

U.S. Senate Committee on Energy and Natural Resources
January 23, 2018 Hearing: *The Performance of the Electric Power System in the Northeast and mid-Atlantic during recent Winter Weather Events, including the Bomb Cyclone*
Questions for the Record Submitted to Mr. Andrew Ott

Questions from Chairman Lisa Murkowski

Question 1: You sometimes refer to the potential need to take emergency measures during a severe cold weather event, including measures like rolling blackouts, or load shedding. While neither ISO-NE nor PJM needed to shed load in this most recent event, where is the trend going? What happens if we have another such event, or even a colder event, five years from now? What should we be doing now, so that we're ready in five years?

PJM's response focuses on two aspects to this question, namely:

- What mechanisms and checks and balances are in place today to address potential extreme weather events in the near future (i.e., over the next five years)?
- What additional actions are needed to address high impact low frequency events?

Mechanisms and Tools in Place to Address Stressed Conditions on the Grid from Extreme Weather Events – As a Regional Transmission Organization (RTO), PJM integrates its planning, operations and markets all to ensure reliability of the grid in response to extreme weather events and peak load conditions.

Starting with the planning process, PJM conducts a long-range Regional Transmission Expansion Planning (RTEP) process that identifies the changes and additions to the grid that are needed to ensure reliability. This process includes compliance with reliability standards promulgated by NERC and FERC pursuant to Section 215 of the Federal Power Act. The PJM planning process employs a 15-year planning horizon to identify and order major transmission investments and upgrades that will maintain grid reliability and improve economic efficiency. To date, net transmission investments authorized under PJM's Regional Transmission Expansion Plan (RTEP) since 2000 total is approximately \$35.4 billion.

On the resource side, it should be noted that although PJM saw about 22,000 MW of coal units retire since 2010, the capacity market attracted more than 37,000 MW of new generation since 2007, of which more than 21,000 MW of new generation was placed in service between 2010 and 2017. This has resulted in a current PJM reserve margin of 29.1 percent, which is well above the targeted reserve margin of 16.6 percent for 2017 and 16.1 percent for 2018. Future capacity Base Residual Auctions through 2021 have yielded almost 50,000 MW of generation capacity additions, of which 80 percent is natural gas.

Since the implementation of the Reliability Pricing Model (RPM), PJM has implemented market rules changes and is currently working on additional changes to ensure system reliability in the future. In the August 2015 RPM capacity auction for the 2018/2019 Delivery Year, PJM implemented a set of market rules called Capacity Performance (CP). These rules were focused on improving resource performance during system emergencies by strengthening the penalty structure for non-performance. These rules were driven by poor generation performance during the 2014 Polar Vortex (22 percent forced outage rate) and have resulted in a material

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improvement. In the most recent cold snap between December 2017 and mid-January 2018, the forced outage rate for generation resources dropped to 11–12 percent.

In short, PJM markets, operations and planning and the tariffed rules approved by FERC that govern each of these work together symbiotically to ensure that reliability of the grid is maintained and enhanced.

Additional Actions Needed to Address Potential Future Low Probability But High Impact Events – PJM is focused, as is FERC, on addressing “grid resilience issues,” i.e., the ability to plan for, operate through and recover from a low-probability, high-impact event. PJM’s efforts in this area range widely. They include efforts to enhance the planning process to address critical infrastructure; the creation of real-time gas pipeline system monitoring by PJM staff (in order to respond to a potential pipeline contingency by triggering additional reserves); and coordination with the U.S. Department of Defense, Argonne National Labs, FEMA and the states to enhance restoration of critical loads on the PJM system.

PJM does not believe that operating outside of the market to preserve a particular class or type of generation is needed at this time for reliability. The markets have been resilient in attracting new investment. In addition, a variety of tools exist as a backstop should specific generation be needed in a particular area.

Finally, there is a legitimate issue for discussion about dependence on one particular fuel. The region is blessed with the availability of multiple pipelines, natural gas storage supplies, rich resources of coal and availability of wind resources. However, in the PJM footprint, we have seen a significant number of new pipelines being developed as the PJM region sits on top of the Marcellus and Utica shale natural gas resources.

