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April 9, 2018

By Electronic Filing

Mr. Joel H. Peck, Clerk
State Corporation Commission
1300 East Main Street
Tyler Building, First Floor
Richmond, VA 23219

RE: ***In re: Virginia Electric and Power Company's Integrated Resource Plan filing pursuant to Va. Code § 56-597 et seq.***
Case No. PUR-2018-00065

Dear Mr. Peck:

Pursuant to the Commission's February 12, 2019, Order, in the above-captioned matter, please find the attached testimony of Michael Volpe and Michael Goggin filed on behalf of the Mid-Atlantic Renewable Energy Coalition.

Thank you for your assistance in this matter.

Sincerely,

/s/ William T. Reisinger

William T. Reisinger

Enclosure

cc: Service List

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COMMONWEALTH OF VIRGINIA

BEFORE THE

STATE CORPORATION COMMISSION

In re: Virginia Electric and Power Company's Integrated Resource Plan filing pursuant to Va. Code § 56-597 *et seq.*	)))	CASE NO. PUR-2018-00065

DIRECT TESTIMONY OF

Mike Volpe and Michael Goggin

ON BEHALF OF

THE MID-ATLANTIC RENEWABLE ENERGY COALITION

April 9, 2019

Summary of Mike Volpe's Direct Testimony

My testimony addresses (i) utility scale solar capacity factors and the technology trends that are driving towards higher capacity factors, (ii) why we believe the Commission's request for Virginia Electric and Power Company ("Dominion Energy Virginia" or the "Company") to model utility scale solar at 23% Capacity Factor in its IRP Compliance Filing is an unfounded request. My testimony will conclude that utility-scale renewable energy is a mainstream, least-cost source of energy that should be widely adopted across the Commonwealth, consistent with the legislative intent of the Grid Transformation and Security Act of 2018 (the "GTSA").

Q. Please state your name, present position, and business address.

A. My name is Michael Volpe. I am currently a Vice President at Open Road Renewables. My business address is 1105 Navasota St, Austin, TX 78702.

Q. On whose behalf are you testifying?

A. I am testifying on behalf of the members of the Mid-Atlantic Renewable Energy Coalition ("MAREC").

Q. Please describe MAREC.

A. As documented on MAREC's website (www.marec.us), the organization's mission is to improve and enhance the opportunities for renewable energy development in Washington, D.C., and the eight states in the Mid-Atlantic region, including Virginia. MAREC provides education and expertise on renewable energy's environmental sustainable value, offers technical expertise and assistance on renewable energy's integration into the electricity grid, and promotes fair policies, rules, and regulations to expand the region's transmission system to accommodate the growth of renewable energy generation.

Q. Who are MAREC's members?

A. Currently, MAREC's membership includes utility-scale wind and solar developers and installers, service companies, non-profit organizations, and wind turbine manufacturers dedicated to the growth of renewable energy technologies.

Q. Please describe your educational background and professional experience.

A. I spent roughly the past decade in the power sector starting my career at General Electric selling gas, steam, and wind turbines to utilities and independent power producers. From General Electric, I transitioned to the solar industry as the Director for the PJM region at

SunEdison developing and financing both distributed and utility-scale solar projects. Currently, I lead the market development efforts for Open Road Renewables in PJM with a focus on Virginia. I have a B.E. in Mechanical Engineering from Vanderbilt University and an MBA from Stanford University.

Q. Have you previously testified in state regulatory proceedings?

A. Yes. I testified in the Company's 2018 Integrated Resource Plan filing CASE NO. PUR-2018-00065 and the Company's 2017 Integrated Resource Plan filing CASE NO. PUR-2017-00051.

Q. What is the purpose of your testimony in this case?

A. The purpose of my testimony is to share the current technology driving the renewable energy industry's competitiveness as a least-cost resource. To that end, my testimony will provide current information on the utility-scale solar technology available to Dominion Energy Virginia and the various technology and design considerations that impact solar capacity factors. I will explain why the 23% solar capacity factors used by the Company in the Compliance Filing is artificially low.

