Ex. AA-D-4

UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF MISSOURI
EASTERN DIVISION

UNITED STATES OF AMERICA, Plaintiff, and SIERRA CLUB, Plaintiff-Intervenor, vs. AMEREN MISSOURI, Defendant.	)	No. 4:11 CV 77 RWS

JUDGMENT

IT IS HEREBY ORDERED, ADJUDGED, AND DECREED that Defendant Ameren Missouri violated the Clean Air Act, 42 U.S.C. § 7401 *et seq.*

IT IS FURTHER ORDERED, ADJUDGED, AND DECREED that Defendant Ameren shall apply for a Prevention of Significant Deterioration permit for the Rush Island Energy Center within ninety days of the date of this Judgment. Ameren must propose wet flue-gas desulfurization as the technology-basis for its Best Available Control Technology proposal.

IT IS FURTHER ORDERED, ADJUDGED, AND DECREED that Defendant Ameren shall operate Rush Island Units 1 and 2 in compliance with an emissions limit that is no less stringent than 0.05 lb SO_2/mmBTU on a thirty-day rolling average within four and one half years of the date of this Judgment.

IT IS FURTHER ORDERED, ADJUDGED, AND DECREED that Defendant Ameren shall install a pollution control technology at least as effective as dry sorbent injection at the Labadie Energy Center within three years from the date of this Judgment. That technology shall remain in use at Labadie until Ameren has achieved emissions reductions totaling the same amount as the excess emissions from Rush Island, as defined in the Memorandum Opinion & Order filed herewith [ECF No. 1122], through the time Ameren installs BACT at Rush Island.

IT IS FURTHER ORDERED, ADJUDGED, AND DECREED that I will retain jurisdiction over this case until Ameren has fully implemented the remedies set forth in this Judgment and the Memorandum Opinion & Order filed herewith [ECF No. 1122].

Rodney W. Sippel

RODNEY W. SIPPEL
UNITED STATES DISTRICT JUDGE

Dated this 30th day of September, 2019.

Ex. AA-D-5

UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF MISSOURI
EASTERN DIVISION

UNITED STATES OF AMERICA,)
)
Plaintiff,)
)
and)
)
SIERRA CLUB,) No. 4:11 CV 77 RWS
)
Plaintiff-Intervenor,)
)
vs.)
)
AMEREN MISSOURI,)
)
Defendant.)

MEMORANDUM OPINION & ORDER

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INTRODUCTION

I. Summary

In 1970, Congress enacted the modern Clean Air Act to protect the nation's air resources and "promote the public health and welfare and the productive capacity" of the people. 42 U.S.C. § 7401(b)(1). Not satisfied with the results achieved under the 1970 statute, Congress amended the Clean Air Act in 1977 to add protections for areas meeting existing federal air quality standards. The 1977 amendments require newly-constructed power plants to install pollution controls. These pollution controls decreased the pollution coming from new plants. Acknowledging the cost of retrofitting old facilities, the 1977 amendments allowed existing plants to continue operating for their natural lifespan without pollution controls. Existing plants retained this "grandfathered" status until they were modified in any way beyond routine maintenance that increased emissions.

Ameren Missouri's (Ameren) Rush Island Energy Center (Rush Island) started operating in 1976, one year before the Clean Air Act Amendments. In the mid-2000's, as Rush Island was reaching the end of its natural lifespan, Ameren decided to conduct the most significant outage in Rush Island history to redesign and rebuild essential parts of Rush Island's boilers. To increase Rush Island's capacity and lengthen its life, Ameren reconstructed Rush Island's Unit 1 in 2007 and Unit 2 in 2010. Collectively, these construction outages lasted about 200 days and required more than 1,360 workers and almost 800,000 hours of labor. Rush Island's generating capacity and pollution emissions both increased as a result of these major modifications.

Before making these major modifications, Ameren should have obtained a Clean Air Act permit and installed the best pollution controls available, which were required after 1977 for all new and rebuilt power plants. Ameren did not apply for a permit. Forty-three years after it first came on-line, Rush Island is still operating without any pollution controls. It is now the tenth-highest source of sulfur dioxide pollution in the United States. More than two and a half years ago, I determined that Ameren had violated the Clean Air Act. During the last two and a half years, the parties have prepared and presented evidence to determine how to bring Ameren into compliance with the 1977 Clean Air Act. I held a trial in April 2019 on this issue.

In this memorandum order and opinion, I provide my findings of fact and conclusions of law from that trial. As a remedy, I will order Rush Island to come into compliance with the Clean Air Act by obtaining a permit under the Prevention of Significant Deterioration (PSD) program. I will also order Ameren to remedy Rush Island's excess pollution with ton-for-ton reductions at its nearby Labadie Energy Center. This remedy will satisfy the purpose of the Clean Air Act to "promote the public health and welfare and the productive capacity" of the people, and it is narrowly tailored to address the harms created by Ameren's violations.

II. Case History

In this Clean Air Act case, Plaintiff United States of America claims that Defendant Ameren increased the risk of negative health impacts and premature deaths by releasing excess pollution from Rush Island. Plaintiff is acting at the request of the United States Environmental Protection Agency (EPA). According to the EPA, Rush Island has released more than 162,000 excess tons of sulfur dioxide into the air because Ameren failed to apply for a permit that would require it to install pollution control technology when it redesigned and rebuilt its boilers at Rush Island. That sulfur dioxide transformed into fine particulate matter ($PM_{2.5}$) that can cause heart attacks, asthma attacks, strokes, and premature death. Had Ameren installed the required pollution control technology, it would have reduced its Rush Island pollution by 95% or more. To remedy these harms, the EPA seeks an order requiring Ameren to (1) obtain the required

Clean Air Act permit (2) install sulfur dioxide "scrubbers" at Rush Island, and (3) install pollution control technology at a second coal-fired power plant to account for the excess emissions Rush Island continues to release while it operates without pollution controls.

I separated the liability and remedies phases of this case to more orderly conduct discovery and presentation of arguments. In August and September 2016, the liability phase concluded with a 12-day bench trial. On January 23, 2017, I issued my memorandum opinion and order on the liability phase. I found that Ameren violated the Clean Air Act, 42 U.S.C. § 7470 et seq., by overhauling its coal-fired boilers at Rush Island without obtaining the required permits. On February 16, 2017, I granted the Sierra Club's motion to intervene in this suit as a matter of right. [ECF No. 863].[1]

In April 2019, I held a six-day bench trial to determine the appropriate remedy in this case. In this memorandum order and opinion, I set forth findings of fact and conclusions of law from the remedies phase trial. These findings and conclusions depend in significant part on the evidence presented and conclusions made during the liability phase. Accordingly, I will summarize aspects of the liability phase trial as follows.

III. Liability Phase Findings of Fact and Conclusions of Law

Rush Island is a pulverized coal-fired power plant in Jefferson County, Missouri, directly adjacent to the Mississippi River. Rush Island's two units went into service in 1976 and 1977, immediately before the 1977 Clean Air Act Amendments. Because of this timing, Rush Island is one of many power plants that were grandfathered into the Clean Air Act's permitting scheme.

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[1] Throughout this memorandum opinion and order, I sometimes refer to the Plaintiffs jointly. Frequently, I refer to the EPA's arguments, experts, and evidence without mentioning Sierra Club. These references reflect that the EPA presented much of the evidence at trial. Sierra Club was also present for the entire remedies trial, and independently has standing to seek the injunctive relief I order in this case.

The Rush Island plant currently emits about 18,000 tons of SO_2 per year. Neither of Rush Island's units has air pollution control devices for SO_2.

Under the Clean Air Act, every new or modified major pollution source must obtain one of two permits: a Non-Attainment Area permit when they are built in areas more polluted than the National Ambient Air Quality Standards (NAAQS), or a Prevention of Significant Deterioration (PSD) permit when they are built in attainment areas, which are less polluted than the NAAQS. 42 U.S.C. § 7470 et seq. The EPA sets NAAQS for six criteria pollutants at levels "requisite to protect the public health." 42 U.S.C. § 7409(b). However, NAAQS alone are insufficient to meet the goals of the Clean Air Act: Congress determined that even in attainment areas, air pollution control was necessary "to ensure that the air quality in . . . areas that are already 'clean' will not degrade." Alaska Dep't of Envtl. Conservation v. E.P.A., 540 U.S. 461, 470 (2004) (quoting R. Belden, Clean Air Act 6 (2001) at 43).

Congress has made some exceptions to blunt the impact of the Clean Air Act. Specifically, the Act does not require existing facilities to immediately install pollution controls. Instead, the Act allows these facilities to continue operating through their normal lifespans. This grandfathering only lasts until these plants cease operating or undergo major modifications. Any plant that is retired but reactivated loses its grandfathered status and must obtain a permit. A plant that is rebuilt in any significant way must obtain a permit as well.

Accordingly, the Clean Air Act represents a compromise: by limiting the duration of grandfathering to facilities' natural life, Congress prevented existing polluters from maintaining in perpetuity their *advantage* over new plants.

> [O]ld plants [are treated] more leniently than new ones because of the expense of retrofitting pollution-control equipment. But there is an expectation that old plants will wear out and be replaced by new ones that will be subject to the more stringent pollution controls that the Clean Air Act imposes on new plants. One

> thing that stimulates replacement of an old plant is that aging produces more frequent breakdowns and so reduces a plant's hours of operation and hence its output.

United States v. Cinergy Corp., 458 F.3d 705, 709 (7th Cir. 2006). Through the "major modification" exception to grandfathering, Congress memorialized this compromise as a matter of law.

Major modifications occur when there is a "physical change" or change in the method of operation of a major stationary source that would significantly increase net emissions. See United States v. Ameren Missouri, 2016 WL 728234, at *4 (citing 40 C.F.R. § 52.21(b)(2)(i)). An increase of 40 tons or more per year of sulfur dioxide ("SO_2"), the pollutant discussed in this case, is "significant" under the regulations. 40 C.F.R. § 52.21(b)(23)(i).

Under the Clean Air Act, if a grandfathered polluter ever modifies its facilities, it must do four things: (1) calculate the impact of those modifications, (2) report the planned modifications to the EPA, (3) obtain the requisite permits, and (4) install the required pollution control technologies at that time. This process ensures that any "major modifications" are identified, reported, and permitted. Ameren made major modifications to Rush Island without reporting those modifications and obtaining a permit.

The natural life of many of Rush Island's component parts is 30 to 40 years. Consistent with those lifespans, by 2005, major boiler components at Rush Island were experiencing performance problems including leaks, slagging, fouling, plugging, gas flow resistance, erosion, and mechanical failure. These problems forced Ameren to take the units offline with increasing frequency so that they could be unplugged, repaired, and otherwise serviced. These aging problems also reduced the capacity of the Rush Island boilers by slowing gas flow and reducing the gas volume moving through each boiler. See United States v. Ameren Missouri, 229 F. Supp.

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3d 906, 922-936 (E.D. Mo. 2017).

Ameren sought to increase its plant capacity by redesigning and replacing essential components of both boilers, specifically the economizer, reheater, air preheater, and the "lower slope" panels surrounding the boiler. Ameren overhauled Unit 1 and Unit 2 in this manner in 2007 and 2010, respectively. After Ameren replaced these components at each unit, that unit's electric generating capacity increased immediately to levels that had not been seen in years. To achieve this improved capacity, Ameren employed more than 1,000 workers over several years. For example, "[t]he 2010 major boiler outage at Rush Island Unit 2 lasted approximately 100 days and required more than 350,000 hours of labor, of which 290,953 hours were performed by contractors. An average of 360 contractor staff worked two 10-hour shifts six days a week during the outage." United States v. Ameren Missouri, 229 F. Supp. 3d 906, 943 (E.D. Mo. 2017). The outage at Unit 1 was similar in scope and length, and both units' projects required years of planning.

Additional evidence presented at trial established that Ameren's work at both units did not constitute "routine maintenance." The new components in each boiler were designed, engineered, and constructed by outside contractors, and the complexity of the replacements was beyond the capacity of Ameren's in-house staff. Id. at 1001. The replaced equipment was so large and heavy that monorails had to be built to transport it at the construction site. Id. Ameren budgeted and paid for these projects out of its capital budget instead of its operations and maintenance budget. Id. at 1002. The Rush Island modifications required approval from high-level Ameren executives, which is unnecessary for routine maintenance. Id. at 1001. Ameren's Vice President called the 2007 modifications the "most significant outage in Rush Island history" and referred to the replacement of the economizer, reheater, air preheater, and lower slopes as distinct from other "routine maintenance that had to be performed" during the outage. Id. at 943.

Ameren's own internal metrics demonstrated an actual increase in emissions at Rush Island. Specifically, Ameren recorded outages and "derate" events, where Rush Island's maximum output was reduced. Ameren recorded these events contemporaneously in its Generating Availability Data System (GADS), and based staff bonuses in part on availability data. Id. at 931-933. Between 1997 and 2007, Unit 1's availability fluctuated between 70% and 90%. Id. at 949. Following its upgrade, Unit 1's availability increased to 96.77% in 2008. Id. at 954. This value was higher than any 12-month period at Unit 1 since 1990. Id. Unit 2's availability increased from 94.5% during a five-year baseline to 97.4% after the modifications. Id. at 958. This value was higher than any 12-month period at Unit 2 since 1987. Id. Ameren's employees have admitted that those availability increases would not have happened but for the projects.

Courts recognize these availability improvements as leading to emissions increases. "A significant decrease in outages results in a significant increase in both production and emissions." United States v. Ohio Edison Co., 276 F. Supp. 2d 829, 834-35 (S.D. Ohio 2003). "If the repair or replacement of a problematic component renders a plant more reliable and less susceptible to future shut-downs, the plant will be able to run consistently for a longer period of time," emitting more pollution as the plant is operated. United States v. Ala. Power Co., 730 F.3d 1278, 1281 (11th Cir. 2013).

With the facts presented at trial, the preponderance of evidence demonstrated that (1) Ameren conducted a "major modification" when it used more than 1,000 workers to design and replace essential components of Rush Islands boiler units in 2007 and 2010; (2) Ameren should have expected those modifications to increase emissions by more than forty tons of sulfur dioxide per year; (3) those modifications actually increased emissions by reducing future stoppages, increasing plant capacity, and extending the life of the plant; and (4) those modifications were, in Ameren's expert's words, not de minimis or routine modifications, nor did emissions increase because of demand alone.

Ameren should have obtained a Clean Air Act permit before beginning its major boiler modification. Ameren did not seek that permit. As a part of the permitting process, major pollution sources like Rush Island are required to have the Best Available Control Technology (BACT) when they undergo major modifications. Rush Island did not have any pollution control technology. Twelve and nine years since Ameren overhauled Unit 1 and Unit 2, respectively, Rush Island still does not have any pollution control technology. Through the end of 2016, Rush Island emitted 162,000 tons of sulfur dioxide more than it would have had Ameren complied with its obligations under the Clean Air Act.

Now, in the remedy phase of the trial, Ameren and the EPA dispute whether I should order injunctive relief in this case and what injunctive relief is appropriate. In September 2018, the parties filed five separate motions for summary judgment, three from Ameren, one from the EPA, and one from Plaintiff-Intervenor Sierra Club on the subject of standing. I granted the Sierra Club's motion for summary judgment on standing with respect to relief requested at Rush Island. [ECF No. 1055] There was no dispute of material fact that Sierra Club's members were injured in fact, their injuries were traceable to Ameren's excess emissions, and pollution reductions at Rush Island would redress their injuries.

I denied the parties' other motions for summary judgment. Neither the EPA nor Ameren demonstrated that there was no dispute of material fact concerning the appropriate remedy. I must evaluate injunctive relief relying on the "well-established principles of equity" the Supreme

Court articulated in eBay Inc. v. MercExchange, L.L.C., 547 U.S. 388, 391 (2006).[2] Based on the parties' filings, I could not say as a matter of law what injunctive relief was required pursuant to the eBay factors.

In April 2019, the EPA and Ameren presented their arguments concerning remedies over six days of trial. The EPA requests an order requiring Ameren to obtain a PSD permit for Rush Island, (2) propose Flue Gas Desulfurization (FGD) scrubbers as the appropriate permit technology, (3) meet an emissions limitation based on FGD scrubbers, and (4) address ton-for-ton excess emissions from Rush Island by installing pollution control technology on Ameren's Labadie Energy Center. Based on the extensive testimony provided by its experts, the EPA argues that the eBay factors support this relief.

Ameren argues that it did not have fair notice of the EPA's legal interpretations, that there is no evidence of harm created by its SO_2 emissions, that Ameren has already decreased its emissions, that it should have had the opportunity to apply for a much less stringent "minor permit," and that the expense of installing scrubbers is unduly burdensome.

In addressing these arguments, I note that by making major modifications without satisfying the requirements of the Clean Air Act, Ameren reaped significant financial benefits. According to Ameren's 2011 estimates, installing wet FGDs at Rush Island would cost between $650 million and $960 million. September 19, 2011 Project Plan (Pl. Ex. 1102), at AM-REM-00294509. Ameren deferred these costs for more than ten years at the expense of downwind communities that it will never have to fully repay. Instead, I may only order remediation enough to account for the total amount of excess emission released by Ameren, a remedy that is more

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[2] Though the eBay case did not establish the governing standard for a permanent injunction, I will rely on the eBay Court's presentation of the "familiar principles" as a four-factor test. eBay, 547 U.S. at 391. In this memorandum opinion and order, I refer to the factors as the "eBay factors" or "eBay standard."

than a decade late, but which is closely tailored to the harm suffered by these communities.

Accordingly, and based on the evidence presented at trial, I conclude that the following injunctive relief is necessary to remedy the harm created by the more than 162,000 tons of excess pollution Ameren released from Rush Island: Ameren must (1) apply for and obtain the applicable Clean Air Act permit from the Missouri Department of Natural Resources (MDNR) for its Rush Island Plant, (2) propose wet flue gas desulfurization (FGD) as the required control technology for Rush Island, (3) meet an emissions limitation of 0.05 lb/mmBTU at Rush Island and (4) install and use dry sorbent injection (DSI) technology, or another more effective control technology, at its Labadie Energy Center (Labadie), until it reduces pollution from Labadie in an amount equal to the excess emissions from Rush Island.

This remedy results from the following findings of fact and conclusions of law. In summary, I find that the EPA's experts convincingly and credibly testified that wet FGD is the most effective control technology that could be used at Rush Island. Additionally, when considering the energy, environmental, and economic impacts, wet FGD is achievable at Rush Island. As a result, wet FGD is the Best Available Control Technology (BACT) for Rush Island. The EPA's experts also convincingly and credibly testified that Ameren's failure to install BACT at Rush Island has led to more than 162,000 tons of excess SO_2 emissions and increased the risk of health problems and premature mortality in the exposed population. Considering this evidence, I conclude that ordering commensurate reductions at Labadie is a remedy that is closely tailored to the harm suffered, addresses irreparable injury that could not be compensated through legal remedies, serves the public interest, and is warranted when considering the balance of hardships in this case.

FINDINGS OF FACT

I. BACKGROUND: RUSH ISLAND'S MAJOR MODIFICATIONS

a. Ameren Redesigned and Rebuilt Units 1 and 2 Near the End of Their Design Life

1. Rush Island Units 1 and 2 began operating in 1976 and 1977. They were originally grandfathered into compliance with the Clean Air Act without needing to install BACT emission limitations imposed by the Prevention of Significant Deterioration (PSD) program. Ameren Missouri, 229 F.Supp.3d at 915.

2. Neither Rush Island Unit 1 nor Rush Island Unit 2 has installed any air pollution control devices for SO_2 emissions. Id.; see also id. at 917 (Liability Findings ¶ 8).

3. Rush Island Units 1 and 2 were originally designed to have an approximately 30-year life, with components typically lasting 30 to 40 years. Id. at 917 (Liability Findings ¶ 5). By 2007 and 2010, when Ameren modified Rush Island Units 1 and 2, they had already been operating for 30 years. Ameren has already run the Rush Island plant ten years longer than it expected at the time the plant was constructed.

4. The 2007 and 2010 modifications ended Rush Island's grandfathered status under the PSD program. The modifications were made during the most significant outage in Rush Island plant history and were justified based on increasing plant operations and revenue. Id. at 915; see also id. at 940 (Liability Findings ¶¶ 155-160), 943 (Liability Findings ¶ 172).

b. Modifications at Rush Island Led to Actual Emissions Increases

5. At trial, Ameren argued that it had reduced both its fleetwide SO_2 emissions and its emissions from Rush Island. In 2010, Ameren began operating pollution control equipment, specifically Flue Gas Desulfurization (FGD) scrubbers, at its Sioux pulverized coal-fired power plant northeast of Rush Island. Knodel, Tr. Vol. 1-A, 88:16-89:2. Ameren also converted two of

its four units at the Meramec Energy Center to natural gas combustion. Michels, Tr. Vol. 5-B at 5:22-6:7. These changes decreased emissions from the Sioux and Meramec plants. (Ex. UU).

6. Ameren did not install pollution control equipment at Rush Island or its Labadie Energy Center, although it began using lower sulfur coal at these two plants. Michels, Tr. Vol. 5-B, 5:22-6:7.

7. Ameren has not submitted evidence demonstrating that Rush Island's emissions have decreased or stayed the same after its major modifications. At the remedies phase trial, and in its proposed findings of fact, Ameren did not present any data demonstrating Rush Island's emission rate before 2007. Without that information, Ameren cannot demonstrate that its emissions decreased or stayed the same after its major modifications.

8. After the liability trial, I found that Ameren's modifications at Rush Island had increased emissions from Unit 1 by about 665 tons per year and from Unit 2 by about 2,171 tons per year. Ameren Missouri, 229 F. Supp. 3d 906, 955, 959.

c. Rush Island Is One of a Small Minority of Similar Plants That Continue to Operate Without SO_2 Scrubbers

i. SO_2 Scrubbers Are Widely Used in the Electric Utility Industry

9. There are two ways to reduce the amount of SO_2 emitted from a pulverized coal-fired electric generating unit: (1) reduce the sulfur content of the source coal, and (2) use a control system to capture SO_2 before it is released to the atmosphere. The main types of control technology used to capture SO_2 are FGD scrubbers and dry sorbent injection (DSI) technology. Staudt Test., Tr. Vol. 1-B, 12:20-13:14; Callahan Dep., Nov. 8, 2017, Tr. 44:3-10 (testimony of Ameren supervisor of environmental projects).

10. FGD scrubbers have been widely used to reduce SO_2 from coal-fired electricity generating units for decades. Staudt Test., Tr. Vol. 1-B, 15:2-4; Mar. 2009 Rush Island FGD

Project Technology Selection Report (Pl. Ex. 1029), at AM-02638262 and AM-02638283; Missouri Department of Natural Resources (MDNR) Rule 30(b)(6) Dep., Aug. 10, 2018, Tr. 141:23-142:3.

11. Scrubbers can either be "wet" or "dry," depending on the amount of moisture introduced into the gas stream. Wet FGD systems introduce more moisture, reducing the temperature of the gas stream and keeping some water in the form of droplets, rather than vapor. Water droplets create a more reactive environment, increasing the amount of SO_2 "scrubbed" from the exhaust. Additionally, the lower temperatures in a wet FGD system are compatible with using limestone as the "scrubbing reagent." Limestone is cheap and readily available in Missouri. Staudt Test., Tr. Vol. 1-B, 13:4-14:12; see also Mar. 2009 Rush Island FGD Project Technology Selection Report (Pl. Ex. 1029), at AM-02638262 and AM-02638283.

