

# Incorporating Multivariate Weather Hazards into System Planning with Energy Storage

## 2025 DOE OE Energy Storage Peer Review

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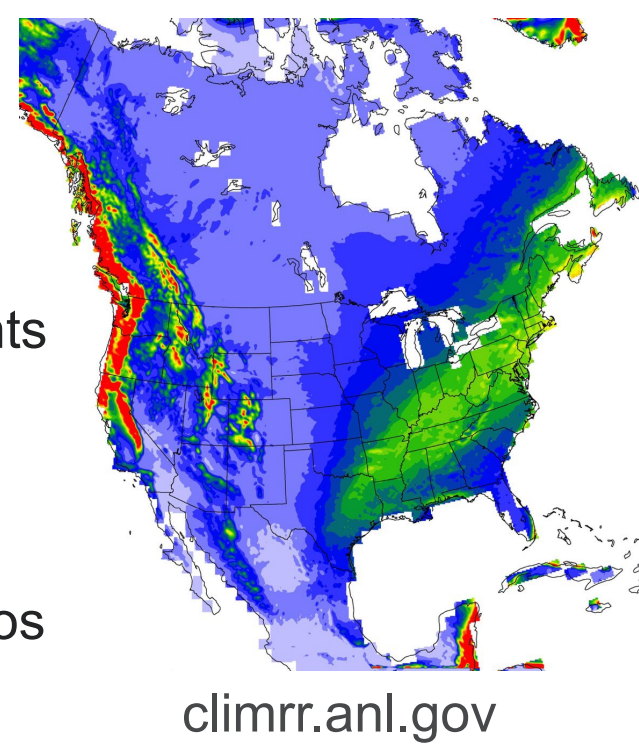
### MOTIVATION

- To uncover how **extreme weather and changing weather patterns** affect the deployment potential for energy storage in power system planning.
- There is limited inclusion of extreme weather events in system planning, and typically only focused on high and low temperatures for peak load.

### HAZARDOUS WEATHER SCENARIOS

#### ANL Synthetic Weather Dataset

- High resolution, 12 km grid covering North America
- Scientific transparency: widely published and scientifically peer reviewed
- Dynamical downscaling offers improvements over statistical downscaling
  - Physics-based, addresses non-stationarity
  - Produces 60+ unique weather variables
- High and medium radiative forcing scenarios
- Three-member ensemble of GCMs
- Three decadal timeframes: historical, mid-century, end-of-century
- Over 100 scenario years @ 3-hourly or hourly time steps

