NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Reliability Guideline

Fuel Assurance and Fuel-Related Reliability Risk Analysis for the Bulk Power System

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RELIABILITY | RESILIENCE | SECURITY




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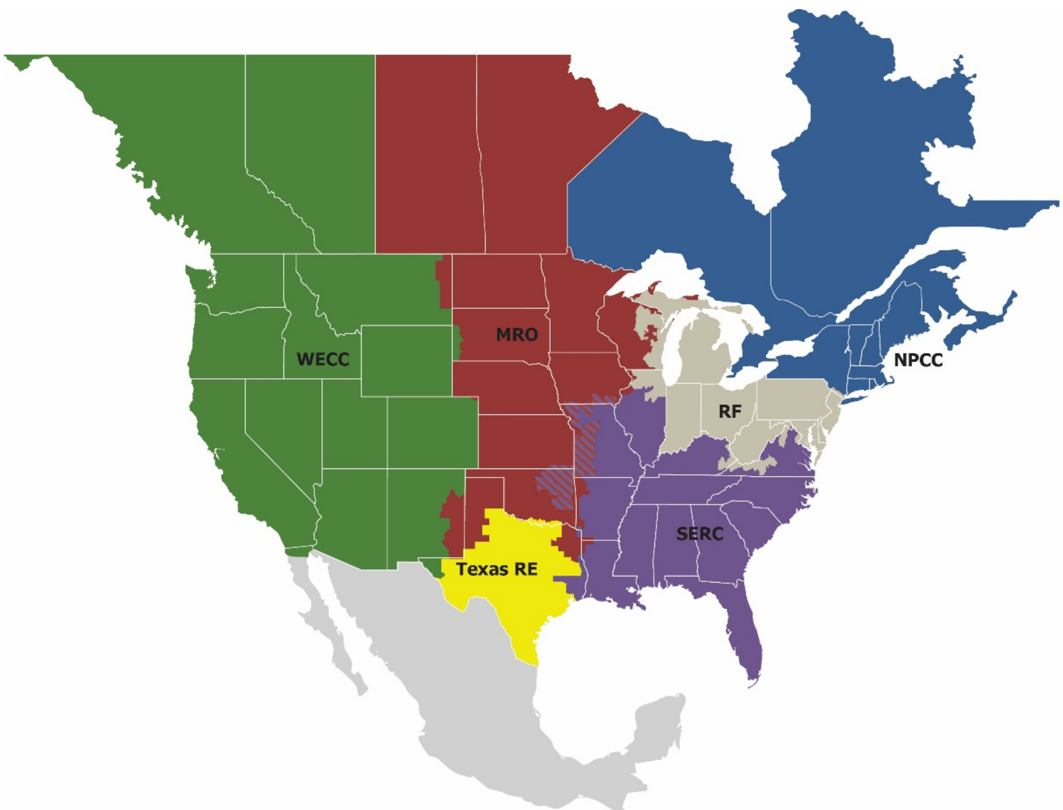
Preface

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 (REs), 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

Preamble

It is in the public interest for NERC to develop guidelines that are useful for maintaining or enhancing the reliability of the Bulk Electric System (BES). The NERC technical committees—the Operating Committee, the Planning Committee, and the Critical Infrastructure Protection Committee—are authorized by the NERC Board of Trustees to develop reliability (Operating and Planning Committees) and security guidelines per their charters.[1] These guidelines establish a voluntary code of practice on a particular topic for consideration and use by BES users, owners, and operators. The technical committees coordinate these guidelines with the collective experience, expertise, and judgment of the industry. The objective of this reliability guideline is to distribute key practices and information on specific issues critical to maintaining the highest levels of BES reliability. Guidelines are not to be used to provide binding norms or create parameters by which compliance to standards is monitored or enforced. While the incorporation of guideline practices is strictly voluntary, reviewing, revising, or developing a program using these practices is highly encouraged to promote and achieve the highest levels of reliability for the BES.

NERC, as the Federal Energy Regulatory Commission (FERC) certified ERO,[2] is responsible for the reliability of the BES and has a suite of tools to accomplish this responsibility, including but not limited to the following:

- Lessons learned
- Reliability and security guidelines
- Assessments and reports
- The Event Analysis program
- The Compliance Monitoring and Enforcement program
- Mandatory Reliability Standards

Each entity, as registered in the NERC compliance registry, is responsible and accountable for maintaining reliability and compliance with the mandatory standards to maintain the reliability of their portions of the BES. Entities should review this guideline in detail and in conjunction with the periodic review of their internal processes and procedures and make any needed changes to their procedures based on their system design, configuration, and business practices.

[1] http://www.nerc.com/comm/OC/Related%20Files%20DL/OC%20Charter%2020131011%20(Clean).pdf
http://www.nerc.com/comm/CIPC/Related%20Files%20DL/CIPC%20Charter%20(2)%20with%20BOT%20approval%20footer.pdf
http://www.nerc.com/comm/PC/Related%20Files%202013/PC%20Charter%20-%20Board%20Approved%20November%202013.pdf
[2] http://www.ferc.gov/whats-new/comm-meet/072006/E-5.pdf

Introduction

The *2019 ERO Risk Priorities Report* highlights a wide array of pertinent risks to the reliable operation of the BPS that merit attention and recommends actions that align with those risks.[3] Among the diverse risks identified in the report, utilities, generators, and other suppliers are experiencing a number of factors that increase the likelihood of fuel/energy supply challenges that exemplify the increased importance of thoroughly characterizing cross-sector interdependencies.

The rapid advancement of renewable generation and increased use of natural gas have necessitated the need to re-evaluate the methods that the industry has historically utilized to analyze and maintain BPS reliability. Increased reliance on natural-gas-fired generation in various parts of North America will have increased by an estimated 55% over the period 2010–2020. This document will provide entities guidance on how to evaluate such risk factors within their own portfolios to address potential impacts on the BPS.

While this guideline addresses present concerns related to natural gas, it offers a broader perspective on the definition of "fuel assurance" in **Chapter 1** and takes a cursory look at all major fuel sources used to supply electric generation in **Chapter 2**. As each fuel type possesses a variety of limiting factors that affect its reliable delivery through its entire supply chain, **Chapter 3** describes specifically what those limiting factors may be and provides guidance to further equip planners with the requisite knowledge to assist in the development of credible fuel supply risks to analyze.

There have been a number of relevant studies performed—especially by regional transmission organizations, independent system operators (RTO/ISO), and other organizations[4] to analyze and assess generator fuel-related concerns. This guideline combines the experience gained from these studies and outlines a framework in **Chapter 4** that may be applied across all NERC Regions for effectively evaluating potential reliability risks to the BPS at all times through the lens of fuel assurance. Applying this framework for a given area will uncover where credible risks to reliability exist in terms of fuel delivery and will highlight those risks for further analysis and consideration.

Background

In November 2017, NERC published the *Special Reliability Assessment: Potential Bulk Power System Impacts Due to Severe Disruptions on the Natural Gas System* (*2017 NERC Special Assessment*).[5] In that report, NERC made numerous recommendations for assessing disruptions to natural gas infrastructure and related impacts to the reliable operation of the BPS in planning studies, several of which were assigned to the NERC PC.

In July 2018, the PC convened a workshop to highlight ongoing "fuel assurance" discussions and studies and to convene experts from across industries to develop a plan for action. Based on reactions from some workshop attendees, it was clear that some entities desired guidance around establishing "contingency selection" and other assumptions to be used for studying the impact on the BPS from fuel unavailability as well as fuel system disturbances. Transmission Planners (TPs) also desired guidance in identifying potential transmission impacts and how to evaluate the level of risk to the BPS, including the ability to serve load they should be willing to accept.

In November 2018, the NERC Board approved a set of recommendations developed by the PC to address concerns from the *2017 NERC Special Assessment*. One such recommendation was the development of this reliability guideline that was assigned by the PC to the newly formed Electric Gas Working Group.

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[3] https://www.nerc.com/comm/RISC/Related%20Files%20DL/RISC%20ERO%20Priorities%20Report_Board_Accpeted_November_5_2019.pdf

[4] E.g., *The Eastern Interconnection Planning Collaborative Gas-Electric Interface Study* performed under the DOE grant and completed in June 2015

[5] https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SPOD_11142017_Final.pdf

In Appendix E of the *2017 NERC Special Assessment*, NERC evaluated existing natural gas infrastructure disruption studies conducted by the industry to gain an understanding of existing planning approaches and to highlight and promote best practices. As a result of this assessment, NERC presented steps for Planning Coordinators to take when performing future analysis (see below). This guideline is intended to expand upon methods to implement these recommendations.

