NATIONAL ENERGY TECHNOLOGY LABORATORY

A REVIEW OF PJM INTERCONNECTION'S APRIL 13, 2018, RESPONSE TO NATIONAL ENERGY TECHNOLOGY LABORATORY'S REPORT ON *RELIABILITY, RESILIENCE AND THE ONCOMING WAVE OF RETIRING BASELOAD UNITS*

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Disclaimer

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ACRONYMS AND ABBREVIATIONS

BC	Bomb Cyclone
CEMS	Continuous emission monitoring system
DOE	Department of Energy
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
GW	Gigawatt
ISO	Independent system operator
ISO-NE	ISO New England
MESA	Mission Execution and Strategic Analysis
MISO	Midcontinent ISO
MMBtu	Million British thermal units
MW	Megawatt
NETL	National Energy Technology Laboratory
NGCC	Natural gas combined cycle
NYISO	New York ISO
PJM	PJM Interconnection LLC
RTO	Regional transmission organization
TVA	Tennessee Valley Authority
U.S.	United States

EXECUTIVE SUMMARY

In a March 2018 report entitled *Reliability, Resilience and the Oncoming Wave of Retiring Baseload Units,* the National Energy Technology Laboratory (NETL) analyzed the fleet performance of market areas impacted by a 13-day storm known colloquially as the "Bomb Cyclone." Special attention was paid to northeastern areas, as these were most impacted. With respect to PJM Interconnection LLC (PJM), the report found that 1) without coal units, the system would have experienced shortfalls; 2) approximately 25 gigawatts (GW) of heretofore underutilized coal-fired plants provided crucial capacity, lending the system resilience; 3) nearly 28 GW of natural gas-fired capacity did not deploy, due to severe spikes in natural gas prices caused in turn by constrained gas deliverability, in the face of tremendous space heating demand and transmission deliverability constraints on the bulk electric system.

In April 2018, PJM issued a response that argued the NETL analysis was misplaced, asserting that gas-fired capacity was available and that it could have been called into service but was not, due to "economics." This brief represents NETL's reaction to PJM's assertions in its April 2018 response.

On November 1, 2018, PJM released its phase I analysis results on fuel security. [1] [2] The PJM summary defines "normal" winter load as approximately 135 GW, and "extreme" load as 148 GW. NETL notes, however, that peak demand in 2014 (143 GW), 2015 (143 GW), and 2018 (138 GW), was neither "normal" nor "extreme," but led to large natural gas price excursions and, therefore, elevated electricity billings. Additional detail with a fuller exposition of study methods and scope is anticipated from PJM in December 2018. Such data will be required prior to NETL's examination of the scenarios presented by PJM; as a result, this brief focuses on the April 2018 PJM document.

1 INTRODUCTION

PJM Interconnection LLC (PJM) is a vitally important regional transmission organization (RTO), among several eastern RTOs/independent system operators (ISOs), in facilitating the efficient, reliable, and secure supply of electricity throughout the Eastern Interconnection of the North American bulk electric system. PJM is also the largest RTO among several RTO/ISOs throughout the United States (U.S.)—in terms of electricity demand, capacity to serve demand, and population served—providing services to 20 percent of the U.S. population and more than 20 percent of the economy. Since 2010, the composition of its fleet has changed, as more than 25 gigawatts (GW) of coal-fired plants have been retired while only 19 GW of natural gas combined cycle (NGCC) has been added.

During the extreme weather event referred to as the "Bomb Cyclone," extending from December 27, 2017, through January 8, 2018, PJM played a crucial role by serving its 65 million customers as well as by intermittently providing electricity exports to each neighboring RTO and ISO including Midcontinent ISO (MISO), New York ISO (NYISO), Tennessee Valley Authority (TVA), and utilities in the Carolinas. PJM's territory was among the most severely impacted by this weather event, in terms of the extended duration of unusually low, daily temperatures. During a subsequent January 23, 2018, Senate Energy and Natural Resources Committee hearing, PJM's representative witness to this hearing, PJM President and CEO, Andrew Ott, testified:

> *The reality is, again for this past event, 45,000 megawatts of the electricity that [PJM] delivered, which is 40% or more, was coal-fired. We could not have served customers without the coal-fired resources. That's the reality. [3]*

Following the Bomb Cyclone weather event, NETL authored a review of the role of existing coal and nuclear electricity generation capacity among several RTOs/ISOs in providing the electricity needed during the event. [4] The NETL review also examined the accuracy of testimony provided by key witnesses at the January 23, 2018, Senate Energy and Natural Resources Committee hearing who had testified that the Bomb Cyclone weather event could have been managed without the contribution of *any* coal-fired generation. [3]

