Exploring the Impacts of Extreme Events on Resource Adequacy

Presented in "Global Advances in Forecasting"

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What is Resource Adequacy and Resilience?

What is Being Assessed

What is the anticipated demand?

- Economic / population growth
- Load portfolio shifts
- Temperature changes

What resources will be available?

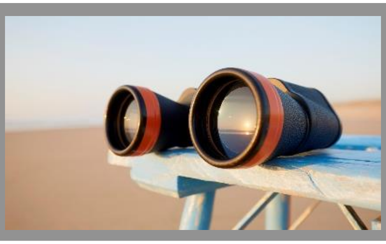
- Conventional generation
- Renewables
- Emerging flexible technologies
- Imports
- Price responsive demand

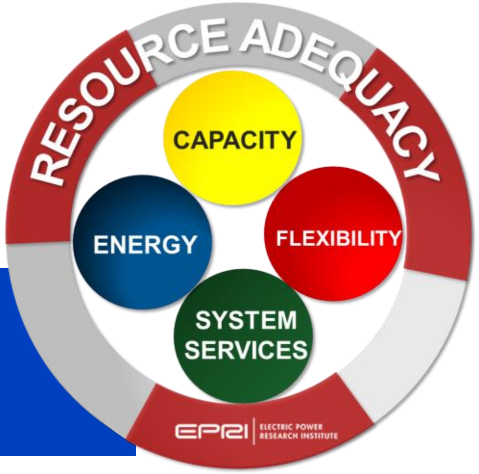
What are the macro supply risks?

- Hydro levels
- Weather year
- Generator failure
- Extreme events
- Renewable availability

What is the residual risk to supply?

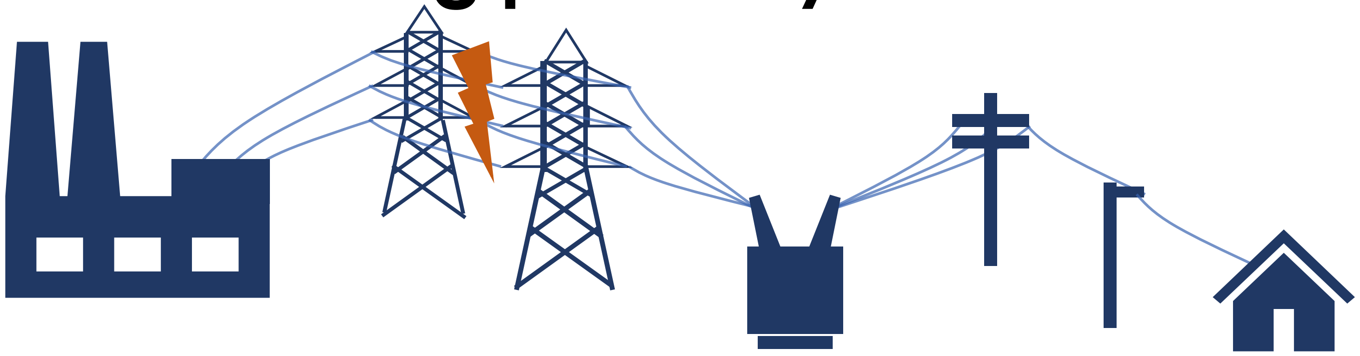
Resource Adequacy Assessment

Long Range Planning	1-3 Years Ahead	Season Ahead	Operational Planning
			
3-10+ Years for long term investment planning	**1-3 Years** for near term resource retirements, builds, markets	**Summer, Winter conditions** incorporating seasonal forecasts	**Month, week, days ahead** to manage generation maintenance outages



