NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Extreme Weather Events Project - Final Update

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

Justin Sharp *Sharply Focused LLC*

Paul Donohoo-Vallett *U.S. DOE*

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

Disclaimer

Material includes unpublished preliminary data and analysis that is subject to change

- Purpose of Presentation
  - To obtain external technical review on methods and analysis and promote robust technical discussion within ESIG community
  - Not to convey findings or conclusions to take away or inform activities
  - Not posted in presentation repository for the meeting
- State of Content Presented
  - Data, results, conclusions, and interpretations presented have received limited review by technical experts outside NREL
  - Does not constitute a comprehensive treatment of the issues discussed or specific advice to inform decisions
- Request to Audience
  - Provide review feedback during or after the session
  - Not for public use - do not distribute, quote, or cite

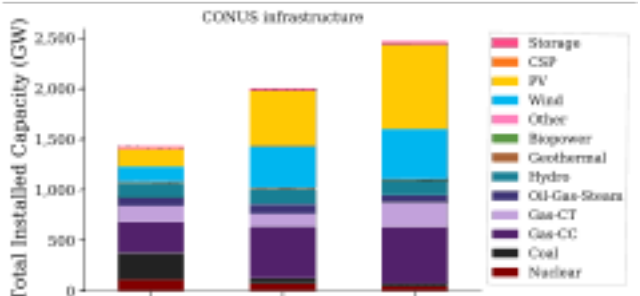
Objectives and Motivation

Identify weather events for deeper meteorological analysis and variable generation resource assessment

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

Model operations of system during events under increasing penetrations of Variable Generation using Production Cost Model

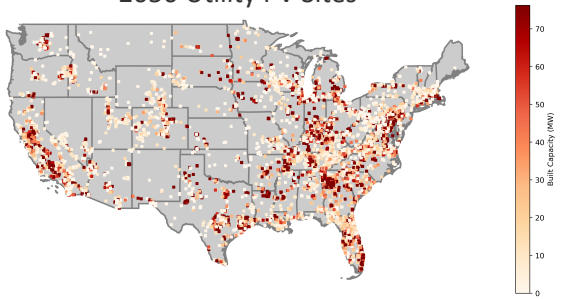
- Three infrastructure scenarios designed by NREL's ReEDS model: 2024, 2036, 2050
- Hydro and wind icing & cold temperature cut-out sensitivities on 2050 infrastructure



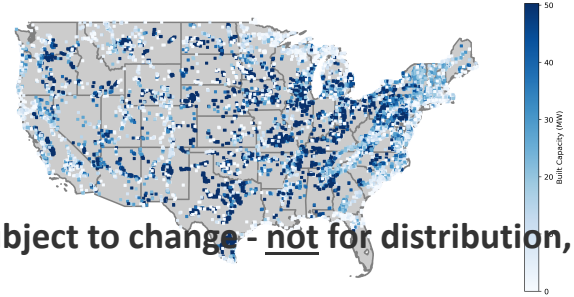
17% 50% 65%

VG Annual Energy Penetration

2050 Utility PV Sites



2050 Wind Sites



Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

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

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

Event Summary with PCM Analysis

News-Worthy

1. **Cold Wave:** 2011 February 1 – 4 **(2024, 2036, 2050 infrastructure scenarios)**
2. **Heat Wave:** 2011 July 19 – 24 **(2024, 2036, 2050)**
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 **(2050 sensitivities)**

Challenges to Planning

1. **Mild Cold Wave with High Net-Load:** 2008 February 20 – 23 **(2024, 2036, 2050)**
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 **(2050 sensitivities)**
4. **Moderate Heat Wave with High Net-Load:** 2010 August 8 – 11 **(2024, 2036, 2050)**
5. **Continental Low Net-Load:** 2011 April 17 **(2050 sensitivities)**
6. Wind Drought: 2010 October 1 – 24