2017 NERC Special Assessment Appendix E Recommendations

Identify potential natural gas system contingencies and their likelihood of occurrence

Assess the impacts for each of the identified contingencies in terms of duration and amount of natural gas supply disrupted

Apply the contingency disruptions to the natural gas supply capabilities to calculate the impact on total natural gas supplies and, more specifically, the amount of natural gas available to electric generators

Determine the transmission systems ability to transport power to load under these extreme conditions

Though this guideline discusses planning, commonalities in the assessment techniques, processes, and procedures discussed are applicable to all time frames and may be adopted by more than just TPs and Planning Coordinators. Terms like “planner,” “generator owner/operator,” and “fuel supplier” are not capitalized intentionally so that the concepts presented may be considered and applied in the broadest sense as they pertain to the BES.

The processes identified within this guide may also be applied to those organizations whose resource mix includes entitlement and bilateral transactions that have resource contingencies. Entities with such arrangements can also benefit from recognizing when limitations may potentially impact their grid operations.

The Electric Gas Working Group will work with NERC to gauge the effectiveness of this reliability guideline and support efforts for continued improvement and opportunities for education and information sharing.

Chapter 1: Fuel Assurance

Fuel assurance is a term that has been utilized in many forums to date but has yet to be given a formal definition. As this guideline directly relates to the conversation taking place across the industry regarding concerns with the rapidly transitioning BPS generation fleet, it is appropriate and timely for NERC to establish its definition for "fuel assurance." Defining this term will ensure consistency and alignment with statements within this guideline and also provide clarity to the industry going forward on the most appropriate areas of focus related to fuel supply risks to generators supporting the BPS.

For the purposes of this guideline, "fuel assurance" will be defined as follows:

> ***Fuel Assurance:*** *proactively taking steps to identify fuel arrangements or other alternatives that would provide confidence such that fuel interruptions are minimized to maintain reliable BPS performance during both normal operations and credible disruptive events*

The criteria to establish the level of confidence referenced in the definition is unique to respective planning areas and is established by planners and/or generator owners/operators based on internal assessments and understanding of their asset characteristics. The role of the regional planner in addressing fuel assurance is related to but separate from actions of individual generator owners to assure fuel assurance for their units. The regional planner's focus is to assess the vulnerabilities of the entire region to withstand fuel disruptions that could impact multiple generators and impact reliable BPS performance. A lack of fuel assurance to a particular generator may affect that unit's ability to receive revenues from the market or otherwise meet their obligations to their customers but not necessarily impact the provision of reliable service to the entire region. As the fuel mix of generation and wholesale electricity market structures can vary greatly across reliability areas, this guideline does not and cannot prescribe a single approach to the process.

NERC encourages planners to proactively model, evaluate and consider specific BPS impacts based on credible events that could compromise the provision of reliable service to all or part of the region within the regional planner's area of responsibility and to develop strategies to mitigate credible risks. Regional planners may consider modeling extreme fuel disruptions to better understand the impact of catastrophic events so that they may prepare for such emergencies. Recognizing that there is no way to anticipate or measure all potential threats and catastrophic scenarios, stakeholders and regional planners should focus on effective measures that will maintain reliable and fuel-secure BPS operations during credible events. While the individual unit owners are ultimately responsible for effectively managing the fuel assurance of particular units, the regional planners should understand the consequences of losing critical generators and take steps to limit the impact of such a loss should a loss of fuel delivery at a particular unit threaten reliability.

[6] https://www.pjm.com/-/media/library/reports-notices/fuel-security/2018-fuel-security-analysis.ashx?la=en

FUEL SECURITY ANALYSIS: A PJM RESILIENCE INITIATIVE[7]

In 2018, PJM performed a fuel security analysis which was designed to stress-test the PJM grid and the fuel delivery systems serving generation in PJM under a series of extreme but plausible future events (using 2023/2024 as the study year). As in any stress test, the analysis was intended to discover the point at which the PJM system begins to be impacted (i.e., when system operators initiate emergency actions) and to identify key drivers of risk. In PJM's phased approach to addressing the Fuel Assurance issue, Phase 1 involved the fuel security analysis. In Phase 2, which began in 2019, the analysis results are being used to inform PJM's stakeholder process, which will help to define fuel security attributes for PJM, location and magnitude of how many fuel secure resources or megawatts are needed, as well as determine how to value fuel secure resources. PJM may also use the results of the study to determine how best to incorporate fuel security into other aspects of its operations, markets and planning. The final Phase 3 is a cooperative effort between PJM and United States (U.S.) federal agencies to define and analyze further scenarios based on classified information about credible risks to fuel security that could have impacts on the power grid.

Fuel Assurance Principles

While each reliability area is unique, there are common principles for fuel assurance that may be applied more broadly to assist planners in their assessments of fuel supply reliability. Below are some examples of actions that various entities may perform to advance fuel assurance initiatives.

Markets

RTOs/ISOs that have not already done so could consider additional mechanisms for generators to meet their obligations during reserve shortages—these could be market (e.g., capacity market reforms) or out-of-market solutions while attempting to avoid out of market solutions where possible or only as a temporary measure while a market-based approach is developed. Such market rules and mechanisms would incentivize generators to maintain or enhance fuel delivery contracts. Additionally, adopting more detailed and timely procedures for communications to members when near-term fuel shortages/reliability concerns arise (e.g., upcoming shortages, disruptive weather) will allow time for generators to assess and react to fuel supply needs. RTOs/ISOs should also consider other mechanisms that would facilitate greater certainty that generators have reliable fuel options regardless of market structure (i.e., restructured or vertically integrated).

Generator Owners/Operators

Generator owners/operators should seek reliable delivery solutions from both a transportation and commodity perspective. Monitor and evaluate risks associated with varying levels of transportation or delivery options associated with the different types of transportation (e.g., interruptible transportation, firm transportation). Consider and evaluate a diverse portfolio of products that can be utilized to deliver fuel both reliably and cost-effectively; examples of these are as follows:

- Delivered bundled products
- Firm call options for periods of heightened fuel uncertainty
- Asset management arrangements
- Potential purchases from suppliers with firm capabilities

[7] Id.

- Enhanced infrastructure considerations
- Storage capacity
- Liquefied natural gas (LNG) options
- Dual-fuel capability
- Interconnection with more than one pipeline
- On-site fuel reserves.

Generator owners/operators should consider credible fuel-related contingencies that impact their facilities and provide fuel-related facility outage concerns as necessary to the reliability authority. Lastly, where fuel delivery constraints are routinely evident, generator owners/operators should consider and investigate whether new options for fuel deliveries to a specific facility or their fleet are available.

Transmission Planners/Planning Coordinators

Planners should consider using steps outlined in **Chapter 4:** of this guideline to develop credible fuel-related contingencies that may be used in planning studies, including (but not limited to) Reliability Standard TPL-001 (Transmission System Planning Performance Requirements).[8] Any identified fuel-related contingencies should be evaluated for reliability risks, and planners should determine what (if any) mitigation should be put in place. Planners might consider conducting generator fuel-related surveys to determine potential risks to the fuel supply of the generators. Using the survey data, planners may perform fuel-related reliability risk analyses as described in **Chapter 4:**. Planners should also seek and use experts familiar with regional markets and practices to help interpret and analyze the survey data.

[8] See NERC Standard TPL-001-4 – Transmission Planning Performance Requirements, Table 1 –Steady State & Stability Performance Extreme Events, 3.a.i.

Chapter 2: Electric Generation Fuel Supply Primer

This section describes the supply chain of each major generator fuel supply type at a high level. It describes illustrative challenges that may be encountered between production and consumption as well as other viable considerations specific to each fuel type. These considerations will assist planners in forming realistic assumptions when developing their own fuel assurance and reliability risk analysis.

Natural Gas

The natural gas supply chain includes three major segments, listed below:

- **Production and Processing**
  Natural gas is primarily found in reservoir pools and shale rock formations in the earth and brought to the surface through production wells by processing plants that heavily rely on electric power to operate. A series of flowlines and gathering lines then transport natural gas to processing plants. Natural gas is also a byproduct of oil-focused production.
- **Transmission and Storage**
  Large-diameter interstate and intrastate pipeline transmission systems transport processed natural gas to end-use customers, such as large-volume customers (e.g., local distribution companies (LDCs), natural gas-fired power generation, industrial users). Alternatively, the processed natural gas may be transported to various storage facilities for future consumption.
- **Distribution**
  Smaller-diameter local natural gas distribution pipelines deliver natural gas to residential, commercial, and industrial customers as well as some natural-gas-fired power generators. These customers are often located behind the city gate and are serviced by LDCs.

