NREL
NATIONAL RENEWABLE ENERGY LABORATORY

The Evolving Role of Extreme Weather Events in the U.S. Power System with High Levels of Variable Renewable Energy

Josh Novacheck, Marty Schwartz, Grant Buster, Zach Tzavelis, Michael Rossol *NREL*

Justin Sharp *Sharply Focused LLC*

Paul Donohoo-Vallett *U.S. DOE*

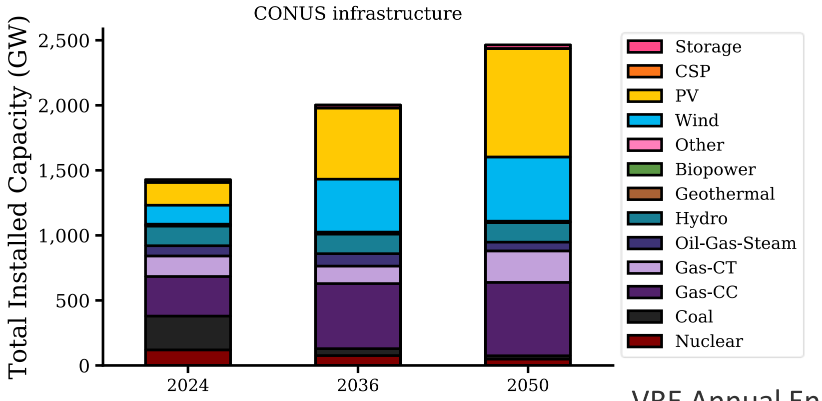
Novacheck, Sharp, et al. 2021. "The Evolving Role of Extreme Weather Events in the U.S. Power System with High Levels of Variable Renewable Energy" https://doi.org/10.2172/1837959

Objectives and Motivation

Identify weather events for deeper meteorological analysis, variable generation resource assessment, and Production Cost Modeling

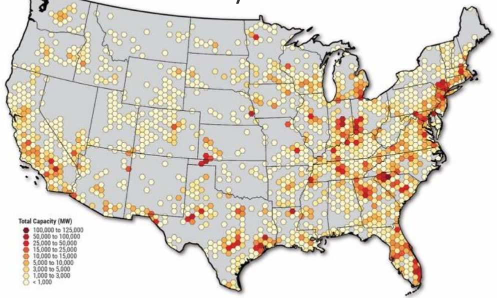
- News-Worthy (Cold/Heat Waves, Major Storms)
- Challenges to Planning in High Variable Generation System

https://www.nrel.gov/analysis/naris.html

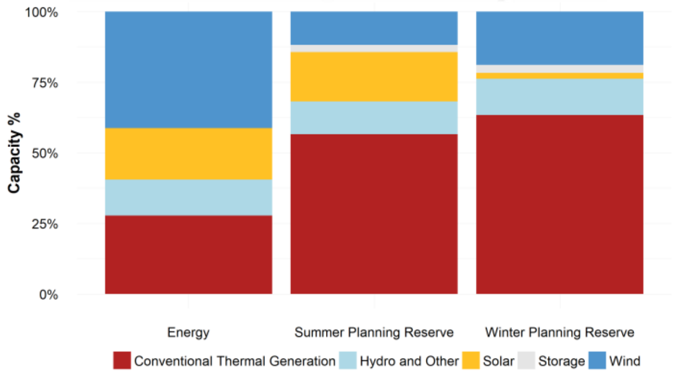


2024	2036	2050	
17%	50%	65%	VRE Annual Energy Contribution

2050 Utility PV Sites



2050 Wind Sites



Resource Data Sets

WIND Toolkit

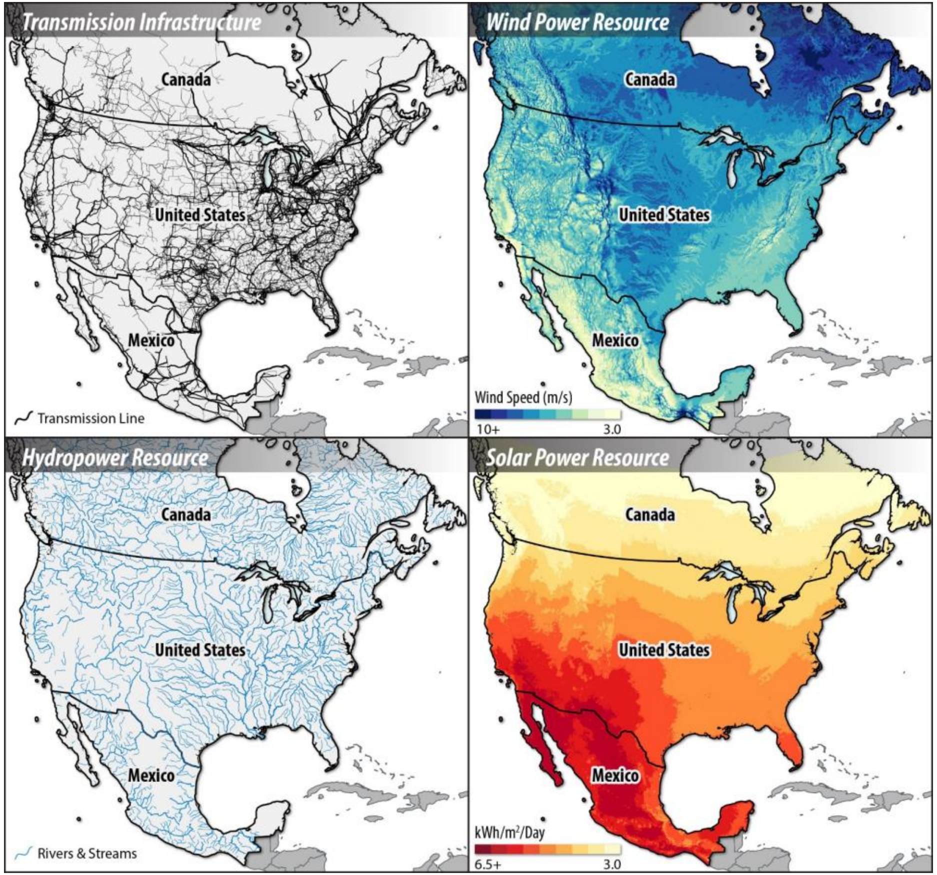
- 2007 – 2013
- 5-minute resolution
- 2km x 2km spatial resolution

