Gerry Cauley
President and Chief Executive Officer

May 9, 2017

The Honorable Rick Perry
Secretary
U.S. Department of Energy
1000 Independence Avenue
Washington, DC 20585-1000

Dear Secretary Perry:

The North American electric power system is undergoing a significant transformation with ongoing retirements of fossil-fired and nuclear capacity, while at the same time, experiencing growth in capacity fueled by natural gas, wind, and solar. This shift is caused by several drivers, such as federal, state, and provincial policies, low natural gas prices, electricity market forces, and integration of both distributed and utility-scale renewable resources. The changing resource mix is altering the operating characteristics of the bulk power system (BPS). In order to assure continued reliability, these changing characteristics must be well understood and properly managed. Understanding that the Department of Energy is reviewing these reliability matters, the accompanying document summarizes NERC's recent work in this area.

The North American Electric Reliability Corporation (NERC) has important responsibilities under federal law to assess the reliability of the BPS. NERC annually assesses seasonal and long-term reliability of the BPS and conducts special assessments relating to issues potentially impacting the reliable operation of the grid. The assessments summarized focus on the impacts from the changing resource mix on the reliability of the BPS, including increased dependency on natural gas, operating characteristics (essential reliability services) and distributed energy resources. By identifying and quantifying the impacts from emerging reliability concerns, NERC is able to provide risk-informed recommendations for their mitigation and support a learning environment for industry.

NERC is an independent, non-profit organization with a single focus on assuring the reliability and security of the grid. We have a strong partnership with DOE and can be a resource as you move forward on numerous policy initiatives.

I look forward to meeting with you on May 18 to discuss critical grid reliability and security issues, and our partnerships with DOE. I thank you for your attention to reliability and look forward to our discussion. In the meantime, please contact Mr. Fritz Hirst (fritz.hirst@nerc.net), NERC's Director of Legislative and Regulatory Affairs, with any questions.

Respectfully,

Gerry Cauley

Gerry Cauley
President and CEO

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Synopsis of NERC Reliability Assessments

The Changing Resource Mix and the Impacts of Conventional Generation Retirements

Introduction

The North American electric power system is undergoing a rapid and significant transformation with ongoing retirements of fossil-fired and nuclear capacity, as well as growth in natural gas, wind, and solar resources. This shift is caused by several drivers, such as federal, state, and provincial policies, low natural gas prices, electricity market forces, and integration of both distributed and utility-scale renewable resources. The changing resource mix is altering the operating characteristics of the bulk power system (BPS). These changing characteristics must be well understood and properly managed in order to assure continued reliability and ensure resiliency.

Voltage control, frequency support, and ramping capability are essential to maintaining BPS reliability. Through this transition, policy makers and stakeholders must recognize the need to maintain these essential reliability services. It is also necessary to assure resilience measures, such as maintaining fuel diversity and new technologies that work with, not against, the BPS.

Growing reliance on natural gas continues to raise reliability concerns regarding the ability of both gas and electric infrastructures to maintain the BPS reliability at acceptable levels. Many efforts have focused on the gas-electric interface and yet, insufficient progress has been made reconciling the planning approaches and operating practices (scheduling situation awareness, information sharing) between these two inter-linked sectors. Planning approaches, operational coordination, and regulatory partnerships are needed to assure fuel deliverability, availability, security (physical and cyber), and resilience to potential disruptions. Unfortunately, an approach not obvious in electricity markets today.

Reliability and How the Changing Resource Mix Affects It

The North American BPS is designed to be a highly reliable, robust, and resilient system. The system is interconnected, and the integrated networks work together to maintain reliability through both wide-area interregional planning and coordinated system operations. The adequacy of the system is maintained by having the right combination and amount of resources and transmission to deal with unexpected facility outages or extreme weather events that increase system demand. Operating reliability is maintained in real-time through highly coordinated operator actions across many operating companies. The system is also planned as many as 15 years in advance by performing highly detailed, complex, and data-intensive power system simulations.

The resource mix of the BPS is changing in fundamental ways. Variable energy resources, especially wind and solar) are rapidly expanding and capturing the majority share of new capacity additions. Conventional generation (such as coal and nuclear) are retiring and have become economically

RELIABILITY

NERC defines the reliability of the interconnected BPS in terms of two basic and functional aspects:

Adequacy — The ability of the electric system to supply the aggregate electric power and energy requirements of the electricity consumers at all times, taking into account scheduled and reasonably expected unscheduled outages of system components.