Q. What considerations impact a solar facility's capacity factor?

A. Consistent with the background that was provided by MAREC in Case No. PUR-2018-00101, the US-3 Solar proceeding, a generator's capacity factor is the calculation of the cumulative energy output, in MWh, divided by the maximum potential output, in MWh, over a given time period. For example, if a 1600 MW combined cycle natural gas plant operates at a continuous output level of 800 MW for a month, the plant's capacity factor is 50% for that given month. Whereas thermal plants with uninterrupted fuel supply have the ability to operate at high capacity factors, solar generators are limited by the supply of

the local renewable resource (i.e., the intensity and volume of sunlight hours in a day). While a facility's location impacts the raw renewable resource (i.e., the annual number of sunlight hours in the Arizona desert will be greater than in the Commonwealth), there are other factors that influence a solar facility's capacity factor. These factors fall into three buckets: i) technology, ii) design, and iii) operations.

While the direct testimony provided in the US-3 proceeding discussed the impact that plant operations and interconnection-related down time have on solar facilities' capacity factors, this testimony will focus on the recent technology trends and plant design considerations.

Q. Could you explain some of the recent solar plant technological improvements?

A. Yes. The utility-scale solar industry has grown tremendously over the past decade thanks to the technological improvements of panels, inverters, and racking components. Panels and inverters have improved both in conversion efficiency and cost. While these cost improvements have had a significant impact on utility-scale solar Levelized Cost of Energy ("LCOE") economics over the past decade, they have had only a modest impact on plant capacity factors. In contrast, the most notable driver of utility-scale solar capacity factor improvements has been technological improvements in single-axis tracking structures.

Historically, utility-scale solar arrays were configured with a fixed-tilt rack that oriented solar panels due south. As the Company explained in its 2018 IRP proceeding, over 80% of the historic utility-scale solar projects that currently sell their output to the

Company are fixed-tilt arrays.[1] Over the past few years, however, single-axis tracking structures have become the default configuration for utility-scale solar projects across the country and nearly all utility-scale projects proposed in the Commonwealth today use single-axis tracking technology.

Q. What has driven the transition from fixed-tilt to single-axis tracking as the default configuration for utility-scale projects in the Commonwealth?

A. A simple cost benefit analysis: the additional revenue from additional energy generation outweighs the incremental cost of single-axis tracking installation and maintenance. Single-axis tracking arrays track the sun as it moves from east to west over the course of a day increasing the plant's energy output by optimizing the angle of incidence between the photons in the sunlight and the solar panels that capture the photons. Empirical evidence shows that single-axis tracking solar plants capture between 20% to 25% more energy on an annual basis than fixed-tilt arrays.[2] This 20 to 25% increase in annual energy production results in a 4 to 5 percentage point increase in solar plant capacity factors from the low 20% range for fixed tilt arrays to the mid 20% range for single-axis tracking arrays in the Commonwealth, for example.

Nationally, cumulative PV capacity factors to date have increased from 23.7% for 2011 vintage projects to 26.8% for 2016 vintage projects. The primary factors are that the share of the annually installed capacity using trackers has increased from 50% to

[1] See Case No. PUR-2018-00065, Rebuttal Testimony of Glenn A. Kelly at Rebuttal Schedule 1, available at http://www.scc.virginia.gov/docketsearch/DOCS/4bx301!.PDF.

[2] See, e.g., PV Magazine, "Trackers dominate U.S. utility-scale solar," September 20, 2017, available at https://pv-magazine-usa.com/2017/09/20/trackers-dominate-u-s-utility-scale-solar-wcharts/.

78%, while Inverter Loading Ratios (the proportion of DC solar module capacity to the AC capacity of the inverter) also increased from 1.19 to 1.33.[3]

The Southeast has lagged other regions in the use of tracking technology, with only 46.1% of Southeast projects in DOE's database using trackers, versus 64.5% nationally.[4] As the Company explained in its 2018 IRP proceeding, only 17% of the historic utility-scale solar projects that currently sell their output to the Company use trackers.[5] As a result, solar capacity factors for the Company and the region have much room to grow as tracker use increases.

