



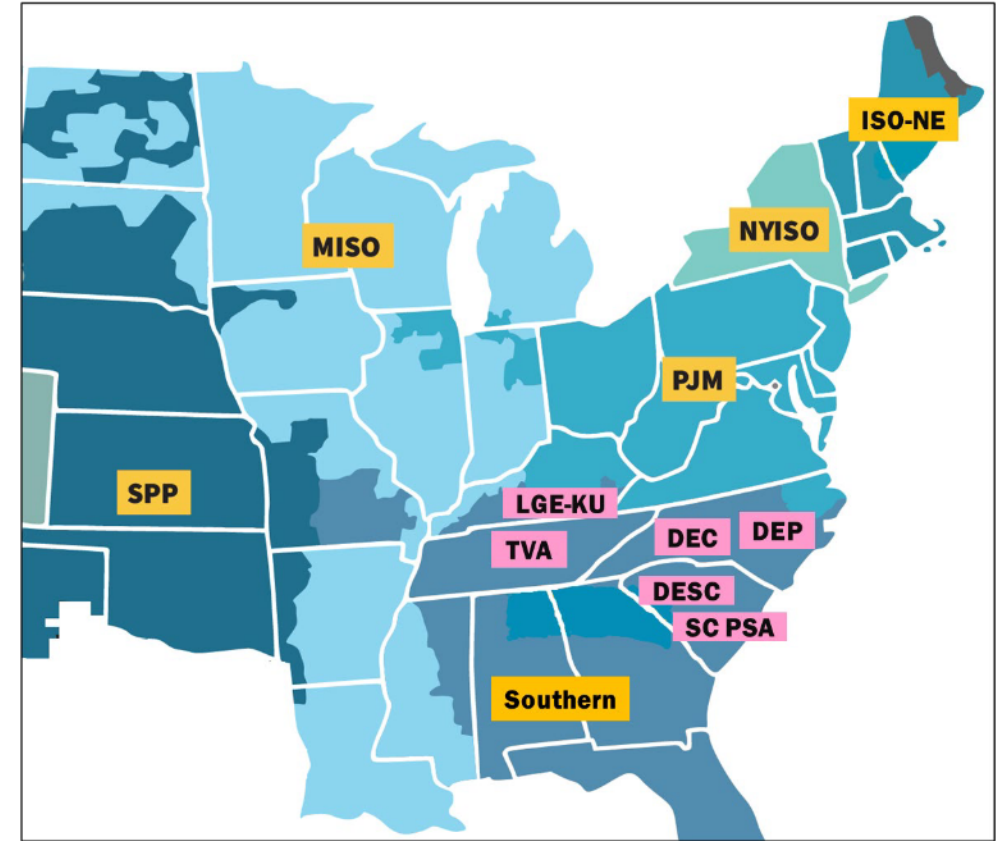
December 2022 Winter Storm Elliott Grid Operations: Key Findings and Recommendations

FERC, NERC, and Regional Entity Joint Staff Inquiry
September 21, 2023



Winter Storm Elliott's Effects on the Bulk-Power System During Worst Conditions, December 23-24, 2022

- Unprecedented electric generation outages coincided with winter peak electricity demands (i.e., winter peak loads)
- Several Balancing Authorities (BAs) in the Eastern U.S. declared Energy Emergencies, and to maintain electric grid reliability, some in the southeastern U.S. ordered firm load shed at different times, in total exceeding **5,000** MW during the extreme cold weather:
 - Tennessee Valley Authority (TVA) BA: nearly eight hours total and at its worst point, **3,000** MW
 - Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) BAs: approximately three hours total and at worst points totaled over **1,900** MW
 - Louisville Gas and Electric – Kentucky Utilities (LGE-KU) BA: approximately four hours total and at its worst point, over **300** MW
 - Dominion Energy South Carolina (DESC) and South Carolina Public Service Administration/Santee Cooper (SC PSA) BAs: at worst point totaling **94** MW (DESC) and **86** MW (Santee Cooper), for 9 and 17 minutes, respectively



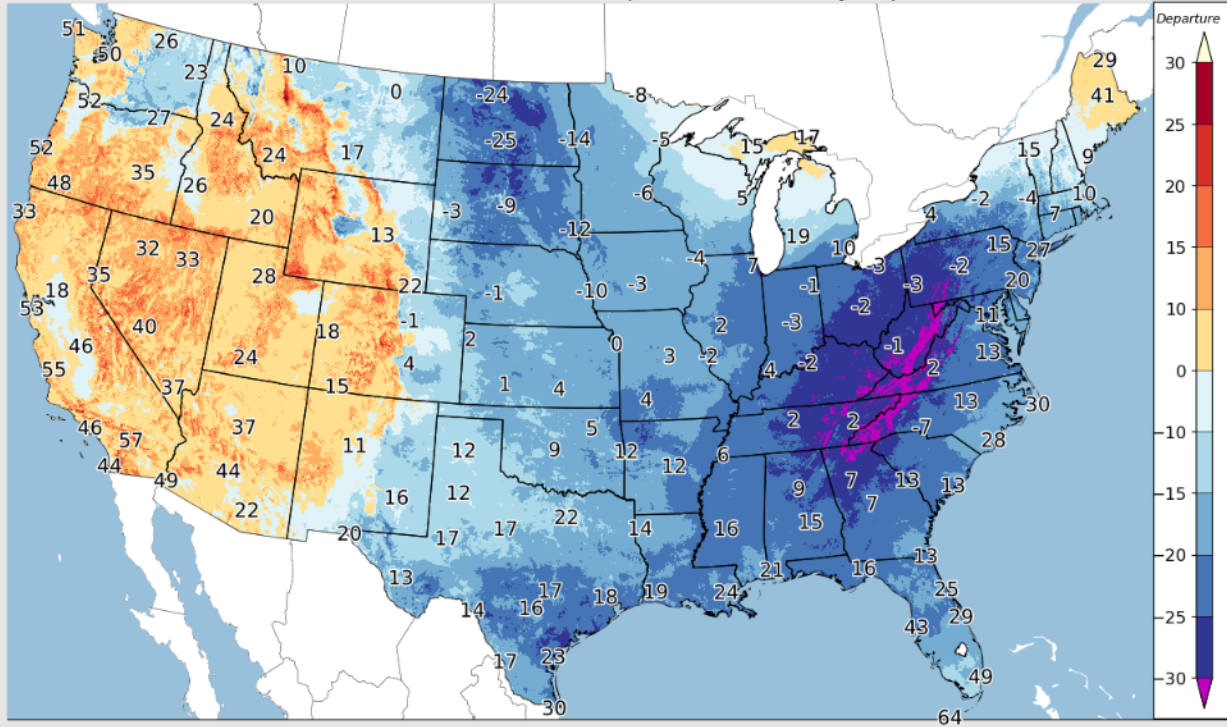
PJM, Southern, MISO, SPP, and ISO-NE BAs also declared Energy Emergencies, but conditions improved, sparing them from the need to order firm load shed.



