BEFORE
THE PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the Long-Term Forecast Report of Ohio Power Company And Related Matters	**)))**	**Case No. 18-0501-EL-FOR**
In the Matter of the Application Seeking Approval of Ohio Power Company's Proposal to Enter Into Renewable Energy Purchase Agreements for Inclusion in the Renewable Generation Rider	**)))))**	**Case No. 18-1392-EL-RDR**
In the Matter of the Application of Ohio Power Company to Amend its Tariffs	**))**	**Case No. 18-1393-EL-ATA**

DIRECT TESTIMONY OF MICHAEL GOGGIN

ON BEHALF OF SIERRA CLUB

JANUARY 2, 2019

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I. INTRODUCTION

Q-1. Please state your name, title, and business affiliation.

A. My name is Michael Goggin, and I am Vice President at Grid Strategies LLC, based in Washington, DC. Grid Strategies primarily serves as a consultant for renewable energy sector clients on electricity market design issues.

Q-2. Please summarize your work and educational experience that are relevant to this proceeding.

A. I have worked on renewable energy and electricity market design issues for over a decade. At Grid Strategies, I serve as an expert on those topics for a range of clean energy sector clients. For the preceding ten years I worked at the American Wind Energy Association, where I provided technical analysis and advocacy regarding how wind is integrated into FERC-regulated wholesale electricity markets, including overseeing the organization's analysis team as Senior Director of Research for the last four years.

In the course of that work, I co-authored nearly one hundred filings with the Federal Energy Regulatory Commission; served as a technical reviewer for over a dozen national laboratory reports, academic articles, and utility wind integration studies; was quoted as an industry expert in hundreds of press articles and had dozens of letters to the editor published, including in the New York Times and the Wall Street Journal; and published academic articles and conference presentations on wind integration, electricity markets, and policy. I have an undergraduate degree with honors from Harvard University.

Q-3. On whose behalf are you submitting this testimony?

A. I am submitting this testimony on behalf of Sierra Club.

Q-4. Have you previously testified before state utility commissions?

A. I have testified before state utility commissions in Illinois, Indiana, Minnesota, Wisconsin, Missouri, Oklahoma, Virginia, and Georgia.

Q-5. Please describe the purpose of your testimony.

A: I offer support for Ohio Power Company's (AEP Ohio's) conclusion that its proposed procurement of renewable resources is necessary because, due to certain aspects of the PJM market design, renewable energy deployment in the PJM wholesale market is falling short of the level that would optimally serve the economic interests of AEP's Ohio customers.

Q-6. Please outline your testimony.

A: First, I present data showing that PJM renewable deployment is falling short of levels seen in other regions, despite strong renewable resources and favorable economic fundamentals in the PJM region.

Second, I discuss how capacity markets in general disadvantage renewable resources, as well as aspects of the PJM capacity market that inhibit the development of renewable resources, including:

1. The tendency of capacity market payments to incentivize the retention of excess generating capacity, depressing energy market revenues for renewable generators.
2. A proposal to deny capacity market payments to renewable resources that receive state policy support.

3. Existing and proposed PJM capacity credit calculation methods that unduly reduce capacity market payments to renewable resources.
4. Capacity Performance rules that impede the participation of renewable resources in the capacity market.

Third, I describe aspects of PJM's energy and ancillary services market rules that result in market prices not fully reflecting the value provided by renewable resources.

Fourth, I discuss how PJM's transmission planning, cost allocation, and generator interconnection processes inhibit the deployment of renewable energy.

Finally, I highlight other economic development and environmental benefits of renewable resources, beyond those described in the testimony of AEP Ohio's witnesses.

II. IMPACT OF PJM MARKET RULES ON RENEWABLE DEPLOYMENT

Q-7. How does the amount of renewable generation in PJM compare to that in other regions?

A. Nationally wind and solar provide around 8.9% of electricity generation,[1] yet they account for only 2.8% of generation in PJM.[2] Said another way, PJM accounts for 20% of all U.S. electricity generation, yet only 6% of all U.S. wind and solar generation. The 7,808 MW of wind capacity in PJM at the end of 2017 accounted for 8.8% of the 88,973 MW installed nationwide, less than half the 20% level one would expect based on PJM providing 20% of nationwide electricity generation.[3] For comparison, in 2017 wind generation provided 23.2% of

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[1] https://www.eia.gov/electricity/monthly/

[2] https://www.pjm.com/-/media/committees-groups/committees/mc/20180322-state-of-market-report-review/20180322-2017-state-of-the-market-report-review.ashx

[3] https://www.awea.org/resources/publications-and-reports/market-reports/2017-u-s-wind-industry-market-reports

generation in SPP and 17.4% in ERCOT, while solar provided around 15% of generation in CAISO.

Q-8. To what extent is this because PJM wind and solar resources are lower quality than those in some other regions?

A: PJM has good wind and solar resources, so that alone cannot explain the lower level of renewable development. In particular, new wind turbine designs utilizing taller towers and longer blades have brought PJM wind project output (as measured by project capacity factor) up to the same range as seen in other regions.

Recent wind projects in the region have averaged a 39.3% capacity factor, only slightly lower than the national average for new projects of 42.2%, and the 43.2% average achieved in the highest-performing region.[4] Similarly, fixed-tilt solar projects in PJM have averaged a capacity factor of around 20%,[5] only somewhat lower than the 24.8% and 26.1% realized in California and the Southwest, respectively.

Q-9. Is that small performance disadvantage in the PJM region somewhat offset by higher energy market value for renewable energy in PJM relative to other regions?

