Regional Haze SIP Analysis for SO_2 Emissions at the James M. Gavin Plant

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DECEMBER 22, 2023

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I. Introduction and Summary

At the request of Gavin Power, LLC, we prepared this review in conjunction with the Ohio Environmental Protection Agency's (Ohio EPA) proposed revisions to the Ohio State Implementation Plan (SIP) to implement the Clean Air Act's (CAA) Regional Haze Rule (RHR). Specifically, this review analyzes SO_2 emissions and removal at the James M. Gavin Power Plant (Gavin or the Plant) in Cheshire, Ohio, and supplements the analysis in the AECOM 2020 Four Factor Analysis for Gavin. Consistent with Ohio EPA's findings, we have concluded that additional SO_2 emission controls are not necessary because they would not result in significant impact to visibility improvements at Class 1 areas (*i.e.*, national parks or wilderness areas) or SO_2 concentrations in the region. Additionally, the costs of additional SO_2 emission controls are prohibitive and would likely result in the premature closure of the Plant and raise regional electricity rates until new replacement resources come online. Moreover, Ohio EPA has already determined that "visibility conditions in 2028 at each Class I area impacted by emissions from Ohio [were] projected to be below (or well below) the uniform rate of progress (URP) glidepath."[1] Thus, the additional SO_2 emission controls are not economically efficient as determined by a benefit-cost standard.

Section II of this report provides background on the U.S. Environmental Protection Agency's (U.S. EPA) objectives under the RHR. Section III presents our review of comments received in response to Ohio EPA's draft SIP submittal. Section IV summarizes our findings on the lack of visibility improvements expected by new emission controls at Gavin. Section V presents an analysis of the incremental cost estimates of additional SO_2 emission controls. Section VI addresses the costs and benefits of any purported visibility improvement resulting from additional SO_2 emission controls. Section VII demonstrates that the cost of additional controls will likely lead to higher electricity costs for consumers until new replacement resources come online. There are also two appendices. Appendix A contains supporting data and calculations. Appendix B presents the authors' qualifications.

II. Background

The RHR was adopted and effective in 1999, and requires: (1) monitoring visibility at Class I areas determined to be affected by power plants and other sources operating within a state;

[1] Ohio EPA, Division of Air Pollution Control, Regional Haze State Implementation Plan for the Second Implementation Period, July 2021, at 3, available at https://epa.ohio.gov/static/Portals/27/sip/regional/RH2021_SIP2ndPlanPer_Final.pdf.

and (2) development of a SIP revision to improve visibility and meet the RHR's ultimate objective of natural visibility at Class I areas by 2064. Ohio submitted its first SIP revision under the first implementation period in 2008 and provided revisions in 2012, 2016, and 2018. A 2017 final rule updating the RHR required Ohio EPA to prepare a second revision by 2022. Subsequently in 2019, U.S. EPA issued its 2019 RHR Guidance.[2]

In its effort to submit a revised SIP, Ohio EPA requested a Four Factor Analysis for Gavin, and Gavin retained AECOM, an engineering consulting firm, to conduct the analysis. Ohio EPA incorporated the AECOM Four Factor Analysis for Gavin into its draft SIP, and circulated its draft SIP revision in May 2021, consistent with U.S. EPA's 2019 RHR Guidance, analyzing the potential visibility impacts from point sources including Gavin. Based in part on the AECOM Four Factor Analysis for Gavin, Ohio EPA's draft SIP revision concluded that additional emission controls at the Plant were not required in order to meet RHR visibility targets.[3]

In July 2021, Ohio EPA submitted its final SIP revision to U.S. EPA and presented similar conclusions, in consideration of public comments advocating for additional emission controls at Gavin.[4] Critically, Ohio EPA concluded that the "visibility conditions in 2028 at each Class I area impacted by emissions from Ohio [were] projected to be below (or well below) the uniform rate of progress (URP) glidepath" and "therefore visibility targets are being met, while acknowledging that this is not a reason, on its own, to not consider additional controls."[5]

As discussed below, this report addresses public comments on Ohio EPA's draft SIP revision and comments received from U.S. EPA following Ohio EPA's submittal of the proposed SIP revision. Several parties, including the National Park Service (NPS) and the Sierra Club, filed comments in response to the draft SIP revision and made various assertions, including that Gavin should be required to remove the existing SO_2 wet flue gas desulfurization (WFGD or FGD) system and retrofit the Plant with new FGD systems (one for each unit). These commenters rejected the use of a "fifth factor" that specifically addresses visibility improvement to determine the need for additional controls. Additionally, this report considers the feasibility of Gavin achieving a 30-day rolling average, SO_2 emission control limit

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2 U.S. EPA, *Guidance on Regional Haze State Implementation Plans for the Second Implementation Period*, Aug. 20, 2019, available at https://www.epa.gov/visibility/guidance-regional-haze-state-implementation-plans-second-implementation-period.

3 AECOM, SO_2 Four Factor Analysis Regional Haze Rule Second Decadal Review: General James M. Gavin Power Plant Units 1 and 2, Dec. 16, 2020, available at https://epa.ohio.gov/static/Portals/27/sip/regional/I1_RH2021_GavinSO2_4Fac-Rev_3-31-21.pdf.

4 Regional Haze State Implementation Plan for the Second Implementation Period, supra note 1.

5 *Id*. at 3, 47, 50, 51.

of 0.3 lb/MMBtu (one million British thermal units), with the possibility of additional cost-effective controls.

