In the United States Court of Appeals
FOR THE EIGHTH CIRCUIT

No. 24-2123(L)
Southwestern Electric Power Company; Utility Water Act Group,
Petitioners,

v.

United States Environmental Protection Agency; Michael S. Regan, Administrator, United States Environmental Protection Agency,
Respondents,

Clean Water Action; Sierra Club; Waterkeeper Alliance, Inc.; Natural Resources Defense Council; Environmental Integrity Project' PennEnvironment, Inc.; and Prairie Rivers Network,
Intervenors.

On Petitions for Review from the
U.S. Environmental Protection Agency

UTILITY AND STATE PETITIONERS' REPLY IN SUPPORT OF MOTION FOR A STAY PENDING REVIEW

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Petitioners,

v.

United States Environmental Protection Agency; Michael S. Regan, Administrator, United States Environmental Protection Agency,

Respondents,

Clean Water Action; Sierra Club; Waterkeeper Alliance, Inc.; Natural Resources Defense Council; Environmental Integrity Project; PennEnvironment, Inc.; and Prairie Rivers Network,

Intervenors.

No. 24-2215

City Utilities of Springfield, Missouri, by and through the Board of Public Utilities,

Petitioner,

v.

United States Environmental Protection Agency; Michael S. Regan, Administrator, United States Environmental Protection Agency,

Respondents,

Clean Water Action; Sierra Club; Waterkeeper Alliance, Inc.; Natural Resources Defense Council; Environmental Integrity Project; PennEnvironment, Inc.; and Prairie Rivers Network,

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TABLE OF ABBREVIATIONS

2020 Rule	*Steam Electric Reconsideration Rule*, 85 Fed. Reg. 64,650 (Oct. 13, 2020)
2024 Rule or "the Rule"	*Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*, 89 Fed. Reg. 40,198 (May 9, 2024)
APA	Administrative Procedure Act
BAT	Best Available Technology Economically Achievable
CWA	Clean Water Act
ELGs	Effluent Limitation Guidelines
EPA	U.S. Environmental Protection Agency
Leachate	Combustion Residual Leachate
NOPP	Notice of Planned Participation
PSES	Pretreatment Standards for Existing Sources
Scrubber Water	Flue Gas Desulfurization Wastewater
UWAG	The Utility Water Act Group
VIP	Voluntary Incentive Program

INTRODUCTION

When an agency discovers evidence that confounds its central hypotheses, it must grapple with that evidence. Reasoned decisionmaking requires no less, especially when the evidence bears on factors Congress mandated the agency consider. It is not enough, the Supreme Court recently instructed, to merely acknowledge the inconvenient evidence and "sidestep it." *Ohio v. EPA*, 144 S.Ct. 2040, 2054–55 (2024).

Yet that is what EPA did here. The statute directs EPA to base its rule on "the best available technology economically achievable." But EPA shrugged off evidence that showed its cost model was flawed. EPA's disinterest ruined its economic analysis, prevented a true accounting of the colossal expenditures made in reliance on EPA's 2020 Rule, and undermined EPA's determination that the systems it requires are actually available to meet the 2024 Rule limits.

The 2024 Rule should be stayed.[1]

[1] If the Court grants Petitioners' motion to expand the word limit, ECF No.5427443, Petitioners will file a 5,200 word version of this reply.

ARGUMENT

I. Petitioners are likely to prevail on the merits.

A. EPA failed to grapple with evidence that revealed serious flaws in its cost-estimation methodology.

The CWA requires EPA to set effluent limitations based on "the best available technology economically achievable," accounting for "the cost of achieving such effluent reduction." 33 U.S.C. §§1311(b)(2)(A), 1314(b)(2)(B). Despite this mandate, EPA ignored real-world data demonstrating its 2020 Rule cost methodology—carried forward in the 2024 Rule without material change—dramatically underestimated costs. Mot. at 14-16, 21-23, ECF No.5417837. EPA thus neglected to "'deal with newly acquired evidence in some reasonable fashion.'" *Catawba Cnty. v. EPA*, 571 F.3d 20, 45 (D.C. Cir. 2009) (citation omitted). And it failed to account for the real-world reliance interests its 2024 reversal harmed. *Dep't of Homeland Sec. v. Regents of the Univ. of California*, 591 U.S. 1, 30 (2020).

EPA cannot point to anything in the record showing it meaningfully engaged evidence demonstrating the 2020 Rule's cost projections dramatically missed the mark. Instead, EPA insists accuracy is overrated; it speculates the figures utilities provided are no more reliable

than its own estimates; and it dismisses unit-level costs as irrelevant. None of these responses justifies EPA's error.

1. The statute requires EPA to make a reasoned evaluation of cost.

EPA first argues (at 9-11) it can ignore the 2020 data because the CWA-mandated cost analysis does not require "precis[ion]." ECF No.5426258. Nothing in the text of the statute suggests a cost methodology that produces estimates that miss the mark by factors of three, five, and even ten is remotely acceptable. *See* 33 U.S.C. §§1311(b)(2)(A), 1314(b)(2)(B).

Under the APA, EPA must estimate the "cost of achieving" its required effluent limitations through reasoned decisionmaking. That requires the agency to "examine the relevant data and articulate a satisfactory explanation for its action" in light of that data. *Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983). An agency that persists in using figures impeached by real-world data disregards "an important aspect of the problem" and provides "an explanation … that runs counter to the evidence before [it]." *Id.* at 43; *see also, e.g., Dist. Hosp. Partners, L.P. v. Burwell*, 786 F.3d 46, 57 (D.C.

Cir. 2015) ("These requirements underscore that an agency cannot *ignore* new and better data."). Yet that is what EPA did.

2. EPA identifies no record basis for dismissing industry-provided cost figures.

EPA next argues (at 13-15) that unit-level costs to comply with the 2020 Rule, which EPA requested and industry participants provided, can be disregarded as mere estimates. This defense fares no better.[2]

To begin, EPA's "mere estimate" explanation appears nowhere in the administrative record, where such explanations belong. *See State Farm*, 463 U.S. at 43 (quotation omitted). The agency's lawyers cannot supply those essential explanations for the first time now. *Gatewood v. Outlaw*, 560 F.3d 843, 846 (8th Cir. 2009).

And the numbers industry provided are much more than estimates. Utilities based those figures on actual contractor bids and months of on-the-ground design work at individual plants and presented them in State Public Utility Commission proceedings. So they provided EPA just the type of credible data needed to validate the accuracy of its methodology.

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[2] EPA (at 12-13) labels Petitioners' references to EPA's 2020 cost methodology a "collateral attack" on the 2020 Rule. Not so. Petitioners argue EPA arbitrarily ignored actual cost data resulting from the 2020 Rule that undermines the same cost methodology used in the 2024 Rule.

That makes EPA's disregard of examples like Plant Bowen so perplexing. EPA estimated $28.6 million in capital costs to install a 2020-Rule-compliant system there, but as even Intervenors[3] acknowledge, the design and ongoing construction effort at Plant Bowen has already cost the utility $50 million and is expected to cost $110 million once complete. Intervenors' Ex.6, Att.A at 3-4, ECF No.5426423. EPA did not even try to explain the discrepancy.

Intervenors engaged consultants to analyze costs. *See* Intervenors' Ex.6, Att.A. But their analysis is not in the administrative record, and EPA was the party obligated to conduct the analysis. *Robinette v. Comm'r of IRS*, 439 F.3d 455, 459 (8th Cir. 2006) (administrative review is "'ordinarily limited'" to the evidence the agency considered). These litigation-retained experts draw the wrong conclusion just the same.[4]

Further, the extra-record evidence Intervenors cite paradoxically shows utilities were right when they told EPA that 2020 Rule compliance

[3] "Intervenors" refers to the parties who signed Intervenors' Response Brief, ECF No.5426423. Those parties include Intervenors in cases 24-2123, 24-2215, 24-2225, and 24-2266, and Environmental Petitioners in case 24-2255.

[4] *See infra* Section I.A.3.

would cost much more than EPA estimated, and that EPA's methodology failed to account for important aspects of the problem.[5]

3. Plant Miller illustrates how EPA irrationally dismissed contrary evidence.

Preliminary estimates of what it would cost to achieve the zero discharge limits required by EPA's 2023 proposed rule similarly confounded EPA's model. Mot. at 16-17, 22-23. The experience at Plant Miller illustrates the problem.

Plant Miller's operator selected an engineering firm to prepare a cost estimate for implementing a system that would achieve zero discharge as required by EPA's Proposed Rule. The firm found that the system EPA pegged for Plant Miller—membranes only—would not work at the plant. *See* Pet'rs' Ex.6, App.A. EPA's analysis generally assumed that every plant could manage and dispose of the byproduct of membrane treatment (brine) by mixing in some ash or lime and *pumping* the

[5] *Compare*, *e.g.*, Trimble County Scrubber Water treatment capital costs in Intervenors' Ex.8 at 12 ($51.6 million) *to* Pet'rs' Ex.13 at 83 (UWAG member's 2020 estimate of $64.8 million versus EPA's 2020 estimate of $12.8 million); *compare* Mill Creek Scrubber Water treatment capital costs in Intervenors' Ex.8 at 13 ($71.2 million) *to* Pet'rs' Ex.13 at 83 (UWAG member's 2020 estimate of $68 million versus EPA's 2020 estimate of $5.6 million).

resulting toothpaste-like substance to a nearby landfill. But Plant Miller does not have a landfill within pumping distance. *Id.* at 42. And while conducive to pumping, the toothpaste-like substance is not sufficiently stable to be trucked offsite. After careful study, the engineers concluded that the most cost-effective way to achieve zero-discharge would be to add a thermal evaporator to the treatment system to further eliminate moisture from the brine, thereby stabilizing it for transport and disposal. *See id.*, App.A. That dramatically multiplied the cost. *Id.*

Rather than pause and assess why its projection of what it would take to comply with the Rule is so different from what industry is experiencing in real time, EPA insists (at 15) it need not consider the additional costs required by Plant Miller's thermal evaporator system because EPA concluded that only membranes were necessary. EPA's tautological approach—"a system is necessary only when we say it's necessary"—drives home how out of touch it is with the problems people face in trying to carry out its dictates.

4. Unit-level errors are significant, because EPA calculates industry-wide costs by summing unit-level costs.

EPA says (at 11, 13) it can ignore the unit-level cost discrepancies because only industry-wide costs matter. This argument is wrong.

First, as EPA admits (at 11), it determined what is economically achievable "by estimating plant-specific compliance costs and summing them up to estimate industry-wide costs." Thus, if unit-level costs consistently underestimate plant-specific costs, EPA's industry-wide sum necessarily compounds that error.

Second, EPA (at 17) wrongly faults Petitioners for not calculating cost errors at the industry-wide level. But it is EPA's job—not Petitioners'—to wrestle with the evidence presented to the agency and explain how it reached its conclusion despite that evidence. *State Farm*, 463 U.S. at 50. That is especially true here, where EPA has the ability to collect information for the entire industry, while much of the cost information available to Petitioners (beyond their own operations) is protected as confidential business information.[6] That only underscores why EPA must conduct the analysis in the first instance.

[6] *See, e.g.*, Pet'rs' Exs.26-29.

B. EPA's arguments on availability reinforce its failure to consider contrary information.

EPA's flawed conclusion on the "availability" of zero-discharge technologies goes hand-in-hand with its indifference to the actual costs utilities are incurring on the ground. Because zero-discharge technologies are not actually "available" to treat these wastestreams, utilities trying to employ those technologies are encountering difficult and costly problems. EPA breezed past these problems.

None of the three technologies EPA touts (membranes and two types of evaporators) are demonstrably "available" to achieve zero discharge in an economically achievable manner industry-wide (including in combination with one another), especially for chemically complex Scrubber Water known to foul membranes and thermal evaporators. *See* Pet'rs' Ex.13 at 58-77, 88-92. So EPA and its allies create an alternative reality, where steam electric plants across the country are essentially identical. In this world, EPA can point to plants in hot-and-dry Texas it says have achieved some form of zero discharge (e.g., via evaporation ponds) to conclude that a plant in muggy South Carolina can achieve the same. But it never drills down to assess the volume, flow rate and chemistry of the treated wastestreams, the period

over which the treatment was used, its reliability, or unique aspects of the facility that may have made the use of zero-discharge technologies feasible. These are critical aspects of the problem, and EPA's failure to deal with them renders its decision arbitrary and capricious. *State Farm*, 464 U.S. at 43.

EPA and its allies also rely on pilot studies that often fail to match real-world scale and conditions. For example, many of the examples of pilot studies and foreign applications EPA cites are based on use of membrane filtration for wastestreams other than Scrubber Water, which is chemically unique and much more difficult to treat than many other wastewaters. Pet'rs' Ex.30 at 65-66. Where EPA's examples do involve Scrubber Water, they generally fail to acknowledge the circumstances unique to those plants or provide sufficient details to allow complete comparisons. For example, EPA includes an April 2024 "Technologies" memo that begins by describing five plants in Italy it says achieve zero discharge of Scrubber Water, but the memo does not describe Scrubber Water flow volumes, rates, or chemistry; whether the equipment maintained full operational status and if so over what period; whether and if so how the local climate supported use of evaporation ponds; actual

system performance in achieving zero discharge; and any problems encountered.[7] It comes as no surprise, then, that Intervenors are wrong to claim (at 7) EPA has "identified at least three domestic plants using membrane filtration." As of today, not one of these three plants has successfully installed membrane treatment.[8]

II. Petitioners will suffer significant irreversible costs over the next year absent a stay.

The Rule's December 2025 deadline for opting into its retirement option is a fork in the road. By that fast-approaching date, Petitioners must decide whether they can (and if so should) retrofit their plants to install EPA's mandated technologies, or retire coal combustion altogether.[9] Petitioners cannot wait to assess those consequential options. They must instead immediately sink millions into research and evaluation necessary to make informed decisions by the deadline. Pet'rs'

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[7] *See* Pet'rs' Ex.31. To the extent EPA has this information somewhere other than the memo, EPA does not explain how it would analyze the information to determine these systems are available to achieve zero discharge in the U.S. industry-wide, particularly in light of EPA's opposite determination in 2020.

[8] *See* Pet'rs' Exs.32-35.

[9] For indirect discharges, the Rule establishes pretreatment standards for existing sources (PSES) that are the same as the BAT limits (with limited exceptions) and apply May 9, 2027. 89 Fed. Reg. 40,198, 40,200 (May 9, 2024). Some Petitioners face that deadline.

Ex.1 ¶¶20-25; Ex.19 ¶40; Ex.21 ¶25.[10] If Petitioners ultimately prevail on the merits, even under EPA's optimistic timeline for a merits decision (EPA Resp. at 25) it will be too late to avoid "certain," "great," and "imminen[t]" expense. Pet'rs' Ex.1 ¶55; Ex.19 ¶45; Ex.21 ¶35; *Iowa Utils. Bd. v. F.C.C.*, 109 F.3d 418, 425 (8th Cir. 1996).

EPA says (at 21-23) Petitioners can hold off assessing their options because the new limitations do not apply immediately. But in addition to the 2025 retirement decision deadline, utilities must submit development plans to State authorities years in advance of operational changes, a reality EPA acknowledged in the Rule. *See* 89 Fed. Reg. at 40,283 ("EPA recommends that each plant ***immediately*** begin evaluating how it intends to comply") (emphasis added).

EPA also downplays (at 24) the December 2025 deadline by suggesting that most plants have already decided whether to retire. This too is out of step with reality. For a host of reasons—the costs of untested zero-discharge technologies first among them—most plants that have not

[10] Intervenors' expert declaration *confirms* the irreparable harm Petitioners will suffer during this litigation. *See* Intervenors' Ex.11 ¶34 ("[T]he maximum risk during the pendency of this litigation for a [2,600 MW plant] would be $17 million.").

previously opted into the retirement schedule are seriously considering it now. Pet'rs' Ex.19 ¶¶25, 30, 44; Ex.20 ¶¶25, 28; Ex.21 ¶30. And that consideration alone involves substantial expense.

EPA argues (at 25) Petitioners face no imminent reputational harm. But EPA misses the point. As the Rule itself contemplates, Petitioners are bearing massive costs associated with its mandates *right now*. And on top of those costs, the Rule strands Petitioners with millions of dollars in costs associated with the 2020 Rule. Pet'rs' Ex.1 ¶38; Ex.19 ¶43; Ex.21 ¶20; Ex.22 ¶¶8, 10. Consumers will feel the effects of those costs well before this case ends and invariably blame Petitioners.

III. The public interest and balance of the equities weigh in favor of a stay.

EPA and Intervenors argue a stay would lead to immediate environmental harm. These predictions find no support in the record. Even under EPA's unrealistic projections, environmental benefits would not begin to accrue before 2026. *See* Pet'rs' Ex.15 at 3-5; 89 Fed. Reg. at 40,257; *but see* Pet'rs' Ex.1 ¶¶22-25. By contrast, Petitioners must spend money planning, designing, and evaluating required treatment systems right now, Pet'rs' Ex.1 ¶29; Ex.19 ¶26; Ex.21 ¶¶20-21, leaving ratepayers

to pick up the tab. Pet'rs' Ex.1 ¶¶29, 52; Ex.19 ¶19; Ex.21 ¶¶7-8; Ex.23 ¶18; Ex.24 ¶7; Ex.25.

IV. The Court should stay the entire rule.

Finally, EPA says (at 27-28) the Court may stay only those aspects of the Rule Petitioners address in their motion. Although Petitioners have focused on Scrubber Water and Leachate, EPA's flawed assessment of economic achievability touches every part of the Rule and requires it be stayed in its entirety.

CONCLUSION

The Court should stay the 2024 Rule.

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CERTIFICATE OF COMPLIANCE

I hereby certify that the foregoing Utility and State Petitioners' Reply in Support of their Motion for A Stay Pending Review complies with the type-volume limitation of Federal Rules of Appellate Procedure 27(d) and 32(a) because it contains 2,593 words. This Reply complies with the typeface and the type style requirements of Federal Rules of Appellate Procedure 27(d) and 32(a) because this brief has been prepared in a proportionally spaced typeface using Word 14-point Century Schoolbook typeface.

Dated: September 4, 2024

/s/ *George P. Sibley, III*
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CERTIFICATE OF SERVICE

I hereby certify that on this 4th day of September 2024, the foregoing Utility and State Petitioners' Reply in Support of their Motion for A Stay Pending Review was electronically filed with the Clerk of Court for the U.S. Court of Appeals for the Eighth Circuit by using the CM/ECF system.

I further certify that all participants in the case are registered CM/ECF users and that service will be accomplished by the CM/ECF system.

/s/ *George P. Sibley, III*
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INDEX OF EXHIBITS

Ex. 26	EPA-HQ-OW-2009-0819-9484 – CBI re: Vendor Cost Data for Heartland FGD Wastewater Treatment Technology
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Ex. 28	EPA-HQ-OW-2009-0819-9681-ATT1 – CBI re: Thermal Evaporation Cost Methodology – Cost Calculation File
Ex. 29	EPA-HQ-OW-2009-0819-9682 – CBI re: Spray Dryer Evaporator Cost Calculation
Ex. 30	EPA-HQ-OW-2009-0819-10161 – Comments of the Utility Water Act Group (UWAG) on EPA's Proposed Rule; Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (May 30, 2023) (Excerpts)
Ex. 31	EPA-HQ-OW-2009-0819-10358 – EPA Memorandum to Steam Electric Rulemaking Record – EPA-HQ-OW-2009-0819, "Technologies for the Treatment of Flue Gas Desulfurization Wastewater, Coal Combustion Residual Leachate, and Pond Dewatering – 2024 Final Rule – DCN SE11695" (Apr. 22, 2024)
Ex. 32	Georgia Power, Plant Scherer – NPDES Permit No. GA0035564, ELG Progress Report – October 12, 2023
Ex. 33	Santee Cooper – Cross Generating Station; Notice of Planned Participation – Annual Report of Progress (Oct. 10, 2023)
Ex. 34	EPA-HQ-OW-2009-0819-10071 – Comments of Santee Cooper on the Proposed Rule to Revise the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Source Category (May 30, 2023) (Excerpts)

Ex. 35	DTE Electric Company, Flue Gas Desulfurization Wastewater (FGD) Voluntary Incentive Program (VIP) 2023 Annual Progress Report (Dec. 21, 2023)

EXHIBIT 26

STEAM ELECTRIC CBI REPLACEMENT PAGE

EPA-HQ-OW-2009-0819

DCN: SE10369

THE FOLLOWING HAS BEEN REMOVED BECAUSE IT CONTAINS CONFIDENTIAL BUSINESS INFORMATION (CBI) PER 40 CFR PART 2, SUBPART B.

EXHIBIT 27

STEAM ELECTRIC CBI REPLACEMENT PAGE

EPA-HQ-OW-2009-0819

DCN: SE10370

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EXHIBIT 28

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DCN: SE10246A1

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EXHIBIT 29

STEAM ELECTRIC CBI REPLACEMENT PAGE

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Re: Comments on EPA's Proposed Rule; Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, 88 Fed. Reg. 18,824 (Mar. 29, 2023), EPA-HQ-OW-2009-0819

Dear Mr. Benware:

Attached are the Comments of the Utility Water Act Group (UWAG) on EPA's Proposed Rule for the Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, EPA-HQ-OW-2009-0819.

We appreciate the opportunity to comment. Please contact me at (202) 955-1629 if you have any questions.

Sincerely,

Brian R. Levey

Brian R. Levey

Attachment

Appellate Case: 24-2123 Page: 1 Date Filed: 09/04/2024 Entry ID: 5432163

Comments of the Utility Water Act Group on
Environmental Protection Agency Proposed Rule;
Supplemental Effluent Limitations Guidelines and Standards for the
Steam Electric Power Generating Point Source Category

88 Fed. Reg. 18,824 (Mar. 29, 2023)
Docket ID No. EPA–HQ–OW–2009–0819

May 30, 2023

www.utilitywateractgroup.org

Executive Summary

EPA's new proposed effluent limitations guidelines (ELG) rule represents a staggering change of course on wastewater treatment requirements that were just imposed in EPA's 2020 ELG rule. The electric power industry is transitioning to low- and zero-carbon power as fast as possible consistent with providing affordable and reliable energy. This rulemaking threatens to disrupt those efforts by diverting time and money to a mid-course change unlikely to yield benefits commensurate with its costs. The Utility Water Act Group (UWAG)[1] urges EPA to preserve key aspects of—and tremendous industry and public investments made in reliance upon—EPA's 2020 ELG rule.

A. EPA Should Preserve Key Aspects of the 2020 ELG Rule.

EPA's final 2020 ELG Rule required covered facilities to either commit millions of dollars and years of time to installing new wastewater treatment equipment, or retire. Numerous plants announced plans to retire, and the remainder are now incurring substantial costs to comply with the 2020 Rule's still-binding requirements. Naturally, the costs to comply with the 2020 Rule will be borne by the public in the form of higher electricity rates.