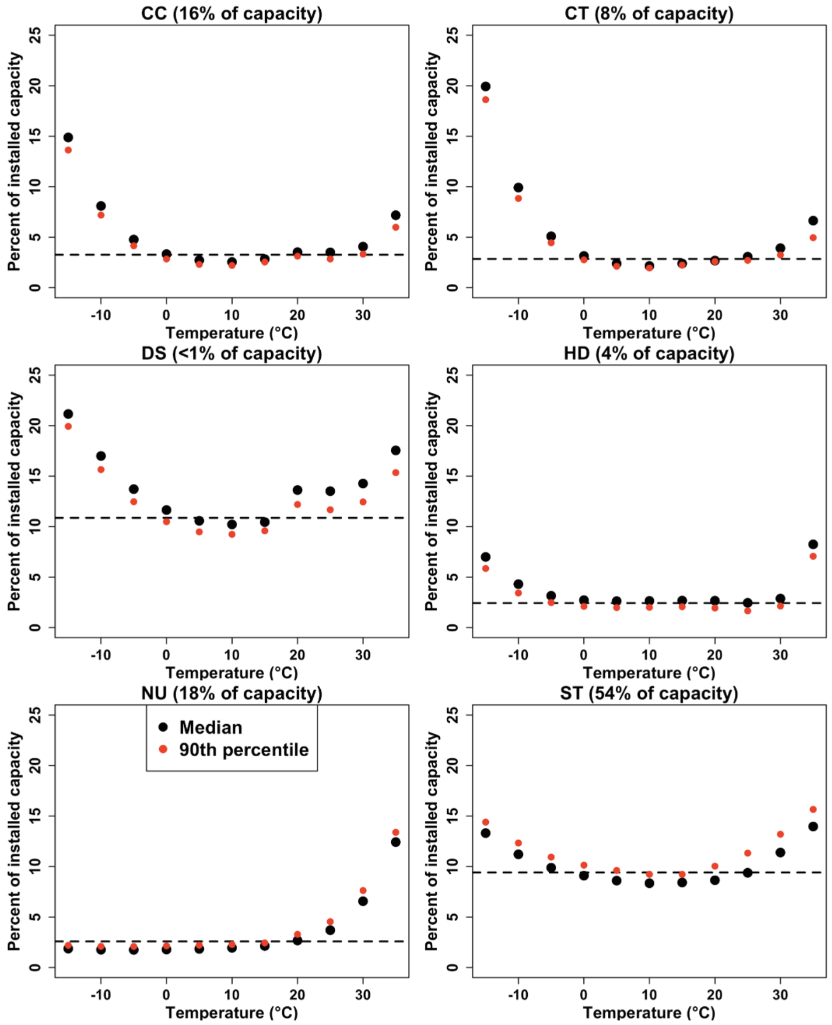
National Solar Radiation Database (NSRDB)

- 1998 – 2020
- 30-minute resolution
- 4km x 4km spatial resolution

Hydropower Resource

- EIA-923 plant level generation data to adjust maximum energy limits.





Weather Correlated Thermal Outages

Match thermal units to WRF modeling in
WIND Toolkit to apply temperature dependent outage rate.

Curves based on analysis of PJM units historical outage pattern

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.

Event Summary

News-Worthy

1. **Cold Wave:** 2011 February 1 – 4
2. **Heat Wave:** 2011 July 19 – 24
3. **Heat Wave:** 2012 June 29 – July 7
4. **Hurricane Irene:** 2011 August 25 – 30
5. **Hurricane Gustav:** 2008 September 1 – 6
6. **Winter Storms Cleon, Dion, and Electra:** 2013 December 4 – 12

Challenges to Planning

1. **Mild Cold Wave with High Net-Load:** 2008 February 20 – 23
2. **Moderate-High Load & Large Swing in VG Resource:** 2009 December 6 – 11
3. **Mild Cold Wave with High Net-Load:** 2010 February 2 – 5
4. **Moderate Heat Wave with High Net-Load:** 2010 August 8 - 11
5. **Continental Low Net-Load:** 2011 April 17
6. **Wind Drought:** 2010 October 1 – 24