A: Yes. Many other regions with better renewable resources have lower energy market prices than PJM, primarily because lower-priced coal generation sets the energy market clearing price more frequently in those markets than in PJM. Specifically, coal generation set PJM's

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[4] https://emp.lbl.gov/wind-technologies-market-report, Figures 35, 40 (using data for what LBNL classifies as the Great Lakes region, which accounts for a large share of PJM's wind capacity)

[5] https://emp.lbl.gov/sites/default/files/lbnl_utility_scale_solar_2018_edition_report.pdf

energy market clearing price only 32% of the time in 2017,[6] versus 36% in SPP,[7] and 55% in MISO.[8] The average delivered price of coal is also significantly lower in those regions than in PJM.[9] This results in a higher value for renewable generation in PJM, at least partially offsetting the higher quality of renewable resources in other regions. As a result, PJM's lagging renewable development cannot be explained by resource quality and economic factors alone, indicating that PJM market structure and rules may be a significant factor impeding renewable development relative to other regions.

The average energy market value of renewable energy can be measured by taking hourly wholesale energy market prices on parts of the grid with renewable energy and weighting those prices in proportion to the renewable output during that hour. Primarily because of regional differences in fossil fuel prices and the fossil generation mix, the average energy market value of PJM wind in 2017 was $24.59/MWh, significantly higher than the average in MISO ($20.00/MWh), ERCOT ($17.10/MWh), and SPP ($14.05/MWh).

The energy market prices realized by renewables in PJM are also higher than in other regions because renewable penetrations have not yet reached levels at which they begin to significantly reduce energy market clearing prices during hours with high renewable output. For example, in California the average energy market value of solar generation has dropped considerably as the solar penetration has become very high. The average energy market value of solar in CAISO dropped to $25/MWh in 2017 as solar's share of annual energy reached 15%;[10]

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[6] https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2017/2017-som-pjm-sec3.pdf, page 108
[7] https://www.spp.org/documents/57928/spp_mmu_asom_2017.pdf, page 39
[8] https://www.potomaceconomics.com/wp-content/uploads/2018/07/2017-MISO-SOM_Report_6-26_Final.pdf, page 4
[9] https://www.eia.gov/electricity/monthly/archive/february2018.pdf, page 111 (table 4.10.B)
[10] https://emp.lbl.gov/sites/default/files/lbnl_utility_scale_solar_2018_edition_report.pdf, page 37

comparable average energy market price data for PJM solar is not available, but should be significantly higher than the PJM average energy market price of $31/MWh[11] given that solar produces during on-peak periods when power prices are higher and PJM's solar market share is around 0.2%.

Q-10. How does PJM compare to other regions for renewable project development going forward?

A: PJM continues to lag other regions in renewable development. The American Wind Energy Association tracks wind projects that have announced they are under construction or in advanced development.[12] Of the 37,965 MW of under construction and advanced development wind projects nationwide, only 2,101 MW or 5% are in PJM states. If one excludes Illinois because some of the wind projects being developed in that state are likely to connect to MISO, the figure drops to 790 MW or 2% of the national total. Either figure is markedly lower than PJM's 20% share of total national electricity generation from all sources. Similarly, the 10,960 MW of proposed wind projects in the PJM queue as of the end of 2017 account for only 6% of the 180,000 MW of wind in the queue nationwide.[13]

Q-11. What other factors have driven wind and solar deployment in PJM?

A: Many PJM states have relatively strong state Renewable Portfolio Standard (RPS) requirements, and many states allow renewable resources connected anywhere on the PJM grid to count for RPS compliance. PJM renewable deployment has still lagged, despite the fact many renewable generators along the PJM seams have an incentive to connect to the PJM grid because

[11] http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2017/2017-som-pjm-volume2.pdf, page 16
[12] http://www.awea.org/3q2018
[13] https://emp.lbl.gov/sites/default/files/lbnl_utility_scale_solar_2018_edition_report.pdf, Figure 8

of the higher Renewable Energy Credit (REC) value. Nearly all solar deployment in PJM to date has been driven by strong solar carveout policies in state RPSs.

Q-12. What does the pricing of RECs in PJM indicate about the impact PJM market rules are having on renewable development?

A: PJM region RECs trade at a higher price than those in almost all other regions, indicating that PJM renewable supply is inadequate to meet the region's aggregate RPS demand. As in any market, prices for RECs are higher if supply is inadequate to meet demand. In particular, PJM state solar RECs regularly trade for hundreds of dollars per MWh,[14] while PJM Tier 1 RECs (typically provided by wind) trade at a higher price than RECs in most other regions. The fact that PJM renewable supply is inadequate to meet RPS demand, even though AEP and others have demonstrated PJM renewable resources are economically attractive, is an additional indicator that PJM market rules may be impeding renewable deployment.

III. PJM CAPACITY MARKET RULES DISADVANTAGE RENEWABLES

A. Impact of Capacity Market on Energy Market Prices

Q-13. How do capacity markets affect wholesale energy market prices?

A: In general, capacity markets tend to reduce prices in wholesale energy markets. Capacity markets are typically designed to provide what economists term "missing money," which are essentially the fixed costs of building and maintaining power plant capacity. In regions without capacity markets, those costs are typically recovered from the energy market when, during a small number of hours per year when energy supply is scarce, energy market prices increase to very high levels.

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[14] For example, New Jersey solar RECs currently trade for over $200/MWh on the spot market.

In contrast, capacity markets procure an administratively-determined level of capacity. That level of capacity is typically determined through a risk-averse calculus and a stakeholder process in which incumbent generation owners have an incentive to increase their capacity market revenue by pushing for higher capacity reserve levels.[15] For the last decade, PJM has consistently overestimated future load growth in its capacity market procurements, which has resulted in few scarcity events in the energy market. By procuring excess capacity, PJM's capacity market tends to cause fewer scarcity hours in the energy market, keeping energy market prices lower than they otherwise would be.

Q-14. What impact does this have on renewable resources?

