UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

PJM Interconnection, L.L.C.	**Docket No. ER19-1486-000**

AFFIDAVIT OF A. JOSEPH CAVICCHI
ON BEHALF OF THE PJM POWER PROVIDERS ("P3") GROUP

May 15, 2019

I. INTRODUCTION AND SUMMARY

A. Qualifications and Introduction

1. My name is A. Joseph Cavicchi and I am an Executive Vice President of Compass Lexecon, 200 State Street, Boston, MA 02109. Compass Lexecon is an economics and financial consulting firm that provides corporations, law firms, and governments with analysis of complex economic and financial issues for use in legal and regulatory proceedings, and in strategic decision-making. Compass Lexecon is actively involved in a wide variety of matters that can arise in the areas of economics and finance. Our practice areas include energy and environmental economics, antitrust, industry regulation, securities, damages, intellectual property, as well as business consulting and public policy analysis.

2. I have testified on several occasions regarding wholesale electricity market competitiveness and design issues at the Federal Energy Regulatory Commission ("FERC" or "Commission"). In addition, I have testified on power supply procurement plans in Pennsylvania and Ohio and on qualifying facility pricing policy and wholesale market design policy in the state of California. Finally, I have written articles on electricity industry structure and policy and run workshops on U.S. energy, capacity and ancillary services market designs. My Curriculum Vitae, Attachment A, describes my experience in greater detail.

3. I have been asked by the P3 Group to review and comment on the PJM Interconnection, L.L.C.'s March 29, 2019 Enhanced Price Formation in Reserve Markets filing.[1] PJM's Filing proposes to modify its existing reserve market structure by: 1) Introducing day-ahead Ten-Minute Synchronized and Non-Synchronized Reserves ("TMSR" and "TMNSR") markets;[2] 2) Eliminating PJM's Day-Ahead Scheduling Reserve ("DASR") market and replacing it with a new thirty minute operating reserve market (or "Secondary Reserve" in PJM's proposed tariff language); 3) Aligning these newly defined day-ahead market reserve products with companion real-time market reserve products; and, 4) Introducing new Operating Reserve Demand Curves ("ORDCs") to value those reserves (and energy as appropriate) beyond Minimum Reserve

[1] Enhanced Price Formation in Reserve Markets of PJM Interconnection, L.L.C., Docket No. ER19-1486, March 29, 2019 ("PJM Filing").

[2] Note PJM's tariff refers to ten-minute synchronized and non-synchronized reserves as "Primary Reserves."

Requirements ("MRRs") that are necessary to reliably operate PJM's system as it confronts the growing supply of intermittent resources.

B. Overview and Summary

4. PJM's current reserves market design does not equitably compensate resources for the services that they provide and PJM's operators must frequently intervene in the market processes to ensure sufficient resources are available to ensure reliable system operations. These interventions occur in large part because PJM's reserve market design is somewhat unconventional when compared to most other U.S. ISOs. PJM does not include ten-minute synchronized and non-synchronized reserves in its day-ahead market and thus does not co-optimize its expected real-time energy and reserve requirements in the day-ahead time frame. PJM instead procures DASR in the day-ahead time frame, and Primary Reserves (TMSR and TMNSR) in the real-time market. In addition, PJM currently bifurcates the provision of synchronized reserves (TMSR) in two tiers, such that resources providing the same service are compensated at different prices and the two tiers' resource performance obligations are not consistent. Because PJM cannot rely on the DASR to reliably meet reserve requirements in real-time, PJM biases net-load inputs into its Intermediate Term Security Constrained Economic Dispatch ("IT SCED") tool (which commits resources with start-up times of two hours or less) to account for net-load uncertainties that require additional reserves be available in real-time. PJM's Filing appropriately recognizes that continued reliance on its current reserve market design structure will perpetuate biasing and other out-of-market actions by PJM operators, and result in unduly discriminatory and inefficient (i.e., unjust and unreasonable) market prices.[3]

5. PJM's Filing proposes to harmonize its day-ahead and real-time reserve markets and introduce improved pricing that recognizes the value of resource flexibility to meet unpredictable shifts in net-load intra-hour and throughout the operating day. In the absence of efficient pricing for resources that stand prepared to provide reserves (and ultimately help PJM meet real-time ramping requirements), PJM would either continue taking non-market-based actions that unreasonably distort prices, unduly discriminate among different resources providing the same product and effectively eliminate shortage pricing or face greater incidence of shortage driven

[3] PJM Filing at 5-9.

pricing and the acknowledged risk of possible loss of load events. Neither approach represents an acceptable long-term, reliable operational paradigm for PJM to accommodate a rapid growth of intermittent resource supply.

6. PJM's two-tier pricing and performance structure for synchronized reserves often results in zero prices at those times when locational marginal prices ("LMPs") are highest. In the first full year since PJM introduced five-minute interval settlement pricing (starting April 1, 2018) Regional Transmission Organization ("RTO") and Mid-Atlantic Dominion ("MAD") synchronized reserve prices have been zero in over one third of the top 5 percent highest energy price intervals. The prices for synchronized and non-synchronized reserves do not come close to covering PJM's cost of these services and uplift payments are required to make up the difference. The prices for these services are not revealed through a uniform clearing price. Finally, the market design does not incentivize consistent performance of those resources providing these services.

7. Approval of PJM's proposal will replace PJM's current reserve market design with a proven design consistent with that used by many U.S. Independent System Operators ("ISOs"). By aligning the provision of reserves in the day-ahead and real-time markets PJM can better maximize energy and ancillary services market efficiency. Resources assigned to provide reserves will receive uniform compensation and face appropriate incentives to perform. Market prices will reflect the value of flexibility necessary to ensure reliable system operations and signal to existing, new and load responsive resources that these services will be compensated equitably and independent of technology type.

8. Moreover, the proposed design of PJM's ORDCs is a reasonable basis for the development of a pricing schedule to value reserves. By basing the shape of the curve on the probability that reserves fall below MRRs measured based on observed real-time net-load uncertainty, PJM explicitly links its flexibility requirements to its reserve pricing schedule. The additional reserves that PJM will procure using the ORDCs will be optimized based on the economic trade-offs among resources that results when procuring a complete set of energy and reserves in the day-ahead and real-time markets. The reserves that are procured will be converted to energy when necessary in real-time and the reserve quantities are carefully calculated to replace the frequent need for operator intervention. PJM proposes 24 ORDCs to capture the intra-day and seasonal variation of net-load uncertainty. The ORDCs strike a balance between the need to ensure market-based

reliable system operations during times of greatest uncertainty while recognizing the considerable variation in these uncertainties throughout the year.

9. In addition, the adoption of the proposed ORDCs includes the important design attribute where energy prices reflect the value of reserves whenever the quantity of cleared reserves falls along the ORDC pricing schedule. In addition, during those infrequent times when there are reserve shortages, prices rise while the supply offers of resources need not reflect energy shortage conditions as the ORDCs incorporate the reserve shortage pricing into the energy prices. The ORDCs incentivize resources to offer at their short-run marginal cost as they are not compensated if they are not providing energy and/or reserves.

10. PJM's analysis of the market impact of its ORDC proposal focuses solely on costs. However, PJM's proposal provides additional benefits that cannot be readily quantified using historical data. First, load will be further incentivized to participate in the energy and reserve markets. With the ongoing move toward increased battery storage resources and transportation electrification, sending efficient wholesale price signals becomes more and more critical to optimize consumption patterns. Next, energy storage resources will be able to better optimize charging and discharging cycles. Third, importers and exporters will face prices that reflect the true value of energy and reserves in PJM facilitating more efficient decision making in the spot markets. Finally, retail and utility default service providers will be able to better hedge the costs of uplift whereas now these costs are unpredictable and drive up costs for consumers.

11. In the absence of PJM's proposal, other action would need to be taken to value resource flexibility and accommodate the increased growth rate of intermittent resources. Experience with potential alternative market design changes such as the development of a ramp capability product, or the introduction of flexibility requirements in the capacity market design, indicates these options would present implementation challenges. PJM's proposal to use increased reserve requirements as a means for valuing additional flexibility is a reasonable and effective approach for accommodating growth in intermittent resources. It also provides virtually the same result – increased flexibility – and there is no requirement that ISOs follow a standardized market design. Additionally, PJM's proposal has been completely developed and can be implemented far quicker than if PJM was required to develop an entirely new product. PJM's proposed market design

changes will position PJM to meet future uncertainties without relying exclusively on net-load biasing and out-of-market actions.

12. The growth of near zero-marginal cost intermittent resources will continue to displace conventional capacity resources. However, there remains a need for a diverse mixture of capacity resources to respond to the now familiar net-load changes associated with variation in intermittent resource output. It is critical that the electric system have available sufficient flexible resources to meet net-load variations. However, capacity resources are not directly compensated for providing the ramping flexibility that PJM already needs to manage forecast and resource availability uncertainties. Providing appropriate compensation for resource flexibility in the energy and reserve markets will offset revenues received from the capacity market and reduce capacity market offer prices and the estimated net-cost of new entry. Those resources that can most cost effectively provide these services will be more competitive than resources that cannot and over the long-term the supply mixture will evolve to represent this difference in resource performance.

13. PJM's proposal is an effective and efficient approach for ensuring that its market design stands ready to accommodate increased uncertainty in the future. Moreover, PJM's proposal will provide price incentives for buyers and sellers to respond to future market conditions and ensure flexibility will be valued more efficiently by the operating reserves markets. Perpetuating a market design that cannot ensure fair and efficient pricing and must rely on persistent operator intervention in the market processes to ensure reliability will further move PJM away from the market design necessary to accommodate the future resource mixture. By relying on market competition PJM will bring forth investment and innovation while minimizing costs to consumers, especially over the longer-term. Finally, PJM's proposal can be expected to provide incremental reliability benefits as it substitutes operator judgement with reserve purchases at quantities that are directly tied to PJM's requirements for maintaining reliability. I recommend that the Commission find PJM's current reserves markets' structure and pricing to be unjust, unreasonable and unduly discriminatory and approve PJM's Filing.

II. PJM'S CURRENT OPERATING RESERVE MARKET DESIGN DOES NOT SUPPORT EFFICIENT MARKET OUTCOMES

14. PJM's current reserve markets are the result of an evolution in market design that built upon the definition of PJM reserves at the time of the market's introduction and does not reflect

operating reserve market design best practices today.[4] PJM's day-ahead market design includes only a single thirty-minute reserve product -- day-ahead scheduling reserve -- that does not align with the ten-minute reserve products that are procured in real-time (synchronized and non-synchronized reserves).[5] PJM's real-time ten-minute synchronized reserve market provides for the purchase of two-different products (referred to as Tier 1 and Tier 2) that are not uniformly priced and do not require suppliers to meet the same performance obligations.[6] The shortage pricing mechanisms associated with the reserves does not properly value reserves during reserve shortage conditions.[7] In the absence of consistent and effective day-ahead and real-time reserve markets PJM finds itself in the position of relying on regular operator (generator dispatcher) intervention to ensure reliable operations.

15. As PJM's Mr. Pilong explains, PJM operators routinely apply a load bias when executing PJM's IT SCED to account for errors in forecasts and generator responses that are observed on a daily basis.[8] However, the application of a bias is not based on transparent rules or protocols, but relies on operator "training, experience, and judgement" with the amount of the bias varying depending on operator.[9] In addition, PJM's Mr. Keech notes, from an "operators'[sic] perspective,

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4 PJM introduced its real-time synchronized reserve market in December of 2002, but its Tier 1 and Tier 2 synchronized reserve product definitions pre-date the establishment of the market. (PJM Market Monitoring Unit, 2002 State of the Market, March 5, 2003 at 96). PJM's DASR was introduced in June of 2008 in association with the PJM RPM settlement agreement (PJM IMM, 2009 State of the Market Report for PJM, Monitoring Analytics, Volume II, March 11, 2010 at 396). PJM's ten-minute non-synchronized reserve market was introduced in 2012 in association with PJM's compliance with Commission Order No. 719 (PJM Interconnection, L.L.C., FERC ¶ 61,057 (2012) at P 96). In 2008, after almost a decade of experience with competitive electricity market designs, it was acknowledged that core design elements of wholesale electricity markets are co-optimized day-ahead and real-time energy and ancillary services markets (Helman, U., Hobbs, B. and O'Neill, R., Competitive Electricity Markets, Design, Implementation and Performance, Chapter 5, The Design of US Wholesale Energy and Ancillary Service Auction Markets: Theory and Practice, Elsevier Global Energy Policy and Economics Series, 2008 at 179).

5 PJM Filing at 39.

6 PJM's Filing and attached affidavits provide considerable detail describing the inefficiencies of the Tier 1 and Tier 2 product definition differences, performance problems, and the resulting undue discrimination under the current synchronized market design.

7 PJM Filing, Attachment D, Affidavit of Adam Keech on Behalf of PJM Interconnection, L.L.C., ("Keech Affidavit") at PPs 10-11.

8 PJM Filing, Attachment E, Affidavit of Christopher Pilong on Behalf of PJM Interconnection, L.L.C., ("Pilong Affidavit") at PP 8-11.

9 Pilong Affidavit at P 9.

it always better to be long than short," which will result in excess supply, suppressing prices, each time being "long" supply was unnecessary.[10]

16. Moreover, the empirical analysis presented by Mr. Pilong is particularly striking as it reveals systematic net-load biasing of the inputs to the IT SCED that appear to have been largely unreported prior to the submission of PJM's filing.[11] In those instances where biases are positive, Mr. Pilong reports average bias quantities of hundreds of megawatts to as much as nearly 1,500 MW depending upon the observed synchronized reserves surplus.[12] The extent to which net-load biasing is an undocumented integral element of PJM operators' day-to-day routine when running the IT SCED is alarming and impacts price formation at precisely those times when it is most important for the markets to signal the value of flexibility to respond to varying system conditions.