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

Figure Explanation

Blue = Wind

Gold = PV

Green = Load

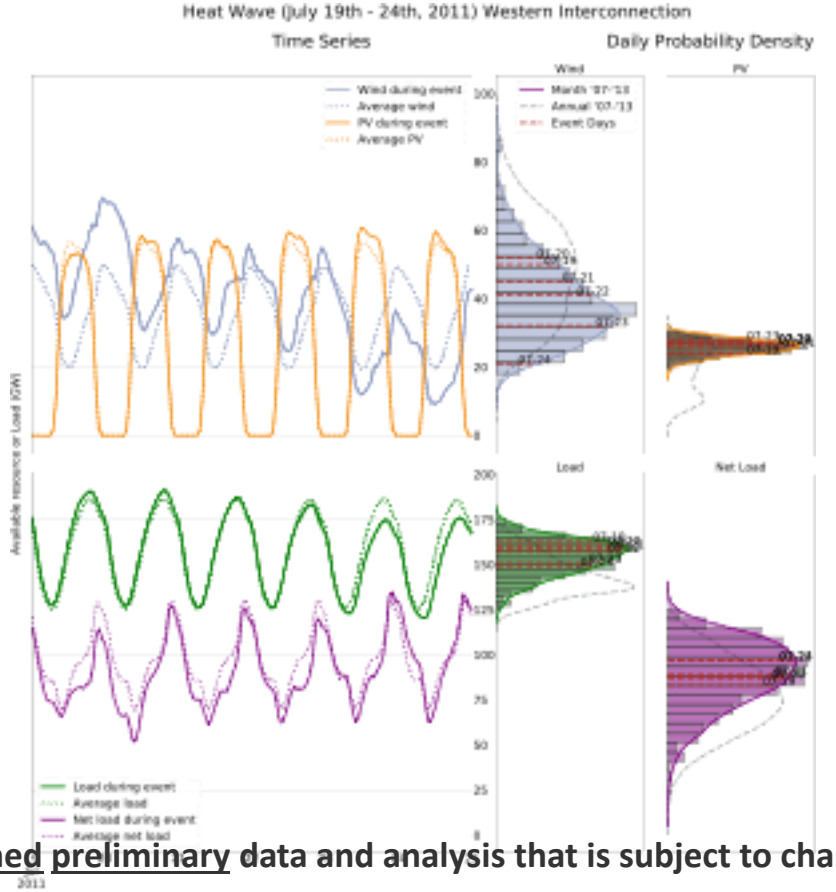
Purple = Net-Load

Solid timeseries line

- Actual generation/load profile during event with 2050 infrastructure

Dotted timeseries line

- Average generation/load profile considering the month around the event for the full dataset (2007-2013) with 2050 infrastructure



Solid distribution

- Distribution of average daily generation/load for the month around the event for the full dataset (2007-2013) with 2050 infrastructure

Dashed distribution

- Distribution of average daily generation/load for all days for the full dataset (2007-2013) with 2050 infrastructure

Red dashed lines

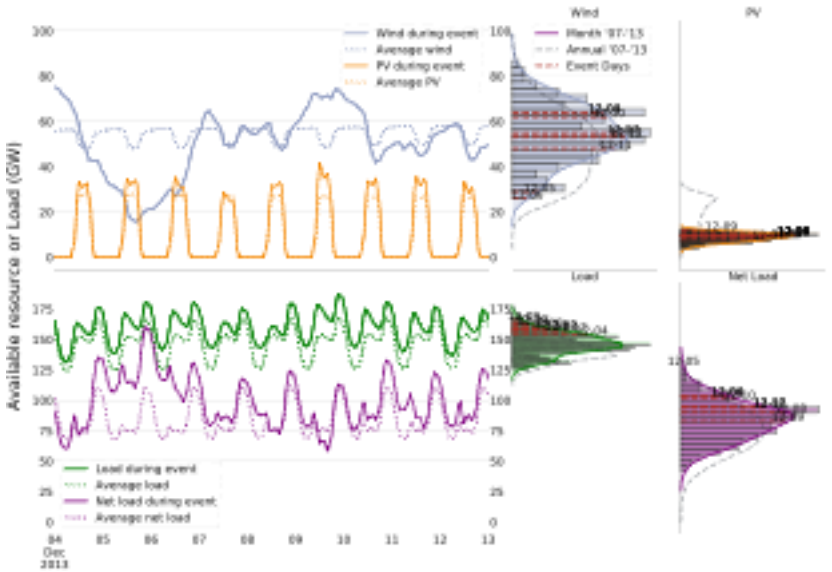
- Location of event days within the distributions

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

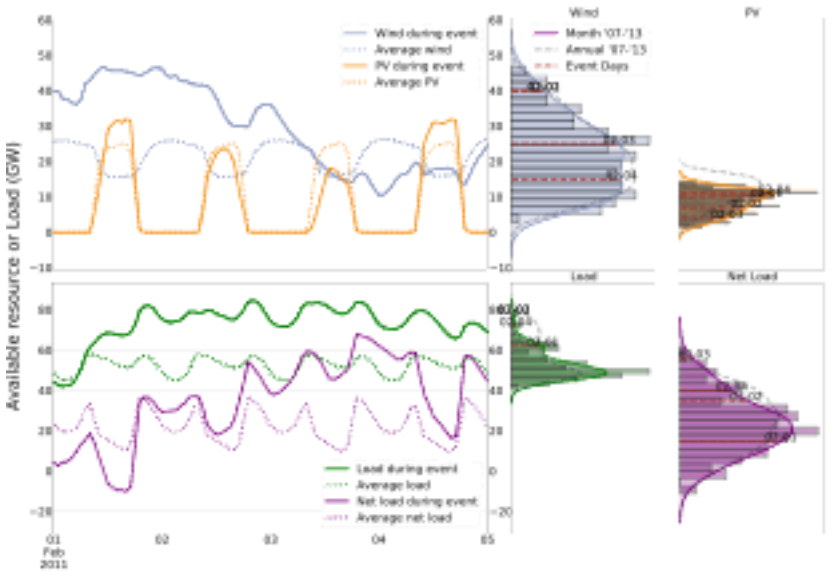
Key Findings

1 Variable generation tends to be available during “News-worthy” events of today

Winter Storms December 2013 – Western Interconnection



Cold Wave February 2011 – ERCOT

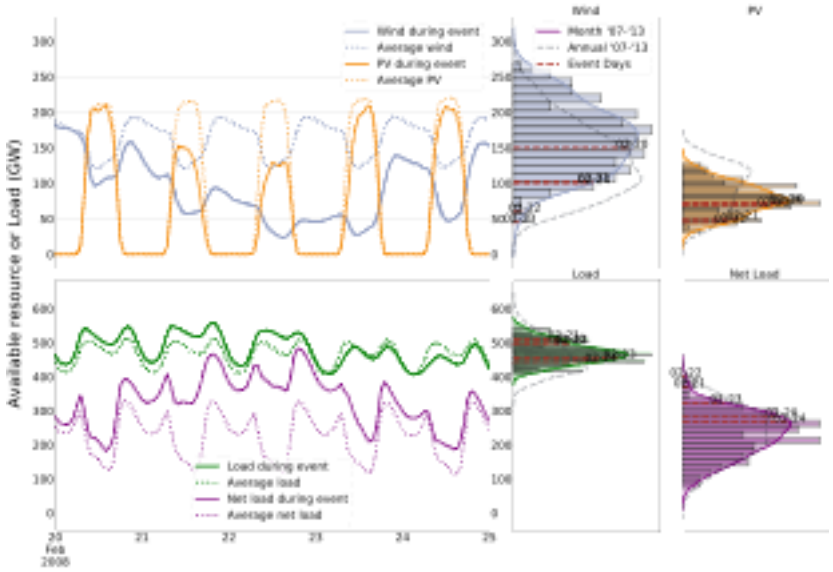


Events that drive-up load are not made worse by increased VG penetration. Exceptions exist, but they tend to be short lived.

