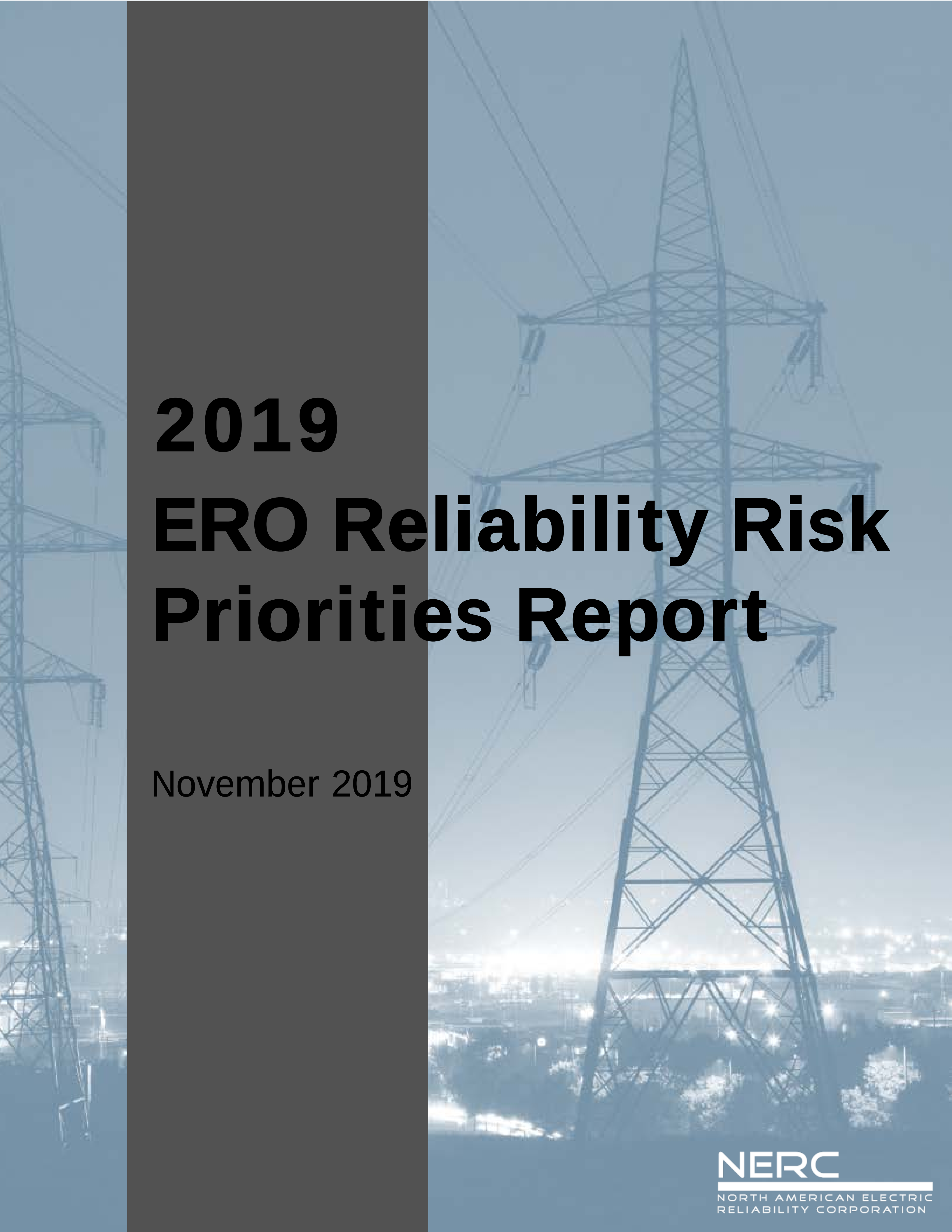

2019
ERO Reliability Risk Priorities Report

November 2019

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

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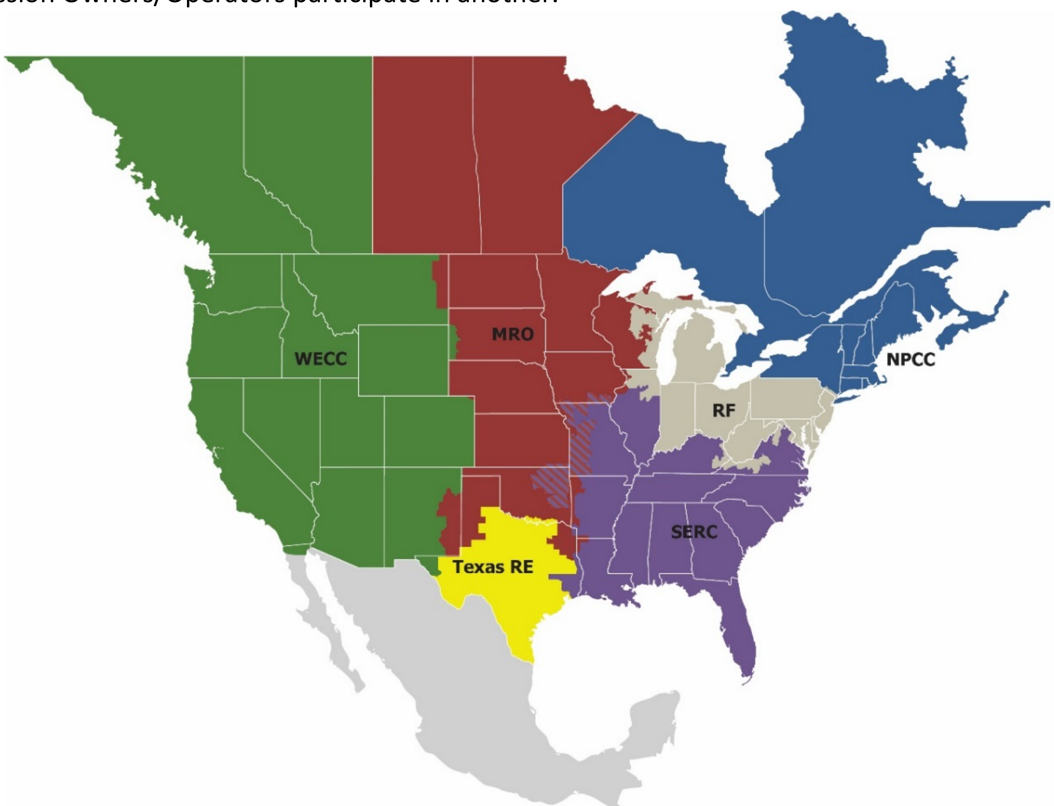
Preface

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 the North American Electric Reliability Corporation (NERC) and the six Regional Entities (RE), is a highly reliable 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 divided into six RE boundaries as shown in the map and corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Region 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	Western Electricity Coordinating Council

The Reliability Issues Steering Committee (RISC) is an advisory committee to the NERC Board of Trustees (Board). The RISC provides key insights, priorities, and high-level leadership for issues of strategic importance to BPS reliability. The RISC advises the Board, NERC committees, NERC staff, regulators, REs, 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[1] and the industry to effectively focus resources on the critical issues to improve the reliability of the BPS.

This ERO *Reliability Risk Priorities Report* (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, and industry should take to enhance reliability and manage those risks.

[1] ERO Enterprise is interpreted to mean NERC, the Regional Entities, and the technical committees of NERC.

Executive Summary

The primary objective of the *2019 ERO Risk Priorities Report* is to highlight risks that merit attention and recommend actions that align with those risks. This report differs from other ERO reports in that it is a forward-looking view of the BPS. For example, this is in contrast to the *State of Reliability*[2] report, which reviews data from previous years to draw objective conclusions about emerging risks and monitors their mitigation.

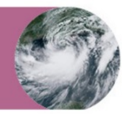
On September 13, 2019, an initial draft of the report was posted for stakeholder comments.

This report reflects the collective opinion of the RISC membership regarding the priorities. The RISC reviewed and assembled information from ERO Enterprise stakeholders and policymakers[3] and focused subgroup work to develop an initial composite set of risk profiles. Further review and consolidation resulted in four high level risks: Grid Transformation, Extreme Natural Events, Security Risks, and Critical Infrastructure Interdependencies. The image below illustrates the encapsulation of the identified risks that are further detailed in the **Risk Profiles** section.

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**

Extreme Natural 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**

[2] 2019 State or Reliability Report: https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2019.pdf

[3] Policymakers is used generally to mean any organization that can impact the legal or regulatory framework in place at various levels, including local, state, federal, and provincial governmental authorities in addition to various trades and lobbying organizations.