Operating Reliability — The ability of the electric system to withstand sudden disturbances to system stability or unanticipated loss of system components.

marginalized. The balancing resource tends to be natural gas as environmental rules and commodity economics tend to make oil fired generation uneconomic). Development of hydro-electric resources, a major energy source in some parts of the country such as the west, is extremely challenging. The confluence of the changing resource mix can fundamentally impact reliability in two major ways:

- A Balancing Authority responsible for managing the balance of demand and resources through unit commitment and forecasting may become capacity deficient and unable to serve firm load. Resources may not be available when needed, particularly those that have ***not*** secured on-site fuel. In that instance, manual load shedding may be required to maintain reliability.
- Large unanticipated voltage or frequency deviations during a disturbance can lead to uncontrolled, cascading instability. With no mass, moving parts, or inertia, increasing amounts of inverter-based resources (such as solar photovoltaic) present new risks to reliability, such as managing faster fault-clearing times, reduced oscillation dampening, and unexpected inverter action.

The rapid changes occurring in the generation resource mix and technologies are altering the operational characteristics of the grid and will challenge system planners and operators to maintain reliability. More specifically:

- Impact of Premature Retirements: Conventional units, such as coal plants, provide frequency support services as a function of their large spinning generators and governor-control settings along with reactive support for voltage control. Power system operators use these services to plan and operate reliably under a variety of system conditions, generally without the concern of having too few of these services available. Coal-fired and nuclear generation have the added benefits of high availability rates, low forced outages, and secured on-site fuel. Many months of on-site fuel allow these units to operate in a manner independent of supply chain disruptions.
- Replacement Resource Capability and Characteristics: As the generation resource mix evolves, the reliability of the electric grid depends on the operating characteristics of the replacement resources. Natural gas-fired units, variable generation, storage, and other resources can provide similar reliability services. However, as a practical matter, costs, market rules, or regulatory requirements (or lack thereof) can affect whether these resources are equipped and available to provide reliability services. To ensure reliability, new generator and load resources must maintain the balance between load and generation, especially during ramping periods. In addition, in some jurisdictions, substantial amounts of generation is now being added “behind the meter” (e.g., roof top solar) and these resources are invisible to system operators.

NERC and the ERO-Enterprise’s Role in Evaluating BPS Reliability

A comprehensive understanding of the complexity of the changing BPS is key to developing effective approaches for achieving reliability and resiliency. The North American Electric reliability Corporation (NERC) and eight regional Entities (the RE’s, or collectively the ERO-Enterprise) are charged with assuring the reliability of the BPS. NERC and RE experts work with industry leaders to create a reliability strategy that is relevant, timely, and effective with regard to addressing the highest priority reliability risks. The ERO-Enterprise maintains a technical framework and understanding of the reliability threats facing our industry and uses those insights to communicate guidance and information to entities and policy-makers across North America to enhance reliability. It accomplishes this through its own engineering and analytical efforts, as well as through marshaling stakeholder resources with subject matter expertise.

Our Reliability Assessments provide a technical platform for important policy discussions on challenges facing the interconnected North American BPS. Each year, the ERO-Enterprise independently assesses and reports on the overall reliability, adequacy, and associated risks that could impact the upcoming summer and winter seasons and the long-term, 10-year period. As emerging risks and potential impacts to reliability are identified, special assessments are conducted that provide similar technical framework and insights about the range and specific aspects of these to guide steps that may be warranted. Unbiased judgment of industry’s plans for maintaining

NERC

The North American Electric Reliability Corporation is a not-for-profit international regulatory authority whose mission is to assure the reliability and security of the bulk power system in North America. NERC develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the bulk power system through system awareness; and educates, trains, and certifies industry personnel. NERC's area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico. NERC is the electric reliability organization for North America, subject to oversight by the Federal Energy Regulatory Commission and governmental authorities in Canada. NERC's jurisdiction includes users, owners, and operators of the bulk power system, which serves more than 334 million people.

electric reliability in the future is founded on solid engineering through collaborative and consensus-based assessments.

By identifying and quantifying emerging reliability issues, we are able to provide risk-informed recommendations and support a learning environment for industry to pursue improved reliability performance. These recommendations, along with the associated technical analysis, provide the basis for actionable enhancements to resource and transmission planning methods, planning and operating guidelines, and NERC Reliability Standards.

