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8045 LEESBURG PIKE
SUITE 200
VIENNA, VA 22182-2760

TEL: (703) 276-8900
FAX: (703) 276-9541
WEB: www.evainc.com

Examining Winter Storm Elliott's Strain on the U.S. Energy System

Introduction

This report, jointly prepared by the Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation (NERC) provides an in-depth analysis of the impact of Winter Storm Elliott, an extreme cold weather event that occurred between December 21 and 26, 2022. The report focuses on how this weather phenomenon affected the reliability of the Bulk Electric System (BES), commonly referred to as 'the grid,' and the associated gas infrastructure within the U.S. Eastern Interconnection.

During Winter Storm Elliott, a total of 1,702 individual BES-connected units in the Eastern Interconnection experienced 3,565 unplanned outages, derates, or failures to start. At the event's peak, there were 90,500 MW of coincident unplanned outages from generating units. Considering the generation already out of service, the cumulative impact resulted in over 127,000 MW of generation being unavailable, constituting 18% of the anticipated resources in the U.S. portion of the Eastern Interconnection. Notably, this event marked the largest controlled firm load shed ever recorded in the history of the Eastern Interconnection, surpassing 5,400 MW.

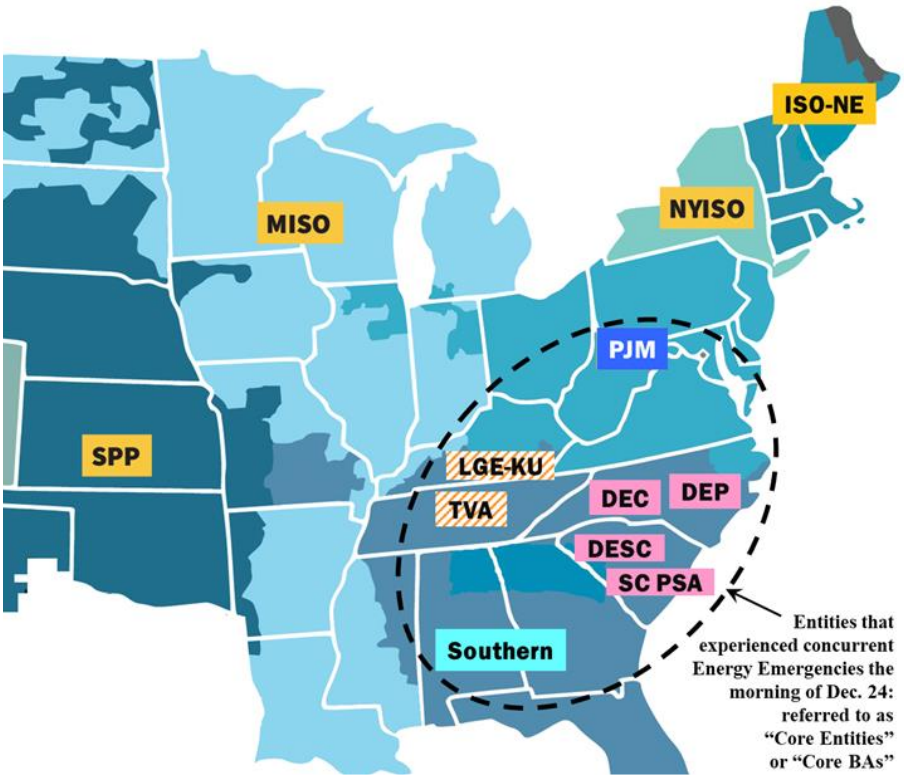
The report meticulously outlines the chronological sequence of the winter storm, shedding light on the factors contributing to the reliability concerns. Furthermore, it provides crucial recommendations aimed at enhancing the resiliency of the system during extreme weather events of this nature. The comprehensive analysis and insights presented in the report serve as valuable guidance for maintaining the reliability and effectiveness of the Bulk Electric System in the face of challenging weather conditions.

The report also juxtaposes 2021 Winter Storm Uri against this weather event. Comparing the severity of both events, it examines the fact that despite the preparedness of the electricity and natural gas system since the previous event, there was still a significant electricity outage and an inability to maintain the gas supply.

Synopsis of Event

The storm variously categorized as a bomb cyclone and an extra-tropical cyclone moved from the upper Plains states eastward. By Wednesday, December 21, 2022, it reached the central U.S. eventually blanketing most of the eastern United States on December 23 and 24 and did not subside until December 26. The extreme weather led to electricity generation outages along with peak winter electricity demands, leading several Balancing Authorities to declare energy emergencies.