Key Finding Summary

1. Variable generation tends to be available during “News-worthy” events of today, though exceptions exist.

2. Mild weather can produce extended periods of low wind and solar and should be a focus of planners in the future.

3. Evolution of operations during cold waves are driven by wind dynamics

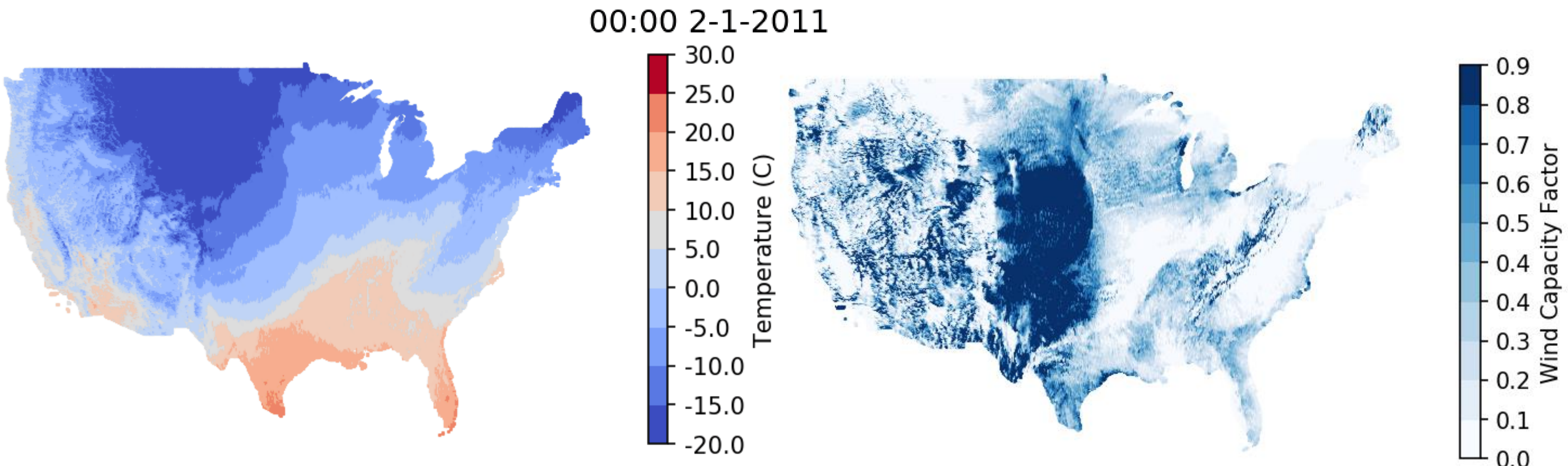
4. Operations in heat waves change due to PV, but adequacy concerns driven by wind