17. In addition, operators also bias other inputs which can affect the real-time dispatch and undermine the efficiency of the energy and ancillary services markets. For example, PJM's IMM regularly reports that PJM's operators can bias the estimate of Tier 1 synchronized reserves in the hour ahead ancillary services optimizer to reflect uncertainty in short-term load forecasting and expected generator performance.[13] By biasing the Tier 1 reserve requirement, demand for Tier 2 reserve resources is modified and affects the prices for Tier 2 reserves. Moreover, under certain hot and cold weather alerts or other specific emergency conditions PJM operators can increase the DASR requirement using a Seasonal Condition Demand Factor that is 3.75% for winter and 2.45% for summer and is yet another way for operators to increase the amount of resources available in real-time to respond to unexpected system operational conditions.[14] PJM relies heavily on a mixture of non-transparent operator actions to ensure that its can operate the power system reliably.

18. Finally, operators may also manually initiate out-of-market actions to commit additional generation reserves.[15] While PJM indicates these operator actions are less frequent and reserved

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10 Keech Affidavit at P 51.

11 Pilong Affidavit at Table 1. A review of the past few years of PJM's IMM's state of the market reports does not appear to mention the biasing practice described by Mr. Pilong.

12 Id.

13 Monitoring Analytics, Independent Market Monitor for PJM, 2018 State of the Market Report for PJM, Volume II: Detailed Analysis, 3.14.2019 ("PJM 2018 SOM") at 463. See also Monitoring Analytics, Independent Market Monitor for PJM, 2017 State of the Market Report for PJM, Volume II: Detailed Analysis, 3.8.2018 at 194 and Table 10-14.

14 PJM 2018 SOM at 479.

15 Pilong Affidavit at P 18.

for those instances where resources with longer start-times and potentially longer minimum commitment periods prevent IT SCED from making these decisions, committing these longer-start time resources for reserves results in other resources being backed down, unnecessarily suppressed market clearing prices, and often results in uplift payments.[16]

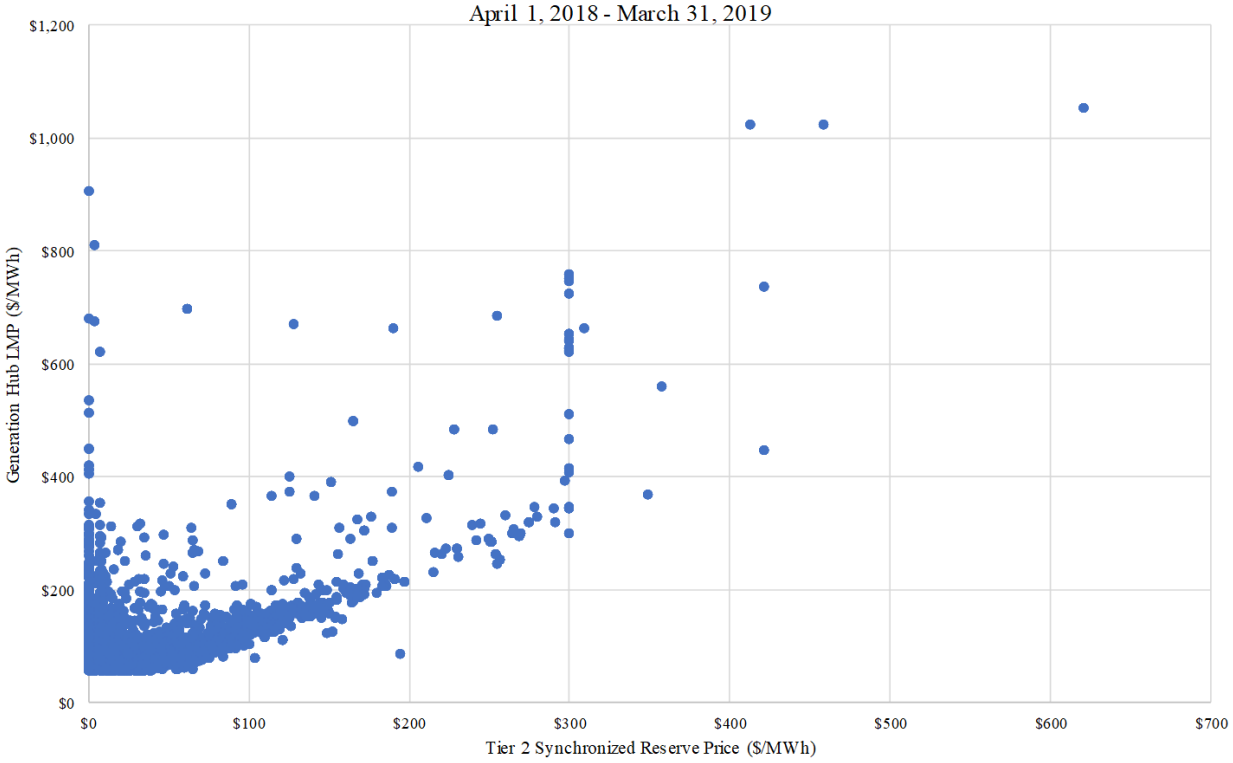
19. Empirical analysis of prices and costs reinforces the inefficiencies associated with the current reserve market design that PJM seeks to resolve with its proposal. Reliance on operator intervention to positively bias modeling inputs to ensure sufficient reserves are available results in additional resource commitments that put downward pressure on prices. As PJM explains, operator actions and other aspects of the Tier 1/Tier 2 product construct often result in synchronized reserve prices of zero, even at times when system conditions would be expected to result in reserves having positive value.[17] Figure 1 further reinforces the frequency with which synchronized reserve prices are zero at times when PJM's energy prices are at their highest levels. Figure 1 plots the top 5% of reported 5-minute Locational Marginal Prices (LMPs) for PJM RTO hub prices (excluding MAD pricing hubs) against the 5-minute synchronized reserve prices for the RTO region for the period April 1, 2018 – March 31, 2019. Figure 1 shows that RTO synchronized reserve prices are often zero in intervals where LMPs are at their highest levels. In fact, 35% of the five-minute interval synchronized reserve prices are zero during those intervals where system energy prices reach their highest values.[18]

[16] Pilong Affidavit at PP 18 and 20 and Keech Affidavit at PP 50-53.

[17] PJM Filing at 7 and 20-21.

[18] Using MAD synchronized reserve prices 33% of the five-minute intervals where system energy prices were highest were equal to zero.

Figure 1: Top 5% Generation Hub Prices vs. Concurrent Tier 2 Synchronized Reserve Prices, PJM RTO
April 1, 2018 - March 31, 2019



Note: Includes the AEP Gen Hub, AEP-Dayton, Chicago Gen, Chicago Hub, N. Illinois, and Ohio Hub generation hubs.
Source: PJM Interconnection LLC and Compass Lexecon Analysis.

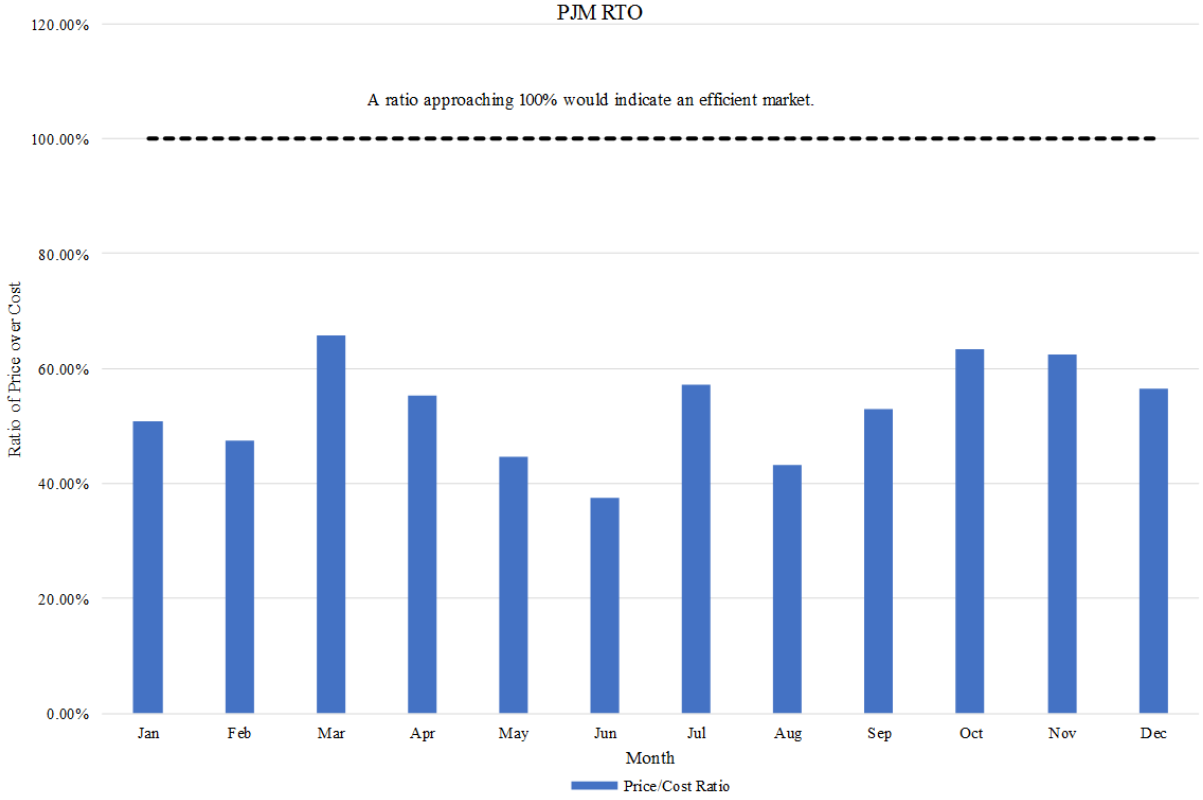
20. In addition to the reserve pricing and performance problems that PJM identifies in its filing,[19] the PJM IMM reports other metrics that reveal further inefficiencies in the PJM reserve market design. For example, Figures 2 and 3 shows Tier 2 synchronized reserve prices for PJM's RTO and MAD regions fall considerably below the level necessary to cover the costs incurred by PJM to compensate providers of these reserves (with a price to cost ratio averaging only a little over 50%).[20] An efficient reserves market outcome would reveal a price to cost ratio that approached 100% indicating that market prices are high enough to cover the cost incurred by PJM to procure reserves. However, PJM's reserve markets -- even after accounting for the introduction

19 PJM Filing at Section II.

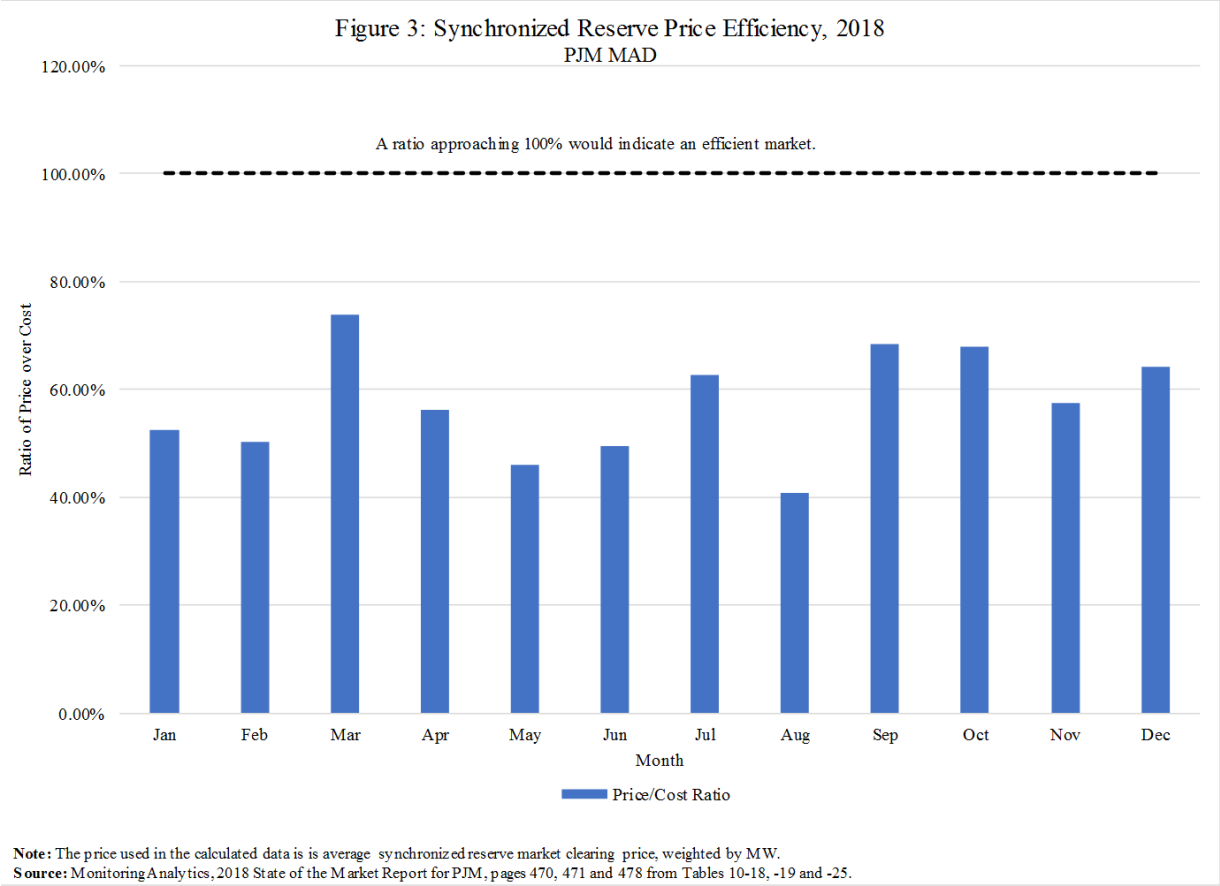
20 PJM's Independent Market Monitor ("IMM") reports that changing grid conditions, load forecasts, and unexpected generator performance, result in prices that do not always cover the full offer cost (including lost opportunity cost) for each resource. Because the synchronized reserve commitment occurs prior to the hour and price formation occurs within the hour (on a five-minute basis integrated over the hour), the realized within hour synchronized reserve price can be zero even when some tier 2 synchronized reserve is cleared. All resources cleared in the market are guaranteed to be made whole and are paid if the synchronized reserve market clearing price does not compensate them for their offer plus lost opportunity cost. See PJM 2018 SOM at 470.

of 5-minute settlements pricing in April of 2018 -- fall considerably below this cost coverage threshold. Similarly, Figure 4 shows the same price to cost ratio for PJM's non-synchronized reserve market. The 2018 average price to cost ratio for non-synchronized reserves is under 20% and clearly reveals the inefficiencies of the current market design.