For the 2019 report, the RISC also significantly reduced the number of recommendations. This was completed by consolidating overlapping recommendations and removing recommendations that reflected ongoing activities; though these activities are important, they are already well underway and monitored as part of NERC's Long-Term Strategy Plan and applicable NERC committee plans. The graphic below depicts the classification for each of the identified risks.

MANAGE	1. Changing Resource Mix	MANAGE	6. Loss of Situational Awareness
MANAGE	2. Bulk Power System Planning	MONITOR	7. Extreme Natural Events
MANAGE	3. Resource Adequacy and Performance	MONITOR	8. Physical Security Vulnerabilities
MONITOR	4. Increasing Complexity in Protection and Control Systems	MANAGE	9. Cybersecurity Vulnerabilities
MONITOR	5. Human Performance and Skilled Workforce	MANAGE	10. Critical Infrastructure Interdependencies

The **Risk Profiles** section of this report provides a statement of risk, descriptors of risk, and recommendations for mitigating the risk for each profile. Through the risk profiles, the RISC recommends actionable mitigating activities that enable the ERO Enterprise and industry to use the composite risk profiles and the risk map for baseline and recurring reliability risk 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, industry, and the various organizations within the ERO Enterprise. The RISC did not assess resource needs for the mitigating actions that will be addressed with industry during the annual ERO Enterprise Business Plan and Budget activities.

Additionally, the committee evaluated risks based on impact to the BPS regardless of the source or location of the risk. To evaluate key risks to the system, the RISC recognized emerging issues emanating from different areas of the grid (e.g., resources like distributed energy resources (DERs) that may not be located or directly connected to the BPS). Operators and planners of the BPS are aware of the need to have a wide-area view of changes to the system to provide an understanding of external conditions that can affect them; therefore, the profiles identify several risks where the BPS can be impacted at interfaces (e.g., customers distributed resources, resources located on the electric distribution system, natural gas delivery system, telecom system, water system). The RISC determined it is important to illuminate external factors that increase BPS risk and offer recommendations to address those risks.

Common Themes and Emerging Trends

For risks that the committee recommends active monitoring for, it is important to note that a convergence of centralized themes and emerging trends is present. These themes and trends underscore not only the increasing interdependency between identified BPS risks but also an increase in potential magnitude of emerging risks. Common themes and emerging trends are indicated as follows:

- Interdependencies between industries and fuel types
- Increased security risks (both cyber and physical)
- The increase in natural gas and renewable generation coupled with the decline in nuclear and coal-fired generation

- The importance of emerging technologies and how to best incorporate those into a reliable and secure BPS
- Significant changes to the grid require new models and tools for reliable integration
- Development of credible and centralized data sharing along with the right tools to proactively analyze system conditions is becoming more critical

Background and Introduction

This report documents the results of the RISC's continued work to identify key risks to the reliable operation of the BPS and provide recommendations to mitigate those risks. This report includes recommendations regarding relative priorities to further 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 in connection with the initial 2013 RISC recommendations[4] that direct continued work by the RISC to define and prioritize risks, develop mitigating activities, and identify accountable parties for those risks.

There are important linkages between the risk priorities and the recommended actions for the ERO Enterprise and industry. While the risk profile recommendations in this report are presented individually, there are interdependencies between many of the risks that present unique challenges to the electric industry. These interdependencies have been acknowledged in the report. Further, many of these risks have been long recognized with commensurate NERC and industry monitoring for proper mitigation whereas others are newly emerging, requiring active management with a more aggressive immediate approach necessary for effective foresight and mitigation. 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 and Business Plan and Budget. The RISC did not assess the resource impacts of the recommendations that will be addressed with industry during the annual ERO Enterprise Business Plan and Budget activities.

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 an Emerging Risks Survey that garnered over 150 responses.

This report relies on and extends the comprehensive initial assessment and corresponding recommendations to the Board made in February 2018 that have been updated and refined. This report and recommendations also reflect discussions with representatives from the NERC committees, the discussion with leaders at the NERC Reliability Leadership Summit, and the many technical reports and assessments conducted by NERC and industry.

Inputs to the Risk Profiles

Reliability Leadership Summit

On March 14, 2019, NERC and the RISC hosted a summit with leaders of the reliability community, including top industry executives, state and federal regulators, and NERC and Regional Entity senior leadership. The summit focused on three specific areas: regulatory and policymaking during unprecedented change, identifying and mitigating significant existing and emerging landscape of risks to reliability, and providing assurance for the availability of adequate fuel delivery to satisfy energy needs. Open discussion at the end of the summit was held to address these and any other risks that required deeper investigation. Below are the pictograph summaries of each of these sessions.

[4] *See* minutes from the Board's February 7, 2013, meeting: http://www.nerc.com/gov/bot/Agenda%20highlights%20and%20Mintues%202013/BOT%20-%20February%207%202013%20Minutes.pdf

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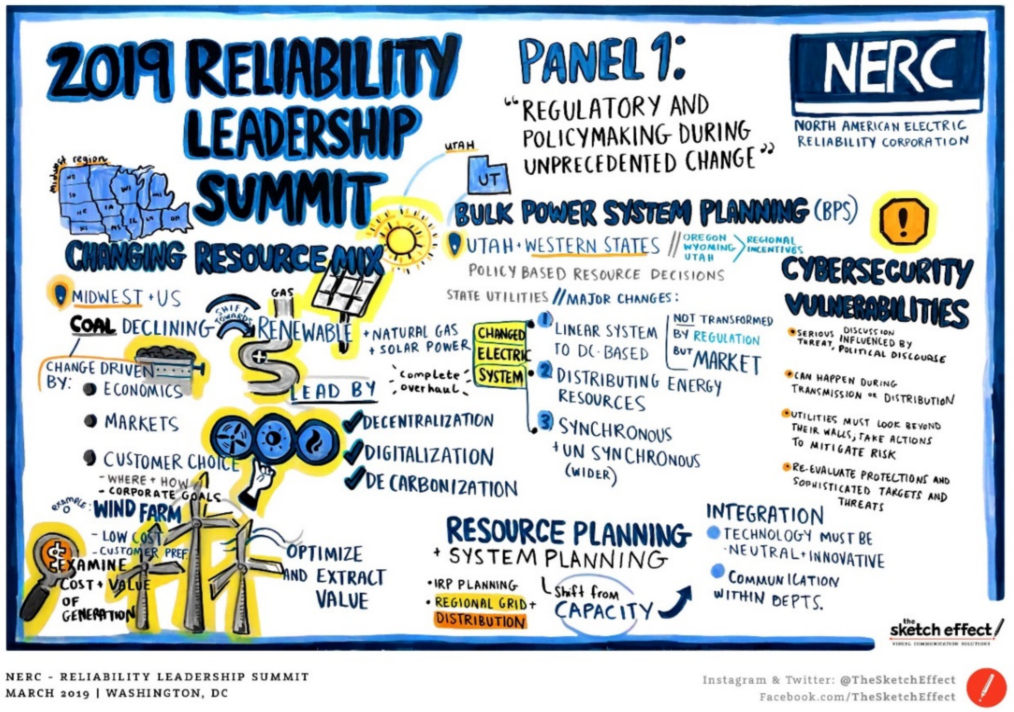

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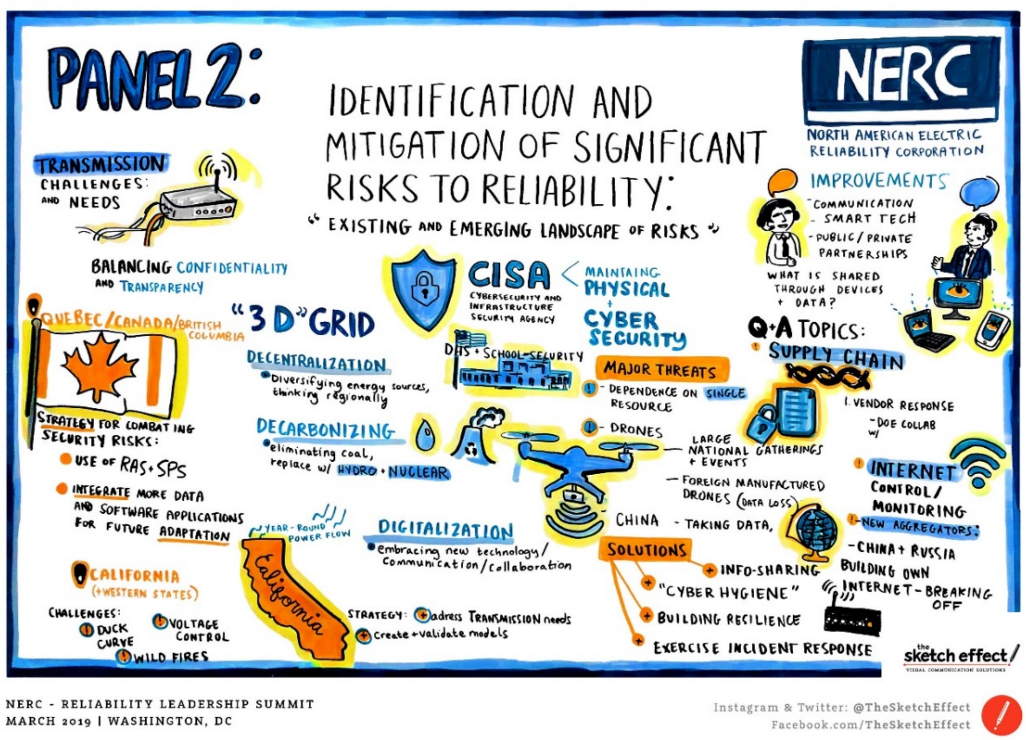