The FERC regulates interstate natural gas transportation and storage. The interstate pipeline industry is contract-based, and pipeline and storage companies contract with customers under the terms of FERC-approved agreements and tariffs. Customers select transportation and storage services (firm or interruptible) based on the level of certainty and reliability desired. FERC regulations preclude interstate pipelines from undue discrimination. The pipeline industry is required to honor all firm service contracts, provided force majeure conditions do not impact such service.[9] Therefore, the level of service and priority that a customer selects for delivery of natural gas is driven by the type of contract that the customer has entered into. In addition to transportation service, customers also purchase the physical commodity to receive natural gas at contracted points into the applicable transportation agreements and/or at other points of points of delivery at their respective interconnection points or market center. Larger volume customers (e.g., LDCs and electric generation facilities) may also purchase natural gas upstream at or near the point of production and contract for pipeline service to transport the commodity to the point of delivery. In addition, based on market conditions, these entities and other market participants may purchase natural gas at a market center and contract for transportation from that point to a delivery point(s). Also, market participants may purchase a bundled commodity and transportation package from marketers, who deliver the natural gas using the pipeline capacity for which they have contracted through utilization of the established secondary bilateral market for capacity and commodity. During periods of high usage and system constraints, pipelines may not be able to schedule interruptible customers because capacity is being fully utilized by firm transportation customers. During force majeure events, pipeline companies may also curtail firm customer pro-rata as needed to maintain system integrity.

Intrastate transportation, balancing, storage, and distribution of natural gas by LDCs is subject to state regulation. LDCs are regulated by most states as local natural gas utilities that have an obligation to serve their firm core customers–the customers for which the system is built to serve reliably (e.g., residential and commercial heating

[9] *See* 18 C.F.R. § 284.7(a) (3).

customers). Similar to interstate pipeline operations, during periods of high usage and system constraints, LDCs may call on interruptible customers to cease gas usage temporarily. State statutes and public utility regulations may allow an LDC to curtail services to some industrial or non-core customers, possibly including power generators, during emergencies to maintain the operational integrity of the system and/or maintain natural gas service to designated high-priority customers. Historically, these state regulatory requirements give the highest priority to residential (essential human need) and small commercial customers without short-term alternatives.

Natural gas pipelines (interstate, intrastate, and distribution) are subject to pipeline safety regulations that are mandated by the Department of Transportation–Pipeline and Hazardous Materials Safety Administration (PHMSA) and by the pipeline cyber-security authority of the Department of Homeland Security–Transportation Security Administration.

The majority of natural gas infrastructure is automated, and pipeline operators, storage owners, and utilities alike rely on industrial control systems for monitoring and/or remote control; however, the physical delivery systems are mechanical by nature and can be run locally if necessary. Natural gas is moved by using pressure to control the amount entering and leaving the system. Compressor stations are placed throughout the network to maintain pressure at serviceable levels and are powered by the natural gas in the pipelines themselves in most cases. Some stations may have both natural gas and electric or even diesel-driven compressors for contingency purposes; others may rely solely on electric power. Mechanical regulators are also layered into the pipeline infrastructure to prevent internal natural gas pressure from threatening pipeline integrity. Typically, limited supply and transportation disruptions can be managed through substitution, transportation rerouting, and storage services (though such infrastructure redundancy is much more limited in portions of North America). While the natural gas transmission system may continue to operate even with the failure of as many as half of the compressors, the pressure may not remain high enough for some power generators to continue to fully operate, depending on the specific pressure requirements of each power generator and its location relative to the failed compressor.[10] Many modern natural gas units have on-site boost compression built in to the unit that is capable of increasing the pressure of the pipeline delivered natural gas to the combustion inlet pressure required by the unit even with a severe deviation in pipeline pressure. In addition, the natural gas distribution network can operate largely unattended and without electric power.

Certain characteristics of the natural gas system contribute to its reliability and resilience. The natural gas transportation network is composed of an extensive network of interconnected pipelines that offer multiple pathways for rerouting deliveries in the unlikely event of a physical disruption. Each customer's ability to use such alternate pathways and capacity to maintain natural gas delivery will depend upon the rights specified in the customer's transportation contract.[11] In addition, pipeline capacity is often increased by installing two or more parallel pipelines in the same right-of-way (called pipeline loops), making it possible to shut off one loop while keeping the other in service.[12] In the event of one or more compressor failures, natural gas pipelines can usually continue to operate at pressures necessary to maintain deliveries to pipeline customers (at least outside the affected segment) subject to the constraints that some power generators may experience due to location and pressure requirements as noted above.[13] "Line pack" in the pipelines is routinely used as necessary to provide some additional operational flexibility.[14] It can facilitate non-ratable flows and support pipeline reliability as

> ***Line pack*** *is the volume of natural gas contained within the pipeline network at any given time. It allows natural gas received in one area of a pipeline system to be delivered simultaneously elsewhere on the system.*

[10] Massachusetts Institute of Technology, Lincoln Laboratory, "Interdependence of the Electricity Generation System and the Natural Gas System and Implications for Energy Security," May 15, 2013.
[11] NGC, *Natural Gas Systems: Reliable & Resilient* at p. 10 (July 2017).
[12] *Id*.
[13] *Id*.
[14] *Id*.

a temporary buffer for imbalances. However, line pack must be kept reasonably stable throughout the system to preserve delivery pressure and system capacity. Thus, line pack neither creates incremental capacity nor is it a substitute for appropriate transportation contracts, however, it can support sustained operation in the short term following a disruption.

Further, the existence of geographically dispersed production and storage and their locations on different parts of the pipeline and distribution system also provide flexibility to maintain service in the event of a disruption on parts of the transportation and distribution system.[15]

Similarly, producers use various methods to help ensure operational continuity. Because producers have an economic incentive and operational need to continue to flow natural gas out of the producing field at a constant rate, many techniques are in place to help ensure that operations continue or that any disruption is minimized when a problem arises. In the unlikely event of an unavoidable disruption of supply at a well or in a field, producers have many other options to balance their supply commitments, including increasing production in other areas or using supplies of natural gas in storage.[16]

A disruption to the delivery or supply of natural gas may occur. For example, as NERC has previously reported in the *2017 Special Assessment*, disruptions to the fuel delivery may result from adverse events, such as line breaks, compressor station fires, well freeze-offs, or storage facility outages.[17] Similarly, the pipeline system can be impacted by events that occur on the electric system (e.g., loss of electric motor driven compressors).[18]

Additionally, there are two distinct reliability risks associated with natural gas supply: interruption and curtailment risk. Operational concerns provide a more typical reason for interruption while a force majeure event would reflect a more extreme curtailment. Curtailment of firm service could occur when an event impacts the scheduled flow of natural gas for various reasons. As stated in **Chapter 1** the risks associated with levels of firm or interruptible service should be monitored.

Oil

Fuel oil is obtained from the petroleum distillation process as either a distillate or a residual and is then distributed to regional terminals for distribution to end users. Transportation to generation sites is typically by pipeline, barge, truck, or a combination of the three methods where it is off-loaded into on-site fuel tanks. Each power plant site with storage tanks will have unloading facilities that frequently limit the ability to replenish the on-site storage tanks. Each generator with oil as either the primary or back-up fuel must decide the maximum capacity of the on-site storage tanks as well as the amount of fuel oil that will be kept in inventory. Key factors in how much fuel oil to have on site are the proximity of the regional terminal, the regional terminal capacity, expected run-time, availability of transport tankers (maritime or over-the-road), pipelines, and expected transportation constraints (e.g., roads impassable due to weather conditions or rivers impassable due to ice conditions).

Coal

Four major types of coal are used to produce electric power, each of which varies in heat content and chemical composition:

- **Anthracite:** The highest rank of coal. It is a hard, brittle, and shiny black coal (often referred to as hard coal). It contains a high percentage of fixed carbon and a low percentage of volatile matter.

[15] *Id*.
[16] *Id*.
[17] 2017 NERC Special Assessment at page 7
[18] *Id.*

- **Bituminous:** Bituminous coal is a middle rank coal between subbituminous and anthracite. Bituminous usually has a high heating (Btu) value and is the most common type of coal used in electricity generation in the United States.
- **Subbituminous:** Subbituminous coal is black and dull (not shiny) and has a higher heating value than lignite.
- **Lignite:** Lignite coal, aka brown coal, is the lowest grade coal with the least concentration of carbon.

Coal is extracted from surface and underground mines in various regions around the United States and the world. It is then crushed and washed in preparation for transport to power plants. Transportation is typically by rail, barge, or truck. Coal may be delivered directly to a power plant or to a nearby unloading terminal from which it proceeds to the power plant by truck or a conveyance system. At the plant, coal is stored on-site in piles to be used as needed for generation, typically in an amount sufficient for several weeks to several months of operation. Coal can be transported by rail using tariff rates shipment-by-shipment or under customer-specific short- or long-term rail contracts. Contracts may provide discounts when compared to the tariff rates but require volume commitments over a specified period of time.

Nuclear

Nuclear plants are refueled every 18–24 months. Required outages cannot normally be delayed. Nuclear plants need to maintain certain reactivity levels in nuclear fuel. At times, this reactivity requirement has led to units derating in shoulder months in order to conserve fuel and be available to operate 100% during peak months.