The combination of market signals, PJM’s geographic location and FERC consideration of the various grid resilience initiatives, which PJM will be detailing in its March 9 comments to FERC, works to keep this region poised to continue to address both extreme weather events and high-impact, low-frequency events.

Question 2: How do options like demand response and energy efficiency fit into these extreme weather events? How much is the grid helped during winter peaks by these options?

In the PJM footprint, demand response (DR) has matured significantly in the last 10 years. It has transitioned from a legacy utility program to a resource that is integrated into the wholesale markets and leveraged to operate the grid. PJM is working to broaden the opportunities for electricity consumers to respond to wholesale prices and grid conditions. The ability to call on demand reductions gives system operators greater flexibility in managing the grid during challenging conditions.

Energy efficiency (EE) is considered a passive resource. It is compensated as a capacity resource based on the average continuous year-round load reduction provided by the EE installation.

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Prior to the implementation of Capacity Performance (CP), demand response and energy efficiency were permitted to be seasonal resources that only had to perform to their stated capability during the summer period. This was based on the assumption that the primary risk for operational emergencies existed during the summer. The 2014 Polar Vortex changed how PJM perceived this risk and led to the conversion of products like demand response and energy efficiency to annual products as opposed to seasonal ones. This requirement will ensure that these resources are available to perform if PJM needs them during an emergency at any time during the year.

Effective 2018/19, capacity resources that do not alone, meet the requirements of a Capacity Performance product may combine their capabilities and offer as a single Aggregate Resource. This applies to intermittent resources, capacity storage resources, demand resources, energy efficiency resources and environmentally limited resources.

Although DR was only a summer product during the 2014 Polar Vortex, PJM deployed DR resources due to the severe operating conditions, and they provided a measurable benefit.¹ During the most recent cold snap, PJM did not reach severe enough emergency conditions to call on DR.

Approximately 60 MW of economic DR participated during the recent cold weather. It is estimated that approximately 5,400 MW of emergency DR was available during the recent cold weather; however, PJM did not need to utilize this emergency DR to manage the grid due to the significant reduction in generation forced-outage rates.

Question 3: In assessing the organized markets, have you considered the need for both entry and exit in a well-functioning marketplace? Notwithstanding the vital contributions of wind, solar, hydro, oil, and other resources to our markets, what are your thoughts on a market design that is structured so that nuclear and coal plants do not have a realistic opportunity for new entry, but do have opportunities to permanently exit during periods of low natural gas prices? Should markets be designed to eventually “ratchet” out all nuclear and coal, so that the natural gas industry ultimately gains a virtual monopoly on fuel supply to the electricity markets?

The changing resource mix is not unique to PJM. Over the last few years, the NERC Reliability Issues Steering Committee (RISC), as part of the ERO Reliability Risk Priorities RISC recommendations to the NERC Board of Trustees,² has identified changing resource mix as a high-priority focus area, assigning it a high risk profile.

¹ <http://www.pjm.com/-/media/library/reports-notice/weather-related/20140509-analysis-of-operational-events-and-market-impacts-during-the-jan-2014-cold-weather-events.ashx?la=en>

² http://www.nerc.com/comm/RISC/Related%20Files%20DL/ERO_Reliability_Risk_Priorities_RISC_Recommendations_Board_Approved_Nov_2016.pdf

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PJM's markets are designed not to favor any one resource type over another. They are designed to allow the market signals to decide which resource types can meet system needs at the lowest cost and incentivize those efficient entry and exit decisions. However, giving the growing concern about over-dependency on natural gas, PJM performed a study and published a paper in 2017 titled "PJM's Evolving Resource Mix and System Reliability,"³ which focused on resource diversity and how it affects reliability. In summary, that study indicated that PJM's generation fleet today is more diverse than it has ever been due to the growth of natural gas and that there is no immediate reliability concern with the current fleet or its foreseeable trajectory.

From PJM's perspective, the new entry prospects of nuclear and coal resources do not appear to be a market design issue, since there are challenges for new coal and nuclear resources in market and non-market areas across the country. These resources require more capital and a longer construction period and are the subject of more regulations (both safety and environmental).

PJM has raised issues associated with the proper setting of energy market clearing prices to ensure that market clearing prices reflect the costs of all resources that are serving demand. PJM has noted that in the recent cold snap, out-of-market uplift payments increased by at least a factor of 10 during the severe cold weather operations which indicates the operating costs of some generation that was needed to meet the electricity demand was not reflected in clearing prices.