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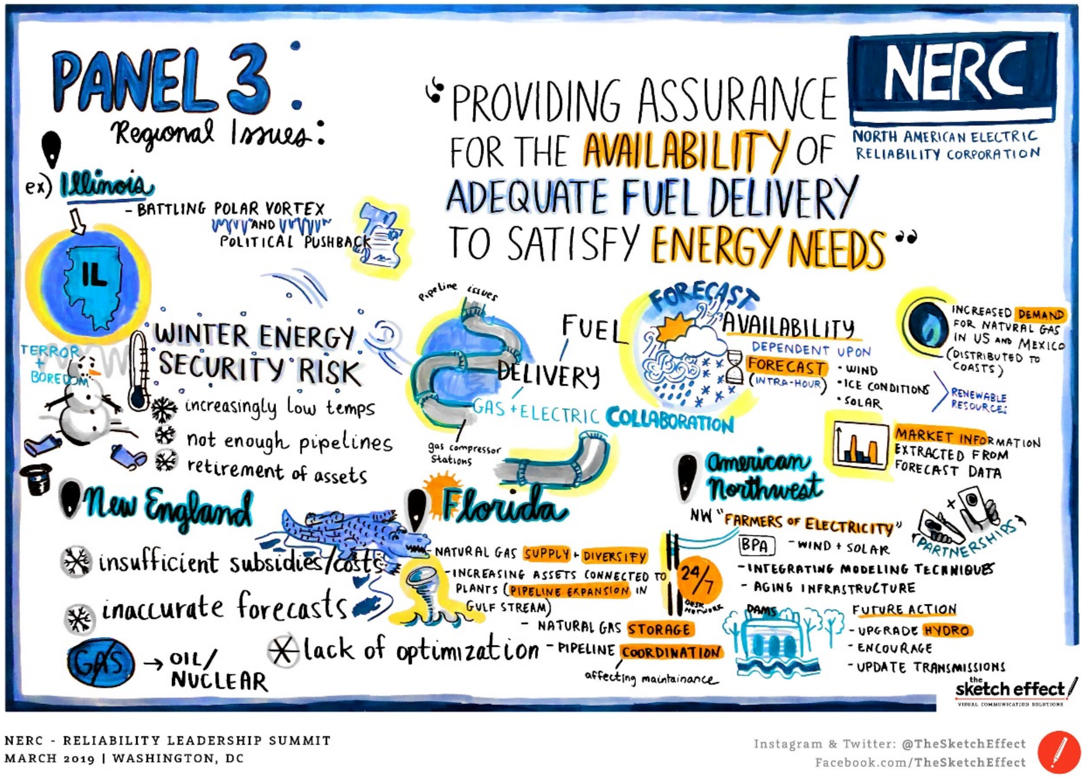

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<td>Open Discussion</td>
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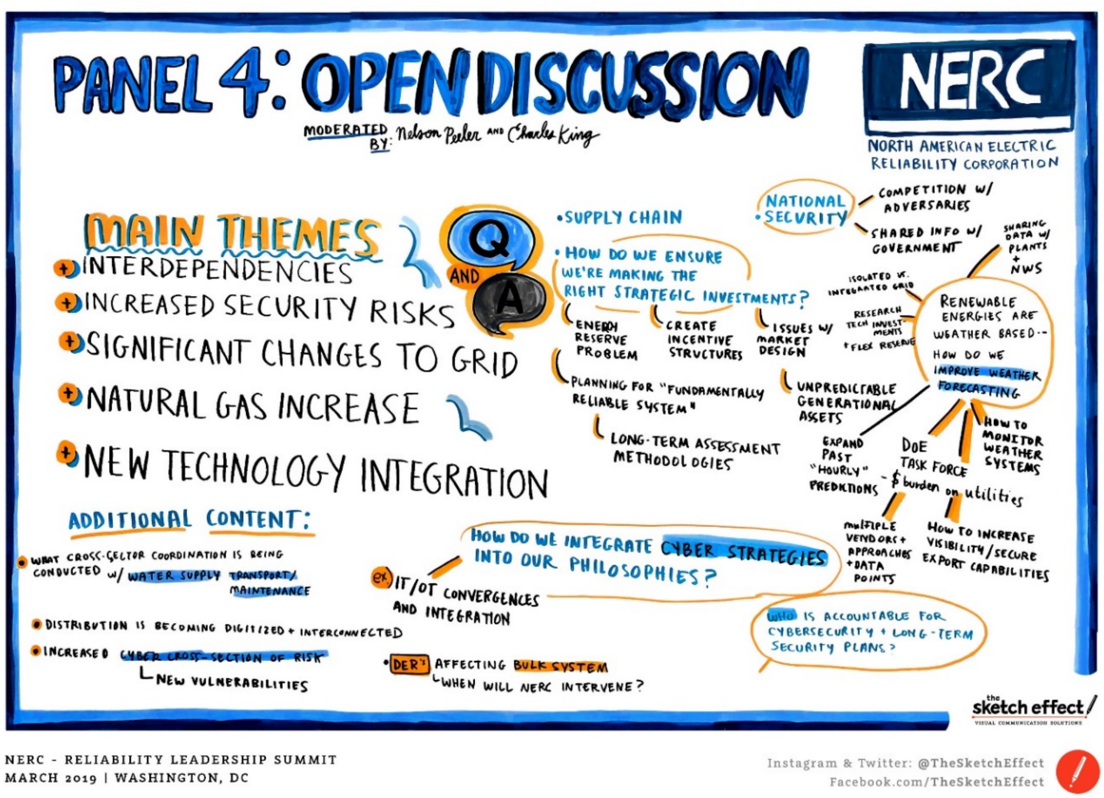

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The panel discussions underscored the importance of conducting cross-sector coordination with other industries. The potential impact on reliability from the accelerating proliferation of DERs was discussed along with potential NERC efforts to assess the effects of DERs on the reliable operation of the BPS.

Recognizing that the performance of renewable energy resources is affected by weather, the discussions reiterated the importance of improving weather forecasting to mitigate risks associated with its uncertainty. With large increases in renewable resources and natural-gas-fired units, continued retirements of coal and nuclear units is expected. All resources must be integrated into the BPS while ensuring sufficient levels of grid essential reliability services (ERSs) are maintained.

While planning for a fundamentally reliable system and recognizing the impacts of grid transformation, it is important to continue to evaluate reserve margins and the appropriate mechanisms for establishing adequate reserve margins, particularly given the changing dynamics of the BPS. The operation of the grid and the relationship between Generator Operators and Balancing Authorities has changed due to proliferation of DERs and the creation of larger Balancing Authorities operated by centralized Regional Transmission Organizations markets.

Lastly, the need for higher levels of cyber security will continue to create additional intricacies to BPS reliability. It is important to understand which organizations are accountable for cyber security and long-term security plans. Information technology and operational technology convergences should be recognized and adequate levels of cyber security should be planned for prospectively. For effective implementation of existing and future cyber security standards developed for each of the critical infrastructure sectors, harmonization may be required. Cross-sector communication will be critical to effective management of cyber risks.