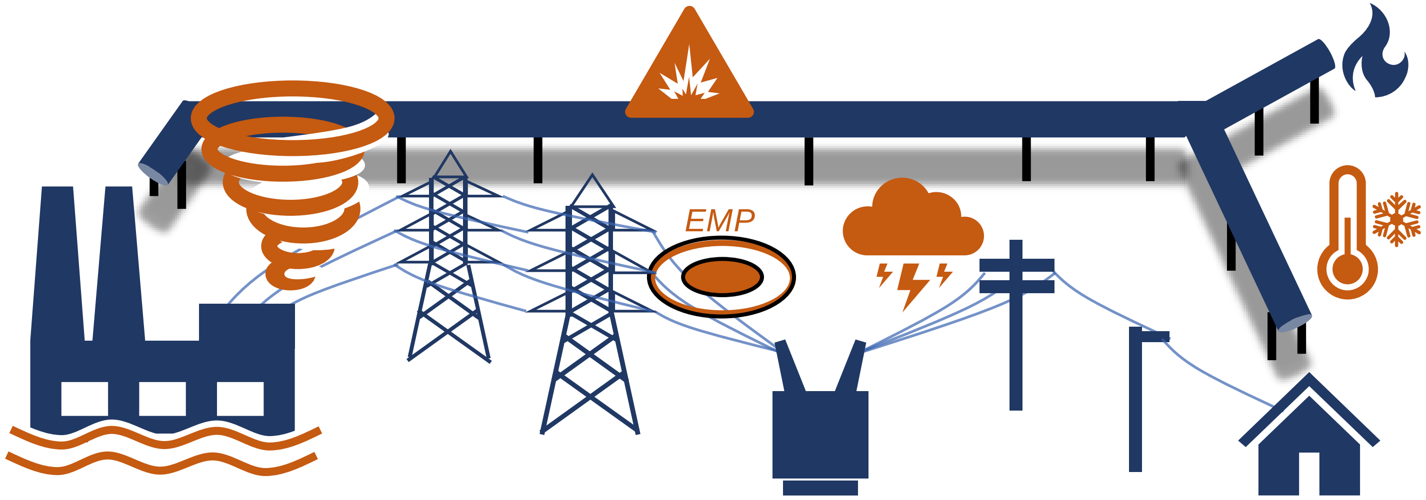
Assessed iteratively up to day-ahead operations; Forecasting is involved at every step

Characterizing power system resilience



Existing criteria based on "traditional*" conditions

Traditional events may include high impact low frequency (HILF) events (e.g., n-2), but based on standard set of events, often power system component failures.



Criteria based on "externally driven HILF" events

Externally-driven events are those that are less known and typically events unrelated to the power system but which affect the power system.

Reliability
Limit customer outages

Restoration/ Recovery
Restoring grid components following customer outage

Definitions, metrics, criteria, solutions (influence but can be distinct)

Resilience
Anticipate, absorb, adapt to, and/or rapidly recover

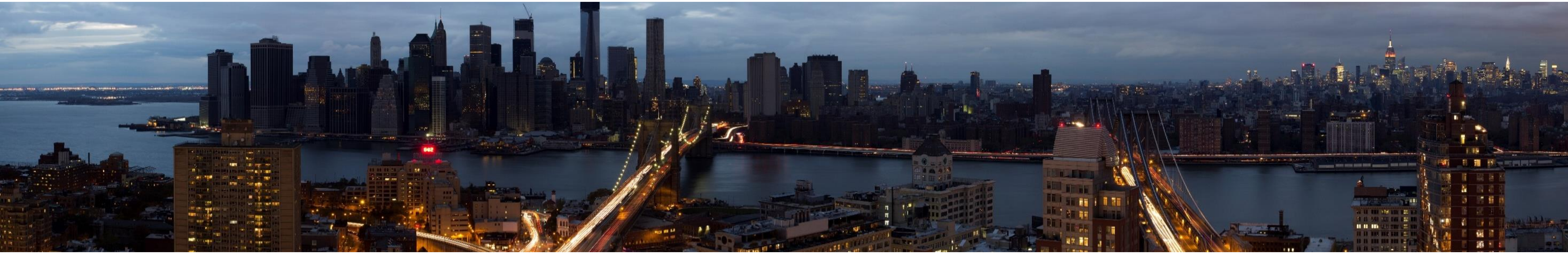
Extreme events & common mode events

Definition: Events when two or more resources simultaneously become unavailable or are output limited