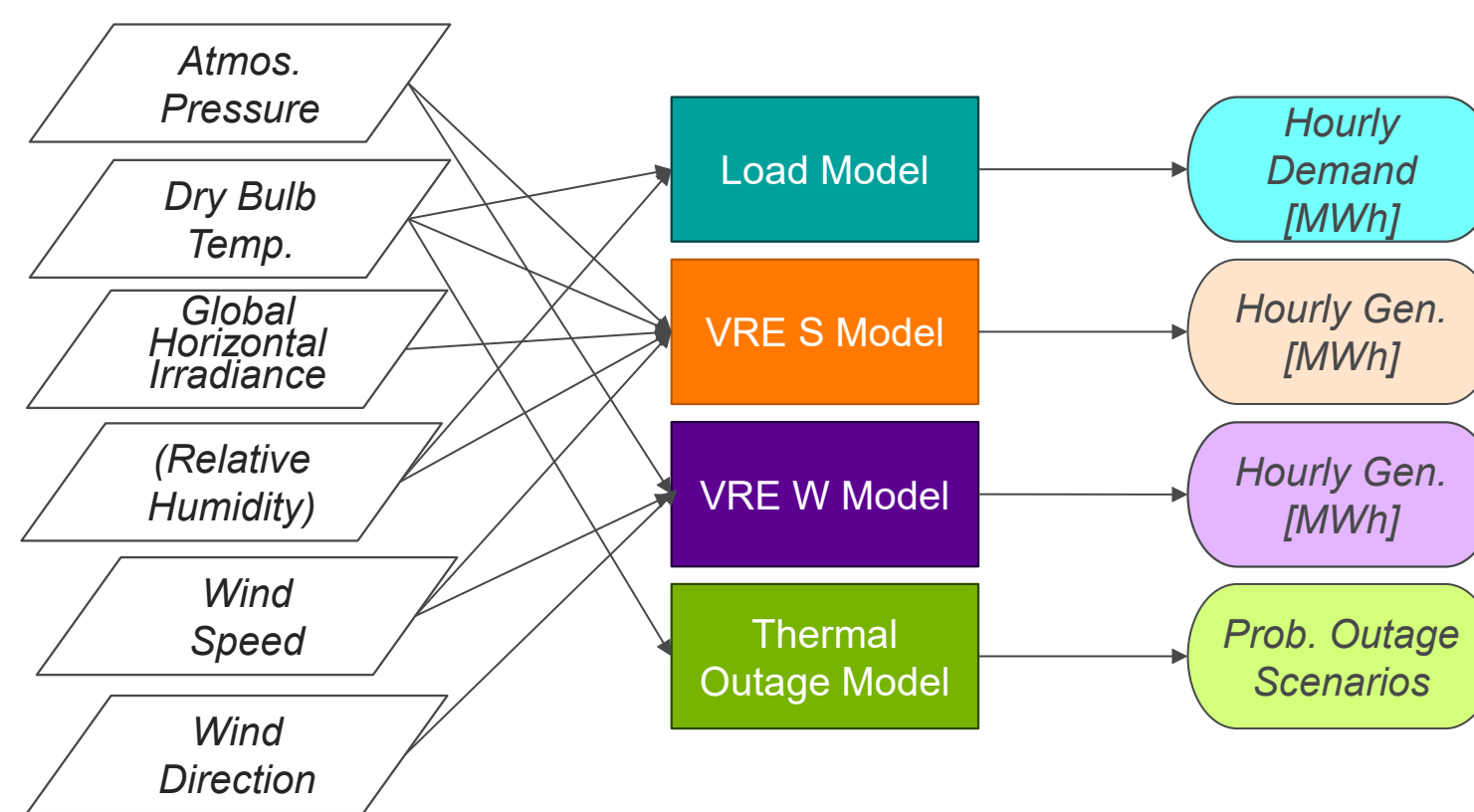


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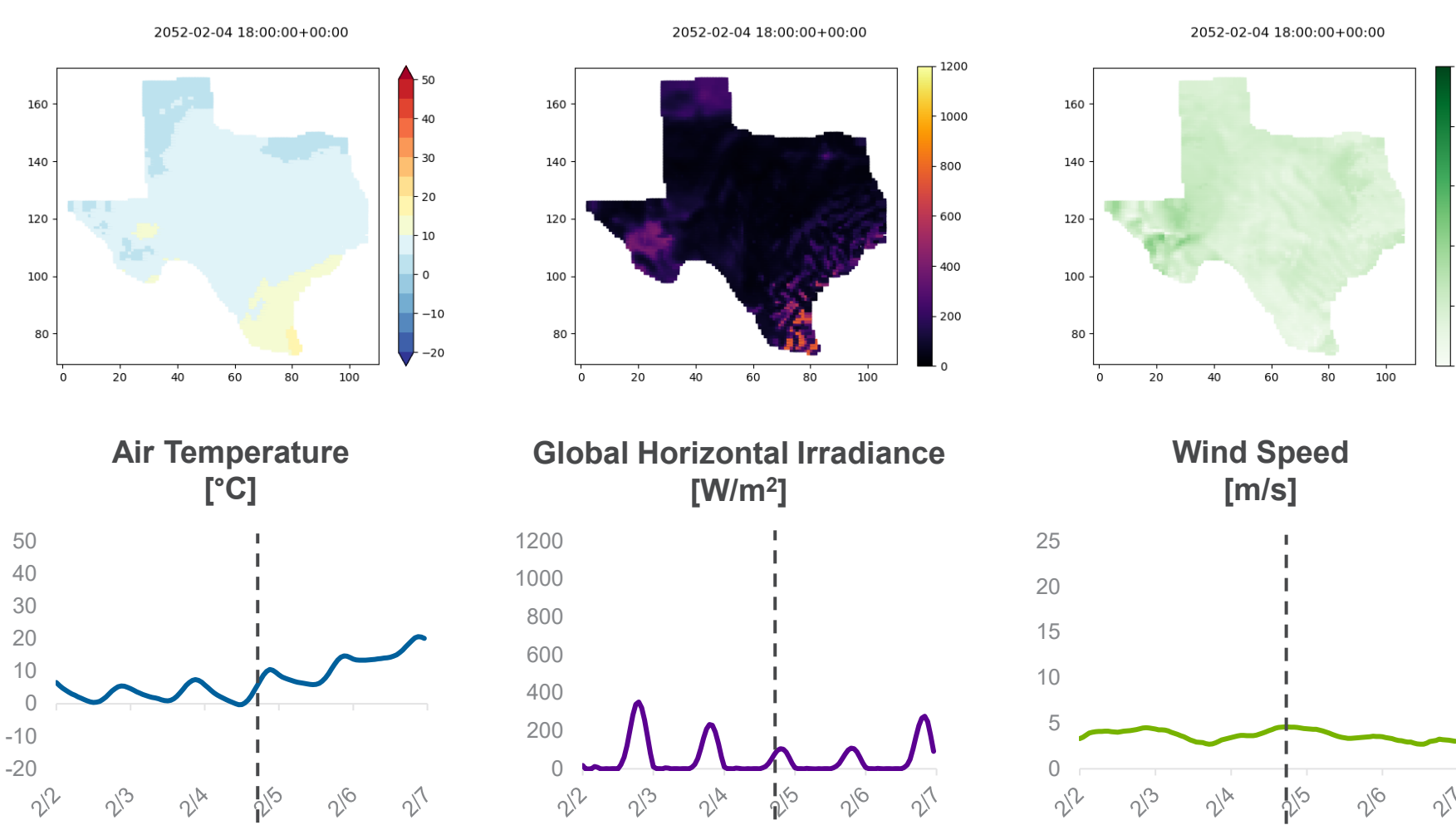
#### Hazardous Event Selection