Prioritization of Inherent Priority Risks

Risk Groupings

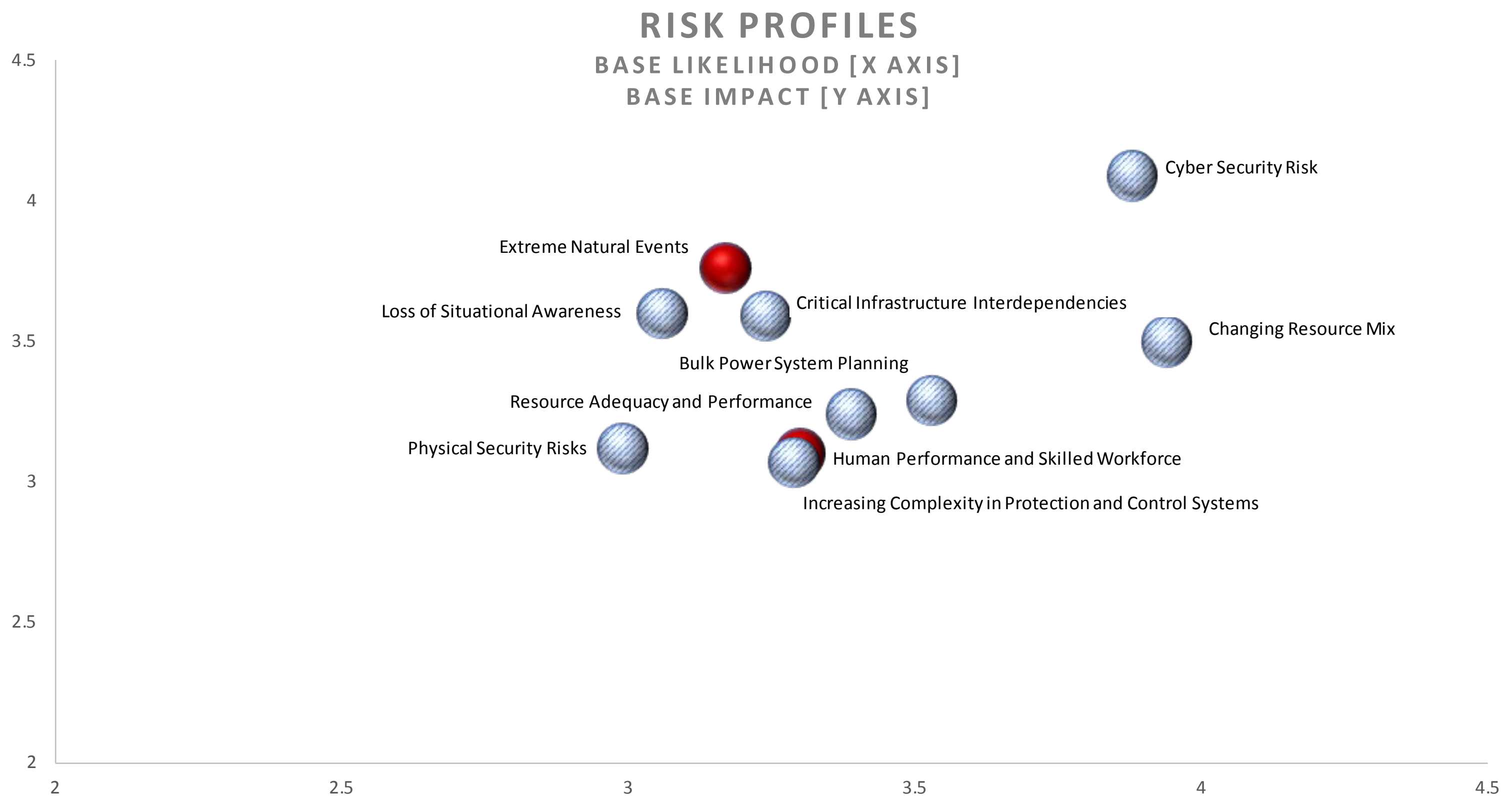
This year is transitional for the RISC Report and includes industry input on each risk profile as well as a new format. In 2018, input was requested from industry for each of the prior year risk profiles. Unlike previous RISC reports where the risk likelihood and impact was derived from the expertise of the RISC members, the 2019 risk mappings of impact and likelihood were derived by using a comprehensive survey provided to industry leaders across the ERO footprint. The survey results have been used to establish a 2020 base line of impacts and likelihood that can be used to trend and benchmark against subsequent RISC reports and analyses. Survey results provided the RISC with a two-fold benefit: a prioritization of the existing risk profiles and the ability to consolidate the profiles from nine[5] to four. The 2018 survey did not provide an overarching data collection for each stated risk profile. The survey data is considered relevant and has been reviewed with the expertise and judgement of the RISC members.

The prioritization by industry did align with prior year's heat map placement of each risk profile "bubble." The data now provides a baseline capability from which the RISC can determine over time how each risk is viewed by industry through its evolution and risk profile lifecycle. In addition, survey data provided quantitative information for the RISC members to discuss prior to heat map finalization. Similar to prior years, the heat map is formatted based on an X-Y axis: X representing the potential likelihood or probability of the risk coming to fruition, and Y representing the perceived impact. Risk profile placement is based on 2019 data where 0 = minimal risk/minimal impact, and 5 = severe risk/severe impact.

Consolidation of prior year's risk profiles from nine to four simplifies high-level discussions on risk identification and phased mitigation or remediation processes.

The heat map tracks the risks so industry can consider potential impacts within their organization. The following graphic shows each of the identified individual inherent risk profiles mapped against likelihood and impact scales. The heat map illustrates RISC's assessment of how the inherent risks of the profiles have changed, if any, from the previous report. Extreme Natural Events and Human Performance and Skilled Workforce had the most significant change (identified in **red** on the heat map) while all other risks remained in the same general location as the previous report. The orange color on the **individual** risk heat maps represents the high-level risk profile they are associated with.

[5] Critical Infrastructure Interdependencies was added as the tenth risk profile mid-year in 2018 while reformatting the report and developing the Industry Risk Profile Survey.


RISK PROFILES
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BASE IMPACT [Y AXIS]
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4
4.5
Cyber Security Risk
Extreme Natural Events
Loss of Situational Awareness
Critical Infrastructure Interdependencies
Changing Resource Mix
Bulk Power System Planning
Resource Adequacy and Performance
Physical Security Risks
Human Performance and Skilled Workforce
Increasing Complexity in Protection and Control Systems

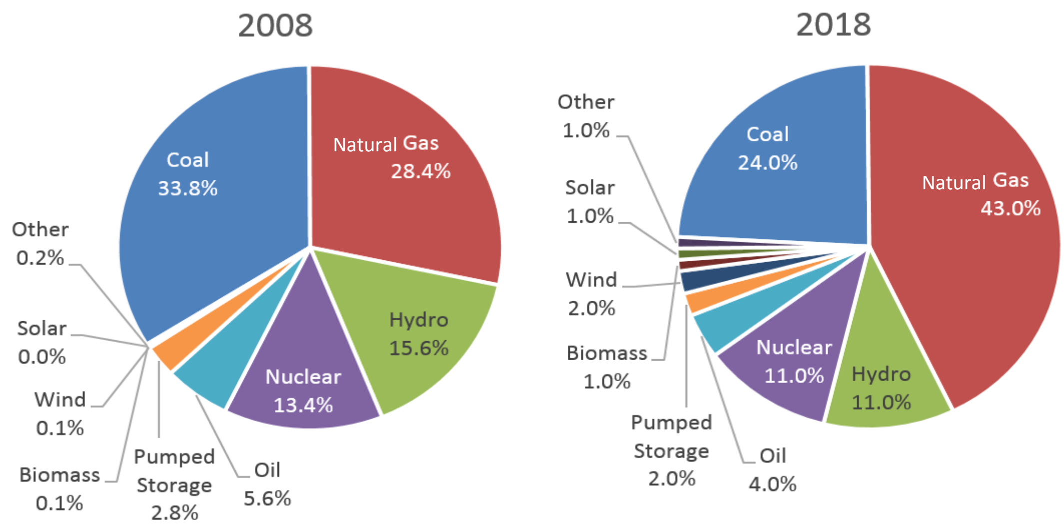
Risk Profiles

Risk Profile #1: Grid Transformation

The transformation of generating resources and fuel sources along with changes in load characteristics is creating new reliability risks from long and short-term planning to real-time operations.