5. Flexible infrastructure can enable planning for geographic diversity

6. Hydro availability and flexibility can mitigate weather event impact

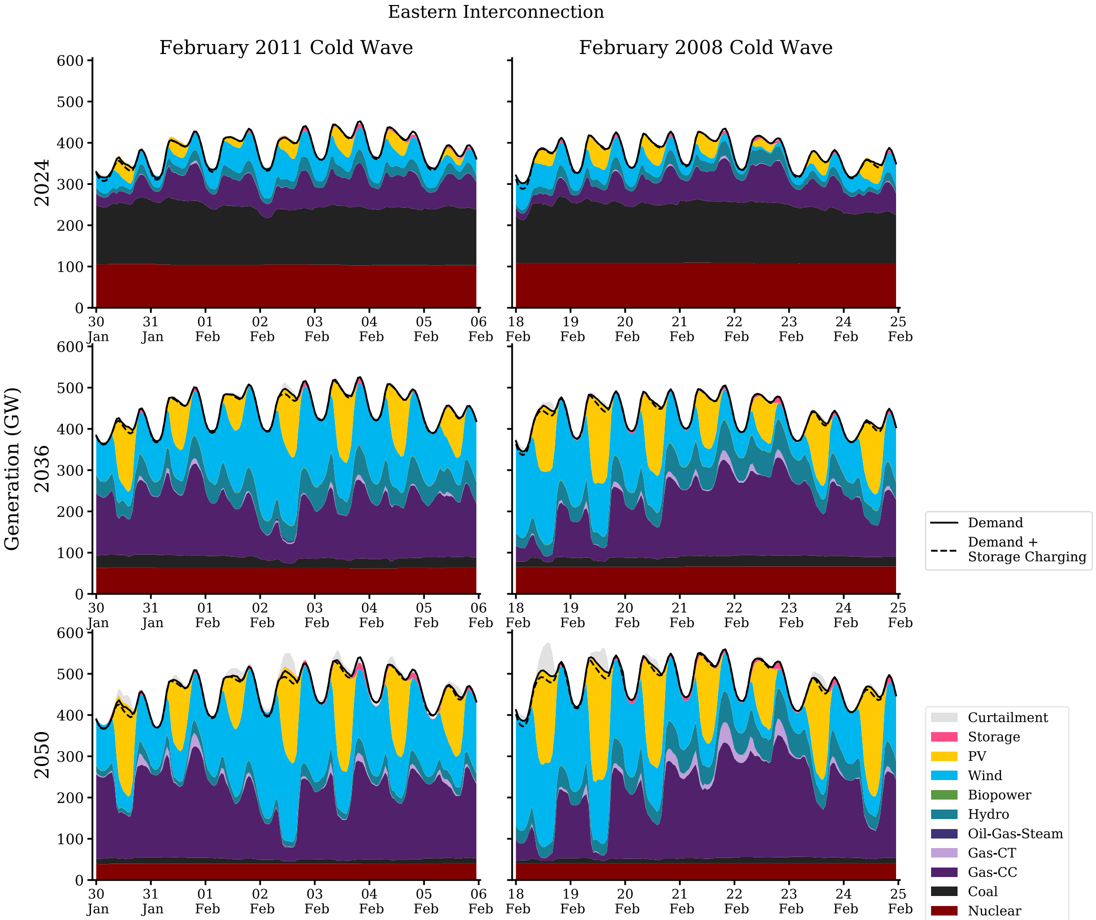
Cold Wave Finding

3 Evolution of operations during cold waves driven by wind dynamics



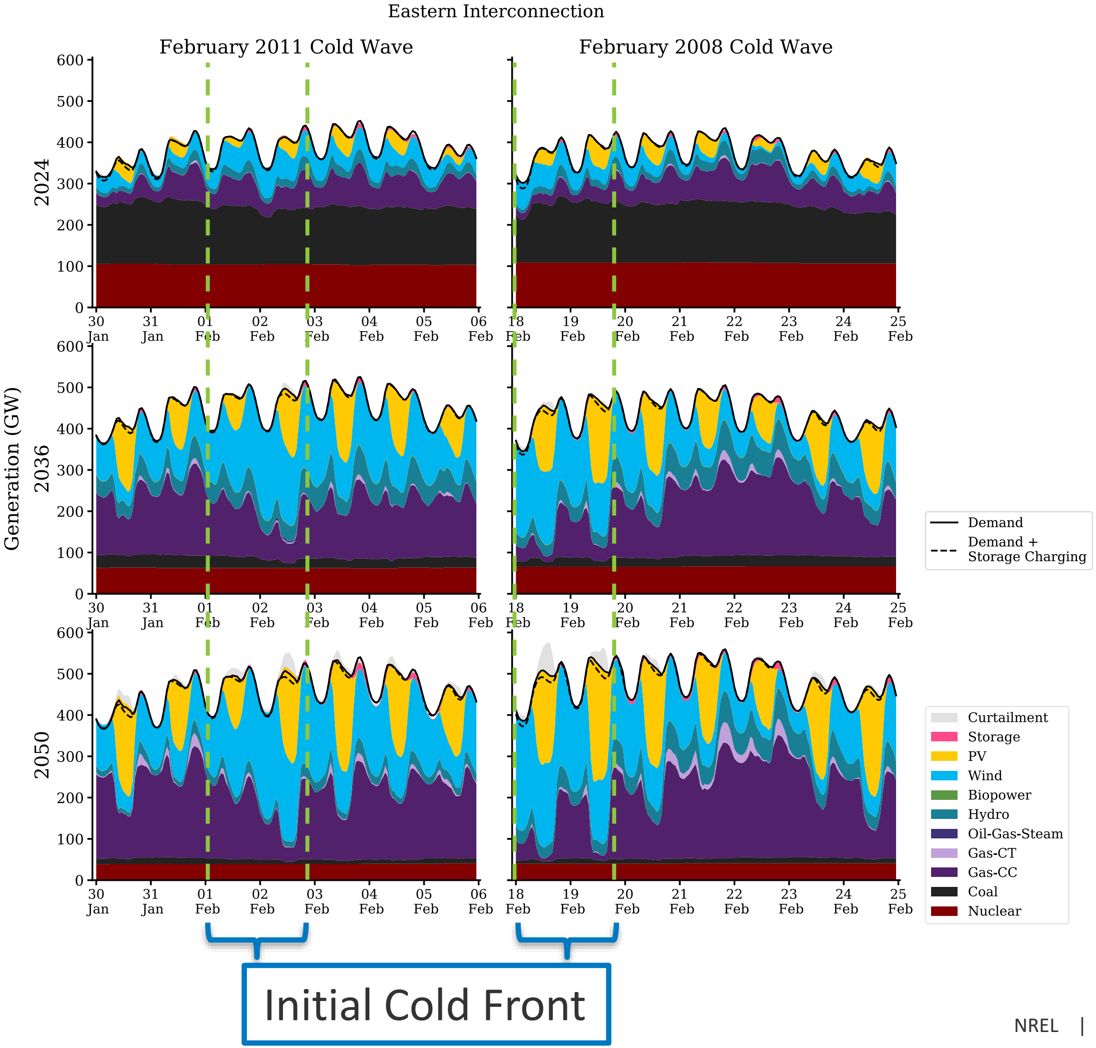
Cold waves (especially in the Eastern and Texas Interconnections) come with high wind resource as cold pushes down the Front Range of the Rocky Mountains.
The challenge for operators and planners are the days that follow. As the cold stays, the wind dies down. How much is uncertain, but our 2007 – 2013 dataset suggests milder cold waves lead to lower wind resource in the days following the cold wave.

3 Evolution of operations during cold waves driven by wind dynamics



3 Evolution of operations during cold waves driven by wind dynamics

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.



