FUEL SECURITY IN THE PJM INTERCONNECT: Natural Gas and Dual-fuel Resources

Prepared by: Energyzt Advisors, LLC

On behalf of: Calpine Corporation

September 2018

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EXECUTIVE SUMMARY

The issue of fuel security and resiliency is front and center at the federal, state and regional transmission operator (RTO) levels. This paper offers a set of conclusions regarding the role of natural gas-fired generation in providing fuel security and provides recommendations for what PJM should consider during its deliberations on resiliency.

Conclusions

- **Definition of Resiliency:** The definition of resiliency, as applied to the power system when faced with a trigger event (e.g., natural, intentional, physical, or digital/cyberterrorism events) should include two concepts:

  1) **Response:** Flexibility of a system to respond quickly to the trigger event; and

  2) **Recovery:** Ability to recover to normal operating levels quickly and efficiently.

  The combination of quick response and recovery addresses the concept of resiliency versus reliability, which reflects ongoing and continuous operations.

- **Role of Natural Gas in Providing PJM Resiliency:** Natural gas-fueled electricity generation is an important source of energy for the U.S. power sector in general, and has grown rapidly in PJM over the past two decades. The natural gas fuel supply and delivery system serving PJM is robust, interconnected, redundant, geographically diversified, and offers storage in the form of both natural gas and liquefied natural gas. Most of the pipeline system is buried underground, offering protection against storms, natural events and physical attack. The redundancy of natural gas networks as well as access to diverse sources of natural gas supply for the generation facilities they serve, provides a highly reliable and highly resilient fuel source for power generation. Although natural gas supply is not impervious to trigger events, it is implausible to assume that the totality of gas supply and transportation will be lost across the entire region.

- **Role of Dual-fuel Units in PJM:** Petroleum fuels also play an important role in PJM's generation mix, both as a primary fuel source and as an alternative option in dual-fuel units. The petroleum delivery system is robust, complex, redundant, diversified, and resilient, providing a multi-modal network that utilizes pipelines, trucks, ocean vessels, barges, and storage tanks. When combining the network benefits of natural gas with the network benefits of petroleum delivery, dual-fuel generation plants using oil as a backup fuel further strengthens PJM's resiliency and provides one of the most robust forms of generation on the system. Natural gas units with dual-fuel capability can switch to an alternative fuel before line-pack is lost, and then recover rapidly after the trigger event has subsided.

As a general proposition, duplication and redundancy can be more effective than sole-source supply. Although on-site fuel alone may seem intuitively resilient, the benefits of an on-site fuel source can break down in the face of adverse conditions such that the redundancy of a fuel supply network is more effective than a single-site solution. Relying on well-established fuel supply networks, built-in redundancy, multi-modal delivery, and dual-fuel capability is the most effective means for responding to trigger events. As a result, any solution – whether market-based or market-intervention -- should recognize the fuel security benefits of dual-fuel units and the redundancy that already is built into the natural gas and petroleum supply networks in order to reward the resiliency that such fuel sources provide.

Recommendations

- **Recommendation 1:** Define the resiliency problem reasonably to be consistent with the stated objective and encourage investment in appropriate technologies.

- **Recommendation 2:** Consider characteristics of a generator's fuel supply source and delivery systems when determining the generator's contribution to fuel security.

- **Recommendation 3:** Reward on-site fuel diversification as a contributor to system-wide fuel diversification and security.

- **Recommendation 4:** Look beyond fuel-type alone as a metric and incorporate the characteristics of broader fuel supply situations servicing a particular generating plant.

- **Recommendation 5:** Expand the PJM Capacity Performance Program to reward fuel supply optionality, redundancy and backup.

1. INTRODUCTION

Key Points:

- **PJM's Review:** In response to a number of policy initiatives, PJM has initiated a review to "define and establish fuel security criteria" and design a set of market rules that allows all generation resources to compete to meet those criteria.
- **Objective:** The purpose of this report is to examine the fuel security implications of networked fuel supply to PJM's system, specifically, natural gas-fired generation, oil-fired generation and dual-fuel capability.

The purpose of this paper is to offer an assessment of the fuel security implications of natural gas-fired generation resources, including natural gas generation with dual-fuel capability, to the PJM Interconnect's generation and delivery system. Based on the research and findings described in this report, recommendations are presented to provide a framework for analyzing the fuel security attributes of different fuel types broadly and natural gas-fired generation as a single fuel source or with dual-fuel capability specifically.

PJM is in the process of examining the vulnerability of its electric system to disruptions resulting from natural or man-made trigger events. A trigger event is a situation that disrupts normal operations to the extent that response and recovery is required. PJM is examining its system resiliency is in response to a number of policy pressures, including a Presidential directive to support nuclear and coal-fired power plants, proposals from the Department of Energy to pay specific generators for on-site fuel tied to resiliency, a docket opened by the Federal Energy Regulatory Commission on resiliency more broadly, and PJM's own reliability assessment of its fuel mix.

On April 30, 2018, PJM President and CEO Andy Ott sent a letter to PJM members announcing PJM's commencement of a fuel security review. The initiative is intended to "define and establish fuel security criteria in order to use market forces to allow all resources to compete to meet those criteria." As Mr. Ott notes, PJM will perform an assessment of the resiliency of the PJM system with various generation mix portfolios and will assess the risks associated with significant disruptive events across those different portfolios.

As fuel security is an underlying theme in the PJM assessment, this report focuses on a key generation source in PJM Interconnect: generators with networked fuel supply. More specifically, this report examines the role, reliability and resiliency of natural gas supply, the natural gas pipeline system, petroleum fuel delivery and dual-fuel capability.

2. DEFINITION OF RESILIENCY

Key Points:

- **Resilience:** The definition of resilience should include the flexibility to respond and recover from a disruption as measured by the length of time it takes a system to return to its normal operations.
- **Diversity:** Reliance on natural gas as the primary fuel source in PJM inherently offers diversity, redundancy and resiliency. Diversity of supply at an individual generator site also increases resiliency.
- **Networks:** Natural gas-fired generation should not be considered a single fuel delivery system for purposes of PJM's analysis of fuel security, but a networked supply chain with multiple sources of supply and pathways for delivery.
- **Timeframe for Analysis:** Any analysis of potential disruptions to fuel delivery should include a range of events that reflect both short-term and long-term recovery periods from realistic, possible and/or probable events.

The North American Electric Reliability Corporation (NERC) defines infrastructure resilience as follows: [1]

> Infrastructure resilience is the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or recover from a potentially disruptive event.

[1] As quoted in the Staff Report to the Secretary on Electricity Markets and Reliability, August 2017, p. 63, https://www.energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf

Therefore, in the simplest terms, the definition of resilience is two-fold:

1) **Response:** Flexibility of a system to respond quickly to a trigger event; and

2) **Recovery:** Ability to minimize the length of time it takes for a system to return to its normal operating condition.

Although resiliency has been tied to fuel security in recent policy decisions, the two are different issues. PJM offers the following distinction between the risk profile of resilience and fuel security:[2]

> ". . . **resilience** describes a broad array of **low-probability but high-impact risks** at all stages of the production, transmission and distribution of electricity . . . Fuel security focuses on the vulnerability of the fuel supply and delivery to generators and the risks inherent in increased dependence on a **single fuel-delivery system**" (emphasis added).

An important term in PJM's definition of fuel security is the focus on a "single fuel-delivery system." PJM currently relies on a mix of fuel resources (Appendix B). Although natural gas has increased its market share within the PJM fuel supply generation mix, it is supported by an abundant set of fuel supply sources and redundant delivery network across the vast PJM system. An increasing reliance on natural gas as the dominant single fuel should only be a concern if the fuel supply and delivery system does not have resiliency and redundancy built into it.

PJM's natural gas-fired generators rely on multiple and diverse fuel supply resources delivered through multiple modes and interconnected networks with redundancy that is bolstered by access to physical natural gas storage. In addition, some natural gas-fired generating plants in the PJM system have "dual-fuel" capability, which enables those generators to switch quickly to an alternative fuel such as fuel oil or diesel to provide backup during periods of emergency, or to use a mixture of both gas and oil for prolonged operations.[3]

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[2] PJM, *Valuing Fuel Security*, April 30, 2018, http://www.pjm.com/-/media/library/reports-notices/special-reports/2018/20180430-valuing-fuel-security.ashx?la=en

[3] Discussions with developers indicate that new fossil fuel generating units being built in PJM frequently have dual-fuel capacity and this has become a much more important criterion in the selection of suitable technologies and siting approvals.

The robustness of both the natural gas and petroleum delivery systems, as well as dual-fuel capability and an ability to refill fuel storage tanks at power plants in situations of extended interruption over long periods of time (i.e., weeks and months), means that reliance on natural gas, although a single fuel-type, is not reliance on a single-fuel-delivery system. Reliance on natural gas as the primary fuel source in PJM inherently offers diversity, redundancy and resiliency.

PJM's definition of fuel security emphasizes the vulnerability of fuel supply and delivery to generators, as well as the risks inherent in fuel supply dependencies.[4]

> As defined by PJM, fuel security is the ability of the system's supply portfolio, given its fuel supply dependencies to continue serving electricity demand through **credible disturbance events**, such as coordinated physical or cyberattacks or extreme weather that could lead to disruptions in fuel delivery systems, which would impact the availability of generation over **extended periods of time**" (emphasis added).