A: Compared to other energy sources, renewable energy projects generally obtain a relatively large share of their value from the energy market, and a relatively small share of their value from the capacity market. The presence of a capacity market drives revenue from the energy market to the capacity market, and thus deprives renewable energy projects of revenue. As the share of total market revenue recovered through the capacity market increases, renewable energy projects tend to be harmed. Renewable resources provide valuable energy including during peak periods, but the credit assigned to their capacity value tends to be smaller, due to a variety of reasons explained below, so moving revenue from the energy market to the capacity market, as occurs in PJM, harms renewables.

In ERCOT, renewable resources have flourished in part because revenue that in PJM is recovered through the capacity market is instead recovered through the energy market. Part of the reason is that capacity markets tend to retain excess levels of generating capacity, which increases supply in the energy market and in turn depresses energy market prices. A large

[15] https://kleinmanenergy.upenn.edu/paper/pjm-governance

amount of coal capacity has recently retired in ERCOT's energy-only market because the market correctly signaled that these units could not compete against lower-priced natural gas-fired and renewable generation; unlike in PJM, these units did not have the economic support of capacity market payments based on a level of capacity need administratively determined several years in advance. This is increasing energy market prices and renewable plant revenue in ERCOT. Later in my testimony I discuss aspects of ERCOT's energy market design that also contribute to higher energy market prices there than in PJM.

PJM capacity market prices are highly volatile, having fluctuated by a factor of 10 from year to year over the last decade.[16] Because capacity market revenue is more volatile than energy market revenue and subject to significant changes through the stakeholder process and at FERC, it is more heavily discounted by renewable developers and their financiers. This disproportionately harms renewable resources because they are far more capital intensive than fossil fuel generators. In contrast to fossil fuel resources, renewable resources have no fuel costs and smaller ongoing O&M costs. A much larger share of their total lifetime cost is incurred upfront, and therefore must be financed. Power generation debt and equity investors are highly risk averse, so they heavily discount uncertain future cash flows. In my opinion, the fact that capacity market payments in PJM have shifted revenues away from the energy market is a significant reason why less renewable generation has been built in PJM than in other regions.

[16] https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2021-2022/2021-2022-base-residual-auction-report.ashx, page 16

B. MOPR and Regulatory Risk for Renewables Projects

Q-15. What has PJM recently proposed with regard to the participation of renewable generating resources in its capacity market?

A: In its Minimum Offer Price Rule (MOPR) and capacity repricing proposals, PJM proposed changes that would exclude resources that receive state policy support, including renewable resources that receive REC revenues, from capacity market revenues in an attempt to mitigate the impact of state policies on capacity market prices. In June 2018, the Federal Energy Regulatory Commission (FERC) rejected those proposals, though its order directed PJM to potentially go even further in mitigating the impact of state subsidized resources on capacity market prices.

The Minimum Offer Price sets a floor price at which state-supported renewable resources can offer into the market, with the effect often being that the resource does not clear the capacity market or receive capacity market revenues. More recently, PJM has developed proposed assumptions for the calculation of the Minimum Offer Price. These assumptions contain numerous flaws that understate the economic competitiveness of renewable energy, which has the effect, if implemented, of setting the Minimum Offer Price even higher and making it even less likely renewable resources will clear the market and receive capacity market payments.

While it is not yet determined what the outcome of this proposal will be, FERC's PJM order in June 2018 and a similar January 2018 ISO-NE order indicate that FERC believes the impact of state renewable policies on the capacity market needs to be mitigated. Most PJM proposals for achieving this result in renewable resources being effectively excluded from receiving capacity market payments. It is possible PJM and FERC will allow utilities to use renewable resources for capacity through the resource-specific Fixed Resource Requirement alternative provision. If this were implemented and AEP Ohio elected to use this provision, renewable generation could provide capacity credit to AEP that it would not be able to realize in the wholesale capacity market. If a MOPR rule is implemented that reduces the ability of renewable resources to generate capacity revenues, owners of capacity may still be able to receive capacity value via bi-lateral contracts with FRR entities and other entities that procure capacity.

Q-16. What has been the impact of this and other regulatory risk related to the capacity market on renewable development in PJM?

A: For the last several years, market participants have understood that the potential mitigation of state policy in the FERC-regulated capacity markets was a major risk. Even if FERC and PJM adopt a policy that does not outright preclude renewable resources from receiving capacity market revenues, there will likely be further uncertainty about the complex rules that will govern capacity self-supply, the determination of which state policies must be mitigated, and other factors. This regulatory risk further exacerbates the already large uncertainty regarding what capacity market prices will be in future years due to changes in capacity supply and demand, as well as the regulatory risk of capacity market rule changes like Capacity Performance or a potential change in how renewable resources' capacity value is calculated. This uncertainty forces renewable developers, purchasers, and project financiers—which, as I explained above, face a larger share of their overall project costs as up-front capital costs than other energy project developers—to significantly discount expectations for capacity market revenue when making renewable development decisions, impairing the deployment of renewable resources in PJM. I believe that this uncertainty regarding the capacity market combined with the financing needs of renewable generation projects is a significant cause of the comparatively low deployment of renewable generation in PJM.

C. Capacity Credit Calculation for Renewables

Q-17. How does PJM currently calculate wind and solar resources' capacity value?

A: Currently, PJM calculates a resource's average capacity factor during the hours ending 3-6 PM from June through August.[17]

Q-18. How does this method compare to other methods of calculating renewable resources' capacity value?

A: PJM's method disadvantages wind and potentially solar relative to capacity value calculation methods that include high demand periods outside of summer afternoons. For example, capacity value calculation methods based on a resource's Effective Load Carrying Capacity for reducing annual Loss of Load Probability account for a resource's contribution across all hours of the year.[18] This Effective Load Carrying Capacity method is presently not used by PJM.