12. Dry FGD systems cool the gas stream less than wet FGD systems do. They use hydrated lime as a reagent, remove less SO_2 than dry systems do, and produce a dry waste product that must be disposed of at cost. Staudt Test., Tr. Vol. 1-B, 13:4-14:12; see also Mar. 2009 Rush Island FGD Project Technology Selection Report (Pl. Ex. 1029), at AM-02638262 and AM-02638283.

13. Wet FGD scrubbers are the most effective SO_2 control technology. They can remove more than 99% of a plant's SO_2 emissions. Dry FGD scrubbers are slightly less effective, but they can still remove more than 95% of a plant's SO_2 emissions, depending on the type of coal being burned. Staudt Test., Tr. Vol. 1-B, 14:13-15:1; Snell Test., Tr. Vol. 4-B, 50:8-22; Harley Dep., Apr. 11, 2018, Tr. 100:17-101:6 (testimony of Ameren Director of Project Engineering); see also March 2008 EPRI Report: Flue Gas Desulfurization Performance Capability (Pl. Ex. 1045), at AM-02699777 ("plants designed for 99% removal are scheduled to

be operating in late 2008 or early 2009").[3]

14. As illustrated by Figure 1, scrubbers have been used at pulverized coal-fired power plants dating back to the early 1970s. As of 2016, most of the coal-fired generating capacity operating in the United States was produced by power plants with scrubbers. Specifically, 200,000 megawatts of capacity was available at scrubbed coal-fired units out of 250,000 megawatts of capacity at all coal-fired electric generating units. Staudt Test., Tr. Vol. 1-B, 15:2-25; Black & Veatch Rush Island FGD Technology Selection Report (Pl. Ex. 1029), at AM-02638262.

15. Of that 200,000 megawatts, wet scrubbers account for about 170,000 megawatts, while dry scrubbers account for the other 30,000 megawatts. Staudt Test., Tr. Vol. 1-B, 15:2-25, 19:9-21:15; see also Black & Veatch Rush Island FGD Technology Selection Report (Pl. Ex. 1029), at AM-02638262. Wet scrubbers are by far the dominant SO_2 control technology for power plants.

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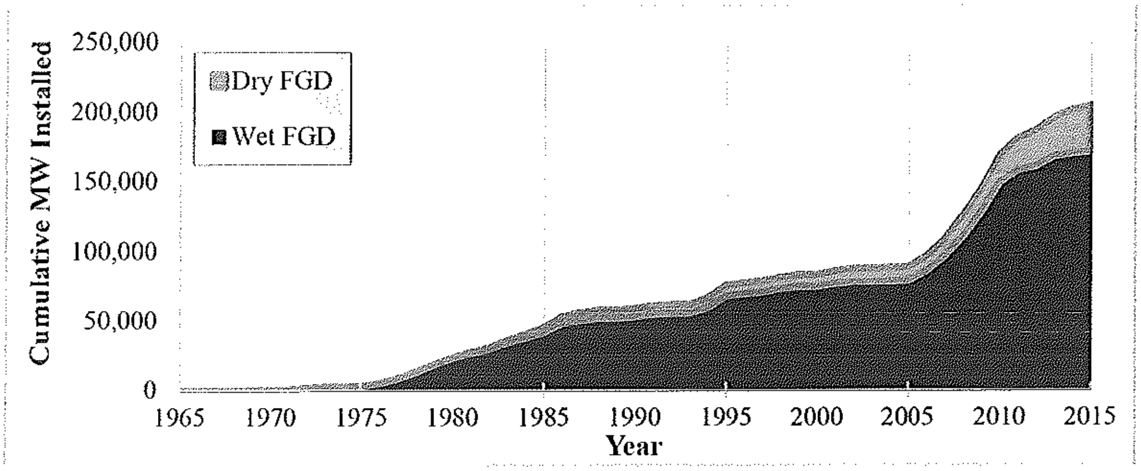
[3] The Electric Power Research Institute (EPRI) is a research arm of the electric utility industry. Ameren and other utilities fund EPRI to research and provide reports on the best practices on a variety of issues, including the performance and cost of pollution controls. Callahan Dep., Nov. 8, 2017, Tr. 58:15-21, 59:8-18; Harley Dep., Apr. 11, 2018, Tr. 38:22-40:3.

Ex. AA-D-5

Figure 1

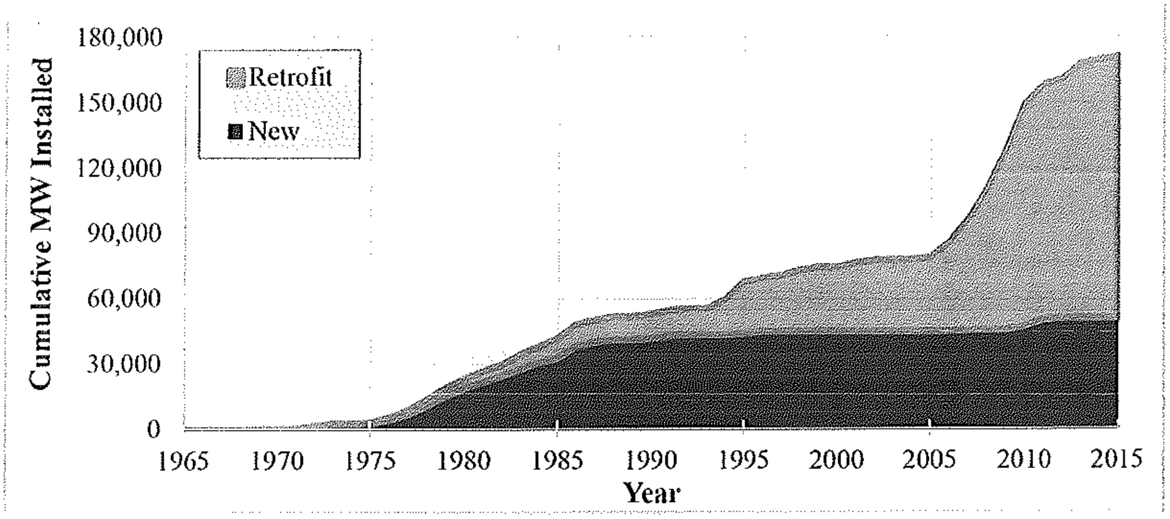


16. Scrubbers are currently installed on hundreds of coal-fired electric generating units, including approximately 84% of coal-fired power plants in the United States, weighted by generating capacity. Knodel Test., Tr. Vol. 1-A, 77:6-9; Staudt Test., Tr. Vol. 1-B, 15:17-16:10; see also Stumpf Dep., Mar. 27, 2018, Tr. 48:18-25 (Ameren project manager testifying that FGDs have become prevalent in the utility industry); Harley Dep., 51:1-52:25 (Ameren senior director testifying about scrubber "boom" in the utility industry); Mitchell Dep., May 30, 2018, Tr. 39:14-18 (Ameren project engineer testifying that scrubbers were well-established at the time of the FGD engineering studies for Rush Island).

17. The vast majority of wet scrubbers operating at power plants today were installed on existing plants, as illustrated by Figure 2. About 120,000 megawatts of the total 170,000 megawatts of wet scrubber capacity operating in 2015 was installed on existing plants. Most of that scrubbed capacity was installed between 2005 and 2015. Staudt Test., Tr. Vol. 1-B, 65:13-66:16.

Ex. AA-D-5

Figure 2



18. Rush Island's continued operation without pollution controls has made it one of the largest sources of SO_2 pollution in the United States. Between 1997 and 2017, Rush Island moved from being the 154th to the 10th highest man-made source of SO_2 emissions in the country. Knodel Test., Tr. Vol. 1-A, 73:6-74:5.[4]

ii. DSI Controls Are Not Commonly Installed on Units of Rush Island's Size

19. Unlike FGD control technology, dry sorbent injection does not require a reaction vessel or added moisture. Instead DSI involves blowing reagent directly into the duct work downstream of the coal-fired boiler. A fabric filter or baghouse (hereinafter referred to as DSI-FF) can be added to remove particulate matter and increase overall removal efficiency of sulfate and other pollutants. Without a baghouse, an ordinary DSI system can remove 50% of SO_2 emissions. With a baghouse, a DSI-FF can remove 70% SO_2 reductions. Staudt Test., Tr. Vol. 1-B, 16:11-17:22; Snell Test., Tr. Vol. 4-B, 10:18-11:9; Harley Dep., Apr. 11, 2018, Tr. 163:2-19

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[4] In that same year, Ameren's Labadie plant ranked as the fourth highest SO_2 emitter in the United States, and Missouri as a whole had become the second highest SO_2 emitting state in the country, behind only Texas. Knodel Test., Tr. Vol. 1-A, 74:6-15.

(testifying that DSI typically can achieve 40 to 50% reductions).

20. There are only a handful of units the size of Rush Island that currently use DSI for SO_2 control. None of those systems were in operation prior to 2007 when Ameren undertook the major modifications at issue in this case. Neither party presented testimony identifying the source category to which those large units with DSI belong. Staudt Test., Tr. Vol. 1-B, 52:10-17; Tr. Vol. 2-A, 33:1-11.

21. Ameren's expert Colin Campbell admitted that Rush Island would be the first power plant to have BACT determined based on the use of DSI, Test., Tr. Vol. 4-A, 98:3-7.

d. Ameren Evaluated FGD Installation at Rush Island

22. Although Ameren did not install control technology at Rush Island, Ameren spent about $8 million between 2008 and 2011 evaluating what control technology it should install. Staudt Test., Tr. Vol. 1-B, 17:23-19:7; Campbell Test., Tr. Vol. 4-A, 93:12-17; September 19, 2011 Project Plan (Pl. Ex. 1102), at AM-REM-00294508.

23. Ameren completed two phases of its evaluation. "[T]he first phase evaluated the various . . . technologies and the second phase utilized the selected technology (Wet FGD system) to develop a design basis, scope and detailed cost estimate." June 2, 2010 Request for Preliminary Work Order Authorization (Pl. Ex. 1095), at AM-REM-00288486.

24. The consulting firms Black & Veatch and Shaw prepared independent feasibility studies during these phases. Staudt Test., Tr. Vol. 1-B, 17:23-20:22; AmerenUE Rush Island Power Plant Technology Selection Report (Pl. Ex. 1029); Shaw Technology Evaluation (Pl. Ex. 1069); Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 134:13-135:2, 135:22-136:11, 138:16-138:20, 138:25-139:6 (identifying Pl. Exs. 1029 and 1069 as the final Phase 1 reports, which were the best estimates available at the time concerning the feasibility of using wet scrubbers at

Rush Island); Callahan Dep., Nov. 8, 2017, Tr. 119:17-120:9 (supervisor of the Phase 1 and 2 studies testifying Ameren hired multiple independent engineering firms to get a "better handle on potential cost as well as schedule").

25. Ameren's internal presentations indicate that these studies were designed to evaluate business planning and compliance options for a number of regulations, including the Cross-State Air Pollution Rule, rules for Hazardous Air Pollutants, and the New Source Review Program, the regulatory program at issue in this case. See June 1, 2010 CPOC Presentation, Scrubber Technology Assessment, Rush Island Plant (Pl. Ex. 1099), at AM-REM-00288980.

26. In Phase 1, Shaw solicited bids from six vendors with extensive experience installing FGDs. Shaw Technology Evaluation (Pl. Ex. 1069), at AM-REM-00191161; Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 138:25-139:12. After reviewing this and other information, Shaw recommended wet FGD for further review and eventual installation at Rush Island. This decision was "[b]ased on the overall evaluation of experience, performance, arrangement, operating flexibility, constructability, modularization, site impacts, capital costs, operating costs, maintenance and repair costs, and other attributes such as permitting, social-economic costs and public relations." Shaw Technology Evaluation (Pl. Ex. 1069), at AM-REM-00191196; Staudt Test., Tr. Vol. 1-B, 20:9-22:9.

27. Black & Veatch also recommended wet FGD for further review in Phase 1.

28. Ameren accepted the consulting firms' recommendations, selecting wet FGD for further evaluation in Phase 2. In Phase 2, Ameren requested more detailed cost estimates, engineering designs, and project execution plans for Rush Island. The Phase 2 reports were thousands of pages long, included bid information from FGD suppliers, and laid out a detailed schedule for installing FGD at Rush Island. Staudt Test., Tr. Vol. 1-B, 33:17-36:7; Callahan

Dep., Nov. 7, 2017, Tr. 165:16-166:20; May 2010 Shaw Final Report (Pl. Ex. 1071); August 2010 Black & Veatch Execution Plan and Report (Pl. Ex. 1115).

i. Ameren's Studies Recommended Wet FGD at Rush Island

29. As part of its efforts, Ameren evaluated the technical and economic feasibility of installing FGDs at Rush Island. These evaluations were summarized in several presentations given to Ameren management. February 5, 2010 Project Review Board Presentation-Rush Island FGD (Pl. Ex. 1100), at AM-REM-00288998 to 289000; June 1, 2010 Corporate Project Oversight Committee (CPOC) Presentation, Scrubber Technology Assessment, Rush Island Plant (Pl. Ex. 1099), at AM-REM-00288981 to 288987; March 2, 2009 Economic Value Analysis for Rush Island FGD Project Plan (Pl. Ex. 1023), at AM-02634859 to 2634860.

30. Based on its evaluations, Ameren's corporate project oversight committee agreed that wet FGD technology (1) was technically and economically feasible at Rush Island, (2) was the right choice for complying with, among other things, New Source Review, and (3) should be pursued further in contract development. Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 58:24-59:12, 59:25-60:22, 82:3-83:17.

31. Ameren explained in one of its management presentations that wet FGD was its "technology choice for SO_2 removal at Rush Island" because of its "advantages in cost, capability and flexibility" over other options. June 1, 2010 CPOC Presentation, Scrubber Technology Assessment, Rush Island Plant (Pl. Ex. 1099), at AM-REM-00288987.

32. For coal-fired power plants, the emission limitation is typically stated in terms of pounds of pollutant per million BTU of heat input (lb/mmBTU). This unit represents the amount of pollution emitted per unit of fuel put into the boiler. Knodel Test., Tr. Vol. 1-A, 39:1-6. The emission limitation is always accompanied by an averaging time; for coal-fired power plants,

typically the averaging time used is a 30-day rolling average to help address variability on a day-to-day basis. Knodel Test., Tr. Vol. 1-A, 39:7-11.

33. Ameren concluded that the wet FGD systems have the advantage of "[d]emonstrated performance" to meet an SO_2 emission rate guarantee of 0.06 lb/mmBTU. June 1, 2010 CPOC Presentation (Pl. Ex. 1099), at AM-REM-00288984; Callahan Dep., Nov. 8, 2017, Tr. 201:13-21 (agreeing that 0.06 pounds per million BTU was a demonstrated number that could be achieved).

34. Ameren rejected the less-effective DSI technology because it was "[n]ot commercially demonstrated" and "not proven to meet low emissions requirements." June 1, 2010 CPOC Presentation (Pl. Ex. 1099), at AM-REM-00288984.

35. Ameren concluded that wet FGD also had advantages with respect to other environmental impacts, including the removal of Hazardous Air Pollutants (HAPs). Staudt Test., Tr. Vol. 1-B, 40:12-41:7. For example, wet FGD helps remove other acid gases. June 1, 2010 CPOC Presentation, Scrubber Technology Assessment, Rush Island Plant (Pl. Ex. 1099), at AM-REM-00288985. Wet FGD also helps remove organic HAPs, in part due to lower flue gas temperatures. Id. Specifically, wet FGD helps remove oxidized mercury, sulfur trioxide, particulate matter, hydrogen chloride, and hydrogen fluoride. Direct Testimony of Mark Birk, Missouri Public Service Commission Case No. ER-2011-0028 ("Birk PSC Testimony"), Sept. 3, 2010 Tr. 3:20-4:2 (Pl. Ex. 1003); see also Callahan Dep., Nov. 8, 2017, Tr. 25:14-23. Wet FGD also eliminates landfill impacts because the gypsum byproduct can be sold to nearby cement plants. Id. at AM-REM-00288986.

36. Ameren concluded that wet FGD was an economically viable option as well. In Ameren's words "[e]conomic evaluation supported" the use of wet FGD at Rush Island. March

2, 2009 Economic Value Analysis for Rush Island FGD Project Plan (Pl. Ex. 1023), at AM-02634859; February 5, 2010 Project Review Board Presentation-Rush Island FGD (Pl. Ex. 1100), at AM-REM-00288999; June 1, 2010 CPOC Presentation: Scrubber Technology Assessment Rush Island Plant (Pl. Ex. 1099), at AM-REM-00288984 to 288986; August 20, 2010 Rush Island Progress Overview (Pl. Ex. 1101), at AM-REM-00289177; Staudt Test., Tr. Vol. 1-B, 23:2-7; Callahan Dep., Nov. 8, 2017, Tr. 186:7-10.

37. Wet FGD has a less expensive reagent than dry FGD or DSI. The wet FGD limestone reagent costs $28/ton; the dry FGD lime reagent costs $75/ton; and the DSI trona reagent costs $150/ton. Shaw Technology Evaluation (Pl. Ex. 1069), at AM-REM-00191180.

38. Ameren also determined that wet FGDs would not require the new induced draft booster fans that dry FGD would require. Instead, the existing fans would only need to be upgraded. Foregoing the new fans would reduce capital costs at Rush island by $37 to $50 million and would result in lower plant energy consumption. An additional $20 million could be saved by using limestone milling equipment at Ameren's Sioux power plant. June 1, 2010 CPOC Presentation, Scrubber Technology Assessment, Rush Island Plant (Pl. Ex. 1099), at AM-REM-00288983; Staudt Test., Tr. Vol. 1-B, 36:20-38:7, 55:5-15.

39. Wet FGD also provides greater fuel flexibility for Rush Island. Because wet FGD removes more SO_2 per ton of coal, Ameren could use higher sulfur coal in some circumstances while still meeting emissions limitations. Staudt Test., Tr. Vol. 1-B, 21:16-22:9; Callahan Dep., Nov. 8, 2017, Tr. 203:13-204:3; <u>see also</u> Birk PSC Testimony (Pl. Ex. 1003) Tr. 4:8-15 (describing fuel flexibility as advantage for wet FGDs in Sioux rate case).

40. Ameren's final project plan estimated that the total cost of installing wet FGDs at Rush Island would range from $650 million to $960 million, based on estimates provided by

multiple engineering firms. September 19, 2011 Project Plan (Pl. Ex. 1102), at AM-REM-00294509; see also February 5, 2010 Project Review Board Presentation-Rush Island FGD (Pl. Ex. 1100), at AM-REM-00289005; Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 87:11-88:1 (identifying these costs as the best estimates available to Ameren at the time of the cost of scrubbing Rush Island).

41. As part of its economic evaluation, Ameren also compared the estimated costs of installing wet FGDs at Rush Island to the costs incurred by other electric utilities for wet FGD installations. Ameren concluded that the costs of installing FGDs at Rush Island would be consistent with the costs borne by the rest of the industry to install scrubbers. See February 5, 2010 Project Review Board Presentation-Rush Island FGD (Pl. Ex. 1100), at AM-REM-00289006; Staudt Test. Tr. Vol. 1-B, 23:10-25:16, 56:20-57:6; Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 90:6-91:3.

42. Ameren also told the Missouri Public Service Commission in a formal planning document that it planned to install scrubbers on Rush Island and Labadie. Michels Test., Tr. Vol. 5-B, 17:6-18:19.

43. Wet FGD is an economically and technically feasible control technology for Rush Island. Staudt Test., Tr. Vol. 1-B, 42:19-24, 48:22-49:11.

ii. Ameren's Studies Confirmed the SO_2 Emission Rates Achievable at Rush Island

44. To design an FGD system cost estimate, a study must define the emission rate requirements of the proposed system. Staudt Test., Tr. Vol. 1-B, 6:19-7:12, 25:19-26:4; Callahan Dep., Nov. 8, 2017, Tr. 92:12-93:3, 129:8-130:9.

45. During the first two phases of Ameren's FGD study efforts, Ameren's engineering firms based their design work and cost estimates on an SO_2 emission rate target of

0.06 lb/mmBTU. May 2010 Shaw Final Report (Pl. Ex. 1071), at AM-REM-00194954 to 194955; August 2010 Black & Veatch Execution Plan and Report (Pl. Ex. 1115), at AM-REM-00324205 to 324206; Staudt Test., Tr. Vol. 1-B, 26:5-27:4; Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 145:21-146:3, 147:21-147:24, 158:13-21, 161:2-21; Callahan Dep., Nov. 8, 2017, Tr. 51:9-15, 123:8-124:14.

46. Ameren initially transmitted this 0.06 lb/mmBTU design rate to its outside engineering firms on October 3, 2008. When it did so, Ameren requested that the engineers assess whether FGDs could be designed to achieve even greater SO_2 reductions. Oct. 3, 2008 Letter to Black & Veatch (Pl. Ex. 1086) (requesting an assessment of "maximum achievable design basis" for SO_2 removal, "even if greater than the design values"); Oct. 3, 2008 Letter to Stone & Webster (Shaw) (Pl. Ex. 1085) (same). Concurrently, Ameren instructed its engineering firms to use a slightly higher "operating" value of 0.08 lb/mmBTU, which would "represent permit requirements" for the FGDs. Id.; Callahan Dep., Nov. 8, 2017, Tr. 93:20-94:5, 123:8-124:14.

47. Depending on the fuel being burned, Ameren estimated that these emission rate targets would reflect removal efficiencies of up to 99%. If Rush Island continued to burn lower sulfur PRB coal, then a design emission rate of 0.06 lb/mmBTU would reflect a 95% SO_2 reduction, while an operating rate of 0.08 lb/mmBTU would reflect a 90% reduction. Mar. 2, 2009 Economic Value Analysis for Rush Island FGD Project Plan (Pl. Ex. 1023), at AM-02634848.

48. As part of its FGD study efforts, Ameren also obtained FGD proposals from all of the major FGD suppliers in the United States, all of whom indicated that they could supply an FGD system capable of meeting Ameren's emission targets. Staudt Test., Tr. Vol. 1-B, 72:19-

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73:24.

49. For example, the company Alstom submitted a wet FGD proposal to Ameren in May 2009. May 21, 2009 Alstom WFGD Indicative Submittal (Pl. Ex. 1068). At that time, Alstom had over 50,000 MW of wet FGD systems either operating or under contract. Id. at AM-REM-00191035. Alstom confirmed it could meet Ameren's emission requirements, id., and highlighted its experience with several relevant wet FGD projects for Rush Island:

- A wet FGD installed for a new 750-MW unit at the JK Spruce plant in 2009. The plant burns PRB coal and was provided an emission guarantee of 0.06 lb/mmBTU or 96% removal.
- Wet FGDs contracted to be installed on two existing 450-MW units at the Coronado plant. The plant burns PRB and was provided an emission guarantee of 0.04 lb/mmBTU or 97% removal.
- A wet FGD installed on an existing 720-MW unit at the Iatan plant in 2008. The Iatan plant is located in Missouri, burns PRB coal, and was provided an emission guarantee of 0.021 lb/mmBTU or 98% removal.