Just to be clear, all of the resources that are serving load are compensated, in some cases through out-of-market "uplift" payments. But in some cases, such costs are not properly reflected in locational marginal prices, which could put these resources – and all other resources needed to meet demand – at a disadvantage because market prices are not reflecting the true cost to serve demand.

PJM has proposed energy market price formation reforms to address these issues, and we believe such reforms should be addressed in a timely manner. These reforms include both enhanced reserve pricing and energy price formation reforms. PJM has also flagged this issue for FERC consideration in the context of FERC's energy price formation efforts.

³ <http://www.pjm.com/-/media/library/reports-notice/special-reports/20170330-pjms-evolving-resource-mix-and-system-reliability.ashx?la=en>

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Questions from Senator Mike Lee

Question 1: What impact did the market reforms enacted in the wake of the 2014 polar vortex have on PJM's ability to ensure safe and reliable grid performance during the recent cold weather event?

While improved performance was seen during the most recent cold weather event, it's important to note that neither the temperatures nor customer demand reached the levels experienced in 2014 during the Polar Vortex. During the recent cold weather event, it was not necessary for PJM to invoke a performance assessment interval, a 72-hour maintenance recall or any transient shortage intervals because the system was performing well. However, the system was stressed, and there were some significant indicators of improved performance of generating resources since 2014.

In the August 2015 RPM capacity auction for the 2018/2019 delivery year, PJM implemented a set of market rules called Capacity Performance (CP). These rules were directly focused on improving resource performance during system emergencies by strengthening the penalty structure for non-performance. These rules were driven by poor generation performance during the 2014 Polar Vortex (22 percent forced outage rate) and have resulted in a material improvement. In the most recent cold snap, between December 2017 and mid-January 2018, the forced outage rate for generation resources dropped to 11–12 percent.

In addition to the implementation of CP, several other factors improved performance from the 2014 Polar Vortex. These include enhancements PJM and its member companies have put in place, such as deployment of more efficient generation resources, increased investment in existing resources, improved performance incentives, enhanced winterization measures and increased gas-electric coordination.

Question 2: How many of the coal and nuclear plants that PJM relied on during the recent cold spell are expected to retire over the next five years? How much capacity will those retirements represent?

There are 44 units representing a total of 8,072 MW of generation capacity currently scheduled to deactivate in PJM over the next five years. Of the 44 units scheduled to deactivate, 23 are coal units representing 4,885 MW and two are nuclear units totaling 1,410 MW of capacity. Of the 23 retiring coal units, 16 coal units representing 3,688 MW of capacity operated during a period of the recent cold snap. All of the 1,410 MW of retiring nuclear generation operated during the cold snap; however, one of the retiring nuclear units was on a partial forced outage for the later portion of the cold snap.

PJM analyzed the performance of retiring coal units as compared to non-retiring units during the recent cold snap, using preliminary forced outage data at various snapshots in time across the

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cold snap duration that aligned with either high load peaks or a high amount of generator forced outages. The chart below shows that, using the forced outage reduction megawatt amounts as a percentage of both retiring coal installed capacity (ICAP) and non-retiring coal ICAP, non-retiring coal units had a lower percentage of forced outages during the recent cold snap.

Coal Forced Outages as a Percentage of ICAP Categorized by Retiring vs. Non-Retiring Units						
Date	Jan. 3, 2018 Hour Ending 8	Jan. 4, 2018 Hour Ending 19	Jan. 5, 2018 Hour Ending 9	Jan. 5, 2018 Hour Ending 19	Jan. 6, 2018 Hour Ending 9	Jan. 7, 2018 Hour Ending 9
Non-Retiring Coal	11.7%	8.0%	9.1%	8.5%	11.0%	10.7%
Retiring Coal	31.7%	16.0%	20.5%	23.2%	19.9%	19.8%
Forced Outage (All Gen)	8.2%	7.1%	8.6%	8.5%	11.7%	12.1%

PJM maintains an active list of pending generator deactivations on the PJM website⁴ and does not see any challenge to reliability or fuel diversity from the announced retirements.

