

STATE CORPORATION COMMISSION  
RECEIVED

JUN 23 2021

Case No. PUR-2020-00258  
Sponsor: ("SIERRA CLUB")  
Exhibit No. 12

Witness: RACHEL WILSON  
Bailiff: JABARI T. ROBINSON

2  
1  
1  
1  
1  
1  
1  
1  
1

I recommend that the Commission approve the CCR costs at both the Amos and Mountaineer plants but deny APCo's petition for recovery of ELG costs, resulting in a retirement date of December 31, 2028 for both the Amos and Mountaineer plants.

## Table of Contents

|    |  |    |
|----|--|----|
| 1. | INTRODUCTION AND QUALIFICATIONS .....  | 1  |
| 2. | OVERVIEW OF TESTIMONY AND CONCLUSIONS .....  | 4  |
| 3. | SUMMARY OF APCO'S PETITION .....   | 7  |
| 4. | SYNAPSE MODELING ANALYSIS .....  | 19 |
| 5. | COMPARING THE SYNAPSE AND APCO MODELING ANALYSES .....                             | 40 |
| 6. | COAL-FIRED POWER PLANTS WILL BECOME INCREASINGLY<br>UNECONOMIC IN THE FUTURE ..... | 45 |
| 7. | CONCLUSIONS AND RECOMMENDATIONS .....  | 51 |

## 1. INTRODUCTION AND QUALIFICATIONS

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

2 A. My name is Rachel Wilson and I am a Principal Associate with Synapse Energy  
3 Economics, Incorporated (Synapse). My business address is 485 Massachusetts  
4 Avenue, Suite 3, Cambridge, Massachusetts 02139.

5 Q. Please describe Synapse Energy Economics.

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

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

14 Q. Please summarize your work experience and educational background.

15 A. At Synapse, I conduct analysis and write testimony and publications that focus on  
16 a variety of issues relating to electric utilities, including: integrated resource  
17 planning; power plant economics; federal and state clean air policies; emissions  
18 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.

22  
21  
20  
19  
18  
17  
16  
15  
14  
13  
12  
11  
10  
9  
8  
7  
6  
5  
4  
3  
2  
1

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

3 A. Yes, in Case No. PUE-2015-00075, Case No. PUR-2018-00065, Case No PUR-  
4 2020-00015, and Case No PUR-2020-00035.

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

6 A. My testimony evaluates Appalachian Power Company's (APCo or the Company)  
7 application for approval of a rate adjustment clause for capital investments and  
8 operations and maintenance (O&M) expenses to comply with the federal Coal  
9 Combustion Residuals (CCR) and Effluent Limitation Guidelines (ELG)  
10 regulations in lieu of retirement of the Amos and Mountaineer coal plants. I present  
11 the results of an alternative modeling analysis that compares three cases:

12 1) **Synapse BAU**, which includes the CCR and ELG investments at APCo's  
13 four existing coal-fired units and operates those units through 2040;

14 2) **Synapse Retirement 1**, which includes the CCR investments at the  
15 Amos plant, and retires those units on December 31, 2028, and includes  
16 both CCR and ELG investments at the Mountaineer plant with a retirement  
17 date of 2040; and

18 3) **Synapse Retirement 2**, which includes the CCR investments at both  
19 Amos and Mountaineer and retires all four units on December 31, 2028.

1     **Q.     Please identify the documents and filings on which you base your opinions.**

2     A.     My findings rely primarily upon the testimony, exhibits, and discovery responses  
3           of APCo and its witnesses. I also rely on certain industry publications and data  
4           sources.

5     **Q.     Are you sponsoring any exhibits?**

6     A.     Yes. I am sponsoring the following exhibits:

| Exhibit Number | Description of Exhibit                                  | Protected Status |
|----------------|---|------------------|
| Exhibit RW-1   | Resume of Rachel S. Wilson                              | Non-Confidential |
| Exhibit RW-2   | Response to Sierra Club 2-15, Confidential Attachment 1 | Confidential     |
| Exhibit RW-3   | Response to Sierra Club 5-3, Attachment 1               | Non-Confidential |
| Exhibit RW-4   | Response to Sierra Club 5-4, Attachment 1               | Non-Confidential |
| Exhibit RW-5   | Response to Sierra Club 5-5, Attachment 1               | Non-Confidential |

## 2.     OVERVIEW OF TESTIMONY AND CONCLUSIONS

7     **Q.     Please summarize your primary conclusions.**

8     A.     My independent modeling demonstrates that it is uneconomic, and not in the best  
9           interest of ratepayers, for APCo to invest in CCR and ELG costs at both Amos and  
10          Mountaineer in order to continue running the plants through 2040. Investing only  
11          in CCR costs at the Amos plant and retiring the three units in 2028 results in  
12          ratepayer savings of more than \$200 million under a Base with No Carbon  
13          commodity price forecast.

1 When a price on carbon dioxide (CO<sub>2</sub>) emissions is included as part of the analysis,  
 2 ratepayer savings rises to more than \$1 billion when Amos is retired and replaced  
 3 with a combination of renewable and battery storage resources. A scenario in which  
 4 both Amos and Mountaineer are retired at the end of 2028 results in a savings to  
 5 ratepayers of approximately \$670 million relative to a scenario that operates the  
 6 plants through 2040.

7 A summary of the resource additions, retirements, and net present value of revenue  
 8 requirements in the Synapse modeling is shown in Table 1 under the No Carbon  
 9 commodity forecast, and in Table 2 under the commodity forecast With Carbon.

**Table 1. Summary of Synapse modeling results (2040), No Carbon**

|  | Synapse BAU | Synapse Retirement 1 | Synapse Retirement 2 |
|--|-------------|----------------------|----------------------|
| NPV (2021-2040)                          | \$11.8      | \$11.6               | \$12.3               |
| CO <sub>2</sub> Emissions (million tons) | 21.7        | 8.6                  | 2.2                  |
| Solar (MW)                               | 1,520       | 10,080               | 10,220               |
| Wind (MW)                                | 695         | 495                  | 495                  |
| Storage (MW)                             | 0           | 888                  | 2,272                |
| Gas (MW)                                 | 1,020       | 1,020                | 1,020                |
| Coal (MW)                                | 4,568       | 1,638                | 333                  |

**Table 2. Summary of Synapse modeling results (2040), With Carbon**

|  | Synapse BAU | Synapse Retirement 1 | Synapse Retirement 2 |
|--|-------------|----------------------|----------------------|
| NPV (2021-2040)                          | \$13.7      | \$12.5               | \$13.0               |
| CO <sub>2</sub> Emissions (million tons) | 15.5        | 6.6                  | 2.2                  |
| Solar (MW)                               | 1,520       | 10,160               | 10,260               |
| Wind (MW)                                | 695         | 695                  | 895                  |
| Storage (MW)                             | 0           | 908                  | 2,272                |
| Gas (MW)                                 | 1,020       | 1,020                | 1,020                |
| Coal (MW)                                | 4,568       | 1,638                | 333                  |



1 Q. Please summarize your primary recommendations.

2 A. Based on my findings, I recommend that the Commission approve the CCR  
3 compliance costs at the Amos plant, but deny the ELG costs. The use of industry  
4 standard pricing for replacement capacity and energy shows that the retirement of  
5 the Amos plant in 2028 is economic and results in savings to customers, even in a  
6 scenario that does not include a price or constraint on future CO<sub>2</sub> emissions.

7 Second, I recommend that the Commission approve the CCR costs at the  
8 Mountaineer plant, but deny the costs associated with ELG compliance at this time.

9 The Synapse analysis shows that in a scenario with a constraint on carbon (in the  
10 form of a CO<sub>2</sub> price), the retirement of both Amos and Mountaineer in 2028 yields  
11 savings to ratepayers when compared to a scenario in which both plants continue  
12 to operate through 2040. While the Synapse modeling in this docket shows that the  
13 retirement of both Amos and Mountaineer is more expensive than the retirement of  
14 Amos alone, we only model a single type of constraint on CO<sub>2</sub>. It is expected that  
15 the Biden administration will soon be implementing some type of carbon policy,  
16 but it remains to be seen what form that policy might take, or how stringent it might  
17 be. It is thus premature, at the current time, to approve the ELG costs at  
18 Mountaineer. Rather, the Commission should deny the ELG costs until APCo can  
19 present an analysis of the effect of upcoming carbon regulations on the operation  
20 of the plant.

2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15

### 3. SUMMARY OF APCO'S PETITION

1 Q. What is APCo requesting in its Petition in this docket?

2 A. APCo is requesting the Commission's approval of its environmental rate  
3 adjustment clause (E-RAC), which includes cost recovery relating to environmental  
4 projects at the Amos and Mountaineer plants. Specifically, APCo is seeking the  
5 recovery of \$125 million in capital projects to comply with the federal CCR Rule,  
6 which regulates the disposal of the fly ash, bottom ash, and gypsum generated at  
7 coal-fired generating units. It is also seeking the recovery of \$125 million in capital  
8 projects to comply with the federal ELG, which establishes limits on the discharge  
9 of wastewater from flue gas desulfurization, fly ash and bottom ash transport water,  
10 and flue gas mercury control.<sup>1</sup>

11 Broken down by plant, the total cost of compliance with CCR and ELG for Amos  
12 is \$177.1 million, while the cost for Mountaineer is \$72.9 million.<sup>2</sup>

13 Q. Did APCo present any analysis supporting its Petition?

14 A. Yes. According to the Direct Testimony of James F. Martin, he prepared an  
15 economic analysis that compared three compliance scenarios:

---

1 Direct Testimony of Christian T. Beam at 4:11-4:14.

2 Direct Testimony of Brian D. Sherrick at 9:14-9:21.

- 1 • Case 1 assumes CCR and ELG investments at both Amos and
- 2 Mountaineer, and continued operation of both plants until 2040;
- 3 • Case 2 assumes CCR investments at Amos and retirement in 2028, with
- 4 CCR and ELG investments at Mountaineer with retirement in 2040; and
- 5 • Case 3 assumes CCR investments at both Amos and Mountaineer, with
- 6 a retirement date of 2028.<sup>3</sup>

7 This analysis was done under three forecasted commodity price assumptions: Base  
 8 No Carbon, Base With Carbon, and Low Band, which has a lower gas price  
 9 forecast.

10 **Q. What were the results of APCo's analysis?**

11 A. APCo found that its Case 1, which installs CCR and ELG technologies at both  
 12 Amos and Mountaineer and operates the plants through 2040, was the least-cost  
 13 option when comparing the net present value of revenue requirements (NPVRR).  
 14 The revenue requirements for each case, under each commodity forecast, are shown  
 15 in Table 3, along with the change in costs (delta) relative to Case 1.

---

3 Direct Testimony of James F. Martin at 4:3–4:14.

**Table 3. Comparison of net present value of revenue requirements,  
APCo modeled scenarios**

|        |                  | NPVRR<br>(\$ Millions) | Delta from Case 1<br>(\$ Millions) | Delta from Case 1<br>(Percent) |
|--------|------------------|------------------------|------------------------------------|--------------------------------|
| Case 1 | Base With Carbon | \$20,578               |                                    |                                |
|        | Base No Carbon   | \$18,435               |                                    |                                |
|        | Low Band         | \$17,088               |                                    |                                |
| Case 2 | Base With Carbon | \$20,754               | \$176                              | 0.86%                          |
|        | Base No Carbon   | \$18,730               | \$295                              | 1.60%                          |
|        | Low Band         | \$17,333               | \$245                              | 1.43%                          |
| Case 3 | Base With Carbon | \$20,951               | \$374                              | 1.81%                          |
|        | Base No Carbon   | \$19,057               | \$622                              | 3.37%                          |
|        | Low Band         | \$17,569               | \$480                              | 2.81%                          |

Source: *APCo response to Sierra Club 1-02, Martin Sch 46 Section 2 and Testimony Tables Workpaper.xlsx*<sup>4</sup>

1 The percentage differences reflected above between Cases were calculated by  
2 Synapse. Notably, Case 2 (which retires the Amos units in 2028) is less than 1  
3 percent more expensive in the Company's modeling than Case 1 under the Base  
4 With Carbon forecast, and only 1.6 percent more expensive when carbon is  
5 excluded. These differentials are extremely small, and thus even a small adjustment  
6 to APCo's input assumptions would shift the results such that the 2028 retirement  
7 of one or both coal plants becomes the more economic option.

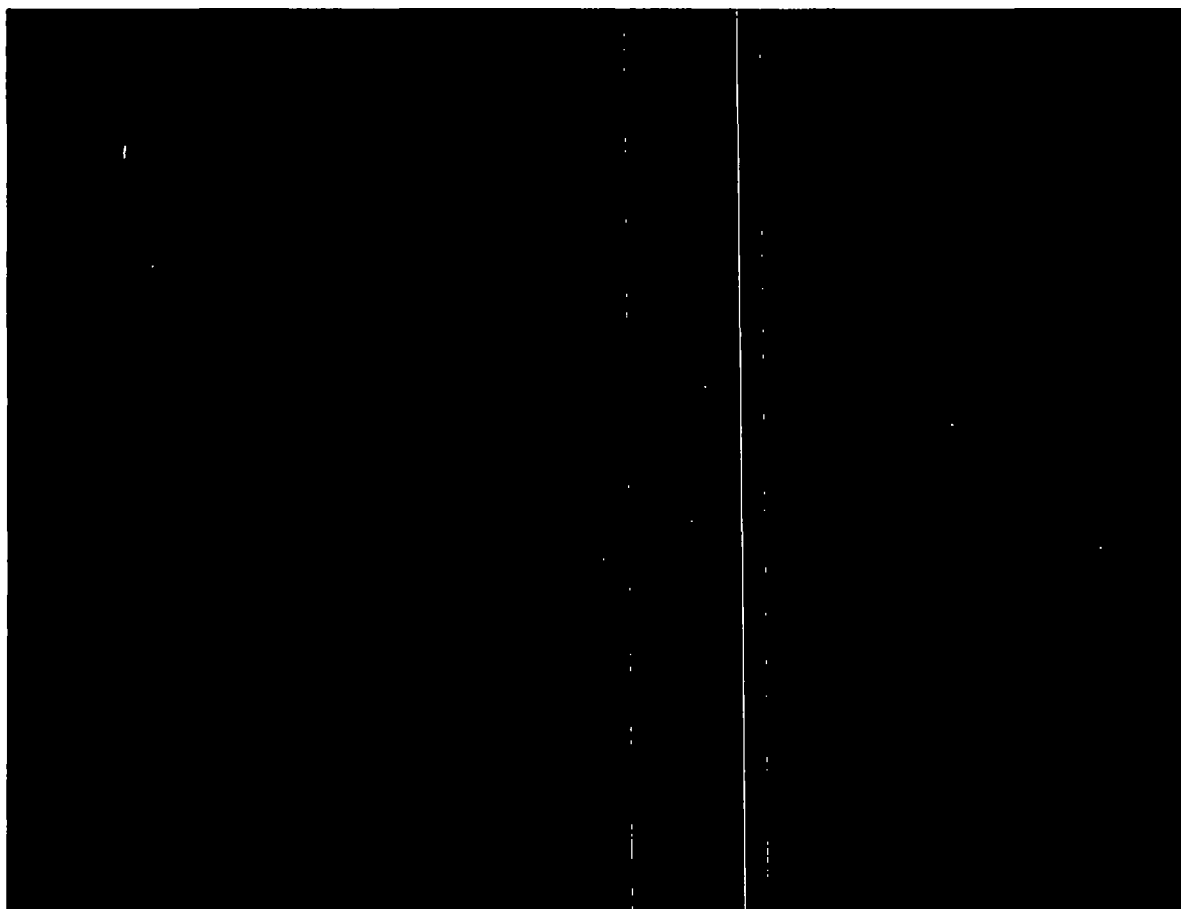
8 **Q. How do the Amos and Mountaineer units operate in APCo's analysis?**

9 A. Under a No Carbon commodity price forecast, APCo's results show generation at  
10 APCo's thermal units, including both Amos and Mountaineer, increasing between

---

4 This document contains spreadsheet data contained in numerous tabs and can be produced upon request.

1        2021 and 2028, after which generation falls until 2032 and then grows more slowly  
2        until the units retire at the end of 2040. Those patterns are shown in  
3        CONFIDENTIAL Figure 1.



