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April 9, 2019

VIA ELECTRONIC FILING

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**RE: Commonwealth of Virginia, *ex rel.* State Corporation Commission
In re: Virginia Electric and Power Company's Integrated Resource Plan filing pursuant to Virginia Code § 56-597 *et seq.***

Case No. PUR-2018-00065

Dear Mr. Peck,

Please find attached for filing in the above-captioned case the Direct Testimony of Rachel Wilson on behalf of the Sierra Club. Should you have any questions or concerns regarding these filings, please do not hesitate to contact me directly.

Thank you,

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DIRECT TESTIMONY OF
RACHEL S. WILSON

ON BEHALF OF
THE SIERRA CLUB

BEFORE THE
STATE CORPORATION COMMISSION OF VIRGINIA

Case No. PUR-2018-00065

Commonwealth of Virginia *ex rel.* State Corporation Commission,
In re: Virginia Electric and Power Company's Integrated Resource Plan
filing pursuant to Virginia Code § 56-597 et seq.

April 9, 2019

Summary of the Direct Testimony of Rachel Wilson

My testimony evaluates whether Virginia Electric & Power Company's (the Company) 2018 Compliance Filing complies with the Virginia State Corporation Commission's (Commission) Order rejecting the Company's 2018 IRP. It also critiques certain resource assumptions made by the Company which, if modified, would change the results of its analysis.

Based on my review, I conclude that while the Company's 2018 Compliance Filing has met most of the criteria contained in the Commission's Order requiring the Company to revise and refile its 2018 IRP, the 2018 Compliance Filing still contains significant omissions. First, the Company failed to include all of the Grid Transformation and Security Act's (GTSA) mandated $870 million in energy efficiency (EE) investment, including detailed plans for EE under that level of investment. Second, the Company failed to include battery storage technologies as selectable resources in its PLEXOS capacity optimization at industry-sourced costs. Third, the Company failed to include any expected de-escalation in the future costs of solar resources. The combination of these factors has likely resulted in resource plans that result in higher costs to customers, continued reliance on fossil fuels, and increased levels of air emissions.

I recommend that for future IRPs filed in Virginia, the Commission require the Company to update its load forecast to include the full $870 million in proposed energy efficiency spending to which the Company has now committed (excluding lost revenues) and include detailed plans for its energy efficiency programs underlying this level of spending. Next, the Company should be required to provide a detailed unit-by-unit analysis of its existing coal fleet, done in PLEXOS. All resources, both existing and possible replacement resources, should be evaluated on a fair and consistent basis, with th focus on forward-going costs and benefits of continued unit operation. In addition, the Commission should require the Company to include solar projects, battery storage projects, and solar-plus-storage projects as selectable resources in capacity expansion modeling used to create resource portfolios. The Company should use up-to-date estimates of costs and operational parameters reflecting both the Company's historical and current experience with these resources, as well as industry projections of cost and technology trends. Lastly for any future resource solicitations, the Commission should direct the Company to use All-Resource Solicitations, which would allow the Company to determine the actual current costs and operating parameters of renewable and storage resources in its region.

1. INTRODUCTION AND QUALIFICATIONS

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

A. My name is Rachel Wilson and I am a Principal Associate with Synapse Energy Economics, Incorporated ("Synapse"). My business address is 485 Massachusetts Avenue, Suite 2, Cambridge, Massachusetts 02139.

Q. Please describe Synapse Energy Economics.

A. Synapse is a research and consulting firm specializing in energy and environmental issues, including electric generation, transmission and distribution system reliability, ratemaking and rate design, electric industry restructuring and market power, electricity market prices, stranded costs, efficiency, renewable energy, environmental quality, and nuclear power.

Synapse's clients include state consumer advocates, public utilities commission staff, attorneys general, environmental organizations, federal government agencies, and utilities.

Q. Please summarize your work experience and educational background.

A. At Synapse, I conduct analysis and write testimony and publications that focus on a variety of issues relating to electric utilities, including: integrated resource planning; federal and state clean air policies; emissions from electricity generation; environmental compliance technologies, strategies, and costs; electrical system dispatch; and valuation of environmental externalities from power plants.

I also perform modeling analyses of electric power systems. I am proficient in the use of spreadsheet analysis tools, as well as optimization and electricity dispatch models to conduct analyses of utility service territories and regional energy markets. I have direct experience running the Strategist, PROMOD IV, PROSYM/Market Analytics, PLEXOS, EnCompass, and PCI Gentrader models, and have reviewed input and output data for several other industry models.

Prior to joining Synapse in 2008, I worked for the Analysis Group, Inc., an economic and business consulting firm, where I provided litigation support in the form of research and quantitative analyses on a variety of issues relating to the electric industry.

I hold a Master of Environmental Management from Yale University and a Bachelor of Arts in Environment, Economics, and Politics from Claremont McKenna College in Claremont, California.

A copy of my current resume is attached as Exhibit RW-1.

Q. On whose behalf are you testifying in this case?

A. I am testifying on behalf of Sierra Club.

Q. Have you testified previously before the State Corporation Commission of Virginia?

A. Yes, in Case No. PUE-2015-00075.

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

A. My testimony evaluates whether the Company's 2018 Compliance Filing complies with the Virginia State Corporation Commission's (Commission) Order rejecting the Company's 2018 IRP. It also critiques certain resource assumptions made by the Company which, if modified, would change the results of its analysis.

Q. Please identify the documents and filings on which you base your opinions regarding the Company's 2018 Compliance Filing.

A. In addition to the Company's 2018 Compliance Filing, I reviewed the Company's responses to discovery filed by intervenors and Commission Staff as well as a number of industry documents relating to the cost and proliferation of battery storage resources.

Q. Are you sponsoring any exhibits?

A. Yes. I am sponsoring the following exhibits:

Exhibit RW-1: Resume of Rachel S. Wilson

Exhibit RW-2: Dominion's response to ER Set 12-25

Exhibit RW-3: *Dominion Energy Efficiency Potential Study: 2018-2027*, Appendix I, page I-5

Exhibit RW-4: Dominion's response to SC 7-1 with attachment SC 7-1(d)(KS)

Exhibit RW-5: Dominion's response to ER Set 12-18

Exhibit RW-6: Dominion's response to ER Set 5-5

Exhibit RW-7: Dominion's response to SC Set 3-10 with attachment SC 3-10(a)(TF)

2. MODELING CRITIQUES AND ADJUSTMENTS

Q. Please describe the critiques made by the Commission in its 2018 Order rejecting the IRP regarding the original modeling and resource portfolios created by the Company.

A. The Commission made several critiques related to the modeling in the Company's 2018 IRP, including:

- Directing the Company to use PJM's load forecast of coincident peak load and energy sales for the Dominion Zone in its revised IRP filing, noting that forecasts in the Company's previous IRPs have been consistently overstated;
- Finding that the Company's modeling included some, but not all, of the mandates contained in Senate Bill 966, the Grid Transformation and Security Act (GTSA), including $870 million in energy efficiency programs and additions of wind and solar resources totaling 5,000 MW by 2028;
- Requiring the Company to include a true least-cost resource optimization plan.

Q. Did the Company make all of these adjustments in its 2018 Compliance Filing?

A. No. the Company made some of the adjustments asked for by the Commission but did not make them all.

Q. Did the Company's 2018 Compliance Filing use PJM's forecast of coincident peak load and energy sales in the resource modeling?

A. Yes, the Company began with the 2018 PJM load forecast for the DOM zone and adjusted it downward to the level of the Dominion Load Serving Entity (LSE). I take no position on the methodology used to make the adjustment, nor the accuracy of the resulting numbers.

Q. Did the Company's 2018 Compliance Filing include an $870 million investment in energy efficiency programs?

A. No. the Company stated in the 2018 Compliance Filing that it added generic DSM that totaled $870 million and modeled these energy efficiency and peak demand savings as a load reducer. However, in response to discovery[1] the Company admitted that the $870 million investment included lost revenues that would be incurred due to reduced energy use by customers. If the Company had modeled an actual $870 million investment in energy efficiency programs, its peak load and annual energy forecasts would have been lower than what was modeled in the 2018 Compliance Filing.

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1 *See* Company's Response to Environmental Respondents' Request No. 12-25, attached as Exhibit RSW-2.

The Commission also ordered the Company to include "detailed plans to implement the mandates contained in (the GTSA) legislation."[2] The inclusion by the Company of "generic EE" fails to meet this requirement.

Q. Did you calculate the potential increased energy efficiency savings commensurate with an actual $870 million energy efficiency (EE) investment?

A. I calculated a similar value using the information that was available in the docket. The *Dominion Energy Efficiency Potential Study: 2018-2027*, done for the Company by DNV GL in October 2017,[3] includes the scenario "Program Savings Potential: 50% Incentives" which includes $891 million (present value of program cost) in utility energy efficiency spending. I used this "50% Incentives" scenario as a proxy for the GTSA's $870 million mandate, as the level of investment in this scenario approximated most closely the spending required under the GTSA.

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2 *See Commonwealth of Virginia, State Corporation Commission, In re: Virginia Electric and Power Company's Integrated Resource Plan filing pursuant to Va. Code § 56-597 et seq.* No. PUR-2018-00065, Order at 3 (December 7, 2018).

3 *See Commonwealth of Virginia, State Corporation Commission, Application of Virginia Electric and Power Company for approval to implement demand side management programs and for approval of two updated rate adjustment clauses pursuant to 56-585.1 A 5 of the Code of Virginia*, Case No. PUR-2018-00168, Direct Testimony of Tim Woolf and Erin Malone, Exhibit 11, TW/EM-21 (February 6, 2019) available at https://bit.ly/2U88i94.

Appendix I, page I-5[4] of the 2017 EE Potential Study contains annual energy and peak load reductions associated with that scenario from 2018 through 2027. I used those values starting in 2020 and reduced them post-2027 at the same rate of decay used by the Company in its calculations of Generic EE.[5] This is a conservative calculation, as it assumes no new energy efficiency programs will occur after this period. I subtracted these efficiency values from the Company's LSE load to calculate a new load forecast, net of GTSA-mandated DSM investments.

Q. **What was the effect of the additional EE savings that you included?**

A. The additional EE savings resulted in peak load savings of 282 MW in 2033 compared to the Company's Generic EE peak savings of 210 MW—an additional 72 MW. In terms of annual energy savings, the Company's forecast with Generic EE savings was 97,194 GWh in 2033. The adjusted annual energy forecast in 2033 was 96,279 GWh—an additional savings of 915 GWh. Again, these estimates are conservative as they assume no new EE programs after 2027, which is unrealistic.

4 *See* Dominion Energy Efficiency Potential Study: 2018-2027, Appendix I, attached as Exhibit RSW-3.

5 *See* Company's response to Sierra Club's Request No. 7-1, Attachment Sierra Club 7-1(d)(KS).xls, attached as Exhibit RSW-4.

Q. Since the filing of the 2018 Compliance Plan, has the Company announced any plans to propose the full $870 million investment on actual energy efficiency programs?

A. Yes. On March 29, 2019, the Company announced that it would propose the entire GTSA-mandated $870 million on energy efficiency programs over the next ten years, excluding lost revenues from its EE spending.[6]

Q. Would the Company need to revise the load forecast in the 2018 Compliance Filing to reflect this commitment?

A. Yes, the Company should be required to revise its load forecast to reflect increased energy efficiency and peak load savings achieved by the higher level of investment in EE.

Q. **Did the 2018 Compliance Filing include the GTSA-mandated battery storage pilot?**

A. Yes, it did.

Q. Did the Company's resource modeling supporting the 2018 Compliance Filing include battery storage technologies as a selectable resource?

A. No, the Company did not include any additional generic battery options in its PLEXOS resource optimization modeling for the 2018 IRP, as noted and discussed in the testimony

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6 *See* Robert Walton, *Dominion reverses on counting lost revenue as part of $870M Virginia efficiency spend*, UTILITY DIVE (March 29, 2019), available at https://bit.ly/2UIJJnt.

of Dr. Ezra Hausman at the 2018 IRP hearing;[7] and none of the Company's resource portfolios in the 2018 Compliance Filing include battery storage technologies beyond the pilot program. In Environmental Respondents Set 12-18, the Company stated that batteries were screened out of its model because they are more costly than other resource options.[8]

Q. **Would a busbar analysis of different energy costs, like the kind done by the Company, be sufficient as a screening tool to determine whether battery resources could be competitive?**

A. No. Battery storage resources offer a number of very specific benefits to the electric grid that are not captured in a busbar analysis, including regulation, spinning reserve, and ancillary support services. They also have the ability to pair with solar resources, charging during periods when there is excess solar energy, and discharging during peak periods to help meet demand in hours when solar resources are offline. A capacity expansion model that includes hourly or sub-hourly electric system dispatch is necessary to fully capture the benefits of battery storage resources to a utility's system. The PLEXOS model used

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7 *See Commonwealth of Virginia, 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 Ezra Hausman, Exhibit 24 (August 10, 2018), available at https://bit.ly/2X0VWBz.

8 *See* Company's Response to Environmental Respondents' Request No. 12-18, attached as Exhibit RSW-5.

by the Company in its analysis has this capability, they simply failed to utilize the model as a tool to evaluate battery resources.

Q. Is sufficient information available about the cost and operational parameters of battery storage to allow the Company to include these technologies in its resource modeling?

A. Yes. In Environmental Respondents Set 5-5, the Company identified *Lazard's Levelized Cost of Storage Analysis 3.0*,[9] dated November 2017, as "publicly-available industry guidance regarding battery storage projects" used to help the company "evaluate the technology's merits as compared to traditional generation sources."[10] Lazard 3.0, as well as Version 4.0 (published in November 2018), have sufficient information about the costs and operational parameters of battery storage resources such that the Company could have included these resources in its 2018 IRP modeling as well as its 2018 Compliance Filing. The Company need not have price quotes in response to an official resource solicitation (or RFP) to explore storage technologies in its resource modeling. IRPs are guidance documents to help guide a utility's procurement of future supply- and demand-side resources, while RFPs are intended to assist with near-term resource procurement. At the very least, the Company can allow the PLEXOS model to select storage resources

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9 *See* Company's Response to Environmental Respondents Request No. 5-5, Attachment ER Set 5-5.pdf, attached as Exhibit RSW-6

10 *Id.*

as a means to explore and identify the role that these technologies will have in the Company's resource portfolio, and to guide both near-term and long-term resource solicitations.

Q. Should the Company, then, have included battery storage as a selectable resource in its PLEXOS resource modeling supporting the 2018 Compliance Filing?

A. Yes, absolutely. In Environmental Respondents Set 5-5, when asked to explain why the Company did not evaluate storage technologies as an alternative to gas, the Company answered that once specific costs were available, it would include storage technologies as potential resources to replace gas-fired generation.[11] As discussed above, the Company currently has access to industry documents detailing generic costs and operational parameters for battery storage, which are sufficient for inclusion of these technologies in resource modeling.

The best way to evaluate the merits of battery storage relative to traditional generation sources is to make them a selectable resource in planning models. By doing so, the Company would be able to determine if battery resources at generic price assumptions can compete both now and in the future, and if so, at what levels of penetration.

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11 *See* Exhibit RSW-6.

Q. Can batteries currently compete with more traditional resources?

A. Yes. Most recently, two agencies reported in March 2019 on the competitiveness of battery storage resources, and storage-plus-renewables projects:

- A report from Bloomberg New Energy Finance found that the costs of battery storage have fallen by 76 percent from 2012, down from $800/MWh. Since the first half of 2018, the levelized cost of energy (LCOE) for lithium-ion batteries have fallen 35 percent to $187/MWh. The decline is attributed to technology innovation, economies of scale, price competition, and manufacturer experience. Finally, the report stated that batteries that are co-located with solar or wind projects (without subsidies) are beginning to compete with coal- and gas-fired generation in many markets for the provision of dispatchable energy.[12]

- A report from Navigant Research states that storage-plus-renewable PPAs are already less expensive than the levelized cost of energy for combined cycle natural gas plants.[13] The development of these projects is helping renewables transition

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12 *See* Veronika Henze, *Battery Power's Latest Plunge in Costs Threatens Coal, Gas*, BLOOMBERG NEW ENERGY FINANCE (March 26, 2019), available at: https://bit.ly/2HEPxIw.

13 *See* Lazard, *Levelized Cost of Energy Analysis—Version 12.0* at 2 (November 2018), available at https://bit.ly/2POeoJq(showing a levelized cost of energy of $41-$74/MWh for natural gas combined cycle units, $60-$143/MWh for coal, and $152-$206/MWh for natural gas peaking units).

from intermittent resources to dispatchable resources capable of displacing thermal assets.[14]

Q. Have any utilities contracted for storage or storage-plus-renewable capacity as a replacement for thermal resources?

A. Yes. Florida Power & Light (FPL) recently announced that it plans to build a 409 MW/900 MWh battery storage project, the Manatee Energy Storage Center, powered by an existing solar plant in order to help phase out two units at its gas-fired Manatee Clean Energy Center. The project will begin operation in 2021. FPL stated that deploying energy from batteries during peak periods will offset the need to run other generating resources, saving customers more than $100 million through avoided fuel costs and reducing CO_2 emissions by more than 1 million tons.[15]

In Hawaii, the Public Utilities Commission approved six grid-scale solar-plus-battery storage projects proposed by HECO—three on Oahu, one on Maui, and two on the island of Hawaii—adding 247 MW of solar capacity with almost one GWh of battery storage with four-hour duration. All six projects came in at a cost per kWh of 10 cents or less. HECO's current cost of fossil generation is approximately 15 cents per kWh. Two of

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14 *See* Navigant Research, *How Utilities Can Look Beyond Natural Gas with Cost-Effective Solar Plus Storage Strategies* (2019), available at https://bit.ly/2u7TgFJ.

15 Florida Power & Light, "FPL announces plan to build the world's largest solar-powered battery and drive accelerated retirement of fossil fuel generation" (March 28, 2019), available at https://bit.ly/2G1iVW9.

these projects are priced at 8 cents/kWh and were offered by Virginia's AES Corporation.[16]

Q. Does the PJM market have a role to play in the deployment of storage resources within its footprint?

A. Yes. According to the US Energy Information Administration (EIA), almost 40 percent of existing large-scale power capacity (MW) from battery storage is located within PJM, and the RTO accounts for 31 percent of total storage capacity deployed—the amount of energy that can be stored or discharged as measured by MWh.[17] Storage projects located in PJM currently in operation tend to be large from a power capacity perspective but have shorter durations or lower energy capacities, which are well-suited for the frequency regulation market created by PJM in 2012.

Deployment of large-scale storage resources intended to provide capacity and energy is set to increase as a result of FERC Order 841, issued in February 2018. The order removes barriers to the participation of storage resources in the capacity, energy, and ancillary services markets operated by Regional Transmission Organizations (RTOS) and Independent System Operators (ISOs). Each regional grid operation was tasked with

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16 Hawaiian Electric, "Six low-priced solar-plus-storage projects approved for Oahu, Maui and Hawaii islands" (March 27, 2019), available at https://bit.ly/2YJB0ka.

17 United States Energy Information Administration, *US Battery Storage Market Trends* (2018), available at https://bit.ly/2ISO3f7.

drafting market rules that recognize the unique physical and operational characteristics of electric storage resources and revising its tariff to establish a participation model for those resources. New market rules are intended to be in place in December 2019.

Q. How will FERC's Order 841 change the way in which battery storage resources are deployed in PJM?

A. Storage resources will be able to participate in PJM's energy and capacity markets under Order 841. The capacity value received by these resources (and thus the contribution to utility reserve margins) is still being determined, however, and that will influence penetration levels of these resources in the future.

In the comments submitted to FERC in the Order 841 docket, PJM sets the capacity value given to battery storage resources in the forward capacity market as the output that can be maintained over a continuous ten-hour period.[18] A battery's duration thus sets its capacity value, and determines the contribution toward a utility's reserve margin during peak periods. A battery with a 10-hour duration would receive a capacity value of 100 percent, while a battery with a 4-hour duration would have a value of 40 percent. NYISO has proposed a 4-hour duration, while ISO-NE proposed a 2- hour duration.

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18 *PJM Interconnection*, FERC Docket No. ER19-460-000, Order No. 841 - Compliance Filing ESR Markets and Operations Proposal at 25 (December 3, 2018), available at https://bit.ly/2UrSJhp.

FERC has yet to make a determination on the appropriate duration requirement for storage resources in PJM, and thus the capacity value awarded to these resources for utility resource planning has yet to be decided. While the outcome of that docket is pending, the required duration, and thus the capacity value given to battery storage, should significantly impact any Dominion "least cost" assessment for future resources.

3. FUTURE DOMINION INTEGRATED RESOURCE PLANS

Q. Are there issues that were not addressed by the Company in the 2018 Compliance Filing that the Commission should be monitoring in future IRP filings?

A. Yes, there are three primary issues that are related to each other: 1) the forward-going economics of the Company's existing coal units; 2) the cost of solar and solar-plus-storage resources; and 3) the cost, operational characteristics, and market rules for battery storage resources.

Q. What should the Commission be looking for with respect to the forward-going economics of the Company's existing coal units?

A. Historically, integrated resource planning focused on meeting increasing electricity demand by building the most cost-effective new resources available from a small subset of generator types, which were largely thermal. However, in recent years, electric loads around the country have experienced little to no growth. Limited load growth combined with rapidly falling costs for renewable energy resources, recent environmental regulations, and low natural gas prices has put increasing economic pressure on existing generation resources, especially coal units. It is no longer safe to assume that all existing generation resources form part of a least-cost, least-risk resource plan. Instead, a utility IRP should include an analysis of the economics of continuing to operate existing units compared to retiring them in the near term.

Q. Are there examples of this kind of analysis from other jurisdictions?

A. Yes. They include the following:

1. **PacifiCorp 2019 Integrated Resource Plan (IRP).** In its current IRP, PacifiCorp is conducting unit-by-unit assessments of alternative retirement dates for each of the 22 coal units that it is currently planning to continue operating through at least the mid-2020s. PacifiCorp's analytic process includes evaluating a variety of alternative retirement dates, using a capacity expansion model to identify an optimal set of resources to replace retiring units, and evaluating various combinations of early retirements for the units identified as least economic. PacifiCorp presented initial modeling results at a December stakeholder meeting that indicated that, when assessed individually, 13 of the 22 units evaluated were

uneconomic to continue operating beyond 2022.[19] Notably, the PacifiCorp analysis was required by an IRP Order from the Oregon Commission.[20]

2. **Northern Indiana Public Service Company (NIPSCO) 2018 IRP**. NIPSCO's most recent IRP evaluated three alternative retirement dates for each of its remaining five coal units, using the Aurora portfolio optimization model to select a least-cost combination of resources to replace any retiring units.[21] The costs of potential replacement resources were established largely based on responses to an all-source request for proposals. NIPSCO's analysis found that it would save its customers more than $4 billion dollars by retiring all of its coal units in 2023 rather than continuing to operate them through at least 2035.[22] Replacement resources include solar, storage, and demand-side management programs.