The Reliability Assessment group conducts evaluations and reports that fulfill the statutory requirements of Section 215 in the Energy Policy Act of 2005.

Summary of Overarching Key Findings

As a common thread in each of our Reliability Assessments, the most pressing reliability issues in North America are:

- As conventional resources prematurely retire, sufficient amounts of essential reliability services, such as frequency and voltage support, ramping capability, etc., must be replaced based on the configuration and needs of the system.
- Resource flexibility is needed to supplement and offset the variable characteristics of solar and wind generation.
- Higher reliance on natural gas exposes electric generation to fuel supply and delivery vulnerabilities, particularly during extreme weather conditions. Maintaining fuel diversity and security provides best assurance for resilience. Premature retirements of fuel secure baseload generating stations reduces resilience to fuel supply disruptions.
- Because the system was designed with large, central-station generation as the primary source of electricity, significant amounts of new transmission may be needed to support renewable resources located far from load centers.

Summary of Recommendations

Three overarching recommendations for policy makers and stakeholders are the focus of our most recent reliability assessments:

- State regulators and market operators should give due consideration to the changing reliability aspects of the grid when considering resource needs, adequacy requirements, distribution-level interconnection requirements, and long-term resiliency. States and FERC should immediately review the economic and policy issues impacting fuel secure baseload generation in an effort to limit early closure of existing assets. States and FERC should ensure that required reliability characteristics are giving consideration when identifying future reliability and capacity needs.
- Regulators and policy makers should evaluate whether the natural gas regulatory framework for transportation priority and construction is compatible with the requirements of the changing BPS, which has significant amounts of natural gas generation, along with identifying a transition plan that provides certainty in the long-term. Market operators should also evaluate whether market rules should be revised to provide assurances that generators will perform in normal and extreme circumstances.

- NERC should conduct a comprehensive evaluation of its Reliability Standards to ensure compatibility with large amounts of non-synchronous resources, as well as for completeness of expectations related to essential reliability services, generator performance, and balancing. This review should include both non-synchronous resources connected directly to the BPS and distributed energy resources connected to the distribution system.

Key Concepts from NERC Reliability Assessments

- **What makes "baseload" generation so important for reliability?**
  There is a distinction between baseload generation and the characteristics of generation providing reliable "baseload" power. Baseload is a term used to describe generation that falls at the bottom of the economic dispatch stack, meaning they are the most economical to run. Coal and nuclear resources, by design, are designed for low cost O&M and continuous operation. However, it is not the economics nor the fuel type that make these resources attractive from a reliability perspective. Rather, these conventional steam-driven generation resources have **low forced and maintenance outage hours** traditionally and have **low exposure to fuel supply chain issues**. Therefore, "baseload" generation is not a requirement; however, having a portion of a resource fleet with high reliability characteristics, such as low forced and maintenance outage rates and low exposure to fuel supply chain issues, is one of the most fundamental necessities of a reliable BPS. These characteristics ensure that "baseload" generation is more resilient to disruptions.

- **What are the reliability benefits of having a diverse resource portfolio?**
  Fuel diversity provides a fundamental benefit of increased resilience. Without this diversity, the impact of rare events impacting availability of resources on the power system increases and are more likely the result of a common-mode failure impacting multiple generation or transmission facilities (e.g., extreme and prolonged cold weather event leads to freezing generator components, transmission line icing, fuel delivery disruption, etc.). **Areas with limited fuel and/or limited resource diversity may be challenged and should increase their attention to resiliency planning**, which requires a strong partnership with state regulators. With natural gas generation primed to continue its growth as the leading choice for new and replacement capacity, important distinctions around fuel security need to be incorporated into reliance and long-term planning at states and with market operators. Mainly, natural gas generation is fueled using just-in-time transportation and delivery, and therefore, is subject to interruption. Roughly 50 percent of natural gas generation resources are considered interruptible, and in constrained natural gas markets these units are not expected to be served during peak pipeline conditions. Many of these plants no longer have the option of burning a liquid fuel. Further, regardless of fuel service arrangements, natural gas generation is subject to curtailment during a force majeure event.