EXHIBIT 1 BULK ELECTRIC SYSTEM MAP OF AFFECTED ENTITIES



The coincident incremental unplanned generation outages alone represented 12 percent of the U.S. portion of the winter 2022-2023 anticipated generation resources in the Eastern Interconnection. During the event, natural gas supply shortages began with freezing issues associated with production facilities and equipment, which rippled throughout the natural gas infrastructure system. Natural gas pipelines experienced decreased supply concurrently with shippers requesting higher volumes of gas. Pipeline pressure decreased, which along with freezing issues, affected critical equipment in the supply chain like compressor stations.

Under the currently effective reliability standards, the generation owners or operators were required to have cold weather preparedness. Over 40% of those who experienced outages due to cold temperatures or mechanical issues, maintained checklists of these standards and performed monthly inspections.

Analysis and Causes for System Issues

Ninety-six percent of the generating unit outages derates, or failures to start were attributed to three primary causes based on the number of megawatts (MW): Mechanical/Electrical issues, Freezing, and Fuel Problems. Among these, Natural gas-fired units accounted for 47 or 63 percent of the incremental unplanned generation loss, considering the number of outages.

The significant impact of natural gas-fired generating units during the storm can be attributed to the substantial presence of natural gas-fired generation in the affected region, constituting nearly 42 percent of the total. This underscores the critical role played by natural gas infrastructure in the context of the extreme weather conditions experienced during the event.

EXHIBIT 2 TOTAL MW LOSS OF INCREMENTAL GENERATION OUTAGES, DERATES, AND FAILURES TO START (OUTAGED MW) BY CAUSE, DECEMBER 21-26, TOTAL EVENT AREA

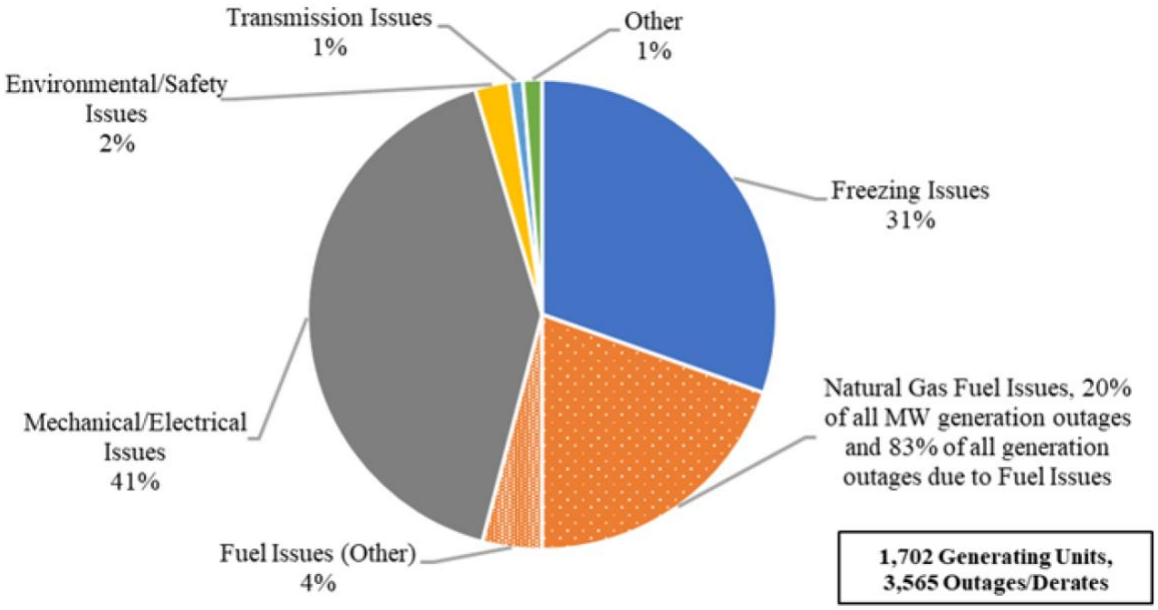
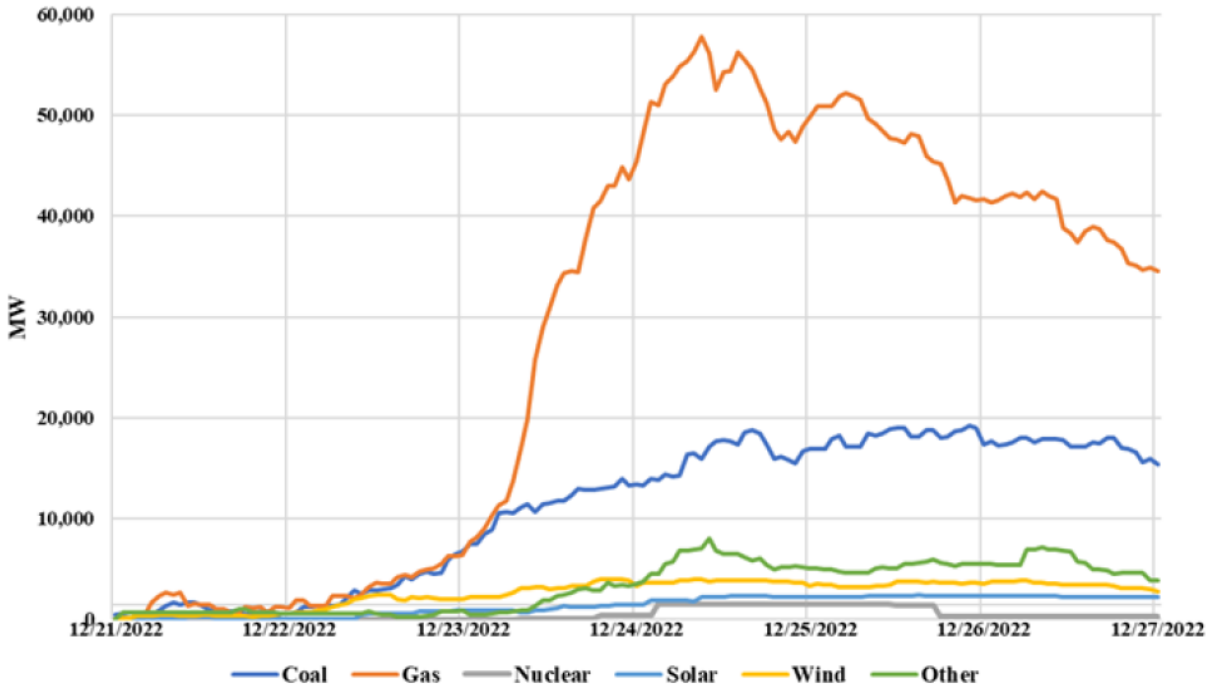