Unplanned Generation Outages Increased to Historic Levels

Departure from Average Daily Minimum December 24, 2022

December 24, 2022, Minimum Temperatures and Daily Departure (F)



(Source: NOAA)

• The Event is the **FIFTH** in the past **11** years in which unplanned cold weather-related generation outages jeopardized bulk-power system reliability:

- 2011 - 29,700 MW
- 2014 - 19,500 MW
- 2018 - 15,800 MW
- 2021 - 61,300 MW
- **2022 - 90,500 MW**

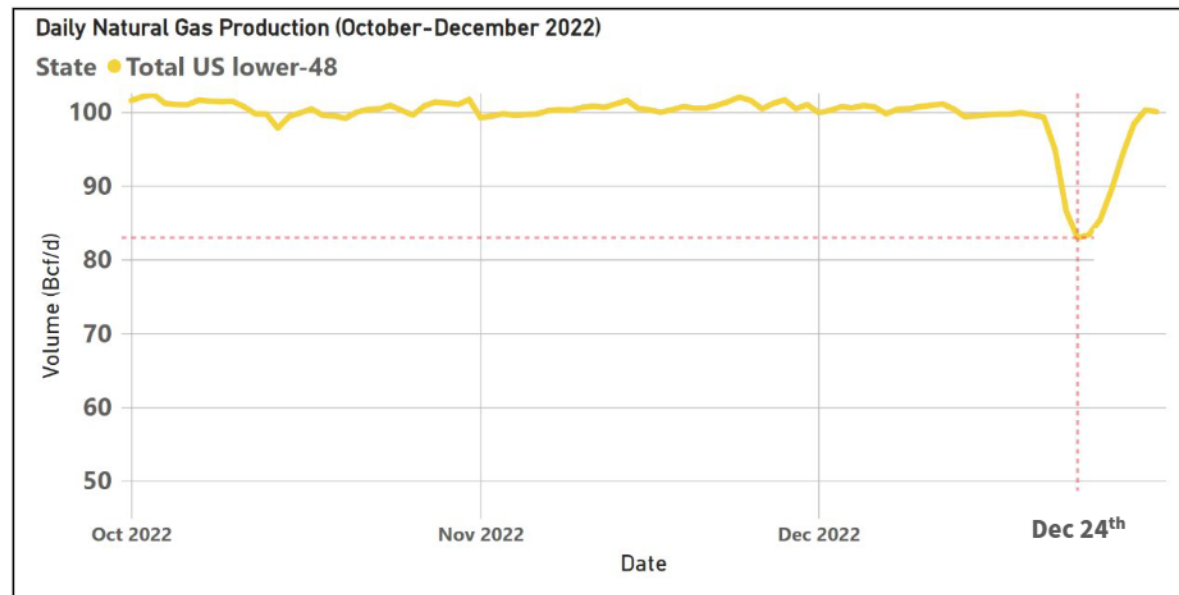
The **90,500 MW** of incremental coincident unplanned outages during Winter Storm Elliott **represented 13%** of the U.S. portion of the anticipated resources* in the Eastern Interconnection.

(*Based on data from NERC 2022-2023 Winter Reliability Assessment)

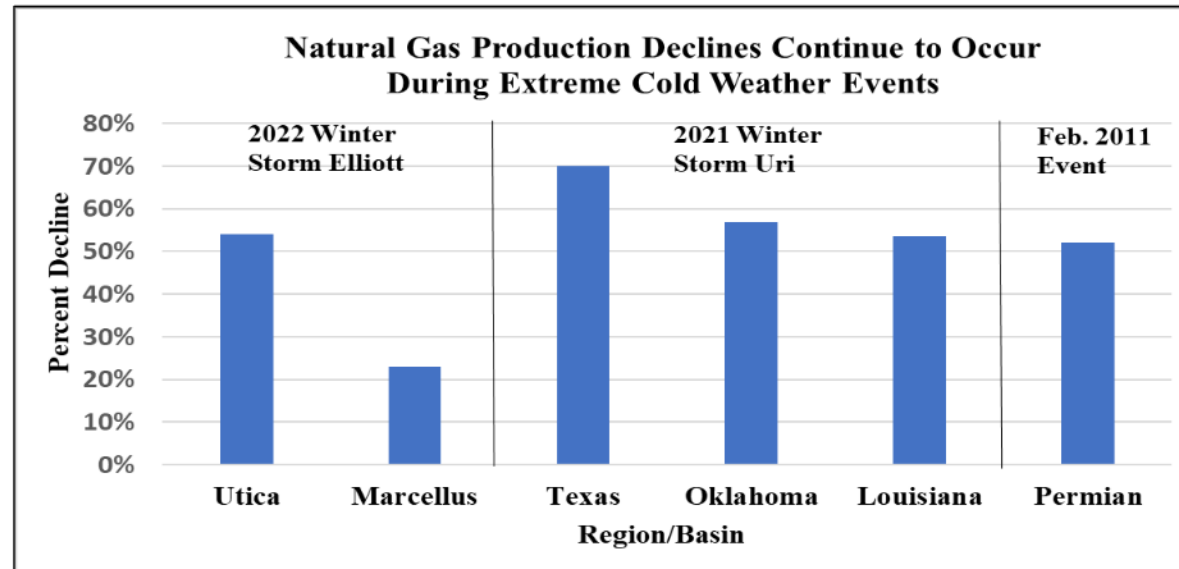


Gas Production Declined

- “Dry natural gas production in the Lower 48 states dropped to a low of 82.5 Bcf on **December 24**, a **16 percent decrease** (16.1 Bcf/d) from December 21...” (EIA)
- Gas production experienced the greatest declines in the Marcellus and Utica Shale formations, where it dropped by 23-54% during The Event. (S&P)
 - “In 2022, the Appalachia region in the Northeast produced more natural gas than any other U.S. region, accounting for 29% of U.S. gross natural gas withdrawals (or 34.6 Bcf/d).” (EIA)