- **What are the challenges with natural gas generation becoming more "baseload?"**
  Natural gas provides "just-in-time" fuel; therefore, disruptions to the fuel supply can impact multiple generators that may be connected to the same supply chain. **Firm transportation, multiple pipeline connections, and dual-fuel capability can significantly reduce the risk of common-mode failure and wider-spread reliability challenges**. As part of future transmission and resource planning studies, planning entities will need to more fully understand how impacts to the natural gas transportation system can impact electric reliability. This level of reliability is not only needed to produce electricity during "average" conditions, but during extreme conditions where fuel supply chains can breakdown or fail. Additionally, since natural gas does not generally have on-site storage, its supply is threatened to disruption by pipeline failure that potentially can lead to the loss of a substantial amount of capacity and threaten the adequacy of the electric system. Regulatory action may be needed to better calibrate electric and gas industries due to regulatory differences in how infrastructure is planned with reliability given due consideration.

  Two major trends are contributing to changes in generator performance: 1) the retirement of large coal and nuclear generation and 2) the addition of large amounts of solar and wind resources. Natural gas generation can be a very flexible resource—particularly combustion turbines. The ability to balance the variability of solar and wind resources make them very attractive. However, the more they are being used as a “baseload” resource (i.e., higher capacity factor), the less they can be used to provide flexibility to the system. Additionally, **as cycling increases, generator’s experience higher forced outage rates and require more maintenance**. This is a common challenge with all thermal-based conventional generation.

Finally, expansion of natural gas and its transition from a “supplemental resource” to the “primary resource” is creating challenges. Natural gas infrastructure has proven to be reliable, but not designed to meet the electric sector needs. Natural gas infrastructure is optimized for economics, not reliability. As a result, it tends to be based on large single elements. When problems occur with major elements, they can significantly disrupt the power system. For example, the operational challenges faced by the BES, and specifically the Los Angeles and greater Southern California area due to the loss of the Aliso Canyon gas storage facility. Also, a major disruption on a key pipeline could also interrupt fuel supply for thousands of megawatts of generation, because it is a common-mode element.

- **How do resource mix changes impact the pace at which infrastructure can be developed?**
  From an adequacy perspective, the existing transmission system was planned and designed to support the existing generation fleet, which is comprised mostly of larger, central-station electric generation. Therefore, accommodating new resources, particularly those located in areas different from the existing fleet, transmission lines, facilities, and/or other transmission elements will likely be necessary. Generation retirements can happen quickly, but adequate replacement facilities must be in-service prior to retirement.

  The lead times required and associated uncertainties for the planning, engineering, permitting, and construction of new generating resources, transmission facilities, and fuel infrastructure adds complexity to the pace at which new facilities can be built. Uncertainty in the timing of such resource decisions and the ability to construct the necessary energy infrastructure to implement those decisions stems from the following factors:

  - The addition of new generating resources can take several years to permit and construct. There will be a range of time periods depending on the circumstances related to each project, including regulatory approvals at various state, municipal, county, federal, and provincial levels, secured financing and fuel supply chain, and the availability of construction crews and equipment.
  - Changes to resources (such as retirements or new generation) can require a need for additional electric transmission infrastructure. Such transmission can require many years to permit and construct, typically longer than generation construction, and timing will depend on the facts and circumstances of each project.
  - Where new or repowered generating resources are dependent on natural gas as a fuel, there will be a requirement for additional gas pipeline infrastructure. Depending on the location of the plant relative to interstate gas pipelines, plant-specific gas infrastructure will require several years to permit and construct. The resource decisions of neighboring states can also impact the transmission infrastructure required to maintain reliability within a given state.

Reliability Assessments from NERC and the Regional Entities

- ### 2016 Long-Term Reliability Assessment, NERC (December 2016)

  Summary: NERC prepares seasonal and long-term assessments to examine current and future adequacy and operational reliability of the North American BPS. NERC’s primary objective with this assessment is to assess resource and transmission adequacy across the NERC footprint, and to assess emerging issues that have an impact on BPS reliability over the next ten years.