Q. Looking forward, what technological advancements and design considerations will drive utility-scale solar capacity factors further above their current levels?

A. As evidenced by the performance guarantee that the Commission accepted in the US-3 solar proceeding (i.e. annual capacity factor of 25% or greater for the Company to recover costs), today's vintage utility-scale solar projects in the Commonwealth are forecasted to perform at or above 25% capacity factor. Looking forward, the capacity factors of utility-scale solar projects will continue to increase as "bifacial" solar panels are deployed at scale. While some may have never heard of bifacial panels, they are currently being deployed across the country in pilot programs and are expected to become the norm by 2021 or 2022. As the name suggests, "bifacial modules produce solar power from both sides of the panel. Whereas traditional opaque-backsheeted panels are monofacial, bifacial modules expose both the front and backside of the solar cells.

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[3] See Lawrence Berkeley National Laboratory, Electricity Markets & Policy Group, Utility Scale Solar (Figures 7, 16), available https://emp.lbl.gov/utility-scale-solar.
[4] *Ibid.*, Figure 15
[5] See Case No. PUR-2018-00101, Rebuttal Testimony of Glen Kelly at 15.

When bifacial modules are installed on a highly reflective surface (like a white TPO roof or on the ground with light-colored stones), some bifacial module manufacturers claim up to a 30% increase in production just from the extra power generated from the rear."[6] The graphic below shows the solar energy that's captured both from the front side of the panel that's facing the sun and the backside of the panel that captures energy that's reflected off the ground.[7]

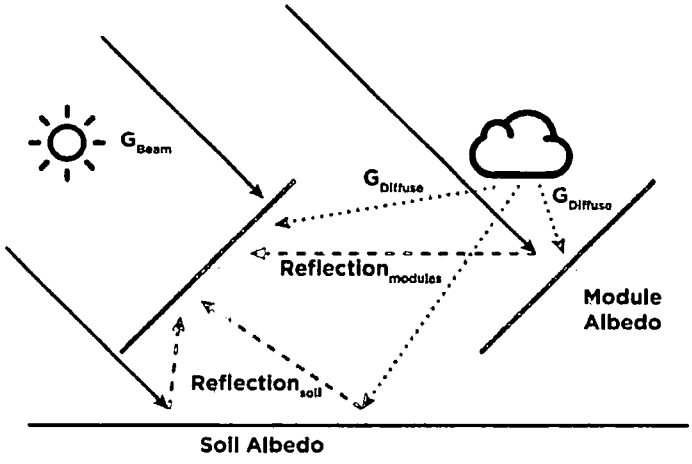

Figure 1. Graphic representation of irradiation in a bifacial plant. Source: Soltec

Some may question whether the light reflected off the ground is sufficient enough to generate electricity; however, in practice all field tests confirm additional energy capture and production with bifacial solar panels. What does the cost-benefit analysis conclude? Current estimates forecast negligible increases in plant cost with the use of bifacial panels. On the benefits side, it is expected that the use of bifacial panels on solar projects

[6] Solar Power World, *What are bifacial solar modules?* available at https://www.solarpowerworldonline.com/2018/04/what-are-bifacial-solar-modules/

[7] Soltec Whitepaper, *Bifacial Trackers, the Real Deal*, available at https://lab.soltec.com/wp-content/uploads/2019/04/BiTEC-whitepaper_en-1.pdf.

in the Commonwealth will result in capacity factors nearing 30% over the next few years as the use of both single-axis trackers and bifacial panels become the norm.

Q. Why do you believe that the Commission's request for Dominion Energy Virginia to model utility scale solar at 23% Capacity Factor in their IRP Compliance Filing is unfounded?