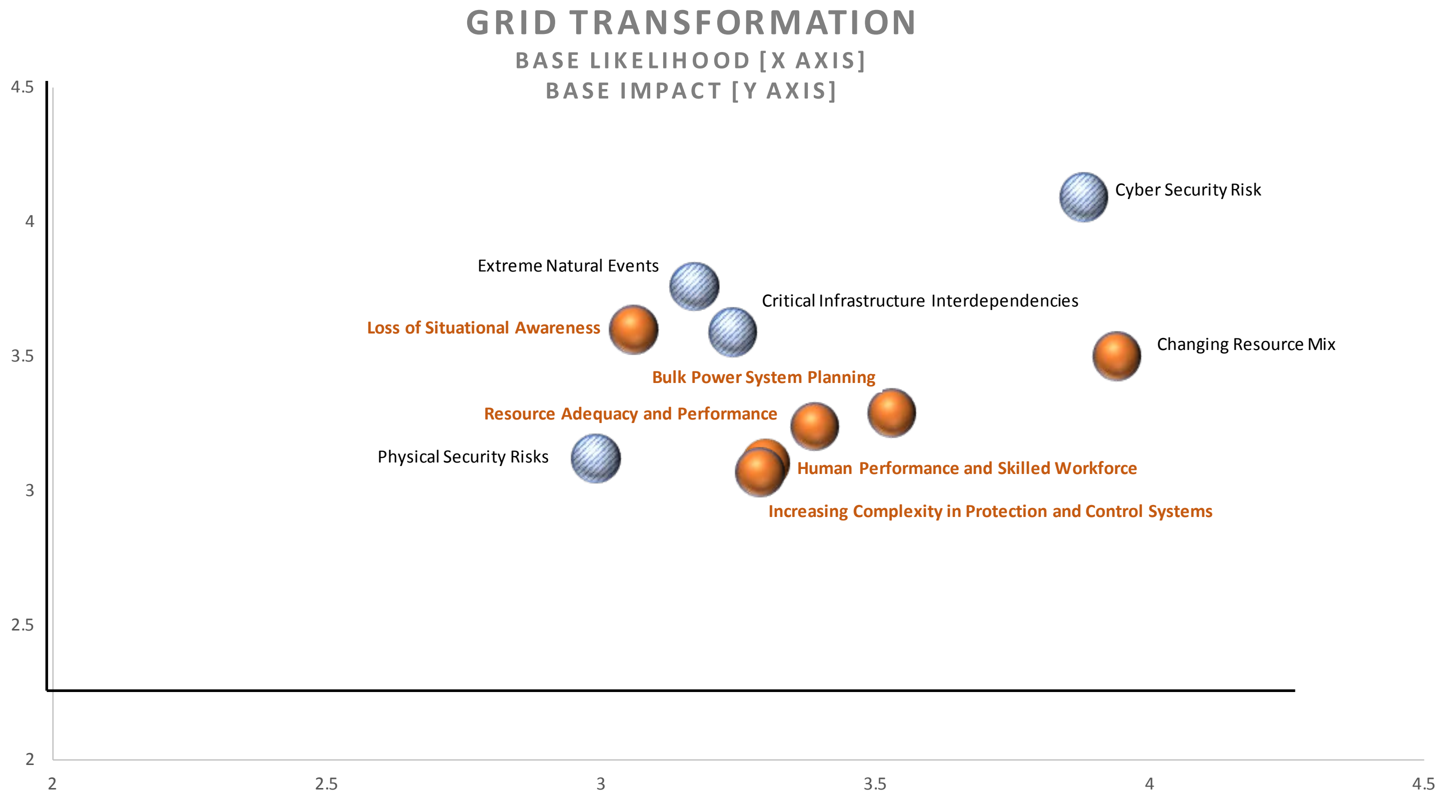
Statement of the Risk

Public inputs along with the influence of regulatory and socioeconomic policies are continuing to drive a significant evolution in the mix of power resources. The shift away from conventional synchronous central-station generators toward a new mix of resources continues to challenge generation and grid planners and operators. This new paradigm of the resource mix includes natural-gas-fired generation; unprecedented proportions of non-synchronous resources, including renewables and battery storage; demand response; smart- and micro-grids; and other emerging technologies. Collectively, the new resources are more susceptible to energy sufficiency issues through common mode contingencies in fuel supply whether the fuel is natural gas or inverter-based. Looking forward, consumers' desire to decarbonize, individual states' legislative and regulatory initiatives, expected lower production costs of new resources, and the aging of existing generation infrastructure all will alter the nature and dispatch of generation, leading to further resource and grid transformation.



This transformation presents a number of potential challenges and opportunities when it comes to reliability of the BPS as detailed in the risk descriptors below.

Risk Mapping



Descriptors of the Risk

- **Changing Resource Mix, Bulk Power System Planning, and Resource Adequacy and Performance**
    - **Potential Impact on Essential Reliability Services:** Transformation of the resource mix can alter the provision of and need for ERSs and other ancillary services needed for BPS reliability and system operations, such as voltage control and reactive support, frequency response, and ramping/balancing. Restoration services, such as blackstart capabilities and procedures, could be affected as well.
    - **Technology with Different Design and Performance Characteristics:** The continued integration of large amounts of new resource technologies (e.g., DERs, grid and distribution system-connected inverter-based resources, and energy storage) could lead to inaccurate forecasting of anticipated demand. Further, this integration can also result in other planning and operational challenges if these resource additions are not observable or predictable or are otherwise not taken into account. The dynamic and transient performance and response of these technologies also brings new challenges.
    - **New Data and Information Requirements:** The need for data and information about new and changing resource characteristics must be incorporated into the long-term planning, operational planning, and operating time horizons. Some of this new information will be from nontraditional sources (e.g., breakout of penetrations of DERs and inverter operating parameters) that in itself may present challenges to those responsible for incorporating the information into models representing future conditions.
    - **Energy Storage Technologies:** Storage capabilities and uses will likely transform both distributed and bulk system operations. Whether in combination with renewables or conventional resources and whether 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.

- **Fuel Supply Considerations:** Fuel sourcing and disruption capabilities, such as from weather events and other nature-based extreme conditions, are driving new scenarios and case studies and broadening the range of dependencies for reliability planning and operations. Fuel constraints and environmental limitations might not be reflected in assessment of resource adequacy.
- **Resource Adequacy Guidelines Consideration:** In addition to fuel sourcing, other elements of resource adequacy (e.g., transmission development, pipeline construction, and environmental permitting) may need much more lead-time in order to assure future reliability and resource adequacy of the system.
- **Ensuring Sufficient Flexible Resources to Meet Demand:** With the volume of wind and solar resources expected and their characteristic fuel-driven commitment and dispatch capabilities as well as the characteristics of other resources that may constrain their near-term ability to respond, sufficient flexible resources will be needed to meet demand when the less flexible resources are unavailable. The flexible resources will need to be dispatchable within the forecasting period of the less flexible resources becoming unavailable.
- **Coordination of Behind-the-Meter DERs with the BPS:** Distributed generation as well as storage, and other DER technologies currently follow local interconnection requirements and operational protocols, posing potential challenges to the BPS from a planning and forecasting perspective.

- **Human Performance and Skilled Workforce:** 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.
- **Loss of Situational Awareness:** Loss or degradation of situational awareness poses BPS challenges as it affects the ability of personnel or automatic control systems to perceive and anticipate degradation of system reliability and take pre-emptive action.
- **Control and Protection Systems Complexity:** The interaction and performance of control systems during transient events, including the control systems in remedial action schemes (RASs) and other protection systems, must be understood to prevent new common-mode failures that may not have been anticipated (e.g., the inverter performance as demonstrated during the Blue Cut Fire and related events, misoperation of RAS logic and control systems, interdependencies of RAS operations in sequence and follow through).

Recommendations for Mitigating the Risk

As a result of this complex set of factors, the traditional methods of assessing resource adequacy (i.e., by focusing primarily on generating capacity, transmission and pipeline capacity, and fuel availability at traditional peak load times) may not accurately or fully reflect the ability of the new resource mix to supply energy and reserves for all operating conditions. Historic methods of assessing and allocating ancillary services (e.g., regulation, ramping, frequency response, and voltage support during transient, recovery and follow through) may no longer ensure that sufficient ERSs and contingency reserves are available at all times during real time, next hour, and next day operations. Balancing and ramping concerns that up to now have been largely confined to limited locations will likely expand regionally as solar and wind generation continues to grow and provides a larger portion of the energy mix. Such resources provide challenges in counting as available capacity in traditional integrated resource planning to assure reliability of the BPS in near-term to long-term planning horizons.

The combination of these many factors related to resource and grid transformation that offer both challenges and opportunities as a result of the transformation calls for a planned set of NERC activities as described in the following action plan.