Key Findings:

- **Resource Adequacy:** Factors that are included when performing a resource adequacy assessment include a reserve margin analysis and the study of emerging reliability issues that can impact generation and demand projections. The results of this study identified four assessment areas as having a medium resource adequacy risk in the first five years of the assessment period.
- **Single-Fuel Dependency:** NERC has identified that reliance on a single fuel increases vulnerabilities, particularly during extreme weather conditions. Over the past decade, several areas have significantly increased their dependence on natural gas. This trend has continued amidst historically low natural gas prices and regulatory rulings that continue to promote increased natural gas generation. The Aliso Canyon outage in Southern California illustrates the effects of a potential single point of disruption. This one underground gas storage facility in SoCal Gas' service territory contains 86 BCF of gas capacity, providing fuel to approximately 9,800 MWs of electric generation. The facility also supports ramping requirements to accommodate the variability of renewable energy resources. This outage has the potential to cause rolling black outs in Southern California until the facility is completely operational again or other mitigation approaches have been employed.
- **Nuclear Uncertainty:** Low natural gas prices continue to affect the competitiveness of nuclear generation and are a key contributing factor to nuclear generation's difficulty in remaining economic with competing fuel sources. While new nuclear facilities are being built in Georgia, Tennessee, and South Carolina, potential retirements have been announced for nuclear facilities in Illinois, California, Nebraska, Massachusetts, and New York, creating longer-term uncertainty for system planners.
- **Distributed Energy Resources:** Increasing installations of distributed energy resources modify how distribution and transmission systems interact with each other. Many utilities currently lack sufficient visibility and operational control of these resources, increasing the risk to BPS reliability. This visibility is a crucial aspect of power system planning, forecasting, and modeling that requires adequate data and information exchanges across the transmission and distribution interface.

Recommendations:

- As the resource mix changes, the need for more investments in transmission and natural gas infrastructure is projected. The lengthy lead times involved in acquiring, siting, and permitting for infrastructure should also be considered when assessing reliability impacts.
- As natural gas-fired resources continue to increase, system planners, and operators should evaluate the potential effects of an increased reliance on natural gas on BPS reliability. As part of future transmission and resource planning studies, planning entities will need to more fully understand how impacts to the natural gas transportation system can affect electric reliability.
- Regulators and legislators should consider the uncertainties in resource retirements and resource mix changes projected by resource planners. The implementation of a regulatory framework (e.g., interconnection requirements) that helps ensure an adequate level of essential reliability services could help to address these uncertainties.

Report Link: http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/2016%20Long-Term%20Reliability%20Assessment.pdf

Letter from Jim Robb (CEO WECC) to Michael Picker, President of the CPUC (appendix to this document)

- **A Concept Paper on Essential Reliability Services that Characterizes Bulk Power System Reliability, NERC (October 2014)**

Summary: Conventional generation with large rotating mass (steam, hydro, and combustion turbine technologies) provide necessary operating characteristics, defined as essential reliability services, needed to reliably operate the North American electric grid. Essential reliability services represent a necessary and critical part of the fundamental reliability functions that are vital to ensuring reliability. They are key services and attributes that are needed to maintain operating reliability—primarily voltage and frequency support. Many of these services and attributes are provided by baseload conventional generating plants; however, as the resource mix changes, NERC must ensure that essential reliability services are maintained.

Key Findings:

- Generating resources need to be able to provide voltage control, frequency support, and ramping capability as essential reliability services to balance and maintain the electric grid. Without these characteristics, the grid could not be operated reliably.
- Federal, state, and local jurisdictional policy decisions have a direct influence on changes in the resource mix and can also affect the reliability of the electric grid. As resources retire, in addition to replacing lost capacity, it is necessary for policy decisions to recognize the need for essential reliability services from the current and future mix of resources.
- Some variable energy resources and storage technologies can contribute to essential reliability services; however, policies and market mechanisms may not provide enough incentive or clarity to ensure these services are maintained across the system.

Recommendations:

- All new resources should have the capability to support voltage and frequency. Ensuring that these capabilities are present in the future resource mix is prudent and necessary.
- Monitoring of the essential reliability services measures, investigation of trends, and use of recommended industry practices will highlight aspects that could become reliability concerns if not addressed with suitable planning and engineering practices.
- Distributed energy resources will increasingly impact the planning and operation of the grid. The task force recommends further examination of the forecasting, visibility, and participation of distributed energy resources as an active part of the electric grid.

Abstract: http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERS%20Abstract%20Report%20Final.pdf
Report Link: http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSTF%20Concept%20Paper.pdf
Multi-Media Link: https://vimeopro.com/nerclearning/erstf-1

- **Distributed Energy Resources: Connection, Modeling, and Reliability Considerations, NERC (February 2017)**

Summary: Increasing amounts of distributed energy resources can change how the distribution system interacts with the BPS and will transform the distribution system into an active source for energy and essential reliability services. Attention must be paid to potential reliability impacts, the time frame required to address reliability concerns, coordination of essential reliability services and system protection considerations for both the transmission and distribution system, and the growing importance of information sharing across the transmission-distribution interface.