Id. at AM-REM-00191071-73; see also Staudt Test., Tr. Vol. 1-B, 74:4-76:9.

50. After the Phase 2 reports were finalized, Ameren began the specification development process for wet FGD at Rush Island. Aug. 5, 2010 Conference Mem. (Pl. Ex. 1088). The final specification was thousands of pages long and extremely detailed. Staudt Test., Tr. Vol. 1-B, 42:25-44:13; Construction Specification Section 1600—Design Basis (Pl. Ex. 1144).

51. As part of the specification development process, Ameren tasked a team of its engineers to confirm the emission rate targets for the FGDs and prepare the specification in coordination with Ameren's outside engineers. Stumpf Dep., Mar. 27, 2008, Tr. 63:21-64:15, 151:6-153:22, 154:11-17, 158:22-159:20.

52. As a result of the specification development process, on September 23, 2010, Ameren lowered its SO_2 emission rate requirements for the Rush Island FGDs to 0.04

lb/mmBTU. Sept. 23, 2010 Letter to Black & Veatch (Pl. Ex. 1076); Nov. 1, 2010 Conference Mem. (Pl. Ex. 1091), at AM-REM-00286756; Stumpf Dep., Mar. 27, 2008, Tr. 190:12-22, 198:2-8, 218:17-219:9, 238:11-19.

53. The 0.04 lb/mmBTU SO_2 emission rate was the same emission rate guarantee that Ameren obtained for the FGD installed in late 2010 at its Sioux plant. Staudt Test., Tr. Vol. 1-B, 71:13-20; Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 206:10-207:11, 208:6-9.

54. Based on the coal expected to be used at Rush Island, the 0.04 lb/mmBTU emission rate reflects SO_2 removal efficiencies of 95 to 97 percent. Nov. 17, 2010 Letter from BV to Ameren (Pl. Ex. 1174) at BV2_0204414-15; Staudt Test. Tr. Vol. 1-B, 44:14-46:4.

55. Ultimately, an emission rate of 0.04 lb/mmBTU was used as the design basis in the construction specification. Staudt Test., Tr. Vol. 1-B, 42:25-44:13; Construction Specification Section 1600—Design Basis (Pl. Ex. 1144), at AM-REM-00538825; see also Stumpf Dep., Mar. 27, 2008, Tr. 252:6-253:10, 254:9-23, 286:20-287:5. This rate was retained as the design basis until Ameren suspended the FGD project in September 2011. September 19, 2011 Project Plan (Pl. Ex. 1102), at AM-REM-00294511; Staudt Test., Tr. Vol. 1-B, 44:14-46:4; Stumpf Dep., Mar. 27, 2008, Tr. 286:20-287:5.

56. The pollution control experts in this case agree that an SO_2 emission rate of 0.04 lb/mmBTU would be an achievable design emission rate for a wet FGD at Rush Island. Staudt Test., Tr. Vol. 1-B, 46:5-8; Snell Test., Tr. Vol. 4-B, 51:13-52:16.

iii. Ameren's Studies Demonstrate How Quickly Wet FGD Can Be Installed

57. When Ameren suspended the Rush Island FGD project in September 2011, its engineers put into place a "reactivation plan" in case FGDs later became required. September 9, 2011 Project Plan (Pl. Ex. 1102) at AM-REM-00294510 ("The following link is to a document

that outlines instructions for reactivating the project including … an estimated schedule . . . [:] WFGD Specification Reactivation."); see also Staudt Test., Tr. Vol. 1-B, 46:9-47:23; Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 228:6-15.

58. Ameren's reactivation plan provided that the "Complete WFGD Specification turn-over from Shaw" should be "considered the starting point for picking up where the original [FGD] team left off." WFGD Specification Reactivation Instructions (Pl. Ex. 1141).

59. The reactivation plan also included a schedule for completing the project upon reactivation. The plan provided that, upon reactivation, engineers would need two weeks to verify the chosen SO_2 technology (wet FGD). If the technology selection changed, engineers would need an additional ten weeks to create a new specification. After management approval, Ameren could send the project to FGD suppliers for bid within six months from re-activation (which was May 2016, under the then-proposed schedule). September 19, 2011 Project Plan (Pl. Ex. 1102), at AM-REM-00294512, AM-REM-00294580. Based on that schedule, the FGD could have been "on-line" by the end of 2020, representing a four and one-half-year process from the time of reactivation. Id.

60. This reactivation plan allows Ameren to install FGD controls more quickly by taking advantage of all the resources already invested in engineering wet FGDs for Rush Island. Staudt Test., Tr. Vol. 1-B, 46:18-48:6. By the time the project was suspended, Ameren had invested 3 years of engineering work and approximately $8 million on the project. September 19, 2011 Project Plan (Pl. Ex. 1102), at AM-REM-00294508; see also Stumpf Dep., Mar. 27, 2008, Tr. 64:21-65:2, 291:18-292:19.

61. Company documents refer to the "[e]ngineering activities for Rush Island FGD" as "a significant risk mitigation strategy in terms of cost and schedule." 2010 Project Review

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Board Presentation—Rush Island FGD (Pl. Ex. 1100), at AM-REM-00289019; see also, e.g., Ex. 1095, at AM-REM-00288487 ("Continuing with engineering activities for Rush Island FGD is a risk mitigation strategy for both cost and schedule."). The "risk" was the possibility that FGDs could be required by various drivers. Ameren's "response" was to "[g]et an early start on engineering in order to act as quickly as possible." Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 44:21-45:10, 47:24-48:13, 48:16-49:12, 101:18-103:1.

62. In light of the extensive amount of engineering work already completed, I find that Ameren would be able to install FGDs at Rush Island within four and one-half years from the date of the requirement to do so. September 19, 2011 Project Plan (Pl. Ex. 1102), at AM-REM-00294512, AM-REM-00294580 (May 2016 reactivation date and December 2020 online date).

II. RUSH ISLAND'S VIOLATIONS HAVE LED TO MORE THAN 162,000 TONS OF EXCESS SULFUR DIOXIDE POLLUTION

63. At the time Rush Island's boilers were modified, the surrounding airshed had attained the NAAQS for fine particulate matter, a key by-product of SO_2. Morris Test., Tr. Vol. 4-B, 69:4-24. Although part of Jefferson County is currently a non-attainment area for SO_2 itself, at the time of the modifications at Rush Island, it was in attainment of the SO_2 NAAQS. Therefore, the requirement to obtain a PSD permit and meet BACT emissions limitations applied to Rush Island. Ameren Missouri, 229 F.Supp.3d at 986; 42 U.S.C. §§ 7471, 7475.

64. Missouri is the PSD permitting authority for facilities in Missouri, pursuant to an EPA-approved State Implementation Plan, and is subject to EPA oversight. Knodel Test., Tr. Vol. 1-A, 45:2-23, 79:10-17; MDNR Rule 30(b)(6) Dep., Aug, 10, 2018, Tr. 101:13-15.

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a. PSD Requires the Best Available Control Technology

i. BACT Determination Is a Five-Step Process

65. Missouri and the EPA use the same definition of BACT, which applies to both new and modified sources. Campbell Test., Tr. Vol. 4-A, 90:24-91:6.

66. BACT is "an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation . . . which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility . . . ." 42 U.S.C. § 7479(3); Knodel Test., Tr. Vol. 1-A, 38:11-41:13.

67. An applicant for a PSD permit bears the responsibility when submitting its application of addressing all the steps in the BACT analysis. Knodel Test., Tr. Vol. 1-A, 51:19-23.

68. The permitting authority reviews each submission and determines if the analysis is correct. If the applicant's BACT analysis is incorrect, the permitting authority modifies the analysis to arrive at the appropriate BACT emissions limitation. In this case, Ameren should have prepared the initial BACT analysis, but the final BACT determination would have been made by MDNR with EPA oversight. Knodel Test., Tr. Vol. 1-A, 44:18-45:23, 53:11-54:18; Dec. 1, 1987 Memo on Improving NSR Implementation (Pl. Ex. 1320) at Campbell_EXP_0039928.

69. Because BACT requires "the maximum degree of reduction," BACT rates tend to get more stringent over time as pollution control technologies improve. Staudt Test., Tr. Vol. 1-B, 70:10-14, 80:23-81:3.

70. The EPA's Draft NSR Workshop Manual ("NSR Manual") outlines the BACT analysis process used by most permitting authorities, including MDNR. Knodel Test., Tr. Vol.

1-A, 48:12-20, 49:23-26, 50:2-6; MDNR Rule 30(b)(6) Dep., Aug. 10, 2018, Tr. 140:3-21.

71. The NSR Manual is the most commonly-referenced, commonly used guidance document for BACT analyses in the country. It is the most widely-distributed guidance relating to NSR that is not the regulations themselves. Campbell Test., Tr. Vol. 4-A, 90:4-10; see also id. at 88:17-89:19 (Ameren expert explaining that he provides a copy of the NSR Manual to participants in his BACT course, which focuses on the top-down method).

72. MDNR permit engineers rely on the NSR Manual in doing PSD reviews. MDNR Rule 30(b)(6) Dep., Aug. 10, 2018, Tr. 140:3-21.

73. Determining BACT involves a five-step, top-down process. Knodel Test., Tr. Vol. 1-A, 50:2-6; NSR Manual (Pl. Ex. 1190), at AM-REM-00544123-MDNR; MDNR Rule 30(b)(6) Dep., Aug. 10, 2018, Tr. 101:25-102:24, 106:4-7.

74. As part of the five-step process, the permit applicant

a. [Step One] Identifies all relevant control technologies for reducing the pollutant at issue, Knodel Test., Tr. Vol. 1-A, 50:7-16; NSR Manual (Pl. Ex. 1190), at AM-REM-00544123-MDNR.

b. [Step Two] Removes any technologies that are not technically feasible for the project in question, Knodel Test., Tr. Vol. 1-A, 50:17-24; NSR Manual (Pl. Ex. 1190), at AM-REM-00544123-MDNR,

c. [Step Three] Ranks the remaining technologies in order of control effectiveness, Knodel Test., Tr. Vol. 1-A, 50:25-51:10; NSR Manual (Pl. Ex. 1190), at AM-REM-00544123-MDNR,

d. [Step Four] Evaluates the technologies in sequence, from most effective to least effective, and selects the most effective technology that is achievable based on energy, environmental, and economic impacts and other costs, Knodel Test., Tr. Vol. 1-A, 51:11-13, 80:8-81:3; NSR Manual (Pl. Ex. 1190), at AM-REM-00544123-MDNR, and

e. [Step Five] Selects an emissions limitation rate based on the design and performance of other pollution sources that have already installed the control technology. Knodel Test., Tr. Vol. 1-A, 51:14-18; NSR Manual (Pl. Ex. 1190), at AM-REM-00544123-MDNR.

75. Step Four of the method gives the BACT determination a "top-down" character, because it starts with the top control option and moves in sequence to lesser options. If the energy, environmental, and economic impacts of the top option indicate that the technology is "achievable," then the analysis stops: the top control is the BACT technology. If the top control is not achievable, the next most-stringent control options are considered in sequence, until an achievable technology is settled on. Staudt Test., Tr. Vol. 1-B, 53:16-54:21; Campbell Test., Tr. Vol. 4-A, 92:20-25; NSR Manual (Pl. Ex. 1190), at AM-REM-00544119-MDNR. Again, as soon as an achievable technology is found in this sequence, the analysis stops, and that technology determines BACT.

76. The top-down approach applies regardless of whether a plant is new or is undergoing a modification. Knodel Test., Tr. Vol. 1-A, 106:20-25. Under the top-down approach, the burden of proof is on the applicant to justify why the proposed source is unable to apply the best technology available. Dec. 1, 1987 Memo on Improving NSR Implementation (Pl. Ex. 1320) at Campbell_EXP_0039928; Knodel Test., Tr. Vol. 1-A, 44:5-17.

77. Almost all Clean Air Act permitting agencies, including the Missouri Department of Natural Resources (MDNR), use the top-down method that is set forth in the

EPA's 1990 New Source Review Workshop Manual. Campbell Test., Tr. Vol. 4-A, 48:7-16, 90:20-23; Knodel Test., Tr. Vol. 1-A, 49:21-50:1, 79:22-80:2.

Cost-Effectiveness Calculations in a Top-Down BACT Analysis

78. Cost is one of several criteria considered in Step 4 of the BACT process, where applicants determine whether each control technology is achievable. Knodel Test., Tr. Vol. 1-A, 80:8-81:3.

79. However, step four of the BACT process is not a search for the most cost-effective controls; nor is it a cost-benefit analysis. Id.; Staudt Test., Tr. Vol. 1-B, 58:5-16. Rather, cost considerations are measured by what is achievable. 42 U.S.C. § 7479(3). "In the absence of unusual circumstance, the presumption is that sources within the same source category are similar in nature, and that cost and other impacts that have been borne by one source of a given source category may be borne by another source of the same source category." NSR Manual (Pl. Ex. 1190), at AM-REM-00544146-MDNR; Staudt Test. Vol. 1-B, at 63:14-64:6.

80. Similar language is found elsewhere in the NSR Manual: "BACT is required by law. Its costs are integral to the overall cost of doing business . . . Thus, where a control technology has been successfully applied to similar sources in a source category, an applicant should concentrate on documenting significant costs differences, if any, between the application of the control technology on those other sources and the particular source under review." NSR Manual (Pl. Ex. 1190) at AM-REM-00544148-MDNR.

81. MDNR specifically relies on the NSR Manual's guidance in considering the economic impacts of pollution controls under a BACT analysis. Staudt Test., Tr. Vol. 1-B, 64:7-10; Norborne PSD Permit (Pl. Ex. 1180), at AM-REM-00503313-MDNR (quoting NSR Manual); see also MDNR Rule 30(b)(6) Dep., at 138:20-139:6, 140:22-141:22) (MDNR witness

testifying that "when a permit writer looks at a permit application from, for example, a coal-fired utility, [] they would look towards other coal-fired utilities to determine the appropriate controls and what controls are already being used"). The focus is on other sources in the same source category, because they would face similar technical and economic circumstances. Staudt Test., Tr. Vol. 1-B, 64:11-19.

ii. Cost-Effectiveness Does Not Determine BACT

82. As one criterion under step four of the top-down method, applicants can also prepare calculations of cost-effectiveness. Average (or total) cost-effectiveness measures the cost of a control option in annualized costs per ton of pollution that it would reduce in a year. Staudt Test., Tr. Vol. 1-B, 57:19-58:4; NSR Manual (Pl. Ex. 1190), at AM-REM-00544153-MDNR to 544154-MDNR.

83. In contrast, incremental cost-effectiveness compares how much each additional ton of reduction costs as compared to another control option. Campbell Test., Tr. Vol. 4-A, 114:19-115:7. Staudt Test., Tr. Vol. 1-B, 92:1-14; NSR Manual (Pl. Ex. 1190), at AM-REM-00544158. Incremental cost-effectiveness is useful when comparing technologies "next" to each other in the effectiveness rankings, provided those controls result in similar emission rates. Staudt Test., Tr. Vol. 1-B, 92:15-23, NSR Manual (Pl. Ex. 1190), at AM-REM-00544158-MDNR ("The incremental cost effectiveness calculation compares the costs and emissions performance level of a control option to those of the next most stringent control option …") (emphasis added).

84. The NSR Manual cautions against over-reliance on incremental cost-effectiveness in eliminating a control under Step Four of the top-down method. Pl. Ex. 1190, at AM-REM-00544163-MDNR ("[U]ndue focus on incremental cost effectiveness can give an impression that

the cost of a control alternative is unreasonably high, when, in fact, the cost effectiveness, in terms of dollars per total ton removed, is well within the normal range of acceptable BACT costs."); see also In re General Motors, Inc., PSD Appeal No. 01-30, 10 E.A.D 360, 371 (E.A.B. Mar. 6, 2002) (the NSR Manual "places primary stress on the average cost measure").

iii. NSPS Do Not Fundamentally Alter the BACT Process

85. Alongside BACT requirements, all new major sources of pollution must meet "New Source Performance Standards" (NSPS). Pursuant to Section 111 of the Clean Air Act, the EPA establishes NSPS for different source categories. See 42 U.S.C. § 7411.

86. Ameren's expert admitted that the EPA sets the NSPS at rates that can be reasonably met by all new and modified sources in a source category, even though individual sources might be capable of lower emission rates. Campbell Test., Tr. Vol. 4-A, 98:14-18.

87. An applicable NSPS serves as a "floor" for the emission limit established as BACT. The BACT limit cannot be less stringent than the NSPS. 42 U.S.C. § 7479(3); In re Columbia Gulf Transm'n Co., PSD Appeal No. 88-11, 2 E.A.D. 824, 1989 WL 266361, at *4 (EPA 1989).

88. As the NSR Manual explains: "[T]he only reason for comparing control options to an NSPS is to determine whether the control option would result in an emission level less stringent than the NSPS. If so, the option is unacceptable." Ex. 1190, at AM-REM-00544129-MDNR (emphasis added).

89. "Simply meeting or exceeding the NSPS does not attest to the correctness of a BACT determination." Columbia Gulf, 1989 WL 266361, at *4. That NSPS sets "a 'floor' on emissions does not fundamentally change the BACT process of determining the 'best' available technology." United States v. Ameren Missouri, No. 4:11 CV 77 RWS, 2019 WL 1384631, at *3 (E.D. Mo. Mar. 27, 2019) (citing Columbia Gulf at *4).

90. The top-down method was originally developed in response to concerns that BACT analyses were inappropriately defaulting to the less-stringent and generally-applicable NSPS standards, without giving enough consideration to more stringent control options required for BACT. Knodel Test., Tr. Vol. 1-A, 47:14-48:9; June 13, 1989 Statement on Top Down BACT (Pl. Ex. 1321), at Campbell_EXP_0040089.

b. FGD Scrubbers Constitute BACT for the Vast Majority of Pulverized Coal-Fired Power Plants

i. The Electric Power Utility Industry Recognizes That FGD Constitutes BACT

91. BACT for a pulverized coal-fired power plant generally requires either wet or dry FGD scrubbers. Staudt Test., Tr. Vol. 1-B, 95:1-12. This trend results from the top-down process: scrubbers are the most-effective pollution controls. As the industry has progressed, an increasing number of plants have used scrubbers, demonstrating their achievability in different circumstances. See, e.g., supra Figure 1; ¶ 14.

92. As Ameren's Senior Director of Engineering and Project Management, Duane Harley, explained: "There's lots of different types of scrubbers in the market. Any one of those could be considered BACT. … Could be wet. Could be dry." According to Harley, dry scrubbers would be preferred in arid locations such as the West and wet scrubbers would typically be installed on plants that are larger than 300 MW. Harley Dep. Tr., Apr. 11, 2018, 97:5-98:8.

93. The electric power utility industry recognizes that FGD constitutes BACT for coal-fired units. In March 2008, the Electric Power Research Institute published a report on the performance capability of FGD systems. Staudt Test., Tr. Vol. 1-B, 85:7-86:19; see also supra Footnote 3. The report noted: "Many coal-fired units must comply with the Clean Air Act

(through New Source Review), consent decrees, or the Clean Air Visibility rules. Operators of these units have or will have to commit to installing FGD systems that meet the regulatory requirements of best available control technology (BACT) … ." 2008 EPRI Report (Pl. Ex. 1045), at AM-02699795.

94. Ameren itself has acknowledged that BACT may require FGD at Rush Island. Specifically, an Ameren presentation prepared in 2011 for the Missouri Public Service Commission indicates: "New Source Review lawsuit by EPA may require flue gas desulfurization (FGD) systems or scrubbers at Rush Island." April 2011 Presentation: Ameren Missouri Long Term Low Sulfur Coal Supply (Pl. Ex. 1009), at AM-02225205. It is well-understood that BACT at Rush Island would likely require installing scrubbers.

ii. During The Past Twenty Years, Every BACT SO_2 Determination for a Pulverized Coal-Fired Power Plant Has Required FGD

95. The prevalence of FGD at other plants is demonstrated by databases maintained by EPA Headquarters and Region 7. EPA Headquarters maintains a RACT BACT LAER Clearinghouse (RBLC) with a searchable database of BACT permit decisions made throughout the United States. The RBLC catalogues permitted technology and emissions limitations for individual facilities. Knodel Test., Tr. Vol. 1-A, 52:5-53:7.

96. From about 2002 until about 2015, EPA Region 7 also maintained a New Source Review Electricity Generating Unit Coal-Fired Spreadsheet on its website. The spreadsheet was designed to include every NSR application that had been submitted across the United States. It included information such as unit size, type of controls, and BACT limits. Knodel Test., Tr. Vol. 1-A, 34:20-35:8, 52:24-53:10.

97. Every BACT determination for SO_2 emissions from pulverized coal-fired power plants during the past twenty years has required wet or dry FGD as the required pollution control

technology. Staudt Test., Tr. Vol. 1-B, 77:20-78:2.

98. During this period, MDNR determined that BACT at a coal-fired power plant in Southwest Missouri requires the use of FGD controls for SO_2. Chipperfield v. Mo. Air Conservation Comm'n, 229 S.W.3d 226, 240 (Mo. Ct. App. 2007). As noted by the Missouri Court of Appeals in a decision upholding MDNR's BACT determination: "In general, pulverized coal-fired boilers burning low-sulfur coal, such as Powder River Basin ('PRB') coal, may use dry FGD, while boilers burning high-sulfur coals, such as eastern bituminous coal, must use wet FGD." Id.

99. EPA expert Jon Knodel is an environmental engineer with EPA Region VII who reviews permits for coal-fired power plants in Missouri. Id. at 32:17-20, 54:3-55:3. Based on Knodel's count, between 1999 and 2008, MDNR issued four air permits for coal-fired power plants. Knodel Test., Tr. Vol. 1-A, 54:22-55:3. All of these required either wet or dry FGD as the SO_2 control technology. Id. at 57:23-58:2, 59:10-15, 59:18-60:21, 60:24-61:3.

100. In 1999, MDNR issued a PSD permit to Kansas City Power and Light's Hawthorn plant with a 30-day SO_2 BACT limit of 0.12 lb/mmBTU, based on the use of a dry FGD. Knodel Test., Tr. Vol. 1-A, 59:10-17.

101. In 2004, MDNR issued a PSD permit for City Utilities' proposed Southwest power plant with a 30-day SO_2 limit of 0.095 lb/mmBTU, based on the use of dry FGD. Knodel Test., Tr. Vol. 1-A, 55:4-58:2; Dec. 15, 2004 Permit to Construct (Pl. Ex. 1004), AM-00134223-EPA, AM-00134224-EPA; see also Chipperfield, 229 S.W.3d at 240 (describing determination of BACT rate). In doing so, MDNR explicitly found that the costs of both wet and dry FGD were reasonable. Staudt Test., Tr. Vol. 1-B, 67:3-68:13; In the Matter of Appeal of City Utilities PSD Permit, 10/11/05 Hr'g Tr. (Pl. Ex. 1177) at 16:18-17:16.

