2023
ERO Reliability Risk Priorities Report

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NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

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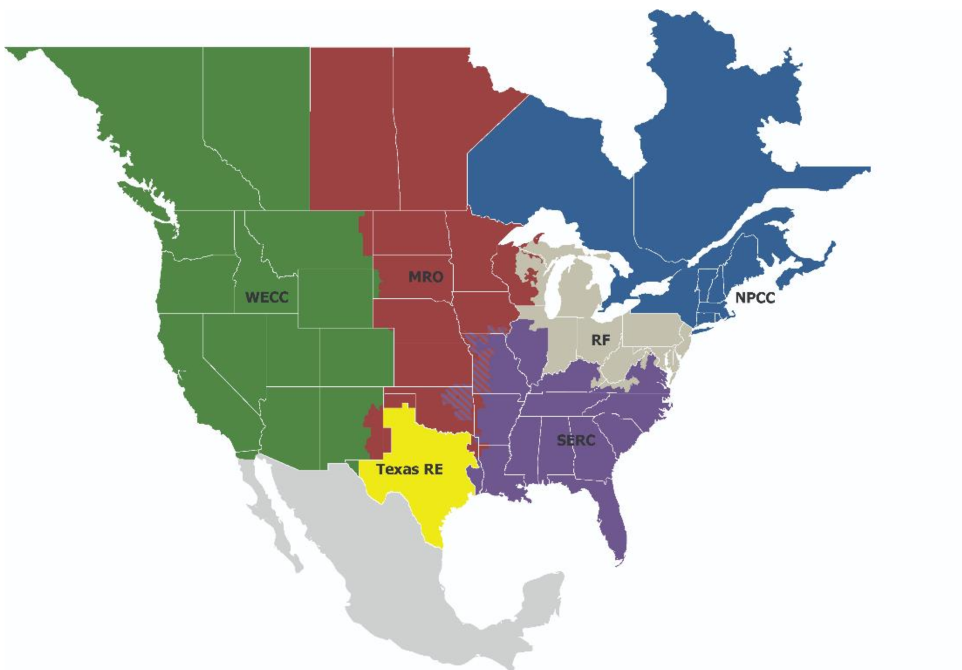
Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of NERC and the six Regional Entities, is a highly reliable, resilient, and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

Reliability | Resilience | Security
Because nearly 400 million citizens in North America are counting on us

The North American BPS is made up of six Regional Entities as shown on the map and in the corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Regional Entity while associated Transmission Owners/Operators participate in another.



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	WECC

RISC

The Reliability Issues Steering Committee (RISC)[1] advises the NERC Board of Trustees (Board) and provides key insights, priorities, and high-level leadership for issues of strategic importance to BPS reliability. Additionally, the RISC advises NERC committees, NERC staff, regulators, Regional Entities, and industry stakeholders to establish a common understanding of the scope, priority, and goals for the development of solutions to address emerging reliability issues. The RISC provides guidance to the ERO Enterprise[2] and the industry to effectively focus resources on the critical issues to improve the reliability of the BPS.

This ERO *Reliability Risk Priorities Report* (*2023 RISC Report*) presents the results of the RISC's continued work to strategically define and prioritize risks to the reliable operation of the BPS and thereby provide recommendations to the Board regarding the approach that NERC, the ERO Enterprise, and industry should take to enhance reliability and manage those risks.

[1] https://www.nerc.com/comm/RISC/Pages/default.aspx
[2] ERO Enterprise is interpreted to mean NERC, the Regional Entities, and NERC's technical committees.

Executive Summary

Introduction

This *2023 RISC Report* primary objectives are to identify key risks to the BPS that merit attention and to recommend mitigating actions that align with those risks; it differs from other NERC reports in that it provides industry with strategic direction to plan for imminent risks and their mitigation. This is in contrast to the State of Reliability report or event analysis reports that review data from previous years or events to draw objective conclusions about events, emerging risks, and the appropriate monitoring for their mitigation. This report compliments NERC's Long-Term Reliability Assessment, which is a data-driven assessment of potential future scenarios during the next 10 years.

This 2023 RISC Report reflects the collective opinion and conclusions drawn from RISC membership regarding present and emerging risks and their respective priorities. The RISC assembled and reviewed information from ERO Enterprise stakeholders and policymakers. Focused subgroups then worked to determine and evaluate the current set of risk profiles, added descriptors for each, and recommended mitigating activities. Additional risks and potential mitigating activities were identified during the 2023 Reliability Leadership Summit (Leadership Summit) that NERC and the RISC hosted in January 2023. The Leadership Summit participants were comprised of industry leaders, executives, regulators, policymakers, and subject matter experts with keen perspectives on the inherent and trending risks that affect BPS reliability.

This 2023 RISC Report includes a new risk profile, titled "Energy Policy." Energy Policy, much like "Grid Transformation," has broad implications across the risk profiles as it catalyzes changes and often amplifies their effects. Energy Policy can drive change in BPS planning and operations in short time periods, affecting reliability and resilience. Consequently, Energy Policy should consider potential impacts on the reliability and resilience of the BPS, and it can create potential risks when it does not. For example, Energy Policy decisions regarding decarbonization and electrification are some of the driving factors of grid transformation.

Risk Profiles

The five risk profile sections of this report each provide a statement, descriptors, and recommendations for mitigating each risk type:

1. **Risk Profile #1: Energy Policy**
2. **Risk Profile #2: Grid Transformation**
3. **Risk Profile #3: Resilience to Extreme Events**
4. **Risk Profile #4: Security Risks**
5. **Risk Profile #5: Critical Infrastructure Interdependencies**

The RISC recommends actionable mitigating activities that enable the ERO Enterprise and industry to use the risk profiles and the mitigating activities map for baseline and recurring evaluations. When possible, the RISC also identified the group or organization that it believes should lead the mitigating action. However, some recommendations do not present a clear owner or responsible party. In these cases, the recommendation is presented as a more generalized action item that can apply to numerous entities, including policymakers, regulators, industry, and the ERO Enterprise. The RISC did not assess resource needs for the mitigating actions. These are addressed with industry during the annual ERO Enterprise business plan and budget activities.

Additionally, the RISC evaluated each risk based on its impact to the BPS regardless of the source or location of the risk. Recognizing that BPS operators and planners require a wide-area view of the system to provide them awareness of external conditions that could affect them, the RISC broadened the risk profiles to include risks associated with grid infrastructure impacting energy deliverability (e.g., telecom and water systems), natural gas delivery systems, and resources located on the electricity distribution system, such as distributed energy resources (DER) and customer distributed resources. Recommendations for potential mitigations of these external risks are also provided.

Common Themes and Emerging Trends

For the risks recommended for active monitoring, there is a convergence of centralized themes and emerging trends. These themes and trends underscore not only the increasing interdependencies between identified BPS risks but also an increase in the potential magnitude of emerging risks. Common themes and emerging trends are indicated as follows:

- **Collaboration is key to future BPS reliability:**
  - NERC needs to be an advocate for BPS reliability by increasing communication, collaboration, and coordination with federal, provincial, and state policy makers, owners, and operators of the BPS.
- **The BPS depends on and is impacted by other infrastructure providers:**
  - Interdependencies between other industries (e.g., water and communications) and fuel types for generation are vital for reliability.
  - The increase in natural gas and renewable variable energy generation and the simultaneous decline in nuclear, natural gas, oil, and coal-fired generation have implications on the resource adequacy and the dynamic performance of the BPS.
- **Security threats continue to increase:**
  - Increased security risks (both cyber and physical) and the evolving nature of these risks are developing and changing quickly.
- **Grid transformation is happening quickly, and reliability considerations must align with the pace of change:**
  - Emerging technologies and how to best plan and incorporate those into a reliable, resilient, and secure BPS remains important.
  - With the accelerated pace of integrating new resources on the BPS, sufficient effort is needed to develop new system models, more advanced tools, and grid infrastructure improvements for their reliable and resilient integration.
  - Development of credible and centralized data sharing along with the right tools to proactively analyze system conditions towards development of mitigations is becoming more critical.

Background and Introduction

RISC Activities

This *2023 RISC Report* documents the results of the RISC's continued work to identify key risks to the reliable planning and operation of the BPS and provide recommendations to mitigate those risks; this includes recommendations regarding priorities to assist the Board and NERC management as well as industry and its stakeholders. The RISC's efforts are both responsive to and in support of the Board's resolutions on RISC's initial 2013 recommendations. The RISC continues to define and prioritize risks, develop mitigating activities, and identify accountable parties for those risks. The RISC acknowledges and appreciates the increased reliance of the Board and ERO Enterprise leadership on the results of the RISC's activities as an input for the ERO Enterprise's Long-Term Strategy Plan, the Reliability and Security Technical Committee's (RSTC) Work Plan, and NERC's Business Plan and Budget.

New Risk Profile

A new risk profile has been created this year on Energy Policy. Given the increased legislation focus and mandates on decarbonization, decentralization, and electrification, the Energy Policy will drive many rapid changes in the energy sector. There is an undeniable need to increase coordination and collaboration among all policy makers and regulators as well as on the owners and operators of the BPS. The need for this collaboration is highlighted as a risk because there is no single jurisdiction that regulates or owns all policy directives or implications and state, federal, provincial—and private jurisdictions are to be respected. Although there are numerous policy issues to mitigate, there should be a priority focus on three policy areas for reliability purposes: energy adequacy, natural gas and electric industry coordination, and DERs.

Overlapping Risk Profiles

Policy risk areas will overlap with the other risk profiles, and certain themes are repeated throughout this report at times. There are important linkages between the risk priorities and the recommended actions for the ERO Enterprise, policy makers, and industry. While the risk mitigation recommendations in each of the risk profiles of this report are presented individually, there are interdependencies acknowledged in this report between many of the risks that present unique challenges to the electric industry. Furthermore, many of these risks have been long recognized with commensurate NERC and industry monitoring for proper mitigation; however, other risks are newly emerging and require active management with a more aggressive immediate approach being necessary for the effective foresight and mitigation.

The RISC participants include representatives from the NERC committees, the Member Representatives Committee, and "at large" industry executives. The observations, findings, and guidance presented in this report include input from industry forums, trade associations, and other industry groups through multiple channels. The RISC also received feedback through both the Leadership Summit and the RISC Emerging Risks Survey. This report relies on and extends the comprehensive assessment and corresponding recommendations to the Board made in August 2021 that have been updated and refined. This *2023 RISC Report* reflects and subsequent recommendations will address discussions with representatives from the NERC standing committees and technical reports and assessments conducted by NERC and industry.

ERO Collaboration

Reliability Risk Framework

The RISC supports a reliability risk framework, *Framework to Address Known and Emerging Reliability and Security Risks*,[3] and communicates with the RSTC[4] on identified risks and mitigating activities. The RSTC works with industry to implement work plans as described below for executing those plans and developing commensurate timelines around those activities. Moving forward, the RSTC work plans will ensure that mitigating tasks and work plans will be tracked through a risk registry where ERO Enterprise projects will be tracked over time.

This reliability risk framework guides the ERO Enterprise and industry in the prioritization of risks and provides guidance on the application of ERO policies, procedures, and programs to inform resource allocation and project prioritization in the mitigation of those risks. Additionally, the framework accommodates measuring residual risk after mitigation is in place, enabling the ERO Enterprise and industry to evaluate the success of its efforts in mitigating risk and providing feedback necessary for future prioritization, mitigation efforts, and program improvements.

Collaborative Process

The successful reduction of risk is a collaborative process between the ERO, industry, technical committees, the RSTC and RISC as well as regulators and policy makers. The framework provides a transparent process that uses industry experts in parallel with ERO experts throughout the process—from risk identification to deployment of mitigation strategies to monitoring the success of these mitigations.

Process Steps

Six specific steps have been identified that are consistent with risk management frameworks used by other organizations and industries:

1. Risk Identification and Validation
2. Risk Prioritization
3. Remediation Mitigation Identification and Evaluation
4. Mitigation Deployment
5. Measurement of Success
6. Monitoring Residual Risk

[3] *https://www.nerc.com/comm/RISC/Related%20Files%20DL/Framework-Address%20Known-Emerging%20Reliabilit-Securit%20%20Risks_ERRATTA_V1.pdf*
[4] https://www.nerc.com/comm/RSTC/Pages/default.aspx

Each of these steps will require process development, including stakeholder engagement, validation/triage approaches, residual risk monitoring, and the ERO's level of purview over a risk, etc. The following provides additional detail for each specific step:

1. **Risk Identification and Validation:** The ERO identifies risks by using both leading and lagging approaches. This RISC biennial risk report and the ERO's long-term and seasonal reliability assessments (leading) have successfully brought together industry experts to identify and prioritize emerging risks as well as to suggest mitigation activities. A partnership between the ERO leadership and both the RISC and RSTC enables input from the ERO program areas as well as industry forums and trade associations to provide additional context in risk identification.

   Once the ERO and its committees, forums, and/or industry subject matter experts identify and validate a risk, it is critical that the corresponding recommendation(s) for mitigation describe, explain, and provide basis support for selecting the particular approach to mitigation. A template will be created that mirrors the standards authorization request template and requires an explanation of the risk, approach(es) for mitigation, and estimate of residual risk.

   Risk Identification: The following are the various means the ERO identifies risks:

   - Stakeholder supported technical organizations, industry forums, and associated subject matter experts
   - Focused compliance monitoring activities
   - Reliability and risk assessments
   - Event analyses
   - State of Reliability reports,[5] including the analysis of availability data systems (e.g., battery energy storage systems, TADS, GADS, DADS, MIDAS)
   - Frequency response, inertia, and other essential reliability service measurements
   - Interconnection simulation base case quality and fidelity metrics
   - RISC biennial risk report
   - Regional risk assessments
   - Communication with external parties, such as the Department of Energy (DOE), the Department of Homeland Security, Natural Resources Canada, Canadian Electricity Association, and Electric Power Research Institute (EPRI)
   - Shared public and/or government intelligence with special emphasis on cyber security

   Risk Validation: The ERO and industry subject matter experts continuously work together to validate risks to the reliable and secure operation of the BPS based on analysis of ongoing performance of the system (lagging). Validation of the magnitude and priority of the risks includes analysis from the ERO databases of system performance and event analysis. These outputs are generally covered in NERC's State of Reliability reports. In addition, the risks are further validated through the work of NERC's committees and socializing the risks with forums, government, and research organizations. Leading risk validation requires analysis of system simulations, forecasts, and performance projections.