Key Findings:

- **Modeling and Data Requirements**: The effect of aggregated distributed energy resources is not fully represented in BPS models and operating tools. This could result in unanticipated power flows and increased demand forecast errors.
- **Frequency and Voltage Ride-Through:** Distributed energy resources are not coordinated with the voltage and frequency ride-through requirements of NERC Reliability Standard PRC-024-2.
- **System Protection:** Distributed energy resources are not completely coordinated with under frequency load shedding (UFLS) and under voltage load shedding (UVLS) programs or other system protection measures. High levels of distributed energy resources with inverters can also result in a decline in short circuit current, which can make it more difficult for protection devices to detect and clear system faults.

Recommendations:

- **Guidelines**: The Distributed Energy Resources Task Force recommends that a set of guidelines be developed to assist in modeling and assessments, such that owners and operators of the BPS can account for the impact of distributed energy resources.
- **Data Sharing**: Data requirements and sharing of information across the transmission-distribution interface should be further evaluated to allow for adequate assessment of future distributed energy resources deployments.
- **Modeling:** Based on reliability considerations for modeling purposes, generation from distributed energy resources should not be netted with load as penetration increases. Load and distributed energy resources should be explicitly modeled in 1) steady-state power flow and short-circuit studies and 2) dynamic disturbance ride-through studies and transient stability studies for BPS planning with a level of detail that is appropriate to represent the aggregate impact of distributed energy resources on the modeling results over a five- to 10-year planning horizon.
- **Coordination:** A coordinated effort by transmission and distribution entities is needed to determine the appropriate use of future distributed energy resources capabilities (such as settings available under proposed IEEE 1547 revisions). This must be coordinated with voltage and frequency ride-through performance and potentially coordinated with UFLS programs and BPS performance under PRC-024. Note that PRC-024 was developed with BPS issues in mind and where PRC-024-2 and desired distribution-level protection and operations conflict, the transmission and distribution utilities will need to coordinate the required distributed energy resources ride-through settings to meet BPS reliability needs while minimizing distribution impact.

Report Link: http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report.pdf

- **Western Interconnection Flexibility Assessment, WECC (December 2015)**

Summary: With growing penetrations of renewable resources, new challenges will arise for resource planners and operators. The report assesses the ability of the fleet of resources in the Western Interconnection to accommodate high renewable penetrations while maintaining reliable operations. Higher penetrations of renewable generation will test the flexibility of the electric systems by requiring individual power plants to operate in fundamentally new ways, changing operating practices as well as the dynamics of wholesale power markets.

Wind and solar resources, which will likely account for a significant share of the additional renewable generation in the Western Interconnection, are characterized by three key attributes that have important implications for power system operations:

- **Variability:** production changes from moment to moment, and from hour to hour;
- **Uncertainty:** production over a given period of time cannot be predicted with perfect accuracy; and
- **Concentration:** production is highly concentrated during certain hours of the year in which the resource is available.

As the penetrations of variable renewable resources in the Western Interconnection continue to increase, planners must confront the question of how to build and operate a reliable system in which a large portion of the energy available has these qualities.

Key Findings:

- The analysis conducted in this study identifies no technical barriers to the achievement penetrations of renewable generation of up to 40 percent of total supply in the Western Interconnection.
- Because the penalty prices for unserved energy and curtailment prioritize load service over the delivery of renewable generation, renewable curtailment is the key indicator of a system that is constrained in its ability to integrate renewables.
- Routine, automated renewable curtailment is a fundamental necessity to electric systems at high renewable penetrations, as it provides operators with a relief valve to manage net load conditions to ensure a system can be operated reliably at increasing penetrations. Renewable curtailment is identified as the “default solution” to flexibility challenges as it represents a last recourse for system operators—prior to shedding load—once the flexibility of the existing traditional dispatchable system has been exhausted. However, there are many options for alternative strategies that, if identified and deployed in advance, can provide operators with additional flexibility and mitigate the need to curtail renewable generation.
- While renewable curtailment is identified as the predominant challenge in operations at high renewable penetrations, its magnitude can be mitigated through efficient coordination of operations throughout the Western Interconnection.