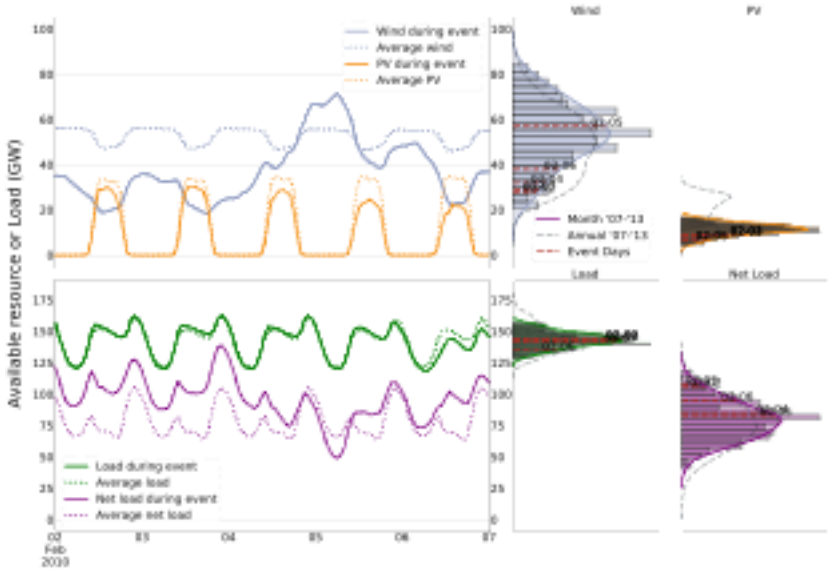
Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

2 Benign weather can produce periods of low wind and solar

Mild Cold Wave February 2008 – Eastern Interconnection



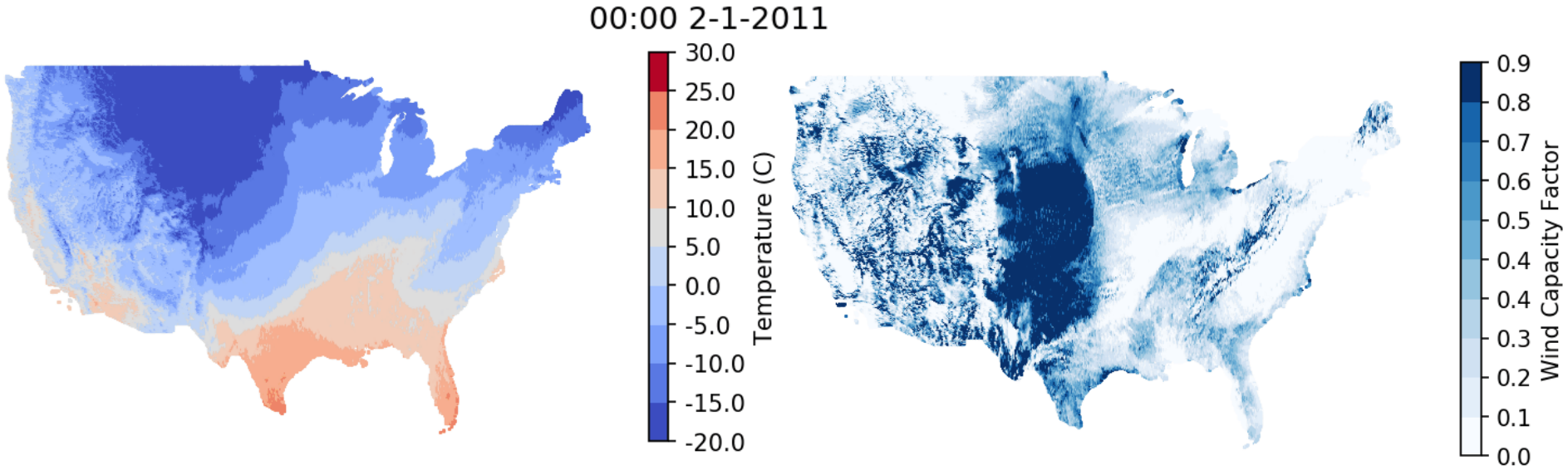
Mild Cold Wave February 2010 – Western Interconnection



Many periods of the highest annual and seasonal net-load are driven by uninteresting weather patterns.