EXHIBIT 3 GENERATION OUTAGES, DERATES, AND FAILURES TO START (MW) BY FUEL TYPE, DECEMBER 21-26, TOTAL EVENT AREA



Mechanical and Electrical Issues (p. 94):

During the event, generating units reported a total of 1,418 unplanned outages, derates, or failures to start, with Mechanical/Electrical Issues being the predominant cause, accounting for 40% of all generation losses. At its peak, this category contributed to over 31,000 MW of incremental unplanned generation loss. Notably, 48% of these incidents manifested as forced outages, while 43% were forced derates. Among the sub-causes, Equipment Failures/Issues played

a significant role, contributing to 72% of the outages, with Control System Issues representing the only other material sub-cause (approximately 10%).

Freezing Issues (p. 97):

A total of 1,030 freezing issue-related unplanned outages, derates, or start-up failures were reported, resulting in 110,962 MW of generation loss, constituting 31% of the total MW of generation outages during the storm. Frozen transmitters, sensing lines, and other instrumentation accounted for approximately 42% of all generation losses due to freezing issues. Remarkably, Freezing Issues caused a substantial percentage of unplanned wind generation outages and derates (53% by MW or 40% by the number of outages) and had a significant impact on nuclear units, causing 75% of the MW and 43% of the number of outages.

Blackstart Units (p. 105):

Blackstart-designated generating units, critical for grid reliability, experienced forced outages, derates, or failures to start totaling 19,000 MW during the storm. Of the 155 blackstart-designated units, 119 were natural gas-fired, reporting over 248 discrete outages, derates, or failures to start. Notably, 29% reported multiple outages, and 23% were start-up failures, indicating a concerning occurrence of units failing to perform their essential blackstart functions.

High Wind Shutoffs (p. 106):

While some generating units experienced brief outages due to high wind speeds, these shutoffs did not constitute a significant source of generation loss, attributing fewer than 1,000 MW of loss in aggregate.

