"The Reliability and Resiliency of Electric Service in the United States in Light of Recent Reliability Assessments and Alerts"
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Introduction

The bulk power system (BPS) is at an inflection point. The electric transmission grid is highly reliable and resilient, and has grown more so under the current reliability regime. Yet the risk profile to customers is steadily deteriorating. Factors contribution to this deterioration include:

- Rapid, often disorderly transformation of the generation resource base,
- Performance issues associated with replacement resources as conventional units retire,
- Wide-area, long duration extreme weather events, which are becoming more frequent,
- And increased demand due to electrification, coupled with slow development of new energy infrastructure needed to support grid resilience and the clean energy future.

Independent technical assessments by the North American Electric Reliability Corporation (NERC) find that the energy transformation can be navigated in a reliable way, provided reliability is recognized as a central priority. NERC is concerned that the pace of change is overtaking the reliability needs of the system. Unless reliability and resilience are appropriately prioritized, current trends indicate the potential for more frequent and more serious long duration reliability disruptions, including the possibility of national consequence events.

Outside of cyber/physical security, which presents complex issues worthy of separate discussion, three reliability priorities must be addressed:

- First, we must manage the pace of the transformation in an orderly way, which is currently not happening. Conventional generation is retiring at an unprecedented rate.
- Second, we must identify new resources to replace retiring generation that provides both sufficient energy *and* essential reliability services (such as flexibility, voltage support, frequency response, and dispatchability) needed for stable grid operations.
- Finally, we must shift focus from planning for solely "capacity on peak" to "energy 24x7" due to the changing fuel mix. Further, we need to better understand the impact on the bulk power system from the dynamic performance associated with inverter based resources (IBRs) and distributed energy resources (DERs). These understandings can then

be balanced against the potential for demand side management (both energy efficiency and demand response) to support reliability and resilience.

Within the limits of Section 215 of the Federal Power Act, NERC acts as a reliability regulator for the BPS. NERC has authority over transmission and generation facilities needed to maintain transmission system reliability. However, NERC may not order the enlargement of these facilities, nor may NERC require construction of new transmission or generation capacity. Furthermore, local distribution of electricity and fuel supply are excluded from NERC jurisdiction and fall under State oversight. While the current reliability regime significantly strengthens reliability of North America's transmission system, transformation of the generation resource mix and the expansion of DERs have injected new jurisdictional complexities. Adding to these challenges is the need for industry, regulators, and policymakers to constantly balance reliability with customer affordability and environment impacts, priorities that are outside of NERC's jurisdiction. When viewed through the lens of balancing reliability, economics, and the environment, the challenges for the electricity sector become highly complex.

With a highly reliable, resilient, and secure BPS at the core of NERC's mission, our focus is on proactively addressing the reliability risks of the transforming grid. This testimony examines the growing potential for regional energy shortfalls across North America, NERC's actions to mitigate this risk, and next steps for industry, regulators, Congress, and other policymakers.

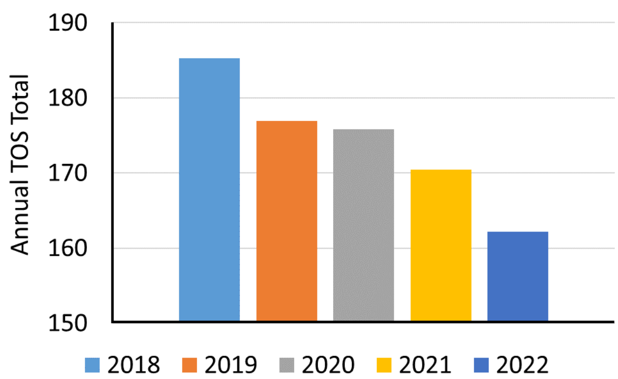
While the Transmission System is Highly Reliable, the Aggregate Electric System is Threatened by a Deteriorating Risk Profile

When the Federal Energy Regulatory Commission (FERC) designated NERC as the Electric Reliability Organization (ERO) in 2006, establishment of a mandatory regime focused on transmission system reliability was the central focus. Through a suite of mandatory enforceable standards, the goal was to align the electricity industry along a common set of essential practices to mitigate reliability risks. Reliability Standards are aimed at avoiding instability, uncontrolled separation, and cascading within an interconnection. While reliability risk mitigation is a complex endeavor, Federal Power Act Section 215 has the distinct advantage of direct jurisdiction tailored to addressing the most pressing risks existing at the time.