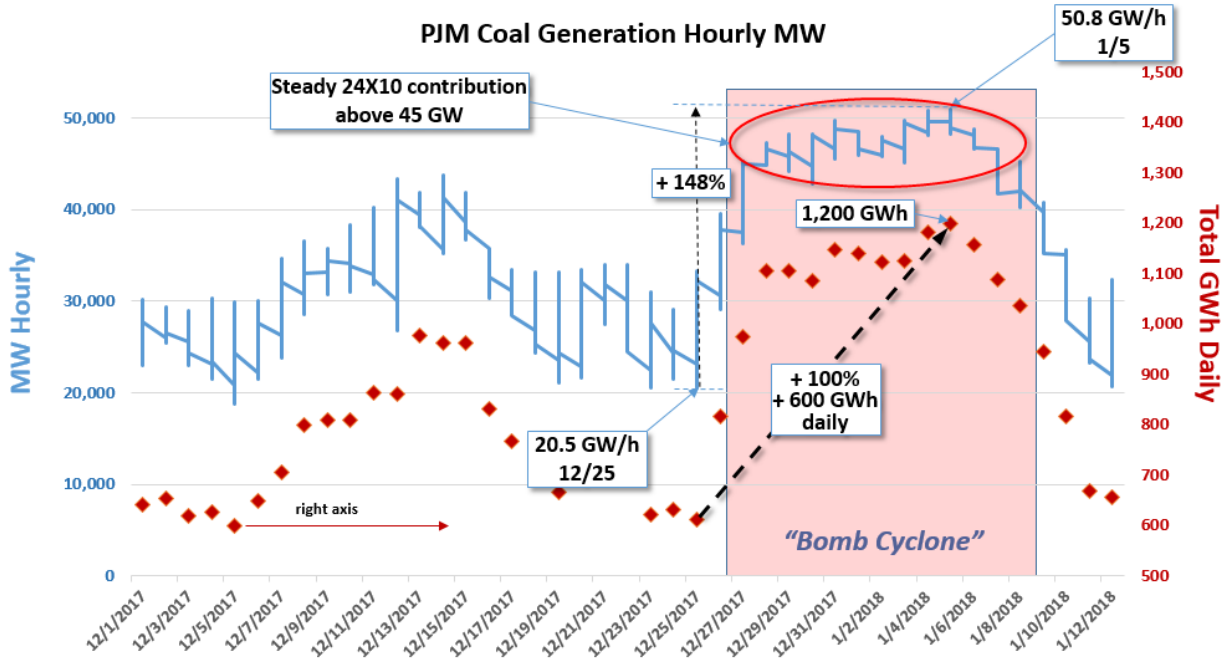
NETL published the results of their review in the report *Reliability, Resilience and the Oncoming Wave of Retiring Baseload Units* (the "NETL Resilience Report"), which provided a review of the power generation industry response to the Bomb Cyclone with a focus on the resilience of various forms of electricity generating assets in meeting the significantly increased demand caused by this extreme weather event. [5] Because of PJM's large and central role in the national electricity industry's response to the Bomb Cyclone event and due to PJM's commendable, publicly available, contemporary operating data, a principal focus of NETL's electricity resource resilience analysis was the performance of the generating capacity within PJM. Years of hourly PJM operating data, by generator fuel type, can be downloaded from PJM's website, which clearly illuminates resiliency issues. [6]

To summarize NETL's key findings regarding the resilience of PJM's generation sources during the Bomb Cyclone, about 25 GW of coal and 35 GW of nuclear generation that had been serving as baseload shortly before the event continued to operate reliably throughout the Bomb

Cyclone. These fuel-secure, baseloaded units displayed absorptive resilience in withstanding the effects of the weather event on unit operability and fuel supplies.

NETL also cited the unique adaptive resilience capacity of approximately 26 GW of coal units that deployed at the beginning of the Bomb Cyclone to meet the preponderance of increased demand within PJM during the Bomb Cyclone. The scale of 26 GW of adaptively resilient PJM coal units, which were dispatched at the beginning of the weather event, could not have been matched by any other sources of undispatched generation assets, as was agreed by PJM, in PJM President Ott's aforementioned Congressional testimony. Many of these incrementally dispatched coal units had experienced capacity factors well below 50 percent in PJM's 2017 market. Yet, together with the previously dispatched baseload coal units, they collectively served as baseload to support PJM generation demand, operating at a level above 45 GW for nearly every hour, for ten consecutive days (Exhibit 1-1). [6]

Exhibit 1-1. Coal-fired hourly and daily generation, early December 2017 and during the Bomb Cyclone



In its response to the NETL Resilience Report, PJM did not directly address the generation-by-fuel analyses of NETL, which used PJM's own published operating data. [6] However, PJM's response to NETL's report downplayed the significant role that resilient coal and nuclear generation played for PJM during the Bomb Cyclone by suggesting that availability and competitiveness of natural gas supply for power generation had not become a serious problem. PJM asserted three basic claims in this regard [7]:

1. The Bomb Cyclone incremental generation demand was met by normal "hour-by-hour" dispatch decisions between coal and natural gas units with the availability of natural gas supply for power generation not at issue.

2. The average of PJM morning and evening peak generation using natural gas, across the Bomb Cyclone period, was unchanged from the early December 2017 average, the result of which signified "stable" gas-fired generation throughout both periods.
3. PJM had maintained a 23 percent reserve margin at peak demand of the Bomb Cyclone, with 28,883 MW of undispatched and "mechanically operable" gas-fired capacity available as reserves.

On April 30, 2018, two weeks after PJM published its response to the NETL Resilience Report, PJM made a public announcement that substantially undermined the certainty of the natural gas fuel security assertions of PJM in its response to NETL. PJM President Ott publicly announced, PJM's intention to conduct a targeted analysis aimed at ***Valuing Fuel Security***:

> *As a first step, PJM will perform targeted analyses to identify fuel security risks that could affect specific locations on the system (or depending on the nature of the fuel supply risk on the aggregate PJM system) and establish criteria to apply to existing market mechanisms in order to produce efficient and cost-effective results for customers. [8]*

A news report indicated (emphasis added) that during PJM's announcement of its *Valuing Fuel Security* analysis:

> *Ott said PJM's current reliability analyses do not take potential fuel supply constraints into account, making the new initiative necessary.*
>
> *PJM's new fuel security analysis takes aim at a persistent concern for the grid operator — that a growing reliance on natural gas generation will make the system vulnerable, particularly in the winter months, when gas is diverted to home heating.*
>
> *PJM CEO Andy Ott told reporters Monday that while fuel supply is not at risk today, replacing more coal and nuclear generation — which keep their fuel onsite — with natural gas could make the system more prone to disruption from weather or attack. [9]*

The acknowledgement by PJM executive management that their reliability analyses "do not take potential fuel supply constraints into account," highlights a shortcoming of their response to NETL. [9] This clarifies the primary basis for dissimilarities between NETL and PJM views of the Bomb Cyclone operating experience and potential reliability issues that existed.