2. **Risk Prioritization:** Risk prioritization is accomplished through an analysis of their exposure, scope, and duration as well as impact and likelihood. The primary sources of data used to support this analysis come from Step 1.

[5] https://www.nerc.com/pa/RAPA/PA/Pages/default.aspx

Deciding if the risk requires near-term mitigation or continued monitoring is informed by technical expertise. Depending on the complexity of the risk, new models, algorithms, and processes may need to be developed to better understand the potential impacts of the risk, a necessary step to develop risk mitigation tactics. The process would be consistent with other risk management frameworks used by other industries; it was recently successfully tested in collaboration with industry through a survey issued by the RISC that was based upon the risks that the group prioritized in early 2019.

The ERO Risk Registry was developed in 2023, and encompasses RISC report findings, ongoing technical committee activities, and the risks being monitored. The Registry will be updated periodically and shared with the technical committees twice a year as their works plans are developed. The Registry will track the projects detailed in the RSTC work plans and any other projects across the ERO Enterprise that mitigates an identified risk. In the future, the Registry will allow the ability to track mitigations identified in this report as they progress over time. Work plans of the technical committees will then be periodically reviewed to ensure that ongoing activities are tied to identified risks in the Registry. Furthermore, new risks can be added to the Registry and moved to the monitored portion if it is deemed that the risks are sufficiently mitigated. Following publication of the RISC biennial risk report, the RISC and RSTC will review the Registry to perform the following:

- Evaluate how ongoing and completed work addresses these identified risks
- Determine if any new risks have been identified by either committee that need to be added to the Registry
- Document monitored risks that require no additional mitigation

This review of the Registry by the RSTC will fuel the development of the RSTC's annual work plan.

3. **Remediation and Mitigation Identification and Evaluation:** The right mix of mitigation activities is balanced against both the effective and efficient use of resources and the potential risk impact and likelihood. Furthermore, the risk tolerances need to be balanced against potential impacts so that the remediation/mitigation plans can be developed accordingly. Determining the best mix depends on a number of factors:

   - What is the potential impact or severity of the risk?
   - How probable is the risk? Is it sustained, decreasing, or growing?
   - Is the risk here today or anticipated in the next 3–5 years?
   - How pervasive is the risk?
   - Is mitigation expected to be a one-time action or ongoing?
   - Have we had experience with events being exacerbated by the risks, or there is no experience, but the probability is growing (i.e., cyber or physical security)?
   - Have previous mitigation efforts been deployed and by what means? If so, were they effective? Why or why not?
   - What is an acceptable residual risk level after mitigating activities have been deployed?
   - Is the risk man-made or by natural causes?
   - Does the mix of mitigations vary based on jurisdictional or regional differences?
   - Is the risk fully or partially within the purview of the ERO?

Input from and allocation of subject matter expertise through multiple sources is part of this consideration, including resources within the ERO Enterprise and its stakeholders, such as standing technical committees and their subgroups or standard drafting teams. External parties are important sources of input as well, such as the

North American Transmission (NATF) and Generation Forums, the North American Energy Standards Board, the Institute of Electrical and Electronic Engineers, and EPRI to name a few.

Once a risk to the BPS has been prioritized according to its impact and likelihood, the ERO, NERC committees, forums, and industry subject matter experts can recommend and take on potential mitigation activities and assess their anticipated effectiveness. Coordination is key to avoid duplication and provide supportive rather than conflicting actions. The ERO remains responsible for risks to the reliable and secure operation of the BPS. Risk mitigation should still be followed by the ERO no matter which organization takes on activities. Examples of mitigation efforts include, but are not limited to, the following:

- Mandatory Reliability Standards[6] with compliance and enforcement for risks
  - Sustained, moderate to severe impact, and likely
  - Sustained, severe impact, and unlikely
  - Focused monitoring based on risk and in response to major events
- Reliability guidelines[7] for risks
  - Sustained, low to moderate impact, and likely
- Lessons Learned[8] for risks
  - Sustained, low impact, and likely
- Assist visits for risks
  - Compliance-related
  - Focused on a very specific situation or configuration
  - Generally on specific industry or entity practices or conditions
- Analysis of major events for risks
  - Identified after a major event (e.g., Category 3 or higher, definitions can be found in the *2020 State of Reliability Report*)
  - Discreet/one-time, severe impact, unlikely
  - Identified through recommended reliability improvements or best practices and lessons learned
- Analysis of "off-normal" events for risks
  - Identified after an unusual operational condition has occurred and likely not a categorized event
  - Discreet/one-time, moderate impact, unlikely
  - Identified through recommended reliability improvements or best practices and lessons learned
- Advisories, Recommendations or Essential Actions[9]

[6] https://www.nerc.com/comm/SC/Pages/default.aspx
[7] https://www.nerc.com/comm/Pages/Reliability-and-Security-Guidelines.aspx
[8] https://www.nerc.com/pa/RAPA/Pages/default.aspx
[9] LEVEL 1 (Advisories): Purely informational, intended to advise certain segments of the owners, operators, and users of the BPS of findings and lessons learned; LEVEL 2 (Recommendations): Specific actions that NERC is recommending be considered on a particular topic by certain segments of owners, operators, and users of the BPS according to each entity's facts and circumstances; LEVEL 3 (Essential Actions): Specific

- Alerts[10]
- Technical Conferences and Workshops

When reviewing the type and/or depth of remediation and mitigation, a form of cost-effectiveness analysis may be considered to understand industry impacts and potential burdens. This analysis can then be compared to potential impacts of the risk.

4. **Mitigation Deployment**: Mitigation projects will be deployed by the ERO and/or industry stakeholder groups as determined by the Mitigation Identification and Evaluation Step 3. A specific mitigation plan would involve a suitable mix of the ERO policies, procedures, and programs discussed in Section I of the *Framework to Address Known and Emerging Reliability and Security Risks.* These mitigations would be coordinated with industry partners, and stakeholders.

   Occasionally, the Federal Energy Regulatory Commission (FERC) may order the development of Reliability Standards; this can occur in this step.

5. **Measurement of Success:** Once a set of solutions has been deployed, the effectiveness of the mitigation must be measured to determine if the residual risk has been reduced to an acceptable level. Effectively, if the desired level of risk mitigation is not met, the risk is fed back to Step 1, enabling a new risk prioritization while factoring in historic mitigation and ensuring resource allocation is adapted to the changing risk landscape. This measure of success step also informs future mitigation efforts as industry and the ERO learn from the effectiveness of mitigation mixes for reducing risk. A partnership between the ERO leadership and the RISC and RSTC will enable input from the ERO program areas, industry Forums, and trade associations to provide additional context in the measurement of success. That said, criteria and other related processes should be developed for determining risk severity, likelihood, and mitigation activity effectiveness.

6. **Monitoring Residual Risk:** Once the level of residual risk is at an acceptable level, the risk is monitored through ongoing performance measures to ensure that risk remains at acceptable risk levels. The residual risk should be monitored for progress and to ensure that the mitigations that are in place continue to address the risk (Step 5). At times, mitigations need to be deployed on a periodic basis (e.g., annual workshops, reliability guideline updates) to ensure continued success (Step 4). If the risk levels heighten or increased mitigation efforts are necessary due to the changing nature of the BPS, the risk can be fed back (Step 1) for prioritization and the development of additional mitigation approaches. The ERO—working with its industry partners, technical committees, stakeholders, and forums—would determine if the residual risk was acceptable or if additional mitigations required.

Sometimes, risks are identified and validated that require accelerated industry attention. The ERO risk framework can support quick implementation of industry awareness and mitigation activities. **Figure 1** provides a pictorial flow chart of the ERO's risk management process.

actions that NERC has determined are essential for certain segments of owners, operators, or users of the BPS to take to ensure the reliability of the BPS. Such essential actions require NERC Board approval before issuance.

[10] ALERT 1: Industry Action Requested—Fast moving or recently detected, impacts moderate, ALERT 2: Industry Action Required—Fast moving or recently detected, impacts moderate to severe, ALERT 3: Industry Action Mandatory—Fast moving or recently detected, impacts moderate to severe.

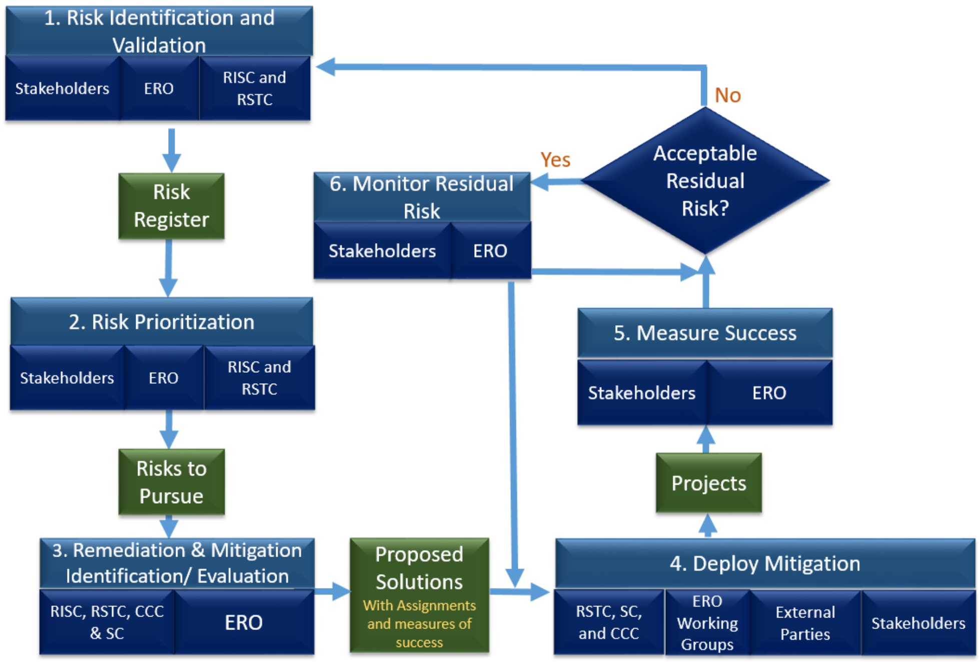


Figure 1: ERO Risk Management Process

The ERO risk framework serves to ensure effective collaboration within the ERO and industry (see **Figure 2**[11]), and it provides appropriate identification of critical industry risks; it also provides an effective establishment of work plans that ensure mitigating activities are implemented, measured, evaluated, and reevaluated in a strategic and effective manner.

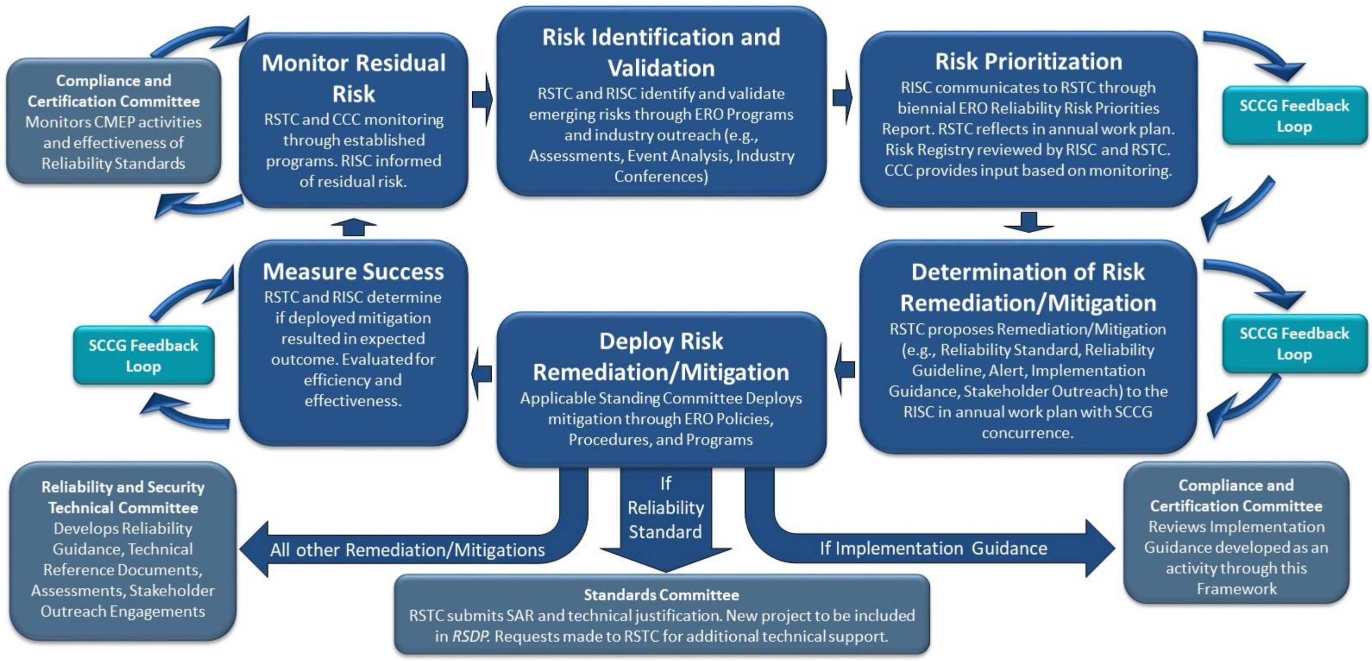


Figure 2: ERO and Industry Collaboration

[11] Graphic is from the *Framework to Address Known and Emerging Reliability and Security Risks*

Inputs to the Risk Profiles

Reliability Leadership Summit

On January 25, 2023, NERC and the RISC hosted its first in-person summit since the pandemic with leaders of the reliability community, including top industry executives; state, provincial, and federal regulators; and ERO Enterprise senior leadership. The summit focused on four specific areas: Energy Policy, Security, Grid Transformation and Impact on Resiliency, and New Technologies. An open panel discussion was held at the end of the day to address these and any other risks that required deeper discussion.