A. The request for the Company to model utility-scale solar at 23% capacity factor was made prior to the performance guarantee of 25% capacity factor that was included as a condition to cost recovery in the recent US-3 proceeding. Our understanding is that the performance guarantee established in the US-3 proceeding of 25% was seen as economically viable by the Company and holds the ratepayers harmless for project underperformance. With this context in mind, we think that it is appropriate to model utility-scale solar projects at 25% capacity factor or greater for this Compliance Filing and for future Planning documents. Simply put, the Company is putting its money on the line standing behind a 25% capacity factor, and thus, the request for the Company to model utility-scale solar projects at 23% should be seen as an outdated request.

Q. What comments do you have regarding the Commission's request for the Company to calculate the "incremental costs" of the GTSA?

A. There are two concerns with this approach. First, this approach does not take into account the benefits, but rather only looks only at the costs. The benefits of a cleaner, more resilient grid should be taken into consideration when evaluating the merits of the grid transformation envisioned by the legislature with the passage of the GTSA. Environmental benefits aside, portfolio theory states that there are economic and

consumer benefits from increasing the penetration of fixed-cost renewable energy as a hedge against uncertain and potentially increasing natural gas prices.

As MAREC's expert witness Michael Goggin explained in VEPCO's 2017 IRP proceeding, the Company's analysis of the gas price hedging value of adding a third nuclear unit at North Anna applies at least equally well to additions of renewable energy, as wind and solar have no fuel price or fuel price risk. Specifically, Mr. Goggin explained that: "VEPCO's North Anna 3 analysis shows this benefit to be significant, equivalent to the risk reduction of fully hedging around 16% of VEPCO's gas consumption needs. This was found to provide a 12% reduction in the standard deviation of electricity prices (as a share of the standard deviation), reducing the standard deviation by around $1.10/MWh.[8] Substituting that amount of a fixed-price resource, whether wind or nuclear, for gas generation would therefore result in savings of around $175 million annually in the credible scenario in which fuel prices are two standard deviations higher than expected."[9]

The second concern with the Commission's request to calculate the "incremental cost" of the GTSA is that the company used current vintage data that does not reflect the build cost and capacity factors of future vintage renewable energy technology over the Planning horizon. Case in point, this modeling was done with an assumed solar capacity factor of 23%. As noted in the Company's Compliance Filing, this drives the incremental cost up by $400M versus using the 25.4% capacity factor used in the 2018 IRP. Alternatively, if the Company ran the Compliance Filing analysis using a solar capacity

[8] Case No. PUR-2017-00051, 2017 IRP at 126-136.
[9] Case No. PUR-2017-00051, Direct Testimony of Michael Goggin at 27.

factor that increased from 25% to 30% over the Planning horizon, the costs would have been even lower.

Q. Does this conclude your prepared testimony?

A. Yes, it does.

Summary of Michael Goggin's Direct Testimony

My testimony addresses the capacity value that renewable energy generators provide to the Virginia Electric Power Company ("Dominion Energy Virginia" or the "Company") electric system. My testimony will conclude that utility-scale renewable energy provides significant value to Virginia ratepayers and should be widely adopted across the Commonwealth, consistent with the legislative intent of the Grid Transformation and Security Act of 2018 (the "GTSA").

Q. Please state your name, present position, and business address.

A. My name is Michael Goggin, and I am the Vice President of Grid Strategies LLC, a consulting firm based in the Washington, D.C., area.

Q. On whose behalf are you testifying?

A. I am testifying on behalf of the members of the Mid-Atlantic Renewable Energy Coalition ("MAREC").

Q. Please describe MAREC.

A. As documented on MAREC's website (www.marec.us), the organization's mission is to improve and enhance the opportunities for renewable energy development in Washington, D.C., and the eight states in the Mid-Atlantic region, including Virginia. MAREC provides education and expertise on renewable energy's environmental sustainable value, offers technical expertise and assistance on renewable energy's integration into the electricity grid, and promotes fair policies, rules, and regulations to expand the region's transmission system to accommodate the growth of renewable energy generation.