Figure 2: Synchronized Reserve Price Efficiency, 2018
PJM RTO



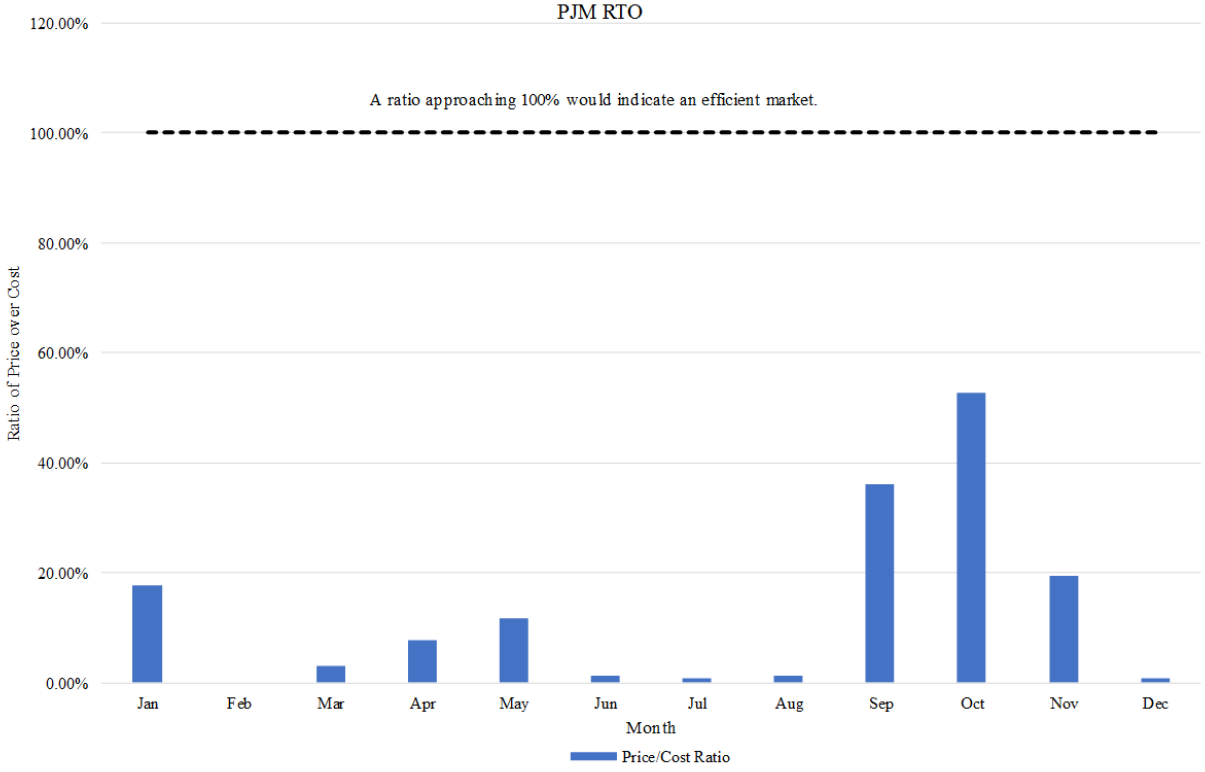
Note: The price used in the calculated data is average synchronized reserve market clearing price, weighted by MW.
Source: Monitoring Analytics, 2018 State of the Market Report for PJM, pages 470, 471 and 478 from Tables 10-18, -19 and -25.



21. The lack of cost recovery by those resources that are providing PJM's reserve services is in conflict with the Commission's prior finding that "[p]ayments made only to individual resources and recovered in uplift fail to send clear market signals."[21] In the absence of a transparent market clearing price that appropriately compensates resources providing reserves PJM will continue to incur uplift and not signal the value of flexibility that it requires to maintain reliable system operations.

[21] PJM Interconnection, L.L.C., 139 FERC ¶ 61,057 (2012) at P 63.

Figure 4: Non-Synchronized Reserve Price Efficiency, 2018
PJM RTO



Note: The price used in the calculated data is is average non-synchronized reserve market clearing price, weighted by MW.
Source: Monitoring Analytics, 2018 State of the Market Report for PJM, pages 470, 471 and 478 from Tables 10-18, -19 and -25.

22. Next, the design of the DASR that allows PJM operators to bias the DASR quantities creates additional inefficiencies.[22] It is likely that the absence of financially binding day-ahead primary reserve markets, and a real-time secondary reserve market, cause operators to bias the quantity of DASR to include a seasonal adjustment factor to ensure that a sufficient amount of reserves will be available in real-time. This increases the cost of DASR[23] and often requires the downward dispatch of other resources that would not be expected to result in the cost minimizing mixture of resources if the day-ahead market cleared the same reserve products as the real-time market. Again, operator actions are necessary which interfere with market efficiency and suppress prices.

23. Finally, PJM's real-time shortage pricing framework cannot be expected to accurately reflect real-time shortage conditions with continued operator initiated biasing. Operator actions

22 PJM 2018 SOM at 480-481.

23 Id.

should be reduced by accounting for uncertainties that can be estimated based on actual operational data used to define the ORDCs. Thus, minimizing operator intervention should allow real-time reserve and shortage prices to increase when appropriate and "ensure that a resource is compensated based on a price that reflects the value of the service the resource provides."[24] Moreover, the penalty factors relied upon by PJM in its market design should be consistent for resources providing energy and reserves.

24. As is shown above, the positive biasing that results from PJM operator actions puts downward pressure on market prices and ultimately distorts the incentives of buyers and sellers by not appropriately signaling the value of reserves and resource flexibility.[25] Also, operator initiated biases can be expected to reduce or wholly avoid instances where emergency procedures occur, which while good for reliability, also pushes down prices. It is understandable that PJM operators prefer not to be "short," but pricing is expected to reflect system conditions and accurately reflect the value of a resource providing reserves. Biasing the commitment and dispatch tools in a way that clearly suppresses prices, pays resources providing the same services different prices, and produces uplift, is not indicative of an efficient market design.

25. PJM's IMM also recognizes the inefficiencies that result when operators take actions that should be accounted for in the market design. For example, PJM's IMM recently noted in the Commission's PJM fast-start resource pricing docket that: "conservative operators take actions that mean that PJM needs additional reserves," and "these extra reserves are not included in reserve targets when defining scarcity [fn omitted]. Conservative operator actions are not directly priced and suppress prices at times when prices should be higher."[26] PJM's proposal responds head-on to the ongoing and likely growing market inefficiencies by reducing and minimizing the need for frequent significant operator intervention in the market processes.

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[24] Order No. 825, Settlement Intervals and Shortage Pricing in Markets Operated by Regional Transmission Organizations and Independent System Operators, 155 FERC ¶ 61,276 (2016), (hereinafter "Order No. 825") at P 162.

[25] While PJM seeks to limit the biases it introduces via its operator actions, the impacts are clearly significant. See PJM Manual 11: Energy & Ancillary Services Market Operations, Revision: 104, Effective Date: February 7, 2019, Section 6: Reserve Requirements in PJM Energy Markets at 104 ("The goal of the PJM is to develop schedules that preserve the security of the PJM RTO on an unbiased basis for all PJM Members.")

[26] Initial Brief of the Independent Market Monitor for PJM, FERC Docket No. EL18-34-000, February 12, 2018 at 2.

26. In addition, PJM's current reserve market design reliance on different reserve products in the day-ahead and real-time markets can contribute to energy price divergence between the day-ahead and real-time markets and create opportunities for virtual traders to profit without enhancing market efficiency. In the case of PJM's current energy and reserve market design, the day-ahead market does not account for the synchronized and non-synchronized reserves required in real-time and instead commits resources to provide DASR regardless of whether those resources represent the day-ahead market welfare maximizing mixture of resources.[27] Thus, the resources that receive schedules in the day-ahead market would not be expected to be the least cost mixture of resources to provide energy and reserves in real-time. Moreover, given the operator biasing to account for uncertainties, the mixture and dispatch of resources operating in real-time may notably differ relative to day-ahead schedules. The variation in reserves procurement can result in different system transmission constraints between day-ahead and real-time and create energy arbitrage opportunities that are driven by the definition of the reserve products as opposed to price convergence driven by underlying differences in expected supply and demand.

27. It is well understood that when modeling inputs vary between the day-ahead and real-time markets it may create opportunities for virtual traders to profit without enhancing market efficiency.[28] If a market participant uncovers profitable pricing differences that are driven by modeling differences, there can be opportunities to profit using virtual trades. However, because the modeling differences are driving the price differences, day-ahead and real-time price convergence would not result, and the expected price convergence efficiencies associated with virtual trading would not be realized.

28. PJM's experience with its current reserve market design clearly shows that its operators cannot rely on this market design to provide a sufficient amount of reserve resources to reliably meet demand. Continued reliance by PJM operators on net-load biasing in its IT SCED and biasing in other operator system reserve requirements undermine energy and ancillary services market efficiency and perpetuate a lack of transparency in the market commitment and dispatch process.

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[27] Specifically, the day-ahead market maximizes the benefits minus the costs for a given set of supply offers and demand bids subject to system and resource operational constraints. This maximizes welfare and minimizes the costs of those resources receiving day-ahead market schedules.

[28] See, for example, Virtual Transactions in the PJM Energy Markets, PJM Interconnection, October 12, 2015 at 41-47. Note that market participants may find these virtual trading profit opportunities without having any knowledge of what is causing the pricing patterns.

An efficient market design should ensure reliable system operations without placing operators in the position of regularly having to make so many significant adjustments. PJM's current reserve market design drives up costs, does not maximize welfare, and unduly discriminates providers of synchronized reserves. Given this situation, the Commission should conclude that PJM's current reserve markets design is unjust and unreasonable.

III. PJM'S PROPOSAL IMPROVES MARKET EFFICIENCY AND ENSURES RELIABLE SYSTEM OPERATIONS

A. PJM's Proposal Adopts a Standard Wholesale Electricity Reserve Market Framework with an Efficient Pricing Structure

29. The PJM Filing proposes to make the following changes to PJM's reserve markets:

- consolidate the Tier 1 and Tier 2 products into one product, called "Synchronized Reserve," with uniform commitment, compensation, and performance obligations to meet all Synchronized Reserve needs;
- align the day-ahead and real-time reserve markets to ensure that the reserves needed for real-time operation are recognized on a forward basis during the scheduling processes for the next operating day.
- revise the current ORDC by:
    - changing the ORDC curve shape based on a systematic, probabilistic quantification of the same categories of load and supply uncertainties that PJM operators are currently trying to address when they bias dispatch schedules or take other out-of-market actions to guard against PJM falling short of its MRRs; and
    - raising the Reserve Penalty Factor to $ 2,000/MWh, to recognize that sellers could have legitimate opportunity costs up to that level during shortage conditions from foregoing energy market sales (or load reductions) in order to commit as reserves.[29]

[29] PJM Filing at 9.

30. PJM's proposed changes eliminate the inefficiencies described in Section II herein. First, the Tier 1/Tier 2 synchronized reserve product structure and pricing is clearly failing and consolidating these two tiers into a single synchronized reserve product is a logical evolution for PJM's synchronized reserves. Next, aligning the day-ahead and real-time reserve market designs ensures the appropriate mixture of reserves needed to maintain reliability is procured on a forward basis and creates strong incentives for resources with reserve schedules to perform in real-time when called upon to provide energy. Third, deriving operating reserve quantities that are consistent with the actual day-to-day and month-to-month variations that PJM's operators must be prepared to respond to so as to ensure reliability links the reserve obligations directly to the uncertainty that drives PJM's operator interventions. Finally, pricing these operating reserve quantities based on the probability of reserves falling below the MRR provides a strong theoretical foundation and appropriately values the reserves that PJM requires to operate its system reliably.

1. Tier 1/Tier 2 Consolidation and Day-Ahead/Real-Time Reserve Market Alignment

31. PJM's proposal to eliminate its discriminatory synchronized reserve products and introduce companion reserve markets in the day-ahead for synchronized and non-synchronized reserves and in real-time for secondary reserves will vastly improve PJM's reserve markets. Not only does PJM's proposal bring PJM's market design in line with the best practices of almost all other U.S. ISOs, but it importantly will establish day-ahead reserve obligations that will be the primary means by which reserves will be procured in PJM's markets. The day-ahead market will create schedules that better maximize welfare and new incentives will be created for resources that receive reserve schedules to perform in real-time.

