Weather Datasets for Systems Planning

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ENERGY SYSTEMS INTEGRATION GROUP

11 June 2024

What weather data do we use for systems planning?

Wind and solar generation potential

- Most common, first example of integrating weather and power systems planning
- Sometimes forecasts too
- Mostly profile from resource availability, but increasingly used to estimate derates (e.g., turbine blade icing, snow cover on panels, etc.)

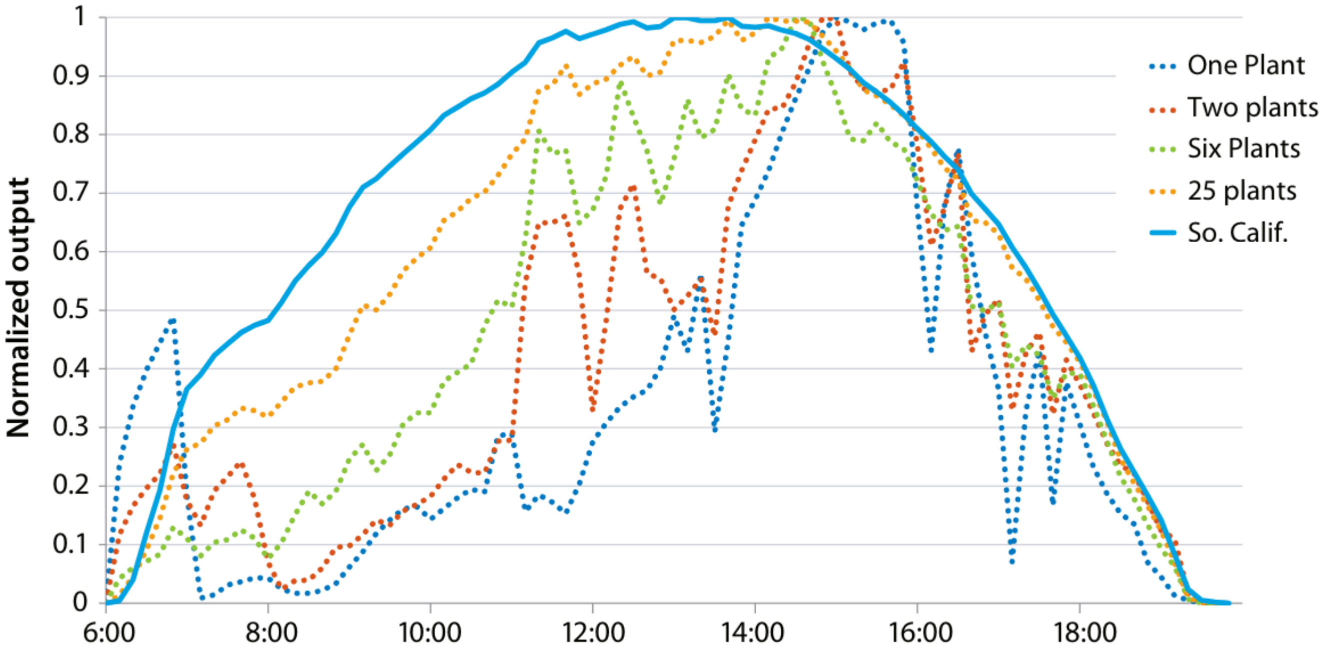
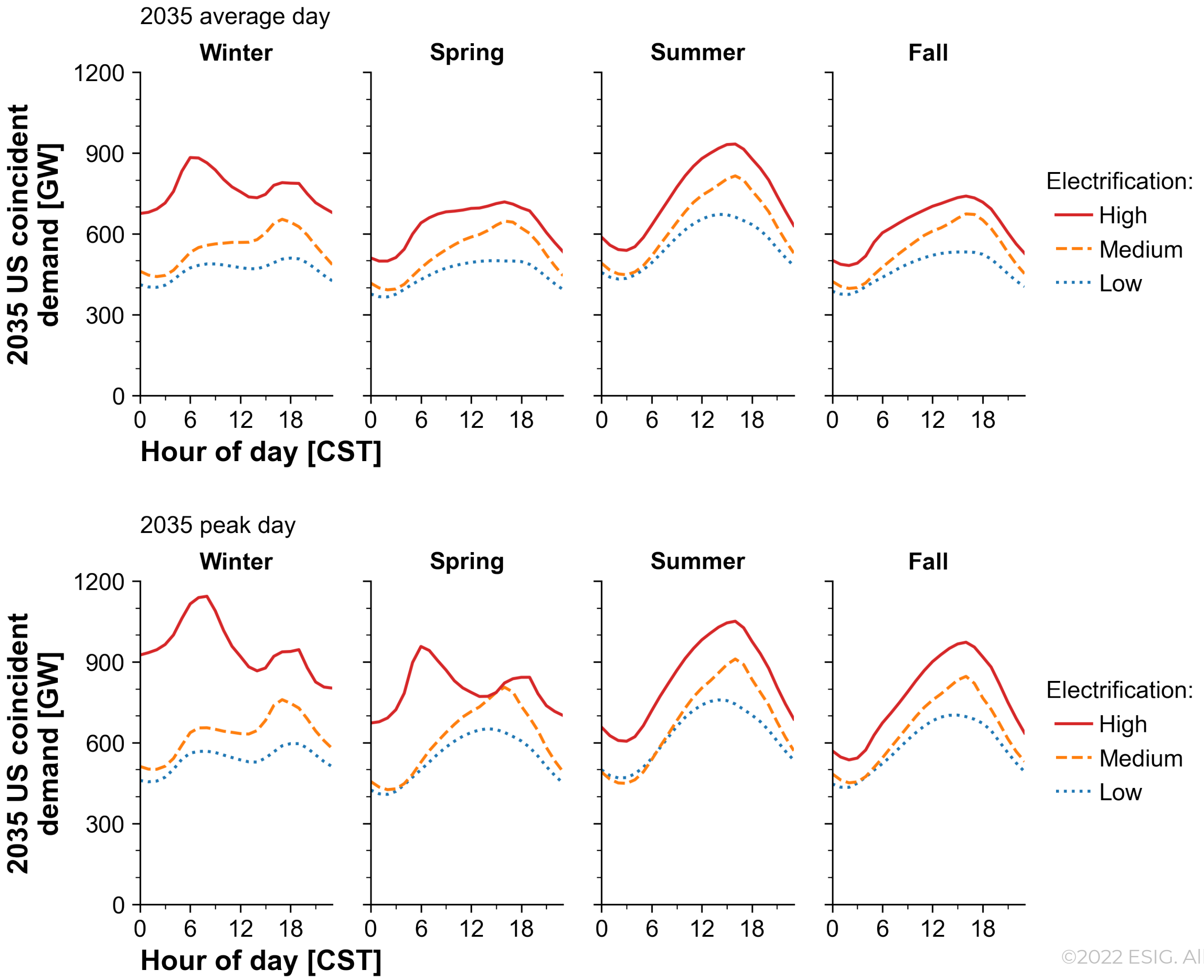


Figure ES-26. Normalized power output for increasing aggregation of PV in Southern California for a partly cloudy day