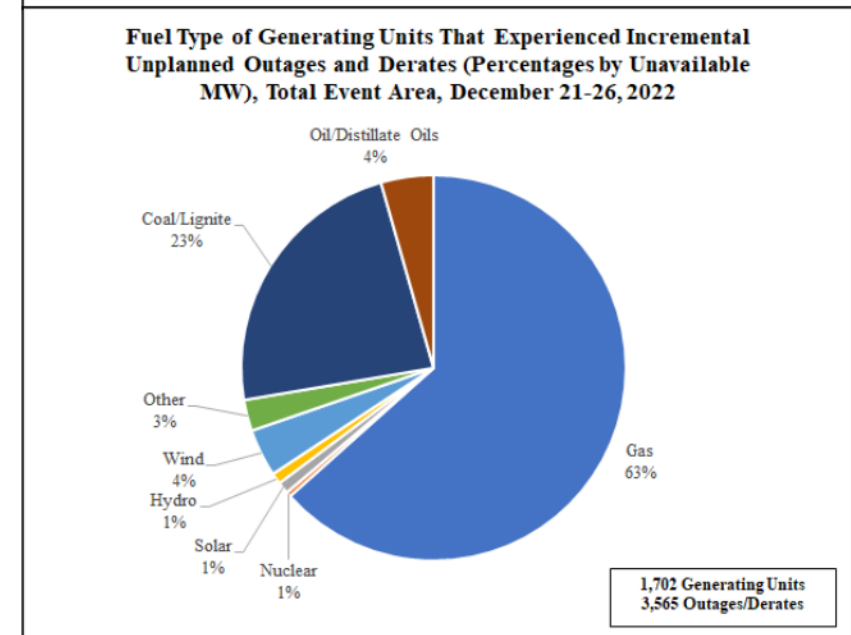
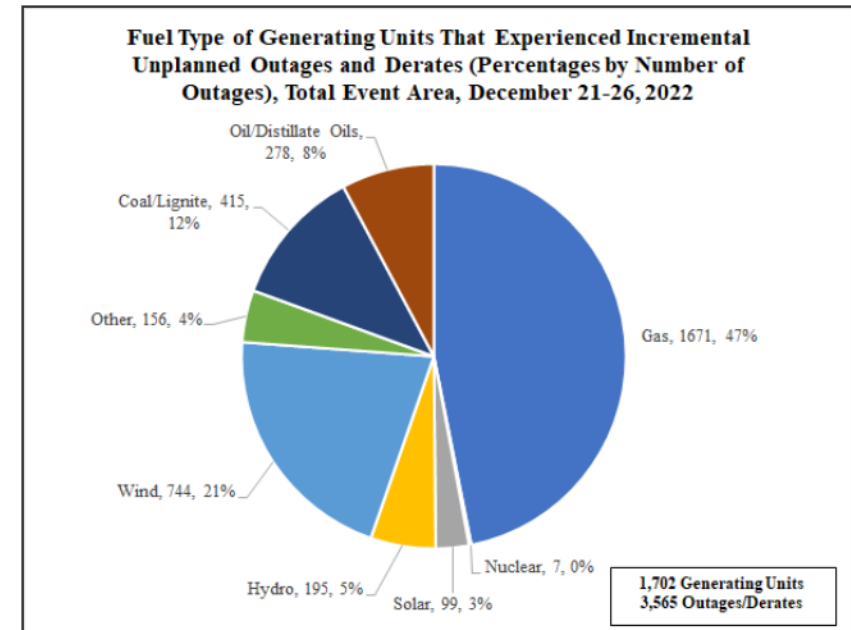
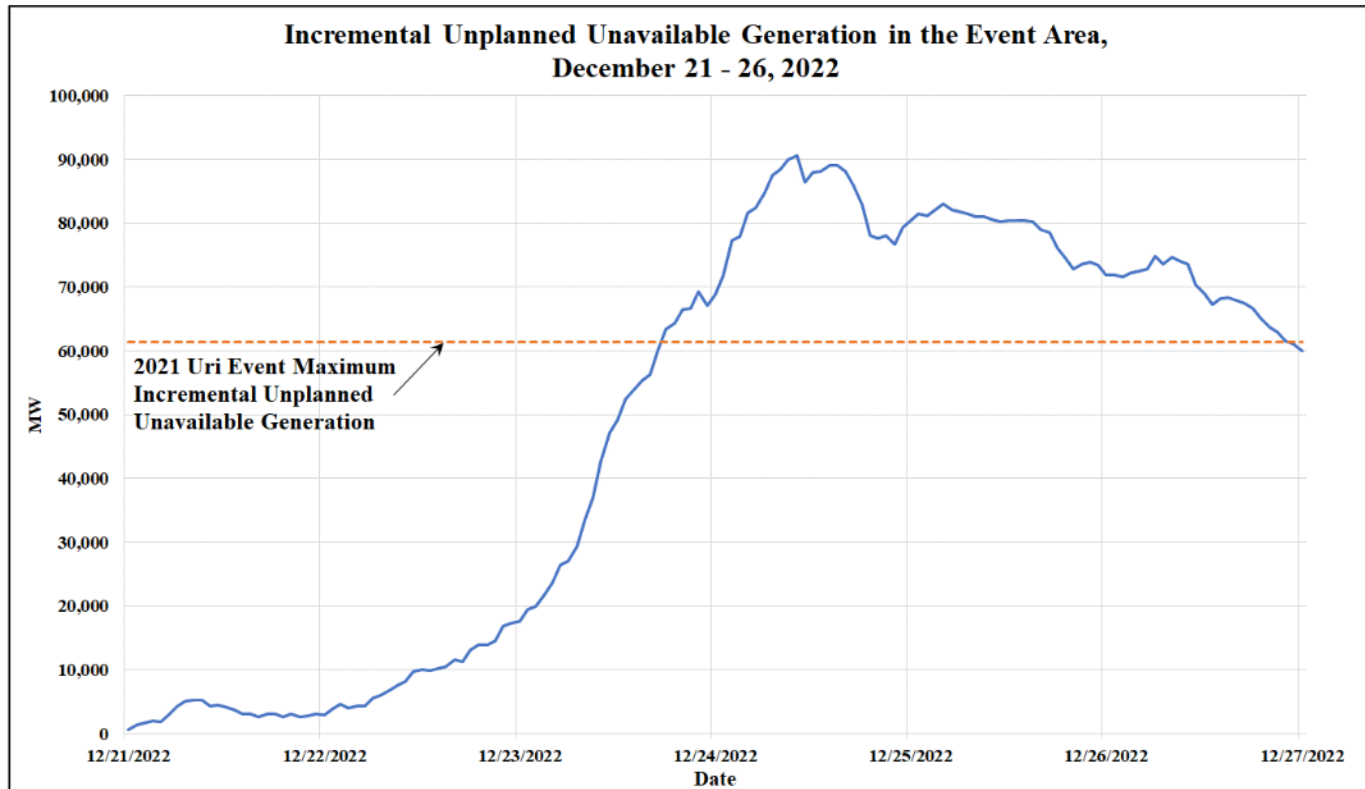


(Source: S&P Global Commodity Insights)