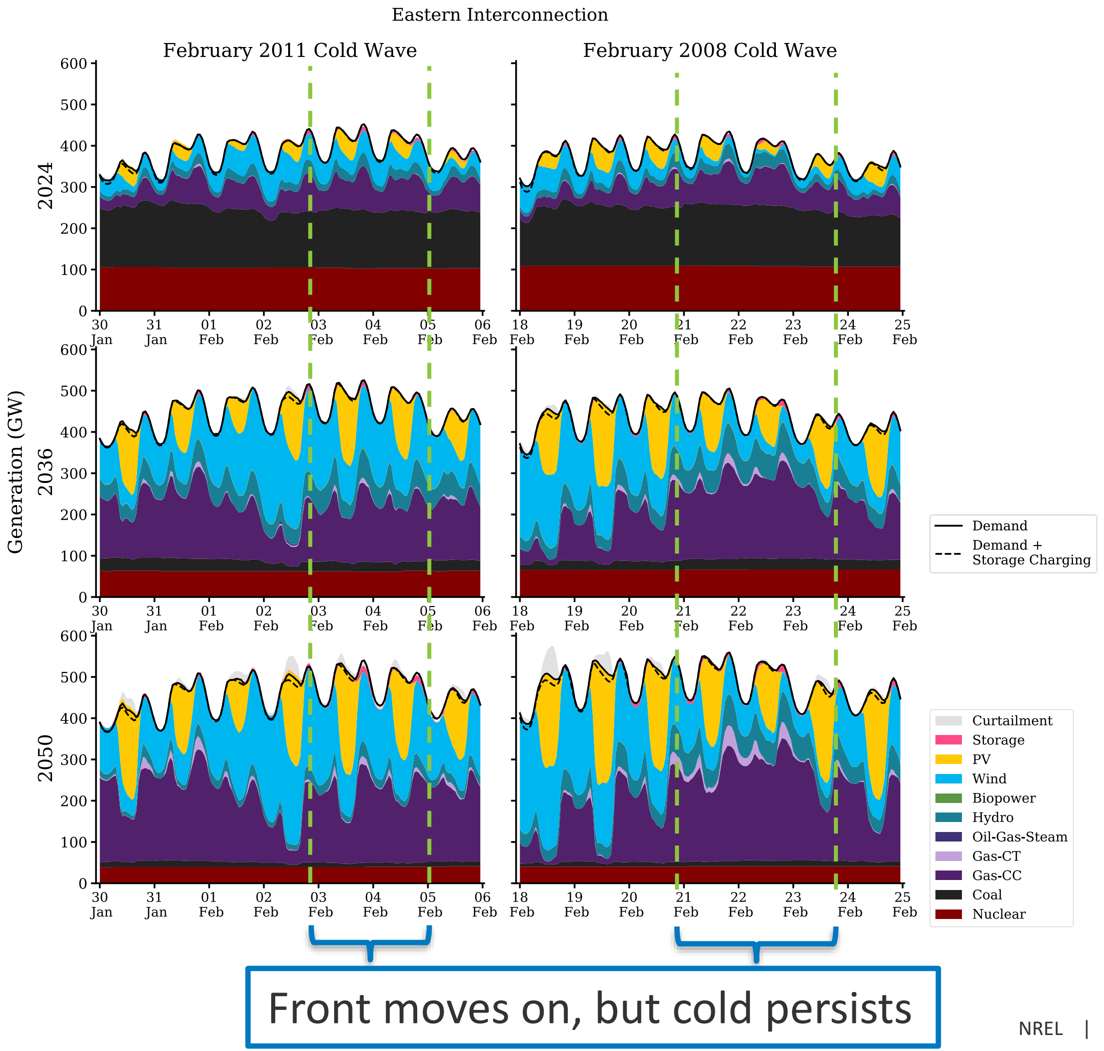
3 Evolution of operations during cold waves driven by wind dynamics