The ERO model has been highly successful in reducing risk. By objective measures, today's BPS transmission system is demonstrably more reliable and resilient. Many conventional risks that challenge the grid have now been reduced by significant margins and continue to trend in a positive direction overall. NERC's *2023 State of Reliability Assessment*– to be published later this month – documents a five-year trend of significantly improved transmission system reliability. This includes a system of declining equipment failures, improved human performance, better situational awareness, and effective vegetation management programs. There have been no cyber events impacting bulk electric system facilities, and there have been no outages associated with substations deemed critical to BPS performance and protected under NERC Reliability

Standards. Since 2016, the duration and severity of transmission outages in North America have declined by statistically significant margins.[1] The chart below depicts the decline in transmission outage severity, documented in the upcoming *2023 State of Reliability*. In short, the ERO model is paying significant dividends for the nearly 400 million North Americans who depend upon a reliable bulk power system.

Transmission Outage Severity (TOS)



Source: ***2023 State of Reliability*** *(to be published June 2023)*

However, significant risks have emerged relative to the electricity supply for North America in ways that were not contemplated when the ERO model was established. Mitigation of these new and emerging reliability risks involves a multidimensional set of issues, including a rapidly changing generation resource mix, a changing climate, changing electricity demand profiles, and new technologies, some of which are not quite ready for full deployment. Successful navigation of these issues require multidimensional solutions, often requiring effective coordination of multiple jurisdictions, or examination of new authority where no jurisdiction effectively exists.

If "conventional risk" is defined by risks around which federal jurisdiction provides adequate mitigation, "new risk" is defined by risks to the BPS that cross jurisdictions, are the exclusive province of the states (such as resource and transmission adequacy, and distributed energy resources), or where jurisdiction is unclear or insufficient (such as the interface between the natural gas sector and the electric sector). Solutions to these risks are considerably more complex because, unlike conventional risks, new risks require coordinated engagement among differing jurisdictions or even the establishment of new jurisdictional authorities.

There are three key reliability priorities, outside of cyber/physical security, that will help us address these challenges and be successful. First, we must manage the pace of the transformation in an orderly way, which is currently not happening. Second, we must identify and integrate new resources to replace retiring generation that provides both sufficient energy *and* essential reliability services needed for stable grid operations. Finally, due to the changing

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[1] NERC, *2022 State of Reliability: An Assessment of 2021 Bulk Power System Performance (July 2022),* https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2022.pdf.

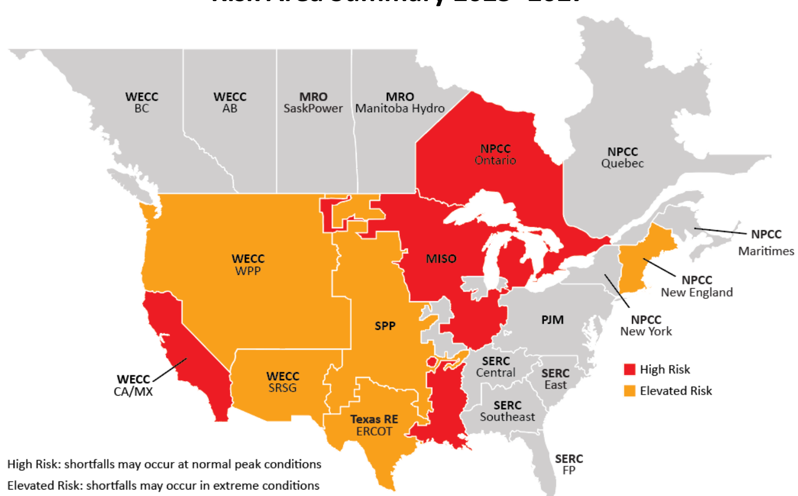
fuel mix, the dynamics associated with DERs, and the potential for demand side management to support reliability, we must shift the planning focus. Whereas resource planning traditionally focused on having enough generation capacity during peak demand conditions ("capacity on peak"), the focus must be broadened to include the need for sufficient energy at all times ("energy 24x7").