1.1 RESPONSE TO PJM MARCH 13, 2018, ASSERTIONS CONCERNING THE NETL RESILIENCE REPORT

1.1.1 Claim #1

The Bomb Cyclone incremental generation demand was met by normal "hour-by-hour" dispatch decisions between coal and natural gas units with the availability of natural gas supply for power generation not at issue

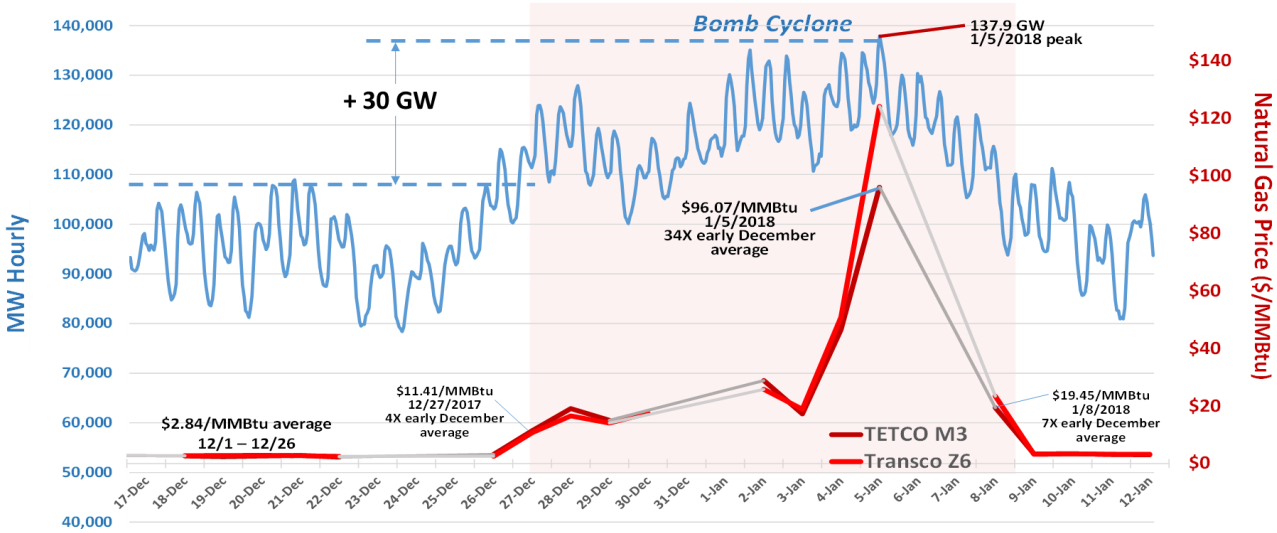
PJM suggested that NETL overstated the significance of the rapid dispatch of all remaining available coal generation within PJM during the Bomb Cyclone, as this deployment had only represented ordinary hour-by-hour dispatch decisions, under a normally operating PJM marketplace, implying natural gas resource availability had not been impaired. As a result, PJM declined to recognize this crucial added generation as representing "resilience" of coal generating assets. PJM repeated this opinion in various statements, several times within the first two pages of their response to NETL (emphasis added):

- *Although the NETL report contains some appropriate analysis and asks valid questions, the report's overall conclusion is incorrect about the reasons for PJM's dispatch of coal units during the cold snap. PJM dispatched coal units because their costs were lower during certain hours of the cold snap. (page 1)*
- *When using the term "resilience," the NETL report mixes the availability of adequate generation to meet load with the costs of particular resources in a given hour and their impact on economic dispatch. (page 2)*
- *The [NETL] report then labels the incremental change in resource fuel types supplying electricity during the cold snap period as "resilience," implying resource availability was physically impaired, which led to a shift in dispatch during the cold snap between coal and natural gas. (page 2)*
- *However, as noted above, the driver of the higher dependence on coal during the cold snap was the economics (i.e., lower cost) of coal vs. natural gas on an hour-by-hour basis. (page 2)*
- *During a number of hours of the cold snap, coal resources were more economic (i.e., less expensive) than natural gas resources. (page 2) [7]*

This repeated assurance—that during the Bomb Cyclone PJM electricity consumers remained unexposed to reliability issues caused by natural gas scarcity—is factually incorrect. The dispatch of coal-fired units ahead of incremental natural gas units during the Bomb Cyclone was not based on "the economics (i.e., lower cost) of coal vs. natural gas on an hour-by-hour basis" or because "coal costs were lower during certain hours of the cold snap." [7] However, PJM's operating data, [6] combined with regional natural gas price data, [10] (Exhibit 1-2) show that during the Bomb Cyclone period there was no longer a competitive relationship between additional coal and additional natural gas generation. From beginning to end of the period, natural gas prices at major supply points had moved to several multiples of normally competitive prices with coal. For the last several days of the Bomb Cyclone, natural gas price

exceeded $20 per million British thermal units (MMBtu), allowing oil generation to displace gas-fired generation at a price equal to seven times the early December 2017 average PJM natural gas price for generation. At the PJM peak demand day, January 5, 2018, natural gas prices within PJM had reached 30 to 40 times the early December 2017 average price. Such spiking prices were a direct reflection of resource availability impairment, which PJM's response implied had not been a market factor. [7]

Exhibit 1-2. Natural gas prices and PJM total generation during the Bomb Cyclone



Natural gas pipelines are essentially full by the time they cross into Ohio, serving primarily space heating demand, and cannot be used to serve power generation demand farther east. The map in Exhibit 1-3 depicts pipeline utilization as well as electricity locational marginal prices (LMPs) for January 5, 2018, the peak day of the event. [11] As the pipes move east, their capacity had become fully- or over-subscribed, resulting in not only spiking gas prices but spiking electricity prices, since gas-fired capacity has increased across the northeast. This general situation is also illustrated by examining the Texas Eastern Transmission system below (Exhibit 1-4).