It is important to emphasize the focus on "credible disturbance events," which requires a distinction between occasions that actually could happen, even with a low likelihood of occurrence, and events that are reasonably likely to occur. Examining extreme situations as if they were expected outcomes, although useful in stress-testing, creates the risk of misleading results, false conclusions and potentially incorrect solutions to problems that have negligible risk of occurring. Investing in mitigation for such extreme conditions, without an associated assessment of the likelihood of occurrence or means of mitigating individual components, can result in an inefficient outcome.

Another point to emphasize is the phrase "extended periods of time" which should have a basis in reality, but be of a sufficient duration such that it captures the full extent of a potential disruption. A few days may be too short a time period to understand the full direct and indirect consequences of a disruption that requires substantial recovery time. Similarly, a timeframe spanning multiple weeks or longer could be too long of a period to assume that a disruption will continue unmitigated. The appropriate timeframe for

[4] PJM, *Valuing Fuel Security*, April 30, 2018. http://www.pjm.com/-/media/library/reports-notices/special-reports/2018/20180430-valuing-fuel-security.ashx?la=en

analysis should be tied to the scenario being examined and include realistic, possible and/or probable events.

An underlying assumption in the PJM review appears to be that diversity in fuel supplies can be more resilient than reliance on a single fuel source. However, the benefit of relying on multiple fuel sources on a system-wide basis, also can be applied at the generator level.

A number of generating units in PJM rely on multiple fuel sources (e.g., dual-fuel units) that can be delivered via different delivery modes and stored in different locations. This diversity at the generator level serves to offer a similar form of resiliency to the fuel security objectives identified by PJM and should be considered in the same context as diversified fuel supply at the system-wide level. Importantly, flexible units with quicker start-up and ramp-up/down times, such as gas and oil-fired units, may be better able to provide real-time balancing of supply and demand during trigger events, allowing less flexible and intermittent generating units to recovers and reconnect to the grid in a reliable fashion.

3. Role of Natural Gas in Providing PJM Resiliency

Key Points:

- **Supply:** PJM's natural gas supply is sourced from multiple wells and fields that are widely dispersed across the country, including the Marcellus and Utica Shale fields.
- **Delivery:** Natural gas is delivered via a highly-interconnected pipeline network that provides backup and redundancy.
- **Storage:** Natural gas storage along the pipeline network provides peak-shaving, supplemental supplies and long-term resiliency.
- **Redundancy:** Multiple pipelines serving generation plants via an extended delivery network provide alternative delivery options.
- **Protection:** Many pipelines are buried underground and are not as exposed to physical attack as other fuel delivery systems.
- **Commercial Arrangements:** Mature markets allow for gas that is sold on firm transmission agreements to minimize interruption to power plants.

The natural gas supply and distribution system in the United States, and specifically in PJM, is a diverse system with multiple sources of gas resources and a highly interconnected pipeline network. PJM receives gas from a wide array of oil and gas fields in the Gulf Coast, Western States, Marcellus Shale in Pennsylvania and West Virginia , Utica Shale in Ohio, and LNG imports. Virtually all natural gas is delivered by interstate and intrastate pipelines in this country, although gas in a liquefied state can be delivered via ship, rail and truck.[5]

The region is serviced through multiple pipelines including:

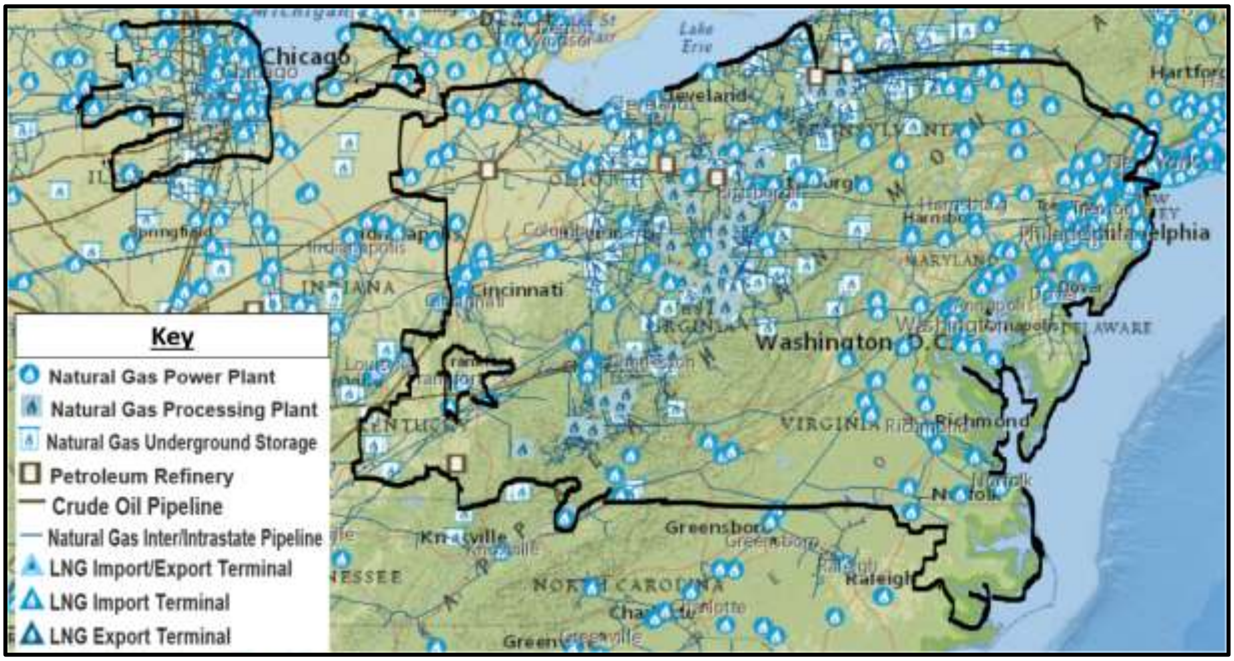
- TransCanada's Columbia Gas Pipeline (TCO)
- Texas Eastern Transmission, LP (Tetco)
- Dominion Energy Transmission, Inc.
- Natural Gas Pipeline Company of America, LLC
- Tennessee Gas Pipeline Company, LLC
- Transcontinental Gas Pipeline Company, LLC (Transco)

Many of the natural gas-fired generating plants in PJM are served by multiple pipelines, thus providing redundancy which helps mitigate the impacts of a disruption that may occur on a single pipeline.

Figure 1 shows a map with locations of the generating plants and pipeline systems that interconnect the PJM system. The robustness of the system is enhanced by the dispersion of plants throughout PJM; system nodes are not concentrated in just one region or served by a single pipeline which could have a larger impact resulting from a physical disruption.

[5] Natural Gas Council, *Natural Gas Systems: Reliable & Resilient*, July 2017. http://martelli.us/ngcouncil/wp-content/uploads/2018/03/Report-Natural-Gas-Systems-Reliable-Resilient.pdf

Figure 1: Natural Gas Plants and Delivery Topography for PJM



Source: US EIA https://www.eia.gov/state/maps.php

According to PJM, the natural gas delivery system serving its generation fleet consists of: [6]

- 15 Interstate Pipelines
- 32 Local Distribution Companies
- 420 Natural Gas Fired Generators
- Natural Gas Fired Generation
    - 75% served via interstate pipelines
    - 24% served via local distribution companies

(see Appendix B for list of pipelines and LDCs serving the PJM area).

3.1 Resiliency of the Natural Gas Pipeline System

A critical feature of the natural gas pipeline network is that interstate pipelines are interconnected so that an interruption or disruption that occurs at one location on a pipeline typically can be by-passed and diverted by gas supply flowing through another

[6] PJM, "PJM Natural Gas Generation and Fuel Assurance," July 10, 2018. www.pjm.com

pipeline system that is interconnected and serving the same final destinations. In addition, pipeline companies are continually monitoring and inspecting their pipelines and compressor stations to identify and repair possible hazards and take necessary actions to address suspicious activity.

In response to increased dependency on natural gas, the Eastern Interconnection Planning Collaborative (EIPC) working with PJM, ISO-New England, MISO, New York ISO, the Ontario Electric System Operator and the Tennessee Valley Authority, with the financial support of the U.S. Department of Energy, commissioned an independent analysis of the robustness of pipeline infrastructure in those regions to meet future electric demand under a variety of scenarios. The EIPC study, representing a comprehensive analysis of the gas infrastructure's capability to serve the future needs of electric generation over a region that encompasses 35 states and the province of Ontario, found a redundant networked infrastructure that limits the impact of any single event on system delivery.[7]

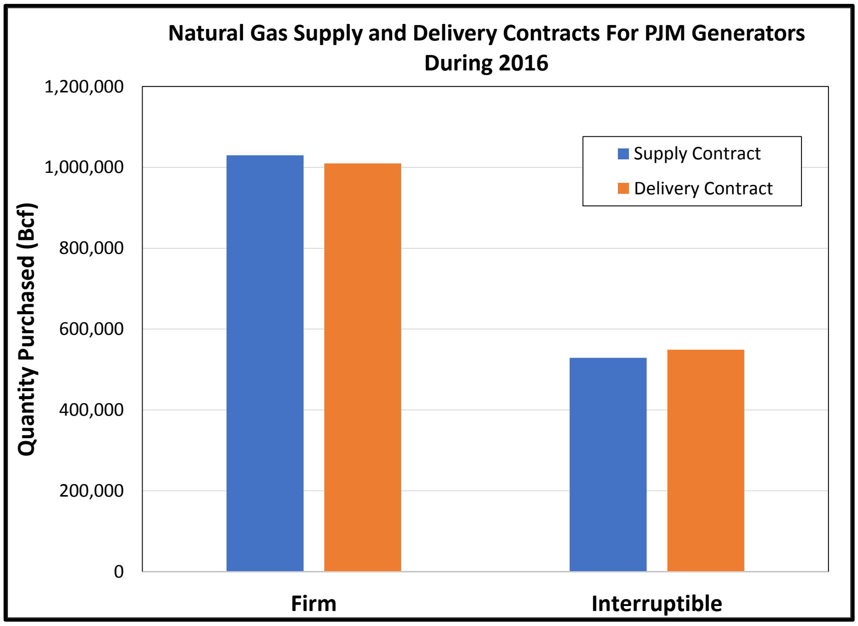
> "Overall, the EIPC analysis demonstrated that, even under a high-gas-demand scenario, **a robust pipeline infrastructure is available through 2023 to serve generation through the overwhelming majority of the PJM footprint.** Limited potential locational constraints were identified during the peak heating season in eastern PJM, with most issues associated with generators dependent on the local gas distribution company. **Modeling of gas-side contingencies, such as a pipeline break, found that affected generators were spread across many pipelines, thus limiting the impact of a single contingency**" (emphasis added).