In recent years, many of PJM's notable scarcity events involving significant generation shortages relative to load have occurred at times other than summer peak demand, such as the 2014 Polar Vortex and 2018 Bomb Cyclone winter events. Renewable resources and particularly wind generation have performed well during those events, greatly exceeding the annual capacity

[17] https://www.pjm.com/-/media/documents/manuals/archive/m21/m21v10.ashx, page 16
[18] https://www.nerc.com/files/ivgtf1-2.pdf

value PJM credits to wind generation.[19] PJM's own analysis confirms the contribution of renewable resources to system reliability during extreme winter scarcity events.[20]

PJM's capacity value method does not account for renewable resources' contributions during these winter periods, or for that matter any period other than summer afternoons. The PJM method's focus on summer afternoons to the exclusion of other time periods can also harm solar generators.[21] Wind output tends to be highest during spring and fall, while solar output is often high during the spring when cooler temperatures boost the output of solar modules. Many conventional generators go on outage during these periods, which can lead to reliability risks if hot weather causes an unexpected increase in demand. A capacity value method based on annual loss of load probability would account for the contribution of renewable resources during these periods.

PJM's 2012 renewable integration study used a loss of load probability method to calculate a wind capacity value of 16.8% of nameplate capacity, higher than PJM's current 13%, while solar's capacity value was found to be in excess of 50%.[22] MISO uses a similar method, which indicates that its wind fleet has a capacity credit of 15.2%.[23]

Q-19. Is PJM currently examining its calculation of the capacity value of renewable resources?

A: Yes. PJM recently proposed reducing wind's capacity value from 13% to 7.9% of nameplate capacity, based on historical data for the last decade showing that while wind's

[19] https://www.aweablog.org/wind-energy-perform-bomb-cyclone/
[20] http://www.pjm.com/~/media/library/reports-notices/special-reports/20170330-pjms-evolving-resource-mix-and-system-reliability.ashx
[21] https://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=14887607
[22] https://www.pjm.com/-/media/committees-groups/subcommittees/irs/postings/pjm-pris-task-3a-part-f-capacity-valuation.ashx?la=en
[23] https://cdn.misoenergy.org/2018%20Wind%20Capacity%20Report89288.pdf

average summer afternoon capacity factor is close to 13%, the median value is lower. PJM's proposed change would result in a 2.9% decrease in wind plant revenue (a reduction of $0.74/MWh), again assuming a 40% capacity factor and prevailing PJM market prices.

PJM is currently evaluating new methods to calculate renewable capacity value. On the positive side, PJM staff have proposed moving to a method based on annual effective load carrying capability instead of the summer capacity factor method. However, their proposed method would use old historical data and give equal weight to the wind and solar capacity value observed in each of the last 9 years for wind and 6 years for solar, even though the fleet installed in the earlier years accounts for a small share of the current fleet.

This reduces the credit awarded to wind and solar generators as it misses the large performance improvements for wind and solar plants installed in recent years that have been driven by technological advances. Wind turbines installed 5 or more years ago have much lower output, and particularly on-peak output, than today's due to technological advances driving the greater use of taller turbine towers and longer blades. As a result, wind projects installed nationwide in 2016 averaged a 42.5% capacity factor in 2017, while wind projects installed in 2011 averaged a 31.6% capacity factor.[24] With taller towers and longer blades, wind's on-peak output and therefore capacity value is improving much faster than even its average output, as the average capacity factor improvements primarily come from increasing output in hours with lower wind speeds.[25]

PJM's use of old performance data also disadvantages solar due to recent and ongoing performance improvements like use of trackers and higher inverter loading ratios that result in

[24] https://emp.lbl.gov/wind-technologies-market-report, Figures 35
[25] https://www.neon-energie.de/Hirth-Mueller-2016-System-Friendly-Wind-Power.pdf

higher output, particularly later in the afternoon. This technological trend can be seen in the fact that solar project capacity factors have increased significantly, from a national average of 21.8% for projects installed in 2010 to 26.8% for projects installed in 2016.[26]

Many of the older wind projects were also Section 1603 grant projects that were often sited in poor wind resource areas and generally not designed to maximize output because the federal incentive was awarded for 30% of project cost, instead of production. In contrast, the vast majority of wind projects installed before and after the stimulus bill's Section 1603 grant program have opted for the Production Tax Credit (PTC), which directly incentivizes production.

Moreover, even current data is not representative of the average wind fleet in the 2021/2022 capacity year. PJM's own analysis indicates that roughly 1/3 of the expected 2021 wind fleet has not been installed yet.[27] The ongoing re-powering of older projects that have been weighing the fleet's performance down, particularly the Section 1603 grant projects that are prime candidates for repowering because they are not receiving the PTC, should also bring up the fleet average. As noted above, PJM's 2012 renewable integration study modeled the use of modern wind turbines and calculated a capacity value of 16.8%, which is in the range found by other analyses, including MISO's.[28]

Renewable resources are also disadvantaged in that capacity accrediting rules do not account for the well-documented[29] correlated failures of conventional generators by assuming those outages are random independent events, yet correlations in wind and solar output are used to reduce those resources' capacity value. In sum, while the PJM capacity credit for solar and

[26] https://emp.lbl.gov/utility-scale-solar, Figure 16
[27] https://www.pjm.com/-/media/committees-groups/committees/pc/20180913/20180913-item-05b-wind-effective-load-carrying-capability-elcc.ashx
[28] https://cdn.misoenergy.org/2018%20Wind%20Capacity%20Report89288.pdf
[29] https://econpapers.repec.org/article/eeeappene/v_3a212_3ay_3a2018_3ai_3ac_3ap_3a1360-1376.htm

wind may improve over time as technology continues to advance and as PJM refines its methodology, PJM capacity credits today do not fully credit wind and solar for the capacity value they provide to the grid.

D. Capacity Performance and Fuel Security Study

Q-20. How did the Capacity Performance rules change PJM's capacity market?

To receive credit under the Capacity Performance rules, PJM requires that a resource must have "made, or is capable of demonstrating that it will make, the necessary investment to ensure the Capacity Resource has the capability for the entire such Delivery Year to provide energy at any time when called upon."[30] This requirement is very difficult if not impossible for a wind or solar resource to meet given the variability in their output over the course of a year.