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

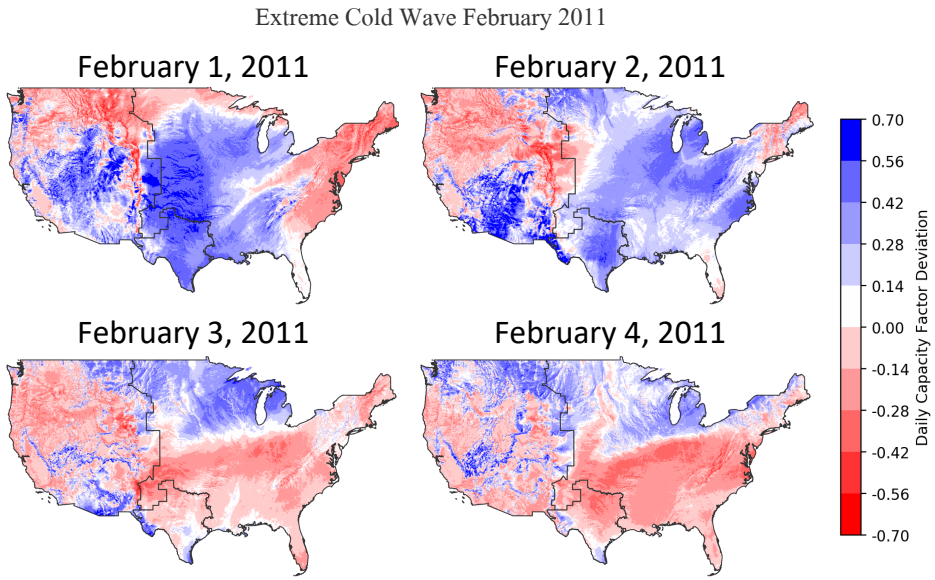
3 Evolution of operations during cold waves driven by wind dynamics

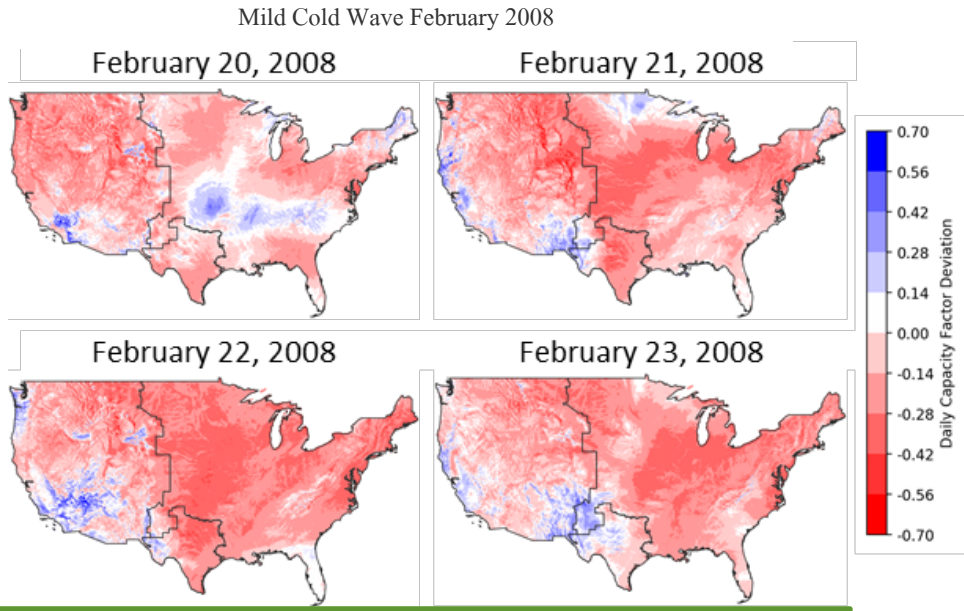


Cold waves (especially in the Eastern and Texas Interconnections) come with high wind resource as cold pushes down the Front Range of the Rocky Mountains.

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

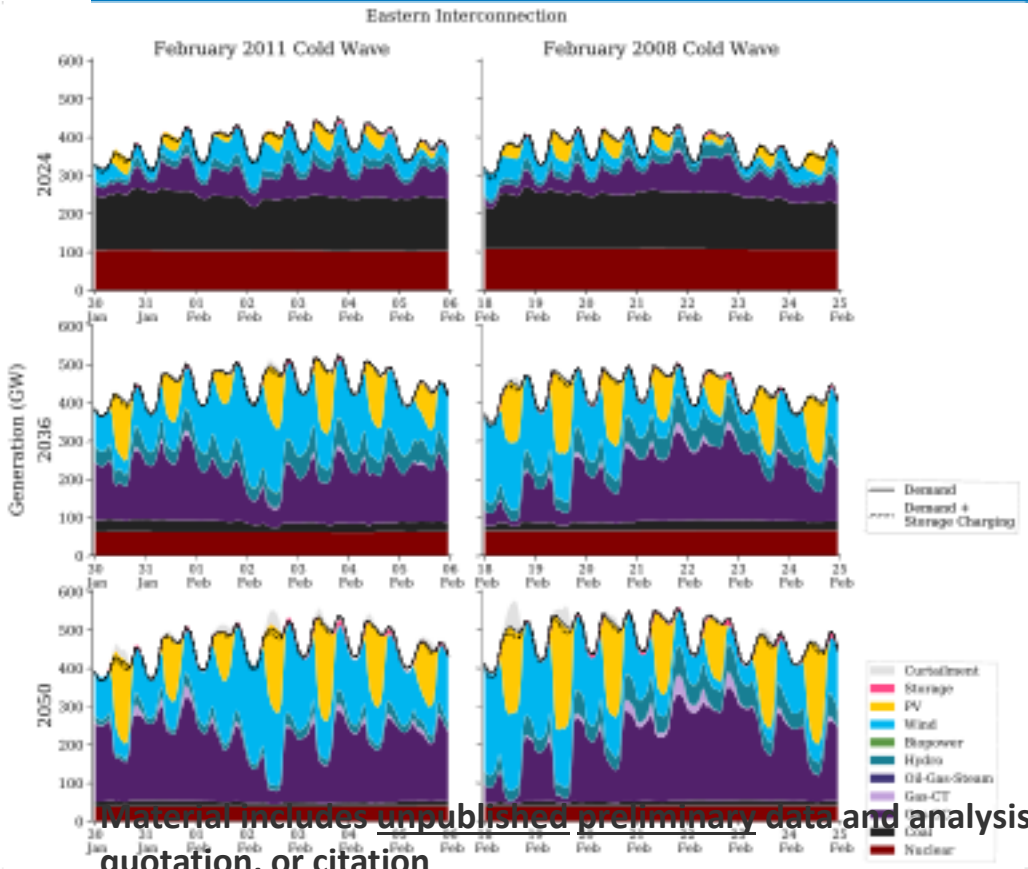
3 Evolution of operations during cold waves driven by wind dynamics