Now EPA is proposing another new ELG rule that would require facilities to abandon ongoing installation and startup of new equipment required by the 2020 Rule, and replace it with different, highly expensive and unproven technology EPA specifically rejected in the 2020 Rule. The result will be a loss of hundreds of millions of dollars on equipment the rule renders obsolete

[1] UWAG is a voluntary, non-profit, unincorporated group of 129 energy companies, which own and operate over fifty percent of the nation's total generating capacity, and three national trade associations of energy companies. The individual energy companies operate power plants and other facilities that generate, transmit, and distribute electricity to residential, commercial, industrial, and institutional customers. UWAG's purpose is to participate on behalf of its members in federal agency rulemakings under the Clean Water Act and related statutes, such as NEPA, and in related proceedings.

just as it is being installed and started up, compounded by substantial additional costs for new equipment required by the proposed rule, further increasing the total cost of electricity to the public and prompting more retirements of reliable baseload sources of electricity. The proposed rule's reversal in course is not supported by the facts and lacks a proper basis under the law.

EPA should preserve the key aspects of, and industry's investments to comply with, the 2020 Rule. Specifically, UWAG urges EPA to preserve its 2020 determinations as to membrane technology by either:

- continuing to recognize that membrane filtration is not nationally available or economically achievable, and poses unacceptable environmental risks; or
- allowing facilities that have made irreversible commitments of resources to comply with the 2020 Rule to continue under the limits established by that rule until 2032, at which point those facilities must either meet new proposed zero discharge requirements or retire or repower by 2035.

These recommendations will allow EPA to ensure that electric utilities and the public are not compelled to incur significant costs in reliance on the 2020 Rule, then suddenly deprived of the benefits of those expenditures and compelled to incur another layer of substantial costs that renders continued operation of reliable baseload facilities uneconomic. As the Supreme Court explained nearly thirty years ago:

> Elementary considerations of fairness dictate that individuals should have an opportunity to know what the law is and to conform their conduct accordingly; settled expectations should not be lightly disrupted. … In a free, dynamic society, creativity in both commercial and artistic endeavors is fostered by a rule of law that gives people confidence about the legal consequences of their actions."

Landgraf v. USI Film Prods., 511 U.S. 244, 265–66 (1994).

B. EPA Must Explain and Support Its Reversal In Course.

UWAG urges EPA not to proceed toward final ELG limits based on unsupported membrane technology that it rejected in 2020. If EPA nonetheless proceeds with a membrane-

based ELG rule, it must explain its reversal in course. In particular, EPA should specifically address substantial reliance interests by utilities and the public who irretrievably incurred hundreds of millions of dollars in costs due to the still-binding 2020 Rule.

EPA should further confirm that it has not, as suggested by various media reports, reversed course and proposed costly new ELG requirements on top of ongoing costs to comply with the 2020 Rule in furtherance of an "all in" goal to close coal plants. EPA also should explain and, as appropriate, adjust the retirement provisions of the Proposed Rule so that facilities that have made irretrievable investments in compliance with the 2020 Rule are not unduly excluded from the opportunity to either continue to operate under the 2020 Rule or retire.

C. Any New ELG Rule Must Be Reproposed and Make Important Changes.

EPA should make fundamental changes to the proposed rule and republish it for an adequate public comment period. The current record in support of the proposed rule does not demonstrate that membrane technology is nationally available or economically achievable, or that its environmental risks are acceptable. To the contrary, the few examples of uses of membrane technology referenced in the proposed rule lack detail, are technically flawed, and do not account for full-scale operations. And EPA's analysis of wastewater treatment technology for leachate excludes nearly half of the potentially regulated facilities. Equally problematic, the 60-day comment period was not only shorter than prior, less complex ELG proposals but was far less than necessary for regulated entities to analyze the 80-page, single-space proposal with over 1,300 attachments, and address EPA's request for comments on over 125 topics.

EPA should issue a new proposal that addresses and corrects these flaws and allow a sufficient time for public comment if it intends to proceed with this rulemaking. If EPA declines to do so, it should (at a minimum) make the following key adjustments:

- **Tailor the Rule to Preserve Investments Made in Reliance on EPA's 2020 ELG Rule.**
  - Modify the proposed Early Adopter subcategory to:
    - establish a qualification deadline based on meeting the 2020 Rule discharge limits by the applicability date in a facility's permit;
    - allow facilities that have installed biological treatment based on the 2020 Rule to either: (i) cease coal combustion at a later date than December 31, 2032 (no earlier than December 31, 2035) or (ii) continue to operate subject to zero liquid discharge (ZLD) limits by a permit writer's "as soon as possible" (ASAP) date between December 31, 2032, and December 31, 2040.
  - Establish a new subcategory, if EPA does not incorporate UWAG's recommendations into the proposed Early Adopter subcategory, that would:
    - allow facilities the option to either comply with the zero discharge limits no later than December 31, 2032, or avoid new ELG requirements by committing to repower or retire by December 31, 2035.

- **Maintain the 2020 Rule's Sound Determinations on Flue Gas Desulfurization (FGD) Wastewater Treatment.**
  - Maintain EPA's position that membrane filtration is not nationally available, economically achievable, or environmentally sound for covered units.
  - Maintain EPA's position that chemical precipitation plus biological treatment is best available technology economically achievable (BAT), not membranes, thermal evaporation, or other technologies.

- **Reevaluate, Revise, and Repropose Combustion Residual Leachate (CRL) Limits.**
  - Repropose leachate requirements after EPA evaluates BAT for the complete population of potentially impacted landfills and impoundments.
  - Provide flexibility for landfills and impoundments nearing closure or recently closed or retired, especially if EPA proceeds based on chemical precipitation.
  - Recognize that other stringent technologies are not BAT for leachate because the record lacks sufficient information to support such a determination.

- **Recognize that BAT Determinations Apply only to Direct Surface Water Discharges.**
  - ELG rules are inherently designed to address effluent discharges via outfalls into surface waters; releases into groundwater are subject to separate requirements.
  - BAT determinations do not logically apply to indirect discharges via groundwater to waters of the United States and should not be part of this rule.
    - If EPA proceeds with addressing groundwater issues in the ELG rule, it must address fundamental problems with applying the National Pollutant Discharge Elimination System (NPDES) permit program to these types of releases.

- **Maintain the 2020 Rule's Sound Determinations on Bottom Ash Transport Water (BATW).**
  - Maintain EPA's 2020 determination that a high recycle rate BATW system with a limited purge is the appropriate model technology for BAT limits for BATW.

- **Do Not Apply New ELG's Retroactively to Legacy Wastewater.**
  - EPA should not apply new ELGs retroactively to discharges associated with wastewater that was generated prior to the new ELGs' effective date.
  - EPA should not specify a nationwide technology basis for legacy wastewater if EPA's new ELG applies to wastewater generated before the applicability date.

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Reference List R-1

Acronyms

ACRONYM	DEFINITION
2030 Baseline	IPM 2030 Pre-Inflation Reduction Act 2022 Reference Case
AMWA	Association of Metropolitan Water Agencies
APA	Administrative Procedure Act
ASAP	as soon as possible
AWWA	American Water Works Association
BA	bottom ash
BAT	best available technology economically achievable
BATW	bottom ash transport water
BCT	best conventional technology
BOD5	biochemical oxygen demand
BPJ	best professional judgment
BPT	best practicable control technology
CAA	Clean Air Act
CBI	confidential business information
CCR	coal combustion residual
CP+LRTR	chemical precipitation followed by a low hydraulic residence time biological reduction treatment
CPCN	Certificate of Public Convenience and Necessity
CRL	combustion residual leachate
CWA	Clean Water Act
DESC	Dominion Energy South Carolina
EDR	electrodialysis reversal
EGU	electric generating unit

ACRONYM	DEFINITION
ELGs	effluent limitations guidelines
EPRI	Electric Power Research Institute
ERCOT	Electric Reliability Council of Texas
ERG	Eastern Research Group, Inc.
ESA	Endangered Species Act
FATW	fly ash transport water
FERC	Federal Energy Regulatory Commission
FGD	flue gas desulfurization
FGDW	flue gas desulfurization wastewater
FIP	Federal Implementation Plan
FOIA	Freedom of Information Act
GHG	greenhouse gas
gpd	gallons per day
gpm	gallons per minute
Gw	gigawatts
IPL	Indianapolis Power & Light
IPM	Integrated Planning Model
LRTR	low hydrologic residence time biological reduction
LWW	legacy wastewater
MATS Rule	Mercury and Air Toxics Standard regulations
MCL	maximum contaminant level
MDL	method detection limit
MDS	mechanical drag system
MISO	Midcontinent Independent System Operator

ACRONYM	DEFINITION
MWh	megawatt hour
NARUC	National Association of Regulatory Utility Commissioners
NEEDS	National Electric Energy Data System
NERC	North American Electric Reliability Corporation
NLT	no later than
NOPP	Notices of Planned Participation
NPDES	National Pollutant Discharge Elimination System
NSPS	new source performance standards
O&M	operating and maintenance
OMB	Office of Management and Budget
ORSANCO	Ohio River Valley Water Sanitation Commission
PFAS	per- and polyfluoroalkyl substances
PP15	Preliminary Effluent Guidelines Program Plan 15
ppm	parts per million
PRA	Paperwork Reduction Act
PSC	public service commission
PUC	public utility commissions
RCRA	Resource Conservation and Recovery Act
RML	reference margin level
RO	reverse osmosis
RPA	reasonable potential analyses
RTO/ISO	transmission organization/independent system operator
SCC	state corporation commission
SDE	spray dryer evaporator

ACRONYM	DEFINITION
SGC	submerged grind conveyer
TBELs	technology-based effluent limitations
TDS	total dissolved solids
TSS	total suspended solids
TTHM	total trihalomethanes
TWF	toxic weighting factor
TWPE	toxic-weighted pounds-equivalent
UWAG	Utility Water Act Group
VIP	Voluntary Incentives Program
VSEP	vibratory shear enhanced process
WV PSC	West Virginia Public Service Commission
WQBELs	water quality-based effluent limits
ZLD	zero liquid discharge

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Comments of the Utility Water Act Group on
Environmental Protection Agency Proposed Rule;
Supplemental Effluent Limitations Guidelines and Standards for the
Steam Electric Power Generating Point Source Category

I. Overarching Comments

A. Any New ELG Rule Must Be Based on Available, Economically Achievable Wastewater Treatment Technology.

The proposed ELG rule (Proposed Rule or Proposal)[2] must conform to governing Clean Water Act (CWA) requirements. The CWA requires EPA to set ELG limits based on a determination of the BAT for each category. CWA § 301(b)(2)(A), 33 U.S.C. § 1311(b)(2)(A). Specifically, the technology on which ELG limits are based must be available, economically achievable, and reflect the best performance in the point source category. When developing ELGs, the CWA requires EPA to consider "the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, the cost of achieving such effluent reduction, non-water quality environmental impact (including energy requirements), and such other factors as the Administrator deems appropriate." CWA § 304(b)(2)(B), 33 U.S.C. § 1314(b)(2)(B). Rulemakings to establish ELG limits also must comply with the Administrative Procedure Act (APA) and applicable case law.

The economic achievability requirement is particularly relevant where EPA proposes to require new technology at an especially high cost that immediately renders obsolete new technology EPA just required three years earlier, which has not even become fully operational and which will continue to influence electricity costs for years to come. EPA may not simply assume that the costs of yet another layer of new ELG requirements can be absorbed by utilities

[2] 88 Fed. Reg. 18,824 (Mar. 29, 2023), EPA-HQ-OW-2009-0819-9025.

Environmental Petitioners in *Appalachian Voices v. EPA*, No. 20-2187 (4th Cir.), FOIA EPA-2022-003242, Response Documents 1, ED_006652_00039079-00001.

2. Membrane filtration is not technologically "available."

Contrary to EPA's assertions, membrane filtration is not technologically available for the treatment of FGDW. Membrane filtration is an emerging technology. There are no commercial installations of membranes for FGDW treatment in the United States. New Logic, one of the membrane vendors EPA has contacted, claims that it has one full-scale installation in the United States.[78] This is misleading. While New Logic provided a full-scale membrane system for the Colstrip Power Plant in Montana, that system has been decommissioned[79] and treated groundwater only, not FGDW.[80] In treating groundwater, a wastestream with less salts and pollutants than FGDW, Colstrip ran into significant challenges with New Logic's VSEP system, including the inability to control scaling of the membranes and high maintenance costs. And while EPA points to GenOn's plans to use membrane technology for FGDW treatment at two of its facilities,[81] as the Agency knows, GenOn decided to close the coal-fired units at Morgantown and Chalk Point and never deployed any membranes there.[82]

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[78] Memorandum from U.S. EPA, to Steam Electric Rulemaking Record – EPA-HQ-OW-2009-0819, Notes from Vendor Call with New Logic on October 1, 2021 (Sept. 26, 2022), EPA-HQ-OW-2009-0819-9380 (DCN SE10290).

[79] Hydrometrics, Inc., *Performance Evaluation Report Plant Site Remedy – 2021 Colstrip Steam Electric Station, Colstrip, Montana,* at 2-1 (Oct. 2021) (noting equipment to be housed in the former building used to house the New Logic vibratory shear enhanced process (VSEP) system).

[80] EPA Feb. 15, 2023 Memo at K-10, EPA-HQ-OW-2009-0819-9656 (DCN SE10281) (Table 6 on page K-10 suggests the VSEP system also treated cooling tower blowdown but, according to the operator, the system only treated groundwater).

[81] 88 Fed. Reg. at 18,842.

[82] *See* GenOn, Press Release, GenOn Holdings, Inc. Announces Retirement of Chalk Point Coal Units at 1 (Aug. 10, 2020), EPA-HQ-OW-2009-0819-9101 (DCN SE09604); Memorandum from U.S. EPA, to Steam Electric Rulemaking Record – EPA-HQ-OW-2009-

a. Information on international installations is very limited and should not be used to demonstrate "availability" within the United States.

Lacking any full-scale installations in the United States, for the 2020 Rule, EPA did a thorough search for international installations, and it identified installations in China, South Korea, and Finland. EPA, Response to Public Comments for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category at 2-108 (Aug. 2020) EPA-HQ-OW-2009-0819-9015 (DCN SE08615) (2020 Response to Comments). Despite identifying these facilities, "EPA was unable to obtain operation, maintenance, or performance information from these foreign plants, either directly from the facility, from the vendors, or from site visits." *Id.* Further, the Agency acknowledged that it did not have the following critical information:

- "how these systems are configured or operated,"
- "what levels of reductions they achieve,"
- "whether there are any particular performance difficulties that result from continuous operation," or
- "importantly, how applicable these operations would be to plants across the United States."

Id.

EPA previously concluded that membrane filtration is not available industry-wide and also found it "cannot predict with certainty that the technology will be nationally available in 2028." 2020 Response to Comments at 2-109. To reverse this conclusion, as discussed at length above, EPA needs more than a few conversations with a self-interested vendor or two.

0819, Update to Industry Profile for the 2023 Steam Electric Power Generating Effluent Guidelines Proposed Rule at 8 (Feb. 7, 2023), EPA-HQ-OW-2009-0819-9622 (DCN SE10241) (Industry Profile Update).

Additionally, EPA has not demonstrated that its new information on membranes is applicable to plants in the United States. A great deal of uncertainty regarding the foreign installations, including a lack of information on the types, qualities, and quantities of coal being burned, remains to this day.[83] There is no information on whether the Chinese plants operate as peaker plants or as baseload plants; variations in operations can affect the sufficiency of wastewater treatment or the design of the treatment system in the first place. Without more information, it is impossible to tell if the international facilities are processing wastewater with similar characteristics to that found in U.S. plants.[84] It is impossible to know whether the systems have similar components and similar operating procedures as the systems that EPA is proposing. And it is impossible to know whether these facilities are meeting similar environmental standards (for all media) as those imposed in the United States.

Indeed, the record contains evidence indicating that the international installations are very different from those in the United States. First, DuPont notes that FGD systems in China are

[83] For the 2020 Rule, EPA gathered extensive coal quality data through Section 308 requests to several industry members. *See, e.g.*, Letter from Robert K. Wood, Dir., Eng'r & Analysis Div., EPA, to Mark McCullough, Executive Vice President – Generation, American Electric Power (Jan. 3, 2018), EPA-HQ-OW-2009-0819-7296 (DCN SE06675) (308 Request Letter) (requesting daily identification of type of coal used during FGD pilot- or laboratory-scale testing, including sulfur, chlorine, bromine, and iodine content). In contrast, there appears to be a lack of any data regarding the quality of coal being burned in the Chinese facilities.

[84] This is in contrast to EPA's assessment of Italian facilities for the 2015 Rule. There, EPA conducted a 3-day sampling event, collecting untreated scrubber purge and treated FGD wastewater, at the Federico II Power Plant in Brindisi. EPA also requested and received 1-day grab samples from a second Italian plant. EPA, Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, EPA-821-R-15-007, at 3-12 to 3-13 (Sept. 2015), EPA-HQ-OW-2009-0819-6432 (DCN SE05904) (2015 TDD). The 2015 record contains detailed sampling event and site visit reports from these facilities. But for the international installations EPA points to in the Proposed Rule, EPA has not conducted any sampling, nor does the record contain much wastewater characterization data.

often lower capacity and have smaller waste flows than U.S. systems.[85] The volume of wastewater flows to be treated is a critical factor in determining the costs of a wastewater treatment system. The larger the flow, the more expensive it will be to treat. EPA should have compared the flows of the Chinese facilities to the range of flows it has documented for United States facilities producing FGD wastewater. But there does not appear to be any analysis of this type in the record.

Second, according to DuPont, some facilities in China are producing industrial-grade salt as a byproduct from FGD wastewater treatment. 2021 DuPont Meeting Notes at 2, EPA-HQ-OW-2009-0819-9378 (DCN SE10245). There is no such market in the United States, which means that, in the United States, the byproduct brine must be disposed of, presenting a significant engineering challenge and adding to the costs of disposal.

Third, DuPont recommends softening prior to wastewater entering the membrane system, and EPA's notes of its meeting with DuPont say that "softening … is a key component." *Id.* But EPA's proposed treatment system does not account for softening. In contrast, chemical precipitation as required in EPA's Proposal does not remove all hardness and produces a much smaller volume of solids than would occur with softening. If EPA were to add softening to its model technology, then it would add both capital and O&M costs.

Fourth, it is not clear that EPA has investigated the disposal or other management of the byproducts from the foreign treatment systems. DuPont appears to have limited information about disposal practices. For the Hanchuan Power Plant, DuPont states that "[f]inal disposal of the salt product is unknown." [86] EPA cannot assess the availability of a technology without

[85] 2021 DuPont Meeting Notes at 2, EPA-HQ-OW-2009-0819-9378 (DCN SE10245).

[86] EPA Feb. 15, 2023 Memo at S-2, EPA-HQ-OW-2009-0819-9656 (DCN SE10281).

studying how its byproducts are handled or disposed. This is a major gap in its understanding of the foreign installations.

Fifth, the record appears to contain very little wastewater characterization and performance data for the Chinese facilities. One International Water Conference paper offers a summary chart showing the recovery of the first pass reverse osmosis unit for the Changxing Power Plant over 100 days.[87] This is insufficient to support a finding that the Chinese plants have demonstrated the effective use of membranes for FGDW treatment.

For all these reasons, EPA's reliance on the international installations is clearly inappropriate. While EPA often cites *American Frozen Food Institute v. Train,* 539 F.2d 107 (D.C. Cir. 1976) (*AFFI*), for the proposition that it may use technology data from foreign facilities, that case is distinguishable here. In *AFFI*, EPA contacted two Canadian potato processors and used their effluent reduction data—along with data from one American plant—to set biochemical oxygen demand (BOD5) and total suspended solids (TSS) limits based on biological treatment systems. *Id.* at 148–49. EPA also followed up with the Canadian government to ensure that the Canadian processors operated within "similar tax guidelines, receive no direct pollution control subsidies, and compete in similar markets." *Id.* at 159, *reprinting* 39 Fed. Reg. 10,862, 10,862 (Mar. 21, 1974).

Thus, *AFFI* differs from the current proposal in two important ways. First, EPA had performance data from an American facility that it used—in conjunction with data from the two Canadian facilities—to develop limits. In the proposal, EPA has presented no FGDW treatment performance data from the United States because there is no full-scale installation. Having data from at least one full-scale domestic installation—and correlating that data with reliable

[87] Stevens et al., EPA-HQ-OW-2009-0819-8887 ATT 3 (DCN SE08618A3).

performance data from a foreign installation—is helpful for ensuring appropriate, attainable limits. This reasonable approach is what the Court in *AFFI* approved. This is far different from taking limited data from a foreign installation, failing to sample or even visit that installation, and then using full-scale foreign installations only to determine that the BAT technology is "available" within the United States.

Second, in *AFFI*, EPA was careful, when dealing with the foreign installations, to obtain information beyond technological aspects when determining whether the operations and constraints on Canadian processors were fairly comparable to American processors. The Agency contacted the Canadian government to discuss whether the Canadian facilities operated in a similar market, with similar incentives and regulations. But for this Proposal, there is no indication that EPA made attempts to determine whether the Chinese facilities operate under similar environmental laws across media, whether their disposal of byproducts from the FGDW treatment is appropriate and subject to similar restrictions as in the United States, or whether the technologies applied are heavily subsidized by the government or subject to other types of favorable treatment. Therefore, EPA's reliance on *AFFI* as precedent for its use of the limited data from Chinese installations is not warranted.

b. EPA's reliance on new information about three pilot studies is not warranted.

EPA also relies on new information about pilot studies to justify selection of membrane filtration as BAT for FGDW treatment. All pilot studies have their limitations, and all pilots must be understood in a proper context. Many pilot studies are designed to determine the outer bounds of treatability using the technology, and thus "push" the system to its limits, in ways that are unrealistic for routine operation. It is not clear that EPA has fully assessed the pilot studies dealing with membranes and taken into consideration their limitations and their objectives.