NERC Assessments Show Growing Risk of Energy Shortages

NERC's *2021 ERO Reliability Risk Priorities Report*[2] finds that the rapid interconnection of BPS-connected IBRs and how they interact with the high voltage power grid and other resources is the most significant driver of grid transformation and poses a high risk to BPS reliability. The rapidly transforming generation resource mix elevates energy availability as a growing concern for BPS reliability. The dynamic performance of IBRs has not been satisfactory, further elevating the risks for shortfalls when events on the system are experienced. Whether looking out ten years or two months, the risk of energy shortfalls is real and is growing more acute.

NERC's *2022 Long-Term Reliability Assessment*[3] (LTRA) examines future reliability risk over a ten-year horizon. The LTRA finds numerous regions are at risk of energy shortfalls during normal peak conditions and during extreme conditions over the next five years. Factors that contribute to this risk include (1) retirements of flexible, dispatchable resources where their capacity, energy production, and essential reliability services have yet to be fully replaced, (2) extreme weather driven by a changing climate coupled with a generation resource portfolio that has grown more sensitive to extreme weather, and (3) limited addition of interstate electric transmission and fuel delivery infrastructure.

Risk Area Summary 2023–2027



Source: ***2022 Long-Term Reliability Assessment***

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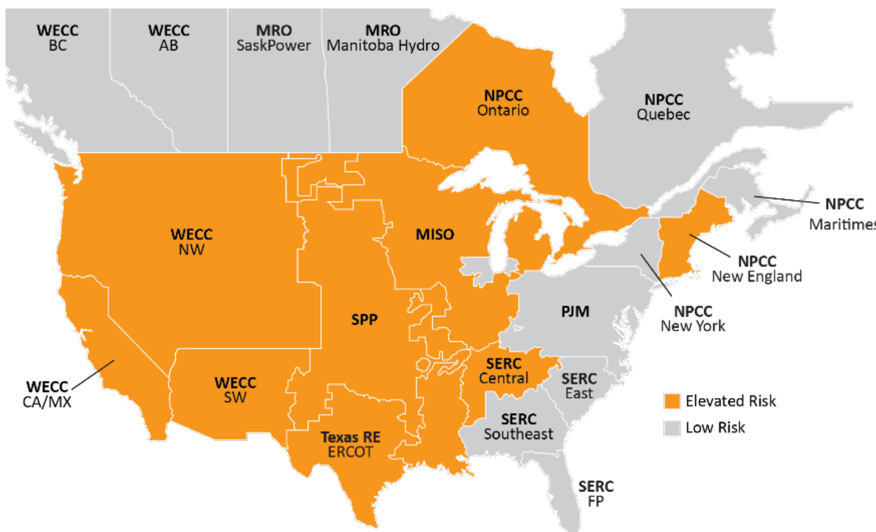
[2] NERC, *2021 ERO Reliability Risk Priorities Report* (July 2021), https://www.nerc.com/comm/RISC/Documents/RISC%20ERO%20Priorities%20Report_Final_RISC_Approved_July_8_2021_Board_Submitted_Copy.pdf.

[3] NERC, *2022 Long-Term Reliability Assessment* (December 2022), *https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf*.

The risk outlook for the upcoming summer is also concerning. NERC's *2023 Summer Reliability Assessment*[4] reviews the energy outlook for the upcoming summer season, showing a step change in the risk environment. Among positive findings, the below risk map shows improvement over previous years in that there are no areas at risk of energy shortfalls during *normal summer conditions*. Increased deployments of wind, solar, and batteries positively impact resource adequacy. However, the map shows growing contagion of orange areas compared to previous summer assessments. In these areas, during extreme above-normal heat, long duration conditions, there is a ten percent chance of energy shortfalls occurring.

Summer Reliability Risk Area Summary



Source: *2023 Summer Reliability Assessment*

NERC Actions to Address Risks

To address the myriad challenges for BPS reliability, NERC has developed a comprehensive risk framework to guide the ERO in the prioritization of risks and provide guidance on the application of ERO policies, procedures, and programs to inform resource allocation and project prioritization. Certain key actions are described below.