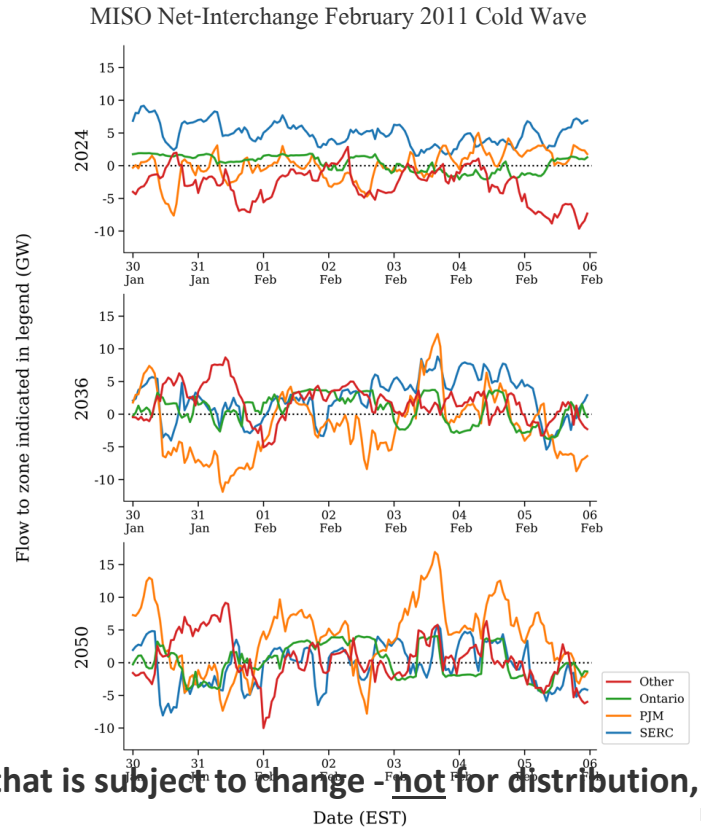




The challenge for operators and planners are the days that follow. As the cold stays, the wind dies down. How much is uncertain, but our 2007 – 2013 dataset suggests milder cold waves lead to lower wind resource in the days following the cold wave.

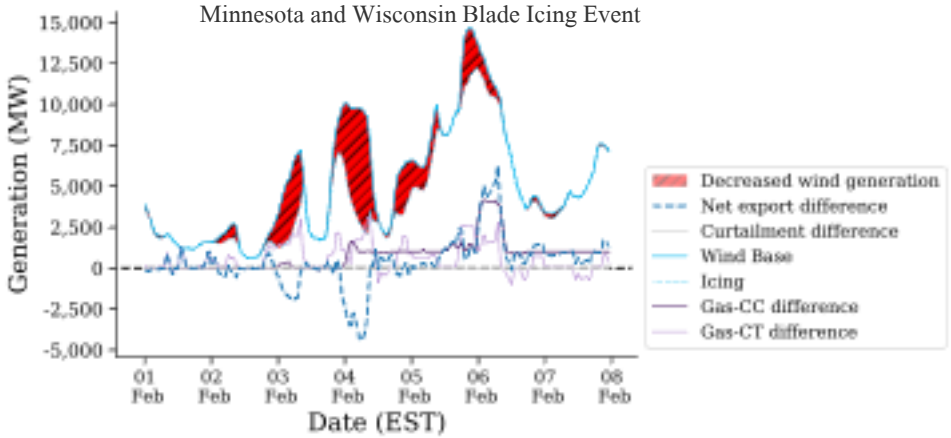
3 Evolution of operations during cold waves driven by wind dynamics