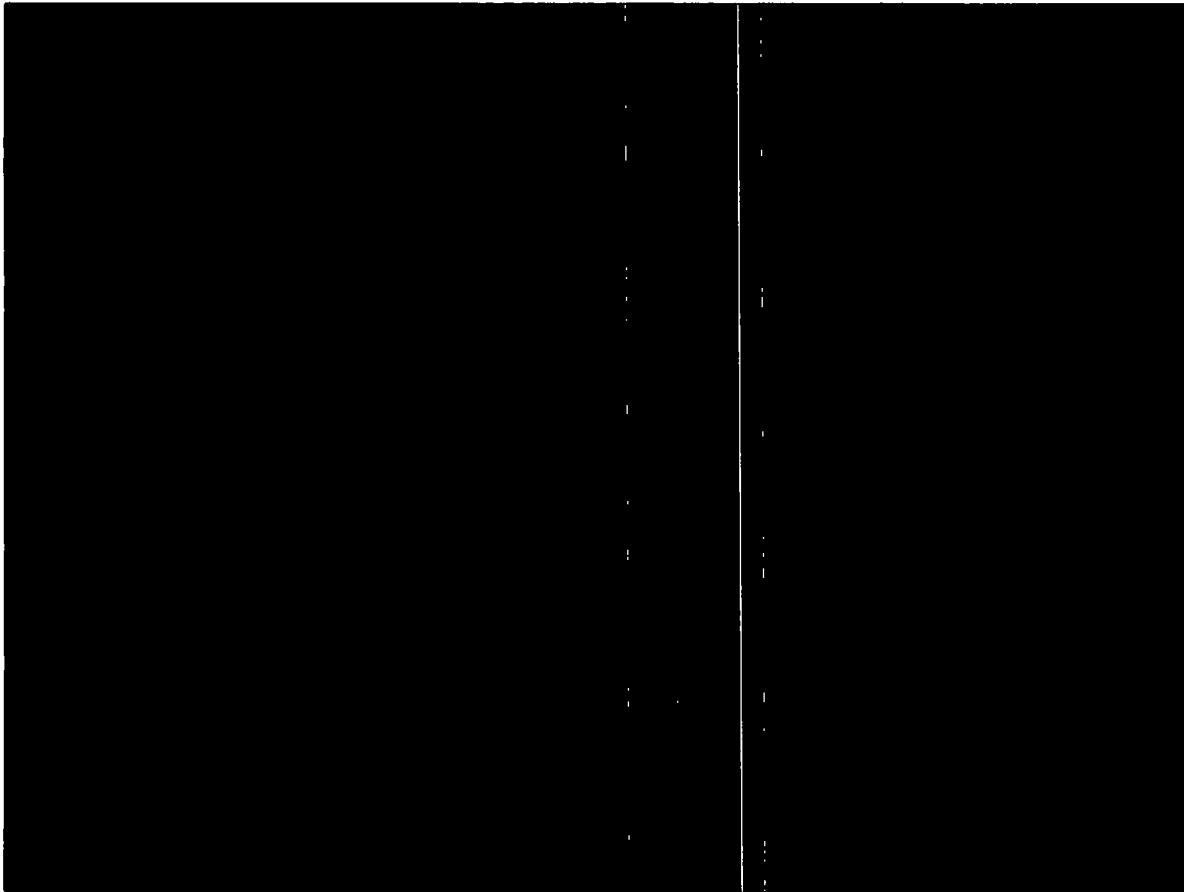
*Source: Response to Sierra Club 1-02. Confidential APCo Base without Carbon –  
AM+MNTR CCR&ELG Optimal Plan.xlsx<sup>5</sup>*

---

5        This document contains spreadsheet data contained in numerous tabs and can be  
         produced upon request.

1     **Q.**     **What does generation look like in APCo's other cases?**

2     **A.**     In Case 2, which retires Amos at the end of 2028, generation looks very similar.  
3             The retirement of the Amos plant causes coal generation to make a steep drop from  
4             2028 to 2029, and it rises more slowly in the 2030s. One might expect to see a  
5             greater volume of renewables added as replacement for the retiring Amos plant, but  
6             CONFIDENTIAL Figure 2 shows only a slight increase near the end of the analysis  
7             period, with much of the generation gap being filled by imported energy from PJM.



*Source: Response to Sierra Club 1-02. Confidential APCo Base without Carbon – AM CCR Only+MNTR CCR&ELG Optimal Plan.xlsx<sup>6</sup>*

1    **Q.**    In the scenarios in which Amos and Mountaineer retire, what sort of  
2           replacement capacity is selected in APCo's analysis?

3    **A.**    The PLEXOS model selects between 2,618 MW and 3,094 MW of gas-fired  
4           combustion turbines, the capacity-only PPA, and varying amounts of solar,  
5           depending on whether a carbon price was included. Mr. Martin states in his direct

\_\_\_\_\_

6           This document contains spreadsheet data contained in numerous tabs and can be  
             produced upon request.

1 testimony that the PLEXOS model chose the cheapest capacity options available to  
2 replace Amos and Mountaineer, due to the low level of market energy prices in the  
3 AEP Fundamentals Forecast. Because energy from the PJM market is inexpensive,  
4 the model did not choose thermal units with low heat rates, which might be  
5 expected to run more, or renewable resources, which Mr. Martin says are less  
6 valuable when market prices are low.<sup>7</sup> Instead, APCo's plans "result in very heavy  
7 reliance on the PJM energy market for the energy needed to serve customers."<sup>8</sup>  
8 Even when Amos and Mountaineer continue to operate until 2040, the PLEXOS  
9 model begins to select large volumes of imports beginning in 2030, as shown in  
10 CONFIDENTIAL Figure 1, above.

11 **Q. Can you draw any conclusions about APCo's input assumptions from this**  
12 **heavy reliance on imports from PJM?**

13 **A.** Yes. When making the decision about which resources to build, PLEXOS considers  
14 both the cost of capacity (MW) and the cost of energy (\$/MWh) of different types  
15 of replacement resource. The calculation is complicated by APCo's ability to  
16 purchase from or sell to the PJM market. The PLEXOS model chose primarily  
17 capacity resources (combustion turbines) in APCo's analysis, rather than energy  
18 resources (solar and wind), instead choosing to purchase energy from PJM. This

---

7 Direct Testimony of James F. Martin at 21:13 to 21:18.

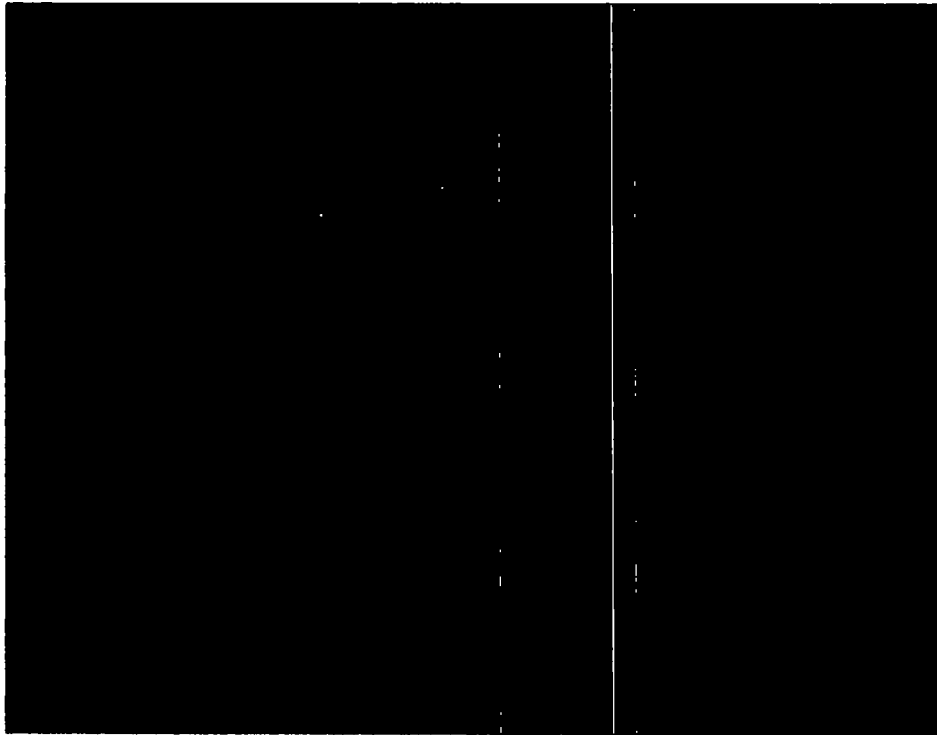
8 Direct Testimony of James F. Martin at 20:6 to 20:7.



1 suggests that APCo's market energy price forecast is low, its renewable prices are  
2 high, or both.

3 **Q. What does APCo forecast about the performance of the units at the Amos**  
4 **and Mountaineer plants in its Case 1?**

5 A. APCo projects that the capacity factors of these units are going to increase in the  
6 near term and peak in 2026 or 2027. By 2031, capacity factors are around [BEGIN  
7 CONFIDENTIAL INFORMATION] [REDACTED] [END CONFIDENTIAL  
8 INFORMATION] for Amos Units 1 and 2, and just under [BEGIN  
9 CONFIDENTIAL INFORMATION] [REDACTED] [END CONFIDENTIAL  
10 INFORMATION] for Amos 3. APCo would essentially be running these  
11 "baseload" units, designed for high levels of output, as peaking units. We see a  
12 similar but slower decline at Mountaineer, and by 2035 the plant is operating at a  
13 capacity factor of only [BEGIN CONFIDENTIAL INFORMATION] [REDACTED]  
14 [REDACTED] [END CONFIDENTIAL INFORMATION]. Annual capacity factor  
15 projections are shown in CONFIDENTIAL Table 4.



*Source: Response to Sierra Club 2-15, Confidential Attachment I<sup>9</sup>*

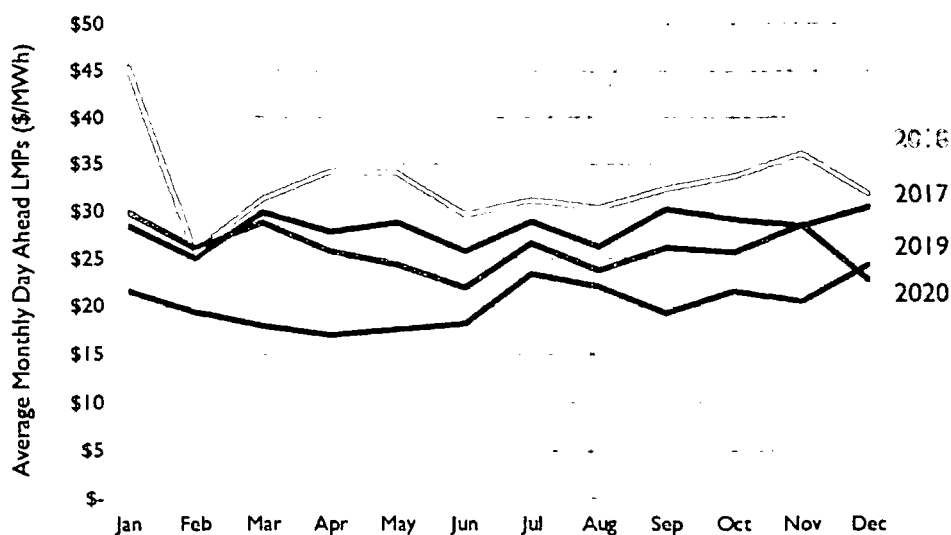
1    **Q.    Are these projections consistent with recent experience at the Amos and**  
 2       **Mountaineer plants?**

3    **A.    No. Except for 2018, locational marginal prices at the Amos node in PJM have**  
 4       **come down each year since 2017. Monthly average day-ahead prices are shown in**  
 5       **Figure 3.**

---

9       Attached as Exhibit RW-2.

Figure 3. Historical average monthly day ahead LMPs at the Amos node



Source: PJM Data Miner, available at: <https://www.pjm.com/markets-and-operations/etools/data-miner-2>.

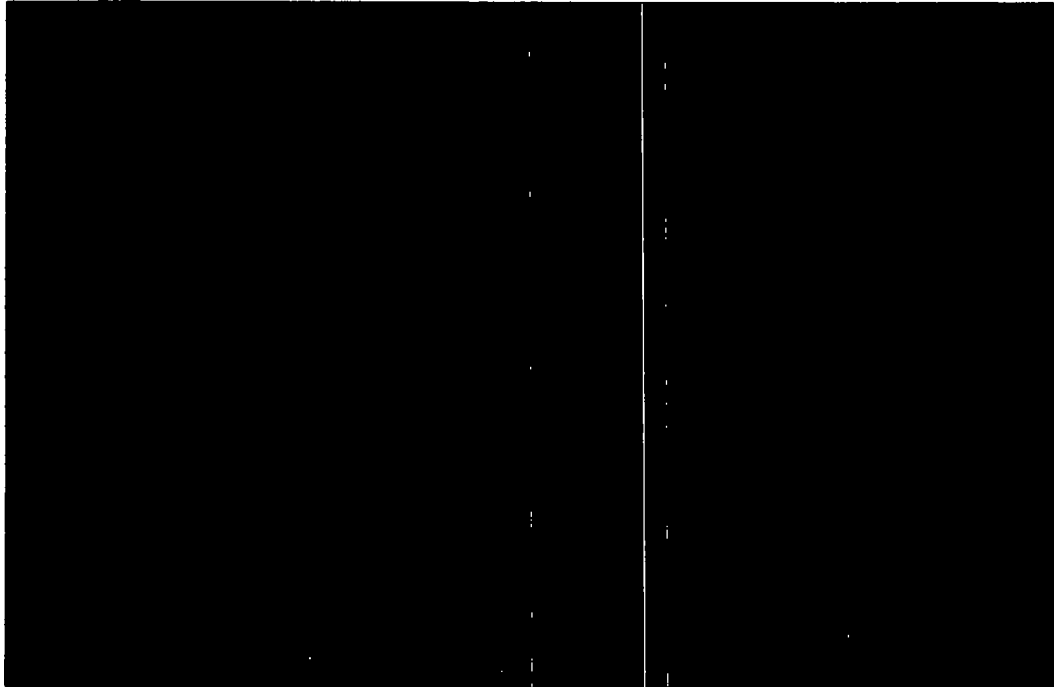
- 1       APCo's coal units have generally responded to these LMPs by generating less as
- 2       prices decline.
- 3       In contrast to recent historical declines in LMPs, APCo's market energy price
- 4       forecast shows a steady increase over time. The Company's existing coal units
- 5       respond by increasing generation steeply before falling off after 2027. Those
- 6       patterns are shown, using the forecasted capacity factors for the Amos 1 unit, in
- 7       CONFIDENTIAL Figure 4.



*Sources: Historical LMPs come from the PJM Data Miner. Historical capacity factors come from EPA's Clean Air Markets Database. Projected market prices come from the AEP Fundamentals Forecast. Projected capacity factors come from Response to SC 2-15, Confidential Attachment 1.*

1       When we compare the operating costs of the Amos and Mountaineer plants,  
 2       calculated from APCo's PLEXOS outputs as the sum of fuel, variable O&M,  
 3       emissions costs, and start/shutdown costs, to the AEP Fundamentals Forecast for  
 4       market energy, we see that [BEGIN CONFIDENTIAL INFORMATION] [REDACTED]  
 5       [REDACTED] [END CONFIDENTIAL  
 6       INFORMATION] Mountaineer is a better performer, as shown in  
 7       CONFIDENTIAL Figure 5, but operates at [BEGIN CONFIDENTIAL  
 8       INFORMATION] [REDACTED]

██████████ [END CONFIDENTIAL INFORMATION], meaning that it is uneconomic during a large portion of hours.