Resource and grid transformation will require new and updated tools, methods, and strategies that are used in planning, modeling, and operating the BPS. In order to best achieve those goals, the RISC encourages the following actions:

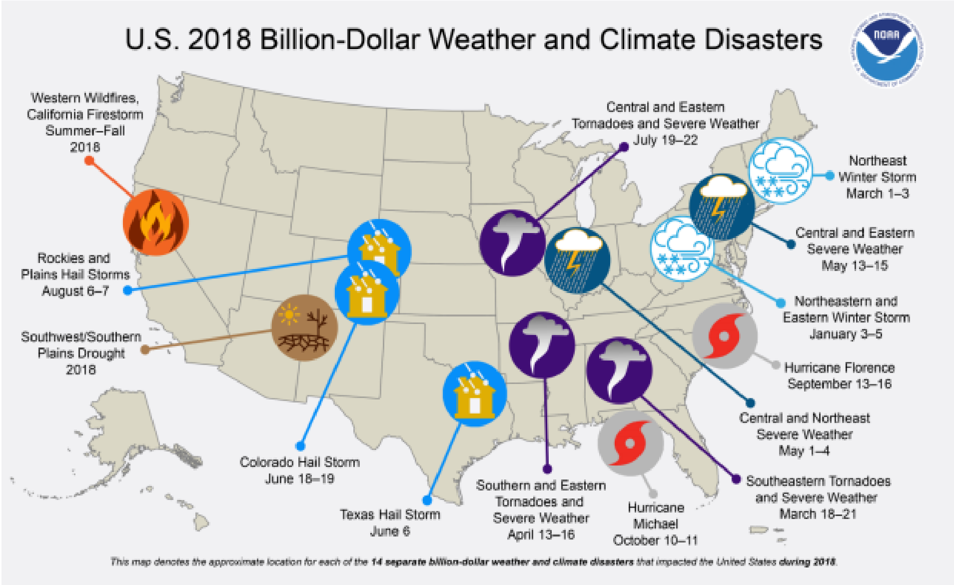
- **Update data, modeling and assessment requirements to ensure valid and accurate results given resource and grid transformation (ongoing effort):** The ERO's Committees should identify the information and modeling capabilities needed to ensure the efficacy of assessments while taking into consideration the complex and interrelated aspects of the ongoing transformation. The ERO should also pay close attention on settings of controllable devices and power electronics installed to stabilize the system. The risk of cascading continues to increase and more remedial action schemes with its complexity are added to BPS system.
- **The technical committees should establish and implement an approach to evaluate the potential impacts of energy storage on reliability:** Work with industry stakeholders to use available information and experience to support an evaluation of energy storage implications.
- **Improve inverter-based resource BPS interconnection and operation and stay abreast of new technologies, such as storage/hybrid resources:** The ERO Enterprise should continue its effort to address the recommendations of the Inverter-Based Resource Performance Task Force (IRPTF)[6].
- **Ensure sufficient operating flexibility at all stages of resource and grid transformation:** System operators and planners should ensure sufficient flexible ramping/balancing capacity is available as a tool to meet needs of changing patterns of variability and new characteristics of system performance.

[6] IRPTF Recommendations - https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_IBR_Interconnection_Requirements_Improvements.pdf

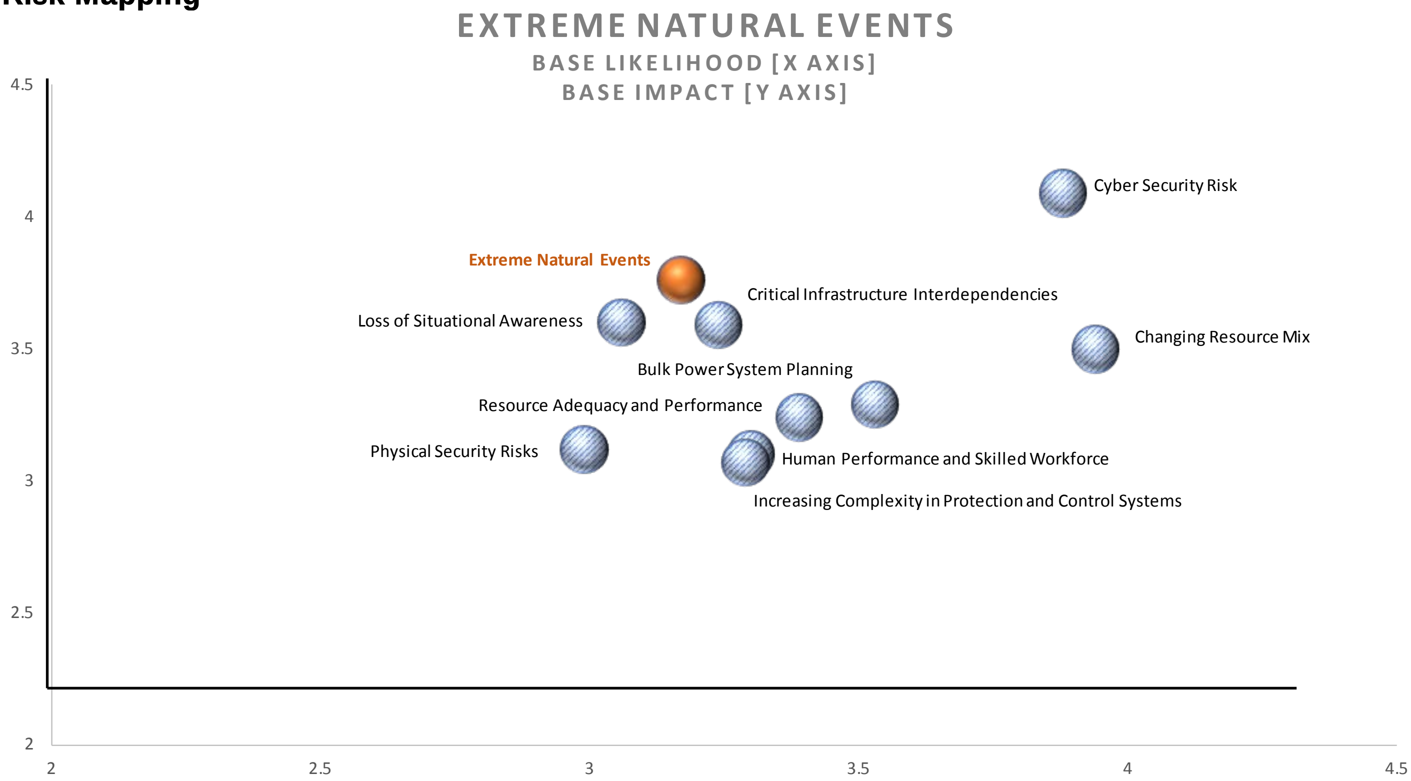
Risk Profile #2: Extreme Natural Events

Statement of the Risk

Extreme natural events (e.g., storms, wildfire) cause a significant proportion of major BPS impacts. For example, NERC's 2019 *State of Reliability* report[7] noted weather was responsible for both Category 3 events (there were no Category 4 or 5 events) across the ERO Enterprise's footprint in 2018. Extreme natural events tend to be regional in nature. Natural events may affect BES equipment, resources, or infrastructure required to operate the BES. Certain events are unique to areas that they impact while others may occur in any area of the BPS. Each type of event brings unique challenges from supply sufficiency, spare-parts availability, delivery, and restoration perspectives. Preparation and proactive planning of procedures and protocols are critical for utilities to assess and determine appropriate steps for both reliability and resiliency.



Risk Mapping



[7] https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2019.pdf

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, the relative impact on the BPS is low. See the following examples:

- **Hurricanes:** They can cause widespread destruction to BES 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 and damage to interdependent infrastructure.
- **Tornados/Derecho:** They can cause localized destruction to BES 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:** They can cause higher than anticipated demand, overloading and failure of BES 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 wild fire risk as described in the next bullet.
- **Wild Fires:** They can be a direct threat to BES equipment. Pre-emptive actions must be taken to de-energize equipment without causing additional cascading effects in areas where wild fire risk is significant.
- **Flooding:** This can occur in any area and in any season of the year. The impacts from flooding include mechanical damage to BES equipment, degradation of clearances, fuel infrastructure, personnel access, and communications capabilities.
- **Extreme Cold Weather (Polar Vortices):** This can cause higher than anticipated demand, overloading and stress failure of BES equipment, and degradation of resource availability via mechanical failure or fuel supply interruption.

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:** These are possible in many areas of the United States and Canada. Depending on the scope and magnitude of the event, mechanical damage may occur to BES facilities and interdependent infrastructure (e.g., communications, fuel, transportation). The duration to recover from earthquakes could be long, and further assessment and coordination is required among utilities and the ERO Enterprise.
- **Geomagnetic Disturbances:** These can induce harmonic currents in BES circuits and equipment. The impacts of these induced currents may include overheating of transformers, relay misoperations, and increased reactive demand or damage to reactive resources. GMD events can also affect communications capabilities, fuel delivery, and GPS systems.