III. Review of Comments on and Responses to the Draft SIP

Ohio EPA received over 500 comments on its draft SIP revision. The most critical comments were provided by the NPS and a collection of conservation organizations.[6] NPS asserted that a Four Factor Analysis prescribed by the RHR showed that requiring new scrubbers at Gavin was cost-effective, and recommended that new scrubbers be required in the SIP revision. The conservation groups by comment made similar assertions and also rejected Ohio EPA's reliance on a fifth factor – the consideration of the benefits from anticipated visibility improvements – as a basis to reject the need for new emission controls. U.S. EPA introduced this fifth factor in its Memorandum, *Clarifications Regarding Regional Haze State Implementation Plans for the Second Implementation Period*, on July 8, 2021[7]:

> *"Section 51.308(f)(2)(i) of the Regional Haze Rule requires consideration of four factors listed in CAA section 169A(g)(1) and does not mention visibility benefits.* ***However*** *(emphasis added), neither the CAA nor the Rule suggests that only the listed factors must be considered. Because the goal of the regional haze program is to improve visibility, it is reasonable for a state to consider whether and by how much an emissions control measure would help achieve that goal."*

The commenters asserted that the above language creates an "off-ramp" for sources to avoid additional controls. Given the objective of the RHR and U.S. EPA's economic guidelines for the implementation of regulations, this language may result in a source foregoing additional or newer controls that are cost prohibitive and result in minimal additional benefit. Imposing additional emission control requirements on Gavin to meet existing air quality regulations

6 Comments by conservation organizations included the Sierra Club, the National Parks Conservation Association, the Coalition to Save America's Parks and the Ohio Environmental Counsel.

7 U.S. EPA, Memorandum, *Clarifications Regarding Regional Haze State Implementation Plans for the Second Implementation Period*, July 8, 2021, at 13, available at https://www.epa.gov/system/files/documents/2021-07/clarifications-regarding-regional-haze-state-implementation-plans-for-the-second-implementation-period.pdf.

requires a benefit-cost analysis, which is a measure of efficiency. As the U.S. EPA clarifies in its Guidelines for Preparing Economic Analysis:

> *"The efficiency of a policy option differs from its cost-effectiveness. A policy is cost-effective if it meets a given goal at least cost, but cost-effectiveness does not encompass an evaluation of whether the goal has been set appropriately to maximize social welfare."*[8]

Applied to the RHR, where the goal is visibility improvements, the proposed SIP revisions should be evaluated with respect to their impact on visibility improvement and *not* their impact on other objectives unless the improvements are necessary to meet a human health-based or other air quality objectives at the same time. Here, Ohio is in attainment with the CAA's SO_2 national ambient air quality standards (NAAQS) in all but parts of two of Ohio's 88 counties.[9] Gallia County, where Gavin is located, and the surrounding counties meet the SO_2 NAAQS. Therefore, additional controls are not required to meet the SO_2 NAAQS. Similarly, there is no evidence that new FGD systems would otherwise meaningfully improve air quality. In other words, any proposed controls should be evaluated solely with respect to their impact on visibility.

In considering the feasibility of achieving a 30-day rolling average SO_2 emission control limit of 0.3 lb/MMBtu, this report concludes that installment of new FGD systems does not further the goal of the RHR because the visibility improvements would be marginal at best, as discussed in Section IV. Moreover, the cost associated with additional SO_2 emission controls would be prohibitive because, as we understand from the Gavin facility engineers, Gavin is already running current plant equipment at maximum efficiency and capacity for emission control purposes based on performance and design limitations, and the only way to further reduce SO_2 emissions would be to install new FGD systems. More specifically, we understand from the facility engineers at Gavin that:

- There is no equipment that can be placed in service as part of Gavin's existing emission control system to boost SO_2 removal performance. Gavin's scrubbers are designed to

8 U.S EPA, Guidelines for Preparing Economic Analyses, Dec. 17, 2010, Section 4.1.2, at 34, available at https://www.epa.gov/sites/default/files/2017-08/documents/ee-0568-50.pdf.

9 U.S. EPA, Current Nonattainment Counties for All Criteria Pollutants (current as of November 30, 2023), available at https://www3.epa.gov/airquality/greenbook/ancl.html.

remove 95% of SO_2 using inlet coal up to 7.5 lbs/MMBtu SO_2 with all six absorbers in service and both recirculating pumps in service on each absorber.

- Gavin already uses a critical additive (available through only one supplier in the U.S.) to boost the performance of the scrubbers to 95%. Without the additive, SO_2 removal would be approximately 90%.
- Gavin already utilizes low-sulfur fuel to the extent possible given the design specifications of the system.

In other words, Gavin has already maximally enhanced SO_2 removal by way of reasonable cost improvements. The only enhancement option remaining – installing new FGD systems – would require significant investment. As discussed below in Section V, this is a cost-prohibitive investment that is not justified by the modest visibility benefits that could result by replacing scrubbers at Gavin.

IV. Visibility Improvements of Additional Controls Are Very Modest

In considering the potential visibility improvements of additional emission controls — *i.e.*, new FGD systems — at Gavin, it is important to consider a few findings. First, as mentioned above, Ohio EPA concluded in its July 2021 revised SIP that the Class 1 area impacted by emissions from Ohio, including Gavin, are below (or well below) the URP glidepath and therefore, visibility targets are currently being met.[10] Second, Ohio EPA's visibility benefit analysis found that Gavin's SO_2 emissions only marginally affected 26 Class 1 national parks and wilderness areas.[11] The AECOM 2020 Four Factor Analysis for Gavin confirmed this finding using VISTAS model estimates of Gavin's SO_2 emission impacts on visibility at the six national parks and wilderness areas in closest proximity to the plant.[12] Table 1 demonstrates that if Gavin had ***no SO_2 emissions at all,*** visibility would improve by a mere 0.3% to 1.4% at these sites.

[10] Ohio EPA, Division of Air Pollution Control, Regional Haze State Implementation Plan for the Second Implementation Period, July 2021, at 3, 47, 50, 51 and available at https://epa.ohio.gov/static/Portals/27/sip/regional/RH2021_SIP2ndPlanPer_Final.pdf.

[11] *Id.* at 50, 51.