Although, the EIPC analysis found a robust natural gas pipeline infrastructure from a physical viewpoint, the study highlighted differences between the available infrastructure and the contractual availability of that infrastructure to meet power generation sector needs.[8] Since the study, a high percentage of gas supply contracts are now sold on a firm (non-interruptible) basis and delivery is under firm transport contracts (Figure 2).

[7] EIPC, *Gas -Electric Interface Study*, 2013, http://www.eipconline.com/gas-electric-documents.html

[8] Energyzt made a similar finding on the results of the Winter 2013/14 polar vortex event in New England. Although there was more than adequate infrastructure to address the series of events that strained the system, that infrastructure was not fully utilized from a contractual perspective. See *Report: Winter Reliability Analysis of New England Energy Markets*, prepared by Energyzt for the New England Power Generators Association, October 2014. https://nepga.org/2014/10/energyzt-report-on-winter-reliability/

Figure 2: Firm and Interruptible Natural Gas Contracts in PJM



Source: Energyzt analysis of EIA Form 860/923 data (2016)

Those electric generation plants with firm supply and delivery are more secure from a physical and commercial perspective to continue receiving gas shipments on a priority basis without interruption during severe weather conditions.

Dual-fuel capability further contributes to "firm" fuel supply. Gas-fired generation with dual-fuel oil backup provides another layer of reliability and resiliency allowing for uninterrupted operation even in the rare instances when firm natural gas supply is interrupted or when non-firm natural gas delivery is interrupted. In addition to modifying market rules to allow for better and more efficient utilization of existing gas pipeline infrastructure, greater fuel flexibility through dual-fuel capability at the generator site offers another solution.

Following the Polar Vortex, the Department of Energy commissioned a detailed analysis of the resiliency of oil and natural gas infrastructure in 2014.[9] Analyses of resiliency were

[9] Intak Inc. and AOC Petroleum Support Services. *United States Fuel Resiliency: Volume III, U.S. Fuels Supply Infrastructure --Vulnerabilities and Resiliency*, September 2014, pp. 19 – 22. https://www.energy.gov/sites/prod/files/2015/04/f22/QER%20Analysis%20-%20United%20States%20Fuel%20Resiliency%20Volume%20III.pdf

performed on a regional basis including Petroleum Administration for Defense District (PADD) Sub-PADD IB and Sub-PADD II N&E regions that approximately overlay the PJM Interconnect.

The report's conclusions on the natural gas infrastructure in those areas are as follows:

> The natural gas transmission system is highly resilient. **Multiple trunk lines within systems, interconnections between the lines, and interconnections between systems at numerous market hubs provide important redundancy.** In the event of damage to a trunk line or transfer point, gas can be rerouted through the system to assure supply to city gates and local distribution systems.
>
> In the event of a gas supply interruption due to a hurricane, **gas can be sourced from other systems or withdrawn from underground storage to meet demand until production is restored**.
>
> Local distribution systems may suffer damage due to flooding, but supply can usually be restored **within a few days**. (Emphasis added.)

Summaries of these analyses for Sub-PADD IB and II N&E are included in Appendix B.

A recent report and presentation by natural gas expert Rick Smead for the Natural Gas Council ("Natural Gas Council Report") provides further strong evidence of how gas-fired generation held up during the Bomb Cyclone of January 2018.[10] The conclusions from this report are summarized as follows:

> The regions [PJM, NYISO, ISO-NE] heavy in gas-fired generation performed well during the Bomb Cyclone. **Firm gas customers received their fuel as needed, without interruption**.

[10] Rick Smead, *Weather Resilience in the Natural Gas Industry: The 2017-18 Test and Results*, Presentation to Natural Gas Council, August 6, 2018, http://naturalgascouncil.org/weather-resilience-in-the-natural-gas-industry/

> On a broader scale, when spot price dependent generation became very expensive markets such as New England **caused generators to move to alternate fuels, primarily oil.**
>
> **In PJM, a market where generators make extensive use of firm transportation**, the escalation in Henry Hub prices caused coal to be temporarily more economic, so the generation mix was adjusted to run existing coal plants. **Gas plants could have run at a higher level, but were held in reserve.**

Overall, **no threats to reliability were reported**. (emphasis added).

The Natural Gas Council Report illustrates the resiliency and redundancy of the natural gas system and dual-fuel capability during extreme weather conditions.

Case Study # 1 - Flexibility of the Natural Gas System[11]

On January 1, 2018, as the Bomb Cyclone brought a blizzard to the Northeast and snow to Florida, a gas pipeline which sprawls across PJM and NYISO experienced isolated and temporary, weather-related loss of supply at two receipt points, primarily as the result of freeze-offs in the Marcellus shale.

Despite an approximately 3-day loss of certain supplies, the resiliency of the natural gas pipeline network was demonstrated as gas consumers and providers coordinated efforts to increase their withdrawals from gas storage wells across 30 unique gas storage facilitates, dispatch operations personnel to make production field adjustments, and re-route other gas supplies in order to meet a record level of demand and preventing any curtailments.

During this event, gas storage fields performed reliably with no significant operational issues other than about a dozen frozen well-head valves. Field operations personnel simply turned on alternate wells to offset the wells that were frozen. Once the loss of supply issue abated, within 2-5 days, the well-tenders returned to the wells that were frozen off and cleared the freezes with no lasting damage.

Response time: Immediate **Recovery Time:** 5 days **Impact:** Minimal

[11] Conversations with Rick Smead, RBN Energy Inc., August 7, 2018.

3.2 PJM Analysis of System Capacity Performance

Following the cold snap that occurred from December 28, 2017 to January 7, 2018, PJM performed an analysis of how PJM's Capacity Performance System (CP) performed.[12]

> Capacity Performance is similar to an insurance policy; for a cost, consumers have greater protection from power interruptions – especially when extreme weather challenges the grid. The better individual resources perform during peak system conditions, the more reliable the system is to serve demand. Resources that exceed performance requirements are entitled to funds collected from resources that underperform. Resources assume virtually all financial risks if they do not meet their power supply obligations.

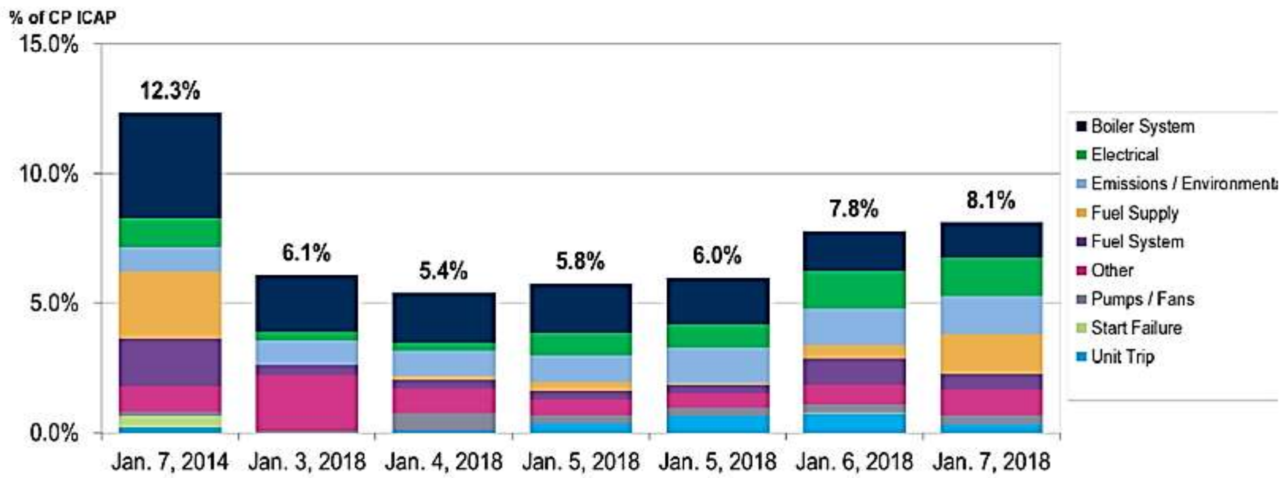
As PJM noted, fuel supply and fuel system availability has been improved:

> On the peak load and outage day of the 2014 Polar Vortex, fuel supply issues were significant, accounting for nearly 40 percent of overall outage megawatts. By contrast, during the recent cold snap [January 2018], fuel supply issues for **Capacity Performance resources (including oil supply, replenishment and gas supply-related issues) were minimal, averaging around 3 percent of outage megawatts,** until the last day of the cold snap, when they reached nearly 19 percent of outage megawatts. (emphasis added)

PJM's study shows that outages were dramatically reduced during the January 2018 Bomb Cyclone episode compared to four years earlier during the January 2014 Polar Vortex, with fuel supply playing a minimal role in the 2018 Bomb Cyclone.