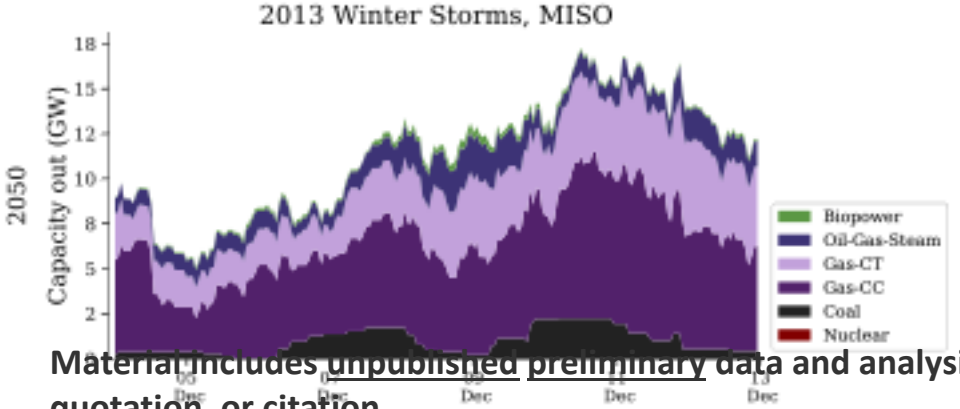




Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

3 Evolution of operations during cold waves driven by wind dynamics





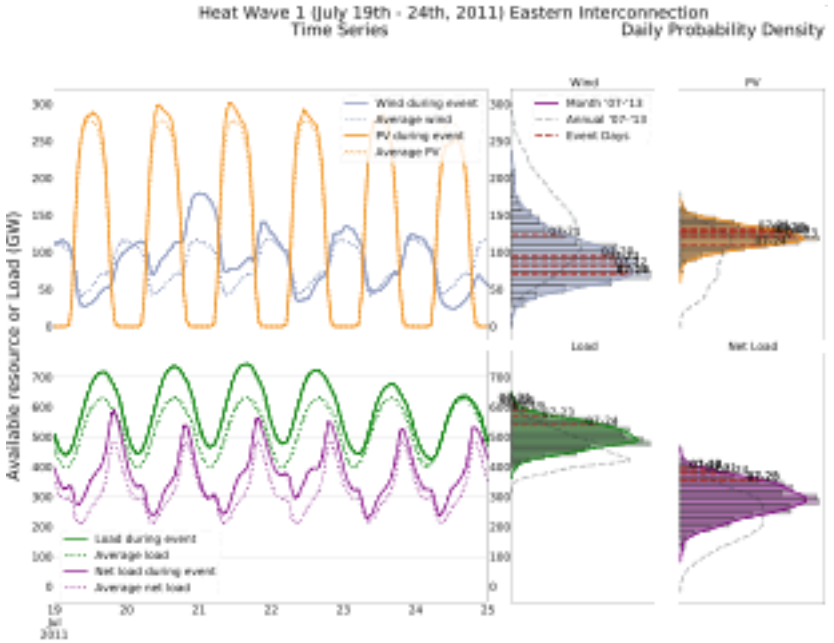
CONUS wide icing and low temperature cutout derates at most 10% of wind generation.

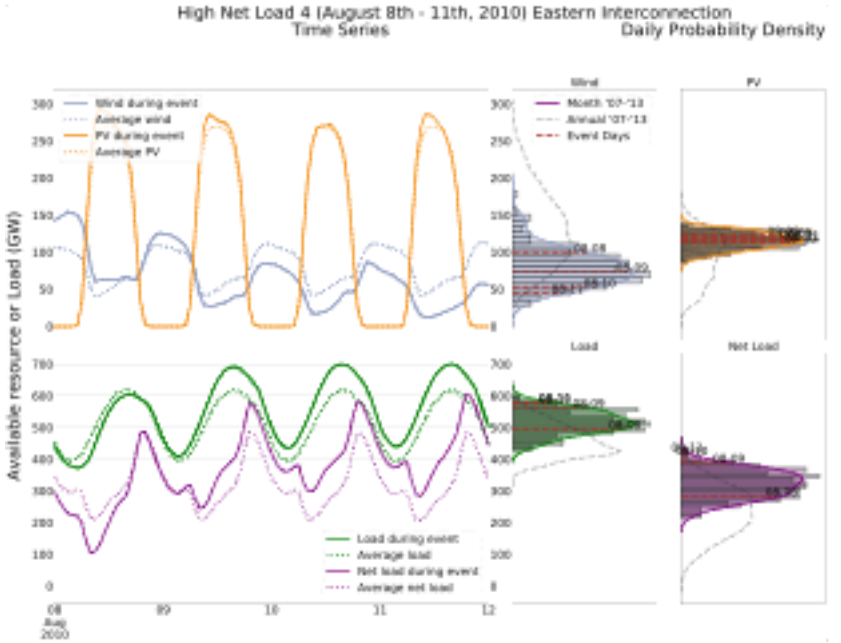
Local impacts can be much larger, with gas and changing interchange to make up the gap.

Gas availability can also be reduced during Cold waves.