102. In 2006, MDNR issued a permit for Kansas City Power and Light's Iatan power plant with 30-day SO_2 limits of 0.1 lb/mmBTU for the existing unit (Unit 1) and 0.09 lb/mmBTU for the new unit (Unit 2), based on the use of wet FGD at both units. Knodel Test., Tr. Vol. 1-A, 59:18-60:9; Jan. 31, 2006 Permit to Construct (Pl. Ex. 1034), at AM-02693650-53. After these permit limits were challenged by a third party, an amended permit was issued in 2007 with lower SO_2 limits of 0.07 lb/mmBTU for Unit 1 and 0.06 lb/mmBTU for Unit 2. Knodel Test., Tr. Vol. 1-A, 60:10-21; July 13, 2007 Amendment to Permit (Pl. Ex. 1283), at AMEREM_JES0007121-25; Staudt Test., Tr. Vol. 1-B, 81:20-82:13.

103. In 2008, MDNR issued a PSD permit to Associated Electric Cooperative, Inc. (AECI) for the proposed Norborne plant with 30-day SO_2 limits of 0.07 to 0.08 lb/mmBTU, based on the use of dry FGD. Knodel Test., Tr. Vol. 1-A, 60:22-61:3; Feb. 22, 2008 Letter Enclosing Permit to Construct (Pl. Ex. 1180), at AM-REM-00503274-MDNR to 3275-MDNR.

104. These Missouri permit limits are consistent with those issued by other permitting authorities for coal-fired power plants during the same period, all of which also required the use of wet or dry FGD. Staudt Test., Tr. Vol. 1-B, 77:20-78:2.

105. For example, Ameren's expert Colin Campbell testified about a PSD permit issued for the following non-Missouri plants: (1) In 2005, Newmont's TS power plant was permitted for an SO_2 limit of 0.065 lb/mmBTU; (2) in 2007, LS Power's Longleaf power plant was permitted for the same emission rate (0.065 lb/mmBTU); and (3) also in 2007, Basin Electric's Dry Fork power plant in Wyoming was permitted for an SO_2 limit of 0.07 lb/mmBTU. See Campbell Test., Tr. Vol. 4-A, 107:13-108:4, 131:17-132:1.

c. The Parties' Competing BACT Analyses

106. During trial, the parties each presented expert testimony concerning what BACT

would have been at the time that Ameren modified Rush Island. Based on what BACT would have been, I can determine how much SO_2 Ameren would have emitted had it complied with the law. Then, I can subtract that lower pollution amount from the SO_2 emissions that were actually released to determine Rush Island's "excess emissions." For clarity, I refer to this determination as a "historic BACT analysis." According the correct historic BACT analysis, Ameren's failure to install scrubbers at Rush Island resulted in 162,000 tons of excess SO_2 emissions through the end of 2016. The excess emissions are a measure of the harm suffered by Plaintiffs because of Ameren's violation of the Clean Air Act.

107. In support of their proposed historic BACT analysis, Plaintiffs presented the expert testimony of Dr. James Staudt. Dr. Staudt has a bachelor's degree in mechanical engineering from the Naval Academy and a Ph.D in mechanical engineering from Massachusetts Institute of Technology. Staudt Test., Tr. Vol. 1-B, 4:25-5:6. Dr. Staudt has decades of experience in the air pollution control industry, first working for supply companies and then later as a consultant on control technology issues for government agencies and industry clients. Id. at 5:20-11:14. Because of his work, Dr. Staudt has been familiar with the BACT requirements for decades, and has previously been accepted as an expert on SO_2 BACT issues in United States v. Westvaco, No. MGJ-00-2602 Trial Transcript, ECF No. 985-4 at 8:19-9:23; id. at 10:12-11:14.

108. Dr. Staudt conducted two BACT analyses using the five-step process: one to determine historic BACT and a second to determine current BACT. Staudt Test., Tr. Vol. 1-B, 49:12-50:1.

109. In conducting his historic BACT analysis, Dr. Staudt considered (1) the engineering analyses and cost estimates prepared for Ameren's Rush Island FGD studies discussed above in Section I.d, (2) vendor proposals, (3) relevant BACT determinations reported

in the EPA Clearinghouse, (4) contemporaneous Missouri permits for coal-fired power plants, (5) industry performance data for scrubbers, and the (6) 0.04 lb/mmBTU SO_2 performance guarantee that Ameren obtained for the FGD system installed at its Sioux power plant. Staudt Test., Tr. Vol. 1-B, 35:23-36:6. 71:2-72:14, 76:10-77:19.

110. To challenge Dr. Staudt's testimony, Ameren presented the expert testimony of Colin Campbell. Campbell is a permit engineer with a bachelor's degree in mechanical engineering and economics from North Carolina State University. Campbell Test., Tr. Vol. 4-A, 39:12-16. Campbell teaches courses for agency employees and permit engineers on NSR issues, including a course on how to do a BACT analysis. Campbell Test., Tr. Vol. 4-A, 40:9-13, 40:24-41:25, 88:17-89:19.

111. Campbell performed an analysis of what BACT would be for Rush Island today. He did not conduct a historic BACT analysis. Instead, he assumed that historic BACT would have been the same as current day BACT. Campbell Test., Tr. Vol. 4-A, 94:12-95:5.

112. For both historic and current BACT, Campbell testified that Ameren could satisfy the law by installing DSI. According to Campbell, if Rush Island were permitted today, MDNR would set an emission rate of 0.275 lb/mmBTU, based on a DSI system with 50% SO_2 reduction. Campbell Test., Tr. Vol. 4-A, 69:10-22.

113. Campbell reached this determination by 1) ranking wet FGD, dry FGD, DSI with a fabric filter, and DSI without a fabric filter, in that order, 2) eliminating dry FGD and DSI with a fabric filter because they were too expensive, 3) calculating the incremental cost effectiveness between wet FGD with DSI without a fabric filter, 4) rejecting wet FGD because MDNR would find its incremental cost effectiveness too expensive, and 5) selecting the remaining option: DSI without a fabric filter.

114. I carefully observed and reviewed Campbell's and Dr. Staudt's conflicting testimony to determine their credibility. Based in part on the following credibility findings, I make factual findings concerning BACT for Rush Island in Section III.

d. Campbell's Testimony Rejecting Wet FGD and Choosing DSI Was Not Credible

115. Ameren primarily relies on Colin Campbell's expert testimony to argue that DSI constitutes BACT. Campbell testified that wet FGD's incremental cost effectiveness was too high for wet FGD to be BACT. Campbell Test., Tr. Vol. 4-A, at 97:21-98:7. Campbell further testified that Ameren should be able to come into compliance with the PSD program without obtaining a PSD permit. Id. at Tr. Vol. 4-A, 132:2-5.

116. Before trial, the EPA made a Daubert challenge to exclude these opinions. The EPA argued that Campbell's methods were unreliable because he did not follow the five-step process laid out in the NSR manual, among other arguments. I denied the EPA's motion because I could not say that Campbell's opinion was so unreliable as to be unhelpful to the trier of fact. United States v. Ameren Missouri, No. 4:11 CV 77 RWS, 2019 WL 1384580, at *3 (E.D. Mo. Mar. 27, 2019). However, I explained that Campbell's opinion would be more credible if he had completed and documented the five-step process used by permitting authorities across the country. Id. I noted that

> [Campbell's] methods depart significantly from the five-step process used in preparing a permit application or supporting documents. (Campbell deposition, filed under seal at ECF No. 968-5 at 196:11-18). Most importantly, Campbell eliminated the second-highest and third-highest ranking options before evaluating the first-highest ranking option. As a result, Campbell's incremental cost effectiveness compared the highest and lowest ranking options. This error violates Campbell's own advice to permit engineers. (BACT workshop presentation, filed under seal at ECF No. 970 at 3, 5-6). In his BACT workshop presentation, Campbell explained that incremental cost effectiveness should be performed between the "'dominant' control option [and] the next most stringent option." (Id. at 3). He cautioned that incremental cost is appropriate when "[D]ominant control

> options have similar average cost effectiveness numbers" or similar emission rate reductions. (Id. at 5).

Id. at *2.

117. Having now heard Campbell's testimony during trial, I will give little weight to his testimony because of flaws in his economic analysis, inconsistencies in his statements at trial, and his mischaracterization of how NSPS factors into the BACT process.

i. Campbell Overly Relied on Incremental Cost Effectiveness at Rush Island

118. Campbell's BACT determination hinges upon on his incremental cost effectiveness analysis. Campbell rejected wet FGD because it purportedly had an incremental cost effectiveness of $9,500/ton, well above the $6,800/ton limit he inferred from reviewing PSD permits issued by MDNR. Campbell Test., Tr. Vol. 4-A, 84:9-25.

119. Campbell did not reach any conclusions in this case about whether the average cost-effectiveness of wet FGD at Rush Island would represent unreasonable economic impacts for Ameren. Id. at 115:8-116:17.

120. As a general matter, Campbell's heavy reliance on incremental cost-effectiveness, without consideration of average cost-effectiveness, is inconsistent with BACT permitting practices. The NSR manual explains that "undue focus on incremental cost effectiveness can give an impression that the cost of a control alternative is unreasonably high, when, in fact, the cost effectiveness, in terms of dollars per total ton removed, is well within the normal range of acceptable BACT costs." NSR Manual (Pl. Ex. 1190), at AM-REM-00544163-MDNR.

121. Additionally, Campbell's testimony concerning incremental cost effectiveness was not credible for the following reasons: (1) he included non-comparable cost categories

when comparing wet FGD at Rush Island to MDNR's past permit decisions; (2) he compared the most effective with the least effective technology when calculating incremental cost effectiveness; (3) his cost thresholds are not supported by the MDNR permits he cites; and (4) he ignored the presumption that facilities in the same source category can bear the same costs.

122. Each of these flaws was necessary to Campbell's decision to reject wet FGD. Together they demonstrate that Campbell's cost analysis of wet FGD is not credible. Accordingly, I give little weight to Campbell's testimony rejecting wet FGD.

ii. Campbell's Cost Comparisons Include Cost Categories Not Included in Other Plants' BACT Determinations

123. To calculate incremental cost-effectiveness, Campbell relied on wet FGD cost estimates provided by Kenneth Snell, Ameren's control costs expert. Snell estimated that installing wet FGD at Rush Island would cost $896 million in 2016 dollars or $1 billion in 2025 dollars. Snell Test., Tr. Vol. 4-B, 28:1-9, 28:24-29:10.

124. In contrast, the EPA's expert Dr. Staudt estimated that installing wet FGDs at Rush Island would cost $582 million in 2016 dollars. Dr. Staudt based his estimate on costs included in Ameren's engineering studies, but he subtracted a set of variable costs normally excluded from comparative cost estimates. Under this "overnight" cost methodology, Dr. Staudt excluded the Allowance for Funds Used During Construction (or AFUDC), an inflation-like metric called escalation, overhead, and property taxes. Staudt Test., Tr. Vol. 1-B, 59:24-61:5; Tr. Vol. 2-A, 25:25-26:6, 28:18-30:18.

125. Snell's cost estimate differs from Dr. Staudt's estimate because Snell included $150 million for financing,[5] $64 million for escalation, $44 million for overhead, and $22 million for property taxes. Snell Test., Tr. Vol. 4-B, 57:19-59:25; Ex. HW, Ex. HX.

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[5] Specifically, Snell calculated $150 million in AFUDC, the financing charge incurred over the time it takes to complete a project. Staudt Test., Tr. Vol. 1-B, 24:7-24; Vol. 2-A, 30:1-18.

126. Traditionally, these costs are excluded from cost comparisons across power plant and control technologies because they are extrinsic to the technologies themselves and vary dramatically. For example, different companies have different cost recovery rates and execute projects on different timelines. Excluding extrinsic costs allows for a more consistent way to compare costs across the industry. Staudt Test., Tr. Vol. 1-B, 24:7-24; Vol. 2-A, 30:1-18.

127. When Ameren conducted its own economic analysis comparing the costs of wet FGDs at Rush Island to others in the industry, it did not include AFUDC in its estimates. See February 5, 2010 Project Review Board Presentation—Rush Island FGD (Pl. Ex. 1100), at AM-REM-00289006.

128. Dr. Staudt's decision to remove the extrinsic expenses for the purpose of comparing project costs was not refuted by Snell or any of Ameren's other witnesses. Snell testified that he was "not offering an opinion as to whether or not it's appropriate to include [AFUDC or escalation] costs for the purposes of a BACT analysis." Snell Test., Tr. Vol. 4-B, 50:4-6. "[His] opinion is . . . the real costs that Ameren would incur if they were to install these technologies." Id. at 50:6-7.

129. Because Dr. Staudt's testimony concerning the appropriateness of excluding extrinsic expenses is uncontested, and I find Dr. Staudt's testimony to be credible, I also find that Dr. Staudt correctly excluded these extrinsic expenses from his BACT analysis.

130. In contrast, Snell used the total project costs, including the expenses Dr. Staudt excluded, to compare the cost of installing FGD at Rush Island to the costs at facilities featured in other permit determinations made by MDNR. In making this comparison, Snell should have instead relied on the cost calculating conventions normally used in BACT determinations.

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131. When calculating incremental and average cost effectiveness between the various pollution control options for Rush Island, Campbell also should have excluded these variable costs.

132. Campbell did not ask Snell whether Snell's total cost estimates would be appropriate to use in conducting a BACT analysis. Snell Test., Tr. Vol. 4-B, 49:13-25.

133. I find that it was inappropriate for Campbell to rely on Snell's total cost estimates for purposes of doing a BACT analysis for Rush Island.

iii. Campbell's Incremental Cost Effectiveness Analysis Was Inconsistent With His Prior Trainings and Advice

134. To determine the incremental cost effectiveness at Rush Island, Campbell compared the per-ton cost of FGD with the per-ton cost of DSI.

135. Incremental cost effectiveness is appropriate for BACT determinations when the two compared technologies rank directly adjacent to each other in their effectiveness. See United States v. Ameren Missouri, No. 4:11 CV 77 RWS, 2019 WL 1384580, at *2 (E.D. Mo. Mar. 27, 2019), (citing In re General Motors, Inc., No. 27947, 10 E.A.D. 360, 2002 WL 373983 ,*9); see also Staudt Test., Tr. Vol. 1-B, 92:25-93:15; Campbell Test., Tr. Vol. 4-A, 119:16-18; NSR Manual (Pl. Ex. 1190), at AM-REM-00544158-MDNR ("The incremental cost effectiveness calculation compares the costs and emissions performance level of a control option to those of the next most stringent option") (emphasis added).

136. Additionally, the two compared technologies should have similar levels of effectiveness. Staudt Test, Tr. Vol. 1-B, 92:25-93:15. By following these rules, permit applicants can identify technologies that are unnecessarily expensive relative to similarly or equally effective technologies. Technologies with very different effectiveness should not be used for incremental cost effectiveness; the more effective technology is better. See id. at 92:15-23; NSR

Manual (Pl. Ex. 1190), at AM-REM-00544158-MDNR

137. Campbell ignored both of these conventions. First, he compared the most effective technology, wet FGD, with the least effective technology, DSI. The two are not ranked adjacent to each other. Second, wet FGD and DSI have do not have similar levels of effectiveness; the two have dramatically different levels of effectiveness. Staudt Test., Tr. Vol. 1-B, 92:25-93:15. Specifically, Campbell compared a wet FGD capable of achieving SO_2 reductions of more than 90% to a DSI system that can only achieve 50% reductions and an emission rate 5 ½ times higher than what could be achieved by the top controls. Campbell Test., Tr. Vol. 4-A, 118:24-119:15.

138. Campbell's comparison of wet FGD and DSI is inconsistent with his own guidelines used outside of litigation and the guidelines used by other practitioners. See Campbell Test., Tr. Vol. 4-A, 117:15-118:20 (discussing inconsistencies between Campbell's method in this case and his training materials).

139. Campbell now purportedly "vigorously" disagrees that incremental cost-effectiveness should be reserved for control technologies with similar reduction capabilities. Campbell Test., Tr. Vol. 4-A, 70:9-19.

140. Nonetheless, I find Campbell's testimony on the incremental cost comparison between wet FGD and DSI to be not credible, as it is inconsistent with established standards in the field and even his own past work.

iv. Campbell's Cost Threshold Opinion Is Unsupported

141. Campbell ultimately rejected wet FGD as BACT because its incremental cost effectiveness exceeded a threshold he inferred from MDNR and other permitting authorities' determinations. Campbell Test., Tr. Vol. 4-A, 119:19-120:3. Campbell's testimony on this point

was inconsistent, unsupported, and not credible.

142. Specifically, Campbell testified that permitting authorities across the country, and MDNR specifically, apply a "de facto line at $5,000" per ton for incremental cost-effectiveness. Campbell Test., Tr. Vol. 4-A, 61:8-9, 62:19-22, 67:4-12, 119:9-120:3, 121:14-17. Campbell testified on direct that permitting authorities will reject control technologies above this threshold.

143. On cross-examination, however, Campbell admitted that permitting authorities have accepted technologies with incremental cost-effectiveness values of $10,000/ton. Id. at 120:11-23.

144. Campbell also admitted he was only speculating when he said MDNR had a threshold at $5,000. He later testified that the limit in Missouri was actually $6,800/ton. Id. at 121:18-21.

145. According to Campbell, four Missouri permits supported his purported $6,800/ton threshold: Continental, Noranda, Norborne, and Southwest. Nothing in these permits actually establishes this limit. Staudt Test., Tr. Vol. 1-B, 93:16-22.

146. Two of these permits (Continental and Noranda) relate to, respectively, a cement plant and an aluminum smelter. Permits in these source categories are minimally relevant to a BACT determination at a pulverized coal-fired power plant. Campbell Test., Tr. Vol. 4-A, 111:5-113:9; Staudt Test., Tr. Vol. 1-B, 91:9-25; MDNR Rule 30(b)(6) Dep., Aug. 10, 2018, Tr. 137:24-142:3. Unlike power plants, it is "very unusual" for cement plants to use FGDs. Cement plants have "a great deal of intrinsic SO_2 capture" built into their process because SO_2 is a useful ingredient in their product. Staudt Test., Tr. Vol. 1-B, 91:9-25.

147. Additionally, the Noranda permit did not discuss incremental cost-effectiveness in its BACT analysis. Campbell admitted this fact on cross examination. Campbell Test., Tr. Vol.

4-A, 121:23-122:12. Therefore, the Noranda permit does not support Campbell's purported $6,800 threshold.

148. For the remaining two permits (Norborne and Southwest), Campbell admitted on cross-examination that the incremental cost-effectiveness values presented in those decisions "didn't much factor into the analysis." Campbell Test., Tr. Vol. 4-A, 122:14-123:12.

149. For the Norborne permit, Campbell admitted that MDNR's decision to select dry FGD over wet FGD was based largely on environmental and energy impacts and not costs. Campbell Test., Tr. Vol. 4-A, 123:25-125:20.

150. Even if the Norborne decision had been based on costs, it would not support a finding of a $6,800/ton threshold. The incremental cost effectiveness at Norborne was $20,218/ton, based on a 95% removal wet FGD with a 93% removal dry FGD. On cross-examination, Campbell admitted that Missouri's BACT determination at Norborne did not support the $6,800/ton threshold he claimed:

> Q. … So in terms of whether we can get a $6,800-per-ton incremental cost threshold out of the Norborne permit, we can't; right?
> A. That's right.

Id. at 125:23-126:1.

151. For the Southwest City Utilities permit, MDNR did not consider costs in its determination. MDNR Rule 30(b)(6) Dep., Aug. 10, 2018, Tr. 142:6-143:15, 144:18-24; Missouri Air Conservation 11/28/05 Decision (Pl. Ex. 1007) at AM-00151141 ("However, Hale agreed that dry FGD was BACT for this particular pulverized coal-fired boiler based on his review of the energy and environmental impacts of dry versus wet FGD. … Hale did not consider economic impacts of costs as part of his analysis of BACT for SO_2.").

152. Additionally, the applicant calculated an incremental cost-effectiveness of over

$10,000/ton when comparing wet and dry FGD, two adjacent technologies in the "top down" analysis. Staudt Test., Tr. Vol. 2-A, 7:1-9, 24:4-16. The Southwest City Utilities permit does not support the purported $6,800 threshold as Campbell applied it in this case.

153. Campbell pointed to only these four Missouri permits to support the purported $6,800/ton threshold. None of those permits actually support that threshold. I find that Campbell's testimony on this issue is not based on established criteria to evaluate cost-effectiveness and is not credible.

154. Ameren presents no credible evidence that MDNR or any permitting authority will reject technologies with incremental cost effectiveness above $6,800/ton.

v. Campbell Disregards MDNR Practice Concerning Sources in the Same Category

155. Campbell also undermines his credibility by contradicting the NSR's source category "cost presumption." This principal of NSR permitting holds that "in the absence of unusual circumstance, the presumption is that sources within the same category are similar in nature, and that cost and other impacts that have been borne by one source of a given source category may be borne by another source of the same source category." NSR Manual (Pl. Ex. 1190), at AM-REM-00544146-MDNR.

156. MDNR included the same language in a PSD permit for the Norborne coal-fired power plant. In that permit, MDNR rejected an applicant's attempt to rely on incremental cost-effectiveness over the same source category cost presumption. MDNR stated the following:

> [A]s per the draft of NSR Workshop manual, "in the absence of unusual circumstance, the presumption is that sources within the same category are similar in nature, and that cost and other impacts that have been borne by one source of a given source category may be borne by another source of the same source category." Since AECI has not provided any data which differentiates this project from previously permitted units which have limits of 0.05 lb/MMBTU on an annual basis, it is presumed that the costs these systems will

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> incur can also be incurred by AECI. Therefore, the economic analysis provided by AECI was not considered in selecting the NO_x limit.

Norborne PSD Permit (Pl. Ex. 1180), at AM-REM-00503313-MDNR (quoting NSR Manual); see also MDNR Rule 30(b)(6) Dep., at 139:21-141:22) (testifying that "when a permit writer looks at a permit application from, for example, a coal-fired utility, [] they would look towards other coal-fired utilities to determine the appropriate controls and what controls are already being used").

157. Campbell claimed during his direct examination that "there is no such presumption" in the "real world." Campbell Test., Tr. Vol. 4-A, 58:8-59:4. But this testimony was not supported by any evidence.

158. Campbell's statement—that the same source category cost presumption does not apply in the real world—undermines his credibility.

vi. Campbell Incorrectly Rejects Information From Power Plants Subject to NSPS

159. Campbell testified that SO_2 BACT determinations for coal-fired power plants during the past couple decades are not informative for Rush Island in 2019 because they involved "new" plants subject to NSPS. Campbell Test., Tr. Vol. 4-A, 75:20-22, 100:5-102:11.

160. Campbell's decision to disregard new plants subject to NSPS is inconsistent with the design and function of NSPS and is unsupported by the evidence presented in this case. See FOF ¶ 85-90.

161. Despite these features, Campbell testified that sources subject to NSPS should not be compared to Rush Island, because the NSPS fundamentally altered the range of options available in a BACT determination. Campbell Test., Tr. Vol. 4-A, 75:20-22, 100:5-102:11.