Under PJM's Capacity Performance rules, the penalties for resources that under-perform are typically greater and more certain than the incentives for resources that over-perform,[31] creating an asymmetric and distortionary incentive for renewable resources to offer less capacity into the market than they truly provide to the power system. A more symmetric system of penalties and incentives, as is used in New England's Pay for Performance capacity market, incentivizes renewable resources to offer their actual capacity value, as this yields the highest expected value for that resource's revenue.

The asymmetric penalty structure made sense for gas generators because measures could be taken to reduce the forced outage rate. Asymmetric penalties work well for conventional

[30] PJM Capacity Performance December 12, 2014 filing to FERC, Section 5.5A.a.i.A

[31] Specifically, PJM sets the penalty for under-performance at the net Cost of New Entry (CONE), in $/MW-Day, multiplied by the number of days per year and divided by the expected number of Compliance Hours per year. In contrast, the reward for over-performance is far less certain and is typically smaller. The over-performance incentive is that penalties collected from under-performing resources will be allocated pro-rata to all over-performing resources in the hour.

generators that tend to have binary output levels (either 0% or 100% of nameplate capacity) and low probabilities of forced outages, not a renewable resource whose output is typically somewhere between 0% and 100%.

Q-21. How do other provisions of Capacity Performance affect the ability of renewable energy resources to participate in PJM's capacity market?

A: The asymmetry of PJM's reward and penalty system is exacerbated by the excessively high stop-loss provisions that set limits on penalties under Capacity Performance. As a result, the maximum potential penalty is 3-4 times higher in PJM than in ISO-NE. PJM's stop-loss provision is .5 times net CONE (in $/MW-Day) times 365 times the cleared capacity in a given month and 1.5 times Net CONE (in $/MW-Day) times 365 times the cleared capacity for a given year. In contrast, in ISO-NE the stop-loss is based on the starting price of the auction, which is a function of Net CONE. However, in ISO-NE the monthly stop-loss is equal to the auction starting price (in $/kW/Month) times the cleared capacity and the annual stop-loss is 3 times the monthly stop-loss.[32]

By causing higher credit requirements to cover potential penalties, PJM's high stop-loss provision also unduly harms smaller generation owners. Many wind and solar development firms are smaller than conventional generation owners, exacerbating the harm to wind and solar development in PJM.

[32] Consider an example where the Net CONE in PJM is $300 / MW-Day and the auction starting price for ISO-NE is $480 / MW-Day (Net CONE times 1.6). For a resource with 1 MW of cleared capacity, the monthly stop-loss in PJM would be $54,750 (.5 * $300 * 365 days * 1 MW) and the annual stop-loss would be $164,250 (1.5 * $300 * 365 days * 1 MW). For ISO-NE, the monthly stop-loss would be $14,600 ($480 * 365 days / 12 months * 1 MW) and the annual stop-loss would be $43,800 (monthly stop-loss times 3). Based on this example, the monthly and annual stop-loss in PJM is 3.75 times higher than the monthly and annual ISO-NE stop-loss limits.

Q-22. How have these reforms affected renewable resources' participation in the capacity market?

A: The distortionary inefficiencies caused by the incentives for renewable resources to offer less than their true capacity value to PJM are demonstrated by the fact that contractually "pairing" wind generators with other resources can be more attractive under PJM's proposal than each resource offering its individual capacity value into the market. The primary benefits of centralized grid operations and markets, as realized through Independent System Operators such as PJM, are the efficiencies obtained from aggregating the diversity of supply and demand to achieve the same level of electric reliability at lower cost.

While the flexibility to pair resources is better than not having that option as it allows a renewable generator to receive credit for some of the capacity value it provides to PJM, the fact that pairing makes financial sense demonstrates that PJM's methodology under-credits renewable generators. A resource's actual capacity value provided to the system is unaffected by a contractual agreement to pair with another resource, as the total physical contribution for both resources is the sum of their individual contributions. Bilateral agreements to pair resources are far less efficient at capturing diversity of supply than the aggregation that inherently occurs across all resources under a centralized grid operator, and results in an under-reporting of the true capacity value provided by renewable resources to PJM.

Q-23. What does PJM's fuel security study portend for potential changes to the PJM capacity market?

A: In December 2018, PJM released its fuel security study, which concluded that "The findings underscore the importance of PJM exploring proactive measures to value fuel security attributes, and PJM believes this is best done through competitive wholesale markets. In order to enhance the fuel security of the grid into the future, PJM believes market-based mechanisms for retaining or procuring resources with the necessary fuel secure attributes should be explored."[33]

A primary concern is that PJM could move in the direction of a tiered capacity market, in which only resources with certain attributes, like on-site fuel, could qualify for the highest tier and receive a large share of the compensation, while renewable resources without the specified on-site fuel attribute would be left with much lower compensation.

Focusing on generator attributes, as opposed to reliability services that can be provided by a range of resources including renewables, lends itself to a focus on on-site fuel. Confirming those concerns, PJM's summary of its study focused on attributes associated with fuel delivery and on-site fuel, describing "Key elements such as on-site fuel inventory, oil deliverability, location of a fuel supply disruption, availability of non-firm natural gas service, pipeline configuration and demand response become increasingly important as the system comes under more stress." In general, both Capacity Performance and PJM's interest in incorporating fuel security attributes into its capacity market tend to directly harm renewable resources by reducing their capacity market revenue, and indirectly harm renewable resources by shifting revenues from the energy market to the capacity market by retaining excess generating resources.

[33] https://pjm.com/-/media/library/reports-notices/fuel-security/2018-fuel-security-analysis.ashx?la=en, page 41

IV. RENEWABLE GENERATORS ARE DISADVANTAGED BY PJM ENERGY AND ANCILLARY SERVICES MARKET RULES AND OTHER ASPECTS OF SYSTEM DESIGN

A. Energy Market Rules

Q-24. How do PJM's energy market price caps differ from those in ERCOT, and how does this affect renewable resources?