Since the 2020 Rule, EPA has supposedly identified new information about three pilot studies. 88 Fed. Reg. at 18,840. In particular, EPA points to an Electric Power Research Institute (EPRI) study of the Saltworks Electrodialysis Reversal (EDR) Selective Technology[88] and claims it supports the proposed conclusion that membrane filtration is BAT for FGDW. However, EPA fails to put this pilot into proper context. First, it was a small-scale pilot, operating at 264 to 793 gallons gpd. EPA's estimated FGD purge flow rates for the 22 plants that it predicts would need to comply with FGDW zero discharge requirements range from 7,000 to 1,810,080 gpd. EPRI, EPRI Comments on Proposed Effluent Limitations Guidelines Rule at 11–12, Tbl. 1-2 (May 26, 2023) (EPRI Comments). This EDR pilot is no indication that the technology will properly scale up to handle these much larger flows. Second, as EPRI notes, only 15 grab samples were taken during the entire pilot study. *Id*. at 25. Third, as EPRI describes in more detail, the EDR system has significant limitations in the quality of treated water entering the treatment system and also in the extent of concentration possible. *Id*. at 25–26. According to EPRI, because of these limitations, most sites would need additional treatment, such as through a thermal evaporator and/or crystallizer, to minimize the volume of brine for encapsulation. *Id.* at 26–29. Fourth, EPRI explains that the system requires a high-pH physical/chemical treatment step (pH of 11) to remove low solubility metals, fluoride, and silica. EPRI believes most existing physical/chemical treatment systems cannot achieve this pH without significant equipment modifications, which will require significant increased costs. *Id.* at 25. After the high pH stage, the system would need acidification to a pH of 3 with sulfuric acid, so there would be additional equipment modifications, with their attendant costs, to allow for the acidification stage. *Id.* Therefore, this pilot does not demonstrate that membrane filtration is

[88] 88 Fed. Reg. at 18,840.

BAT. It does not even demonstrate that the EDR technology is suitable for FGDW treatment. Much more research would be needed before reaching any determinative answer. This is particularly true given the many adjustments that would be needed to the physical/chemical treatment processes.

EPA also claims in the preamble to have new information on two additional domestic pilot applications of membrane treatment for FGDW, but EPA has not identified what it is claiming as "new information" and has not identified which two additional pilots it is referring to.

Also, EPA's information regarding some of the pilots is very limited. For instance, in the 2023 TDD, EPA states that it has identified 17 pilot-scale studies of nanofiltration and reverse osmosis used for FGD wastewater treatment world-wide. However, EPA explains in a footnote that "EPA has limited data on the performance and configuration of these full-scale membrane systems. … Some references include only plant name or location. For this reason, some references may be describing the same installation, and EPA does not have enough information to determine where this may be the case." 2023 TDD at 24 n.14, 25 n.15. Where EPA only has a name and location of an installation—and no further details—it is critically important *not to use that information as support for a nationwide regulation.* In fact, it appears that EPA has not done its homework when it cannot, by its own admission, determine whether all the references are to separate facilities or if there might be some overlap that is causing an overestimate of the actual number of installations.

c. Use of membrane filtration for other purposes or in other industries is irrelevant for determining whether it is BAT for FGDW.

EPA also claims that use of membrane filtration in other applications for other wastestreams supports its selection as BAT for FGDW. 88 Fed. Reg. at 18,840–41. That

members of the power industry use membranes for very different water treatment issues, such as to treat side-streams of intake water to purify boiler makeup water or for treatment of ash transport water or cooling tower blowdown, is not relevant to whether membrane filtration is an appropriate model technology for FGDW. The flow volumes and characteristics of each of these waters are unique and must be evaluated separately. Also, operation and maintenance of membranes in these circumstances (*e.g.*, number and timing of membrane cleaning backwashes; appropriate length of membrane use prior to replacement, etc.) would be very different from operation and maintenance for treating FGDW. For example, the source of boiler makeup water is usually a local waterbody or potable water. For either source, the total dissolved solids (TDS) are generally less than 600 parts per million (ppm),[89] where EPA has estimated the average concentration of TDS in FGDW as 32,500,000 ug/L, or 32,500 ppm.[90] Additionally, the few gallons-per-minute flow for boiler makeup water is very much lower than the typical flow rate of FGDW.

Additionally, EPA enumerates the other industries that are using membrane filtration in some form or fashion, including use of membranes for agricultural uses, such as manure management and oil processing as part of oil and gas extraction. 88 Fed. Reg. at 18,841. But again FGDW is quite variable, depending on other system components and the type of coal being burned, and has unique fouling and scaling characteristics. Therefore, referencing these other, far-afield uses of membranes is not at all useful to demonstrating that membrane filtration is BAT for FGDW.

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[89] World Health Organization, Total dissolved solids in Drinking-water; Background document for development of WHO *Guidelines for Drinking-water Quality* at 1, WHO/SDE/WSH/03.04/16 (2003).

[90] 2015 TDD at 10-10, Tbl. 10-3 (average effluent pollutant concentrations for FGD surface impoundments).

d. The management of brine produced by membrane filtration raises substantial technological and environmental concerns.

Membrane filtration produces two streams: a clean stream, often known as "permeate," which sometimes can be recycled into other processes; and a concentrated brine, which must be disposed of in an appropriate manner. As it evaluates membrane filtration, EPA also should make a thorough investigation of the means of disposing of the brine it produces.

i. Brine treatment and disposal processes and impacts to landfills

In some circumstances, facilities heat the brine until all of the water evaporates and only crystallized solids remain (*i.e.*, thermal evaporation). The solids then are placed in a landfill. This is an expensive process due to the thermal energy required to evaporate off the excess liquid and the cost of removing and disposing of the solids. Also, there are growing concerns with the placement of this material in landfills, due to the high salt content of the solids and the natural solubility of salts. In one case, a landfill in Orlando, Florida, experienced landfill liner degradation once FGD solids were added.[91] The strong leachate was incompatible with the landfill's geo-composite liner. Aside from the risk of compromising the liner of the receiving landfill, the long-term stability of the crystallized brine in a landfill is questionable, due to its hygroscopic nature. To our knowledge, there are no long-term tests of the stability of crystallized FGDW brine in landfills.

A recent paper on brine management issues states:

> Disposal of concentrates, brines, physical chemical treatment residuals, and crystallizer salts (collectively described as salt-laden wastes) should aim for environmentally and economically responsible disposal today without creating future environmental challenges. The haphazard combination of salt-laden wastes and coal combustion products (CCPs) in existing CCP landfills may not achieve

[91] *See* Tetra Tech et al., "Orlando Coal Ash Landfill: A Case History for Designing and Building New Coal Ash Landfills" presented by Mohamad Alhawaree (June 10-11, 2013).

> this goal, and could lead to serious challenges….The chemistry of both the salt-laden [waste] and CCP materials will dictate whether they can react compatibly to achieve solidification or stabilization of the mixture so that all pollutants are properly sequestered over the long-term.[92]

The paper goes on to describe the many factors that affect the stabilization of materials, including the properties and compatibility of the concentrates/brines, the "mix design" of the ingredients, the introduction of additives such as lime, and landfill operations. *Id.* In addition, the use of softening agents upstream can impact the chemical composition of the liquid waste and change how it will interact with CCP materials. *Id.* Moreover, site-specific factors, such as topography of the disposal site, distance between the power plant and the disposal site, and local and state landfill regulations are important to consider when deciding upon a mix design and identifying proper disposal practices. *Id.* at 5.

For this Proposal, EPA has not chosen thermal evaporation as the model means of treating and disposing of brine. Instead, EPA has selected paste encapsulation as its technology of choice. 2023 TDD at 36. For paste encapsulation, the brine is mixed with fly ash and some additives, such as quicklime, so as to convert the brine to a material that can be pumped at high velocity to an on-site disposal landfill. Without an on-site landfill, it would be impossible to use a pumping system to deliver the material to the landfill. Alternatively, the brine can be mixed with additional fly ash and additives, so that it has a much drier consistency, and then trucked to a landfill. According to EPRI, a pumpable mixture of brine contains a greater weight percentage of brine than a trucked mixture. EPRI Comments at 6. EPRI provides the following general percentages for pumpable and truckable mixtures. *Id.*

[92] EPRI, Considerations for Concentrate Management from Wastewater Volume Reduction Technologies, No. 3002024773, at 3 (2023).

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Type of Mixture	Weight Percentage of Brine	Weight Percentage of Fly Ash	Weight Percentage of Quicklime
Pumpable	35	60	5
Truckable	18	77	5

As EPRI explains, the moisture content suitable for a pumpable mixture is not suitable for a truckable mixture, due to the potential for liquefaction of the material during transit. *Id.* Therefore, much more fly ash needs to be mixed in with the brine if the method of disposal is by trucking to an on-site or off-site landfill. Of course, this difference in fly ash content is very significant for forecasting the costs of transportation and disposal of brine. The more fly ash needed to create the correct moisture content for transportation, the greater the amount of mixture that will need to be hauled or pumped away for disposal. *See* Section III.A.2.d.iv.(a) below for further discussion of this issue.

ii. Further research is needed on paste encapsulation.

As EPRI explained in its 2019 report,[93] research to support paste encapsulation of FGDW brine is far from complete. EPRI noted the following gaps in existing research.

First, most wastewater encapsulation relies on cement hydration chemistry, in that typical hydration reactions observed in concrete also typically occur in encapsulation systems. However, in a paste system, a higher moisture content might be favorable to optimize permeability. In practice, the specific liquid-to-solid ratios and the types and amounts of additives will depend on site-specific conditions and could change over time due to fluctuations in temperature or brine content.[94] Therefore, EPRI recommends that expanded research be

[93] EPRI, Considerations for Treating Flue Gas Desulfurization Wastewater Using Membrane and Paste Encapsulation Technologies, No. 3002017134 (Nov. 2019), EPA-HQ-OW-2009-0819-9672 (DCN SE10396) (EPRI Membrane Report).

[94] EPA agrees that "[e]lectric utilities may have to conduct research and complete pilot testing to determine the most effective encapsulation blend, considering plant-specific details such as coal-type and FGD wastewater characterization." Memorandum from U.S. EPA, to

conducted to include more chemistries and time-based results and to evaluate long-term encapsulation properties.[95]

Second, systems needing chemical softening prior to introduction into the membranes create sodium-based compounds. In such cases, isolation of the salts is based solely on physical solidification, rather than chemical stabilization. Therefore, the implications of chemical softening and its downstream effects on safe disposal should be further researched.[96] This is particularly critical research since DuPont, a leading vendor of membranes, stresses the importance of softening prior to introduction of the wastewater to the membranes. According to EPA, DuPont stated that "[p]retreatment and softening for FGD wastewater is a key component of membrane filtration treatment systems to reduce suspended solids and hardness."[97]

Another critical research concern is the long-term stability of encapsulated materials.[98] While research has been conducted at the laboratory scale, most of the current physical and environmental property data is for material cured for 90 days or less, and there is limited field testing of encapsulated brine. Without long-term data, it is impossible to be sure whether or not the material will be subject to leaching or other degradation in the future or will threaten the integrity of landfill liners.

Steam Electric Rulemaking Record – EPA-HQ-OW-2009-0819, 2023 Steam Electric Supplemental Proposed Rule: Fly Ash Availability at 1 (Feb. 27, 2023), EPA-HQ-OW-2009-0819-9685 (DCN SE10242) (EPA Feb. 27, 2023 Fly Ash Memo). EPA also agrees that "the exact encapsulation blend may vary from plant to plant." *Id*.

[95] EPRI Membrane Report at 15.

[96] *Id.*

[97] 2021 DuPont Meeting Notes at 2, EPA-HQ-OW-2009-0819-9378 (DCN SE10245).

[98] Kirk Ellison, *Landfill Sequestration of Brine: Research Updates*, 2019 World of Coal Ash Conference, May 13-16, 2019, EPA-HQ-OW-2009-0819-8721, ATT 23 (DCN SE 08655A023).

iii. There are obstacles to obtaining permits for disposal of brine encapsulation wastes.

Even if the substantial, unanswered technical questions about brine encapsulation were not a concern, there would still be regulatory hurdles to its disposal in some locations. State regulations for solid waste disposal vary considerably, but nearly all of them attempt to regulate important factors such as compaction and liquid content. As EPRI points out, compaction performance is important to long-term landfill stability. EPRI Comments at 7. Further, EPRI notes that compaction requirements may limit the allowable moisture added to fly ash destined for landfills because the optimum moisture content for compaction is often lower than the moisture limit needed for transport to the landfill. *Id.* If power plants were to attempt to solve this problem by putting the mixture on a stack-out pad to promote drying and lower the moisture content, then the Proposal would need to consider the costs of this additional step, including construction and maintenance of the pads and equipment used to move the waste material to the pads and then to trucks. *Id.*

There are other good reasons why solid waste landfills are cautious about receiving paste encapsulation materials. As noted in UWAG's comments on the 2020 Rule, once it is disposed of in a landfill, paste encapsulation materials would have a very low infiltration rate and, when commingled with CCRs that have a higher infiltration rate, would create layers of impenetrable barriers. These layers could prevent drainage from reaching the leachate collection system and cause or contribute to a "blow out," such as what occurred at the King George County Landfill in Virginia. *See* 84 Fed. Reg. 64,620, 64,633 (Nov. 22, 2019), EPA-HQ-OW-2009-0819-7106.

In any event, it is not clear that disposal of brine encapsulation waste materials in state-regulated landfills would be possible nationwide. This could be a major obstacle to use of EPA's choice of model technology. States generally are concerned with liquid wastes entering landfills,

and many require that all wastes pass the "paint filter test" (and certify no free liquids in the waste) prior to placement in a landfill.[99]

iv. EPA has greatly underestimated the amount of fly ash needed to encapsulate brine.

Research by EPRI indicates that EPA has greatly underestimated the amount of fly ash needed for the encapsulation of FGDW brine. EPA has not provided its individual facility fly ash estimates, apparently due to confidential business information concerns. And it is not clear on the record whether EPA assumes that the mixture for encapsulation is pumpable or truckable or perhaps assumes that some plants will pump the mixture and others will truck it. Despite the ambiguity of the record, EPRI's detailed analysis has identified several problems. *See* EPRI Comments, Sec. 1.

(a) EPA used erroneous values to estimate brine and fly ash.

The amount of brine produced by a membrane filtration system depends on its percent recovery rate. With a higher percent recovery rate, the system will produce higher amounts of permeate and lower amounts of brine. With a lower percent recovery rate, the system will produce less permeate and more brine. EPRI believes that EPA's method of estimating fly ash based on a ratio of fly ash to FGD purge flow is a flawed approach. EPRI Comments at 1. EPRI points out that EPA used a value from EPRI's 2020 comments (160,000 tons per year for fly ash

[99] *See, e.g.*, Tenn. Dep't of Env't & Conservation solid waste management regulations, TENN. COMP. R. & REGS. 0400-11-01-.01, defining "industrial by-product" to mean "materials generated by manufacturing or industrial processes that are non-toxic, non-hazardous, contain no domestic wastewater, and pass the paint filter test (Method 9095B)." *See also* 9 VA. ADMIN. CODE § 20-81-140.B.4.a, prohibiting sanitary landfills from accepting, unless specifically authorized, "free liquids," defined as "liquids that readily separate from the solid portion of a waste under ambient temperature and pressure as determined by the Paint Filter Liquids Test, Method 9095." 9 VA. ADMIN. CODE § 20-81-10.

to encapsulate 432,000 gpd flow of brine) incorrectly. In EPRI's example, it was estimating fly ash for the encapsulation of ***brine generated from a thermal evaporator,*** which can achieve a higher recovery rate than membrane systems. *Id*. at 2. Therefore, the values given in EPRI's example are not applicable to brine generated from a membrane system.[100]

Instead of EPA's flawed system for estimating brine and fly ash, EPRI recommends using the FGD purge flow for each plant and the overall recovery rate that can be consistently achieved, calculating the volume and mass of brine generated, and using those results to calculate the mass of fly ash and other additives required to encapsulate the brine mass. *Id.* For example, for a plant with 100 gallons per minute (gpm) of FGD purge flow and a 70 percent overall membrane recovery rate, EPRI estimates that 298,151 tons per year of fly ash will be needed. But for the same flow, EPA estimated only 26,640 tons per year of fly ash. *Id.* at 4, Fig. 1-2. This is a very significant difference, as EPRI's estimate is more than 10 times EPA's estimate, and the mass of fly ash used to encapsulate the brine, of course, will affect the costs of transportation and disposal.

A key component here is percent recovery. What percent recovery did EPA assume when it estimated brine generation and then estimated fly ash needed to encapsulate that brine? EPRI took EPA's fly ash estimates and EPA's assumed ratio of 0.185 tons of fly ash per year per gpd of FGDW and evaluated the overall membrane recovery that would be needed to meet EPA's fly ash estimate of 26,640 tons per year. EPRI discovered that the applicable membrane recovery rates were 99.0 percent (assuming all plants use a truckable mixture) and 94.7 percent (assuming all plants use a pumpable mixture). *Id.* at 7, Tbl. 1-1. As EPA knows, these percent

[100] EPRI noted that it provided in its 2020 comments a different value for fly ash tons per year for encapsulation of brine from a membrane system. *See* EPRI Comments at 2.

recovery rates are not realistic on a routine basis for membrane filtration of FGDW.[101] In the 2023 TDD, EPA states that it "calculated brine flow rate based on the average recovery from the membrane treatment vendors used for FGD wastewater." 2023 TDD at 47. EPA then sets forth a formula showing that 30 percent of the FGDW volume would end up, after treatment, as brine. *Id.* Therefore, EPA acknowledges that a 70 percent average recovery rate is appropriate; EPRI agrees with a 70 percent average recovery rate for membrane filtration, assuming the FGD purge is the industry average of 24,100 mg/L TDS and that 100 percent of the permeate is reused. EPRI Comments at 21. Given this, EPA must correct its calculations of fly ash to accurately reflect this recovery rate, rather than the inordinate recovery rates EPRI has shown are applicable to EPA's fly ash analysis. *See Id.* at 7, Tbl. 1-1.

The magnitude of error here is too great, and it directly impacts the estimated costs of selecting membrane filtration as BAT. Therefore, UWAG requests that EPA recalculate its brine and fly ash estimates, in consultation with EPRI's experts.

(b) EPA overestimates the numbers of plants with sufficient fly ash.

According to EPA, 20 of the 22 plants it expects to install membrane filtration will have sufficient fly ash to encapsulate their brine if they do not sell any of the available fly ash.[102] EPRI disputes these findings. It finds that only 3 of 22 plants will have sufficient fly ash to encapsulate their brine assuming no fly ash is sold. *See* EPRI Comments at 8 and 9, Fig. 1-5. EPRI's estimate is based on a 70 percent overall recovery rate and use of a truckable mixture.

[101] While EPA notes that EPRI's pilot of the Flex EDR Selective system averaged a 93 percent recovery rate, 88 Fed. Reg. at 18,840, that is not indicative of what can be expected during normal operations. The pilot was a short-term pilot and was very small-scale.

[102] EPA Feb. 27, 2023 Fly Ash Memo at 5, EPA-HQ-OW-2009-0819-9685 (DCN SE10242).

EPRI goes on to show that EPA's total fly ash estimate for the 22 plants during the years 2017–2020 are greater than the plant-specific values reported on EIA Form 923 for the same years. EPA's calculations estimated about 20 percent more fly ash was produced than what the plants actually reported to EIA. *Id.* at 13. Since the EIA data is readily available, it would make sense to use actual fly ash tons reported, rather than attempt to estimate them.[103] This is the best data available, and the data should not be ignored.

Again, EPRI's estimates of the number of plants with insufficient fly ash and its demonstration, using EIA data, that EPA is overestimating fly ash produced are very significant issues. EPA needs to make a very careful reexamination of its methods and conclusions. UWAG urges EPA to undertake such a reexamination in consultation with EPRI prior to issuing a final new rule.

(c) Contrary to EPA's conclusion, brine encapsulation using fly ash will impact fly ash sales and beneficial reuse.

EPA also claims that 16 of the 22 plants expected to install membrane filtration will "have enough fly ash remaining to encapsulate brine generated from membrane filtration with no impact on the revenue generated from selling fly ash."[104] This is inaccurate, according to EPRI. Using reported EIA data and EPRI's estimates of fly ash needed to encapsulate brine, EPRI determined that only five of the 22 plants did not sell ash between 2018–2020. EPRI Comments at 17. The remaining 17 plants would have to divert fly ash from beneficial reuse to encapsulate

[103] EPA's apparent reason for not using EIA-923 data is that the form "requires only thermoelectric power plants with a total steam turbine capacity of 100 megawatts or greater that produce combustion byproducts to report such information." EPA Feb. 27, 2023 Fly Ash Memo at 4 n.2, EPA-HQ-OW-2009-0819-9685 (DCN SE10242). But all of the 22 plants that EPA expects to install membrane filtration are above the specified capacity threshold.

[104] EPA Feb. 27, 2023 Fly Ash Memo at 5, EPA-HQ-OW-2009-0819-9685 (DCN SE10242).

their membrane filtration brine and would suffer a loss of revenue because of the diversion. In fact, EPRI found that 15 of the 17 plants would have to use all of their fly ash for brine encapsulation, thereby forfeiting 100 percent of fly ash sales. *Id.*

EPRI estimates—again based on EIA data—that 1.5 million tons of fly ash that is currently being beneficially reused by the 22 plants at issue will be diverted to encapsulation, while an average of 13 million tons of fly ash was used in concrete and waste stabilization applications for the years 2018–2020. *Id*. The removal of 1.5 million tons from this market is a significant percentage and belies EPA's conclusion that it "does not anticipate that the fly ash needed for brine encapsulation [will] significantly impact the fly ash market."[105]

Not to worry, claims EPA, because, based on EIA reports, it has "identified more than 100 coal-fired power plants generating over 9.6 million tons of unsold [fly ash (FA)] that could be redirected from disposal towards either encapsulation or beneficial reuse." 88 Fed. Reg. at 18,842. But many of the plants generating unsold fly ash may be located in areas where transportation costs would make it prohibitive to sell the ash, or they may be using it for their own waste stabilization needs. A lack of sales does not equate to having fly ash available for sale. The impact on beneficial reuse and overall fly ash sales is another area where UWAG urges EPA to reassess its analysis, taking into account all of EPRI's research and conclusions.

EPA's second proposed "solution" to the problem of fly ash shortfalls is to harvest previously disposed ash for use in encapsulation. 88 Fed. Reg. at 18,842. Again, EPA overlooks the hurdles involved in this process. The harvesting of previously disposed ash is largely

[105] EPA Feb. 27, 2023 Fly Ash Memo at 4, EPA-HQ-OW-2009-0819-9685 (DCN SE10242).

unworkable due to the additional costs of digging up and transporting the fly ash. These costs would add enormously to the costs of disposal.

3. EPA's analysis of whether membrane filtration/paste encapsulation is economically achievable is deeply flawed.

The many flaws in estimations of fly ash needed for brine encapsulation, fly ash sales forfeited, and the potential impacts on beneficial reuse of fly ash are reason enough to call into question EPA's conclusion that membrane filtration and paste encapsulation is BAT and is economically achievable. But these issues are just part of the story of EPA's failure to properly consider costs.

a. EPA's cost estimates fail to include some units that will continue to operate.