32. As PJM explains in its filing, reserve resources' synchronized reserve performance is not surprisingly lacking.[30] Without a financially binding day-ahead market for reserves, the synchronized reserve penalty is the only means available for PJM to penalize non-performance in real-time, and even then assuring its effectiveness can be complex.[31] Moreover, the current

[30] PJM Filing at 17-20.

[31] The definition of an appropriate penalty is difficult in the absence of a readily available price to use that is related to the obligation assigned to the reserve provider. See, for example, the New York Independent System Operator's Manual 14, 4.3.3 Balancing Market Supplier Settlement – LBMP Energy Imports where a seller is charged a penalty based on the advisory price for those intervals for which it was scheduled in real-time and did not meet its obligations.

framework does not obligate Tier 1 synchronized reserve performance.[32] PJM's proposal, however, ensures resources will be available in the day-ahead market to provide reserves through its must offer requirement.[33] As PJM states in its filing: "all Generation Capacity Resources must offer all available reserve capability at all times, regardless of whether the resource is online or offline[fns omitted]."[34] Moreover, PJM's proposal improves the measurement of resources' ability to provide all reserves and revises aspects of its current market design that result in potentially inaccurate reserve capability data being relied upon by PJM.[35] Finally, PJM clarifies how demand response resources can participate as "economic load response" and the offer pricing rules that will be applied to these resources.[36]

33. The introduction of day-ahead markets for synchronized and non-synchronized reserves will improve PJM's market efficiency by aligning the procurement of reserves in the day-ahead market with the reserves currently procured in the real-time market. The day-ahead market unit commitment and scheduling will include accurate constraints for each of the reserve products and will ensure that the resources that receive schedules in the day-ahead represent the least-cost, welfare maximining mixture of resources. Moreover, PJM's proposal includes a newly added listing of synchronized and primary reserve provider requirements that must be met in order for resources to be eligible for certain credits provided as part of lost opportunity cost payments.[37] These changes will provide synchronized and primary reserve suppliers with improved incentives to be available and perform in the real-time market.

34. Similarly, the introduction of a secondary reserve real-time market provides alignment with the secondary reserves that will now be procured in the day-ahead market under PJM's proposal and also improves PJM's overall market efficiency. Secondary reserves will be subject to new performance requirements where resources that do not meet their day-ahead obligations will have to purchase secondary reserves in the real-time market to cover their non-performance.[38]

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32 Keech Affidavit at P 6.

33 PJM also proposes to retain a synchronized reserve performance penalty that has not been notably effective for incenting performance (See, for example, PJM 2018 SOM at 471-472).

34 PJM Filing at 81, noting that Capacity Generation Resources include Capacity Storage Resources. Note also PJM has some specific exceptions related to resources that cannot reliably provide reserves.

35 PJM Filing at 87-91.

36 PJM Filing at 91-94

37 PJM Filing, proposed Operating Agreement, Schedule 1, Section 3.2.3A.(f)(iii) and 3.2.3A.001(d)(ii).

38 PJM Filing, proposed Operating Agreement, Schedule 1, Section 3.2.3A.01 (f)-(h).

The introduction of the secondary real-time market represents a considerable improvement that will ensure that the value of secondary reserves are realized by PJM.[39]

2. ORDC Definition

35. The shape of PJM's proposed ORDCs is derived based on the uncertainties that underlie its forecasting processes, generator availability and net-interchange (imports minus exports).[40] As explained in Section II, these uncertainties currently result in PJM's operators being unable to ensure that sufficient reserves are available to maintain reliability in real-time without taking additional actions that often result in the commitment of additional resources, changes in other resources' dispatch, distorted prices and at times increased uplift. PJM's proposal represents a transparent market-based mechanism that will ensure the procurement of sufficient reserves and account for PJM's current and evolving system operational conditions. As PJM's IMM states: "The need to commit more reserves could instead be reflected in the ORDC, allowing the market to efficiently account for the reliability commitment in the energy and reserve markets."[41] This is what the approval of PJM's proposal achieves.

36. Basing the ORDC's derivation on actual PJM system operational conditions provides a demonstrated linkage to the uncertainties that PJM faces to maintain reliability day-to-day. A key innovation that PJM's proposed ORDCs introduce is the measurement of the historical probability that reserves will fall below PJM's Minimum Reliability Requirement (MRR).[42] Using a statistical analysis of the uncertainties that operators have faced over the most recent three years PJM can estimate the value of maintaining reserves beyond the MRR. To make this calculation PJM gathers historical data on the uncertainties faced when executing its real-time commitment and dispatch models and calculates the ratio of the number of instances where the total net-load variation (in MWs) would have resulted in reserves falling below the MRR for a number of individual reserve levels (i.e., reserve levels (MWs) above the MRR).[43] These resulting ratios are the probabilities that are then multiplied by a penalty factor representing the cost of maintaining

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39 PJM's DASR resulted in the payment of millions of dollars each year without an effective means to penalize non-performance (PJM 2018 SOM at 481.)

40 PJM Filing, Attachment F, Affidavit of Dr. Patricio Rocha Garrido on Behalf of the PJM Interconnection, L.L.C. ("Rocha Garrido Affidavit"), at P 11.

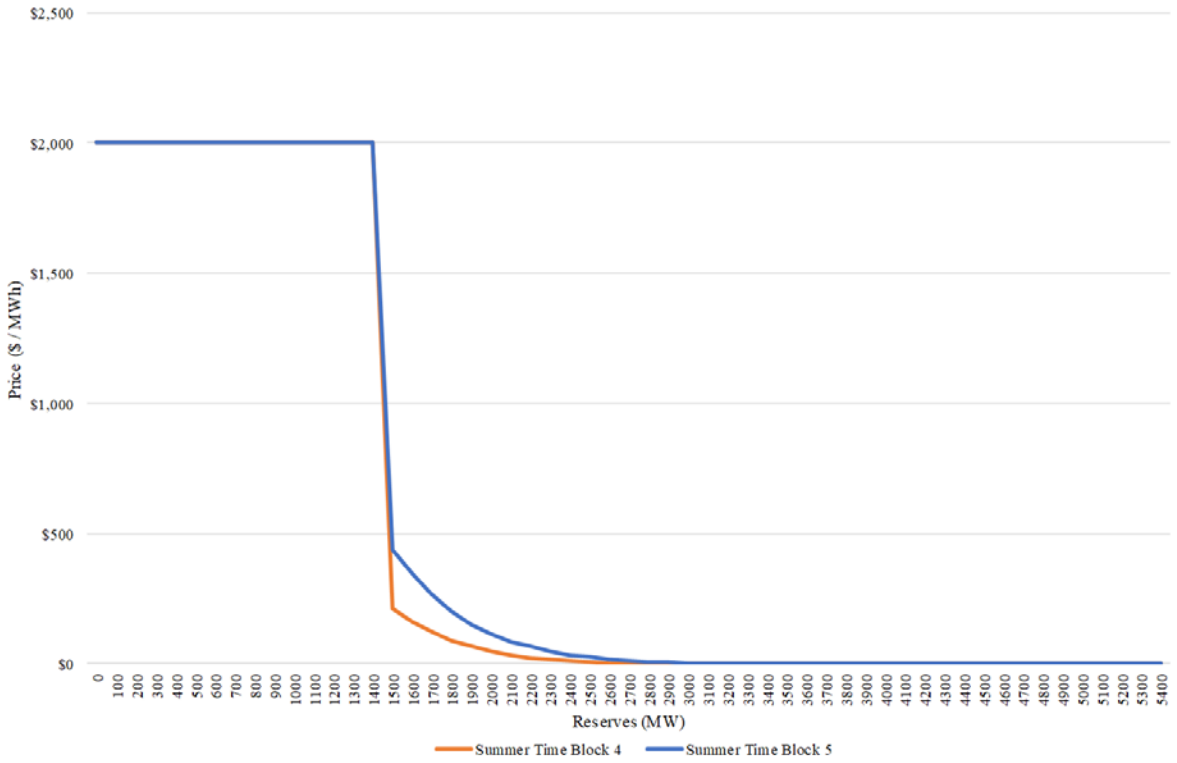
41 PJM 2018 SOM at 209.

42 Rocha Garrido Affidavit at PPs 15-19.

43 This process is described in greater detail in the Rocha Garrido Affidavit at PPs 15-19.

reserves above the MRR; the results are estimates of the expected value of maintaining reserves above the MRR. An example of the results of these calculations is shown in Figure 5 for summer time blocks 4 (11:00 – 14:00) and 5 (15:00 – 18:00).

Figure 5: Example of ORDC—Synchronized Reserves, Summer Time Blocks 4 and 5



Source: Synchronized Reserves—New Forced Outages Methodology, 3.13.2019, available at: https://www.pjm.com/committees-and-groups/task-forces/epfstf.aspx

37. The proposed ORDC shapes will vary diurnally and seasonally to ensure that the different system operating conditions that PJM faces throughout the year are captured accurately.[44] In total PJM identifies 24 time periods with ORDCs for each reserve product and the pricing schedule for the ORDCs can vary considerably for different times of the day and the year. For example, Figure 5 shows that the estimated probabilities of falling below the MRR for summer late afternoon time block 5 (15:00-18:00), relative to the early afternoon summer time block 4, reflect the increased value of reserves during peak summer hours when there is greater net-load uncertainty. Conversely, time blocks that have lower net-load uncertainty at reserve levels beyond

[44] The proposed shapes of the ORDCs can be seen at: https://www.pjm.com/-/media/committees-groups/task-forces/epfstf/20190314-pf/20190314-operating-reserve-demand-curves-new-forced-outages-methodology.ashx

the MRR have lower values.[45] However, importantly, the intra-day variations are accurately captured for the different seasons as each season has a period where the ORDC varies relative to other ORDCs for that season demonstrating the reasonableness of PJM's selection of multiple time periods across the four annual seasons.

38. Anchoring the ORDC's penalty factor at the MRR is consistent with the value of PJM's proposed penalty factor which represents the lowest cost at which PJM will incur costs to maintain reserves.[46] PJM's objective to avoid instances where reserves fall below the MRR is reasonable and consistent with the way the that PJM's operators ensure reliable system operations. Moreover, under PJM's proposal it would be expected that that most load will be hedged against real-time energy and reserve shortages, as is almost certainly the case now.[47]

39. PJM's proposed ORDCs will not be static and will be updated annually to reflect the evolution of PJM's system and the tools available to its operators to forecast load and intermittent resource output.[48] To the extent that PJM's resources perform better as the resource mixture turns over and/or becomes more flexible and responsive given the improved performance requirements, generator availability would be expected to improve. Forecasting tools can be expected to become more refined, and to the extent this reduces forecast uncertainty, this will be captured in the ORDCs.

40. The derivation of the proposed ORDCs will result in the procurement of additional secondary reserves relative to the DASR currently scheduled by PJM. As Mr. Pilong notes, an increase in the availability of secondary reserves can be expected to help respond to fuel supply disruptions that could impact a particular natural gas pipeline.[49] Moreover, to the extent that the future system reserve mixture can accommodate the risk of fuel supply disruption through increased reserves and more flexible resources, other potential market design changes may be unnecessary.

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45 Id.

46 Keech Affidavit at P 9.

47 While it is impossible to know exactly how much load is exposed to real-time prices, residential and small commercial customers purchase power under utility default service plans or retail supplier agreements which are typically priced over monthly, multi-monthly, yearly and multi-year terms.

48 PJM Filing at 68.

49 Pilong Affidavit at P 29.

41. Finally, an important underlying feature of the ORDC design is that it allows prices to rise as a result of a reserve shortage without relying on resource energy market offers to set prices. Moreover, in the absence of an ORDC, energy market scarcity pricing can only result in PJM under specific system conditions where market power mitigation is relaxed and energy supply (or load response) offers are allowed up to the level of price caps. With the ORDC, supplier offers are capped and reserve price increases under reserve shortage conditions appropriately drive up energy prices. In other words, in those instances where reserves are tight energy and reserve pricing will be driven by ORDC values based on actual system operational situations where the probability of reserves falling below the MRR is driving the determination of the value of reserves. Thus, during an operating reserve shortage the value of reserves that are relied upon to maintain reliability are in included in the energy prices.[50]

3. Additional Benefits Associated with PJM's Proposal

42. Greater efficiency in day-ahead and real-time energy and ancillary services prices provides additional important benefits to PJM. Not only will the mixture of resources committed and dispatched day-to-day be more efficient, the resulting energy and ancillary services market prices will reflect the value of the provision of these products to consumers and PJM's need to manually intervene in the markets will be materially reduced.[51] Resources providing energy and reserves facing these more efficient prices will be motivated to respond in the most cost-effective ways. Over time, buyer and seller responses will drive innovation and consumers will be better off.[52]

43. There are at least four additional benefits that can be expected with PJM's proposal. First, economic load response will have improved revenue opportunities and a greater incentive to participate in PJM markets. Next, new resources such as energy storage will be valued more

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[50] This is consistent with the Commission's finding that "shortage pricing … will help ensure that prices rise sufficiently and appropriately to allow supply to meet demand during an operating reserve shortage, and thus will more accurately reflect the value a resource provides" (Order No. 825 at P 163).

[51] It is critical to recognize that when PJM values the reserves beyond the MRR, the resources that provide these reserves become the resources that are committed and dispatched to provide energy as net-load changes. Operator intervention is minimized and competition among buyers and sellers is reflected in transparent market clearing prices as opposed to being obfuscated in uplift payments.

[52] The Commission recognized in Order No. 825 the importance of price formation for incentivizing appropriate market participant responses to commitment and dispatch instructions, maintaining reliable system operations and encouraging efficient investment in facilities and equipment (Order No. 825 at P 163).

efficiently by the market and existing resources will see increased value to improving flexibility. Third, retail suppliers and wholesale suppliers of utility default service will be able to hedge their costs of supply more completely as forward prices can be expected to include costs that are now recovered in uplift. Finally, importers and exporters can be expected to respond more efficiently when supplying energy and ancillary services in PJM.