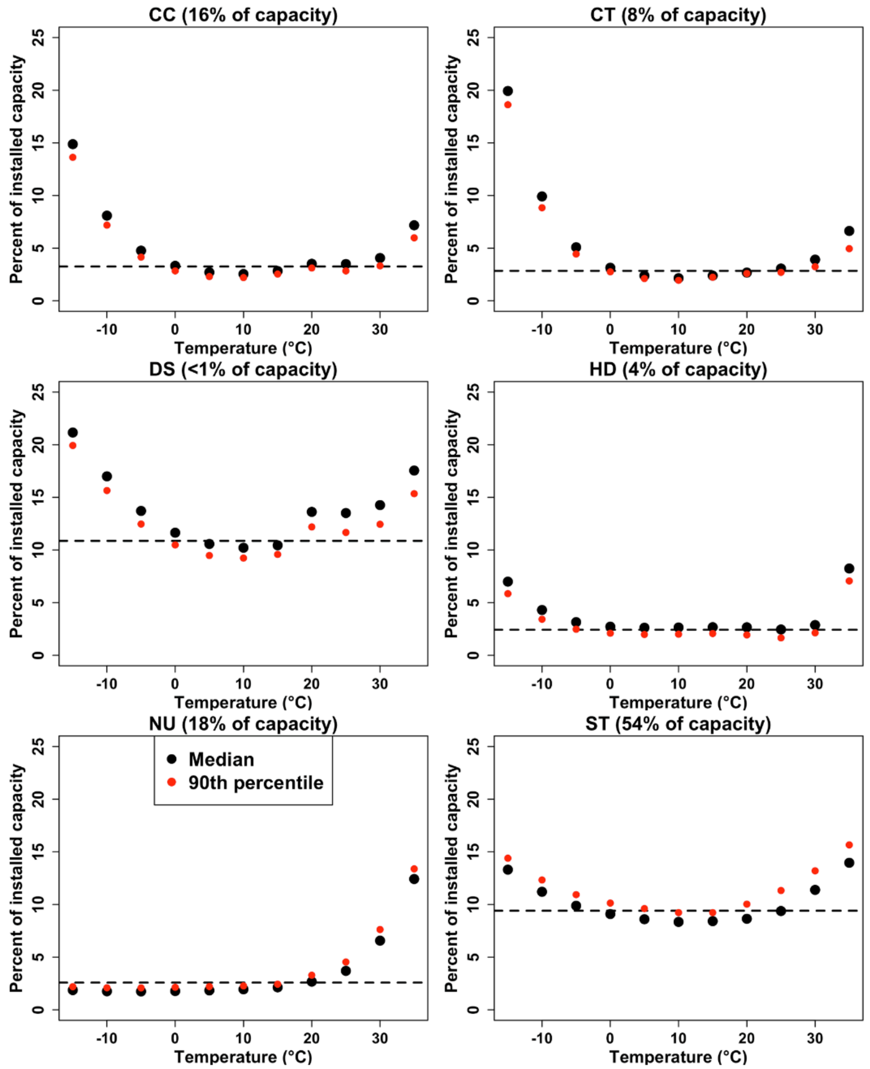
Lew, Debbie and Brinkman, Greg. The Western Wind and Solar Integration Study: Phase II.
https://www.nrel.gov/docs/fy13osti/58798.pdf

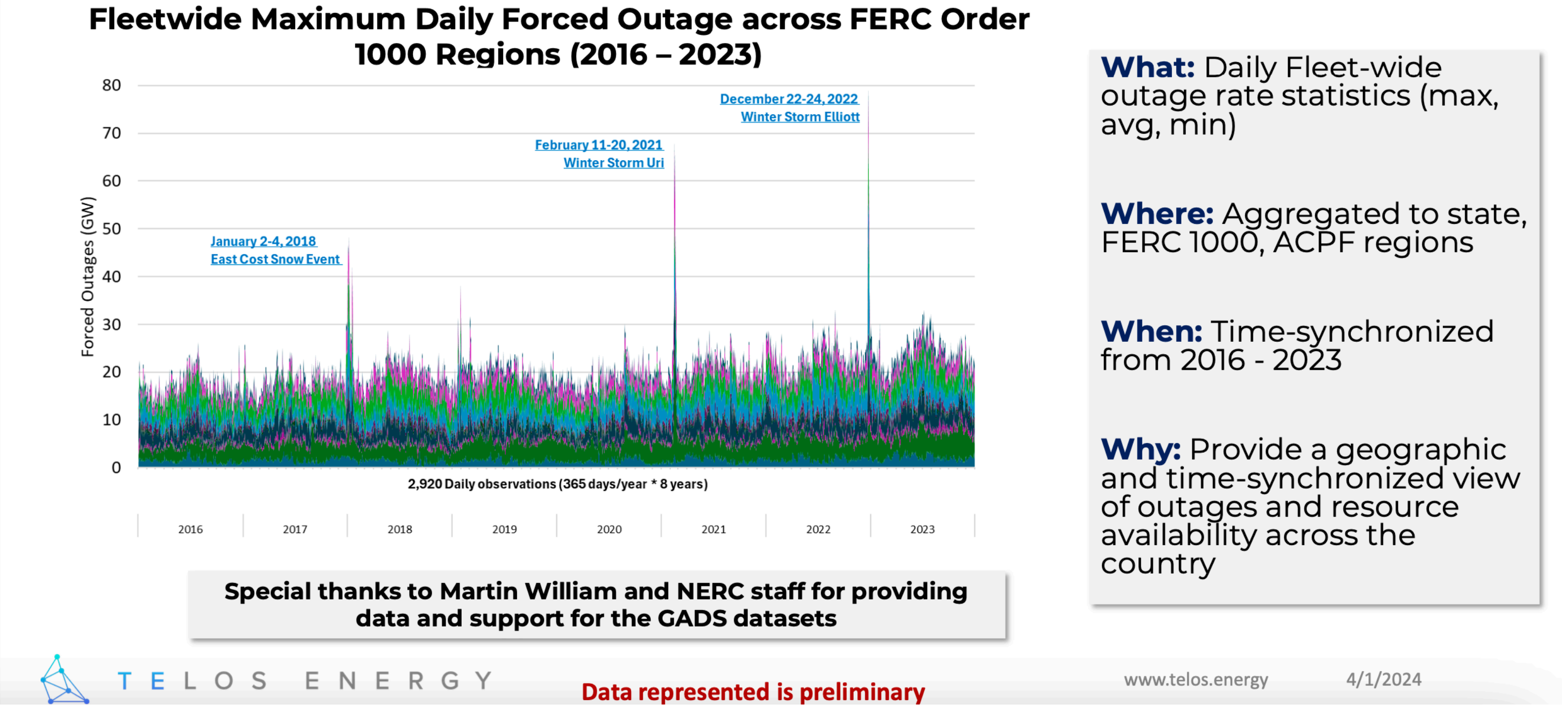
Electrification and System Planning Uncertainty

- Added recently
- Electrification impacts requires weather data as input to profile creation
- Load flexibility is critical, but need base profile to consider flexibility needs/potential



Performance of other system components





What: Daily Fleet-wide outage rate statistics (max, avg, min)

Where: Aggregated to state, FERC 1000, ACPF regions

When: Time-synchronized from 2016 - 2023

Why: Provide a geographic and time-synchronized view of outages and resource availability across the country

Ryan Deyoe. Resilience and Transmission Task Force. ESIG 2024 Spring Technical Workshop (Tucson, AZ). https://www.esig.energy/event/2024-spring-technical-workshop/

Murphy, S., Sowell, F., Apt J. “A time-dependent model of generator failures and recoveries captures correlated events and quantifies temperature dependence.” Applied Energy. November 2019.

Hydro: The unsynchronized synchronous machine

- Most system planners content to model wet and dry sensitivities
- Many other constraints on hydro operations that have little to do with weather
- Most important to capture climate change impacts to availability and storage volume seasonally and inter-annually