In reviewing EPA's estimates of individual generating unit costs, UWAG noted some apparent discrepancies. By all accounts, EPA expects units at Plants Bowen, Cardinal, and Ghent to continue operating; therefore, under the Proposal's preferred option, they will need to install membrane filtration. EPA lists these plants as "discharging FGD wastewater after 2028."[106] It also calculates fly ash availability for purposes of brine encapsulation for each of these plants.[107] But in its compilation of generating unit level costs by option, EPA assigns zero costs to Bowen, Cardinal, and Ghent for Regulatory Option 3, which would require membrane filtration for FGDW.[108] The table below consists of all units that EPA has identified as having

[106] Memorandum from U.S. EPA, to Steam Electric Rulemaking Record – EPA-HQ-OW-2009-0819, Flue Gas Desulfurization Flow Methodology for Compliance Costs and Pollutant Loadings at 1 & 3, Tbl. 1, (Sept. 12, 2022), EPA-HQ-OW-2009-0819-9379 (DCN SE10287).

[107] EPA Feb. 27, 2023 Fly Ash Memo at 6, Tbl. 3 & 7, Tbl. 4, EPA-HQ-OW-2009-0819-9685 (DCN SE10242).

[108] Memorandum from U.S. EPA, to Steam Electric Rulemaking Record – EPA-HQ-OW-2009-0819, Generating Unit-Level Costs and Loadings Estimates by Regulatory Option for the

c. EPA has failed to account for stranded costs from 2020 Rule compliance.

In addition to underestimating technology costs, EPA appears to ignore the financial issues created for industry members when new pollution control equipment, such as biological reactors, must be scrapped and replaced within a few years of their deployment. Typically, EPA does not revisit an industry with a recent revision of its effluent guidelines. The Agency tends to wait about seven years before considering whether the industry is again ripe for a revision of its ELGs. But when the Agency returns to the same industry for another round of ELG revisions within a three-year period, the result will be stranded assets and stranded costs. In early 2021, rather than stay the 2020 Rule while reconsidering it, EPA explicitly stated that facilities remained subject to the 2020 Rule and instructed permitting authorities to continue to implement the 2020 Rule. 86 Fed. Reg. at 41,802. As a result, many companies have continued to plan, design, engineer, and install technologies, including complex systems such as CP+LRTR and technologies to minimize BATW purge, to ensure compliance with the 2020 Rule.

If facilities now must replace those technologies with new technology to meet the Proposed Rule's ZLD requirements for BATW and FGDW, they will not be able to fully amortize their investments in 2020 Rule technologies. For example, to employ membrane filtration/paste encapsulation (EPA's preferred option), a facility would have to abandon use of its LRTR well before the end of the system's useful life and well before the end of its amortization period. EPA should take into account these stranded costs when evaluating the overall economic impact of its Proposal.

B. Chemical Precipitation Plus Biological Treatment—Not Membranes, Thermal Evaporation, or Other Technologies—Is BAT for FGDW.

In addition to membranes, EPA asks the public to assess the applicability of many other technologies to FGDW. None of the other "zero discharge" technologies EPA lists (thermal

evaporation, spray dryer evaporators (SDEs), evaporation ponds, recycling) should be selected as BAT for FGDW. Like membrane filtration, thermal evaporation presents a range of technical difficulties when used for FGDW treatment. Also, it does not solve the issues surrounding brine disposal. EPA did not select other zero discharge technologies as BAT "because they achieve the same pollutant reductions as the proposed BAT technology basis (membrane filtration) but at a higher cost." 88 Fed. Reg. at 18,843. Nonetheless, EPA asks for comment on whether it should determine in the final rule "that any one or more of these technologies constitutes an additional BAT technology basis for controlling pollutants discharged in FGD wastewater in addition to membrane technology, or alternatively, in place of membrane technology." *Id.*

The correct BAT technology for FGDW is chemical precipitation plus biological treatment, as set forth in the 2020 Rule. As discussed earlier, EPA has not established a detailed justification for reversing its position on BAT for FGDW, and it cannot do so merely by waving off adverse comments in the final rule. No amount of sensitivity analyses and corrections to the industry profile will cure a rushed and flawed Proposed Rule.

1. Thermal evaporation is prone to operational difficulties.

UWAG agrees with EPA that thermal evaporation technologies are not BAT for FGDW, but for reasons beyond costs. The full-scale thermal evaporators that have been used for FGDW are prone to operational difficulties. UWAG urges EPA not to overlook this aspect of the technology, as part of the proper consideration of the BAT factor "engineering aspects of the application of various types of control techniques." CWA § 304(b)(2)(B), 33 USC § 1314(b)(2)(B). Significant operational difficulties should not routinely occur for a "best available" technology, and yet the industry's experience with thermal evaporators reveals routine difficulties.

At the Petersburg Station, Indianapolis Power & Light (IPL) installed a thermal evaporator in 2018. Since that time, the system's performance has been less than ideal. When EPA held a conference call with IPL after 2.5 years of system operation, IPL reported "it is important to consider the water balance and changes in the hydraulic load, including rainfall and evaporation, so that the thermal FGD system is not overwhelmed."[126] The thermal system has not lived up to its intended purpose:

> The thermal system can only handle a portion of the FGD wastewater at the station. IPL previously assumed that if the FGD wastewater treatment system can handle the full load, then It can also handle reduced loads; this assumption did not hold due to evaporative losses. In hindsight, plant staff recommend testing a system at all levels throughout the operating range prior to selecting a treatment technology. … Since installation, IPL has added many flow meters to try to identify when the flow balance is upset.

IPL Call Notes at 3–4, EPA-HQ-OW-2009-0819-8891 (DCN SE09218).

EPA also reports that IPL stated that its "pretreatment process for the evaporation system should be two to three times more robust than it was designed for." *Id.* at 4. Clearly, this is not a thermal evaporator that has operated without difficulties.

Other operators of thermal evaporators also have had significant problems. The Iatan Power Plant's thermal evaporator was taken out of service in 2017. EPRI reports that its evaluation of five ZLD thermal wastewater treatment systems "demonstrate that crystallizer systems are complex and very challenging to operate." EPRI Comments at 29. EPRI found common challenges among the systems, including scaling and line plugging, system foaming, flow obstructions, and overall equipment performance not meeting design criteria. *Id.* With this type of operating record, EPA should not select this technology as BAT.

[126] Memorandum from Danielle Stewart, ERG et al., to Steam Electric Rulemaking Record, Notes from Call with Indianapolis Power & Light – Petersburg Generating Station at 3 (Aug. 14, 2020), EPA-HQ-OW-2009-0819-8891 (DCN SE 09218) (IPL Call Notes).

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2. Thermal evaporators present other types of challenges.

Aside from a poor operational record within the industry when it comes to treating FGDW, thermal evaporators present challenges that go to their overall costs and efficiency. These challenges are summarized below.

- An evaporator/crystallizer uses a large amount of energy to create a concentrated brine. EPA has estimated, based on data obtained from vendors, that the energy requirements for an evaporation system are approximately 110kW/100 gallons treated.[127]

- Thermal evaporators use large amounts of chemicals for chemical precipitation and conditioning of the wastewater prior to concentration of the blowdown stream. The process to soften the FGDW consumes a large amount of lime and soda ash.[128] In the 2015 Response to Comments, EPA agreed that an evaporation system capable of treating 410 gpm FGDW with 40,000 ppm chlorine in the water would require ***as much as 40 tons of lime and 80 tons of soda ash per day.***[129]

- The large amounts of lime and soda ash added to the system means that a large amount of byproduct sludge is created, which must be dewatered and sent for disposal.

- Because FGDW is so corrosive, many metal components must be made from exotic, corrosion-resistant metals, at additional expense. As Duke told EPA, "[s]ome replacement parts have long lead times and high costs due to metallurgies."[130]

See also EPRI Comments at 29 (noting that achieving ZLD for FGDW will require more than half of industry plants to install crystallizers).

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[127] H.A. Nebrig et al., "Preliminary Assessment of a Thermal Zero Liquid Discharge Strategy for Coal-Fired Power Plants," Paper 11-36, at 3, presented at the International Water Conference (Nov. 13–17, 2011).

[128] *Id.* at 5.

[129] EPA, Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category: EPA's Response to Public Comments at 6-98 (Sept. 2015), EPA-HQ-OW-2009-0819-6469 (DCN SE05958).

[130] Memorandum from Deb Bartram & Danielle Stewart, ERG, to Steam Electric Rulemaking Record, Notes from Site Call with Duke Energy's Mayo Steam Station at 4 (June 15, 2020), EPA-HQ-OW-2009-0819-8558 (DCN SE 08964).

3. SDEs also present challenges and are not BAT.

As with other thermal systems, SDEs are not suitable as BAT because their application is limited and because SDEs do not solve the problem of handling the solids byproducts. As one vendor told EPA, SDEs are a potential technology for plants with a single power block and a small wastewater flow rate.[131] For plants with multiple power blocks that are not in close proximity, the flue gas ducting systems would not be easy to combine.[132]

Further, SDEs produce solids byproducts that contain a high level of salts and are very hygroscopic. The handling of the solids in a landfill (and the proper long-term sequestration of pollutants in the solids) remains just as much an issue for plants with SDEs as it is for plants with thermal evaporators and crystallizers.

C. If EPA Imposes New FGDW Requirements, EPA's "No Later Than" Date Is the Minimum Necessary for Membrane Filtration or Thermal Evaporator Retrofits.

If EPA imposes any new ELGs in the final rule, EPA's proposal to set a "no later than" date of December 31, 2029, would provide companies with the minimum time necessary to plan, design, test, procure, and install new equipment, such as membrane filtration and paste encapsulation for FGDW, assuming the final rule is issued by mid-2024. In light of a number of concerns facing the industry, EPA should provide facilities until at least December 2030 to implement the new requirements.

1. Supply chain problems persist, along with worker shortages.

Procurement and installation of new systems at power plants have been hampered recently by supply chain problems, despite the official end of the pandemic. PJM is concerned

[131] EPA Feb. 15, 2023 Memo at P-1 to P-2, EPA-HQ-OW-2009-0819-9656 (DCN SE10281).

[132] *Id.*

EXHIBIT 31

MEMORANDUM

TO: Steam Electric Rulemaking Record – EPA-HQ-OW-2009-0819

FROM: U.S. EPA

DATE: April 22, 2024

SUBJECT: Technologies for the Treatment of Flue Gas Desulfurization Wastewater, Coal Combustion Residual Leachate, and Pond Dewatering – 2024 Final Rule - DCN SE11695

The U.S. Environmental Protection Agency (EPA), with the support of ERG, collected information on technologies available for the treatment of power plant wastewater, including flue gas desulfurization (FGD) wastewater, combustion residual leachate (CRL), and technologies for pond dewatering. This memorandum is a compilation of treatment technology information gathered since the 2015 rule. Organizationally, this memorandum is a compendium of individual appendix documents, one for each technology and/or vendor. As noted in the *Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD), the EPA determined that CRL from landfills and surface impoundments includes similar types of constituents as FGD wastewater, although the concentrations of the constituents in CRL are generally lower than in FGD wastewater (U.S. EPA, 2024). Based on this characterization of the wastewater and knowledge of treatment technologies, the EPA determined that certain treatment technologies identified for FGD wastewater could also be used to treat CRL.

Table 1 lists the treatment technologies summarized in this memorandum. For each technology, the table identifies the relevant appendix name and the wastestreams (FGD wastewater, leachate, or pond dewatering) the technology has been demonstrated to treat to date (as opposed to which wastestreams the technology is capable of treating). For leachate, the table also indicates whether the technology has been demonstrated for CRL and/or for municipal landfill leachate.

Table 1. Treatment Technologies

Vendor and/or Treatment Technology Name	Location of Technology Summary	Wastestreams Treated		
		FGD Wastewater	Leachate	Pond Dewatering
Aquatech Thermal Technology	Appendix A	✓		
BKT FMX Membrane Technology	Appendix B	✓		
Envirogen Technology	Appendix C	✓		
Evoqua Technology	Appendix D	✓		
Frontier Technology	Appendix E	✓		
GE Alstom Spray Dryer Technology	Appendix F	✓		
Heartland Technology	Appendix G	✓	✓ (CRL, municipal landfill leachate)	
HPD Thermal Technology	Appendix H	✓		
KLeenWater Technology	Appendix I	✓	✓ (CRL)	
Mitsubishi Spray Dryer Technology	Appendix J	✓		✓

Table 1. Treatment Technologies

Vendor and/or Treatment Technology Name	Location of Technology Summary	Wastestreams Treated		
		FGD Wastewater	Leachate	Pond Dewatering
New Logic Membrane Technology	Appendix K	✓	✓ (CRL)	
Oasys Forward Osmosis Technology	Appendix L	✓		
Purestream Advanced Vapor Recompression Technology	Appendix M	✓	✓ (CRL)	
Saltworks Technology	Appendix N	✓	✓	
SUEZ ABMet Biological Treatment Technology	Appendix O	✓	✓ (CRL)	
SUEZ Thermal Technology	Appendix P	✓		
Sylvan Source Technology	Appendix Q	✓		
Vacom Technology	Appendix R	✓	✓ (municipal landfill leachate)	
Dupont Technology	Appendix S	✓	✓ (municipal landfill leachate)	
Ljungström Spray Dryer Technology	Appendix T	✓		
MDS Technology	Appendix U		✓ (municipal landfill leachate)	✓
Slurry Management Technology	Appendix V			✓

References

1. U.S. EPA. 2024. U.S. Environmental Protection Agency. *Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD). EPA-821-R-24-004. (April) DCN SE11757.

Appendix A - Aquatech Thermal Technology

1. Technology Description

Aquatech is a privately owned, global water treatment technology provider with over 1,500 installations in 60 countries. Primary markets include the oil and gas, petrochemical and refining, power, mining and metals, and infrastructure (i.e., desalination) industries. Aquatech provides options for treatment and discharge as well as complete reuse (i.e., zero liquid discharge (ZLD)). Aquatech designs, builds, and installs treatment systems and offers operation and maintenance services to their customers.

For FGD wastewater treatment, Aquatech primarily markets their falling-film evaporator which uses a proprietary two-stage external mist eliminator with horizontal flow chevrons and a vapor compressor. Aquatech has implemented different FGD wastewater treatment configurations at full scale using the evaporator in conjunction with one or more additional treatment technologies for pretreatment and/or brine concentrate management. Clarification as a pretreatment step is required in all configurations to precipitate metal hydroxides, thereby reducing total suspended solids (TSS) concentration (to 25 parts per million (ppm) or less) and lowering hardness. Additional lime and soda ash softening pretreatment may be required for the full evaporation configurations to efficiently generate salt crystals.

Aquatech advertises four system configurations, shown in Figure 1 and described below in order of least to most expensive capital cost.

2. Partial evaporation: consists of physical/chemical pretreatment for TSS reduction followed by a mechanical vapor compressor (MVC) brine concentrator to produce a distillate and 16 to 18 percent brine concentrate. The plant can recycle distillate for reuse and mix the brine with fly ash for solidification, also referred to as encapsulation. Aquatech believes any coal-fired power plant could treat FGD wastewater using this configuration to a quality that would permit reuse in plant operations for complete zero discharge.
3. Partial evaporation: consists of physical/chemical pretreatment for TSS reduction, MVC brine concentration, and steam driven crystallization. The concentrated brine is sent to a crystallizer for further volume reduction, but the evaporation process in the crystallizer is not operated to produce crystallized salt. Plants can recycle evaporator and crystallizer distillate back to the process for reuse and mix the crystallizer brine with fly ash. This configuration may be appropriate for large FGD flow rates where the brine volume needs to be further reduced for optimal encapsulation with available ash.
4. Full evaporation: consists of physical/chemical pretreatment, softening, MVC brine concentration, and steam-driven crystallization to produce salt crystals instead of a brine. Crystallization salts are dewatered in a filter press before landfill disposal. This system configuration uses the most energy.
5. Full evaporation: consists of physical/chemical pretreatment, softening, and MVC brine crystallization. Crystallization salts can be dewatered with a filter press and landfilled. This configuration is used for smaller systems, specifically those below 30 gallons per minute (gpm). As this system configuration has a standalone crystallizer (without a brine concentrator), it is the most expensive, produces the most sludge, has the highest steam consumption, but uses the least energy per unit volume of water treated, comparatively.

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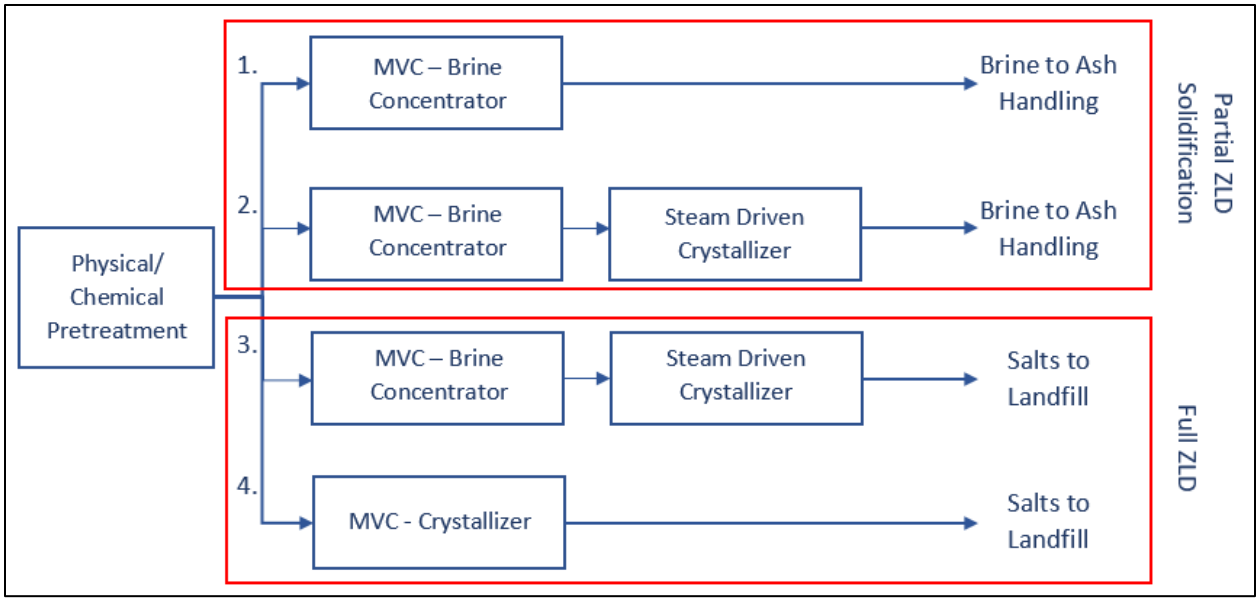


Figure 1. Aquatech ZLD Configurations

Evaporators typically require annual cleaning, with less frequent cleaning required for crystallizers. For example, Enel's Torrevaldaliga Plant cleans their concentrators once every 12 to 18 months and has not needed to clean the crystallizer in five years.

Aquatech stated that two 60 percent treatment trains with a large holding tank would be sufficient redundancy for maintaining a system and would be far less costly than full redundancy (two 100 percent treatment trains). When coal-fired generating units are not operating, the evaporation system can be put in "hot standby" where the system does not produce a distillate stream. When the system is completely shut down, such as during cleaning, plants need to seed the system with gypsum and allow the slurry to mature.

2. Technology Status and Performance

Aquatech has provided design, build, and installation of full-scale thermal ZLD systems for the treatment of FGD wastewater at eight coal-fired power plants in the United States and Italy. The company has conducted one pilot study on FGD wastewater in Germany and is exploring the market in India. An additional power plant in South Korea has commissioned Aquatech to install a ZLD treatment system for FGD wastewater. Aquatech is also bidding on an Eastern Kentucky power plant's FGD wastewater treatment system (Spurlock Generating Station) that will target selenium removal. Some power plants have also expressed interest in coupling reverse osmosis (RO) and thermal technologies for the treatment of FGD wastewater, with some already using a hybrid technology for the treatment of cooling tower blowdown.

Table 2 provides treatment configuration information on the eight full-scale Aquatech installations.

Table 2. Full Scale Aquatech FGD Wastewater Treatment Systems

Plant Name	Location	Treatment Configuration Notes
Brindisi (Enel)	Italy	Two clarifiers, two falling film brine concentrators, crystallizer

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Table 2. Full Scale Aquatech FGD Wastewater Treatment Systems

Plant Name	Location	Treatment Configuration Notes
La Spezia (Enel)	Italy	Clarifier, falling film brine concentrator, crystallizer
Fusina (Enel)	Italy	Two clarifiers, two falling film brine concentrators, crystallizer
Sulcis (Enel)	Italy	Clarifier, falling film brine concentrator, crystallizer
Torrevaldaliga (Enel)	Italy	Clarifier, two falling film brine concentrators, two crystallizers
Merrimack (Granite Shore Power (GSP))	New Hampshire	Chemical precipitation, partial softening, falling film evaporator, crystallizer
Dallman (City Water, Light, and Power (CWLP))	Illinois	Two falling film evaporators with mist eliminator and vapor compressor
Iatan (Kansas City Power and Light (KCPL))	Missouri	Clarifier, two brine concentrators, distillate recycle to process, brine mixed with fly ash prior to on-site landfill disposal

2.1 Enel Power Plants (Various locations in Italy)

Changes in environmental regulations led five Enel coal-fired power plants in Italy to install full-scale Aquatech ZLD systems to treat FGD wastewater. All five plants were designed to send FGD purge to pretreatment that includes chemical precipitation with lime and sulfide addition followed by partial softening with soda ash. The wastewater then flows through falling-film brine concentrators/evaporators and forced circulation crystallizers. Evaporator and crystallizer distillate are recycled to plant operations. The crystallizer salts are separated from the concentrate and sent to a belt filter press for dewatering prior to disposal, and remaining brine are mixed with fly ash for disposal in a landfill.

The five Enel power-plants are listed below and range in capacity from 55 gpm to 310 gpm:

- Brindisi Power Plant (2,640 MW)
- La Spezia Power Plant (1,300 MW)
- Fusina Power Plant (975 MW)[1]
- Sulcis Power Plant (585 MW)
- Torrevaldaliga Nord Power Plant (1,980 MW)

Aquatech operated the five systems for approximately two years following installation; following this period, Enel assumed operation for all systems.

As part of the 2015 Rule, the EPA collected effluent data from Brindisi Power Plant. The EPA used a subset of these data to characterize effluent concentrations for power plants treating FGD wastewater with chemical precipitation followed by evaporation. See the *Statistical Support Document: Effluent Limitations for FGD Wastewater, Gasification Wastewater, and Combustion Residual Leachate for the Final Steam Electric Power Generating Effluent Limitations Guidelines and Standards* (DCN SE05733) for detailed information regarding the pollutant removal efficacy of this treatment technology.