- Cases with a single external event (e.g., gas pipeline failure)
- Cases with a combination of factors (e.g., decline in renewable output due to weather and gas pipeline unavailability)

Outages have been assumed to be independent and uncorrelated

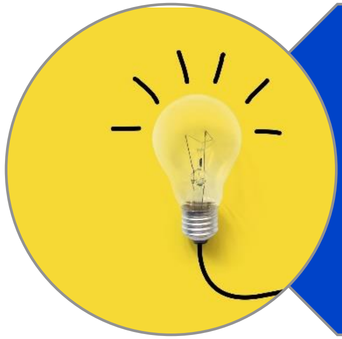
- Given increases in common mode events, this assumption is no longer valid
- Planners might need to consider the impact of multiple events



Extreme Events, Natural Gas and Resource Adequacy

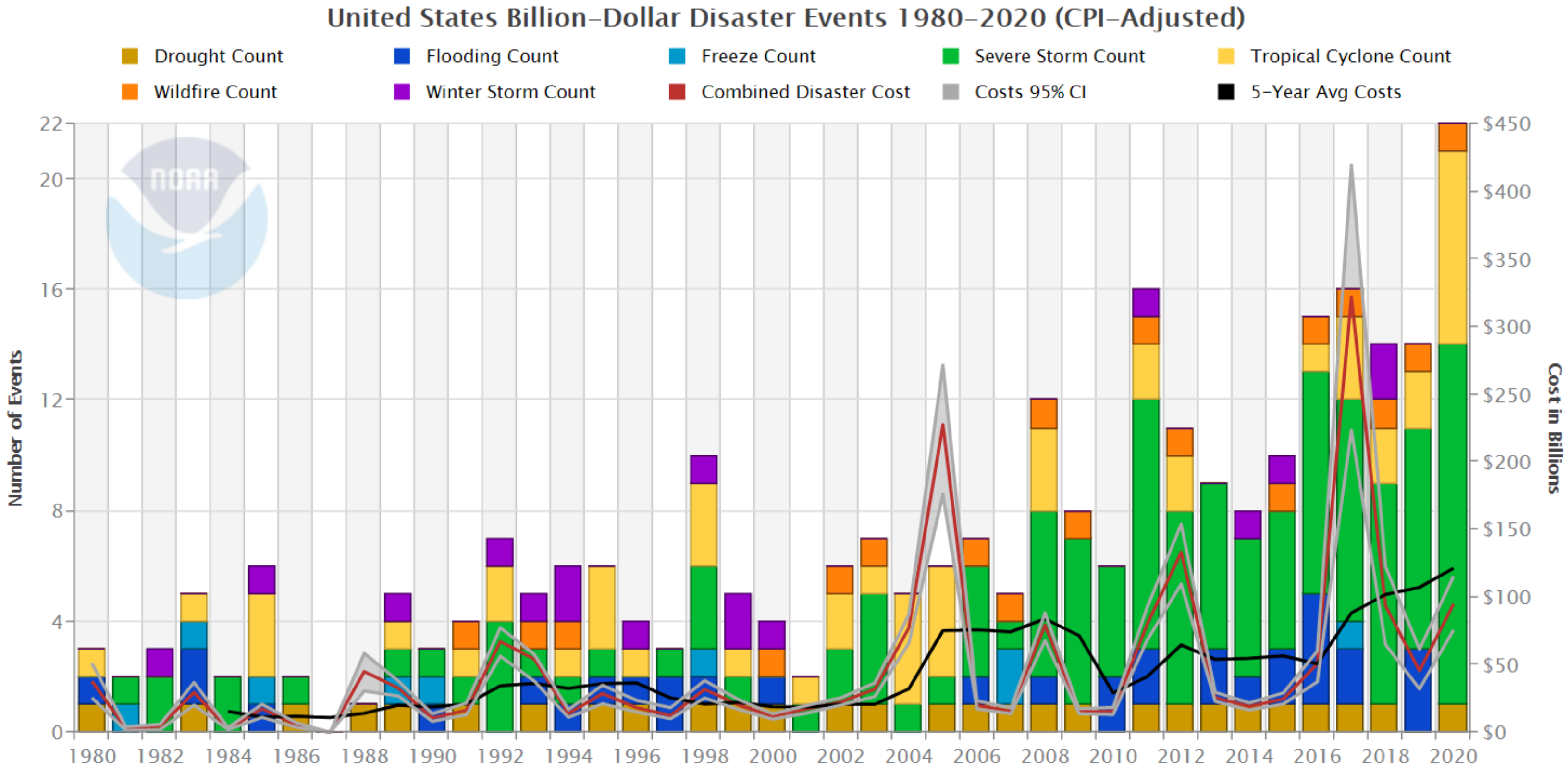
Key Findings Overview

The electric industry systematically understates the probability and depth of many high impact common mode events