Fuel Issues (p. 106):

Fuel issues accounted for 24% of all generation losses during the storm, totaling more than 86,000 MW. A total of 452 generating units reported 730 distinct forced outages, derates, or failures to start due to fuel issues. Notably, natural gas-fired units bore the brunt, with 83% of all Fuel Issue-caused generation outages and derates, including impacts on production, gathering, processing, and pipeline facilities, as well as supply and transportation interruptions.

Natural Gas Supply and Delivery Facility Outages (p. 110):

The decrease in natural gas production during Winter Storm Elliott, particularly in Pennsylvania, Ohio, and West Virginia, was attributed to freeze-offs and downstream issues. These issues included outages in gathering systems, compressors, processing plants, and pipelines, resulting in reduced gas supply and processing losses. Valves and compressor units along the pipeline system froze due to cold temperatures, hindering the flow of gas through the facilities. Poor road conditions further exacerbated these challenges, hindering personnel and water-hauling trucks from reaching remote sites.

Recommendations

Post this thorough analysis and understanding of the key causes of the energy system issues caused by Winter Storm Elliott, the report provides some crucial recommendations to alleviate the impacts of such an extreme weather event occurring again.

1. Urgent Implementation of Reliability Standard (p. 131):

Promptly develop and implement the remaining revisions to the Reliability Standards recommended by Key Recommendation 1 (page 184 of the report on Winter Storm Uri) from the 2021 Report to address freezing issues in generating units.

For context, in August 2021, the Commission approved the adoption of EOP-011-2, effective April 1, 2023, in response to a recommendation from the 2018 Report, and required Generator Owners to have cold weather preparedness plans for their units. The 2021 Report took the next logical step by recommending that generating units be required to "(i) identify cold weather-critical components and systems and (ii) identify and implement freeze protection measures for those

components and systems." The 2021 Report also recommended that generating units that experienced unplanned outages due to freezing should be required to develop Corrective Action Plans to guard against future outages.
Data suggests that many generating unit owners or operators had already started implementing these standards before this event, thus this report does not recommend additional standards but urges upon the need to effectively execute them in time. This also means that there is a need for robust monitoring by the NERC and the regional entities if these standards have been met and are maintained.
Additionally, the generating owners and operators must conduct their assessments of their freeze protection measures, verified by NERC and regional entities. Those whose units have experienced outages derates, or failures should consider an engineering design review to evaluate the accuracy and completeness of existing design as it relates to cold weather and analyze if existing measures are adequate. They should also consider testing their "active" freeze protection system.

2. Technical Review of Cold-Related Outages (p. 134):

NERC should initiate a technical review of the individual causes of cold-weather-related unplanned generation outages caused by mechanical and electrical issues during the storm to identify the root causes of these failures to determine what can be done to reduce the frequency of these outages during extreme weather events. The study should also consider whether additional Reliability Standards are appropriate to address the root causes of these issues. The study should be conducted by either an independent subject-matter expert such as the Electric Power Research Institute or an academic institution, with participation by the Generation Owners/Generation Operators on scoping and providing generating-unit-specific technical expertise.

Successive reports reviewing cold weather events have consistently demonstrated a steady relationship between decreasing temperatures and a rise in Mechanical/Electrical Issues in generating units. The 2021 Report suggested that further analysis was required by Generation Owners to "understand the impact of extreme cold weather on mechanical/electrical failures so that GOs can identify possible methods of reducing the incidence of unplanned outages, derates, and failures to start due to Mechanical/Electrical Issues] during similar events." The persistence of these issues, even in the face of increased awareness, suggests further action needs to be taken.

3. Blackstart Study for Eastern and Western Interconnections (p. 135):

A joint NERC-Regional Entity team, collaborating with FERC staff, should study the overall availability and readiness of blackstart units to operate during cold weather conditions. This study should cover all portions of the U.S. not already studied and should incorporate existing literature, studies, reports, and other analyses as to the availability and readiness of black start units.

The scope of this study should be detailed and cover an evaluation of existing blackstart restoration plans, availability, readiness, and testing standards among other categories. Over 19,000 MW of blackstart designated generating units (155 units) incurred outages, derates, or failures to start during the event. The readiness and availability of blackstart units is paramount to the reliability of the grid during extreme weather scenarios, and the breadth (both in numbers and causes) of the outages and derates to blackstart units during Winter Storm Elliott suggests the need for systematic evaluation of the readiness of these units.