[1] As of 2018, Enel is not operating the Fusina ZLD system.

2.2 Iatan Generating Station (Weston, MO)

The Iatan Generating Station, owned by KCPL, operates two coal-fired electric generating units with a total capacity of 1,520 MW. Prior to its replacement with a different treatment system, the wastewater treatment system installed in March 2009 had a design flow rate of 60 gpm. The system contained pretreatment consisting of clarification for suspended solids reduction and metals removal followed by two MVC brine concentrators. Sludge from the clarifier was dewatered with a belt press prior to disposal. The brine concentrators produced a high purity distillate stream with less than 10 ppm TDS that was recycled to the plant's water system. Brine concentrate went to the fly ash silo where it was mixed with fly ash for final disposal in an onsite landfill.

Iatan Generating Station installed a ZLD FGD wastewater treatment system for multiple reasons, including preventing delays in plant project timelines (i.e., the time to receive a discharge permit), improving the environmental footprint of the station, and avoiding the need for a crystallizer and solids removal device.

During the installation and initial troubleshooting of the system, Iatan and Aquatech found high amounts of salt in the system feed water. As a result, the mineral witherite (i.e., barium carbonate) was produced. Witherite concentrations above 15 percent may cause issues in the system. Aquatech noted that an additional brine concentrator on the back end of the system would have been a better design for this plant.

As part of the 2015 Rule, the EPA collected data from the Iatan Generating Station. These data were not used to characterize loads from power plants using evaporation for the 2015 Rule because Iatan's FGD wastewater treatment system did not include chemical precipitation or a softening step. Table 3 provides a summary of Iatan effluent data collected by the EPA.

Table 3. Pollutants Average Data Summary for Iatan FGD Wastewater Treatment System

Analyte	Unit	FGD Scrubber Purge (4-day avg.)	FGD Brine Concentrator Distillate (4-day avg.)
Arsenic	µg/L	87.3	ND (4.00)
Mercury	ng/L	7,470	213
Selenium	µg/L	495	ND (4.00)
Nitrate/nitrate as N	mg/L	230	NQ (0.100)
TDS	mg/L	81,000	<49.0

< - Average Result includes at least one value measured below the quantitation limit. (Calculation uses ½ calculation limit for values below the quantitation limit).

ND – Not detected (number in parentheses is quantitation limit).

NQ – Analyte was measured above the method detection limit, but below the quantitation limit (number shown in parentheses is the quantitation limit).

2.3 Dallman Power Station (Springfield, IL)

Dallman Power Station is owned by CWLP and is located in Springfield, Illinois. The station operates four coal-fired units. The Dallman Power Station acquired Aquatech equipment for a ZLD FGD wastewater treatment system to treat increased boron concentrations in FGD wastewater that were caused by ammonia carryover from Dallman's Selective Catalytic Reduction systems' nitrogen removal process. The treatment system never began operating because a publicly owned treatment works (POTW) agreed to take Springfield's FGD wastewater. Dallman's ZLD FGD wastewater treatment system was designed with a feed preheater, a deaerator, and two falling-film evaporators with mist eliminator and vapor compressor. The mist eliminator was designed to prevent droplets containing concentrated chloride salts from traveling to the vapor compressor, which minimizes corrosion. Aquatech equipment remains onsite at Dallman Power Station.

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2.4 Merrimack Station (Bow, NH)

Merrimack Station is located in Bow, New Hampshire. The wastewater treatment system was designed to send FGD purge to pretreatment that includes chemical precipitation with lime and sulfide addition followed by partial softening with soda ash. Resulting sludge is disposed of in a landfill and pretreated wastewater is sent to a 65-gpm capacity evaporator. Evaporator brine is sent through an 8-gpm capacity two-effect crystallizer for further concentration. Evaporator and crystallizer distillate are reused in plant operations. The crystallizer salts are separated from the concentrate and sent to a belt filter press for dewatering prior to beneficial reuse. The salt produced is greater than 95% pure sodium chloride (NaCl). Remaining concentrate is mixed with fly ash for disposal in a landfill.

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Appendix B – BKT FMX Membrane Technology

1. Technology Description

BKT originally started as a company specializing in biological treatment technologies for livestock wastewater but has since developed the FMX system and expanded their applications to the shale gas, food and beverage, biotechnology, and power industries. BKT developed their anti-fouling membrane filtration system in Korea, and this system has now been operating in the U.S. for over ten years.

The FMX membrane system is an advanced membrane filtration system designed for wastewaters containing high total suspended solids (TSS) and total dissolved solids (TDS) and uses vortex-generating blades to minimize fouling of membrane surfaces. Blades are used to generate a vortex that maintains turbulent flows on the membrane surfaces; these eddies serve to reduce deposits on the membrane surface that could lead to fouling or scaling. The blades are made of a lightweight engineered plastic and are resistant to chemicals, corrosion, and heat. The blades are connected to a center drive shaft and positioned between trays of membranes vertically. The center shaft rotates the blades resulting in the turbulence. Depending on the membrane surface area required, the number of membrane/blade stacks and size of the membrane pores can be customized to meet the desired removals.

The FMX system processes wastewater between 50 and 150 liters per square meter per hour (LMH) (or 30 and 88 gallons per square foot per day (GFD)). Depending on the application, microfiltration, ultrafiltration, or nanofiltration membranes can be used in the system. For FGD wastewater applications, BKT recommends using nanofiltration membranes. The FMX system can be operated in conjunction with a downstream conventional RO system. In this configuration, the FMX system reduces the TDS concentrations and total hardness in the FGD wastewater which prevents scaling in the RO system, while the RO system further treats the permeate to reduce the pollutant concentrations to very low levels prior to discharge.

According to BKT, pretreatment prior to entering the FMX system is dependent on the concentration of TSS in the feed. If FGD wastewater undergoes settling (e.g., impoundment, settling tank), only a light particle filter may be needed; however, the FMX cannot receive influent directly from a hydrocyclone without pretreatment. At one half to two percent solids, the concentration is too high for the FMX system and would require either ultrafiltration or a physical/chemical pretreatment system with pH adjustment and coagulation/flocculation to remove solids.

As shown in pilot studies, the FMX system can also be incorporated into an existing treatment train. A treatment system using FMX nanofiltration followed by conventional RO could be used as a treatment process for FGD wastewater. Including pretreatment prior to the FMX system may increase overall process efficiency of the FMX system and help lower the capital and operations and maintenance costs of the FMX portion of the system. Treating FGD wastewater with the FMX system can also be used to achieve significant volume reduction upstream of thermal or brine solidification/encapsulation zero discharge technologies, thereby reducing the size and cost of the thermal or encapsulation equipment. Figure 1 shows an example process flow diagram for FGD wastewater treatment with an FMX system that includes a chemical precipitation pretreatment step using lime addition, the FMX stage, a post-processing RO system, and an evaporator/crystallizer system to handle the concentrate stream.

Industry sources report that the FMX tests summarized in Section 2 demonstrate that anti-fouling technology can enable the use of membrane filtration to treat FGD wastewater and that the FMX/RO treatment train is effective at removing selenium, arsenic, mercury, and nitrate-nitrite to concentrations well below the ELG limitations. These sources also report that the onsite tests demonstrate that the anti-fouling properties of the FMX system enable it to treat FGD wastewater without the need for extensive pretreatment. Additionally, the FMX/RO treatment process has a relatively small footprint and obviates the need for the reaction tanks and much of the other equipment typically included as part of chemical-biological treatment trains.

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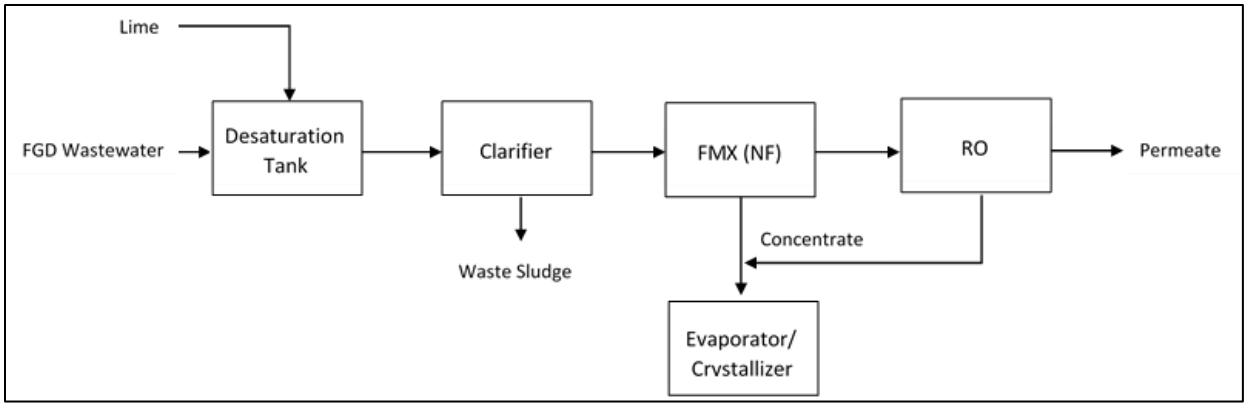


Figure 1. Example Process Flow Diagram for FMX Membrane System with Pretreatment and RO System

Like other membrane systems, the FMX membranes require periodic flushing and chemical cleanings. The FMX system provides the ability to replace membranes without replacing other associated equipment. BKT estimates that the membranes will need to be replaced every one to two years depending on the operation of the system. Chemical cleaning requirements and frequencies for the membranes are variable and dependent on the characteristics of the influent wastewater and treatment system configuration. As demonstrated in one pilot study, permeate from the FMX system treatment process can be further treated and reused to clean the membranes, eliminating the need for implementation of chemical clean-in-place (CIP) procedures. BKT has also indicated that influent characteristics affect the cost of operation of the system, as a high TDS concentration combined with a lower sulfate concentration is less expensive to operate than a lower TDS concentration combined with a higher sulfate concentration due to the impacts on membrane flux.

2. Technology Status and Performance

BKT has conducted at least six onsite pilot-scale studies for the treatment of FGD wastewater from coal-fired power plants using the FMX system. These pilot tests are summarized below.

2.1 Pilot Study #1

A commercial-scale FMX system was tested for three months at a coal-fired power plant to treat FGD wastewater. The FMX module contained nanofiltration membranes and was used in conjunction with a conventional spiral-wound reverse osmosis membrane. The system was operated in batch mode, with the FMX system receiving untreated FGD wastewater from the plant's FGD storage tank. During each batch, the concentrate from the FMX system was returned to the feed tank and the system continued to process the wastewater until the desired recovery was reached (i.e., 70-80 percent of the feed volume passes through the membrane as permeate).

The permeate from the FMX stage was transferred to the RO stage for further treatment and was able to meet the 2015 ELGs for selenium in FGD wastewater. Other than gravity settling in a surface impoundment, no pretreatment of the wastewater was performed prior to the FMX system. Using the combination of FMX and spiral RO, the treatment train consistently met the discharge limits for FGD wastewater established by the 2015 ELGs (in fact, the effluent concentrations were lower than the limits proposed by the EPA in 2013, which were lower than the limits established by the 2015 ELGs). Average pollutant concentrations are shown in Table 1. The pilot test results demonstrated that anti-fouling technology enables the use of membrane filtration to treat FGD wastewater, with no loss of flux and no irreversible fouling or scaling of the membranes over the duration of the study. The pilot test also showed that chemical pretreatment of the wastewater was unnecessary.

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Table 1. Pilot Study #1 – Average Pollutant Concentrations

Parameter	Feed	FMX Permeate	RO Permeate
pH	7.2	7.1	6.05
Conductivity (µS/cm)	21,700	13,000	149
Alkalinity (mg/L as CaCO3)	57.6	30	5
Total Dissolved Solids (mg/L)	17,500	8,930	201
Total Suspended Solids (mg/L)	38	19.5	1.5
Total Solids (mg/L)	17,500	8,950	202
Fluoride (mg/L)	7.8	3.35	< 0.039
Chloride (mg/L)	7,250	4,300	< 28.9
Bromide (mg/L)	59.8	36.2	< 0.283
Nitrate-Nitrite (mg/L as N)	< 27.3	< 17.6	< 0.234
Phosphate (mg/L as P)	< 4.56	< 2.93	< 0.039
Sulfate (mg/L)	1,070	252	< 1.75
Beryllium (µg/L)	< 1.7	< 0.75	< 0.5
Boron (µg/L)	120,000	106,000	39,900
Sodium (µg/L)	32,000	30,200	2,750
Magnesium (µg/L)	661,000	293,000	1,780
Aluminum (µg/L)	867	105	< 135
Silicon (µg/L)	24,700	17,500	< 1220
Potassium (µg/L)	14,600	15,000	< 2780
Calcium (µg/L)	3,540,000	2,120,000	14,100
Titanium (µg/L)	< 32.8	< 3	< 3
Chromium (µg/L)	7.7	< 2	< 2
Manganese (µg/L)	8,750	4,780	31.2
Iron (µg/L)	< 476	< 100	< 100
Cobalt (µg/L)	64.1	31.3	< 0.75
Nickel (µg/L)	325	160	< 5
Zinc (µg/L)	1,740	1,250	12.7
Arsenic (µg/L)	< 12.7	< 5.35	< 2
Selenium (µg/L)	219	55.4	< 1
Strontium (µg/L)	1,140	589	4.05
Molybdenum (µg/L)	62.6	15.4	< 0.5
Silver (µg/L)	< 1.5	< 0.5	< 0.5
Cadmium (µg/L)	72.7	56.3	< 0.75
Antimony (µg/L)	7.6	2.65	< 0.5
Barium (µg/L)	496	265	2.4
Tungsten (µg/L)	3.8	1.95	< 0.5
Mercury (ng/L)	2,030	94.7	< 5
Lead (µg/L)	< 2.015	< 0.5	< 0.5
Uranium (µg/L)	24.8	6.08	< 0.5

2.2 Pilot Study #2

BKT conducted a pilot study of the FMX system at a coal-fired power plant, testing two different nanofiltration membranes during the study. Permeate generated from the FMX system was further treated by a conventional RO system.

Both pretreated FGD wastewater, which had been injected with a polymer for coagulation in a clarifier, and untreated FGD wastewater were tested as influent streams to the FMX system. Based on the results of the study, BKT determined that polymers have the potential to coat the membranes and, thereby, decrease the performance of the FMX system. Table 2 presents the average pollutant concentrations feed, FMX permeate, and RO permeate.

Table 2. Average Pollutant Concentrations in the Feed and Permeate for FMX Nanofiltration and RO During Pilot Study #2

Parameter	Feed	FMX Permeate	RO Permeate
Arsenic (Total, µg/L)	2.21	1.14	0.673
Mercury (Total, ng/L)	77.4	7.18	0.81
Selenium (Total, µg/L)	275	96.7	2.13

2.3 Pilot Study #3

BKT conducted an 8-month pilot test of the FMX system using a commercial-scale unit with nanofiltration membranes at a coal-fired power plant. The pilot system treated FGD wastewater in 1,000-gallon batches. Effluent from chemical precipitation treatment was transferred to a feed tank at the head of the FMX system. Wastewater from the feed tank was fed to the FMX nanofiltration system. Permeate from the pilot system was returned to the equalization tank at the front end of the plant's existing full-scale FGD wastewater treatment system; concentrate (i.e., membrane reject) was transferred back to the feed tank. A polishing RO unit was not used in this test to further treat the FMX permeate. Plant staff reported that the permeate from the FMX nanofiltration system was pure enough for reuse in the FGD system. The wastewater was treated in two to three batches per day and the system was drained and flushed with hot water at the end of each day and at the end of each batch cycle. A clean-in-place (CIP) procedure was conducted once per month using hydrochloric acid and sodium hydroxide.

The FMX concentrate was collected so that it could be used to evaluate encapsulation processes. The primary goal of the study was to produce enough brine that could be used to test various cement recipes and evaluate whether the FMX system could be operated as a closed-loop system. Additionally, plant staff determined that the FMX permeate would be fit for reuse in the FGD system and that the closed-loop system recovered 80 percent of the influent wastewater. This means that the volume of wastewater ultimately requiring additional disposal or management (e.g., encapsulation, crystallization, underground injection) was reduced to 20 percent of the original volume. Table 3 presents the average pollutant concentrations measured at the influent and effluent of the FMX system during the testing. Since a polishing RO unit was not included during this test, the data in Table 3 does not show the effluent quality following combined FMX and RO treatment.

Table 3. Average Pollutant Concentrations in the Feed and Permeate for FMX Nanofiltration During Pilot Test #3

Parameter	Feed	FMX Permeate
Arsenic (Total, µg/L)	10	2
Mercury (Total, ng/L)	50	3
Selenium (Total, µg/L)	200	69

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The plant intended to conduct an encapsulation study using brine from the FMX nanofiltration system and the plant's fly ash. The encapsulation study had not yet been conducted at the time the EPA obtained information about this test.

2.4 Pilot Study #4

An FMX system with nanofiltration membranes was used for over a year to treat FGD wastewater at a coal-fired power plant. FGD wastewater was transferred directly from the plant's existing holding ponds to the FMX system without any additional pretreatment. Permeate from the FMX system was recirculated back to the holding ponds. The system was set up to treat one batch per day at an 80 percent water recovery rate. During testing, a CIP procedure was performed once per month using the FMX system permeate. Table 4 presents the average pollutant concentrations in the FMX feed and permeate for data collected over approximately six months. Since a polishing RO unit was not included for this pilot test, the data in Table 4 does not show the effluent quality following combined FMX and RO treatment.

Table 4. Pilot Study #4 – Average Pollutant Concentrations

Parameter	Feed	FMX Permeate
Total Suspended Solids (mg/L)	1,360	<10
Total Dissolved Solids (mg/L)	25,400	5,230
Bromide (mg/L)	73	15
Nitrate (as N, mg/L)	27.8	6
Calcium (Dissolved, µg/L)	5,620,000	1,297,000
Arsenic (Total, µg/L)	<5.5	<5.5
Mercury (Total, ng/L)	1,610	334
Selenium (Total, µg/L)	423	30.4

2.5 Pilot Study #5

BKT conducted a 3-month pilot study of the FMX system at a coal-fired power plant. Wastewater from the plant's FGD holding pond was transferred to a feed tank prior to treatment through the FMX system. Permeate from the FMX system was further treated using a conventional RO system and the FMX system concentrate was transferred back to the FGD holding pond.

Based on the results of the study, BKT determined that increasing the speed of the FMX system blades increases flux and reduces the rate of flux decline as more permeate is produced. BKT also determined that introducing an anti-scalant to the feed water reduces the change in flux, which successively reduces CIP needs and increases membrane lifespan. Table 5 presents the average pollutant concentrations in the treatment system influent, the FMX permeate, and the RO permeate.

Table 5. Average Pollutant Concentrations in the Feed and Permeate for FMX Nanofiltration and RO During Pilot Study #5

Parameter	Feed	FMX Permeate	RO Permeate
Total Dissolved Solids (mg/L)	3,890	1,860	192
Sulfate, mg/L	2,380	929	20
Arsenic (Total), µg/L	11.1	8.46	6.09
Mercury (Total), ng/L	240	16.6	< 5
Selenium (Total), µg/L	1,930	726	6.84
Nitrate-Nitrite, mg/L as N	5.6	5.6	1.25

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2.6 Pilot Study #6

BKT conducted a pilot study of a 400 gallon per minute (GPM) FMX system in 2018 at a large coal-fired power plant in the Southeastern U.S. The FMX system was set up to be able to function in either a batch or a single pass (SP) mode. Wastewater was drawn from the plant's FGD holding ponds and sent through the FMX system; batch tests were performed with approximately 1,000 gallons of feed. Effluent from the FMX system was also intermittently sent through a RO system in order to assess the performance of a treatment strategy combining the two methods.

BKT found that operating in batch mode results in the lowest operating and maintenance costs, as compared to continuous, single-pass operation and would therefore be the most advantageous operation mode for steam electric plants. BKT also found that combining the FMX system with an RO system resulted in continuous flow rates through the RO membranes, suggesting that FMX treatment successfully prevented scaling. Table 6 presents the average pollutant concentrations in the treatment system influent, the FMX permeate, and the RO permeate over the course of two months of operation.

Table 6. Average Pollutant Concentrations in the Feed and Permeate for FMX Nanofiltration and RO During Pilot Study #6

Parameter	Feed	FMX Permeate	RO Permeate
TSS (ppm)	14.4	0.00	0.00
Alkalinity (ppm)	40.3	34.4	-
Chloride (ppm)	227	209	11.3
Nitrate (ppm)	19.0	19.2	3.5
Sulfate (ppm)	2,350	1,115	12
Phosphate (ppm)	≤ 0.25	≤ 0.25	≤ 0.25
Sodium (ppm)	59	43	4.11
Magnesium (ppm)	231	117	0.84
Aluminum (ppb)	108	≤ 107	≤ 107
Silica (ppm)	15	12	1.07
Calcium (ppm)	501	246	≤ 2.11
Iron (ppb)	166	116	107
Arsenic (ppb)	≤ 8.1	≤ 6.69	≤ 5.73
Selenium (ppb)	2,062	974	8.44
NO_2+NO_3 as N (ppm)	5.54	5.66	1.17
Total Mercury (ppt)	151	≤ 10.2	≤ 12.3
TDS (ppm)	3,995	2,193	224

Note: Underlined average pollutant concentration values include samples below the detection limit.

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Appendix C – Envirogen Technology

1. Technology Description

Envirogen, an environmental technology and process solutions provider, markets a fluidized bed reactor (FBR) system, which consists of attached growth cultures. The FBR is an active, fixed-film bioreactor that fosters the growth of microorganisms on a hydraulically fluidized bed of fine media, usually sand or activated carbon. In this reactor, the wastewater is passed through a granular solid material at velocities sufficient to suspend or fluidize the solid media. The small, fluidized media provide an extremely large active surface area on which a film of microorganisms can grow while treating contaminants thus producing a large inventory of biomass. This high concentration of biomass – typically 5 to 10 times greater than in conventional activated sludge bioreactors – provides the system's high volumetric efficiency. The attached growth process uses a granular activated carbon media in an anaerobic fluidized bed process to reduce selenium. As the biomass increases, the microorganisms grow on the carbon media causing the density of the media to decrease, thus increasing the height of the media in the FBR.

The process biologically reduces selenate to elemental selenium that precipitates out of solution. The process also reduces sulfate to sulfide, forming metal sulfide compounds that precipitate in the wastewater and remove other metals including mercury, cadmium, chromium, copper, and zinc.