*Sources: Energy market prices come from Response to SC 1-02, Trecuzzi-FF-Appendix B-Base.xlsx. Operating costs were calculated using Response to Sierra Club 1-02. Confidential APCo Base without Carbon – AM+MNTR CCR&ELG Optimal Plan.xlsx.*

APCo's analysis, then, shows that the Amos and Mountaineer plants offer capacity and energy value to its customers in the near term, but offer very little energy value (as evidenced by declining capacity factors) in the later part of the decade and beyond.

#### 4. SYNAPSE MODELING ANALYSIS

1 Q. Do you present an alternative to APCo's modeling analysis?

2 A. Yes, and I describe that alternative modeling analysis in this section.

3 Q. Which model did you use to perform your analysis?

4 A. The Synapse analysis uses the EnCompass capacity optimization and dispatch  
5 model, developed by Anchor Power Solutions, to simulate resource choice impacts  
6 in APCo's service territory.

7 Q. Is EnCompass a widely accepted industry model?

8 A. Yes. EnCompass was released in 2016 and several major utilities have transitioned  
9 to the model since that time. For example, the three investor-owned utilities in  
10 Minnesota (Minnesota Power, Otter Tail Power, and Xcel Energy) adopted the  
11 EnCompass model in 2019, along with Great River Energy, the largest of the state's  
12 electric cooperatives.<sup>10</sup> Duke Energy announced in 2020 that it had chosen  
13 EnCompass to expand its capabilities in resource planning.<sup>11</sup> Public Service New  
14 Mexico and Public Service Company of Colorado are two other IOUs that have  
15 adopted EnCompass in recent years.

---

10 Anchor Power Solutions. December 2019. Available at: <https://anchor-power.com/news/minnesota-plans-for-its-energy-future-with-encompass/>

11 Anchor Power Solutions. May 2020. Available at: <https://anchor-power.com/news/duke-energy-implemented-encompass-software/>

1 Q. What did Synapse model in its analysis?

2 A. Synapse modeled three different scenarios in our analysis:

3 1) Synapse BAU includes the CCR and ELG investments at APCo's four existing  
4 coal-fired units and operates those units through 2040;

5 2) Synapse Retirement 1 includes the CCR investments at the Amos plant, and  
6 retires those units on December 31, 2028, and includes both CCR and ELG  
7 investments at the Mountaineer plant; and

8 3) Synapse Retirement 2 includes the CCR investments at both Amos and  
9 Mountaineer and retires all four units on December 31, 2028.<sup>12</sup>

10 A matrix of these scenarios is shown in Table 5.

---

12 As noted by APCo in its petition, CCR compliance will be required by October 17, 2023. ELG costs, however, can be avoided if a plant is shut down by 2028 (and makes a commitment to do so by October 2021). Because of the short time necessary to comply with CCR regulations, and because it is not clear that all costs could be avoided even if a plant ceased operations, I have not considered a scenario where CCR costs were not included.

2465

|                     | Plant       | Synapse BAU | Synapse Retirement 1 | Synapse Retirement 2 |
|---------------------|-------------|-------------|----------------------|----------------------|
| Retrofit Technology | Amos        | CCR/ELG     | CCR                  | CCR                  |
|                     | Mountaineer | CCR/ELG     | CCR/ELG              | CCR                  |
| Retirement Date     | Amos        | 2040        | 2028                 | 2028                 |
|                     | Mountaineer | 2040        | 2040                 | 2028                 |

1 Q. Do the input assumptions used in the Synapse analysis conform to APCo's  
2 assumptions?

3 A. Largely, yes. To ensure a valid comparison, the Synapse analysis uses APCo's  
4 assumptions for peak and annual energy, load shape, reserve margin, unit  
5 retirements, distributed solar additions, commodity prices (fuel, CO<sub>2</sub>, and energy  
6 market prices), and compliance costs for CCR/ELG at both Amos and Mountaineer  
7 under the 2028 and 2040 retirement dates.<sup>13</sup> The sources for key input assumptions  
8 in the Synapse modeling are shown in Table 6.



2166

2166

2166

2166

2166

1 from EIA in AEO 2021 for solar resources in 2026, which is \$33.68/MWh.<sup>15</sup> APCo  
2 has stated that its cost assumptions come from EIA, and yet there is a substantial  
3 discrepancy between APCo's assumed costs for new resources and those reported  
4 by EIA in AEO 2021. This discrepancy makes solar appear much more expensive  
5 than it actually is, and therefore overstates the cost of alternatives to the continued  
6 operation of Amos and Mountaineer.

7 **Q. Are you able to determine the source of that discrepancy?**

8 A. No. In the responses provided as part of Sierra Club Set 5, APCo's values are not  
9 adequately sourced and many of the Company's calculations lack underlying  
10 formulas, so it was impossible to determine how APCo's values deviated from EIA  
11 and if those deviations were reasonable.<sup>16</sup>

12 **Q. Are there any other data points that lead you to believe that APCo's new**  
13 **resource costs are unreasonably high?**

14 A. Yes. The current prices of wind and solar in PJM also lead me to believe that  
15 APCo's assumptions are unreasonably high. Solar PPA pricing in PJM in Q4 2020

---

15 Energy Information Administration, *Levelized Costs of New Generation Resources in the Annual Energy Outlook 2021* (February 2021), available at [https://www.eia.gov/outlooks/aeo/pdf/electricity\\_generation.pdf](https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf).

This document shows a cost of \$29.04 in 2020\$. That value was converted to nominal dollars using APCo's assumed inflation rate of 2.5% from Response to SC 5-003, Attachment 1.

16 Exhibit RW-3.

09/10/2021 10:00 AM

1 was \$37.50/MWh while wind PPAs were priced at \$35.50/MWh.<sup>17</sup> Analysts note  
2 that both prices are an increase over prior years because of both disruptions due to  
3 COVID-19 and supply constraints that have arisen due to high demand.<sup>18</sup> Over the  
4 longer term, basic economics suggests that we can expect the market to respond to  
5 these supply constraints and for prices to stabilize.

6 **Q. What source did the Synapse modeling analysis use as the basis for its**  
7 **assumptions around the cost of replacement resources?**

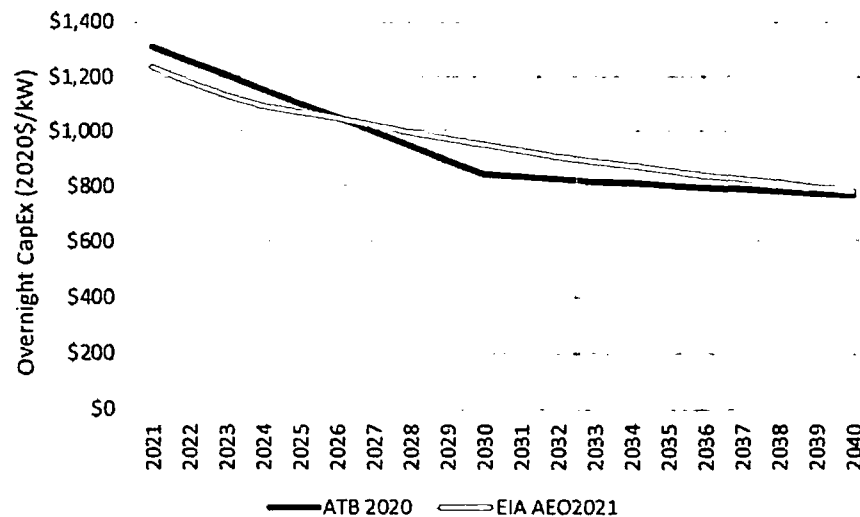
8 A. The Synapse modeling uses industry standard cost assumptions from the National  
9 Renewable Laboratory's (NREL) 2020 Advanced Technology Baseline (ATB) for  
10 utility-scale solar PV, onshore wind, and battery storage resources. NREL's data is  
11 similar to the estimates of overnight capital costs from EIA 2021. A comparison of  
12 the capital costs for solar PV from both sources is shown in Figure 6.

---

17 Level 10 Energy. *North America, Q4 2020 LevelTen Energy PPA Price Index*,  
available at: <https://leveltenenergy.com/blog/ppa-price-index/q4-2020/>

18 *Id.*

Figure 6. Comparison of overnight capital cost forecasts for solar PV, ATB 2020 and AEO 2021



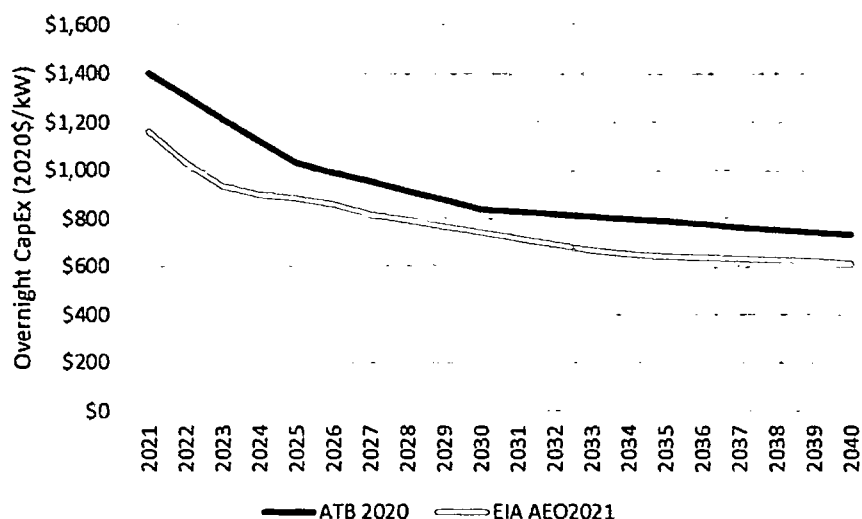
Sources: NREL, ATB 2020, <https://atb.nrel.gov/electricity/2020/data.php>

Energy Information Administration, *Annual Energy Outlook 2021*. Table 55, <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=123-AEO2021&cases=ref2021&sourcekey=0>.

- 1 Battery storage costs are more conservative in NREL's ATB Moderate Case than
- 2 in AEO 2021. Those overnight capital costs are shown in Figure 7.<sup>19</sup>

<sup>19</sup> A comparison of wind costs is not presented here because they are not directly comparable between sources, as AEO 2021 presents wind costs by region while NREL ATB presents costs by wind class. Synapse selected Class 7 to represent the wind resource that would be available to APCo for the purposes of this analysis.

2210060221



Sources: NREL, ATB 2020, <https://atb.nrel.gov/electricity/2020/data.php>

*Energy Information Administration, Annual Energy Outlook 2021. Table 55, <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=123-AEO2021&cases=ref2021&sourcekey=0>.*

- 1 Q. The capital costs you have shown from EIA are generally similar to or lower  
2 than ATB. Why are you suggesting that APCo's costs are too high?
- 3 A. Costs for wind, solar, and battery storage have two major components: capital and  
4 fixed O&M. A comparison of these components between APCo and EIA for a solar  
5 PV resource coming online in 2026 shows that APCo's fixed O&M costs are much  
6 higher than those being used in AEO 2021.



1       APCo in responses to discovery.<sup>24</sup> The NREL ATB, on the other hand, incorporates  
 2       several different sources, including analyses from both NREL and Oak Ridge  
 3       National Laboratory, data from EIA, and information from a variety of published  
 4       reports to arrive at its forecasts of generation technology cost and performance.<sup>25</sup>  
 5       NREL's ATB is a widely used source of renewable and storage pricing data. Detroit  
 6       Edison used the 2018 ATB Mid costs in its 2019 Integrated Resource Plan, with  
 7       some intervenors arguing that the costs were too conservative.<sup>26</sup> In its recent  
 8       Integrated Resource Plan filing in Minnesota, Xcel Energy used ATB 2019 as the  
 9       basis for its renewable and storage costs.<sup>27</sup>  
 10       Lastly, in order to accurately model these replacement resources, we need more  
 11       than just the forecasted capital costs. We also need annual estimates of fixed O&M  
 12       costs. The EIA AEO 2021 does not provide such annual estimates. NREL's ATB

---

24       Response to Sierra Club 2-28, Attachment 1, available online at:  
[https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital\\_cost\\_AEO2020.pdf](https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital_cost_AEO2020.pdf).

25       NREL. July 9, 2020. *2020 Annual Technology Baseline Electricity Data Now Available*. Available at: <https://www.nrel.gov/news/program/2020/2020-annual-technology-baseline-electricity-data-now-available.html>.

26       Michigan Public Service Commission. February 20, 2020. In the matter of the application of DTE Electric Company for approval of its integrated resource plan pursuant to MCL 460.6t and for other relief. Case No. U-20471. Available at: <https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t0000009jWc2AAE>.

27       Xcel Energy's 2020-2034 Upper Midwest Resource Plan before the Minnesota Public Utilities Commission. PUC Docket No. E002/RP-19-368.

1 does provide these data, however, which, when combined with performance data,  
2 allows for a levelized cost calculation that utilizes data from a single source.

3 **Q. What were the results of the Synapse modeling analysis?**

4 **A.** In contrast to APCo's modeling analysis, the Synapse modeling found that the  
5 retirement of Amos in 2028 is the least-cost scenario under the Base No Carbon  
6 commodity price forecast, with a cost savings to customers of just over \$200  
7 million.

8 Under the Base With Carbon, however, both Retirement 1 and Retirement 2 result  
9 in savings to ratepayers relative to the BAU. The retirement of Amos in 2028 results  
10 in ratepayer savings of \$1.1 billion, while the retirement of both Amos and  
11 Mountaineer results in savings of almost \$670 million. The revenue requirements  
12 for each of the four Synapse scenarios, under APCo's Base No Carbon and Base  
13 With Carbon pricing forecasts are shown in Table 8.

**Table 8. Net present value of revenue requirements, Synapse modeling scenarios**

| Scenario             | Base No Carbon        |                                   | Base With Carbon      |                                   |
|----------------------|-----------------------|-----------------------------------|-----------------------|-----------------------------------|
|                      | NPVRR<br>(\$Millions) | Delta from<br>BAU<br>(\$Millions) | NPVRR<br>(\$Millions) | Delta from<br>BAU<br>(\$Millions) |
| Synapse BAU          | \$11,803              |                                   | \$13,654              |                                   |
| Synapse Retirement 1 | \$11,597              | (\$206)                           | \$12,514              | (\$1,140)                         |
| Synapse Retirement 2 | \$12,281              | \$478                             | \$12,985              | (\$669)                           |



1 Q. Can the NPVRR values for the Synapse scenarios be compared directly to the  
2 NPVRR values from APCO's analysis?

3 A. No. There are a number of reasons why results would differ, and I will highlight  
4 the key reasons here. First, APCo used the PLEXOS model while Synapse used  
5 EnCompass. Each model has different optimization and dispatch algorithms and  
6 would produce different results even when using the same inputs. For this reason,  
7 Synapse always reproduces a utility's base case scenario, or BAU, in order to  
8 produce an NPVRR value to which we can compare results from alternative  
9 scenarios. In this case we updated the resource cost assumptions in the Synapse  
10 BAU as well as in our Retirement scenarios so that the BAU costs were not  
11 artificially high.

12 Second, Synapse is an independent consulting firm that is not afforded the same  
13 level of access to the details of APCo's electric system as is given to AEP's  
14 modelers. As a result, there may be certain inputs in APCo's analysis that are  
15 represented slightly differently in the Synapse analysis. The key, however, is that  
16 these elements are the same amongst all of the modeled Synapse scenarios and are  
17 not driving the differences in these scenarios. The only way that one can perfectly  
18 replicate a utility's analysis is to use the same model and version number and use  
19 that utility's exact input files. The models used by utilities often must be licensed  
20 by intervenors on a project basis and are cost prohibitive. While I am familiar with  
21 the PLEXOS model and have used it in previous work, there are limits to the extent

1 to which one can reconstruct an analysis without the opportunity to spend time  
2 exploring a utility's database within the model's interface.