The rising trend in disruptive events and common mode outages suggests traditional RA approaches must evolve

Why Consider Extreme & Common Mode Events Now?



Source: NOAA U.S. Billion-dollar Weather and Climate Disasters – 2020

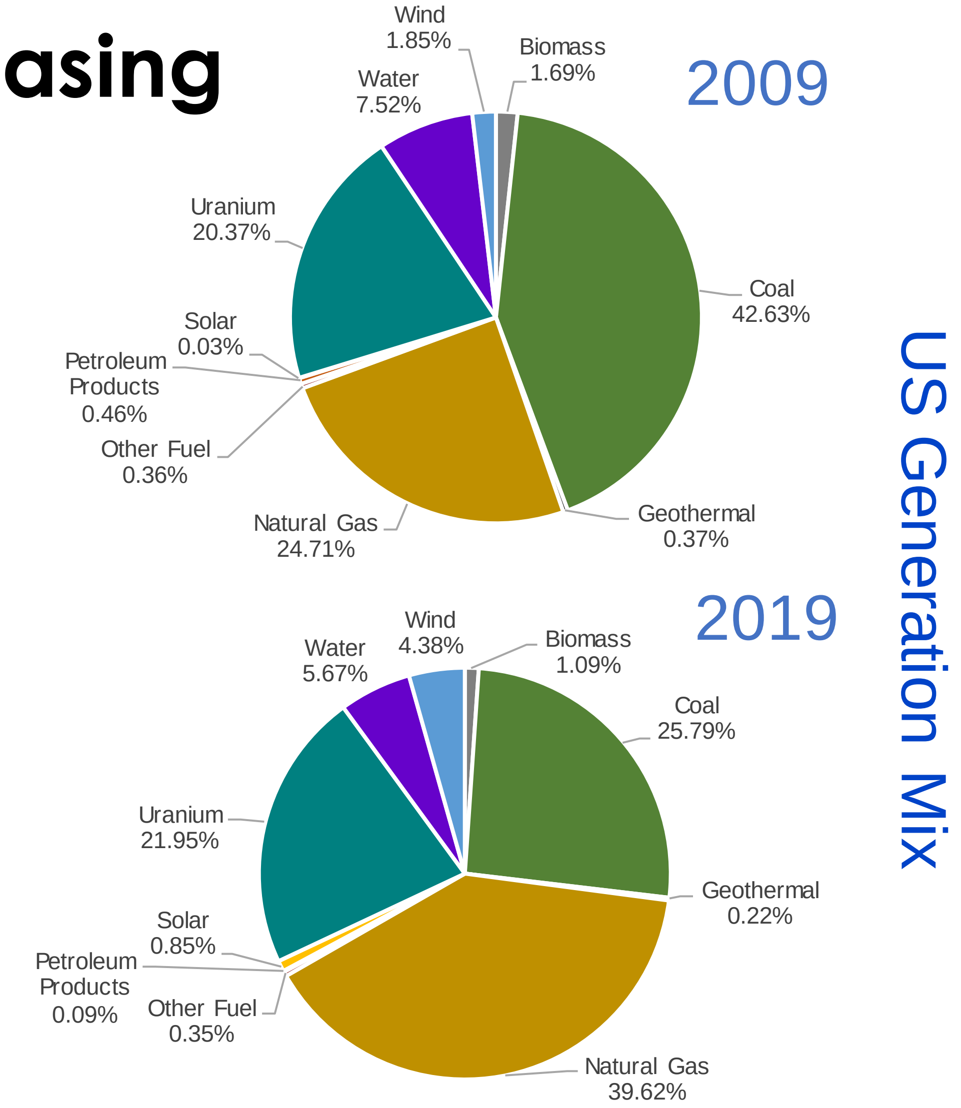
- Extreme weather events are rising in frequency, intensity, geographic scope, and duration
- 10-year historical calculation of extreme event probability potentially understates the likelihood of an extreme event in a changing climate
- Study showed weather caused 52.9% of all outages from 2000 to 2016