[12] AECOM, SO_2 Four Factor Analysis Regional Haze Rule Second Decadal Review: General James M. Gavin Power Plant Units 1 and 2, Dec. 16, 2020, at Section 6.5, available at https://epa.ohio.gov/static/Portals/27/sip/regional/I1_RH2021_GavinSO2_4Fac-Rev_3-31-21.pdf.

TABLE 1. VISIBILITY IMPACT OF GAVIN'S SO_2 EMISSIONS

Class I Areas	Baseline Visibility (km)	Visibility without Gavin's Emissions (km)	Increase in Visibility (km)	Increase in Visibility (%)
	[1]	[2]	[3]	[4]
Shenandoah NP	85.62	86.34	0.72	0.8%
Great Smoky Mountain NP	80.79	81.40	0.61	0.8%
Mammoth Cave NP	61.44	61.62	0.18	0.3%
James River Face WA	77.87	78.54	0.66	0.9%
Dolly Sods WA	76.11	77.16	1.05	1.4%
Linville Gorge WA	84.41	84.96	0.55	0.7%

Source and Notes:
[1]: Visibility in the most impaired days in 2019 published by EPA for "Our Nations' Air: Trends Through 2022" Report. Converted from DV to km using the conversion formula provided in http://vista.cira.colostate.edu/Improve/haze-metrics-converter/.
[2]: [1]+[3].
[3]: Data reflects values converted from DV to km as reported in the AECOM, SO_2 Four Factor Analysis Regional Haze Rule Second Decadal Review: General James M. Gavin Power Plant Units 1 and 2, Dec. 16, 2020, available at https://epa.ohio.gov/static/Portals/27/sip/regional/I1_RH2021_GavinSO2_4Fac-Rev_3-31-21.pdf.
[4]: [3]/[1].

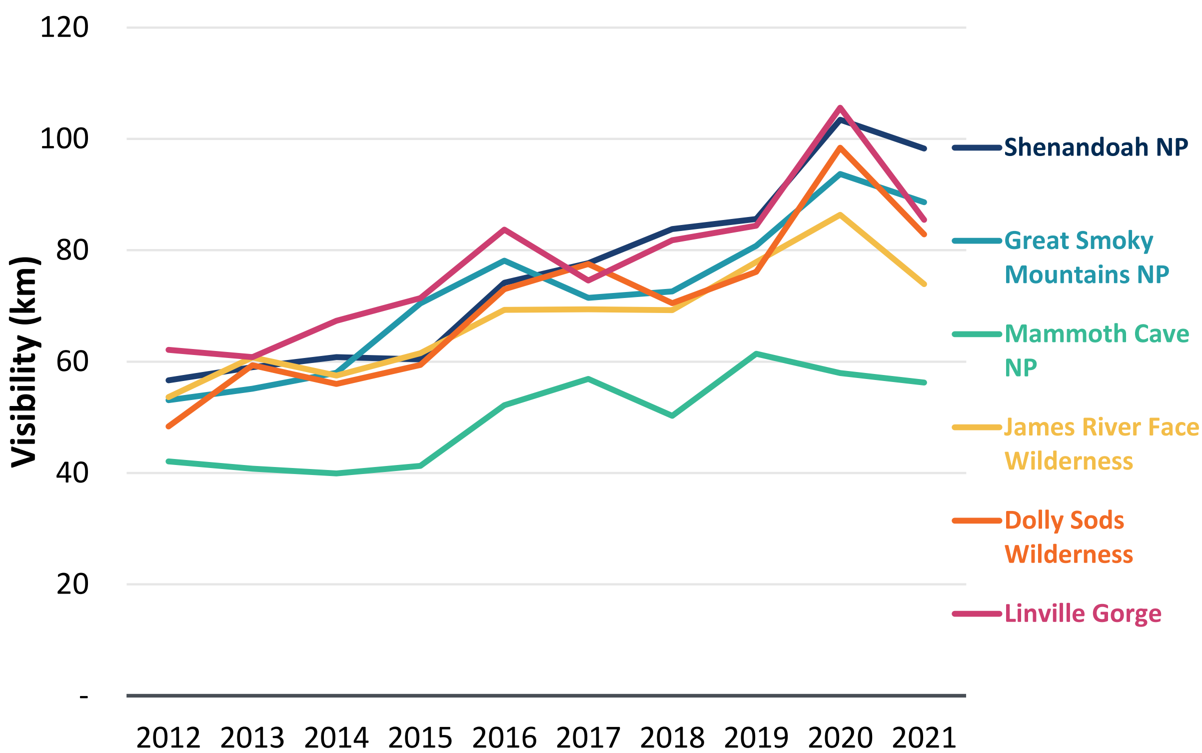
Yet replacing the FGD systems entirely would reduce Gavin's SO_2 emissions by only 4.4% or less – not the 100% reduction modeled by AECOM – meaning that it is highly unlikely that even those emission controls would improve visibility at all.[13]

AECOM also reviewed visibility trends at all six Class 1 sites and found that all have been improving and are expected to meet federal visibility targets by 2060, as required by the RHR, which further supports Ohio EPA's conclusion that additional controls are not needed at Gavin. As shown in Figure 1, below, visibility in the six Class 1 sites has been improving since the AECOM study, even without replacing the FGD systems at Gavin. In addition, forecasted visibility conditions, taking into account continued operations at Gavin, show continued improvement.[14]

13 Gavin investments would reduce SO_2 by 4.4% at Unit 1 and by 3.6% at Unit 2. *See* Appendix Tables A1, A-2.

14 *See* Table 1. *See also* Ohio EPA, Division of Air Pollution Control, Regional Haze State Implementation Plan for the Second Implementation Period, July 2021, available at https://epa.ohio.gov/static/Portals/27/sip/regional/RH2021_SIP2ndPlanPer_Final.pdf.

FIGURE 1. TREND IN VISIBILITY CONDITIONS



Source: EPA's "Our Nations' Air: Trends Through 2022" Report.