3 Finally, APCo's NPVRR values include an analysis period from 2021 to 2050 and  
4 include an end effects period, while the Synapse values only include the period  
5 from 2021 to 2040. The Synapse NPVRR values in all scenarios will thus be lower  
6 than APCo's values because they include fewer years.

7 It is not the delta between the APCo scenarios and the Synapse scenarios that  
8 matters in this case, but the deltas between each entity's own set of modeled  
9 scenarios. For all of these reasons, the Synapse NPVRR values should be compared  
10 to each other and not compared directly to the APCo values.

11 **Q. What types and quantities of replacement resources are added in the**  
12 **Synapse scenarios?**

13 **A.** In the Synapse BAU, we include new units similar to APCo's own capacity  
14 expansion, adding 160 MW of new solar in 2024, which grows to a cumulative MW  
15 total of 1,420 by 2040,<sup>28</sup> and 200 MW of new wind in 2025. In all other scenarios,  
16 EnCompass was allowed to optimize the buildout of replacement resources for the  
17 retiring coal units beginning in 2023 with wind and 2024 with replacement solar

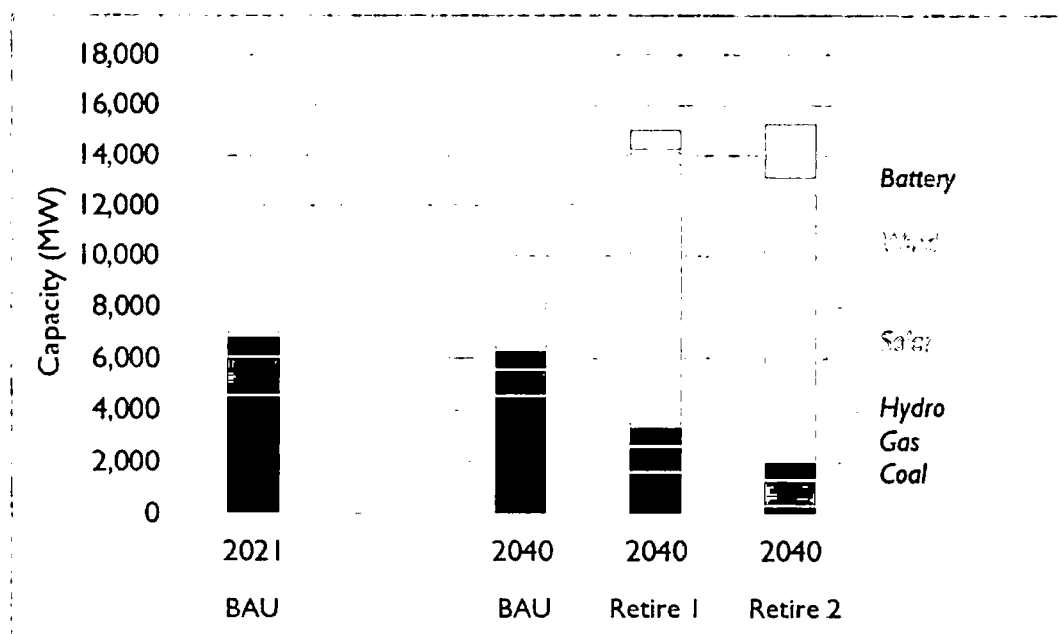
---

28 Solar units were offered in 20 MW increments in the Synapse EnCompass modeling, so the unit additions are slightly larger than in APCo's modeling, which starts with 150 MW of new solar in 2025 and increases to 1,350 MW in 2040.

PV and battery storage resources. Solar PV and battery storage were offered as both standalone and paired resources.

Capacity in 2040 looks different in each of the Synapse scenarios, as shown in Figure 8.

**Figure 8. Comparison of nameplate capacity in Synapse modeled scenarios, Base No Carbon**



The BAU adds the solar and wind increments described above, but looks largely unchanged relative to 2021. In contrast, the Retirement 1 scenario has retired a large volume of coal capacity and added additional solar and battery storage. The Retirement 2 scenario has even greater coal retirements and further additions of replacement renewables and storage.

1 Renewables and storage in the Retirement I scenario begin building slightly ahead  
2 of the Amos retirement in 2028. They provide inexpensive energy, in the case of  
3 renewables, and to provide capacity and to store energy for later use in the case of  
4 battery storage. Note that batteries can also provide ancillary services, which were  
5 not valued in this analysis.

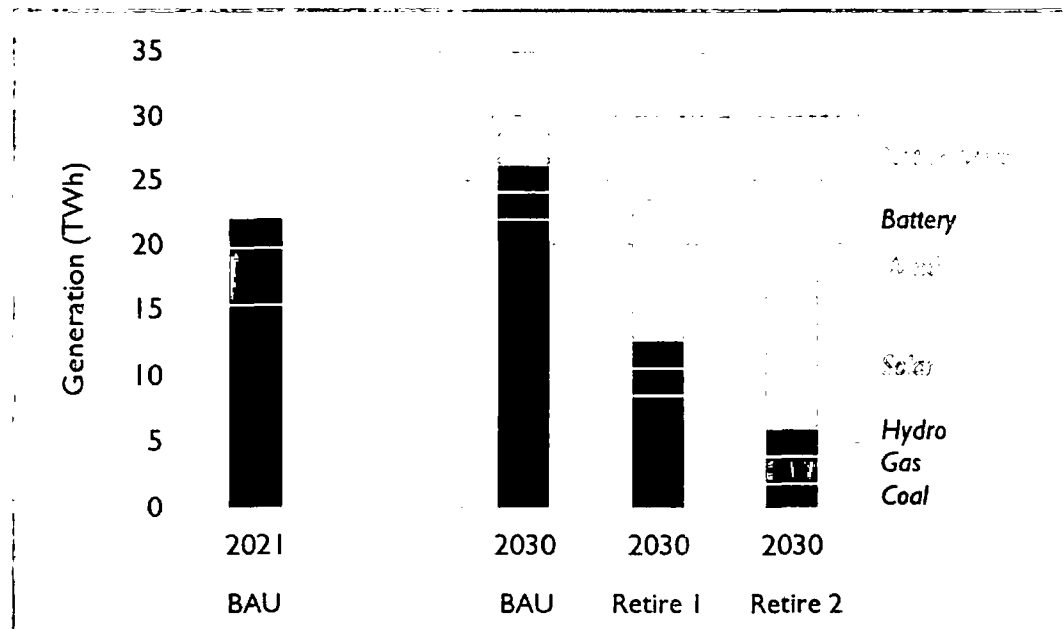
6 Because of their lower capacity credits relative to fossil resources, EnCompass has  
7 to build more solar and storage to replace the capacity at the retiring Amos plant.  
8 Cumulative capacity, by year and resource, is shown in Table 9 for Synapse  
9 Retirement I.



1 Q. How does modeled generation compare between the Synapse modeling  
2 scenarios?

3 A. The addition of solar and storage resources causes the generation profiles of  
4 Retirement 1 and Retirement 2 to look much different than the Synapse BAU.  
5 Generation in 2030 (after the modeled coal retirements) for each of the scenarios is  
6 shown in Figure 9, below.

**Figure 9. Generation in the Synapse modeling scenarios, 2030, Base No Carbon**



7 When compared to 2021, coal generation in the BAU has increased. There is more  
8 wind and solar, but less generation from gas and fewer imports. Retirement 1 and  
9 Retirement 2, comparatively, have much less fossil fuel generation than in 2021  
10 and large amounts of new solar generation. The primary differences between

2025 RELEASE UNDER E.O. 14176

1 Retirement 1 and Retirement 2 is that there is less coal generation and a greater  
2 number of net imports in 2030 when Mountaineer also retires.

3 **Q. How do CO<sub>2</sub> emissions compare between the various Synapse scenarios?**

4 A. Emissions of CO<sub>2</sub> in the Retirement 1 and Retirement 2 scenarios fall dramatically  
5 relative to the BAU after the retirement of three to four existing coal units at the  
6 end of 2028. Emissions in 2030 and 2040 for these three scenarios are shown in  
7 Table 10. By 2040, CO<sub>2</sub> emissions in the Retirement 1 scenario are only 40 percent  
8 of the emissions in the BAU, while emissions in Retirement 2 are 90 percent lower  
9 than the BAU.

**Table 10. Comparison of CO<sub>2</sub> emissions  
in the Synapse modeled scenarios**

|              | 2030 | 2040 |
|--------------|------|------|
| Synapse BAU  | 22.6 | 21.7 |
| Retirement 1 | 9.5  | 8.6  |
| Retirement 2 | 3.0  | 2.2  |

10 Like many of its utility peers, AEP has committed itself to net-zero CO<sub>2</sub> emissions  
11 by 2050 and has an interim goal to cut emissions 80 percent from 2000 levels by  
12 2030 while adding more than 10,000 MW of regulated wind and solar.<sup>29</sup> The  
13 Retirement 1 and 2 scenarios allow APCo to contribute to these AEP corporate

---

29 AEP. Clean Energy Future. Available at:  
<https://www.aep.com/about/ourstory/cleanenergy#:~:text=Achieving%20net%20zero%20carbon%20dioxide,billion%20in%20renewables%20through%202025>

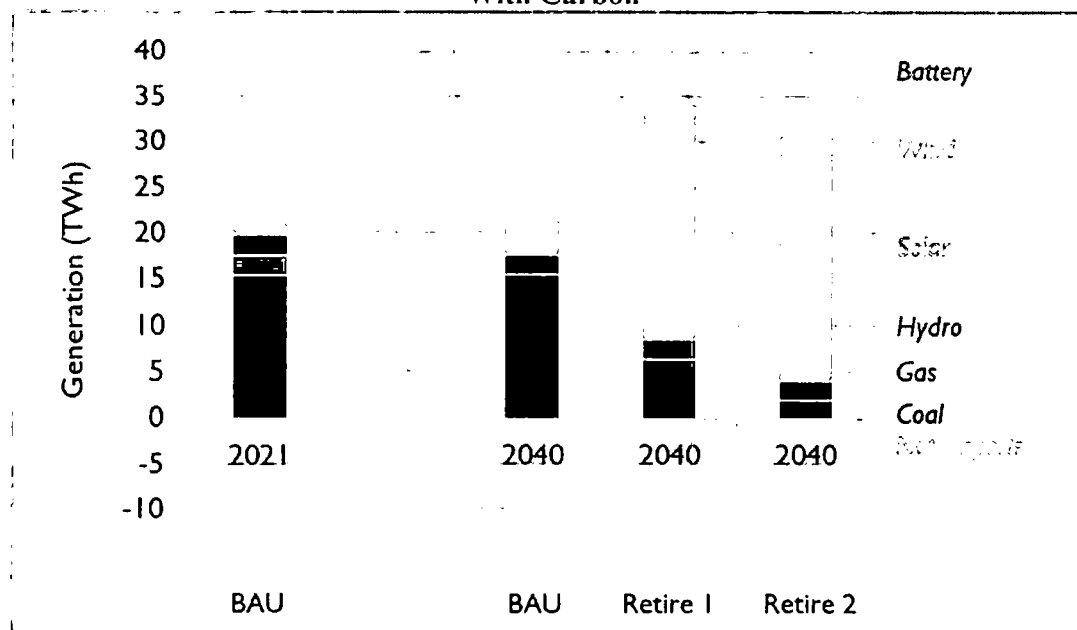




1 Q. What happens to generation in the Retirement 2 scenario when a CO<sub>2</sub> price is  
2 included?

3 A. With a CO<sub>2</sub> price, the generation mix in the Retirement 2 scenario is almost entirely  
4 renewable by 2040, as shown in Figure 10. The remaining coal on the system comes  
5 from the OVEC units (Kyger Creek and Clifty Creek), which have modeled  
6 retirement dates of December 31, 2040.

**Figure 10. Generation in the Synapse modeling scenarios, 2040, Base  
With Carbon**



7 By 2040, APCo has become a net energy exporter in both the Retirement 1 and  
8 Retirement 2 scenarios.

1     **Q.     What should the Commission conclude from the Synapse modeling analysis?**

2     A.     There are several important takeaways from the Synapse modeling analysis. First,  
3             that the retirement of Amos in 2028 has been shown to be the least-cost scenario  
4             and is in the best interests of Virginia ratepayers because it saves more than \$200  
5             million between 2021 and 2040.

6             Second, the Commission should note that it is in the economic interest of APCo's  
7             ratepayers to integrate additional renewable and storage capacity slightly ahead of  
8             the actual retirement year for Amos and Mountaineer. This low-variable-cost  
9             energy both displaces more expensive fossil generation and/or imported energy and  
10            reduces APCo's reliance on the PJM market.

11           Lastly, the importance of APCo's forecasts for both replacement resources and  
12           market energy prices cannot be understated. These two sets of input assumptions,  
13           both separately and together, are the primary drivers of the revenue requirements  
14           in all of the modeled scenarios. Synapse used the Mid set of forecasts from ATB  
15           2020, but as noted above, these have often been judged as too conservative. NREL  
16           ATB also publishes Low and High cost forecasts for each technology, and APCo  
17           would be advised to model specific nascent resources, like battery storage, using  
18           the Low value to test the sensitivity of its results to changes in technology costs.

## 5. COMPARING THE SYNAPSE AND APCO MODELING ANALYSES

1 Q. How do the resource additions in APCo's Case 2, which retires Amos in  
2 2028, compare to Synapse Retirement 1?

3 A. APCo's Case 2 adds more than 2,000 MW of new combustion turbines and short-  
4 term capacity only PPAs and small amounts of new solar to replace the retiring  
5 Amos plant in 2028. The Synapse Retirement 1 scenario, by contrast, adds 2,900  
6 MW of new solar and 600 MW of battery storage resources, as shown in Table 12.<sup>30</sup>

30 In the Synapse modeling, Amos retires on December 31, 2028 and 2,900 MW of  
new solar and 600 MW of new battery are online on or before January 1, 2029.