2011 Extreme Cold Wave

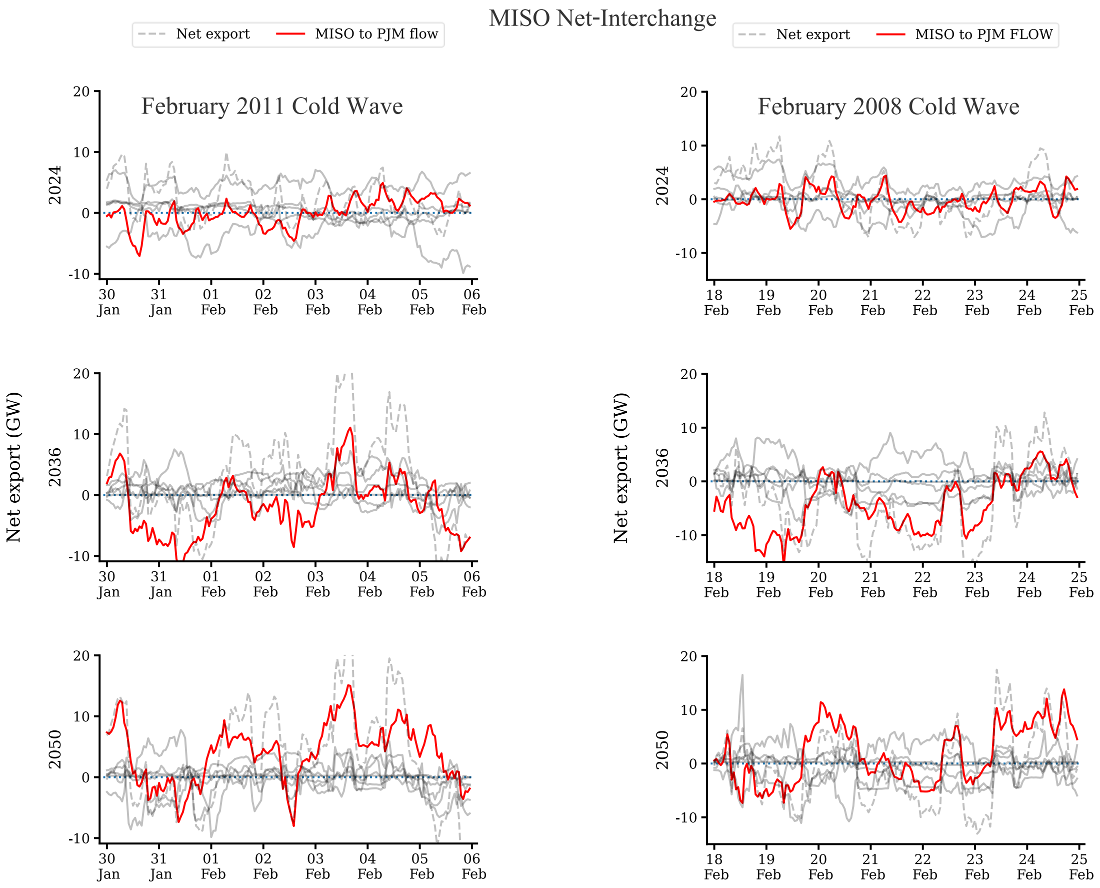
Wind and solar continues to serve ~50% of load after front moves through and load is elevated.

2008 Milder Cold Wave

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



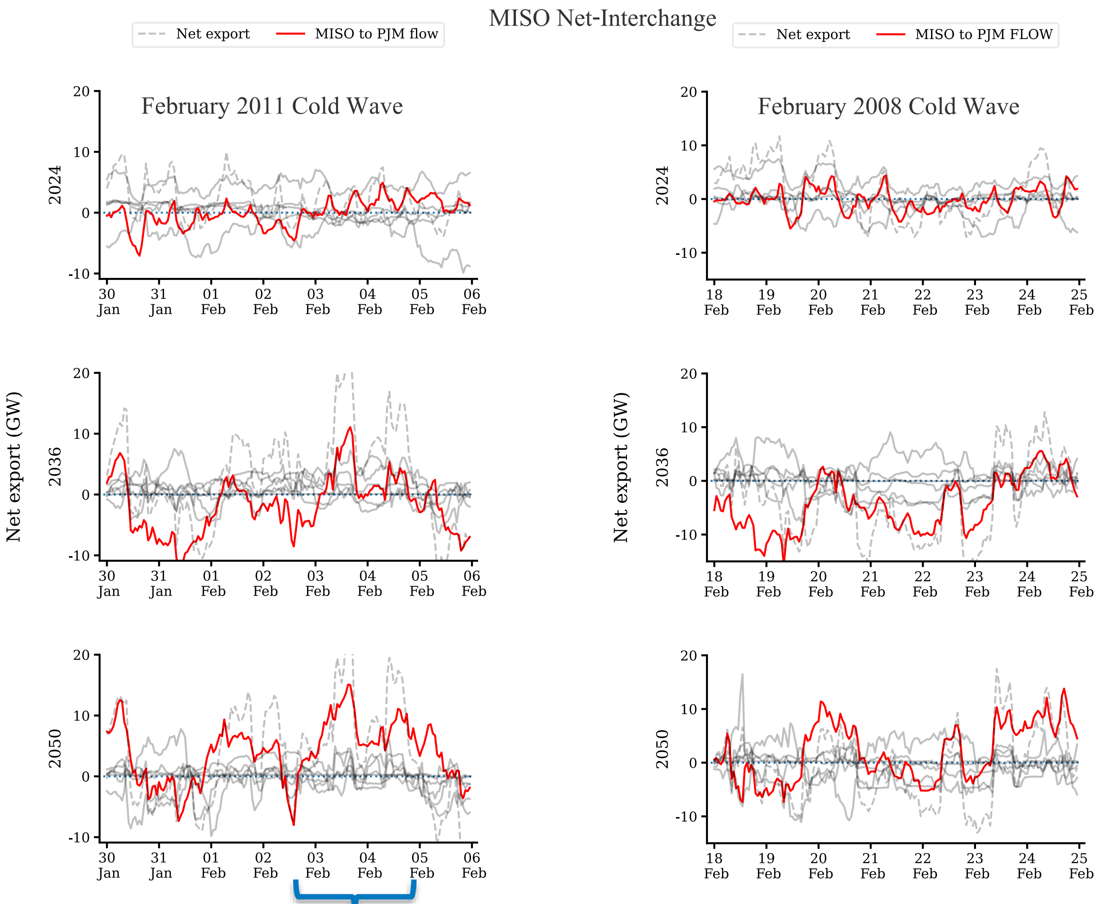
3 Evolution of operations during cold waves driven by wind dynamics



3 Evolution of operations during cold waves driven by wind dynamics

2011 Extreme Cold Wave

Transmission enables usage of geographic diverse wind and solar resources.