Recommendations:

- To facilitate increased coordination in operations, the report recommends increased regional coordination and scheduling, investments in energy storage technologies, and investments in flexible gas generation.
- System operators must fully understand the conditions and circumstances under which renewable curtailment is necessary or desirable.
- The consequences of extended periods of negative pricing must be examined and understood.

Report Link: https://www.wecc.biz/Reliability/WECC_Flexibility_Assessment_Report_2016-01-11.pdf

- **Accommodating an Increased Dependence on Natural Gas for Electric Power, NERC (May 2013)**

Summary: The combination of growth in natural gas demand within the electricity sector and its changing status among the gas-consuming sectors continues to significantly increase the interdependencies between the gas and electricity industries. As a result, the interface between the two industries has become the focus of industry discussions and policy considerations. In its effort to maintain and improve the reliability of the North American BPS, NERC examined this issue in detail and developed recommendations for the power industry. These recommendations will help improve existing coordination between the gas and electricity sectors and facilitate the reliable operation of the two industries.

Key Findings:

- Gas use is expected to continue to increase in the future, both in absolute terms and as a share of total power generation and capacity. Unlike coal and fuel oil, natural gas is not easily stored on-site. As a result, real-time delivery of natural gas through a network of pipelines and bulk gas storage is critical to support electric generators.
- Natural gas is widely used outside the power sector, and the demand from other sectors—particularly coincident end-user gas peak demand during cold winter weather—critically affects the ability to deliver interruptible transportation service in the power sector. Additionally, demand for natural gas is expected to grow in other sectors (e.g., transportation, exports, and manufacturing).
- While extremely rare, disruptions in natural gas supply and/or transportation to power generators have prompted industry to seek an understanding of the reliability implications associated with increasing gas-fired generation. Contracts for firm natural gas supply and transportation affect the risk profile of each power plant (or group of power plants).
- Natural gas is expected to play a growing role in offsetting the variability and uncertainty associated with renewable resources. As variable generation increases, swings in variable generation may call for dispatch of gas-fired generation at a larger and less predictable rate.

Recommendations:
Policy makers, market operators, and asset owners should consider factors that reduce risk, such as:

- **Maintaining Alternative Fuel Capabilities:** Evaluate capabilities across generator fleet, maintain back-up fuel inventories at key stations, and annually test fuel switching capability.
- **Enhancing Market and Regulatory Rules:** Provide additional incentives for behavior and investments that support reliability and resiliency.
- **Evaluating Single Points of Disruption:** Assess reliability under extreme conditions, loss of major pipeline infrastructure, or supply.
- **Continuing Pipeline Expansion:** Keep pace with generation expansion and increasing electricity production.
- **Limiting Exposure to Supply Chain Failures:** Increase resiliency by maintaining alternative supply chains and paths.
- **Maintaining Situational Awareness:** Electric system operators need awareness of pipeline conditions and must be able to predict generators that may become unavailable.

- **Communicating Risks to Policymakers:** Results and conclusions of studies that evaluate electric reliability should be shared and clarified with policymakers and regulators.
- **Maintaining Fuel Diversity**: Maintaining fuel diversity provides inherent resiliency to common-mode risk.

Report Link: http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_PhaseII_FINAL.pdf

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MEMO

Date: June 22, 2016

To: Michael Picker, President of the California Public Utilities Commission

Subject: WECC Electric Reliability Analysis of Issues Related to Aliso Canyon

President Picker:

I am responding to your request that WECC provide its view of the reliability issues created by the situation at the Aliso Canyon natural gas storage facility. As you know, WECC is the Regional Entity responsible for assuring the reliability of the Bulk Electric System in the Western Interconnection. The limited ability to draw from Aliso Canyon is likely to cause electric generation fuel supply challenges in Southern California. During this challenging energy supply situation, WECC's chief concern will be that the reliability of the broader interconnection is protected. To this end, WECC conducted an independent assessment of potential impacts to the electric system resulting from potential fuel limitations in Southern California stemming from the Aliso Canyon issues. In this letter I highlight some of the key takeaways from that analysis and would like to express our appreciation for the transparency and collaboration taking place among affected entities.

We performed two types of analyses: a resource adequacy assessment to determine whether the Interconnection has enough generation to support Southern California's needs, and a series of power system contingency analyses to understand how the entire system performs under different stressors. Overall, our studies showed no major Interconnection-wide impacts but did reveal important operational considerations for Southern California.