**Table 12. Comparison of new resource capacity (MW), Amos retires**

| Year | APCo Case 2 |        |           |          | Synapse Retirement 1 |          |             |
|------|-------------|--------|-----------|----------|----------------------|----------|-------------|
|      | New CT      | ST PPA | New Solar | New Wind | New Solar            | New Wind | New Battery |
| 2021 | 0           |        | 0         | 0        | 0                    | 0        | 0           |
| 2022 | 0           |        | 0         | 0        | 0                    | 0        | 0           |
| 2023 | 0           |        | 0         | 0        | 0                    | 0        | 0           |
| 2024 | 0           |        | 150       | 0        | 0                    | 0        | 0           |
| 2025 | 0           |        | 150       | 0        | 0                    | 0        | 0           |
| 2026 | 0           |        | 150       | 0        | 600                  | 0        | 0           |
| 2027 | 0           |        | 150       | 0        | 1,200                | 0        | 0           |
| 2028 | 1,666       | 400    | 150       | 0        | 1,800                | 0        | 0           |
| 2029 | 1,666       | 350    | 150       | 0        | 2,900                | 0        | 600         |
| 2030 | 1,666       | 400    | 150       | 0        | 3,980                | 0        | 888         |
| 2031 | 1,666       | 400    | 150       | 0        | 4,580                | 0        | 888         |
| 2032 | 1,666       | 400    | 150       | 0        | 5,180                | 0        | 888         |
| 2033 | 1,666       | 400    | 150       | 0        | 5,780                | 0        | 888         |
| 2034 | 1,666       | 400    | 150       | 0        | 6,380                | 0        | 888         |
| 2035 | 1,666       | 400    | 150       | 0        | 6,980                | 0        | 888         |
| 2036 | 1,666       | 400    | 300       | 0        | 7,580                | 0        | 888         |
| 2037 | 1,666       | 400    | 300       | 0        | 8,180                | 0        | 888         |
| 2038 | 1,666       | 350    | 450       | 0        | 8,780                | 0        | 888         |
| 2039 | 1,904       | 100    | 600       | 0        | 9,380                | 0        | 888         |
| 2040 | 3,094       | 350    | 750       | 0        | 9,980                | 0        | 888         |

- 1    **Q.**    How do the resource additions in APCo's Case 3, which retires both Amos and
- 2            Mountaineer in 2028, compare to Synapse Retirement 2?
- 3    **A.**    APCo's Case 3 adds more than 3,200 MW of new combustion turbines and short-
- 4            term capacity only PPAs and small amounts of new solar to replace the retiring
- 5            Amos and Mountaineer plants. The Synapse Retirement I scenario, by contrast,

1 adds 2,900 MW of new solar and 1,100 MW of battery storage resources, as shown  
 2 in Table 13.<sup>31</sup>

**Table 13. Comparison of new resource capacity (MW), Amos and Mountaineer retire**

|      | APCO Case 3 |        |           |          | Synapse Retirement 2 |          |             |
|------|-------------|--------|-----------|----------|----------------------|----------|-------------|
|      | New CT      | ST PPA | New Solar | New Wind | New Solar            | New Wind | New Battery |
| 2021 | 0           | 0      | 0         | 0        | 0                    | 0        | 0           |
| 2022 | 0           | 0      | 0         | 0        | 0                    | 0        | 0           |
| 2023 | 0           | 0      | 0         | 0        | 0                    | 0        | 0           |
| 2024 | 0           | 0      | 150       | 0        | 0                    | 0        | 0           |
| 2025 | 0           | 0      | 150       | 0        | 0                    | 0        | 0           |
| 2026 | 0           | 0      | 150       | 0        | 600                  | 0        | 0           |
| 2027 | 0           | 0      | 150       | 0        | 1,200                | 0        | 0           |
| 2028 | 2,856       | 400    | 150       | 0        | 1,800                | 0        | 0           |
| 2029 | 2,856       | 350    | 150       | 0        | 2,900                | 0        | 1,100       |
| 2030 | 2,856       | 400    | 150       | 0        | 4,100                | 0        | 2,260       |
| 2031 | 2,856       | 400    | 150       | 0        | 4,720                | 0        | 2,272       |
| 2032 | 2,856       | 400    | 150       | 0        | 5,320                | 0        | 2,272       |
| 2033 | 2,856       | 400    | 150       | 0        | 5,920                | 0        | 2,272       |
| 2034 | 2,856       | 400    | 150       | 0        | 6,520                | 0        | 2,272       |
| 2035 | 2,856       | 400    | 150       | 0        | 7,120                | 0        | 2,272       |
| 2036 | 2,856       | 400    | 300       | 0        | 7,720                | 0        | 2,272       |
| 2037 | 2,856       | 400    | 300       | 0        | 8,320                | 0        | 2,272       |
| 2038 | 2,856       | 350    | 450       | 0        | 8,920                | 0        | 2,272       |
| 2039 | 3,094       | 100    | 600       | 0        | 9,520                | 0        | 2,272       |
| 2040 | 3,094       | 350    | 750       | 0        | 10,120               | 0        | 2,272       |

---

31 In the Synapse modeling, Amos retires on December 31, 2028 and 2,900 MW of new solar and 600 MW of new battery are online on or before January 1, 2029.

1 Q. Why do APCO's replacement resource selections look so much different than  
2 those in the Synapse scenarios?

3 A. In its modeling, Synapse used widely accepted price forecasts for replacement  
4 renewables and storage resources. Prices used by both APCo and Synapse for wind  
5 and solar are shown in Table 14.

**Table 14. Comparison of prices for new resources in APCO and Synapse modeling**

| Year | Solar (\$/MWh) |         | Wind (\$/MWh) |         |
|------|----------------|---------|---------------|---------|
|      | APCo           | Synapse | APCo          | Synapse |
| 2021 | \$49.70        | \$33.25 |               |         |
| 2022 | \$48.34        | \$32.43 | \$40.77       |         |
| 2023 | \$47.33        | \$31.58 | \$45.77       | \$44.82 |
| 2024 | \$56.11        | \$30.70 | \$41.44       | \$44.57 |
| 2025 | \$60.46        | \$29.78 | \$56.52       | \$44.28 |
| 2026 | \$60.31        | \$28.82 | \$57.21       | \$43.97 |
| 2027 | \$60.38        | \$27.83 | \$57.89       | \$43.62 |
| 2028 | \$60.51        | \$26.80 | \$58.58       | \$43.24 |
| 2029 | \$60.65        | \$25.73 | \$59.23       | \$42.82 |
| 2030 | \$60.85        | \$24.62 | \$59.91       | \$42.36 |
| 2031 | \$61.17        | \$24.83 | \$60.55       | \$42.88 |
| 2032 | \$61.56        | \$25.05 | \$61.21       | \$43.40 |
| 2033 | \$61.87        | \$25.26 | \$61.80       | \$43.92 |
| 2034 | \$62.15        | \$25.48 | \$62.35       | \$44.44 |
| 2035 | \$62.34        | \$25.70 | \$62.84       | \$44.96 |
| 2036 | \$62.59        | \$25.91 | \$63.40       | \$45.49 |
| 2037 | \$62.76        | \$26.13 | \$63.91       | \$46.02 |
| 2038 | \$62.91        | \$26.34 | \$64.41       | \$46.55 |
| 2039 | \$63.11        | \$26.56 | \$64.97       | \$47.08 |
| 2040 | \$63.39        | \$26.77 | \$65.66       | \$47.61 |

1 In 2028, for example, APCo's solar PPA price is \$60.51/MWh.<sup>32</sup> In contrast, the  
 2 solar PPA price in the Synapse modeling is \$26.80/MWh, which reflects the  
 3 projection from NREL ATB 2020 that capital and fixed O&M for solar PV will  
 4 both be lower than APCo's projections. Similarly, APCo's levelized cost for wind  
 5 in 2028 is \$58.58/MWh,<sup>33</sup> while the Synapse wind cost is \$43.24/MWh. The  
 6 Synapse modeled resources are much more cost-effective and competitive with  
 7 APCo's forecasted on-peak market price of \$34.87/MWh and the off-peak market  
 8 energy price of \$28.21/MWh.<sup>34</sup> Because wind and solar are more economic  
 9 resources than in APCo's modeling, EnCompass builds renewables in the  
 10 Retirement I scenario in order to displace generation from more expensive fossil-  
 11 fueled units, to displace imports, and to be able to sell energy to the market. This is  
 12 in stark contrast to APCo's modeled scenarios, which build fewer renewables and  
 13 rely instead on existing fossil generation and imports from PJM.

14 APCo's modeling builds no battery storage resources because of the Company's  
 15 high assumed build costs for these resources. The build costs used by APCo in the  
 16 PLEXOS model are shown in comparison to ATB and EIA.

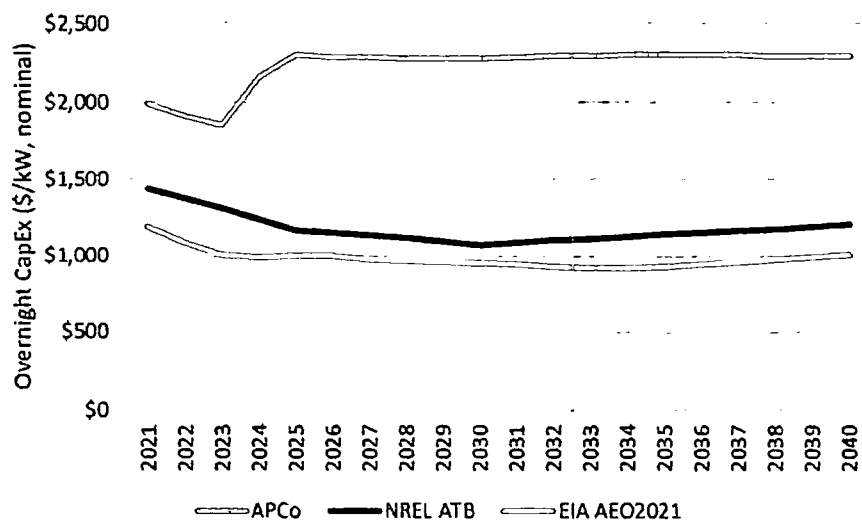
---

32 Exhibit RW-3.

33 Response to SC 5-4, Attachment I, attached as Exhibit RW-4.

34 Response to SC 1-02, Trecuzzi-FF-Appendix B-Base.xlsx, is not attached as an exhibit due to its voluminous size. It can be made available upon request.

**Figure 11. Comparison of overnight capital cost forecasts for battery storage, APCo, ATB 2020, and AEO 2021**



Sources: NREL, ATB 2020, <https://atb.nrel.gov/electricity/2020/data.php>

Energy Information Administration, Annual Energy Outlook 2021.

Table 55, <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=123-AEO2021&cases=ref2021&sourcekey=0>

Response to Sierra Club 5-5, Attachment 1.<sup>35</sup>

## 6. COAL-FIRED POWER PLANTS WILL BECOME INCREASINGLY UNECONOMIC IN THE FUTURE

1 Q. What does the future look like for coal-fired generating units in the United  
2 States?

3 A. Existing coal-fired generating units will become even less economic than they  
4 are today, because of both economic and regulatory forces that will increase the

35 Attached as Exhibit RW-5.



1 costs of operation at coal units relative to other types of capacity. In the past five  
2 years, 48 GW of coal has retired in the United States, with an additional 2.7 GW  
3 scheduled to retire in 2021.<sup>36</sup>

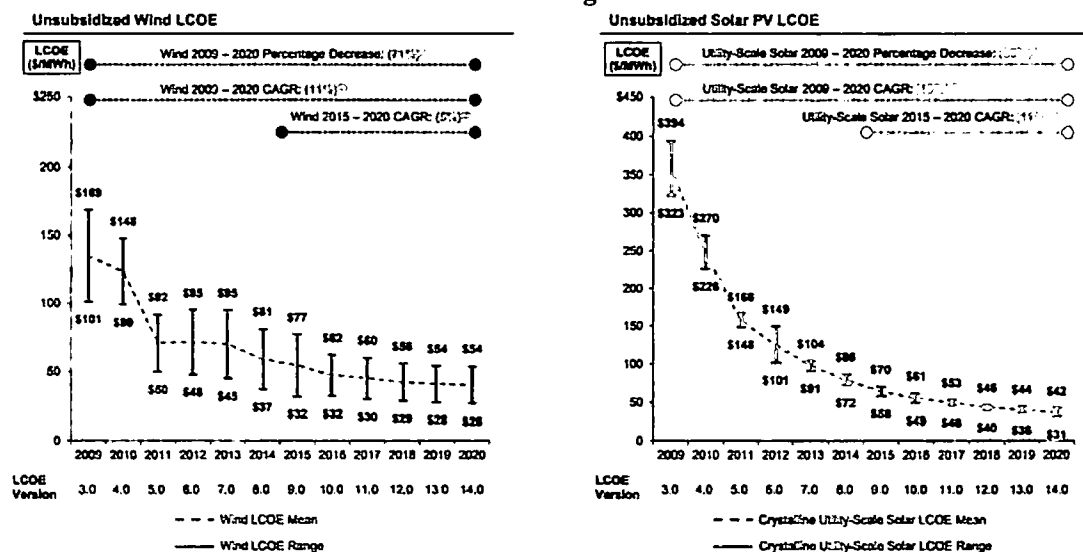
4 **Q. What are the economic forces that affect the operation of existing coal units?**

5 A. The primary economic factor is the cost of clean generation technologies, which  
6 have fallen dramatically over the previous decade. On a levelized cost of energy  
7 (LCOE) basis, costs for wind are now 71 percent lower than the costs in 2009, with  
8 a compound annual rate of decline of 11 percent per year. Costs for solar are now  
9 90 percent lower than in 2009, with a compound annual rate of decline of 19 percent  
10 per year. Those annual trends are shown in Figure 12.

---

36 US EIA. January 12, 2021. *Nuclear and coal will account for majority of U.S. generating capacity retirements in 2021*. Available at: <https://www.eia.gov/todayinenergy/detail.php?id=46436#:~:text=After%20substantial%20retirements%20of%20coal,of%20the%20U.S.%20coal%20fleet>.

Figure 12. Historic leveled cost of energy for wind and solar technologies



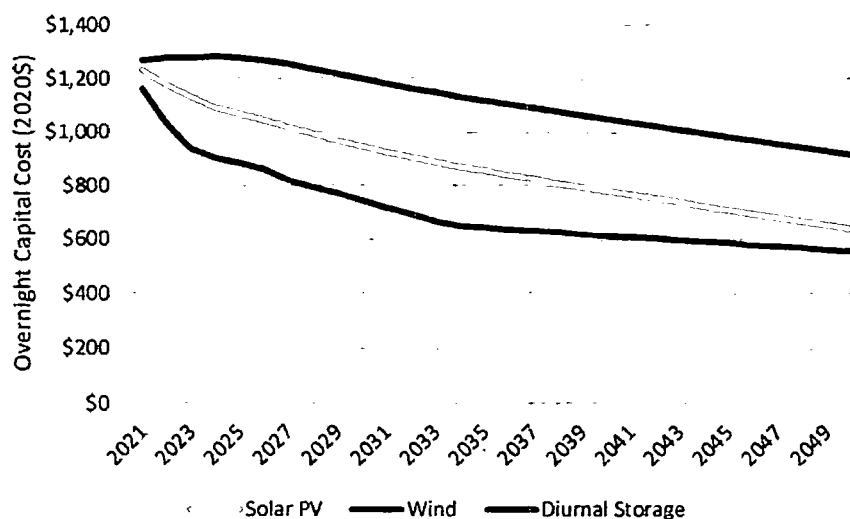
Source: Lazard. 2020. Levelized Cost of Energy Analysis—Version 14.0, available at: <https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf>.

1 Battery storage technologies have experienced similar cost declines, but over a  
 2 shorter period of time. Bloomberg New Energy Finance (BNEF) analyzed  
 3 historical battery storage costs, finding that costs for lithium-ion batteries have  
 4 fallen 76 percent between 2012 and the first half of 2019 and noting that these  
 5 declines were the most striking of all observed energy technology cost trends.<sup>37</sup>

37 Utility Dive. 2019. Electricity costs from battery storage down 76 percent since 2012: BNEF. Available at: <https://www.utilitydive.com/news/electricity-costs-from-battery-storage-down-76-since-2012-bnef/551337/>.

These three technologies are predicted to experience continued cost declines, though at varying rates. The US EIA's forecasts used in developing AEO 2021 for solar PV, wind, and storage resources are shown below in Figure 13.

**Figure 13. Forecast of overnight capital costs for new solar, wind, and storage**



Source: Energy Information Administration, *Annual Energy Outlook 2021*, Table 55, available at <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=123-AEO2021&region=5-11&cases=ref2021&start=2019&end=2050&f=A&linechart=ref2021-d113020a.3-123-AEO2021.5-11&map=&sourcekey=0>.

Given APCo's emphasis on inexpensive capacity in the form of new gas-fired combustion turbines as the primary resource selection in its own modeling,<sup>38</sup> we should pay particular attention to battery storage costs. The Synapse modeling uses APCo's values for firm capacity credit, with solar PV and wind receiving 40

<sup>38</sup> Direct Testimony of James F. Martin at 21:13 to 21:18.