Q. Who are MAREC's members?

A. Currently, MAREC's membership includes utility-scale wind and solar developers and installers, service companies, non-profit organizations, and wind turbine manufacturers dedicated to the growth of renewable energy technologies.

Q. Please describe your educational background and professional experience.

A. I have worked on renewable energy integration and market design issues for over a decade. At Grid Strategies I serve as an expert on those topics for a range of electric industry 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 like PJM, 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. What is the purpose of your testimony in this case?

A. The purpose of my testimony is to describe the capacity value that wind and solar generators provide to Virginia customers by helping to reliably and cost-effectively meet peak electricity demand. I explain that PJM currently credits wind and solar generation with significant capacity value, that technology trends and the growth of energy storage are increasing the capacity value of wind and solar generation, and that PJM analysis confirms wind and solar capacity values will remain high at even greater renewable penetrations, with PJM finding that it would experience no reliability challenges of any type at renewable levels many times higher than required under the Grid Transformation and Security Act.

Q. In Mr. Volpe's testimony we heard that technology is increasing renewable energy generators' capacity factors. How is the increasing capacity factor of wind and solar generation affecting the capacity value of those resources?

A. First, I should distinguish that capacity factor refers to the energy production of a resource relative to its theoretical maximum output if it ran at full output, while capacity value refers to the contribution of a resource to meeting peak or near-peak electricity demand on the power system. A resource's capacity contributions are measured in MWs, while energy contributions are measured in MWh. Capacity value is typically expressed as a percent, indicating the capacity value provided by a resource in MW divided by the nameplate capacity of the resource in MW. PJM calculates the capacity value provided by resources, which typically determines the capacity market credit awarded to a resource. No resource generally provides 100% capacity value, as all resources are subject to planned and unplanned outages.[10]

Returning to the question, technological advances that are increasing the capacity factor of wind and solar resources also tend to increase their already significant capacity value. This is because technological advances like the use of trackers and higher Inverter Loading Ratios for solar PV, and taller towers and longer blades for wind, increase the capacity factor of those resources by increasing their output in hours when they were not at maximum output.[11] Those hours tend to coincide with hours when PJM electricity

[10] See 2012-2016 PJM Class Average Outdate Data, available at https://www.pjm.com/-/media/planning/res-adeq/res-reports/2012-2016-pjm-generating-unit-class-average-values.ashx?la=en

[11] See, generally, "System-friendly wind power: How advanced wind turbine design can increase the economic value of electricity generated through wind power," Energy Economics, February, 2016, available at http://neon-energie.de/Hirth-Mueller-2016-System-Friendly-Wind-Power.pdf

demand is at or near its peak, as in PJM peak electricity demand typically occurs during late afternoons during the summer, when solar and wind plants are not typically producing their maximum output. As a result, technological advances that are increasing wind and solar capacity factors are also increasing their capacity value and the economic value of the energy they provide.[12]

Q. What is the current capacity value contribution of renewable energy generators to PJM and the Dominion Energy Virginia system?

A. PJM awards significant credit to wind and solar generators for their capacity value contributions, which in turn helps Dominion Energy Virginia meet its capacity obligations and ensures that capacity market clearing prices in Virginia, which have a direct impact on customer electricity costs, remain low. PJM's current capacity value calculation method is based on a resource's output during late afternoons in the summer.[13] This method shows a capacity contribution as a share of nameplate capacity of 14.7% for wind in mountainous terrain and 17.6% for wind on flat terrain, and 42% for fixed solar installations and 60% for tracking solar plants.[14]

Q. What will be the capacity value of PJM renewable resources going forward?

A. What is known as the Effective Load Carrying Capability or ELCC method is the best indicator of what the future renewable capacity credit for Dominion Energy Virginia's

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[12] See, generally, Hirth and Muller, *System-friendly wind power*, available at https://www.diw.de/documents/dokumentenarchiv/17/diw_01.c.506693.de/hirth_belec.pdf.