Unprecedented Electric Generation Outages Due to Cold Weather

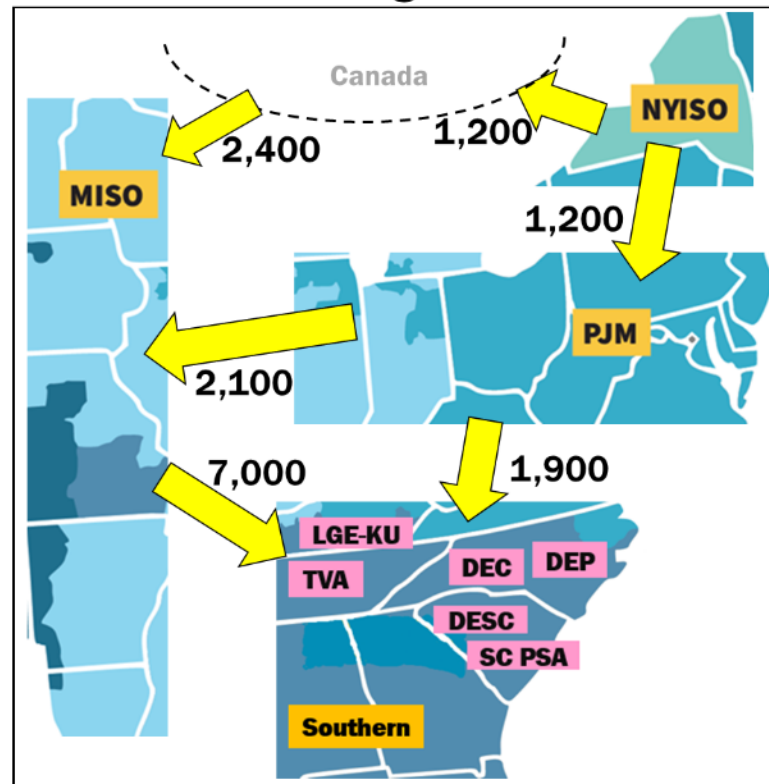
- **1,702** individual generating units experienced **3,565** outages, derates, or failures to start, of which **825** units were natural gas-fired generators.



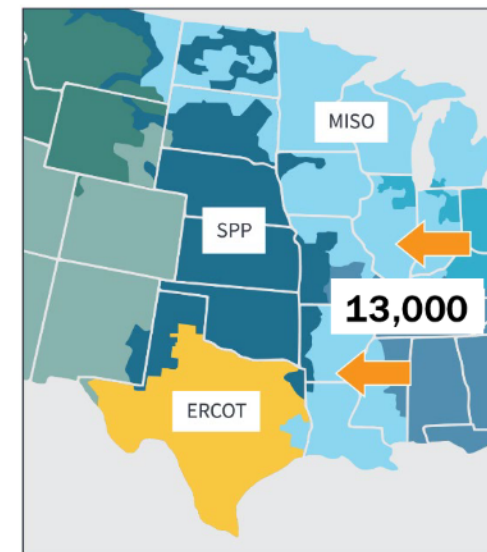
Higher Transmission Flows Resulted in Constraints - Mitigated by Electric Grid Operators' Actions

- PJM, MISO, TVA, Southern, and SPP used generation redispatch and post-contingency mitigation procedures to alleviate most transmission constraints.
- PJM curtailed a power transfer to TVA to resolve a real-time constraint on Dec. 23.
- MISO declared two Local Transmission Emergencies (LTEs) (one was declared to access additional hydro capacity); neither LTE resulted in customer interruptions, Interconnection Reliability Operating Limits (IROLs), or load shed.

Approximate Power Flows (MW), December 24, 2022
Hour Ending 5 A.M. EST



Comparison:
2021 Winter Storm Uri
East-to-West Power Flow (MW) February 15, 2021

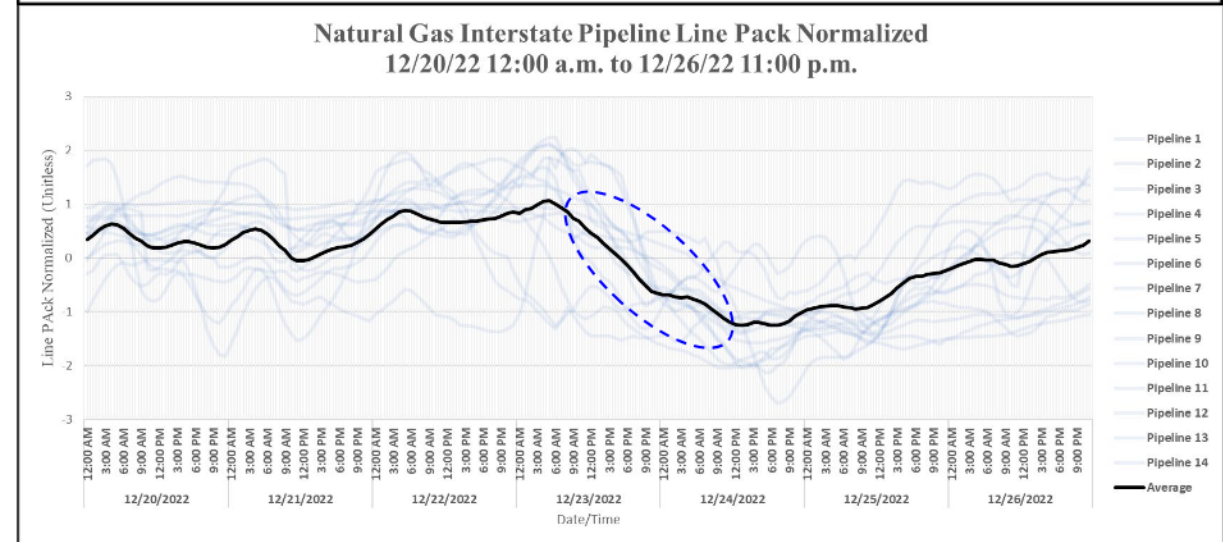
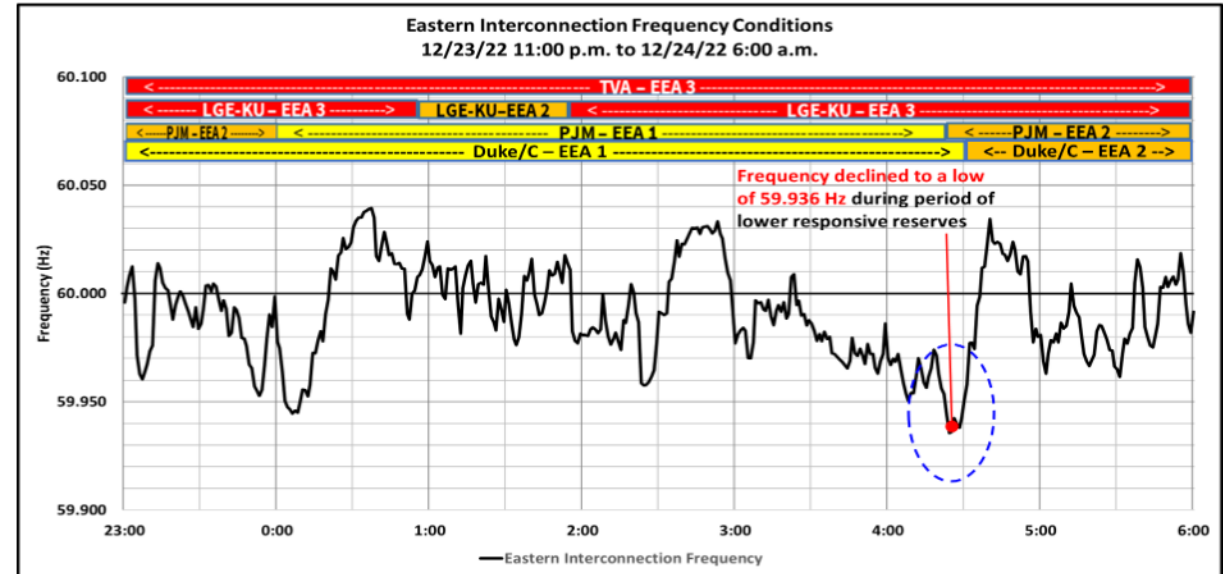