- From 20 synthetic weather years, rolling 5-day average multivariate hazard indices were calculated
- Eight potentially hazardous events were selected

### WEATHER TO GRID



### EXAMPLE HAZARDOUS EVENT



### MODELING & SIMULATION

#### Power System Modeling with A-LEAF

- Advanced Optimization
- Detailed U.S. Grid Database
- Weather Data
- Reliability and Resource Adequacy Assessment
- Multi-Sector Interdependency
- Policies and Regulations
- Wholesale Market Design



#### Combining Representative Period Selection with Extreme Events

- The ScenRed scenario reduction method was used first
- ScenRed output was combined with hazardous periods
  - Hazardous periods were manually added to the ScenRed output
  - ScenRed weights were reduced proportionally

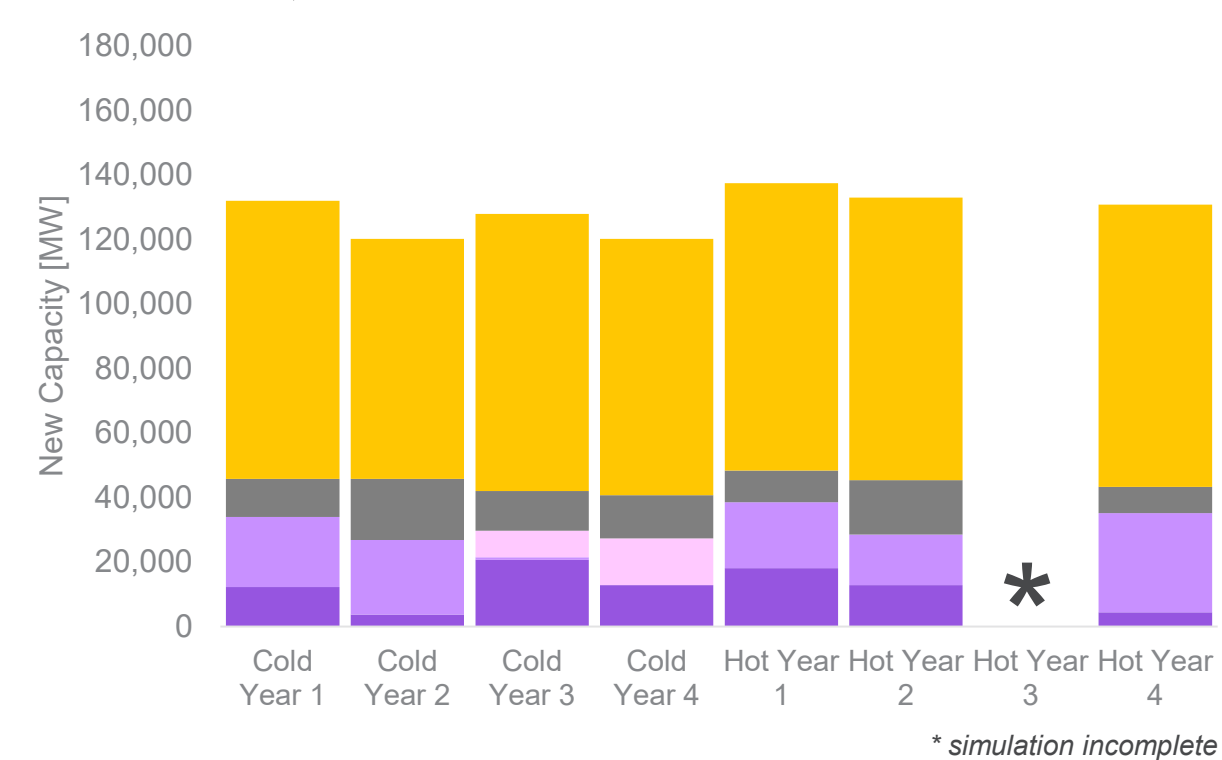
#### Summary of Model Setup and Assumptions

Parameter	Value
Planning years	2050 (1 stage)
Representative chronology	10 groups of 5 consecutive days
Network scope	ERCOT Weather Zones
Tax credits / RPS	None
Generator expansion options	NGCC, NGCT, nuclear, VRE S, VRE W
Storage expansion options	Lithium ion (LFP) 100 MW @ 2, 4, 8 hours duration
Energy storage scenarios	Thermal energy storage (TESS), 10 GW @ 0, 10, 24, 100 hours duration
Weather years	8 selected for weather extremes