162. There is no difference between the emissions rates that can be achieved through

use of FGDs at NSPS-subject new units and existing units. Campbell Test., Tr. Vol. 4-A, 105:9-13.

163. Instead of relying on recent BACT determinations, Campbell based his testimony on BACT determinations made in the late 1970s and early 1980s. He also considered a 1990 BACT determination for a CFB boiler in Hawaii to be relevant. Campbell Test., Tr. Vol. 4-A, 102:12-104:3.

164. Campbell's testimony on this point is inconsistent with the permit application he helped electric utility DTE prepare for its Monroe power plant. Campbell Test., Tr. Vol. 4-A, 104:4-19.

e. I Reject Campbell's Testimony That DSI Is BACT for Rush Island

165. In addition to the flaws in Campbell's testimony, the following facts contradict Campbell's claims that DSI is BACT for Rush Island.

166. In 2008, MDNR rejected DSI for a coal-fired power plant because it did not "represent the upper level of SO_2 controls" necessary to constitute BACT. Staudt Test., Tr. Vol. 1-B, 93:23-94:25; 2/22/08 Norborne PSD Permit (Pl. Ex. 1180) at AM-REM-00503315-MDNR to 3316-MDNR (rejecting control efficiencies of up to 85%).

167. No permitting authority anywhere in the country has ever determined SO_2 BACT for a pulverized coal-fired power plant based on DSI. If I were to accept Campbell's testimony, Rush Island would be the first pulverized coal-fired power plant to have BACT based on DSI. Staudt Test., Tr. Vol. 1-B, 89:7-9; Campbell Test., Tr. Vol. 4-A, 97:21-98:7; Knodel Test., Tr. Vol. 1-A, 63:22-25.

168. Under a top-down BACT analysis, to arrive at his BACT determination, Campbell would have had to evaluate and then eliminate wet FGD, dry FGD, and DSI-FF in that

order, before settling on the least effective control technology available for Rush Island. FOF ¶¶ 75, 113.

169. Campbell admitted he "gave dry FGD relatively little consideration in [his] analysis [and] didn't assess its impacts in any quantitative way in Step 4." Campbell Test., Tr. Vol. 4-A, 85:1-4. Similarly, he did not evaluate DSI with a fabric filter in "any quantitative way." Id. at 85:16-25.

170. Campbell then compared the very effective, more capital-intensive wet FGD with the least effective and least expensive option—DSI without a fabric filter. Id. at 119:7-11.

171. The flaws in Campbell's analysis affect the core of his testimony that DSI constitutes BACT at Rush Island. Campbell rejected wet FGD specifically because his calculated incremental cost effectiveness was higher than a threshold he allegedly derived from BACT permits. In doing so, Campbell (1) overly relied on incremental cost effectiveness, (2) considered extrinsic expenses not normally included in BACT cost comparisons, (3) inappropriately compared the most- and least-effective technology, (4) derived a cost threshold that is not supported by the evidence, and (5) disregarded consistency among pulverized coal-fired power plants installing FGD. Campbell also inappropriately disregarded BACT permits for power plants subject to NSPS. I reject Campbell's testimony that DSI is BACT for Rush island.

f. Dr. Staudt's Testimony Concerning BACT at Rush Island Was Credible

172. In contrast to Campbell, Dr. Staudt conducted the well-established five-step BACT determination as outlined in the NSR manual and as practiced by MDNR and other permitting authorities.

173. Specifically, Dr. Staudt started step four by analyzing the most effective control technology, wet FGD. Dr. Staudt evaluated the energy, environmental, and economic costs of

wet FGD and concluded that wet FGD was achievable.

174. In coming to these conclusions, Dr. Staudt relied on standards and practices outlined in the EPA's Draft NSR Manual, the EPA's Cost Control Manual, and in permits issued by MDNR. Dr. Staudt carefully explained his methods, provided consistent testimony, and supported his testimony with credible evidence.

175. Ameren attempted to challenge Dr. Staudt's credibility by arguing that Staudt 1) overly relied on plants that had to meet the NSPS, 2) evaluated natural gas conversion as a control technology throughout the five-step process, and 3) did not evaluate the incremental cost effectiveness of wet FGD.

176. These arguments do not demonstrate that Dr. Staudt's testimony is not credible. With respect to NSPS, Dr. Staudt convincingly testified that NSPS provides a floor that does not fundamentally alter the BACT determination. Staudt Test., Tr. Vol. 1-B, 89:21-91:8; Tr. Vol. 2-A, 7:10-8:1. With respect to the natural gas conversion, Dr. Staudt eliminated the natural gas option because it was a different kind of fuel, and its inclusion did not affect how wet FGD was analyzed in step four. Tr. Vol. 2-A, 21:6-17, 22:23-23:18.

177. Dr. Staudt's economic evaluation may have been more compelling if he had discussed incremental cost effectiveness, even if BACT determinations do not specifically require it.

178. Still, I find that Dr. Staudt's testimony is credible, helpful to the trier of fact, and instrumental to determining what BACT was at the time of Rush Island's modifications. I heavily rely on Dr. Staudt's testimony when discussing facts surrounding BACT determinations in this case.

g. BACT Requirements at Rush Island in 2007 and 2010

179. Staudt and Campbell—and ultimately the parties in this case—did not have any material disagreement over Steps 1 through 3 of BACT process. Campbell Test., Tr. Vol. 4-A, 97:9-20. The results of those analyses are identified below:

Step One: Identify Available Control Options

180. The available SO_2 control technologies for Rush Island Units 1 and 2 include wet FGD, dry FGD, DSI-FF, and ordinary DSI. Staudt Test., Tr. Vol. 1-B, 50:19-51:1; Campbell Test., Tr. Vol. 4-A, 50:16-51:13. I find that Dr. Staudt's and Campbell's testimony on this point is credible and that this is the appropriate ranking.

Step Two: Eliminate Technically Infeasible Options

181. None of these control technologies can be eliminated as technically infeasible for Rush Island. Staudt Test., Tr. Vol. 1-B, 51:24-52:5; Campbell Test., Tr. Vol. 4-A, 50:16-51:13, 93:1-8; Ameren Rule 30(b)(6) Dep., Nov. 7, 2017, Tr. 59:1-12.

Step Three: Rank Technically-Feasible Options by Effectiveness

182. Wet FGD is the most effective control technology (about 99% removal efficiency), followed by dry FGD (about 95%), DSI with a fabric filter (about 70%), and DSI without a fabric filter (about 50%). Staudt Test., Tr. Vol. 1-B, 14:13-15:1, 52:21-53:15, 16:11-17:14; Campbell Test., Tr. Vol. 4-A, 50:16-51:13; Snell Test., Tr. Vol. 4-B, 5:19-6:3, 18:19-19:7, 50:8-22.

Step Four: Evaluate Most Effective Controls

183. Dr. Staudt and Campbell disagreed about the results of the fourth and fifth steps.

184. Dr. Staudt concluded that wet FGD could not be eliminated because it was achievable, taking into account energy, environmental, and economic impacts and other costs. Staudt Test., Tr. Vol. 1-B, 54:22-55:4.

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185. Campbell concluded that wet FGD could be eliminated because its incremental cost effectiveness was unacceptably costly when compared with DSI. As noted above, Campbell did not use the top-down method here. Instead Campbell eliminated the middle two options—because dry FGD and DSI-FF were not "dominant control options." Id. at 74:3-12.

186. Neither Campbell nor Ameren cites to any permitting authority, permitting applicant, permitting guide, or other authority supporting Campbell's method of excluding "non-dominant" control options before conducting the step four analysis.

187. In contrast, Dr. Staudt employed the top-down method, as practiced by MDNR and other permitting authorities. Dr. Staudt evaluated the energy, environmental, economic, and other costs associated with wet FGD.

188. Based on Dr. Staudt's credible, well-supported testimony, I find that the energy, environmental and economic impacts of wet FGD do not make wet FGD unachievable. Instead, these impacts are reasonable and comparable to the impacts experienced at other permitted pulverized coal-fired power plants.

Energy Impacts

189. The evidence does not show that wet FGD's energy impacts would be unreasonable for Rush Island. Staudt Test., Tr. Vol. 1-B, 54:22-55:4. Ameren's engineering studies determined that Ameren would not have to install power-intensive fans for wet FGD, but it would have to install them for dry FGD or DSI with a fabric filter. Staudt Test., Tr. Vol. 1-B, 55:5-19. These fans would decrease the overall power output of the plant.

190. Ameren presented evidence that wet FGD would reduce power output at Rush Island, due to the energy demands of the wet FGD controls. Snell Test., Tr. Vol. 4-B, 38:6-17. Ameren did not argue that this energy demand was different from the energy demand of

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scrubbers at other pulverized coal-fired power plants. Additionally, Ameren did not present evidence that this energy demand would make wet FGD unachievable. As a result, the weight of the evidence demonstrates that the energy impacts of wet FGD do not make it unachievable for Rush Island.

Environmental Impacts

191. Relatedly, the evidence does not show that wet FGD would impose unreasonable environmental impacts at Rush Island. Instead, Ameren would have the environmental benefit of producing saleable gypsum instead of landfill waste. Staudt Test., Tr. Vol. 1-B, 40:12-41:24, 55:20-56:5; see FOF ¶¶ 35. Additionally, water limitations would not be an issue for Rush Island, because it is in close proximity to the Mississippi River. Staudt Test., Tr. Vol. 1-B, 56:6-14.

192. Ameren presented evidence at trial that wet FGD would require more wastewater treatment and new mercury controls, creating more costs for Ameren than DSI would impose. Snell Test., Tr. Vol. 4-B, 37:24-39:10. However, Ameren made no effort to explain how these environmental impacts made wet FGD unachievable. Nor did Ameren suggest that these environmental impacts are different from the kinds of impacts experienced at other pulverized coal-fired power plants. See NSR Manual (Pl. Ex. 1190), at AM-REM-00544146-MDNR; Staudt Test. Vol. 1-B, 63:14-64:6.

Economic Impacts

193. Finally, wet FGD would not impose unreasonable economic impacts at Rush Island. Staudt Test., Tr. Vol. 1-B, 56:15-19.

194. Ameren openly concedes that it can afford to install scrubbers at Rush Island. Ameren's contemporaneous studies confirmed that wet FGDs would be economically feasible.

The same studies show that, from a cost perspective, wet FGDs are preferable to dry FGDs at Rush Island. FOF ¶¶ 26, 31-33, 36, 38.

195. The large number of coal-fired electric generating units already equipped with wet FGDs provides strong evidence that the cost of wet FGD is achievable for a pulverized coal-fired power plant like Rush Island. Staudt Test., Tr. Vol. 1-B, at 62:8-21, 64:20-65:7, 66:17-67:2.

196. Ameren's engineering studies confirmed that the capital costs of installing wet scrubbers at Rush Island would be consistent with costs borne by other utilities. Staudt Test. Tr. Vol. 2-A, 56:20-57:6.

197. Rush Island does not have any unique characteristics that would make the typical costs of wet FGDs unreasonable in this context. Staudt Test., Tr. Vol. 1-B, 65:8-12; Snell Test., Tr. Vol. 4-B, 57:15-18. None of Ameren's experts have identified any circumstances at Rush Island that would make the costs to install wet FGDs at Rush Island unusual compared to other plants. Staudt Test., Tr. Vol. 1-B, 65:8-12; Snell Test., Tr. Vol. 4-B, 57:15-18.

198. On the contrary, Ameren's own engineers have admitted that there is nothing about Rush Island that makes it different from any of the other plants where FGDs have been installed. Mitchell Dep., May 30, 2018, Tr. 81:13-23, 192:2-10.

199. For purposes of historic BACT, Dr. Staudt calculated the average cost-effectiveness of wet FGD to be about $2800/ton for Rush Island Unit 1 and Unit 2. Staudt Test., Tr. Vol. 1-B, 57:7-58:22. Based on these figures, Dr. Staudt testified that wet FGD could not be eliminated as unachievable due to cost concerns. Id. at 62:3-7.[6]

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[6] Dr. Staudt made conservative assumptions when calculating the average cost effectiveness for wet FGD. He based his baseline emission rate on low sulfur coal, leading to lower emissions reductions, a larger demoninator, and a higher per ton cost. Staudt Test., Tr. Vol. 1-B, 59:3-15, 61:16-62:2. Dr. Staudt also used a capacity factor of 80% rather than 100%. Staudt Test., Tr. Vol. 1-B, 61:16-62:2.

200. Wet FGD is achievable at Rush Island, taking into account the energy, environmental, economic impacts and other costs of this technology. I find no basis for eliminating the top control, wet FGD, at Step Four of the BACT analysis.

Step Five: Select BACT

201. In Step Five, the permit applicant and permitting authority determine what emissions limit can be achieved by installing the selected control technology.

202. For Rush Island Unit 1, Dr. Staudt testified that historic BACT would have been 0.08 lb/mmBTU, based on a 30-day rolling average. This corresponds to a design removal efficiency of 91.4%. Staudt Test., Tr. Vol. 1-B, 69:13-22.

203. For Rush Island Unit 2, Dr. Staudt testified that historic BACT would have been 0.06 lb/mmBTU, based on a 30-day rolling average. That would represent a 94% design removal efficiency. Staudt Test., Tr. Vol. 1-B, 69:23-70:2.

204. Dr. Staudt's historic BACT rates include a reasonable compliance margin and are consistent with the rates that Ameren's engineering studies confirmed would be achievable at Rush Island. FOF ¶ 30.

205. Dr. Staudt's historic BACT rates are consistent with permits issued by MDNR and other permitting authorities during the relevant period. Staudt Test., Tr. Vol. 1-B, 70:15-17, 79:6-18, 80:23-81:19. FOF ¶¶ 99-105.

206. Dr. Staudt's historic BACT rates are also consistent with the design specifications used for Ameren's engineering studies, and performance of FGDs at Ameren's other plants. By the time Rush Island Unit 2 was modified, Ameren already had a plant "perform[ing] at 0.06 pounds per million Btu, so [it] knew that number could be achieved." Callahan Dep., Nov. 8, 2017, Tr. 201:13-21; see also id. at 78:2-8, 84:8-23 (the FGDs at Ameren Illinois's Duck Creek

plant were achieving 99% removal or 0.06 lb/mmBTU).

207. Finally, Dr. Staudt's historic BACT rates are consistent with industry performance data. In 2008 and 2011, the years after each of the modifications at issue, the top 20% of performing scrubbers in the industry were achieving SO_2 rates, respectively, of 0.059 lb/mmBTU and 0.037 lb/mmBTU. Staudt Test., Tr. Vol. 1-B, 82:21-88:3.

208. For these reasons, I find that, at the time Ameren modified Rush Island, BACT required SO_2 emissions limitations at least as stringent as 0.08 lb/mmBTU for the 2007 modification of Rush Island Unit 1, and 0.06 lb/mmBTU for the 2010 modification of Rush Island Unit 2, based on 30-day rolling averages.

h. Rush Island's Excess Emissions Total More Than 162,000 Tons

209. Dr. Staudt calculated the excess emissions from Ameren's failure to install scrubbers in 2007 and 2010, based on Dr. Staudt's historic BACT determinations and Rush Island's actual emissions reported by Ameren to the EPA's Air Market Program. Staudt Test., Tr. Vol. 1-B, 99:17-101:4.

210. Based on Dr. Staudt's testimony and the evidence at trial, I find that Ameren's failure to install scrubbers at Rush Island resulted in 162,000 tons of excess SO_2 emissions through the end of 2016. These excess emissions continue at a rate of about 16,000 tons per year, and will be emitted each year that Rush Island operates without scrubbers. Staudt Test., Tr. Vol. 1-B, 101:5-9.

211. If Ameren finishes installation of wet FGD scrubbers at Rush Island in 2023, the excess emissions will total nearly 275,000 tons. Staudt Test., Tr. Vol. 1-B, 99:17-102:1. Obviously, the sooner Ameren installs scrubbers, the lower its excess emissions will be. Id. at 101:18-102:1.

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III. CURRENT BACT ANALYSIS

212. While the historic BACT determination was necessary to calculate Rush Island's excess emissions between 2007 and the present day, a current BACT determination helps identify the appropriate relief in this case. The EPA has asked me to (1) determine what technology constitutes BACT for Rush Island and (2) order Ameren to propose that technology in its permit application. Without this relief, the EPA is concerned that Ameren will continue to delay and oppose the installation of the appropriate pollution control technology.

213. I find that wet FGD constitutes BACT for Rush Island today. I also find that BACT for Rush Island Units 1 and 2 is a 30-day rolling average of 0.05 lb SO_2/mmBTU. This emission limitation is lower than the historic BACT for Rush Island because BACT rates decrease over time due to the technology-forcing nature of the requirement.

a. Current BACT Requires Wet FGD

214. Ameren's and the EPA's expert testimony concerning current BACT is essentially identical to their expert testimony concerning historic BACT. On behalf of Ameren, Campbell conducted one BACT analysis used for historic and current BACT. On behalf of the EPA, Dr. Staudt conducted a current BACT analysis that had the same process and result as his historic BACT analysis, save an updated emissions limitation.

215. The parties agree on the results of steps one, two, and three. Additionally, Ameren's experts admitted that the rate the EPA determined in Step Five would be achievable with wet FGD. Campbell Test., Tr. Vol. 4-A, 93:18-94:3; see also Snell Test., Tr. Vol. 4-B, 51:13-52:16 (conceding that a design SO_2 emission rate of 0.04 lb/mmBTU is achievable at Rush Island).

216. For the same reasons as were applicable to the historic BACT analysis, I find that

wet FGD cannot be eliminated at Step Four of the top-down method based on unreasonable energy, environmental or economic impacts. FOF ¶ 189-200.

217. Between 2010 and the present day, scrubber technologies, including wet FGD, have become more prevalent at pulverized coal-fired power plants. Between 2005 and 2015, wet FGD technology was installed on nearly 100,000 megawatts of pulverized coal-fired electric generating capacity in the United States. FOF ¶ 17 and Figure 1. Almost all of that scrubbed generating capacity is at existing plants that installed scrubbers. FOF ¶ 17. Today, there are very few units the size of the Rush Island that continue to operate without any type of FGD controls. FOF ¶¶ 16, 18.

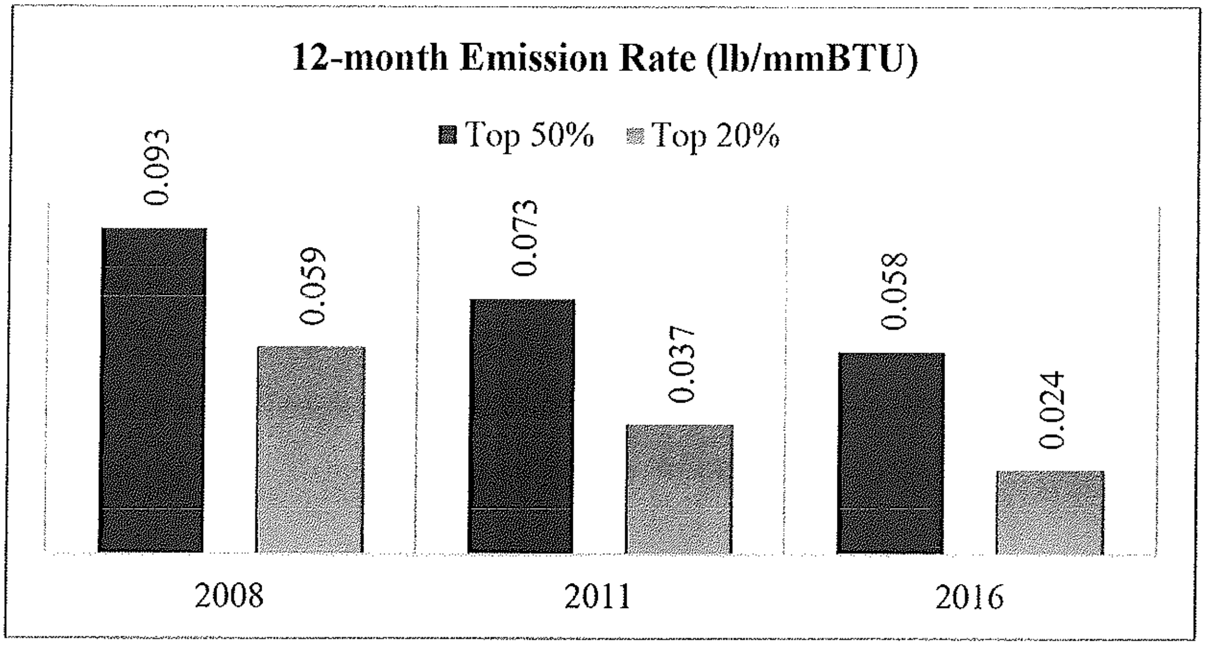
218. The more widespread use of FGD scrubbers at coal-fired power plants strengthens the argument that wet FGD is achievable today at Rush Island. As quoted by MDNR in its Norborne permit, "in the absence of unusual circumstance, the presumption is that sources within the same category are similar in nature, and that cost and other impacts that have been borne by one source of a given source category may be borne by another source of the same source category." Norborne PSD Permit (Pl. Ex. 1180), at AM-REM-00503313-MDNR (quoting NSR Manual and emphasis added).

219. Ameren presented no evidence at trial to distinguish Rush Island from the other pulverized coal-fired power plants using scrubbers today. FOF ¶¶ 197-98. The only Ameren witness who attempted to do so was Campbell, who testified that the most unusual circumstance about Rush Island is that it is "not equipped with a scrubber and not otherwise required to install a scrubber . . ." Campbell Test., Tr. Vol. 4-A, 114:5-12.

220. The performance of scrubbers in the electric utility industry has continued to improve over the past decade, as illustrated in Figure 3. Figure 3 identifies the 12-month

averaged emission rate for the top performing 50% of plants and the top performing 20% of plants in 2008, 2011, and 2016.

Figure 3



221. As shown in Figure 3, the average emission rate achieved by the top 20% of units (57 units) in 2016 was 0.024 lb/mmBTU. In 2008 and 2011, the average emission rate being achieved by the top 20% of units was 0.059 and 0.037 lb/mmBTU, more than 100% and 50% higher than in 2016, respectively. These trends demonstrate a significant and sustained improvement in performance between 2008 and 2016. Staudt Test., Tr. Vol. 1-B, 82:21-83:20.

222. In Missouri, the Iatan plant reflects the low emissions rates that FGD can achieve today. Like Rush island, Iatan burns low-sulfur coal. Using wet FGDs since 2008, Iatan now achieves emission rates as low as 0.004 to 0.006 lb/mmBTU. Although similar in size to Rush Island, Iatan's total SO_2 emissions (250 tons) are a small fraction of Rush Island's (18,000 tons). Staudt Test., Tr. Vol. 1-B, 76:6-76:9, 84:10-84:25.

223. With respect to economic impacts, Ameren does not dispute that it can afford FGDs at Rush Island, and it presented no evidence that installing FGDs would otherwise impose an undue financial burden on the company. FOF ¶¶ 37-41, 194.