The impact of weather is non-linear and rising much faster than frequency

Natural Gas Resources are an Increasing Share of US Generation

Lack of attention to simultaneous events in analysis occurs for multiple reasons:

- Statistical data reflecting correlated outages of gas-fired generators are not frequently collected
  - Complicates event modeling
- Known RA models have no logic for modeling correlated generator outages
- Modeling / planning simulation studies of electric & gas sectors are conducted assuming outages are independent events
  - Underestimates the probability of loss of load

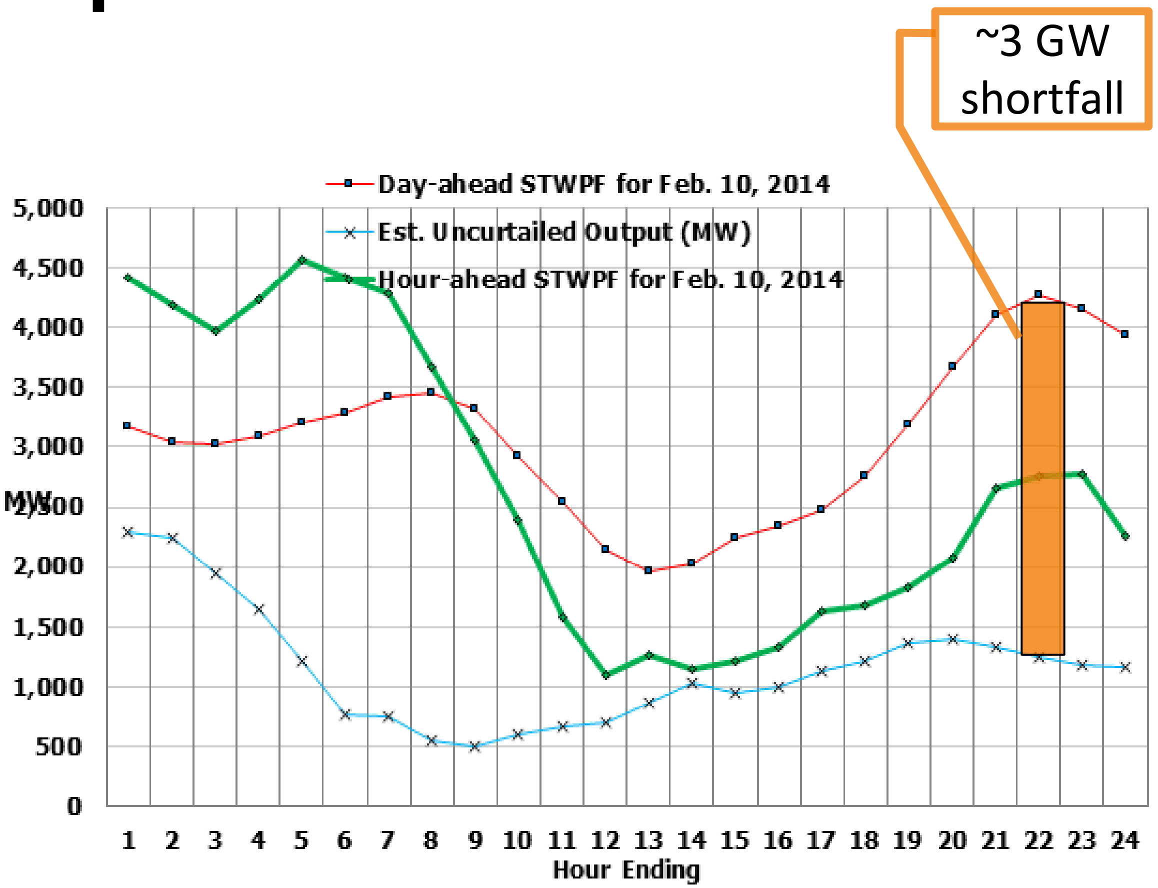


Data Source: S&P Global

Natural gas gens are assumed to be an "available resource" even though operational and regulatory issues can lead to unavailability

Outage and availability assumptions