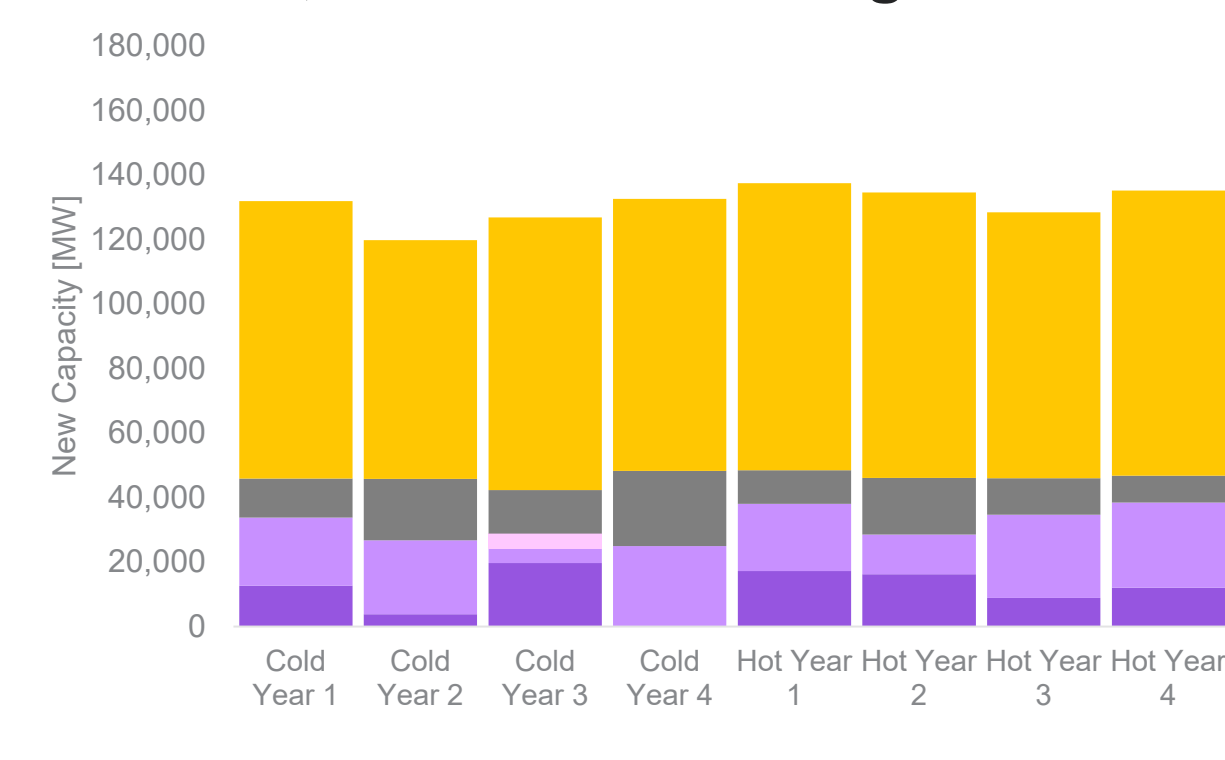
### RESULTS: CHANGING WEIGHT OF EXTREME PERIOD

Legend: VRE (Yellow), NGCC (Grey), Battery (100MW, 2Hr) (Purple), Battery (100MW, 4Hr) (Light Purple), Battery (100MW, 8Hr) (Pink)