3. **Georgia Power Company 2019 IRP**. Georgia Power's recently released IRP incorporated unit retirement assessments for each of its coal-fired and gas-steam

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19 PacifiCorp, 2019 Integrated Resource Plan Public Input Meeting December 3-4 at 8-9 (2018), available at https://bit.ly/2KQsx8b.

20 Oregon Public Utility Commission, Docket No. LC 67, Order No. 18-138 (April 27, 2018).

21 *See* Northern Indiana Public Service Company, 2018 Integrated Resource Plan (October 31, 2018), available at https://bit.ly/2VEJSWx.

22 *See id* at 151.

units.[23] Georgia Power's assessment compared the costs and benefits of continuing to operate each unit compared to a proxy replacement resource determined through capacity expansion modeling. Georgia Power's publicly filed IRP redacted the detailed results of its unit retirement analyses, but Georgia Power announced that the retirement analysis results led it to propose to retire five of its coal units earlier than previously planned.[24]

4. **Idaho Power Company (IPC) 2017 IRP**. IPC designed its 2017 IRP portfolios around two decisions: whether to build a new transmission line and when to retire two of its coal units.[25] IPC evaluated four alternative retirement dates for two coal units at its Bridger plant. IPC determined that it could save customers money by retiring those units earlier than planned rather than investing in environmental control technologies to prolong their operation.

Q. Why should the Commission pay attention to the Company's estimate of the costs of solar and solar-plus-storage resources?

A. Capital costs for solar have declined over the past decade and are projected to continue to decline into the future, though at a slower pace. The Company has assumed that solar

23 Georgia Power, 2019 Integrated Resource Plan, Technical Appendix Volume 2: Unit Retirement Study (January 31, 2019), available at https://bit.ly/2UDLz9i.

24 *See id* at 1-7.

25 Idaho Power, 2017 Integrated Resource Plan (2017), available at https://bit.ly/2YWJ2q9.

costs stay constant into the future[26] rather than de-escalating over time. Utilities around the country continue to sign solar PPAs at lower rates, however, with Idaho Power announcing on March 26, 2019 that it has entered into a contract to purchase 120 MW of solar power for $21.75/MWh—less than 2.2 cents/kWh—a price that is among the lowest on record.[27] The Company can likely add solar resources at a lower cost in the future than what it assumed in the 2018 IRP and 2018 Compliance Filing.

Section 3 of my testimony gives specific examples of the current low cost of solar-plus-storage projects. Given the individual declining cost trajectories for stand-alone storage and battery projects, costs will decline for combined projects as well. The Company should be required to include these projects in future IRPs as selectable resources in its PLEXOS modeling at reasonable costs.

These declining cost trajectories would likely allow solar resources and/or solar-plus-storage resources to displace at least a portion of the natural gas peaking units that appear in all of the Company's resource plans presented in the 2018 Compliance Filing.

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26 *See* Company's Response to Sierra Club's Request No. 3-10, Attachment Sierra Club Set 3-10(a) (TR).xlsx, attached as Exhibit RSW-7.

27 *See* Idaho Power, "Idaho Power invests in clean, affordable solar energy" (March 26, 2019), available at https://bit.ly/2uDJnjr.

Q. Why should the Commission monitor the cost, operational characteristics, and market rules for battery storage resources?

A. Battery storage resources are rapidly becoming, and have become, cost-competitive for a number of different applications, including the potential to replace the traditional role of gas turbines as peaking resources. Whether a given battery resource needs to maintain output for 2 hours, or for 4 hours, versus 10 hours, greatly affects the underlying economics of considering battery vs. conventional gas turbine resources as part of a "least cost" expansion plan. Thus, any jurisdiction that is monitoring the effect of retiring uneconomic assets, and analyzing the overall costs of meeting peaking needs, must carefully monitor actual replacement peaking costs, given the final regulations that a utility will have in place to meet FERC requirements under Order 841.

4. CONCLUSIONS AND RECOMMENDATIONS

Q. Please summarize your conclusions.

A. Based on my review, I conclude that while the Company's 2018 Compliance Filing has met most of the criteria contained in the Commission's 2018 IRP Order, the 2018 Compliance Filing still contains significant omissions. First, the Company failed to include the GTSA mandated $870 million in energy efficiency investment, and the detailed plans for that level of investment. Second, the Company failed to include battery storage technologies as selectable resources in its PLEXOS capacity optimization at industry-sourced costs. Third, the Company failed to include any expected de-escalation in the future costs of solar resources. The combination of these factors has likely resulted in resource plans that result in higher costs to customers, continued reliance on fossil fuels, and increased levels of air emissions.

Q. Please summarize your recommendations.

A. I recommend that for future IRPs, the Commission require the Company to update its load forecast to include the full $870 million in proposed energy efficiency spending to which the Company has now committed. The Company should also include detailed plans for its energy efficiency programs underlying this level of spending.

The Company should be required to provide a detailed unit-by-unit analysis of its existing coal fleet. All resources, both existing and possible replacement resources, should be evaluated on a fair and consistent basis, with the focus on forward-going costs and benefits of continued unit operation. This analysis should be done in the PLEXOS model—a screening level analysis is acceptable at a high-level, but this type of analysis requires a model with capacity expansion, endogenous retirement, and hourly or sub-hourly dispatch capabilities.

Next, the Commission should also require that the Company include solar projects, battery storage projects, and solar-plus-storage projects as selectable resources in capacity expansion modeling used to create resource portfolios. The Company should use up-to-date estimates of costs and operational parameters that reflect both the Company's historical and current experience with these resources, as well as industry projections of cost and technology trends.

Lastly, the Commission should direct the Company that any future resource solicitations should be All-Resource Solicitations, which would allow the Company to determine the actual current costs and operating parameters of renewable and storage resources in its region.

Q. Does this conclude your direct testimony?

A. Yes.

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DIRECT TESTIMONY OF
RACHEL S. WILSON

Case No. PUR-2018-00065

**Commonwealth of Virginia *ex rel.* State Corporation Commission,
In re: Virginia Electric and Power Company's Integrated Resource Plan
filing pursuant to Viriginia Code § 56-597 et seq.**

EXHIBIT RSW-1

RESUME OF RACHEL S. WILSON

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PROFESSIONAL EXPERIENCE

Synapse Energy Economics Inc., Cambridge, MA. *Principal Associate*, April 2019 – present, *Senior Associate*, 2013 – 2019, *Associate*, 2010 – 2013, *Research Associate*, 2008 – 2010.

Provides consulting services and expert analysis on a wide range of issues relating to the electricity and natural gas sectors including: integrated resource planning; federal and state clean air policies; emissions from electricity generation; electric system dispatch; and environmental compliance technologies, strategies, and costs. Uses optimization and electricity dispatch models, including Strategist, PLEXOS, EnCompass, PROMOD, and PROSYM/Market Analytics to conduct analyses of utility service territories and regional energy markets.

Analysis Group, Inc., Boston, MA.

Associate, 2007 – 2008, *Senior Analyst Intern*, 2006 – 2007.

Provided litigation support and performed data analysis on various topics in the electric sector, including tradeable emissions permitting, coal production and contractual royalties, and utility financing and rate structures. Contributed to policy research, reports, and presentations relating to domestic and international cap-and-trade systems and linkage of international tradeable permit systems. Managed analysts' work processes and evaluated work products.

Yale Center for Environmental Law and Policy, New Haven, CT. *Research Assistant*, 2005 – 2007.

Gathered and managed data for the Environmental Performance Index, presented at the 2006 World Economic Forum. Interpreted statistical output, wrote critical analyses of results, and edited report drafts. Member of the team that produced *Green to Gold*, an award-winning book on corporate environmental management and strategy. Managed data, conducted research, and implemented marketing strategy.

Marsh Risk and Insurance Services, Inc., Los Angeles, CA. *Risk Analyst*, Casualty Department, 2003 – 2005.

Evaluated Fortune 500 clients' risk management programs/requirements and formulated strategic plans and recommendations for customized risk solutions. Supported the placement of $2 million in insurance premiums in the first year and $3 million in the second year. Utilized quantitative models to create loss forecasts, cash flow analyses and benchmarking reports. Completed a year-long Graduate Training Program in risk management; ranked #1 in the western region of the US and shared #1 national ranking in a class of 200 young professionals.

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EDUCATION

Yale School of Forestry & Environmental Studies, New Haven, CT
Masters of Environmental Management, concentration in Law, Economics, and Policy with a focus on energy issues and markets, 2007

Claremont McKenna College, Claremont, California
Bachelor of Arts in Environment, Economics, Politics (EEP), 2003. *Cum laude* and EEP departmental honors.

School for International Training, Quito, Ecuador
Semester abroad studying Comparative Ecology. Microfinance Intern – Viviendas del Hogar de Cristo in Guayaquil, Ecuador, Spring 2002.

ADDITIONAL SKILLS AND ACCOMPLISHMENTS

- Microsoft Office Suite, Lexis-Nexis, Platts Energy Database, Strategist, PROMOD, PROSYM/Market Analytics, EnCompass, and PLEXOS, some SAS and STATA.
- Competent in oral and written Spanish.
- Hold the Associate in Risk Management (ARM) professional designation.

PUBLICATIONS

Camp, E., B. Fagan, J. Frost, D. Glick, A. Hopkins, A. Napoleon, N. Peluso, K. Takahashi, D. White, R. Wilson, T. Woolf. 2018. *Phase 1 Findings on Muskrat Falls Project Rate Mitigation.* Prepared by Synapse Energy Economics for Board of Commissioners of Public Utilities, Province of Newfoundland and Labrador.

Allison, A., R. Wilson, D. Glick, J. Frost. 2018. *Comments on South Africa 2018 Integrated Resource Plan.* Prepared by Synapse Energy Economics for Centre for Environmental Rights.

Hall, J., R. Wilson, J. Kallay. 2018. *Effects of the Draft CAFE Standard Rule on Vehicle Safety*. Prepared by Synapse Energy Economics on behalf of Consumers Union.

Whited, M., A. Allison, R. Wilson. 2018. *Driving Transportation Electrification Forward in New York: Considerations for Effective Transportation Electrification Rate Design*. Prepared by Synapse Energy Economics on behalf of the Natural Resources Defense Council.

Wilson, R., S. Fields, P. Knight, E. McGee, W. Ong, N. Santen, T. Vitolo, E. A. Stanton. 2016. *Are the Atlantic Coast Pipeline and the Mountain Valley Pipeline Necessary? An examination of the need for additional pipeline capacity in Virginia and Carolinas.* Synapse Energy Economics for Southern Environmental Law Center and Appalachian Mountain Advocates.

Wilson, R., T. Comings, E. A. Stanton. 2015. *Analysis of the Tongue River Railroad Draft Environmental Impact Statement.* Synapse Energy Economics for Sierra Club and Earthjustice.

Wilson, R., M. Whited, S. Jackson, B. Biewald, E. A. Stanton. 2015. *Best Practices in Planning for Clean Power Plan Compliance.* Synapse Energy Economics for the National Association of State Utility Consumer Advocates.

Luckow, P., E. A. Stanton, S. Fields, B. Biewald, S. Jackson, J. Fisher, R. Wilson. 2015. *2015 Carbon Dioxide Price Forecast.* Synapse Energy Economics.

Stanton, E. A., P. Knight, J. Daniel, B. Fagan, D. Hurley, J. Kallay, E. Karaca, G. Keith, E. Malone, W. Ong, P. Peterson, L. Silvestrini, K. Takahashi, R. Wilson. 2015. *Massachusetts Low Gas Demand Analysis: Final Report.* Synapse Energy Economics for the Massachusetts Department of Energy Resources.

Fagan, B., R. Wilson, D. White, T. Woolf. 2014. *Filing to the Nova Scotia Utility and Review Board on Nova Scotia Power's October 15, 2014 Integrated Resource Plan: Key Planning Observations and Action Plan Elements.* Synapse Energy Economics for the Nova Scotia Utility and Review Board.

Wilson, R., B. Biewald, D. White. 2014. *Review of BC Hydro's Alternatives Assessment Methodology.* Synapse Energy Economics for BC Hydro.

Wilson, R., B. Biewald. 2013. *Best Practices in Electric Utility Integrated Resource Planning: Examples of State Regulations and Recent Utility Plans.* Synapse Energy Economics for Regulatory Assistance Project.

Fagan, R., P. Luckow, D. White, R. Wilson. 2013. *The Net Benefits of Increased Wind Power in PJM.* Synapse Energy Economics for Energy Future Coalition.

Hornby, R., R. Wilson. 2013. *Evaluation of Merger Application filed by APCo and WPCo.* Synapse Energy Economics for West Virginia Consumer Advocate Division.

Johnston, L., R. Wilson. 2012. *Strategies for Decarbonizing Electric Power Supply.* Synapse Energy Economics for Regulatory Assistance Project, Global Power Best Practice Series, Paper #6.

Wilson, R., P. Luckow, B. Biewald, F. Ackerman, E. Hausman. 2012. *2012 Carbon Dioxide Price Forecast.* Synapse Energy Economics.

Hornby, R., R. Fagan, D. White, J. Rosenkranz, P. Knight, R. Wilson. 2012. *Potential Impacts of Replacing Retiring Coal Capacity in the Midwest Independent System Operator (MISO) Region with Natural Gas or Wind Capacity.* Synapse Energy Economics for Iowa Utilities Board.

Fagan, R., M. Chang, P. Knight, M. Schultz, T. Comings, E. Hausman, R. Wilson. 2012. *The Potential Rate Effects of Wind Energy and Transmission in the Midwest ISO Region.* Synapse Energy Economics for Energy Future Coalition.

Fisher, J., C. James, N. Hughes, D. White, R. Wilson, and B. Biewald. 2011. *Emissions Reductions from Renewable Energy and Energy Efficiency in California Air Quality Management Districts.* Synapse Energy Economics for California Energy Commission.

Wilson, R. 2011. *Comments Regarding MidAmerican Energy Company Filing on Coal-Fired Generation in Iowa*. Synapse Energy Economics for the Iowa Office of the Consumer Advocate.

Hausman, E., T. Comings, R. Wilson, and D. White. 2011. *Electricity Scenario Analysis for the Vermont Comprehensive Energy Plan 2011*. Synapse Energy Economics for Vermont Department of Public Service.

Hornby, R., P. Chernick, C. Swanson, D. White, J. Gifford, M. Chang, N. Hughes, M. Wittenstein, R. Wilson, B. Biewald. 2011. *Avoided Energy Supply Costs in New England: 2011 Report*. Synapse Energy Economics for Avoided-Energy-Supply-Component (AESC) Study Group.

Wilson, R., P. Peterson. 2011. *A Brief Survey of State Integrated Resource Planning Rules and Requirements*. Synapse Energy Economics for American Clean Skies Foundation.

Johnston, L., E. Hausman., B. Biewald, R. Wilson, D. White. 2011. *2011 Carbon Dioxide Price Forecast*. Synapse Energy Economics.

Fisher, J., R. Wilson, N. Hughes, M. Wittenstein, B. Biewald. 2011. *Benefits of Beyond BAU: Human, Social, and Environmental Damages Avoided Through the Retirement of the US Coal Fleet*. Synapse Energy Economics for Civil Society Institute.

Peterson, P., V. Sabodash, R. Wilson, D. Hurley. 2010. *Public Policy Impacts on Transmission Planning*. Synapse Energy Economics for Earthjustice.

Fisher, J., J. Levy, Y. Nishioka, P. Kirshen, R. Wilson, M. Chang, J. Kallay, C. James. 2010. *Co-Benefits of Energy Efficiency and Renewable Energy in Utah: Air Quality, Health and Water Benefits.* Synapse Energy Economics, Harvard School of Public Health, Tufts University for State of Utah Energy Office.

Fisher, J., C. James, L. Johnston, D. Schlissel, R. Wilson. 2009. *Energy Future: A Green Alternative for Michigan*. Synapse Energy Economics for Natural Resources Defense Council (NRDC) and Energy Foundation.

Schlissel, D., R. Wilson, L. Johnston, D. White. 2009. *An Assessment of Santee Cooper's 2008 Resource Planning*. Synapse Energy Economics for Rockefeller Family Fund.

Schlissel, D., A. Smith, R. Wilson. 2008. *Coal-Fired Power Plant Construction Costs*. Synapse Energy Economics.

TESTIMONY

Washington Utilities and Transportation Commission (Dockets UE-170485 & UG-170486): Response testimony regarding Avista Corporation's production cost modeling. On behalf of Public Counsel Unit of the Washington Attorney General's Office. October 27, 2017.

Texas Public Utilities Commission (SOAH Docket No. 473-17-1764, PUC Docket No. 46449): Cross-rebuttal testimony evaluating Southwestern Electric Power Company's application for authority to change rates to recover the costs of investments in pollution control equipment. On behalf of Sierra Club and Dr. Lawrence Brough. May 19, 2017.

Texas Public Utilities Commission (SOAH Docket No. 473-17-1764, PUC Docket No. 46449): Direct testimony evaluating Southwestern Electric Power Company's application for authority to change rates to recover the costs of investments in pollution control equipment. On behalf of Sierra Club and Dr. Lawrence Brough. April 25, 2017.

Virginia State Corporation Commission (Case No. PUE-2015-00075): Direct testimony evaluating the petition for a Certificate of Public Convenience and Necessity filed by Virginia Electric and Power Company to construct and operate the Greensville County Power Station and to increase electric rates to recover the cost of the project. On behalf of Environmental Respondents. November 5, 2015.

Missouri Public Service Commission (Case No. ER-2014-0370): Direct and surrebuttal testimony evaluating the prudence of environmental retrofits at Kansas City Power & Light Company's La Cygne Generating Station. On behalf of Sierra Club. April 2, 2015 and June 5, 2015.

Oklahoma Corporation Commission (Cause No. PUD 201400229): Direct testimony evaluating the modeling of Oklahoma Gas & Electric supporting its request for approval and cost recovery of a Clean Air Act compliance plan and Mustang modernization, and presenting results of independent Gentrader modeling analysis. On behalf of Sierra Club. December 16, 2014.

Michigan Public Service Commission (Case No. U-17087): Direct testimony before the Commission discussing Strategist modeling relating to the application of Consumers Energy Company for the authority to increase its rates for the generation and distribution of electricity. On behalf of the Michigan Environmental Council and Natural Resources Defense Council. February 21, 2013.

Indiana Utility Regulatory Commission (Cause No. 44217): Direct testimony before the Commission discussing PROSYM/Market Analytics modeling relating to the application of Duke Energy Indiana for Certificates of Public Convenience and Necessity. On behalf of Citizens Action Coalition, Sierra Club, Save the Valley, and Valley Watch. November 29, 2012.

Kentucky Public Service Commission (Case No. 2012-00063): Direct testimony before the Commission discussing upcoming environmental regulations and electric system modeling relating to the application of Big Rivers Electric Corporation for a Certificate of Public Convenience and Necessity and for approval of its 2012 environmental compliance plan. On behalf of Sierra Club. July 23, 2012.

Kentucky Public Service Commission (Case No. 2011-00401): Direct testimony before the Commission discussing STRATEGIST modeling relating to the application of Kentucky Power Company for a Certificate of Public Convenience and Necessity, and for approval of its 2011 environmental compliance plan and amended environmental cost recovery surcharge. On behalf of Sierra Club. March 12, 2012.

Kentucky Public Service Commission (Case No. 2011-00161 and Case No. 2011-00162): Direct testimony before the Commission discussing STRATEGIST modeling relating to the applications of Kentucky Utilities Company, and Louisville Gas and Electric Company for Certificates of Public Convenience and Necessity, and approval of its 2011 compliance plan for recovery by environmental surcharge. On behalf of Sierra Club and Natural Resources Defense Council (NRDC). September 16, 2011.

Minnesota Public Utilities Commission (OAH Docket No. 8-2500-22094-2 and MPUC Docket No. E-017/M-10-1082): Rebuttal testimony before the Commission describing STRATEGIST modeling performed in the docket considering Otter Tail Power's application for an Advanced Determination of Prudence for BART retrofits at its Big Stone plant. On behalf of Izaak Walton League of America, Fresh Energy, Sierra Club, and Minnesota Center for Environmental Advocacy. September 7, 2011.

PRESENTATIONS

Wilson, R. 2017. "Integrated Resource Planning: Past, Present, and Future." Presentation for the Michigan State University Institute of Public Utilities Grid School. March 29, 2017.

Wilson, R. 2015. "Best Practices in Clean Power Plan Planning." NASEO/ACEEE Webinar. June 29, 2015.

Wilson, R. 2009. "The Energy-Water Nexus: Interactions, Challenges, and Policy Solutions." Presentation for the National Drinking Water Symposium. October 13, 2009.

Resume dated April 2019

DIRECT TESTIMONY OF WILLIAM H. PENNIMAN

Case No. PUR-2018-00065

Commonwealth of Virginia *ex rel.* State Corporation Commission,
In re: Virginia Electric and Power Company's Integrated Resource Plan
filing pursuant to Viriginia Code § 56-597 et seq.

EXHIBIT RSW-2

COMPANY'S RESPONSE TO ENVIRONMENTAL RESPONDENTS' DISCOVERY REQUEST NO. 12-25

190410277

Virginia Electric and Power Company
Case No. PUR-2018-00065
Environmental Respondents
Twelfth Set

The following response to Question No. 25 of the Twelfth Set of Interrogatories and Requests for Production of Documents Propounded by the Environmental Respondents received on March 12, 2019 has been prepared under my supervision.

[signature] for
Deanna R. Kesler
Regulatory Consultant
Dominion Energy Services, Inc.

Question No. 25

Reference page 5 of the Compliance Filing, which mentions "spending of $870 million by year 2028." Does any of the $870 million in spending included the Company's modeling include recovery of lost revenue? If yes, how much?

Response:

The $870 million of DSM included in the refiling includes two components. The first reflects the DSM programs that were filed in October 2018 with the proposed cost cap requested by the Company which includes the lost revenue component for those programs and spending associated with those programs beyond the requested 5 year cost cap period through 2028 (EM&V, program continuation, etc.). This amounts to approximately $298 million by 2028 for the programs which the Company is currently seeking approval. On March 20, 2019, the Company corrected the 5-year cost cap in its DSM proceeding (Case No. PUR-2018-00168). The effect of this correction in the DSM proceeding should be minimal on the 2018 Compliance Filing, and, therefore, the Company has not re-run its analysis to reflect that correction.