Finally, in view of the very modest reduction in emissions that would be achieved by replacing the FGD systems at Gavin, and the fact that Ohio is (with minor exceptions) in attainment for the CAA's NAAQS, it seems implausible that the emission-control investment to install new FGD systems, as discussed in Section V, would result in any significant improvements in other air quality metrics, including human health.

V. Incremental Costs of Emission Reductions are Substantial

The cost of new FGD systems at Gavin is not justified because the visibility benefits that may be gained from the improvement is *de minimis* and the cost is prohibitive (and greater than NPS estimated in their comments). NPS provided the cost of a new Wet FGD system at Gavin Unit 1 as $3,327 per incremental ton of SO_2 removed and a new Wet FGD system at Gavin Unit

2 as $4,072 per incremental ton of SO_2 removed, all in 2019 dollars.[15] NPS concluded that "replacement of the old scrubbers with new, much more efficient WFGDs represents a very cost-effective solution to these high-emitting EGUs."

Two key assumptions in NPS's analysis are not reasonable and result in a vast underestimate of the cost of the new FGD equipment. First, the NPS assumption of a 30-year economic life of the new equipment is too long under the current market and regulatory outlooks for coal plants. Increased penetration of renewables and storage and climate policy goals to decarbonize the electricity sector are likely to result in the retirement of a large portion of the coal-fired plants in Ohio and surrounding states over the next 10-20 years. For example, about 1,750 MW of coal-fired capacity in the PJM[16] region is set to retire in 2024 and 2025.[17] More than half of the existing coal-fired capacity of about 50,000 MW in the PJM region will likely retire over the next 10 years.[18] Projections for the nationwide coal fleet are similar: Energy Information Administration (EIA) projects the coal-fired capacity to drop from 198 GW currently to 93-126 GW levels by 2030 and to 77-106 GW levels by 2040 depending on gas price uncertainties in the future.[19]

Second, the NPS assumption of a 3.25% interest rate is too low to represent the current cost of capital for a merchant generator. In February 2021, EIA estimated the levelized cost of the new generation assuming a real ATWACC of 5.4% but with the caveat that the Plant's actual After Tax Weighted Average Cost of Capital (ATWACC) is dependent on project and technology type. PJM assumes an ATWACC of 8% as recent as August 2023.[20]

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15 Updated NPS Regional Haze SIP feedback for Ohio EPA, June 21, 2021, at 1. See Appendix Table A-1 and A-2 for NPS estimate and our sensitivity results. Note, the incremental cost of sulfur reduction at Gavin would be even higher if the AECOM 2020 Four-Factor Analysis for Gavin accounted for greater efficiency at the existing wet FGD (i.e., 95%).

16 "PJM is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia." See https://www.pjm.com/about-pjm.

17 PJM Generation Deactivation List, last accessed on December 8, 2023, at https://www.pjm.com/planning/service-requests/gen-deactivations.

18 *See, e.g.*, "Coal plant owners seek to shut 3.2 GW in PJM in face of economic, regulatory and market pressures," Mar. 22, 2022, available at https://www.utilitydive.com/news/coal-plant-owners-seek-to-retire-power-in-pjm/620781/?utm_source=Sailthru&utm_medium=email&utm_campaign=Issue:%202022-03-22%20Utility%20Dive%20Newsletter%20%5Bissue:40552%5D&utm_term=Utility%20Dive.

19 EIA Annual Energy Outlook (AEO) 2023, available at https://www.eia.gov/outlooks/aeo/data/browser/#/?id=9-AEO2023&region=0-0&cases=ref2023~highogs~lowogs&start=2021&end=2050&f=Q&linechart=ref2023-d020623a.4-9-AEO2023~highogs-d020623a.4-9-AEO2023~lowogs-d020623a.4-9-AEO2023&map=&sourcekey=0.

20 PJM Manual 15: Cost Development Guidelines, Aug. 1, 2023, at 109, available at https://www.pjm.com/-/media/documents/manuals/m15.ashx.

Assuming a shorter economic life (10 years) and a higher discount rate (8%) results in an increased incremental cost of $12,037 per incremental ton of SO_2 removed at Unit 1 and $14,863 per incremental ton of SO_2 removed at Unit 2, in 2022 dollars, as demonstrated in Table 2, below.

TABLE 2. COST OF INCREMENTAL SO2 REMOVAL WITH A NEW WET FGD AT GAVIN (2022$/TON)

Scenarios	Cost Effectiveness of SO2 Removal	
	Unit 1	Unit 2
NPS Estimate		
30-Year Equipment Life and 3.25% Discount Rate	$ 4,469	$ 5,469
Sensitivities		
20-Year Equipment Life and 3.25% Discount Rate	$ 5,734	$ 7,039
10-Year Equipment Life and 3.25% Discount Rate	$ 9,655	$ 11,907
30-Year Equipment Life and 5% Discount Rate	$ 5,443	$ 6,679
30-Year Equipment Life and 8% Discount Rate	$ 7,306	$ 8,990
10-Year Equipment Life and 8% Discount Rate	$ 12,037	$ 14,863

Source: *See* Appendix Table A-1, A-2. Inflated from 2019 dollars to 2022 dollars using CEPCI Cost Indices from University of Manchester - Chemical Engineering Plant Cost Index, as specified in the EPA model.

Moreover, NPS's estimated cost-effectiveness for the new FGD systems is not inclusive of all the possible costs that would be incurred by Gavin, including labor costs and lost net revenues from reduced generation associated with the prolonged outages necessary to remove the existing scrubbers at both units at Gavin.