Four major processing steps must occur to make usable nuclear fuel: mining and milling, conversion, enrichment, and fuel fabrication. The uranium used in power plants comes from Kazakhstan, Canada, Australia, and several western states in the United States. Major commercial fuel enrichment facilities are in the United States, France, Germany, the Netherlands, the United Kingdom, and Russia.[19]

Fuel is stored on site at nuclear plants that are built to withstand significant physical events, including weather, seismic, and other types of natural disaster. Licensees must abide by robust security measures (e.g., armed security officers), physical barriers, and intrusion detection and surveillance systems.[20]

The Nuclear Regulatory Commission regulates nuclear facilities in the United States. Nuclear power plants must show that they can defend against a set of adversary characteristics called the Design Basis Threat (DBT). DBT imposes security requirements on nuclear power plants based on analyses of various factors, such as the potential for a terrorist threat. The Nuclear Regulatory Commission regularly evaluates the DBT for updates and alignment with the threat environment.

Nuclear facilities use digital and analog systems to monitor, operate, control, and protect their plants. Digital assets critical to plant systems for performing safety and security functions are isolated from the external networks, including the internet. This separation provides protection from many cyber threats.

Hydro

An integrated hydro-electric system, like those found in the Pacific Northwest, is more frequently energy limited than capacity limited from its mix of storage and run-of-river projects. The storage projects fill and draft annually and tend to have a steady discharge. Fluctuations in discharge (generation) are usually driven by flood control and downstream water temperature objectives. The run-of-river projects more closely follow demand as the projects fill and draft daily. However, run of river projects have limited storage to meet demand because the water needs to be in the right place(s) at the right time(s). Hydro-electric generation also has many non-power objectives that can limit hydro-

[19] https://www.nei.org/fundamentals/nuclear-fuel

[20] https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/security-enhancements.html and https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/cyber-security-bg.html

electric power production (e.g., lake level management, recreational use). Information sharing, communication, and coordination is critical across different hydro projects, utilities, states, and countries.

Solar, Wind, and Other

Technologies like BPS-connected solar photovoltaic and wind generation have grown rapidly and will likely remain a part of the resource mix of the future. These resources are asynchronously connected to the grid and only interface with the BPS through power inverters. This rapid adoption of inverter-based resources has presented new opportunities in terms of grid control and response to abnormal grid conditions and has necessitated the standardization of performance characteristics for inverter-based resources. NERC produced a reliability guideline for this purpose in late 2018.[21] The "fuel" for wind and solar generation are the wind and sunlight that are effectively limitless but are only available as weather permits.

Other technologies (e.g., battery storage) are still in early stages of development, and deployment of these technologies will require further evaluation and consideration as they mature.

[21] https://www.nerc.com/comm/OC_Reliability_Guidelines_DL/Inverter-Based_Resource_Performance_Guideline.pdf

Chapter 3: Fuel Supply Risk Analysis Consideration

At a high level, this chapter describes the supply chain considerations of each generator fuel supply type that will help planners form realistic assumptions when developing their own fuel-related reliability risk analyses.

Natural Gas

While the natural gas industry does not have a history of being susceptible to failure in general or to wide-spread failure from a single point of disruption because of the dispersion of production and storage,[22] redundancies due to the integrated pipeline and distribution network, and its low vulnerability to weather-related events, a temporary outage of a section of a single pipeline or a delivery point is a credible scenario to examine. When considering such a natural gas supply disruption within a given area, the examination would not just be limited to the loss of the natural gas supply but also the associated loss of electric generation and any ancillary needs, such as the loss of electric natural gas compression.

Planners should fully examine the credible reliability risks associated with the natural gas supplied to generators within the reliability footprint of the planner. Further, planners should view the system through an "all-hazards" lens and evaluate additional considerations, including weather, regional policies, and cyber-related risks. The following paragraphs outline the information that planners should seek to understand as a precursor to a more rigorous fuel assurance and reliability risk analysis.

To begin, planners should seek to understand the strategies employed regarding natural gas supply to each generator within their reliability footprint and any applicable regulatory requirements. This could include regular and emergency transportation/service agreements, call options, or other marketing arrangements being employed by the generator owners/operators to meet its resources capacity obligations. This examination could also include reviewing access to on-site fuel storage (e.g., fuel oil, propane, LNG, compressed natural gas), access to off-site storage,[23] access and availability of an alternate pipeline connection, and the availability of non-firm natural gas services and supply. Planners may also consider the alternative fuel capability of the generator, how any such alternatives are contracted and managed, and any environmental and regulatory requirements that may limit the use of the alternative fuel.

The PJM study "Fuel Security Analysis:[24] A PJM Resilience Initiative" investigated the two following natural gas "disruption" scenarios with different recovery expectations:	
"Line Hit," such as an excavating crew accident This type of disruption is easily identified, isolated to a smaller area requiring repairs, and would only cause about a five-day disruption.	**"Other," such as corrosion** This could take longer as investigations are needed over a larger area and will likely be a more "sustained" type of outage.

Planners should examine each generator and its potential physical access to supply (including access to pipeline, distribution, and storage facilities), the amount of capacity subscribed and available at each supply facility, and the ability of the facility to meet daily and seasonal demand swings. In addition, planners should review potential curtailments to key supply points on their respective transportation agreements (e.g., LDCs needing to redirect supply to "essential human needs" if a severe supply disruption occurs). These details are important in order to formulate

[22] Although it is noted that prior to shale natural gas, hurricanes in the Gulf of Mexico caused large amounts of supply to be shut-in.

[23] Storage facilities are different in the various regions of the United States; therefore, understanding the configuration, operation, and services available in the different regions is recommended.

[24] https://www.pjm.com/-/media/library/reports-notices/fuel-security/2018-fuel-security-analysis.ashx?la=en

supply alternatives to consider when examining a possible supply shortage or failure. While physically severing an interstate pipeline is very uncommon, it can occur in situations like third-party damage. Furthermore, a facility may need to be taken out of service for maintenance. Other considerations include specific pipeline resilience, geography, and potential state or federal restrictions on pipeline expansion, competition for supply with heating and industrial demands, and upstream demand that may impact the region.[25] Environmental permits, such as those that allow streambed alteration, may be required and will vary by repair required and specific location. Quick agreement on any environmental mitigation measures will speed obtaining those permits. As noted previously, the planner's role is to have specific knowledge of the fuel assurance of individual generators in order to be able to assess, over the planning area, whether any fuel assurance problems at a particular unit can impact the maintenance of reliability to the area as opposed to just impacting the deliverability of that particular unit. Planners need to recognize this distinction so as to avoid taking on management responsibilities that more appropriately lie with the individual unit owner.

In order to assess the forgoing, data can be obtained from certain public sources. FERC regulations and the business practice standards of the Wholesale Gas Quadrant of the North American Energy Standards Board applicable to natural gas pipelines, which are incorporated by reference into FERC regulations, include various posting requirements for regulated pipelines. These standards require the posting of information related to pipeline capacity, natural gas quality, operational notices, customer indices, tariff provisions, and other items. The U.S. Energy Information Administration also publishes detailed information on U.S. natural gas pipelines and underground storage.[26] FERC also requires that interstate pipelines and certain intrastate and Hinshaw[27] facilities file various forms and operational reports.[28] In addition to the forgoing, the various states also require LDCs to file certain information with the state commissions and/or publicly post certain information. The aforementioned information and data from the applicable generators should also be used to evaluate fuel risk.

Oil

The main risks associated with fuel oil are typically regional depot capacity and transportation (e.g., pipeline, barge, or truck) from the depot to the plant site. Since the fuel oil is stored in tanks, the capacity of the regional depot(s) limits the amount of fuel oil that can be purchased when a need arises. Even in cases where depot levels are adequate to meet the plant needs, the ability to move the fuel oil from the depot to the plant may be challenging due to inclement weather that affects the ability of trucks to move the fuel oil safely. There may also be emissions limitations or other environmental constraints that may limit the amounts or location for liquid fuel storage and/or prevent full utilization of fuel oil in certain areas during portions of the year. For example, oil-fired generation cannot run between May and September in ozone nonattainment locations unless the state governor declares an emergency.

Coal

Risks associated with coal supply are primarily in the transportation of coal from the mine to the power plant. The rail network is comprised of an extensive grid of intersecting and interconnected tracks that offer multiple pathways for rerouting deliveries in the event of a physical disruption, but temporary slow-downs or disruptions to supply can occur in the rail system due to weather (e.g., floods or snow), derailments, or track repairs. Barge transport can be temporarily impaired by icy, low-level, or flooded conditions on river systems. Generators rely on their on-site coal supply for operation until deliveries can be restored. However, conditions like frozen or wet coal could impact on-site coal supply. Coal commodity and rail transportation contracts may contain ratability language that states shipments must be taken consistently even though there may be some month-to-month flexibility. This ratability causes a natural rise and fall of the on-site stockpile based on periods of high and low demand. Any disruptions during the periods of high demand may exacerbate low inventories. Additionally, coal plants are typically optimized to run

[25] Such analyses are very similar to what many lenders offering non-recourse finance obtained from an Independent Fuel Consultant.