224. For his BACT analysis, Dr. Staudt estimated that the capital cost of installing wet FGDs at Rush Island would be about $582 million in 2016 dollars. This estimate was based on the costs calculated by Ameren's engineering studies, excluding AFUDC, escalation, corporate overhead, and property taxes consistent with the standard methodology for BACT cost calculations. Staudt Test., Tr. Vol. 1-B, 59:24-61:5; Tr. Vol. 2-A, 25:25-26:6, 28:18-30:18.

225. Based on those capital cost estimates, Dr. Staudt calculated the average cost-effectiveness of wet FGDs at Rush Island to be $3,854 per ton of SO_2 removed. Staudt Test., Tr. Vol. 1-B, 58:23:59-2. Dr. Staudt testified that wet FGD could not be eliminated based on these average cost-effectiveness figures, Staudt Test., Tr. Vol. 2-A, 26:17-27:5, and his testimony is unrebutted: Ameren's BACT expert reached no opinion on whether the average cost-effectiveness of wet FGDs at Rush Island would be considered unreasonable. Campbell Test., Tr. Vol. 4-A, 115:8-116:17.[7]

226. According to Ameren's engineering studies, this average cost effectiveness result is consistent with costs borne by other coal-fired power plants installing scrubbers. See February 5, 2010 Project Review Board Presentation-Rush Island FGD (Pl. Ex. 1100), at AM-REM-00289006; Staudt Test. Tr. Vol. 1-B, 23:10-25:16, 56:20-57:6; Ameren Rule 30(b)(6) Dep., Nov.

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[7] On cross-examination, Campbell testified that permitting authorities generally use a $5000/ton threshold for average cost-effectiveness. Campbell Test., Tr. Vol. 4-A, at 115:8-14. While Campbell's testimony was inconsistent with his prior sworn deposition testimony that he knew of no "rule of thumb" limit for average cost-effectiveness, (id. at 115:8-116:17), I note that—if credited—Campbell's testimony would provide further support that $3,854/ton would be considered an acceptable average cost-effectiveness for purposes of BACT.

7, 2017, Tr. 90:6-91:3.

227. I find that the average cost-effectiveness of wet FGD at Rush Island is reasonable for a pulverized coal-fired power plant today. I also find that the economic costs of installing wet FGD at Rush Island do not make wet FGD unachievable.

228. Additionally, I find that neither the energy nor environmental costs of installing wet FGD at Rush Island make wet FGD unachievable. Ameren presents no evidence demonstrating, and I have no reason to find, that the energy and environmental costs for a current BACT determination at Rush Island are any greater or less reasonable than the energy and environmental costs for a historic BACT determination.

b. Current BACT Requires an Emissions Limitation of 0.05 lb/mmBTU

229. Dr. Staudt testified that, based on a selection of wet FGD, the appropriate emissions limitation for Rush Island is 0.05 lb/mmBTU. Staudt Test., Tr. Vol. 1-B, 70:3-17.

230. In 2011, Ameren accepted its consultants' recommendation that it solicit bids for a wet FGD system designed to meet an SO_2 emission rate of 0.04 lb/mmBTU, regardless of the type of coal burned. FOF ¶¶ 52-55.

231. Ameren's expert Campbell admitted that 0.05 lb/mmBTU would be an achievable emission rate at Rush Island and a good estimate of what MDNR would set as BACT if scrubbers were required. Campbell Test., Tr. Vol. 4-A, 93:18-94:3; see also Snell Test., Tr. Vol. 4-B, 51:13-52:16 (conceding that a design SO_2 emission rate of 0.04 lb/mmBTU is achievable at Rush Island).

232. An SO_2 emission rate of 0.05 lb/mmBTU could be achieved through use of either wet or dry scrubbers and does not represent the lowest achievable SO_2 emission rate at Rush Island. Staudt Test., Tr. Vol. 1-B, 70:18-25.

Ex. AA-D-5

233. I find that wet FGD constitutes BACT today for Rush Island and the appropriate operating emissions limitation for this technology would be set at 0.05 lb/mmBTU, based on a 30-day rolling average.

IV. RUSH ISLAND'S EXCESS EMISSIONS CAUSED IRREPARABLE INJURY, INCLUDING INCREASED RISK OF PREMATURE MORTALITY

234. The EPA offered evidence to demonstrate that the excess SO_2 emissions resulting from Ameren's decision to ignore PSD requirements caused irreparable injury that could not be compensated through legal remedies. See eBay Inc. v. MercExchange, L.L.C., 547 U.S. 388, 391 (2006). The EPA also offered evidence to demonstrate that the balance of hardships and public interest favors injunctive relief. See id. Based on both parties' evidence, I make the following findings of fact concerning the result of Rush Island's excess pollution.

a. Rush Island's Excess Pollution Is Substantial

235. SO_2 is a regulated pollutant under the Clean Air Act. Any source that releases more than 100 tons of SO_2 yearly is considered a "major" source. 42 U.S.C. § 7479(1); see also 40 C.F.R. § 52.21(b)(1)(i) (same regulatory threshold).

236. Rush Island's annual SO_2 emissions and its excess emissions that should have been captured by BACT (16,000 tons per year) both far exceed this threshold. Compare Staudt Test., Tr. Vol. 1-B, 101:10-13 with 42 U.S.C. § 7479(1) and 40 C.F.R. § 52.21(b)(1)(i). The annual excess pollution from Rush Island alone is equivalent to the amount of pollution that would be emitted by more than 160 sources that each would be considered "major" sources of harmful air pollution under the Clean Air Act.

b. Rush Island's Excess SO_2 Emissions Created Harmful $PM_{2.5}$

237. SO_2 is directly emitted from Rush Island as a gas. However, SO_2 is not stable in the atmosphere. Over time, all the SO_2 released by Rush Island will convert to fine particulate

matter known as "$PM_{2.5}$." $PM_{2.5}$ includes all particles that are 2.5 micrometers in diameter or smaller. Chinkin Test., Tr. Vol. 2-A, 97:6-19.

238. On average, about five percent of the SO_2 emitted by a facility will convert into $PM_{2.5}$ each hour, with a range of one to ten percent depending on meteorological variables. Chinkin Test., Tr. Vol. 2-A, 97:20-98:21. $PM_{2.5}$ pollution resulting from Rush Island's excess SO_2 emissions travels hundreds of miles from Rush Island's smokestack. Chinkin Test., Tr. Vol. 2-B, 22:15-19.

239. $PM_{2.5}$ derived from burning coal and other fossil fuels is known as combustion-related $PM_{2.5}$ or combustion particles. These combustion particles are generally less than one micrometer in diameter, about the same size as a virus. By contrast, most naturally-occurring particles in the atmosphere are greater than ten micrometers in diameter.

240. Because of their size, combustion-related $PM_{2.5}$ particles have a better chance of getting past the body's natural defenses. $PM_{2.5}$ particles are more likely to get into deeper lung structures such as the alveoli, where they can do greater damage for more sustained periods of time. Schwartz Test., Tr. Vol. 3-A, 21:9-22:18, 59:5-11.

241. $PM_{2.5}$ is made up of different chemical constituents, which react with each other in the atmosphere. One of the constituents of combustion-related $PM_{2.5}$ is sulfate $PM_{2.5}$, which forms from SO_2 emissions. Sulfate $PM_{2.5}$ is one of the largest components of $PM_{2.5}$ in the atmosphere. Schwartz Test., Tr. Vol. 3-A, 22:19-23:10, 59:5-59:11.

242. Sulfate combustion particles are not pure, homogenous specimens. They chemically bind to other substances present in the outdoor air. Sulfate tends to combine with metals in the atmosphere, forming compounds that magnify the human health effects of $PM_{2.5}$. Schwartz Test., Tr. Vol. 3-A, 24:23-26:13, 27:5-28:24; <u>see also</u> Valberg Test., Tr. Vol. 5-A,

111:5-16 (conceding that the sulfate ion does not exist in the air by itself).

243. The available scientific evidence indicates that all constituents of $PM_{2.5}$ are toxic. Insufficient evidence exists to determine whether any particular constituent is more toxic than any other. Schwartz Test., Tr. Vol. 3-A, 23:11-13.

244. $PM_{2.5}$ is regulated in the United States and throughout the world on a mass basis, rather than on a constituent-by-constituent basis. Id. at 23:22-24:19, 58:23-59:24; see also Valberg Test., Tr. Vol. 5-A, 111:17-19, 113:2-5 (conceding that $PM_{2.5}$ is regulated on a mass basis, not a constituent basis).

i. Dr. Schwartz Presented Credible, Well-Supported, Expert Testimony Concerning the Health Impacts of $PM_{2.5}$

245. To demonstrate the health effects of $PM_{2.5}$, the EPA offered the expert testimony of Dr. Joel Schwartz. Dr. Schwartz is a tenured professor in the Department of Environmental Health and the Department of Epidemiology at the Harvard School of Public Health and is also a professor in the Department of Medicine at the Harvard Medical School. Schwartz Test., Tr. Vol. 3-A, 4:25-5:5, 8:17-20; see also Curriculum Vitae of Dr. Joel Schwartz (Pl. Ex. 1324).

246. Dr. Schwartz is one of the world's leading scientists on the health effects of air pollution. He has published about 790 peer-reviewed articles. Schwartz Test., Tr. Vol. 3-A, 12:8-11; Pl. 1324. His published research has been cited more than 60,000 times in the scientific literature. Id. at 12:18-19. Dr. Schwartz is not aware of any person who has published more articles than he has in the field of air pollution research. Id. at 13:1-4.

247. Dr. Schwartz performs extensive research on air pollution, teaches courses on epidemiology, and serves as the director of the Harvard Center for Risk Analysis. Schwartz Test., Tr. Vol. 3-A, 5:6-8, 7:13-10:10, 13:5-15:13. Dr. Schwartz's research has been cited by the EPA in its Integrated Science Assessments and has been relied upon by the World Health

Organization in setting standards for air pollution. Schwartz Test., Tr. Vol. 3-A, 15:14-16:1. Dr. Schwartz has also testified before Congress as to the health effects of air pollution, and recently provided a keynote presentation on $PM_{2.5}$ health effects to a World Health Organization conference of international public health ministers. Schwartz Test., Tr. Vol. 3-A, 16:2-25.

248. Dr. Schwartz has testified in federal court two times before this case. He was received as an expert in those cases. Id. at 18:2-5.

249. Dr. Schwartz's testimony is consistent with the scientific consensus that $PM_{2.5}$ harms public health and that there is no threshold below which $PM_{2.5}$ does not cause adverse health effects in exposed populations.

250. During his testimony and during cross-examination, Dr. Schwartz's answers were detailed, credible, and supported by an overwhelming amount of evidence. I find Dr. Schwartz's testimony concerning the health effects of $PM_{2.5}$ to be credible.

ii. $PM_{2.5}$ Causes Heart Attacks, Strokes, Asthma Attacks, and Premature Mortality

251. $PM_{2.5}$ is harmful to human health, causing numerous adverse health effects in exposed populations. Inhaling $PM_{2.5}$ leads to increased risk of high blood pressure, hardened arties, heart attacks, strokes, asthma attacks, and premature mortality. Schwartz Test., Tr. Vol. 3-A, 19:18-20:4, 49:6-50:13 (explaining the American Heart Association's official statement on health effects of $PM_{2.5}$ inhalation), 60:6-62:5 (explaining the EPA's Integrated Science Assessment on health effects of health effects of $PM_{2.5}$ inhalation).

252. The health effects from $PM_{2.5}$ are well-established, and the harmful mechanisms of $PM_{2.5}$ exposure have been demonstrated in many epidemiological, toxicology, and clinical studies. Schwartz Test., Tr. Vol. 3-A, 49:6-50:13, 60:6-62:5.

253. The effect of $PM_{2.5}$ exposure on life expectancy, heart attacks, and strokes is both

acute and chronic, based on short-term and long-term exposure, respectively. Schwartz Test., Tr. Vol. 3-A, 49:6-17, 60:18-61:11.

254. The harmful nature of $PM_{2.5}$ exposure is widely known and agreed upon. Schwartz Test., Tr. Vol. 3-A, 19:18-20:22, 47:6-24. Dr. Schwartz cited statements from the U.S. Centers for Disease Control, the U.S. Environmental Protection Agency, the American Heart Association, the American Thoracic Society, the American Medical Association, the National Academy of Sciences, the World Health Organization, the Royal College of Physicians of the United Kingdom, and the United Nations Environment Program to support his expert testimony on this point. Id.

255. The relationship between the concentration of $PM_{2.5}$ in the ambient air and resulting health effects is known as a concentration-response function. For premature mortality, the concentration-response function indicates the percent change in mortality that is expected from a given change in $PM_{2.5}$ exposure. Schwartz Test., Tr. Vol. 3-A, 36:4-38:2, 86:13-15.

256. The scientific consensus concerning ambient $PM_{2.5}$ concentrations is that there is no safe level below which $PM_{2.5}$ is not harmful. The $PM_{2.5}$ concentration-response relationship has been extensively analyzed in the scientific literature, and studies of both short- and long-term exposure to $PM_{2.5}$ have consistently found no evidence of a safe threshold. Schwartz Test., Tr. Vol. 3-A, 42:17-43:5, 43:22-45:17, 46:19-47:15, 57:16-58:10, 62:6-63:5, 64:11-24, 67:17-68:10.

257. The concentration-response relationship between $PM_{2.5}$ and mortality is linear. Researchers have *not* found a population threshold for ambient $PM_{2.5}$, including at the concentrations experienced in communities near Rush Island. Less data exists to determine the shape of the concentration-response relationship at annual ambient levels below 3 or 4 micrograms per cubic meter. However, the areas impacted by Rush Island's excess emissions are

all above those concentrations. Schwartz Test., Tr. Vol. 3-A, 38:6-39:16, 64:11-66:11, Schwartz Test., Tr. Vol. 3-B, 49:6-21.

258. Dr. Schwartz agrees with the World Health Organization that there is "no evidence of a safe level of exposure or a threshold below which no adverse health effects occur" from exposure to $PM_{2.5}$. Schwartz Test., Tr. Vol. 3-A, 57:16-58:10 (discussing statement on $PM_{2.5}$ health effects issued by World Health Organization).

259. Dr. Schwartz's testimony about the scientific consensus concerning the $PM_{2.5}$ concentration-response relationship was in part based on a 2009 Integrated Science Assessment published by the EPA. Schwartz Test., Tr. Vol. 3-A, 60:4-63:5; see generally 2009 Integrated Science Assessment for Particulate Matter (Pl. Ex. 1209) at 2-8 to 2-17 (evaluating "evidence from toxicological, controlled human exposure, and epidemiologic studies" and concluding that $PM_{2.5}$ causes premature mortality and other health effects); id. at 6-75 (explaining that short- and long-term studies of concentration-response relationships have "consistently found no evidence for deviations from linearity or a safe threshold"); id. at 6-158 to 6-201 and 7-82 to 7-96 (further summarizing evidence for causal determinations for short- and long-term exposure).

260. The evidence demonstrating that there is no safe threshold for $PM_{2.5}$ has only increased since the EPA's 2009 Integrated Science Assessment. Schwartz Test., Tr. Vol. 3-A, 64:11-66:11, 68:1-69:15; Schwartz Test., Tr. Vol. 3-B, 49:6-21.

261. Interpreting more recent studies, Dr. Schwartz testified that the linear concentration-response function between $PM_{2.5}$ and premature death has been demonstrated at lower concentrations than before. Schwartz Test., Tr. Vol. 3-A, 64:11-66:11, 68:1-69:15; Schwartz Test., Tr. Vol. 3-B, 49:6-21.

262. The concentration-response function cited by Dr. Schwartz is derived from

substantial sets of data that have been extensively analyzed in the peer-reviewed literature. In part, Dr. Schwartz relied on a recent study published in the New England Journal of Medicine that included approximately 500,000 unique $PM_{2.5}$ concentration data points at ambient levels between 6 and 16 micrograms per cubic meter, and 70,000 unique data points clustered between ambient $PM_{2.5}$ concentrations of 10 and 11 micrograms per cubic meter. The study found a linear relationship in these two ranges. Schwartz Test., Tr. Vol. 3-A, 36:10-37:12, 39:9-43:5.

263. Based on the no-threshold, linear concentration-response relationship for $PM_{2.5}$, any incremental increase in $PM_{2.5}$ exposure produces an incremental increased risk of mortality and other health effects in the population exposed to Rush Island's excess emissions. Similarly, any incremental decrease in exposure produces a positive impact on public health. Schwartz Test., Tr. Vol. 3-A, 39:9-16, 41:11-43:5, 46:19-47:5, 79:15-21.

264. Both of Ameren's toxicologists conceded that, if a substance is actually a no-threshold pollutant, any incremental increase in exposure produces an incremental increase in risk in the rate of mortality. Fraiser Test., Tr. Vol. 4-A, 28:9-15, Valberg Test., Tr. Vol. 5-A, 137:14-19.

265. Based on (1) the linear concentration-response function for $PM_{2.5}$, (2) the lack of a threshold for $PM_{2.5}$, (3) the conversion of 162,000 tons of excess SO_2 pollution into $PM_{2.5}$, and (4) the scientific consensus that $PM_{2.5}$ increases the risk of high blood pressure, heart attack, stroke, asthma attack, and premature mortality, I find that the pollution resulting from Ameren's failure to obtain a PSD permit has harmed—and continues to harm—public health. Schwartz Test., Tr. Vol. 3-A, 19:18-20:22, 42:17-43:5, 46:19-47:1, 65:17-66:11, 82:1-8.

iii. Dr. Fraiser's and Dr. Valberg's Testimonies Were Not Credible

266. In contrast with Dr. Schwartz, Defendants' testifying experts Dr. Lucy Fraiser and

Dr. Peter Valberg provided testimony that is inconsistent with and not supported by the scientific consensus on $PM_{2.5}$'s human health impacts.

<u>Dr. Lucy Fraiser</u>

267. Dr. Fraiser is a toxicological consultant who spends about 85% of her time on litigation support. Fraiser Test., Tr. Vol. 4-A, 23:3-7.

268. Dr. Frasier has not written any peer-reviewed publications or performed any original research on air pollution. Fraiser Test., Tr. Vol. 4-A, 22:21-23, 23:14-16. Dr. Fraiser has written five publications concerning the effects of cancer drugs based on her dissertation work, the last of which was published almost 25 years ago in 1995. <u>Id.</u> at 22:14-20.

269. At trial, Dr. Frasier testified that $PM_{2.5}$ concentrations below the NAAQS do not cause actual adverse health effects. Dr. Frasier's other opinions primarily flow from this assertion. This testimony contradicts the EPA statements and congressional reports regarding the NAAQS. <u>Compare</u> Fraiser Test., Tr. Vol. 4-A, 24:18-25:12 <u>with, e.g.</u>, H.R. Rep. 95-294 at 112 (quoting National Academy of Sciences, Summary of Proceedings: Conference on Health Effects of Air Pollution (Nov. 1973); H.R. Rep. 95-294 at 111.

270. The House Report concerning the NAAQS states that "[i]n the absence of evidence to the contrary, for a population of various stages and initial states of health, no threshold should be stipulated below which exposure is harmless. Instead, the response to exposure should be assumed to be directly related to successively greater or lesser concentrations of the toxic materials and the level of resistance of those exposed." H.R. Rep. 95-294 at 111.

271. In the publication of the 2013 National Ambient Air Quality Standards, the EPA stated that "there is no discernible population-level threshold below which effects would not occur, such that it is reasonable to consider that health effects may occur over the full range of concentrations observed in the epidemiological studies, including the lower concentrations in the

latter years." 78 Fed. Reg. 3086, 3098, 3118-19, 3148 (Jan. 15, 2013).

272. Dr. Fraiser concedes that her opinions are contrary to the determinations of the World Health Organization, the American Heart Association, the EPA, and other mainstream scientific organizations that have concluded that $PM_{2.5}$ is a no-threshold pollutant that causes increased mortality. Fraiser Test., Tr. Vol. 4-A, 26:6-33:25.

273. Dr. Fraiser also admits that the NAAQS do not guarantee zero risk. Id. at 25:13-23. Instead, she argues that concentrations below the NAAQS "are not an unacceptable risk." Id.

274. Dr. Fraiser is not a statistician. Id. 21:18-22:6. Dr. Fraiser performs quantitative risk assessments, but she did not perform a quantitative risk assessment in this case. Id. at 24:6-9. Dr. Fraiser reviewed the EPA's health impacts modeling in this case, but her opinion is primarily based on her interpretation of the NAAQS. Id. at 24:10-22.

275. Dr. Fraiser's direct criticism of the EPA's health impacts testimony is outside of her area of expertise. For example, Dr. Fraiser criticized the epidemiological literature on health effects of $PM_{2.5}$, stating that confounding factors undermine these studies. However, Dr. Fraiser is not an epidemiologist and has never performed an epidemiological study. Fraiser Test., Tr. Vol. 4-A, 21:18-21. Dr. Fraiser's bare assertion that "innumerable potential confounding factors" mar these studies is not credible. Many $PM_{2.5}$ studies have analyzed the effects of confounders and found that they do not undermine the epidemiological results of these studies. Compare Fraiser Test., Tr. Vol. 3-B, 71:21-72:3 with Schwartz Test., Tr. Vol. 3-A, 69:16-76:15; see also 2009 Integrated Science Assessment for Particulate Matter (Pl. Ex. 1209) at 1-21 (explaining that that $PM_{2.5}$ "has been shown to result in health effects in studies in which chance, bias, and confounding could be ruled out with reasonable confidence"), 2-9 (summary of causal determinations for short-term $PM_{2.5}$ exposure), 2-11 (summary of causal determinations for long-

term $PM_{2.5}$ exposure).

276. Dr. Fraiser also testified that more recent epidemiological studies show uncertainty between $PM_{2.5}$ and mortality effects at levels below the NAAQS. Her testimony on this point is contradicted by the very studies she references. Explaining those studies, the EPA's 2018 draft Integrated Science Assessment states:

> A number of recent studies have conducted analyses to inform the shape of the concentration response relationship for the association between long-term exposure to $PM_{2.5}$ and mortality, and are summarized in Table 11-7. Generally, the results of these analyses continue to support a linear, no-threshold relationship for total, nonaccidental, mortality, especially at lower ambient concentrations of $PM_{2.5}$, i.e., less than or equal to 12 micrograms per meter cubed. Lepeule, et al. 2012; Di, et al. 2017 C; and Shi, et al. 2015 observed linear no-threshold concentration response relationships for total nonaccidental mortality with confidence in the relationship down to a concentration of 8, 5, and 6 micrograms respectively. Figure 1122.
>
> [...]
>
> Similar linear no-threshold concentration response curves were observed for total nonaccidental mortality in other studies: Chen, et al. 2016; Hart, et al. 2015; Thurston, et al. 2015; Cesaroni, et al., 2013.

Fraiser Test., Tr. Vol. 4-A, 19:15-21:17 (quoting from the 2018 EPA Integrated Science Assessment for Particulate Matter (External Review Draft), Section 11.2.4, at 11-81). These contradictions make Dr. Fraiser's testimony less credible.

277. For all these reasons, I give little weight to Dr. Fraiser's testimony. Specifically, I find her testimony less credible because (1) she has no expertise in epidemiology and statistics, two areas on which she opines, (2) she has not published original research regarding the health impacts of air pollution, (3) her NAAQS opinion contradicts the scientific consensus about the lack of a human health population threshold for $PM_{2.5}$, and (4) she mischaracterizes the findings of recent epidemiological studies.