[13] See PJM Manual 21, Rules and Procedures for Determination of Generating Capacity, Revision 12, at 19 available at https://www.pjm.com/-/media/training/nerc-certifications/markets-exam-materials/manuals/m21.ashx?la=en.

[14] See PJM Class Average Capacity Factors for Wind and Solar Resources, June 1, 2017, available at https://www.pjm.com/-/media/planning/res-adeq/class-average-wind-capacity-factors.ashx?la=en

resources will be, as PJM is strongly considering moving to that method from its current method based on output during summer late afternoons.[15] The ELCC method is more accurate than PJM's current capacity value calculation method and generally provides a higher estimate for wind and solar capacity value, as it accounts for the contribution of wind and solar during electricity shortage periods that occur outside of summer late afternoon periods. For example, this method accounts for how renewable resources have made important contributions during multiple recent winter shortage events driven by the failure of conventional generators due to extreme cold, including the Polar Vortex events this year and in 2014, and the Bomb Cyclone last winter.[16]

PJM's renewable integration study used an ELCC method, and found that wind and solar provide even larger capacity value to the system than indicated under PJM's current method. That analysis found utility-scale solar PV provides 62-72% capacity value, offshore wind provides 21-28%, and land-based wind provides between 14-20% capacity value.[17]

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[15] PJM Inside Lines, *PJM, Stakeholders Review ELCC*, available at http://insidelines.pjm.com/pjm-stakeholders-review-elcc/

[16] See, e.g., PJM Inside Lines, Winder Marked by Reliability and Strong Generator Performance, available at http://insidelines.pjm.com/winter-marked-by-reliability-and-strong-generator-performance/; American Wind Energy Association blog, *How transmission helped keep the lights on the during the polar vortex*, available at https://www.aweablog.org/transmission-helped-keep-lights-polar-vortex/; American Wind Energy Association blog, How did wind energy perform during the bomb cyclone, available at https://www.aweablog.org/wind-energy-perform-bomb-cyclone/; American Wind Energy Association blog, PJM Study quantifies wind's value for building a reliable, resilient power system, available at https://www.aweablog.org/pjm-study-quantifies-winds-value-building-reliable-resilient-power-system/; American Wind Energy Association, Wind energy saves consumers money during the polar vortex, available at https://www.awea.org/Awea/media/Resources/Publications%20and%20Reports/White%20Papers/AWEA-Cold-Snap-Report-Final-January-2015.pdf.

[17] See PJM Renewable Integration Study, Capacity Valuation at 29-30, available at https://www.pjm.com/-/media/committees-groups/subcommittees/irs/postings/pjm-pris-task-3a-part-f-capacity-valuation.ashx?la=en.

Importantly, those capacity value ranges include scenarios in which wind and solar provided up to 30% of PJM's energy, more than ten times higher than current levels.[18] Because renewable capacity values tend to be higher at lower renewable penetrations, the capacity value of wind and solar for the foreseeable future will fall on the high end of those ranges. Specifically, PJM's scenario which accounted for actual renewable penetrations as of 2014 found wind's capacity value was 20%, while solar's was 72%. These figures are likely the best indicators of the capacity value VEPCO renewable resources will provide going forward, as PJM renewable penetrations are likely to remain relatively low. Capacity value is calculated based on a resource's contribution to the PJM supply mix, so even if Virginia's renewable penetration increases dramatically, PJM capacity values are likely to remain high. Regardless, PJM's renewable integration study shows that renewable capacity values are still high at renewable energy penetrations of up to 30%.

Q. How does a mix of geographic diversity and technology diversity among the renewable generators impact the capacity value that they provide to PJM and the Dominion Energy Virginia system?