Most power transfers/imports that were curtailed were not due to transmission constraints during the Elliott Event.

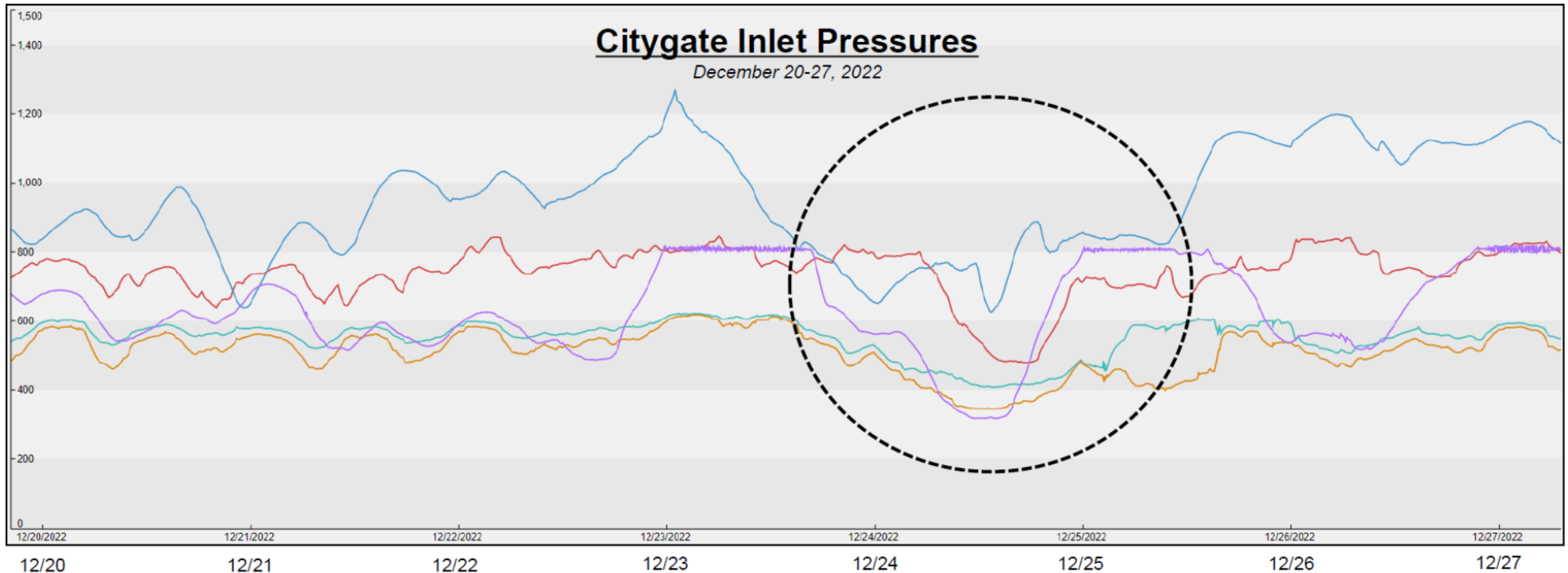


Real-Time Operators' Actions

- Electric grid operators: mitigated Eastern Interconnection Frequency (indicator of grid “health”) excursions during periods of lower responsive reserves by implementing emergency actions (reduced demand).
- Natural gas pipeline operators: managed system line pack and storage to maintain system integrity despite decreasing receipts on multiple pipelines and increased demand.



Con Edison (ConEd) Gas Operations - 12/24/22 Reliability-Threatening Delivery Pressure Decreases Across all Pipelines



(Source: Con Edison)



This information was prepared by the staff of the Federal Energy Regulatory Commission in consultation with staff from the North American Electric Reliability Corporation and its Regional Entities. This information does not necessarily reflect the views of the Commission.

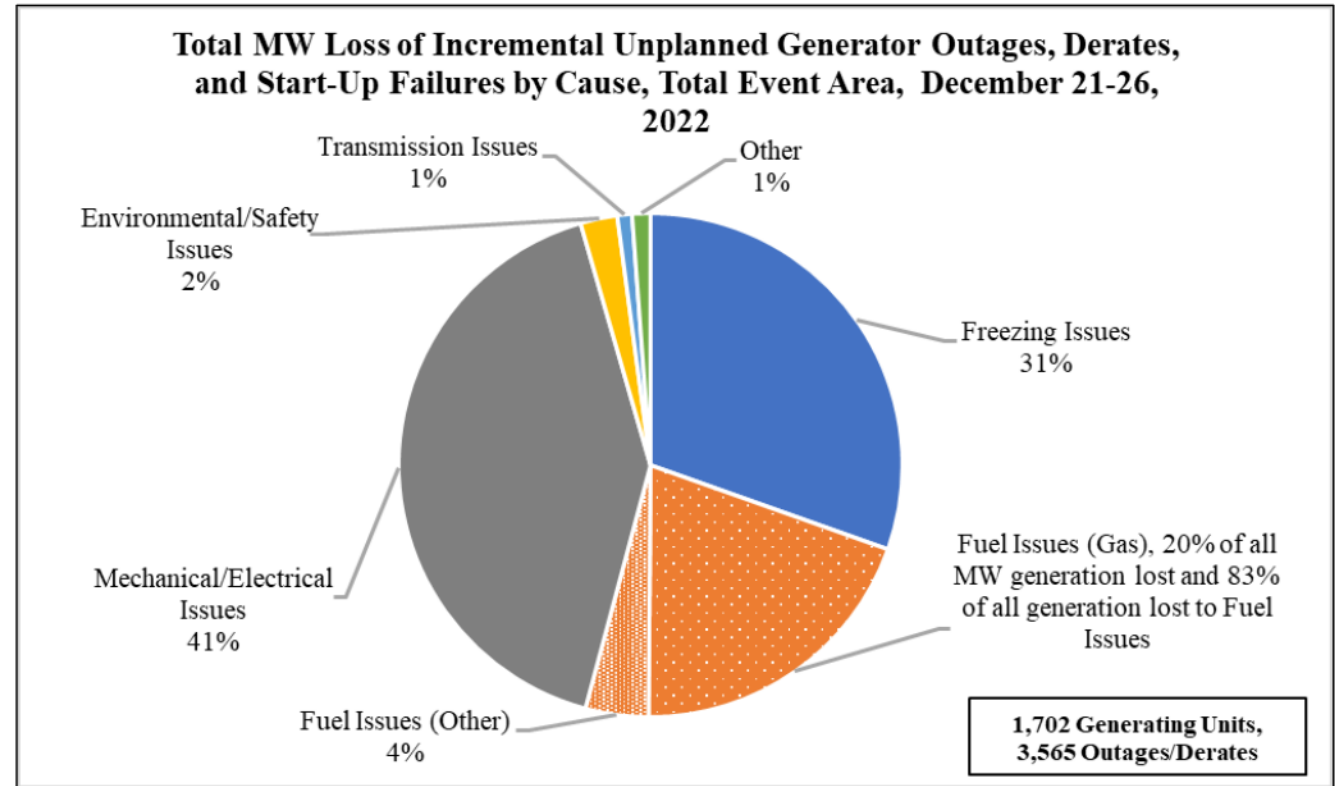
ConEd Natural Gas Operations - 12/24/22 Reliability Threatening Delivery Pressure Decreases Across all Pipelines (cont'd.)