The second component is a 'generic' block of reductions. The remaining approximately $572 million of cost is reflected in this component. Based upon the 2018 program bids, the Company assumed a cost of $200/MWh, which resulted in a MWh volume of approximately 2,862,000 MWh (approximately $572.39 M ÷ $200/MWh = 2,861,950 MWh), which was allocated equally over the 2021 - 2028 time period. There is no specific assumption made regarding what 'costs' the $200/MWh represents other than they are costs that would be incurred by the Company (including lost revenues) and not participants. However, because the total volume of EE savings (2,862,000 MWh) was calculated based on a straight multiplication of the total assumed program cost ($200/MWh), those total savings could reflect lost revenues.

DIRECT TESTIMONY OF
RACHEL S. WILSON

Case No. PUR-2018-00065

Commonwealth of Virginia *ex rel.* State Corporation Commission,
In re: Virginia Electric and Power Company's Integrated Resource Plan
filing pursuant to Viriginia Code § 56-597 et seq.

EXHIBIT RSW-3

DOMINION ENERGY EFFICIENCY POTENTIAL STUDY: 2018-2027

APPENDIX I — PAGE I-5

Electricity
All Segments
Total
50

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Cumulative Gross Energy - kWh	647,758,643	1,100,703,533	1,674,294,563	2,267,266,049	2,724,375,000	3,111,470,020	3,340,347,924	3;609,778,429	3,883,476,488	4,130,729,909
Cumulative Gross Peak Demand - kW	115,835	207,406	322,158	445,876	557,176	660,133	733,399	813,414	891,346	960,850
Cumulative Net Energy Savings - kWh	341,021,395	696,176,227	1,169,704,917	1,651,989,146	1,998,923,845	2,283,517,499	2,524,997,140	2,727,892,758	2,897,208,966	3,041,795,757
Cumulative Net Peak Demand Savings - kW	57,359	131,274	228,464	333,429	426,079	511,390	589,423	659,352	719,695	771,852
New Net Energy Savings - kWh	341,021,395	355,154,831	473,528,690	482,284,229	346,934,699	284,593,654	241,479,641	202,895,618	169,316,208	144,586,792
New Net Peak Demand Savings - kW	57,359	73,915	97,190	104,965	92,650	85,311	78,033	69,930	60,343	52,157
Administration Costs	11,321,028	11,197,240	12,102,645	11,109,221	10,480,104	10,040,755	9,670,692	9,310,971	9,007,509	8,763,285
Marketing Costs	10,107,147	10,107,147	10,107,147	10,107,147	10,107,147	10,107,147	10,107,147	10,107,147	10,107,147	10,107,147
Incentives Costs	94,098,421	96,909,847	104,098,729	98,047,052	89,896,884	83,443,498	77,704,807	71,995,621	67,182,478	62,934,861
Total	115,526,596	118,214,234	126,308,522	119,263,420	110,484,136	103,591,400	97,482,646	91,413,740	86,297,134	81,805,293
PV Net Avoided Cost Benefits	228,536,903	247,916,069	348,638,861	351,598,832	251,751,869	206,951,856	174,429,565	145,637,362	119,871,711	100,871,224
PV Annual Program Marketing and Admin Costs	21,428,175	20,437,274	20,438,657	18,729,787	17,434,684	16,368,145	15,413,541	14,517,260	13,708,752	12,982,766
PV Net Measure Costs	165,287,525	163,022,589	161,558,137	148,737,392	131,640,809	116,824,936	103,573,874	91,281,149	80,846,438	71,653,692
TRC Ratio	1.22	1.35	1.92	2.10	1.69	1.55	1.47	1.38	1.27	1.19
Free Riders - kWh	79,564,291	156,462,323	242,586,124	339,146,458	436,893,579	532,207,576	626,515,380	720,685,413	813,824,391	905,600,842
Free Riders - kW	14,981	29,340	44,733	61,293	77,926	94,378	110,513	126,706	142,337	157,787
Other Naturally Occurring - kWh	227,172,957	248,064,984	262,003,522	276,130,445	288,557,576	295,744,944	188,835,403	161,200,259	172,443,131	183,333,310
Other Naturally Occurring - kW	43,495	46,792	48,961	51,154	53,171	54,365	33,464	27,356	29,315	31,211
Cost per First-Year Net kWh	$0.34	$0.33	$0.27	$0.25	$0.32	$0.36	$0.40	$0.45	$0.51	$0.57
PV Annual Program Costs	115,526,596	113,402,781	116,235,961	105,285,617	93,565,478	84,157,601	75,971,532	68,342,204	61,891,044	56,281,643
PV Lost Revenue	382,953,713	395,538,382	596,724,240	588,888,133	374,651,837	286,677,670	229,467,231	183,637,881	146,111,608	121,382,315
RIM	0.46	0.49	0.49	0.51	0.54	0.56	0.57	0.58	0.58	0.57

190410277

DIRECT TESTIMONY OF
RACHEL S. WILSON

Case No. PUR-2018-00065

Commonwealth of Virginia *ex rel.* State Corporation Commission,
In re: Virginia Electric and Power Company's Integrated Resource Plan
filing pursuant to Viriginia Code § 56-597 et seq.

EXHIBIT RSW-4

COMPANY'S RESPONSE TO
SIERRA CLUB'S DISCOVERY
REQUEST NO. 7-1 / ATTACHMENT SC 7-1(d)

Virginia Electric and Power Company
Case No. PUR-2018-00065
Sierra Club
Seventh Set

The following response to Question No. 1 (a, b, d, e) of the Seventh Set of Interrogatories and Requests for Production of Documents Propounded by the Sierra Club received on March 8, 2019 has been prepared under my supervision as it pertains to load forecast.

Karim Siamer
Lead Economist,
Load Research and Forecast
Dominion Energy Services, Inc.

Question No. 1 (a, b, d, e)

Regarding the Company's load forecast in its 2018 Compliance Filing:

(a) Please indicate the date of the Dominion Zone PJM forecast shown on page 12 of the Compliance Filing.

(b) Please provide the calculations, in machine-readable format with all formulae intact and unlocked, that scales the PJM coincident peak load forecast and energy sales forecast down to the Dominion LSE level, as described on page 11 of the Compliance Filing.

(d) Page 6 of the Compliance Filing states that "In the PLEXOS modeling, DSM is modeled as a load reducer." Please provide the load forecast, net of DSM, used in the Plexos model.

(e) Provide the annual energy and peak reductions included in the load forecast (net of DSM) that are associated with Dominion's existing Energy Efficiency (EE) programs, distinguishing between the DSM filed in the 2018 Virginia DSM filing, and the "generic DSM" that totals to $870 million.

Response:

(a) PJM Load Forecast Report (January 2018) released on December 28, 2017 and prepared by PJM Resource Adequacy Planning Department.

(b) See Attachment Sierra Club Set 7-1 (b) (KS).

(d) See Attachment Sierra Club Set 7-1 (d) (KS).

(e) See Attachment Sierra Club Set 7-1 (d) (KS).

Year	Month	Zonal Energy (MWh)	LSE Energy (MWh)	EE Energy w/o Generic (MWh)	EE Energy w Generic3 (MWh)	LSE Energy Net EE w/o Generic (MWh)	LSE Energy Net EE w Generic3 (MWh)	Zonal Peak (MW)	LSE_Peak (MW)	EE Peak w/o Generic (MW)	EE Peak w Generic3 (MW)	EE Cost w/o Generic	EE Cost w Generic3	CumEE Cost w/o Generic	CumEE w Generic3
2019	1	9,367,000	8,177,391	97,454	97,454	8,079,937	8,079,937	18,407	16,080	149	149	$ 2,349,099	$ 2,349,099	$ 2,349,099	$ 2,349,099
2019	2	8,173,000	7,135,029	87,039	87,039	7,047,990	7,047,990	17,045	14,891	249	249	$ 2,349,099	$ 2,349,099	$ 4,698,199	$ 4,698,199
2019	3	7,931,000	6,923,763	81,936	81,936	6,841,827	6,841,827	15,909	13,898	101	101	$ 2,349,099	$ 2,349,099	$ 7,047,298	$ 7,047,298
2019	4	7,076,000	6,177,348	65,412	65,412	6,111,936	6,111,936	15,743	13,753	64	64	$ 2,349,099	$ 2,349,099	$ 9,396,398	$ 9,396,398
2019	5	7,368,000	6,432,264	67,530	67,530	6,364,734	6,364,734	17,177	15,006	133	133	$ 2,349,099	$ 2,349,099	$ 11,745,497	$ 11,745,497
2019	6	8,842,000	7,719,066	76,851	76,851	7,642,215	7,642,215	18,947	16,552	173	173	$ 2,349,099	$ 2,349,099	$ 14,094,596	$ 14,094,596
2019	7	9,815,000	8,568,495	81,061	81,061	8,487,434	8,487,434	19,800	17,297	106	106	$ 4,377,301	$ 4,377,301	$ 18,471,897	$ 18,471,897
2019	8	9,556,000	8,342,388	84,072	84,072	8,258,316	8,258,316	19,485	17,022	102	102	$ 4,377,301	$ 4,377,301	$ 22,849,198	$ 22,849,198
2019	9	7,959,000	6,948,207	72,091	72,091	6,876,116	6,876,116	17,572	15,351	91	91	$ 4,377,301	$ 4,377,301	$ 27,226,499	$ 27,226,499
2019	10	7,326,000	6,395,598	75,739	75,739	6,319,859	6,319,859	15,291	13,358	127	127	$ 4,377,302	$ 4,377,302	$ 31,603,801	$ 31,603,801
2019	11	7,557,000	6,597,261	80,835	80,835	6,516,426	6,516,426	14,836	12,961	96	96	$ 4,377,302	$ 4,377,302	$ 35,981,103	$ 35,981,103
2019	12	8,804,000	7,685,892	99,530	99,530	7,586,362	7,586,362	16,547	14,455	210	210	$ 4,377,302	$ 4,377,302	$ 40,358,405	$ 40,358,405
2020	1	9,381,000	8,189,613	118,276	118,276	8,071,337	8,071,337	18,514	16,174	166	166	$ 3,680,584	$ 3,680,584	$ 44,038,989	$ 44,038,989
2020	2	8,461,000	7,386,453	111,353	111,353	7,275,100	7,275,100	17,159	14,990	285	285	$ 3,680,584	$ 3,680,584	$ 47,719,573	$ 47,719,573
2020	3	7,965,000	6,953,445	104,482	104,482	6,848,963	6,848,963	16,276	14,219	151	151	$ 3,680,584	$ 3,680,584	$ 51,400,157	$ 51,400,157
2020	4	7,074,000	6,175,602	87,451	87,451	6,088,151	6,088,151	16,181	14,136	195	195	$ 3,680,584	$ 3,680,584	$ 55,080,741	$ 55,080,741
2020	5	7,370,000	6,434,010	91,774	91,774	6,342,236	6,342,236	17,258	15,077	142	142	$ 3,680,584	$ 3,680,584	$ 58,761,325	$ 58,761,325
2020	6	8,871,000	7,744,383	101,352	101,352	7,643,031	7,643,031	18,989	16,589	152	152	$ 3,746,425	$ 3,746,425	$ 62,507,750	$ 62,507,750
2020	7	9,855,000	8,603,415	108,848	108,848	8,494,567	8,494,567	19,858	17,348	161	161	$ 1,906,101	$ 1,906,101	$ 64,413,851	$ 64,413,851
2020	8	9,555,000	8,341,515	112,525	112,525	8,228,990	8,228,990	19,512	17,046	194	194	$ 1,906,101	$ 1,906,101	$ 66,319,952	$ 66,319,952
2020	9	7,985,000	6,970,905	96,591	96,591	6,874,314	6,874,314	17,774	15,527	171	171	$ 1,906,101	$ 1,906,101	$ 68,226,052	$ 68,226,052
2020	10	7,338,000	6,406,074	97,695	97,695	6,308,379	6,308,379	15,202	13,280	234	234	$ 1,906,101	$ 1,906,101	$ 70,132,153	$ 70,132,153
2020	11	7,572,000	6,610,356	100,912	100,912	6,509,444	6,509,444	14,870	12,990	117	117	$ 1,906,101	$ 1,906,101	$ 72,038,254	$ 72,038,254
2020	12	8,857,000	7,732,161	118,149	118,149	7,614,012	7,614,012	16,833	14,705	255	255	$ 1,906,101	$ 1,906,101	$ 73,944,354	$ 73,944,354
2021	1	9,386,000	8,193,978	131,853	166,188	8,062,125	8,027,790	18,677	16,316	178	235	$ 3,778,038	$ 9,740,431	$ 77,722,393	$ 83,684,785
2021	2	8,228,000	7,183,044	118,253	148,216	7,064,791	7,034,828	17,371	15,175	141	195	$ 3,778,038	$ 9,740,431	$ 81,500,431	$ 93,425,216
2021	3	8,090,000	7,062,570	115,421	144,301	6,947,149	6,918,269	16,580	14,484	210	258	$ 3,778,038	$ 9,740,431	$ 85,278,469	$ 103,165,646
2021	4	7,131,000	6,225,363	96,426	121,034	6,128,937	6,104,329	16,359	14,291	306	344	$ 3,778,038	$ 9,740,431	$ 89,056,508	$ 112,906,077
2021	5	7,430,000	6,486,390	99,972	126,157	6,386,418	6,360,233	17,411	15,210	146	195	$ 3,778,038	$ 9,740,431	$ 92,834,546	$ 122,646,507
2021	6	8,940,000	7,804,620	108,305	138,828	7,696,315	7,665,792	19,198	16,771	221	274	$ 3,778,038	$ 9,740,431	$ 96,612,585	$ 132,386,938
2021	7	9,911,000	8,652,303	115,752	151,344	8,536,551	8,500,959	20,031	17,499	205	267	$ 3,778,038	$ 9,740,431	$ 100,390,623	$ 142,127,369
2021	8	9,654,000	8,427,942	118,455	153,069	8,309,487	8,274,873	19,728	17,234	198	257	$ 3,778,038	$ 9,740,431	$ 104,168,661	$ 151,867,799
2021	9	8,059,000	7,035,507	101,560	130,184	6,933,947	6,905,323	17,887	15,626	172	221	$ 3,778,038	$ 9,740,431	$ 107,946,700	$ 161,608,230
2021	10	7,395,000	6,455,835	102,197	127,861	6,353,638	6,327,974	15,466	13,511	291	329	$ 3,778,038	$ 9,740,431	$ 111,724,738	$ 171,348,661
2021	11	7,671,000	6,696,783	105,634	132,156	6,591,149	6,564,627	15,158	13,242	120	159	$ 3,778,038	$ 9,740,431	$ 115,502,777	$ 181,089,091
2021	12	8,947,000	7,810,731	123,117	155,351	7,687,614	7,655,380	17,029	14,877	238	290	$ 3,778,038	$ 9,740,431	$ 119,280,815	$ 190,829,522
2022	1	9,495,000	8,289,135	139,044	173,380	8,150,091	8,115,755	18,883	16,496	297	347	$ 4,780,389	$ 10,742,781	$ 124,061,204	$ 201,572,303
2022	2	8,306,000	7,251,138	125,191	155,153	7,125,947	7,095,985	17,567	15,347	275	323	$ 4,780,389	$ 10,742,781	$ 128,841,593	$ 212,315,085
2022	3	8,171,000	7,133,283	122,702	151,583	7,010,581	6,981,700	16,298	14,238	248	296	$ 4,780,389	$ 10,742,781	$ 133,621,983	$ 223,057,866
2022	4	7,197,000	6,282,981	103,171	127,779	6,179,810	6,155,202	16,102	14,067	371	411	$ 4,780,389	$ 10,742,781	$ 138,402,372	$ 233,800,648
2022	5	7,511,000	6,557,103	107,182	133,367	6,449,921	6,423,736	17,425	15,222	149	198	$ 4,780,389	$ 10,742,781	$ 143,182,761	$ 244,543,429
2022	6	9,024,000	7,877,952	116,833	147,356	7,761,119	7,730,596	19,413	16,959	193	249	$ 4,780,389	$ 10,742,781	$ 147,963,150	$ 255,286,211
2022	7	9,985,000	8,716,905	127,225	162,817	8,589,680	8,554,088	20,227	17,670	214	276	$ 4,780,389	$ 10,742,781	$ 152,743,539	$ 266,028,992
2022	8	9,769,000	8,528,337	130,558	165,172	8,397,779	8,363,165	19,894	17,379	213	272	$ 4,780,389	$ 10,742,781	$ 157,523,929	$ 276,771,774
2022	9	8,144,000	7,109,712	113,269	141,892	6,996,443	6,967,820	17,997	15,722	185	235	$ 4,780,389	$ 10,742,781	$ 162,304,318	$ 287,514,555
2022	10	7,491,000	6,539,643	114,466	140,130	6,425,177	6,399,513	15,725	13,737	476	517	$ 4,780,389	$ 10,742,781	$ 167,084,707	$ 298,257,337
2022	11	7,761,000	6,775,353	119,789	146,311	6,655,564	6,629,042	15,347	13,407	137	175	$ 4,780,389	$ 10,742,781	$ 171,865,096	$ 309,000,118
2022	12	9,043,000	7,894,539	140,939	173,173	7,753,600	7,721,366	17,209	15,034	261	313	$ 4,780,389	$ 10,742,781	$ 176,645,486	$ 319,742,900
2023	1	9,595,000	8,376,435	158,206	192,542	8,218,229	8,183,893	19,019	16,615	306	356	$ 5,853,041	$ 11,815,434	$ 182,498,527	$ 331,558,333
2023	2	8,383,000	7,318,359	141,874	171,836	7,176,485	7,146,523	17,726	15,485	386	441	$ 5,853,041	$ 11,815,434	$ 188,351,568	$ 343,373,767
2023	3	8,240,000	7,193,520	139,077	167,958	7,054,443	7,025,562	16,216	14,166	247	294	$ 5,853,041	$ 11,815,434	$ 194,204,610	$ 355,189,200
2023	4	7,247,000	6,326,631	117,438	142,046	6,209,193	6,184,585	15,784	13,789	477	516	$ 5,853,041	$ 11,815,434	$ 200,057,651	$ 367,004,634
2023	5	7,575,000	6,612,975	121,584	147,769	6,491,391	6,465,206	17,522	15,307	165	214	$ 5,853,041	$ 11,815,434	$ 205,910,692	$ 378,820,067
2023	6	9,095,000	7,939,935	132,219	162,742	7,807,716	7,777,193	19,505	17,040	222	279	$ 5,853,041	$ 11,815,434	$ 211,763,733	$ 390,635,501
2023	7	10,043,000	8,767,539	145,286	180,878	8,622,253	8,586,661	20,331	17,761	238	300	$ 5,853,041	$ 11,815,434	$ 217,616,775	$ 402,450,935
2023	8	9,840,000	8,590,320	148,040	182,654	8,442,280	8,407,666	19,960	17,437	238	296	$ 5,853,041	$ 11,815,434	$ 223,469,816	$ 414,266,368
2023	9	8,196,000	7,155,108	128,997	157,620	7,026,111	6,997,488	18,061	15,778	210	260	$ 5,853,041	$ 11,815,434	$ 229,322,857	$ 426,081,802
2023	10	7,545,000	6,586,785	129,803	155,467	6,456,982	6,431,318	15,828	13,827	537	578	$ 5,853,041	$ 11,815,434	$ 235,175,899	$ 437,897,235