4. Reliability Rules for Natural Gas Infrastructure (p. 137):

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 the natural gas infrastructure necessary to support the grid and natural gas local distribution companies specifically addressing cold weather preparedness/freeze protection, regional situational awareness, and critical infrastructure designation.

The reliability rules mentioned above should address, among other things, regulations on infrastructure from the wellhead through pipelines, requiring cold weather preparedness. This recommendation also emphasizes the need for regional

natural gas coordinators, with situational awareness of the natural gas infrastructure for timely communication through the supply chain.

It also suggests that natural gas infrastructure entities identify those loads that should be designated as critical for priority treatment during load shed and the rules should provide criteria for identifying such critical loads.

5. Natural Gas-Electric Coordination (p. 143):

The North American Energy Standards Board should convene natural gas infrastructure entities, electric grid operators, and LDCs to identify improvements in communication during extreme cold weather events to enhance situational awareness. This recommendation differs from recommendation 4 in the way that it does not ask for legislation. The report recognizes that the entities involved in the operations of the natural gas and electricity infrastructure could improve upon their communication without the need for a reliability coordinator equivalent for natural gas infrastructure.

There is a need for improved communication among the operators of production facilities (producers, gatherers, processors) and the timely dissemination of this coordinated communication from the production facilities to other natural gas infrastructure entities, BAs, shippers, and end-use customers (i.e., Local Distribution Companies). Discussions should include what should be communicated, how it should be communicated, and to whom it should be communicated.

6. Report on Natural Gas Entities Response to Cold Weather Events (p. 144):

This recommendation discusses the Commission's consideration of ordering natural gas entities within its jurisdiction to submit one-time reports on their roles in addressing vulnerabilities during extreme cold weather events. It highlights the impact of freezing on pipeline equipment outages during Winter Storm Elliott and notes common preparation practices shared by pipelines. The suggestion is to analyze experiences in Winter Storms Uri and Elliott, outlining plans to mitigate vulnerabilities. The data collected would help the Commission assess the need for additional actions to address risks from extreme cold weather events on the natural gas infrastructure. Entities submitting reports may seek confidentiality protection under the Commission's regulations.

7. Independent Research for Additional Gas Infrastructure (p. 144):

An independent research group, such as selected National Laboratories from the Department of Energy (DOE), should conduct studies to analyze the necessity of additional natural gas infrastructure, including interstate pipelines and storage. This initiative aims to support the reliability of the electric grid and meet the requirements of natural gas Local Distribution Companies (LDCs). The study should encompass information on the associated costs of the infrastructure expansion and ideally begin in Q1 of 2024.

Given the Commission's role in reviewing interstate natural gas projects and the complexity of gas infrastructure, the Team recommends an entity with robust modeling capabilities, preferably one of the DOE National Laboratories. The study's purpose is to identify additional natural gas infrastructure needs, if any, considering the reliability of both the electric and natural gas systems. It should analyze regional requirements, current and forecasted future needs, and adaptability to the evolving energy system. The study should also factor in recent natural gas production declines during extreme weather events like Winter Storm Uri and Winter Storm Elliott. Furthermore, the study is expected to provide insights into the cost of the proposed infrastructure buildout. This recommendation aligns with the North American Energy Standards Board Report, emphasizing the importance of studying the costs of natural gas infrastructure, as outlined in its recommendations.

8. New Processes to Anticipate Capacity Shortages (p. 146):

Recommendation 8 suggests that Balancing Authorities (BAs) should evaluate the need for new processes or modifications to existing ones to address potential capacity shortages or transmission-related reliability issues during anticipated extreme cold weather events. These could include multi-day risk assessment processes or advance/multi-day reliability commitments. The recommendation emphasizes the importance of considering uncertainties in load forecasts, generating

unit fuel availability, and extreme cold weather effects across multiple regions. It also underscores the commitment of generating units before the onset of extreme cold weather, ensuring compensation for commitment costs, even if no dispatch occurs.

The recommendation stems from the challenges faced by BAs in the five recent extreme cold weather events, where unexpectedly high numbers of unplanned generating unit outages and discrepancies in short-term load forecasts were recurrent issues. The suggestion urges BAs to proactively assess uncertainties in advance, incorporating multi-day reliability unit commitment processes to enhance preparedness and maintain system reliability. The experience of SPP during Winter Storm Elliott serves as an illustrative example, emphasizing the importance of flexibility in evaluating uncertainties and effectively combining them with multi-day unit commitment processes. This approach enables BAs to address challenges, such as uncertain load forecasting, resource availability, and potential equipment freezing, in a timely and efficient manner. The report notes support from industry recommendations, including the North American Energy Standards Board and PJM, emphasizing the adoption of multi-day commitment processes to enhance industry preparedness. Additionally, pre-operational warming is highlighted as a practice to mitigate the risk of unplanned freezing-related outages, emphasizing the manual commitment of generating units before extreme cold conditions.