A key element to preserving electric reliability in Southern California is the ability to supply an adequate level of imports to support its needs under a range of conditions. To study this, we used our established annual resource adequacy assessment with assumptions changed to reflect potential local supply conditions in Southern California this summer. The study showed adequate generation across the Interconnection to supply Southern California in all but the most extreme scenarios. It is important to note that this type of study assumes that generating resources are available to generate when called upon and that the power can get to where it needs to go—it does not address restrictions in deliverability.

To address deliverability, WECC regularly uses advanced study tools to identify system stability power flow issues. We used this capability to study the potential operational impacts to the Interconnection and Southern California. We created a baseline for comparison using our 2016 "Heavy Summer Base

Case," a model of the Interconnection that assumes high summer loads and moderate power transfers to reflect a stressed system scenario. From here, we created two comparison cases to reflect potential conditions in Southern California, one with all of the natural gas generation in the L.A. Basin at minimum output and one with it all turned off. We chose these cases specifically because they are expected to emphasize potential negative study results, making them worst-case bookends. We then tested these cases by applying a number of contingencies, or hypothetical system element outages.

In running the model, we were concerned with the following indicators of system health:

- Generation availability and unit stability – With low generation in the L.A. Basin, would there be sufficient resources elsewhere to replace the generation?
- Overloading of transmission lines – Assuming the resources are available, can they be imported without causing overloading of transmission lines and exceedances of WECC Transmission Path Ratings?
- Voltage stability – With low generation in the L.A. Basin, would there be sufficient voltage support in the area to maintain acceptable transmission and distribution voltages?

There are four takeaways from our power system contingency analyses:

- There is a minimum amount of generation that must be online in the L.A. Basin to provide voltage support to the local system and allow power to be imported. Without this generation, there is a high likelihood of voltage collapse within the L.A. Basin and concomitant risk to the interconnection if such a collapse is not quickly isolated. LADWP and CAISO have the detailed tools to determine the minimum level of generation that must remain online for system stability and have estimated 1300 MW to be the "must-run" capacity to support transmission import capability. Our analytics have affirmed that this is a reasonable estimate.
- The generation facilities capable of producing reactive power to provide voltage support include the natural gas facilities in the L.A. Basin. Some of these units are dual-fuel units and were designed with the capability to burn distillate. The ability to run these plants on an alternative fuel, other than natural gas, will help ensure adequate minimum levels of generation when gas supply is scarce.
- The location of the online generation within the L.A. Basin is critical to stability. Certain combinations of online units can lead to poor voltage support or additional stress on the transmission system in the L.A. Basin area due to unusual or abnormal power flows. CAISO will be in the best position to determine the correct units to run in real time based on the actual operating configuration of the system.
- Communication and collaboration among the affected entities is critical. This situation highlights the interdependency of the gas and electric infrastructures and operating protocols.

> The high level of communication and information sharing occurring now between the entities will need to be closely managed throughout the summer and until the Aliso Canyon natural gas storage facility can be further utilized.

It is important to note that this study assumes all normally operating transmission lines in the L.A. Basin, and the rest of the interconnection, are in service. The study also assumes availability of the additional generating resources used in the simulations. If either transmission or generation capacity is limited for any reason (e.g., a fire that takes out multiple transmission lines, unforeseen events that result in the unavailability of major generating resources such as gas constraints or unscheduled maintenance), the additional stress to the Western Interconnection could result in negative impacts that have not yet been identified.

I hope you find this assessment useful in your policy deliberations. We believe very positive steps are in place to preserve electric reliability in Southern California. First are the recent actions to allow at least some of the Aliso Canyon facility to be used this summer to support the L.A. Basin electric system. Second are the conditional waivers issued by SCAQMD to allow LADWP to burn distillate under certain circumstances. We continue to be impressed with the coordination between the affected entities and involved agencies in California and believe it will serve the state well through this energy supply challenge. We are appreciative of the transparency with which LADWP, CAISO, and SoCal Gas have dealt with this issue and allowing us to be directly involved in the winter studies. We have also been coordinating closely with Peak Reliability and it appears they are taking appropriate steps to execute their responsibilities to protect the broader interconnection from any cascading outages.

Please feel free to contact me if you would like to discuss this analysis further. We look forward to continuing to work with the Western states, CAISO, LADWP, and Peak Reliability on this important matter.

Cc: Dr. Robert Weisenmiller, Chairman of the California Energy Commission