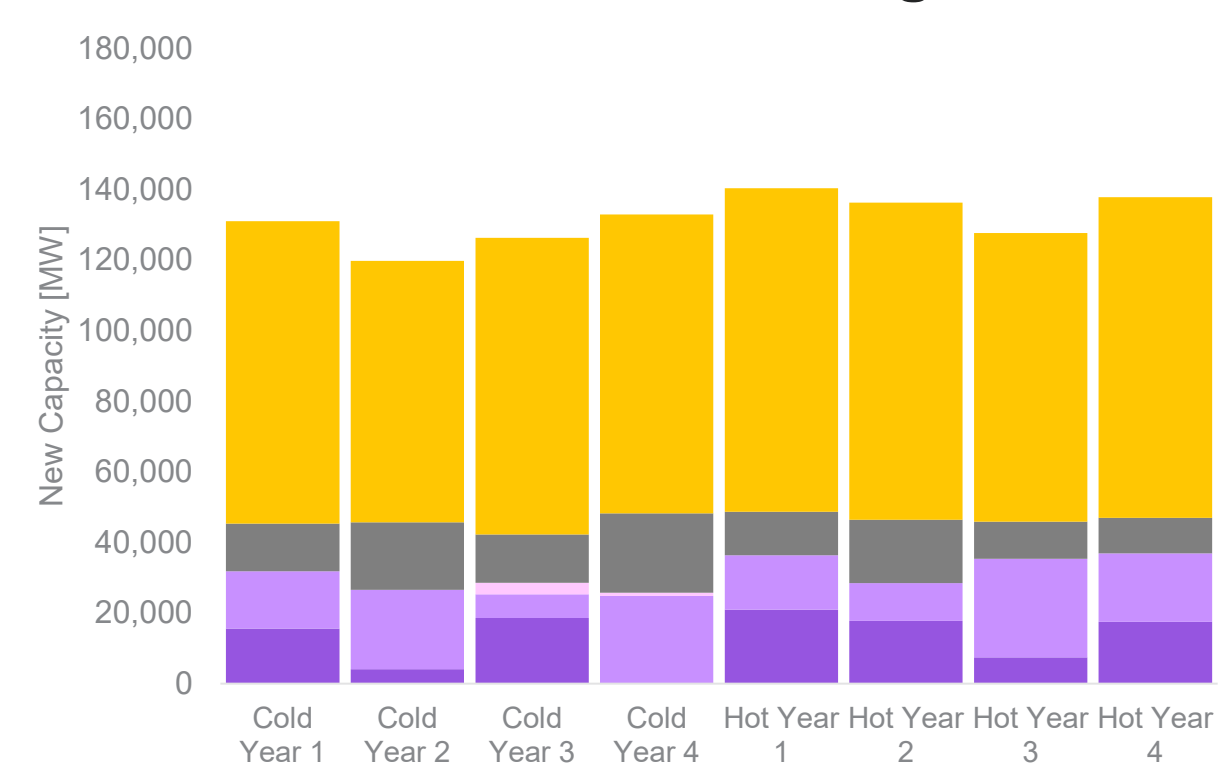
#### No TESS, No Extremes



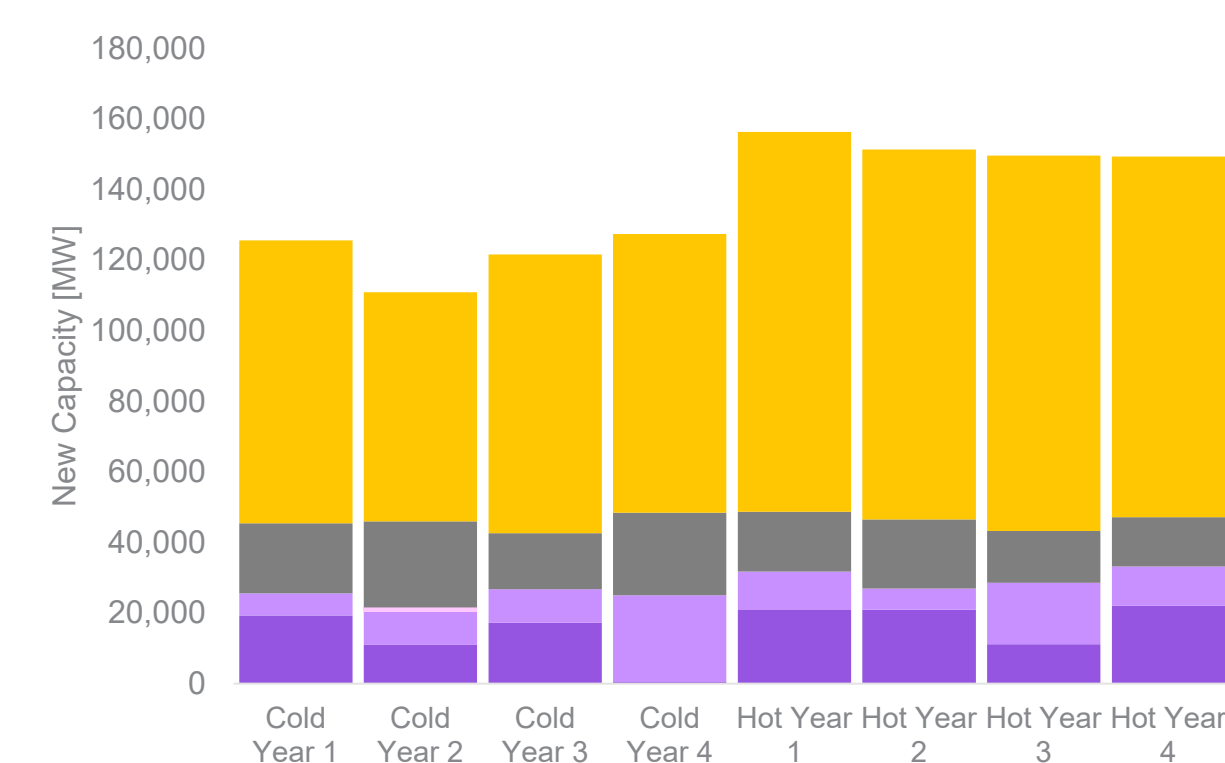
#### No TESS, 1% Extremes Weight



#### No TESS, 