecasting Extremes in the Power System
Sep 30 - Oct 1, 2025

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- What is EPRI - Interest in Researching Extremes
- Meteorological vs Power System Extremes
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Vision

To be a world leader in advancing science and technology solutions for a clean energy future

Mission

Advancing safe, reliable, affordable, and clean energy for society through global collaboration, science and technology innovation, and applied research.

Together…Shaping the Future of Energy®

Who We Are

Founded in 1972, the Electric Power Research Institute (EPRI) is the world's preeminent independent, non-profit energy research and development organization, with offices around the world.

Our Experts

EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe.

EPRI Spans the Entire Electric Industry

Nuclear

Generation

Power Delivery & Utilization

STRATEGIC RESEARCH

- Low-Carbon Resources
- End-Use/ Economy-Wide Carbon Reduction
- Electric System Reliability/Resilience
- Electric System Flexibility
- Market Transformation/ Policy/Regulatory Education

Reimagining the Future Energy System

Near-term
~10–15 years

Decarbonization

Accelerate economy-wide, low-carbon solutions

Resiliency

Mitigate climate impacts and cyber/physical risks

Near-term
~10–15 years

Reimagining the Future Energy System

	Decarbonization	Resiliency
Near-term ~10–15 years	Accelerate economy-wide, low-carbon solutions	Mitigate climate impacts and cyber/physical risks
Long-term ~15–30 years	Net-zero clean energy system	Future proof energy system design basis

Transformation

Drive affordability of a clean and resilient energy system through digital transformation and power system modernization

Reimagining the Future Energy System

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Future proof energy system design basis

Making Energy More

Clean | **Affordable** | **Reliable**

Meteorological vs Power System Extremes

Defining and Quantifying “Extreme” Events

Climatological/Meteorological Extreme Events

- Derived from climate data or model simulations, or observations
- Defined relative to climatology (30-year period)
- Probabilistic in nature (characterized by return periods)
- May exhibit long-term changes due to climate change
- Characterized for one variable or caused by a variety of extreme events
- Acute event vs chronic hazards | Extremes – Variability – Volatility
- Can be location specific

Power System Extremes

- Climatological extremes can provide initial insight, may overlap with or differ from extreme operating conditions.
- Need additional information from asset managers, engineers, system operators to understand what may be considered “extreme operating conditions for power system assets or components”.
- Define performance thresholds relative to the operating characteristics of assets/system
- Can be location- and asset specific
- What is considered extreme may change through the adoption of new technology or operating methods (and climate change)
- Can be caused by internal equipment failure, malfunctions, supply shortages, human error, manmade attacks…
- Goal: ensure that power system assets can maintain adequate operations or ensure rapid recovery

Meteorological vs Power System Extremes - Examples

	Temperature Extremes	Precipitation Extremes	Wind Extremes
Climatological extremes			
Power system extremes			

Changes in extreme events are likely to be more impactful than changes in average conditions

Meteorological vs Power System Extremes - Examples

	Temperature Extremes	Precipitation Extremes	Wind Extremes
Climatological extremes	historical 99th percentile of summer daily high		
Power system extremes	Distribution transformers are at risk of failure if subjected to 2-3 consecutive days of > 40 C		