44. Currently there is very little load that participates in PJM's energy and ancillary services markets.[53] However, as the electric system evolves and there are increased numbers of battery storage resources and growing electrification of transportation, the opportunity for economic load response commensurately grows and so too will the benefits of efficient wholesale electricity market prices. To optimize the timing of battery charging loads on the electricity system requires price signals that clearly indicate those times when it is least expensive to charge. At the same time, it is critical to signal to system loads those times when energy and reserves are most valuable as this will reward reductions in consumption that are also critical for optimizing the use of the underlying resource mixture. PJM's proposal recognizes the importance of being prepared to accommodate increased load responsiveness in its reserve markets and expands the opportunity for load to provide reserves at a level of up to 50%.[54] Moreover, as the supply of new resources that are designed to be directly responsive to wholesale market pricing grows, the competition between economic load response and supply side resources can be expected to also grow. PJM's proposed pricing structure supports greater load participation in both its energy and ancillary services markets.

45. PJM's proposal will also provide a much better market design for storage resources to be able to realize the value for the services that they can provide to the wholesale market. As the Commission recognizes, energy storage resources can provide a mixture of wholesale market products and can benefit significantly from PJM's proposal.[55] For example, when considering current battery technology, the degree to which charging and discharging cycles can occur (or

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53 McAnany, James, 2018 Demand Response Operations Report, Markets Activity Report: March 11, 2019, PJM at 12, and 15-18. PJM obtains load response primarily from demand response resources that receive capacity payments. These resources typically make energy offers at very high prices indicative of primarily obtaining value through capacity payments (2018 Demand Response Operations Report at Figure 9).

54 PJM Filing at 96.

55 Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, 162 FERC ¶ 61,127, (2018), Order No. 841, at P 4.

overall throughput maximized) is limited by degradation which shortens battery cell life. However, with synchronized reserve prices that reflect the value that energy storage resources provide, revenues can be increased during those times when the energy storage system state of charge allows.[56] With PJM's proposal energy storage resource's energy and synchronized reserves would be valued appropriately and recognize the flexibility that these resources have to respond to system requirements. The revenues available from reserve markets can be an important revenue stream for energy storage resources.

46. PJM's proposal can be expected to reduce uplift, which improves price transparency and allows these costs to be hedged reducing retail supplier pricing uncertainty. Moreover, establishing a $2000/MWh penalty factor price will provide a strong incentive for load to participate in the day-ahead market. Physical load hedging in the day-ahead market can be expected to reduce exposure to potential real-time energy and reserve shortage prices.[57] It is likely that very little energy and reserves will transact at shortage prices, however even with only a small probability of very high prices, buyers will exercise care and take those actions deemed appropriate for managing the cost associated with a possible shortage.

47. PJM's proposal can also be expected to benefit importers and exporters as more efficient pricing can guide better decision making on when to import and/or export to and from PJM. Improved price signals will appropriately signal the economic value to external sellers offering imports that can compete against more costly PJM internal resources. At the same time, when it is economical for PJM's internal resources to export power to adjacent regions improved price signals can be expected to result in more efficient PJM market seller decisions. However, because PJM's current reserve markets often show little or no value for the provision of reserves, it can be the case that energy is exported when it may be of more value if it remained within PJM and imports may be deterred when PJM would benefit from the additional supply.[58] PJM's

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[56] This assumes an energy storage system that is optimized to provide capacity, energy and reserves.

[57] To the extent that physical load does not hedge now, it can be the case that virtual trading would account for underbid load.

[58] The extent to which imports and exports are currently economic depends on a number of considerations and the discussion here does not take into account the specific requirements that can influence import and export transactions. Regardless, more efficient energy and reserve market pricing can be expected to result in more cost-effective import/export decision making at the margin.

proposal will provide more efficient price signals which can be expected to improve import/export decisions and enhance market competitiveness.

B. Projections of the Future Impact of PJM's Proposal on Energy and Operating Reserve Market Prices Cannot Capture all the Benefits of PJM's Proposal

48. PJM's Filing includes an analysis that projects the potential cost impact of PJM's proposal on wholesale load using data from 2018.[59] However, as PJM acknowledges,[60] its analysis can only provide a narrow examination of short-term market impacts based on the available historical bid and offer data without capturing the longer-term dynamic efficiency gains in social welfare that are expected to result given the improvement in commitment and dispatch.[61] While quantification of longer-term benefits is difficult absent accurate projections of underlying resource mixture changes and buyer and seller market bid and offer strategies, the longer-term dynamic efficiency impacts cannot be ignored. As such, the results of PJM's analysis can only be viewed in the limited context of the data available and don't represent a full analysis of the societal costs and benefits.[62]

49. As the Commission has recognized, focusing solely on the potential changes in market prices does not capture the benefits that result when "more accurate prices better inform investment decisions and increase overall market efficiency."[63] While PJM's analysis appropriately seeks to isolate the impact of its proposed ORDCs by acknowledging the important improvements in day-ahead schedules that will result with an appropriate representation of day-ahead reserve requirements in its day-ahead market (i.e., including a ten-minute reserve requirement), it cannot capture the total change in social welfare over time.[64] Supplier and load responses to the proposed market design over time can be expected to drive costs lower and increase overall welfare.

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59 Keech Affidavit at Section D.

60 Keech Affidavit at PPs 38 and 46.

61 Dynamic efficiency is concerned with the productive efficiency and innovation of firms over the longer-term.

62 PJM's ORDC impact analysis (Case B relative to Case C) primarily captures a transfer of market surplus from consumers to suppliers (Keech Affidavit at Table 5.).

63 PJM Interconnection, L.L.C., 167 FERC ¶ 61,058 (2019) at P 72.

64 PJM's IMM alleges that PJM's definition of "Case B" is inappropriate because it allows the Perfect Dispatch software to estimate day-ahead market commitments (by allowing the re-optimization of the commitment of steam units knowing the actual real-time requirements) that would be aligned with the reserve products proposed by PJM in its Filing (Monitoring Analytics, The Independent Market Monitor for PJM, ORDC Simulation Results: Version 2, May 10, 2019 at 2). However, contrary to the IMM's argument that this is a "departure from reality," it is clearly inappropriate to assume that the introduction of reserve requirements in

50. For example, as described in III.A., more efficient energy and operating reserve prices can be expected to bring forth market participant responses that appropriately value resource flexibility and provide incentives that reward both new and existing resources. At the same time, market participants that directly face operating reserve costs can be expected to take actions to reduce or hedge the financial impact.[65] These longer-term responses can be expected to increase competition in the provision of reserves and lower costs to consumers, offsetting prices increases that may result in the short-run.[66]

51. In addition, PJM's analysis does not consider the incremental improvement in reliability that will result from better reserve resource availability and performance. Assuming hypothetically that operators did not regularly intervene in the markets, Mr. Pilong shows that there would be a substantially increased frequency in synchronized reserves falling below the MRR.[67] This would result in an increased likelihood of emergency actions that could result in PJM taking actions to interrupt load. Under PJM's proposal the improved definition and valuation of reserves will provide operators with a level of reserves that is consistent with expected system operational requirements and ensure reliable operations and prices that reflect the value of these reserves.

52. Finally, over time PJM's capacity market pricing will decline, all else equal, relative to outcomes that what would have resulted in the absence of PJM's proposal. PJM's capacity market design purposefully results in prescribed offer and cost of new entry estimate adjustments as operating margins realized by resources in the energy and ancillary services markets change. At the same time, the mixture of capacity resources can be expected to evolve such that more flexible resources will be more competitive. To the extent that resources cannot meet the new reserve

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the day-ahead market that mirror the real-time market would not result in an improved unit commitment such that a comparison of PJM's Case A to Case C is wholly inappropriate.

65 Large loads could hedge against these reserve costs by entering into agreements with storage resources that provide for a means to hedge and self-provide these services.

66 It is also important to note that PJM's historical analysis appears to hold imports and exports constant, and these would change in the short-run, especially to the extent that exports realize greater value by remaining within PJM's region.

67 Pilong Affidavit at P 16 and Table 1.

obligations under PJM's proposal, they will be subject to financial penalties and would eventually be under pressure to retire.[68] This evolution will be beneficial to PJM's consumers.

C. PJM's Proposal is a Reasonable Approach to Address Future Operational Uncertainty

53. Absent the proposed package of operating reserve market changes PJM would need to implement other market design changes to eliminate load biasing and be prepared for an increasing supply of intermittent resources.[69] To date there is limited experience when relying on newly designed market mechanisms to incorporate operational uncertainty into the marketplace. Because system regulation service represents the first response available to system operators to meet uncertain net-load, regulation can respond to a certain amount of net-load uncertainty. However, regulation service is designed to meet very precise variations in system frequency and system operators carry only the limited amount necessary to meet the area control error frequency response requirements. To respond to growing net-load variations ISOs have elected to implement (or are considering) ramping products, and in the case of California, sought to introduce ramping requirements into capacity resource requirements. While these are approaches that can likely account for uncertainty and value resource flexibility, to date there is little evidence that either of these market design approaches are performing effectively.

54. The experience to date with ramping products indicates that proper implementation requires careful attention to the details, and that the product design must account for locational ramping needs.[70] A ramp capability product requires a pricing design, the establishment of a target ramp requirement (which experience to date indicates should be locational), and a penalty price. The ramp requirement is an additional constraint in the market optimization that reserves ramping capability to account for future net-load uncertainty. When the ramping requirement constraint

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[68] The impact of non-performance may also contribute to capacity performance penalties which result in additional financial burdens on poorly performing resources.

[69] It is important to note that while the Commission's recent order on PJM's fast-start resource pricing is expected to improve price formation (PJM Interconnection, L.L.C., 167 FERC ¶ 61,058 (2019)), PJM's enhanced reserve markets filing focuses on distinct problems associated with PJM's reserve market design and the accommodation of a growing supply of intermittent resources that need to be addressed separately.

[70] For an overview of ramping product performance, see Joseph Cavicchi and Scott Harvey, Performance of Ramp Capability Dispatch in the California ISO and MISO Electricity Markets, Monterey, California, Center for Research in Regulated Industries, 31st Annual Western Conference, June 29, 2018, available at: https://drive.google.com/drive/folders/0B7EOIMImYPaNbHZ4SFI1Wlh4Tlk

signals the need for additional ramp capability, a positive price results, up to the penalty price. The MISO and the California ISO each introduced a ramp capability product in 2016 and the experience thus far has been indeterminate.

55. In the case of the MISO, there was an extended period prior to the introduction of the ramp capability dispatch where MISO carefully analyzed the impact of introducing a ramp capability constraint prior to its introduction. The MISO's implementation has gone smoothly, but thus far ramp capability prices have often been zero.[71] While it may be the case that ramp capability is of little value in many dispatch intervals, there are a number of instances where prices are high in certain locations and ramp capability price is zero, which indicates that ramp capability may not be available in the appropriate location.

56. The CAISO's introduction of ramp capability dispatch in 2016 encountered some implementation problems.[72] The most significant difficulty centered on calculating the ramp capability target, which for over a year was not capturing the ramp capability required in future dispatch intervals.[73] However, both before and after the errors in the calculation of the ramp target were corrected on February 21, 2018, the shadow price of ramp capability was almost always zero in the real-time dispatch, implying that the ramp capability dispatch is still almost never impacting the ramp capability available in real-time.[74] The California ISO has carried out analysis suggesting that the lack of available ramp in the dispatch despite a zero price of ramp capability is a result of the current design allowing the ramp target for the California ISO to be met with resources located in other balancing areas within the energy imbalance market that are export constrained.[75] Thus, locational issues are also affecting the California ISO's ramp capability dispatch implementation.

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71 Id.

72 In the CAISO, there was also a several year period prior to the introduction of the ramp capability dispatch where CAISO had incorporated a "flexiramp" constraint in its real-time pre-dispatch that sought to account for upward ramping capability that may be needed in future intervals (See California ISO October 7, 2011 filing in Commission Docket ER12-50). The CAISO changed to ramp capability dispatch in late 2016 in order to introduce a more robust ramp capability product.

73 California ISO, Department of Market Monitoring, "Flexible Ramping Product Uncertainty Calculation and Implementation Issues, April 18, 2018; California ISO, Market Performance and Planning Forum, February 20, 2018; and Amber Motley, California ISO, "Flexible ramping product requirement and load forecast discussion," Market Surveillance Committee meeting, June 7, 2018.

74 Ibid. Cavicchi and Harvey at 15-16.

75 See, Lin Xu, California ISO, "Discussion on flexible ramping product," Market Surveillance Committee meeting, September 8, 2017, and California ISO, Market Planning and Performance Forum, October 5, 2017.

57. Next, in the state of California, the California ISO and California Public Utilities Commission (CPUC) have sought to define flexible capacity attributes as part of the resource adequacy process. However, they have encountered difficulty in defining attributes for flexible capacity and establishing appropriate "counting rules," have suspended the related stakeholder process, and are now focused on day-ahead market design initiatives that would incorporate flexibility requirements in the day-ahead market.[76] Thus, while the CPUC does require its resource adequacy process to ensure sufficient ramping capability, the ongoing efforts of the California ISO to modify its market design to compensate for resource ramping flexibility demonstrate continued concerns that do not appear to be fully resolved through the state's resource adequacy process.