1 percent and 12 percent, respectively, and battery storage resources given a higher  
 2 amount of firm capacity at 80 percent. These firm capacity values, coupled with  
 3 declining prices, make storage resources a cost-effective replacement resource for  
 4 traditional peaking units. In fact, a 2018 report by GTM Research and Wood  
 5 Mackenzie predicted that energy storage technologies will regularly compete head-  
 6 to-head with new gas-fired peaking units by 2022, and that new gas peaking units  
 7 will be rare by 2028.<sup>39</sup>

8 **Q. What are the regulatory forces that challenge the operation of existing coal**  
 9 **units?**

10 A. One such regulatory force is the increase to RPS standards in neighboring states  
 11 that also operate in the PJM market. The volume of zero-variable cost resources on  
 12 the grid in PJM will increase in future years as neighboring states increase their  
 13 renewable energy targets, implement more stringent targets for carbon dioxide  
 14 emissions reductions, or both. In 2018, for example, New Jersey increased its  
 15 renewable portfolio standard (RPS) to 50 percent by 2030.<sup>40</sup> In 2019, Maryland

---

39 Greentech Media, Will Energy Storage Replace Peaker Plants? (March 1, 2018), available at: <https://www.greentechmedia.com/webinars/webinar/will-energy-storage-replace-peaker-plants#gs.6JwDozs>.

40 Energy Information Administration, *Today in energy: Updated renewable portfolio standards will lead to more renewable electricity generation* (2019), available at: <https://www.eia.gov/todayinenergy/detail.php?id=38492#:~:text=Under%20the%20previous%20target%2C%20the,35%25%20of%20sales%20by%202030.>

1 legislators passed a bill that also increases its RPS to 50 percent by 2030.<sup>41</sup> The  
2 District of Columbia increased its RPS to 100 percent renewable energy by 2040.<sup>42</sup>  
3 The locational marginal price for energy will decline as a greater number of these  
4 renewable generators come online, further lowering energy revenues earned by coal  
5 units.

6 **Q. Are there other relevant regulatory forces?**

7 A. Yes, almost certainly, though we do not yet know what they will look like. President  
8 Biden has announced the goal of net-zero carbon dioxide emissions on the  
9 country's power grid by 2035. There are no policies currently in place that are  
10 explicitly intended to achieve this goal; however, it might be assumed that they will  
11 consist of a combination of incentives for zero-carbon energy and additional costs  
12 for fossil-fueled generators. Earlier this year, the U.S Court of Appeals for the D.C.  
13 Circuit struck down President Trump's Affordable Clean Energy Rule, requiring  
14 the EPA to draft new regulations governing emissions of CO<sub>2</sub> from power plants.  
15 We can almost certainly expect new regulations from the EPA in the next four  
16 years.

---

41 Utility Dive. *Maryland 50% RPS bill doubles offshore wind target, expands solar-carve out* (2019), available at: <https://www.utilitydive.com/news/maryland-50-rps-bill-doubles-offshore-wind-target-expands-solar-carve-out/552421/>.

42 Utility Dive, *DC eases path for renewable generators as it pursues 100% goal* (2019), available at: <https://www.utilitydive.com/news/dc-eases-path-for-renewable-generators-as-it-pursues-100-goal/548259/>.

## 7. CONCLUSIONS AND RECOMMENDATIONS

1 Q. Please summarize your conclusions.

2 A. My independent modeling demonstrates that it is uneconomic, and not in the best  
3 interest of ratepayers, for APCo to invest in CCR and ELG costs at both Amos and  
4 Mountaineer in order to continue running the plants through 2040. Investing only  
5 in CCR costs at the Amos plant and retiring the three units in 2028 results in  
6 ratepayer savings of more than \$200 million under a Base with No Carbon  
7 commodity price forecast.

8 When a price on carbon dioxide (CO<sub>2</sub>) emissions is included as part of the analysis,  
9 ratepayer savings rises to more than \$1 billion when Amos is retired and replaced  
10 with a combination of renewable and battery storage resources. A scenario in which  
11 both Amos and Mountaineer are retired at the end of 2028 results in a savings to  
12 ratepayers of approximately \$670 million relative to a scenario that operates the  
13 plants through 2040.

14 Q. Please summarize your recommendations.

15 A. I offer two recommendations. First, that the Commission approve the CCR  
16 compliance costs at the Amos plant, but deny the ELG costs. The use of current  
17 industry standard pricing for replacement capacity and energy shows that the  
18 retirement of the Amos plant in 2028 is economic and results in savings to  
19 customers, even in a scenario that does not include a price or constraint on future  
20 CO<sub>2</sub> emissions.

1       Second, I recommend that the Commission approve the CCR costs at the  
 2       Mountaineer plant, but deny the costs associated with ELG compliance at this time.  
 3       The Synapse analysis shows that in a scenario with a constraint on carbon (in the  
 4       form of a CO<sub>2</sub> price), the retirement of both Amos and Mountaineer in 2028 yields  
 5       savings to ratepayers when compared to a scenario in which both plants continue  
 6       to operate through 2040. While the Synapse modeling in this docket shows that the  
 7       retirement of both Amos and Mountaineer is more expensive than the retirement of  
 8       Amos alone, we only model a single type of constraint on CO<sub>2</sub>. It is expected that  
 9       the Biden administration will soon be implementing some type of carbon policy,  
 10      but it remains to be seen what form that policy might take, or how stringent it might  
 11      be. It is thus premature, at the current time, to approve the ELG costs at  
 12      Mountaineer. Rather, the Commission should deny the ELG costs until APCo can  
 13      present an analysis of the effect of upcoming carbon regulations on the operation  
 14      of the plant.

15    **Q.    Does this conclude your direct testimony?**

16    **A.    Yes.**

## **EXHIBIT RW-1**

### **Resume of Rachel S. Wilson**



## **Rachel Wilson, Principal Associate**

Synapse Energy Economics | 485 Massachusetts Avenue, Suite 3 | Cambridge, MA 02139 | 617-453-7044  
rwilson@synapse-energy.com

### **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.

24.03.2021

Master of Environmental Management, concentration in Law, Economics, and Policy with a focus on energy issues and markets, 2007

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

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

- 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.

Wilson, R., E. Camp, N. Garner, T. Vitolo. 2020. *Obsolete Atlantic Coast Pipeline Has Nothing to Deliver: An examination of the dramatic shifts in the energy, policy, and economic landscape in Virginia and North Carolina since 2017 shows there is little need for new gas generation*. Synapse Energy Economics for Southern Environmental Law Center.

Eash-Gates, P., D. Glick, S. Kwok, R. Wilson. 2020. *Orlando's Renewable Energy Future: The Path to 100 Percent Renewable Energy by 2020*. Synapse Energy Economics for the First 50 Coalition.

Biewald, B., D. Glick, J. Hall, C. Odom, C. Roberto, R. Wilson. 2020. *Investing In Failure: How Large Power Companies are Undermining their Decarbonization Targets*. Synapse Energy Economics for Climate Majority Project.

Wilson, R., D. Bhandari. 2019. *The Least-Cost Resource Plan for Santee Cooper: A Path to Meet Santee Cooper's Customer Electricity Needs at the Lowest Cost and Risk*. Synapse Energy Economics for the Sierra Club, Southern Environmental Law Center, and Coastal Conservation League.

Wilson, R., N. Peluso, A. Allison. 2019. *North Carolina's Clean Energy Future: An Alternative to Duke's Integrated Resource Plan*. Synapse Energy Economics for the North Carolina Sustainable Energy Association.

- Wilson, R., N. Peluso, A. Allison. 2019. *Modeling Clean Energy for South Carolina: An Alternative to Duke's Integrated Resource Plan*. Synapse Energy Economics for the South Carolina Solar Business Alliance.
- 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*. 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*. 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*. 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*. 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

**Virginia State Corporation Commission (Case No. PUR-2020-00035):** Direct testimony of Rachel Wilson evaluating Dominion's 2020 Integrated Resource Plan and providing independent capacity optimization modeling. On behalf of the Sierra Club. September 15, 2020.

**Virginia State Corporation Commission (Case No. PUR-2020-00015):** Direct testimony of Rachel Wilson examining the economics of the coal units owned by Appalachian Power Company as part of the rate case. On behalf of the Sierra Club. July 30, 2020.

**North Carolina Utilities Commission (Docket No. E-2, SUB 1219):** Direct testimony of Rachel Wilson examining the economics of the coal units owned by Duke Energy Progress as part of the rate case. On behalf of the Sierra Club. April 13, 2020.

**North Carolina Utilities Commission (Docket No. E-2, SUB 1219):** Direct testimony of Rachel Wilson examining the economics of the coal units owned by Duke Energy Carolinas as part of the rate case. On behalf of the Sierra Club. February 25, 2020.

**Alabama Public Service Commission (Docket No. 32953):** Direct testimony of Rachel Wilson regarding Alabama Power Company's petition for a Certificate of Convenience and Necessity. On behalf of the Sierra Club. December 4, 2019.

**Georgia Public Service Commission (Docket No. 42516):** Direct testimony of Rachel Wilson regarding coal ash spending in Georgia Power's 2019 Rate Case. On behalf of the Sierra Club. October 17, 2019.

**Mississippi Public Service Commission (Docket No. 2019-UA-116):** Direct testimony of Rachel Wilson regarding Mississippi Power Company's petition to the Mississippi Public Service Commission for a Certification of Public Convenience and Necessity for ratepayer-funded investments required to meet Coal Combustion Residuals regulations at the Victor J. Daniel Electric Generating Facility. On behalf of the Sierra Club. October 16, 2019.



2106421

## **EXHIBIT RW-3**

### **Response to Sierra Club 5-3 Attachment 1**





2020 APCo IRP  
Solar Alternative Pricing

2020 APCo IRP  
SC 5-3 Attachment 1  
Page 2 of 5

| COD EOY | Modelling YR | Annual<br>Levelized Cost (\$/MWh) | Annual<br>Levelized Cost (\$000) | esc  | \$/kW<br>FOM | Input<br>FOM<br>T2 FOM |
|---------|--------------|-----------------------------------|----------------------------------|------|--------------|------------------------|
|         |              | EIA<br>T2 (w ITC)                 | EIA<br>T2 (w ITC)                |      |              |                        |
| 2021    | 2022         | \$37.08                           | 11,982                           |      | -            | \$38.62                |
| 2022    | 2023         | \$35.66                           | 11,522                           | 0.96 | -            | \$38.25                |
| 2023    | 2024         | \$34.55                           | 11,164                           | 0.97 | -            | \$38.06                |
| 2024    | 2025         | \$40.19                           | 12,985                           | 1.16 | -            | \$38.36                |
| 2025    | 2026         | \$42.89                           | 13,858                           | 1.07 | -            | \$38.66                |
| 2026    | 2027         | \$42.60                           | 13,763                           | 0.99 | -            | \$38.94                |
| 2027    | 2028         | \$42.49                           | 13,728                           | 1.00 | -            | \$39.30                |
| 2028    | 2029         | \$42.43                           | 13,710                           | 1.00 | -            | \$39.68                |
| 2029    | 2030         | \$42.38                           | 13,695                           | 1.00 | -            | \$40.07                |
| 2030    | 2031         | \$42.38                           | 13,694                           | 1.00 | -            | \$40.48                |
| 2031    | 2032         | \$42.48                           | 13,726                           | 1.00 | -            | \$40.93                |
| 2032    | 2033         | \$42.64                           | 13,778                           | 1.00 | -            | \$41.40                |
| 2033    | 2034         | \$42.73                           | 13,807                           | 1.00 | -            | \$41.86                |
| 2034    | 2035         | \$42.80                           | 13,829                           | 1.00 | -            | \$42.31                |
| 2035    | 2036         | \$42.78                           | 13,821                           | 1.00 | -            | \$42.73                |
| 2036    | 2037         | \$42.81                           | 13,831                           | 1.00 | -            | \$43.18                |
| 2037    | 2038         | \$42.77                           | 13,820                           | 1.00 | -            | \$43.61                |
| 2038    | 2039         | \$42.71                           | 13,800                           | 1.00 | -            | \$44.04                |
| 2039    | 2040         | \$42.69                           | 13,794                           | 1.00 | -            | \$44.48                |
| 2040    | 2041         | \$42.73                           | 13,808                           | 1.00 | -            | \$44.96                |
| 2041    | 2042         | \$42.69                           | 13,794                           | 1.00 | -            | \$45.41                |
| 2042    | 2043         | \$42.72                           | 13,803                           | 1.00 | -            | \$45.89                |
| 2043    | 2044         | \$42.75                           | 13,814                           | 1.00 | -            | \$46.37                |
| 2044    | 2045         | \$42.74                           | 13,811                           | 1.00 | -            | \$46.84                |
| 2045    | 2046         | \$42.74                           | 13,809                           | 1.00 | -            | \$47.31                |
| 2046    | 2047         | \$42.74                           | 13,811                           | 1.00 | -            | \$47.79                |
| 2047    | 2048         | \$42.75                           | 13,813                           | 1.00 | -            | \$48.28                |
| 2048    | 2049         | \$42.73                           | 13,806                           | 1.00 | -            | \$48.75                |
| 2049    | 2050         | \$42.70                           | 13,797                           | 1.00 | -            | \$49.22                |
| 2050    | 2051         | \$43.00                           | 13,895                           | 1.01 | -            | \$49.83                |

| Generic Solar       |          |          |
|---------------------|----------|----------|
| EIA                 |          |          |
| Annual Energy (GWh) | 323.1126 | 107.7042 |
| Capacity (MW)       | 150      | 50       |
| Capacity Factor (%) | 24.6     | 24.6     |
| Inflation (%)       | 1%       |          |

21060221

| Project Name           | OpCo | Capacity<br>MW | COD  | Tier   | 30 Year<br>PPA Proxy<br>(Upfront<br>ITC) |
|------------------------|------|----------------|------|--------|--|
| 2021COD-ApCo-Tier 1-F1 | ApCo | 150            | 2021 | Tier 1 | \$49.70                                  |
| 2022COD-ApCo-Tier 1-F1 | ApCo | 150            | 2022 | Tier 1 | \$48.34                                  |
| 2023COD-ApCo-Tier 1-F1 | ApCo | 150            | 2023 | Tier 1 | \$47.33                                  |
| 2024COD-ApCo-Tier 1-F1 | ApCo | 150            | 2024 | Tier 1 | \$56.11                                  |
| 2025COD-ApCo-Tier 1-F1 | ApCo | 150            | 2025 | Tier 1 | \$60.46                                  |
| 2026COD-ApCo-Tier 1-F1 | ApCo | 150            | 2026 | Tier 1 | \$60.31                                  |
| 2027COD-ApCo-Tier 1-F1 | ApCo | 150            | 2027 | Tier 1 | \$60.38                                  |
| 2028COD-ApCo-Tier 1-F1 | ApCo | 150            | 2028 | Tier 1 | \$60.51                                  |
| 2029COD-ApCo-Tier 1-F1 | ApCo | 150            | 2029 | Tier 1 | \$60.65                                  |
| 2030COD-ApCo-Tier 1-F1 | ApCo | 150            | 2030 | Tier 1 | \$60.85                                  |
| 2031COD-ApCo-Tier 1-F1 | ApCo | 150            | 2031 | Tier 1 | \$61.17                                  |
| 2032COD-ApCo-Tier 1-F1 | ApCo | 150            | 2032 | Tier 1 | \$61.56                                  |
| 2033COD-ApCo-Tier 1-F1 | ApCo | 150            | 2033 | Tier 1 | \$61.87                                  |
| 2034COD-ApCo-Tier 1-F1 | ApCo | 150            | 2034 | Tier 1 | \$62.15                                  |
| 2035COD-ApCo-Tier 1-F1 | ApCo | 150            | 2035 | Tier 1 | \$62.34                                  |
| 2036COD-ApCo-Tier 1-F1 | ApCo | 150            | 2036 | Tier 1 | \$62.59                                  |
| 2037COD-ApCo-Tier 1-F1 | ApCo | 150            | 2037 | Tier 1 | \$62.76                                  |
| 2038COD-ApCo-Tier 1-F1 | ApCo | 150            | 2038 | Tier 1 | \$62.91                                  |
| 2039COD-ApCo-Tier 1-F1 | ApCo | 150            | 2039 | Tier 1 | \$63.11                                  |
| 2040COD-ApCo-Tier 1-F1 | ApCo | 150            | 2040 | Tier 1 | \$63.39                                  |
| 2041COD-ApCo-Tier 1-F1 | ApCo | 150            | 2041 | Tier 1 | \$63.56                                  |
| 2042COD-ApCo-Tier 1-F1 | ApCo | 150            | 2042 | Tier 1 | \$63.82                                  |
| 2043COD-ApCo-Tier 1-F1 | ApCo | 150            | 2043 | Tier 1 | \$64.09                                  |
| 2044COD-ApCo-Tier 1-F1 | ApCo | 150            | 2044 | Tier 1 | \$64.31                                  |
| 2045COD-ApCo-Tier 1-F1 | ApCo | 150            | 2045 | Tier 1 | \$64.54                                  |
| 2046COD-ApCo-Tier 1-F1 | ApCo | 150            | 2046 | Tier 1 | \$64.78                                  |
| 2047COD-ApCo-Tier 1-F1 | ApCo | 150            | 2047 | Tier 1 | \$65.02                                  |
| 2048COD-ApCo-Tier 1-F1 | ApCo | 150            | 2048 | Tier 1 | \$65.23                                  |
| 2049COD-ApCo-Tier 1-F1 | ApCo | 150            | 2049 | Tier 1 | \$65.43                                  |
| 2050COD-ApCo-Tier 1-F1 | ApCo | 150            | 2050 | Tier 1 | \$66.02                                  |