[26] Energy Information Administration, Natural Gas Storage Report, and Wholesale Electricity and Natural Gas Market Data: https://www.eia.gov/naturalgas/.

[27] Hinshaw Pipelines are local distribution pipelines or companies served by interstate pipelines that are not subject to FERC jurisdiction by reason of section 1(c) of the Natural Gas Act.

[28] *See* FERC Forms: https://www.ferc.gov/docs-filing/forms.asp.

using only one of the four types of coal, potentially limiting generation capability if that coal becomes unavailable due to long-term supply or transportation disruptions.

Nuclear

As described in **Chapter 2** nuclear facilities store fuel on-site in a highly controlled and secure environment. There are many layers of safety at nuclear sites to protect from physical and cyber risks.

Hydro

All hydroelectric projects are dependent on upstream sources for fuel supply water. Those sources can be snowpack, other hydro projects, free flowing rivers, lakes, streams, or a combination. Ultimately, the source is a function of precipitation. History has shown quite a diversity in the volume of water available for hydropower generation. The total volume can run between 50–150% of the expected average. In some areas, much of the precipitation falls in the form of snow and becomes useable water during the spring thaw. The rate of the melt or “run-off” is almost as important as the volume. Slow melts are best as fast melts can lead to spilling water past fully loaded turbines or loss of water as a fuel due to lack of storage. Deeply cold winters can also result in frozen rivers and streams, cutting off fuel to downstream projects during times of elevated power demand. Temperature and precipitation are critical factors in the availability of water for hydropower production.

Chapter 4: Fuel-Related Reliability Risk Analysis Framework

The BES, for the most part, is similar enough from area to area that a specified baseline set of criteria can be defined and followed, resulting in similar and comparable results from transmission planning studies. TPL-001 defines and prescribes these planning studies very well; criteria have been developed over many years, resulting in multiple revisions to the standard. Even though TPL-001 references a fuel contingency analysis in Table 1 Steady State & Stability Performance Extreme Events as a possible study contingency, the (default) contingency results in the loss of only two generating stations and may not represent a significant pipeline segment, compressor station, storage facility, barge transport, or other fuel supply disruption for many systems. This chapter provides details regarding the scope of fuel-related generator outages beyond the minimum requirements for TPL-001 transmission system planning assessments.

The framework presented below does not identify a single methodology but rather outlines an approach to assist planners in determining what factors may be considered to conduct a meaningful fuel-related reliability risk analysis for the BPS. The actions described are intended to be flexible enough to account for all fuel types, broad enough to support the unique circumstances in each region, and performable out of order (or in some cases not at all). This framework does not provide specific solutions or next steps that could be taken after assessing the results of any particular study.

Appendix A outlines this framework in checklist format

The methodology described in this section may be applied narrowly or across a broad range of credible assumptions as determined by the planner performing the study. The selected assumptions should ensure that the study is both relevant and meaningful. It may be prudent to subject the BPS system under study to a range of high-probability, low-impact (HPLI) contingencies as well as some high-impact, low-probability (HILP) contingencies. Studying HPLI contingencies may shed light on operational needs during such instances and inform changes to processes and procedures to preserve reliability (e.g., improvements in the ability of generators to schedule or contract for natural gas). Even if they are not the primary motivation for the analysis, studying HILP contingencies that stress test the system will bookend the study set and may inform regulators or other interested parties of the reliability impact of such extreme conditions and may inform emergency preparedness efforts. Examples of HILP scenarios include severe reduction of non-firm natural gas supply, prolonged pipeline repair, extreme prolonged weather events that affect both supply of and demand for natural gas, or unanticipated low production from variable energy resources (VERs).

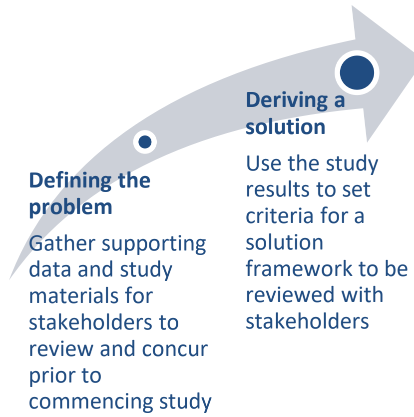
The examples used throughout this chapter are intended to be illustrative and do not imply or prescribe mandatory actions

Based on the unique risks in different regions, the fuel-related reliability risk analysis outlined in this chapter (although not required) is recommended as a best-practice approach for supporting existing studies (e.g., TPL-001 extreme events analysis) or for conducting a stand-alone analysis. In either case, documentation of each step of the process is critical. Documenting the rationale behind the methodology and assumptions will better inform those reviewing the study both presently and in the future and may also inform subsequent studies.

Step 1: Problem Statement and Study Prerequisites

To perform a valid fuel-related reliability risk analysis, there are numerous considerations that should be taken into account that will help shape the direction and results of the analysis. Prior to beginning any analysis, the planner must determine the purpose or goal of the study and, just as importantly, what the study will not do. It is at this point that the criteria, concerns, scenarios and required data will become more evident. Determining which elements of fuel supply risk are to be examined in a single study can be challenging as different combinations of risks can lead to an unmanageable number of model runs.

Consider the following to help define the study:



- Have a clearly defined goal for the study. Set the criteria of the study and define the criteria for system performance. A study that crosses the threshold of meeting certain criteria will do so when fuel is in short supply, generators are no longer able to run, or there is a supply/demand imbalance. The imbalance can be system-wide or, equally as important, a local area imbalance that results in the potential exceedance of a NERC Reliability Standard defined System Operating Limit (SOL) or Interconnection Reliability Operating Limit (IROL) of the BPS. This philosophy can help determine contingencies that may not be obviously catastrophic, but still highlight issues that may need mitigation.
- Communicate the goals of the study with stakeholders and gain agreement on principal concepts.
- Decide the analysis timeline prior to commencing work. If the problem definition and the solution are going to be two separate phases of a study, set that expectation early in the process. Often, the deriving solution means following the directives of governing entities (NERC, FERC, governmental agencies, state public utility commissions, etc.). If this is the case, that is the goal of the study.

> For example: “The purpose of this study is to determine the minimum required resources to be retained in a capacity auction while accounting for system-wide fuel supply constraints.”

- Clearly state the boundaries of the study. If there are certain aspects that will not be addressed by the study, make that distinction clear as early in the process as possible.

> For example: “The study will be limited only to the generators that are currently in the interconnection queue through 2030.” Or “The analysis being performed will only consider credible single points of disruption in the gas and fuel oil supply chains.”

Step 2: Data Gathering

Data is essential for a valid fuel-related reliability risk analysis. While the planners performing the study are very familiar with the transmission system and the inputs needed to perform traditional studies, there are many considerations outside the normal inputs that are needed for this analysis. Much of the data needed is likely not directly accessible to the planner and will therefore require the assistance of others in their company (e.g., operations personnel) or even fuel suppliers themselves. FERC has through its Order 787 authorized the sharing of confidential information between jurisdictional pipelines and system operators in order to ensure reliability. Planners should consider using that authority to obtain needed information from the pipelines on a cooperative basis. The following is a list of data sources and methods for acquiring data that can be used by planners to collect the information that they need to perform the study outlined in Step 1:

- Coordinate fuel assurance assumptions with generator owners/operators:
  - This may be achieved with surveys that may include, but are not limited to, primary fuel availability, details of fuel supply and transport agreements, usable on-site storage capability, historic inventory levels, resupply and back-up fuel availability and strategy, resource limitations on alternate fuels (MW output, switching time and process details, changes in heat rate), emissions concerns, and staffing concerns.
    - It may be helpful to discuss the formation of such a survey with generator owners/operators and other stakeholders to seek their guidance and expertise on the level of data they may be able and willing to provide.
  - Validate/benchmark that the data received is consistent with the recent operational experiences when possible

Appendix B contains a detailed list of potential survey questions

Suggestions to Establish and Maintain a Suitable Fuel Survey

Consider managing a survey of this type through an established stakeholder forum

- This will ensure that any changes to the survey are subject to stakeholder discussion and therefore more thoroughly vetted
- Ensure that the information is reaching the target audience as there can be a disconnect between generator owners/operators and the stakeholder representatives

Consider hosting additional engagements like a winter generator readiness seminar

- This offers the opportunity to discuss with a more targeted audience of generator owners/operators and not just their representatives

Consider conducting fuel-constrained scenarios as part of your regular training cycle

- This offers an opportunity to solicit concerns and gather potential impacts of limited fuel supply on system operations across a wide spectrum of electric and cross-sector stakeholders
- This exercise also has the potential to identify fuel disruption impacts that can be further addressed directly with fuel suppliers to seek actions to mitigate these impacts

- Gather appropriate fuel supply contingencies (to be further analyzed and filtered in Step 4):
  - Coordinate with fuel suppliers or fuel specialists within your company, member companies, and/or collaborate with the experts who own and operate the fuel supply chains, including (but not limited to) natural gas and fuel oil pipelines, fuel producers, fuel oil refineries, storage and trucking companies, rail carriers, and ocean or river bound tanker ships/barges. Their input will aid in the assessment of the potential for disruption or failure. It will also lend credence to the assumptions.
  - Discuss the fuel supplier's response plans if fuel supply disruptions were to happen. Rather than rely solely on a hands-off type of study (which still has value), consider the possible mitigating actions of the fuel supplier after the disruptions occur in order to incorporate the impact to the BPS into your analysis. Also consider the time considerations between the disruption and when it will impact the power system. Not all failures have immediate impact.
    - Outreach may include a review of disruption scenarios with each of the fuel suppliers operating within the studied region to assess the viability of both the assumed disruption scenarios as well as the potential downstream impacts.