58. Finally, refining reserve requirements and providing compensation for reserves beyond MRRs, as PJM proposes in its filing, is another approach to accommodate net-load uncertainty. PJM's proposal: (i) defines and values reserve products that are expected to provide essentially the same service as a specific ramping product (i.e., provide resource flexibility responsive to net-load uncertainty); (ii) can be readily implemented as it represents a completed market design that can replace the current unjust, unreasonable and unduly discriminatory reserves pricing mechanisms; and, (iii) complements responses that other ISOs may adopt to accommodate increased intermittent resources recognizing a one-size fits all approach is not necessary. By building upon current market design features PJM can readily implement a proven market design that will ensure reserves are available to reliably accommodate increasing amounts of intermittent resources.

IV. PJM'S MARKET DESIGN MUST EVOLVE ALONG SIDE ITS SHIFTING SUPPLY MIXTURE

59. As is widely recognized, PJM's supply resource mixture will become more and more reliant on intermittent resources in the coming years.[77] PJM's proposal, however, can be expected to accommodate increased growth in intermittent resources and ensure efficient spot market energy

[76] See, for example, California ISO, "Flexible Resource Adequacy Criteria and Must Offer Obligation – Phase 2, Second Revised Flexible Capacity Framework," April 27, 2018 section 5.4.3 and Appendix A at 39-40; California ISO, "Flexible Resource Adequacy Criteria and Most Offer Obligation Working Group Meeting," September 26, 2017, California ISO, "Fracmoo2 Working Group," August 2, 2017, and California ISO, "Flexible Resource Adequacy Criteria and Must Offer Obligation – Phase 2 Supplemental Issue Paper: Expanding the Scope of the Initiative," November 8, 2016. See also: http://www.caiso.com/informed/Pages/StakeholderProcesses/Day-AheadMarketEnhancements.aspx

[77] Keech Affidavit at PP 47-48 and Emma Nicholson White Paper submitted in this docket at Section III.

and reserves price formation. Ensuring that spot market prices are responsive to increased net-load uncertainty is critical to bring forth innovative market driven responses and to provide existing resources opportunities to invest in, and maintain and operate resources, that are flexible sources of energy supply.

60. PJM values this supply flexibility through energy and ancillary services spot market prices. While the capacity market performance framework addresses infrequent instances of performance assessment hours among actual capacity suppliers, the need for resource flexibility occurs intra-hour and its value is not directly captured in the capacity market (although flexible resources should be more competitive in the capacity market auctions). By signaling the value of flexibility in the energy and reserve markets any of a number of capable resources can respond to the requirements under PJM's proposed market design changes. This provides a platform for innovation such as the ongoing evolution with energy storage resources and the increased likelihood for growing load responsiveness. It will also more efficiently compensate conventional resources that are already being relied upon to provide flexibility.

61. Providing compensation for the provision of these reserve services in the energy and reserves markets will signal to resources that there is value in cost-effectively providing these services. In other words, relative to the current framework where a large amount of these reserves is not compensated, resources will be compensated, and subject to performance obligations. This will provide an incentive to improve the provision of these services and create more robust competition to provide these services.

62. Moreover, to the extent that some resources may have seen operating reserves of limited financial relevance in the past, the ongoing increase in intermittent resources will make revenues available for the provision of these resources more critical. The growth in intermittent resources decreases the financial viability of resources that continue to be needed to maintain reliable operations of the electricity system as these resources' production declines and system energy prices are pushed downward.[78]

[78] This impact has been observed primarily in California (See, Bushnell, J. and Novan, K., Setting With The Sun: The Impacts of Renewable Energy on Wholesale Power Markets, Energy Institute at Hass, Energy Institute WP 292, August 2018), however these same impacts have been projected for both New England and New York as a result of intermittent resource growth (See DeSocio, M., Market Implications of Significant Renewable Penetration, New York ISO, November 3, 2017 and ISO New England, 2016 Economic Study: NEPOOL Scenario Analysis, Implications of Public Policies on ISO New England Market Design, System

63. As the electricity system resource supply mixture evolves electricity market designs must also evolve when necessary. PJM is fortunate to enjoy the benefits associated with numerous new, low variable cost, gas-fired resources that have been constructed to replace aging and uneconomic resources. PJM's proposal recognizes the importance of efficiently pricing resource flexibility, which is relevant for both existing and new resources. While there is an expectation that spot market prices will rise modestly in the short-run in association with PJM's proposal (all else equal), maintaining reliability in the future while supporting innovation is essential. Increasingly nearly zero marginal cost resources and the increased likelihood of declining real-time price volatility will fundamentally change electric spot market pricing patterns making it critical to signal when and where flexibility is most needed.

64. This concludes my affidavit.

Reliability and Operability, Resource Costs and Revenues, and Emissions, November 17, 2017 at Figures 6-1 and 6-2 and Tables 6-6 and 6-7)

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

PJM Interconnection, L.L.C.)	**Docket No. ER19-1486-000**

AFFIDAVIT

I, A. Joseph Cavicchi, do hereby swear and affirm under penalty of law that the statements in the foregoing Affidavit of A. Joseph Cavicchi. are true to the best of my knowledge, information and belief.

Executed this 14th day of May, 2019

A. Joseph Cavicchi

Attachment A

CURRICULUM VITAE

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PROFESSIONAL EXPERIENCE

Compass Lexecon, Boston, MA
Executive Vice President, April 2013 – present
Senior Vice President, January 2007 – March 2013
Managing Director, 2003 – 2006
Vice President, 2001 – 2003
Senior Consultant, 1999 – 2001
Consultant, 1997 – 1999

Provides wholesale and retail electricity market regulatory economic analyses in connection with the restructuring of the US electricity industry. In particular, he advises clients in Federal Energy Regulatory Commission matters, state regulatory proceedings, and arbitration and court proceedings. He files testimony, affidavits and expert reports supported by economic analyses.

Extensive knowledge of wholesale market operations with general economic theory of contracting and electricity generation plant dispatch that provides companies with detailed analyses that impact both regulatory and business decisions. Actively involved in the electricity industry both before and after restructuring for a total of more than 20 years.

Tufts University, Medford, MA
Adjunct Instructor, Summer 2000

Taught graduate-level environmental economics.

Massachusetts Institute of Technology, Cambridge, MA
Research Engineer, 1997
Research Assistant, 1995 – 1997

Performed an analysis of water and electricity resources in Mendoza, Argentina. Developed a computer simulation model to support analysis and permit the display of results to a diverse group of stakeholders. Traveled frequently to Mendoza to interact with government officials and relevant institutions in an effort to establish electricity and water policy.

Massachusetts Institute of Technology, Cambridge, MA
Project Manager/Staff Mechanical Engineer, 1989 – 1995

Managed the development, engineering, and construction of a $40 million, 20 MW gas turbine-based cogeneration facility at the Cambridge campus. Directed all attributes of the project for its three-year duration. Involved extensively in energy conservation programs with emphasis on building and utility plant optimization through innovative engineering applications.

Carrier Building Systems and Services, Waltham, MA
Project Engineer, 1987 – 1988

Engineered and managed the installation of Energy Management Systems used exclusively for demand-side management. Interfaced direct digital control systems to mechanical equipment associated with thermal systems of industrial, commercial, and educational buildings.

EDUCATION

Massachusetts Institute of Technology, Cambridge, MA
S.M. in Technology Policy, 1997

Tufts University, Medford, MA
S.M. in Environmental Engineering, 1992

University of Connecticut, Storrs, CT
B.S. in Mechanical Engineering, 1987

CONSULTING EXPERIENCE

Electric Generation Companies, Trade Associations and Independent System Operators

Conducts economic analyses of the interaction of regulatory policies and wholesale power markets to support a wide variety of testimony, presentations and papers. Analyzes power market designs and evaluates the effectiveness of market power mitigation frameworks in conjunction with anti-trust analyses. Leads economic investigations of market participant bidding behavior associated with allegations of electricity marketplace manipulation. Runs workshops and seminars on power market design features.

Electricity Generation and Transmission Facility Developers

Oversees the development and implementation of security constrained dispatch modeling for proposed electricity generation units and transmission facilities locating in the Northeastern, Mid-Atlantic, and Midwestern United States. Analyses typically focus on determining infrastructure impacts on local and regional air pollutant emissions as well as on wholesale electricity prices. In addition, these analyses often include evaluation of estimated impact on social welfare of proposed infrastructure investment.

Electricity Distribution Companies

Provides economic analysis for electricity distribution companies in association with new wholesale electricity marketplaces in order to fulfill company regulatory commitments as providers of last resort or default electricity service. In most instances these companies require assistance with the development and issuance of requests for proposals, power purchase contract terms and conditions as well as rapid evaluation of commodity bids. Additionally, each assignment typically requires extensive analysis of customer demand patterns and wholesale market prices in order to develop market-based customer service cost forecasts.

TESTIMONY

NextEra Energy Resources, LLC

Before the Federal Energy Regulatory Commission, Docket No. ER18-1639-000. Prepared Answering Testimony of A. Joseph Cavicchi on behalf of NextEraEnergy Resources, LLC, August 23, 2018, Written, Public and Confidential.

CXA La Paloma, LLC

Before the Federal Energy Regulatory Commission. RE : CXA La Paloma, LLC v. California Independent System Operator Corporation, Docket No. EL18-177. Affidavit of Jeffrey Tranen and Joseph Cavicchi, June 20, 2018, Written, Public.

Talen Montana, LLC and Talen Energy Marketing, LLC

Before the Federal Energy Regulatory Commission. RE : Triennial Market-Based Rate Update for the Northwest Region, Talen Montana, L.L.C. et al, Dockets ER 15-2013 et al. Affidavit of A. Joseph Cavicchi, April 27, 2018, Written, Public.

Talen Montana, LLC and Talen Energy Marketing, LLC

Before the Federal Energy Regulatory Commission. RE : Triennial Market-Based Rate Update for the Northwest Region, Talen Montana, L.L.C. et al, Dockets ER 10-2016 et al. Affidavit of A. Joseph Cavicchi, December 20, 2016, Written, Public.

PPL Electric Utilities Corporation and LG&E Energy Marketing Inc.

Before the Federal Energy Regulatory Commission. RE : Triennial Market-Based Rate Update for the Northeast Region, PPL Electric Utilities Corporation et al, Dockets ER 10-2010 et al. Affidavit of A. Joseph Cavicchi, December 20, 2016, Written, Public.

NextEra Energy Resources, LLC

Before the Commonwealth of Massachusetts, Department of Public Utilities, Docket D.P.U. 16-05, Petition for Approval of Gas Infrastructure Contracts with Algonquin Gas Transmission Co. for the Access Northeast Project, Direct Testimony of Joseph P. Kalt and A. Joseph Cavicchi, June 20, 2016 (corrected June 28, 2016), Written, Public and Confidential. Surrebuttal Testimony of Joseph P. Kalt and A. Joseph Cavicchi, July 18, 2016, Written, Public and Confidential.

NextEra Energy Resources, LLC

Before the Commonwealth of Massachusetts, Department of Public Utilities, Docket D.P.U. 15-181, Petition for Approval of Gas Infrastructure Contracts with Algonquin Gas Transmission Co. for the Access Northeast Project, Direct Testimony of Joseph P. Kalt and A. Joseph Cavicchi, June 13, 2016 (corrected June 28, 2016), Written, Public and Confidential. Surrebuttal Testimony of Joseph P. Kalt and A. Joseph Cavicchi, July 12, 2016, Written, Public and Confidential.

PPL Electric Utilities Corporation

Before the Pennsylvania Public Utility Commission, Docket No. P-2016-2526627, PPL Electric Utilities Corporation. Statement No. 2. Direct Testimony of A. Joseph Cavicchi, January 29, 2016, Written, Public. Statement No. 2-Supp. Supplemental Testimony of A. Joseph Cavicchi, March 9, 2016, Written, Public. Statement No. 2-R Rebuttal Testimony of A. Joseph Cavicchi, May 23, 2016. Written, Public.

Calpine Corporation et al.

Before the Federal Energy Regulatory Commission. Calpine Corporation et al., Complainants v. PJM Interconnection, L.L.C., Respondent. RE: Complaint Requesting Fast Track Processing, PJM Interconnection, L.L.C., Docket No. EL 16-49-000. Affidavit of A. Joseph Cavicchi, March 21, 2016, Written, Public.

PJM Power Providers Group

Before the Public Utilities Commission of Ohio, In the Matter of the Application Seeking Approval of Ohio Power Company's Proposal to Enter into an Affiliate Power Purchase Agreement for Inclusion in the Power Purchase Agreement

Rider, Case No. 14-1693-EL-RHR et al. Supplement Testimony of A. Joseph Cavicchi on behalf of the PJM Power Providers Group and The Electric Power Supply Association, December 28, 2015, Written, public and Confidential. Deposition of A. Joseph Cavicchi on behalf of the PJM Power Providers Group and The Electric Power Supply Association, January 5, 2016. Deposition Testimony of A. Joseph Cavicchi, January 5, 2016. Testimony of A. Joseph Cavicchi, January 7, 2016, Oral, Public.

Exelon Generation Company, LLC

Before the Federal Energy Regulatory Commission, San Diego Gas & Electric Company v. Sellers of Energy and Ancillary Services, Into Markets Operated by the California, Independent System Operator Corporation, And the California Power Exchange, Docket EL 00-95-280 et al. Affidavit of A. Joseph Cavicchi in Support of the Exelon Generation Company, LLC's Fuel Cost Allowing Filing, December 4, 2015, Written, Public.

PJM Power Providers Group

Before the Public Utilities Commission of Ohio, In the Matter of the Application Seeking Approval of Ohio Power Company's Proposal to Enter into an Affiliate Power Purchase Agreement for Inclusion in the Power Purchase Agreement Rider, Case No. 14-1693-EL-RHR et al. Direct Testimony of A. Joseph Cavicchi on behalf of the PJM Power Providers Group and The Electric Power Supply Association, September 11, 2015, Written, Public and Confidential. Testimony of A. Joseph Cavicchi on behalf of the PJM Power Providers Group and The Electric Power Supply Association, October 20, 2015, Oral, Public.