Questions from Senator Joe Manchin III

Question 1: Mr. Ott, I want to thank you for all you have done in working with my office and the Committee in advance of this important hearing. There are 17 PJM coal units – 4,266 MW – that are going to retire during the 2018 through 2020 period. The average age of those retiring units is 43 years and the average size is 249 megawatts. Nine of those units – totaling about 3,600 MW – are large enough that I would think that at least some of these were probably relied on during the “bomb cyclone”. I know that on a unit by unit basis you all are still doing some post-event analysis.

Mr. Ott, have you identified which of these units performed during the deep freeze we just experienced?

There are 44 units representing a total of 8,072 MW of generation capacity currently scheduled to deactivate in PJM over the next five years. Of the 44 units scheduled to deactivate, 23 are coal units representing 4,885 MW and two are nuclear units totaling 1,410 MW of capacity. Of the 23 retiring coal units, 16 coal units representing 3,688 MW of capacity operated during a period of the recent cold snap. All of the 1,410 MW of retiring nuclear generation operated during the cold

⁴ <http://www.pjm.com/-/media/planning/gen-retire/pending-deactivation-requests-xls.ashx?la=en>

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snap; however, one of the retiring nuclear units was on a partial forced outage for the later portion of the cold snap.

PJM analyzed the performance of retiring coal units as compared to non-retiring units during the recent cold snap, using preliminary forced outage data at various snapshots in time across the cold snap duration that aligned with either high load peaks or a high amount of generator forced outages. The chart below shows that, using the forced outage reduction MW amounts as a percentage of both retiring coal installed capacity (ICAP) and non-retiring coal ICAP, non-retiring coal units had a lower percentage of forced outages during the recent cold snap.

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Non-Retiring Coal	11.7%	8.0%	9.1%	8.5%	11.0%	10.7%
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PJM maintains an active list of pending generator deactivations on the PJM website⁵ and does not see any challenge to reliability or fuel diversity from the announced retirements.

During the bomb cyclone, would electricity prices have been higher without coal and nuclear generation? Do you know how much higher?

As stated in Andrew Ott’s testimony to the Committee on Energy and Natural Resources, in terms of energy production, PJM’s generation fleet is almost evenly split between coal, natural gas and nuclear resources, with ever-growing penetration of renewable generation and healthy levels of demand response and energy efficiency. This means that without coal and nuclear it would have been very difficult or impossible for PJM to serve all of the electricity demand during the bomb cyclone. However, it is also true that without natural gas-fired and oil-fired generation, it would have been equally difficult to serve the load because of the significant amount of power generation this part of the fleet contributes to meeting demand.

In the extremely unlikely scenario that all of the coal and nuclear generation was not available during the recent bomb cyclone, it is difficult to speculate how much higher electricity prices would have been because in such a scenario the electricity demand could not have been met.

⁵ <http://www.pjm.com/-/media/planning/gen-retire/pending-deactivation-requests-xls.ashx?la=en>

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However, we do not believe such a scenario could happen because PJM operations and planning processes ensure margins on the system are robust enough to operate through extreme weather scenarios. PJM's current reserve margin of 29.1 percent is well above PJM's targeted reserve margin of 16.6 percent for 2017 and 16.1 percent for 2018.

Question 2: In 2014, Congress called for an independent assessment and a comprehensive study on the resilience and reliability of the electric transmission and distribution system. The National Academy of Science published its report on Enhancing the Resilience of the Electric System in 2017. The Report contains specific recommendations directed to DOE, including a recommendation that DOE should partner directly with the North American Electric Reliability Corporation (NERC) to implement resilience metrics in the utility setting. Further, it's my understanding that NERC has established standards for grid reliability but not for grid resilience.

To your knowledge, has an independent study ever been undertaken to evaluate individual generation resources based on a comprehensive set of resilience factors including geography, weather, transmission infrastructure, and ancillary capabilities?

In 2017, PJM evaluated individual generation resources based on a comprehensive set of resilience factors. PJM conducted an independent analysis of the PJM footprint to include resource attributes and those attributes' contribution to promoting reliability and resilience with additional conclusions drawn about resilience and necessary next steps to better understand the impacts of particular resource mix portfolio.⁶ To PJM's knowledge there has been no comprehensive study across the United States.