Exhibit 1-3. Pipeline utilization and electricity LMPs on January 5, 2018

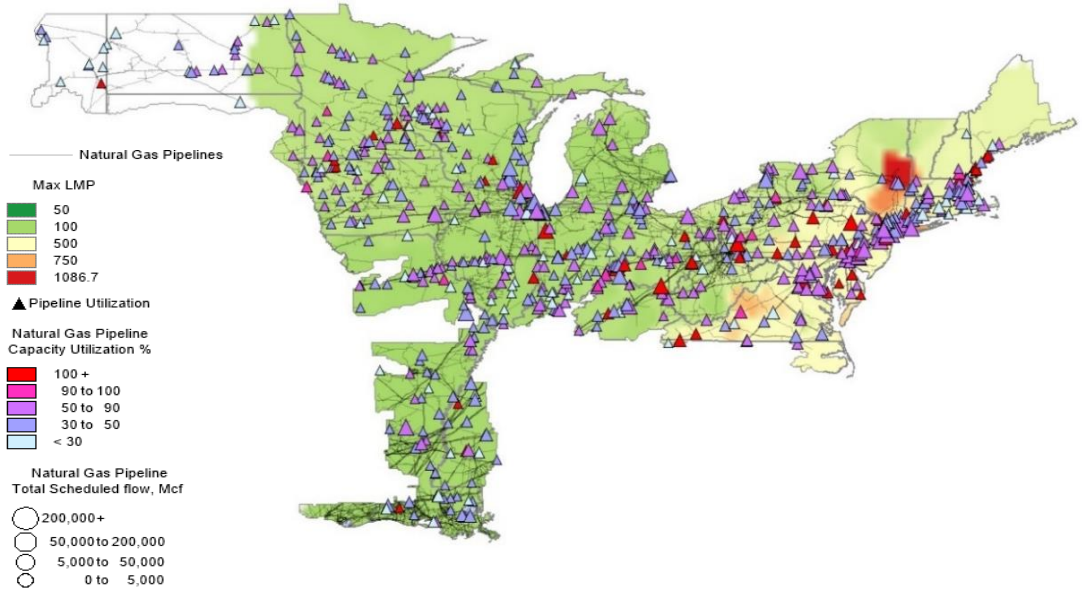
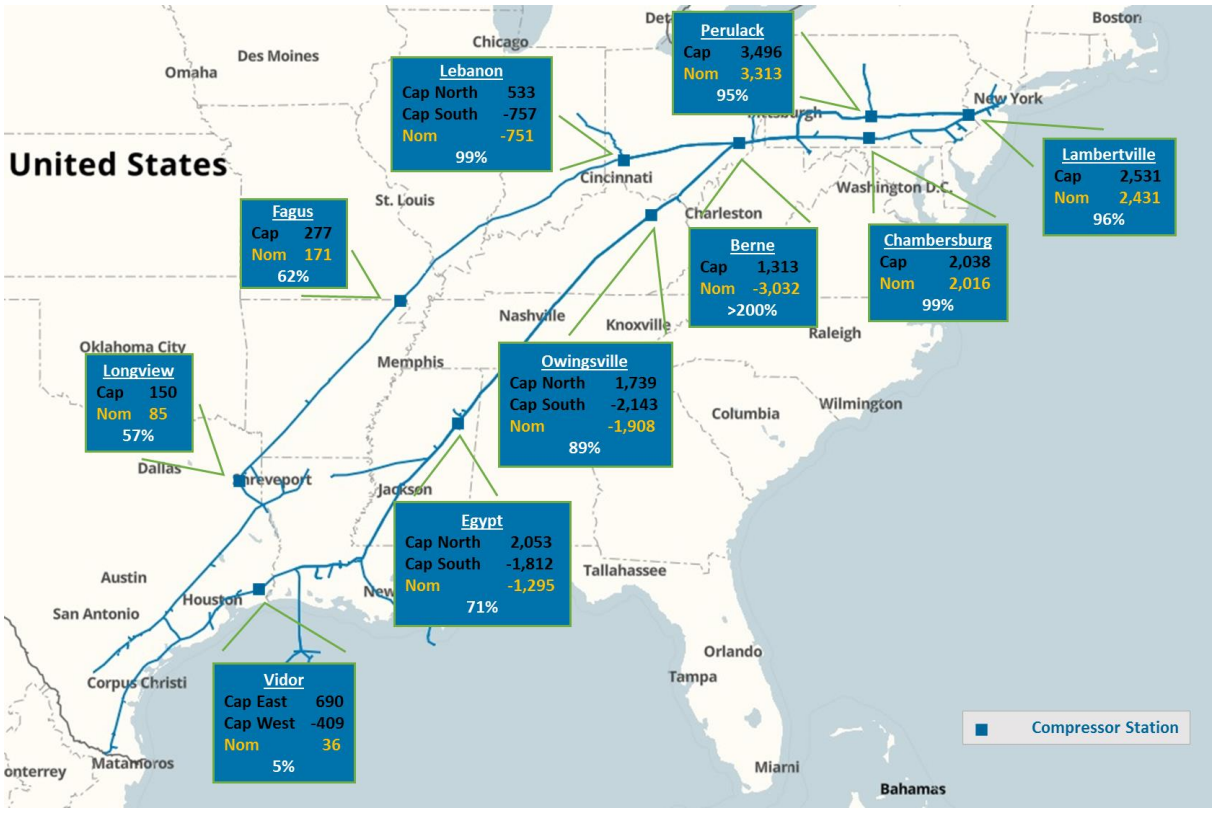


Exhibit 1-4. Texas Eastern Transmission system on January 5, 2018

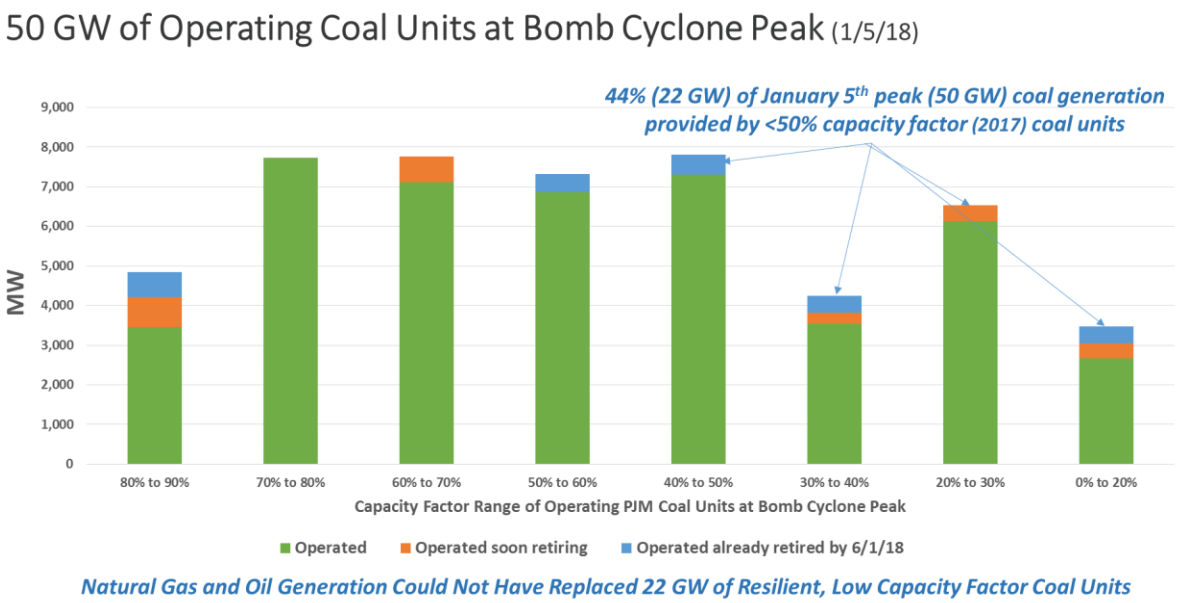


Modified with permission from Enbridge [12]