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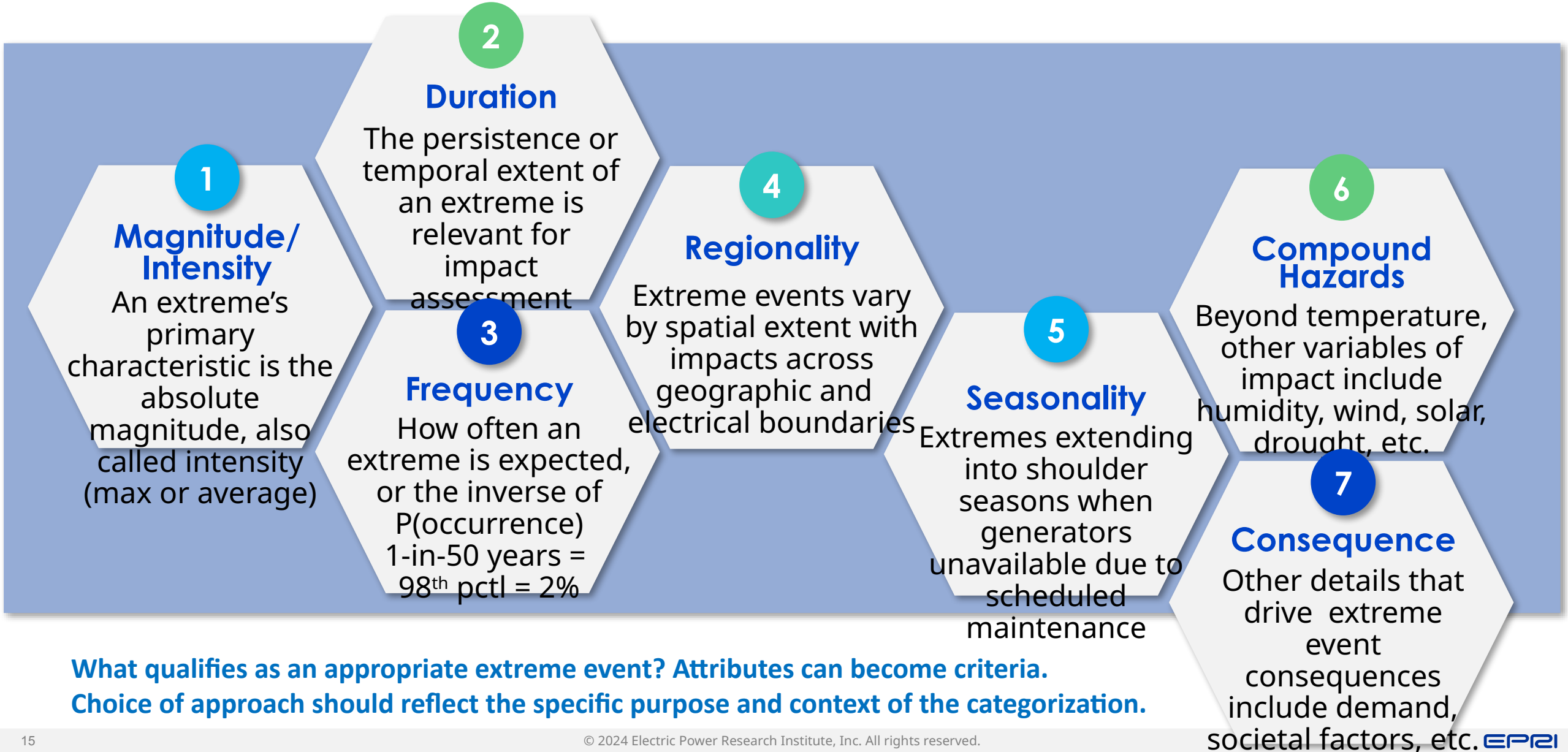
Meteorological vs Power System Extremes - Examples

	Temperature Extremes	Precipitation Extremes	Wind Extremes
Climatological extremes	historical 99th percentile of summer daily high	100-year rainfall / 13 mm in a day	hurricanes, thunderstorms, derechos, gusts
Power system extremes	Distribution transformers are at risk of failure if subjected to 2-3 consecutive days of > 40 C	Sensitive electronics can fail if submerged in floods. Severity of flood impact depends on the elevation/waterproofing of equipment.	Extreme wind gusts damaging power lines, which in turn can cause wildfires; turbines unable to operate > 25 m/s

Changes in extreme events are likely to be more impactful than changes in average conditions