VI. Proposed Emission Control Investment Fails a Benefit-Cost Analysis

The primary measure available to policymakers and regulators to determine whether a proposed investment is justified is a benefit-cost test.[21] The information necessary to conduct this test with respect to replacing the FGD systems at Gavin is available. As discussed above,

[21] U.S. EPA, Guidelines for Preparing Economic Analysis, Mar. 2016, at Section 4.1; *see also* Appendix A.

the benefit of the proposed investment is defined under the RHR as improved visibility at Class I sites. The expected change in visibility from reducing SO_2 emissions at Gavin has been measured based on air quality modeling in the form of changes in Deciview and kilometers. These measurements can be translated into dollars that can be used to conduct a benefit-cost test. Economists measure the dollar value of visibility improvement by measuring how much people are willing to pay for a given improvement.

An academic study designed to address this willingness to pay at one of the Class 1 sites considered by Ohio – the Great Smokey Mountain National Park (GSMNP) – was conducted several years ago.[22] This study found that the number of visitors to GSMNP increased as visibility improved, and it quantified how many more visitors would visit with a change in visibility. Specifically, the authors found that the elasticity of recreational visits to increase in visibility is 1.01. This relationship provides the basis for estimating how many more visitors would visit GSMNP in relation to the expected changes in visibility. The change in visitors yields a value of change by virtue of increased fees paid to enter GSMNP. The calculations are summarized in Table 3 the six sites in close proximity to Gavin.

[22] Neelam C. Poudyal, Bamadev Paudel, and Gary T. Green, "Estimating the Impact of Impaired Visibility on the Demand for Visits to National Parks," Tourism Economics 19 No. 2 (April 2013).

TABLE 3. ECONOMIC IMPACT OF IMPROVED VISIBILITY WITHOUT GAVIN'S SO_2 EMISSIONS

Class I Areas		Baseline Economic and Visibility Conditions			Increase in Visibility		Increase in Recreational Visit		Increase in Visitor Spending	
		Visibility (km)	Recreational Visits	Visitor Spending (2022$000s)	km	%	# of Visits	%	2022$000s	%
		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Shenandoah NP	[A]	86	1,666,265	$ 122,431	0.72	0.84%	13,384	0.80%	$ 983	0.80%
Great Smoky Mountain NP	[B]	81	12,095,721	$ 1,167,387	0.61	0.76%	87,535	0.72%	$ 8,448	0.72%
Mammoth Cave NP	[C]	61	290,392	$ 28,666	0.18	0.30%	815	0.28%	$ 80	0.28%
James River Face WA	[D]	78	1,404,903	$ 40,670	0.66	0.85%	11,407	0.81%	$ 330	0.81%
Dolly Sods WA	[E]	76	76,000	$ 2,200	1.05	1.38%	1,008	1.33%	$ 29	1.33%
Linville Gorge WA	[F]	84	350,000	$ 10,132	0.55	0.65%	2,167	0.62%	$ 63	0.62%
Annual Total	**[G]**		**15,883,281**	**$ 1,371,488**			**116,316**	**0.73%**	**$ 9,934**	**0.72%**
Present Value Total (10 years, 3% discount)	**[H]**								**$ 84,741**	
Present Value Total (10 years, 7% discount)	**[I]**								**$ 69,774**	

[1][4][5]: See Table 1.
[2][A] - [3][D]: 2020 National Park Visitor Spending Effects, https://www.nps.gov/nature/customcf/NPS_Data_Visualization/docs/NPS_2020_Visitor_Spending_Effects.pdf, Inflated to 2022$ from 2020$ using BLS CPI Inflator.
[2][D]&[3][D]: Economic Impact of the James River Park System, http://files.constantcontact.com/db3a319f001/4d802e0f-ccb4-4093-82c4-047e9c4099a6.pdf. Inflated to 2022 $ from 2017 $ using BLS' Inflation calculator.
[2][E]: Dolly Sods Region Project, https://www.lrh.usace.army.mil/Missions/DERP-FUDS-WVOW-PBOW-WVMA-/West-Virginia-Maneuver-Area/8-Dolly-Sods-Region-Project/.
[2][F]: Linville Falls, https://www.blueridgeparkway.org/poi/linville-falls/.
[3][E]&[3][F]: [2]*([3][D]/[2][D]). Assuming that the spending per visit is similar between James River Face WA, Dolly Sods, and Linville Gorge WA, we scaled up the total visitor spending.
[6]: [2]*[7].
[7]: [5]^1.01. 1.01 is the elasticity of recreational visits. See Appendix Table A-3.
[8]: [3]*[9].
[9]: [5]^1.01. 1.01 is the elasticity of recreational visits. See Appendix Table A-3.

As shown in Table 3, based on the expected visibility improvement at GSMNP resulting from the removal of Gavin's SO_2 emissions, the fees charged at the Park, and the relationship between visibility and visitor levels established by the study, is worth $8.4 million (in 2022 dollars) annually or between $59 -72 million over 10 years starting in 2020 on a net present value basis depending on the discount rate. Applying this method to all six Class I sites in closest proximity to Gavin, visibility improvements from ceasing all emissions at Gavin are worth between $70-$85 million depending on the discount rate over 10 years starting in 2020. These values overstate the value that can be attributed to the modest reduction in SO_2

emissions expected by replacing the FGD systems at Gavin. Doing so would reduce emissions at the Plant by only 4% for SO_2.[23]

As demonstrated in Table 4, below, accounting for SO_2 emission reductions, visibility benefits from closing Gavin would total no more than $9.3 million annually or $85 million on an NPV basis over 10 years starting in 2020. Consequently, the benefit of the visibility improvements attributable to the proposed SO_2 emissions control investments over 10 years will be considerably less in view of their modest emission reductions.

As discussed in Section V, the cost of implementing additional control measures, to replace existing emission controls at Gavin, is substantial. The per ton removal costs presented in Table 3 reflect capital and operating investments that exceed $1.6 billion on an NPV basis for 10 years starting in 2020.[24] See Table 6 below.

Using the costs and benefit described above, a benefit-cost analysis can be conducted by netting the costs against the benefits. As shown in Table 6, below, the costs far exceed the benefit when using a conservative approach that includes benefits from plant closure rather than the minor benefits that would be achieved by new FGD systems. In addition, as discussed below, closing Gavin will likely increase electricity rates further increasing the cost relative to benefit. This outcome supports Ohio EPA's decision to reject the proposals to add emission control equipment to Gavin.