[12] PJM, *Strengthening Reliability: An Analysis of Capacity Performance*, June 20, 2018, pp 15 – 20. https://pjm.com/-/media/library/reports-notices/capacity-performance/20180620-capacity-performance-analysis.ashx?la=en

Figure 3: Causes of Outages in PJM During 2018 Bomb Cyclone vs. 2014 Polar Vortex



Source: PJM, *Strengthening Reliability: An Analysis of Capacity Performance*, 2018.

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In combination, these two responses demonstrate that CP is achieving its intended purpose – better generator response during times of severe weather events. Any further fuel-security action contemplated by PJM should take into account the improvements achieved thus far as a result of CP and consider whether additional experience is needed under CP before further actions are taken.

[13] PJM, *Strengthening Reliability: An Analysis of Capacity Performance*, 2018. p. 20. https://pjm.com/-/media/library/reports-notices/capacity-performance/20180620-capacity-performance-analysis.ashx?la=en

4. Role of Oil in Providing PJM Resiliency

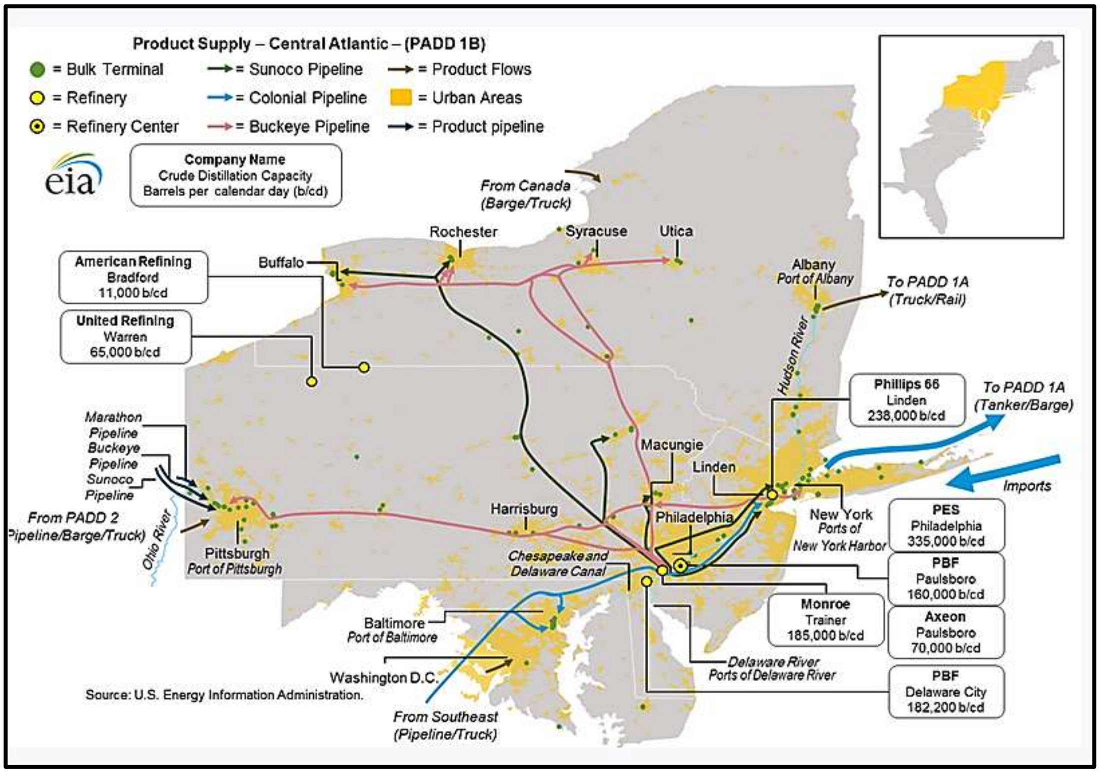
Key Points:

- **Networked:** Oil provides a diverse fuel supply network that includes rail, barge, truck and pipeline delivery systems.
- **Supply Chain Redundancy:** Refining capacity, storage, distribution and integration of pipeline and delivery systems provides for network redundancy and resiliency.
- **No Correlation to Natural Gas Delivery:** The extended network of oil and petroleum supply is unrelated to the network of natural gas delivery, making a scenario of widespread damage to oil delivery infrastructure at the same time as natural gas networks unnecessary.
- **Multiple Delivery Modes:** Generators with oil fuel use multiple modes of oil transportation and redundant carriers, increasing diversity and decreasing vulnerability to disruption.
- **Diversification:** Resupply can occur by different modes of transportation and while the plant is in operation.
- **Geographic Proximity to PJM:** PJM is geographically located in PADD I and PADD II, close to refineries and oil storage depots, limiting transportation and fuel supply disruptions.

PJM has 1.2 million Bbls/d of refining capacity nearby along the East Coast in PADD I and an additional 4.0 million Bbls/d in PADD II (Midwest).[14] The region also has a number of operating refineries and product pipelines throughout, servicing many of the states in the PJM area and beyond (see Figure 4). These refineries receive their crude oil supply from multiple sources including the United States (e.g., Gulf Coast), Middle East, Caribbean, and Europe.

[14] EIA, Refinery Report by PADD. https://www.eia.gov/petroleum/refinerycapacity/table1.pdf, January 1, 2018

Figure 4: Refining Capacity and Oil Pipeline Network in PJM

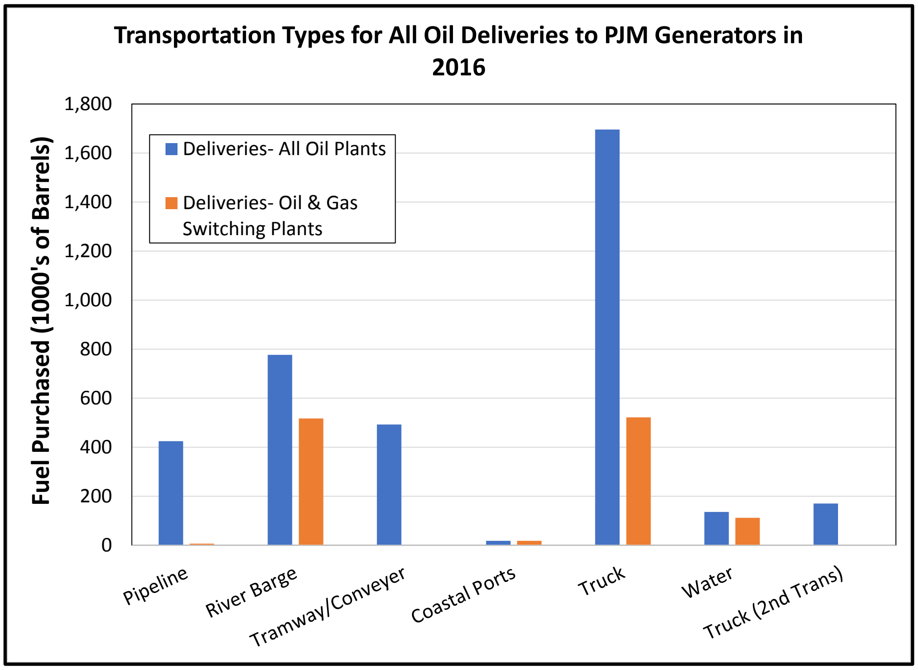


Source: https://www.hellenicshippingnews.com/pipelines-tankers-and-barges-convey-transportation-fuels-from-gulf-coast-to-east-coast/

Delivery shipments are made by large liquid oceangoing tankers, rail, truck, pipelines, and barges. Crude oil is stored in large tanks located adjacent to the refineries, and refined petroleum products are stored in other refinery tanks, at storage depots, distribution centers, and throughout the supply system down to local gas stations. Shipments of petroleum products -- such as gasoline, naphtha, jet fuel, kerosene and middle distillates -- are made to oil-fired power plants in the PJM system and are used for supplying and refueling dual-fueled power generation plants. The system is very elaborate, distributed and diversified.

Figure 5 summarizes the transportation methods used for shipments of petroleum to generating plants in PJM for the year 2016. These transportation methods include pipelines, river barges, trucks, water and other modes of delivery.

Figure 5: Transportation Methods for Oil Deliveries to PJM Plants



Source: Energyzt analysis of EIA Form 860/923 data (2016)

The petroleum resiliency study conducted for the DOE in 2014 provides additional details about resiliency of the petroleum production and distribution system in PJM, reaching the following conclusions: [15]

> **Sufficient Storage:** To date, PADD IB East Coast refineries have never suffered a shortage of crude oil supply sufficient to curtail operations. Stocks in storage have always been sufficient to meet requirements, even during major hurricanes Irene and Sandy.
>
> **East Coast Hurricane:** Refined products could be shipped from PADD III by marine vessels, but would require 10 - 14 days and Jones Act waivers.