Inverter-Based Resource Strategy

The speed of IBR resource deployment continues to challenge grid planners, operators, protection engineers, and many other facets of the electricity sector. Implemented correctly, inverter technology can provide significant benefits for the BPS. However, the new technology can introduce significant risks if not integrated properly. In *2022 State of Reliability*, NERC finds that large assessment areas have become dependent upon renewable resources to meet peak loads, but multiple events resulting in the loss of significant amounts of solar resources in Texas

[4] NERC, *2023 Summer Reliability Assessment* (May 2023), https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2023.pdf.

and California confirm that unaddressed inverter interconnection and performance issues increased reliability risk.[5] The *2021 Long-Term Reliability Assessment*[6] projects a rapid growth of IBRs – mostly wind, solar photovoltaic (PV), battery energy storage systems, and hybrid plants – with projections of nameplate capacity for solar PV projects in all development stages exceeding 500 GW over the next 10 years. NERC has developed an IBR mitigation strategy comprised of specific activities under four core tenets: Risk analysis, interconnection process improvements, best practices and education, and new standards to govern the planning and operations of IBRs.[7] NERC is also revising its rules to ensure that a greater portion of IBRs are subject to such standards and fall within the nation's regime for a reliable bulk power system.

Energy Assessments

Historically, analyses of energy available to the bulk electric system focused on capacity reserve levels across peak-demand time periods. Energy availability and essential reliability services were assumed to be a direct result of this certain capacity. The variability of renewable generation, demand volatility, the need for sufficient flexibility from balancing generation resources, and the potential for natural gas supply interruptions all create uncertainty in the system's ability to provide energy and essential reliability services needed for reliable operation. Recent events, including Winter Storm Uri, have highlighted the need for energy reliability assessments that analyze all hours of a given study period rather than just the peak hours.

After undertaking extensive industry stakeholder engagement, NERC's Energy Reliability Assessment Task Force initiated two Standard Authorization Requests (SARs) which were endorsed by the Reliability Security Technical Committee (RSTC) to mitigate this risk through energy assessments with corrective action plans. Various regulatory jurisdictions then would assess these plans for implementation or modification. The SARs, which are working through the NERC Reliability Standards process, would require Reliability Coordinators and Balancing Authorities to conduct energy assessments needed to evaluate energy requirements in their regions. One SAR would require energy assessments for the long term planning horizon (1 to 5 years), with corrective actions plans toward ensuring sufficient amounts of energy are available for a select set of scenarios.[8] The second SAR is for operational planning (1 year or less), with energy surveys and actions that can be taken to ensure sufficient amount of energy reserves are available to meet energy requirements.[9] Subject to the standards development process, review

[5] NERC, *2022 State of Reliability* (July 2022), https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2022.pdf.

[6] NERC, *2021 Long-Term Reliability Assessment* (Dec. 2021), https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2021.pdf.

[7] NERC, *Quick Reference Guide: Inverter-Based Resource Activities and Strategy* (March 2023), https://www.nerc.com/pa/Documents/IBR_Quick%20Reference%20Guide.pdf.

[8] SAR, "Energy Assessments with Energy-Constrained Resources in the Planning Time Horizon," (June 8, 2022), https://www.nerc.com/pa/Stand/Project202203EnergyAssurancewithEnergyConstrainedR/2022-03%20Constrained%20Resources%20in%20the%20Planning%20Time%20Horizon%20Standard%20Authorization%20Request.pdf.

[9] SAR, "Energy Assessments with Energy–Constrained Resources in the Operations and Operations Planning Time Horizons," (June 8, 2022), https://www.nerc.com/pa/Stand/Project202203EnergyAssurancewithEnergyConstrainedR/2022-03%20Constrained%20Resources%20in%20the%20Operations%20and%20Operations%20Planning%20Time%20Horizons%20Standard%20Authorization%20Request.pdf.

and approval by the NERC Board and FERC, these new requirements will provide important planning tools to help assure energy availability.