10% Extremes Weight



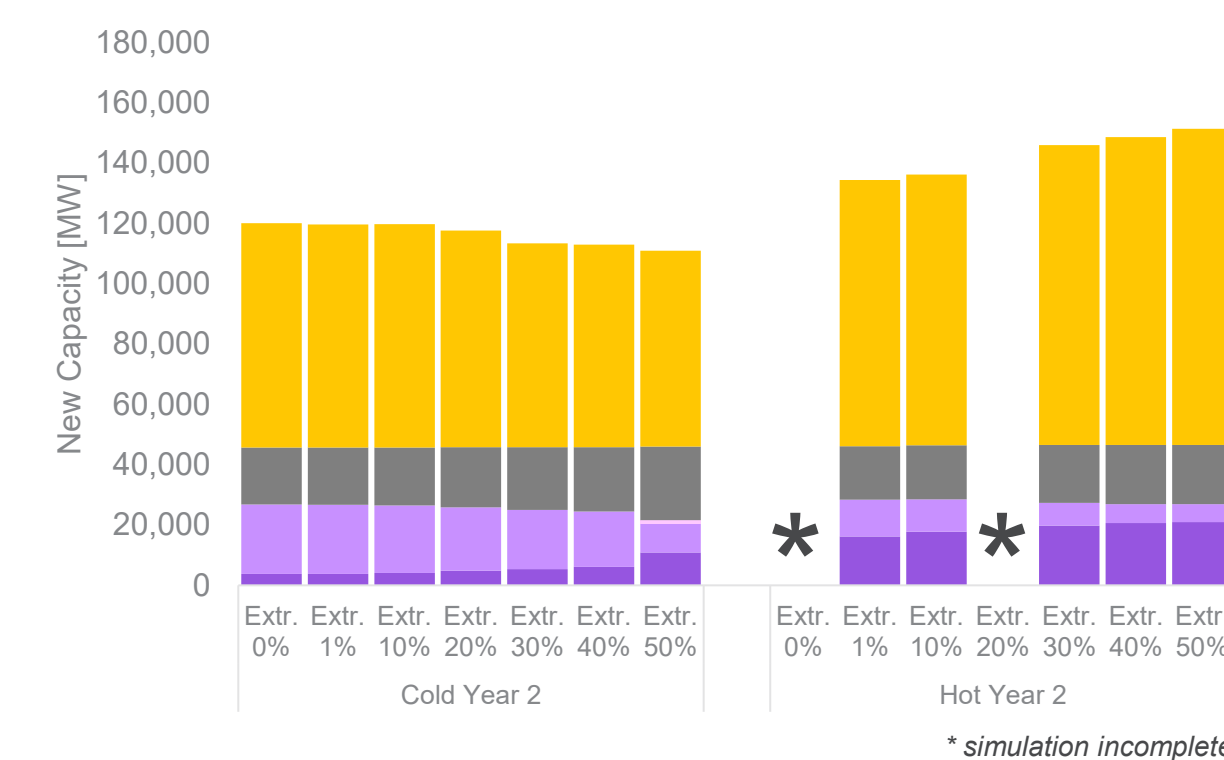
#### No TESS, 50% Extremes Weight



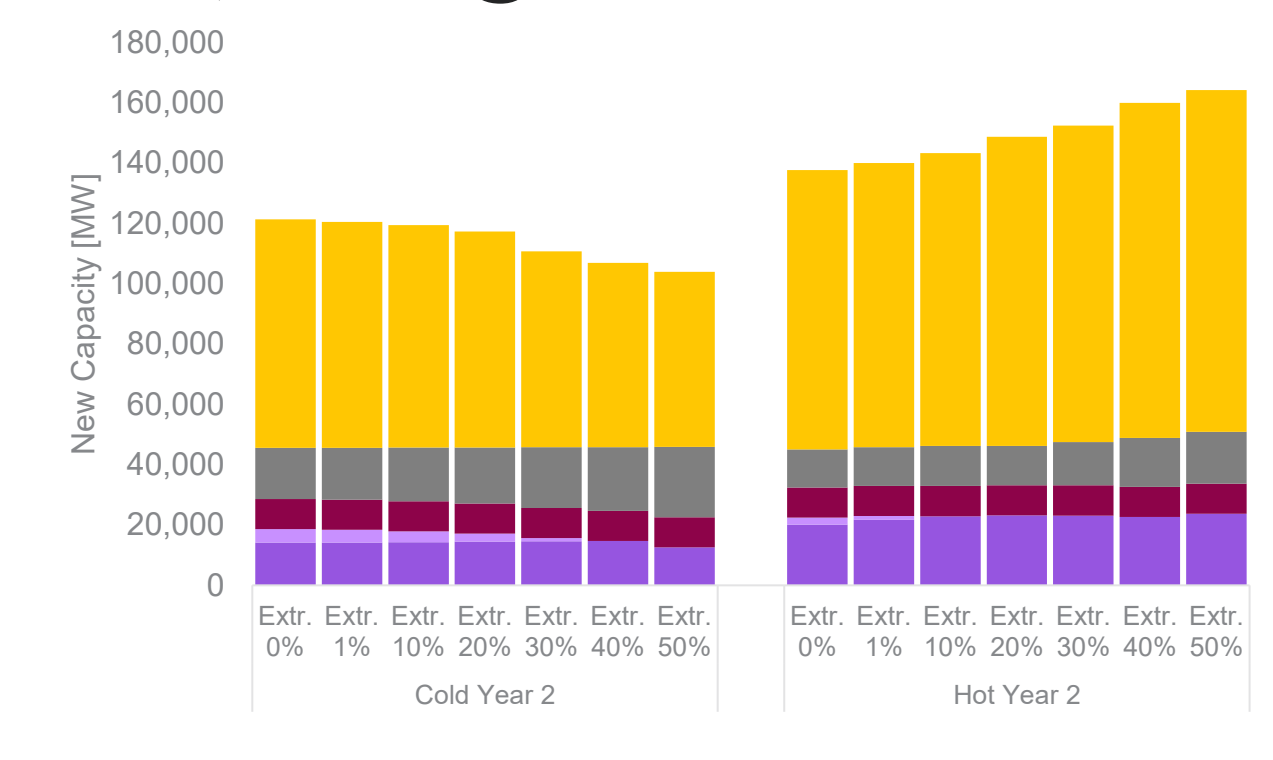
### RESULTS: EXTREMES + CHANGING TESS SIZE

Legend: VRE (Yellow), NGCC (Grey), Battery (100MW, 2Hr) (Purple), Battery (100MW, 4Hr) (Light Purple), Battery (100MW, 8Hr) (Pink), TESS (Dark Purple)