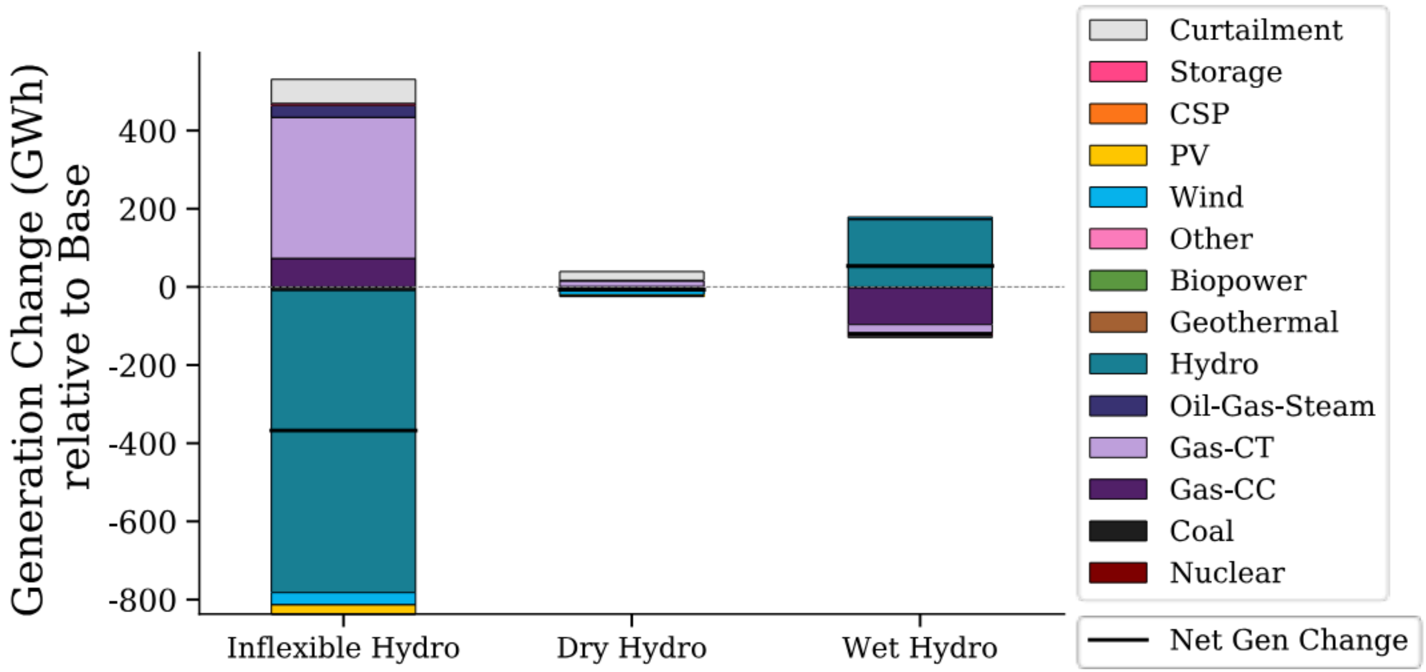
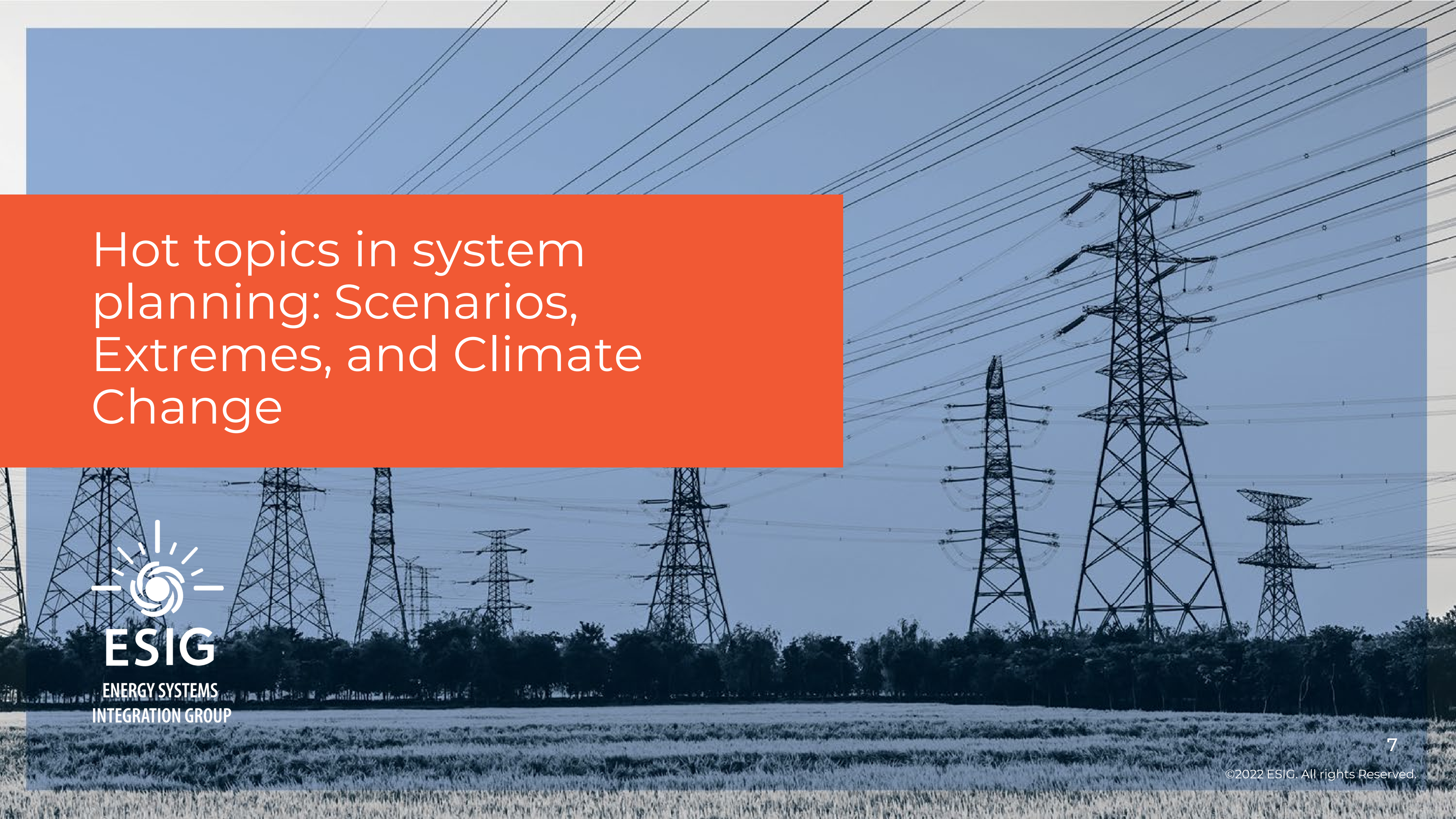


Figure TS-10. Change in total WI generation by type for different hydropower flexibility and availability assumptions during the 2013 Winter Storms event

Novacheck, Joshua; Sharp, Justin; et al. The Evolving Role of Exterme Weather Events in the U.S. Power System with High Levels of Variable Renewable Energy. https://www.nrel.gov/docs/fy22osti/78394.pdf

Hot topics in system planning: Scenarios, Extremes, and Climate Change



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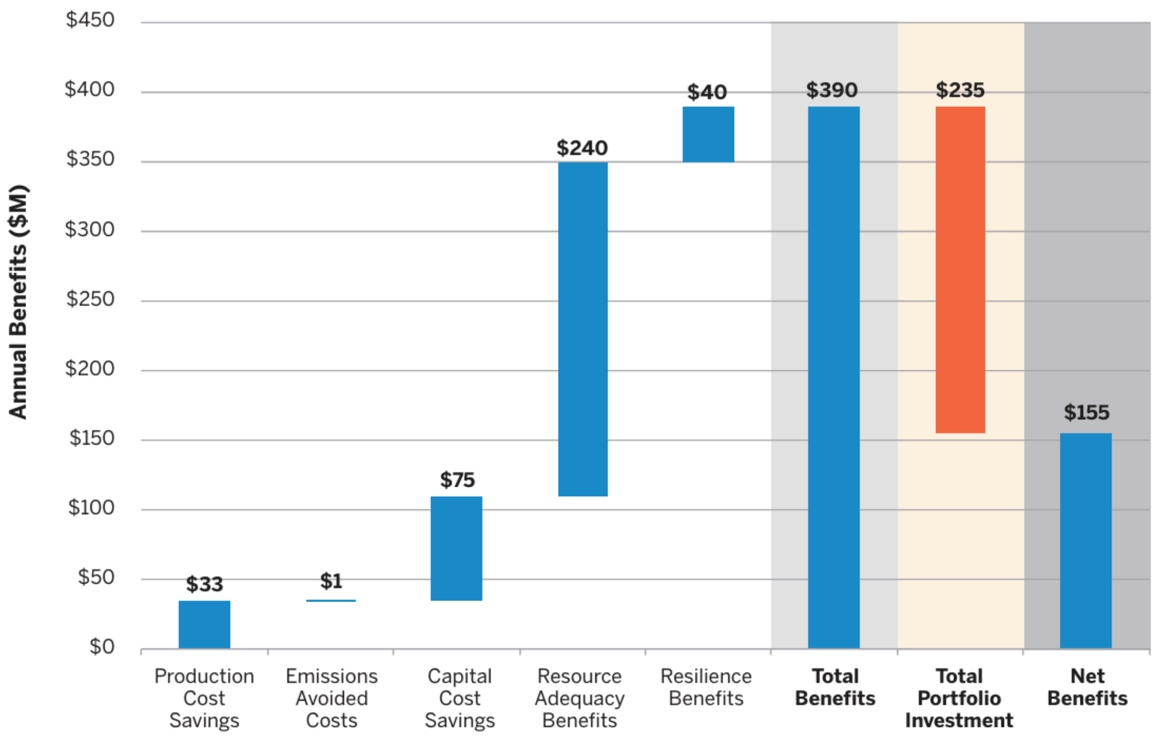
FERC Order 1920: Scenario and Multi-Benefit Planning

FIGURE ES-2

Multi-Value Benefit Stacking for the Transmission Line Connecting ERCOT and Southern Company, 2030