It is precisely this type of sudden adverse energy event, in this case the inadequate availability of a crucial fuel supply source affecting the ability of the electricity system to perform normally[a], for which the qualifying term "resilience" has become recognized as a characteristic that needs to be properly valued. Resilient technologies exhibit an ability to continue to stably supply power to meet market demand (as was demonstrated by PJM's coal and nuclear baseload units) or, importantly, to show adaptive resilience to incrementally meet significantly higher demand and to replace lost supply, as tens of GW of supplemental PJM coal generation assets were able to accomplish.

Resilience was particularly evident in the high level of reliable baseload performance of the incremental coal generation that responded to increased PJM demand during the Bomb Cyclone. Of the approximate 26,000 MW of incremental coal-fired generation that was deployed to meet surging demand during the Bomb Cyclone, a substantial majority of units, amounting to roughly 22,000 MW, had operated at less than 50 percent capacity factor throughout 2017 (Exhibit 1-5. [13] Yet, as reflected in Exhibit 1-1, the PJM coal units deployed during the Bomb Cyclone collectively provided above 45,000 MW for nearly every hour, 24 hours a day, for 10 days. There was no hourly competitive alternative for the generation these units provided during the entire Bomb Cyclone period; the scale of the incremental generation provided by coal generation could not have been matched by any other power generation resources.

Exhibit 1-5. Capacity factors and operating status of coal units during Bomb Cyclone peak



The suggestion that this segment of PJM's installed capacity was deployed based on normal hourly market competition and did not perform resiliently in response to a significant fuel

[a] This point is recognized explicitly by ISO New England (ISO-NE), which points out that while on January 4, 2018, the average Marcellus wellhead price was $5.75/MMBtu, the average (not peak) Massachusetts gas index price was $78.35/MMBtu, with corresponding average electricity LMP of $287.85/megawatt-hour (MWh). See Gordon van Welie, slide 5. [15]

supply issue is inaccurate and doesn't adequately recognize the importance of the unique service provided by these units and their operating personnel.

1.1.2 Claim #2

The average of PJM morning and evening peak generation using natural gas, across the Bomb Cyclone period, was unchanged from the early December 2017 average, the result of which signified "stable" gas-fired generation throughout both periods

PJM asserted that the average of peak MW provided by gas-fired generation during typical morning and evening peak hours, across both the early December 2017 and the Bomb Cyclone periods, were essentially the same. The implication drawn was that PJM's gas-fired generation capability had remained "relatively stable" during the Bomb Cyclone.

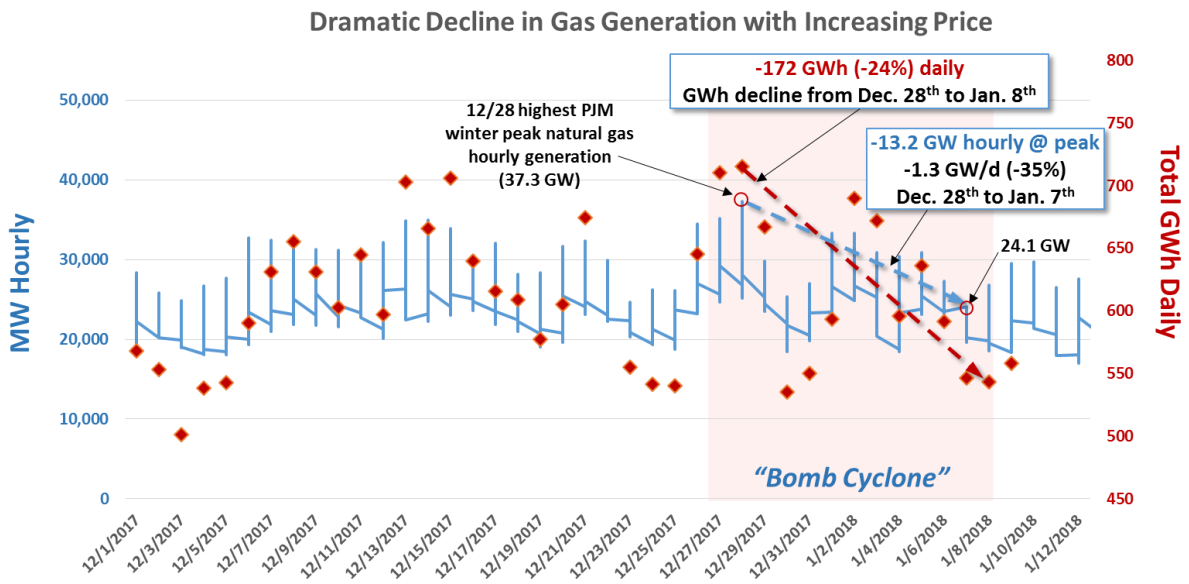
Under the heading "Economic Dispatch" PJM indicated the following:

> *The average megawatt contribution by fuel type for the morning and evening peaks of Dec. 1, 2017–Jan. 7, 2018 are shown below. The megawatts obtained from natural gas and nuclear capacity remain relatively stable in both periods. Coal and oil generation output increased. [7]*

The assertion that natural gas capacity remained "relatively stable" in both the early December 2017 and Bomb Cyclone periods suggested that gas-fired generation capacity within PJM was able to remain resilient to the winter-induced tightness in the natural gas market. However, there were approximately 69 GW of installed gas-fired capacity in PJM. Of that, on January 5, 2018, 9 GW were in outages, 31 GW were deployed, and 29 GW remained offline. On December 28, a little over 37 GW gas units had been deployed, the most during the event. PJM implies that the 26 GW of coal capacity that surged to meet load did so because coal power was cheaper and that the 29 GW of offline gas represented available reserves. Given the gas deliverability issues displayed above (Exhibit 1-3 and Exhibit 1-4), NETL finds it impossible that that "reserve" could have been used in place of the aforementioned 26 GW of coal power. That gas generation averaged 27–29 GW during the period and was, therefore, stable is an artifact that NETL does not find particularly relevant.