Envirogen's FBR operates continuously in an aerobic, anaerobic, or anoxic environment. Anoxic FBR systems are used to treat inorganic constituents, including nitrate and selenium. The reactors are available up to 30 feet tall with diameters ranging from 2 to 18.5 feet. The deep bed design and vertical orientation contributes to the FBR's smaller footprint compared to other biological treatment systems such as packed bed reactors. The FBR distribution system maintains uniform upflow of influent wastewater through the suspended media at a constant hydraulic loading rate.

Envirogen FBRs include patented biomass control systems, which are critical to retaining media and steady-state operation and plug-flow. The FBR system is maintained without backwashing as the treated water (with biomass sheared from the media) overflows from the top of the reactor to the downstream biosolids removal unit. In Envirogen's systems, biomass is removed in a steady-state manner with their patented biomass control devices. These systems allow the FBR to operate with an optimized and consistently high biomass concentration, resulting in reliably high performance. A portion of the wastewater passing through the suspended media is recycled back to the reactor, combining with the influent wastewater stream.

During start-up, the FBR is seeded with heterotrophic bacteria that are suited for nitrate and selenium removal. Electron donor materials and nutrients are pumped into the FBR to promote microbial growth. As microorganisms envelope the media, the fluidized bed height expands. With time, a biofilm develops on the media surface. Nitrate and selenate/selenite reduction occur on this biofilm. Treated water from the FBR system is discharged to a downstream liquid/solid separation system where the biological solids and elemental selenium are separated. Thickened or dewatered bio-solids and elemental selenium are disposed.

For FGD wastewater applications, pretreatment is required prior to entering the bioreactor to soften the water to prevent scaling (dropping hardness levels to where traditional scaling indices, e.g., Langelier and Ryzner, indicate low risk of scaling) and to achieve removal of arsenic and mercury. This may consist of traditional physical/chemical unit operations, such as chemical precipitation. Sand filters may be used following traditional clarification to remove residual solids including particulate arsenic and mercury.

The FBR system requires solids separation post-treatment to remove suspended solids (particulate selenium) and polish wastewater to final permit limits. This may be accomplished with a ballasted sand clarifier, which is in full-scale operation at two mining operations; a multi-media filter, which has been pilot tested at Mill Creek; or with ultrafiltration (UF) membrane treatment, which has been pilot tested at Winyah Generating Station. The UF membrane has proven most effective for solids and selenium removal from final effluent but is also the most prone to upsets related to scaling, especially for FGD wastewaters high in dissolved solids.

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2. Technology Status and Performance

Envirogen has either conducted or provided equipment for 12 pilot studies for selenium removal using an FBR in the mining, refinery/petrochemical, and coal-fired power plant industries. Three of these pilots treated FGD wastewater and are listed in Table 1. See the *Supplemental Statistical Support Document: Effluent Limitations for Final Steam Electric Power Generating Effluent Limitations Guidelines and Standards* (DCN SE09642) for detailed information regarding the pollutant removal efficacy of this treatment technology.

Table 1. Pilot Scale Envirogen FBR FGD Wastewater Treatment Systems

Pilot Number	Test Duration
Pilot #1	6 Months
Pilot #2	8 Months
Pilot #3	6 Months

3. References

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Appendix D – Evoqua Technology

1. Technology Description

The underlying technology for Evoqua's Pironox™ system was developed in conjunction with Dr. Yongheng Huang of Texas A&M University. The system is commonly referred to as hybrid zero-valent iron (ZVI), activated iron, or advanced reactive media. It is designed as an add-on system to be used in conjunction with other treatment systems, such as chemical and physical treatment, to target specific inorganics such as selenium, arsenic, nitrate, and mercury.

The principle behind the Pironox™ technology is the mixing of influent wastewater with ZVI, or pure elemental iron, which spontaneously reacts with oxyanions, metal cations, and some organic molecules in the wastewater. A reduction reaction of these pollutants occurs with the ZVI. After the reduction reaction, these pollutants immobilize through surface adsorption to the iron oxide coating on the ZVI. The quantity of ZVI required for treating FGD wastewater depends on multiple factors such as wastewater flow rate and the concentration of selenium and nitrate. For example, for an influent nitrate concentration of 25 milligrams per liter (mg/L), a ZVI dosage rate of 250 to 450 mg/L is expected. If a nitrate removal system is used upstream of the Pironox™ system, ZVI consumption may be reduced by 70 percent.

Figure 1 shows the treatment configuration using the Pironox™ treatment system in an FGD wastewater application. In this configuration, the Pironox™ system treats concentrate from an upstream reverse osmosis (RO) treatment system. The Pironox™ system focuses on reducing selenium and nitrate from the RO concentrate to levels that, when blended back with the RO permeate, is intended to meet 2015 ELG discharge standards. In this example, the Pironox™ system includes three reactors in series with ferric chloride dosed in each reactor to encourage flocculation. Other designs may incorporate four reactors. Having multiple reactors allows the operator to bypass individual units for maintenance or repair without having to take down the entire system. After sodium hydroxide addition for pH adjustment and polymer addition for coagulation, ZVI reactor effluent is further treated through a clarifier before discharge.

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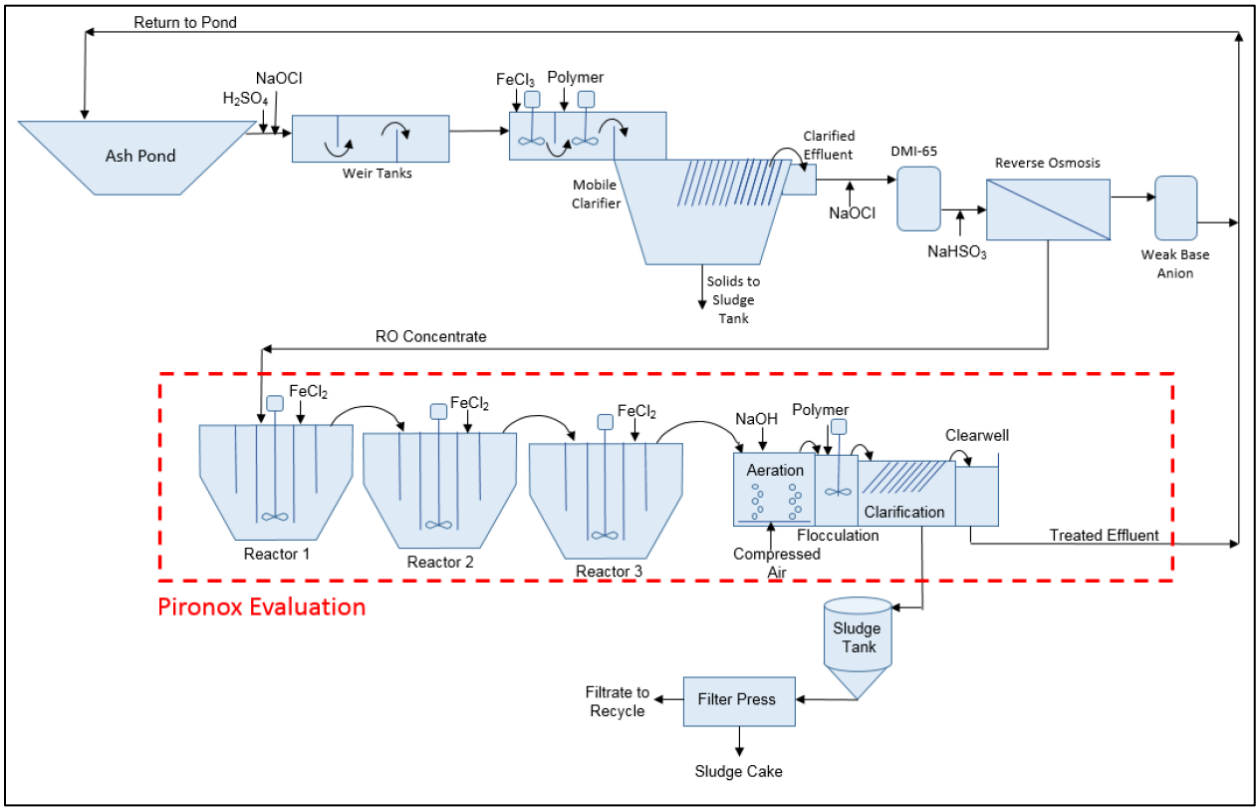


Figure 1. Example Process Flow Diagram for the Pironox™ System

2. Technology Status and Performance

Evoqua has conducted at least eight FGD wastewater pilot tests at seven coal-fired power plants (shown in Table 1). Evoqua's objective in conducting pilot tests has been to demonstrate the long-term stability of metals removal performance and to establish the minimum hydraulic retention time (HRT) of the reactor series. The typical treatment train in the pilots included wastewater pretreatment (e.g., settling ponds or chemical precipitation), multiple ZVI reactors, followed by clarification and filtration (multimedia or sand filtration). The following sections contain details of the seven pilot studies where additional information is available.

Table 1. Pilot Scale Pironox FGD Wastewater Treatment Systems

Pilot Number/Plant Name	Test Dates
Pilot #1 (Section 2.1)	1/17/2011 – 6/22/2011
Pilot #2 (Section 2.2)	9/25/2012 – 11/19/2012
Pilot #3 (Section 2.3)	9/11/2013 – 12/2/2013 and 1/21/2014 – 4/2/2014
Pilot #4 (Section 2.4)	11/2014 – 4/2015
Pilot #5 (Section 2.5)	12/22/2014 – 3/22/2016
Pilot #6 (Section 2.6)	7/20/2015 – 3/31/2016
Pilot #7 (Section 2.7)	9/15/16 – 3/16/17
Pilot #8 [a]	2017

a—No further details available.

2.1 Pilot Study #1

A pilot-scale demonstration continuously treated 1–2 gallons per minute (gpm) of FGD wastewater for five months. After developing the pilot-scale system, the power company used it to conduct longer-term demonstration under various field conditions to evaluate the performance and cost-effectiveness of the hybrid ZVI process for removing nitrates and trace metals, including mercury to less than 14 parts per trillion (ppt) and selenium to less than 10 parts per billion (ppb). The pilot study also evaluated the lower range of hydraulic residence time (HRT) required to achieve the desired removal efficiency.

FGD wastewater from a gypsum pond was pumped into an equalization tank that trapped large particles from the FGD pond; a second pump sent water from the equalization tank to the treatment train, consisting of four ZVI reactors, aeration, clarification, and two sand filtration beds operated in parallel. The reactors operated as a four-stage, single-train system and as a two-stage dual-train system at different points during the study. Water flowed by gravity between the ZVI reactors for a total HRT of 17.4 hours for the single-train operation and 8.7 hours on average for the dual-train operation. Treated effluent from the sand filters was pumped to the plant's ash pond. When operating as a single-train system, the pilot configuration reduced selenium to less than 10 ppb. When operating as a dual-train system at an HRT of 5 hours, mercury was reduced to less than 14 ppt.

2.2 Pilot Study #2

A pilot-scale demonstration continuously treated 1 gpm of FGD wastewater for a period of two months. In addition to meeting 2015 ELG limits for selenium and mercury, the pilot study focused on whether addition of bromide to coal for mercury control affected selenium concentration in FGD wastewater. Blowdown from a gypsum pond overflowed into an equalization pond, where a slipstream was pumped to the treatment train at a rate of 2 gpm. The pilot study evaluation consisted of four ZVI reactors with a retention time of 17.4 hours, aeration, clarification, and sand filtration. The study demonstrated that the technology could reduce selenium to 50 ppb and mercury to less than 10 ppt. Bromide addition did not affect operation of the Pironox reactors.

2.3 Pilot Study #3

The Pironox™ pilot study operated from September 11, 2013, to December 3, 2013 (Phase 1) and again from January 21, 2014, to April 2, 2014 (Phase 2). The pilot-scale system treated effluent from the plant's existing FGD settling ponds. The pilot treatment train consisted of four ZVI reactors, an oxidation step, a clarifier, and a sand filter. Each of the four ZVI reactors was specifically designed to allow for optimum mixing to reduce selenate to selenite, elemental selenium, or selenide and allow the selenite to adsorb to the iron oxyhydroxides generated in the process. Following the fourth reactor, an oxidation step was used to oxidize the ferrous iron that is generated as a by-product during the reaction to ferric iron. Sodium hydroxide and an anionic polymer were added for pH control and to promote settling. The ferric iron was settled out in the clarifier. The overflow from the clarifier was polished using a two-stage sand filter prior to being discharged.

Influent water to the pilot varied considerably during the study. During Phase 1, the FGD wastewater was highly oxidized, had a low pH, and had high concentrations of selenium, mercury, and nitrate. In December 2013, the FGD absorber was removed from service for repair, absorber control points were re-programmed, and the facility changed the quality of coal it burned. As a result, the FGD wastewater treated during Phase 2 exhibited a lower ORP, neutral pH, lower concentrations of selenium, mercury, and nitrate, as well as higher concentrations of manganese and iron. Changing the absorber operation to produce a less oxidizing wastewater reduced the mercury concentration by roughly two orders of magnitude and selenium by one order of magnitude.

2.3.1 Phase 1 (September 11, 2013, to December 3, 2013)

During Phase 1, the pilot was fed with a flow rate of 0.5 gpm (HRT of 26 hours) except for September 29 through October 29 when the feed flow rate was increased to approximately 1 gpm (HRT of 13 hours).

Selenium removal ranged from around 80 percent to 95 percent. Effluent selenium mostly consisted of selenate and the unknown selenium species. After one week of operation, the effluent selenium was 6.14 ppb. After two weeks, it increased to 63 ppb, and to 300 ppb after three weeks. During the remainder of Phase 1, effluent selenium ranged from 92 ppb to 437 ppb, with an average of 261 ppb.

One potential reason for the poor selenium removal during Phase 1 was improper system start-up. Although the system was operated by Evoqua staff for the entirety of the study, anti-passivation reagents were not added to the system until October 2 at which point a definite decrease in selenium was observed. The high levels of oxidant may have resulted in passivation of a significant portion of the media. Evoqua believes that the doses of anti-passivation reagents used at the pilot were not high enough to ensure continuously good selenium removal. A definite decrease in selenium was observed in the following two weekly samples after the anti-passivation reagents were added. A second reason for poor selenium removals was a lack of fresh ZVI media. Evoqua decided to re-use media from a previous pilot test for this study because they felt the media had a sufficient life expectancy. The life expectancy of the ZVI media was further reduced due to higher than expected nitrate and oxidant compounds in the untreated FGD wastewater. In addition to poor start-up procedures, the analytical laboratory used during Phase 1 had long turnaround times, up to 4-5 weeks for selenium analysis. This resulted in poorly timed treatment system improvements; there were several weeks of poor results before operators were even aware of system performance. The pilot study used an alternative analytical lab during Phase 2 with a faster turnaround time.

Over 99.9 percent mercury removal was achieved during the early part of Phase 1 when the influent concentration was greater than 100 micrograms per liter (µg/L). However, during the second half of Phase 1, the mercury concentrations were close to 1 µg/L. Evoqua hypothesizes that the higher mercury concentrations were the result of high levels of oxidants and nitrates in the FGD wastewater that left very little active ZVI media in the reactors.

2.3.2 Phase 2 (January 21, 2014, to April 2, 2014)

By the end of November, the treated effluent contained high concentrations of selenium, so Evoqua decided to remove the ZVI media from the system and re-start the study in 2014. During Phase 2, the pilot treatment system was modified to include a sedimentation step following Reactor 2. Sludge from the sedimentation step was recycled back to the first reactor and overflow was directed to Reactor 3. The FGD wastewater was treated at a rate of 0.5 gpm with an HRT of 26 hours for all of Phase 2. The sedimentation step was added in response to the high levels of nitrate seen in Phase 1. The high nitrates were resulting in higher concentrations of waste sludge. Allowing time for this sludge to settle and recycling of these solids within the ZVI reactors allowed for more complete use of the ZVI. Additionally, a finer grade and higher concentration of ZVI media was used in each reactor.

During the first four weeks of Phase 2, the selenium concentration in the treated effluent was below 10 ppb. On February 21, the flow was increased from 0.5 gpm to 1.0 gpm (HRT was reduced from 24 to 12 hours). Evoqua observed that this increase was done too quickly, and a significant quantity of the ZVI media was washed out of the system as a result. The effluent selenium increased to 12.5 ppb, but it's unknown whether this was the result of media washout or another factor. For the remainder of the study, the effluent selenium ranged from 17 µg/L to 37 µg/L (using the Applied Speciation data) and up to 100 µg/L (EPA 200.7 data). On March 7, Evoqua started experimenting with various doses of anti-passivation reagents, including very low doses. From March 18 through the end of the study, slightly higher selenium concentrations were seen in the treated effluent. It is unclear whether the increase in selenium was due to changes in reagent dose.

Mercury concentrations in the treated effluent were below 100 ng/L for all of Phase 2. However, changes in the operation of the FGD scrubber resulted in lower concentrations of mercury in the untreated FGD wastewater used for Phase 2.

Nitrate plays an important role in the ZVI process because it is chemically reduced along with the selenium. The nitrate present in the untreated FGD wastewater was converted to ammonia within the treatment system.

2.4 Pilot Study #4

Evoqua conducted a pilot-scale demonstration of the Pironox™ system at a power plant from November 2014 to April 2015. The pilot system treated FGD blowdown wastewater at an average flow rate of 12 gpm.[2] The Pironox™ system included four separate reactors followed by aeration, pH adjustment, clarification, and sludge thickening and dewatering. The primary goal of the study was to demonstrate performance of the Pironox™ system over 30 consecutive days of operation. Over a testing period of 106 days, the treatment train met the 2015 ELG limits for arsenic, mercury, selenium, and nitrate-nitrite.

2.5 Pilot Study #5

A Pironox pilot study was conducted at a power plant from December 22, 2014, to March 22, 2016, to determine whether the technology could meet the 2015 ELG limits. The pilot received a slipstream of FGD wastewater from a pond. The treatment train consisted of four ZVI reactors followed by clarification and multimedia filters with flow rates between 12 and 20 gpm. Ultimately, the pilot exhibited unreliable compliance with the ELG limits.

2.6 Pilot Study #6

To evaluate the scalability of the Pironox technology on a mobile platform, a pilot study was conducted from July 20, 2015, to March 31, 2016. A 1 gpm slipstream of FGD wastewater from a pond was treated through a series of four ZVI reactors, a clarifier, and multimedia filters. The pilot study was not scaled to handle a larger flow rate. No performance data were provided with the pilot study documentation.

2.7 Pilot Study #7

To evaluate potential long-term compliance with the 2015 ELG limits, a pilot study was conducted using a 1 gpm slipstream of FGD wastewater at a power plant. The pilot received pretreated effluent from a system consisting of pH adjustment, primary clarification, addition of organosulfide and ferric chloride, and secondary clarification. The pH of the pretreated effluent was adjusted with hydrochloric acid before being pumped to a series of four ZVI reactors. Following ZVI filtration, FGD wastewater was pumped through an aeration tank as well as a mix tank with polymer addition. Finally, precipitated iron was settled in a clarifier prior to discharge. Average performance data collected during the pilot study are presented in Table 2.

Table 2. Performance Data for FGD Wastewater Pilot Study Using Evoqua's Pironox™

Parameter	Average Influent	Average Effluent
Arsenic, µg/L	156	< 5
Bromide, mg/L	57.9	42.6
Chloride, mg/L	1,390	1,220
Mercury, µg/L	53.4	0.00579
Nitrate-Nitrite (as N) mg/L	< 5.15	< 2.37
Selenium, µg/L	789	< 10.1
TDS, mg/L	45,80	4,780

[2] The report includes no information regarding the source of the FGD wastewater and whether the wastewater was pretreated.

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Appendix E – Frontier Technology

1. Technology Description

Frontier's SeHAWK is a modular, fixed-film, biological treatment system that is prefabricated and can be delivered directly to a treatment site. Frontier manufactures four sizes based on flow capacity (50 gallons per minute (gpm), 250 gpm, 500 gpm, and 1,000 gpm) so that steam electric facilities may implement several modules of varying sizes to meet the flow rate and retention time needed for treatment.

Frontier recommends installing a physical/chemical pretreatment system prior to the bioreactor. In addition, depending on wastewater characteristics, it may be appropriate to include an additive such as sodium bisulfite prior to the SeHAWK unit to remove oxidants that can inhibit biological performance. The pretreatment system typically includes two reaction tanks with organosulfide and coagulant chemical addition followed by a clarifier with polymer addition. Sludge generated through clarification is dewatered while the process wastewater continues to a gravity filter. The SeHAWK treatment train begins at an equalization tank that receives process wastewater from the gravity filter as well as the filtrate from the dewatering process. If the FGD purge contains a nitrate concentration greater than 50 milligrams per liter (mg/L), wastewater stored in the equalization tank would first need to be sent to a nitrate pre-treatment stage. Following nitrate pre-treatment (if needed), the wastewater would then be transferred to the anoxic, two-stage bioreactor. Water flows by gravity from the first stage upflow bioreactor to the second stage downflow biofilter. The bioreactors reduce selenate and selenite to elemental selenium that then precipitates out of solution. Filtrate from the biofilter is further treated by an ultrafiltration (UF) membrane that removes suspended solids exiting the bioreactor. The bioreactor system also includes oxidation-reduction potential (ORP) monitoring as a process control to optimize nutrient addition (food for microorganisms) and reducing agent dosage when needed. See Figure 1 for a general block flow diagram of the Frontier SeHAWK treatment process for FGD wastewater.