Given the extensive network and diverse set of delivery modes that are completely unrelated to the natural gas pipeline and shipping delivery network, oil and gas offer

[15] Intak. Ob. Cit.,. pp. 27-30. https://www.energy.gov/sites/prod/files/2015/04/f22/QER%20Analysis%20-%20United%20States%20Fuel%20Resiliency%20Volume%20III.pdf

diversified fuel supply options. It is not credible to assume a scenario where the wide-spread oil infrastructure system will be fatally damaged at the same time that the natural gas system also is shut down.

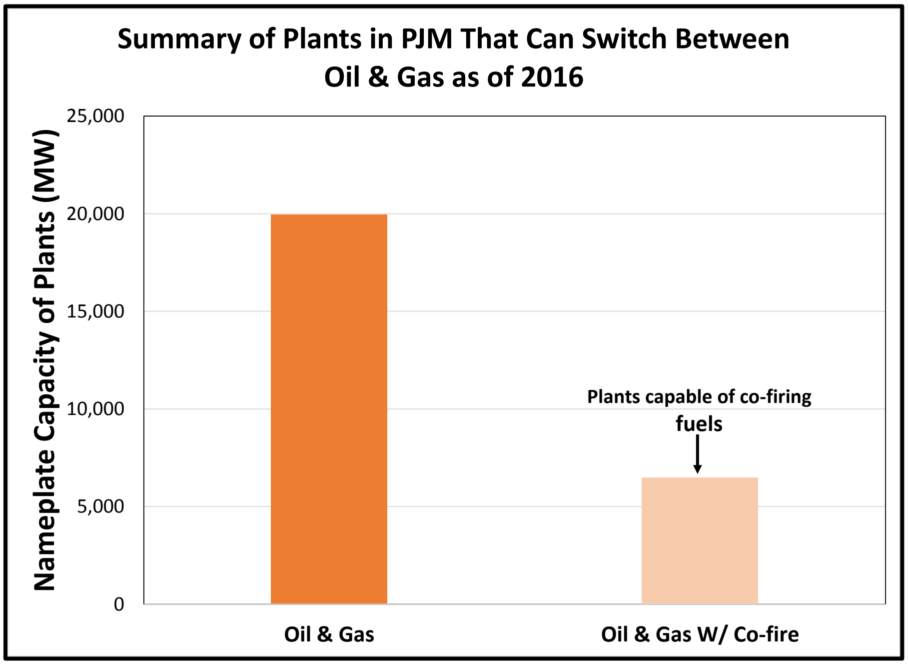
5. Role of Dual-fuel Capability

Key Points:

- **On-site Diversification:** Certain natural gas-fired power plants include the capability to burn either natural gas or fuel oil.
- **Flexibility:** Dual-fuel power plants have rapid recovery time and ramp-up following disruption.
- **Black-start Capability:** Some dual-fuel plants have black-start capability.
- **Diversified Resupply:** Storage refueling options include on-site tanks and multiple transportation methods (pipeline, rail, truck, barge).
- **Continuous Operations:** Fuel storage tanks can be refueled while plant is operating.

Dual-fuel capacity allows for energy to be produced from both a primary fuel (e.g., natural gas) and a secondary fuel (e.g., distillate and low-sulfur diesel fuel). The secondary fuel is available when there is a disruption in the plants' gas supply system, thus ensuring continuous operations even if the primary fuel source is disrupted, enhancing winter reliability and resiliency. The ability to switch also is available when market economics make the secondary fuel less expensive, mitigating price spikes and shortages. In PJM, about one-third of the nameplate capacity of gas-fired generation plants includes the ability to switch from natural gas to oil or to be co-fired simultaneously by burning both oil and gas. More than 25 GW are dual-fuel units, with 5 GW allowing for co-firing (Figure 6).

Figure 6: PJM Plants Capable of Switching Between Oil & Gas



Source: Energyzt analysis of EIA Form 860/923 data (2016)

Further analysis of gas plants in the PJM region indicates that two-thirds of the units with capability to switch from natural gas to oil can make the change within one hour, and 94 percent of the units can switch within six hours.[16]

The EIPC's Gas-Electric System Interface Study, previously referenced above, specifically noted PJM's dual-fuel capability and its impact on resiliency.[17]

> Moreover, dual-fuel capability was found to be available, deliverable and economically advantageous in PJM, providing additional resilience to mitigate the risk of gas pipeline contingencies on the electric grid.

This section describes the role of dual-fuel capability in maintaining grid resiliency in PJM.

5.1 Analysis of Dual-Fuel Generation During Storm Weather Periods

Energyzt conducted a detailed analysis of the role of dual-fuel generation in the PJM system during two major extreme weather periods:

[16] Energyzt analysis of EIA 923/860 data. See Table B-2.

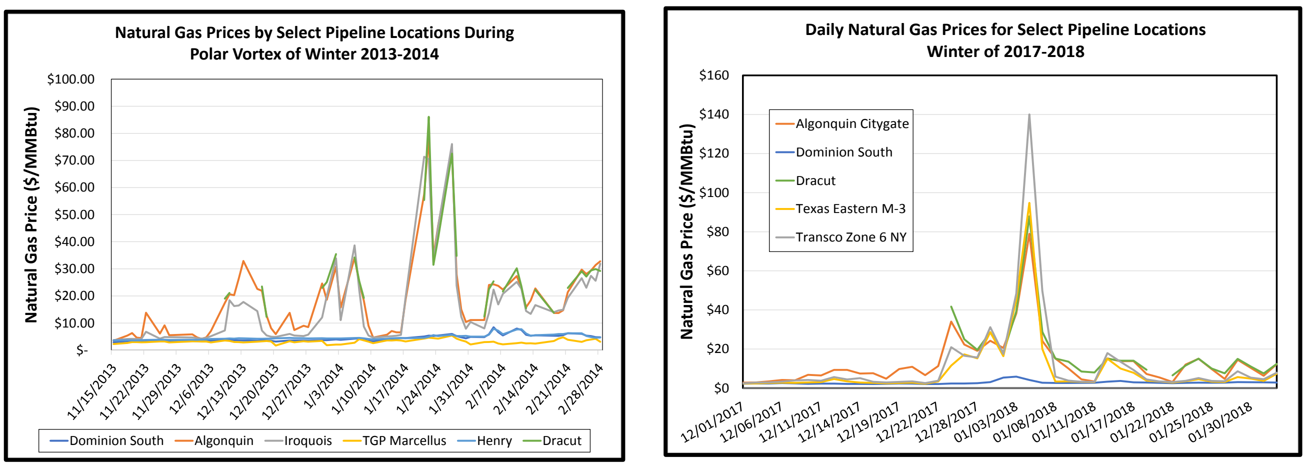
[17] EIPC, Gas -Electric Interface Study, 2013, http://www.eipconline.com/gas-electric-documents.html

1) Polar Vortex 2013-2014

2) Bomb Cyclone 2017–2018

Figure 7 shows that high daily prices and volatility began around December 27 and peaked during the coldest days January 4 – 8, 2018. While natural gas prices spiked significantly during the weather event, there were no supply disruptions. Although gas users who relied on interruptible supply and/or pipeline capacity were exposed to volatile spot market prices, generators with firm supply and firm gas pipeline contracts experienced little to no price volatility. Wholesale gas customers with firm contracts received their supply in accordance with the contractual requirements.

Figure 7: Daily Natural Gas Prices for Selected Hubs - Winters 2013/14 and 2017/18

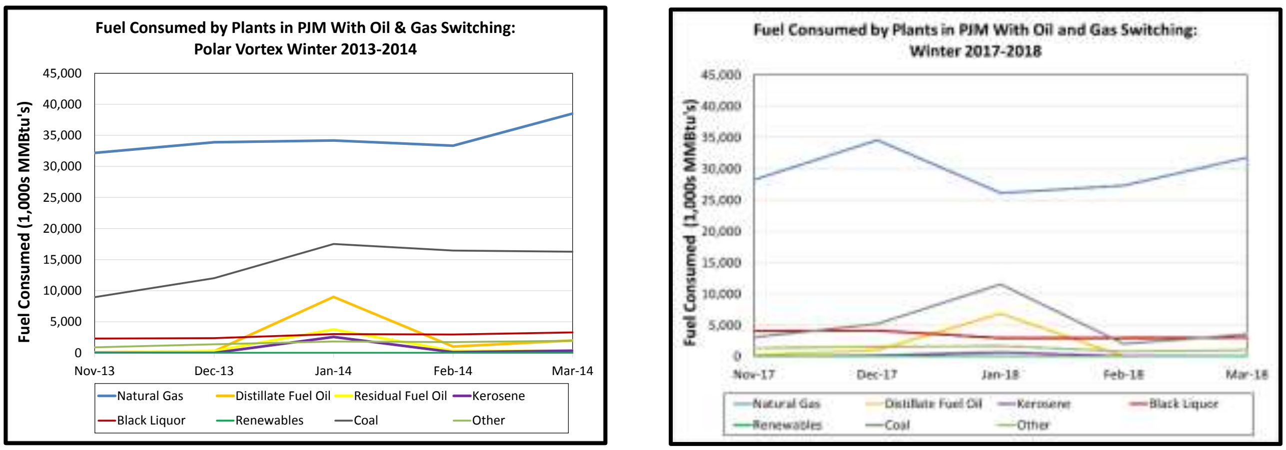


Sources: Ventyx, National Gas Intelligence Agency

Dominion South is a good proxy hub from Marcellus and shows almost no variation during the winter storms (blue line). The large spikes were driven by downstream issues and a rationalization of natural gas among customers with interruptible contracts dependent on spot market purchasers. Prices quickly returned to normal levels after the winter weather returned to normal temperatures. The natural gas supply and pipeline delivery systems proved resilient.