Extreme events can be defined along multiple characteristics

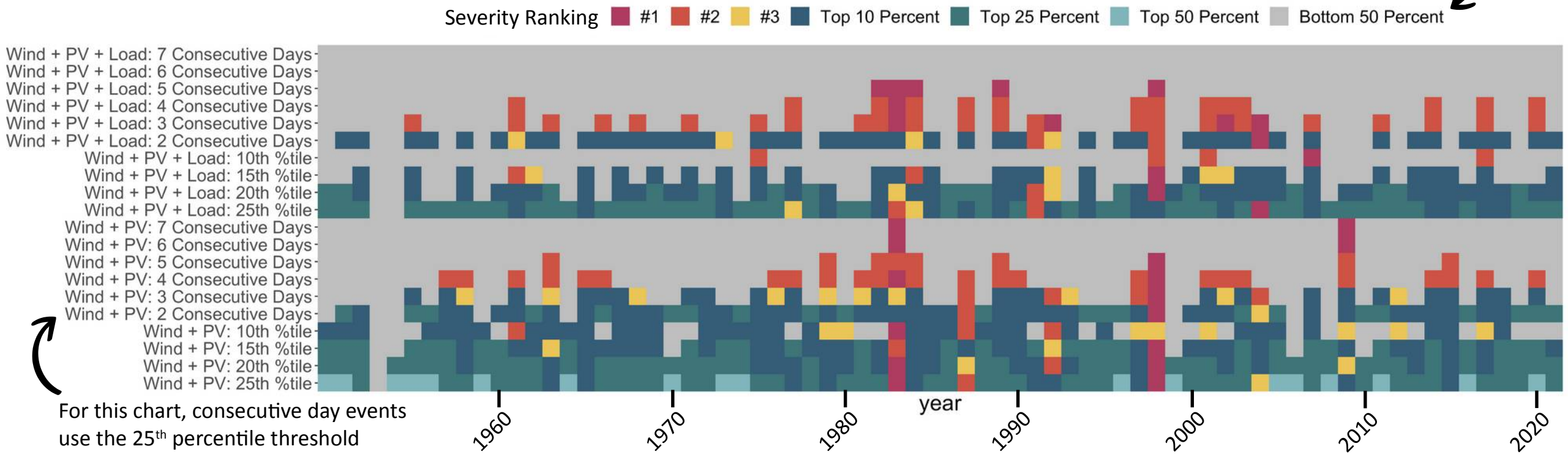


What qualifies as an appropriate extreme event? Attributes can become criteria.
Choice of approach should reflect the specific purpose and context of the categorization.

How extreme an event is depends on how you define it

In many cases, a grey box means the definition does not apply (e.g., there are zero instances of consecutive-day events)

IPCO Ranking of "bad" dark doldrum years

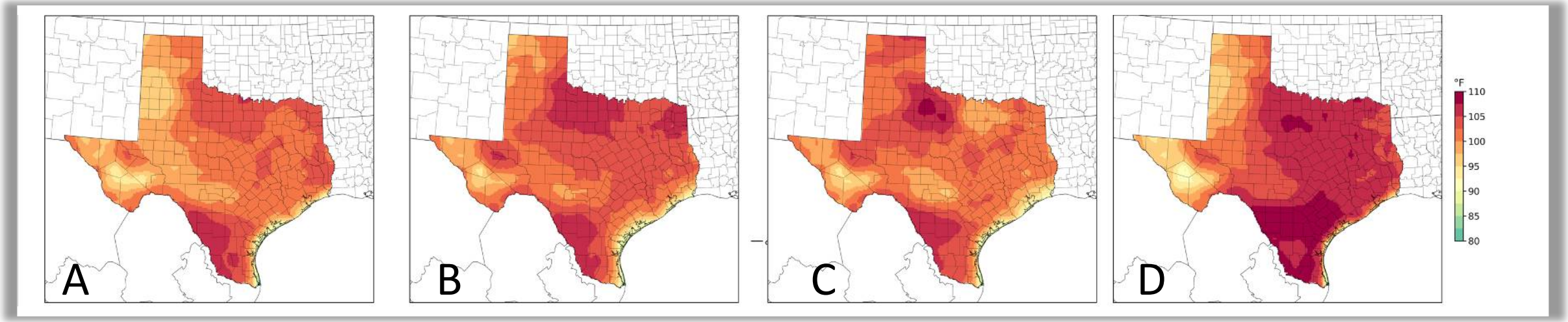


For this chart, consecutive day events use the 25th percentile threshold

The "worst" year depends on how you define it!

Risk Screening Tool

Selecting extreme events is not always straightforward



- Consider four 1-in-50-year extreme heat events in Texas that differ depending on criteria around duration (3 vs 10 days) and spatial extent (city vs state):

A) 10-day statewide average temps

B) 10-day average temps of a single city

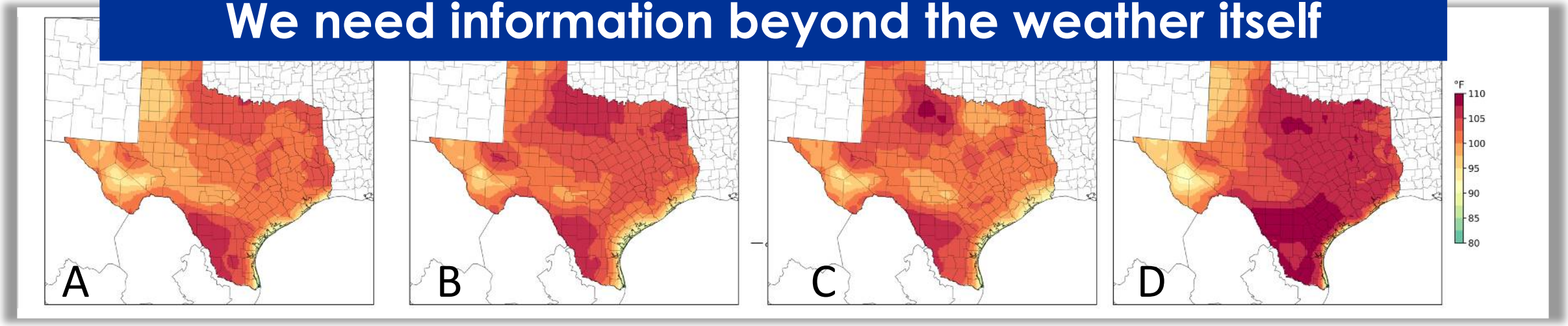
C) 3-day statewide average temps

D) 3-day average temps of a single city

How do we evaluate which event poses the highest risk to the power system?