> As an example, ask the pipeline companies what remaining capacity would be available if they lost a particular pipeline segment. Depending on the pipeline configuration, the capacity serving the area's generators may be reduced by 10%, 50%, or not impacted at all. Each case would produce different input assumptions for the study.
>
> Consider review of internal operational policies and procedures with the pipelines to better understand the impact of those procedures during a fuel supply disruption scenario.

Step 3: Formulate Study Input Assumptions and Initial System Conditions

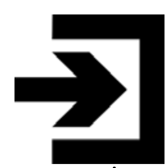
Assumptions and system conditions may be developed by using information obtained from data gathering efforts outlined in Step 2 as well as regional historical experience to establish relevant scenarios for incorporation into the analysis. These assumptions may be specific (e.g., specific generator outage rates determined from regional historical averages) or expressed in terms of a range (e.g., low, medium, and high ranges of projected generator retirements affecting future fuel mix). Steps to develop these assumptions and conditions for the analysis include (but are not limited to) the following:

> One existing analysis modeled a 14-day cold weather duration based on historical weather analysis. The study focused on cold weather events because historical risks to procurement of adequate fuel were most prominent during the winter when the needs of commercial and residential heating were competing with natural-gas-fired and dual-fuel generators. The study considered projected typical winter load conditions as well as extreme winter load.

- Determine which fuel(s) to study. When doing so, consider the interdependence of various fuel types and how a large disruption to one fuel source may impact another fuel source.
- Develop fuel assumptions using the best available information:
  - Document fuel supply assumptions for plants where data is not available or up to date to maintain visibility of areas where the study may have weaknesses.
  - Consider fuel supply alternatives, such as dual fuel use and service from alternate pipelines.
- Determine weather and load assumptions:
  - Weather input to the study can be historical normal and extreme weather applied to future scenarios or some version of a weather or climate forecast that describes the study time frame.
  - For a fuel risk analysis, the system under study is more than just the BPS. There are going to be shared resources between different sub-systems that are interdependent; for example, natural gas is used for both heating and power generation. Understanding the relationship between those two classes of natural gas demand is paramount when performing this study. Knowing what will happen when the natural gas system is full due to colder temperatures will define what direction the study goes and, in large-part, the results of the study. Fuel oil works in a similar fashion but with a different mode of transportation. Although pipelines can carry fuel oil, it is typically via truck or barge. But the fundamental concept is the same—when it gets cold and the demand for fuel is up, supply chains become full and resulting supply options and priorities may be unexpected.

- Determine interchange assumptions and interface capability:
  - This should include coordination with neighboring entities to ensure accuracy and agreement of their interchange contribution. Consider whether the conditions selected for the study will also impact an adjacent area's interchange contribution.
  - A study may assume interchange transaction quantities that reflect the economic interaction between the studied systems and neighboring systems consistent with real-time operations. Alternatively, a historical analysis may be performed to determine an upper and lower bound for capacity and energy imports and exports.

    Coordination with neighboring systems should also include potential impacts of a natural gas disruption in one area on gas-fired generation in adjacent areas—affecting the amount of electric interchange support available.



- Determine generator outage rates and reductions assumptions:

- Generator outage rates may be defined by using standard methods (e.g., EFORd) or using a simple analysis of historical performance. Depending on the approach or assumptions, this may deviate from the normally accepted methods.

EFORd – *Equivalent Forced Outage Rate demand*
the probability a generator will fail completely or in part when needed

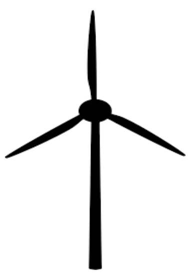
- Take care not to double count outages. Understand that if a generator is out of service due to normal outages, it cannot also be counted as a generator that is out of service due to fuel and vice-versa.

One analysis may assume generator forced outage rates across a 5-year historical period

Another may consider the impact of extreme cold weather on generator performance and calculate forced outage rates using a regression analysis

If fuel supply-related contingencies are explicitly modeled, then be sure to exclude them from the regression

- Determine assumptions related to VERs



- These considerations will be critical in areas with high penetration of VERs where the output range can vary significantly.

As of 2019, wind generation output ranged from 0.5 GW to 16 GW in SPP

- Consider the evolution of generation technology, changes in fuel mix, and the interdependency of future resource installation:
  - The current interconnection queue and integrated resource plans/resource adequacy plans may inform planners of resources to be selected in longer-term analyses.
  - Resource planning forecasts are performed on a regular basis. These studies evaluate the future needs and technologies to meet those needs:
    - These studies may reveal, for example, the likelihood of renewable energy additions that result in early retirement of coal or fuel oil resources.
    - State initiatives for additional dual-fuel resources, as another example, would likely introduce more gas/fuel oil generators into the interconnection queue.
  - It may be difficult to predict how the future resource mix will vary based on factors like governmental policy initiatives. Include a range of assumptions for items that have uncertainty.[29]

[29] https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf

ISO-NE OPERATIONAL FUEL SECURITY ANALYSIS[30]

ISO New England's Operational Fuel Security Analysis modeled a wide range of resource combinations that might be possible several years into the future. The study examined varying resource retirements, LNG availability, oil inventory, interchange, and renewable resources. In addition to a reference case which incorporated the likely levels of each variable, these input assumptions were varied individually to characterize the sensitivity between unfavorable to favorable boundary cases. Several combination scenarios, examining how multiple related changes would affect the outcome, were also examined which adjusted more than one of the key variables to represent future resource portfolios that could develop and their effects on fuel security.

- Determine performance criteria. For example:
  - If the study being performed contemplates a HILP contingency, perhaps the performance criteria would be that 90% of firm load is maintained for a short period of time. However, when HILP is studied, it should be done for emergency preparedness and not for measuring the reliability of specific system resources. Another consideration in this scenario would be acceptable system ratings and limits. If the study being performed contemplates a HPLI contingency, perhaps the performance criteria would be set to a base case, or up to unavailability of interruptible load.
- Determine the study frequency, outlook, and duration according to the risks identified through data gathering. Depending on the assumptions, electric system, or fuel supply chains that may have changed, the planner should use engineering judgement and historical information. See the three-column graphic on the next page for additional information.

[30] Id.

Frequency	Outlook	Duration
For choosing a study frequency (i.e., how often the study is performed), consider the following: • Operational time frame studies could be performed on a weekly, or monthly basis, or other near-term periodicity. For example, one existing analysis involves a winter weekly or non-winter biweekly energy study that is used on an ongoing basis for operations planning. • Seasonal studies could be performed periodically in the prewinter or presummer time frames in anticipation of the peak load seasons. • Longer-term studies could be performed annually, every few years, or on a longer-term periodicity as necessary. • Ad-hoc (one-time) studies could also be performed to assess a unique set of conditions and to achieve specific objectives, and may be more limited in scope.	For choosing a study outlook (i.e., when does the studied time horizon begin) consider the following: • Short-term operations planning study outlooks (e.g., one-week out, one-month out, six-months out, other-less than a year out) could be used. • Alternatively, near-term (1–5 years), long-term (6–10 years) transmission planning time horizons, or even greater study outlooks could be used if appropriate for the objectives of the study. For example, one existing analysis was based on a five-year look-ahead study to assess system resilience under future resource portfolios.	For choosing a study duration (i.e., what is length of the study window), consider the following: • The duration could be anywhere from a snapshot of the current system to a few days out or even to multiple years, depending on what is appropriate for the assumptions or objectives of the study. For example, one existing analysis involves a 14-day study window to model a plausible 14-day extreme cold weather scenario based on historical weather analysis. • Consider varying durations of fuel disruptions to determine how reliability conditions may change over time given a particular fuel disruption.