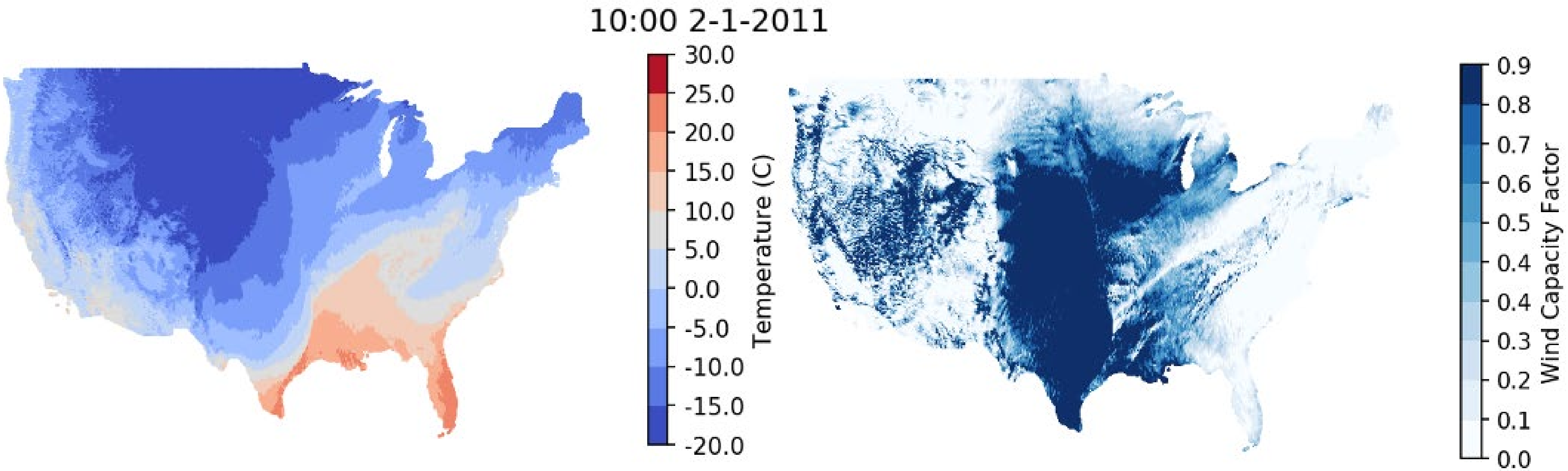
Results from stacking the multi-value benefits for the ERCOT-Southern Company transmission line show total benefits of $390 million, compared to $33 million when considering production cost savings only. This increases the benefit-cost ratio from 0.14 to 1.66.

Source: Energy Systems Integration Group.

https://www.esig.energy/wp-content/uploads/2022/07/ESIG-Multi-Value-Transmission-Planning-report-2022a.pdf

- Major update to transmission planning requirements across much of the country
  - Still common to model very limited set of conditions (e.g., peak summer/winter load, shoulder, etc.)
- Implication for weather datasets:
  - 20-year horizon
  - >= 3 plausible scenarios
  - Multi-benefit planning including resilience to extreme weather events

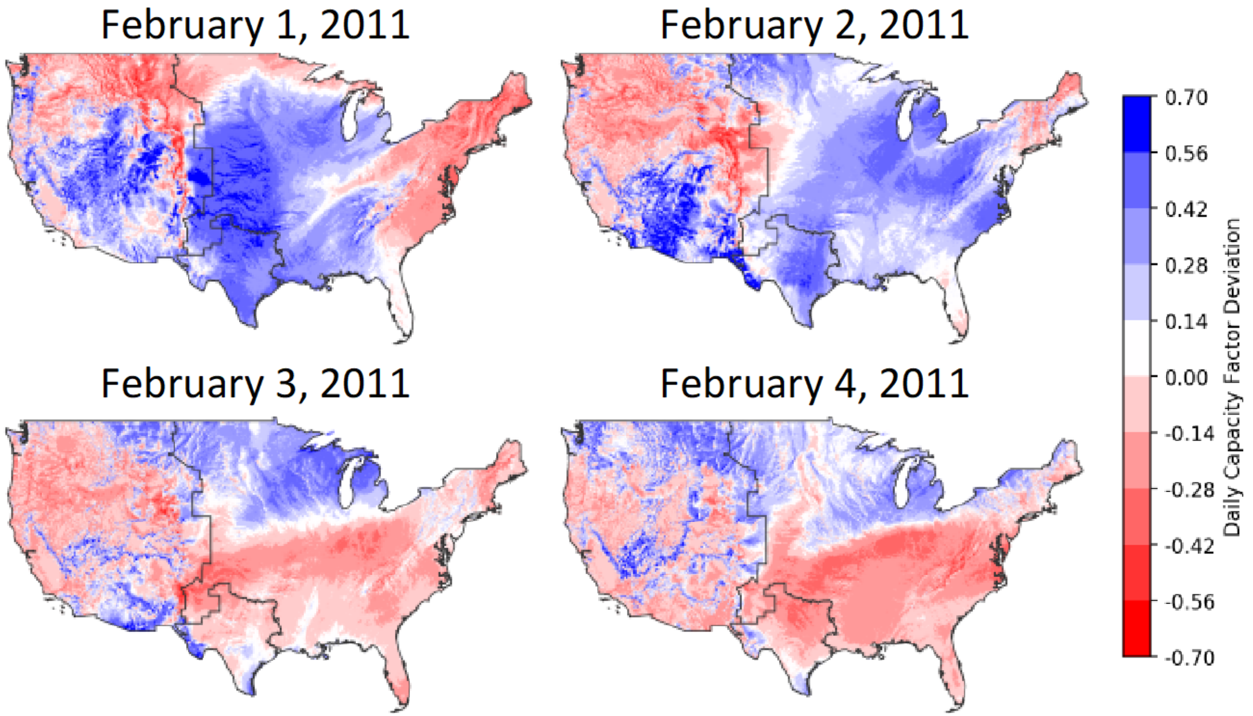
Wind generation lull after a cold wave determines severity of winter weather events



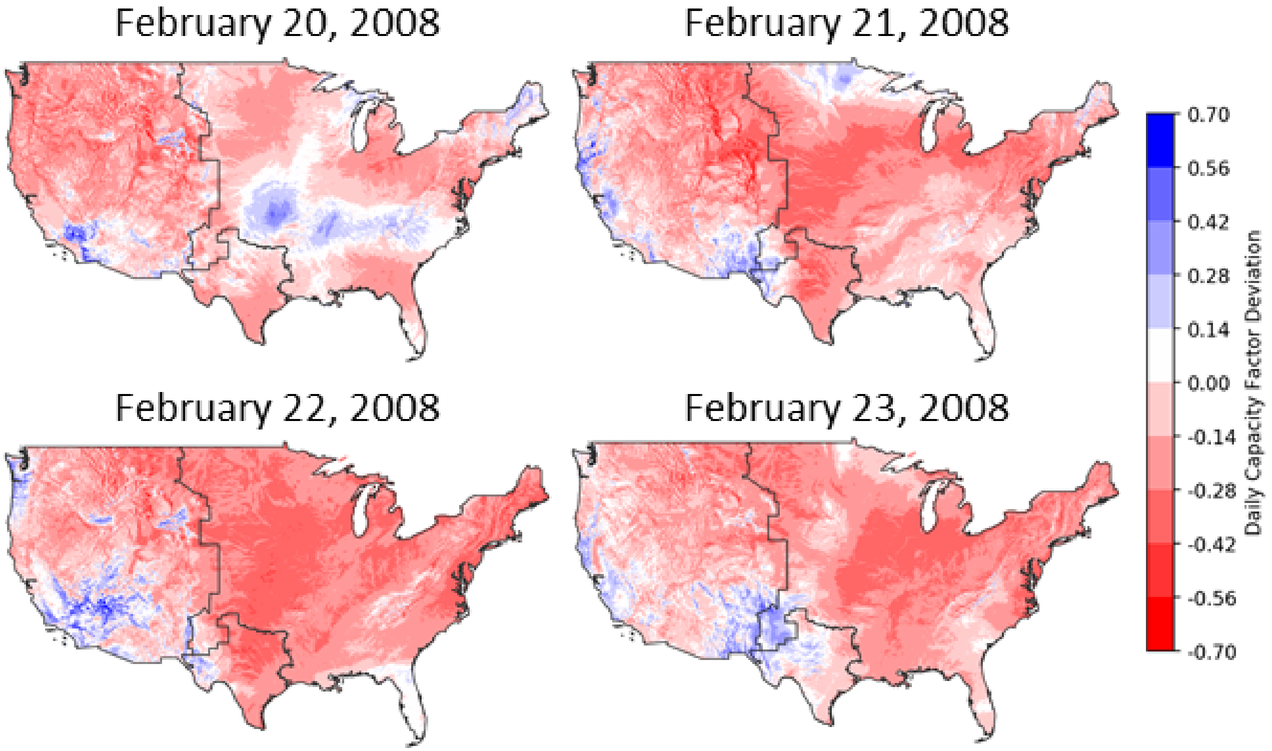
Cold waves (especially in the Eastern and Texas Interconnections) come with high wind resource potential as cold temperatures push down the Front Range of the Rocky Mountains.