9. Improving Short-Term Forecasts (p. 148):

BAs are recommended to enhance their short-term load forecasts for extreme cold weather periods by implementing identified lessons and practices. The recommendation stems from observations that, in four of the last five extreme cold weather events, short-term load forecasts were lower than the actual peak electricity demand for some BAs in the Core Event Area. Accurate short-term load forecasts are crucial for BAs to effectively commit long-lead-time resources, plan for additional imports, and notify customers in advance of potential emergencies, fostering greater awareness and voluntary load reduction.

The use of distribution-level smart meter data, combined with Artificial Intelligence (AI)-powered predictive intelligence, is identified as a promising approach. The report acknowledges that some entities already engage in sharing effective practices but believes that the sharing of such practices can be further enhanced to improve the accuracy of short-term load forecasts, especially considering the wide variety of load forecasting practices observed within the affected region during Elliott.

10. Regional Reliability Assessments of Grid Conditions (p. 149):

Resource Planners and entities responsible for serving firm load should sponsor joint-regional reliability assessments of electric grid conditions during extreme cold weather events. These assessments aim to enhance power supply planning, reducing the risk of firm load shed. The focus is on extreme cold weather events that simultaneously impact multiple operating areas and Regional Entity footprints, and the assessments are encouraged to involve multiple planning regions, Regional Entities, and BA footprints within regions. To account for uncertainties in external generation resource availability, potential simultaneous winter peak load conditions, and uncertainties in resource deliverability, planners should consider probabilistic approaches.

In assessing risks, planners should account for potential higher levels of unplanned generation outages across multiple regions during extreme cold weather. The recommendation draws attention to NERC's operational risk analysis, which factors in scenarios impacting resource adequacy. The analysis considers the cumulative effects of various factors affecting resources and demand.

11. Expert Study on Eastern Interconnection Condition from Dec 23-24, 2022 (p. 151):

Recommendation 11 proposes a study conducted by subject-matter experts, such as the Eastern Interconnection Planning Collaborative, to assess the state of the Eastern Interconnection during the evening of December 23 and the early morning hours of December 24. The study aims to investigate dynamic stability, system inertia, and the potential proximity to triggering an under-frequency load shed event. Drawing attention to the vulnerabilities exposed during Winter Storm Uri,

where extreme loss of generation resources led to ERCOT shedding firm loads to avoid a complete blackout, the recommendation highlights the need for a detailed examination of the Eastern Interconnection during high-demand periods.

The recommendation underscores the occurrence of frequent frequency excursions below the lower band limit for maintaining frequency during the specified period, raising concerns about the potential instability of the Eastern Interconnection. The Eastern Interconnection Planning Collaborative, in coordination with NERC, Regional Entity, and FERC staff, is suggested to conduct assessments of next-contingency/single-point of failure conditions to evaluate dynamic stability through modeling. The findings from this study can be utilized to identify necessary actions for improving situational awareness, enhancing operator tools, and bolstering analysis capabilities. The real-time evaluation of system conditions in the future could provide Reliability Coordinators with visibility into dynamic system conditions, aiding in determining appropriate actions, particularly when faced with resource mix changes that may expose the grid to increased stability risks, such as the retirement of "high-inertia" coal units replaced by smaller intermittent resources with less inertia.

Conclusion

The joint report by FERC and NERC presents a comprehensive evaluation of Winter Storm Elliott, delving into the root causes behind the disruptions it inflicted on the nation's energy infrastructure and the consequential impact on consumer services. Leveraging insights from the Winter Storm Uri report and the Gas Electric Harmonization Forum Report by the North American Energy Standards Board, the analysis revisits key factors. The report underscores critical themes such as enhanced reliability standards, the imperative for seamless communication within both electric and natural gas supply chains, the need for legislative backing for gas infrastructure, and the importance of collaborative efforts among gas-electric entities. These themes, previously highlighted in the reports on Winter Storm Uri and the Gas Electric Harmonization Forum, underscore the ongoing imperative for a holistic approach to fortify the resilience of the nation's energy systems.