Plexos YR

AP\_PPA Solar T1 2024  
AP\_PPA Solar T1 2025  
AP\_PPA Solar T1 2026  
AP\_PPA Solar T1 2027  
AP\_PPA Solar T1 2028  
AP\_PPA Solar T1 2029  
AP\_PPA Solar T1 2030  
AP\_PPA Solar T1 2031  
AP\_PPA Solar T1 2032  
AP\_PPA Solar T1 2033  
AP\_PPA Solar T1 2034  
AP\_PPA Solar T1 2035  
AP\_PPA Solar T1 2036  
AP\_PPA Solar T1 2037  
AP\_PPA Solar T1 2038  
AP\_PPA Solar T1 2039  
AP\_PPA Solar T1 2040  
AP\_PPA Solar T1 2041  
AP\_PPA Solar T1 2042  
AP\_PPA Solar T1 2043  
AP\_PPA Solar T1 2044  
AP\_PPA Solar T1 2045  
AP\_PPA Solar T1 2046  
AP\_PPA Solar T1 2047  
AP\_PPA Solar T1 2048  
AP\_PPA Solar T1 2049  
AP\_PPA Solar T1 2050

## Appalachian Power

Investment Carrying Charges - Updated October 2020

### For Economic Analyses

AS of 12/31/2019

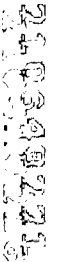
|  | Investment and (Year) |       |       |       |       |       |       |       |       |       |       |      |
|--|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
|  | 2                     | 3     | 4     | 5     | 10    | 15    | 20    | 25    | 30    | 33    | 40    | 50   |
| Return (1)                               | 7.27                  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27 |
| Depreciation (2)                         | 49.02                 | 31.87 | 23.28 | 18.14 | 7.99  | 4.74  | 3.20  | 2.33  | 1.78  | 1.55  | 1.17  | 0.85 |
| FIT (3) (4)                              | 1.06                  | 0.76  | 0.82  | 0.68  | 0.64  | 0.77  | 0.80  | 0.69  | 0.62  | 0.59  | 0.54  | 0.49 |
| Property Taxes, General & Admin Expenses | 1.22                  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22 |
| Carrying Cost Per Year                   | 58.58                 | 41.13 | 32.59 | 27.31 | 17.12 | 14.01 | 12.49 | 11.51 | 10.90 | 10.63 | 10.20 | 9.82 |

(1) Based on a 100% (as of 12/31/2019) and 0% incremental weighting of capital costs

**(2) Sinking Fund annuity with R1 Dispersion of Retirements**

### (3) Assuming MACRS Tax Depreciation

(4) @ 21% Federal Income Tax Rate



| Project Name           | OpCo | Capacity<br>MW | COD  | Tier   | Solar CF | Levelized<br>CF | ITC % | Build Cost<br>\$/kW | Levelized<br>O&M<br>\$/kW | Levelized<br>O&M<br>\$/MWh | Levelized<br>Cost of<br>Energy<br>\$/MWh | Levelized<br>Capital<br>Cost<br>\$/MWh | 30 Year<br>PPA<br>Proxy<br>(Upfront<br>ITC) |
|------------------------|------|----------------|------|--------|----------|-----------------|-------|---------------------|---------------------------|----------------------------|--|--|---|
| 2021COD-ApCo-Tier 2-F1 | ApCo | 150            | 2021 | Tier 2 | 24.59%   | 23.45%          | 30%   | \$1,195             | \$38.62                   | \$18.88                    | \$55.97                                  | \$37.08                                | \$49.70                                     |
| 2022COD-ApCo-Tier 2-F1 | ApCo | 150            | 2022 | Tier 2 | 24.59%   | 23.45%          | 30%   | \$1,149             | \$38.25                   | \$18.70                    | \$54.36                                  | \$35.66                                | \$48.34                                     |
| 2023COD-ApCo-Tier 2-F1 | ApCo | 150            | 2023 | Tier 2 | 24.59%   | 23.45%          | 30%   | \$1,113             | \$38.06                   | \$18.61                    | \$53.16                                  | \$34.55                                | \$47.33                                     |
| 2024COD-ApCo-Tier 2-F1 | ApCo | 150            | 2024 | Tier 2 | 24.59%   | 23.45%          | 10%   | \$1,108             | \$38.36                   | \$18.76                    | \$58.94                                  | \$40.19                                | \$56.11                                     |
| 2025COD-ApCo-Tier 2-F1 | ApCo | 150            | 2025 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,102             | \$38.66                   | \$18.91                    | \$61.80                                  | \$42.89                                | \$60.46                                     |
| 2026COD-ApCo-Tier 2-F1 | ApCo | 150            | 2026 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,095             | \$38.94                   | \$19.04                    | \$61.64                                  | \$42.60                                | \$60.31                                     |
| 2027COD-ApCo-Tier 2-F1 | ApCo | 150            | 2027 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,092             | \$39.30                   | \$19.22                    | \$61.70                                  | \$42.49                                | \$60.38                                     |
| 2028COD-ApCo-Tier 2-F1 | ApCo | 150            | 2028 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,091             | \$39.68                   | \$19.40                    | \$61.83                                  | \$42.43                                | \$60.51                                     |
| 2029COD-ApCo-Tier 2-F1 | ApCo | 150            | 2029 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,089             | \$40.07                   | \$19.59                    | \$61.98                                  | \$42.38                                | \$60.65                                     |
| 2030COD-ApCo-Tier 2-F1 | ApCo | 150            | 2030 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,089             | \$40.48                   | \$19.79                    | \$62.17                                  | \$42.38                                | \$60.85                                     |
| 2031COD-ApCo-Tier 2-F1 | ApCo | 150            | 2031 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,092             | \$40.93                   | \$20.01                    | \$62.49                                  | \$42.48                                | \$61.17                                     |
| 2032COD-ApCo-Tier 2-F1 | ApCo | 150            | 2032 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,096             | \$41.40                   | \$20.25                    | \$62.89                                  | \$42.64                                | \$61.56                                     |
| 2033COD-ApCo-Tier 2-F1 | ApCo | 150            | 2033 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$41.86                   | \$20.47                    | \$63.20                                  | \$42.73                                | \$61.87                                     |
| 2034COD-ApCo-Tier 2-F1 | ApCo | 150            | 2034 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,100             | \$42.31                   | \$20.69                    | \$63.49                                  | \$42.80                                | \$62.15                                     |
| 2035COD-ApCo-Tier 2-F1 | ApCo | 150            | 2035 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,100             | \$42.73                   | \$20.90                    | \$63.67                                  | \$42.78                                | \$62.34                                     |
| 2036COD-ApCo-Tier 2-F1 | ApCo | 150            | 2036 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,100             | \$43.18                   | \$21.12                    | \$63.92                                  | \$42.81                                | \$62.59                                     |
| 2037COD-ApCo-Tier 2-F1 | ApCo | 150            | 2037 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$43.61                   | \$21.33                    | \$64.10                                  | \$42.77                                | \$62.76                                     |
| 2038COD-ApCo-Tier 2-F1 | ApCo | 150            | 2038 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$44.04                   | \$21.53                    | \$64.24                                  | \$42.71                                | \$62.91                                     |
| 2039COD-ApCo-Tier 2-F1 | ApCo | 150            | 2039 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,097             | \$44.48                   | \$21.75                    | \$64.44                                  | \$42.69                                | \$63.11                                     |
| 2040COD-ApCo-Tier 2-F1 | ApCo | 150            | 2040 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$44.96                   | \$21.98                    | \$64.72                                  | \$42.73                                | \$63.39                                     |
| 2041COD-ApCo-Tier 2-F1 | ApCo | 150            | 2041 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,097             | \$45.41                   | \$22.20                    | \$64.89                                  | \$42.69                                | \$63.56                                     |
| 2042COD-ApCo-Tier 2-F1 | ApCo | 150            | 2042 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$45.89                   | \$22.44                    | \$65.15                                  | \$42.72                                | \$63.82                                     |
| 2043COD-ApCo-Tier 2-F1 | ApCo | 150            | 2043 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$46.37                   | \$22.67                    | \$65.42                                  | \$42.75                                | \$64.09                                     |
| 2044COD-ApCo-Tier 2-F1 | ApCo | 150            | 2044 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$46.84                   | \$22.90                    | \$65.65                                  | \$42.74                                | \$64.31                                     |
| 2045COD-ApCo-Tier 2-F1 | ApCo | 150            | 2045 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$47.31                   | \$23.13                    | \$65.87                                  | \$42.74                                | \$64.54                                     |
| 2046COD-ApCo-Tier 2-F1 | ApCo | 150            | 2046 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$47.79                   | \$23.37                    | \$66.11                                  | \$42.74                                | \$64.78                                     |
| 2047COD-ApCo-Tier 2-F1 | ApCo | 150            | 2047 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$48.28                   | \$23.60                    | \$66.35                                  | \$42.75                                | \$65.02                                     |
| 2048COD-ApCo-Tier 2-F1 | ApCo | 150            | 2048 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$48.75                   | \$23.83                    | \$66.56                                  | \$42.73                                | \$65.23                                     |
| 2049COD-ApCo-Tier 2-F1 | ApCo | 150            | 2049 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,097             | \$49.22                   | \$24.06                    | \$66.76                                  | \$42.70                                | \$65.43                                     |
| 2050COD-ApCo-Tier 2-F1 | ApCo | 150            | 2050 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,105             | \$49.83                   | \$24.36                    | \$67.36                                  | \$43.00                                | \$66.02                                     |

## **EXHIBIT RW-4**

### **Response to Sierra Club 5-4 Attachment 1**



|                     |       |
|---------------------|-------|
| Annual Energy (GWh) | 613.2 |
| Capacity (MW)       | 200   |
| Capacity Factor (%) | 35    |
| Inflation (%)       | 1.0%  |





| Scenario            | OpCo | Capacity<br>MW | COD<br>Year | Wind<br>CF | Build Cost<br>(\$/kW) | PTC<br>Cred<br>it | Levelized<br>O&M<br>\$/kW | Levelized<br>O&M<br>\$/MWh | Levelized<br>Cost of<br>Energy<br>\$/MWh | Levelized<br>Capital Cost<br>\$/MWh |
|---------------------|------|----------------|-------------|------------|-----------------------|-------------------|---------------------------|----------------------------|--|-------------------------------------|
| 2022COD-ApCo-0.35CF | ApCo | 200            | 2022        | 35%        | \$1,296               | 60%               | \$56.38                   | \$18.37                    | \$40.77                                  | \$22.40                             |
| 2023COD-ApCo-0.35CF | ApCo | 200            | 2023        | 35%        | \$1,306               | 40%               | \$57.26                   | \$18.66                    | \$45.77                                  | \$27.11                             |
| 2024COD-ApCo-0.35CF | ApCo | 200            | 2024        | 35%        | \$1,317               | 60%               | \$58.19                   | \$18.96                    | \$41.44                                  | \$22.48                             |
| 2025COD-ApCo-0.35CF | ApCo | 200            | 2025        | 35%        | \$1,333               | 0%                | \$59.17                   | \$19.28                    | \$56.52                                  | \$37.24                             |
| 2026COD-ApCo-0.35CF | ApCo | 200            | 2026        | 35%        | \$1,346               | 0%                | \$60.14                   | \$19.60                    | \$57.21                                  | \$37.61                             |
| 2027COD-ApCo-0.35CF | ApCo | 200            | 2027        | 35%        | \$1,359               | 0%                | \$61.12                   | \$19.92                    | \$57.89                                  | \$37.97                             |
| 2028COD-ApCo-0.35CF | ApCo | 200            | 2028        | 35%        | \$1,372               | 0%                | \$62.10                   | \$20.24                    | \$58.58                                  | \$38.34                             |
| 2029COD-ApCo-0.35CF | ApCo | 200            | 2029        | 35%        | \$1,384               | 0%                | \$63.08                   | \$20.56                    | \$59.23                                  | \$38.68                             |
| 2030COD-ApCo-0.35CF | ApCo | 200            | 2030        | 35%        | \$1,397               | 0%                | \$64.07                   | \$20.88                    | \$59.91                                  | \$39.03                             |
| 2031COD-ApCo-0.35CF | ApCo | 200            | 2031        | 35%        | \$1,409               | 0%                | \$65.05                   | \$21.20                    | \$60.55                                  | \$39.36                             |
| 2032COD-ApCo-0.35CF | ApCo | 200            | 2032        | 35%        | \$1,420               | 0%                | \$66.03                   | \$21.52                    | \$61.21                                  | \$39.69                             |
| 2033COD-ApCo-0.35CF | ApCo | 200            | 2033        | 35%        | \$1,430               | 0%                | \$67.00                   | \$21.84                    | \$61.80                                  | \$39.97                             |
| 2034COD-ApCo-0.35CF | ApCo | 200            | 2034        | 35%        | \$1,439               | 0%                | \$67.96                   | \$22.15                    | \$62.35                                  | \$40.20                             |
| 2035COD-ApCo-0.35CF | ApCo | 200            | 2035        | 35%        | \$1,446               | 0%                | \$68.92                   | \$22.46                    | \$62.84                                  | \$40.38                             |
| 2036COD-ApCo-0.35CF | ApCo | 200            | 2036        | 35%        | \$1,454               | 0%                | \$69.90                   | \$22.78                    | \$63.40                                  | \$40.61                             |
| 2037COD-ApCo-0.35CF | ApCo | 200            | 2037        | 35%        | \$1,460               | 0%                | \$70.88                   | \$23.10                    | \$63.91                                  | \$40.81                             |
| 2038COD-ApCo-0.35CF | ApCo | 200            | 2038        | 35%        | \$1,467               | 0%                | \$71.87                   | \$23.42                    | \$64.41                                  | \$40.99                             |
| 2039COD-ApCo-0.35CF | ApCo | 200            | 2039        | 35%        | \$1,476               | 0%                | \$72.91                   | \$23.76                    | \$64.97                                  | \$41.22                             |
| 2040COD-ApCo-0.35CF | ApCo | 200            | 2040        | 35%        | \$1,487               | 0%                | \$73.98                   | \$24.11                    | \$65.66                                  | \$41.54                             |
| 2041COD-ApCo-0.35CF | ApCo | 200            | 2041        | 35%        | \$1,497               | 0%                | \$75.05                   | \$24.46                    | \$66.28                                  | \$41.82                             |
| 2042COD-ApCo-0.35CF | ApCo | 200            | 2042        | 35%        | \$1,508               | 0%                | \$76.14                   | \$24.81                    | \$66.94                                  | \$42.13                             |
| 2043COD-ApCo-0.35CF | ApCo | 200            | 2043        | 35%        | \$1,519               | 0%                | \$77.24                   | \$25.17                    | \$67.61                                  | \$42.44                             |
| 2044COD-ApCo-0.35CF | ApCo | 200            | 2044        | 35%        | \$1,530               | 0%                | \$78.34                   | \$25.53                    | \$68.28                                  | \$42.75                             |
| 2045COD-ApCo-0.35CF | ApCo | 200            | 2045        | 35%        | \$1,539               | 0%                | \$79.42                   | \$25.88                    | \$68.89                                  | \$43.01                             |
| 2046COD-ApCo-0.35CF | ApCo | 200            | 2046        | 35%        | \$1,551               | 0%                | \$80.54                   | \$26.25                    | \$69.56                                  | \$43.32                             |
| 2047COD-ApCo-0.35CF | ApCo | 200            | 2047        | 35%        | \$1,561               | 0%                | \$81.65                   | \$26.60                    | \$70.21                                  | \$43.61                             |
| 2048COD-ApCo-0.35CF | ApCo | 200            | 2048        | 35%        | \$1,571               | 0%                | \$82.75                   | \$26.97                    | \$70.87                                  | \$43.90                             |
| 2049COD-ApCo-0.35CF | ApCo | 200            | 2049        | 35%        | \$1,580               | 0%                | \$83.85                   | \$27.33                    | \$71.48                                  | \$44.15                             |
| 2050COD-ApCo-0.35CF | ApCo | 200            | 2050        | 35%        | \$1,602               | 0%                | \$85.12                   | \$27.74                    | \$72.50                                  | \$44.76                             |