Selecting extreme events is not always straightforward

We need information beyond the weather itself



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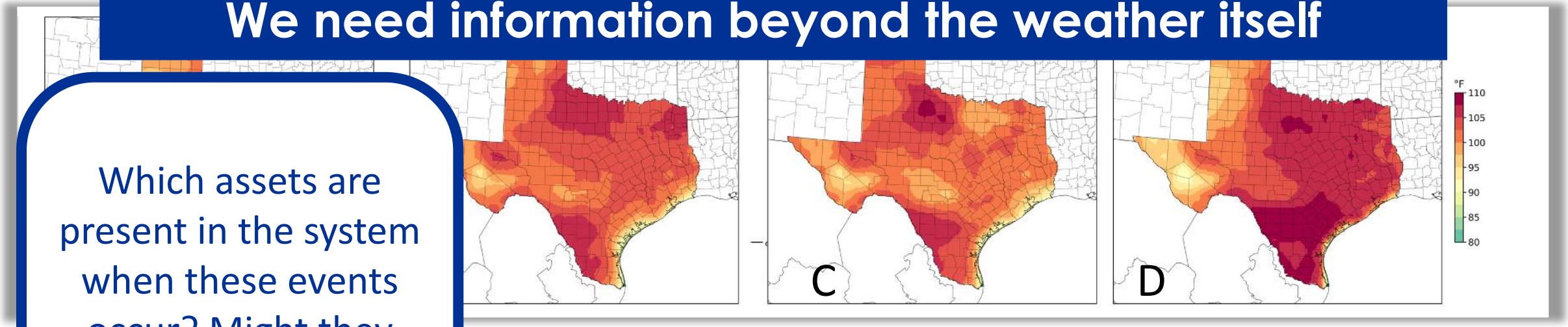

Which assets are present in the system when these events occur? Might they suffer performance impacts from high temperatures?

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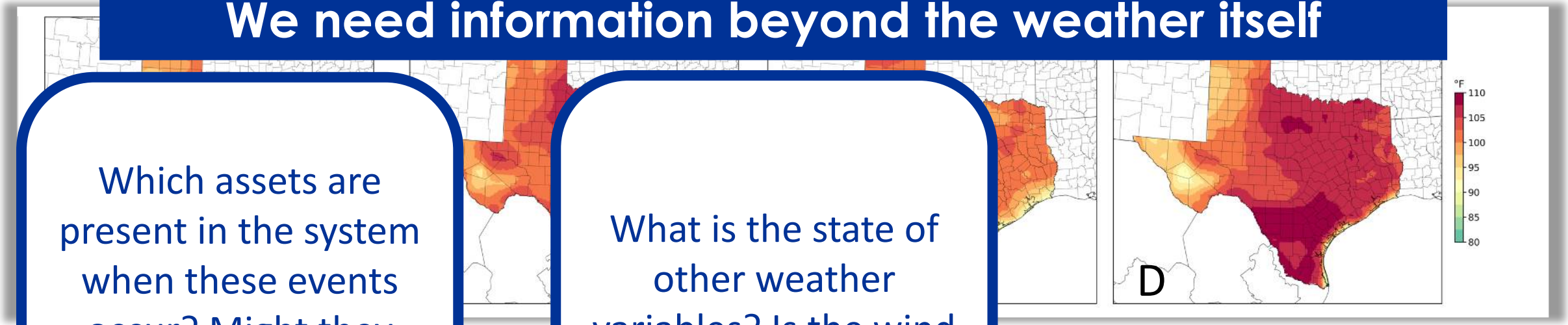
What is the state of other weather variables? Is the wind blowing? Is it cloudy? Is it humid?