The methodology of averaging daily MWh production, at two peak hours, throughout these periods produced artificially low results, as the averaging was performed across too broad a period for the Bomb Cyclone. The daily peak averages for the Bomb Cyclone period, in figures 1 and 2 of the PJM report, were calculated for a period that extended through January 10, 2018, instead of the end date for the Bomb Cyclone, January 8, 2018, resulting in an average for the comparison. [6] The consistency of the averaging result during the Bomb Cyclone with the early December 2017 period was purely coincidental. The coincidence on the high side averages was due to natural gas generation beginning the Bomb Cyclone with a PJM record winter-time high for the natural gas generation, peaking at 37.3 GW on December 28, 2017, and ending on January 8, 2018, with a multi-week low for daily peak generation, at 24.1 GW—a 35 percent decline throughout the Bomb Cyclone period, due to increasing supply and cost constraints on natural gas generation (Exhibit 1-6). [6]

Exhibit 1-6. PJM natural gas hourly and daily generation during Bomb Cyclone



Additionally, the total of daily natural gas generation declined by 24 percent throughout the Bomb Cyclone period, from December 28, 2017, to January 8, 2018. Thus, the averaging over the Bomb Cyclone period disguised a significant, steady decline in both daily and peak natural gas generation that did not reflect generating "stability," despite producing a similar average result to early December 2017.

1.1.3 Claim #3

PJM had maintained a 23 percent reserve margin at peak demand of the Bomb Cyclone, with 28,883 MW of undispatched and "mechanically operable" gas-fired capacity available as reserves

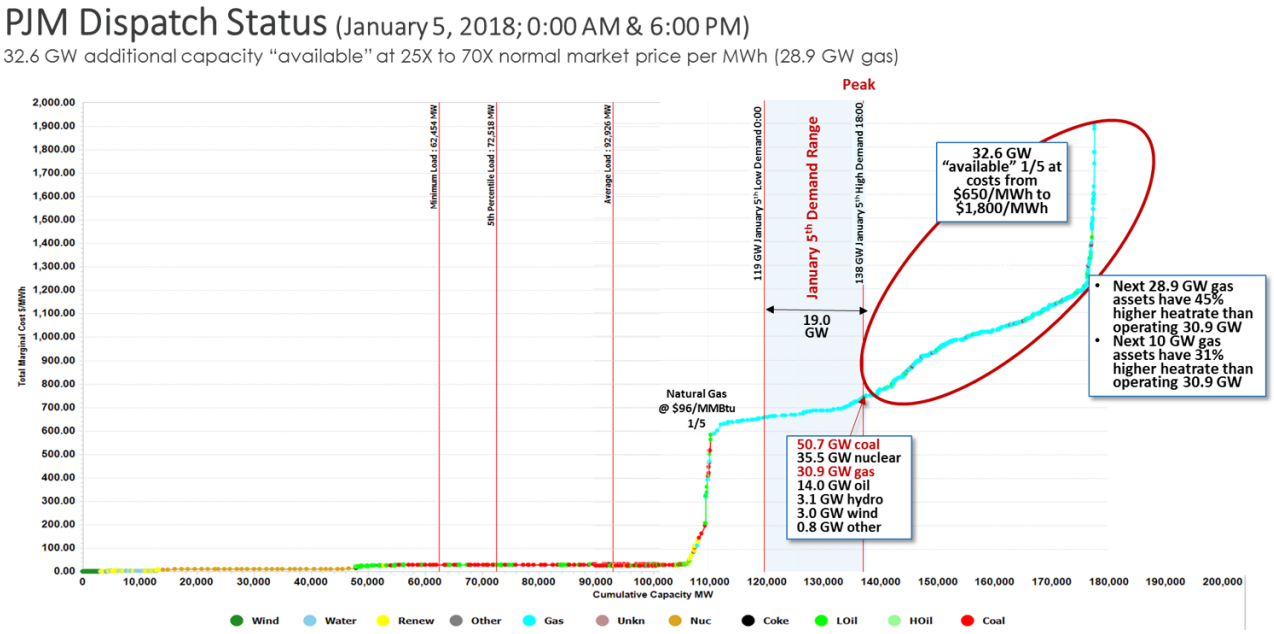
Of the three PJM assertions in its response to the NETL Resilience Report, this claim was the most concerning, as it greatly underestimated the costs and improbability of attaining the necessary natural gas fuel for generation and seriously overestimated the available natural gas generation reserve capacity at the peak of the Bomb Cyclone. PJM claimed:

> *By the same token, any natural gas units that were available[3] but not scheduled were counted as offline reserves and, therefore, can also be considered adaptive resilient generation. This is the primary mechanism PJM uses to make reserves available on the system. Those resources that are the most economic (i.e., lowest cost) to provide energy are dispatched to do so, while more expensive resources are held offline and provide reserves. For the peak day of Jan. 5, 28,883 MW of natural gas were available but not scheduled as energy or reserves. These units can also be considered as adaptive reserves using the NETL approach.*
>
> *PJM footnote 3 Available units are mechanically able to operate but may not be scheduled based on economics. A simple call to those units would get those units operating on the system. [7]*

As mentioned above, two weeks after the issuance of the PJM response to the NETL Resilience Report, PJM President Ott publicly acknowledged that "PJM's current reliability analyses do not take potential fuel supply constraints into account." [9] With this clarification taken in perspective, the third claim of PJM in response to NETL warrants closer scrutiny. It would be possible for 28,883 MW of unused PJM natural gas generating capacity deemed "mechanically able to operate" on January 5, 2018, and with "no fuel supply constraints," to be theoretically considered "available reserves." However, in reality, the natural gas fuel supply constraints were significant on January 5, leading to prices more than 30 times normal, and by January 7, the forced outages identified by PJM as a result of gas supply issues had increased by 3,732 MW (+171 percent) over January 5 outages, in just two weekend days. [7] The assertion of significant natural gas generation reserve capacity, under the circumstances, was misleading without qualification concerning the lack of consideration to fuel supply constraints.