The panel discussions underscored the importance of conducting cross-sector coordination with other industries and covered the transformation of the grid; reliability and security impacts and considerations; lessons learned and unique challenges posed by cyber and physical security risks, their evolution, and potential impacts that could cause damage; and implications of the increased critical infrastructure interdependencies and how to address the jurisdictional issues that need to be tackled to address the risks they present.

2022 RISC Emerging Risks Survey

A refined Emerging Risks Survey was issued in October 2022 (with responses due early-January 2023) that sought stakeholder input on the continued relevancy of the 11 individually identified risks in the *2021 RISC Report*, the overall risk profile groups (in the next section), and the mitigating activities within each of the profile groups as detailed in the *2021 ERO Reliability Risk Priorities Report (2021 Risk Report).*[12] The objective of this year's survey was to gauge if the RISC reports are providing the correct recommendations and level of information to ultimately have an effect on the likelihood and impact of the BPS risks.

As part of the 2022 Emerging Risks Survey, respondents were asked if each of the 11 identified risks from the *2021 RISC Report* were still relevant and to rank them on a scale of 1–11. Each risk was identified as still relevant, and the responses were classified as Low (1–4), Moderate (5–8), and High (9–11) to provide an overall view of each risk (see **Figure 4**).

Risk Categories and Rankings

The following chart reveals that risks associated with the Changing Resource Mix followed by Resource Adequacy and Performance lead industry's perception on the criticality of these risks. Although Extreme Events was the fourth item ranked as a critical risk by industry, this contrasts with the most recent *2023 State of Reliability* report, which noted that Extreme Events pose the greatest risk to reliability and stability (see **Figure 3**). This information is useful for industry as a whole to prioritize and dedicate resources and budget.

[12] *2021 ERO Reliability Risk Priorities Report*: https://www.nerc.com/comm/RISC/Documents/RISC%20ERO%20Priorities%20Report_Final_RISC_Approved_July_8_2021_Board_Submitted_Copy.pdf

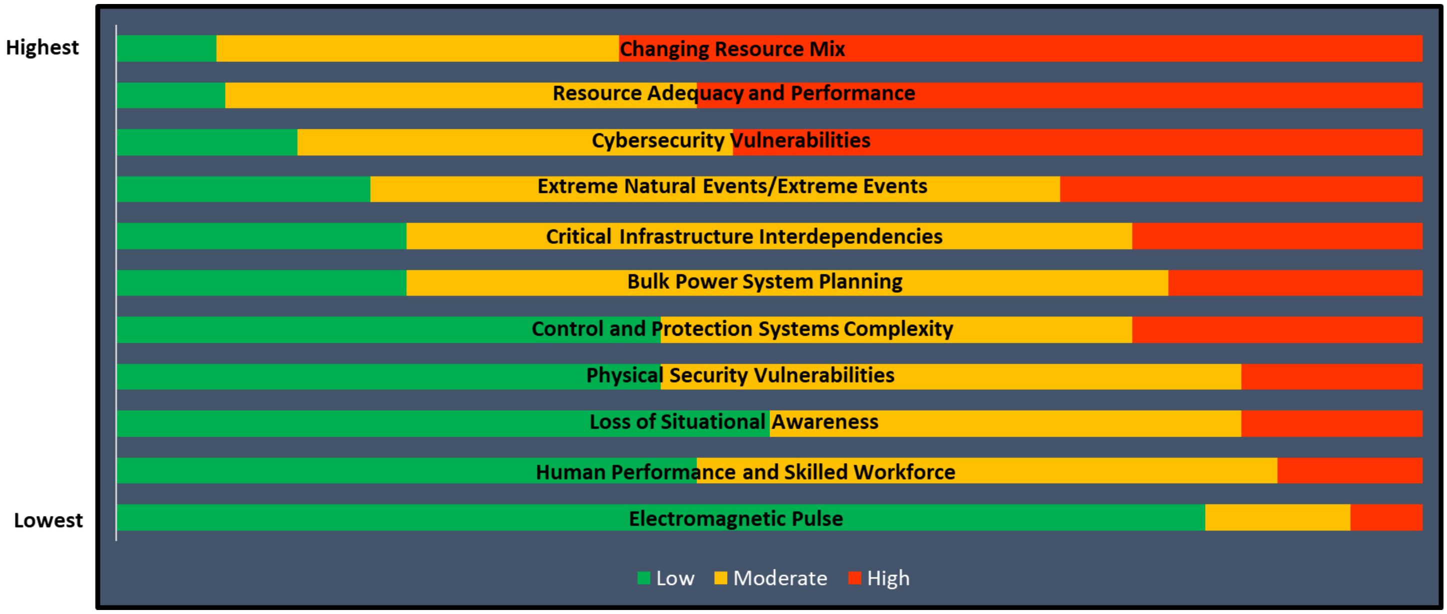


Figure 3: 2023 Risk Ranking

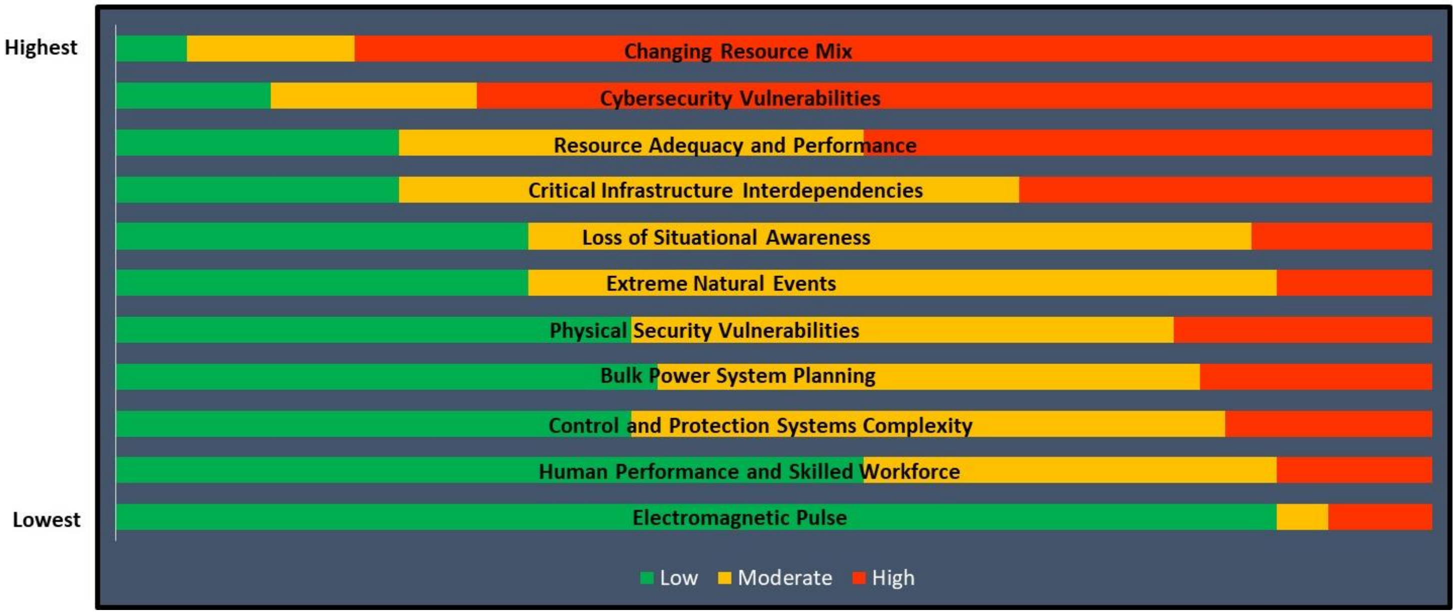


Figure 4: 2021 Risk Ranking

Figure 5 depicts the classification of manage or monitor for each of the identified risks. These risks identified as "**Manage**" are emerging, imminent, pose significant threats, and require thorough strategic planning and industry collaboration to mitigate. The risks identified as "**Monitor**" are risks that are of critical importance to BPS reliability but are considered well managed with established industry practices to mitigate and lessen potential impacts on BPS reliability.

Figure 5 also indicates that extreme events should be monitored going forward, which may seem counterintuitive with recent events. However, the Extreme Events category is comprised of events that the industry has a great deal of experience dealing with, such as hurricanes, tornadoes, or derechos by implementing emergency operating plans, mutual aid programs, drills, and studies. Recent events, such as hurricanes, show a distinct difference between the performance of BPS and the distribution system. As a result, many organizations are hardening the BPS and applicable distribution systems, so the risk is labeled "**Monitor - 2023**."

With the recent grid transformation, the resource mix is increasingly characterized as one that is sensitive to extreme, widespread, and long duration temperatures as well as wind and solar droughts. For example, having sufficient capacity does not necessarily mean that adequate energy will be available as widespread extreme temperatures are experienced.

Figure 5: Risk Classifications

Electromagnetic pulse was not individually surveyed as **Manage vs. **Monitor** in the *2019 Risk Report.*

Stakeholder Comments

The report was posted for stakeholder comment in June 2023, and the comments received were reviewed and incorporated as applicable.

Risk Profiles

Energy Policy

A. Federal
B. State
C. Provincial

Grid Transformation

A. Bulk Power System Planning
B. Resource Adequacy and Performance
C. Increased Complexity in Protection and Control Systems
D. Situational Awareness Challenges
E. Human Performance and Skilled Workforce
F. Changing Resource Mix

Resilience/ Extreme Events

A. Extreme Natural Events, Widespread Impact
- GMD

B. Other Extreme Natural Events

Security Risks

A. Physical
B. Cyber
C. Electromagnetic Pulse

Critical Infrastructure Interdependencies

A. Communications
B. Water/Wastewater
C. Oil
D. Natural Gas

Changing Resource Mix

The resource mix is transforming from large coal-fired and nuclear power plants toward natural-gas-fired, renewable, and distributed energy resources. The changing resource mix has resulted in a large amount of weather-dependent renewable variable energy resources, distributed energy resources, micro- and smart-grids, and demand response technologies as well as an increasing reliance on just-in-time delivery of natural gas to fuel new generating capacity. This transformation is resulting in a different use of the power lines and changing the system's dynamic. In parallel, the potential for cyber and physical attacks has increased as the adoption of advanced technologies compounds the reliance on digital controls and communication systems.

The electrification of many sectors, such as transportation and technology, increases demand for electricity and the importance of reliability and resilience of generation energy supply. Effective management of the significant changes the grid is presently undergoing, coupled with this electrification, is critical. There are three main characteristics of these changes: decarbonization, digitalization, and decentralization. Decarbonization is occurring as a result of improved technologies and governmental mandates. Increased digitalization poses potential challenges from a cyber-security standpoint. Decentralization, including the proliferation of microgrids and behind-the-meter-generation, is another grid development that necessitates proper system planning and effective deployment of risk mitigation strategies.

The Five Significant Evolving Risk Profiles

The five significant evolving risk profiles, which are not independent from each other, result from the previous mentioned electric industry developments. Given the rate of change and increase in regulations and policies that drive industry activities, there is need to address policy matters that impact the grid.

Energy Policy at the federal, province, state, provincial and local levels is providing incentives and targets for resource changes and end-use applications of electricity. It is further contributing to the **Grid Transformation**, which includes the shift away from conventional synchronous central-station generators toward a new mix of resources that include natural-gas-fired generation; unprecedented proportions of non-synchronous resources, including renewables and energy storage; demand response; smart- and micro-grids; and other emerging technologies which will be more dependent on communications and advanced coordinated controls that can increase the potential **Security Risks**. Collectively, the new resource mix can be more susceptible to long-term, widespread **Extreme Events,** such as extreme temperatures or sustained loss of wind/solar, that can impact the ability to provide sufficient energy as the fuel supply is less certain. Furthermore, there is an associated increase in **Critical Infrastructure Interdependencies**. For example, for natural-gas-fired generation, there is increased interdependency on delivery of fuel from the natural gas industry that also depends on electricity to support its ability to extract and transport gas.

Each of these five evolving risk profiles requires diligent awareness and steps to mitigate or control their impacts to ensure the continued reliable planning and operation of the BPS. In this way, the industry can meet its goals to ensure a reliable, secure, and resilient BPS. These mitigating activities and controls are further detailed in the individual profile sections.

Heat Maps

The RISC has adjusted the heat maps in each individual profile section (except Energy Policy) to reflect the current state as opposed to a past state. In the prior reports, the heat maps were based on the Emerging Risks Survey results, which provided a visual demonstration of the potential or actual effects that the mitigating activities from the prior year report could have if implemented (or did have when implemented) on both the likelihood and impact of baseline risks. In the *2023 RISC ERO Reliability Priorities Report*, the heat maps are based on the Committee's recommended ranking of the mitigating activities within each risk profile (except Energy Policy). This can be used as a potential tool for industry to compare mitigating activities, their individual potential effects, and resource allocation and budget.