- Pipeline pressures at the city gate for ConEd of NY, the natural gas Local Distribution Company for Manhattan, declined precipitously during the morning of December 24. At noon on 12/24/22, ConEd learned on a call with the four interstate gas pipeline companies serving its city gate that their “storage withdrawals were at maximum, line-pack had been expended across the entire transportation system, and low inlet pressures at area meter stations would not recover until demand decreased.”
- ConEd declared a Gas System Emergency. It was able to maintain necessary pressure on its system by, among other things, activating its LNG facility.
- Had ConEd's city gate pressures continued to decline, it was in danger of losing pressure below the level needed to operate the system resulting in loss of service to all or portions of its system.
- Loss of natural gas service to its system would not only have left many customers in the life-threatening position of being without heat during extreme cold; but would likely have caused extensive property damage due to damaged water pipes. Restoring service to impacted customers would have required entering each customer site and manually re-lighting gas appliance pilots. Even with assistance of mutual assistance resources, this process could have taken several months.



Key Findings

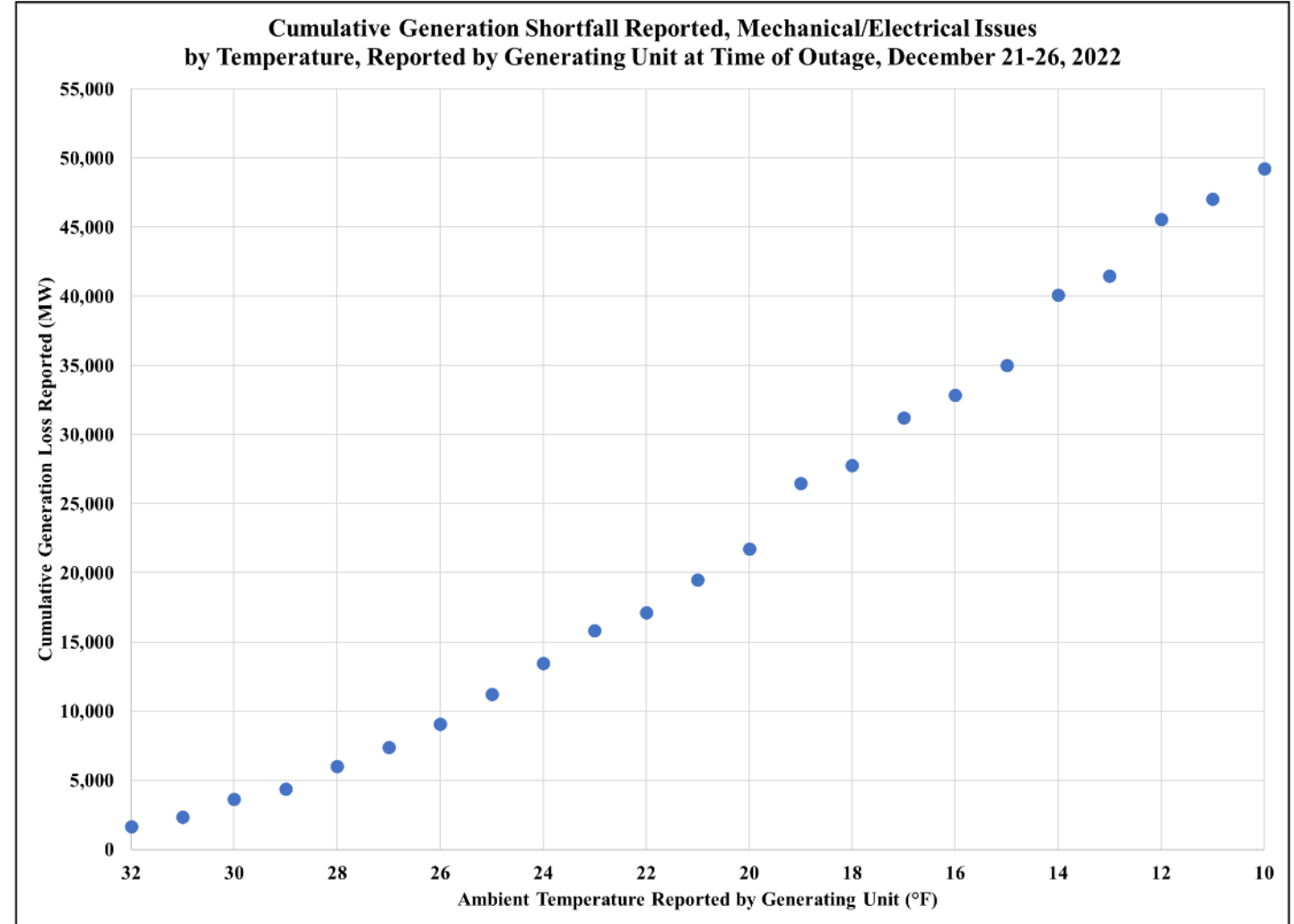
- **55 percent** of the generating unit outages, derates, and failures to start, were caused by:
 - **Freezing Issues (31 percent)**
 - **Fuel Issues (24 percent)**
 - **Natural Gas Fuel Issues** were **20 percent** of all causes and other fuels were 4 percent)
- **41 percent** indicated by Generator Owners to be caused by **Mechanical/Electrical Issues**, but the team found them to be correlated with subfreezing temperatures



Key Findings

Freezing and Mechanical/Electrical Issues

- Those that were attributed to having “Mechanical/Electrical Issues” increased with decreasing ambient temperatures
- Of those generating unit outages, derates, and failures to start that were attributed to having “Freezing Issues” **nearly 80%** occurred at ambient temperatures that were **above** their documented minimum operating temperatures.