The status of PJM generation dispatch for the PJM peak demand on January 5, 2018, appeared as follows (Exhibit 1-7), [11] with the peak hour deployment of various forms of generation shown. [6]

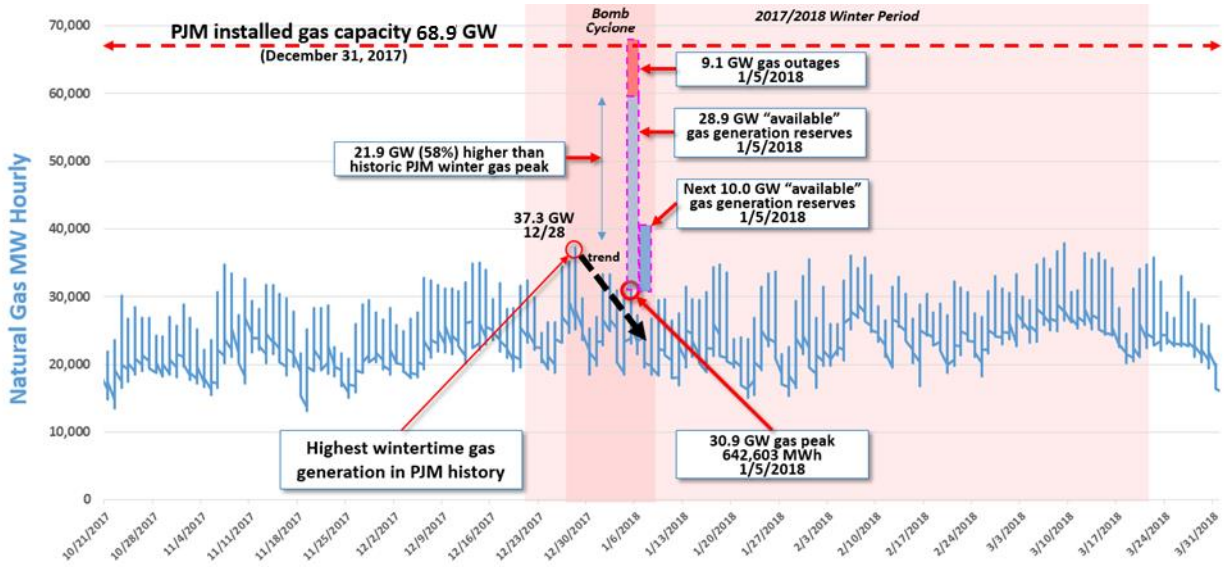
Exhibit 1-7. PJM dispatch curve at January 5, 2018, Bomb Cyclone peak generation



With natural gas prices at TETCO-M3, in southeast Pennsylvania, at $96 per MMBtu, PJM's remaining capacity to meet even higher demand predominantly consisted of much less efficient oil and natural gas units that would deploy at several hundred dollars per MW hour. It is estimated that the average heat rate of the 28.9 GW of undispatched natural gas units, asserted by PJM, was 45 percent higher than the 30.9 GW already deployed on January 5, 2018. [14] To fully dispatch these units would have required nearly another 150 percent of additional natural gas than was already being consumed for PJM power generation—an impossibility under the existing market and delivery infrastructure circumstances. The suggested 28.9 GW of additional natural gas capacity, on top of the January 5 peak, would have been nearly 22 GW (58 percent) higher than PJM's historic winter-time natural gas generation peak, established early in the

Bomb Cyclone operation, on December 28, 2017, from which point gas-fired generation continually fell throughout the Bomb Cyclone period (Exhibit 1-8). [11] [6] Dispatching the next 10 GW of natural gas generation available in the dispatch curve would have required nearly 50 percent more natural gas than was already being consumed for power generation, which, even if attainable, would have led to an enormous additional upward spike in the market price for natural gas and the further taxing of already constrained infrastructure for natural gas delivery.

Exhibit 1-8. PJM natural gas-fired generation during Bomb Cyclone: issues for further dispatch



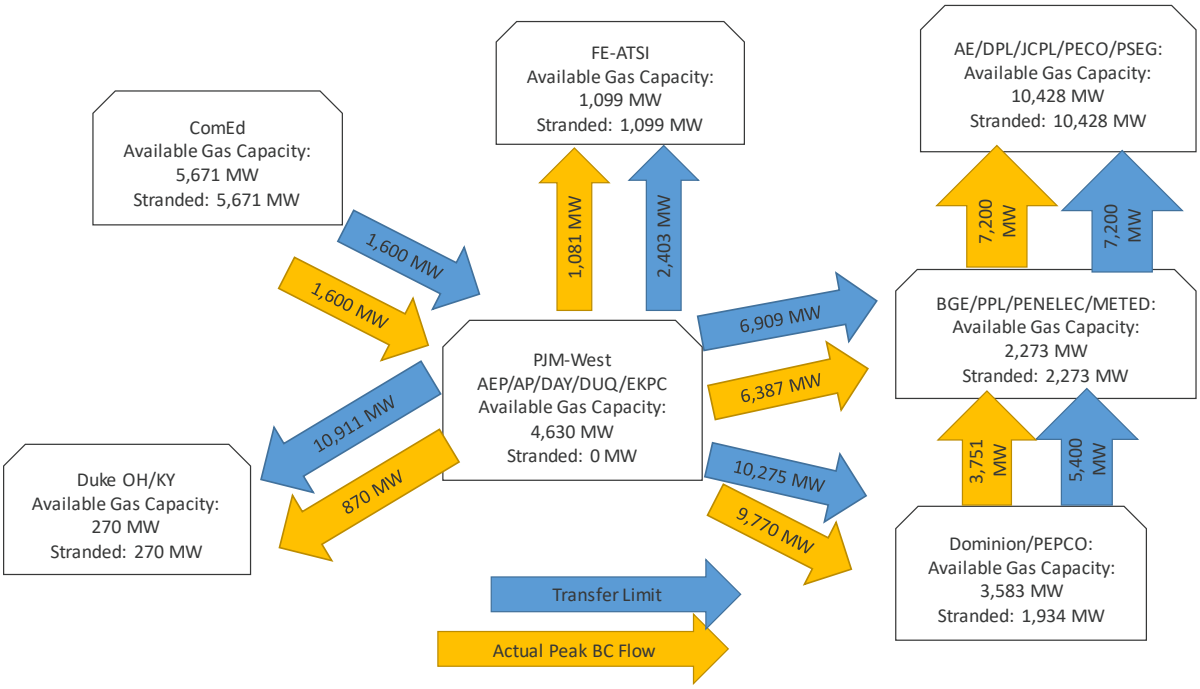
The assertion that PJM's 28,883 MW of undeployed gas-fired generation capacity on January 5, 2018, could be considered adaptive reserves was not meaningful, without due consideration to not just the fuel supply constraints that existed at the time, but also transmission system deliverability constraints. Of those uncommitted gas resources, only 20 percent could have been wheeled to eastern PJM, *had the gas been deliverable.*