Risk Profile #1: Energy Policy

Reliability Impacts of Energy Policy

Policy as a Reliability Risk Factor

Energy Policy can drive changes in the planning and operation of the BPS. Accordingly, policy can affect BPS reliability and resilience and could present risks to its reliable operation. Ensuring reliability during and after policy driven transitions should be a key consideration in setting Energy Policy. The implementation of policy decisions can significantly affect the reliability and resilience of the BPS. Decarbonization, decentralization, and electrification have been active policy areas. Implementation of policies in these areas is accelerating, and, with changes in the resource mix, extreme weather events, and physical and cyber security challenges, reliability implications are emerging. Demonstrated risks, such as energy sufficiency as well as natural gas and electric interdependence, are becoming increasingly critical. Emerging potential risks, such as aggregate DERs, are increasingly concerning. Due to the interdependency of critical infrastructures (i.e., electricity, natural gas, water, transportation, and communications), potential reliability risks are magnified when cross industry segments and agencies act independently to create or implement policy. Development of reliability standards and processes recognizes and respects the jurisdictional authorities setting and implementing policy decisions. It will take strong collaboration and partnerships across a multitude of boundaries to mitigate the emerging risks we face today – state, federal, provincial and private – ensuring reliability of the grid is a prioritized tenet of critical infrastructure.

Consider Reliability Impacts in Active Policy Areas

- **Energy Sufficiency is Increasingly Critical**
  Existing resource sufficiency requirements and underlying studies are based on a pre-decarbonization paradigm that traditionally focused on peak capacity requirements and assumed energy sufficiency would result; traditional resource adequacy planning is capacity focused. Energy sufficiency is when the resources meeting the capacity requirement are able to produce enough energy to meet demand at any given time. With a higher proportion of variable and renewable fueled resources evolving, this aspect of resource adequacy must be more specifically assessed.

  As the resource mix continues to rapidly change from one that was limited by rated capacity to one that is more fuel/energy-constrained, new approaches are needed to assess and ensure energy sufficiency for all hours throughout the year. Broadly impactful, long-term, and widespread weather events (geography, duration/time of year, generation technologies) are highlighting energy sufficiency issues related to changing characteristics of the resource mix and technology lag. Policy implementation timelines should actively consider the ability to ensure energy sufficiency.

  Additionally, as the resource mix evolves with new and different resources being brought into the system, upfront planning is needed to ensure that sufficient associated infrastructure, both transmission and distribution, is built to support the interconnection and delivery of the new resources.

- **Natural Gas and Electric Interdependency Increasing Impacts**
  Natural gas and electricity markets are significantly out of synchronism. Natural gas access is further challenged by multiple priority uses, including home heating and industrial processes. Coordination should focus on increased alignment of natural gas and electric nominations and the challenges electric generators face in accessing natural gas during critical periods, such as severe winter weather events.

  The electric reliability and resilience impacts resulting from the ongoing challenges between natural gas and electricity markets must be better accounted for in risk assessment, planning, and operations. These natural gas and electric coordination challenges can benefit from increased cross-industry and cross-jurisdictional communication, coordination, and collaboration. Because the electric and natural gas infrastructures arguably have a higher degree of critical infrastructure interdependencies, increased policy collaboration and coordination should occur between these sectors.

- **Resources From All Sides: Reliably Incorporating Aggregate DERs**
  DER growth is projected to continue at an increasing rate. Aggregate DERs can impact BPS reliability under certain circumstances and in some areas. NERC's role regarding distribution system resources should continue to focus on the impacts to the BPS due to the aggregate behavior of DERs and loads at the interface with the BPS. Progress is needed to better capture, communicate, and plan for the increasingly complex, dynamic nature of aggregated DERs, and loads at the interface with the BPS.

  State, provincial, and utility level implementation of updated interconnection standards, such as IEEE 1547-2018, is underway. Continued timely deployment of updated interconnection standards is important. Better understanding and planning for the impacts of aggregate DERs would benefit from improved cross-jurisdictional and cross-industry communication, coordination, and collaboration.

  The modeling of demand-side resources may require a similar level of inputs used to model supply-side resources. The rapid growth of energy storage, demand response, electric vehicles, and dynamic rate design bring new options for load flexibility that are changing the demand-side equation rapidly. As load becomes more flexible, the options to balance both the supply and demand sides of the resource adequacy calculation becomes much more dynamic and complex. More information is needed on this significant source of flexibility.

Recommendations for Mitigating the Risk

Increased coordination and collaboration between federal, provincial, and state policy makers, regulators, owners, and operators of the BPS as well as with the critical interdependent sectors is needed. Communication, coordination, and collaboration should be early, consistent, and clear to bridge increasingly complex jurisdictional lines. Education for policymakers and regulators to increase awareness of the reliability implications of policy decisions is a critical need. In addition, education for the industry, as the developers of reliability standards, is needed to better understand the processes and implications of policy decisions.

Power system reliability requires many actively engaged, closely coordinated partners. NERC and state commissions share common goals in ensuring a reliable, resilient, safe, affordable electricity system that serves all customers. States, and the utilities they regulate, are responsible for the distribution systems, including DERs, and with some utilities responsible for resource acquisition and adequacy. As economic regulators, state commissions review and approve utility investment proposals which have long term impacts on power system reliability. State perspectives are important to NERC's success – translating BPS considerations to state-level needs, experience, and policy objectives. Concurrently, NERC's perspectives are important to the States' success. NERC should continue and build on its outreach and collaboration with state commissions and with the National Association of Regulatory Utility Commissioners (NARUC).

Summary

1. Energy Policy, including time lines for implementation, can be a reliability risk factor.
2. Traditional resource adequacy approaches need to be amended to ensure energy sufficiency throughout the year.
3. Natural gas and electricity policymakers should work together with interactive infrastructure reliability in mind.
4. Resources coming from all parts of the grid require new considerations to integrate reliably.
5. Increased communication, coordination, and collaboration are needed.

Risk Profile #2: Grid Transformation

Statement of the Risk

Transformation of the grid continues to accelerate toward generation and load resources that are increasingly non-synchronous, diverse, digital, and dynamic—while dependence on uninterrupted electric energy increases. At the same time, electricity demand for homes, transportation, commerce, and industry has been increasing for decades. This rapid transformation results in an array of nontraditional operating conditions and risks.

While progress on the recommendations from the prior *Reliability Risk Priorities Report* has been made, several aspects of the grid transformation risk landscape are rapidly evolving and will require additional attention:

- Grid transformation is accelerating in all dimensions. Rapid resource deployments—on both transmission and distribution systems and with both centralized and distributed resources—are resulting in BPS operating conditions that were not within the original planning criteria. Resource types are also getting more complex and difficult to categorize in traditional ways with "private use networks" that incorporate loads, generation, and transmission already common and growing in ERCOT.
- Energy adequacy or sufficiency is increasingly important. Broader and scenario-based analyses are needed to illustrate potential reliability impacts and inform energy policies and associated time lines. The interrelated contributions to system adequacy and reliability from generation, loads, fuel supplies, electricity storage, on-site fuel storage, and transmission must be incorporated in all time horizons of planning and operations. Collaborative studies, standards and protocols across interdependent energy systems and infrastructures are needed to ensure situational awareness and reliability throughout the transforming grid.
- Load growth will be large and rapid. Driven by electrification, hydrogen production, changing load characteristics, data centers, and crypto mining, these demands can emerge and grow faster than generation and transmission can be built. System operators and asset owners must coordinate infrastructure expansion and view new loads as sources of useful and necessary reliability services. Coordinating existing and new loads with grid additions may be important for reliability but require multiparty agreements and collaboration.
- The BPS is becoming more complex, and the need to model, analyze, and operate the BPS at higher fidelity further exacerbates training, staffing, and workforce issues. Competition for available skilled workers is becoming a roadblock and an emerging risk.
- The cadence of innovation and deployment is overwhelming traditional grid operation software platforms, interconnection processes, and performance standards. Today, new renewable and storage projects can be completed in eighteen months and the next generations of inverters with valuable capabilities are released every two years. The multi-year cycles for clearing interconnect queues and updating grid management and market software platforms are becoming reliability risks.

It is no longer sufficient to assume that the system will be adequately planned by comparing the peak load hours with the generation capacity plus a planning reserve margin. To ensure reliability and resilience in all conditions under this grid transformation, assessments must consider the magnitude, duration, and impact across all hours and many years while considering that future events and operations may be outside of historical patterns. Assessments must also consider that load resources, neighboring grids, and transmission can increasingly be viewed as contributors to reliability. The highest system risk periods may no longer be peak load hours, and energy availability and real-time performance during periods of risk will be of paramount importance.

As is further emphasized in the new Energy Policy section of this report, the regulatory and socioeconomic policies driving grid transformation continue to grow in impact. Looking forward, with additional Energy Policy requirements and associated schedules to decarbonize the energy systems may further accelerate the pace and extend of grid transformation. Changes in the economics of energy sources, deployment of storage in many configurations, participation of distribution-connected energy resources and large variable loads, and the aging of existing infrastructure will all alter the nature and dispatch of generation. Grid transformation has broad implications across the other risk profiles as it catalyzes other changes and often amplifies their effects. Therefore, grid transformation challenges, opportunities, risks, and recommendations are broad in nature and provide a framework for all recommendations in this report.

Descriptors of the Risk

- **Energy Adequacy or Sufficiency—Questioning the Sufficiency of Planning Reserve Margins:** The grid has been actively transforming since the *2021 RISK Report* with accelerating changes in resource mix and performance coming from renewables-driven dispatch. Resource adequacy assessments have historically focused on ensuring generation and transmission capacity to serve peak demand, and it was assumed that energy from those peak planned resources would be sufficient to meet demand in all other hours of the year. Recent extreme events show energy sufficiency to be a significant dimension of risk given the changing resource mix and actual performance of the grid versus assumptions used in previous assessments. It is now insufficient to assume that the system is adequately planned by comparing the peak load hours with the generation capacity. Assessments must look at the magnitude, duration, and impact of resource adequacy across all hours and many years while considering that future events may be outside of historical patterns. Grid planners must realize that all resources, including load resources, neighboring grids, and transmission, have limitations and contributions to reliability. Traditional dispatchable resources will not be present in similar proportions as in the past, and resources on the path to retirement will not be able to perform at historical levels of availability and reliability. Periods of highest system risk may no longer be peak load hours, and energy availability and real-time performance during periods of risk will be of paramount importance. Effective and coordinated planning through the long-term planning, operational planning, and operating time horizons will be essential.
- **Resource Adequacy—Network Realities vs. Political Boundaries and Benefits of Improved Interregional Connection**: Resource planning, resource adequacy assessments, and operating practices are sometimes constrained by political or utility boundaries that do not fully consider the potentially significant benefits, impacts, and interactions from the interconnected nature of the BPS. The *2021 RISC Report* noted that this may result in resource, energy, and/or transmission capacity insufficiencies in an operational time frame and that remains true. However, recent extreme events and studies have highlighted the significant benefits of interregional transmission and cooperation as a capacity resource. While assessments must consider situations where neighboring areas could simultaneously experience critical energy shortage conditions, these assessments should also consider the important contributions of increased interchange and cooperation between and across areas for the many periods when resources are available.
- **Increasing Demand from Large Flexible Loads:** Rapid growth of data centers, crypto mining, and emerging green hydrogen (with significant incentives under the Inflation Reduction Act of 2022, Pub. L. No. 117-169, Stat. pg. 1,818) is resulting in many interconnection requests for large loads that, in addition to significant

incremental demand, could also be sources of grid services and flexibility. Such large loads may also be paired with significant amounts of new generation, perhaps in a "behind the point of interconnection" or "behind-the-meter" configuration. The Inflation Reduction Act and related DOE Hydrogen Hub opportunities are very real, very big, and under aggressive time lines to interconnect and energize. Timely integration of large flexible loads into reliable BPS operations will be challenging and important.

- **Increasing Demand from Electrification and DER:** Government drivers like the IRA and 2021 Infrastructure Investment and Jobs Act (Pub. L. No. 117-58, Stat. 429) are further accelerating load growth from electrification and electric vehicles, the amount of DERs, and the need for coordination with distribution system operators. The BPS will see significant increases in demand from electrification of transportation (including large and rapid fleet electrification) and broad residential, commercial, and industrial electrification. The rate of growth in electricity demand is entering a new era.
- **Consideration of Weather, Forecasting, and Combined Effects**: With the changing resource mix, traditional analytical methods do not fully account for system characteristics associated with the uncertainty of variable resources, interactions of inverters and dynamic power system devices, the declining performance of fossil-fueled resources that are nearing retirement, uncertainties associated with emerging technologies, and increased sensitivity to widespread weather situations (e.g., extreme temperatures). The result may be resource, energy, and/or transmission capacity insufficiencies in the operational horizon. Forecasts of weather and energy demand as well as the implications of such forecasts on the increasingly interrelated combined effects between resources, fuel supplies, and extreme events (e.g., natural gas production/transport and generation plus heating load under extreme cold conditions) must be more explicitly incorporated into planning and operational methodologies to ensure ongoing BPS reliability.
- **Deeper Understanding of Essential Reliability Services and Newer Technologies:** Transformation of the resource mix can alter the provision of and need for essential reliability services, interconnection capabilities and settings, and other ancillary services for BPS reliability and system operations, such as voltage control and reactive support, frequency response, ride-through, ramping/balancing, and stability. It is important to understand the grid-supporting capabilities and potential interactions of all technologies and resources (including conventional resources, inverter-based resources in their grid-following and grid-forming versions, and loads) and accurately include them in planning and operating analyses. Restoration services, such as blackstart capabilities and procedures, must also be considered. For services that may become scarce in the future, both organized markets and bilateral markets must anticipate and procure sufficient services to ensure reliable operations.
- **Equipment Standards and Settings:** Detailed information on equipment characteristics, capabilities and settings, and limitations must be incorporated into the long-term planning, operational planning, and operating time horizons. This is particularly true for digital controls and inverter-based resources. For example, future inverters connecting at transmission voltages must comply with the IEEE 2800 standard. The system planner must specify the parameter settings for the desired performance characteristics for a given resource, the resource operator must set the parameters accordingly, and the commissioning process and performance monitoring must be able to verify the desired operation of the resource. Planning and operational challenges can result if these resource addition attributes are not observable, predictable, or otherwise accounted for. Parallel development of control systems and operational models should match the pace of resource development.
- **Grid Management System and Modeling Gaps:** The speed of deployment of new resource technologies and innovative combinations of existing technologies is outpacing the cadence and timing of updates to grid management software, planning models, and operational models. In some cases, these new resource types are being delayed or even prohibited from interconnecting even though their services would be useful to the grid because legacy grid management and market software platforms are onerous and expensive to update, or it may not even be feasible to update them at all. Currently, this gap is especially true when technology is associated with energy storage and hybrid resources. The reliable, wide-spread interconnection of new resource technologies will require parallel development and innovation in grid management software and

operational/planning models at a pace that is comparable to the innovation rate of emerging technologies. This can be difficult to accomplish with legacy grid management systems and may require some innovative rethinking of roles and responsibilities of market participants and the system operator. When combined into one interconnected grid, the interactions between increasing numbers of separate new resources and load control systems with their varying operating characteristics may also create new system risks and analytical complexities.