Wind generation lull after a cold wave determines severity of winter weather events

Extreme Cold Wave February 2011

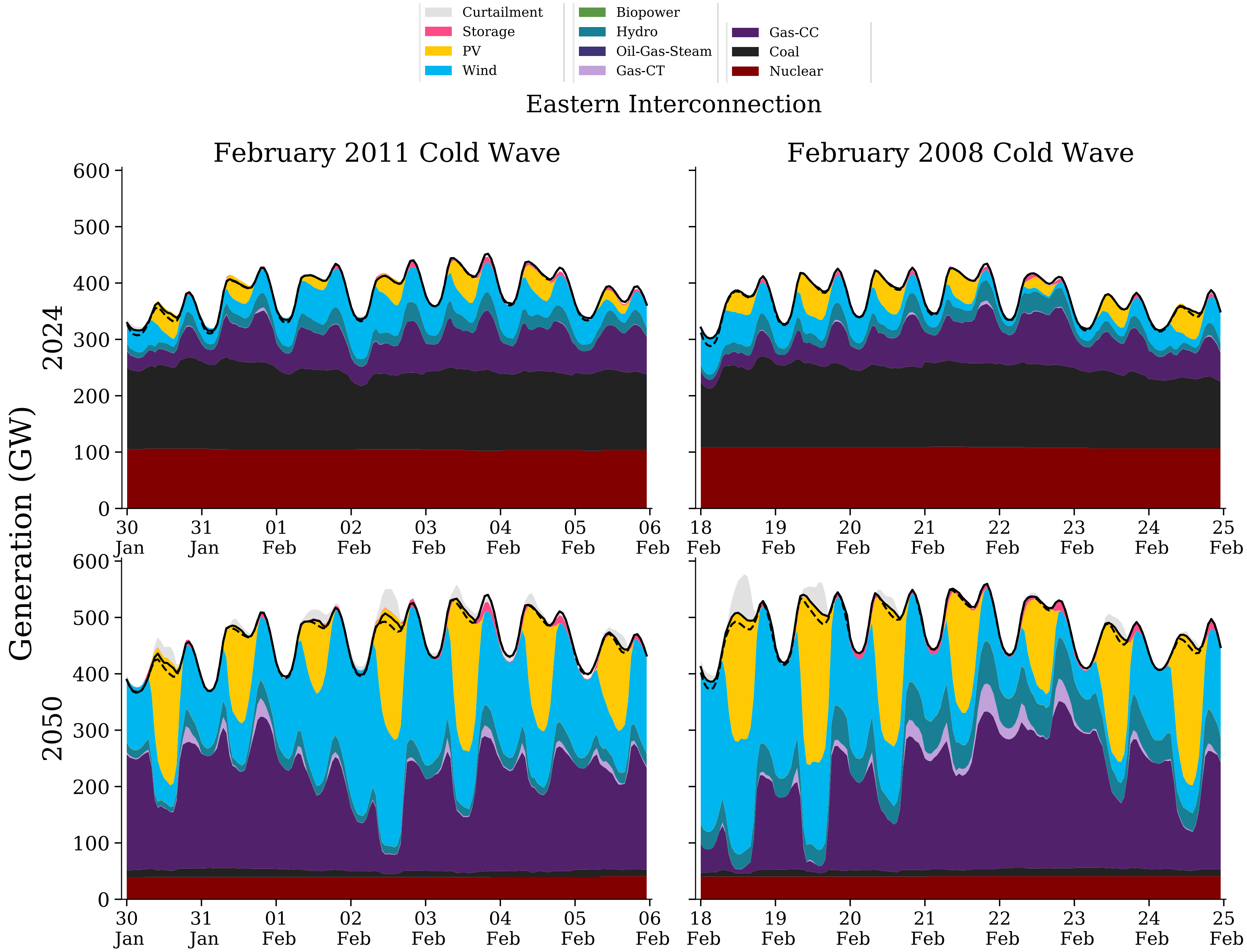


Mild Cold Wave February 2008



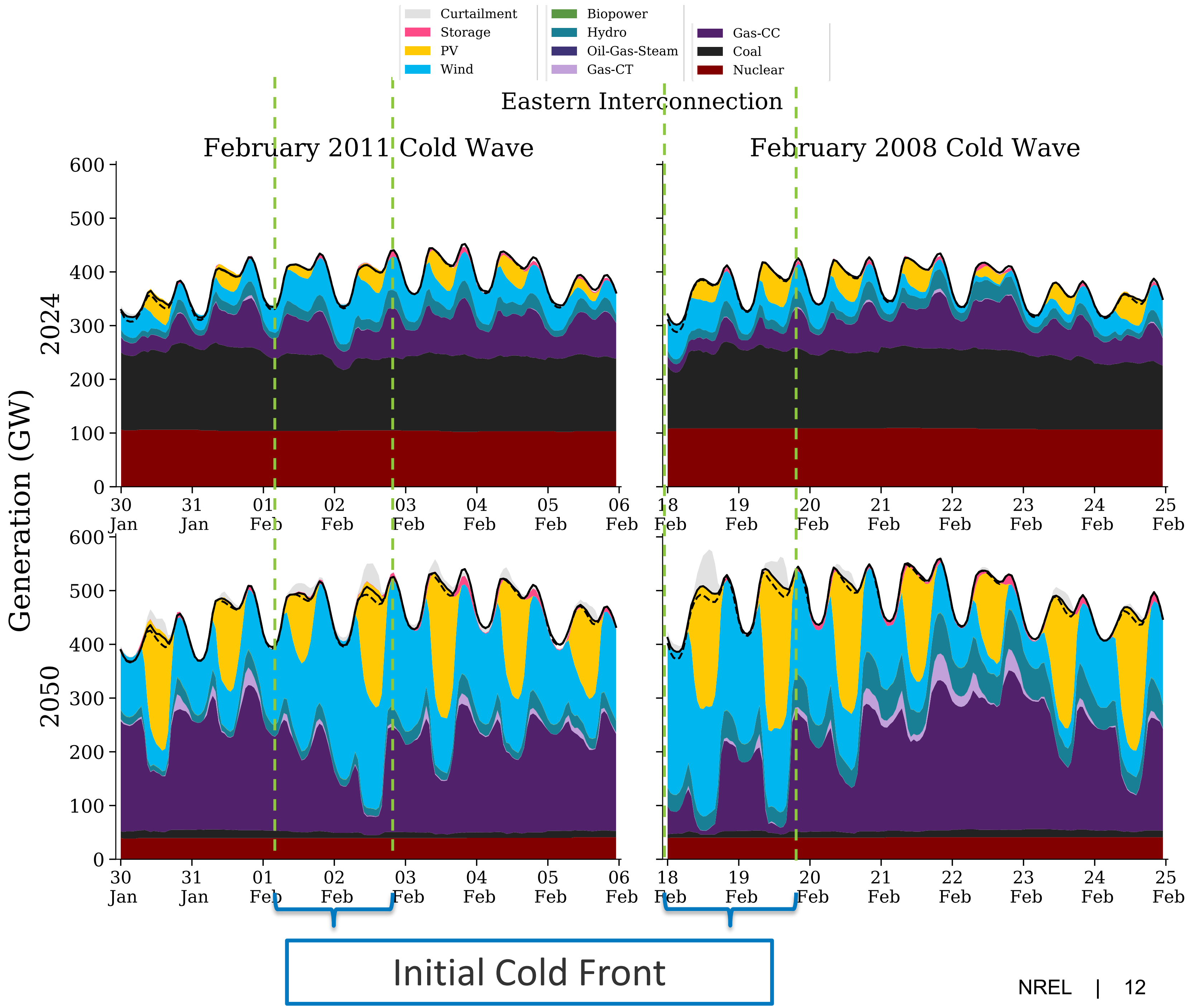
The challenge for operators and planners are the days that follow. As the cold stays, the wind dies down. How much is uncertain, but our 2007 – 2013 dataset suggests milder cold waves lead to lower wind resource in the days following the cold wave.

Wind generation lull after a cold wave determines severity of winter weather events



Wind generation lull after a cold wave determines severity of winter weather events

In both cold waves, wind and solar generation provide >80% of generation in the EI even as load increases as the cold front moves across the continent.