2023	11	7,815,000	6,822,495	135,937	162,459	6,686,558	6,660,036	15,458	13,504	223	263	$ 5,853,041	$ 11,815,434	$ 241,028,940	$ 449,712,669
2023	12	9,092,000	7,937,316	159,834	192,069	7,777,482	7,745,247	17,250	15,070	283	335	$ 5,853,041	$ 11,815,434	$ 246,881,981	$ 461,528,102
2024	1	9,689,000	8,458,497	176,265	210,601	8,282,232	8,247,896	19,142	16,722	221	278	$ 829,519	$ 6,791,911	$ 247,711,500	$ 468,320,014
2024	2	8,744,000	7,633,512	161,925	192,874	7,471,587	7,440,638	17,822	15,569	420	475	$ 829,519	$ 6,791,911	$ 248,541,020	$ 475,111,925
2024	3	8,257,000	7,208,361	150,581	179,462	7,057,780	7,028,899	16,383	14,312	352	399	$ 829,519	$ 6,791,911	$ 249,370,539	$ 481,903,837
2024	4	7,338,000	6,406,074	126,127	150,735	6,279,947	6,255,339	16,310	14,248	531	571	$ 829,519	$ 6,791,911	$ 250,200,058	$ 488,695,748
2024	5	7,629,000	6,660,117	128,463	154,648	6,531,654	6,505,469	17,777	15,530	196	245	$ 829,519	$ 6,791,911	$ 251,029,577	$ 495,487,660
2024	6	9,129,000	7,969,617	137,542	168,065	7,832,075	7,801,552	19,556	17,084	219	275	$ 829,519	$ 6,791,911	$ 251,859,096	$ 502,279,571
2024	7	10,142,000	8,853,966	150,405	185,997	8,703,561	8,667,969	20,466	17,879	229	292	$ 829,519	$ 6,791,911	$ 252,688,616	$ 509,071,482
2024	8	9,888,000	8,632,224	150,336	184,950	8,481,888	8,447,274	20,112	17,570	187	247	$ 829,519	$ 6,791,911	$ 253,518,135	$ 515,863,394
2024	9	8,260,000	7,210,980	129,496	158,120	7,081,484	7,052,860	18,275	15,965	155	208	$ 829,519	$ 6,791,911	$ 254,347,654	$ 522,655,305
2024	10	7,616,000	6,648,768	128,154	153,818	6,520,614	6,494,950	16,033	14,006	553	594	$ 829,519	$ 6,791,911	$ 255,177,173	$ 529,447,217
2024	11	7,853,000	6,855,669	133,234	159,756	6,722,435	6,695,913	15,473	13,517	144	188	$ 829,519	$ 6,791,911	$ 256,006,692	$ 536,239,128
2024	12	9,134,000	7,973,982	155,482	187,716	7,818,500	7,786,266	17,292	15,106	274	326	$ 829,519	$ 6,791,911	$ 256,836,211	$ 543,031,040
2025	1	9,767,000	8,526,591	171,664	206,000	8,354,927	8,320,591	19,265	16,830	218	274	$ 838,009	$ 6,800,401	$ 257,674,221	$ 549,831,441
2025	2	8,512,000	7,430,976	151,178	181,141	7,279,798	7,249,835	17,909	15,645	410	465	$ 838,009	$ 6,800,401	$ 258,512,230	$ 556,631,842
2025	3	8,335,000	7,276,455	145,468	174,348	7,130,987	7,102,107	16,598	14,500	350	397	$ 838,009	$ 6,800,401	$ 259,350,239	$ 563,432,244
2025	4	7,397,000	6,457,581	121,474	146,082	6,336,107	6,311,499	16,567	14,473	532	572	$ 838,009	$ 6,800,401	$ 260,188,248	$ 570,232,645
2025	5	7,697,000	6,719,481	123,723	149,908	6,595,758	6,569,573	17,783	15,535	202	250	$ 838,009	$ 6,800,401	$ 261,026,257	$ 577,033,046
2025	6	9,214,000	8,043,822	132,438	162,961	7,911,384	7,880,861	19,664	17,178	207	264	$ 838,009	$ 6,800,401	$ 261,864,266	$ 583,833,448
2025	7	10,253,000	8,950,869	145,667	181,258	8,805,202	8,769,611	20,625	18,018	225	288	$ 838,009	$ 6,800,401	$ 262,702,275	$ 590,633,849
2025	8	9,949,000	8,685,477	145,002	179,616	8,540,475	8,505,861	20,126	17,582	229	288	$ 838,009	$ 6,800,401	$ 263,540,284	$ 597,434,250
2025	9	8,363,000	7,300,899	125,083	153,706	7,175,816	7,147,193	18,507	16,168	158	209	$ 838,009	$ 6,800,401	$ 264,378,293	$ 604,234,652
2025	10	7,696,000	6,718,608	123,401	149,065	6,595,207	6,569,543	16,065	14,034	553	594	$ 838,009	$ 6,800,401	$ 265,216,302	$ 611,035,053
2025	11	7,902,000	6,898,446	129,035	155,557	6,769,411	6,742,889	15,482	13,525	152	196	$ 838,009	$ 6,800,401	$ 266,054,312	$ 617,835,454
2025	12	9,239,000	8,065,647	151,250	183,484	7,914,397	7,882,163	17,625	15,397	214	265	$ 838,009	$ 6,800,401	$ 266,892,321	$ 624,635,856
2026	1	9,824,000	8,576,352	167,495	201,831	8,408,857	8,374,521	19,446	16,988	215	271	$ 903,790	$ 6,866,182	$ 267,796,111	$ 631,502,038
2026	2	8,590,000	7,499,070	147,165	177,127	7,351,905	7,321,943	18,128	15,837	401	456	$ 903,790	$ 6,866,182	$ 268,699,901	$ 638,368,221
2026	3	8,430,000	7,359,390	140,903	169,784	7,218,487	7,189,606	16,936	14,795	348	396	$ 903,790	$ 6,866,182	$ 269,603,691	$ 645,234,403
2026	4	7,468,000	6,519,564	116,745	141,353	6,402,819	6,378,211	16,882	14,748	534	574	$ 903,790	$ 6,866,182	$ 270,507,481	$ 652,100,585
2026	5	7,768,000	6,781,464	117,839	144,024	6,663,625	6,637,440	17,956	15,686	151	200	$ 903,790	$ 6,866,182	$ 271,411,271	$ 658,966,768
2026	6	9,320,000	8,136,360	124,699	155,222	8,011,661	7,981,138	19,825	17,319	231	287	$ 903,790	$ 6,866,182	$ 272,315,062	$ 665,832,950
2026	7	10,349,000	9,034,677	137,392	172,983	8,897,285	8,861,694	20,768	18,143	206	269	$ 903,790	$ 6,866,182	$ 273,218,852	$ 672,699,133
2026	8	10,048,000	8,771,904	136,803	171,417	8,635,101	8,600,487	20,372	17,797	217	276	$ 903,790	$ 6,866,182	$ 274,122,642	$ 679,565,315
2026	9	8,424,000	7,354,152	119,799	148,422	7,234,353	7,205,730	18,671	16,311	183	233	$ 903,790	$ 6,866,182	$ 275,026,432	$ 686,431,497
2026	10	7,760,000	6,774,480	119,642	145,306	6,654,838	6,629,174	16,110	14,074	482	520	$ 903,790	$ 6,866,182	$ 275,930,222	$ 693,297,680
2026	11	7,998,000	6,982,254	126,096	152,618	6,856,158	6,829,636	15,662	13,682	150	193	$ 903,790	$ 6,866,182	$ 276,834,012	$ 700,163,862
2026	12	9,336,000	8,150,328	148,410	180,644	8,001,918	7,969,684	17,797	15,547	283	328	$ 903,790	$ 6,866,182	$ 277,737,802	$ 707,030,045
2027	1	9,889,000	8,633,097	164,174	198,510	8,468,923	8,434,587	19,613	17,134	212	268	$ 1,082,723	$ 7,045,115	$ 278,820,525	$ 714,075,160
2027	2	8,675,000	7,573,275	143,660	173,622	7,429,615	7,399,653	18,312	15,997	124	177	$ 1,082,723	$ 7,045,115	$ 279,903,249	$ 721,120,275
2027	3	8,544,000	7,458,912	136,636	165,516	7,322,276	7,293,396	17,217	15,041	346	394	$ 1,082,723	$ 7,045,115	$ 280,985,972	$ 728,165,391
2027	4	7,544,000	6,585,912	112,680	137,288	6,473,232	6,448,624	17,060	14,904	537	577	$ 1,082,723	$ 7,045,115	$ 282,068,695	$ 735,210,506
2027	5	7,853,000	6,855,669	113,535	139,720	6,742,134	6,715,949	18,080	15,795	144	193	$ 1,082,723	$ 7,045,115	$ 283,151,418	$ 742,255,621
2027	6	9,418,000	8,221,914	119,922	150,445	8,101,992	8,071,469	20,105	17,564	234	287	$ 1,082,723	$ 7,045,115	$ 284,234,141	$ 749,300,736
2027	7	10,432,000	9,107,136	132,963	168,554	8,974,173	8,938,582	20,956	18,307	217	278	$ 1,082,723	$ 7,045,115	$ 285,316,864	$ 756,345,852
2027	8	10,172,000	8,880,156	131,299	165,913	8,748,857	8,714,243	20,642	18,033	205	264	$ 1,082,723	$ 7,045,115	$ 286,399,587	$ 763,390,967
2027	9	8,515,000	7,433,595	114,882	143,506	7,318,713	7,290,089	18,764	16,392	172	221	$ 1,082,723	$ 7,045,115	$ 287,482,310	$ 770,436,082
2027	10	7,820,000	6,826,860	113,708	139,372	6,713,152	6,687,488	16,340	14,275	480	518	$ 1,082,723	$ 7,045,115	$ 288,565,033	$ 777,481,198
2027	11	8,107,000	7,077,411	120,680	147,201	6,956,731	6,930,210	15,926	13,913	143	181	$ 1,082,723	$ 7,045,115	$ 289,647,756	$ 784,526,313
2027	12	9,436,000	8,237,628	142,785	175,020	8,094,843	8,062,608	17,916	15,651	245	297	$ 1,082,723	$ 7,045,115	$ 290,730,479	$ 791,571,428
2028	1	10,015,000	8,743,095	158,783	193,119	8,584,312	8,549,976	19,769	17,270	271	320	$ 573,322	$ 6,535,714	$ 291,303,801	$ 798,107,143
2028	2	9,074,000	7,921,602	144,393	175,342	7,777,209	7,746,260	18,480	16,144	279	327	$ 573,322	$ 6,535,714	$ 291,877,123	$ 804,642,857
2028	3	8,644,000	7,546,212	131,640	160,521	7,414,572	7,385,691	16,775	14,655	222	269	$ 573,322	$ 6,535,714	$ 292,450,445	$ 811,178,571
2028	4	7,622,000	6,654,006	108,826	133,434	6,545,180	6,520,572	16,495	14,410	556	595	$ 573,322	$ 6,535,714	$ 293,023,767	$ 817,714,286
2028	5	7,963,000	6,951,699	110,330	136,515	6,841,369	6,815,184	18,168	15,872	135	184	$ 573,322	$ 6,535,714	$ 293,597,089	$ 824,250,000
2028	6	9,532,000	8,321,436	117,056	147,579	8,204,380	8,173,857	20,306	17,739	168	225	$ 573,322	$ 6,535,714	$ 294,170,412	$ 830,785,714
2028	7	10,519,000	9,183,087	130,925	166,516	9,052,162	9,016,571	21,161	18,486	202	264	$ 573,322	$ 6,535,714	$ 294,743,734	$ 837,321,429
2028	8	10,311,000	9,001,503	129,518	164,132	8,871,985	8,837,371	20,761	18,137	205	263	$ 573,322	$ 6,535,714	$ 295,317,056	$ 843,857,143
2028	9	8,607,000	7,513,911	113,904	142,527	7,400,007	7,371,384	18,785	16,411	167	217	$ 573,322	$ 6,535,714	$ 295,890,378	$ 850,392,857
2028	10	7,933,000	6,925,509	113,061	138,725	6,812,448	6,786,784	16,571	14,476	555	596	$ 573,322	$ 6,535,714	$ 296,463,700	$ 856,928,572
2028	11	8,205,000	7,162,965	120,525	147,047	7,042,440	7,015,918	16,103	14,068	188	228	$ 573,322	$ 6,535,714	$ 297,037,022	$ 863,464,286
2028	12	9,512,000	8,303,976	143,336	175,570	8,160,640	8,128,406	17,985	15,712	246	298	$ 573,322	$ 6,535,714	$ 297,610,344	$ 870,000,000

2029	1	10,163,000	8,872,299	159,255	159,255	8,713,044	8,713,044	19,927	17,408	206	206	$ 659,510	$ 659,510	$ 298,269,854	$ 870,659,510
2029	2	8,869,000	7,742,637	139,285	139,285	7,603,352	7,603,352	18,635	16,280	385	385	$ 659,510	$ 659,510	$ 298,929,363	$ 871,319,020
2029	3	8,716,000	7,609,068	132,282	132,282	7,476,786	7,476,786	16,963	14,819	222	222	$ 659,510	$ 659,510	$ 299,588,873	$ 871,978,529
2029	4	7,725,000	6,743,925	109,577	109,577	6,634,348	6,634,348	16,913	14,775	542	542	$ 659,510	$ 659,510	$ 300,248,383	$ 872,638,039
2029	5	8,058,000	7,034,634	111,205	111,205	6,923,429	6,923,429	18,427	16,098	146	146	$ 659,510	$ 659,510	$ 300,907,892	$ 873,297,548
2029	6	9,627,000	8,404,371	117,886	117,886	8,286,485	8,286,485	20,431	17,849	169	169	$ 659,510	$ 659,510	$ 301,567,402	$ 873,957,058
2029	7	10,653,000	9,300,069	131,797	131,797	9,168,272	9,168,272	21,339	18,642	200	200	$ 659,510	$ 659,510	$ 302,226,912	$ 874,616,568
2029	8	10,419,000	9,095,787	130,422	130,422	8,965,365	8,965,365	20,969	18,319	339	339	$ 659,510	$ 659,510	$ 302,886,421	$ 875,276,077
2029	9	8,698,000	7,593,354	114,774	114,774	7,478,580	7,478,580	19,014	16,611	148	148	$ 659,510	$ 659,510	$ 303,545,931	$ 875,935,587
2029	10	8,030,000	7,010,190	113,734	113,734	6,896,456	6,896,456	16,914	14,776	559	559	$ 659,510	$ 659,510	$ 304,205,440	$ 876,595,097
2029	11	8,297,000	7,243,281	121,208	121,208	7,122,073	7,122,073	16,346	14,280	134	134	$ 659,510	$ 659,510	$ 304,864,950	$ 877,254,606
2029	12	9,629,000	8,406,117	143,950	143,950	8,262,167	8,262,167	18,203	15,902	247	247	$ 659,510	$ 659,510	$ 305,524,460	$ 877,914,116
2030	1	10,246,000	8,944,758	159,506	159,506	8,785,252	8,785,252	20,103	17,562	206	206	$ 1,651,606	$ 1,651,606	$ 307,176,065	$ 879,565,722
2030	2	8,942,000	7,806,366	139,446	139,446	7,666,920	7,666,920	18,785	16,411	385	385	$ 1,651,606	$ 1,651,606	$ 308,827,671	$ 881,217,327
2030	3	8,776,000	7,661,448	132,555	132,555	7,528,893	7,528,893	17,143	14,976	348	348	$ 1,651,606	$ 1,651,606	$ 310,479,277	$ 882,868,933
2030	4	7,817,000	6,824,241	110,029	110,029	6,714,212	6,714,212	17,170	15,000	547	547	$ 1,651,606	$ 1,651,606	$ 312,130,882	$ 884,520,538
2030	5	8,130,000	7,097,490	111,749	111,749	6,985,741	6,985,741	18,610	16,258	147	147	$ 1,651,606	$ 1,651,606	$ 313,782,488	$ 886,172,144
2030	6	9,689,000	8,458,497	118,277	118,277	8,340,220	8,340,220	20,565	17,966	168	168	$ 1,651,606	$ 1,651,606	$ 315,434,093	$ 887,823,750
2030	7	10,758,000	9,391,734	132,133	132,133	9,259,601	9,259,601	21,536	18,814	201	201	$ 1,651,606	$ 1,651,606	$ 317,085,699	$ 889,475,355
2030	8	10,490,000	9,157,770	130,692	130,692	9,027,078	9,027,078	21,124	18,454	73	73	$ 1,651,606	$ 1,651,606	$ 318,737,305	$ 891,126,961
2030	9	8,788,000	7,671,924	115,120	115,120	7,556,804	7,556,804	19,250	16,817	139	139	$ 1,651,606	$ 1,651,606	$ 320,388,910	$ 892,778,566
2030	10	8,115,000	7,084,395	113,771	113,771	6,970,624	6,970,624	16,936	14,795	563	563	$ 1,651,606	$ 1,651,606	$ 322,040,516	$ 894,430,172
2030	11	8,352,000	7,291,296	121,042	121,042	7,170,254	7,170,254	16,324	14,261	133	133	$ 1,651,606	$ 1,651,606	$ 323,692,121	$ 896,081,778
2030	12	9,683,000	8,453,259	143,222	143,222	8,310,037	8,310,037	18,220	15,917	243	243	$ 1,651,606	$ 1,651,606	$ 325,343,727	$ 897,733,383
2031	1	10,337,000	9,024,201	158,309	158,309	8,865,892	8,865,892	20,217	17,662	203	203	$ 3,319,216	$ 3,319,216	$ 328,662,942	$ 901,052,599
2031	2	9,020,000	7,874,460	138,476	138,476	7,735,984	7,735,984	18,867	16,482	380	380	$ 3,319,216	$ 3,319,216	$ 331,982,158	$ 904,371,814
2031	3	8,861,000	7,735,653	132,063	132,063	7,603,590	7,603,590	17,465	15,257	349	349	$ 3,319,216	$ 3,319,216	$ 335,301,373	$ 907,691,030
2031	4	7,890,000	6,887,970	110,114	110,114	6,777,856	6,777,856	17,516	15,302	551	551	$ 3,319,216	$ 3,319,216	$ 338,620,589	$ 911,010,245
2031	5	8,205,000	7,162,965	112,020	112,020	7,050,945	7,050,945	18,721	16,355	146	146	$ 3,319,216	$ 3,319,216	$ 341,939,805	$ 914,329,461
2031	6	9,790,000	8,546,670	118,353	118,353	8,428,317	8,428,317	20,741	18,119	167	167	$ 3,319,216	$ 3,319,216	$ 345,259,020	$ 917,648,676
2031	7	10,884,000	9,501,732	132,170	132,170	9,369,562	9,369,562	21,724	18,978	201	201	$ 3,319,216	$ 3,319,216	$ 348,578,236	$ 920,967,892
2031	8	10,562,000	9,220,626	130,708	130,708	9,089,918	9,089,918	21,189	18,511	205	205	$ 3,319,216	$ 3,319,216	$ 351,897,451	$ 924,287,107
2031	9	8,906,000	7,774,938	115,322	115,322	7,659,616	7,659,616	19,511	17,045	153	153	$ 3,319,216	$ 3,319,216	$ 355,216,667	$ 927,606,323
2031	10	8,198,000	7,156,854	113,649	113,649	7,043,205	7,043,205	16,975	14,829	567	567	$ 3,319,216	$ 3,319,216	$ 358,535,882	$ 930,925,538
2031	11	8,414,000	7,345,422	120,794	120,794	7,224,628	7,224,628	16,378	14,308	147	147	$ 3,319,216	$ 3,319,216	$ 361,855,098	$ 934,244,754
2031	12	9,798,000	8,553,654	142,537	142,537	8,411,117	8,411,117	18,552	16,207	183	183	$ 3,319,216	$ 3,319,216	$ 365,174,313	$ 937,563,970
2032	1	10,407,000	9,085,311	157,384	157,384	8,927,927	8,927,927	20,422	17,841	200	200	$ 3,389,017	$ 3,389,017	$ 368,563,330	$ 940,952,986
2032	2	9,407,000	8,212,311	143,263	143,263	8,069,048	8,069,048	19,099	16,685	376	376	$ 3,389,017	$ 3,389,017	$ 371,952,347	$ 944,342,003
2032	3	8,995,000	7,852,635	131,879	131,879	7,720,756	7,720,756	17,781	15,533	348	348	$ 3,389,017	$ 3,389,017	$ 375,341,363	$ 947,731,019
2032	4	7,962,000	6,950,826	110,481	110,481	6,840,345	6,840,345	17,731	15,490	554	554	$ 3,389,017	$ 3,389,017	$ 378,730,380	$ 951,120,036
2032	5	8,285,000	7,232,805	112,630	112,630	7,120,175	7,120,175	18,760	16,389	141	141	$ 3,389,017	$ 3,389,017	$ 382,119,396	$ 954,509,053
2032	6	9,906,000	8,647,938	118,742	118,742	8,529,196	8,529,196	21,010	18,354	233	233	$ 3,389,017	$ 3,389,017	$ 385,508,413	$ 957,898,069
2032	7	10,965,000	9,572,445	132,678	132,678	9,439,767	9,439,767	21,898	19,130	210	210	$ 3,389,017	$ 3,389,017	$ 388,897,430	$ 961,287,086
2032	8	10,694,000	9,335,862	131,086	131,086	9,204,776	9,204,776	21,533	18,811	204	204	$ 3,389,017	$ 3,389,017	$ 392,286,446	$ 964,676,103
2032	9	8,978,000	7,837,794	115,701	115,701	7,722,093	7,722,093	19,571	17,097	174	174	$ 3,389,017	$ 3,389,017	$ 395,675,463	$ 968,065,119
2032	10	8,246,000	7,198,758	114,110	114,110	7,084,648	7,084,648	17,159	14,990	503	503	$ 3,389,017	$ 3,389,017	$ 399,064,480	$ 971,454,136
2032	11	8,537,000	7,452,801	121,031	121,031	7,331,770	7,331,770	16,619	14,518	139	139	$ 3,389,017	$ 3,389,017	$ 402,453,496	$ 974,843,152
2032	12	9,907,000	8,648,811	142,427	142,427	8,506,384	8,506,384	18,731	16,363	231	231	$ 3,389,017	$ 3,389,017	$ 405,842,513	$ 978,232,169
2033	1	10,492,000	9,159,516	157,001	157,001	9,002,515	9,002,515	20,584	17,982	244	244	$ 3,323,517	$ 3,323,517	$ 409,166,030	$ 981,555,686
2033	2	9,192,000	8,024,616	137,610	137,610	7,887,006	7,887,006	19,292	16,853	264	264	$ 3,323,517	$ 3,323,517	$ 412,489,548	$ 984,879,204
2033	3	9,091,000	7,936,443	132,041	132,041	7,804,402	7,804,402	17,665	15,432	350	350	$ 3,323,517	$ 3,323,517	$ 415,813,065	$ 988,202,721
2033	4	8,033,000	7,012,809	110,938	110,938	6,901,871	6,901,871	17,549	15,331	572	572	$ 3,323,517	$ 3,323,517	$ 419,136,582	$ 991,526,239
2033	5	8,375,000	7,311,375	113,200	113,200	7,198,175	7,198,175	18,959	16,563	142	142	$ 3,323,517	$ 3,323,517	$ 422,460,100	$ 994,849,756
2033	6	10,004,000	8,733,492	119,247	119,247	8,614,245	8,614,245	21,221	18,539	163	163	$ 3,323,517	$ 3,323,517	$ 425,783,617	$ 998,173,274
2033	7	11,055,000	9,651,015	133,265	133,265	9,517,750	9,517,750	22,083	19,292	210	210	$ 3,323,517	$ 3,323,517	$ 429,107,135	$ 1,001,496,791
2033	8	10,820,000	9,445,860	131,700	131,700	9,314,160	9,314,160	21,688	18,947	205	205	$ 3,323,517	$ 3,323,517	$ 432,430,652	$ 1,004,820,308
2033	9	9,065,000	7,913,745	116,381	116,381	7,797,364	7,797,364	19,710	17,219	174	174	$ 3,323,517	$ 3,323,517	$ 435,754,170	$ 1,008,143,826
2033	10	8,340,000	7,280,820	114,814	114,814	7,166,006	7,166,006	17,433	15,229	542	542	$ 3,323,517	$ 3,323,517	$ 439,077,687	$ 1,011,467,343
2033	11	8,622,000	7,527,006	121,796	121,796	7,405,210	7,405,210	16,841	14,712	140	140	$ 3,323,517	$ 3,323,517	$ 442,401,204	$ 1,014,790,861
2033	12	9,998,000	8,728,254	143,333	143,333	8,584,921	8,584,921	18,684	16,322	232	232	$ 3,323,517	$ 3,323,517	$ 445,724,722	$ 1,018,114,378
2034	1	10,582,329	9,238,373	157,962	157,962	9,080,411	9,080,411	20,762	18,137	244	244	$ 3,147,306	$ 3,147,306	$ 448,872,027	$ 1,021,261,684
2034	2	9,273,579	8,095,834	138,468	138,468	7,957,366	7,957,366	19,473	17,012	377	377	$ 3,147,306	$ 3,147,306	$ 452,019,333	$ 1,024,408,989