Question 3: Since there are no standards for resilience, would you support having NERC develop resilience standards? How long do you think that would take?

PJM supports a uniform definition and clear metrics for resilience; however, regarding national standards, NERC has indeed established standards that reach to resilience issues by addressing specific threats such as the Critical Infrastructure Protection (CIP) standard, CIP-014: Physical Security. The purpose of this standard is to "to identify and protect Transmission stations and Transmission substations, and their associated primary control centers, that if rendered inoperable or damaged as a result of a physical attack could result in instability, uncontrolled separation, or Cascading within an Interconnection." Similarly, NERC Standard EOP-010: Geomagnetic Disturbance Operations establishes requirements to mitigate the effects of geomagnetic disturbance (GMD) events by implementing operating plans, processes and procedures, and TPL-001: Transmission System Planning Performance Requirements specifies

⁶ <http://www.pjm.com/-/media/library/reports-notice/special-reports/20170330-pjms-evolving-resource-mix-and-system-reliability.ashx?la=en>

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that transmission planners, such as PJM, establish system planning performance requirements that will result in reliable operations over a broad spectrum of system conditions and probable contingencies. PJM believes that not all threats to resilience are applicable nationally; rather, resilience issues can also be and are regionally oriented. NERC should endeavor to develop an overall resilience framework that includes assessing threats to resilience – those that are national in nature – and promoting a common definition.

NERC should be encouraged to contribute to the development of a set of resilience metrics that can be used to apply consistent approaches across the various regions of the nation.

There may also be an opportunity for NERC to continue to improve on the standards mentioned above. The NERC standard process is thorough but could potentially take years to develop new requirements.

Due to the increased importance of natural gas generation and gas-electric coordination, it is also important to look at the standards governing cyber and physical security for pipelines. The governing models for standards are vastly different between the bulk electric system and the pipelines. For the bulk electric system, detailed cyber and physical security standards (and penalties for non-compliance with these standards) are promulgated by NERC and approved by FERC. Pipeline cyber standards and physical security standards (beyond specific pipeline standards promulgated by PHMSA) are overseen by TSA and largely voluntary in nature. Although legislation would be needed to change this disparate paradigm, there is little reason why the approaches taken by TSA and FERC to these cross-industry topics need to be so diverse, and increased alignment between the two would improve coordination.

Question 4: If DOE and NERC determined that certain generation resources were critical to system resilience, would you agree that those resources should be compensated for the resilience attributes they provide?

PJM's market design already compensates units for a number of resilience services and products they provide. Ancillary services such as spinning reserve and voltage support are services PJM compensates for under its tariff. PJM is also in the process of addressing additional compensation and requirements for primary frequency support, dual-fuel requirements for black start service, and rules that will allow generators to recover costs for emergency operations where market rules do not provide cost recovery.

PJM has raised issues associated with the proper setting of energy market clearing prices to ensure that market clearing prices reflect the costs of all resources that are serving load. PJM has noted that in the recent cold snap, out-of-market uplift payments increased by at least a factor of 10 during the severe cold weather operations which indicates the operating costs of some generation that was needed to meet the electricity demand was not reflected in clearing prices. Just to be clear, all of the resources that are serving load are compensated, in some cases through