A. One of the most important strategies for increasing power system reliability has always been diversity in both the geographic dispersion and type of generating resources. This is because different resources tend to have less-correlated or even negatively-correlated output profiles, so that one is available when the other is not. Dominion Energy Virginia

[18] Wind provided 2.6% of PJM's generation in 2018, and solar provided 0.3%. See PJM Independent Market Monitor, 2018 State of the Market Report at 122, available at https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2018/2018-som-pjm-volume2.pdf.

adding solar generation will provide significant capacity value and add to the technology diversity of the generating fleet, as PJM currently has about 10 times more wind generation than solar generation. Regardless, with PJM's wind penetration at 2.6% and solar at 0.3%,[19] capacity values will remain high even if large amounts of wind and solar generation are added, as documented above.

Solar and wind output profiles tend to be strongly negatively correlated, with solar's daytime and summer output complementing wind's tendency to produce more at night and during the fall, winter, and spring. As a result of that complementarity, national laboratory analysis of California's power system found that the value of solar PV at a 10% penetration is increased by $7.40/MWh if wind also provides 10% of energy.[20] Offshore and coastal wind resources also provide a useful complement to land-based wind and solar, and offshore wind output tends to be high during late afternoon and early morning during the summer, when the sea breeze effect is at its maximum due to the high temperature differential between land and ocean. PJM's renewable integration study confirmed that due to these complementarities, land-based wind has the highest capacity value in scenarios with more offshore wind or solar deployment, and solar capacity value is higher in scenarios with more wind.[21]

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[19] See PJM Independent Market Monitor, 2018 State of the Market Report at 122, available at https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2018/2018-som-pjm-volume2.pdf.

[20] See Lawrence Berkeley National Laboratory, *Strategies for Mitigating the Reducting in Economic Value of Variable Generation with Increasing Penetration Levels* at 5, available at https://emp.lbl.gov/sites/default/files/lbnl-6590e.pdf.

[21] See PJM Renewable Integration Study, Capacity Valuation, at 29-30, available at https://www.pjm.com/-/media/committees-groups/subcommittees/irs/postings/pjm-pris-task-3a-part-f-capacity-valuation.ashx?la=en.

Geographic diversity is also very important for obtaining a diverse output profile and higher capacity value from renewable resources.[22] The fundamental reason is that weather and climate at one location in PJM are typically very different from, or at least not perfectly correlated with, weather at a distant location in PJM. For example, it may be cloudy and windy near Chicago, while it is sunny and calm in New Jersey at the same point in time, so the different patterns of wind and solar output from those locations cancel each other out and increase the aggregate capacity value of the renewable fleet. As a result, the analysis of California's power system mentioned above found that increasing the geographic diversity of the wind fleet increased its economic value by $2.50/MWh at a 20% wind penetration, $4.90 at a 30% penetration, and $10.60/MWh at a 40% penetration. Dominion Energy Virginia's wind and solar additions will add significant geographic diversity to PJM's generating fleet, as most PJM wind generation is located in the western part of the PJM footprint, while Virginia currently accounts for a relatively small share of PJM's total solar capacity.

Q. Is it your view that Dominion Energy Virginia will have the opportunity to maximize the capacity value of the renewable generators on their system if they are company-owned?

A. As noted above, choices of renewable technology and deployment can significantly increase capacity value. For example, capacity value can be significantly increased through the use of trackers and higher Inverter Loading Ratios for solar PV, and the use

[22] For examples of studies documenting this fact, see Renewable Energy 101, *Is it always windy somewhere? Occurrence of low-wind-power events over large areas*, available at https://ceic.tepper.cmu.edu/media/files/tepper/centers/ceic/publications/published%20papers/2017%20and%202018/handschy%20et%20al%202017%20pdf.pdf?la=en

of taller towers and longer blades for wind. The choice of wind resource locations where output is more coincident with electricity demand patterns also increases the resource's capacity value, as demonstrated by the regional differences in wind capacity credit within MISO.[23] With system reliability as one of their key considerations and with planning done at the system level, I believe that the Company is well positioned to optimize the geographic and technological diversity of renewable resources across the Commonwealth.

Q. Should we expect any reliability concerns with the level of renewable penetration proposed by Dominion Energy Virginia, given the variable generation profile of wind and solar?