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2034	3	9,182,812	8,016,595	132,936	132,936	7,883,659	7,883,659	17,815	15,563	212	212	$ 3,147,306	$ 3,147,306	$ 455,166,638	$ 1,027,556,295
2034	4	8,110,308	7,080,299	111,752	111,752	6,968,547	6,968,547	17,705	15,467	576	576	$ 3,147,306	$ 3,147,306	$ 458,313,944	$ 1,030,703,600
2034	5	8,454,918	7,381,143	114,041	114,041	7,267,103	7,267,103	19,106	16,691	150	150	$ 3,147,306	$ 3,147,306	$ 461,461,249	$ 1,033,850,906
2034	6	10,093,723	8,811,820	120,067	120,067	8,691,753	8,691,753	21,398	18,693	173	173	$ 3,147,306	$ 3,147,306	$ 464,608,555	$ 1,036,998,211
2034	7	11,151,329	9,735,110	134,159	134,159	9,600,951	9,600,951	22,260	19,446	199	199	$ 3,147,306	$ 3,147,306	$ 467,755,860	$ 1,040,145,517
2034	8	10,916,328	9,529,954	132,613	132,613	9,397,342	9,397,342	21,858	19,095	206	206	$ 3,147,306	$ 3,147,306	$ 470,903,166	$ 1,043,292,822
2034	9	9,153,009	7,990,577	117,252	117,252	7,873,325	7,873,325	19,883	17,369	175	175	$ 3,147,306	$ 3,147,306	$ 474,050,471	$ 1,046,440,128
2034	10	8,419,790	7,350,477	115,683	115,683	7,234,794	7,234,794	17,589	15,365	581	581	$ 3,147,306	$ 3,147,306	$ 477,197,777	$ 1,049,587,433
2034	11	8,703,748	7,598,372	122,691	122,691	7,475,681	7,475,681	16,985	14,838	179	179	$ 3,147,306	$ 3,147,306	$ 480,345,083	$ 1,052,734,739
2034	12	10,088,805	8,807,527	144,352	144,352	8,663,175	8,663,175	18,849	16,466	234	234	$ 3,147,306	$ 3,147,306	$ 483,492,388	$ 1,055,882,044
2035	1	10,673,436	9,317,910	159,211	159,211	9,158,699	9,158,699	20,941	18,294	201	201	$ 3,291,297	$ 3,291,297	$ 486,783,685	$ 1,059,173,342
2035	2	9,355,881	8,167,684	139,591	139,591	8,028,093	8,028,093	19,657	17,172	379	379	$ 3,291,297	$ 3,291,297	$ 490,074,983	$ 1,062,464,639
2035	3	9,275,551	8,097,556	134,120	134,120	7,963,436	7,963,436	17,966	15,695	213	213	$ 3,291,297	$ 3,291,297	$ 493,366,280	$ 1,065,755,937
2035	4	8,188,359	7,148,437	112,847	112,847	7,035,591	7,035,591	17,863	15,605	569	569	$ 3,291,297	$ 3,291,297	$ 496,657,578	$ 1,069,047,234
2035	5	8,535,599	7,451,578	115,214	115,214	7,336,364	7,336,364	19,254	16,820	151	151	$ 3,291,297	$ 3,291,297	$ 499,948,875	$ 1,072,338,532
2035	6	10,184,251	8,890,851	121,269	121,269	8,769,582	8,769,582	21,577	18,849	174	174	$ 3,291,297	$ 3,291,297	$ 503,240,173	$ 1,075,629,829
2035	7	11,248,498	9,819,939	135,501	135,501	9,684,437	9,684,437	22,438	19,602	197	197	$ 3,291,297	$ 3,291,297	$ 506,531,470	$ 1,078,921,127
2035	8	11,013,514	9,614,798	133,961	133,961	9,480,837	9,480,837	22,029	19,245	352	352	$ 3,291,297	$ 3,291,297	$ 509,822,768	$ 1,082,212,424
2035	9	9,241,872	8,068,154	118,494	118,494	7,949,660	7,949,660	20,057	17,522	94	94	$ 3,291,297	$ 3,291,297	$ 513,114,065	$ 1,085,503,721
2035	10	8,500,342	7,420,799	116,889	116,889	7,303,909	7,303,909	17,746	15,503	587	587	$ 3,291,297	$ 3,291,297	$ 516,405,363	$ 1,088,795,019
2035	11	8,786,271	7,670,415	123,923	123,923	7,546,491	7,546,491	17,131	14,965	135	135	$ 3,291,297	$ 3,291,297	$ 519,696,660	$ 1,092,086,316
2035	12	10,180,435	8,887,520	145,694	145,694	8,741,825	8,741,825	19,015	16,612	235	235	$ 3,291,297	$ 3,291,297	$ 522,987,958	$ 1,095,377,614
2036	1	10,765,328	9,398,131	160,482	160,482	9,237,649	9,237,649	21,121	18,452	202	202	$ 3,271,155	$ 3,271,155	$ 526,259,113	$ 1,098,648,769
2036	2	9,438,915	8,240,173	146,275	146,275	8,093,898	8,093,898	19,841	17,333	382	382	$ 3,271,155	$ 3,271,155	$ 529,530,268	$ 1,101,919,924
2036	3	9,369,227	8,179,335	135,199	135,199	8,044,136	8,044,136	18,119	15,829	359	359	$ 3,271,155	$ 3,271,155	$ 532,801,423	$ 1,105,191,079
2036	4	8,267,162	7,217,232	114,061	114,061	7,103,172	7,103,172	18,022	15,744	576	576	$ 3,271,155	$ 3,271,155	$ 536,072,578	$ 1,108,462,234
2036	5	8,617,049	7,522,684	116,311	116,311	7,406,373	7,406,373	19,403	16,950	154	154	$ 3,271,155	$ 3,271,155	$ 539,343,733	$ 1,111,733,389
2036	6	10,275,591	8,970,591	122,341	122,341	8,848,250	8,848,250	21,757	19,007	172	172	$ 3,271,155	$ 3,271,155	$ 542,614,888	$ 1,115,004,544
2036	7	11,346,514	9,905,507	136,813	136,813	9,768,693	9,768,693	22,617	19,758	170	170	$ 3,271,155	$ 3,271,155	$ 545,886,043	$ 1,118,275,699
2036	8	11,111,564	9,700,395	135,171	135,171	9,565,224	9,565,224	22,202	19,395	203	203	$ 3,271,155	$ 3,271,155	$ 549,157,198	$ 1,121,546,854
2036	9	9,331,598	8,146,485	119,411	119,411	8,027,075	8,027,075	20,233	17,675	154	154	$ 3,271,155	$ 3,271,155	$ 552,428,353	$ 1,124,818,009
2036	10	8,581,666	7,491,794	117,997	117,997	7,373,797	7,373,797	17,904	15,641	588	588	$ 3,271,155	$ 3,271,155	$ 555,699,508	$ 1,128,089,164
2036	11	8,869,576	7,743,140	125,017	125,017	7,618,123	7,618,123	17,277	15,094	150	150	$ 3,271,155	$ 3,271,155	$ 558,970,663	$ 1,131,360,319
2036	12	10,272,896	8,968,238	146,867	146,867	8,821,371	8,821,371	19,183	16,758	258	258	$ 3,271,155	$ 3,271,155	$ 562,241,818	$ 1,134,631,474
2037	1	10,858,010	9,479,043	161,705	161,705	9,317,338	9,317,338	21,303	18,611	205	205	$ 3,457,294	$ 3,457,294	$ 565,699,112	$ 1,138,088,769
2037	2	9,522,685	8,313,304	141,877	141,877	8,171,427	8,171,427	20,028	17,496	385	385	$ 3,457,294	$ 3,457,294	$ 569,156,407	$ 1,141,546,063
2037	3	9,463,848	8,261,939	136,282	136,282	8,125,657	8,125,657	18,273	15,963	362	362	$ 3,457,294	$ 3,457,294	$ 572,613,701	$ 1,145,003,357
2037	4	8,346,723	7,286,689	115,033	115,033	7,171,656	7,171,656	18,182	15,884	582	582	$ 3,457,294	$ 3,457,294	$ 576,070,996	$ 1,148,460,652
2037	5	8,699,277	7,594,469	117,310	117,310	7,477,159	7,477,159	19,553	17,081	146	146	$ 3,457,294	$ 3,457,294	$ 579,528,290	$ 1,151,917,946
2037	6	10,367,750	9,051,046	123,370	123,370	8,927,676	8,927,676	21,939	19,166	243	243	$ 3,457,294	$ 3,457,294	$ 582,985,584	$ 1,155,375,240
2037	7	11,445,383	9,991,819	137,981	137,981	9,853,838	9,853,838	22,798	19,916	196	196	$ 3,457,294	$ 3,457,294	$ 586,442,879	$ 1,158,832,535
2037	8	11,210,488	9,786,756	136,289	136,289	9,650,467	9,650,467	22,376	19,547	205	205	$ 3,457,294	$ 3,457,294	$ 589,900,173	$ 1,162,289,829
2037	9	9,422,195	8,225,576	120,386	120,386	8,105,191	8,105,191	20,410	17,830	175	175	$ 3,457,294	$ 3,457,294	$ 593,357,467	$ 1,165,747,124
2037	10	8,663,767	7,563,469	118,904	118,904	7,444,564	7,444,564	18,064	15,781	527	527	$ 3,457,294	$ 3,457,294	$ 596,814,762	$ 1,169,204,418
2037	11	8,953,671	7,816,555	125,896	125,896	7,690,659	7,690,659	17,425	15,223	150	150	$ 3,457,294	$ 3,457,294	$ 600,272,056	$ 1,172,661,712
2037	12	10,366,198	9,049,691	147,835	147,835	8,901,856	8,901,856	19,352	16,906	265	265	$ 3,457,294	$ 3,457,294	$ 603,729,350	$ 1,176,119,007
2038	1	10,951,490	9,560,651	162,770	162,770	9,397,881	9,397,881	21,487	18,771	206	206	$ 3,399,447	$ 3,399,447	$ 607,128,797	$ 1,179,518,454
2038	2	9,607,198	8,387,084	142,686	142,686	8,244,398	8,244,398	20,216	17,661	111	111	$ 3,399,447	$ 3,399,447	$ 610,528,244	$ 1,182,917,900
2038	3	9,559,426	8,345,379	137,120	137,120	8,208,258	8,208,258	18,428	16,098	365	365	$ 3,399,447	$ 3,399,447	$ 613,927,691	$ 1,186,317,347
2038	4	8,427,050	7,356,815	115,886	115,886	7,240,928	7,240,928	18,344	16,026	586	586	$ 3,399,447	$ 3,399,447	$ 617,327,138	$ 1,189,716,794
2038	5	8,782,289	7,666,938	118,242	118,242	7,548,696	7,548,696	19,704	17,213	147	147	$ 3,399,447	$ 3,399,447	$ 620,726,585	$ 1,193,116,241
2038	6	10,460,736	9,132,223	124,304	124,304	9,007,919	9,007,919	22,122	19,326	239	239	$ 3,399,447	$ 3,399,447	$ 624,126,032	$ 1,196,515,688
2038	7	11,545,114	10,078,884	139,012	139,012	9,939,873	9,939,873	22,980	20,076	198	198	$ 3,399,447	$ 3,399,447	$ 627,525,479	$ 1,199,915,135
2038	8	11,310,292	9,873,885	137,239	137,239	9,736,646	9,736,646	22,551	19,701	206	206	$ 3,399,447	$ 3,399,447	$ 630,924,926	$ 1,203,314,582
2038	9	9,513,671	8,305,435	121,189	121,189	8,184,246	8,184,246	20,589	17,986	176	176	$ 3,399,447	$ 3,399,447	$ 634,324,373	$ 1,206,714,029
2038	10	8,746,654	7,635,829	119,445	119,445	7,516,384	7,516,384	18,225	15,922	236	236	$ 3,399,447	$ 3,399,447	$ 637,723,819	$ 1,210,113,476
2038	11	9,038,564	7,890,666	126,057	126,057	7,764,609	7,764,609	17,575	15,353	146	146	$ 3,399,447	$ 3,399,447	$ 641,123,266	$ 1,213,512,923
2038	12	10,460,347	9,131,883	147,438	147,438	8,984,445	8,984,445	19,523	17,055	238	238	$ 3,399,447	$ 3,399,447	$ 644,522,713	$ 1,216,912,370
2039	1	11,045,776	9,642,962	161,591	161,591	9,481,372	9,481,372	21,672	18,933	238	238	$ 2,655,554	$ 2,655,554	$ 647,178,267	$ 1,219,567,923
2039	2	9,692,462	8,461,519	141,352	141,352	8,320,167	8,320,167	20,406	17,827	312	312	$ 2,655,554	$ 2,655,554	$ 649,833,820	$ 1,222,223,477
2039	3	9,655,968	8,429,660	136,279	136,279	8,293,381	8,293,381	18,584	16,235	366	366	$ 2,655,554	$ 2,655,554	$ 652,489,374	$ 1,224,879,030
2039	4	8,508,149	7,427,614	115,929	115,929	7,311,685	7,311,685	18,508	16,168	601	601	$ 2,655,554	$ 2,655,554	$ 655,144,927	$ 1,227,534,584

2039	5	8,866,094	7,740,100	118,648	118,648	7,621,452	7,621,452	19,856	17,347	157	157	$ 2,655,554	$ 2,655,554	$ 657,800,481	$ 1,230,190,137
2039	6	10,554,555	9,214,127	124,676	124,676	9,089,450	9,089,450	22,306	19,487	239	239	$ 2,655,554	$ 2,655,554	$ 660,456,035	$ 1,232,845,691
2039	7	11,645,714	10,166,708	139,447	139,447	10,027,262	10,027,262	23,164	20,236	200	200	$ 2,655,554	$ 2,655,554	$ 663,111,588	$ 1,235,501,244
2039	8	11,410,985	9,961,790	137,590	137,590	9,824,200	9,824,200	22,728	19,855	206	206	$ 2,655,554	$ 2,655,554	$ 665,767,142	$ 1,238,156,798
2039	9	9,606,036	8,386,069	121,634	121,634	8,264,435	8,264,435	20,769	18,144	176	176	$ 2,655,554	$ 2,655,554	$ 668,422,695	$ 1,240,812,351
2039	10	8,830,334	7,708,882	119,198	119,198	7,589,683	7,589,683	18,388	16,064	421	421	$ 2,655,554	$ 2,655,554	$ 671,078,249	$ 1,243,467,905
2039	11	9,124,261	7,965,480	124,391	124,391	7,841,089	7,841,089	17,725	15,485	143	143	$ 2,655,554	$ 2,655,554	$ 673,733,802	$ 1,246,123,459
2039	12	10,555,351	9,214,821	143,514	143,514	9,071,307	9,071,307	19,695	17,206	220	220	$ 2,655,554	$ 2,655,554	$ 676,389,356	$ 1,248,779,012
2040	1	11,140,872	9,725,981	155,974	155,974	9,570,007	9,570,007	21,859	19,096	199	199	$ 899,930	$ 899,930	$ 677,289,286	$ 1,249,678,942
2040	2	9,778,482	8,536,615	141,950	141,950	8,394,665	8,394,665	20,598	17,995	351	351	$ 899,930	$ 899,930	$ 678,189,216	$ 1,250,578,872
2040	3	9,753,486	8,514,793	133,447	133,447	8,381,347	8,381,347	18,742	16,373	404	404	$ 899,930	$ 899,930	$ 679,089,146	$ 1,251,478,802
2040	4	8,590,030	7,499,096	115,681	115,681	7,383,415	7,383,415	18,672	16,312	591	591	$ 899,930	$ 899,930	$ 679,989,076	$ 1,252,378,732
2040	5	8,950,698	7,813,959	119,021	119,021	7,694,938	7,694,938	20,010	17,481	156	156	$ 899,930	$ 899,930	$ 680,889,006	$ 1,253,278,662
2040	6	10,649,216	9,296,766	124,857	124,857	9,171,908	9,171,908	22,493	19,650	172	172	$ 899,930	$ 899,930	$ 681,788,936	$ 1,254,178,592
2040	7	11,747,191	10,255,298	139,723	139,723	10,115,575	10,115,575	23,349	20,398	203	203	$ 899,930	$ 899,930	$ 682,688,866	$ 1,255,078,522
2040	8	11,512,575	10,050,478	137,688	137,688	9,912,790	9,912,790	22,906	20,011	356	356	$ 899,930	$ 899,930	$ 683,588,796	$ 1,255,978,452
2040	9	9,699,297	8,467,486	121,924	121,924	8,345,562	8,345,562	20,951	18,303	98	98	$ 899,930	$ 899,930	$ 684,488,726	$ 1,256,878,382
2040	10	8,914,815	7,782,634	118,763	118,763	7,663,871	7,663,871	18,552	16,207	606	606	$ 899,930	$ 899,930	$ 685,388,656	$ 1,257,778,312
2040	11	9,210,771	8,041,003	122,334	122,334	7,918,669	7,918,669	17,877	15,617	130	130	$ 899,930	$ 899,930	$ 686,288,586	$ 1,258,678,242
2040	12	10,651,218	9,298,513	139,444	139,444	9,159,069	9,159,069	19,869	17,358	203	203	$ 899,930	$ 899,930	$ 687,188,516	$ 1,259,578,172
2041	1	11,236,788	9,809,716	150,588	150,588	9,659,128	9,659,128	22,048	19,261	177	177	$ 1,065,100	$ 1,065,100	$ 688,253,615	$ 1,260,643,272
2041	2	9,865,266	8,612,377	132,471	132,471	8,479,906	8,479,906	20,792	18,164	319	319	$ 1,065,100	$ 1,065,100	$ 689,318,715	$ 1,261,708,371
2041	3	9,851,988	8,600,786	131,295	131,295	8,469,490	8,469,490	18,901	16,512	362	362	$ 1,065,100	$ 1,065,100	$ 690,383,815	$ 1,262,773,471
2041	4	8,672,698	7,571,265	115,599	115,599	7,455,666	7,455,666	18,839	16,458	595	595	$ 1,065,100	$ 1,065,100	$ 691,448,915	$ 1,263,838,571
2041	5	9,036,110	7,888,524	119,601	119,601	7,768,923	7,768,923	20,165	17,616	157	157	$ 1,065,100	$ 1,065,100	$ 692,514,015	$ 1,264,903,671
2041	6	10,744,726	9,380,146	125,394	125,394	9,254,752	9,254,752	22,680	19,814	172	172	$ 1,065,100	$ 1,065,100	$ 693,579,114	$ 1,265,968,771
2041	7	11,849,552	10,344,659	140,361	140,361	10,204,298	10,204,298	23,536	20,561	181	181	$ 1,065,100	$ 1,065,100	$ 694,644,214	$ 1,267,033,870
2041	8	11,615,069	10,139,955	138,310	138,310	10,001,645	10,001,645	23,085	20,167	175	175	$ 1,065,100	$ 1,065,100	$ 695,709,314	$ 1,268,098,970
2041	9	9,793,464	8,549,694	122,627	122,627	8,427,067	8,427,067	21,134	18,463	149	149	$ 1,065,100	$ 1,065,100	$ 696,774,414	$ 1,269,164,070
2041	10	9,000,104	7,857,091	119,070	119,070	7,738,021	7,738,021	18,718	16,352	609	609	$ 1,065,100	$ 1,065,100	$ 697,839,513	$ 1,270,229,170
2041	11	9,298,101	8,117,242	122,062	122,062	7,995,180	7,995,180	18,030	15,751	143	143	$ 1,065,100	$ 1,065,100	$ 698,904,613	$ 1,271,294,270
2041	12	10,747,956	9,382,966	138,505	138,505	9,244,461	9,244,461	20,045	17,511	197	197	$ 1,065,100	$ 1,065,100	$ 699,969,713	$ 1,272,359,369
2042	1	11,333,530	9,894,172	149,069	149,069	9,745,103	9,745,103	22,238	19,427	172	172	$ 1,977,553	$ 1,977,553	$ 701,947,266	$ 1,274,336,922
2042	2	9,952,820	8,688,812	131,371	131,371	8,557,440	8,557,440	20,988	18,335	311	311	$ 1,977,553	$ 1,977,553	$ 703,924,819	$ 1,276,314,475
2042	3	9,951,486	8,687,647	130,942	130,942	8,556,705	8,556,705	19,062	16,652	362	362	$ 1,977,553	$ 1,977,553	$ 705,902,372	$ 1,278,292,028
2042	4	8,756,162	7,644,129	115,919	115,919	7,528,211	7,528,211	19,006	16,604	597	597	$ 1,977,553	$ 1,977,553	$ 707,879,925	$ 1,280,269,581
2042	5	9,122,336	7,963,799	120,152	120,152	7,843,647	7,843,647	20,321	17,752	157	157	$ 1,977,553	$ 1,977,553	$ 709,857,478	$ 1,282,247,134
2042	6	10,841,093	9,464,274	125,954	125,954	9,338,320	9,338,320	22,870	19,979	172	172	$ 1,977,553	$ 1,977,553	$ 711,835,031	$ 1,284,224,687
2042	7	11,952,805	10,434,799	140,992	140,992	10,293,807	10,293,807	23,724	20,726	197	197	$ 1,977,553	$ 1,977,553	$ 713,812,584	$ 1,286,202,240
2042	8	11,718,475	10,230,229	138,934	138,934	10,091,295	10,091,295	23,266	20,325	206	206	$ 1,977,553	$ 1,977,553	$ 715,790,137	$ 1,288,179,793
2042	9	9,888,545	8,632,700	123,220	123,220	8,509,480	8,509,480	21,319	18,625	164	164	$ 1,977,553	$ 1,977,553	$ 717,767,690	$ 1,290,157,347
2042	10	9,086,209	7,932,260	119,558	119,558	7,812,702	7,812,702	18,885	16,498	611	611	$ 1,977,553	$ 1,977,553	$ 719,745,243	$ 1,292,134,900
2042	11	9,386,260	8,194,205	122,474	122,474	8,071,731	8,071,731	18,184	15,886	144	144	$ 1,977,553	$ 1,977,553	$ 721,722,796	$ 1,294,112,453
2042	12	10,845,572	9,468,184	134,342	134,342	9,333,842	9,333,842	20,221	17,665	173	173	$ 1,977,553	$ 1,977,553	$ 723,700,349	$ 1,296,090,006
2043	1	11,431,104	9,979,354	125,588	125,588	9,853,766	9,853,766	22,430	19,595	138	138	$ 2,642,084	$ 2,642,084	$ 726,342,433	$ 1,298,732,089
2043	2	10,041,150	8,765,924	109,872	109,872	8,656,052	8,656,052	21,185	18,507	283	283	$ 2,642,084	$ 2,642,084	$ 728,984,517	$ 1,301,374,173
2043	3	10,051,988	8,775,386	107,027	107,027	8,668,359	8,668,359	19,223	16,794	329	329	$ 2,642,084	$ 2,642,084	$ 731,626,601	$ 1,304,016,257
2043	4	8,840,429	7,717,695	92,211	92,211	7,625,483	7,625,483	19,176	16,752	572	572	$ 2,642,084	$ 2,642,084	$ 734,268,685	$ 1,306,658,341
2043	5	9,209,386	8,039,794	92,797	92,797	7,946,997	7,946,997	20,478	17,890	109	109	$ 2,642,084	$ 2,642,084	$ 736,910,769	$ 1,309,300,425
2043	6	10,938,324	9,549,157	98,937	98,937	9,450,219	9,450,219	23,061	20,146	204	204	$ 2,642,084	$ 2,642,084	$ 739,552,853	$ 1,311,942,509
2043	7	12,056,957	10,525,723	112,330	112,330	10,413,394	10,413,394	23,914	20,891	156	156	$ 2,642,084	$ 2,642,084	$ 742,194,936	$ 1,314,584,593
2043	8	11,822,802	10,321,306	110,152	110,152	10,211,154	10,211,154	23,448	20,485	165	165	$ 2,642,084	$ 2,642,084	$ 744,837,020	$ 1,317,226,677
2043	9	9,984,549	8,716,511	97,023	97,023	8,619,489	8,619,489	21,506	18,788	137	137	$ 2,642,084	$ 2,642,084	$ 747,479,104	$ 1,319,868,760
2043	10	9,173,137	8,008,149	95,637	95,637	7,912,512	7,912,512	19,053	16,645	508	508	$ 2,642,084	$ 2,642,084	$ 750,121,188	$ 1,322,510,844
2043	11	9,475,254	8,271,897	99,362	99,362	8,172,535	8,172,535	18,340	16,022	111	111	$ 2,642,084	$ 2,642,084	$ 752,763,272	$ 1,325,152,928
2043	12	10,944,075	9,554,177	116,181	116,181	9,437,997	9,437,997	20,400	17,821	175	175	$ 2,642,084	$ 2,642,084	$ 755,405,356	$ 1,327,795,012
2044	1	11,529,518	10,065,269	125,969	125,969	9,939,300	9,939,300	22,623	19,764	139	139	$ 3,060,642	$ 3,060,642	$ 758,465,998	$ 1,330,855,654
2044	2	10,130,265	8,843,721	114,432	114,432	8,729,289	8,729,289	21,384	18,681	297	297	$ 3,060,642	$ 3,060,642	$ 761,526,640	$ 1,333,916,296
2044	3	10,153,505	8,864,010	107,343	107,343	8,756,667	8,756,667	19,387	16,936	329	329	$ 3,060,642	$ 3,060,642	$ 764,587,282	$ 1,336,976,938
2044	4	8,925,507	7,791,968	92,472	92,472	7,699,496	7,699,496	19,346	16,901	582	582	$ 3,060,642	$ 3,060,642	$ 767,647,924	$ 1,340,037,581
2044	5	9,297,266	8,116,513	93,060	93,060	8,023,454	8,023,454	20,637	18,028	112	112	$ 3,060,642	$ 3,060,642	$ 770,708,566	$ 1,343,098,223
2044	6	11,036,427	9,634,801	99,233	99,233	9,535,568	9,535,568	23,253	20,314	199	199	$ 3,060,642	$ 3,060,642	$ 773,769,209	$ 1,346,158,865