While a unit may be "mechanically able to operate," this is no indication of whether the output of that unit would be deliverable to serve load. This is a particular concern during times of high demand and transmission utilization, such as during the peak demand on January 5, 2018. Public data readily available from PJM and hourly generation reports from Environmental Protection Agency (EPA) continuous emission monitoring system (CEMS) allow for an after-action deliverability evaluation. Deliverability across the PJM system is governed by a set of Reactive Transfer Interfaces, which are the amalgamation of select high voltage lines within the footprint that impose transmission limitations on the system, whose transfer limits set the volume of generation that can be transmitted.

Exceeding these transfer limits would result in cascading voltage collapse throughout the system resulting in an outage event. During the peak demand hour on January 5, 2018, the regional disposition of the 28,883 MW of unused generating capacity and transfer availability was as follows in Exhibit 1-9. This simplified map illustrates that while there was available capacity in each of the footprint's reactive transfer zones, the ability of additional generation to flow across the reactive transfer interfaces was limited to less than 20 percent of the unused gas capacity,

and completely out of the question for several zones. This illustrates the tenuous nature of the reserves, as just 5,600 MW were deliverable with the balance only available to serve loads within their respective zones due to either the direction of transmission flows across the interfaces or that the interfaces flowing in an exporting direction were already at full capacity.[b]

Exhibit 1-9. PJM January 5, 2018, peak hour transmission deliverability and available gas capacity disposition



Because of the transmission constraints, although reserves were available, reporting a total reserve -across the footprint as available in aggregate- promotes an overly =optimistic view of security. Calculating the local reserve margins, using undispatched capacity, excess capacity at dispatched units, and units within the footprint serving external entities, indicates that there were ample reserves across the footprint, assuming no fuel supply constraints. However, with the existence of gas constraints and forced outages, aggregating available reserves to the footprint level is questionably appropriate. Tabulating the breakdown of reserves into each reactive power zone and comparing against the total RTO footprint reveals a heavy reliance upon gas-fired units for reserve, particularly in the eastern zones of PJM, where natural gas constraints demonstrably exist. As stated by PJM, total reserves were likely more than adequate in the aggregate; however, considering gas limitations and forced outages, functional and truly operable reserves were likely significantly less, on the order of half or less that of the reported reserves (Exhibit 1-10). Because forced outage values were only publicly available at the footprint level, it is critical to note that the disaggregated zonal reserve numbers were much less. Using the CEMS data-calculated RTO footprint reserves based on the forced outage totals reported in *PJM's Response to NETL* indicates that there was only 601 MW of idle fuel secure

[b] Transmission system limitations would have impacted the dispatchability of all available reserve resources within each zone regardless of fuel type, meaning that the available and stranded capacity values in each zone may have been greater depending on the availability of additional units. For the purposes of this analysis, only gas-fired resources are shown, as PJM argues that 28,883 MW of gas-fired resources were available.

generation within the entire footprint at peak, with the balance providing some level of service to the system.

Exhibit 1-10. Reserve margin comparison

Reserve Zone	Reserve from Operating Gas Units (A)	Reserve from Operating Fuel Secure Units (B)	Reserve from Idle and Forced Outage Gas Units (C)	Reserve from Idle and Forced Outage Fuel Secure Units (D)	Total Reserve from Gas Units (E=A+C)	Total Reserve from Fuel Secure Units (F=B+D)	Total Footprint Reserve (E+F)
COMED	4.50%	0.66%	38.37%	9.94%	42.87%	10.60%	53.46%
DEOK	11.62%	3.91%	6.10%	11.51%	17.72%	15.42%	33.14%
PJM-West	6.06%	5.56%	11.86%	3.58%	17.92%	9.14%	27.05%
FE-ATSI	5.58%	12.96%	10.40%	11.26%	15.98%	24.22%	40.19%
Dominion/PEPCO	6.37%	5.97%	14.19%	5.91%	20.56%	11.88%	32.44%
BGE/PPL/PENELEC/METED	11.68%	7.09%	11.67%	6.76%	23.35%	13.85%	37.20%
AE/DPL/JCPL/PECO/PSEG	9.47%	3.11%	45.16%	3.59%	54.63%	6.70%	61.34%
RTO	7.47%	5.43%	20.46%	6.00%	27.93%	11.43%	39.36%
RTO Ex-Forced Outages	7.47%	5.43%	13.82%	0.44%	21.29%	5.87%	27.16%

2 CONCLUSION

The NETL Resilience Report sought to put into proper perspective the significance of secure fuel assets during the Bomb Cyclone weather event. In particular, the NETL Resilience Report highlighted the significant contribution of predominantly coal-fired generation assets in providing a resilient response in meeting increased power demand. PJM's President Andrew Ott affirmed, in subsequent Congressional testimony shortly after the March 2018 publication of the NETL Resilience Report, that PJM "could not have served customers without coal-fired assets." [3] The PJM response to the NETL Resilience Report, however, suggested that "mechanically operable" natural gas generation assets existed at sufficient scale to have alternatively met this need, that fuel availability was not at issue, and that "economics" drove the dispatch in favor of coal. [7] However, PJM's President Ott acknowledged in a subsequent April announcement of their planned *Valuing Fuel Security* analyses, that "PJM's current reliability analyses do not take potential fuel supply constraints into account." [8] It is the existence and the extent of natural gas fuel supply constraints that is at the root of much of the difference in opinions between NETL and PJM regarding the important role of secure fuel assets during the Bomb Cyclone.

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