A. No. As mentioned above, the PJM renewable integration study comprehensively analyzed reliability issues for wind and solar levels ranging up to 30% and found no significant concerns.[24] For comparison, this is nearly 10 times greater than PJM's current renewable penetration level. In fact, the study found that the impact of wind and solar variability on operating reserve needs was quite small.[25] More recently, PJM analyzed power system resilience under a range of possible generation mixes, and found that scenarios with very high levels of renewable resources were among the most resilient to severe weather threats.[26] Dozens of other utility, grid operator, and national laboratory

[23] See MISO, Planning Year 2018-2019 Wind Capacity Credit, December 2017, available at https://cdn.misoenergy.org/2018%20Wind%20Capacity%20Report97278.pdf

[24] See PJM Integration Study Reports, available at https://www.pjm.com/committees-and-groups/subcommittees/irs/pris.aspx

[25] See PJM Renewable Integration Study, available at https://www.pjm.com/-/media/committees-groups/subcommittees/irs/postings/pjm-pris-task-3a-part-b-statistical-analysis-and-reserves.ashx?la=en

[26] https://www.pjm.com/~/media/library/reports-notices/special-reports/20170330-pjms-evolving-resource-mix-and-system-reliability.ashx; for analysis of that study's findings, see

studies confirm that very large amounts of renewable energy can be reliably and efficiently integrated onto the power system,[27] a finding confirmed with real-world operating experience in places like Colorado, Texas, and the Southwest Power Pool. This operating experience has also shown that wind and solar resources can now provide needed grid reliability services as well as or better than conventional power plants.[28]

Q. What are your views on battery storage technology and the role it will play in the Dominion Energy Virginia system over the Planning horizon?

A. Battery storage appears poised to play an increasingly important role in meeting power system reliability needs in Virginia and nationwide. This includes providing capacity to meet power system peak electricity demand, as well as providing flexibility and other needed reliability services. Capacity and flexibility are needed by the power system regardless of the generation mix, but adding storage to provide those services can help facilitate the integration of renewable generation as storage can charge when renewables are abundant and discharge when they are not.

There is a particularly strong complementarity between solar PV and battery storage. First, battery storage is ideally-suited for shifting early afternoon solar output several hours later to meet late afternoon peak demand, and also helping to address

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https://www.aweablog.org/pjm-study-quantifies-winds-value-building-reliable-resilient-power-system/

[27] See NREL, *Relevant Studies of NERC's Analysis of EPA's Clean Power Plan 111(d) Compliance*, available at https://www.nrel.gov/docs/fy15osti/63979.pdf and International Energy Association October, 2017, conference paper, *Comparison of integration studies of 30-40 percent energy share from variable renewable sources*, available at https://community.ieawind.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=f0f06ab8-982b-bb47-5ff1-dae9a20fd408.

[28] See IEEE Power & Energy Magazine, *Alternatives No More*, November/December 2015, available at http://iiesi.org/assets/pdfs/ieee-power-energy-mag-2015.pdf

morning and evening ramps in solar output. Analysis of the California power system shows that, by increasing the energy and capacity value of solar and providing needed flexibility, battery storage increases the value of solar PV by $3.30/MWh at a 10% solar penetration, $8.40/MWh at 20% solar, and $19.70/MWh at 30% solar.[29]

In addition, by producing a large amount of energy during the early to mid-afternoon, solar PV tends to reduce the duration of system peak demand periods, increasing the value of shorter-duration energy storage resources for meeting peak demand. As noted above, PJM currently defines its peak demand period as 2-6 PM during June through August. Solar output is significant throughout that period, but particularly during the earlier part of that window. Thus, solar shortens the peak demand period, allowing batteries with limited duration to better contribute throughout the peak demand period.

Q. Does this conclude your prepared testimony?

A. Yes, it does.

[29] See Lawrence Berkeley National Laboratory, *Strategies for Mitigating the Reduction in Economic Value of Variable Generation with Increasing Penetration Levels* at 5, available at https://emp.lbl.gov/sites/default/files/lbnl-6590e.pdf.