2044	7	12,162,017	10,617,441	112,643	112,643	10,504,798	10,504,798	24,105	21,058	157	157	$ 3,060,642	$ 3,060,642	$ 776,829,851	$ 1,349,219,507
2044	8	11,928,058	10,413,194	110,472	110,472	10,302,722	10,302,722	23,632	20,645	166	166	$ 3,060,642	$ 3,060,642	$ 779,890,493	$ 1,352,280,149
2044	9	10,081,485	8,801,136	97,302	97,302	8,703,835	8,703,835	21,695	18,952	137	137	$ 3,060,642	$ 3,060,642	$ 782,951,135	$ 1,355,340,791
2044	10	9,260,897	8,084,763	95,907	95,907	7,988,856	7,988,856	19,224	16,794	560	560	$ 3,060,642	$ 3,060,642	$ 786,011,777	$ 1,358,401,433
2044	11	9,565,091	8,350,324	99,651	99,651	8,250,674	8,250,674	18,497	16,159	105	105	$ 3,060,642	$ 3,060,642	$ 789,072,419	$ 1,361,462,075
2044	12	11,043,472	9,640,951	116,525	116,525	9,524,426	9,524,426	20,580	17,979	165	165	$ 3,060,642	$ 3,060,642	$ 792,133,061	$ 1,364,522,718

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DIRECT TESTIMONY OF RACHEL S. WILSON

Case No. PUR-2018-00065

Commonwealth of Virginia *ex rel.* State Corporation Commission, In re: Virginia Electric and Power Company's Integrated Resource Plan filing pursuant to Viriginia Code § 56-597 et seq.

EXHIBIT RSW-5

COMPANY'S RESPONSE TO ENVIRONMENTAL RESPONDENTS' DISCOVERY REQUEST NO. 12-18

Virginia Electric and Power Company
Case No. PUR-2018-00065
Environmental Respondents
Twelfth Set

The following response to Question No. 18 of the Twelfth Set of Interrogatories and Requests for Production of Documents Propounded by the Environmental Respondents received on March 12, 2019 has been prepared under my supervision.

Jennifer Valaiko for
Ted Fasca
Manager – Generation System Planning
Dominion Energy Virginia

Question No. 18

Other than the 30 MW battery storage pilot, was utility-scale storage a selectable option for the model? If not, why not?

Response:

Battery storage technology was economically screened out from the model because it is more costly than other options.

DIRECT TESTIMONY OF
RACHEL S. WILSON

Case No. PUR-2018-00065

Commonwealth of Virginia *ex rel.* State Corporation Commission,
In re: Virginia Electric and Power Company's Integrated Resource Plan
filing pursuant to Viriginia Code § 56-597 et seq.

EXHIBIT RSW-6

COMPANY'S RESPONSE TO
ENVIRONMENTAL RESPONDENTS'
DISCOVERY REQUEST NO. 5-5

Virginia Electric and Power Company
Case No. PUR-2018-00065
Environmental Respondents
Fifth Set

The following response to Question No. 5 (a-d) of the Fifth Set of Interrogatories and Requests for Production of Documents Propounded by the Environmental Respondents received on June 22, 2018 has been prepared under my supervision as it pertains to generation construction.

Bradley M. Hanks
Supervisor, Regulatory and Data Support
Dominion Energy Services, Inc.

The following response to Question No. 5 (a-d) of the Fifth Set of Interrogatories and Requests for Production of Documents Propounded by the Environmental Respondents received on June 22, 2018 has been prepared under my supervision as it pertains to generation system planning.

for

Ted Fasca
Manager – Generation System Planning
Dominion Energy Virginia

The following response to Question No. 5 (a-b) of the Fifth Set of Interrogatories and Requests for Production of Documents Propounded by the Environmental Respondents received on June 22, 2018 has been prepared under my supervision as it pertains to legal matters.

for

Vishwa B. Link
McGuireWoods LLP

Question No. 5 (a-d)

Reference Fig. 5.1.1.1 and Section 5.1.2.

(a) Please explain in detail what specific kinds of battery or other storage technologies the Company evaluated, how the Company evaluated these technologies, what findings regarding price and performance the Company found for these technologies, and what specific assumptions the Company modeled for batteries and other storage technologies. Please provide copies of all studies, data sets, or analysis that the

Company relied upon in assessing and in developing assumptions batteries and other storage technologies.

(b) Please explain in detail why batteries are not classified as a busbar resource. Please detail all sources and references for the Company's judgments and opinions about whether batteries should or should not be classified as a busbar resource.

(c) Please explain why fuel cells are classified as a busbar resource while batteries are not classified as a busbar resource.

(d) Please explain whether and why or why not the Company evaluated storage technologies as an alternative to gas-fired generation.

Response:

(a) The Company objects to this request as overly broad, unduly burdensome and not relevant or reasonably calculated to lead to the production of admissible evidence in this proceeding to the extent it seeks "all studies, data sets, or analysis that the Company relied upon in assessing and in developing assumptions batteries and other storage technologies." Notwithstanding and subject to these objections, the Company provides the following response.

The Company is in the early stages of battery research and has relied on publically-available industry guidance regarding battery storage projects to help evaluate the technology's merits as compared to traditional generation sources. This information has provided a better understanding of the latest trends with differing battery technologies, installed capital costs, maintenance costs, and variation in levelized costs for storage systems, dependent on use case application. See Attachment ER Set 5-5.

(b) The Company objects to this request as overly broad, unduly burdensome and not relevant or reasonably calculated to lead to the production of admissible evidence in this proceeding to the extent it seeks "all sources and references for the Company's judgments and opinions about whether batteries should or should not be classified as a busbar resource." Notwithstanding and subject to these objections, the Company provides the following response.

Batteries were not considered for further analysis as a busbar resource at this time based on the information as seen in answer ER Set 5-5 (a) above and subpart (c) of this set.

(c) Fuel cells are classified as a busbar resource because they are dispatchable over an entire 24-hour period, whereas batteries are not dispatchable over a full 24-hour period. Furthermore, batteries and other storage technologies (e.g. pump storage) are not included as busbar resources because the busbar tool does not lend itself to evaluating storage technologies.

(d) The company did not include any batteries or pump storage resources in the Plan; however, the Company is evaluating both technologies as utility scale resources. Once we have specific costs for battery and pump storage units, we will include them in our modeling as potential resources to replace gas fired generation.

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CONFIDENTIAL

NOVEMBER 2017

LAZARD'S LEVELIZED COST OF STORAGE ANALYSIS—VERSION 3.0

LAZARD

LAZARD

I Introduction and Executive Summary

Summary of LCOS 3.0 Findings

Continued Decreasing Cost Trends

- Among commercially deployed technologies, lithium-ion continues to provide most economic solution across all use cases; however, flow battery technologies claim to offer lower costs for longer duration, in-front-of-the-meter applications
- Compared to LCOS 2.0, cost improvements for lithium-ion modules (particularly lithium-ion deliveries scheduled for post-2019) are offset by increases in engineering, procurement and construction ("EPC") costs (in addition to revised roundtrip efficiency figures)
  - Limited direct evidence of impact of rising commodity costs (e.g., Cobalt) on prices
- Reduced variance in cost and performance estimates for lithium-ion compared to LCOS 2.0, with narrowed ranges for in-front-of-the-meter use cases
  - Larger dispersion of estimates for Commercial and very large dispersion for Residential use cases
  - Evidence of significant variance and potential cost increases in EPC/installation costs for projects reported by industry participants
- Slight flattening of projected capital cost decreases for lithium-ion (i.e., median of ~10% CAGR vs. ~12%) compared to LCOS 2.0
  - Similar trend for other storage technologies except for zinc flow batteries

Evolving Revenue Streams

- The mix of monetizable revenue streams vary significantly across geographic regions in the U.S., mirroring state/ISO subsidies and storage-related product design
- Among wholesale revenue sources:
  - Demand response ("DR") represents potentially lucrative revenue opportunities in selected markets (e.g., ERCOT and ISO-NE)
  - Energy arbitrage and spinning reserves generally offer lower revenue opportunities in contrast to other wholesale products
- Utility revenue streams for T&D deferral are highly situation-specific and opaque and DR revenues are also diverse and complex; however, in high-cost regions (e.g., ConEd's territory) they can be attractive
- Customer revenue sources are dominated by bill savings, which are highly lucrative in high-cost investor-owned utility ("IOU") service territories for selected tariffs
  - Data on actual revenue associated with specific payments for enhanced reliability is limited (exceptions include ERCOT, where gas-fired Distributed Generation ("DG") is reported to have received $8 – $10/kW-mo.)

Project Economics Remain Highly Variable

- The Value Snapshots illustrate the wide range of project economics for energy storage:
  - Commercial use case in CAISO provides an attractive illustrative ~11% IRR, reflecting a combination of Local Capacity Requirements ("LCR") and bill management savings
  - Distribution Deferral use case in NYISO provides an illustrative ~21% IRR, reflecting T&D deferral plus resource adequacy (estimate based on ConEd's Brooklyn-Queens Demand Management ("BQDM") program)
  - Peaker Replacement use case in CAISO provides a potentially viable illustrative IRR of ~9% reflecting LCR payments as a dominant revenue source
  - Microgrid project revenue sources in ISO-NE were limited and provides negative illustrative returns and Residential use case in California also reflected negative illustrative project economics due to the relatively high installed cost of the storage unit, which offset revenues from bill savings and participation in DR

II LCOS Methodology, Use Cases and Technology Overview

What Is Lazard's Levelized Cost of Storage Analysis?

Lazard's LCOS study analyzes the observed costs and revenue streams associated with the leading energy storage technologies and provides an overview of illustrative project returns; the LCOS is focused on providing a robust, empirically based indication of actual cash costs and revenues associated with leading energy storage technologies

- **It does not purport to measure the full set of potential benefits associated with energy storage to Industry participants or society, but merely those demonstrable in the form of strictly financial measures of observable costs and revenues**

LCOS Methodology

It clearly defines a set of use cases in terms of output and operating characteristics (e.g., number of charging cycles, depth of discharge, etc.) ➡ It applies a transparent set of financial and operating assumptions provided by industry participants across a range of commonly employed energy storage technologies to calculate the levelized cost of each ➡ In addition, the study surveys the range of identifiable revenue streams available to energy storage projects ➡ Finally, it applies currently observed costs and revenues associated with existing storage projects, as well as available local and national subsidies, to measure the financial returns realized by a representative set of storage projects

What the LCOS Does

- Defines operational parameters associated with energy storage systems designed for a selected subset of the most prevalent use cases of storage
- Aggregates cost and operational survey data from original equipment manufacturers and energy storage developers, after validation from additional Industry participants/energy storage users
- Analyzes, based on the installed cost, what revenue is required over the indicated project life to achieve certain levelized returns for various technologies, designed for a selected subset of identified use cases
- Provides an "apples-to-apples" basis of comparison among various technologies within a selected subset of identified use cases
- Aggregates robust survey data to define a range of future/expected capital cost decreases by technology
- Surveys currently available, pecuniary revenue streams associated with each use case across selected geographies
- Profiles the economics of typical examples of each use case, located in geographic regions where they are most common, providing a Value Snapshot of the associated financial returns

What the LCOS Does Not Do

- Identify the full range of use cases for energy storage, including "stacked" use cases (i.e., those in which multiple value streams are obtainable from a single storage installation)
- Profile all potentially viable energy storage technologies and use cases
- Authoritatively establish or predict prices for energy storage projects/products
- Provide parameter values which, by themselves, are applicable to detailed project evaluation or resource planning
- Identify and quantify all potential types of benefits provided by energy storage for power grids or consumers
- Provide a definitive view of project profitability, overall or to specific individuals/entities, for the various use cases across all potential locations and specific circumstances
- Purport to provide an "apples-to-apples" comparison to conventional or renewable electric generation

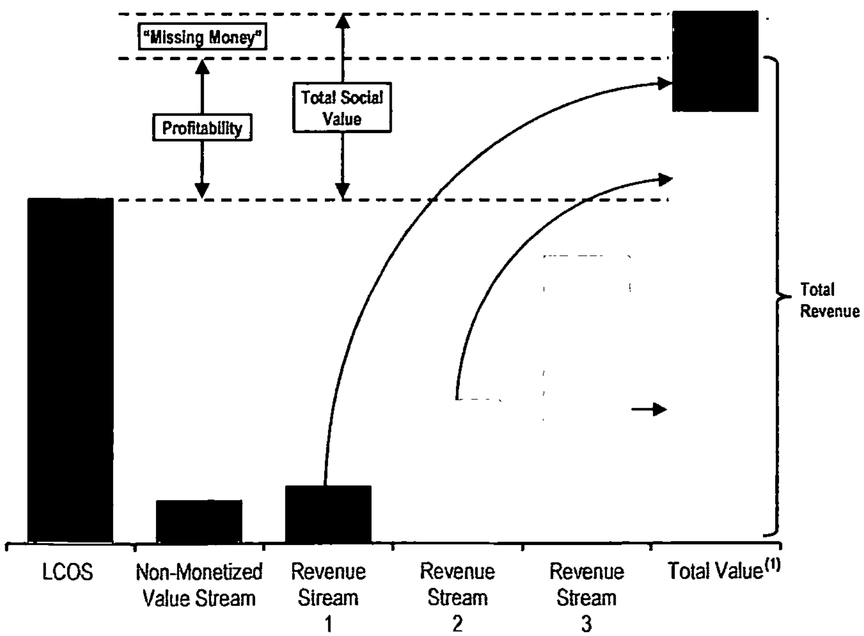
LAZARD

The Energy Storage Value Proposition—Balancing Costs and Revenues

Understanding the economics of energy storage is challenging due to the highly tailored nature of potential value streams associated with an energy storage installation

- **This study takes a decidedly practical view by analyzing the levelized cost and the currently monetized sources of revenue (or savings) available to energy storage projects**
- **Conversely, it ignores what may be even larger sources of value—for the power grid, or for individual users, or for society at large—for which current regulatory and market rules do not assign a pecuniary value**

Energy Storage Value Proposition—Monetized and Total Social Value



Selected Observations

- Energy storage systems are configured to support one or more specific revenue streams. The operating requirements of one use case may preclude efficient/economic operations in another use case for the same system
  - The availability and magnitude of different revenue sources reflect local regulatory and energy market conditions
  - The ability to participate in multiple revenue streams depends on the commercial terms of different potential streams, physical constraints and the cost implications of operating an energy storage system
  - Optimizing the design and operation of a storage system to maximize combined revenue streams can be a source of competitive differentiation
- The total of all potential value streams available for a given system thus defines the maximum, economically viable cost for that system
- Importantly, incremental sources of revenue may only become available as costs (or elements of levelized cost) decrease below a certain value
- In many cases, local market/regulatory rules are not available to reward the owner of an energy storage project to provide all (or the optimal combination) of potential revenue streams

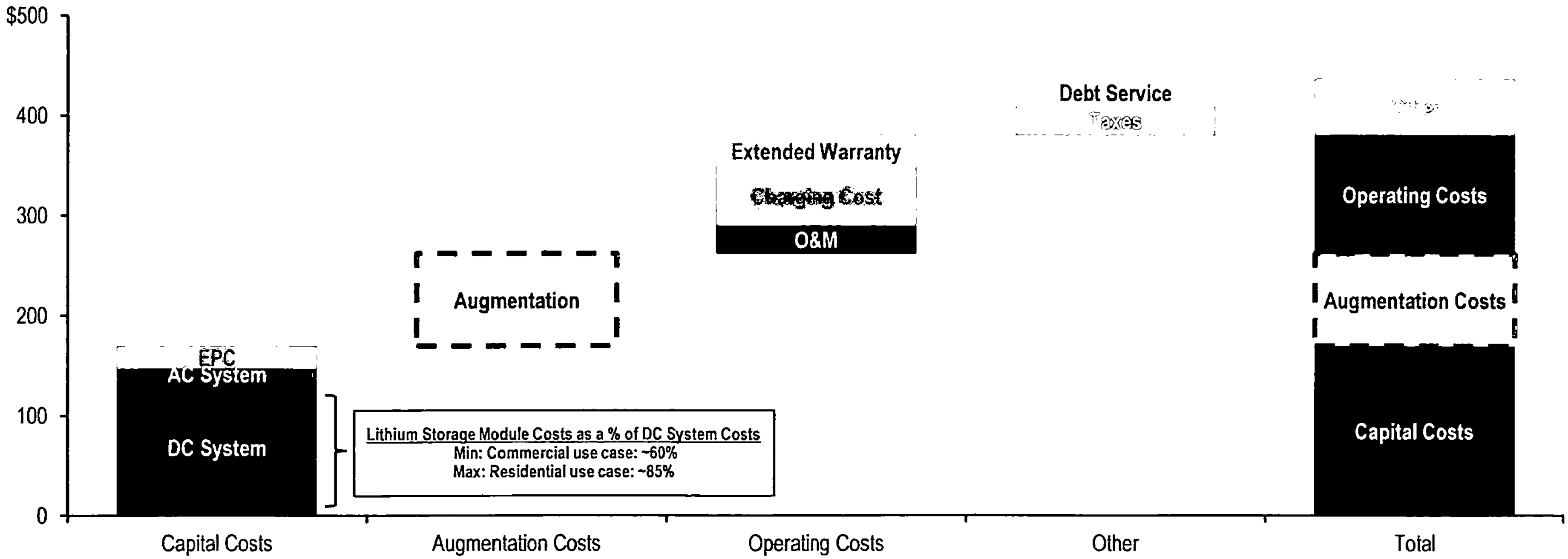
(1) Presented here as the simple sum of all available value streams. Due to operational and other factors, such "stacked" value would likely differ from the simple sum of all value streams in practice.

Illustrative Energy Storage System Costs

LCOS values are examined in the context of a particular project's specific application

- A cost category's contribution to total levelized cost varies dramatically across use cases and technologies
- Where applicable, amortized technology augmentation costs are included to ensure the system maintains its required output for the duration of the project's contracted life

Illustrative System Costs: LCOS by Category ($/kW-yr.)

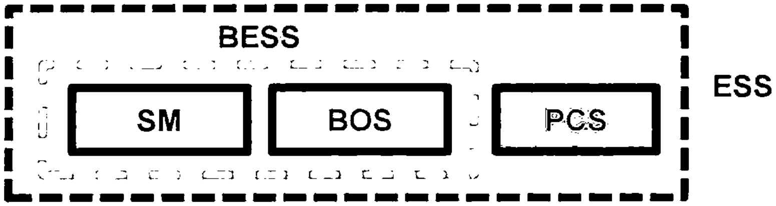


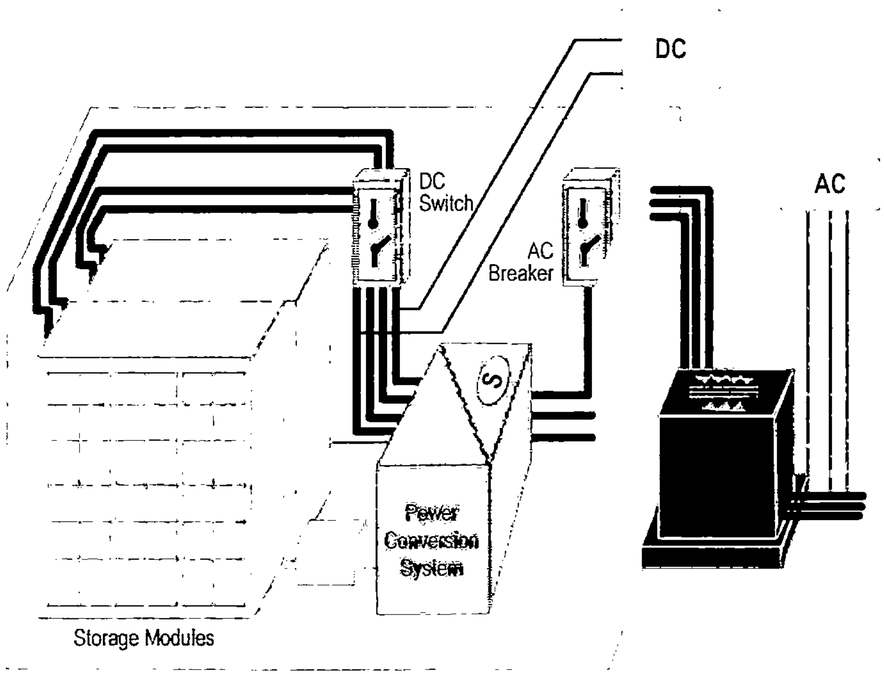
Note: Augmentation costs represent the additional energy storage system ("ESS") equipment needed to maintain the "Usable Energy" capability to cycle the unit according to the usage profile in the particular use case for the life of the system. Additional equipment is required in the following circumstances: (1) if the particular unit does not charge and discharge 100% of the rated energy capacity (kWh) per cycle; (2) if the battery chemistry does not have the cycle-life needed to support the entire operating life of the use case; or (3) if the energy rating (kWh) of the battery chemistry degrades due to usage. The cost of these additional ESS equipment takes into account the falling price of ESS system costs, specified for each chemistry. This time-series of varying costs is then converted into a level charge over the life of the system to provide greater clarity for project developers.