TABLE 4. BENEFIT-COST ANALYSIS

		Cost of Installation	Benefit from Visibility Improvements	Net Benefit
		[1]	[2]	[3]
SO2 - New Wet FGD	[A]	$ 1,673,576,908	$ 84,740,585	$ (1,588,836,323)

Sources and Notes:
[1]: See Appendix Table A-1 and A-2. PV is calculated using a discount rate of 8% over 10 years. Inflated from 2019 dollars to 2022 dollars using the
CEPCI Cost Indices from University of Manchester - Chemical Engineering Plant Cost Index, as specified in the EPA model.
[2]: See Table 3. NPV is calculated using a discount rate of 3% over 10 years.
[3]: [2]-[1].

[23] This assumes a change in control efficiency from 94% to 98%; see Appendix Table A-1.

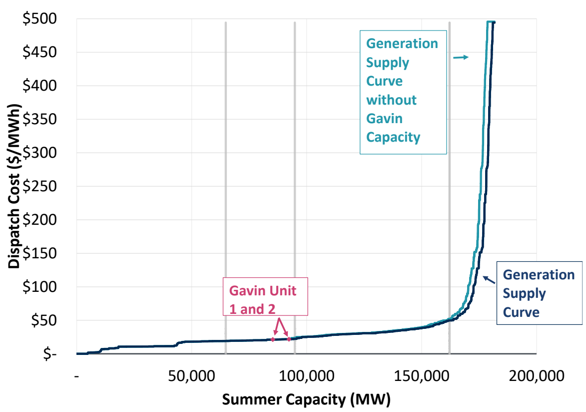
[24] *See* Appendix Tables A-1 to A-3.

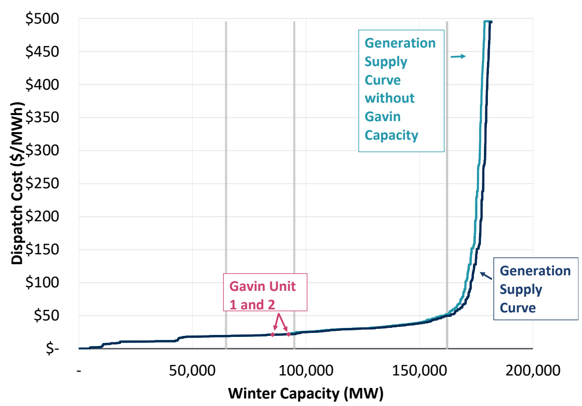
VII. Proposed Control Investments Are Likely To Raise Wholesale Electricity Rates

Comments by NPS and others do not account for the additional economic consequences of potential for Gavin's premature retirement. Gavin generates low-cost energy in the PJM wholesale energy market. The PJM wholesale energy market is, therefore, likely to experience higher energy prices as existing resources with higher dispatch costs would replace Gavin's output until new replacement resources come online.

We illustrate this price impact by using the estimated generation supply curve and load, plus net exports, in 2020 in the PJM region. As shown in Figure 2, the supply curve is the aggregation of the capacity of individual resources and marginal dispatch costs of providing energy in the PJM region, starting with the lowest-cost resources. The clearing price in any hour is where the vertical demand intersects the supply curve. Removing Gavin's capacity from the market shifts the supply curve to the left starting at the aggregate capacity with marginal costs higher than Gavin's marginal cost, resulting in an increased clearing price in the market until the new replacement resources are installed. This impact is pronounced in peak hours since the load intersects the supply curve at its steeper portion on the right. We also estimate the additional payments by the load in the PJM region because of the estimated increase in wholesale energy prices.

FIGURE 2. PJM'S 2020 SUMMER AND WINTER SUPPLY CURVES WITH AND WITHOUT GAVIN'S CAPACITY





Source: CapIQ.

We estimate an average annual price impact of $0.48/MWh (and up to $0.82/MWh in July) based on market conditions in 2020. The resulting increase in annual load payment in the PJM region is $411 million, as shown in Table 5.

TABLE 5. PRICE IMPACT OF GAVIN CLOSURE BASED ON MARKET CONDITIONS IN 2020

				Annual Impact
Derived PJM Average Energy Price with Gavin	[A]	($/MWh)	**$**	**24.73**
Derived PJM Average Energy Price without Gavin	[B]	($/MWh)	**$**	**25.21**
Increase in PJM Average Energy Price	[C]	($/MWh)	**$**	**0.48**
Total Load	[D]	(MWh)		**859,417,010**
Increase in Load Payments	[E]	($)	**$**	**411,377,330**

Sources and Notes:
[A][B]: Prices derived based on 2020 PJM supply curve published by CapIQ. See Figure 2.
[C]: [B]-[A].
[D]: Historical Load adjusted for next export. See PJM Public Data, available at https://dataminer2.pjm.com/list.
[E]: [C]*[D].

If future market conditions reflect the high prices of natural gas and coal observed in 2022, however, the annual price impact would be $0.83/MWh (or about double the estimate increase from the market conditions in 2020). The annual load payment would increase to $737 million. See Table 6. Consequently, closing Gavin would have a substantial impact on price under a range of potential market conditions.

TABLE 6. PRICE IMPACT OF GAVIN CLOSURE BASED ON MARKET CONDITIONS IN 2022

				Annual Impact
Derived PJM Average Energy Price with Gavin	[A]	($/MWh)	**$**	**53.30**
Derived PJM Average Energy Price without Gavin	[B]	($/MWh)	**$**	**54.13**
Increase in PJM Average Energy Price	[C]	($/MWh)	**$**	**0.83**
Total Load	[D]	(MWh)		**893,376,260**
Increase in Load Payments	[E]	($)	**$**	**737,303,768**

Sources and Notes:
[A][B]: Prices derived based on 2022 PJM supply curve published by CapIQ. See Figure 2.
[C]: [B]-[A].
[D]: Historical Load adjusted for next export. See PJM Public Data, available at https://dataminer2.pjm.com/list.
[E]: [C]*[D].