Iberdrola Renewables, LLC

Before the Federal Energy Regulatory Commission, Docket Nos. EL02-60-007 and EL02-62-006, consolidated. Prepared Answering Testimony of A. Joseph Cavicchi on behalf of Iberdrola Renewables, LLC, July 21,2015 Written, Public & Confidential. Deposition of A. Joseph Cavicchi on behalf of the Iberdrola Renewables, LLC, September, 24, 2015, Oral, Confidential. Testimony of A. Joseph Cavicchi, December 3, 2015, Oral, Public.

PPL Electric Utilities Corporation

Before the Pennsylvania Public Utility Commission, Docket No. P-2014-2417907, PPL Electric Utilities Corporation. Statement No. 2. Direct Testimony of A. Joseph Cavicchi, April 25, 2014, Written, Public. Statement No. 2-R Rebuttal Testimony of A. Joseph Cavicchi, July 28, 2014. Written, Public.

San Diego Gas and Electric Company

Naturener USA, LLC, et al. v. San Diego Gas & Electric Company, in the Montana Ninth Judicial District Court, Toole County. Declaration, Non-Public (January 22, 2014).

PPL EnergyPlus

Before the Federal Energy Regulatory Commission. RE : Triennial Market-Based Rate Update for the Northeast Region, PPL Electric Utilities Corporation et al, Dockets ER 10-2010 et al. Affidavit of A. Joseph Cavicchi, December 31, 2013, Written, Public.

Before the Federal Energy Regulatory Commission. RE : Triennial Market-Based Rate Update for the Northwest Region, PPL EnergyPlus LLC et al, Dockets ER 10-2011 et al. Affidavit of A. Joseph Cavicchi, December 31, 2013, Written, Public.

Transalta Energy Marketing

Before the Federal Energy Regulatory Commission, Puget Sound Energy, Inc., Complainant v. All Jurisdictional Sellers of Energy and/or Capacity at Wholesale into Electric Energy and/or Capacity Markets in the Pacific Northwest, Including Parties to the Western System Power Pool Agreement Participants, Docket. No. EL01-085. Prepared Answering Testimony of A. Joseph Cavicchi on behalf of Transalta Energy Marketing (U.S.) Inc. and Transalta Energy Marketing (California) Inc., December 17, 2012. Deposition of A. Joseph Cavicchi on behalf of Transalta Energy Marketing (California) Inc., February 8, 2013. Testimony of A. Joseph Cavicchi, October 21 and 22, 2013, Oral, Public.

Avista Corporation et al

Before the Federal Energy Regulatory Commission. In the Matter of Puget Sound Energy, Inc. v. All Jurisdictional Sellers of Energy and/or Capacity at Wholesale into Electric Energy and/or Capacity Markets in the Pacific Northwest, including Parties to the Western Systems Power Pool Agreement. Docket EL01-10-085. Testimony of A. Joseph Cavicchi, September 26, 2013. Oral, public. Answering Testimony of A. Joseph Cavicchi on behalf of Avista Corporation et al. ("Joint Defense Group"), June 24, 2013. Deposition of A. Joseph Cavicchi on behalf of Avista Corporation et al, July 9, 2013.

Department of Justice

Before the United States Court of Federal Claims, Pacific Gas and Electric Company and Southern California Edison Company, Plaintiffs et al v. The United States, Defendant, No. 07-157C, No. 07-167C (Consolidated), No. 07-184C. Deposition of A. Joseph Cavicchi, March 27, 2013. Confidential, Subject to Protective Order.

Before the United States Court of Federal Claims, Pacific Gas and Electric Company and Southern California Edison Company, Plaintiffs et al v. The United States, Defendant, No. 07-157C, No. 07-167C (Consolidated), No. 07-184C. Expert Report of A. Joseph Cavicchi, March 1, 2013. Confidential, Subject to Protective Order.

PPL Montana and PPL EnergyPlus

Before the Federal Energy Regulatory Commission, Puget Sound Energy, Inc., Complainant v. All Jurisdictional Sellers of Energy and/or Capacity at Wholesale into Electric Energy and/or Capacity Markets in the Pacific Northwest, Including Parties to the Western System Power Pool Agreement Participants, Docket. No. EL01-

085. Prepared Answering Testimony of A. Joseph Cavicchi on behalf of PPL Montana and PPL EnergyPlus, December 17, 2012. Written, Public. Deposition of A. Joseph Cavicchi on behalf of PPL Montana and PPL EnergyPlus, February 8, 2013.

Constellation New Energy

Before the Federal Energy Regulatory Commission, Puget Sound Energy, Inc., Complainant v. All Jurisdictional Sellers of Energy and/or Capacity at Wholesale into Electric Energy and/or Capacity Markets in the Pacific Northwest, Including Parties to the Western System Power Pool Agreement Participants, Docket. No. EL01-085. Prepared Answering Testimony of A. Joseph Cavicchi on behalf of Constellation Energy Commodities Group, December 17, 2012. Written, Public. Deposition of A. Joseph Cavicchi on behalf of Constellation Energy Commodities Group, February 8, 2013.

Constellation NewEnergy

Before the Federal Energy Regulatory Commission, San Diego Gas & Electric Company, Complainant, v. Sellers of Energy and Ancillary Services into Markets Operated by the CA ISO and CA Power Exchange, et al., Respondents, Docket No. EL00-95-248. Direct Testimony and Exhibits of Constellation NewEnergy, Inc. Testimony of A. Joseph Cavicchi on behalf of Constellation NewEnergy, July 11, 2012. Oral, Public.

PPL Electric Utility Corporation

Before the Pennsylvania Public Utility Commission, Docket No. P-2012-2302074, PPL Electric Utility Corporation. Statement No. 2. Direct Testimony of A. Joseph Cavicchi, May 16, 2012. Statement No. 2-R. Direct Testimony of A. Joseph Cavicchi, August 17, 2012. Statement No. 3. Testimony of A. Joseph Cavicchi, September 10, 2012. Oral, Public.

PPL Corporation

Before the Federal Energy Regulatory Commission, RE: Notice of Change in Status Regarding Market-Based Rate Authority, Docket No. ER10-2016-___ et al. Affidavit of A. Joseph Cavicchi on behalf of PPL Corporation, January 30, 2012. Written, Public.

Entegra Power Services, LLC

Before the Federal Energy Regulatory Commission, Union Power Partners LP, Docket No. ER05-1191-016, Entegra Power Services LLC, Docket No. ER09-838-002. Updated Market Power Analysis for Market-Based Rates. Affidavit of A. Joseph Cavicchi, December 29, 2011.

Constellation NewEnergy, Inc.

Before the Federal Energy Regulatory Commission, San Diego Gas & Electric Company, Complainant, v. Sellers of Energy and Ancillary Services into Markets Operated by the CA ISO and CA Power Exchange, et al., Respondents, Docket No. EL00-95-248. Direct Testimony and Exhibits of Constellation NewEnergy,

Inc. Direct and Answering Testimony and Exhibits of A. Joseph Cavicchi on behalf of Constellation NewEnergy, October 25, 2011. Written, Public.

CP Energy

Before the Federal Energy Regulatory Commission, RE: Triennial Market-Based Rate Update for the Northeast Region, Docket No. ER10-1342 et al. Affidavit of A. Joseph Cavicchi, June 30, 2011. Written, Public.

Edison Mission.

Before the Federal Energy Regulatory Commission, RE: Triennial Market-Based Rate Update for the Northeast Region, Edison Mission Marketing and Trading, et al., Docket No. ER11-___-000, et al. Affidavit of A. Joseph Cavicchi, June 29, 2011. Written, Public.

Entegra Power Services, LLC

Before the Federal Energy Regulatory Commission, Gila River Energy Supply LLC, Docket No. ER11-___-000, Request for Acceptance of Initial Market-Based Rate Tariff, Waivers and Blanket Authority Under Section 205 of the Federal Power Act. Affidavit of A. Joseph Cavicchi, April 11, 2011. Written, Public.

PPL Corporation

Before the Federal Energy Regulatory Commission, Triennial Market-Based Rate Update for the Northwest Region, PPL Northwest Companies, ER10-2011-000 et al. Affidavit of A. Joseph Cavicchi on behalf of the PPL Northwest Companies, January 31, 2011. Written, Public.

Entegra Power Services LLC

Before the Federal Energy Regulatory Commission, Gila River Power, LP, Docket No. ER05-1178-015 and Entegra Power Services LLC, Docket ER09-838-001, Second Supplement to Updated Market Power Analysis for Continued Market-Based Rate Authority in Compliance with Order No. 697. Second Supplement Affidavit of A. Joseph Cavicchi, January 12, 2011. Written, Public.

PPL Corporation

Before the Federal Energy Regulatory Commission, RE: Notice of Change of Status Regarding Market-Based Rate Authority, Docket No. ER10-1511-001 et al. Affidavit of A. Joseph Cavicchi on behalf of PPL Corporation, December 1, 2010. Written, Public.

Entegra Power Services LLC

Before the Federal Energy Regulatory Commission, Gila River Power, LP, Docket No. ER05-1178-015 and Entegra Power Services LLC, Docket ER09-838-001. Supplement to Updated Market Power Analysis for Continued Market-Based Rate Authority in Compliance with Order No. 697. Affidavit of A. Joseph Cavicchi, November 19, 2010. Written, Public.

Chesapeake Energy Corp., et al.

Before the Public Utilities Commission of the State of Colorado, In the Matter of Commission Consideration of Public Service Company of Colorado Plan in Compliance with House Bill 10-1365 "Clean Air Jobs Act," Docket No. 10M-245E. Testimony of A. Joseph Cavicchi on behalf of Noble Energy, Inc., Chesapeake Energy Corporation and Encana Oil & Gas (USA), November 1, 2010. Oral, Public. November 9, 2010. Written, Public. November 18, 2010. Oral, Public.

Chesapeake Energy Corp., et al.

Before the Public Utilities Commission of the State of Colorado, In the Matter of Commission Consideration of Public Service Company of Colorado Plan in Compliance with House Bill 10-1365 "Clean Air Jobs Act," Docket No. 10M-245E. Cross Answer Testimony and Exhibits of A. Joseph Cavicchi on behalf of Noble Energy, Inc., Chesapeake Energy Corporation and Encana Oil & Gas (USA), October 8, 2010. Written Report Public, Exhibits Confidential, Filed Under Seal.

Chesapeake Energy Corp., et al.

Before the Public Utilities Commission of the State of Colorado, In the Matter of Commission Consideration of Public Service Company of Colorado Plan in Compliance with House Bill 10-1365 "Clean Air Jobs Act," Docket No. 10M-245E. Answer Testimony and Exhibits of A. Joseph Cavicchi on behalf of Noble Energy, Inc., Chesapeake Energy Corporation and Encana Oil & Gas (USA), September 17, 2010. Written, Confidential.

PPL Electric Utilities Corporation

Before the Pennsylvania Public Utility Commission, RE: Petition of PPL Electric Utilities Corporation for Approval of a Default Service Program and Procurement Plan for the Period January 1, 2011 through May 31, 2014, Docket No. P-2008-2060309. Statement No. 2. Direct Testimony of A. Joseph Cavicchi on behalf of PPL Electric, September 14, 2010. Oral, Written and Public.

PPL Corporation and E.ON U.S.

Before the Federal Energy Regulatory Commission, RE: PPL Corporation and E.ON U.S. LLC Application for Authorization Under Section 203 of the Federal Power Act, Request for Waivers of Filing Requirements, and Confidential Treatment of Agreement and Workpapers, Docket No. EC10-77-000. Affidavit of Dr. Joseph P. Kalt and Mr. A. Joseph Cavicchi, June 28, 2010.

BG Masspower

Before the Commonwealth of Massachusetts Trial Court, Suffolk, SS, Civil Action 07-3243 (BLS2), Masspower, by its General Partners, BG MP Partners I, LLC, and BG MP Partners II, LLC, Plaintiffs, v. Massachusetts Municipal Wholesale Electric Company, Defendant. Deposition of A. Joseph Cavicchi on behalf of Masspower, February 19, 2010. Testimony of A. Joseph Cavicchi on behalf of Masspower, March 18 and 19, 2010. Oral, Public.

Allegheny

Before the Federal Energy Regulatory Commission, State of California ex rel. Lockyer v. British Columbia Power Exchange Corp., et al., Docket No. EL02-71-017 et al. Prepared Answering Testimony of A. Joseph Cavicchi on behalf of Allegheny Energy, September 17, 2009. Written, Public.

MPS Merchant Services

Before the Federal Energy Regulatory Commission, State of California ex rel. Lockyer v. British Columbia Power Exchange Corp., et al., Docket No. EL02-71-017. Prepared Answering Testimony of A. Joseph Cavicchi on behalf of MPS Merchant Services, September 17, 2009. Written, Public.

PPL Montana, LLC

Before the Federal Energy Regulatory Commission, State of California ex rel. Lockyer v. British Columbia Power Exchange Corp., et al., Docket No. EL02-71-017. Answering Testimony of A. Joseph Cavicchi on behalf of PPL Montana, LLC, September 17, 2009. Written, Public.

Constellation New Energy

Before the Federal Energy Regulatory Commission, San Diego Gas and Electric Co. v. Sellers of Energy and Ancillary Services, Docket No. EL00-95 et al. Affidavit of A. Joseph Cavicchi on behalf of Constellation New Energy, August 4, 2009. Written, Public.