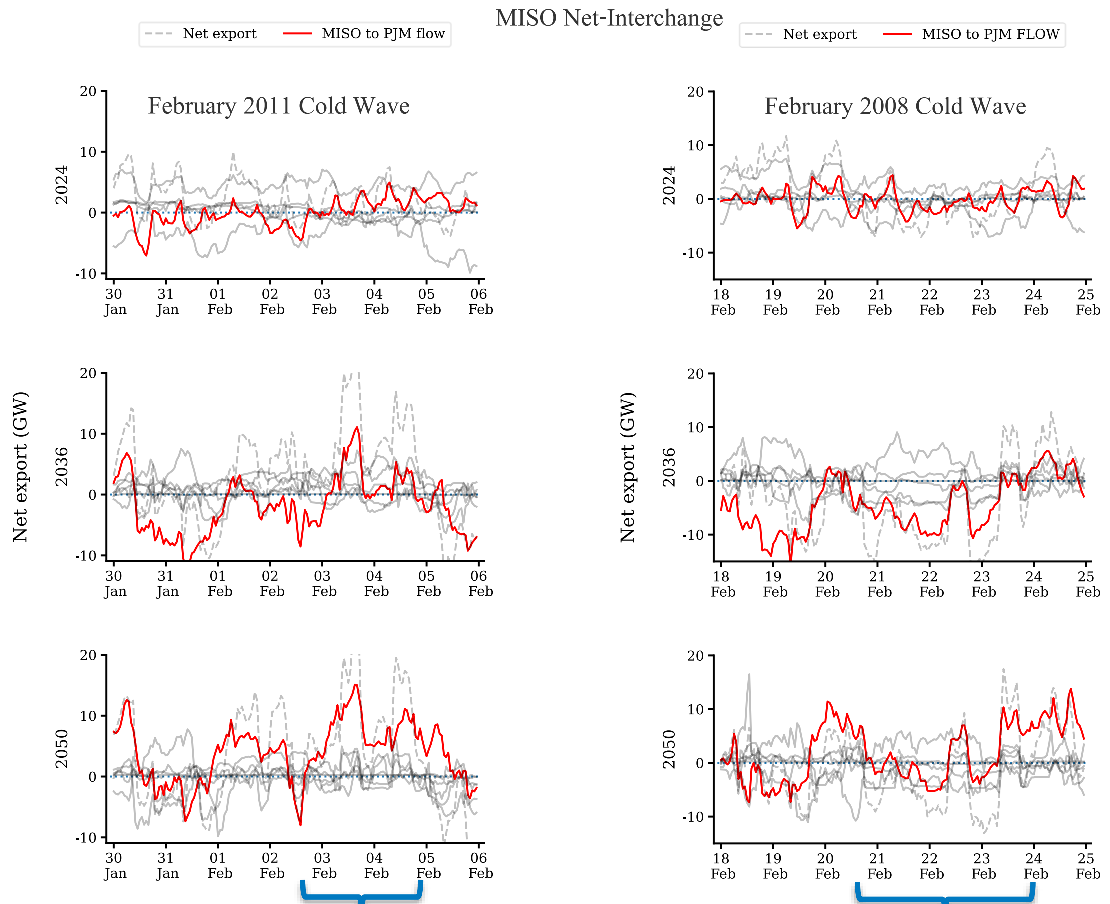


Swing in MISO exports to PJM used to serve SERC and NYISO

3 Evolution of operations during cold waves driven by wind dynamics

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

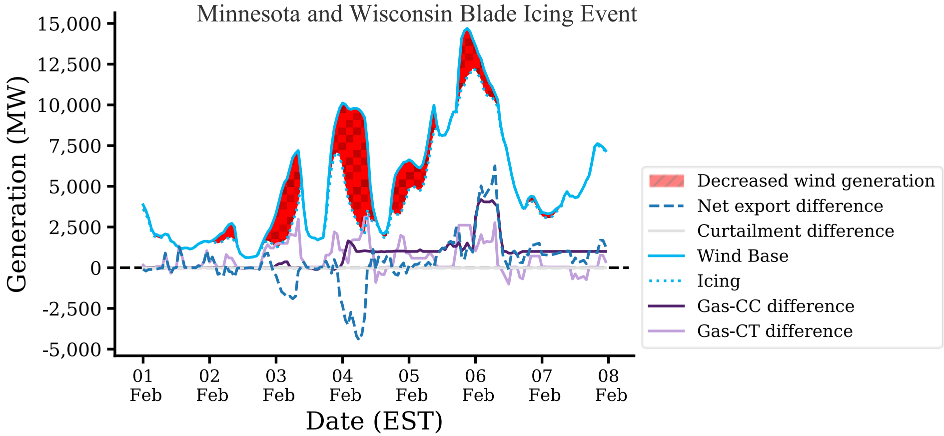
2008 Milder Cold Wave
Transmission <u>also</u> enables uses geographic diverse thermal fleet.