- **Fuel Supply Considerations:** Fuel sourcing and disruption, such as from weather events and other extreme natural events, are driving new scenarios and case studies as well as broadening the range of dependencies for reliability planning and operations. Fuel constraints and environmental limitations might not be sufficiently reflected in current assessments of resource adequacy. While NERC and system operators have devoted substantial efforts to fuel/electricity interdependencies and risks, as illustrated by actual events, these issues are not resolved and will require considerable ongoing attention and effort.
- **Transition Timeline Considerations—Lead Times and Sequencing:** In addition to fuel sourcing, other elements of resource adequacy (e.g., transmission development, generator retirements, pipeline construction, environmental permitting, and right-of-way acquisition) may require long and/or uncertain lead times to assure future reliability and resource adequacy of the system. Various elements may also need to be carefully sequenced to ensure reliability throughout the transition, and the interrelated nature and contribution of transmission, generation, and fuel sources must be appreciated and considered in resource adequacy assessments, energy reliability assessments, time lines, and deployments. This has been further exacerbated by a problematic supply chain, international trade, and import tariff issues that continue to be disruptive to plans and schedules.
- **Integrating Energy Storage Technologies:** Storage is disruptive to established models, markets, and the power systems because it does not fit neatly into any single category of generation, load, or transmission—it can simultaneously exhibit characteristics of any or all these categories. Storage is an energy limited resource that introduces complex concepts of opportunity cost and state of charge optimization. Storage capabilities and uses continue to transform both distribution and BPS operations even as current systems and practices struggle to fully comprehend and exploit its potential. Whether in combination with renewable or conventional resources or connected to distribution systems or the BPS, storage, and hybrid technologies will further magnify the pace of innovation and the evolution of resource capabilities during both steady state and transient conditions.
- **Transition Considerations for Flexible Resources:** With the massive deployment of variable wind and solar resources and the characteristics of other resources that may constrain their near-term ability to respond, sufficient flexible resources will be needed to balance instantaneous supply and demand. Growing levels of storage and demand-side flexibility may contribute to intra-day flexibility needs, but multi-day energy considerations will need additional attention. Also, with societal goals to completely decarbonize energy systems in future decades, new sources of carbon-free energy will be needed to meet this additional demand. This presents a risk and challenge because there will be a series of transitions in what will be most needed and valued as societal decarbonization proceeds, and all transitions must be performed in a planned and careful manner.
- **Coordination of DERs with the BPS:** Distributed generation and storage (including behind-the-meter DERs and other DER technologies) currently follow local interconnection requirements and operational protocols that pose potential challenges to the BPS from a planning and forecasting perspective as penetration levels increase. This could be exacerbated by the "large flexible loads" noted above if these resources connect through distribution interconnection processes due to utility jurisdictional rights under state law rather than through the Bulk Electric System processes and NERC registrations used by large generators. New visibility, control and performance requirements may be needed to ensure BPS situational awareness and reliability.
- **Inconsistency in Interconnection Processes and Data Requirements**: Many entities still rely on rudimentary interconnection requirements, such as FERC pro forma interconnection agreements, that may not provide

adequate specificity regarding detailed performance of resources (conventional, inverter-based, or others). Often the interconnection requirements are not consistent across areas or entities and may lack performance and modeling requirements. The lack of consistency and performance/modeling requirements within the interconnection processes may not only lead to under or abnormal performance of resources but also high levels of ambiguity for prospective resource owners who are looking to integrate new resources (large flexible loads, IBR resources, storage, etc.).

- **Human Performance and Skilled Workforce Adequacy Concerns:** The BPS is becoming more complex, and the industry will have difficulty staffing and maintaining necessary skilled workers as it faces turnover in technical expertise. The proliferation of entities providing services and grid transforming technologies will compete for available skilled workers. For example, the increasing demand for electromagnetic transient studies and models in many regions is an exacerbating problem for entities as the complexity and computational requirements of developing, testing, and maintaining such models are high, and there is very limited expertise in this area.

Recommendations for Mitigating the Risk

Grid transformation will continue to require new and innovative approaches, tools, methods, and strategies to be used in planning and operating the BPS. To address these challenges and opportunities, the RISC encourages the following actions in order of evaluated criticality to have the most impact and likelihood of mitigating the risk:

1. **Develop and include energy sufficiency approaches in planning and operating the grid:** Traditional resource adequacy approaches that assume the system is adequately planned if there is enough generation capacity during peak load hours have become insufficient given the accelerated changes in resource mix, extreme weather events, and fuel dependencies. NERC and the industry should collaborate to better understand and define energy sufficiency and develop approaches that examine the magnitude, duration, and impact across all hours and many years while also considering limitations and contributions to reliability from all resources (including load resources), neighboring grids, and transmission. The RISC encourages the Energy Reliability Assessment Task Force to continue its work in this area. The RSTC should consider additional bookend analyses to help inform policy makers about the implications and pace of grid transformation.

2. **Ensure sufficient operating flexibility during resource and grid transformation:** System operators and planners should ensure that sufficiently flexible ramping/balancing capacity is available to meet the needs of changing patterns of variability and new characteristics of system performance. In future decades, growing storage and demand-side flexibility may help mitigate the concerns for flexibility and attention will turn to multi-day energy concerns, but intraday flexibility remains important during this transition.

3. **Further consider the impacts and benefits of DER resources, electrification, energy storage, hybrid resources, and other emerging technologies:** NERC and the RSTC should work with industry stakeholders to support creative benefits and “out of the box” thinking while evaluating these rapidly emerging and evolving technologies. It is important that the operators of these emerging technologies participate in the ERO process to provide input and information, including at the distribution level. Ongoing innovation and deployment are inevitable, and they can provide many benefits through sufficient education, creativity, and collaboration.

4. **Plan for large and rapid load growth:** Driven by electrification, hydrogen production, data centers, crypto mining, and other computational and energy-intensive methods such as artificial intelligence (AI), new loads can emerge and grow faster than generation and transmission can be built. System operators and asset owners must coordinate infrastructure expansion and encourage new loads to also be sources of useful and necessary reliability services. Coordinating existing and new loads with grid additions may be important for reliability, but they require complex multiparty coordination and collaboration.

5. **Expand marketing to and development of the workforce of the future:** The BPS is becoming more complex, and the need to model, analyze, and operate the BPS at higher fidelity further exacerbates training, staffing, and workforce issues. Competition for available skilled workers is a roadblock and risk. NERC and the industry must attract “the best and the brightest” to work on the challenges of grid transformation and

decarbonization, support development and training of both the current workforce and those making mid-career transitions to our industry, and dramatically grow the educational and training pipeline for new students at all levels from vocational training to advance graduate degrees. Some workforce needs are quite specific as well as highly technical; and therefore, they require specific attention from NERC and the ERO Enterprise, such as the work of the Electromagnetic Transient Modeling Task Force as the demand for electromagnetic transients and more complex models will only increase for the planning and operation of the BPS.

6. **Expect and be open to dramatically new grid operation approaches and platforms:** The cadence of innovation and deployment is overwhelming traditional software platforms, interconnection processes, and performance standards. The multi-year cycles for clearing interconnection queues and updating grid management and market software platforms are becoming reliability risks. While physical interconnection requirements and standards will always be important, with the power grid becoming a central pillar of societal decarbonization, it will also become increasingly necessary to advance software platforms and operating paradigms to encompass a much larger population of complex and interacting entities. At the higher levels, grid management and operational platforms must evolve in new ways to accommodate these roles.

Heat Map

In this and subsequent heat maps (see **Figure 6**), successful mitigating activities would result in the risk migrating away from the red area and toward the green area (as shown by the direction of the arrow). Implementing Mitigating Activity 1 in each heat map is proposed to have the most likelihood and impact on moving the risk down. The numbers correspond to the mitigating activities as ranked in the Recommendations for Mitigating the Risk sections. By implementing successful mitigation activities, the ranking should ideally confirm that both the likelihood and impact of the risk is reduced.

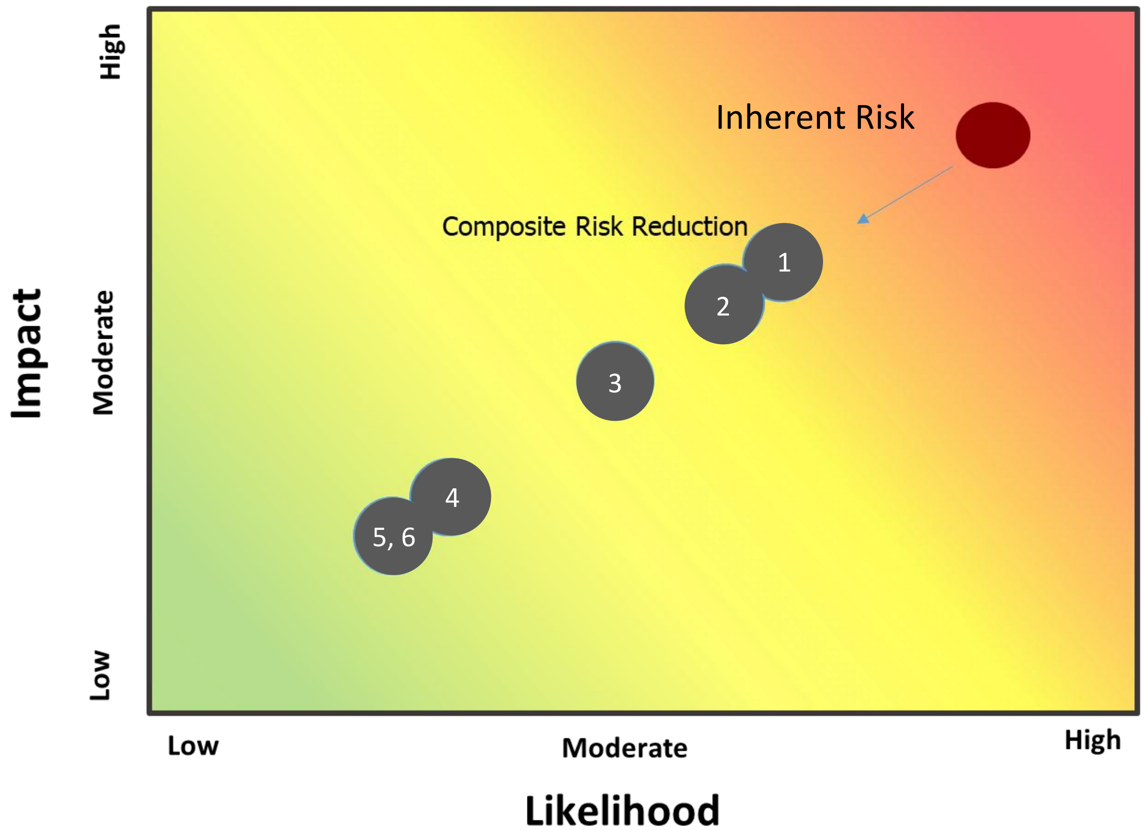
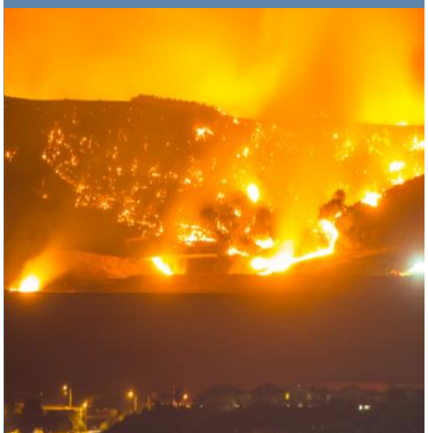
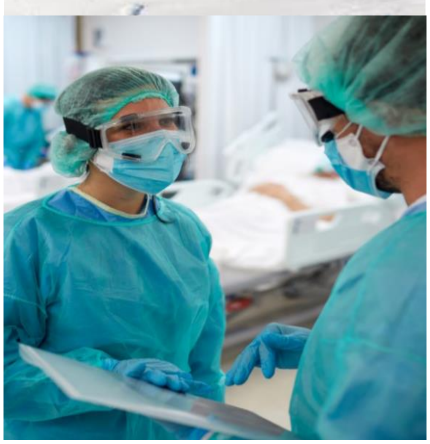


Figure 6: Grid Transformation Heat Map

Risk Profile #3: Resilience to Extreme Events





Statement of the Risk

Over the last several yearly Risk Reports, this profile's name has evolved from extreme natural events to extreme events and then to the current form—Resilience to Extreme Events. This rebranding was intended to make the profile more precise and actionable for several reasons described in this section. Therefore, the *2023 Risk Report* focuses on resilience to extreme events rather than specifically focusing on extreme natural events as identified in earlier risk reports.

BPS resilience to extreme events is an area of increasing focus. Reliability and resilience are related but distinct concepts:[13] BPS reliability involves performance consistency under various reasonably expected known or historical operating conditions. Resilience, on the other hand, involves the ability of the BPS to absorb and recover quickly from significant abnormal conditions or extreme events.