Components of Energy Storage System Equipment Costs

Lazard's LCOS study incorporates capital costs for the entirety of the energy storage system ("ESS"), which is composed of the storage module ("SM"), balance of system ("BOS" and, together with the SM, the Battery Energy Storage System "BESS"), power conversion system ("PCS") and related EPC costs

Physical Energy Storage System





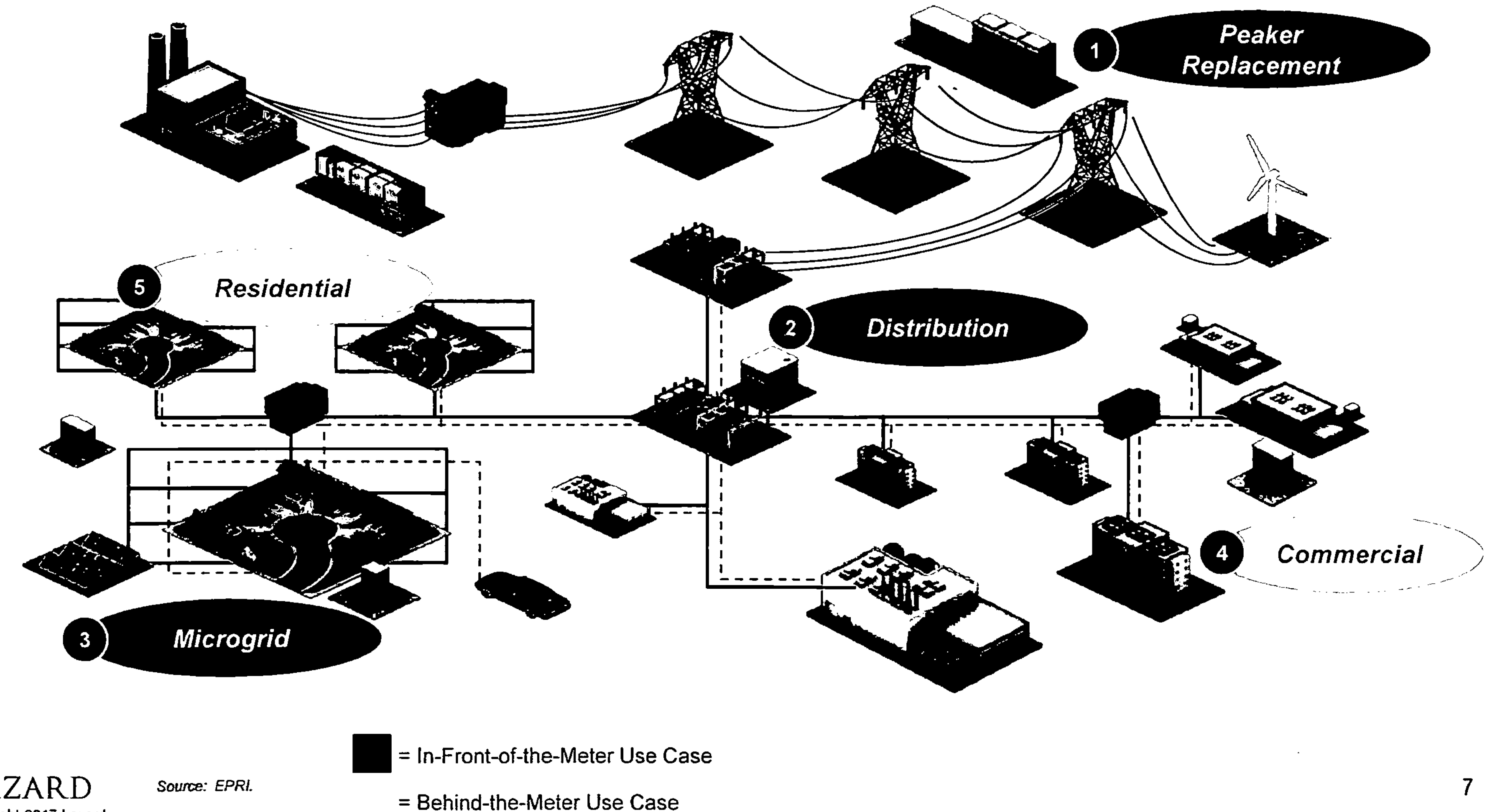
Selected Equipment & Cost Components

System Layer		Component
SM	Storage Module	• Racking Frame/Cabinet • Battery Management System ("BMS") • Battery Modules
BOS	Balance of System	• Container • Monitors and Controls • Thermal Management • Fire Suppression
PCS	Power Conversion System	• Inverter • Protection (Switches, Breakers, etc.) • Energy Management System ("EMS")
EPC	Engineering, Procurement & Construction	• Project Management • Engineering Studies/Permitting • Site Preparation/Construction • Foundation/Mounting • Commissioning
Other (not included in analysis)		• SCADA • Shipping • Grid Integration Equipment • Metering • Land

Source: Sandia National Laboratories.

Use Case Overview

Dozens of potential applications for energy storage technology have been identified and piloted; for the purposes of this assessment, we have chosen to focus on a subset of use cases which are the most identifiable and distinctive



Source: EPRI.

Use Case Overview (cont'd)

Lazard's LCOS examines the cost of energy storage in the context of its specific applications on the grid and behind-the-meter; each use case specified herein represents an application of energy storage that market participants are utilizing now or will be utilizing in the near future

- Commonly employed energy storage technologies for each use case are included below

		Use Case Description	Technologies Assessed[2]
In-Front-of-the-Meter	1 Peaker Replacement	• Large-scale energy storage system designed to replace peaking gas turbine facilities; brought online quickly to meet rapidly increasing demand for power at peak; can be quickly taken offline as power demand diminishes[1]	• Lithium-Ion • Vanadium Flow Battery • Zinc Bromide Flow Batteries
In-Front-of-the-Meter	2 Distribution	• Energy storage system designed to defer distribution upgrades, typically placed at substations or distribution feeder controlled by utilities to provide flexible peaking capacity while also mitigating stability problems (typically integrated into utility distribution management systems)	• Lithium-Ion • Vanadium Flow Battery
In-Front-of-the-Meter	3 Microgrid	• Energy storage system designed to support small power systems that can "island" or otherwise disconnect from the broader power grid (e.g., military bases, universities, etc.) – Provides ramping support to enhance system stability and increase reliability of service (emphasis is on short-term power output vs. load shifting, etc.)	• Lithium-Ion • Vanadium Flow Battery
Behind-the-Meter	4 Commercial	• Energy storage system designed for behind-the-meter peak shaving and demand charge reduction services for commercial energy users – Units typically sized to have sufficient power/energy to support multiple Commercial energy management strategies and provide option of the system providing grid services to utility or wholesale market	• Lithium-Ion • Lead-Acid • Advanced Lead (Lead Carbon)
Behind-the-Meter	5 Residential	• Energy storage system designed for behind-the-meter residential home use—provides backup power, power quality improvements and extends usefulness of self-generation (e.g., "solar plus storage") – Regulates the power supply and smooths the quantity of electricity sold back to the grid from distributed PV applications	• Lithium-Ion • Lead-Acid • Advanced Lead (Lead Carbon)

(1) Specific operational revenue streams include: capacity, energy sales (e.g., time-shift/arbitrage, etc.), spinning reserve and non-spinning reserve.
(2) Microgrid and Distribution use cases are beginning to use ZnBr flow batteries; however, they are not included in the LCOS output due to the limited sample size.

Energy Storage Use Cases—Operational Parameters

For comparison purposes, this study assumes and quantitatively operationalizes five use cases for energy storage; while there may be alternative or combined/"stacked" use cases available to energy storage systems, the five use cases below represent illustrative current and contemplated energy storage applications and are derived from Industry survey data

		Project Life (Years)	MW(1)	MWh of Capacity(2)	100% DOD Cycles/Day(3)	Days/ Year(4)	Annual MWh	Project MWh
In-Front-of-the-Meter	1 Peaker Replacement	20	100	400	1	350	140,000	2,800,000
	2 Distribution	20	10	60	1	350	21,000	420,000
	3 Microgrid	10	1	4	2	350	2,800	28,000
Behind-the-Meter	4 Commercial	10	0.125	0.25	1	250	62.5	625
	5 Residential	10	0.005	0.01	1	250	2.5	25

[dashed box] = "Usable Energy"(5)

Note: Distribution use case represents emerging longer duration application.
(1) Indicates power rating of system (i.e., system size).
(2) Indicates total battery energy content on a single, 100% charge, or "usable energy." Usable energy divided by power rating (in MW) reflects hourly duration of system.
(3) "DOD" denotes depth of battery discharge (i.e., the percent of the battery's energy content that is discharged). Depth of discharge of 100% indicates that a fully charged battery discharges all of its energy. For example, a battery that cycles 48 times per day with a 10% depth of discharge would be rated at 4.8 100% DOD Cycles per Day.
(4) Indicates number of days of system operation per calendar year.
(5) Usable energy indicates energy stored and able to be dispatched from system.

Overview of Selected Energy Storage Technologies

A wide variety of energy storage technologies are currently available or in development; however, given limited current or future commercial deployment expectations, only a subset are assessed in this study

		Description	Size (MW)	Selected Providers	Life (Yrs)[1]
Mechanical/Gravity/Thermal	Compressed Air	• Compressed Air Energy Storage ("CAES") uses electricity to compress air into confined spaces (e.g., underground mines, salt caverns, etc.) where the pressurized air is stored. When required, this pressurized air is released to drive the compressor of a natural gas turbine	150 MW+	Dresser Rand, Alstom Power	20 years
Mechanical/Gravity/Thermal	Flywheel	• Flywheels are mechanical devices that spin at high speeds, storing electricity as rotational energy, which is released by decelerating the flywheel's rotor, releasing quick bursts of energy (i.e., high power and short duration) or releasing energy slowly (i.e., low power and long duration), depending on short-duration or long-duration flywheel technology, respectively	30 kW – 1 MW	Amber Kinetics, Vycon	20+ years
Mechanical/Gravity/Thermal	Pumped Hydro	• Pumped hydro storage uses two vertically separated water reservoirs, using low cost electricity to pump water from the lower to the higher reservoir and running as a conventional hydro power plant during high electricity cost periods	100 MW+	MWH Global	20+ years
Mechanical/Gravity/Thermal	Thermal	• Thermal energy storage uses conventional cryogenic technology, compressing and storing air into a liquid form (charging) then releasing it at a later time (discharge). Best suited for large-scale applications; the technology is still emerging, but has a number of units in early development and operation	5 MW – 100 MW+	Highview Power	20+ years
Chemical	Flow Battery‡	• Flow batteries store energy through chemically changing the electrolyte (vanadium) or plating zinc (zinc bromide). Physically, systems typically contain two electrolyte solutions in two separate tanks, circulated through two independent loops, separated by a membrane. Emerging alternatives allow for simpler and less costly designs utilizing a single tank, single loop, and no membrane. • The subcategories of flow batteries are defined by the chemical composition of the electrolyte solution; the most prevalent of such solutions are vanadium and zinc-bromide. Other solutions include zinc-chloride, ferrochrome and zinc chromate	25 kW – 100 MW+	Sumitomo, UET, Primus Power	20 years
Chemical	Lead-Acid‡	• Lead-acid batteries date from the 19th century and are the most common batteries; they are low-cost and adaptable to numerous uses (e.g., electric vehicles, off-grid power systems, uninterruptible power supplies, etc.) • "Advanced" lead-acid battery technology adds ultra-capacitors, increasing efficiency, lifetimes and improve partial state-of-charge operability[2]	5 kW – 2 MW	Enersys, GS Yuasa, East Penn Mfg.	5 – 10 years
Chemical	Lithium-Ion‡	• Lithium-ion batteries have historically been used in electronics and advanced transportation industries; they are increasingly replacing lead-acid batteries in many applications, and have relatively high energy density, low self-discharge and high charging efficiency • Lithium-ion systems designed for energy applications are designed to have a higher efficiency and longer life at slower discharges, while systems designed for power applications are designed to support faster charging and discharging rates, requiring extra capital equipment	5 kW – 100 MW+	LG Chem, Samsung, Panasonic, BYD	10 years[3]
Chemical	Sodium‡	• "High temperature"/"liquid-electrolyte-flow" sodium batteries have high power and energy density and are designed for large commercial and utility scale projects; "low temperature" batteries are designed for residential and small commercial applications	1 MW – 100 MW+	NGK	10 years
Chemical	Zinc‡	• Zinc batteries cover a wide range of possible technology variations, including metal-air derivatives; they are non-toxic, non-combustible and potentially low-cost due to the abundance of the primary metal; however, this technology remains unproven in widespread commercial deployment	5 kW – 100 MW+	Fluidic Energy, EOS Energy Storage	10 years

[dashed box] Technologies analyzed in LCOS 3.0.
‡ Denotes battery technology.
(1) Indicates general ranges of useful economic life for a given family of technology. Useful life will vary in practice depending on sub-technology, intensity of use/cycling, engineering factors, etc.
(2) Advanced lead-acid is an emerging technology with wider potential applications and greater cost than traditional lead-acid batteries.
(3) In this report, augmentation costs account for the assumed a 20-year project life for Peaker Replacement and Distribution Substation.

Overview of Selected Energy Storage Technologies (cont'd)

A wide variety of energy storage technologies are currently available or in development; however, given limited current or future commercial deployment expectations, only a subset are assessed in this study

		Selected Advantages	Selected Disadvantages
Mechanical/Gravity/Thermal	Compressed Air	• Low cost, flexible sizing, relatively large-scale • Mature technology and well-developed design • Proven track record of safe operation • Leverages existing gas turbine technologies	• Requires suitable geology • Relatively difficult to modularize for smaller installations • Exposure to natural gas price changes • Relies on natural gas
	Flywheel	• High power density and scalability for short-duration technology; low power, higher energy for long-duration technology • High depth of discharge capability • Compact design with integrated AC motor	• Relatively low energy capacity • High heat generation • Sensitive to vibrations
	Pumped Hydro	• Mature technology (commercially available; leverages existing hydropower technology) • High-power capacity solution • Large scale, easily scalable in power rating	• Relatively low energy density • Limited available sites (i.e., water availability required) • Cycling generally limited to once per day
	Thermal	• Low cost, flexible sizing, relatively large-scale • Power and energy ratings independently scalable • Leverages mature industrial cryogenic technology base; can utilize waste industrial heat to improve efficiency	• Technology is pre-commercial • Difficult to modularize for smaller installations • On-site safely concerns from cryogenic storage
Chemical	Flow Battery‡	• Power and energy profiles independently scalable for Vanadium system • Zinc-Bromide designed in fixed modular blocks for system design • No degradation in "energy storage capacity" • No potential for fire • High cycle/lifespan	• Power and energy rating scaled in a fixed manner for zinc-bromide technology • Electrolyte based on acid • Relatively high balance of system costs • Reduced efficiency due to rapid charge/discharge
	Lead-Acid‡	• Mature technology with established recycling infrastructure • Advanced lead-acid technologies leverage existing technologies • Low cost	• Poor ability to operate in a partially charged state • Relatively poor depth of discharge and short lifespan • Acid based electrolyte
	Lithium-Ion‡(1)	• Multiple chemistries available • Rapidly expanding manufacturing base leading to cost reductions • Efficient power and energy density • Cost reduction continues	• Cycle life limited, especially in harsh conditions • Safety issues from overheating • Requires advanced manufacturing capabilities to achieve high performance
	Sodium‡	• High temperature technology: Relatively mature technology (commercially available); high energy capacity and long duration • Low temperature technology: Smaller scale design; emerging technology and low-cost potential; safer	• Although mature, inherently higher costs—low temperature batteries currently have a higher cost with lower efficiency • Potential flammability issues for high-temperature batteries • Poor cycling capability
	Zinc‡	• Deep discharge capability • Designed for long life • Designed for safe operation	• Currently unproven commercially • Lower efficiency • Poor cycling/rate of charge/discharge

[dashed box] Technologies analyzed in LCOS 3.0.
Source: *DOE Energy Storage Database.*
‡ Denotes battery technology.
(1) Lithium-Ion assessed on this report is NMC (Lithium, Nickel, Manganese, Cobalt).

DIRECT TESTIMONY OF RACHEL S. WILSON

Case No. PUR-2018-00065

Commonwealth of Virginia *ex rel.* State Corporation Commission, In re: Virginia Electric and Power Company's Integrated Resource Plan filing pursuant to Viriginia Code § 56-597 et seq.

EXHIBIT RSW-7

COMPANY'S RESPONSE TO SIERRA CLUB'S DISCOVERY REQUEST NO. 3-10 / ATTACHMENT SC 3-10(a)

Virginia Electric and Power Company
Case No. PUR-2018-00065
Sierra Club
Third Set

The following response to Question No. 10 of the Third Set of Interrogatories and Requests for Production of Documents Propounded by the Sierra Club received on July 9, 2018 has been prepared under my supervision.

Ted Fasca
Ted Fasca
Manager – Generation System Planning
Dominion Energy Virginia

Question No. 10

Regarding Figures 5.2.1 and 5.2.2:

a. Please provide workpapers supporting these figures in their native electronic format with formulas intact.

b. Please explain what is meant by the term "Busbar Cost" in this context, and its relationship to energy and capacity costs. Please provide and/or identify industry-standard references to support this calculation as an appropriate means of comparing resource economics as a function of capacity factor.

Response:

a. See Attachment Sierra Club Set 3-10(a) (TF).

b. See 2018 Plan Section 5.2 Levelized Busbar Costs.

   www.eia.gov/outlooks/aeo/electricity_generation.php

INDEX	UNIT INPUT DATA							
1	Calculation Tab Index (Do Not Change)		A	B	C	D	E	F
2	Unit Type (Description)	Menu Item	VA Generic 3X1 Dual Fuel	VA Generic 2X1 Dual Fuel	Generic 1X1 Dual Fuel	Greenfield CT	Brownfield CT	SCPC w/ CCS
3	Bases Point Adder	Menu Item	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM
4	Fuel Type	Menu Item	NG (IRP)	NG (IRP)	NG (IRP)	Generic CT	Generic CT	COAL (IRP)
5	REC Type	Menu Item	NO RECs	NO RECs	NO RECs	NO RECs	NO RECs	NO RECs
6	PTC Type	Menu Item	NO PTCs	NO PTCs	NO PTCs	NO PTCs	NO PTCs	NO PTCs
7	ITC Type	Menu Item	NO ITCs	NO ITCs	NO ITCs	NO ITCs	NO ITCs	NO ITCs
8	COD	Year	2023	2023	2023	2023	2023	2023
9	Book Life	Years	36	36	36	36	36	55
10	Tax Life	Years	20	20	20	15	15	20
12	Overnight Installed Cost (Base Year $'s)	$/KW	$ 1,013	$ 1,233	$ 1,668	$ 527	$ 476	$ 5,366
13	Total Annual Fixed O&M (Base Year $'s)	$1,000's	$ 11,511	$ 10,102	$ 9,181	$ 3,721	$ 2,000	$ 33,375
15	Gas FT (Base Year $'s)		$ 73,206	$ 49,191	$ 24,607	$ -	$ -	
16	Peak Capacity (Summer Peak)	MW	1591	1062	529	458	458	640
17	Heat Rate	MMBtu/MWh	6.547	6.591	6.628	10.070	10.070	11.063
18	Variable O&M (Single Rate)	$/MWh	$ 0.31	$ 0.31	$ 0.31			$ 66.64
19	VOM Tier # 1 (1st 10 Years)	$/MWh						
20	VOM Tier # 2 (Through Perpetuity)	$/MWh						
22	Avg Cost Per Fired Hour	$/Hour	$ 5,506	$ 4,130	$ 2,753			
23	Average Startup Costs	$/Start				$ 30,551	$ 31,743	
24	Average Run Time	Hours				8	8	
26	NOX	Lbs/Mmbtu	0.0072	0.0072	0.0072	0.0400	0.0400	0.0700
27	SO2	Lbs/Mmbtu	0.0011	0.0011	0.0011	0.0010	0.0010	0.1200
28	CO2	Lbs/Mmbtu	116.9800	116.9800	116.9800	128.0000	128.0000	20.6890
30	HG	Lbs/Mmbtu						1.1200
33	State		Virginia	Virginia	Virginia	Virginia	Virginia	Virginia
34	Property Tax	Menu Item	0.80%	0.80%	0.80%	0.80%	0.80%	0.80%
36								
37								

			A	B	C	D	E	F
G29	FIXED	$/kW-yr	$ 168.55	$ 186.54	$ 256.56	$ 69.18	$ 57.97	$ 635.92
H30	VARIABLE	$/Mwh	$ 38.81	$ 39.68	$ 41.83	$ 73.48	$ 73.86	$ 164.74

Screening Curve Graph Data Output ($/kW-yr)

Capacity Factor	VA Generic 3X1 Dual Fuel	VA Generic 2X1 Dual Fuel	Generic 1X1 Dual Fuel	Greenfield CT	Brownfield CT	SCPC w/ CCS
0%	$ 169	$ 197	$ 257	$ 69	$ 58	$ 636
10%	$ 203	$ 231	$ 293	$ 134	$ 123	$ 780
20%	$ 237	$ 266	$ 330	$ 198	$ 188	$ 925
30%	$ 271	$ 301	$ 367	$ 262	$ 252	$ 1,069
40%	$ 305	$ 336	$ 403	$ 327	$ 317	$ 1,213
50%	$ 339	$ 370	$ 440	$ 391	$ 382	$ 1,357
60%	$ 373	$ 405	$ 476	$ 455	$ 447	$ 1,502
70%	$ 407	$ 440	$ 513	$ 520	$ 512	$ 1,646
80%	$ 441	$ 475	$ 550	$ 584	$ 576	$ 1,790
90%	$ 475	$ 509	$ 586	$ 648	$ 641	$ 1,935
100%	$ 509	$ 544	$ 623	$ 713	$ 706	$ 2,079