A: A primary difference is that energy market prices in PJM are capped at $3,700/MWh,[34] well below the $9,000/MWh cap used in ERCOT.[35] This results in lower energy market value at times of high demand and low supply. Because renewable resources receive a larger share of their total market value through the energy market relative to other types of resources that receive a higher capacity value credit, this policy disproportionately disadvantages renewable resources.

Q-25. How does conventional generator self-scheduling affect the energy market prices received by renewable generation?

A: Many conventional generators in PJM are self-committed or self-scheduled by their owners rather than dispatched through PJM's centralized unit commitment and scheduling process.[36] Some of these generators are owned by regulated utilities that are under the jurisdiction of state regulators, which in some cases can create a perverse incentive for self-commitment and self-scheduling. Regulated generators pass through operating costs to utility customers, and the utility has an incentive to operate the plant to demonstrate its continued

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[34] https://www.pjm.com/-/media/committees-groups/committees/mic/20160106/20160106-item-07-2000-offer-cap-implementation.ashx

[35] https://www.ferc.gov/CalendarFiles/20160629114652-3%20-%20FERC2016_Scarcity%20Pricing_ERCOT_Resmi%20Surendran.pdf

[36] Unit commitment is the process that selects, a day in advance, which generators (and other resources) will operate the next day; scheduling and dispatch refer to hourly output levels and instructions for each resource.

usefulness so that it can justify to regulators that the plant should remain in the utility's rate-base, where it earns a rate of return for the utility. Analysts have identified regulated coal plants in PJM that incur operating losses of about $230 million annually and merchant coal generators that incur an additional $450 million in average annual operating losses.[37]

Both self-commitment and self-scheduling tend to increase overall system costs because the self-scheduled unit is not necessarily the least-cost unit and it may force more economic plants, like renewable resources, to curtail their output. A plant that is self-committed and self-scheduled typically produces more energy in more hours than that plant would produce if it were to compete with other resources in the RTO's security-constrained unit commitment and dispatch process. This suppresses the energy market revenues paid to renewable generators and other resources serving loads through the centralized RTO market.

B. Ancillary Services Market Rules

Q-26. Do PJM ancillary services rules make it possible for renewable resources to provide operating reserves?

A: PJM uses operating reserves, such as frequency regulation reserves, synchronized reserves, and non-synchronized reserves, to balance the supply and demand for electricity and keep power system frequency within an acceptable range. Resources that provide operating reserves are compensated through PJM's markets for those services, which are collectively referred to as ancillary services.

[37] https://blog.ucsusa.org/joseph-daniel/the-coal-bailout-nobody-is-talking-about, http://www.usaee.org/usaee2018/submissions/Presentations/Out-of-Merit%20Dispatch%20In%20organized%20Energy%20Markets%20Final.pdf

However, PJM market rules effectively bar renewable resources from providing many operating reserves, including frequency regulation service. This is primarily because PJM's test to become eligible to provide frequency regulation requires that a resource be able to maintain its baseline power output for 40 minutes.[38] This is not typically feasible for wind and solar generators, but if the test interval were shortened or they were allowed to provide frequency regulation response relative to a changing level of output, they could qualify to provide the service with the same level of confidence as other resources. Renewable resources currently provide operating reserves and other reliability services in other regions.[39] As renewable resources grow to make up a larger share of the generation mix, it is likely that PJM's market design will evolve to allow renewable resources to provide these services.

Q-27. What impact does this have on the economic value of renewable resources in PJM's markets?

A: PJM market rules that prevent renewable resources from supplying ancillary services have a negative impact on the economic value of renewable resources. NREL found wind providing frequency regulation at moderate renewable penetration has a value of $1/MWh.[40] At higher renewable penetrations, the value grows significantly. At high solar penetrations, allowing solar to be fully dispatchable and provide operating reserves can more than double the value of solar generation.[41] Most of the value is from reducing renewable curtailment by decommitting

[38] https://www.pjm.com/directory/manuals/m12/index.html#Sections/4.5%20Qualifying%20Regulating%20Resources.html
[39] http://iiesi.org/assets/pdfs/ieee-power-energy-mag-2015.pdf, https://www.nrel.gov/docs/fy17osti/67799.pdf
[40] https://www.nrel.gov/docs/fy14osti/60574.pdf, page 35
[41] https://www.ethree.com/wp-content/uploads/2018/10/Investigating-the-Economic-Value-of-Flexible-Solar-Power-Plant-Operation.pdf

conventional generators that otherwise would have stayed online to provide flexibility and operating reserves.

Q-28. Does the lack of separate markets for up and down frequency regulation in PJM impair development of renewable energy?

A: Yes. Because wind and solar typically face a greater opportunity cost for providing up-regulation than down-regulation, the lack of separate markets for up- and down-frequency regulation also inhibits the ability of renewable resources to provide frequency regulation.[42] Providing up-regulation ("reg-up") requires holding a plant below its maximum output at all times while it is offering the service so that it can increase output when needed to provide the reg-up service. In contrast, reducing the output of a plant to provide frequency down-regulation ("reg-down") only requires withholding the amount of output that is necessary to bring the system back into balance. Unlike CAISO, ERCOT, and SPP, PJM's frequency regulation market lacks separate regulation for up and down products, which tends to disadvantage renewable resources. PJM stakeholders have considered significant changes to the regulation market design, so it is likely that the market design will evolve over time to better accommodate the participation of renewable resources.[43]

Q-29. Are most wind and solar plants in PJM compensated for providing reactive power and voltage control?

[42] Up-regulation ("reg-up") entails quickly increasing generation to restore frequency to safe operating levels when load on the grid exceeds available generation (as when a large generator fails). Down-regulation ("reg-down") involves a fast drop in generation to restore frequency to safe operating levels when generation on the grid exceeds load (as when an extensive transmission or distribution event drops a large amount of load).