Put simply, resilience involves BPS risks with the potential to affect a broad geographic area and last an extended time.

NERC assessments over the last several years indicate that extreme ***natural*** events (e.g., storms, extreme temperatures) have caused a significant proportion of major BPS impacts. These extreme natural events can impact BPS resilience in several ways including:

- Increased intensity or frequency of events historically typical to a given area
- Instances of historically atypical events in a given area
- Longer term trends (e.g., higher average temperatures impacting ratings)
- Impacts on supply chain due to geographically larger events

Extreme natural events may affect the BPS equipment, resources, or infrastructure required to operate the BPS. Certain events are unique to the regions they impact, while others may occur in any area of the BPS. Planning studies confined to regional boundaries may not account for events that cross these boundaries. Recent cold weather events (like in ERCOT, MISO, and SPP) as well as heat events, such as the 2020 California event, underscore that extreme events pose challenges due to their nature, breadth, duration, and frequency. Also, aspects and characteristics of the grid transformation underway heighten the effects of these events and complicate mitigation. Each event type brings unique challenges from energy sufficiency, spare-parts availability, delivery, and restoration perspectives. Impacts from recent weather-related events have resulted in longer duration load loss and exacerbated consequences for customers. Preparation and proactive planning, procedures, and protocols are critical to assess and determine appropriate steps for both reliability and resiliency.

[13] Reference NATF/EPRI Resilience definition and NERC Resilience Framework.

More recently, other non-weather-related extreme events have posed challenges to BPS resilience. Most notably, the Covid-19 Pandemic altered all aspects of BPS management—increasing the probability of a severe impact while increasing the complexity of recovery (e.g., through staffing shortages, added challenges managing personnel in a remote mode, and supply chain impacts). Additionally, physical attacks have produced tangible impacts to the BPS.

For instance, reliance on natural gas generation is challenging due to the just-in-time nature of the fuel supply. While battery storage extends to 12-hour capacities, batteries do not provide the same level of resilience that multi-day or multi-week onsite fuel storage provide. To support the decarbonization of the economies, there is an active transition to electric vehicles, electric heating, etc. This will increase demand and call for higher levels of reliability as society becomes more tethered to a single clean energy source. This increasing dependence will further the ongoing shift of customer expectations regarding the reliability, resilience, and overall availability of electricity.

Historical planning and operations techniques cannot assure desired current and future performance as indicated by recent events and associated outages. For example, the BPS has increasing amounts of new technologies and resources that have not fully experienced extreme weather phenomena and may be more sensitive to extreme events in some cases. Furthermore, the new technologies have a significant digital component and represent an increased cyber-attack surface as such. Industry awareness of these changes and prospective performance deficits is being raised by NERC issuances (e.g., Level 3 Extreme Winter Weather Alert and Standards changes, such as EOP-11 and 12 updates). As the industry gains more experience and learns more lessons during this generation fleet evolution, the Reliability Standards program will be needed to ensure that the risks are appropriately managed.

While new technologies performance does not signal that these technologies and resources are incapable of operating in extreme conditions, it does underscore the need for added integrated system analysis to address them when inverter-based resources, distributed energy resources, and behind-the-meter generation become more prevalent. This evolving resource availability during extreme conditions must be considered, such as lack of wind during extreme temperatures or lack of solar during winter conditions. The precise risk of these having widespread impacts cannot yet be proven because the full penetration of these resources is yet to be realized; however, from a planning and preparation perspective, this cannot be ignored. Other risks described in this report can be “driven” by extreme events: grid transformation, cyber threats, and critical infrastructure interdependencies all have underlying issues that can be exacerbated with the advent of extreme events.

Descriptors of the Risk

Various North American regions routinely incur severe natural events, such as hurricanes and extreme cold weather. While the risk of these events in those regions is high, to date the relative impact on the BPS has been low:

- **Hurricanes** can cause widespread destruction to BPS equipment, degradation of communication capabilities, loss of load, and damage to generation resources. Recovery and restoration efforts can be hampered due to the size or scope of the storm as well as damage to interdependent infrastructure.
- **Tornados/Derecho** can cause localized destruction to BPS equipment, local degradation of communication capabilities, loss of load, and damage to generation resources. Recovery and restoration efforts can be hampered due to local damage to interdependent infrastructure.
- **Extreme Heat and Drought** can cause higher than anticipated demand, overloading and failure of BPS equipment, and degradation of resource availability. There can be limited water available for operating hydroelectric generation or reduced cooling water capacity. Drought can also be a precursor to wildfire risk as described in the next bullet.
- **Wildfires** can be a direct threat to BPS equipment. Pre-emptive actions, such as de-energizing equipment, can be taken where wildfire risk is significant. Communication programs and applications, such as new sensing equipment, can address some of the risks. However, such action needs to be balanced against the added system risk from the associated reconfiguration. Furthermore, wildfires can reduce output from

variable energy resources such as solar, requiring operators to find alternative sources to make up for the loss of energy from these resources.

- **Flooding** can occur in any area and in any season of the year. The impacts from flooding include mechanical damage to BPS equipment, degradation of clearances, fuel infrastructure, personnel access, and communications capabilities.
- **Extreme Cold Weather (Polar Vortices)** can cause higher than anticipated demand, overloading and stress failure of BPS equipment, increased reliance on interdependent critical infrastructures, and degradation of energy availability via resource mechanical failure or fuel supply interruption.[14]
- **Ice Storms** can be a direct threat to BPS equipment. The impacts from these storms combined with high winds include infrastructure damage as well as limited personnel access and communication capabilities.

Added, going forward considerations regarding severe natural events that are historically atypical. This could include the above examples but with added intensity or frequency, gradual longer-term effects, or events atypical to a geographic area, such as the following:

- **Extreme events,** such as Super Storm Sandy, which caused extensive flooding in Manhattan, New York. This type of storm was not especially large compared to storms seen in the Southeastern United States, but the storm surge combined with tidal conditions caused unprecedented flooding. This caused significant outages and required subsequent revision to design basis assumptions for flooding.
- **Increased average temperature,** such as those experienced in 2021 where temperatures rose to 120F, challenge facility ratings assumptions.[15]
- **Significant low wind conditions** that impact large amounts of wind generation over a large area can result in the loss of tens of gigawatts of capacity all at the same time. Recent experiences, such as that on June 7, 2023, in the Midwestern United States may signal the need for deeper analysis of these events when they happen and what resources need to be available to address them.

Other types of severe natural events, though less likely, could have a higher impact given the potentially broader geographic footprint. See the following examples:

- **Earthquakes** are possible in many areas of the United States and Canada. Depending on the scope and magnitude of the event, BPS facilities and interdependent critical infrastructure may suffer mechanical damage (e.g., communications, fuel, transportation). Earthquake recovery could be long and require further assessment and coordination among utilities and the ERO Enterprise.
- **Geomagnetic Disturbances** can induce harmonic currents in BPS circuits and equipment. In addition, the impacts of these disturbances result in induced direct currents that may overheat some older transformers, result in relay misoperations, and increased reactive demand or damage to reactive resources. Geomagnetic disturbance events can also affect communications capabilities, fuel delivery, and GPS systems.
- **Pandemics** can greatly alter the way the BPS is operated, specifically Covid-19. Effective telecommuting and cloud-based data exchanges enabled the grid to continue reliable operation and resulted in no major disruptions for power deliveries. However, this new paradigm also underscores the necessity to maintain proper controls and protocols for security around both systems and human capital.

[14] Cold Weather Project 2021-07: https://www.nerc.com/pa/Stand/Pages/Balloting.aspx
[15] In June 2021, a new maximum temperature of 120F was set in Washington State.

Man-made events could have a higher impact given the potentially broader geographic footprint and/or the potential for initiation in conjunction with a natural event See the following examples:

- **National Security Risks** such as civil unrest, riots, labor action/strikes, and other events could create potential issues around the physical security of the BPS as well as safety of critical personnel necessary to carry out the actions needed to maintain the reliable operation of the BPS.
- **Coordinated cyber and/or physical attack on the BPS or generation fuel sources,** especially in conjunction with another event (e.g., hurricane, severe cold), could be especially impactful.

Furthermore, there are events that pose added challenges for BPS resilience: concurrent significant increases in electrical demand (see Energy Policy); dramatic changes to BPS operating characteristics (see Grid Transformation); the growing prevalence and sophistication of security threats (Security); and de facto reliance on natural gas generation (Critical Interdependencies); and lagging construction of well-placed, highly resilient transmission. Insufficient integration of these considerations and harmonization of associated actions exacerbate the risk in the following situations:

- **Electrical demand** is expected to increase by approximately 30% by 2050 to meet de-carbonization and electrification goals.
- **Operating characteristics** are changing across North America, including changes in peak demand timing (e.g., intra-day, winter to summer, summer to winter, peaking overnight with electric vehicle charging) and increased sensitivity to small temperature changes due to penetration of electric heat pumps with resistive heating.
- **Security challenges** are continuing to evolve**.** As recently witnessed, even unsophisticated ballistic attacks can result in load loss. Cyber threats are increasing in frequency and sophistication and are benefitting from an increased attack surface as the grid becomes more digitized. Supply chain concerns at the component and subcomponent level introduce another dimension to the security challenge along with a growing deliverability concern that could impede restoration activities. Furthermore, while the recent acceleration of artificial intelligence provides prospective benefits to engineering and operating the BPS, it also likely adds another cyber security dimension for use by bad actors.
- **Reliance on natural gas generation is increasing** as traditional coal- and oil-fired generation is being retired faster than new renewable generation can come online. This is resulting in added de facto reliance on natural gas-fired generation as the interim “bridge” resource. This increases generation uncertainty given the just-in-time nature of that fuel supply and observed shortcomings in natural gas reliability.
- **Construction of well-placed, highly resilient transmission** is not keeping pace with other changes. Transmission siting and permitting is historically arduous, and this combined with jurisdictional issues may result in insufficient timely construction of resilient-design, cross-regional transmission.

Lastly, the cumulative set of above challenges increases the risk of a significant event impacting resilience. Better harmonization and pacing of the associated changes, more strategic deployment of transmission (both location and design) and further emphasis on restoration capabilities (e.g., formal Emergency Management Programs and Incident Command Structures) are among the needed mitigations.

Recommendations for Mitigating the Risk

Extreme events and their potential impacts on BPS should be monitored and addressed to maintain reliability and improve resiliency. Based on uncertainties predicting some events, it is important for operations and planning personnel to remain vigilant and prepare for high-risk seasons by learning from prior events, practicing recovery efforts, and anticipating impacts of an event to critical infrastructure. Seasonal reliability assessments should consider how more prolonged and widespread natural events may stress the system. Sufficient capacity and energy are needed to prepare for, operate, or when necessary, restore the BPS. NERC and industry have taken actions to mitigate some of these risks by recent efforts in developing a Cold Weather standard for generators,[16] the development of a joint NERC/WECC guide on effective management of wildfire,[17] and the formation of the Energy Reliability Assessment Task Force /Working Group as well as the first Level 3 NERC alert.[18] Furthermore, certain regions may become more dependent on neighboring regions if greater than anticipated forced outages of generators occur. These dependencies should be identified.

The RISC encourages the following actions in order of evaluated criticality to have the most impact and likelihood of mitigating the risk from extreme events:

1. Conduct special assessments of extreme event impacts, including capturing lessons learned, create simulation models, and establish protocols and procedures for system recovery and resiliency: The ERO Enterprise and industry should conduct detailed special assessments of extreme event impacts by geographical areas that integrate the following:
   - Critical Infrastructure interdependencies (e.g., telecommunications, water supply, generator fuel supply)
   - Analytic data and insights regarding resilience under extreme events
   - Continue to address the root causes identified under the FERC/NERC joint inquiry(s) on cold weather outages in ERCOT, MISO, and SPP; and weather impacts related to Winter Storm Elliot. Augment those efforts by determining effects of the changing resource mix over time and the performance of those resources during these widespread extreme temperature events.

Based on those assessments, ERO Enterprise should develop detailed special assessments on possible mitigation plans and provide a roadmap for their implementation. The roadmap should include specific protocols and procedures for system restoration and system resiliency. Furthermore, the ERO Enterprise and industry should do the following:

2. **Accelerate planning and construction of strategic, resilient transmission.** The ERO Enterprise should work with DOE, FERC, state regulators, Provincial, and others to enable timely and sufficient construction of resilient transmission. Such transmission should enable power routing from remotely located renewable sources to areas of high demand (even if cross-region); it should be planned, designed, and constructed with resilience in mind. For instance, prioritize transmission installation with the explicit objective of reducing resilience risk and ensuring "hardening" for anticipated risks (e.g., use of metal/concrete structures in areas of anticipated wildfire risk). Ensure the increased risk of physical attack from added circuit miles is more than compensated for given risk reduction benefits associated with added redundancy, diversity, and minimization of very high-risk assets.[19]
3. **Development of tools for BPS resiliency:** DOE is performing analyses to evaluate both static, dynamic, and real-time scenarios that affect BPS reliability and resilience including transmission needs and planning studies, and evaluation of asset performance under extremes. NERC should continue to work with DOE on these efforts to ensure robust tools that can be used industry wide to evaluate potential threats to generation, transmission, and fuel supplies.
4. **Regional coordination:** States and any other applicable governmental authorities should meet collectively to discuss and understand impacts to ensure they are a part of the resiliency discussion. This regional

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[16] https://www.nerc.com/pa/Stand/Reliability%20Standards/EOP-012-1.pdf

[17] https://www.nerc.com/comm/RSTC/Documents/Wildfire%20Mitigation%20Reference%20Guide_January_2021.pdf#search=NERC%2FWECC%20guide%20on%20effective%20management%20of%20wildfire

[18] https://www.nerc.com/pa/rrm/bpsa/Alerts%20DL/Level%203%20Alert%20Essential%20Actions%20to%20Industry%20Cold%20Weather%20Preparations%20for%20Extreme%20Weather%20Events%20III.pdf

[19] Debt Ceiling Legislation: Interregional Transfer Capability Determination Study

coordination will ensure the acknowledgement of roles in understanding the impacts, resilience investments, and implementing mitigating activities, such as formal mutual aid agreements.