Recommendations for Mitigating the Risk

Extreme natural events and their potential impacts on BPS reliability 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 needed to operate or restore the BES.

In order to best achieve those goals, the RISC encourages the following actions:

- **Special assessments of extreme natural event impacts, including capturing lessons learned, creating simulation models, and establishing protocols and procedures for system recovery and resiliency:** The ERO Enterprise should conduct detailed special assessments of extreme natural event impacts by geographical areas that integrate the following:
  - Infrastructure interdependencies (e.g., telecommunications, water supply, generator fuel supply)
  - Analytic data and insights regarding resilience under severe weather conditions

  Based on those assessments, the ERO Enterprise should develop detailed special assessments on possible mitigation plans and provide a roadmap for its implementations. The road map should include specific protocols and procedures for system restoration and system resiliency.
- **Development of tools for BPS resiliency:** The Department of Energy (DOE) is in process of developing appropriate tools for BPS resiliency and NERC, the ERO, the North American Transmission Forum (NATF), and the North American Generator Forum (NAGF) should work with DOE in assessing the tools as well as develop guidelines, industry recommendations, and procedures for industry to follow.
- **Understanding of Geomagnetic Disturbance (GMD) events on BPS:** The ERO Enterprise should continue working with the Electric Power Research Institute (EPRI) and others to conduct research and development to further understand impacts from geomagnetically induced current on BES facilities to support enhancements to models and standards and to facilitate preparedness consider preparing sensitivity analyses to simulate the impacts in a planning area. The ERO Enterprise should assist the industry to implement the necessary protocols and mitigation plans to reduce the risk in maintain reliability and security for the BPS.

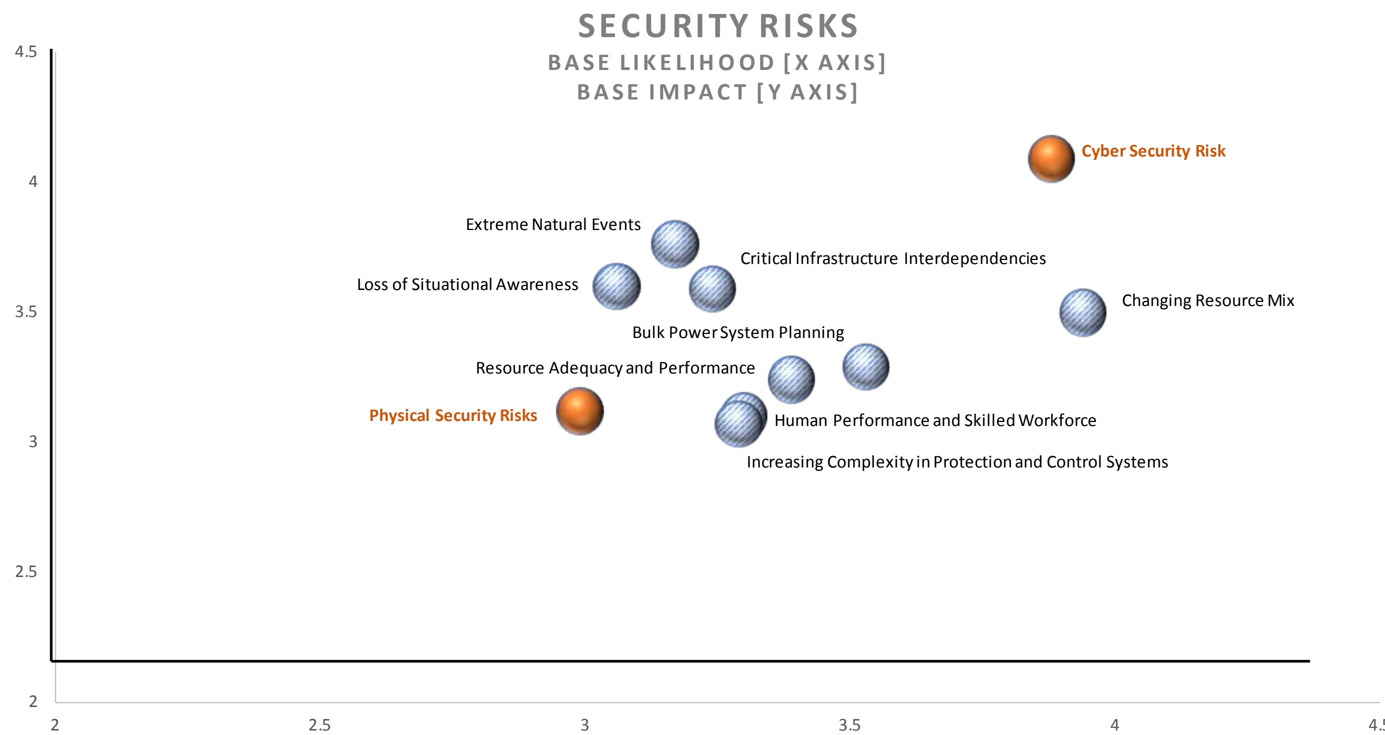
Risk Profile #3: Security Risks

Statement of the Risk

Operational security is an essential component of a highly reliable BPS. Cyber and physical security are interdependent aspects as exploitation of either physical or cyber security risks could be used to compromise the other dimension. Resulting impacts could cause asset damage or loss of functionality and situational awareness needed to reliably operate or restore the BPS. Exploitation could occur directly against equipment used to monitor, protect, and control the BPS or indirectly through supporting systems, such as voice communications or interdependent critical infrastructure sectors[8] and subsectors (e.g., water supply and natural gas used for electrical power generation). A coordinated cyber and physical attack scenario that is, potentially targeted to occur simultaneously with an extreme natural event, could further impact reliability and/or complicate recovery activities. A man-made electromagnetic pulse (EMP) event targeted at the BPS may impact operations and result in damaged equipment that may require an extended period of time to replace.

The volume, frequency, and sophistication of cyber exploits is increasing and could potentially disrupt a broad (e.g., interconnection-wide) footprint. Significant physical security events have been rare and the impact is likely to be more geographically constrained. EMP events are far less likely to occur but may carry a highly consequential security risk.

Risk Mapping



8 https://www.dhs.gov/cisa/critical-infrastructure-sectors

Descriptors of the Risk

- **Physical Security Risks:** The nature and impact of physical vulnerabilities are better understood than other security risks (e.g., cyber or EMP). The impacts from significant physical attacks are likely to be more localized geographically. There is modest, ongoing evolution of the physical security risk via drones. The largest risk considerations are considered to be the 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 electrical grid is evolving significantly and rapidly, potentially increasing the potential cyberattack-surface. Sources of potential exploitation include increasingly sophisticated attacks by nation states, terrorist, and criminal organizations. Vulnerability to such exploits are exacerbated by insider threats, poor cyber hygiene, supply-chain considerations, and dramatic transformation of the grid's operational and technological environment. These transformative changes include convergence of information and operational technology (IT/OT), reliance on cloud-based technology, and potential workforce knowledge gaps.
- **Electromagnetic Pulse Risk:** An EMP is a short-duration, high-energy burst that may be disruptive or damaging to electronic equipment. For security purposes, EMP refers to man-made sources. A high-altitude EMP (HEMP) is an electromagnetic pulse stimulated by a nuclear blast in the atmosphere and such action would likely be initiated by a nation-state and thus have clear national security implications. HEMP concerns include the large geographic footprint susceptible to the pulse, range of electric grid equipment at risk (generation, transmission, distribution, and load), and lack of definitive forewarning. Smaller, handheld devices are relatively limited in potential impact and can be considered analogous to a physical attack.