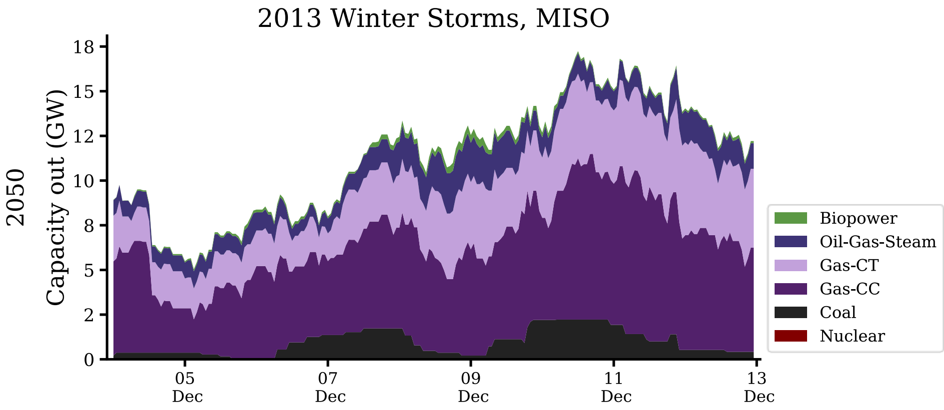


Swing in MISO exports to PJM used to serve SERC and NYISO

Thermal, wind, and PV less impacted in Atlantic states

3 Evolution of operations during cold waves driven by wind dynamics





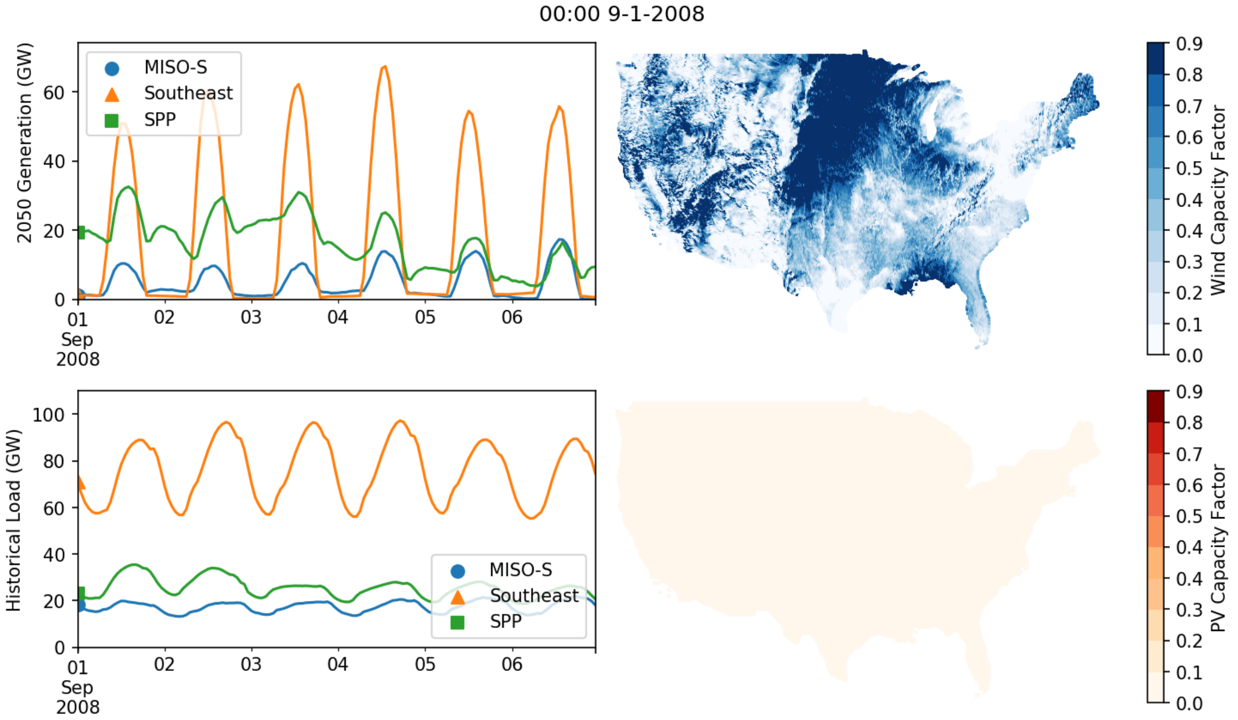
CONUS wide icing and low temperature cutout derates at most 10% of wind generation.

Local impacts can be much larger, with gas and changing interchange to make up the gap.

Gas availability can also be reduced during Cold waves.

Summary and Next Steps

- For cold waves, the spatial and temporal extent of the wind lull that that follows the initial front is uncertain.
  - Operational forecast tends to capture this well, but do resource adequacy studies?
- With our limited sample size, mild cold waves appear to be more concerning.
- Transmission operated much differently to take advantage of diverse resources.
- Next Steps:
  - Increase, wind, solar, hydro, and load data sets to capture more types of weather and longer duration atmospheric trends (e.g., climate change, etc.).
  - Improve operational and resource adequacy modeling of weather events to provide quantitative metrics for planning.



Thank you

joshua.novacheck@nrel.gov

NREL
NATIONAL RENEWABLE ENERGY LABORATORY