[43] https://www.pjm.com/committees-and-groups/closed-groups/rmistf.aspx

A: No. Inverter-based resources such as wind and solar generators can provide reactive power and voltage control using their inverter and under FERC Order 827 are now required to do so at levels comparable to conventional generators.[44] PJM and FERC provide a policy for compensating resources that provide reactive power. However, most renewable generators currently forego the sizeable revenue they can earn for providing reactive power because of the cost, uncertainty, and complexity of applying for compensation, which typically requires a litigated settlement proceeding versus the Transmission Owner at FERC. In contrast, large conventional generators face smaller cost hurdles in applying relative to the potential revenue, due to their larger plant size and larger body of precedent for how such compensation is determined. In recent settlement cases at FERC, the compensation for wind plants providing reactive power service has been around $1/MWh when averaged across total plant energy production. Compensation for solar plants is likely to be comparable. It may be that AEP Ohio will apply for and receive compensation for reactive power and voltage control for projects that it undertakes in Ohio. Regardless, Ohio customers will receive the benefit of renewable resources providing voltage and reactive power support.

Q-30. Do PJM's policies for frequency response compensation harm renewable energy deployment?

A: Yes. In PJM, resources are not compensated for the cost of installing the capability to provide frequency response or the cost of providing frequency response service. Frequency response refers to the increase in output of generators to help stabilize power system frequency in the seconds and minutes following the loss of a large source of supply or demand. Wind and

[44] https://www.ferc.gov/whats-new/comm-meet/2016/061616/E-1.pdf

solar plants can provide frequency response, with wind plants currently providing a large share of the service today on the main Texas power system.[45]

Because wind and solar plants are able to provide frequency response service more quickly than conventional generators,[46] a market for frequency response or fast frequency response would provide additional revenue to renewable generators. In particular, wind and solar generators that are already curtailed for localized transmission congestion could provide frequency response service with no opportunity cost, but they do not currently do so in PJM because there is no compensation for providing that service.

PJM's Independent Market Monitor has also proposed requiring existing wind and solar generators to undergo retrofits to install primary frequency response capability without compensation for the costs incurred.[47] Most fossil and hydropower generators have frequency response capability, while nuclear facilities are exempted from the requirement, and therefore this requirement would disproportionately if not exclusively disadvantage renewable resources.

V. PJM'S TRANSMISSION PLANNING AND COST ALLOCATION POLICIES IMPEDE RENEWABLE DEPLOYMENT

Q-31. How has PJM's transmission expansion into renewable resource areas compared to that in other regions?

A: Relative to other regional transmission organizations like ERCOT, SPP, and MISO, PJM has built very little new transmission into high renewable resource areas. ERCOT, SPP, and MISO have each built billions of dollars of new transmission into high renewable resource areas.

[45] http://www.ercot.com/content/meetings/ros/keydocs/2009/0331/WIND_GENERATION_GOVERNOR_RESPONSE_REQUIREMENT_draft.doc

[46] http://iiesi.org/assets/pdfs/ieee-power-energy-mag-2015.pdf, https://www.nrel.gov/docs/fy17osti/67799.pdf

[47] https://www.pjm.com/-/media/committees-groups/task-forces/pfrstf/20181127/20181127-options-and-packages-matrix.ashx?la=en

Q-32. Why has PJM's development of transmission into renewable resource areas lagged that in other regions?

A: The primary reason is that other regions pro-actively plan transmission into renewable resource areas and broadly allocate the cost of high-voltage transmission upgrades across the entire regional footprint. In contrast, PJM allocates a large share of transmission upgrade costs to interconnecting generators or to the local zones where the transmission is built.

Moreover, in its transmission planning processes PJM categorizes transmission upgrades as either for generator interconnection, reliability, or market efficiency purposes, while other regions study those transmission benefits together. This results in fewer transmission projects passing PJM's benefit-cost test and proceeding to construction, as PJM's planning process does not account for the market efficiency or generator interconnection benefits of a reliability project, and vice versa. In contrast, MISO's transmission planning process, and the resulting transmission construction, has centered on developing "multi-value projects."

Q-33. How does a lack of new transmission impede renewable energy development in PJM?

A: When transmission congestion reduces wholesale market power prices (called locational marginal prices) locally in a renewable generating area, or there is risk of that occurring over a prospective renewable project's life, that reduces the value of renewable to customers and makes them less willing to sign Power Purchase Agreements (PPAs) at pricing and other terms that are economically feasible for the renewable project.

When congestion is so extreme that it results in wind curtailment, there is an additional economic cost to wind owners, wind purchasers, consumers, and the environment from "throwing away" zero-fuel-cost, zero-emission energy that would have been used by consumers if sufficient transmission capacity were available. The cost of this lost revenue, as well as the risk of experiencing this cost, significantly deters renewable energy development and reduces the willingness of lenders or investors to finance renewable energy development in constrained areas.

Another impediment to renewable energy deployment is that renewable projects applying to interconnect in congested parts of the grid are often required to pay cost-prohibitive transmission upgrade costs as a condition of their interconnection. Developers have little incentive to pay for transmission through the generator interconnection process because under Federal Energy Regulatory Commission-mandated Open Access rules, any competing generator would be able to use the transmission once it was built. This is the classic "tragedy of the commons" that, per economic theory, exists for many "public goods."

Finally, transmission congestion, curtailment, and interconnection upgrade costs tend to force renewable energy development into lower quality resource areas with lower capacity factors. Lower output also reduces the MWh of wind energy output over which the capital and other fixed costs of operating the plant must be recovered, increasing the $/MWh PPA price that the developer can offer and still make the project financially viable. That higher PPA price is directly passed on to the utility's customers, and also impedes renewable development by making it less attractive relative to other options.