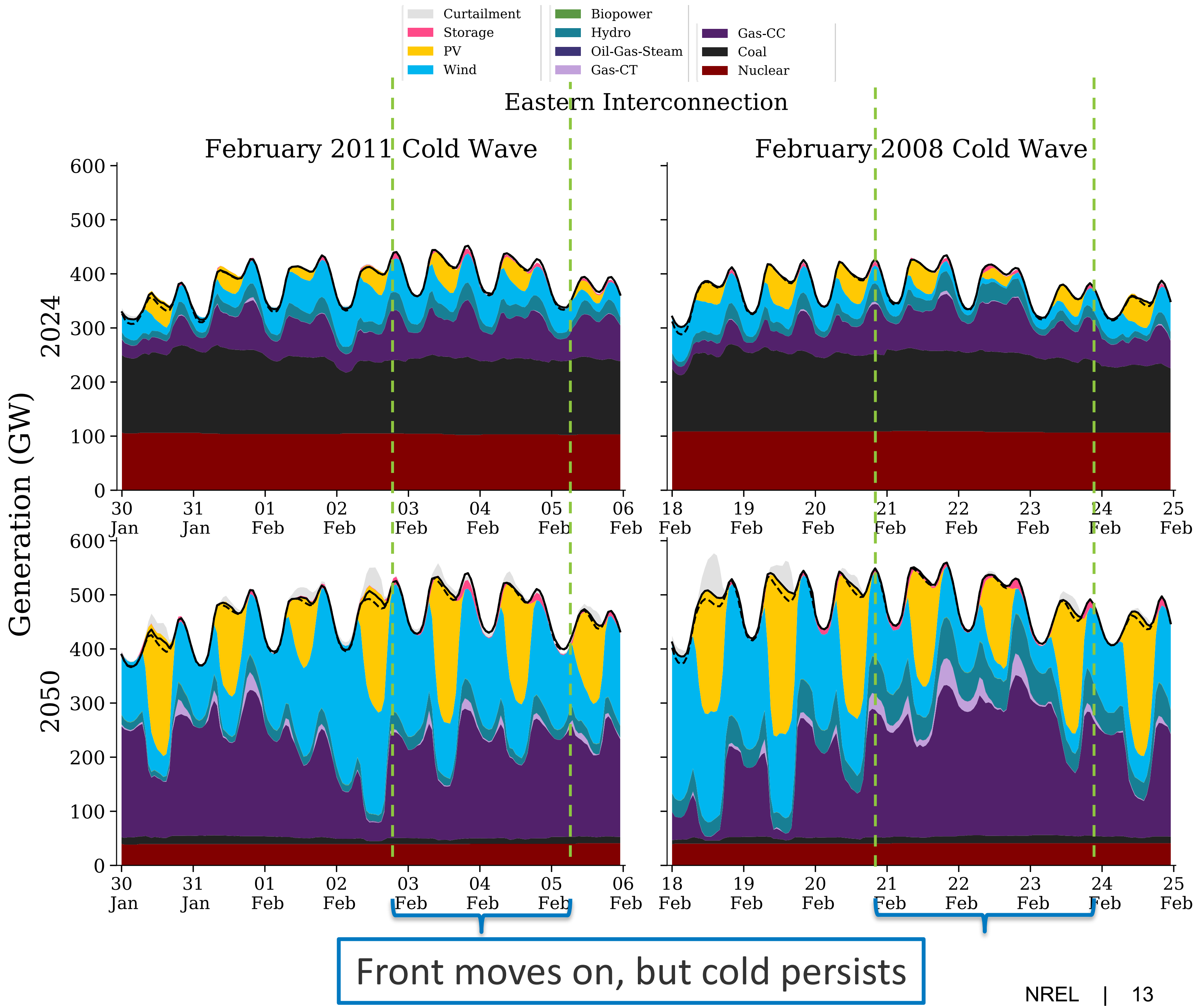
Wind generation lull after a cold wave determines severity of winter weather events

2011 Extreme Cold Wave

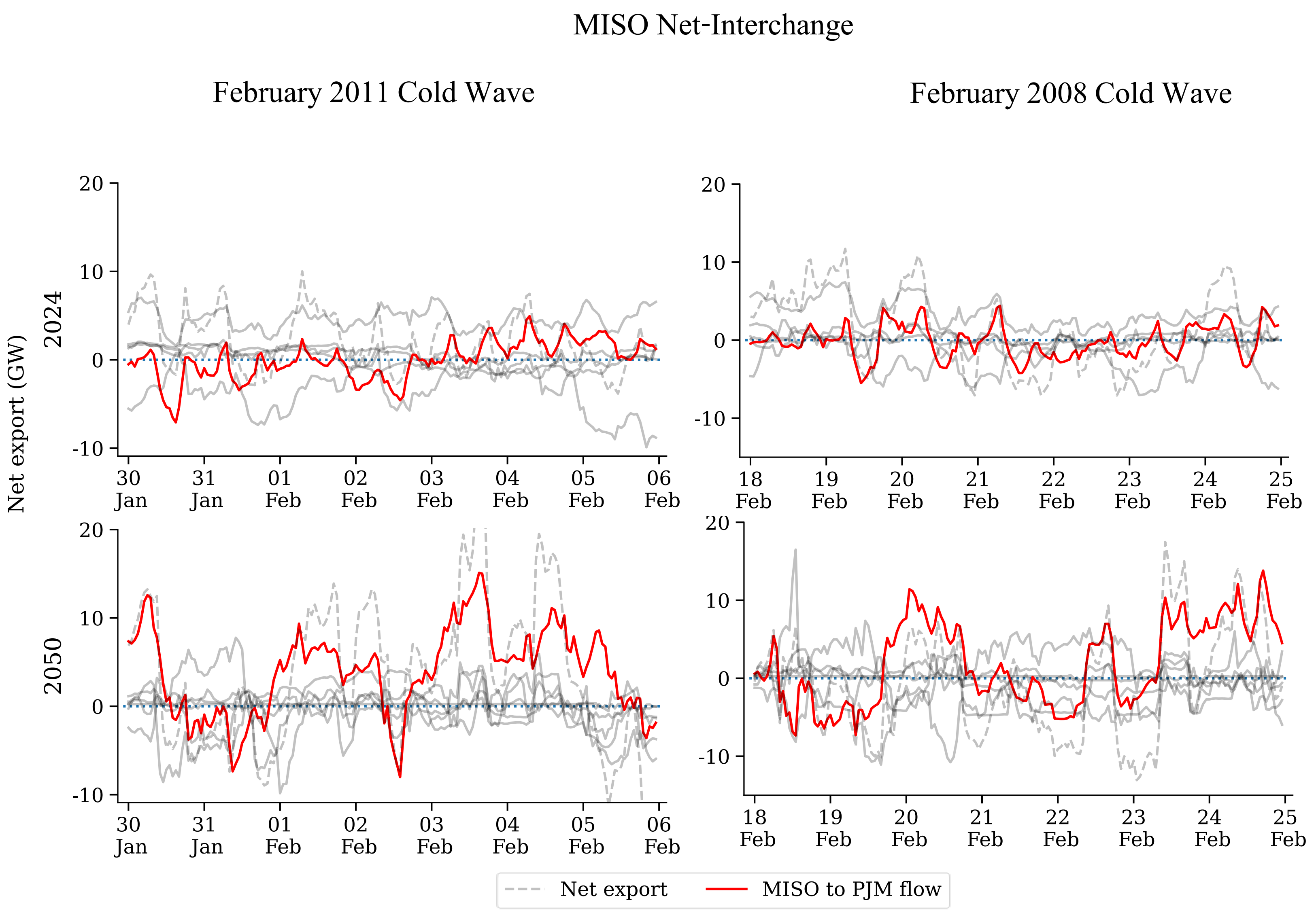
Wind and solar continues to serve ~50% of load after front moves through and load is elevated.

2008 Milder Cold Wave

Overnight wind penetrations drops below 10% of all generation. Offline thermal reserves drop in MISO and SPP.