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

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



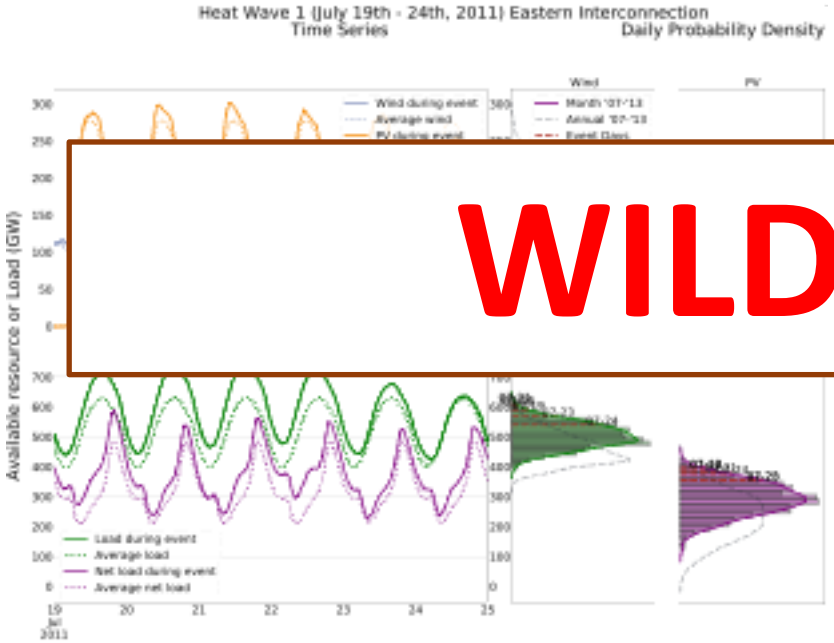


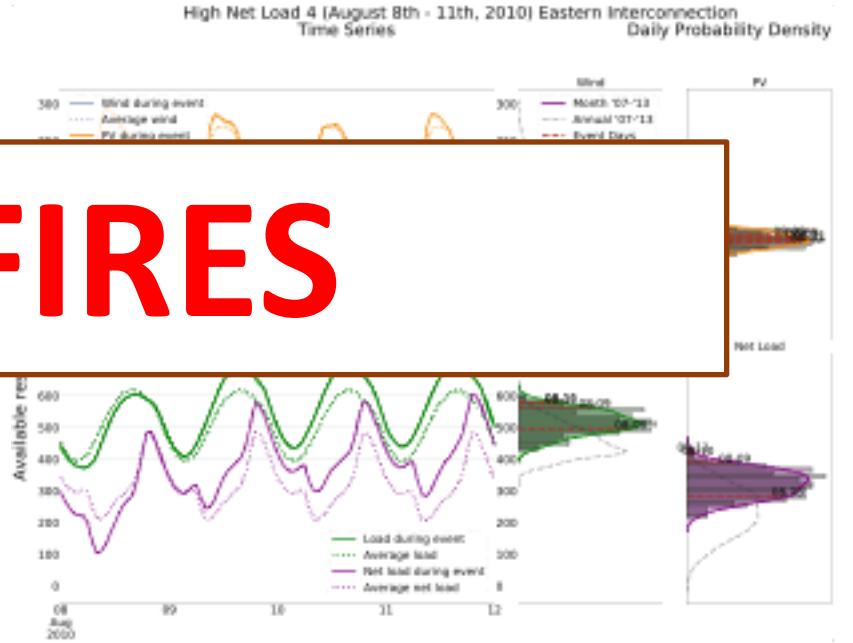
Highest EI load days in dataset are mitigated by average wind and PV resource.

High, but not extreme high, EI load become extreme high net-load days with below average wind but average PV resource

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

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





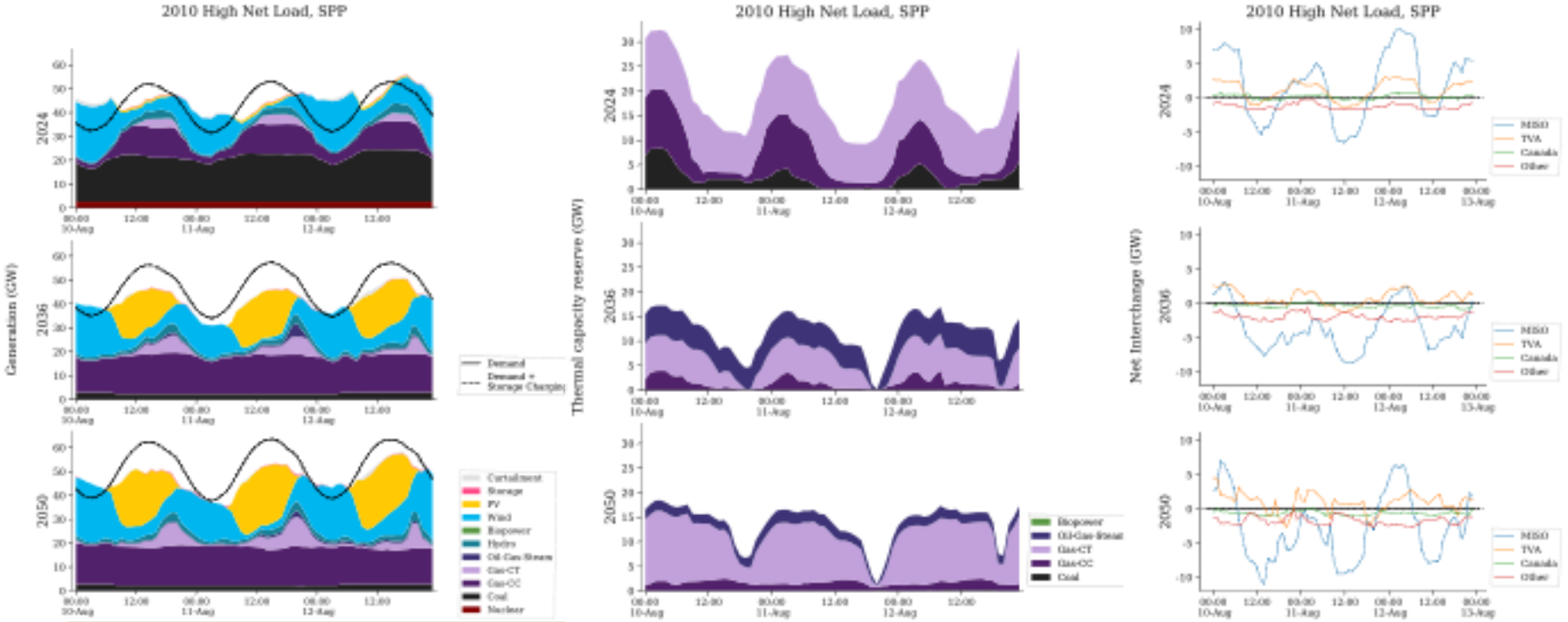
WILDFIRES

Highest EI load days in dataset are mitigated by average wind and PV resource.