ISO-NE performs a 21-day look ahead energy assessment based on the lead time it takes to schedule an LNG and fuel oil truck delivery within the associated region.

- Include any special or additional scenarios or assumptions, such as the following:
  - Heavy seasonal directional power transfers
  - Changes in generation mix
  - Drought or flooding conditions
  - Changes in fuel supply situation (e.g., closure of refineries or LNG storage facilities, new provisions that limit or prevent local gas and fuel oil transport)
  - System-wide blackout scenario (e.g., scenario studying fuel-related reliability risks to blackstart units and potential impact on system restoration following a blackout)
- Document the rationale behind study assumptions and initial system conditions

Step 4: Contingency Selection

The data gathered at this point will help to form the basis for contingencies to the fuel supply of the studied system. Some aspects will be known, and some will be assumed. It is possible that not all contingencies will be included in the final study once the probability and credibility of the various scenarios are better established. It may be prudent to establish a priority level for different contingencies based on the planner's experiences. There are many factors to consider in filtering and selecting the appropriate contingencies to study; this may include, but is not limited to, the following:

- The cause of the fuel disruption (which helps with developing proper mitigation)[31]
- The frequency with which the disruption has occurred in the past in this or other locations
- The probability or likelihood that the disruption will occur in the future
- The expected duration of the disruption based on historical data or reasonable assumptions that acknowledge system improvements over historical data:
  - Fuel disruption duration can be seasonally dependent. For example, a failed fuel delivery system during the high-demand winter months will likely be shorter in duration than a disruption during low-demand periods.
- The amount of fuel supply interrupted (This is a line to be drawn based on relevance to the scenario being studied.)

The loss of a single natural gas compressor engine at a station is more likely than the loss of an entire compressor station. Many fuel supply systems contain redundancies and safeguards, making a full outage of service less likely than a partial outage.

- The location of the disruption, even outside of your footprint as fuel delivery is a worldwide operation
  - Interdependence of global markets on local systems should not be overlooked (e.g., LNG imports in Japan surged following the 2011 Fukushima nuclear power shutdown.)
- The generating units that may be affected by the disruption (Be sure to account for remaining generating capability if any.)
  - Consider alternatives available to impacted generating units, such as dual fuel use and service from alternate pipelines[32]
- The extent or scope of the interruption as to whether it impacts other companies, industries, or other subsystems, such as the following:

[31] NERC Generator Availability Data System data collection was updated for 2020 reporting and going forward cause coding for "lack of fuel" reporting will be much improved.

[32] Eastern Interconnection Planning Collaborative (EIPC), 2015 Gas-Electric System Interface Study, Section 10 on Natural Gas and Electric System Contingency Analysis, https://eipconline.com/phase-ii-documents.

  - If flooding has washed out the railways in a particular area, rerouting coal delivery around that area will likely be more difficult due to all rail traffic trying to reroute to meet guaranteed delivery dates.
  - Consider the likelihood of mutual assistance between suppliers. It is within the realm of possibility that a pipeline or fuel oil transporter could suffer a loss of capability and receive assistance from an interconnected pipeline or associated supplier.
  - Consider whether electric load shedding to resolve BPS problems will impact fuel availability or subsequent plant operations.
  - Consider the impact of electric contingencies on the natural gas system or recovery from a natural gas disruption (e.g., loss of power to electric driven natural gas compressor stations or transmission contingencies that may restrict the redispatch of non-natural-gas-fired generators).
- The influence of governmental agencies may also factor into the studied response to contingencies:
  - Consider historical reactions by governing agencies.
  - Consider guidance from governmental agencies, such as the potential for cyber and/or man-made threats to fuel delivery systems.
  - Consider working with relevant governmental agencies to share the analysis, develop and gain any needed approval for mitigation measures.
- Nontraditional solutions may be available when directed by emergency management or similar agencies. Conversely, fuel supply could be made unavailable due to decisions made at the governmental level. For example, a port necessary for the delivery of LNG or fuel oil may be shut down following worldwide events that result in a state of heightened security. Another example may be the limited usage of fuel oil unless a special (environmental) waiver is granted by state or federal officials.

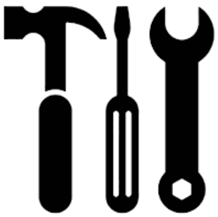
PJM FUEL SECURITY ANALYSIS

PJM introduced four different gas pipeline contingencies that represented disruption of supply in a segment for four different natural gas pipelines within the PJM region. Each contingency resulted in reduced capacity on the affected segment of the interstate pipeline, thereby impacting the ability to deliver natural gas to generating units downstream of the disruption. For each contingency, PJM simulated partial disruptions (medium impact event resulting in loss of a one out of multiple parallel lines in a pipeline segment) and full disruptions (high impact event resulting in loss of all parallel lines in a pipeline segment). Each of these contingencies modeled took into consideration the design of the affected pipeline segment to determine the reduced capacity of the pipeline and impact to downstream generator availability. The methodology for layering in the disruption scenarios and the assumptions for the duration of the disruptions were based on observed conditions during recent pipeline disruption events as well as consultations with the Natural Gas Council and major interstate pipeline companies serving the PJM region.

Following a pipeline disruption event impacting one of the looped lines in a pipeline segment, PHMSA has historically required a mandatory capacity reduction (typically about 20% firm capacity reduction) in the adjacent non-impacted lines within the same pipeline right-of-way until initial investigation of the incident is complete. PHMSA has also historically restricted access to an affected pipeline segment following an event for safety reasons, delaying immediate restoration efforts by pipeline operators. Both the capacity reduction and delayed restoration due to PHMSA's response should be considered when studying the natural gas pipeline contingency impact and duration.

- Document the rationale for each contingency selected.

Step 5: Selection of Tool(s) for Analysis



Because of individual system conditions and goals, no single type of transmission system analysis will meet the need of every planner. Therefore, each planner should consider the information gathered in the steps above and choose analysis tools that can provide information that will allow for a thorough assessment of their supply and transmission systems. This analysis may be power flow, stability or dynamic simulation, production cost modeling, market simulation, fuel oil and natural gas pipeline hydraulic flow modeling, deterministic versus probabilistic modeling, in-house tools, or any combination of these tools and others.

Regardless of the tool(s) chosen, the rationale for the selection should be documented and reviewed periodically to ensure that the appropriate tools continue to be utilized and provide continuity from the end of the analysis to what was defined in the goals.

- ☐ Power flow
- ☐ Stability simulation
- ☐ Production cost modeling
- ☐ Market simulation
- ☐ Pipeline flow model
- ☐ Deterministic vs. probabilistic model
- ☐ In-house tools

Step 6: Perform Analysis and Assess Results

Based on the information from Steps 1–5, system analysis will be performed and assessed. The assessment will evaluate system performance based on the criteria defined in Step 3 to determine if system deficiencies exist and, if so, what actions might be considered to improve the observed deficiencies. Every step of the process was defined, including the criteria for system performance. At this point of the analysis, the state of the system is known. If the assessment determines that the system does not meet the prescribed criteria for reliable operation of the power system, and corrective actions are needed, this step is where that would happen.

When delivering the results of the study, consider the audience. Consider their level of knowledge of the system being studied and speak to the audience at a level they will understand. Use commonly understood terminology, processes, and procedures so that the audience will more likely comprehend the results as intended.

Step 7: Develop Solution Framework

As noted in Step 3, fuel assurance studies should be completed on an ongoing basis. Regular analysis will help planners and other stakeholders better understand emerging risks as the power grid undergoes rapid transformation. Planners are encouraged to develop a solution framework to ensure fuel assurance in advance of any potential credible reliability issues. It is at this point that the planner should consider engaging governmental agencies that may be able to assist with developing a framework of potential solutions. One example might be contacting state environmental departments to discuss power plant air and water permits should a HILP contingency occur. At a larger regional level, planners are encouraged to consider developing a response and mitigation plan for grid, generator, and natural gas operators to guide their response to fuel assurance contingencies as identified in Step 4. Further, the development of a communications protocol for grid, generator, and natural gas operators could benefit the regional response to and mitigation of contingencies as identified in the risk analysis framework. These proactive actions will ensure preparedness and improved situational awareness to handle these potential risks in the future.

Appendix A: Risk Analysis Framework Checklist

This checklist outlines the actions recommended in **Chapter 4** into a list that entities may use as a reference when performing their own analysis. As mentioned at the beginning of **Chapter 4**, the listed steps are intended to be flexible enough to account for all fuel types, broad enough to support the unique circumstances in each region, and may be performed out of order (or in some cases not at all).

Step 1: Problem Statement and Study Prerequisites

- ☐ Define the study goal (i.e., problem statement)
- ☐ Set the criteria for system performance
- ☐ Communicate the goals of the study with all stakeholders (electric and fuel suppliers)
- ☐ Gain agreement on principal concepts
- ☐ Determine the timeline prior to commencing work
- ☐ Set the boundaries of the study
- ☐ Document agreed upon goals, time line, boundaries, etc.