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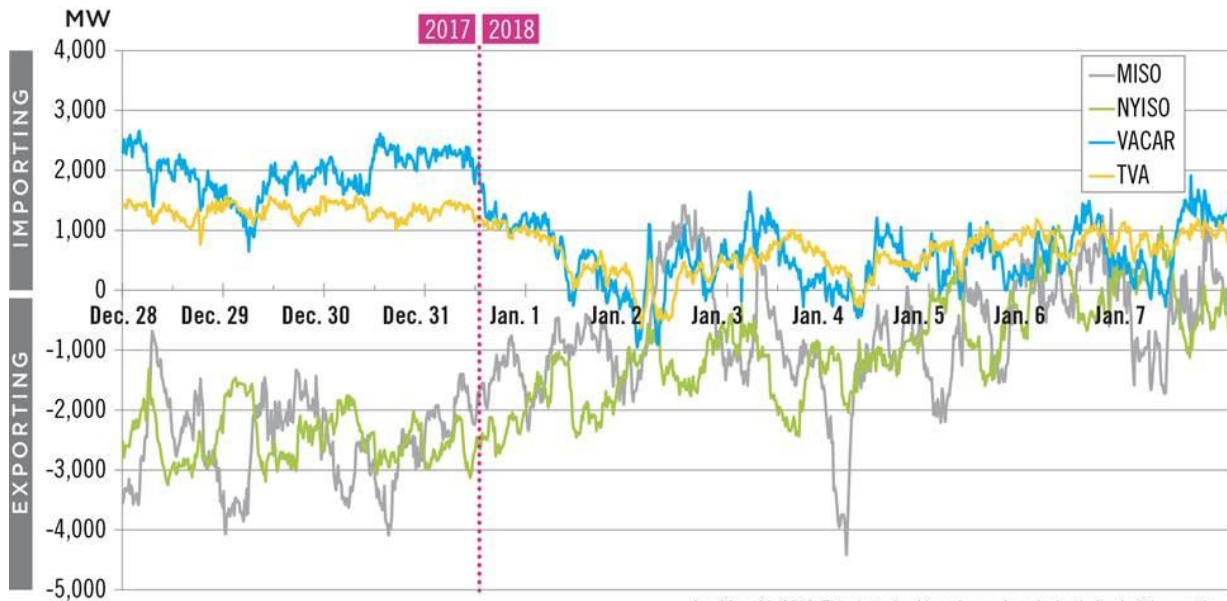
out-of-market “uplift” payments. But in some cases, such costs are not properly reflected in locational marginal prices, which could put these resources and all other resources needed to meet demand at a disadvantage because market prices are not reflecting the true cost to serve electricity demand. PJM has proposed energy market price formation reforms to address these issues and we believe such reforms should be addressed in a timely manner. These reforms include both enhanced reserve pricing and energy price formation reforms. PJM has also flagged this issue for FERC consideration in the context of FERC’s energy price formation efforts.

Questions from Senator Tina Smith

Question 1: I understand that transmission played a key role in keeping up with high energy demand on the East Coast. PJM, for example, was reportedly importing power from MISO in the Midwest during the bomb cyclone. Do you feel that new transmission lines connecting the Midwest to the East Coast would be good for grid reliability and resilience?

As outlined below, power flowed from MISO to PJM in a number of hours during the recent cold weather snap. This power flow was as a result of economic decisions made by generators in the MISO region to sell into PJM as a result of higher prices during this period in the PJM region.

PJM Interchange, Dec. 28, 2017 to Jan. 7, 2018



As of Jan. 31, 2018. This data should not be used as the basis for decision-making.

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Question 2: What are the obstacles to getting more transmission lines built? How can the federal government help facilitate more transmission projects in the future?

In general, PJM has been successful in getting more transmission lines built. To date, net transmission investments authorized under PJM's Regional Transmission Expansion Plan (RTEP) since 2000 total is approximately \$35.4 billion.

With respect to getting more transmission built for resilience, Mr. Ott's written testimony regarding "balancing the need for transparency with the need to protect critical infrastructure" indicated that although a hallmark of RTO operations and PJM's planning process has been transparency, in the future, PJM believes a balance needs to be struck in this area. On the one hand, transparency in detailing to stakeholders the need for particular grid improvements is very important, and on the other, we do not want to inadvertently publicly release highly sensitive information about vulnerabilities on the grid.

To date, the regulators and the RTOs have addressed this issue through labeling highly sensitive grid information as Critical Electric Infrastructure Information (CEII). But the CEII rules utilized at FERC and at the state level are designed around a "right to know" approach, with some verification of the bona fides of the requestor. However, the federal government doesn't approach classified information this way. Rather, that system is based on the provision of access based on a demonstrated "need to know."

It may be time to consider evolving our release of a limited set of highly sensitive infrastructure information from a "right to know" to a "need to know" basis. PJM thinks this can be accomplished in a manner that also allows the opportunity at the appropriate time for customers and the public to examine (and potentially challenge) the costs of any grid upgrade through the regulatory process. But for this balance to be workable, PJM will need direction from FERC – as much of its regulatory regime to date has, understandably, been driven by moving toward greater transparency without a corresponding focus on tightening rules around CEII.