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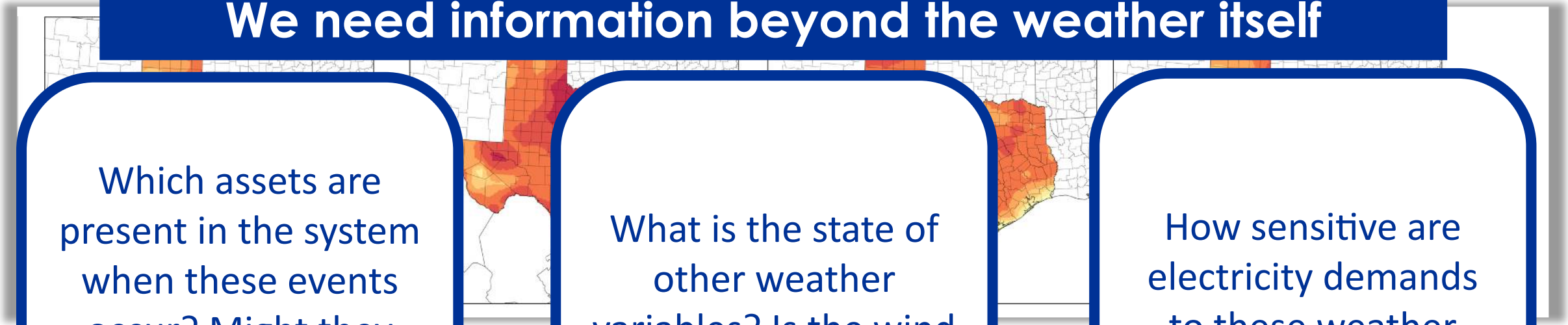

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How sensitive are electricity demands to these weather conditions, in space and in time?

How do we evaluate which event poses the highest risk to the power system?

RiSc Tool: Combine weather, asset vulnerability, and demand information

1. Take a large amount of climate data and pass it through fast, approximate models of asset vulnerabilities to identify high-stress grid conditions: high loads and high likelihood of generator unavailability
2. Identify key time periods and/or conditions for more detailed downstream modeling or as scenario inputs for planning studies

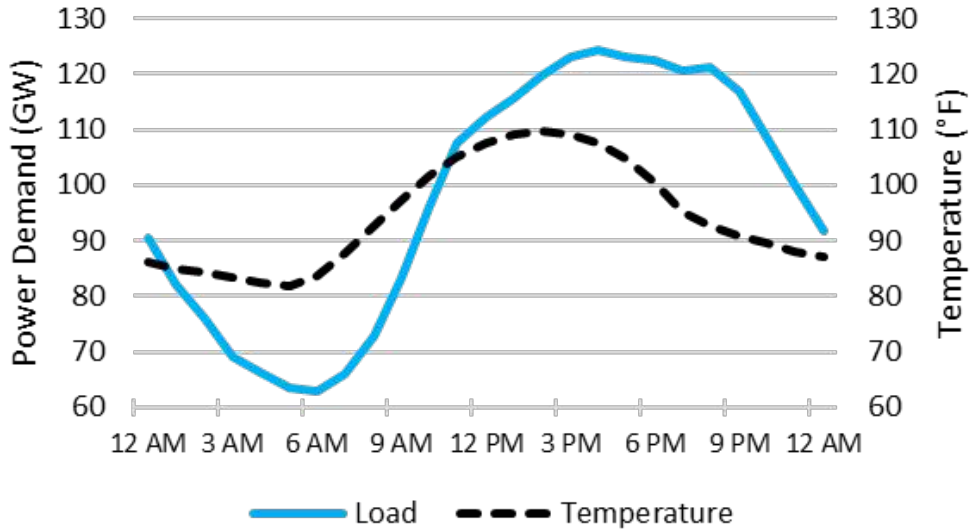
Pass Weather Data through Asset Vulnerability Functions

Goal: Define asset vulnerability matrix and derating factors as a function of weather variables

Resource Type	Weather Variable 1	Threshold 1	Weather Variable 2	Threshold 2	Derating	Event
Onshore Wind	Temperature	< 32 F	Precipitation	> 0 in	90%	Blade Icing
	Wind Speed	> 25 m/s			100%	Cutoff Speed
Gas CC	Temperature	> 105 F	Temperature	< 123 F	18%	Temp Derate

Note: These are generic examples; Specific asset vulnerabilities may be dependent on the region of study and design standards.

Pass Weather Data through Asset Vulnerability Functions



Electricity demand estimates incorporate:

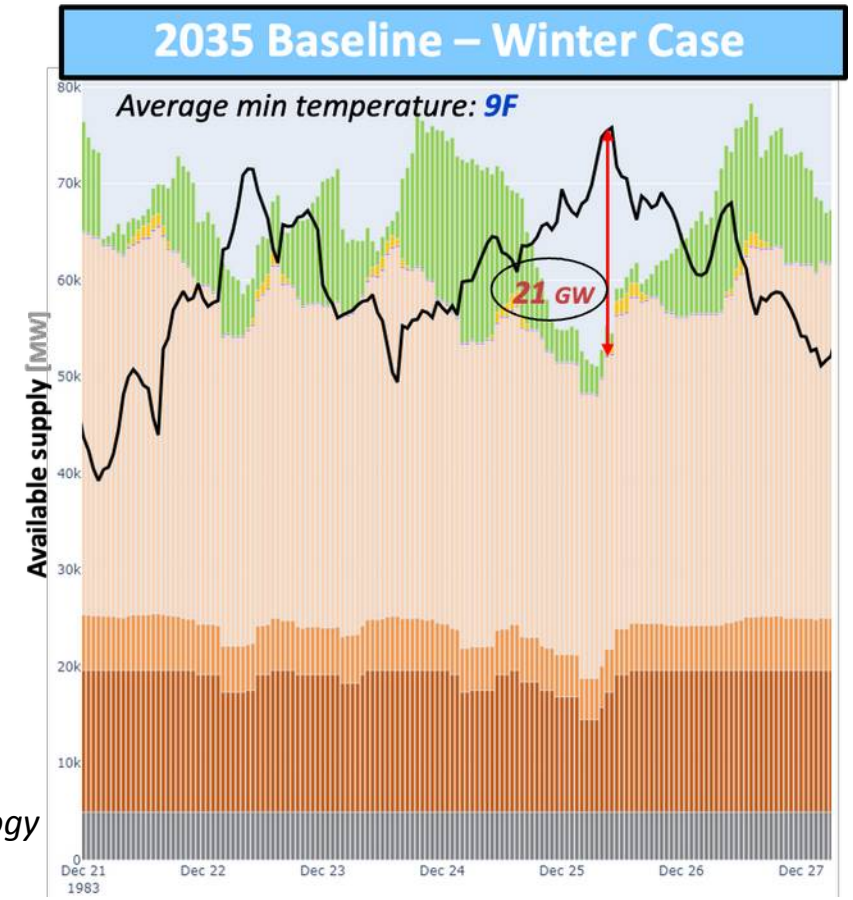
- Local weather sensitivity
- Future technology adoption
- Energy efficiency improvements
- Temporal correlations

Risk Screening Tool: Moving from Weather to System Stress

Large Weather Dataset + **Asset Vulnerability Functions** + **Load Projections** = **Identification of High-Stress Operating Periods**

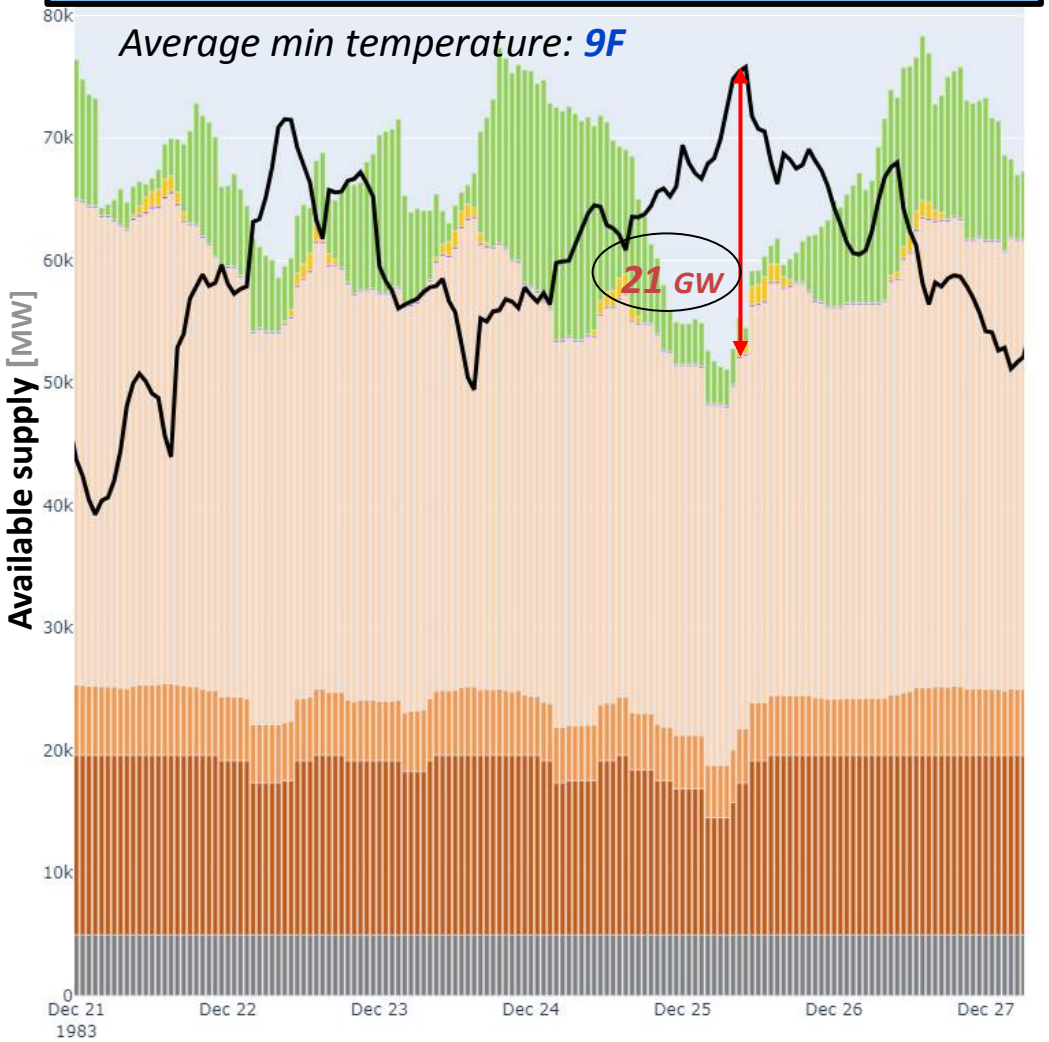
Can quickly screen for changing risks based on:

- New system buildouts
- Addition of adaptation measures
- Different climate data inputs
- Adjusted asset vulnerability functions
- New load assumptions

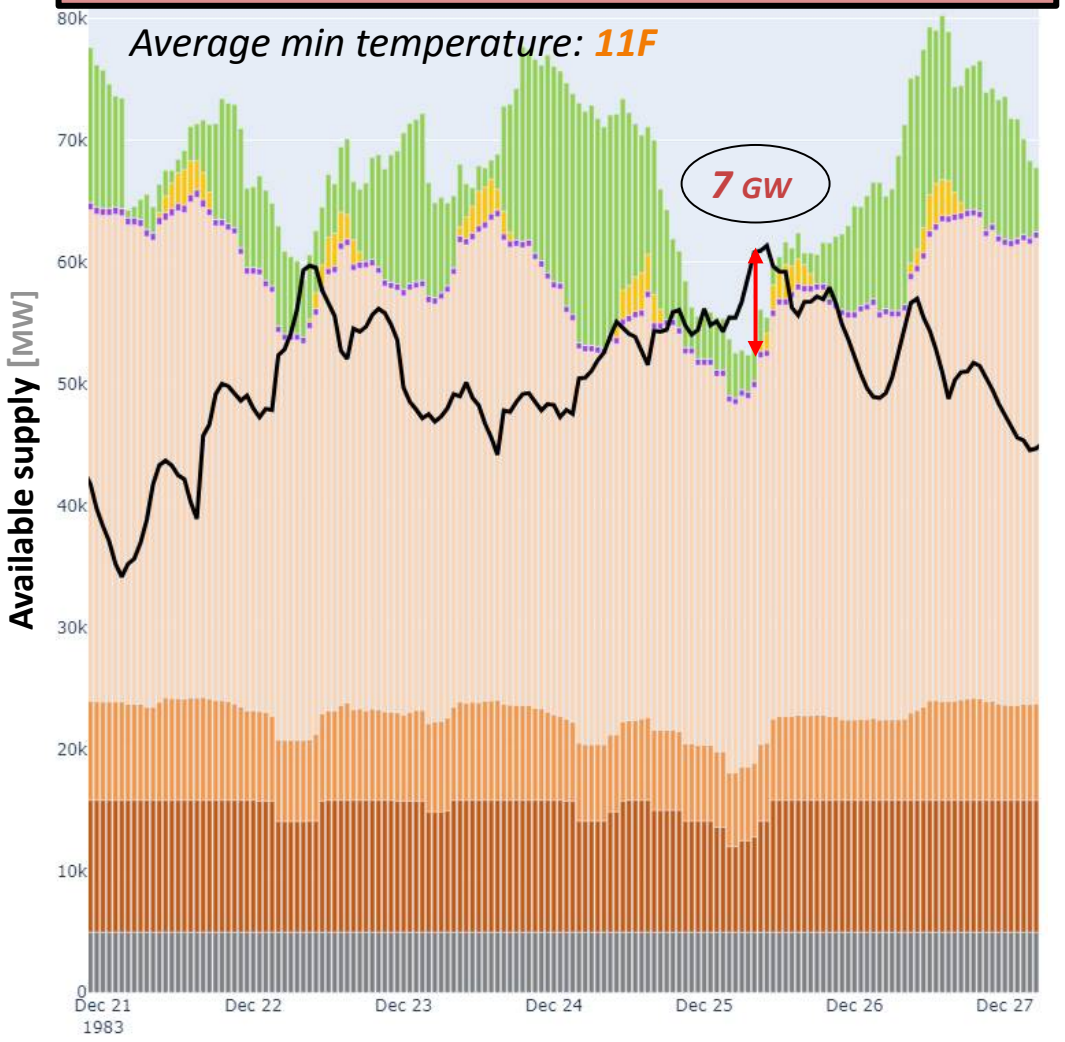


Simplified representation of synchronous meteorology (temperature, wind, solar, etc.)