Figure 8 shows the fuels consumed by generation plants in the PJM System with fuel switching capability during these two weather events. Higher natural gas prices during the winter storm resulted in natural gas consumption declines (blue line), causing units to switch to alternative fuels -- principally distillate fuel oil (orange line). Some coal units also became competitive and were dispatched, with coal fuel consumption therefore increasing for a brief period (black line) before returning to recent historical averages. A similar pattern is displayed for the Polar Vortex 2013/14 and illustrates less of a dip in natural gas consumption.

Figure 8: PJM Dual-fuel Consumption - Winters 2013/14 and 2017/18

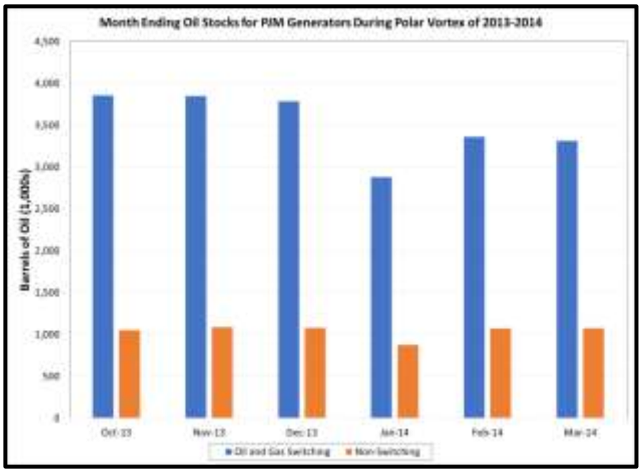


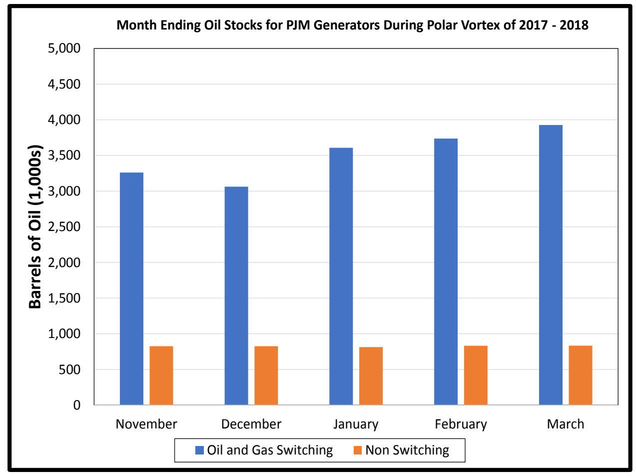
Source: Energyzt analysis of EIA Form 860/923 data (2016)

Figure 9 shows the oil stocks for all PJM power plants with and without dual-fuel capability at the end of each month. Although some depletion in oil inventories is seen during the disruption periods (e.g., January 2014), oil inventories generally remained high and recovered quickly after the inclement weather, indicating functioning of the oil storage and refueling system.[18]

[18] Inventories of coal stocked at generation plants demonstrate much different patterns. Following a stock draw-down as a consequence of a severe winter storm or summer hot period, they take a much longer period to recover to normal operating levels, sometimes many months. Also, coal piles are subject to weather-related problems. In Texas, for example, stocks at generation plants in February 2011 resulted in 7 GW of power plants being shut down because of burst pipes, frozen coal piles, and other cold-weather problems.

Figure 9: Inventory of Oil Stocks at PJM Plants - Winters 2013/14 and 2017/18





Source: Energyzt analysis of EIA Form 860/923 data (2016)

5.2 Winter Reliability Programs in ISO-NE and PJM

In response to severe weather conditions occurring over the last five years in the Northeast, multiple transmission operators implemented an incentive system to promote winter-reliability.

- **PJM:** PJM's Capacity Performance (CP) model has incentive-based features that promote robust, fuel supply. Recent surveys conducted of developers find strong preference for fossil fuel generation technologies utilizing natural gas as the primary fuel supply along with dual-fuel capability to burn an alternative fuel (primarily oil).[19] This investment is being driven by concerns with fuel security and building greater resiliency into the system to respond quickly and recover quickly to potential disruptions. The incremental investment is justified by the option value of dual-fuel capability as well as performance payments associated with increased

See Lovins, Amory B., "Does 'Fuel on Hand' Make Coal and Nuclear Power Plants More Valuable?," Forbes, May 5, 2017. https://www.forbes.com/sites/amorylovins/2017/05/01/does-fuel-on-hand-make-coal-and-nuclear-power-plants-more-valuable/

[19] Energyzt Advisors telephone survey of developers and financers for PJM CONE Studies, July 2018.

availability during extreme weather events. The CP construct also is leading to a preference for dual-fuel capability to mitigate potential CP penalty exposure.

- **ISO-NE:** ISO New England implemented a Winter Reliability Program and then converted this program into a Pay for Performance (PFP) program approved by FERC.[20] Since FERC approved the PFP model, ISO-NE has seen about 2,500 MW of dual-fuel capability added or proposed.[21]

The experiences in both PJM and ISO-NE show that market-based approaches can encourage investment that allows for fuel supply resiliency. One cost-effective solution is dual-fuel capability. As a result, companies such as Calpine are increasing their investments in dual-fuel capability (Case Study 2).

Case Study # 2 – Calpine Corporation's Dual-fuel Investments in PJM[22]

Calpine Corporation is investing in dual-fuel capability. Nearly 90 percent of Calpine Corporation's approximately 5,000 MWs in PJM is either dual-fuel capable or is oil-fired; the company is evaluating its oil capacity by the addition of pipe and storage tanks at three of its sites (Bethlehem, York and Garrison Energy Center). In direct response to higher penalties for being unable to meet CP regulations, Calpine has acquired almost 1 million barrels of on-site storage in PJM with refueling typically by barge and/or truck.

Response time: Pre-event **Recovery Time:** 1 – 6 hours **Impact:** Minimal

[20] ISO - New England, *FCM Performance Incentives Key Project*, https://www.iso-ne.com/committees/key-projects/fcm-performance-incentives

[21] Utility Dive, "ISO-NE Implements 'Pay-for-Performance' Capacity Market Incentives," June 13, 2018.

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[22] Calpine Corporation, *Fuel Security Discussion*, July 17, 2018.

6. Conclusions and Recommendations

The following recommendations are based on the research presented in this report concerning fuel security and resiliency:

Recommendation #1: Define the problem reasonably. Any discussion of fuel supply security in the context of resiliency of the PJM system should include a definition of the objective for resiliency and assess how that objective currently is being met. Only then can an assessment of potential shortcomings or conditions under which existing resources cannot meet the objective be performed.

Recommendation #2: Consider characteristics of each generating site's supply source and delivery system. PJM contains tens of thousands of miles of natural gas pipeline, over 600 Bcf of storage and over 24 Bcf/day of natural gas production. Many gas-fired generating units are strategically located on large interstate pipeline systems that offer multiple connections and are capable of receiving supply from a variety of sources both within and outside of PJM's footprint. Natural gas and oil can be delivered via multiple modes. The diversification and network benefits of a fuel supply source should be considered in any discussion of resiliency.

Recommendation #3: Reward fuel diversification at individual sites. The addition of dual-fuel capability at a generation site increases the diversity and resiliency of PJM generators by diversifying reliance on any single fuel source. Dual-fuel capability is a non-contractual means of firming fuel supply by allowing for optionality under conditions of duress. Combining the advantages of natural gas with the features and characteristics of petroleum as an alternative fuel in dual-fueled units further strengthens PJM system's reliability and resiliency.

Recommendation #4: Look beyond fuel-type to overarching fuel supply situations - all gas-fired generators are not supplied equally. PJM's natural gas generation cannot be viewed as a homogenous group. While some gas-fired generation units are in more isolated locations with limited supply options and incapable of quickly responding to changing supply conditions or interruptions, others have multiple fuel supply sources including dual-fuel capability. Viewing all gas-fired generators as the same when developing incentive structures fails to reward investment in resiliency and hinders potentially advantageous deployment of private capital.

Recommendation #5: Expand PJM's Capacity Performance Program. The PJM CP should be expanded to reward fuel supply optionality (including redundancy and backup,) and provide flexibility in operations to help system recovery from trigger events. Evidence based on analyses of recent extreme weather events indicates that the CP program is working and should be extended and built upon to apply to more generation resources.