5. **Workforce development:** Entities should continue to focus on attracting, developing, and retaining the skilled workforce needed to plan, construct, and operate the transforming BPS**.**
6. **Industry forums:** Forums should share and coordinate information sharing on best practices around resiliency efforts related to design considerations, supply chain deliverability issues, and identification and response to major storm events. Sharing experiences and best practices is critical.
7. **Drills and emergency response:** BPS operators should have formal emergency management programs that include periodic drills and exercises. The intention is to prepare operators to respond quickly and effectively to potentially larger incidents impacting BPS reliability as well as help ensure appropriate coordination with applicable state and local resources.
8. **Understanding of geomagnetic disturbance events on BPS:** The ERO Enterprise should monitor industry implementation of applicable actions to help reduce geomagnetic disturbance event risk to the BPS.

Heat Map

In this and subsequent heat maps (see **Figure 7**), successful mitigating activities would result in the risk migrating away from the red area and toward the green area (as shown by the direction of the arrow). Implementing Mitigating Activity 1 in each heat map is proposed to have the most likelihood and impact on moving the risk down. The numbers correspond to the mitigating activities as ranked in the Recommendations for Mitigating the Risk section. By implementing successful mitigation activities, the ranking should ideally confirm that both the likelihood and impact of the risk is reduced.

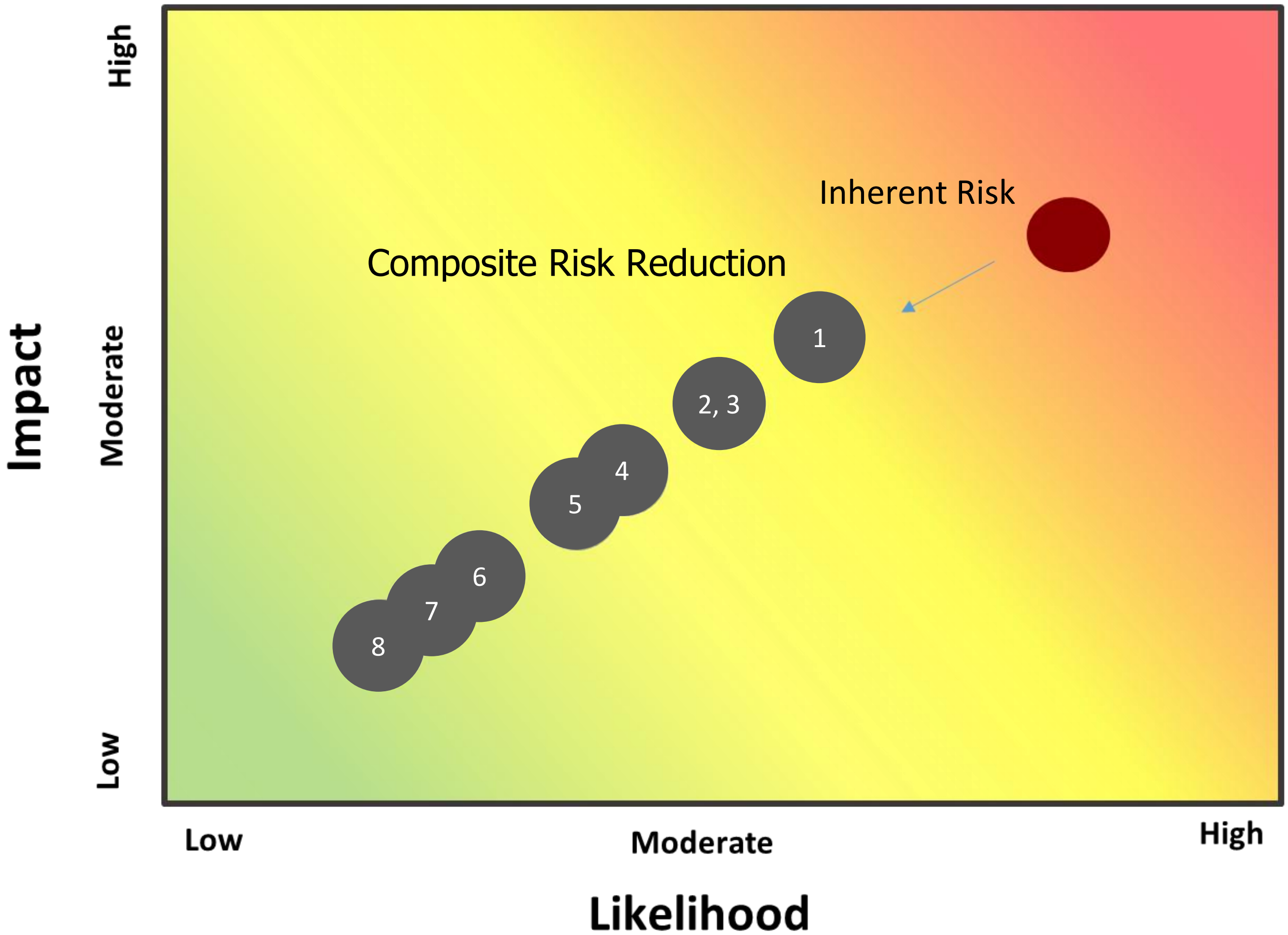
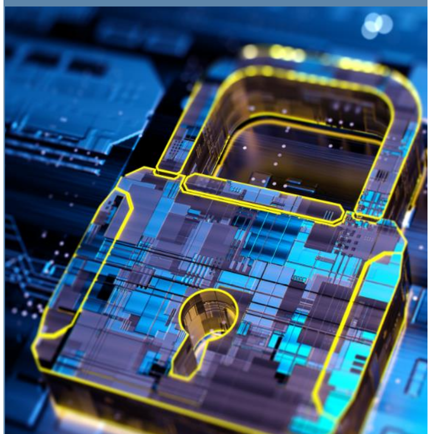


Figure 7: Resilience/Extreme Events Heat Map

Risk Profile #4: Security Risks



Statement of the Risk

The North American BPS is a vast, interconnected network that serves almost 400 million consumers across North America, and its security hinges on measures facilitated by the ERO. Over the past few years, BPS infrastructure is growing rapidly with new facilities, services, and technology integration. These all lead to many challenges for operational security, an essential element of a highly reliable and resilient BPS. This rapid expansion is increasing the potential cyber-attack surface and is raising the potential impact of coordinated attacks. Cyber and physical security are interdependent aspects as exploitation of either physical or cyber security vulnerabilities could be used to compromise the other dimension. Resultant impacts could cause asset damage, functionality loss, or limit the situational awareness needed to reliably and resiliently operate or promptly restore the BPS. These vulnerabilities are exacerbated by insider threats, poor cyber hygiene, equipment technical feasibility limitations, and supply-chain considerations. Sources of potential exploitation include increasingly sophisticated attacks by nation-state, terrorist, and criminal organizations.

These transformative changes include the convergence of information and operational technology, reliance on cloud-based technology, the emergence of (AI) technology, and potential workforce knowledge gaps. Additionally, dispersed management systems, such as those used by DER aggregators, Internet-of-Things devices, outage management systems, and increased automation/integration of operational technology networks are increasing the cyber-attack surface while the use of cloud-based hosting or services introduces the risk of code and/or data breach vulnerabilities through the use of third-party software and/or hardware. Equipment used to monitor, protect, and control the BPS as well as externally connected support systems (e.g., OMS, voice communications) could be directly exploited. Additionally, interdependent critical infrastructure sectors and subsectors (e.g., communications, water supply and natural gas used for electric power generation) can be exploited or infiltrated in a manner that impacts BPS reliability.

In recent years, there has been an uptick in physical security events, including copper theft and ballistic damage, against the BPS and specifically at distribution substations. Vulnerabilities to such events are exacerbated by commodity prices, supply chain constraints, environmental activists, and domestic violent extremists.

Descriptors of the Risk

Whereas the incidence of both cyber and physical security attacks specifically targeted against BPS and distribution substations have not resulted in any significant impacts to BPS reliability to date, recent threats in other industries underscore a need for increased vigilance and concerted effort to continue development of counter-measures to prevent, detect, respond and recover from more serious attacks.

To continue the efforts toward mitigating the effects of security risks, the RISC is providing further details on the following:

- **Physical Security Risks:** The nature and impact of physical vulnerabilities are better understood than cyber security risks. The impacts from significant physical attacks are likely to be more localized geographically. Recent on-line chatter regarding (and disrupted efforts to perpetrate) coordinated attacks are concerning. There is an ongoing evolution of the physical security risk posed by drones and limitations on response capabilities with existing laws and regulations. Some of the largest risks are considered to be co-dependence with cyber security (e.g., computer controls for physical access) and the prospective impact of replacing long lead-time equipment (e.g., large power transformers) damaged during an attack.
- **Cyber Security Risks:** Exploitation of cyber security risks could arise from a variety of external and/or internal sources. Additionally, the operational and technological environment of the electric grid is evolving significantly and rapidly as well as potentially increasing the cyber-attack surface:
  - Cyber attacks across all critical infrastructure sectors have increased; for example, the 2021 Colonial pipeline attack, the 2021 Microsoft Exchange On-Premise Product Vulnerability Exploitation, the 2021 Log4J vulnerability, the 2023 Black & MacDonald attack, and numerous variations of ransomware attacks accentuate supply chain vulnerabilities and threats from both foreign and domestic adversaries.
  - AIand machine learning can also be used as tools that cyber criminals employ to increase the success probability of attacks.
  - The increasing trend towards the virtualization and hosting of critical systems in "the cloud" could expose the electric industry to additional risks.
  - Supply chains provide opportunities for nation-states, terrorists, and criminals to impact organizations through procurement of information technology, operational technology, software, firmware, hardware, equipment, components, and/or services.
  - The increased connection of DERs and DER aggregators may pose increased cyber risks to the reliable operation of the BPS. There are currently no cyber security regulations that address the risks from all of these new industry participants.
  - The 2023 National Cybersecurity Strategy incorporates concepts like "Secure by Design" that promote security controls being implemented during installation and construction, not added later. This further reinforces the need to define, design, and encourage security controls for new entrants and participants at the time of implementation and interconnection.
  - Additionally, in the 2023 National Cybersecurity Strategy, developing "a diverse and robust national cyber workforce" needs to be a priority for government and industry going forward.
  - An electromagnetic pulse (EMP) is a man-made short-duration, high-energy burst that may be disruptive or damaging to electronic equipment. Grid operators need to understand and recognize the hallmarks of an EMP event. A high-altitude EMP is an electromagnetic pulse stimulated by a nuclear blast in the atmosphere; such an action would likely be initiated by a nation-state and thus have clear national security implications. High-altitude EMP concerns include the large geographic footprint susceptible to the pulse, range of electric grid equipment at risk (generation, transmission, distribution, and load), and a lack of definitive forewarning. Smaller portable devices are assumed to result in a relatively limited localized potential impact and can be considered analogous to the physical attack vector.

Recommendations for Mitigating the Risk

To continue the efforts toward mitigating the effects of the security risks, the RISC encourages the following actions in order of evaluated criticality to have the most impact and likelihood of mitigating the risk:

1. **NERC should develop guidance for industry on the best practices** to mitigate the risks from cloud adoption and the use of AI technologies.
2. **NERC should continue to facilitate the development of planning approaches, models, and simulation methods** that may reduce the number of critical facilities and thus mitigate the impact relative to the exposure to attack.
3. **The ERO should take the lead in encouraging government partners to create a supply chain certification system** that can be used by original equipment manufacturers, system integrators, and service providers to submit supply chain risk (SCR) qualifications, similar to the FedRamp program, which the industry can utilize prior to engagements or purchases. (How to Become FedRAMP Authorized | FedRAMP.gov)[20]
4. **NERC should develop guidance to define best practices** for "Secure by Design" and "Adaptive Security" principles in information technology and operational technology systems development and implementation.
5. **The Electricity Information Sharing Analysis Center (E-ISAC) should continue to encourage industry efforts on workforce cyber education** to raise awareness of methods and tactics used by cyber attackers (e.g., email phishing, credential theft).
6. **NERC should highlight key risk areas that arise from the EPRI's EMP analysis** for timely industry action. Additionally, training should be provided to grid operators on the hallmarks and potential impacts of an EMP attack.
7. **NERC, while collaborating with industry, should continue to evaluate the need for additional assessments** of the risks from attack scenarios (e.g., vulnerabilities related to drone activity, attacks on midstream or interstate natural gas pipelines or other critical infrastructure). NERC's lessons learned exercises have been helpful and require additional focus through seminars that educate the industry on best practices in system security planning.
8. **E-ISAC should continue to execute its long-term strategy** to improve cyber and physical security information-sharing, protection, risk analysis, and increase engagement within the electric sector as well as with other ISACs.
9. **Supply chain risk management and the threats from components and sub-components developed by potential foreign adversaries should continue to be addressed** by the E-ISAC, other federal partners, and industry to continue diligently working to mitigate threats.
10. **The industry must continue to focus on early detection and response** to cyber attacks and adopt controls that can be executed to protect critical systems.
11. **GridEx:** NERC has been conducting a biennial industry exercise that helps industry both prepare and react to potential BPS security threats. This exercise, known as GridEx, is a distributed-play grid exercise that enables participants to engage remotely and simulates a cyber and physical attack on the North American electric grid and other critical infrastructure. NERC should continue to expand the scope of GridEx to include and collaborate with cross-sector industries, such as natural gas, telecom, and water as well as state, local, and tribal authorities. Future exercises should increase the focus on detection strategies while continuing to improve the ability to respond and expedite recovery.
12. **Efforts like the Cybersecurity Risk Information Sharing Program,[21] Essence 2.0, and other similar programs similar in nature should continue**. Additional efforts to develop cyber security tools and frameworks are

[20] https://www.fedramp.gov/
[21] https://www.eisac.com/s/crisp

underway with various organizations, including National Institute of Standards and Technology, NATF, trade associations, and government partners.