2035 Baseline – Winter Case

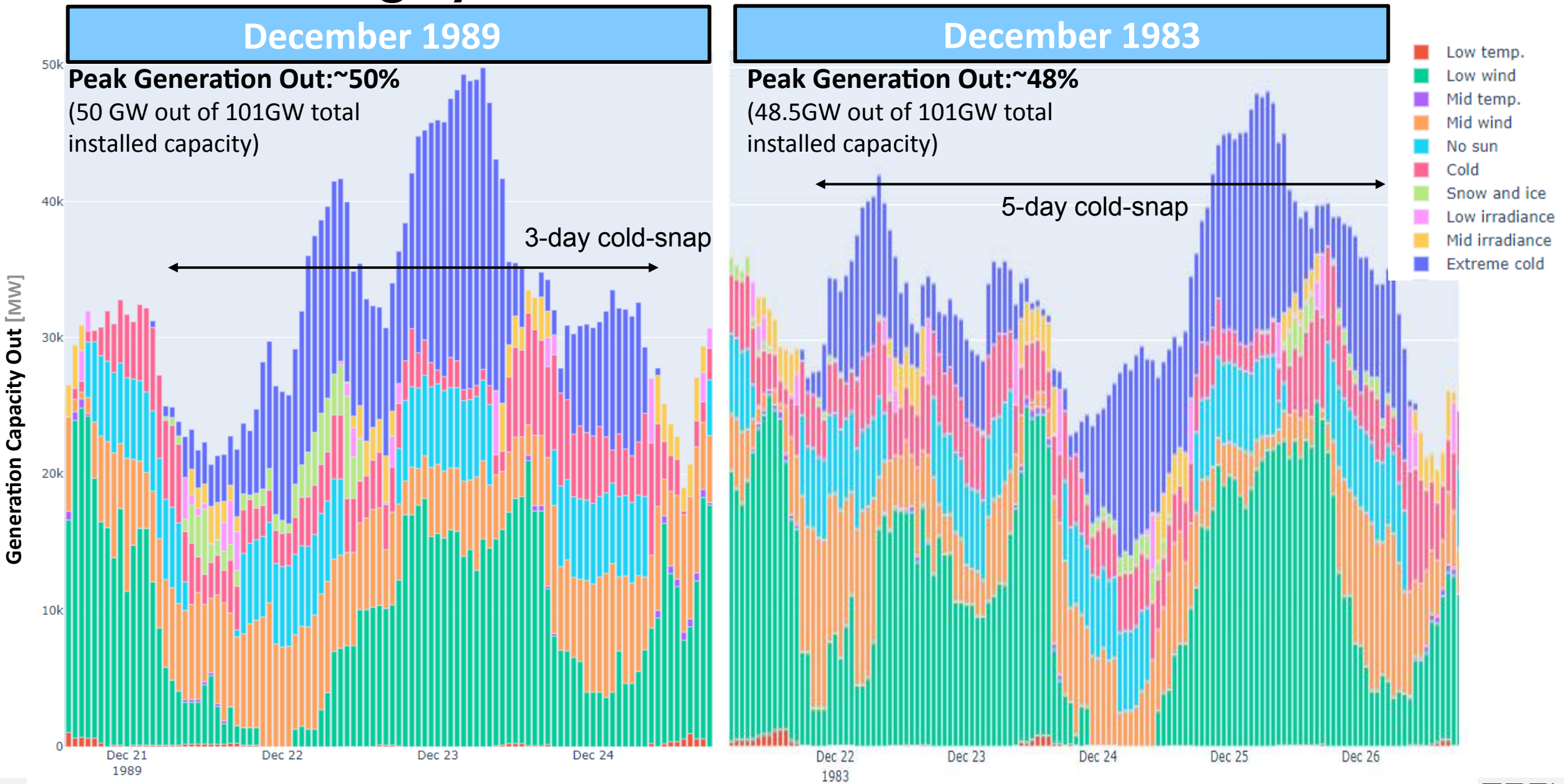


2050 Baseline- Winter Case



With awareness of system risk and potential to invest in hardening options we can be significantly more resilient

Understanding system risks: Dec 1989 versus Dec 1983



Key Takeaways

Identification of extreme events is important when planning for a resilient power system

RiSc is an effective tool to navigate large amounts of climate data, connect it to the asset vulnerabilities, and find periods of highest system risk

RiSc Tool is open-source available at https://github.com/epri-dev/Risk-Screening-Tool/

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