Cold Weather Reliability Standards and Planning

FERC recently approved enhancements to Reliability Standards that address numerous recommendations identified in the FERC/NERC/Regional Entity Joint Inquiry Report that pinpointed lessons learned from the Winter Storm Uri arctic cold front event that affected Texas and the South Central United States in February 2021. The standards also build upon NERC's prior work, further advancing reliability through improved operations, generator cold weather preparedness requirements, and enhanced situation awareness between generators and reliability coordinators and balancing authorities. New and enhanced Reliability Standards address important activities such as cold weather preparedness planning, training requirements, freeze protection measures, and load shedding procedures. A separate joint inquiry is currently ongoing concerning Winter Storm Elliott that affected parts of the Southeast around the Christmas holiday last year. Upon conclusion of the inquiry, NERC intends to act expeditiously on recommendations. Finally, on May 15, 2023, NERC issued a Level 3 "Essential Actions to Industry" Alert urging immediate action and requiring industry to report to NERC on cold weather preparations for next winter.

Expanded Analytics and Modeling

NERC is undertaking a number of initiatives to improve analytics and modeling necessary to support grid transformation in a reliable way. Transmission Planners and Planning Coordinators are concerned about the lack of accurate modeling data and the need to perform more sophisticated studies during the interconnection process and long-term planning horizon. In many ways, the growth of inverter technology has pushed conventional planning tools to their limits, elevating a need for good models required to conduct more detailed studies using electromagnetic transient (EMT) models to address inverter-based resource integration issues. EMT studies have been used since the mid-1970s, and are now needed for studying possible reliability issues related to the interconnection of inverter-based resources. NERC is currently working on Reliability Standards proposing to include EMT models and studies in planning-related NERC Reliability Standards to ensure reliable operation of the BPS.

The NERC Inverter-based Resource Performance Task Force (IRPTF, now the Inverter-based Resource Performance Subcommittee or IRPS) undertook an effort to perform a comprehensive review of all NERC Reliability Standards to determine if there were any potential gaps or improvements. The IRPTF identified several issues as part of this effort and documented its findings and recommendations in the "IRPTF Review of NERC Reliability Standards White Paper."[10] This project includes potential revisions to a number of NERC modeling standards to require, among other things, Generator Owners to provide verified dynamic models to their Transmission Planner for the purposes of power system planning studies. In addition, the IRPTF

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[10] NERC IRPTF, "IRPTF Review of NERC Reliability Standards" (Mar. 2022), https://www.nerc.com/comm/PC/InverterBased%20Resource%20Performance%20Task%20Force%20IRPT/Review_of_NERC_Reliability_Standards_White_Paper.pdf.

recommended revisions to clarify the applicable requirements for synchronous generators and IBRs.

Findings and Recommendations

Managing the pace of change is the central challenge for reliability. The rapid evolution of the generation resource mix is altering the operational characteristics of the grid. Through the transition:

- Until energy, capacity, and essential reliability services are fully replaced, the retirement of traditional units must be managed. This may require a new pricing construct to ensure that necessary reliability investments (e.g., winterization investments, costs to firm up fuel supply, etc.) are adequately compensated for in the competitive markets.
- It is imperative to understand and plan for the different operating characteristics of variable, inverter-based resources and take steps to ensure they contribute to reliability.
- The reliability attributes of all resources, especially fuel security and provision of essential reliability services, must be recognized and valued by the marketplace.
- Interagency coordination is absolutely needed for policies that impact generation, especially coal resources, to keep reliability at the forefront of the policy table.

More transmission and natural gas infrastructure is required to improve the resilience of the electric grid. Whatever approaches may ultimately be pursued, few long-haul transmission lines and pipelines are actually being planned and built. With construction scheduled to begin this summer, the current major project being developed in the desert Southwest underwent sixteen years of development and permitting. And the New England Clean Energy Connect project has resumed production after being halted through a ballot initiative in Maine. Despite these siting and permitting challenges, it is absolutely clear that:

- Electric transmission investment must keep pace with the increase in utility scale wind and solar resources, which are generally located outside of major load centers. Transmission investments can also strengthen the ability to transport power to different load centers, improving resilience through redundancy. Many are discussing the merits of a national transmission system similar to the interstate highway system, point-to-point DC lines, and other interconnections.
- Additional pipeline infrastructure (including gas storage to provide needed in-market flexibility) is needed to reliably serve load and enable natural gas to perform and even expand its role as a balancing resource.