Heat Map

In this and subsequent heat maps (see **Figure 8**), successful mitigating activities would result in the risk migrating away from the red area and toward the green area (as shown by the direction of the arrow). Implementing Mitigating Activity 1 in each heat map is proposed to have the most likelihood and impact on moving the risk down. The numbers correspond to the mitigating activities as ranked in the Recommendations for Mitigating the Risk section. By implementing successful mitigation activities, the ranking should ideally confirm that both the likelihood and impact of the risk is reduced.

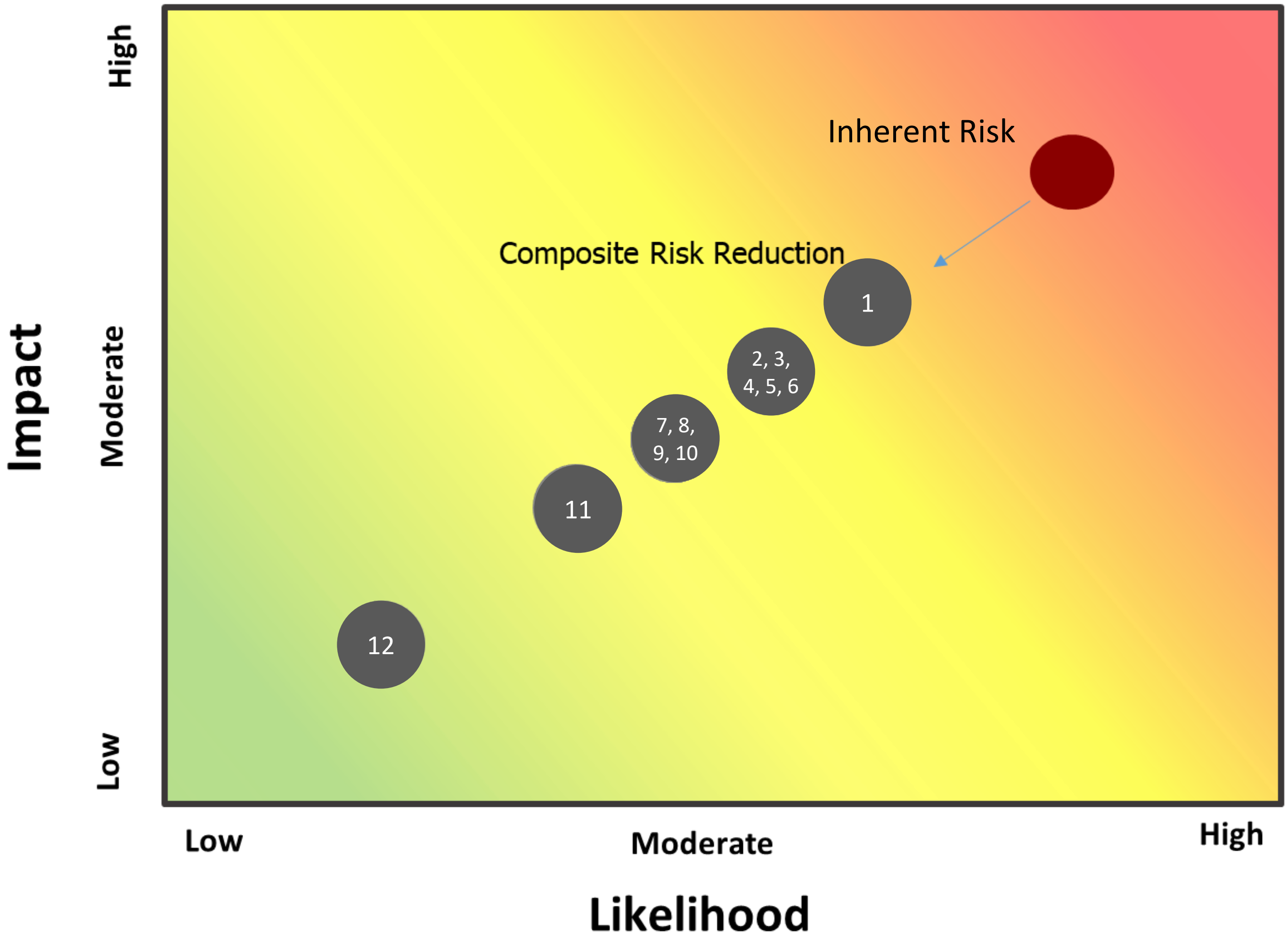


Figure 8: Security Risks Heat Map

Risk Profile #5: Critical Infrastructure Interdependencies

Statement of the Risk

Significant and evolving critical infrastructure sector (e.g., communications, water and wastewater, financial, critical manufacturing, transportation) and energy subsector (e.g., oil, natural gas) interdependencies are not fully or accurately characterized, resulting in incomplete understanding of the impacts of BPS disruptions on other infrastructure sectors or subsectors. Similarly, disruptions or compromise to other critical infrastructures may affect or disrupt reliable BPS operations. Furthermore, as there are increasing interdependencies between these critical infrastructures due to the transformation of the grid, impacts on one can have a rippling effect on others. These interdependencies are likely to increase significantly as the electrification of critical sectors, such as transportation increase. For example, electrified transportation will be challenged to bring materials and emergency services to areas with widespread outages (e.g., after a hurricane) that could hamper restoration efforts. Widespread and extended outages of electric and natural gas compressors can result in natural gas delivery issues across the system, impacting not only home heating, but also electricity generation. Widespread and extended outage of communication systems could potentially hamper situational awareness and real-time operation of the BPS. Furthermore, loss of electricity can impact all of these sectors/subsectors that are dependent on reliable, resilience, and secure energy.

Descriptors of the Risk

- Recent BPS events have highlighted that sector interdependence is becoming more critical, particularly during emergency events. Digital communications for electric system protection and control as well as for voice communications (particularly cellular) for emergency response and restoration are critical. Remote work arrangements by critical electric sector employees further underscores the need for seamless and uninterrupted communications during emergency events.

- Energy subsector interdependence continues to increase and has reached an inflection point with the natural gas subsector. Growing reliance on natural gas as an electric generation fuel source creates the potential for common-mode failures that could have widespread reliability impacts. The dependence of BPS reliability on natural-gas-fired generation does not always align with service priorities within the natural gas delivery system as well as with the weatherization requirements for natural gas gathering and delivery systems. Furthermore, the natural gas delivery system depends on reliable electric service to deliver natural gas at acceptable pressures; however, the foreseeable growth and dependence of BPS reliability on natural-gas-fired generation does not align with the expected pace of pipeline development. The financial sector could also be impacted by major outages, resulting in failure to approve everyday transactions and provide the necessary financial capital needed to ensure restoration.

- Cross-sector and energy subsector implications and coordination are not routinely socialized or thoroughly tested during drills or fully understood by both industry participants and regulators.

- State, provincial and federal governmental oversight and regulatory constructs differ widely among the sectors and energy subsectors, and this impedes information sharing and alignment on the criticality of service.

Recommendations for Mitigating the Risk

To continue the efforts toward mitigating the effects of critical infrastructure interdependencies, the RISC encourages the following actions in order of evaluated criticality to have the most impact and likelihood of mitigating the risk:

- **NERC should conduct a study** to determine the percent of available generation with on-site or firm fuel capacity in each Regional Entity.
- **As the interdependence is strong between the electric and natural gas sub-sectors, these sectors should jointly create weatherization standards**. In areas where weatherization standards already exist, benchmarking of performance versus those standards should be performed.
- **NERC and industry partners should continue to conduct meetings and conferences to highlight the importance of cross-sector and energy subsector interdependence and coordination**, such as the NERC Reliability Summit, NATF/EPRI resiliency summits, the North American Energy Standards Board Forum, and FERC/DOE technical conferences. These strategic interactions among critical infrastructure partners (e.g., industry and regulators) should focus on the identification of mutual priorities and mitigation actions. Traditional planning assumptions used by sectors independently no longer hold true going forward.
- **NERC, in collaboration with industry and industry partners, should continue to identify and prioritize limiting conditions and/or contingencies** that arise from other sectors that affect the BPS.
- **NERC and Reliability Coordinators should continue to conduct special assessments** that address natural gas availability and pipeline common mode failures.
- **NERC and industry partners should continue to increase emphasis on cross-sector coordination** in industry drills (e.g., NERC Grid-Ex, Public Safety Canada's Cy-Phy Exercise, DOE drills, utility exercises (e.g., Southern California Edison Resilient Grid Exercise)).
- **NERC should investigate the feasibility of potential infrastructure improvements,** such as feeder segmentation required to facilitate more pinpoint control of load during emergencies in order to increase the amount of load available for rotating outages.
- **The EPRI and DOE should continue their work on communication alternatives** but also the use of same or similar technologies for critical supervisory control and data acquisition data. New technologies should be explored that could assist in providing unique and hardened back-up telecommunication methods for the most critical data.
- **The ERO Enterprise should continue to communicate to state, provincial, and federal regulators of natural gas** about the critical interdependence of this fuel source with the other infrastructure sectors.
- **NERC and industry partners should continue to evaluate voice and data communication interdependencies and strategies** for ensuring continuous communications during an emergency event, particularly as remote working arrangements grow.
- **NERC should continue to encourage industry to consider the unavailability of other critical infrastructures**, such as water, sewer, roads, rails, and communications in their emergency plans.

Heat Map

In this and subsequent heat maps (see **Figure 9**), successful mitigating activities would result in the risk migrating away from the red area and toward the green area (as shown by the direction of the arrow). Implementing Mitigating Activity 1 in each heat map is proposed to have the most likelihood and impact on moving the risk down. The numbers correspond to the mitigating activities as ranked in the Recommendations for Mitigating the Risk section. By implementing successful mitigation activities, the ranking should ideally confirm that both the likelihood and impact of the risk is reduced.

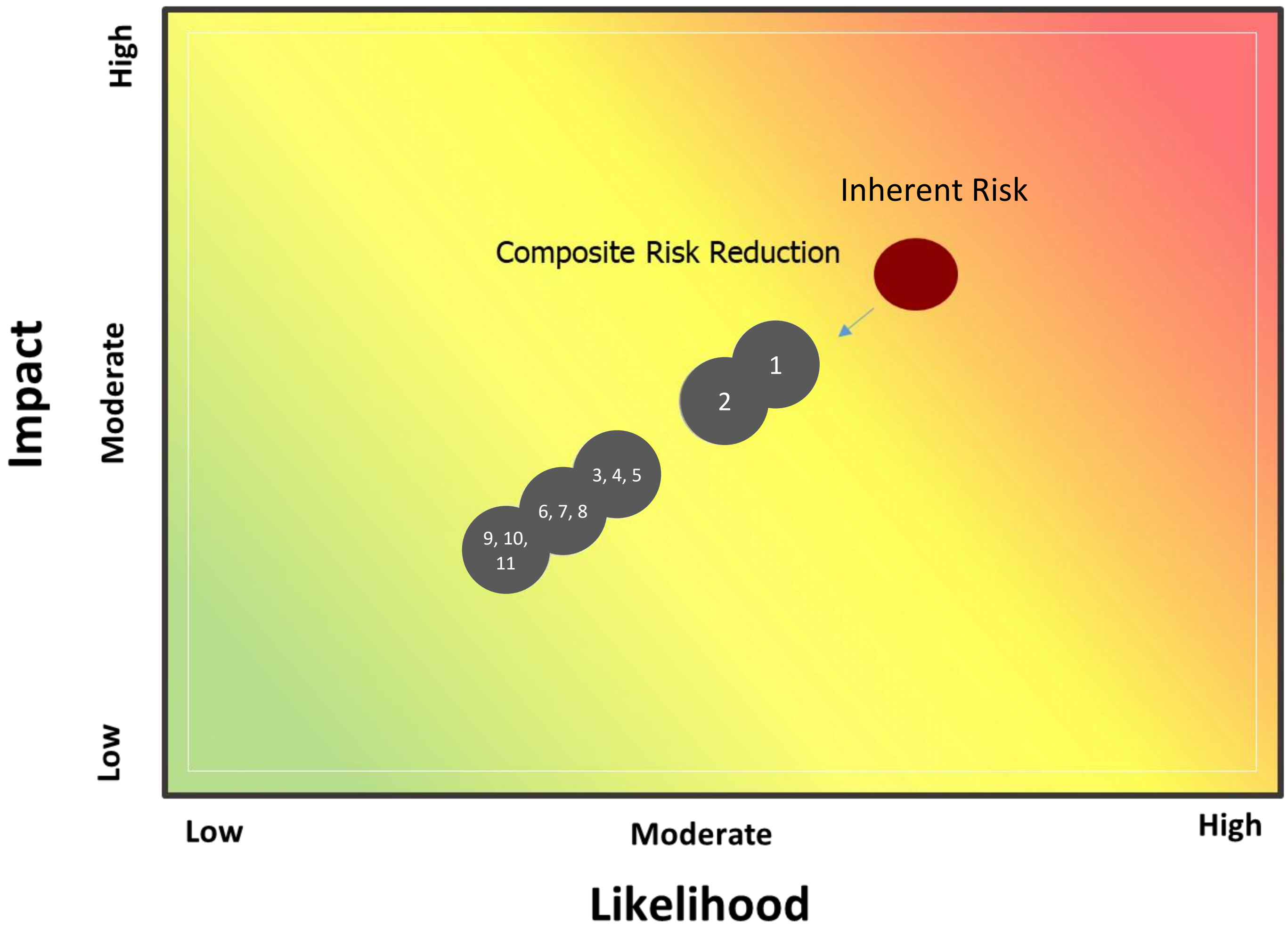


Figure 9: Critical Infrastructure Interdependencies Heat Map