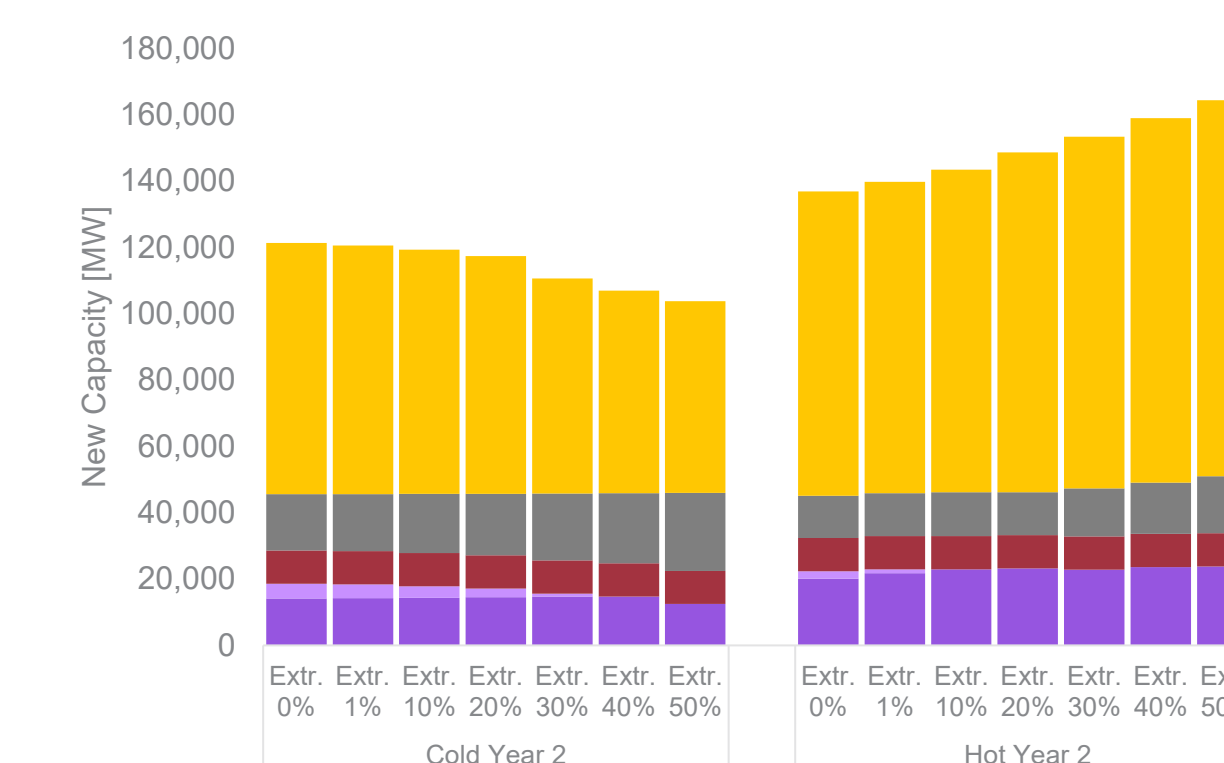
#### No TESS



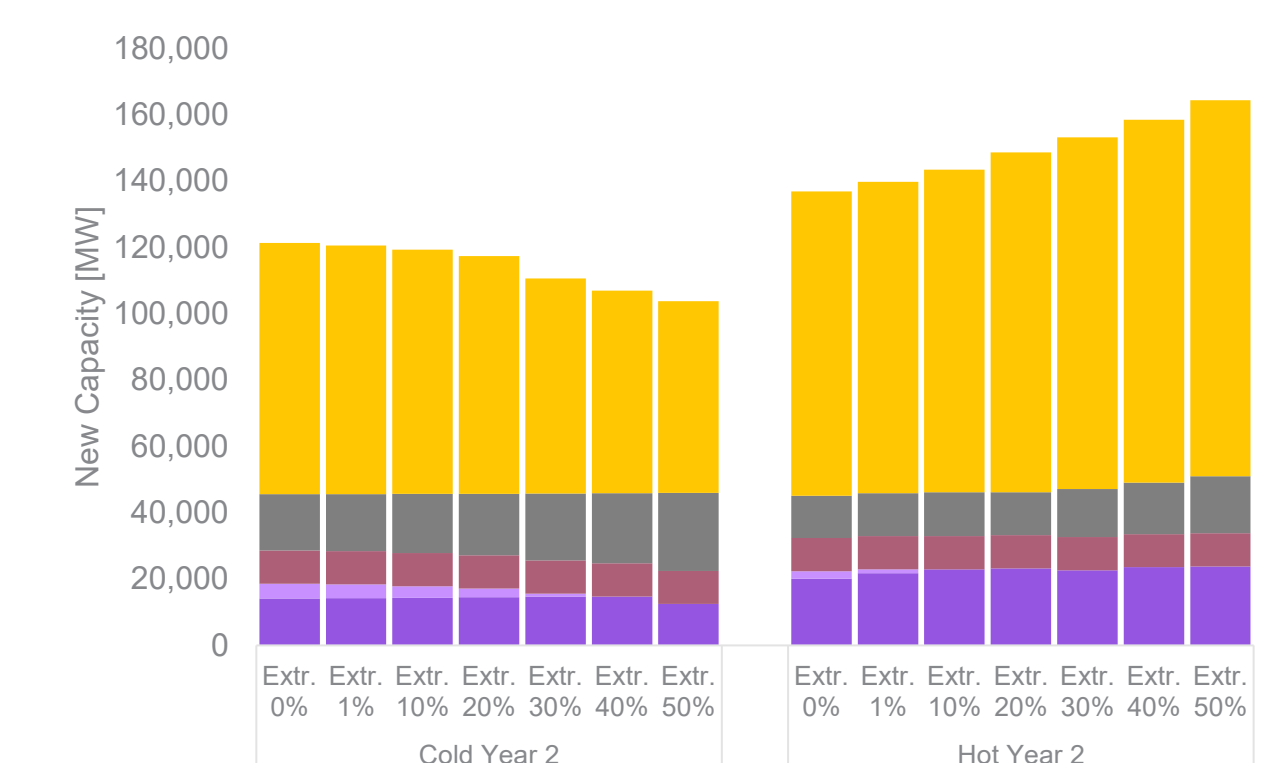
#### TESS, 10 GW @ 10 Hour Duration



#### TESS, 10 GW @ 24 Hour Duration



#### TESS, 10 GW @ 100 Hour Duration



### OBSERVATIONS

- Developed a new workflow to incorporate extreme and hazardous weather events into power system planning
- Including multivariate hazardous weather events **did change** capacity expansion results
- As TESS duration was increased from 10 to 24 to 100 hours (all 10 GW), there was **little change** in the new capacity mix
- Heavier weighting of hazardous events had **mixed effects** on energy storage capacity
- 8-hour storage was seen in **only a few** scenarios

### FUTURE WORK

#### This Project

- Smaller TESS investments: 1 GW, 5 GW
- Longer optimization day groups: 10 days each

#### Extension Ideas

- Select representative periods and extreme days from whole ensemble
- Expand hazard indices to cover all permutations of variables
- Calculate hazard indices for events in all regions of the CONUS
- Apply entire workflow to the rest of the CONUS (scalable from counties to whole interconnections)
- Include more detailed reliability simulations to verify results (including probabilistic outages)

### ACKNOWLEDGEMENTS AND NOTICE

#### Acknowledgements

- DOE OE Energy Storage Program
- Argonne National Laboratory
- ANL Laboratory Computing Resource Center

#### Notice

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