APPENDIX A
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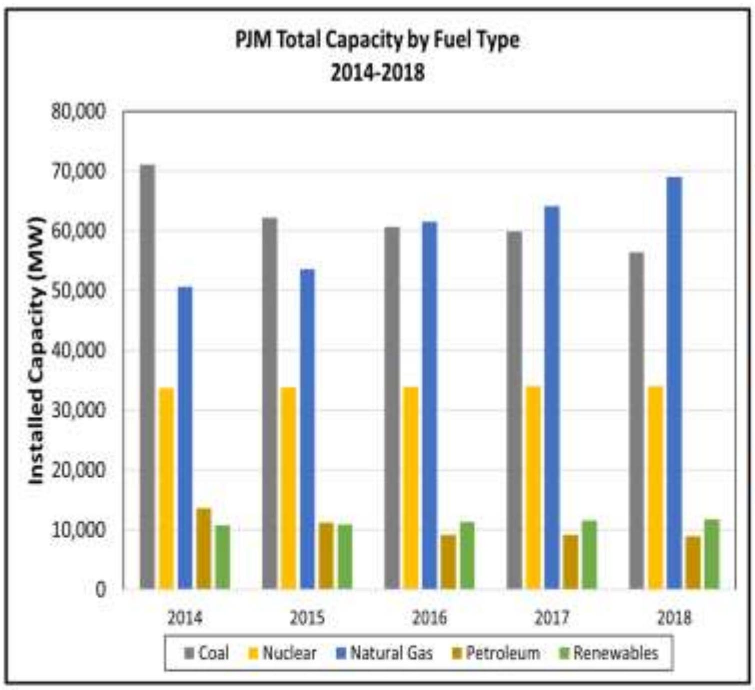
APPENDIX B
Supplemental Analyses of PJM

PJM is experiencing a transition in its generation fuel mix towards natural gas. Natural gas fired generating capacity in PJM (blue bars) has grown to 69 GW (38% of total capacity) while coal (gray bars) have declined to 56 GW (31% of total capacity) in 2018. Nuclear (yellow bars) has remained relatively flat (34 GW, 17%. of total capacity). Renewables (green bars) are also growing (2% per year) and currently represents about 12 GW or 7%% of total capacity.

Figure B-1: Generating Capacity by Fuel Type in PJM



Change in Installed Capacity

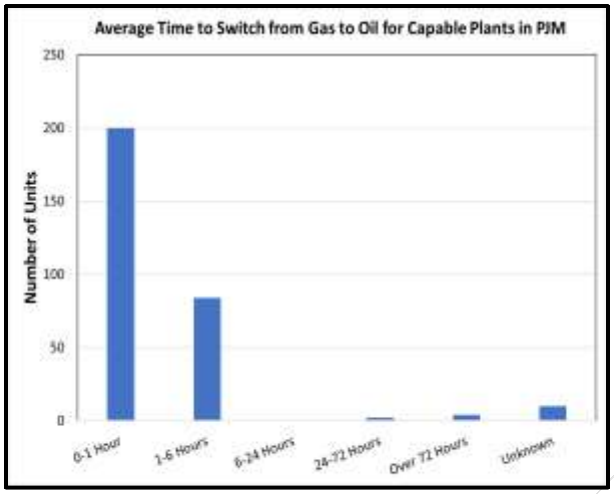
Fuel Type	2015	2016	2017	2018
Coal	-14%	-2%	-1%	-6%
Nuclear	1%	0%	0%	0%
Natural Gas	5%	13%	4%	7%
Petroleum	-22%	-22%	0%	-2%
Renewables	1%	4%	2%	2%

Source: PJM; https://www.pjm.com/markets-and-operations/ops-analysis.aspx, Summary prepared by Energyzt

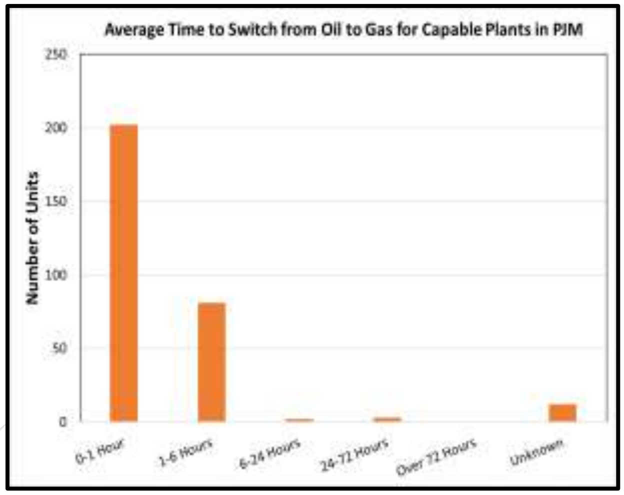
Around two-thirds of dual-fuel units have the capability of switching from natural gas to oil or vice versa (oil to gas) in less than one hour. About 94% of the units can switch within one to six hours.

Figure B-2: Rapid Gas to Oil Fuel Switching Time for Units in PJM

Gas to Oil



Oil to Gas



Source: Energyzt analysis of EIA Form 860/923 data (2016)

Movement		1 Hour	6 Hours	24 Hours	72 Hours	Over	Unknown	Total
Gas to Oil	MW	14,598	10,992	0	165	343	353	26,452
	# Units	200	84	0	2	4	10	300
Oil to Gas	MW	16,224	9,394	16	213	0	605	26,452
	# Units	202	81	2	3	0	12	300

Figure B-3 illustrates the multiple pipelines that service PJM generators. The system is widespread and diverse, creating a built-in redundancy for PJM.

Figure B-3: Interstate and Intrastate Pipelines and Local Distribution Companies

Owner/Operator of Pipelines
Used to Supply PJM Generators

All Plants		Duel Fuel Plants	
Pipeline Owner/Operator	# Plants	Pipeline Owner/Operator	# Plants
5P GAS PIPELINE CO	1	ANR PIPELINE COMPANY	3
ACADIAN GAS P L SYS	1	COLUMBIA GAS TRANSMISSION CORP	5
ALABAMA GAS CORP	1	CPN PIPELINE COMPANY	1
Ameren Illinois	1	DOMINION COVE POINT LNG LP	1
ANR PIPELINE COMPANY	10	DOMINION TRANSMISSION INCORPORATED	9
COLUMBIA GAS TRANSMISSION CORP	21	EASTERN SHORE NATURAL GAS CO	4
CPN PIPELINE COMPANY	1	NATURAL GAS PL CO OF AMERICA	1
DCP MIDSTREAM LP	1	NORTHERN INDIANA PUBLIC SERVICE CO	1
DOMINION COVE POINT LNG LP	2	PANHANDLE EASTERN PIPELINE COMPANY	3
DOMINION TRANSMISSION INCORPORATED	32	PUBLIC SERVICE ELECTRIC & GAS CO	6
EAST TENNESSEE NATURAL GAS LLC	3	TENNESSEE GAS PIPELINE COMPANY	1
EASTERN SHORE NATURAL GAS CO	7	TEXAS EASTERN TRANSMISSION LP	5
HORIZON PIPELINE	1	TRANSCONTINENTAL GAS PIPELINE	19
ILLINOIS GAS TRANSMISSION	1	VECTREN ENERGY DELIVERY OF OHIO	1
KINDER MORGAN BORDER PIPELINE LLC	1	WASHINGTON GAS LIGHT COMPANY	4
MIDWESTERN GAS TRANSMISSION COMPANY	1		
NATIONAL FUEL GAS SUPPLY CORPORATION	1		
NATURAL GAS PL CO OF AMERICA	4		
NATURAL GAS PL CO OF AMERICA LLC	1		
NORTH COAST GAS TRANSMISSION	1		
NORTHERN BORDER P L CO	2		
NORTHERN INDIANA PUBLIC SERVICE CO	2		
NORTHERN NATURAL GAS	1		
PANHANDLE EASTERN PIPELINE COMPANY	5		
PUBLIC SERVICE ELECTRIC & GAS CO	11		
ROCKIES EXPRESS PIPELINE LLC	1		
TENNESSEE GAS PIPELINE COMPANY	7		
TEXAS EASTERN TRANSMISSION LP	27		
TEXAS GAS TRANSMISSION LLC	1		
TRANSCONTINENTAL GAS PIPELINE	49		
VECTOR PIPELINE CO	1		
VECTREN ENERGY DELIVERY OF OHIO	3		
WASHINGTON GAS LIGHT COMPANY	8		

Location Distribution Companies
Connected to Natural Gas Generators in PJM

All Plants		Duel Fuel Plants	
LDC Connected to NG Plants	# Plants	LDC Connected to NG Plants	# Plants
4 COUNTY ENERGY LLC	1	ATMOS ENERGY CORPORATION	1
ATMOS ENERGY CORPORATION	1	BGE	3
BGE	10	CHAMBERSBURG BOROUGH OF	2
CHAMBERSBURG BOROUGH OF	2	COLUMBIA GAS DIST CO	2
COLUMBIA GAS DIST CO	3	COLUMBIA GAS OF OHIO	1
COLUMBIA GAS OF OHIO	7	COLUMBIA GAS OF VIRGINIA	5
COLUMBIA GAS OF PENNSYLVANIA	3	DELMARVA POWER AND LIGHT CO	2
COLUMBIA GAS OF VIRGINIA	8	DUKE ENERGY OHIO	2
DELMARVA POWER AND LIGHT CO	4	EAST OHIO GAS COMP DOMINION EAST OH	3
DUKE ENERGY OHIO	5	ELIZABETH GAS SYSTEM TOWN OF	1
EAST OHIO GAS COMP DOMINION EAST OH	8	ELIZABETHTOWN CITY OF	1
ELIZABETH GAS SYSTEM TOWN OF	1	EQUITABLE GAS DBA PEOPLE NATURAL GAS	1
ELIZABETHTOWN CITY OF	3	MICHIGAN GAS UTILITIES CO	1
EQUITABLE GAS DBA PEOPLE NATURAL GAS	1	MOUNTAINEER GAS CO	1
HAMILTON CITY OF	2	NATIONAL FUEL GAS DIST PA	1
HOPE GAS INC	4	NEW JERSEY NATURAL GAS	2
MICHIGAN GAS UTILITIES CO	1	NICOR GAS	3
MIDAMERICAN ENERGY COMPANY	2	NORTH SHORE GAS COMPANY	1
MOUNTAINEER GAS CO	1	NORTHERN INDIANA PUBLIC SERVICE CO	1
NARRAGANSETT ELECTRIC CO GAS DIV RI	1	OHIO GAS COMPANY	1
NATIONAL FUEL GAS DIST PA	1	PEOPLES GAS LIGHT AND COKE COMPANY	2
NEW JERSEY NATURAL GAS	7	PHILADELPHIA GAS WORKS	2
NICOR GAS	33	PIEDMONT NATURAL GAS	2
NORTH SHORE GAS COMPANY	3	PUBLIC SERVICE ELECTRIC GAS CO	5
NORTHERN INDIANA PUBLIC SERVICE CO	1	SOUTH JERSEY GAS COMPANY	5
OHIO GAS COMPANY	3	UGI CENTRAL PENN GAS INC	1
PECO ENERGY COMPANY	6	UGI PENN NATURAL GAS	1
PEOPLES GAS LIGHT AND COKE COMPANY	8	UGI UTILITIES	2
PEOPLES GAS SYS	1	VIRGINIA NAT GAS INC	1
PHILADELPHIA GAS WORKS	4	WASHINGTON GAS LIGHT COMPANY	3
PIEDMONT NATURAL GAS	2		
PUBLIC SERVICE ELECTRIC GAS CO	10		
SOUTH JERSEY GAS COMPANY	12		
UGI CENTRAL PENN GAS INC	3		
UGI PENN NATURAL GAS	7		
UGI UTILITIES	4		
VALLEY ENERGY	1		
VIRGINIA NAT GAS INC	2		
WASHINGTON GAS LIGHT COMPANY	5		