Levelized Cost of Energy ($/MWh)

Capacity Factor	VA Generic 3X1 Dual Fuel	VA Generic 2X1 Dual Fuel	Generic 1X1 Dual Fuel	Greenfield CT	Brownfield CT	SCPC w/ CCS
5%	$ 424	$ 488	$ 628	$ 231	$ 208	$ 1,617
10%	$ 231	$ 264	$ 335	$ 152	$ 140	$ 891
15%	$ 167	$ 189	$ 237	$ 128	$ 118	$ 649
20%	$ 135	$ 152	$ 188	$ 113	$ 107	$ 528
25%	$ 116	$ 129	$ 159	$ 105	$ 100	$ 455
30%	$ 103	$ 114	$ 139	$ 100	$ 96	$ 407
35%	$ 94	$ 104	$ 126	$ 96	$ 93	$ 372
40%	$ 87	$ 96	$ 115	$ 93	$ 91	$ 346
45%	$ 82	$ 90	$ 107	$ 91	$ 89	$ 326
50%	$ 77	$ 85	$ 100	$ 89	$ 87	$ 310
55%	$ 74	$ 80	$ 95	$ 88	$ 86	$ 297
60%	$ 71	$ 77	$ 91	$ 87	$ 85	$ 286
65%	$ 68	$ 74	$ 87	$ 86	$ 84	$ 276
70%	$ 66	$ 72	$ 84	$ 85	$ 83	$ 268
75%	$ 64	$ 70	$ 81	$ 84	$ 83	$ 262
80%	$ 63	$ 68	$ 78	$ 83	$ 82	$ 255
85%	$ 61	$ 66	$ 76	$ 83	$ 82	$ 250
90%	$ 60	$ 65	$ 74	$ 82	$ 81	$ 245
95%	$ 59	$ 63	$ 73	$ 82	$ 81	$ 241
100%	$ 58	$ 62	$ 71	$ 81	$ 81	$ 237

Levelized Cost of Energy ($/MWh)

	VA Generic 3X1 Dual Fuel	VA Generic 2X1 Dual Fuel	Generic 1X1 Dual Fuel	Greenfield CT	Brownfield CT	SCPC w/ CCS
Capacity Factor	80%	80%	80%	20%	20%	50%
$/MWh	$ 62.86	$ 67.72	$ 78.44	$ 112.96	$ 107.05	$ 309.93

INDEX	UNIT INPUT DATA							
1	Calculation Tab Index (Do Not Change)		G	H	I	J	K	L
2	Unit Type (Description)	Menu Item	IGCC w/CCS	NA3 2030	Biomass	Solar w/ Battery Storage	Fuel Cell	Fixed Tilt Solar 20MW
3	Bases Point Adder	Menu Item	NO BP PREMIUM	100 BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM
4	Fuel Type	Menu Item	COAL (IRP)	NUKE (IRP)	BIO (IRP)	NO FUEL COST	NG (IRP)	NO FUEL COST
5	REC Type	Menu Item	NO RECs	NO RECs	TIER-1	TIER-1	NO RECs	TIER-1
6	PTC Type	Menu Item	NO PTCs	NO PTCs	NO PTCs	NO PTCs	NO PTCs	NO PTCs
7	ITC Type	Menu Item	NO ITCs	NO ITCs	NO ITCs	10%	NO ITCs	30%
8	COD	Year	2023	2023	2023	2021	2023	2021
9	Book Life	Years	40	60	40		15	35
10	Tax Life	Years	20	15	7		5	5
12	Overnight Installed Cost (Base Year $'s)	$/KW	$ 10,839	$ 9,133	$ 6,698		$ 5,880	$ 1,639
13	Total Annual Fixed O&M (Base Year $'s)	$1,000's	$ 37,644	$ 116,558	$ 9,434		$ 5,279	$ 374
15	Gas FT (Base Year $'s)							
16	Peak Capacity (Summer Peak)	MW	503	1452	50		15.1	20
17	Heat Rate	MMBtu/MWh	10.875	10.500	13.000		8.542	
18	Variable O&M (Single Rate)	$/MWh	$ 64.97	$ 1.90	$ 5.80		$ 0.0021	
19	VOM Tier # 1 (1st 10 Years)	$/MWh						
20	VOM Tier # 2 (Through Perpetuity)	$/MWh						
22	Avg Cost Per Fired Hour	$/Hour						
23	Average Startup Costs	$/Start						
24	Average Run Time	Hours						
26	NOX	Lbs/Mmbtu	0.0200		0.0850		0.0012	
27	SO2	Lbs/Mmbtu	0.0140		0.0125		0.0000	
28	CO2	Lbs/Mmbtu	20.6900		206.8000		118.0000	
30	HG	Lbs/Mmbtu	0.2750		0.8600		0.0000	
33	State		Virginia	Virginia	Virginia	Virginia	Virginia	Virginia
34	Property Tax	Menu Item	0.80%	0.40%	0.80%	0.80%	0.80%	NO PROP TAX
36								
37								

			G	H	I	J	K	L
G29	FIXED	$/kW-yr	$ 1,282.21	$ 1,047.69	$ 968.35	#DIV/0!	$ 1,312.75	$ 144.33
H30	VARIABLE	$/Mwh	$ 152.17	$ 11.52	$ 87.57	#NUM!	$ 32.74	$ (9.67)

Screening Curve Graph Data Output ($/kW-yr)

Capacity Factor	IGCC w/CCS	NA3 2030	Biomass	Solar w/ Battery Storage	Fuel Cell	Fixed Tilt Solar 20MW
0%	$ 1,282	$ 1,048	$ 968	#DIV/0!	$ 1,313	$ 144
10%	$ 1,416	$ 1,058	$ 1,045	#DIV/0!	$ 1,341	$ 136
20%	$ 1,549	$ 1,068	$ 1,122	#DIV/0!	$ 1,370	$ 127
30%	$ 1,682	$ 1,078	$ 1,198	#DIV/0!	$ 1,399	$ 119
40%	$ 1,815	$ 1,088	$ 1,275	#DIV/0!	$ 1,427	$ 110
50%	$ 1,949	$ 1,098	$ 1,352	#DIV/0!	$ 1,456	$ 102
60%	$ 2,082	$ 1,108	$ 1,429	#DIV/0!	$ 1,485	$ 94
70%	$ 2,215	$ 1,118	$ 1,505	#DIV/0!	$ 1,514	$ 85
80%	$ 2,349	$ 1,128	$ 1,582	#DIV/0!	$ 1,542	$ 77
90%	$ 2,482	$ 1,139	$ 1,659	#DIV/0!	$ 1,571	$ 68
100%	$ 2,615	$ 1,149	$ 1,735	#DIV/0!	$ 1,600	$ 60

Levelized Cost of Energy ($/MWh)

Capacity Factor	IGCC w/CCS	NA3 2030	Biomass	Solar w/ Battery Storage	Fuel Cell	Fixed Tilt Solar 20MW
5%	$ 3,080	$ 2,404	$ 2,298	#DIV/0!	$ 3,030	$ 320
10%	$ 1,616	$ 1,208	$ 1,183	#DIV/0!	$ 1,531	$ 155
15%	$ 1,128	$ 809	$ 825	#DIV/0!	$ 1,032	$ 100
20%	$ 884	$ 610	$ 640	#DIV/0!	$ 782	$ 73
25%	$ 738	$ 490	$ 530	#DIV/0!	$ 632	$ 56
30%	$ 640	$ 410	$ 456	#DIV/0!	$ 532	$ 45
35%	$ 570	$ 353	$ 403	#DIV/0!	$ 461	$ 37
40%	$ 518	$ 311	$ 364	#DIV/0!	$ 407	$ 32
45%	$ 477	$ 277	$ 333	#DIV/0!	$ 366	$ 27
50%	$ 445	$ 251	$ 309	#DIV/0!	$ 332	$ 23
55%	$ 418	$ 229	$ 289	#DIV/0!	$ 305	$ 20
60%	$ 396	$ 211	$ 272	#DIV/0!	$ 283	$ 18
65%	$ 377	$ 196	$ 258	#DIV/0!	$ 263	$ 16
70%	$ 361	$ 182	$ 245	#DIV/0!	$ 247	$ 14
75%	$ 347	$ 171	$ 235	#DIV/0!	$ 233	$ 12
80%	$ 335	$ 161	$ 226	#DIV/0!	$ 220	$ 11
85%	$ 324	$ 152	$ 218	#DIV/0!	$ 209	$ 10
90%	$ 315	$ 144	$ 210	#DIV/0!	$ 199	$ 9
95%	$ 306	$ 137	$ 204	#DIV/0!	$ 190	$ 8
100%	$ 299	$ 131	$ 198	#DIV/0!	$ 183	$ 7

Levelized Cost of Energy ($/MWh)

	IGCC w/CCS	NA3 2030	Biomass	Solar w/ Battery Storage	Fuel Cell	Fixed Tilt Solar 20MW
Capacity Factor	50%	92%	90%		90%	23%
$/MWh	$ 444.91	$ 141.52	$ 210.40	#DIV/0!	$ 199.25	$ 61.96

NDE	UNIT INPUT DATA							
1	Calculation Tab Index (Do Not Change)		M	N	O	P	Q	R
2	Unit Type (Description)	Menu Item	Horizontal Tracking Solar 20MW	Fixed Tilt Solar 80MW	Horizontal Tracking Solar 80MW	On Shore Wind	Off Shore Wind	CVOW
3	Bases Point Adder	Menu Item	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	100 BP PREMIUM	100 BP PREMIUM
4	Fuel Type	Menu Item	NO FUEL COST	NO FUEL COST	NO FUEL COST	NO FUEL COST	NO FUEL COST	NO FUEL COST
5	REC Type	Menu Item	TIER-1	TIER-1	TIER-1	TIER-1	TIER-1	TIER-1
6	PTC Type	Menu Item	NO PTCs	NO PTCs	NO PTCs	NO PTCs	NO PTCs	NO PTCs
7	ITC Type	Menu Item	30%	30%	30%	NO ITCs	NO ITCs	6%
8	COD	Year	2021	2021	2021	2021	2021	2021
9	Book Life	Years	35	35	35	25	30	25
10	Tax Life	Years	5	5	5	5	5	5
12	Overnight Installed Cost (Base Year $'s)	$/KW	$ 1,735	$ 1,341	$ 1,436	$ 2,112	$ 4,021	$ 25,838
13	Total Annual Fixed O&M (Base Year $'s)	$1,000's	$ 398	$ 1,225	$ 1,267	$ 4,587	$ 31,330	$ 2,950
15	Gas FT (Base Year $'s)							
16	Peak Capacity (Summer Peak)	MW	20	80	80	80	440	11,126
17	Heat Rate	MMBtu/MWh						
18	Variable O&M (Single Rate)	$/MWh						
19	VOM Tier # 1 (1st 10 Years)	$/MWh						
20	VOM Tier # 2 (Through Perpetuity)	$/MWh						
22	Avg Cost Per Fired Hour	$/Hour						
23	Average Startup Costs	$/Start						
24	Average Run Time	Hours						
26	NOX	Lbs/Mmbtu						
27	SO2	Lbs/Mmbtu						
28	CO2	Lbs/Mmbtu						
30	HG	Lbs/Mmbtu						
33	State		Virginia	Virginia	Virginia	Virginia	Virginia	Virginia
34	Property Tax	Menu Item	NO PROP TAX	0.16%	0.16%	0.80%	NO PROP TAX	NO PROP TAX
36								
37								

			M	N	O	P	Q	R
G29	FIXED	$/kW-yr	$ 152.93	$ 120.67	$ 128.40	$ 300.89	$ 475.91	$ 2,841.39
H30	VARIABLE	$/Mwh	$ (9.67)	$ (9.67)	$ (9.67)	$ (9.00)	$ (9.40)	$ (9.00)

Screening Curve Graph Data Output ($/kW-yr)

Capacity Factor	Horizontal Tracking Solar 20MW	Fixed Tilt Solar 80MW	Horizontal Tracking Solar 80MW	On Shore Wind	Off Shore Wind	CVOW
0%	$ 153	$ 121	$ 128	$ 301	$ 478	$ 2,841
10%	$ 144	$ 112	$ 120	$ 293	$ 468	$ 2,834
20%	$ 136	$ 104	$ 111	$ 285	$ 459	$ 2,826
30%	$ 128	$ 95	$ 103	$ 277	$ 451	$ 2,818
40%	$ 119	$ 87	$ 95	$ 269	$ 443	$ 2,810
50%	$ 111	$ 78	$ 86	$ 261	$ 435	$ 2,802
60%	$ 102	$ 70	$ 78	$ 254	$ 427	$ 2,794
70%	$ 94	$ 61	$ 69	$ 246	$ 418	$ 2,786
80%	$ 85	$ 53	$ 61	$ 238	$ 410	$ 2,778
90%	$ 77	$ 44	$ 52	$ 230	$ 402	$ 2,770
100%	$ 68	$ 36	$ 44	$ 222	$ 394	$ 2,763

Levelized Cost of Energy ($/MWh)

Capacity Factor	Horizontal Tracking Solar 20MW	Fixed Tilt Solar 80MW	Horizontal Tracking Solar 80MW	On Shore Wind	Off Shore Wind	CVOW
5%	$ 339	$ 266	$ 283	$ 678	$ 1,077	$ 6,478
10%	$ 165	$ 128	$ 137	$ 334	$ 534	$ 3,235
15%	$ 107	$ 82	$ 88	$ 220	$ 353	$ 2,153
20%	$ 78	$ 59	$ 64	$ 163	$ 262	$ 1,613
25%	$ 60	$ 45	$ 49	$ 128	$ 208	$ 1,288
30%	$ 49	$ 36	$ 39	$ 105	$ 172	$ 1,072
35%	$ 40	$ 30	$ 32	$ 89	$ 148	$ 918
40%	$ 34	$ 25	$ 27	$ 77	$ 128	$ 802
45%	$ 29	$ 21	$ 23	$ 67	$ 111	$ 712
50%	$ 25	$ 18	$ 20	$ 60	$ 99	$ 640
55%	$ 22	$ 15	$ 17	$ 53	$ 89	$ 581
60%	$ 19	$ 13	$ 15	$ 48	$ 81	$ 532
65%	$ 17	$ 12	$ 13	$ 44	$ 74	$ 490
70%	$ 15	$ 10	$ 11	$ 40	$ 68	$ 454
75%	$ 14	$ 9	$ 10	$ 37	$ 63	$ 423
80%	$ 12	$ 8	$ 9	$ 34	$ 59	$ 396
85%	$ 11	$ 7	$ 8	$ 31	$ 55	$ 373
90%	$ 10	$ 6	$ 7	$ 29	$ 51	$ 351
95%	$ 9	$ 5	$ 6	$ 27	$ 48	$ 332
100%	$ 8	$ 4	$ 5	$ 25	$ 45	$ 315

Levelized Cost of Energy ($/MWh)

	Horizontal Tracking Solar 20MW	Fixed Tilt Solar 80MW	Horizontal Tracking Solar 80MW	On Shore Wind	Off Shore Wind	CVOW
Capacity Factor	26%	23%	26%	37%	42%	42%
$/MWh	$ 57.48	$ 50.22	$ 46.71	$ 85.10	$ 121.20	$ 770.71

INDEX	UNIT INPUT DATA								
1	Calculation Tab Index (Do Not Change)		S	T	U	V	W	X	Y
2	Unit Type (Description)	Menu Item	4X CT Aeroderivative	2X CT Aeroderivative	Solar & Aero CT	WV Generic 2X1 Dual Fuel	1X CT Aeroderivative	1X Recip Brownfield	
3	Bases Point Adder	Menu Item	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	NO BP PREMIUM	
4	Fuel Type	Menu Item	Generic CT	Generic CT	Generic CT	NG (IRP)	Generic CT	Generic CT	
5	REC Type	Menu Item	NO RECs	NO RECs	TIER-1	NO RECs	NO RECs	NO RECs	
6	PTC Type	Menu Item	NO PTCs	NO PTCs	NO PTCs	NO PTCs	NO PTCs	NO PTCs	
7	ITC Type	Menu Item	NO ITCs	NO ITCs	10%	NO ITCs	NO ITCs	NO ITCs	
8	COD	Year	2023	2023	2023	2023	2023	2023	
9	Book Life	Years	36	36		36	36	36	
10	Tax Life	Years	15	15		20	15	15	
12	Overnight Installed Cost (Base Year $'s)	$/KW	$ 1,074	$ 1,680		$ 1,233	$ 1,930	$ 3,562	
13	Total Annual Fixed O&M (Base Year $'s)	$1,000's	$ 1,177	$ 1,320		$ 10,102	$ 1,042	$ 1,026	
15	Gas FT (Base Year $'s)					$ 8,138			
16	Peak Capacity (Summer Peak)	MW	238	119		1062	60	18	
17	Heat Rate	MMBtu/MWh	9.324	9.324		6.591	9.324	8.260	
18	Variable O&M (Single Rate)	$/MWh	$ 0.31	$ 0.3110		$ 0.31	$ 0.31	$ 1.04	
19	VOM Tier # 1 (1st 10 Years)	$/MWh							
20	VOM Tier # 2 (Through Perpetuity)	$/MWh							
22	Avg Cost Per Fired Hour	$/Hour				$ 3,081			
23	Average Startup Costs	$/Start	$ 3,000	$ 1,500			$ 750	$ 10	
24	Average Run Time	Hours	8	8			8	8	
26	NOX	Lbs/Mmbtu	0.0072	0.0072		0.0072	0.0072	0.0150	
27	SO2	Lbs/Mmbtu	0.0011	0.0011		0.0011	0.0011	0.0000	
28	CO2	Lbs/Mmbtu	116.9800	116.9800		116.9800	116.9800	117.0000	
30	HG	Lbs/Mmbtu							
33	State		Virginia	Virginia		West Virginia	Virginia	Virginia	
34	Property Tax	Menu Item	0.80%	0.80%		0.80%	0.80%	0.80%	
36									
37									

			S	T	U	V	W	X	Y
G29	FIXED	$/kW-yr	$ 123.31	$ 198.03	$ 309.32	$ 157.89	$ 234.53	$ 470.79	#DIV/0!
H30	VARIABLE	$/Mwh	$ 58.51	$ 58.51	$ 44.86	$ 32.51	$ 58.49	$ 51.00	#NUM!

Screening Curve Graph Data Output ($/kW-yr)

Capacity Factor	4X CT Aeroderivative	2X CT Aeroderivative	Solar & Aero CT	WV Generic 2X1 Dual Fuel	1X CT Aeroderivative	1X Recip Brownfield	-
0%	$ 123	$ 198	$ 309	$ 158	$ 235	$ 471	#DIV/0!
10%	$ 175	$ 249	$ 349	$ 186	$ 288	$ 515	#DIV/0!
20%	$ 226	$ 301	$ 388	$ 215	$ 337	$ 560	#DIV/0!
30%	$ 277	$ 352	$ 427	$ 243	$ 388	$ 605	#DIV/0!
40%	$ 328	$ 403	$ 467	$ 272	$ 439	$ 649	#DIV/0!
50%	$ 380	$ 454	$ 506	$ 300	$ 491	$ 694	#DIV/0!
60%	$ 431	$ 506	$ 545	$ 329	$ 542	$ 739	#DIV/0!
70%	$ 482	$ 557	$ 584	$ 357	$ 593	$ 784	#DIV/0!
80%	$ 533	$ 608	$ 624	$ 386	$ 644	$ 828	#DIV/0!
90%	$ 585	$ 659	$ 663	$ 414	$ 696	$ 873	#DIV/0!
100%	$ 636	$ 711	$ 702	$ 443	$ 747	$ 918	#DIV/0!

Levelized Cost of Energy ($/MWh)

Capacity Factor	4X CT Aeroderivative	2X CT Aeroderivative	Solar & Aero CT	WV Generic 2X1 Dual Fuel	1X CT Aeroderivative	1X Recip Brownfield	-
5%	$ 340	$ 511	$ 751	$ 393	$ 594	$ 1,128	#DIV/0!
10%	$ 199	$ 285	$ 398	$ 213	$ 326	$ 588	#DIV/0!
15%	$ 152	$ 209	$ 280	$ 153	$ 237	$ 409	#DIV/0!
20%	$ 129	$ 172	$ 221	$ 123	$ 192	$ 320	#DIV/0!
25%	$ 115	$ 149	$ 186	$ 105	$ 166	$ 266	#DIV/0!
30%	$ 105	$ 134	$ 163	$ 93	$ 148	$ 230	#DIV/0!
35%	$ 99	$ 123	$ 146	$ 84	$ 135	$ 205	#DIV/0!
40%	$ 94	$ 115	$ 133	$ 78	$ 125	$ 185	#DIV/0!
45%	$ 90	$ 109	$ 123	$ 73	$ 118	$ 170	#DIV/0!
50%	$ 87	$ 104	$ 115	$ 69	$ 112	$ 158	#DIV/0!
55%	$ 84	$ 100	$ 109	$ 65	$ 107	$ 149	#DIV/0!
60%	$ 82	$ 96	$ 104	$ 63	$ 103	$ 141	#DIV/0!
65%	$ 80	$ 93	$ 99	$ 60	$ 100	$ 134	#DIV/0!
70%	$ 79	$ 91	$ 95	$ 58	$ 97	$ 128	#DIV/0!
75%	$ 77	$ 89	$ 92	$ 57	$ 94	$ 123	#DIV/0!
80%	$ 76	$ 87	$ 89	$ 55	$ 92	$ 118	#DIV/0!
85%	$ 75	$ 85	$ 86	$ 54	$ 90	$ 114	#DIV/0!
90%	$ 74	$ 84	$ 84	$ 53	$ 88	$ 111	#DIV/0!
95%	$ 73	$ 82	$ 82	$ 51	$ 87	$ 108	#DIV/0!
100%	$ 73	$ 81	$ 80	$ 51	$ 85	$ 105	#DIV/0!

Levelized Cost of Energy ($/MWh)

	4X CT Aeroderivative	2X CT Aeroderivative	Solar & Aero CT	WV Generic 2X1 Dual Fuel	1X CT Aeroderivative	1X Recip Brownfield	-
Capacity Factor	20%	20%	20%	80%	20%	20%	
$/MWh	$ 128.89	$ 171.54	$ 239.06	$ 55.04	$ 192.35	$ 319.71	#DIV/0!

190410277

CERTIFICATE OF SERVICE

I, Evan D. Johns, hereby certify that, on April 9, 2019, per the agreement of the parties, I served an accurate copy of the foregoing by electronic mail to:

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