<u>Dr. Peter Valberg</u>

278. Dr. Valberg's opinions also conflict with the generally held scientific consensus

on $PM_{2.5}$.

279. Dr. Valberg is a toxicologist at Gradient Corporation, where he has provided litigation services as an expert witness since 1990. Litigation consulting constitutes between 40% and 60% of his time. Valberg Test., Tr. Vol. 5-A, 98:20-100:15.

280. As part of litigation consulting, Dr. Valberg has provided testimony on behalf Clean Air Act Defendants in which he has unsuccessfully offered the same opinions he offered in this case. In a Clean Air Act case concerning excess SO_2 emissions released by an illegally modified plant, Dr. Valberg testified that the resulting $PM_{2.5}$ caused no harm to human health based on his opinion that sulfate particles are harmless. Valberg Test., Tr. Vol. 5-A, 103:4-104:25 (referring to United States v Cinergy Corp., 618 F.Supp.2d 942, 950 (S.D. Ind. 2009).[8]

281. The Cinergy court found that Dr. Valberg's opinions were contrary to mainstream science. In rejecting Dr. Valberg's opinions, that court concluded his opinions were a "minority view" that is contrary to the "bulk of the scientific literature on the subject [that] concludes that $PM_{2.5}$ has significant effects on human health." United States v. Cinergy Corp., 618 F.Supp.2d 942, 950 (S.D. Ind. 2009).

282. Dr. Valberg has also provided expert witness testimony in tobacco litigation. His opinions in tobacco cases have departed from the scientific consensus as well. Valberg Test., Tr. Vol. 5-A, 102:9-103:3; Geanacopoulos v. Phillip Morris USA Inc., No. 98-6002, 33 Mass. L.Rptr. 308, 2016 WL 757536, at *9 (Mass. Dist. Ct. Feb. 24, 2016) ("Dr. Valberg's analysis of the data provided by the published studies was shown to be inconsistent and contrary to the consensus of the scientific community.").

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[8] The Cinergy opinion at 618 F.Supp.2d 942 was reversed by the Seventh Circuit. See 623 F.3d 455 (7th Cir. 2010). I cite the Cinergy opinion at 618 F.Supp.2d 942 several times in this memorandum opinion. These citations are for propositions that did not form the grounds for the Seventh Circuit's reversal.

283. In addition to litigation consulting, Dr. Valberg also provides consulting services to parties who want to comment on EPA regulatory proceedings. Valberg Test., Tr. Vol. 5-A, 119:5-8.

284. Dr. Valberg submitted comments to the EPA on behalf of the Utility Air Regulatory Group (UARG), a group of electric generating utilities, as well as other industry trade associations. In those comments, Dr. Valberg argued against lowering $PM_{2.5}$ standards. Valberg Test., Tr. Vol. 5-A, 125:22-126:20; see 78 Fed. Reg. 3086, 3111 (Jan. 25, 2013) (Def. Ex. AS). These comments included the same views expressed by Dr. Valberg in this litigation. The EPA rejected the comments and extensively explained its reasons for rejecting them. See id. at 3111-3120.

285. The EPA specifically rejected Dr. Valberg's testimony on the following points: (1) that the causal relationship the EPA found between $PM_{2.5}$ and human health impacts is not credible, id. at 3112-13; (2) that toxicological and epidemiology studies indicate a lack of "coherence or biological plausibility" between $PM_{2.5}$ and human health effects, id. at 3114(3); (3) that observed health effects of $PM_{2.5}$ are due to "confounding" variables, id. at 3115, and are biased by exposure measurement error, id. at 3118; (4) that the EPA's no-threshold determination is not credible, id. at 3119; and (5) that $PM_{2.5}$ should be regulated on a constituent-by-constituent basis rather than on a mass basis, id. at 3119.

286. Dr. Valberg also previously submitted comments criticizing the EPA's 2009 Integrated Science Assessment. Valberg Test., Tr. Vol. 5-A, 119:9-20. In those comments, Dr. Valberg argued the evidence was too weak to support the conclusion that $PM_{2.5}$ is harmful. On that basis, he urged the EPA to reconsider its determination that $PM_{2.5}$ exposure causes adverse health effects. The EPA rejected these comments. Valberg Test., Tr. Vol. 5-A, 119:25-121:22.

iv. The Evidence Does Not Support Ameren's Argument that Rush Island's Excess Emissions Are Harmless

287. Based in part on Dr. Valberg's and Dr. Fraiser's flawed testimony, Ameren makes five arguments why Rush Island's Excess SO_2 emissions are harmless. Ameren argues (1) that $PM_{2.5}$ concentrations below NAAQS do not pose a risk to human health, (2) that sulfate $PM_{2.5}$ is not toxic, (3) that epidemiological studies have too much variation and uncertainty to show a linear, no-threshold concentration-response function for $PM_{2.5}$, (4) that incremental changes smaller than the EPA's Significant Impact Levels (SILs) are meaningless, and (5) that modeling performed on behalf of the EPA in this litigation is "[u]ncertain, [o]verstated, and [u]nreliable." I will discuss the first three arguments here and the fourth and fifth arguments when addressing facts about the EPA's modeling.[9]

The EPA Does Not Guarantee No Human Health Impacts Due to $PM_{2.5}$ Concentrations Below the NAAQS

288. Pursuant to the Clean Air Act, the EPA must set the NAAQS at levels "the attainment and maintenance of which in the judgment of the Administrator, . . . allowing an adequate margin of safety, are requisite to protect the public health." 42 U.S.C. § 7409(b)(2).

289. Based on this language, Ameren argued throughout the trial that the NAAQS are protective of human health, and that any $PM_{2.5}$ concentration below the NAAQS would not pose a meaningful risk of harm to human health.

290. The structure of the Clean Air Act, the EPA's statements concerning the NAAQS, and the scientific consensus concerning $PM_{2.5}$ refute this argument.

291. Pursuant to the Clean Air Act, pollution sources in areas with air quality meeting

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[9] In its proposed findings of fact, Ameren also presents two other arguments that are really subsets of the first argument (concerning NAAQS) and the fourth argument (concerning SILs).

the NAAQS must obtain PSD permits and must install BACT. When Congress added the PSD elements of the Clean Air Act, it acknowledged that reducing pollution in non-attainment areas was insufficient to meet the lofty goals of the Clean Air Act. See Envtl. Def. v. Duke Energy Corp., 549 U.S. 561, 567-68 (2007). Under this framework, neither Congress nor the EPA has characterized the NAAQS as eliminating all risk or all human health impacts. In fact, Ameren's expert Dr. Fraiser admitted that the NAAQS do not establish a zero-risk threshold. FOF ¶ 264.

292. Instead of referring to the NAAQS as a zero-risk, zero-impact threshold, the EPA has repeatedly stated that $PM_{2.5}$ has no known threshold. See FOF ¶ 271. Dr. Schwartz relied on the EPA's statements when testifying that the linear concentration-response function for $PM_{2.5}$ extends to concentrations below NAAQS. Id.

293. NAAQS attainment does not negate all the other evidence demonstrating human health impacts of $PM_{2.5}$, as Ameren argues. If this argument were true, then no human health impacts would ever arise from ambient air pollution across the United States, except for limited parts of California.

294. For these reasons, the evidence does not demonstrate that the NAAQS establish a zero-risk, zero-impact threshold, below which no human health impacts are meaningful.

The Toxicity of Sulfate $PM_{2.5}$ Cannot be Differentiated from Other Constituents

295. The scientific community has not determined whether sulfates are any less or more harmful than any other constituent of $PM_{2.5}$. FOF ¶ 243. Nonetheless, Ameren argues that sulfate $PM_{2.5}$ is harmless. Dr. Valberg has unsuccessfully made this argument to the EPA on behalf of other clients. Valberg Test., Tr. Vol. 5-A, 122:23-123:19.

296. Neither the EPA nor Congress has determined that sulfate-based particulates should be excluded from the total $PM_{2.5}$ mass when evaluating the health effects of $PM_{2.5}$.

Valberg Test., Tr. Vol. 5-A, 111:17-19, 113:2-5.

297. The consensus scientific opinion is that all $PM_{2.5}$ particles are toxic, including $PM_{2.5}$ derived from power plant SO_2 emissions. Researchers have not been able to determine the precise relative toxicities of different $PM_{2.5}$ constituents. In the absence of consistent evidence that any constituent has a different impact, the scientific community treats particles from all sources, including sulfates, as having the same toxicity. Schwartz Test., Tr. Vol. 3-A, 23:11-13, 23:22-24:19, 58:23-59:24; Tr. Vol. 3-B, 34:22-35:13, 39:12-22.

298. The EPA's Federal Register Notices announcing the $PM_{2.5}$ NAAQS in 2013 and 2006 cite evidence of sulfate $PM_{2.5}$'s toxicity. See 78 Fed. Reg. 3086, 3122-23 (Jan. 25, 2013) (Def. Ex. AS); 71 Fed. Reg. 61,144, 61,163 (Oct. 17, 2006). The 2006 Federal Register Notice stated that "[i]n short, there is not sufficient evidence . . . to suggest that any component should be eliminated from the indicator for fine particles. The Staff Paper continued to recognize the importance of an indicator that not only captures all of the most harmful components of fine particles (i.e., an effective indicator), but also emphasizes control of those constituents or fractions, including sulfates, transition metals, and organics that have been associated with health effects." 71 Fed. Reg. 61,144, 61,163; see also 62 Fed. Reg. 36,652, 38,666 (July 18, 1997) (noting that "the available scientific information does not rule out any one of these components as contributing to fine particle effects").

299. The World Health Organization has singled out combustion-related $PM_{2.5}$ as consistently demonstrating toxicity. Combustion-related $PM_{2.5}$ includes the sulfate $PM_{2.5}$ created by Rush Island's excess emissions. Schwartz Test., Tr. Vol. 3-A, 58:23-59:24.

300. I find that sulfate $PM_{2.5}$ is harmful and contributes to the negative human health impacts of $PM_{2.5}$ noted above.

Dr. Schwartz's Testimony Concerning Health Impacts of $PM_{2.5}$, Based on Epidemiological Studies, is Credible

301. Ameren seeks to discredit Dr. Schwartz's testimony by pointing to variation in the results of epidemiological studies and meta-analyses of those studies. See Ameren's Proposed Findings of Fact, ECF No. 1110, at ¶¶ 166-69. For example, Ameren discusses the results of seven studies used to inform a Regulatory Impact Analysis in California. Id. Some of those studies found a positive, but statistically insignificant slope; one found a positive, insignificant slope; and some of the studies found a positive and statistically significant slope. Schwartz Test., Tr. Vol. 3-B, 22:18-26:14.

302. In his testimony, Dr. Schwartz's explained that variability among different studies' statistical significance does not thwart his analyses. Dr. Schwartz included studies such as these in his meta-analyses, because the meta-analyses incorporate the findings of vast amounts of data and publications to determine the overall trend. Dr. Schwartz used his most recent, most comprehensive meta-analysis when determining the concentration-response relationship for $PM_{2.5}$, as applied to this case. Id. at 23:19-24:8.

303. Schwartz also demonstrated a vast knowledge of these underlying publications, explaining the conditions and results of studies when questioned about them. Id. at 22:25-26:25.

304. For these reasons, the variation in some epidemiological studies does not undermine Dr. Schwartz's testimony concerning the health impacts of $PM_{2.5}$.

c. Rush Island's Excess Pollution Affects the Entire Eastern Half of the United States

i. Plaintiff's Experts Presented Detailed and Credible Modeling Results

305. To quantify the human health impacts of Rush Island's excess emissions, the EPA presented photochemical grid modeling results. Chinkin Test., Tr. Vol. 2-B, 17:23-30:16.

Photochemical grid modeling is a computer modeling technique that tracks the "fate and transport" of air pollution in the atmosphere, namely how pollutants chemically change and where those pollutants travel. Chinkin Test., Tr. Vol. 2-B, 25:15-17 (describing the "fate and transport" of pollution as an assessment of "how air pollution is formed and moves").

306. Most SO_2 released from a power plant converts to $PM_{2.5}$ before being deposited in the environment. Chinkin Test., Tr. Vol. 2-A, 99:9-14. The rate at which SO_2 is converted into $PM_{2.5}$ varies between about 1 percent and 10 percent per hour and is faster in warmer and more humid weather and slower in cool and dry weather. Chinkin Test., Tr. Vol. 2-A, 97:20-98:16.

307. The variation in this rate does not substantially change the ultimate volume of $PM_{2.5}$ resulting from the SO_2 pollution. Under certain circumstances the conversion process may take longer. Slightly more SO_2 may be deposited if conversion rates are slower, but most of the SO_2 that remains in the atmosphere will be converted to $PM_{2.5}$. Chinkin Test., Tr. Vol. 2-A, 97:20-99:23; see also Chinkin Test., Tr. Vol. 2-B, 30:2-16. In general, the SO_2 emitted in the center of the country will transform into $PM_{2.5}$ before it is blown out to sea. Chinkin Test., Tr. Vol. 2-A, 100:6-9.

308. The EPA hired expert Lyle Chinkin to conduct atmospheric fate and transport modeling based on the facts in this case. Chinkin is an expert in atmospheric air quality modeling, air pollution fate and transport analysis, and air quality measurements. Chinkin has more than 40 years of experience working with photochemical models. He has used those models to analyze air quality issues ranging from single-source impacts for private clients to regulatory analyses for state and federal agencies. Chinkin Test., Tr. Vol. 2-A, 91:16-93:1, 94:14-20; Chinkin Resume (Pl. Ex. 1322).

309. Chinkin used a photochemical model called CAMx to estimate the impact of Rush

Ex. AA-D-5

Island's excess pollution on downwind areas. CAMx is a reliable, state-of-the-science, peer-reviewed computer modeling program that is regularly used by both industry members and government regulators. Chinkin Test., Tr. Vol. 2-B, 4:12-5:20, 9:15-22.

310. Models like CAMx are used by air quality scientists, facility operators, and regulators to evaluate (1) the impact of a single source's pollution on the surrounding area, or (2) the downwind effect of an entire state's pollution portfolio. The EPA has long used air quality modeling like CAMx to assess the public health benefits associated with proposed rules and regulations. Chinkin Test., Tr. Vol. 2-B, 6:13-7:7.

311. To isolate the air quality impact from Rush Island's excess SO_2 pollution, Chinkin used a standard analytic technique known as a "with and without analysis." He ran the photochemical grid model twice, once in a "base case" and again in a "controlled case" scenario. In the base case, the inputs include the country's emissions profile and meteorology (wind, humidity, temperature, etc.), and the outputs are meant to replicate the ambient air quality. In the second controlled case scenario, the model setup remains unchanged except the emissions from one source—Rush Island—are reduced to account for the installation of pollution controls, specifically wet FGD. The differences in modeled $PM_{2.5}$ air quality concentrations between the two models are attributable to the difference in SO_2 contributed to the atmosphere from the examined source. Chinkin Test., Tr. Vol. 2-B, 8:3-9:9.

312. Photochemical modeling is time-consuming and expensive. CAMx divides the continental United States into 12-kilometer-square grids and then twenty-five planes of grid squares stacked upon each other, resulting in nearly 2.5 million cubic cells. In each of these cells, the model examines the concentration and influx of atmospheric constituents, calculates chemical reactions, and quantifies the resulting matter's transport into neighboring cells. The

model repeats these steps at five-minute intervals until it calculates an entire year's worth of reactions and physical transport. Because of the immense breadth of data and time-stepped calculations that are performed, modeling a year of pollution effects in CAMx can take weeks. Furthermore, developing the inputs for CAMx, including a verified and reliable emissions inventory, can take months. For these reasons, modeling more than a single year's worth of emissions is often impracticable. Chinkin Test., Tr. Vol. 2-B, 9:23-10:14.

313. A modeled year of results can be useful for estimating emissions impacts for other years, provided that year's weather and temperature data are fairly representative. In 2011, the weather and temperature data were representative of the weather and temperature data for the period Chinkin studied. Specifically, 2011's weather and temperature data were close to the median for years 2007 through 2016. For this reason, Chinkin chose to run the CAMx model for the 2011 emissions and meteorological data sets. Chinkin Test., Tr. Vol. 2-B, 29:9-30:16.

314. Although it is affected by temperature and other parameters, the relationship between the SO_2 concentrations and $PM_{2.5}$ formation is linear. As a result, the modeled $PM_{2.5}$ concentrations for 2011 can be scaled up or down on a percentage basis to estimate air quality impacts for other years. These estimates will not be perfectly accurate, but choosing a representative year such as 2011 decreases the overall bias and allows a larger timespan of emissions to be estimated without unnecessarily increasing litigation costs. Chinkin Test., Tr. Vol. 2-B, 29:18-24; see also id. Tr. Vol. 2-A, 98:22-99:8.

315. Modeling outputs will not perfectly match monitoring data. Any given monitor provides a point measurement of air quality at its location. In contrast, a photochemical grid model returns average air quality concentration values for a 12-square-kilometer area. Some of the locations within the modeled 12-kilometer grids will have higher concentrations, and others

will have lower concentrations. Nevertheless, comparing base case modeling results to monitors helps gauge whether the model is accurate. Chinkin Test., Tr. Vol. 2-B, 15:3-17:7.

316. Chinkin's base case model performed "exceptionally" well when compared with national monitoring networks, with error and bias measures well within industry standards for providing reliable results. Chinkin Test., Tr. Vol. 2-B, 17:8-18.

ii. The Model Predicts Rush Island's Excess Emissions Increased $PM_{2.5}$ Concentrations Across the Entire Eastern Half of the United States

317. The CAMx modeling Chinkin performed indicates that Rush Island's excess pollution impacts the entire Eastern United States. Chinkin Test., Tr. Vol. 2-B, 28:7-15. Ameren's own modeling expert, Ralph Morris, admitted that photochemical grid modeling showed excess pollution from Rush Island impacted $PM_{2.5}$ concentrations in Pennsylvania, Michigan, Louisiana, and even Florida. Morris Test., Tr. Vol. 5-A, 5:2-17.

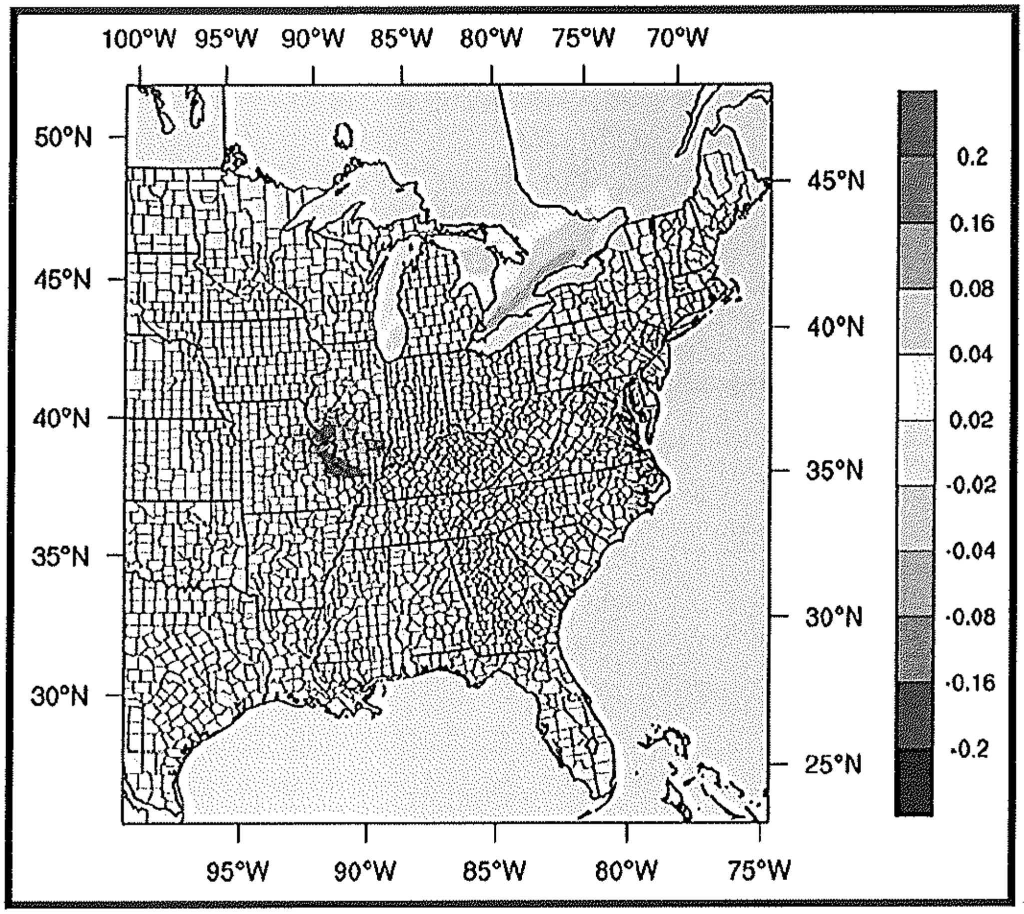
318. The impact of Rush Island's excess pollution depends in part on the wind and weather. <u>See, e.g.</u>, Chinkin Test., Tr. Vol. 2-B, 23:18-25:7; Model Results Maps (Pl. Exs. 1373-76).

319. On some days, the pollution's largest impact on air quality occurs relatively close to the plant. For example, as shown in Figure 4, on August 18, 2011, CAMx modeling shows Rush Island's excess pollution contributed as much as 2.25 $\mu g/m^3$ to ambient $PM_{2.5}$ concentrations in the greater St. Louis area. At the same time, some of the excess pollution was predicted to extend hundreds of miles further in a band stretching from Kansas to north of the Great Lakes. When describing this result, Chinkin testified: "I've been doing this for 30 plus years. That is a very large impact. *It's one of the largest I've seen from a single source on a single day.*" Pl. Ex. 1369; Chinkin Test., Tr. Vol. 2-B, 17:23-20:2 (emphasis added).

320. On other days, excess SO_2 pollution from Rush Island has its greatest air quality

impact hundreds of miles away. For example, as shown in Figure 5, on March 15, 2011, air quality modeling indicates Rush Island's excess SO_2 predominantly affected air quality to the southwest of the plant. The largest contributions for that day measured more than 0.02 $\mu g/m^3$ and occurring around Houston, Texas. See Pl. Ex. 1372. Regarding this result, Chinkin testified: "[C]onsidering it's one source and [the pollution has] now traveled hundreds if not a thousand miles away, that's a very large impact." Chinkin Test., Tr. Vol. 2-B, 22:2-19.