- Correlation between renewable sources and weather requires other resources and/or demand to rapidly respond to changes in renewable output
  - E.g., the figure shows day-ahead forecasts compared to real-time output on 2/10/14 in ERCOT
- Outages are increasingly a result of common mode events impacting multiple generators



Source: ERCOT http://www.ercot.com/content/wcm/key_documents_lists/68798/Operations_Analysis_Impact_of_Cold_Weather_on_Wind_Forecast.pdf

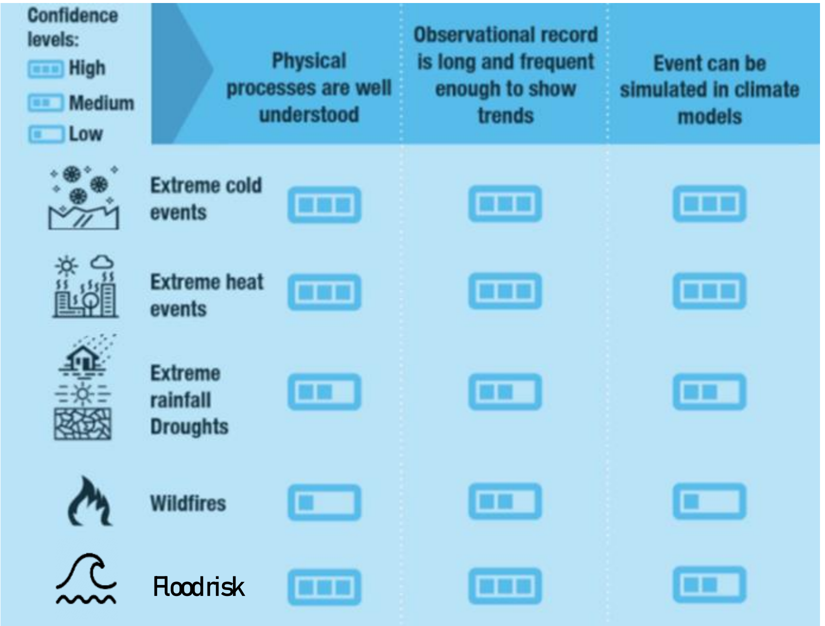
RA calculations assume outages are independent and uncorrelated, this might no longer be valid

Projecting event probabilities

- The likelihood and magnitude of extreme events are changing as the climate warms
  - But many factors contribute, with climate not necessarily the primary driver for any individual event