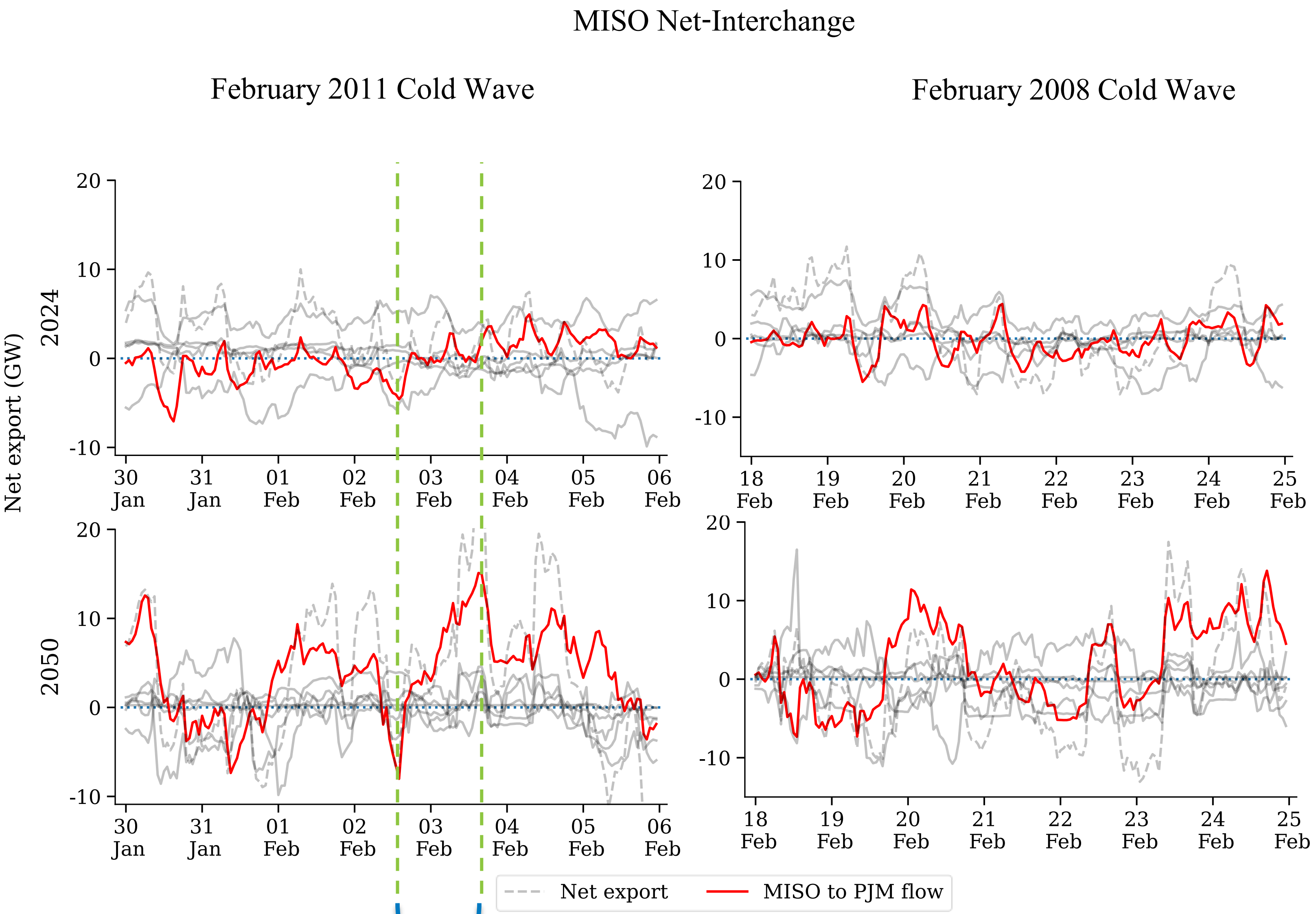
Wind generation lull after a cold wave determines severity of winter weather events



Wind generation lull after a cold wave determines severity of winter weather events

2011 Extreme Cold Wave

Transmission enables usage of geographic diverse wind and solar resources.

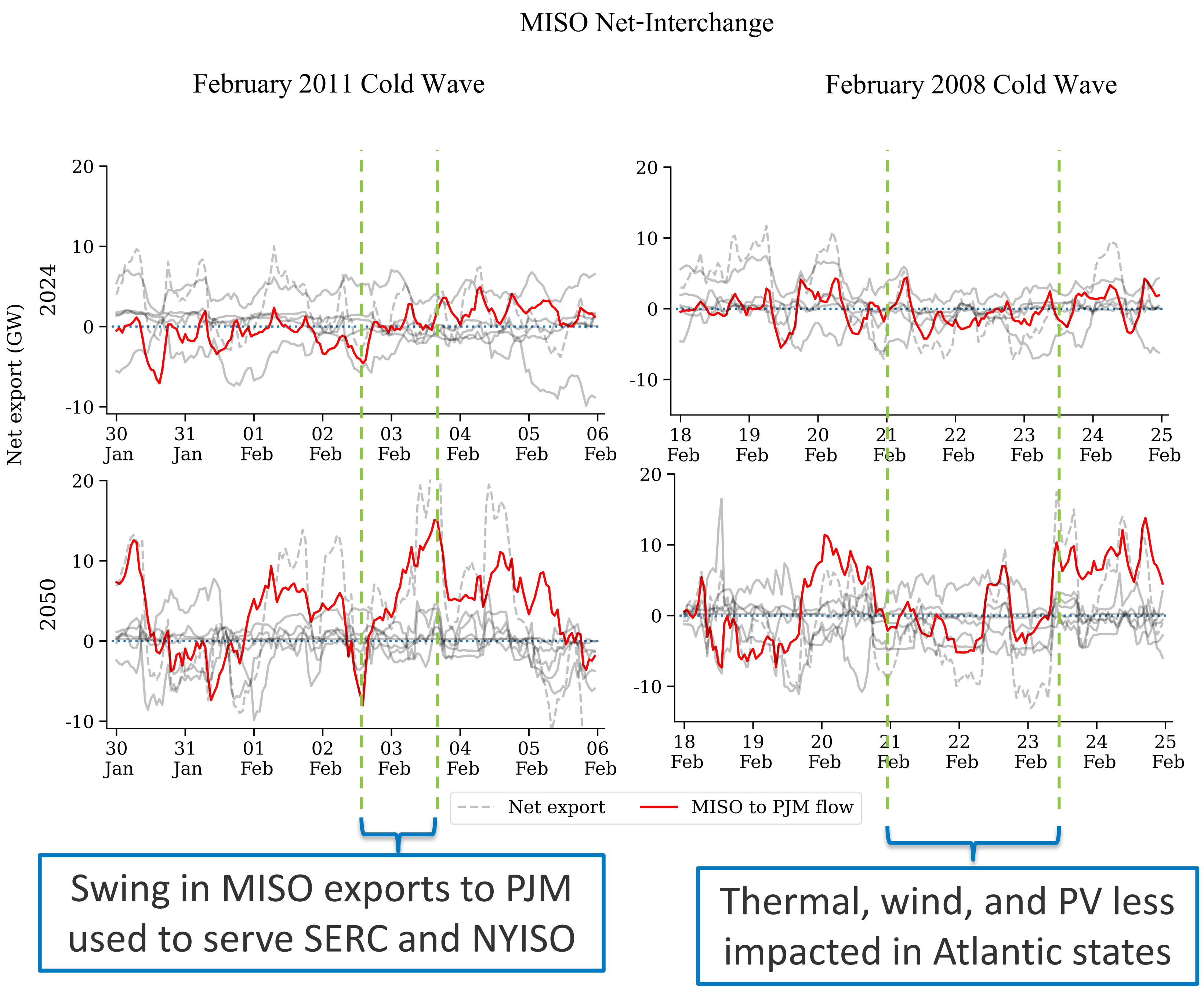


Swing in MISO exports to PJM used to serve SERC and NYISO

Wind generation lull after a cold wave determines severity of winter weather events

2011 Extreme Cold Wave
Transmission enables usage of geographic diverse wind and solar resources.

2008 Milder Cold Wave
Transmission **also** enables uses geographic diverse thermal fleet.



For the Planning Year 23-24 LOLE study, MISO incorporated incremental temperature-dependent forced outages into the model