High, but not extreme high, EI load become extreme high net-load days with below average wind but average PV resource

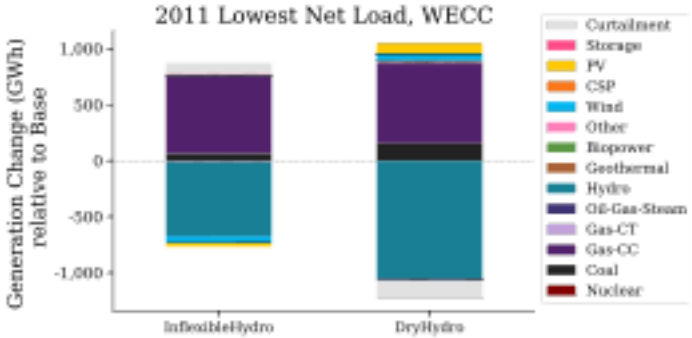
Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

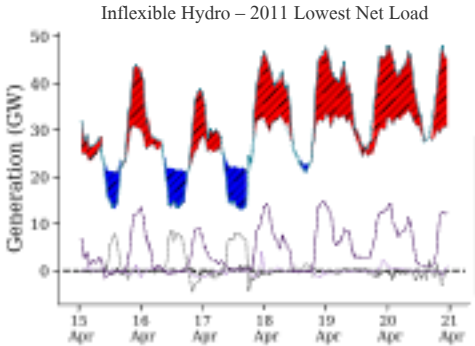
5 Flexible infrastructure can enable planning for geographic diversity

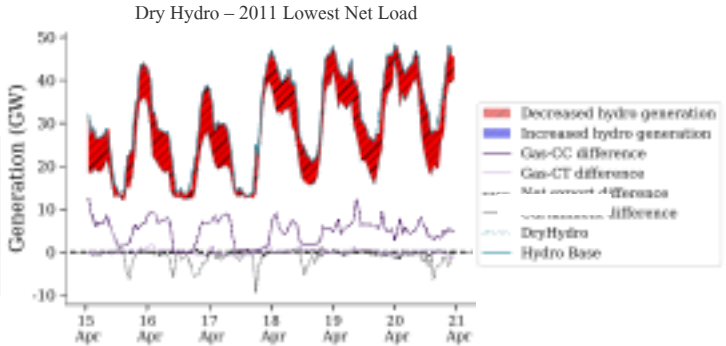


SPP wind as low 5% fleetwide capacity factor midday on August 11 but recovers to 22% by peak net-load. Quick start CTs and flexible transmission operations ensure adequacy.

6 Hydro availability and flexibility can mitigate weather event impact







Inflexible Hydro leads to a 17% (April 2011) and 5% (Winter Storms 2013) increase in production cost

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation

Key Finding Summary

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

2. Benign weather can produce periods of low wind and solar

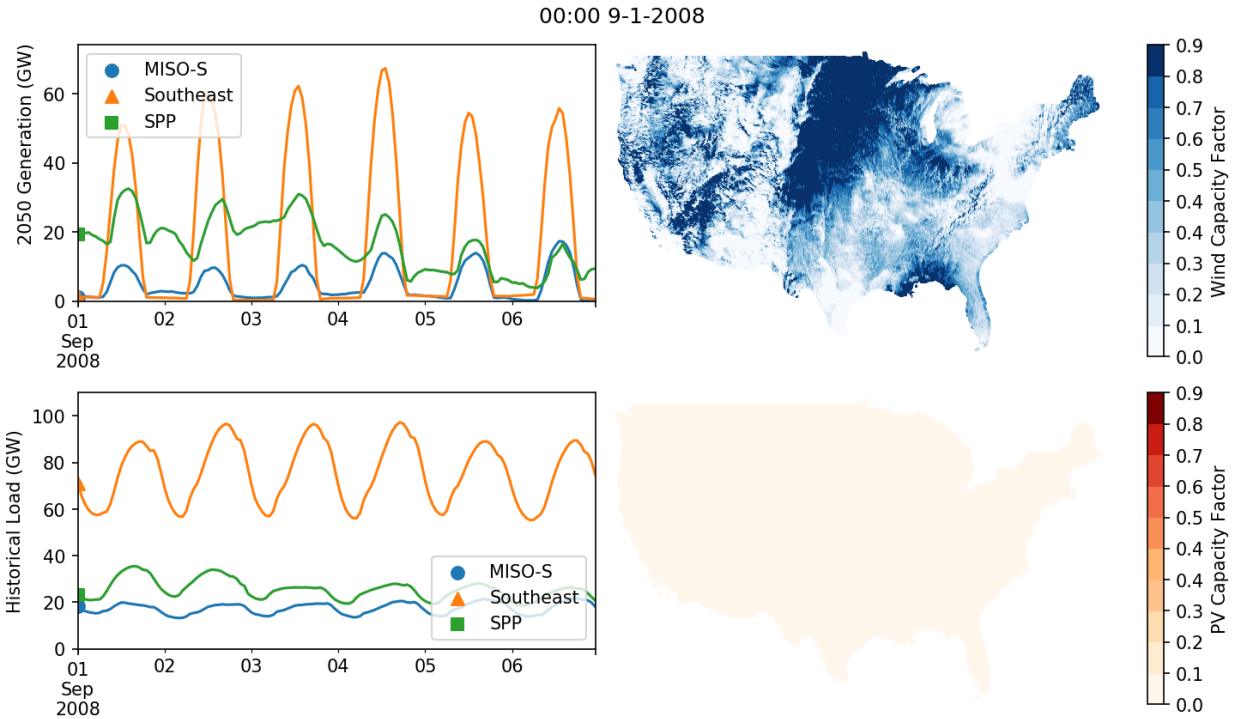
3. Evolution of operations during cold waves driven by wind dynamics

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

Material includes unpublished preliminary data and analysis that is subject to change - not for distribution, quotation, or citation



Thank you

joshua.novacheck@nrel.gov

NREL
NATIONAL RENEWABLE ENERGY LABORATORY