- Historical probabilities do not capture these extremes, making forecasting or projecting future disruptive events difficult

Type of Extreme Weather	Frequency	Intensity	Geographic Extent
Extreme Heat Events	↑	↑	↑
Drought	↑	↑	↑
Wildfires	↑	↑	↑
Extreme Precipitation/ Flooding	↑	↑	↑
Hurricanes/ Tropical Storms	↔	↑	↑
Cold Events	↓	↓	



Graphic adapted from Chapter 4 "Attribution of Particular Types of Extreme Events" in NASEM (2016) Attribution of Extreme Weather Events in the Context of Climate Change https://www.nap.edu/read/21852/chapter/6#86

Event probabilities should be assessed to take current trends and climate science understanding into account

Changes are needed to resource adequacy

- Reserve margins answer the question: Will there be sufficient generation capacity at the time of system peak demand to meet that demand?
  - Does not address the size of the possible capacity shortfall
  - Peak demand was assumed to be exogenously determined & not responsive to short-run prices or system conditions
- Scenario planning for high impact common mode outages should be included in resource planning
  - Including regionally specific scenarios
  - Considering investments and potential operational responses

RA should reflect the depth, duration, and economic costs of unserved energy, and account for common mode events

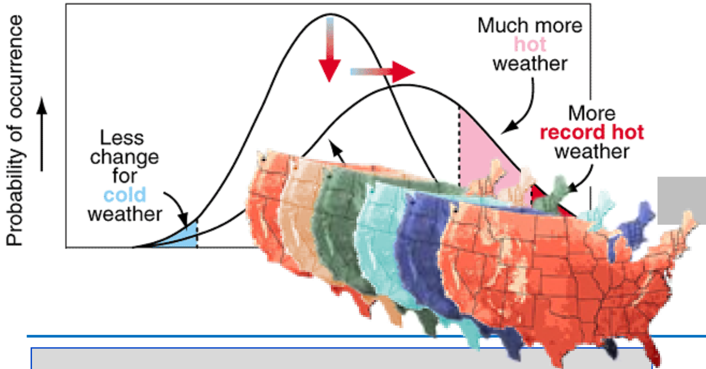
Probabilistic and stochastic metrics and models

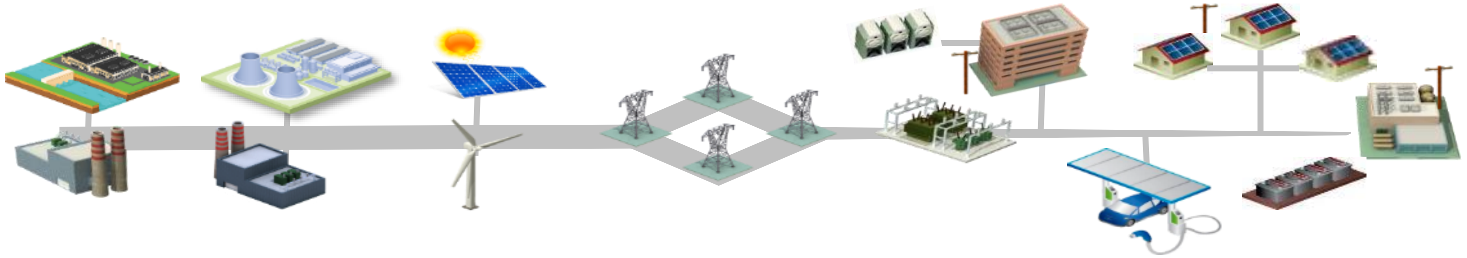
Instead of traditional scenario analysis, common mode events can be incorporated directly into resource optimization

- Stochastic programs capture uncertainties endogenously, e.g.,
  - Load
  - Outages
  - Natural gas prices
  - Solar insolation
  - Wind speed
- Objective would minimize expected value of all states, each with a probability