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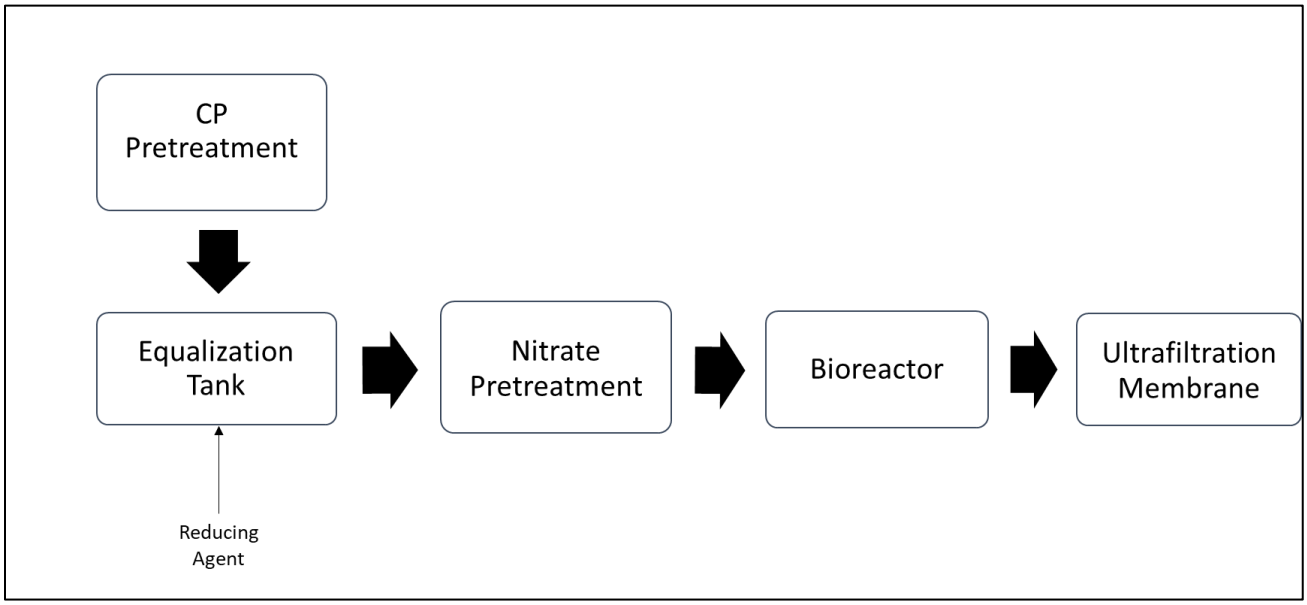


Figure 1. Frontier SeHAWK Biological Treatment Process Flow Diagram

2. Technology Status and Performance

Frontier has conducted 14 FGD wastewater pilot tests at coal-fired power plants in the past six years. Frontier conducts pilot studies to optimize chemical dosages, ultrafiltration efficiency, residuals management for a specific plant's operation, and determine the ideal design criteria to remove FGD wastewater pollutants, including selenium and nitrate nitrogen. In addition to the 14 pilots, Frontier has installed four full-scale SeHAWK treatment systems at coal-fired power plants to treat FGD wastewater to remove selenium, nitrate, and other metals. See the *Supplemental Statistical Support Document: Effluent Limitations for Final Steam Electric Power Generating Effluent Limitations Guidelines and Standards* (DCN SE09642) for detailed information regarding the pollutant removal efficacy of this treatment technology.

Table 2 includes a listing of the pilot demonstrations of the Frontier system on FGD wastewater.

Table 1. Pilot Scale Frontier FGD Wastewater Treatment Systems

Pilot Number	Test Duration (if known)
Pilot #1	3 Months
Pilot #2	7 Months
Pilot #3	5 Months
Pilot #4	2 Months
Pilot #5	2 Months
Pilot #6	5 Months
Pilot #7	Unknown
Pilot #8	5 Months
Pilot #9	4 Months
Pilot #10	1 Month
Pilot #11	8 Months

Table 1. Pilot Scale Frontier FGD Wastewater Treatment Systems

Pilot Number	Test Duration (if known)
Pilot #12	3 Months
Pilot #13	Unknown
Pilot #14	Unknown

The EPA is also aware of four full-scale installations of Frontier's SeHAWK system for treating FGD wastewater. Table 2 includes a list of these full-scale installations.

Table 2. Full Scale Frontier FGD Wastewater Treatment Systems

Plant Name	State
Crystal River	Florida
Marshall	North Carolina
Miller	Alabama
Cliffside	North Carolina

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Appendix F – GE Alstom Spray Dryer Technology

1. Technology Description

The spray dryer evaporator (SDE) system utilizes a spray dryer to combine wastewater with hot flue gas and evaporate the waste stream, resulting in zero liquid discharge from the system. Wastewaters to be treated, including FGD wastewater and other steam electric wastewaters (e.g., cooling tower blowdown, storm water, coal pile runoff), collect in a holding tank and mix with lime. The lime-rich wastewater is injected into a spray dryer with hot flue gas from the boiler, taken from upstream or downstream of the air heater depending on the plant's configuration. The hot gas is used to evaporate the water and dry the suspended and dissolved solids in the wastewater. The temperature of the gaseous outlet from the spray dryer is controlled to ensure all solids are dried completely.

The lime, added to the untreated wastewater, reacts with acid gases in the flue gas forming additional solid particulate. Particulate collection equipment, a fabric filter or an electrostatic precipitator, can then be used to collect the dried wastewater solids, reacted lime particulate, and fly ash from the flue gas stream.

This SDE technology is currently used by at least one steam electric power plant, in the Midwest, to treat FGD wastewater from two 850-megawatt (MW) coal-fired boilers. The system utilizes a small slipstream of hot flue gas from the boilers to evaporate the wastewater and collect solids in the plant's existing downstream particulate collection device.

2. References

1. Alstom. 2014. GE Alstom Spray Dryer Evaporator Brochure. DCN SE07122.
2. Alstom. 2015. Alstom's first-of-its kind water treatment technology to help utility customer meet EPA guidelines. (July 27). Available online at: https://www.alstom.com/press-releases-news/2015/7/alstoms-first-of-its-kind-water-treatment-technology-to-help-utility-customers-meet-epa-guidelines. DCN SE07123. Accessed: September 23, 2019.

Appendix G – Heartland Technology

1. Technology Description

Heartland developed a proprietary adiabatic evaporator technology called the LM-HT concentrator (i.e., Heartland concentrator). The system uses an evaporation zone, an entrainment separator, and a solid/liquid separator to achieve zero liquid discharge without a crystallizer. First, the system injects wastewater and hot feed gas into the contact chamber evaporation zone to form water vapor and concentrated wastewater. The wastewater is introduced into the heat zone via proprietary mist eliminators that allow water to evaporate before meeting the surface of the vessel. The feed gas for the concentrator may be pulled from processes within a coal-fired power plant (e.g., slip stream from flue gas, engine waste heat, or combustion exhaust from dedicated gas burners) and must be at least 400°F prior to injection. The optimal feed gas temperatures are between 900°F and 1,000°F; cooler gas streams require more surface area, and thus a larger footprint concentrator, to evaporate the same amount of water. Once in the concentrator, the feed gas is maintained between 150°F and 800°F. Any remaining wastewater that is not evaporated collects in a sump and is recirculated back through the concentrator. Typically, the concentrator is fed a wastewater stream that is 80 percent recycle from the sump (wastewater that has already been through the concentrator's heat zone) and 20 percent fresh feed.

The temperature at the top of the concentrator is around 900˚F while the temperature in the bottom of the concentrator (near the sump) is around 150˚F. The cooling in the system is conducted rapidly so that solids build up but do not scale the equipment. The only moving parts of the LM-HT concentrator are the sump and an induced draft fan, which pulls hot gasses through the concentrator.

Effluents from the concentrator include a water vapor stream, which can either be vented to atmosphere or captured and condensed, and a residuals stream. The residuals stream is typically sent to a solid/liquid separator such as a cone bottomed separating tank or a centrifuge. The LM-HT can be operated to produce a liquid effluent (either a saturated brine or high-density slurry), or the concentrated wastewater may be recycled back to the evaporation zone and operated in conjunction with solids handling equipment to produce a solid for disposal. The solids can be disposed of directly in a landfill or the brine/slurry can be mixed with fly ash and sent to a landfill. Figure 1 is a simplified process flow schematic of the Heartland LM-HT when used in conjunction with a dedicated heat source (in this example, propane combustion).

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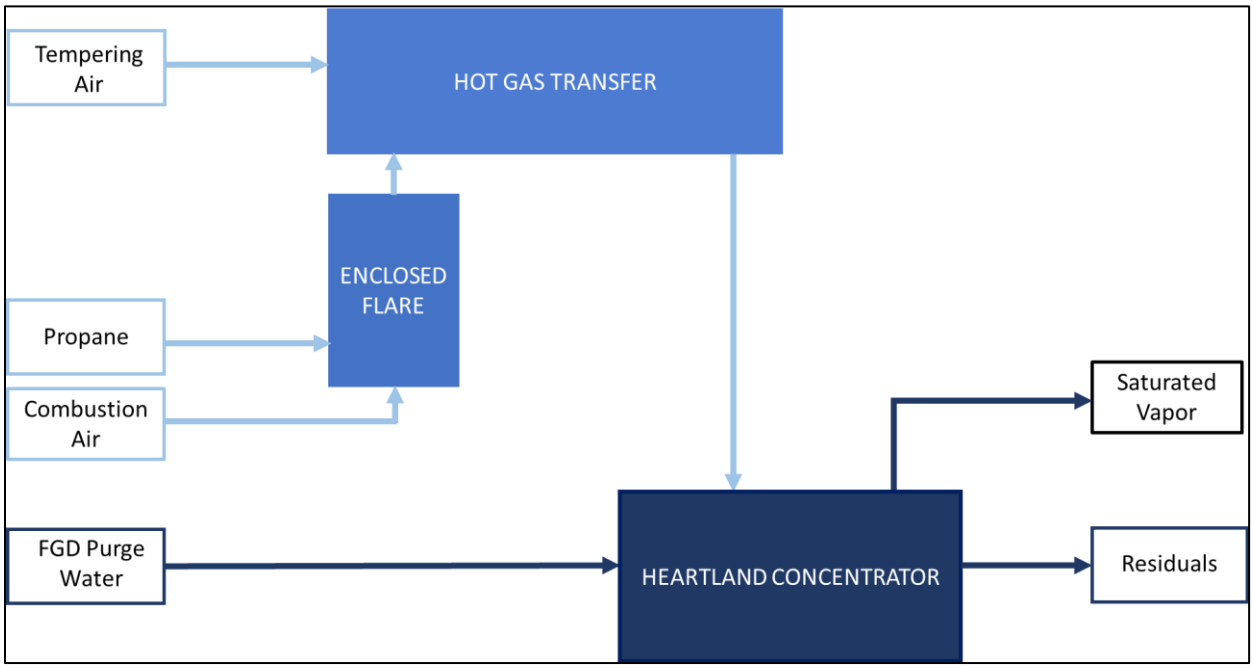


Figure 1. Heartland LM-HT Concentrator Process Flow Diagram (Using Dedicated Gas Burners for Heat Source)

While pretreatment is not required prior to sending FGD purge to the concentrator, if the total suspended solids (TSS) concentration is greater than five percent, a clarifier may be useful in reducing solids produced by the concentrator and would lower concentrator costs. The concentrator can handle up to 200,000 milligrams per liter (mg/L) total dissolved solids (TDS). The maximum chlorides that can be treated using the concentrator is roughly half of TDS, equivalent to 100,000 mg/L.

Each LM-HT concentrator unit is mounted on a pre-packaged skid with an average footprint of 2,500 square feet. The LM-HT requires approximately 1,350 BTUs of heat energy to vaporize one pound of wastewater when operating with optimal feed gas temperatures. Density and temperature are the only process control parameters. Materials of construction include Al6N, a highly corrosion resistant alloy metal for the concentrator, fiberglass for the mist eliminator section of the concentrator, and stainless steel for the induced draft fan.

If the LM-HT uses flue gas from upstream of the air heater as a heat source, the flue gas would be returned to the system at a cooler temperature, downstream of the air heater but upstream of the electrostatic precipitator (ESP). This configuration is similar to a spray dryer. Heartland describes that the difference between their concentrator system and a spray dryer is the location of FGD solids collection. Spray dryers typically rely on the downstream ESP to collect both fly ash and FGD solids. The Heartland concentrator allows the downstream ESP to collect only fly ash solids, as it typically operates, and the FGD solids to be collected from the concentrator's purge stream.

Heartland tested stabilization of produced water concentrate using Portland cement and other additives. Heartland has not conducted similar testing with FGD wastewater yet. Through testing, Heartland has found the key component of encapsulation is the brine consistency, and the most cost-effective solution is evaporation of the brine beyond solids saturation to a slurry solution.

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In addition to operating as a stand-alone wastewater treatment option, the LM-HT can be preceded by a membrane filtration system (e.g., reverse osmosis, nanofiltration) to pre-concentrate wastewater.

Maintenance of the LM-HT concentrator involves cleaning the mist eliminator plates every two weeks. During this process, the concentrator is shutdown, and the plates are removed and cleaned with a pressure washer. As an alternative, the plates can be cleaned in place. Shutting down and restarting the concentrator takes as little as 5 minutes. Other maintenance activities include monitoring and managing foaming with occasional addition of an anti-foaming agent. Heartland also advises dosing the entire system once per week with acid to prevent solids from building up in piping. The concentrator unit does not require housing or cover. The life expectancy of the blower and pump equipment is roughly 20 years.

The LM-HT system has been operating at multiple landfill locations for years to treat landfill leachate. In addition, the system previously operated successfully for three years at a power plant to treat FGD wastewater and has been piloted elsewhere.

2. Technology Status and Performance

Heartland has operated a full-scale treatment system for FGD wastewater at Iatan Generating Station (Section 2.1) and a pilot-scale system for FGD wastewater treatment at the Water Research Center's Plant Bowen (Section 2.2). Section 2.3 describes a pilot test using the Heartland system to treat CRL, and Section 2.4 describes the MSW leachate applications.

2.1 Iatan Generating Station Full-Scale System

Iatan Generating Station operated a full-scale Heartland system to treat FGD wastewater for three years starting in 2014. The system treated 40 gallons per minute (GPM) of FGD wastewater with a clarifier as pretreatment for TSS removal. The system used a direct fire burner fueled with propane as the heat source. The LM-HT concentrator was operated to achieve zero liquid discharge, evaporating the wastewater all the way to a salt that was then centrifuged and disposed of in an on-site landfill.

2.2 Water Research Center at Plant Bowen Pilot Study

Heartland, in combination with the Electric Power Research Institute (EPRI), Southern Company, and Georgia Power, conducted a 14-day demonstration project at Plant Bowen to evaluate the capability of the LM-HT concentrator. The test, conducted in September 2014, used flue-gas waste heat as the thermal energy source. The test system operated on Bowen's Unit 3, a 950-megawatt (MW) unit and pulled hot gas from the selective catalytic reduction unit outlet, returning the cooled gas just downstream of the air heater. The test operated 24 hours per day for the duration of the 14-day trial, treating more than 10,000 gallons of FGD wastewater. The concentrator achieved 90-95 percent volume reduction, concentrating wastewater to 40 percent solids.

The 14-day Bowen test also evaluated options for disposing of the concentrated FGD product to assess the feasibility of zero liquid discharge (ZLD) using encapsulation/stabilization. Six different mixtures of brine, fly ash, Portland cement, and iron sulfate heptahydrate (used to immobilize heavy metals) were tested. Table 1 details the different mixtures tested.

Table 1. Encapsulation/Stabilization Test Mixtures

Mix Number	Brine Slurry (Percentage)	Fly Ash (Percentage)	Portland Cement (Percentage)	Iron Sulfate Heptahydrate (Percentage)
1	75	15	10	0
2	70	20	10	0
3	75	20	5	0
4	70	25	5	0
5	75	8.5	10	6.5
6	70	13.5	10	6.5

Heartland also performed a pilot test at Plant Bowen using the LM-HT concentration with membrane pretreatment to preconcentrate the incoming wastewater.

2.3 Coal Combustion Residual Landfill Leachate Pilot Study

Heartland participated in a pilot test with EPRI at a coal-fired power plant, Plant Harrison in West Virginia. The test concentrated landfill leachate using a membrane system and then treated it using the Heartland concentrator. The project reduced more than 100,000 gallons of wastewater to less than 1,000 gallons. The test also evaluated encapsulation of the resulting concentrated brine stream.

2.4 Municipal Landfill Leachate

The Heartland LM-HT concentrator has treated landfill leachate from municipal landfills at 14 locations. Each system treats leachate directly using biogas generated by the landfill as the thermal energy source. The Heartland system also treats leachate at two landfills where leachate is preconcentrated using reverse osmosis (RO) followed by treatment using the LM-HT concentrator.

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Appendix H – HPD Thermal Technology

1. Technology Description

Veolia offers a variety of technologies for treating FGD wastewater. The primary system, their HPD® technology treats FGD wastewater with evaporation and crystallization. The evaporation portion of the system includes five components:

1. The feed tank;
2. The deaerator;
3. The falling film evaporator (connected to a compression device);
4. The distillate level tank;
5. And the seed recycle tank.

The evaporation process typically recovers 80 to 90 percent of influent water and can concentrate brine up to 25 percent total dissolved solids (TDS).

For FGD wastewater applications, FGD scrubber purge is first treated with minor chemical addition, then pre-heated to atmospheric boiling temperature. The wastewater is deaerated and chemicals are added to remove bicarbonate alkalinity and prevent scaling. Calcium hardness is removed later during crystallization. Wastewater is then sent to the evaporator vessel. As water evaporates, the vapor passes through mist eliminators and a compression device that increases the pressure. The vapor then returns to the evaporator, where it coats the outer evaporator tube walls and condenses as a distillate. The distillate flows to the distillate level tank and is subsequently pumped through the heat exchanger to transfer heat to incoming feed water.

The evaporator also produces a concentrated brine that is sent to a seed tank. Calcium sulfate seed crystals are added to precipitate low solubility calcium salts and silica. The brine is typically sent to a crystallizer for further concentration but can also be sent offsite for disposal. The evaporator, and crystallizer if present, must be taken offline twice a year for cleaning.

Typically, preconcentration using membranes prior to a crystallizer is not desired because the preconcentration equipment is difficult to operate and entails high operation and maintenance costs. At very high flows, it may be more beneficial to preconcentrate the FGD feed to reduce the crystallizer size, so preconcentration using either membranes or a brine concentrator could be advantageous in specific circumstances.

Veolia's steam-driven crystallizer can be operated downstream of the falling film evaporator. The crystallizer allows the system to achieve ZLD. For treatment trains using a crystallizer, concentrated brine is sent from the evaporator to a crystallizer heater, then circulates to the crystallizer vessel. As water evaporates, crystals form and flow out of the vessel as a slipstream before entering a belt filter press or centrifuge for dewatering. The distillate produced by the crystallizer has a low TDS concentration (<50 ppm) and may be reused in the FGD treatment system or elsewhere in the power plant. However, the crystallizer is less efficient than the brine concentrator, as it requires one pound of steam per pound of evaporated water.

Veolia also manufactures a system known as CoLD® Crystallization. This technology does not require as much chemical pretreatment as typical evaporation/crystallization processes because it operates at lower temperatures and pressures. In the CoLD® Crystallization system, a small amount of lime is first added to the FGD wastewater. The FGD wastewater enters the falling film evaporator with seeded slurry. The concentrated brine produced by the evaporator is pumped to the crystallizer, where calcium chloride and other highly soluble salts crystallize. Solids leave the crystallizer vessel as a slipstream that is sent for dewatering, ultimately creating a wet cake. The distillate stream can be recycled or discharged.

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Veolia has documented both full- and pilot-scale installations of its HPD® evaporation and crystallization systems. There are more than 1,000 installations of the traditional falling film evaporator systems at plants worldwide. One of these full-scale installations is at a steam electric power plant in Monfalcone, Italy. Since 2008, this plant has utilized the HPD® falling film evaporation with the ZLD crystallization step. Distillate produced by the treatment system is reused within the plant.

As of August 2019, one steam electric power plant is installing a single train falling film evaporator and steam-driven CoLD® Crystallization treatment system for FGD wastewater. The plant has agreed to install the system under an air emissions consent decree. As designed, the system will not include active pretreatment, but some settling is expected in existing scrubber purge ponds before water enters the evaporator. The plant plans to send residual salts to the landfill and recycle distillate. Veolia anticipates that the treatment train will be operational in late 2019.

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Appendix I – KLeeNwater Technology

1. Technology Description

KLeeNwater is a joint venture between ProChem, Inc. and Environmental Energy Services Corporation (EES). KleeNwater offers three trade-marked technologies for FGD wastewater treatment applications: ProChem's I-MICRO, I-PRO, and B-PRO. I-MICRO is a microfiltration membrane with chemical addition, and I-PRO and B-PRO are reverse osmosis (RO) membranes. The typical application for FGD wastewater treatment consists of pretreatment to reduce suspended solids in the wastewater (using either I-MICRO microfiltration/chemical pretreatment, or physical/chemical pretreatment), followed by the I-PRO and B-PRO RO membranes.

Scale forming ions, including calcium, magnesium, and sulfates, are targeted during pretreatment. When microfiltration is incorporated into the treatment train, KLeeNwater uses ProChem's ceramic microfiltration/chemical pretreatment system (I-MICRO). I-MICRO is designed to remove total suspended solids (TSS) from wastewater containing up to 4 percent (40,000 parts per million) TSS. Solids that are removed from the wastewater by the I-MICRO membrane are typically sent to a filter press. Where chemical precipitation is used for TSS removal in place of the I-MICRO system, KLeeNwater includes a sand filtration system upstream of the I-PRO (downstream of chemical precipitation). After TSS removal with either the I-MICRO or chemical precipitation, KLeeNwater also implements cartridge filters to further protect the I-PRO/B-PRO membranes. The I-PRO system removes contaminants including arsenic, mercury, selenium, nitrates/nitrites, boron, bromides, and chlorides.

I-PRO is designed to handle high concentrations of total dissolved solids (TDS). The technology has a TDS influent limit of 5,000 to 45,000 milligrams per liter (mg/L) and a flow rate range of 15 of 350 gallons per minute (GPM). Multiple membrane systems can be installed in parallel to accommodate larger flows.

KLeeNwater offers its brackish water reverse osmosis system (B-PRO) for further removal of TDS from I-PRO permeate. This polishing step is not needed in all industrial wastewater applications. B-PRO has a TDS influent limit of 10 to 5,000 mg/L and a flow rate range of 10 to 350 GPM; higher flow rates would be managed using additional membrane modules.

Like other membrane systems, KLeeNwater RO membranes require flushing and chemical cleaning. In pilot studies, flushes using system permeate were performed approximately once a day, and chemical cleanings were performed approximately once a week. KLeeNwater estimates the membranes will need to be replaced twice per year.

I-PRO or B-PRO concentrate can be managed using a variety of approaches, including thermal technologies or brine encapsulation or solidification processes to achieve zero liquid discharge. KLeeNwater has tested these technologies for different mixtures (e.g., fly ash, lime, superabsorbent polymer) to improve residual treatment and disposal.

2. Technology Status and Performance

The KLeeNwater system has been tested at coal-fired power plants in both laboratory- and pilot- scale studies. KLeeNwater has conducted at least 23 laboratory-scale studies treating wastewater from coal-fired power plants with at least two of the studies treating FGD wastewater. In addition, the EPA reviewed data for four onsite pilot-scale studies with KLeeNwater systems at steam electric power plants for FGD wastewater treatment; the results consistently show pollutant concentrations in the membrane permeate lower than the limits established by the 2015 ELGs. All pilot systems included I-MICRO, followed by the I-PRO and B-PRO, and were operated using a flow rate of approximately five GPM.

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2.1 Pilot Studies #1 and #2

KLeeNwater conducted a 5-week pilot study at a utility to test membrane technology and confirm the results of a previous bench-scale study. The FGD wastewater used for testing had a chlorides concentration of 14,300 ppm.