VI. RENEWABLE DEPLOYMENT BENEFITS OHIO

Q-34. What would the effect be on energy prices in Ohio if AEP Ohio were to develop 900 MW of solar and wind projects?

A. As I explained above, wind and solar projects have large up-front capital cost requirements and very low marginal production costs, including zero fuel costs. In regions where renewable generation has significantly penetrated the market, such as ERCOT and CAISO, the impact has been generally to lower energy market clearing prices, including peak energy prices. This occurs because energy market clearing prices are set based on marginal production costs, and renewable resources have near-zero marginal production costs. My own analysis has found that renewable generation significantly reduces energy market clearing prices in PJM,[48] ERCOT,[49] and SPP.[50] The development of 900 MW of additional renewable energy projects would tend to further lower locational marginal prices in the Ohio region of PJM, consistent with the analysis presented by AEP Ohio in this proceeding and previous analysis by the Public Utilities Commission of Ohio.[51] As more renewables projects are built, the downward effect on energy market clearing prices would be greater.

Q-35. In its testimony in the Long-Term Forecast Proceeding, AEP accounted for reductions in carbon dioxide emissions associated with this procurement of renewable energy. What impact would adding 900 MW of renewable energy have on air pollutants other than carbon dioxide?

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[48] https://www.awea.org/Awea/media/Resources/Publications%20and%20Reports/White%20Papers/AWEA-Cold-Snap-Report-Final-January-2015.pdf

[49] https://www.awea.org/Awea/media/Resources/Publications%20and%20Reports/White%20Papers/ERCOT-report-11-7FINAL.pdf

[50] https://www.awea.org/Awea/media/Resources/Publications%20and%20Reports/White%20Papers/SPP-report-November-2014-final.pdf

[51] Public Utilities Commission of Ohio, "Renewable Resources and Wholesale Price Suppression," August 2013.

A: Adding 900 MW of renewable generation in Ohio would significantly reduce air pollution in the region, according to a tool developed by the U.S. Environmental Protection Agency (EPA). Specifically, sulfur dioxide emissions would be reduced by 956 tons per year, annual nitrogen oxides emissions would be reduced by 796 tons, and particulate matter (<2.5 micrometer) emissions would be reduced by 168 tons annually. These pollutants cause environmental degradation, including smog and acid rain, and contribute to cardiopulmonary health problems including asthma, bronchitis, heart attacks, and even death.[52]

The emissions benefits of adding renewable energy were calculated using the AVoided Emissions and geneRation Tool (AVERT),[53] a tool developed by the EPA to calculate the emissions reductions achieved at fossil power plants from adding renewable energy or energy efficiency resources to the grid. To estimate the emissions impact of the 900 MW of renewable generation AEP plans to add, 450 MW of solar capacity and 450 MW of wind capacity were added to the model. The AVERT model was run with the default data file for the Great Lakes/MidAtlantic region, which corresponds to the PJM grid operator region that contains American Electric Power's Ohio footprint.

The AVERT tool has been widely used by researchers at national laboratories, the federal government, and academic institutions to analyze the impact of renewable energy, energy efficiency, and other resources on the output and emissions of other power plants. AVERT is based on statistical analysis of observed patterns in how power plants change their output in response to changes in electricity supply and demand.

[52] https://www.epa.gov/sites/production/files/2018-08/documents/utilities_ria_proposed_ace_2018-08.pdf, page 4-18
[53] https://www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert

The model is based on the fundamental physical fact that because electricity supply and demand must be kept in balance, each amount of electricity produced at a renewable plant must displace an equivalent amount of electricity output from another power plant. Wholesale electricity market operators use wind energy to displace the most expensive power plant that otherwise would have operated, which is almost always a fossil-fueled power plant. Markets use wind in this way because wind energy has zero fuel cost, while fossil power plants have much higher fuel costs.

The above calculations are consistent with the results of other recent analysis. For example, in a 2016 study the Lawrence Berkeley National Laboratory (LBNL) and the National Renewable Energy Laboratory (NREL) used the AVERT tool and found similar public health and environmental benefits from state renewable policies,[54] while LBNL found similar benefits from renewable energy deployment in analysis it released in 2017.[55]

Q-36. What economic development benefits would expanded renewable energy provide to Ohio, beyond the jobs and growth created from deploying the renewable resources themselves?

A: As AEP Ohio notes in its testimony, many large corporations now have aggressive renewable energy procurement goals, driven by both the environmental benefits but also the economic savings and fuel price risk hedging benefits of renewable energy. Many companies, from automotive manufacturers to technology companies, factor the availability of renewable energy and renewable energy tariffs into decisions about where to locate new facilities. As a result, the greater availability of renewable energy as a result of AEP Ohio's procurement will

[54] https://www.nrel.gov/docs/fy16osti/65005.pdf
[55] https://emp.lbl.gov/publications/health-and-environmental-benefits

encourage these companies to site facilities in Ohio. For example, Facebook's $750 million data center under construction near Columbus will cover 100% of its electricity consumption using renewable energy purchases.[56] It appears that greater availability of renewable energy at least partially drove Facebook to site its previous data center in Texas rather than Ohio.[57]

Q-37. Is there an advantage for Ohio to AEP Ohio working to developing renewable energy projects as opposed to relying on customers to procure their own renewable energy?

A: Yes. Many customers who want renewable energy may not have the appropriate credit ratings, experience, or access to capital to develop renewable energy projects on their own or to enter into long-term contracts to support renewable development. In addition, many such customers may not have sufficient load to procure renewable energy on their own. Ohio would benefit from AEP Ohio developing renewable energy projects because the utility can take advantage of economies of scale, low-cost financing, and development expertise that some customers cannot take advantage of.

Q-38. Does this conclude your testimony?

A: Yes.

[56] https://money.cnn.com/2017/08/15/technology/facebook-ohio-data-center/index.html
[57] https://energynews.us/2015/07/17/midwest/final-meeting-on-ohio-energy-standards-will-focus-on-jobs/