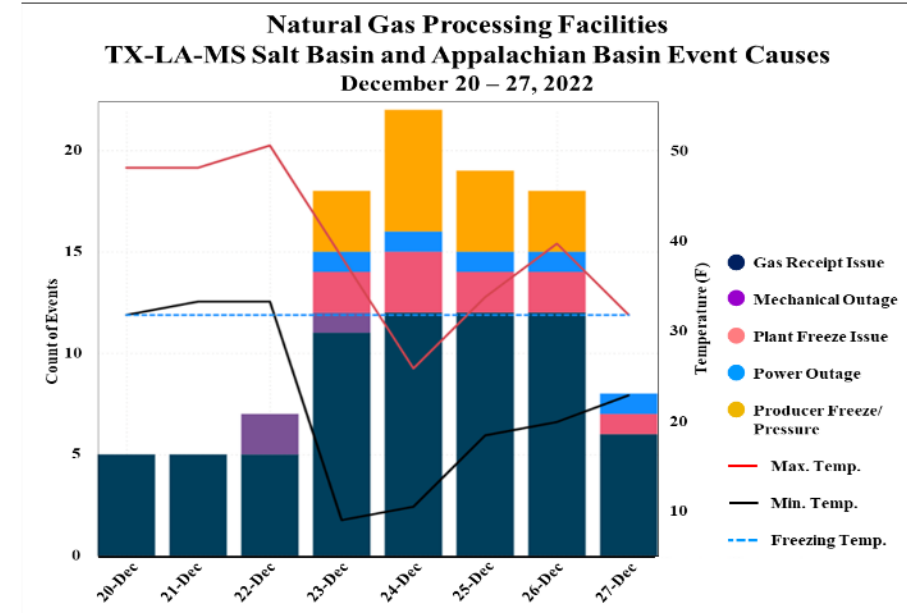
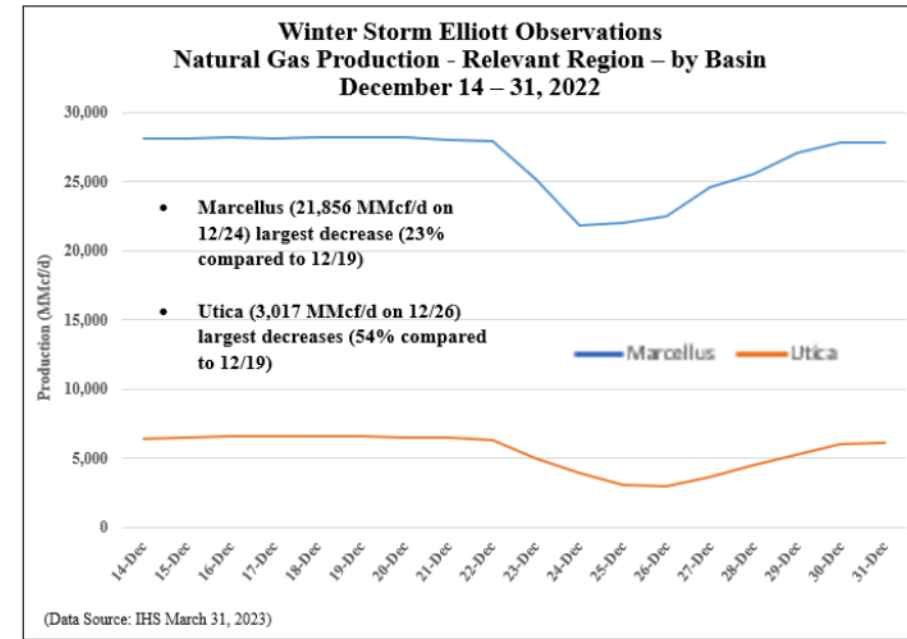
Key Findings

Natural Gas Fuel Issues

Major Cause: Natural Gas Infrastructure Reliability Issues During Extreme Cold Weather

- **Production Infrastructure**
 - Wellhead freeze-offs, other equipment freezing
 - Poor road conditions due to storm/cold weather, preventing maintenance

- **Processing Facility Operating Issues**
 - Reduction in receipt (production) volume
 - Producer freeze and pressure issues
 - Processing plant disruptions and outages caused by freezing and mechanical issues



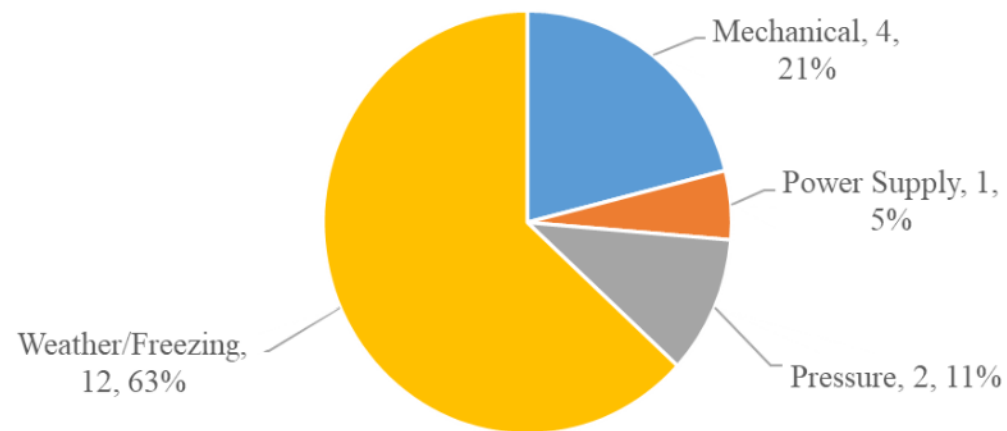
Key Findings

Natural Gas Fuel Issues

Major Cause: Natural Gas Infrastructure Reliability Issues During Extreme Cold Weather

- **Pipeline Infrastructure**
 - Equipment issues directly affecting shippers (e.g., end-users such as generating units, LDCs):
 - Weather/freezing issues (majority)
 - Mechanical issues
 - Interstate pipelines mitigated other equipment issues to avoid impacts to shippers.
- 63 natural gas-fired generating unit outages/derates, totaling 10,038 MW, were due to firm gas transportation curtailments during the Event.