Step 2: Data Gathering

- ☐ Coordinate fuel assurance assumptions with generator owners/operators
- ☐ Survey stakeholders (see **Appendix B**)
- ☐ Identify relevant fuel supply contingency events
- ☐ Maintain documentation for future use

Step 3: Formulate Study Input Assumptions and Initial System Conditions

- ☐ Determine fuel(s) to be studied
- ☐ Determine the interdependence of various fuel types
- ☐ Determine how a large disruption to one fuel source may impact another fuel
  - ☐ If needed, develop fuel assumptions in the absence of actual information
- ☐ Determine weather and load assumptions
- ☐ Determine interchange and interface capability
- ☐ Determine generator outage and reductions rate assumptions (e.g., EFORd)
- ☐ Determine assumptions related to variable energy resources
- ☐ Determine expected changes in regulatory policy, generation technology, and fuel mix, including the interdependency of resource installation
- ☐ Determine performance criteria using stakeholder input (e.g., is load loss acceptable? If so, for how long?)
- ☐ Determine study frequency, outlook, and duration
- ☐ Include any special or additional assumptions or system conditions, the following are examples:
  - ☐ Heavy seasonal energy transfers

- ☐ Changes in generation mix
- ☐ Droughts
- ☐ Flooding
- ☐ System-wide blackout scenario

☐ Document rationale for assumptions and system conditions selected

Step 4: Contingency Selection

Filter down identified contingencies. Consider CEII ramifications. Consider factors like the following:

- ☐ Cause of the fuel disruption
- ☐ Frequency with which the disruption has occurred in the past in this or other locations
- ☐ Probability or likelihood that the disruption will occur in the future
- ☐ Expected duration of the disruption based on historical data or reasonable assumptions
- ☐ Amount of the fuel supply interrupted
- ☐ Location of the disruption
- ☐ Generating units affected by the disruption and remaining generating capability (if any)
- ☐ Extent or scope of the interruption (does it impact other companies, industries, etc.)
- ☐ Influence of governmental agencies on the response to contingencies
- ☐ Document rationale for contingency selection

Step 5: Selection of Tool(s) for Analysis

Select analysis tools appropriate for the study, such as follows:

- ☐ Power flow
- ☐ Stability simulation
- ☐ Production cost modeling
- ☐ Market simulation
- ☐ Pipeline hydraulic flow modeling
- ☐ Deterministic vs. Probabilistic modeling
- ☐ In-house tools
- ☐ Document rationale for selection

Step 6: Perform Analysis and Assess Results

- ☐ Perform analysis
- ☐ Document and assess results
- ☐ Consider CEII ramifications

Step 7: Develop Solution Framework

- ☐ Identify potential risks
- ☐ Develop solution framework as needed and in concert with stakeholders, regulators, etc.
- ☐ Update existing plans and procedures

Appendix B: Items to Include in a Fuel/Energy Survey

This list is indicative but not all encompassing of the questions that planners may ask of its generator owners/operators depending on the regional study goals and the possibility of regional fuel type generation considerations.

When drafting a survey, consider whether certain questions should be made mandatory. Also consider how to format answer selections; should some be limited to multiple choice, is free form text more appropriate, etc. It will also be important to seek consistency in units of measurement. Make an effort to clarify what units are desired (MW, MWh, MMBtu/day, etc.) so that compiling and analyzing responses is straightforward.

General Information

- Resource information
    - Name
    - Contact
    - Unit identifier
    - Type
- Square footage of fence footprint and what percentage of that space is empty
- Is there a “bump-up” compressor on-site? How often is it used?
- Net max and min sustainable rating
- Design and/or current operational max/min ambient temperature
- Unit maximum Summer heat rate
- Unit maximum Winter heat rate
- Dual Fuel Unit heat rate on different fuels
- Primary fuel source
- Alternate fuel source
    - Fuel switching requirements, or other considerations
- Date of last MW disruption (or not received) on primary fuel (within the last 5 years)
- Amount of MWs disrupted (or not received)
    - Reason for disruption (or not received)
- Have any fuel supply procurement processes been compromised?
    - For example, limited trucking capability, navigation issues, lack of refinement capability from supplier
    - How often?
    - Any seasonal issues?
- Planned retirement date
- Is staffing required to start the unit?
- Is staffing required to switch fuels?

- Is unit black-start capable or on ISO/RTO system restoration Plan?
- Consumable item most limiting unit operations (e.g., limestone, chemicals, demineralized water trailers, air or water emission credits)
- Does the unit/station have existing on-site natural gas compression
- Availability of on-site boost compression
- Is there backup power on-site?
- Are there state restrictions on future use of this unit?
- What is the impact and duration of maintenance shutdowns?
- What is the risk of third-party damage to plant, inventory or transportation types to the plant?

Natural Gas Pipeline Information

- Companies providing physical natural gas pipeline connections
- Critical compressor facilities
  - Identify whether natural gas or electric compressors connected to or required by the unit (if known)
  - Identify if spare compression is available at each compressor site
- Required minimum pressure for full, half, and minimum output
- Required minimum pressure for unit operation (<full output)
- Peak burn rate
- Transportation contract
  - No-notice service, firm, enhanced Firm, secondary firm, interruptible, etc.
  - Transportation contract options available for natural-gas-fired generators
- Commodity
  - Type of service—firm or interruptible, Other?
    - Number of available suppliers
  - Number of pipelines
  - Storage access
  - Asset Management Arrangements (e.g., firm delivery expressed in MMBtu/day)
- Seasonal operations considerations
  - Identify any force majeure events called by the pipeline in the last 10 years
  - Identify any critical generators connected to the pipeline that could affect your deliveries
  - What is the nature of the balancing flexibility the pipeline offers you and provide a link to the tariff summary
- Seasonal maintenance considerations

Oil Information

- Limitations on oil burn, number of hours, emissions limitations, seasonality limits

- Number of hours of operation at max/min output on oil
- Maximum fuel storage capability
- Type(s) of oil (e.g., residual fuel oil, fuel oil #2, etc.)
    - Available usable fuel in storage (typical annual-average value)
- Plans to increase available usable fuel amount
- Assurance level for additional deliveries
- Can fuel be replenished faster than it is used?
- Alternate fuel contracts
- Number of alternate fuel suppliers
- Fuel primary and alternate transportation type (pipeline, barge, rail, truck, etc.)
- Fuel resupply limitations
    - Notice time and delivery time
    - Deliveries expected over given period of time (e.g., how many per day)
    - Proximity of supplier(s)
    - Available offloading facilities
- Does unit need natural gas to start?
    - If so, is the fuel stored on site?
- Do other units share oil inventory?
- If so, number of hours of operation at max output on shared oil

Coal Information

- Maximum storage capacity
    - Current inventory amount
- Inventory resupply plans
- Assurance level for additional deliveries
- Alternative suppliers
- Maximum output that can be sustained indefinitely
- Fuel primary transportation type (barge, rail, truck, etc.)
- Can fuel be replenished faster than it is used?
- Secondary transportation
- Fuel delivery time
- Is delivery on a schedule?
- Scheduled time between replenishments
- Maximum amount delivered in a single shipment

- Typical coal level for replenishment order
- Units that share coal inventory
- Max runtime for unit with shared fuel inventory
- Does unit need oil or natural gas to start?
    - If so, what fuel(s) is stored on site?
- What is the unit's history of freezing coal inventory/piles and are any measures in place to mitigate freezing?

Alternate Fuel Information

- Alternate fuel source(s)
- Additional staffing requirements to start the unit on alternate fuel
- Number of hours of operation at max on alternate fuel
- Maximum fuel storage capability
- Available usable fuel in storage
- Plans to increase available usable alternate fuel amount
- Assurance level for additional deliveries
- Alternative suppliers
- Fuel primary transportation type (barge, rail, truck, etc.)
- Can fuel be replenished faster than it is used?
- Secondary transportation
- Alternate fuel resupply time
- Unit net MW max capability on alternate fuel
- Does the unit have to be taken off-line to switch to the alternate fuel?
    - If not, what is the MW output level needed to perform switching?
- Time to transition to alternate fuel
- Date alternate fuel capability was last tested
- Amount of net MW output achieved while on alternate fuel
- Does unit need natural gas to start?
    - If so, is the fuel stored on site?
- Max number of starts per day on alternate fuel
- Number of starts per week on alternate fuel
- Can generator operate on both fuels simultaneously?

Environmental/Emissions

- Unit environmental/emissions limitations
- Pollutant responsible for most limiting emissions limit

- Limit periodicity of pollutant responsible for most limiting emissions limit
- Pollutant responsible for most second most limiting emissions limit
- Limit periodicity of pollutant responsible for most second most limiting emissions limit
- Other environmental/emissions concerns

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