Natural gas is essential to a reliable transition. Natural gas will remain essential to reliability for total energy and as a balancing resource. In many areas, natural gas-fueled generation is needed to meet energy demand during shoulder periods between times of high and low renewable energy availability, and to set frequency needed by IBRs until advanced grid forming inverters are in placed coupled with energy storage. And on a daily basis in areas with significant solar generation, the natural gas fleet is a flexible generation resource to fill the gap. The criticality of natural gas as the "fuel that keeps the lights on" will remain until very large-scale and long duration battery deployments are feasible or an alternative flexible fuel such as hydrogen, or small nuclear reactors can be developed and deployed at scale.

Regulation and oversight of natural gas supply for electric generation needs to be rethought**.** – While natural gas is key to supporting a reliable transformation of the grid, the natural gas system is not built and regulated to serve the needs of an electric power sector that is increasingly dependent upon reliable natural gas service. As it relates to BPS reliability, clear regulatory authority is needed over natural gas when used for electric generation. As seen in Storm Uri, the interdependence between the electric and natural gas sectors are increasing, and therefore the interface between these two energy subsectors require common practices on how to plan and operate these systems to benefit, not reduce, their reliable operation.

Planning for widespread extreme weather. The BPS must remain reliable and resilient during all operating conditions. As the recent extreme weather events show, industry should proactively plan for and recover from rare but expected events. Through event analysis, reliability assessments and Reliability Standards, and NERC Alerts, NERC is identifying and attempting to address these risks within our jurisdictional authorities. Regulatory and market structures need to support this planning, prioritize reliability, and support necessary investments.

Resource adequacy (capacity) does not guarantee energy sufficiency. We must shift focus to 24x7 energy planning, not just capacity plus a reserve margin. A diverse generation portfolio strengthens reliability and resilience, yet the benefits of diversity are lost when all resources underperform or fail. All generation sources have energy limits and physical constraints, and these limits and constraints need to be accurately accounted for in seasonal and long-term planning assessments.

Energy storage can and will be a game changer. As the technology continues to develop and economics continue to support the growing penetration of energy storage, these resources will become a game changer. However, we have to appreciate the gap that currently exists and the scale that we need to obtain. Investment in energy storage technologies and/or a hydrogen production and delivery systems will be required to achieve a largely or completely decarbonized electric system. Namely, a full system approach is needed to support the clean energy systems of the future.

Market Issues. While electricity market issues are outside of NERC's direct purview, policymakers, planners, and market operators need to understand how electricity market policies value reliability and incentivize investments in hardening energy infrastructure.

Conclusion

Bulk power system reliability is at an inflection point. NERC assessments demonstrate that the electric grid is operating ever closer to the edge where reliability is at risk – an edge characterized by the prospect of more frequent and more serious disruptions that threaten human wellbeing and economic productivity. To be clear, NERC believes that the energy transformation can be navigated in a reliable way. To do so, reliability must be anchored as our north star guiding the journey, with flexibility for course corrections that are surely needed for such a highly complex endeavor. The challenge is not whether we have the resources and technical ability to achieve a clean energy future. Rather, the central challenge is calibrating the pace of change with the reliability needs of a transforming system that must remain reliable and resilient at all times and under all conditions. As it exists today, this balance is out of calibration and must be corrected.

As the Electric Reliability Organization for the United States, NERC is exercising its full range of tools to support a highly reliable and secure North American bulk power system. The transmission system is indeed highly reliable, yet the aggregate electric system is threatened by a deteriorating risk profile. NERC's technical work is key to identifying risks and informing reliability actions identified in this testimony. NERC actively communicates risks to industry stakeholders, regulators, and policymakers, and develops additional regulatory measures to help address risks. With reliability as the central focus, solutions are found in coordination among jurisdictions, industry collaboration, and exploration of new authorities where needed. NERC is fully engaged in these endeavors and remains deeply committed to our work with this committee, industry stakeholders, and all policymakers to navigate this journey together.