This analysis was conducted by Brattle Principals, Mark Berkman and Metin Celebi, with the assistance of senior research analyst Shivangi Pant.

Appendix A: Cost Calculations

TABLE A-1. COST-EFFECTIVENESS OF WET FGD AT GAVIN UNIT 1 (2019 $)

			Sensitivities				
		New WFGD	20-Year Equipment Life and 3.25% Discount Rate	10-Year Equipment Life and 3.25% Discount Rate	30-Year Equipment Life and 5% Discount Rate	30-Year Equipment Life and 8% Discount Rate	10-Year Equipment Life and 8% Discount Rate
New							
Control Efficiency	*%*	98	98	98	98	98	98
Capital Cost		$ 612,494,912	$ 612,494,912	$ 612,494,912	$ 612,494,912	$ 612,494,912	$ 612,494,912
Capital Cost/kW	*/kW*	$ 428	$ 428	$ 428	$ 428	$ 428	$ 428
Capital Recovery Cost	*/yr*	$ 32,278,482	$ 42,139,650	$ 72,703,146	$ 39,873,419	$ 54,389,548	$ 91,261,742
Fixed O&M Cost	*/yr*	$ 10,858,811	$ 10,858,811	$ 10,858,811	$ 10,859,901	$ 10,861,831	$ 10,861,831
Variable O&M Cost	*/yr*	$ 48,606,821	$ 48,606,821	$ 48,606,821	$ 48,606,821	$ 48,606,821	$ 48,606,821
Total Annual Cost	*/yr*	$ 91,744,114	$ 101,605,282	$ 132,168,778	$ 99,340,141	$ 113,858,200	$ 150,730,394
Uncontrolled SO2	*ton/yr*	251,139	251,139	251,139	251,139	251,139	251,139
SO_2 removed	*ton/yr*	245,891	245,891	245,891	245,891	245,891	245,891
Average Cost Effectiveness	*/ton removed*	$ 373	$ 413	$ 538	$ 404	$ 463	$ 613
Existing WFGD							
Control Efficiency	*%*	94	94	94	94	94	94
Capital Recovery Cost	*/yr*	$ -	$ -	$ -	$ -	$ -	$ -
Fixed O&M Cost	*/yr*	$ 10,858,811	$ 10,858,811	$ 10,858,811	$ 10,859,901	$ 10,861,831	$ 10,861,831
Variable O&M Cost	*/yr*	$ 46,056,809	$ 46,056,809	$ 46,056,809	$ 46,056,809	$ 46,056,809	$ 46,056,809
Total Annual Cost	*/yr*	$ 56,915,620	$ 56,915,620	$ 56,915,620	$ 56,916,710	$ 56,918,640	$ 56,918,640
Uncontrolled SO2	*ton/yr*	$ 251,139	$ 251,139	$ 251,139	$ 251,139	$ 251,139	$ 251,139
SO_2 removed	*ton/yr*	$ 235,423	$ 235,423	$ 235,423	$ 235,423	$ 235,423	$ 235,423
Average Cost Effectiveness	*/ton removed*	$ 242	$ 242	$ 242	$ 242	$ 242	$ 242
Differentials							
Capital Recovery Cost	*/yr*	$ 32,278,482	$ 42,139,650	$ 72,703,146	$ 39,873,419	$ 54,389,548	$ 91,261,742
Fixed O&M Cost	*/yr*	$ -	$ -	$ -	$ -	$ -	$ -
Variable O&M Cost	*/yr*	$ 2,550,012	$ 2,550,012	$ 2,550,012	$ 2,550,012	$ 2,550,012	$ 2,550,012
Total Annual Cost	*/yr*	$ 34,828,494	$ 44,689,662	$ 75,253,158	$ 42,423,431	$ 56,939,560	$ 93,811,754
SO_2 removed	*ton/yr*	10,469	10,469	10,469	10,469	10,469	10,469
Average Cost Effectiveness	*/ton removed*	**$ 3,327**	**$ 4,269**	**$ 7,188**	**$ 4,052**	**$ 5,439**	**$ 8,961**

Source: U.S. EPA, Air Pollution Control Cost Estimation Spreadsheet (June 2019), available at https://www.epa.gov/sites/default/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm. We understand from facility engineers at Gavin that historically Gavin has been closer to 94% removal but is currently targeting 95% and it's percent removal in 2023 is 95%. *See, e.g.*, AECOM, SO_2 Four Factor Analysis Regional Haze Rule Second Decadal Review, December 16, 2020; TRC Environmental Corporation, Ohio Regional Haze SIP Second Implementation Period Supplemental Analysis, Evaluation of SO_2 Emissions and Reduction Options, December 21, 2023. Here, we assume a 98% removal efficiency with new scrubbers and calculate the additional SO_2 tons removed based on going from 94% to 98% removal efficiency.