System planning should incorporate probabilistic and stochastic metrics and analytical models

EPRI Tools & Capabilities Support Planning for Climate Impacts





Climate Projections
at various scales:

Generation | **Transmission & Distribution** | **End Use**

Chronic / Long-Term Trends
incremental mean ΔT
e.g., 5°F in 2050

Variability
e.g., changes in tails of the temp distribution

Acute / Extreme Events
e.g., outages, hurricane, polar vortex, fire conditions

System-level Optimization
(planning, costs, operations)

Asset-level Assessment
(adaptation actions)

US-REGEN Integrated analysis of system-level climate trends
Integrated scenarios of renewable / decarbonization policy, electrification drivers *and* future climate on supply and demand

US-REGEN End Use Model
Analysis of how shifting temperature patterns changes electricity demand and load shapes

Transmission Operations & Planning Applications
Develop future scenarios to evaluate system resiliency to indicative climate hazards

<u>Climate Projection Assessment and Guidance</u>

- Interpret and translate climate scenario output for decision-making
- Characterize likelihood of locational changes in climate variability and extremes for planning and operations

Electric Sector Resilience Is Required for a Clean Energy Future

2050: 2X Electricity Share of Final Energy

A greater portion of societal needs will be dependent on the reliable supply of electricity.

2050: >4X Renewables Capacity

The resource mix will have significantly different performance characteristics and the grid must adapt.

2050: The Unpredictable

Changing climate, technology, policy, and societal trends must be integrated in scenario planning.

Grid planning and operational practices must evolve.

The biggest challenge to decarbonization of the electricity sector and achieving Net-Zero may be the resiliency of energy supply and the electric grid.

Multi-year Project: Integrating and Accelerating R&D to Ensure Resource Adequacy

RA Process

- Recommended Metrics and Criteria
- Scenario Creation & Comparison Tools

Models and Data

- Emerging Supply and Demand Side Models
- Model Data Development Tools

Analysis Tools

- RA Tool Capability Specs. & Review
- New Algorithms and Open-Source Code

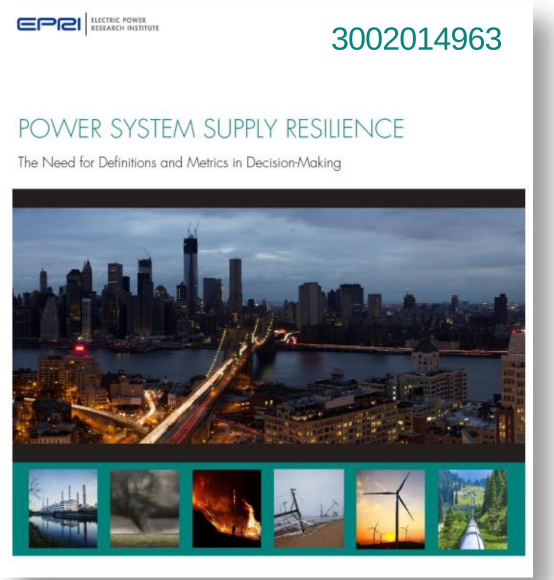
Case Studies	Evaluation of existing and development of new capabilities based on 4-6 regional RA case studies covering differing RA issues and tools.
Tech Transfer	Reports and workshops to be conducted to disseminate results and to promote broad adoption in commercial tools.

Public reports related to this presentation

- *Power System Supply Resilience: The Need for Definitions and Metrics in Decision-Making* (Product ID 3002014963)
  https://www.epri.com/research/products/000000003002014963

- *Exploring the Impacts of Extreme Events, Natural Gas Fuel and Other Contingencies on Resource Adequacy* (Product ID 3002019300)
  https://www.epri.com/research/products/000000003002019300

- *Resource Adequacy Challenges: Issues Identified Through Recent Experience in California* (Product ID 3002019972)
  https://www.epri.com/research/products/000000003002019972



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