**Natural Gas Pipeline Infrastructure
Causes of Reported Equipment Issues/Failures
Directly Affecting Shippers**



Total Number of Reported Equipment Issues/Failures Directly Affecting Shippers: 19



Key Findings

Electricity Demands Exceeded Grid Operators' Forecasts

- The majority of the BAs' short-range forecasts of peak electricity demands underestimated load on December 23 and December 24.*
- One BA's underestimation was as much as **11.6%** for their "Day-Ahead" forecast for December 23.
- Two BAs' underestimations were as much as **5.0%** for their "Day-Ahead" forecasts for the December 24.

Forecasts Produced ->	<u>Peak Load Forecasts for Friday, December 23</u>		<u>Peak Load Forecasts for Saturday, December 24</u>	
	Underestimation		Underestimation	
	<u>2 Days-Ahead</u>	<u>Day-Ahead*</u>	<u>2 Days-Ahead</u>	<u>Day-Ahead*</u>
Total Load Forecast Underestimation (MW) for Grid Entities' Footprints Combined	23,047	17,773	13,316	10,033
Average Percent Forecast Underestimation for Core Entity Footprints Combined	8.8%	6.8%	5.1%	3.9%

*Many BAs target their respective "Day-Ahead" peak load forecast errors to be within 2 – 3 percent of actual peak loads.



Similarities to Past Extreme Cold Weather Events

	2011 Event	2014 Event	2018 Event	2021 Event	2022 Event
Significant levels of incremental unplanned electric generating unit losses with top causes found to be mechanical/electrical, freezing, and fuel issues.	✓	✓	✓	✓	✓
Significant natural gas production decreases occurred, with some areas of the country more severely affected.	✓			✓	✓
Short-range forecasts of peak electricity demands were less than actual demands for some BAs in event area.	✓		✓	✓	✓
Significant natural gas LDC outages or near miss	✓				✓



Recommendations

- 11 recommendations
- Categories of recommendations include improvements to:
 - Generator Cold Weather Reliability
 - Natural Gas Infrastructure Cold Weather Reliability
 - Gas-Electric Coordination Cold Weather Reliability
 - Electric Grid Operations Cold Weather Reliability
- Where appropriate, recommendations have recommended timeframes for implementation/initiation



Improvements to Generator Cold Weather Reliability

1. Findings support (a) the need for prompt NERC development and implementation of remaining recommended revisions to Reliability Standards from 2021 Key Rec. 1 to strengthen generators' ability to maintain extreme cold weather performance; (b) the need for robust ERO monitoring of implementation of currently-effective and approved cold weather Reliability Standards, to determine if reliability gaps exist.
 - **Near-term action:** NERC should identify the generating units that are the highest risk and perform cold weather verifications of these generating units.
2. NERC should initiate a technical review, to be performed by an independent subject-matter expert team, of causes of cold-related mechanical/electrical generation outages to identify preventive measures and determine if additional Standards are needed.
3. NERC and its Regional Entities, with Commission staff engagement, should initiate a study modeled after the 2021 Report Rec. 26/ERCOT black start unit availability study, to assess readiness of other blackstart units to operate during cold weather conditions, including recommended actions for improvement, (if necessary).

Implement Robust Monitoring:
By Q3, 2024

Verify Highest Risk Units:
By Q4, 2023

Initiate Technical Review By:
By Q1, 2024

Initiate Study(s):
By Q1, 2024



Improvements to Natural Gas Infrastructure Cold Weather Reliability

4. LEGISLATION by Congress and state legislatures (and/or regulation by entities with jurisdiction over natural gas infrastructure reliability) IS NEEDED to establish reliability rules for natural gas infrastructure necessary to support the grid and natural gas LDCs that address the following needs:
 - a) the need for natural gas infrastructure reliability rules, from wellhead through pipeline, requiring cold weather preparedness plans, freeze protection measures, and operating measures for when extreme cold weather periods are forecast, and during the extreme cold weather periods,
 - b) the need for situational awareness of natural gas infrastructure reliability, by establishing regional natural gas communications coordinators (similar to a Reliability Coordinator for the electric grid) to communicate timely operational information at all levels of the natural gas supply chain, in advance of and throughout the extreme cold weather period to maintain regional natural gas situational awareness, and communicate potential issues to and from electric grid reliability entities (e.g., BA, RC), and
 - c) the need for designation of critical natural gas infrastructure loads for protection from load shed.



Improvements to Gas-Electric Coordination Cold Weather Reliability

5. Commission should consider obtaining a one-time report from FERC-jurisdictional natural gas entities, describing their vulnerability to extreme cold weather events, and how they are trying to minimize these vulnerabilities.
6. **Near-Term Action:** NAESB should convene natural gas and electric grid operators, and LDCs to identify improvements in communication during extreme cold weather events to enhance situational awareness across natural gas supply chain.
7. Initiate study(s) by an independent research group to analyze whether additional natural gas infrastructure, including interstate pipelines and storage, is needed to support the reliability of the electric grid and meet the needs of LDCs. The study would include information about the cost of the infrastructure buildout.


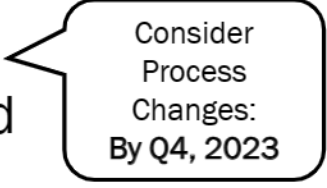
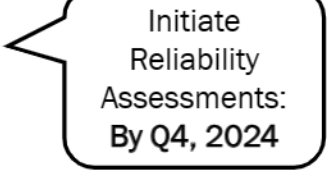
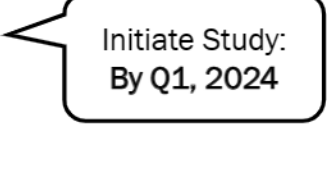
Consider Reporting:
By Q3, 2024

Identify Improvements:
By Q2, 2024

Initiate Study(s):
By Q1, 2024



Improvements to Electric Grid Operations Cold Weather Reliability

8. BAs should improve their short-term load forecasts for extreme cold weather periods by implementing report-identified sound practices and sharing those and newly-identified sound practices with peers for continuous improvement across electric grid.  Implement/
Confirm
Sharing:
By Q4, 2023
9. BAs should assess whether new processes or changes to existing ones, such as multi-day risk assessment processes, advance or multi-day reliability commitments, are needed to address anticipated capacity shortages or transmission system-related reliability problems during well-forecast extreme cold weather events.  Consider
Process
Changes:
By Q4, 2023
10. Resource planners and entities that serve load should sponsor joint-regional reliability assessments of electric grid conditions that could occur during extreme cold weather periods, which can be used in power supply planning to reduce the risk of firm load shed.  Initiate
Reliability
Assessments:
By Q4, 2024
11. NERC should initiate a study to be performed by an independent subject-matter expert team, to examine potential stability risks on December 23-24 for periods of decreased frequency and low responsive reserves during Winter Storm Elliott, to identify enhanced operator tools for situational awareness and mitigation.  Initiate Study:
By Q1, 2024





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Please note: this presentation is not the report. The report will be published soon, and we encourage everyone to read it.



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