TABLE A-2. COST-EFFECTIVENESS OF WET FGD AT GAVIN UNIT 2 (2019 $)

			Sensitivities				
		New WFGD	20-Year Equipment Life and 3.25% Discount Rate	10-Year Equipment Life and 3.25% Discount Rate	30-Year Equipment Life and 5% Discount Rate	30-Year Equipment Life and 8% Discount Rate	10-Year Equipment Life and 8% Discount Rate
New							
Control Efficiency	*%*	98	98	98	98	98	98
Capital Cost		$ 607,474,097	$ 607,474,097	$ 607,474,097	$ 607,474,097	$ 607,474,097	$ 607,474,097
Capital Cost/kW	*/kW*	$ 416	$ 416	$ 416	$ 416	$ 416	$ 416
Capital Recovery Cost	*/yr*	$ 32,013,885	$ 41,794,218	$ 72,107,175	$ 39,546,564	$ 53,943,700	$ 90,513,640
Fixed O&M Cost	*/yr*	$ 10,782,595	$ 10,782,595	$ 10,782,595	$ 10,783,685	$ 10,785,615	$ 10,785,615
Variable O&M Cost	*/yr*	$ 47,157,414	$ 47,157,414	$ 47,157,414	$ 47,157,414	$ 47,157,414	$ 47,157,414
Total Annual Cost	*/yr*	$ 89,953,894	$ 99,734,227	$ 130,047,184	$ 97,487,663	$ 111,886,729	$ 148,456,670
Uncontrolled SO2	*ton/yr*	$ 243,603	243,603	243,603	243,603	243,603	243,603
SO_2 removed	*ton/yr*	238,513	238,513	238,513	238,513	238,513	238,513
Average Cost Effectiveness	*/ton removed*	$ 377	$ 418	$ 545	$ 409	$ 469	$ 622
Existing WFGD							
Control Efficiency	*%*	94	94	94	94	94	94
Capital Recovery Cost	*/yr*	$ -	$ -	$ -	$ -	$ -	$ -
Fixed O&M Cost	*/yr*	$ 10,782,595	$ 10,782,595	$ 10,782,595	$ 10,783,685	$ 10,785,615	$ 10,785,615
Variable O&M Cost	*/yr*	$ 45,113,831	$ 45,113,831	$ 45,113,831	$ 45,113,831	$ 45,113,831	$ 45,113,831
Total Annual Cost	*/yr*	$ 55,896,426	$ 55,896,426	$ 55,896,426	$ 55,897,516	$ 55,899,446	$ 55,899,446
Uncontrolled SO2	*ton/yr*	$ 243,603	$ 243,603	$ 243,603	$ 243,603	$ 243,603	$ 243,603
SO_2 removed	*ton/yr*	$ 230,148	$ 230,148	$ 230,148	$ 230,148	$ 230,148	$ 230,148
Average Cost Effectiveness	*/ton removed*	$ 243	$ 243	$ 243	$ 243	$ 243	$ 243
Differentials							
Capital Recovery Cost	*/yr*	$ 32,013,885	$ 41,794,218	$ 72,107,175	$ 39,546,564	$ 53,943,700	$ 90,513,640
Fixed O&M Cost	*/yr*	$ -	$ -	$ -	$ -	$ -	$ -
Variable O&M Cost	*/yr*	$ 2,043,583	$ 2,043,583	$ 2,043,583	$ 2,043,583	$ 2,043,583	$ 2,043,583
Total Annual Cost	*/yr*	$ 34,057,468	$ 43,837,801	$ 74,150,759	$ 41,590,147	$ 55,987,283	$ 92,557,224
SO_2 removed	*ton/yr*	8,365	8,365	8,365	8,365	8,365	8,365
Average Cost Effectiveness	*/ton removed*	**$ 4,072**	**$ 5,241**	**$ 8,865**	**$ 4,972**	**$ 6,693**	**$ 11,065**

Source: U.S. EPA, Air Pollution Control Cost Estimation Spreadsheet (June 2019), available at https://www.epa.gov/sites/default/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm.

TABLE A-3. EFFECT OF IMPAIRED VISIBILITY ON NATIONAL PARK VISITATION

Visibility Target improvement	Increase in visible range	Recreational visit	Overnight stay	Day visit	Backcountry camping	Front country camping
%	km					
5%	2.75	460,188	26,582	423,907	3,067	10,238
10%	5.50	920,377	53,165	847,814	6,135	20,475
15%	8.25	1,380,565	79,747	1,271,721	9,202	30,713
20%	11.00	1,840,565	106,330	1,695,627	12,269	40,950
25%	13.75	2,300,942	132,912	2,119,534	16,336	51,188
Elasticity		1.01	1.17	0.98	0.76	1.13

Source: Neelam C. Poudyal, Bamadev Paudel, and Gary T. Green, "Estimating the Impact of Impaired Visibility on the Demand for Visits to National Parks," Tourism Economics 19 No. 2 (April 2013).

Appendix B: Expert Qualifications

Mark Berkman, Ph.D. is a Principal at The Brattle Group. He has over 30 years of experience as an applied economist. He has testified before federal and state courts across the United States and Canada on a range of matters for both plaintiffs and defendants. He has also testified before regulatory bodies and legislatures. Dr. Berkman's testimonies have addressed a range of topics including environmental damages, natural resource valuation, power plant siting, economic impacts of power plant closures, intellectual property valuation, regulatory impacts, antitrust, trade disputes, and statistical evidence of discrimination. He has frequently conducted benefit-cost studies regarding proposed environmental rules and regulations. Prior to joining Brattle in 2011, Dr. Berkman was a vice president of Charles River Associates and NERA Economic Consulting. Previously he was a budget and policy analyst at the Congressional Budget Office and a research assistant at the Urban Institute.

Metin Celebi, Ph.D, is a Principal at The Brattle Group. He provides expertise in electricity markets, resource planning, and analysis of environmental and climate policy. Dr. Celebi has consulted primarily in the areas of electricity litigation and regulatory disputes, including on the economic viability of coal-fired and nuclear power plants, wholesale power pricing, and market design. Dr. Celebi also has experience developing and analyzing federal and state climate policies, environmental regulations, LMP modeling, generation plant valuation, and transmission cost allocation.

Dr. Celebi has also served as an expert witness. He has testified on topics such as assessing the impact of mandates to install emission control equipment on economic viability of a coal plant; economic viability of coal plants and recovery of undepreciated past investments; transmission cost allocation; a long-term power contract dispute in California; the impact of coal plant retirements on wholesale energy prices in MISO; causes of locational marginal price (LMP) spikes in PJM; and the allocation of ancillary services costs among market participants in ERCOT.