## Response to Sierra Club 5-5 Attachment 1

21050221

21050221

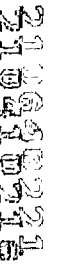
2020 APCo IRP  
Storage Alternative Pricing

25 MW size

| Modeling YR |      | Annual<br>Levelized Cost (\$/MWh) |            | Annual<br>Levelized Cost (\$/000) |           | \$/KW<br>FOM | FOS-M Charge        |              | Scaled up to 25 MW ELCC has 20 MW |
|-------------|------|-----------------------------------|------------|-----------------------------------|-----------|--------------|---------------------|--------------|-----------------------------------|
|             |      | T1 (No PTC)                       | T2 (w PTC) | Storage                           | esc       |              | Flexos<br>\$/KWH-yr | Input<br>FOM |                                   |
| 2021        | 2021 | -                                 | \$37.08    |                                   |           | CAT 2021     | \$25.25             | \$34.17      | \$42.71                           |
| 2022        | 2022 | -                                 | \$35.66    | 5.787                             | 0.96      |              | \$25.04             | 0.99 \$33.84 | \$42.30                           |
| 2023        | 2023 | -                                 | \$34.55    | 5.608                             | 0.97      |              | \$24.92             | 0.99 \$33.67 | \$42.09                           |
| 2024        | 2024 | -                                 | \$40.19    | 6.522                             | 1.1631218 |              | \$25.11             | 1.01 \$33.94 | \$42.42                           |
| 2025        | 2025 | -                                 | \$42.89    | 6.961                             | 1.0672161 |              | \$25.31             | 1.01 \$34.21 | \$42.76                           |
| 2026        | 2026 | -                                 | \$42.60    | 6.913                             | 0.9931339 |              | \$25.49             | 1.01 \$34.45 | \$43.00                           |
| 2027        | 2027 | -                                 | \$42.49    | 6.896                             | 0.9974856 |              | \$25.73             | 1.01 \$34.77 | \$43.46                           |
| 2028        | 2028 | -                                 | \$42.43    | 6.887                             | 0.9986702 |              | \$25.98             | 1.01 \$35.11 | \$43.68                           |
| 2029        | 2029 | -                                 | \$42.38    | 6.879                             | 0.9988593 |              | \$26.23             | 1.01 \$35.45 | \$44.31                           |
| 2030        | 2030 | -                                 | \$42.38    | 6.879                             | 0.9999811 |              | \$26.50             | 1.01 \$35.81 | \$44.76                           |
| 2031        | 2031 | -                                 | \$42.48    | 6.895                             | 1.0023382 |              | \$26.79             | 1.01 \$36.21 | \$44.26                           |
| 2032        | 2032 | -                                 | \$42.64    | 6.920                             | 1.003731  |              | \$27.11             | 1.01 \$36.63 | \$45.79                           |
| 2033        | 2033 | -                                 | \$42.73    | 6.935                             | 1.0021576 |              | \$27.41             | 1.01 \$37.04 | \$46.50                           |
| 2034        | 2034 | -                                 | \$42.80    | 6.946                             | 1.0015398 |              | \$27.70             | 1.01 \$37.44 | \$46.79                           |
| 2035        | 2035 | -                                 | \$42.78    | 6.942                             | 0.9994719 |              | \$27.98             | 1.01 \$37.81 | \$47.26                           |
| 2036        | 2036 | -                                 | \$42.81    | 6.947                             | 1.0007341 |              | \$28.27             | 1.01 \$38.21 | \$47.78                           |
| 2037        | 2037 | -                                 | \$42.77    | 6.942                             | 0.9992034 |              | \$28.55             | 1.01 \$38.59 | \$48.23                           |
| 2038        | 2038 | -                                 | \$42.71    | 6.932                             | 0.9985505 |              | \$28.83             | 1.01 \$38.96 | \$48.70                           |
| 2039        | 2039 | -                                 | \$42.69    | 6.929                             | 0.9995645 |              | \$29.12             | 1.01 \$39.35 | \$49.19                           |
| 2040        | 2040 | -                                 | \$42.73    | 6.936                             | 1.0010002 |              | \$29.44             | 1.01 \$39.78 | \$49.72                           |
| 2041        | 2041 | -                                 | \$42.69    | 6.929                             | 0.9990078 |              | \$29.73             | 1.01 \$40.17 | \$50.22                           |
| 2042        | 2042 | -                                 | \$42.72    | 6.933                             | 1.0006137 |              | \$30.04             | 1.01 \$40.59 | \$50.74                           |
| 2043        | 2043 | -                                 | \$42.75    | 6.938                             | 1.0007772 |              | \$30.35             | 1.01 \$41.02 | \$51.28                           |
| 2044        | 2044 | -                                 | \$42.74    | 6.937                             | 0.9998386 |              | \$30.66             | 1.01 \$41.44 | \$51.80                           |
| 2045        | 2045 | -                                 | \$42.74    | 6.936                             | 0.9998339 |              | \$30.97             | 1.01 \$41.85 | \$52.31                           |
| 2046        | 2046 | -                                 | \$42.74    | 6.937                             | 1.0001521 |              | \$31.29             | 1.01 \$42.28 | \$52.83                           |
| 2047        | 2047 | -                                 | \$42.75    | 6.933                             | 1.0001123 |              | \$31.60             | 1.01 \$42.70 | \$53.38                           |
| 2048        | 2048 | -                                 | \$42.73    | 6.935                             | 0.9995205 |              | \$31.91             | 1.01 \$43.12 | \$53.90                           |
| 2049        | 2049 | -                                 | \$42.70    | 6.930                             | 0.9993634 |              | \$32.22             | 1.01 \$43.54 | \$54.42                           |
| 2050        | 2050 | -                                 | \$43.00    | 6.979                             | 1.0070677 |              | \$32.61             | 1.01 \$44.07 | \$55.07                           |

solar LCOE (reflects learning curve)

21434226



| Project Name           | OpCo | Capacity<br>MW | COD  | Tier   | Solar CF | Levelized<br>CF | ITC % | Build Cost<br>\$/kW | Levelized<br>O&M<br>\$/kW | Levelized<br>O&M<br>\$/MWh | Levelized<br>Cost of<br>Energy<br>\$/MWh | Levelized<br>Capital<br>Cost<br>\$/MWh | 30 Year<br>PPA Proxy<br>(Upfront<br>ITC) |
|------------------------|------|----------------|------|--------|----------|-----------------|-------|---------------------|---------------------------|----------------------------|--|--|--|
| 2021COD-ApCo-Tier 2-F1 | ApCo | 150            | 2021 | Tier 2 | 24.59%   | 23.45%          | 30%   | \$1,195             | \$38.62                   | \$18.88                    | \$55.97                                  | \$37.08                                | \$49.70                                  |
| 2022COD-ApCo-Tier 2-F1 | ApCo | 150            | 2022 | Tier 2 | 24.59%   | 23.45%          | 30%   | \$1,149             | \$38.25                   | \$18.70                    | \$54.36                                  | \$35.66                                | \$48.34                                  |
| 2023COD-ApCo-Tier 2-F1 | ApCo | 150            | 2023 | Tier 2 | 24.59%   | 23.45%          | 30%   | \$1,113             | \$38.06                   | \$18.61                    | \$53.16                                  | \$34.55                                | \$47.33                                  |
| 2024COD-ApCo-Tier 2-F1 | ApCo | 150            | 2024 | Tier 2 | 24.59%   | 23.45%          | 10%   | \$1,108             | \$38.36                   | \$18.76                    | \$58.94                                  | \$40.19                                | \$56.11                                  |
| 2025COD-ApCo-Tier 2-F1 | ApCo | 150            | 2025 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,102             | \$38.66                   | \$18.91                    | \$61.80                                  | \$42.89                                | \$60.46                                  |
| 2026COD-ApCo-Tier 2-F1 | ApCo | 150            | 2026 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,095             | \$38.94                   | \$19.04                    | \$61.64                                  | \$42.60                                | \$60.31                                  |
| 2027COD-ApCo-Tier 2-F1 | ApCo | 150            | 2027 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,092             | \$39.30                   | \$19.22                    | \$61.70                                  | \$42.49                                | \$60.38                                  |
| 2028COD-ApCo-Tier 2-F1 | ApCo | 150            | 2028 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,091             | \$39.68                   | \$19.40                    | \$61.83                                  | \$42.43                                | \$60.51                                  |
| 2029COD-ApCo-Tier 2-F1 | ApCo | 150            | 2029 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,089             | \$40.07                   | \$19.59                    | \$61.98                                  | \$42.38                                | \$60.65                                  |
| 2030COD-ApCo-Tier 2-F1 | ApCo | 150            | 2030 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,089             | \$40.48                   | \$19.79                    | \$62.17                                  | \$42.38                                | \$60.85                                  |
| 2031COD-ApCo-Tier 2-F1 | ApCo | 150            | 2031 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,092             | \$40.93                   | \$20.01                    | \$62.49                                  | \$42.48                                | \$61.17                                  |
| 2032COD-ApCo-Tier 2-F1 | ApCo | 150            | 2032 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,096             | \$41.40                   | \$20.25                    | \$62.89                                  | \$42.64                                | \$61.56                                  |
| 2033COD-ApCo-Tier 2-F1 | ApCo | 150            | 2033 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$41.86                   | \$20.47                    | \$63.20                                  | \$42.73                                | \$61.87                                  |
| 2034COD-ApCo-Tier 2-F1 | ApCo | 150            | 2034 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,100             | \$42.31                   | \$20.69                    | \$63.49                                  | \$42.80                                | \$62.15                                  |
| 2035COD-ApCo-Tier 2-F1 | ApCo | 150            | 2035 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,100             | \$42.73                   | \$20.90                    | \$63.67                                  | \$42.78                                | \$62.34                                  |
| 2036COD-ApCo-Tier 2-F1 | ApCo | 150            | 2036 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,100             | \$43.18                   | \$21.12                    | \$63.92                                  | \$42.81                                | \$62.59                                  |
| 2037COD-ApCo-Tier 2-F1 | ApCo | 150            | 2037 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$43.61                   | \$21.33                    | \$64.10                                  | \$42.77                                | \$62.76                                  |
| 2038COD-ApCo-Tier 2-F1 | ApCo | 150            | 2038 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$44.04                   | \$21.53                    | \$64.24                                  | \$42.71                                | \$62.91                                  |
| 2039COD-ApCo-Tier 2-F1 | ApCo | 150            | 2039 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,097             | \$44.48                   | \$21.75                    | \$64.44                                  | \$42.69                                | \$63.11                                  |
| 2040COD-ApCo-Tier 2-F1 | ApCo | 150            | 2040 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$44.96                   | \$21.98                    | \$64.72                                  | \$42.73                                | \$63.39                                  |
| 2041COD-ApCo-Tier 2-F1 | ApCo | 150            | 2041 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,097             | \$45.41                   | \$22.20                    | \$64.89                                  | \$42.69                                | \$63.56                                  |
| 2042COD-ApCo-Tier 2-F1 | ApCo | 150            | 2042 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$45.89                   | \$22.44                    | \$65.15                                  | \$42.72                                | \$63.82                                  |
| 2043COD-ApCo-Tier 2-F1 | ApCo | 150            | 2043 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$46.37                   | \$22.67                    | \$65.42                                  | \$42.75                                | \$64.09                                  |
| 2044COD-ApCo-Tier 2-F1 | ApCo | 150            | 2044 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$46.84                   | \$22.90                    | \$65.65                                  | \$42.74                                | \$64.31                                  |
| 2045COD-ApCo-Tier 2-F1 | ApCo | 150            | 2045 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$47.31                   | \$23.13                    | \$65.87                                  | \$42.74                                | \$64.54                                  |
| 2046COD-ApCo-Tier 2-F1 | ApCo | 150            | 2046 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$47.79                   | \$23.37                    | \$66.11                                  | \$42.74                                | \$64.78                                  |
| 2047COD-ApCo-Tier 2-F1 | ApCo | 150            | 2047 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,099             | \$48.28                   | \$23.60                    | \$66.35                                  | \$42.75                                | \$65.02                                  |
| 2048COD-ApCo-Tier 2-F1 | ApCo | 150            | 2048 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,098             | \$48.75                   | \$23.83                    | \$66.56                                  | \$42.73                                | \$65.23                                  |
| 2049COD-ApCo-Tier 2-F1 | ApCo | 150            | 2049 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,097             | \$49.22                   | \$24.06                    | \$66.76                                  | \$42.70                                | \$65.43                                  |
| 2050COD-ApCo-Tier 2-F1 | ApCo | 150            | 2050 | Tier 2 | 24.59%   | 23.45%          | 0%    | \$1,105             | \$49.83                   | \$24.36                    | \$67.36                                  | \$43.00                                | \$66.02                                  |

Appalachian Power  
Investment Carrying Charges - Updated October 2020  
For Economic Analyses  
As of 12/31/2019

|  | Investment Life (Years) |       |       |       |       |       |       |       |       |       |       |      |
|--|-------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
|  | 2                       | 3     | 4     | 5     | 10    | 15    | 20    | 25    | 30    | 33    | 40    | 50   |
| Return (1)                               | 7.27                    | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27  | 7.27 |
| Depreciation (2)                         | 49.02                   | 31.87 | 23.28 | 18.14 | 7.99  | 4.74  | 3.20  | 2.33  | 1.78  | 1.55  | 1.17  | 0.85 |
| FIT (3) (4)                              | 1.06                    | 0.76  | 0.82  | 0.68  | 0.64  | 0.77  | 0.80  | 0.68  | 0.62  | 0.59  | 0.54  | 0.49 |
| Property Taxes, General & Admin Expenses | 1.22                    | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22  | 1.22 |
| Carrying Cost Per Year                   | 58.58                   | 41.13 | 32.59 | 27.31 | 17.12 | 14.01 | 12.49 | 11.51 | 10.90 | 10.63 | 10.20 | 9.82 |

(1) Based on a 100% (as of 12/31/2019) and 0% incremental weighting of capital costs

(2) Sinking Fund annuity with R1 Dispersion of Retirements

(3) Assuming MACRS Tax Depreciation

(4) @ 21% Federal Income Tax Rate