Figure 18. LRZ2 Average Coal Outages

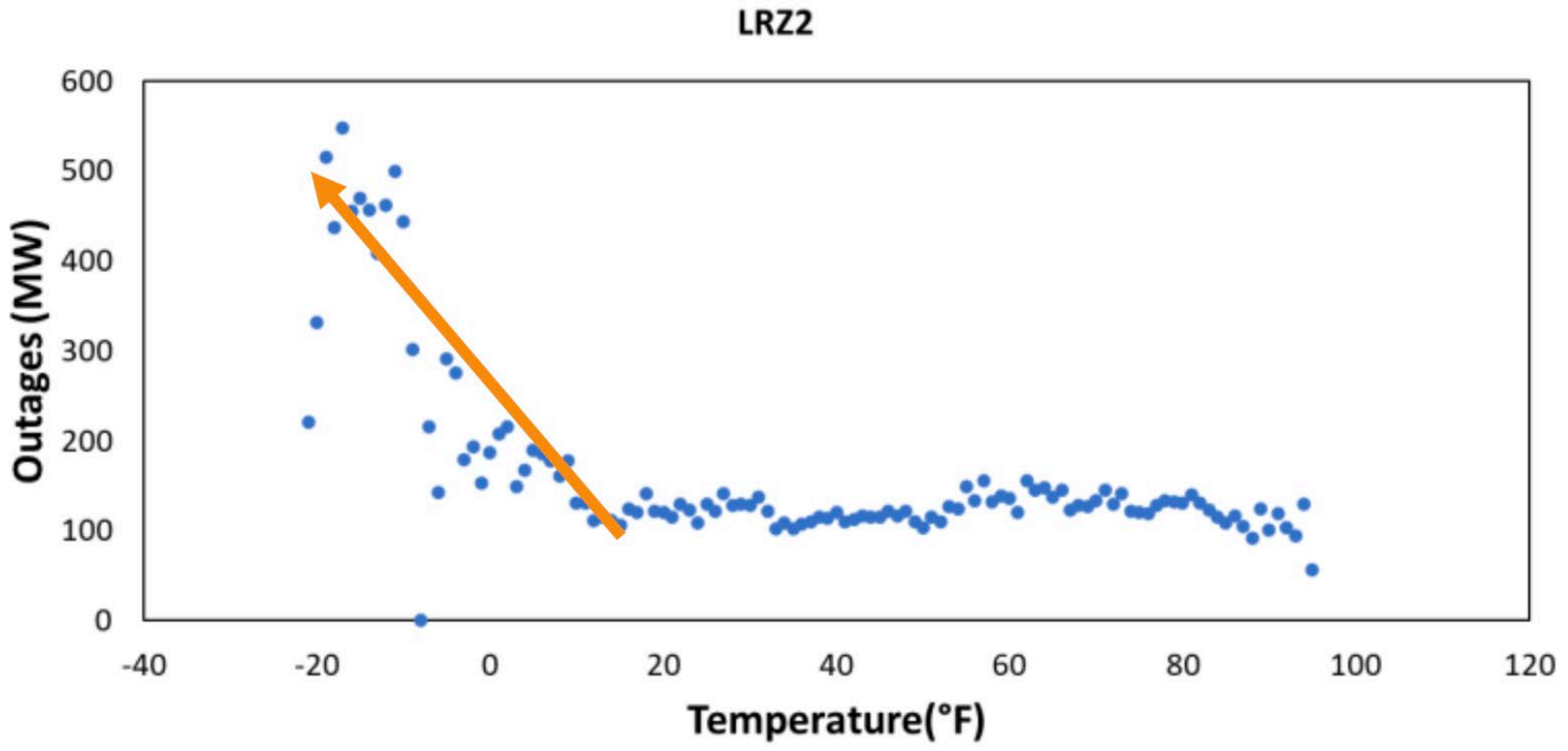


Table 7. Coal Cold Weather Outage Relationships

Zone	Starting Point	MW/° Added
LRZ2	10	14
LRZ3	10	3
LRZ4	21	4
LRZ6	35	2
LRZ7	20	7
LRZ9	42	1

Megan Pamperin. Extreme Events and Transmission Analysis in Probabilistic Modeling. ESIG 2024 Spring Technical Workshop (Tucson, AZ).

https://www.esig.energy/event/2024-spring-technical-workshop/

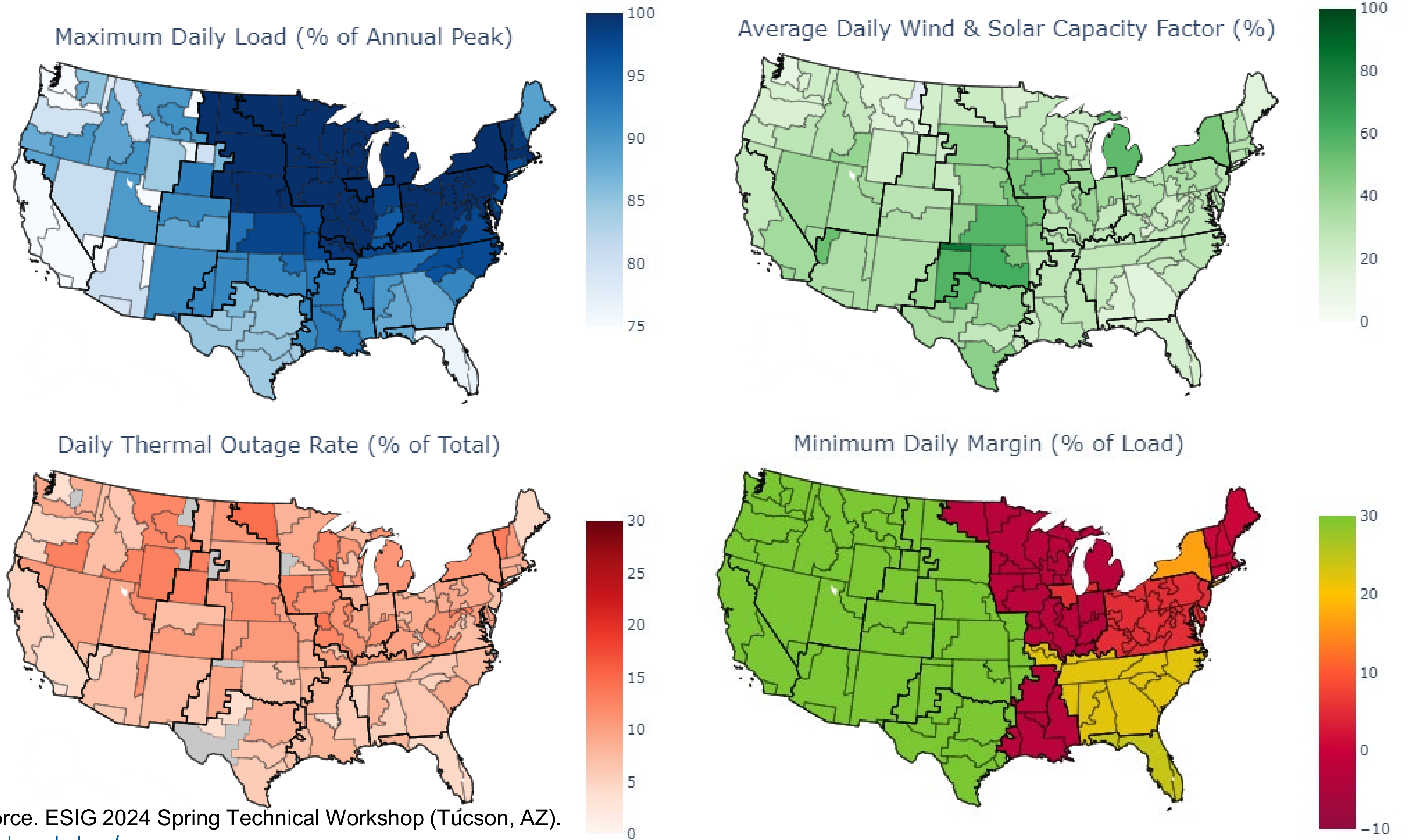
https://cdn.misoenergy.org/20220707%20LOLEWG%20Supplemental%20MISO%20Seasonal%20Inputs%20Documentation%20Astrape625466.pdf

ESIG Resilience and Transmission Task Force

Deep dive into interesting periods of tight margin to visualize geographic diversity.

Particularly helpful in showing the movement and regional concentration of events to identify priority regional connections

e.g., heat wave in Midwest and mild temperatures and load in the Southwest



July 14, Weather Year 2012

Ryan Deyoe. Resilience and Transmission Task Force. ESIG 2024 Spring Technical Workshop (Tucson, AZ). https://www.esig.energy/event/2024-spring-technical-workshop/

Continuum of Stress Testing Approaches

Good

- Testing using historical load-wind-solar-hydro data for a limited number of specific historical events

Better

- Testing using data for a wide range of historical events
- Testing using data based on forcing from a single climate dataset

Best

- Testing using data based on forcing from multiple climate datasets

Casey Burleyson. Forward Looking Extreme Weather Datasets. ESIG 2024 Spring Technical Workshop (Tucson, AZ). https://www.esig.energy/event/2024-spring-technical-workshop/

What do system planners need from weather datasets?

1. Time synchronous
2. Sufficient spatial resolution
3. Many weather years

- Many sources of uncertainty in input data to planning models
- Help characterizing weather dataset uncertainty while enabling infrastructure decisions to be made

TABLE ES-1

The Main Attributes of Time Series Data Necessary to Meet General Power System Modeling Needs

Including the necessary variables	Include the necessary variables at sufficient spatio-temporal resolution and accuracy to reflect actual conditions that define the generation potential at current and future wind/solar sites and temperature at load centers
Covering multiple decades with ongoing extension	Cover multiple decades with consistent methodology and be extended on an ongoing basis to capture the most recent conditions and allow climate trends to be identified
Coincident and physically consistent	Are coincident and physically consistent, in space and time, across weather variables
Validated	Are validated against real conditions with uncertainty quantified
Documented	Are documented transparently and in detail, including limitations and a guide for usage
Periodically refreshed	Are periodically refreshed to account for scientific and technological advancements
Available and accessible	Publicly available, expertly curated, and easily accessible

Source: Energy Systems Integration Group.

https://www.esig.energy/wp-content/uploads/2023/10/ESIG-Weather-Datasets-exec-summary-2023.pdf