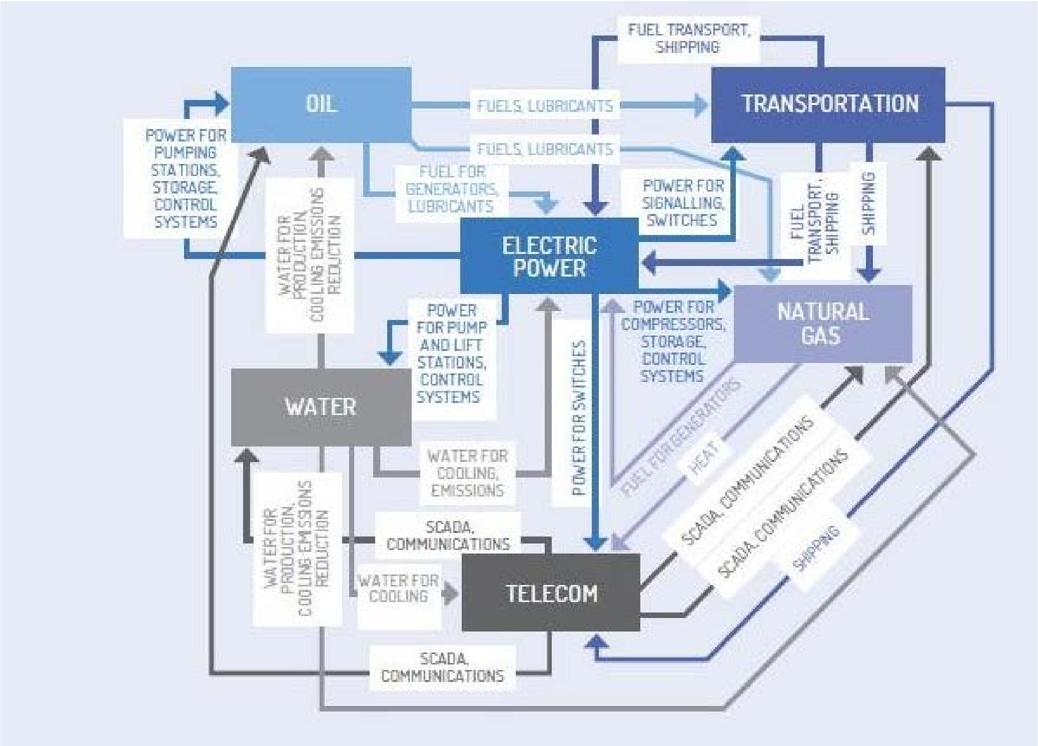
Recommendations for Mitigating the Risk

- NERC, in collaboration with industry, should evaluate the need for additional assessments of the risks of attack scenarios (e.g., vulnerabilities related to drone activity, attacks on midstream or interstate natural gas pipelines or other critical infrastructure).
- The Electricity Information Sharing and Analysis Center (E-ISAC) should encourage continued industry efforts on workforce cyber education to raise awareness of methods and tactics used by cyber attackers (e.g., email phishing, credential theft).
- NATF and NAGF should develop supply chain cyber security superior practices.
- E-ISAC should execute a 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.
- NATF, NAGF, Trades Associations, and E-ISAC should develop tiered security performance metrics. Such metrics would track and evaluate events and use predictive analysis to identify and address prospective vulnerabilities on a risk-prioritized basis.
- NERC should facilitate the development of planning approaches, models, and simulation approaches that reduce the number of critical facilities and mitigate the impact relative to the exposure to attack.
- NERC's EMP taskforce should highlight key risk areas that arise from the EPRI's EMP analysis for timely industry action.

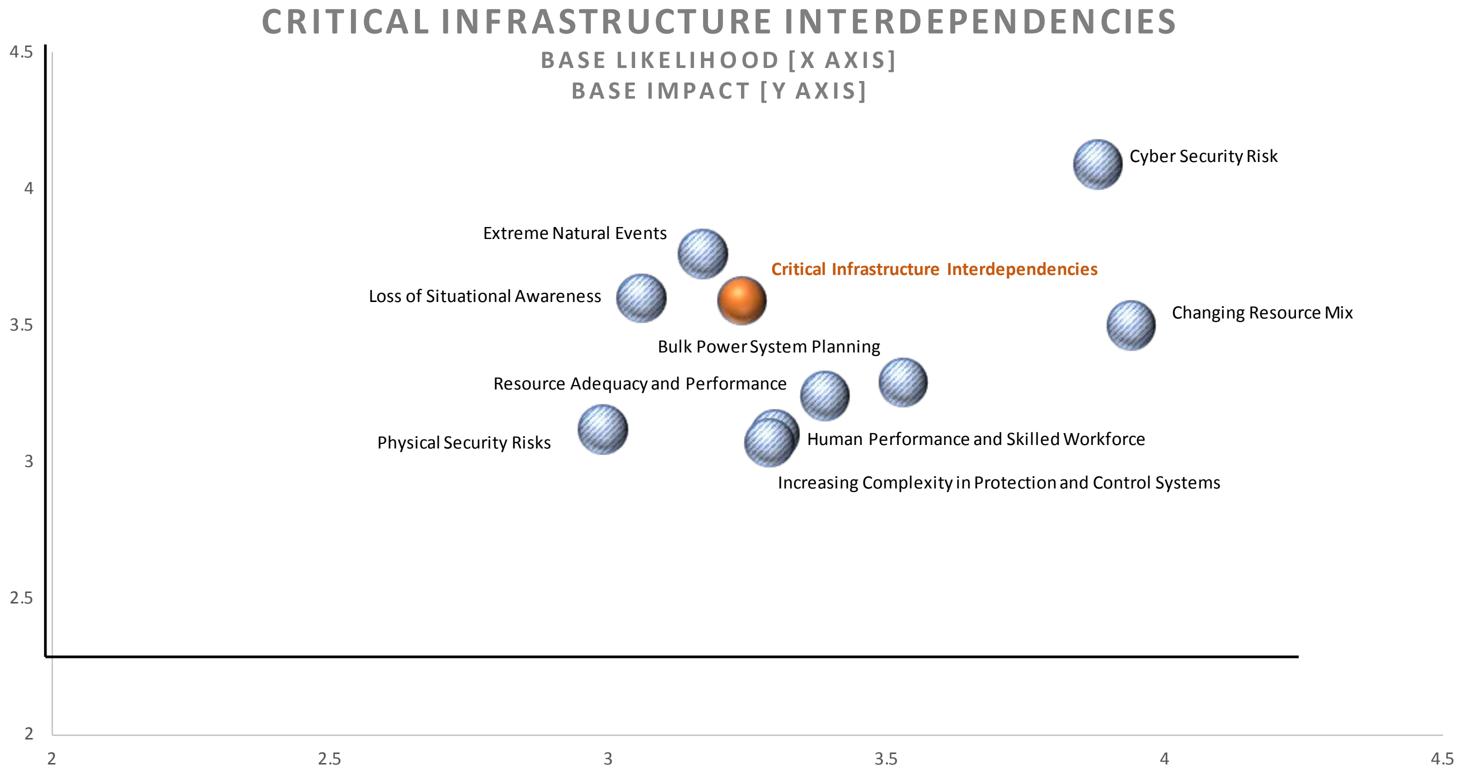
Risk Profile #4: Critical Infrastructure Interdependencies

Statement of the Risk

Significant and evolving critical infrastructure sector (e.g., communications, water/wastewater) and subsector (e.g., oil, natural gas) interdependencies are not fully or accurately characterized, resulting in incomplete information about prospective BPS response to disruptions originating from or impacting other sectors or subsectors and resultant reliability and security implications.



Risk Mapping



Descriptors of the Risk

- Sector interdependence is becoming more critical, such as the added importance of digital communications for electric system protection and control and voice communications for emergency response and restoration.
- Subsector interdependence is increasing (e.g., growing reliance on natural gas as an electrical generation fuel source with potential needs for fuel switching in the event of natural gas unavailability), creating the potential for more limiting contingencies, including single-point failures.
- Cross-sector and subsector implications and coordination are not routinely socialized or thoroughly tested during drills.
- Governmental oversight and regulatory constructs differ widely among the sectors and subsectors, impeding information sharing and alignment.

Recommendations for Mitigating the Risk

- NERC, in collaboration with industry and industry partners, should identify and prioritize limiting conditions and/or contingencies that arise from other sectors that affect the BPS.
- NERC and industry partners should host strategic interactions among critical infrastructure partners (e.g., industry and regulators) to identify and align on mutual priorities.
- NERC and industry partners should increase emphasis on cross-sector considerations in industry drills (e.g., NERC Grid-Ex, DOE drills, utility exercises (e.g., Southern California Edison (SCE) Resilient Grid Exercise)).
- NERC should evaluate the need to conduct special regional assessments that address natural gas availability and pipeline impacts under physical attack scenarios.
- EPRI and the DOE should continue their work on communication alternatives but also the use of same or similar technologies for critical SCADA data. New technologies should be explored that could assist in providing unique and hardened back-up telecommunication methods for the most critical data.
- NERC and industry partners should conduct various meetings and conferences to highlight the importance of cross-sector interdependence and coordination, such as the NERC Reliability Summit, NATF/EPRI resiliency summits, and FERC/DOE technical conferences.