Energy Northwest

Before the American Arbitration Association, Seattle, Washington, Grays Harbor Energy LLC, Claimant, Energy Northwest, Respondent, Case No. 75-158-115-08. Testimony of A. Joseph Cavicchi on behalf of Energy Northwest, June 18, 2009. Oral, Public. Deposition Testimony of A. Joseph Cavicchi on behalf of Energy Northwest, May 13, 2009. Oral, Public. Supplemental Expert Report of A. Joseph Cavicchi on behalf of Energy Northwest, April 30, 2009. Written, Confidential. Expert Report of A. Joseph Cavicchi on behalf of Energy Northwest, April 15, 2009. Written, Confidential

Entegra Power Services LLC

Before the Federal Energy Regulatory Commission, Docket ER09-838-000, Request for Acceptance of Initial Market-Based Rate Tariff, RE: Updated Market Power Analysis for EPS' Affiliate, Gila River. Affidavit of A. Joseph Cavicchi, March 13, 2009. Written, Public.

Union Pacific Railroad Company

In the Matter of the Arbitration between Wisconsin Public Service Corporation and Union Pacific Railroad Company. Rebuttal Expert Report of A. Joseph Cavicchi, February 16, 2009.

PPL Electric Utilities Corporation

Before the Pennsylvania Public Utility Commission, RE: Petition of PPL Electric Utilities Corporation for Approval of a Default Service Program and Procurement

Plan for the Period January 1, 2001 through May 31, 2014, Docket No. P-2008-2060309. Testimony of A. Joseph Cavicchi on behalf of PPL Electric Utilities Corporation, February 11, 2009. Oral, Public.

PPL Electric Utilities Corporation

Before the Pennsylvania Public Utility Commission, Docket No. P-2008-2060309. Rebuttal Testimony of A. Joseph Cavicchi on behalf of PPL Electric Utilities Corporation, January 20, 2009.

Union Power Partners, L.P.

United States of America, Before the Federal Regulatory Commission, Docket No. ER05-1191-014, Updated Market Power Analysis for Continued Market-Based Rate Authority. Affidavit of A. Joseph Cavicchi on behalf Union Power Partners, L.P., December 30, 2008.

PPL Electric Utilities Corporation

Before the Pennsylvania Public Utility Commission, Docket No. P-2008-2060309, Supplemental Testimony of A. Joseph Cavicchi of behalf of PPL Electric Utilities Corporation, November 3, 2008.

PPL Electric Utilities Corporation

Before the Pennsylvania Public Utility Commission, Docket No. P-2008-2060309. Testimony of A. Joseph Cavicchi of behalf of PPL Electric Utilities Corporation, September 11, 2008.

PPL Electric Utilities Corporation

United States of America, Before the Federal Regulatory Commission, Docket No. ER00-1712-008, ER02-2408-003, ER00-744-006, ER02-1327-005, ER00-1703-003, ER02-1749-003, ER02-1747-003, ER99-4503-005, ER00-2186-003, ER01-1559-004. Affidavit of A. Joseph Cavicchi on behalf of PPL Companies, September 2, 2008.

PPL Electric Utilities Corporation

United States of America, Before the Federal Regulatory Commission, Docket No. EL08-67-000. Affidavit of A. Joseph Cavicchi (with Joseph P. Kalt) on behalf of PPL Companies, August 12, 2008.

PPL Electric Utilities Corporation

United States of America, Before the Federal Regulatory Commission, Docket No. EL08-67-000. Affidavit of A. Joseph Cavicchi (with Joseph P. Kalt) on behalf of PPL Companies, July 11, 2008.

Entegra Power Group L.L.C.

United States of America, Before the Federal Regulatory Commission, Docket Nos. ER05-1178-00 and ER05-1191-00. Affidavit of A. Joseph Cavicchi on behalf of Entegra Power Group L.L.C, Gila River Power, L.P., Union Power Partners, L.P.,

Harbinger Capital Partners Master Fund I, Ltd., and Harbinger Capital Partners Special Situations Fund, LP, May 30, 2008.

Harbinger

United States of America, Before the Federal Regulatory Commission, Docket No. EC08-87-000. Affidavit of A. Joseph Cavicchi on behalf of the Entegra Power Group L.L.C, Gila River Power, L.P., Union Power Partners, L.P., Harbinger Capital Partners Master Fund I, Ltd., and Harbinger Capital Partners Special Situations Fund, LP, May 9, 2008.

IEPA

United States of America, Before the Federal Regulatory Commission, Docket Nos. ER08-556-000 and ER06-615-020. Affidavit of A. Joseph Cavicchi on behalf of Independent Energy Producers Association, February 29, 2008.

PJM Power Providers Group

United States of America, Before the Federal Regulatory Commission, Docket No. EL08-34-000. Affidavit of Joseph P. Kalt and A. Joseph Cavicchi on behalf of the P3 Group, responding to the Complaint of the Maryland Public Service Commission against PJM Interconnection, L.L.C., regarding marketing power mitigation, February 19, 2008.

Tractebel Energy Marketing, Inc.

Tractebel Energy Marketing, Inc. v. AEP Power Marketing, Inc., American Electric Power Company, Inc. and Ohio Power Company, 03 CV 6731 (S.D.N.Y.) (HB) (JCF); and Ohio Power Company and AEP Power Marketing, Inc. v. Tractebel Energy Marketing, Inc. and Tractebel S.A., 03 CV 6770 (S.D.N.Y.) (HB) (JCF). Expert Report of A. Joseph Cavicchi on behalf of Tractebel Energy Marketing, Inc., January 21, 2008.

PPL Corporation

United States of America, Before the Federal Regulatory Commission, Docket Nos. ER00-1712-007, ER02-2408-003, ER00-744-006, ER02-1327-005, ER00-1703-002, ER02-1749-003, ER02-1747-003, ER99-4503-005, ER00-2186-003, ER01-1559-004. Affidavit of A. Joseph Cavicchi on behalf of Triennial Market Power Update of PPL Companies, January 14, 2008.

IEPA

United States of America, Before the Federal Regulatory Commission, Docket Nos. ER06-615-003, 005, 012, ER07-1257-000, ER02-1656-017, ER02-1656-018, EL05-146-000 and EL08-20-000. Affidavit of A. Joseph Cavicchi on behalf of Independent Energy Producers Association, January 9, 2008.

NRG

United States of America, Before the Federal Regulatory Commission, New York Independent System Operator – Docket No. EL07-39-000. Affidavits of A. Joseph Cavicchi on behalf of NRG Power Marketing, Inc., Arthur Kill Power LLC, Astoria

Gas Turbine Power LLC, Dunkirk Power LLC, Huntley Power LLC, and Oswego Harbor Power LLC, November 19, 2007, December 10, 2007, and December 21, 2007. Written, Public.

American Electric Power Services Corporation, Conectiv Energy Supplies, Inc., DTE Energy Trading, Inc., Energy America, LLC, Integrys Energy Services, Inc., and PPL Energy Plus, LLC

United States of America, Before the Federal Regulatory Commission, The People of the State of Illinois, ex rel. Illinois Attorney General Lisa Madigan v. Exelon Generation Co., LLC, et al., Docket No. EL07-47-000. Affidavit of Joseph Cavicchi and Joseph P. Kalt, June 18, 2007. Written, Public.

Independent Energy Producers Association of California

United States of America, Before the Federal Regulatory Commission, Docket No. R.06-02-013, Long-Term Procurement Plans, Prepared Testimony of the Independent Energy Producers Association. Prepared Testimony of Joseph Cavicchi and David Reishus on behalf of the IEPA, March 2, 2007. Written, Public.

Cross Hudson

Before the State Of New York Public Service Commission, Request of Hudson Transmission Partners, LLC, for Unredacted Copies of Records Filed In Case 01-T-1474. Affidavit of Joseph Cavicchi in Support of Cross Hudson Corporation's Appeal of Records Access Officer's February 9, 2007, Determination (Trade Secret 07-1), February 21, 2007. Written, Public.

PPL Electric Utilities Corporation

Before The Pennsylvania Public Utility Commission, RE: Petition of PPL Electric Utilities Corporation for Approval of A Competitive Bridge Plan, Docket No. P-00062227. Direct Testimony of Joseph Cavicchi, December 19 and 20, 2006. Oral, Public.

PPL Electric Utilities Corporation

Before The Pennsylvania Public Utility Commission, RE: Petition of PPL Electric Utilities Corporation for Approval of A Competitive Bridge Plan, Docket No. P-00062227. Reply to Surrebuttal Testimony of Marjorie R. Philips, Joseph Cavicchi, December 20, 2006. Written, Public.

PJM Interconnect, LLC

United States of America, Before the Federal Regulatory Commission, Docket No. EL05-148-000, 001; Docket No. ER05-1410-000, 001, Initial Comments of the PPL Parties and the PSEG Companies in Opposition to Proposed Settlement, Exhibit D-1 (Exhibit AJC-1). Affidavit of A. Joseph Cavicchi, October 19, 2006. Written, Public.

Excelsior Energy Inc.

Before The Minnesota Office Of Administrative Hearings, RE: In The Matter Of The Petition Of Excelsior Energy Inc. And Its Wholly-Owned Subsidiary MEP-I, LLC For Approval Of Terms And Conditions For The Sale Of Power From Its Innovative

Energy Project Using Clean Energy Technology Under Minn. Stat. §216B.1694 and a Determination That The Clean Energy Technology Is Or Is Likely To Be A Least-Cost Alternative Under Minn. Stat. §216B.1693, MPUC Docket No. E-6472-/M-05-1993; OAH Docket No. 12-2500-17260-2, Prepared Rebuttal Testimony and Exhibits of Excelsior Energy Inc. and MEP-I LLC. Rebuttal and Exhibits of Joseph Cavicchi, October 10, 2006. Written, Confidential.

PPL Electric Utilities Corporation

Before The Pennsylvania Public Utility Commission, RE: Petition of PPL Electric Utilities Corporation for Approval of A Competitive Bridge Plan, Docket No. P-00062227. Statement No. 2, Direct Testimony of Joseph Cavicchi, September 15, 2006. Written, Public.

Independent Energy Producers Association of California

United States of America, Before the Federal Regulatory Commission, Docket No. EL05-146-000, Reply Comments of the Independent Energy Producers Association, September 26, 2006. Affidavit of Joseph Cavicchi, August 26, 2006. Written, Public.

Independent Energy Producers Association of California

United States of America, Before the Federal Regulatory Commission, Docket No. EL05-146-000, Affidavit in Support of Justness and Reasonableness of the Offer of Settlement's Reference Resource's Cost and Performance Characteristics. Affidavit of Joseph Cavicchi, August 21, 2006. Written, Public.

PPL Maine, LLC

United States of America, Before the Federal Regulatory Commission, RE: PPL Maine, LLC, Docket No. ER00-2186-002, Triennial Market-Based Rate Update. Affidavit of A. Joseph Cavicchi on behalf of the PPL Companies, June 19, 2006. Written, Public.

FirstEnergy Solutions Corp.

United States of America, Before the Federal Regulatory Commission, FirstEnergy Solutions Corp., Docket No. ER06-117-000. Prepared Direct Testimony of Scott T. Jones, Ph.D., and A. Joseph Cavicchi on behalf of FirstEnergy Solutions Corporation, March 15, 2006, confirming the auction price result of the Competitive Bidding Process carried out by the Ohio Public Utilities Commission in December 2004, and establishing that Solutions is not charging a rate greater than market prices for wholesale electricity sold to its affiliated Ohio based regulated distribution companies.

PPL Montana, LLC

United States of America, Before the Federal Energy Regulatory Commission, RE: PPL Montana, LLC, Docket No. ER99-3491-003; PPL Colstrip I, LLC, Docket No. ER00-2184-001; PPL Colstrip II, LLC, Docket No. ER00-2185-001; Answer of the PPL Montana Parties to Montana Consumer Counsel's New Uncommitted Capacity Pivotal Supplier Analysis and Uncommitted Capacity Market Share Analysis. Affidavit (filed with Joseph Kalt), February 28, 2005; Affidavit (filed with Joseph Kalt), November 14, 2005 (original October 31, 2005); First Supplemental Affidavit on behalf of the

PPL Montana Parties (filed with Joseph Kalt), December 23, 2005; Affidavit (filed with Joseph Kalt), February 1, 2006.

PPL Corporation

United States of America, Before the Federal Energy Regulatory Commission, Triennial Market-Based Rate Update, Submitted by PPL Great Works, Docket No. ER05-4503-004. Affidavit, January 24, 2006.

Independent Energy Producers Association of California

Before the Public Utilities Commission of the State of California, Evidentiary Hearings, Dockets Nos. R04-04-025 and R04-04-003. Testimony of Joseph Cavicchi and David Reishus on behalf of Independent Energy Producers Association of California, January 23 and 24, 2006. Oral, Public.

PPL Corporation

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"Projecting Electricity Prices for a Restructured Electricity Industry," EXNET Merchant Power Plant Conference, Washington, DC, June 3, 1999.

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"International Perspective: Lessons from the US Deregulation Experience," Nordic Power '98, Stockholm, Sweden, October 7, 1998.

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"Managing Market Share Loss with the Opening of Retail Markets to Competition," Electric Utility Business Environment Conference, Denver, CO, June 24, 1998.

"Multi-Attribute Trade-Off Analysis for Water and Electricity Policy Development," presented in Mendoza, Argentina, July 1996 and April 1997.

"The Basics of Cogeneration," presented at the Tufts University Forum on Energy Conservation, December 1993.

"Implications and History of the MIT Cogeneration Project," presented to the Massachusetts Society of Professional Engineers, November 1993.

CERTIFICATIONS

Registered Professional Engineer, Commonwealth of Massachusetts, 1992 - .

PROFESSIONAL AFFILIATIONS

Member, Board of Directors, Northeast Energy and Commerce Association, 2002-2012.