Figure 4



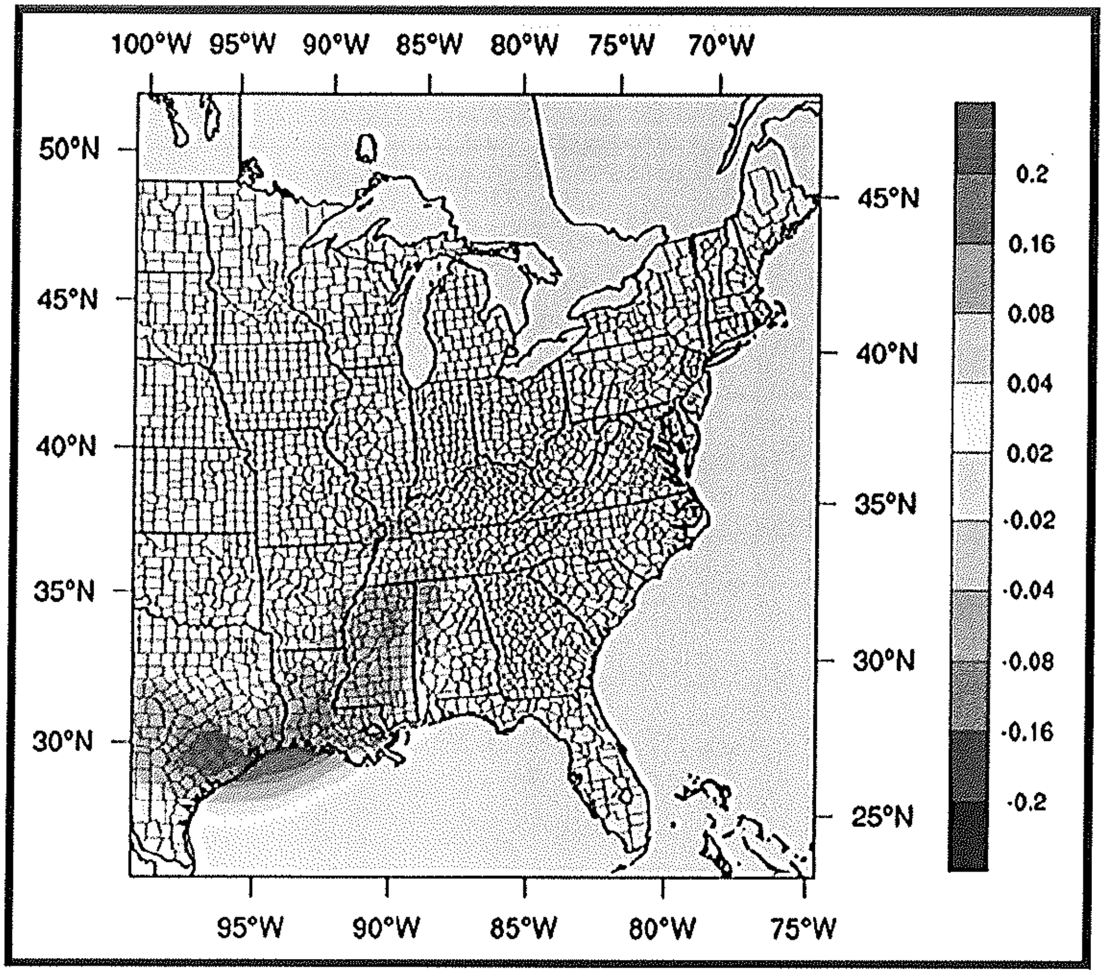
Pl. Ex. 1369 (described at Chinkin Test., Tr. Vol. 2-B, 17:23-20:2).

321. On more than 250 days in 2011 (70% of the days in the year), Rush Island's

excess SO_2 pollution contributed more than 0.1 $\mu g/m^3$ to downwind $PM_{2.5}$ concentrations. Chinkin Test., Tr. Vol. 2-B, 26:14-15.

322. During more than 90 days in 2011 (25% of the year)—and about half of summer days—Rush Island's excess pollution contributed more than 0.25 $\mu g/m^3$ to downwind $PM_{2.5}$ concentrations. Chinkin Test., Tr. Vol. 2-B, 26:15-20.

Figure 5

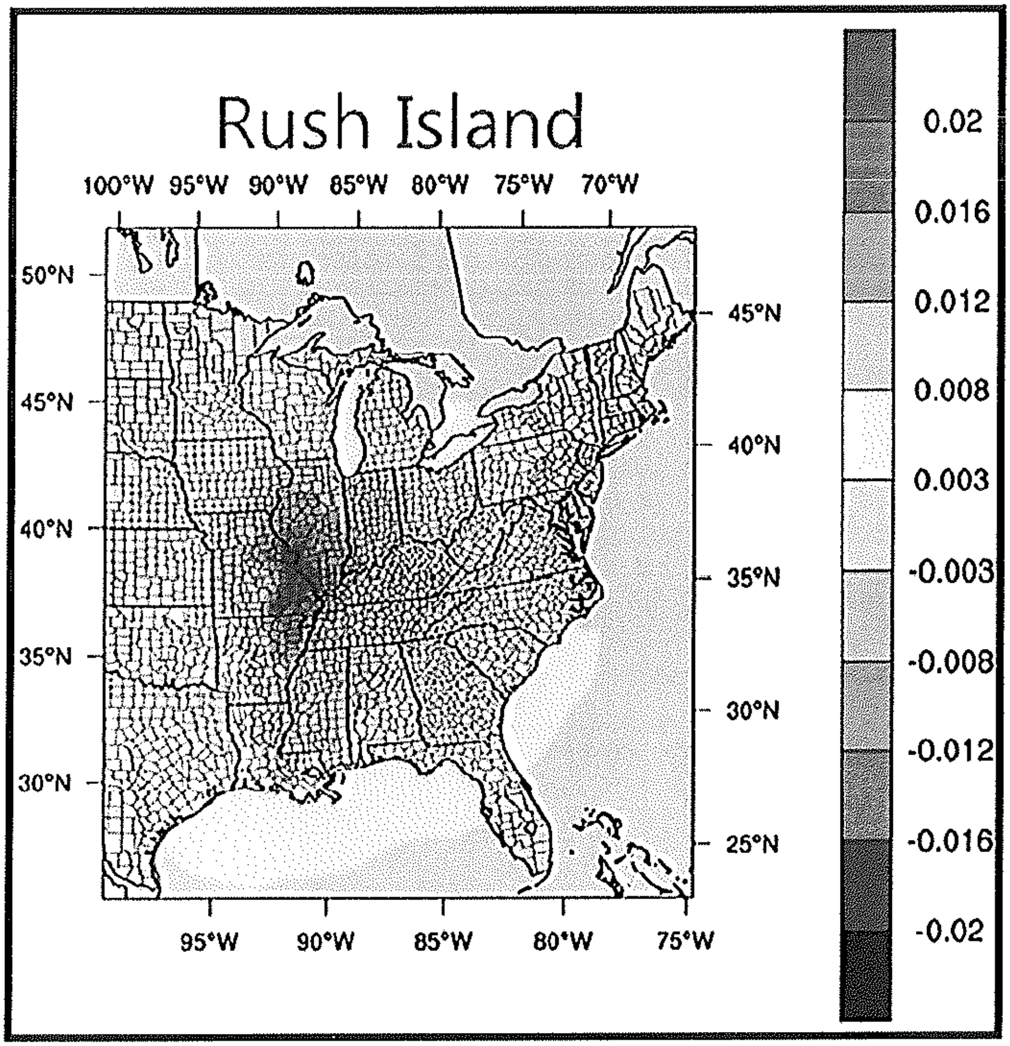


Pl. Ex. 1372 (described at Chinkin Test., Tr. Vol. 2-B, 22:2-19).

323. Compiling daily impact results into a single map and averaging the results provides a view of the annual average impact from Rush Island's excess SO_2 pollution on $PM_{2.5}$ concentrations. As seen in Figure 6, the area affected by Rush Island's excess SO_2 pollution

extends from the Gulf of Mexico to the Great Lakes, and from the middle of Kansas to the Atlantic coast.

Figure 6



Pl. Ex. 1364 (described at Chinkin Test., Tr. Vol. 2-B, 27:15-29:8).

324. The model predicted that at least one grid cell would have $PM_{2.5}$ concentrations 0.057 µg/ m^3 greater when averaged throughout the entirety of 2011. Chinkin Test., Tr. Vol. 2-B, 27:15-29:8.

d. Results of Two Different Models Show Rush Island's Excess Emissions Increased the Risk of Hundreds to Thousands of Premature Deaths

325. Plaintiffs presented two independent quantification methods to measure the harm from Rush Island's excess pollution. The first method relies on the results of a peer-reviewed risk assessment of 407 power plants, including Rush Island, published by Dr. Schwartz in 2009. Schwartz Test., Tr. Vol. 3-A, 88:11-89:18. The second method relies on the CAMx air quality modeling performed specifically for this case by the EPA's expert Chinkin.

326. Both risk assessments modeled $PM_{2.5}$ transport and concentration in ambient air. Using those concentrations, they estimated premature deaths in the exposed population. In doing so, both assessments applied the same approach used by public health agencies to quantify the risk of premature mortalities from exposure to $PM_{2.5}$, including the U.S. Centers for Disease Control, the World Health Organization, the National Academy of Sciences, and the EPA. Schwartz Test., Tr. Vol. 3-A, 83:6-87:9.

327. As described below, the models differ based on how they calculate concentrations and exposure. Despite these differences, the models showed consistent, comparable results among each other.

i. Dr. Schwartz Published a Peer-Reviewed Quantitative Risk Assessment for Rush Island's SO_2 Emissions in 2009

328. Unrelated to any litigation, the EPA's expert Dr. Schwartz previously co-authored a peer-reviewed, quantitative risk assessment of emissions from coal-burning power plants, including Rush Island. That assessment, "Uncertainty and Variability in Health-Related Damages from Coal-Fired Power Plants in the United States," was published in 2009 in the scientific journal "Risk Analysis." Schwartz Test., Tr. Vol. 3-A, 87:17-91:5.

329. Dr. Schwartz's 2009 risk assessment modeled SO_2 and resulting $PM_{2.5}$ pollution

using a pollution transport model known as a reduced-form model. The reduced-form model was calibrated to ensure consistency with actual monitoring data. Schwartz Test., Tr. Vol. 3-A, 89:19-90:10.

330. Reduced form models are commonly used in the scientific community to perform quantitative risk assessments. For instance, the National Academy of Sciences has used the reduced form model in performing similar risk assessments, and cited Dr. Schwartz's 2009 study in doing so. Schwartz Test., Tr. Vol. 3-A, 90:11-19.

331. Dr. Schwartz's 2009 risk assessment calculated 95% confidence intervals and incorporated uncertainties both for the modeled $PM_{2.5}$ exposure estimates as well as the concentration-response relationship. Schwartz Test., Tr. Vol. 3-A, 91:11-94:21. A 95% confidence interval means there is a 95% chance that the number of premature deaths that occurred as a result of excess pollution falls in the range identified in a given study. There is a remaining 5% probability (2.5% above the interval and 2.5% below the interval) that the number falls outside the identified range. Id.

ii. Dr. Schwartz Also Quantified Risk Based on Chinkin's CAMx Modeling

332. Dr. Schwartz also performed a second quantitative risk assessment based on the results of Chinkin's air quality modeling in this case using the CAMx model. Schwartz Test., Tr. Vol. 3-A, 95:5-95:14.

333. To evaluate impacts on premature mortality from the CAMx air quality concentrations, Dr. Schwartz relied on the most up-to-date concentration-response function for $PM_{2.5}$ available in the literature. Dr. Schwartz paired that concentration-response function with a reliable and peer-reviewed EPA risk assessment tool known as "BenMAP." BenMAP includes population and baseline mortality data for the entire country, including the areas impacted by

Rush Island's pollution. Schwartz Test., Tr. Vol. 3-A, 95:15-96:17.

334. Dr. Schwartz derived the specific concentration-response from a published, peer-reviewed meta-analysis he co-authored. The meta-analysis included all data points published by over 50 long-term epidemiological studies, with the goal of creating the best current function. Meta-analysis is "the standard approach for trying to integrate multiple studies . . . and come up with . . . the best estimate." Schwartz Test., Tr. Vol. 3-A, 96:2-11, 97:3-100:17.

335. Dr. Schwartz's meta-analysis included 95% confidence intervals reflecting uncertainty in the calculated $PM_{2.5}$ concentration-response relationship. These confidence intervals are narrower than those derived in Dr. Schwartz's 2009 risk assessment, because the meta-analysis incorporated results from millions of study participants. Schwartz Test., Tr. Vol. 3-A, 99:6-25, 101:21-102:7.

336. The confidence intervals for Dr. Schwartz's CAMx-based risk assessment do not include any uncertainty related to the accuracy of the modeled $PM_{2.5}$ exposure estimates; CAMx is a deterministic model that produces a precise number based on the laws of physics and chemistry and specific inputs. Public health professionals routinely use deterministic models to estimate health effects from incremental changes in air pollution. Chinkin Test., Tr. Vol. 2-B, 8:12-9:1; Schwartz Test., Tr. Vol. 3-A, 93:10-15, 102:8-104:6.

iii. Rush Island's Excess Emissions Caused Hundreds to Thousands of Premature Deaths

337. Public health risk assessments demonstrate the overall effect of exposing a population to an increased risk of harm. They do not identify a specific individual who was, or will be, harmed by an exposure. Schwartz Test., Tr. Vol. 3-A, 82:14-87:2, 104:19-107:2.

338. Based on the two risk assessments described above, Dr. Schwartz calculated premature deaths *expected* to result from Rush Island's excess emissions. This metric represents

an increased risk of harm, not any specific person's death. Table 1 shows Dr. Schwartz's calculated expected premature mortality, based on Rush Island's excess emissions. For 2007 to 2016, Dr. Schwartz calculated 637 and 879 expected premature mortality events based on the reduced form model and CAMx model, respectively. Dr. Schwartz calculated that after 2016, an average of 62 or 86 premature mortality events per year are expected, based on the reduced form and CAMx models, respectively. Schwartz Test., Tr. Vol. 3-A, 91:11-24, 95:25-96:4, 101:15-20, 104:15-18.

Table 1

Premature Mortality	Reduced Form Model (95% confidence interval)	CAMx Model (95% confidence interval)
Per Thousand Tons	3.9	5.4
2007-2016	637 (172 - 1,436)	879 (738 - 1,215)
2017 and beyond	62/ year	86/ year

339. Dr. Schwartz's risk assessments demonstrate that Rush Island's excess emissions pose substantial risk of harm to the exposed populations. They also show that the harm will continue until Rush Island's excess emissions stop. Schwartz Test., Tr. Vol. 3-A, 82:14-83:4, 107:3-16, 109:1-13.

340. The similarity of results, 95% confidence intervals, and peer-reviewed nature of these models provide me with a high degree of confidence in my conclusion that Rush Island's excess emissions have harmed public health and welfare. Schwartz Test., Tr. Vol. 3-A, 87:17-88:8, 89:19-90:10, 91:11-24, 94:13-21, 101:1-102:25, 109:1-13.

e. Ameren's Criticisms of the EPA's Model Are Not Persuasive

341. Ameren makes two main criticisms of the EPA's modeling methods and results: (1) that incremental changes smaller than the EPA's Significant Impact Levels (SILs) are meaningless, and (2) that modeling performed on behalf of the EPA in this litigation is

"[u]ncertain, [o]verstated, and [u]nreliable."

342. The SILs are "screening tools the EPA uses to determine whether a new source may be exempted from certain requirements under § 165 of the Act, 42 U.S.C. § 7475." Sierra Club v. E.P.A., 705 F.3d 458, 459 (D.C. Cir. 2013). "[Section] 165(a)(3) requires that an owner or operator . . . demonstrate that emissions from construction or operation of the facility will not cause or contribute to any violations of the increment more than once per year, or to any violation of the NAAQS ever." Id. at 460.

343. The EPA has not alleged, and its case does not depend on, any NAAQS or PSD increments violations in this case.

344. As a result, Ameren's SILs argument does not make the EPA's modeling methods or results less credible or convincing.

345. With respect to SILs, Ameren asserts that changes in concentrations below the EPA's established SILs do not represent a meaningful or significant threat to human health.

346. The SILs were designed for use in the PSD permitting process, to determine if, despite the installation of BACT, the creation or modification of a source would lead to NAAQS violations. Knodel Test., Tr. Vol. 1-A, 64:25-66:25, 92:23-93:25; NSR Manual (Pl. Ex. 1190), at AM-REM-00544163; MDNR Rule 30(b)(6) Dep., Aug. 10, 2018, Tr. 135:9-20, 135:25-136:4.

347. The SILs were derived from a statistical analysis of the limits of monitoring data, based on a finite network of variably-placed monitors. Morris., Tr. Vol. 5-A, 6:20-25. Recognizing that "there is an inherent variability in the air quality" "due to fluctuating meteorological conditions and changes in day-to-day operations of all air pollution sources in an area," the EPA developed the SILs using "a statistical analysis of the variability of air quality, using data from the U.S. ambient monitoring network for ozone and $PM_{2.5}$." (Ex. HB at HB_12.).

348. The EPA has relied on modeled concentration changes below the SILs in calculating human health benefits—including changes even below 0.01 μg/ m^3, orders of magnitude less than the 0.2 μg/ m^3 SIL value Ameren's expert Ralph E. Morris used as a comparator. Morris Test., Tr. Vol. 5-A, 14:10-16:20; Schwartz Test., Tr. Vol. 3-A, 108:3-25.

349. Independently, Ameren argues that the EPA's modeling results are "[u]ncertain, [o]verstated, and [u]nreliable." Ameren makes this argument based on (1) model noise, (2) the EPA's use of 2011 meteorology data as representative of other years, (3) the EPA's use of a baseline for its Labadie model that included FGD controls on Rush Island, and (4) the difference between 12-kilometer grid cell estimates and monitors point estimates.

350. I find that Ameren's arguments about these features do not render the EPA's modeling methods or results less credible or convincing.

351. First, large-scale models—including the one from the EPA's expert Chinkin—include some noise. This is because algorithms conducting millions of calculations can produce data (the noise) that are not a direct result of the variables that are the focus of the model. In this case, for example, some of the data in Chinkin's model were not tied to a hypothetical reduction in SO_2 pollution. Ameren's expert Morris correctly notes that when relying on "this kind of approach using one simulation subtracting from another," the modeler "need[s] to be very careful" that "[he is] looking at concentrations above model noise." Morris Test. Tr. Vol. 4-B, 79:22-89:12.

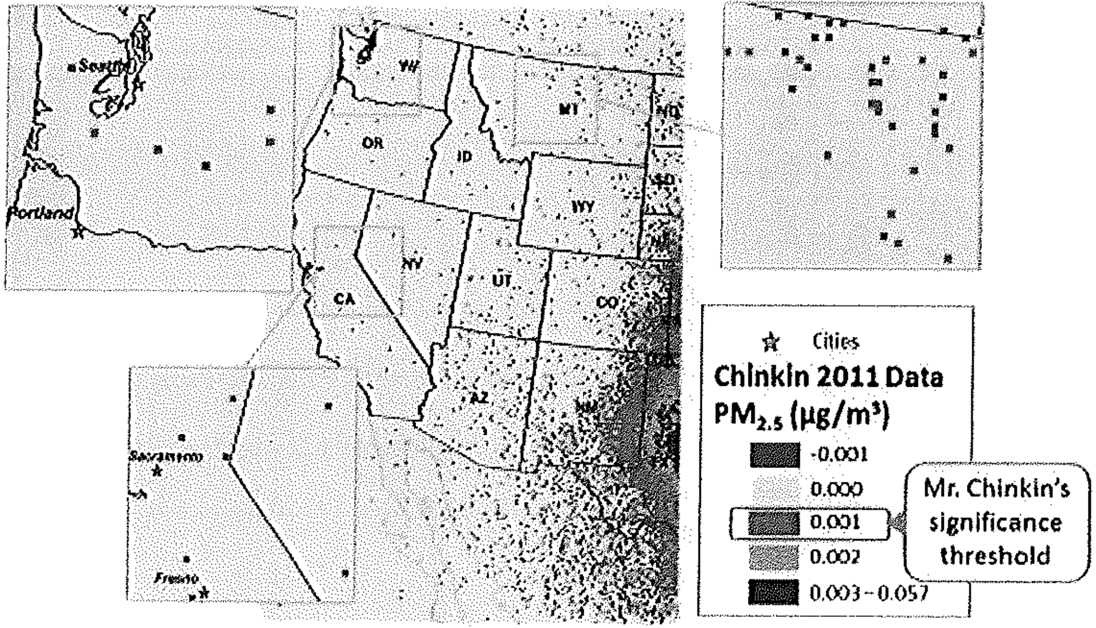
352. Ameren argues that the presence of model noise near the EPA's 0.001 μg/m^3 modeling threshold makes the EPA's CAMx results unreliable. Ameren specifically points to model noise found in Montana, Washington, and California as shown in Def. Figure A.

353. Model noise is both positive and negative in these areas. Ameren does not present

any evidence demonstrating that the model noise has led to any bias or that the model noise played any significant role in the final results of the CAMx modeling. Therefore, Ameren's model noise argument does not make the EPA's modeling methods or results unreliable or unconvincing.

Def. Figure A

Mr. Chinkin's 2011 Modeled Impacts Ignore Model Noise at His Significance Threshold



Source: Mr. Chinkin's Modeling Files; Morris Report pp. 41-43, 48, Fig 3-21

354. Second, Ameren argues that the EPA should have used year-specific meteorology data for every year since the Rush Island major modifications in 2007. I agree with Ameren that the EPA's model results would have been even more precise if they had run the voluminous and expensive CAMx model twelve or more times, for every year from 2007 through 2018. However, the EPA made a reasonable choice to run the data-, time-, and resource-intensive CAMx model four times using 2011 as a representative year (with a base and emissions-

controlled case for both Rush Island and Labadie). Ameren did not present sufficient evidence to demonstrate that this approach was unreliable or unconvincing.[10]

355. Third, Ameren argues that the EPA should have used the same baseline emissions scenario for its Rush Island and Labadie modeling. When the EPA modeled the impact of installing pollution equipment on Labadie, its base case assumed that pollution controls would also be installed on Rush Island, due to the outcome of this litigation. The point of the modeling was to determine whether emissions reductions from Labadie would affect the same population impacted by Rush Island's excess emissions. The EPA reasonably assumed that I would not order emissions reductions at Labadie if I did not also order emissions reductions at Rush Island. Under that condition, it would be inappropriate to use the same base case for Rush Island and Labadie CAMx modeling. Ameren's argument regarding baseline emissions does not make the EPA's modeling methods or results unreliable or unconvincing. Chinkin Test., Tr. Vol. 2-B, 31:21-33:22.

356. Fourth, Ameren argues that differences between 12-kilometer grid-cell model results and point-measurements of the $PM_{2.5}$ concentration near St. Louis make the EPA's CAMx modeling unreliable and unconvincing. As I explained above, modeling outputs will not perfectly match monitoring data. Any given monitor provides a point measurement of air quality at its location. In contrast, a photochemical grid model returns average air quality concentration values for a 12-square-kilometer area. FOF ¶ 312; Chinkin Test., Tr. Vol. 2-B, 15:3-17:7.

357. Ameren's argument about differences between monitoring data and modeled results does not make the EPA's modeling methods or results unreliable or unconvincing. The

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[10] For example, Ameren did not provide a copy of the 2017 guidance document that Ameren's expert Morris says encourages modelers to use year-specific data. Morris Test., Tr. Vol. 4-B, 94:3-95:12. Without more information concerning that guidance, I cannot determine the weight to give this guidance.