Source: Energyzt analysis of EIA Form 860/923 data (2016)

Sub-PADD IB is comprised of the states of Delaware, Maryland, New York, New Jersey, and Pennsylvania. It also includes the nation's capital, Washington, D.C., as well as other major economic and population centers, including Baltimore, Philadelphia, Pittsburgh, New York, and Wilmington. Figure B-4 describes major petroleum infrastructure dependencies within PJM at the Mid-Atlantic states.

Figure B-4: Major Infrastructure Dependency and Resiliency in Mid-Atlantic States (Sub PADD IB)[23]

PADD IB	Major Infrastructure Dependence	Fuel Resiliency
Crude Oil	• The Philadelphia and New York Harbor areas contain critically important crude oil terminals and refineries. • Crude oil is sourced from PADD II, Canada, and other countries. • Most crude oil is received by waterborne transport (tankers and barges) at marine terminals associated with the major refineries. •The Buckeye Global terminal in Albany, NY receives Bakken crude oil by rail from PADD II West and ships it by barge to New York Harbor area refineries. • Philadelphia refineries receive Bakken crude by rail	• To date, PADD IB East Coast refineries have never suffered a shortage of crude oil supply sufficient to curtail operations. Stocks in storage have always been sufficient to meet requirements, even during major hurricanes Irene and Sandy. • In the event of an import disruption, the SPR can supply crude from PADD III. However, the lead time for marine transport is approximately 2 - 3 weeks and requires U.S. flag tankers. • There is a current shortage of such Jones Act vessels, so Jones Act waivers could be required.
Refined Fuels	• The New York Harbor area contains critically important refined product storage and distribution infrastructure for both PADDS IA and IB. It receives products from other PADDs via the Colonial and Sun pipelines. Major ports receive imports	• **East Coast Hurricane**: Refined products could be shipped from PADD III by marine vessels, but would require 10 - 14 days and Jones Act waivers. • **Gulf Coast Hurricane:** Local stocks

[23] Source: Intak Inc. and AOC Petroleum Support Services. *United States Fuel Resiliency: Volume III, U.S. Fuels Supply Infrastructure --Vulnerabilities and Resiliency*, September 2014, pp. 19 – 22, 27- 30. https://www.energy.gov/sites/prod/files/2015/04/f22/QER%20Analysis%20-%20United%20States%20Fuel%20Resiliency%20Volume%20III.pdf

PADD IB	Major Infrastructure Dependence	Fuel Resiliency
	and distribute products to PADDs IA and IB, using a complex infrastructure of pipelines, storage tanks, and marine terminals. • Major product infrastructure includes the Colonial, Harbor, and Buckeye pipeline systems, interconnections, bulk storage, and terminals at Linden, NJ. • Major interconnect points and manifolds are particularly vulnerable. • Products received and stored in the New York Harbor area serve a densely populated region as well as several international airports. The area provides products to western Pennsylvania and upstate New York via the Buckeye system and to New England via barges	may be depleted in 3 - 5 days. Refinery or pipeline recovery to provide products to PADD IB via Colonial and Plantation pipelines could require up to 2 weeks. • Current stocks in NERRPPR (1 MM Bbl total) can meet less than 1 day of combined PADD IA and IB (Northeast) consumption. • New York State Strategic Fuel Reserve (SFR) includes: a 3 million gallon reserve on Long Island to supply the NYC area and a proposed 1 million gallon gasoline and 1 million gallon ULSD reserve distributed over 8 locations across the state.
Natural Gas	• Several major natural gas transmission systems traverse PADD IB with interconnections and market hubs around major metropolitan areas including Washington, Baltimore, Philadelphia, New York, and Pittsburgh. Systems include Columbia Gas Transmission, Old Dominion, Tennessee, and Texas Eastern. • Gas is supplied by local Marcellus producers, PADDs II and III. Local Marcellus wells are subject to freezing in severe winter weather conditions.	• The natural gas transmission system is highly resilient. Multiple trunk lines within systems, interconnections between the lines, and interconnections between systems at numerous market hubs provide important redundancy. In the event of damage to a trunk line or transfer point, gas can be rerouted through the system to assure supply to city gates and local distribution systems. • In the event of a gas supply interruption due to a hurricane, gas

PADD IB	Major Infrastructure Dependence	Fuel Resiliency
	• Gas processing plants, compression stations and custody transfer points (interconnects and market hubs) are vulnerable to damage by hurricanes, flooding, and intentional acts. • NYC receives all of its gas through two city gates, one from Transco serves lower Manhattan and the other from Iroquois which serves uptown.	can be sourced from other systems or withdrawn from underground storage to meet demand until production is restored. • Aging infrastructure within local distribution systems can cause gas supply loss and safety and reliability issues. • Local distribution systems may suffer damage due to flooding, but supply can usually be restored within a few days.

Sub-PADD II East includes the eastern oil and gas producing states of Michigan, Ohio, and Kentucky. Sub-PADD II North includes the central Midwest states of Illinois, Indiana, Iowa, Minnesota, Missouri, Nebraska, Tennessee, and Wisconsin, among which Illinois and Indiana are oil and gas producers. Figure B-5 summarizes the infrastructure dependency of the Midwest states.

Figure B-5: Major Infrastructure Dependency and Resiliency in Mid-West States (Sub PADD II E & N)[24]

PADD II E & N	Major Infrastructure Dependence	Fuel Resiliency
Crude Oil	• Crude oil pipelines ship synthetic crude from Canada to PADD II refineries. • Rail infrastructure moves crude from Bakken (PADD II W) and other domestic producers to PADD II	• Pipeline reversals are limiting flows of crude oil from the Gulf of Mexico region to PADD II refiners, reducing supply resiliency. • Capline can only provide ~500 MBbl/d from SPR or Gulf of Mexico

[24] PJM, *Strengthening Reliability: An Analysis of Capacity Performance*, 2018. p. 20. https://pjm.com/-/media/library/reports-notices/capacity-performance/20180620-capacity-performance-analysis.ashx?la=en

PADD II E & N	Major Infrastructure Dependence	Fuel Resiliency
	refineries. • Critical pipelines include Mid-Valley and Keystone pipelines, the Capline system, and pipelines from West Texas. • Mississippi River ports and marine terminals also supply oil to refineries	producers in the event of a disruption of crude supply from other sources.
Refined Fuels	• PADD III refineries and terminals supply some refined products. (This is a minor dependence; most refined products are supplied from within PADD II.) • Magellan, Centennial, and Explorer pipelines provide products from PADD III	• Local refineries with excess capacity could increase utilization to offset loss of products, but would need sufficient crude stocks. • Tennessee and Kentucky markets could be impacted by shutdowns of Colonial or Plantation pipelines if local demand exceeds stocks in storage and the production capacity of the refinery in Memphis, TN. • Stocks in storage average 5 to 7 days of demand, depending on the fuel
Natural Gas	• Gas transmission lines from Sub-PADD II KS/OK, PADD III, and PADD IV and Canada provide two thirds of the required gas supply. • Canadian pipelines provide gas via Minnesota and Michigan	• PADD II is a producer and net exporter of natural gas. • Gas supply loss due to interruption of production or processing plants can be offset from storage, imports or PADDS II West and KS/OK, other PADDs, or Canada
Heating Oil	• TEPPCO, Explorer, and Centennial product pipelines supply heating oil	• Distillate fuels, including ultra-low sulfur diesel for heating, are supplied

PADD II E & N	Major Infrastructure Dependence	Fuel Resiliency
	and distillates from PADDs III, IV, I, and Canada • Marine terminals and ports for imported volumes	by the refined products transportation and distribution system

Source: Intak Inc. and AOC Petroleum Support Services. *United States Fuel Resiliency: Volume III, U.S. Fuels Supply Infrastructure --Vulnerabilities and Resiliency*, September 2014, pp. 19 – 22, 27- 30. https://www.energy.gov/sites/prod/files/2015/04/f22/QER%20Analysis%20-%20United%20States%20Fuel%20Resiliency%20Volume%20III.pdf