The pilot system included physical/chemical treatment, I-MICRO, I-PRO, and B-PRO. The treated effluent consistently met ELG and state regulations, and the permeate was considered suitable for re-use within the plant or discharge. Encapsulation tests met regulatory requirements for leachability.

The pilot testing used a different pretreatment strategy during each week of the pilot to evaluate the chemical consumption, system performance, and overall costs of the treatment system. The optimal pretreatment design used the addition of an aluminum-based coagulant and a proprietary scale inhibitor formulation prior to the RO. This specific test was conducted during Week 4 and repeated during Week 5 to confirm the results.

Water recovery data for the Week 4 and 5 trials were consistent, even appearing in line with the recovery achieved in bench-scale laboratory trials. The average recovery was 79.5 percent. Table 1 lists the data obtained from the pilot study.

Table 1. Pilot Test #1 - Average Results

Parameter	FGD Purge	Final Effluent
Arsenic (µg/L)	14.5	1.2
Nitrate-Nitrite as N (mg/L)	70.4	0.16
Selenium (µg/L)	563	2.7
TDS (mg/L)	27,900	86.8

The second pilot study was conducted to validate the results of the first pilot study and to refine the pretreatment process. KLeeNwater successfully validated the results of the first study and further optimized the system's pretreatment in the second study.

2.2 Pilot Study #3

KLeeNwater conducted a six-week pilot-scale study at a coal-fired power plant to treat FGD wastewater. The system typically operated 7 days per week during the first shift, demonstrating the ability of the system to handle demands due to load cycling. For one 5-day period, the system operated 24 hours per day to demonstrate continuous operation.

The FGD wastewater used as influent to the pilot system had a chlorides concentration of 865 ppm. The RO system provided 5 GPM of treated water and achieved an average water recovery of greater than 90 percent. The treated effluent met the 2015 ELG requirements. Table 2 lists the data obtained from the pilot study.

Table 2. Pilot Test #3 - Average Results

Parameter	Pretreatment Influent	Final Effluent
Arsenic (µg/L)	158	5.0
Mercury (ng/L)	53,900	9.7
Nitrate-Nitrite as N (mg/L)	5.15	0.40
Selenium (µg/L)	809	9.5
TDS (mg/L)	4,580	90.2

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2.3 Pilot Study #4

KLeeNwater conducted a pilot study for 10 weeks, operating continuously at a coal-fired power plant to treat FGD wastewater. The test objectives were to confirm results of a previous bench-scale test, meet ELGs while reducing I-PRO concentrate volume, assess B-PRO for water reuse applications, compare pretreatment options, and demonstrate long-term feasibility of the technology. The treatment train consisted of chemical pretreatment followed by clarification, microfiltration (I-Micro), and a two-stage RO system (I-PRO/B-PRO). The system yielded on average 85.4 percent recovery. The highest recovery rate achieved was 93 percent while treating 100 percent FGD wastewater; the lowest recovery rate was 69 percent when treating 100 percent brine. Treated effluent consistently met ELG regulations when the B-PRO system was operated; otherwise, B-PRO permeate was of sufficient quality for reuse as scrubber make-up water. Table 3 lists the data obtained from the pilot study.

Table 3. Pilot Test #4 - Average Results

Parameter	Feed Tank Effluent	Final Effluent
Arsenic (µg/L)	18.5	5.0
Mercury (ng/L)	636	0.5
Nitrate-Nitrite as N (mg/L)	294	1.19
Selenium (µg/L)	561	5.0
TDS (mg/L)	19,200	67.1

2.4 Laboratory Scale Treatability Testing

KLeeNwater conducted laboratory-scale treatability testing on samples of FGD wastewater from coal-fired power plants and coal combustion residual (CCR) landfill leachate. Table 4 includes results for FGD wastewater treatment using chemical pretreatment followed by clarification, microfiltration (I-Micro), and a one-stage RO system (I-PRO). KLeeNwater estimates approximately 83 percent recovery could be achieved.

Samples of untreated CCR landfill leachate were tested at the KLeeNwater lab to determine untreated leachate characteristics and evaluate treatment efficacy of the I-PRO/B-PRO system. In the laboratory environment, KLeeNwater simulated physical-chemical treatment to remove solids, I-PRO treatment, and B-PRO treatment simulated. Table 5 provides average wastewater characteristics for untreated leachate, permeate, and concentrate for the I-PRO system.

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Table 4. Average Characteristics for FGD Wastewater Treatability Testing

Parameter	Untreated Wastewater	I-PRO Permeate	I-PRO Concentrate
Boron (µg/L)	215	134	604
Nitrate (µg/L)	2,250	0	0
Nitrite (µg/L)	1,622	0	0
Nitrate-Nitrite as N (mg/L)	3,872	0	0
Bromide (µg/L)	114	1.11	236
Chloride (µg/L)	23,178	175	47,687
TDS (mg/L)	38,038	408	72,255

Table 5. Average Characteristics for CCR Landfill Leachate Treatability Testing

Parameter	Untreated Wastewater	I-PRO Permeate	I-PRO Concentrate
Arsenic (µg/L)	0.265	0.05	1.25
Mercury (ng/L)	<400	1.19	<400
Nitrate-Nitrite as N (mg /L)	<1	<10	<10
Selenium (µg/L)	<0.20	<0.10	<0.20
TDS (mg/L)	17,400	440	75,200

2.5 Concentrate Management Pilot Testing

As part of KLeeNwater's pilot tests, the company evaluated options to manage the concentrate (i.e., membrane reject stream) generated by treatment of FGD wastewater. Concentrate encapsulation technologies were evaluated in four different pilot studies to assess their performance. These included:

- Wetting fly ash with concentrate (*fly ash wetting*).
- Wetting FGD gypsum with concentrate (*gypsum wetting*).
- Wetting fly ash samples with lime and concentrate (*hydrated lime encapsulation*).
- Adding super absorbent polymer and lime with concentrate (*super absorbent polymer encapsulation*).

Based on the results of the pilot studies, KLeeNwater states that their treatment technology produces a concentrate that can be encapsulated using these different approaches in compliance with toxicity characteristic leaching procedure (TCLP) testing.

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Appendix J – Mitsubishi Spray Dryer Technology

1. Technology Description

Mitsubishi Power (Mitsubishi) has developed a spray dryer unit (i.e., the wastewater spray dryer (WSD)) that uses a slipstream of flue gas upstream of the air heater as a heat source. The slipstream is typically at a temperature between 650°F and 800°F. The FGD wastewater evaporates in the WSD, and residual solids are carried along with the slipstream as it exits the WSD and recombines with the main flue gas stream. The solids are subsequently removed along with the fly ash through separate particulate removal equipment (i.e., electrostatic precipitator or fabric filter). Alternatively, solids from the slipstream can be removed separately from fly ash through installation of separate particulate filtration technologies to treat the slipstream only. A booster fan is used to propel the flue gas slipstream through the WSD to overcome any pressure drop. The booster fan also enables the operator to have positive control over the flue gas slipstream. The evaporated wastewater (i.e., water vapor) is carried along with the flue gas as it travels through the air pollution control equipment.

There is no theoretical limit on what can be evaporated in the WSD; however, because the slipstream is taken from the flue gas prior to going through the air heater, thus reducing the energy input to the boiler, there is a practical limit when considering the impact on the plant from using flue gas. Mitsubishi has designed WSDs that extract six to seven percent of the total flue gas volume from the air heater and have less than a one percent impact on the plant. The slipstream is then recirculated back to the main flue gas stream at approximately the same temperature as the flue gas exiting the air heater. Figure 1 shows an example process flow diagram for an FGD wastewater treatment system that uses a WSD to achieve zero discharge.

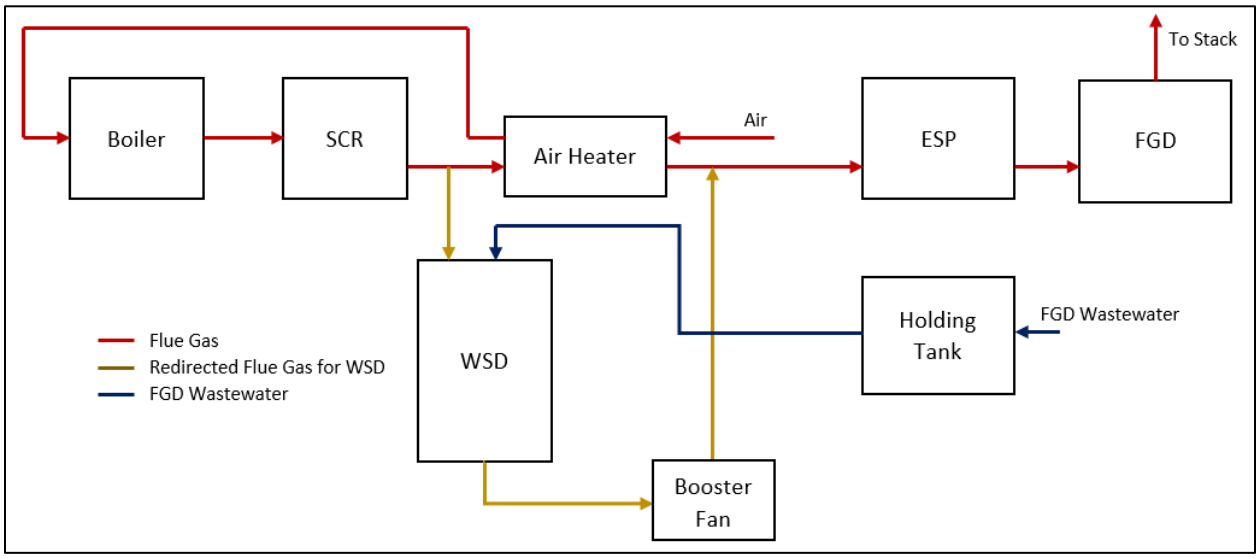


Figure 1. Example Flow Diagram for FGD Wastewater Treatment through WSD

The WSD can either be equipped with dual fluid nozzles or rotary atomizers. Dryers using rotary atomizers are designed to be shorter and wider while dryers using dual fluid nozzles are designed to be taller and thinner based on the spray patterns for each type of atomizer. Each WSD can be equipped with an unlimited number of atomizers. The WSD volume is based on the required volume of flue gas for evaporation, the total volume of wastewater to be treated, and the droplet drying time. The applicable droplet drying time depends on the characteristics of the wastewater inflow. Increased total suspended solids (TSS) concentrations result in reduced total drying times due to the condensation and

crystallization of gypsum nuclei. Increased total dissolved solids (TDS) concentrations result in increased total drying times due to the presence of chloride ions. The effects of TSS and TDS on drying time are somewhat offsetting; however, the effects are not linear and not a 1:1 offset. The volume of flue gas required for evaporation can be calculated using the difference in the inlet and outlet flue gas enthalpy.

In a multi-unit plant, the WSD may either be dedicated to individual units or shared between units. When a WSD is dedicated to a single unit, the WSD is off-line during unit outages. When WSDs are shared between units, the WSD typically operates off a single unit but is ducted to multiple units with suitable isolation dampers. This configuration allows the WSD to process wastewater even when individual units are in an outage. Shared operation by multiple units is possible but not recommended by Mitsubishi as it can result in boiler control issues, since the WSD directly affects air heater operation. Even if the units are identical, the units may not be operating at the same load, have the same temperature profile, air heater leakage, or other operational parameters.

Residual solids generated in the dryer can either be commingled with fly ash in the exiting flue gas and collected using existing particulate removal equipment, such as an electrostatic precipitator or fabric filter, or filtered from the treated slipstream prior to commingling with the main flue gas stream. The configuration for solids management employed at a facility may depend on whether the facility sells the fly ash collected from the flue gas stream. Facilities that do not sell fly ash may opt to use existing particulate removal equipment and landfill commingled solids, while facilities that sell fly ash may elect to install separate particulate removal systems dedicated to collecting residual solids from the WSD exhaust gas stream.

Mitsubishi noted that volume reduction using membrane filtration, other treatment technologies, or wastewater management practices, could be paired with the WSD system to achieve zero discharge. Volume reduction may be most economical for wastewater volumes greater than 200 gallons per minute (gpm).

2. Technology Status and Performance

Treatment systems using WSDs are designed to treat FGD wastewater at 25 gpm per 100 megawatts (MW) of capacity; however, if the influent slipstream temperature is cooler than 650°F, the flow limit will be slightly lower. For facilities with FGD wastewater flows exceeding 25 gpm per 100 MW, Mitsubishi recommends implementing operational changes to reduce FGD wastewater flows.

One method for reducing influent flows to the WSD is to install a reverse osmosis (RO) system upstream of the WSD. Concentrate from the RO system can be processed through the WSD to achieve zero discharge. Mitsubishi estimates that the practical influent recovery rate of the combined unit processes is between 80 and 90 percent when wastewater composition is variable. In order to achieve zero discharge, permeate from the RO system needs to be recirculated back into plant operations as process wastewater.

Other methods for reducing the volume of FGD wastewater influent to the WSD may include reconfiguring process flow to exclude non-FGD wastewater from the treatment system (if wastewater is diluted by utility water streams prior to treatment), adjusting the chloride setpoint for FGD purge to up to 80 percent of the design capacity, or increasing the liquid-to-gas ratio of the absorber, which allows reduced blowdown by re-gearing the absorber recycle pumps.

Mitsubishi has conducted pilot-scale studies using the WSD for the treatment of FGD wastewater from coal-fired power plants at the Mitsubishi Heavy Industries, Ltd. Research and Innovation Center in Hiroshima, Japan. The pilot studies were used to develop design parameters necessary to achieve zero discharge based on the volume and characteristics of FGD wastewater to be treated. Based on pilot

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testing using TSS and TDS as variables, Mitsubishi established a baseline algorithm for calculating total drying time.

Mitsubishi is also working with customers to design a system to treat power plant ash pond water. This system will be designed to operate at flow up to 135 gpm and up to 24 hours per day.

2.1 Linfen Power Station and Other Installations in China

Mitsubishi installed a full-scale WSD system in July 2017 at the Linfen Power Station in China, which operates a single 300-MW generating unit. The treatment system was designed to treat influent FGD wastewater flows up to 35 gpm. The FGD wastewater off the hydrocyclone overflow enters the WSD at an influent flow rate between 20 and 25 gpm. The hydrocyclone overflow is not pretreated prior to entering the WSD. The typical hydrocyclone overflow feed to the WSD is 4.9 percent TSS and 5.8 percent TDS.

Mitsubishi has five other full-scale WSD systems operating or in the process of being installed for FGD wastewater treatment in China. At least three of these systems are in the process of being commissioned, with the original date of service scheduled for the end of 2021 but delayed due to COVID restrictions and other supply chain issues.

2.2 Boswell Energy Center, Minnesota

Mitsubishi installed a spray dryer system at the Boswell Energy Center (Boswell) located in Minnesota. This system is the largest WSD for FGD treatment to date, sized for 145 gpm. The system was brought online in 2022. This system is designed to treat wastewater containing up to 5,000 parts per million chlorides. Boswell will first use the system to dewater a pond that contains FGD wastewater and other miscellaneous wastewater streams. Once pond dewatering is complete, the plant will send FGD wastewater to the WSD, capturing it first in holding tanks that will feed the WSD. Solids generated by the WSD will be collected along with fly ash from the combined flue gas stream.

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Appendix K – New Logic Membrane Technology

1. Technology Description

The first industrial application of New Logic's VSEP technology was for dewatering kaolin clay for coal mining facilities. Since then, New Logic has expanded the use of the VSEP to other industries, including petrochemical, automotive, food and beverage, pulp and paper, and power generation.

The VSEP system is a new generation membrane filtration system designed for wastewaters containing high total suspended solids (TSS) and total dissolved solids (TDS) and uses vibratory movement to reduce fouling on the membrane surface. The technology works by spinning an eccentric weight bearing, which induces a vibratory action that is translated to the torsion spring and on to the filter pack drive (i.e., the membrane). The filter then oscillates 54 times per second up to an amplitude of ¾ of an inch. The shear created by the rapid change in direction makes it difficult for foulants to attach to the membranes. However, clean water may still pass through the membrane pores.

Early applications of VSEP were configured with microfiltration and ultrafiltration membranes, which mainly removed suspended solids and large organics. Today, New Logic also produces fully automated VSEP systems configured with reverse osmosis (RO) membranes. The RO membranes can separate difficult to treat feed streams including those with high levels of suspended and dissolved solids, oils, metals, and organics. New Logic also provides spiral-wound RO membranes that can be used independently or in conjunction with VSEP. Figure 1 shows an example of a process flow diagram for a combination VSEP and spiral RO treatment system for FGD wastewater. The concentrate from stage one (VSEP) can be disposed of using a variety of onsite and offsite techniques, including thermal treatment, solidification (also referred to as encapsulation), and underground disposal. The concentrate from stage two (RO reject) would typically be combined with the feed entering the VSEP membrane (stage one).

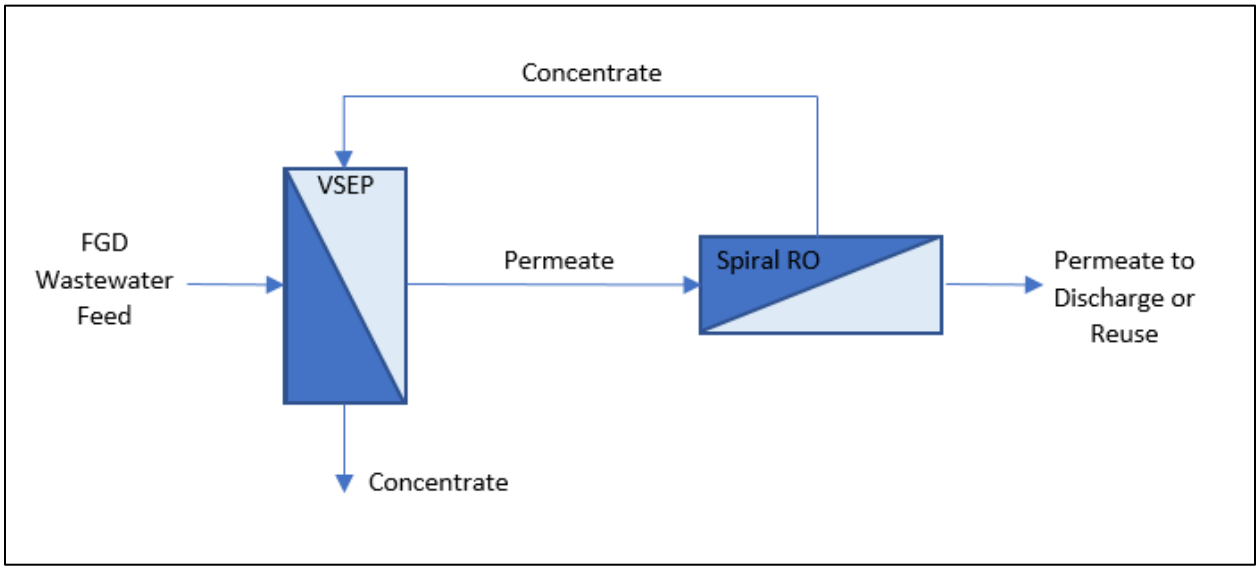


Figure 1. Example Two-Stage VSEP System Process Flow Diagram

Another potential configuration would be a three-stage system with two VSEP RO membrane units followed by a conventional spiral RO membrane to polish the VSEP permeate, as shown in Figure 2. This configuration consists of a low-pressure (500 psi) VSEP RO membrane and a high-pressure (1,000 psi) VSEP RO membrane. Concentrate from the low-pressure VSEP is transferred to a high-pressure VSEP

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stage, with the permeate from the two VSEP stages becoming the influent to the spiral RO membrane. According to New Logic, the number of VSEP/RO stages is determined by the TDS or osmotic pressure limitations and the desired amount of water recovery (or to reduce the volume of reject requiring disposal).

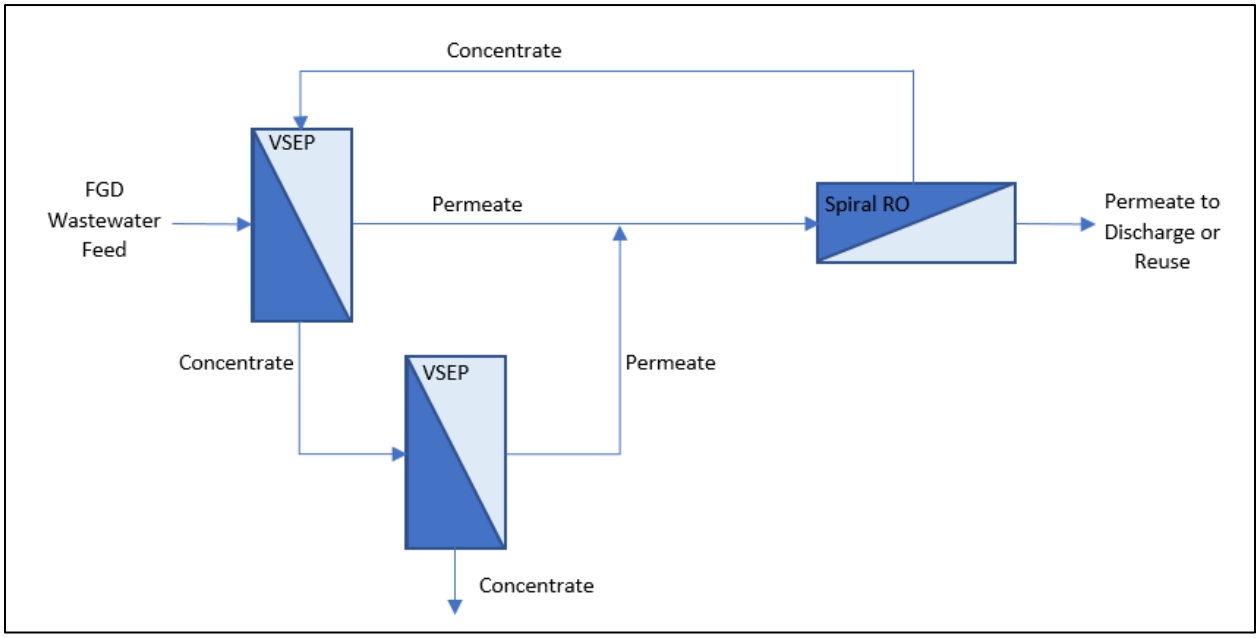


Figure 2. Example Three-Stage VSEP System Process Flow Diagram

New Logic's VSEP modules are available in several sizes. The largest VSEP module currently offered by New Logic is 1,400 ft^2. The capacity of a single 1,400 ft^2 VSEP module will depend on the TDS of the feed, temperature, and recovery rate. But assuming an average flux rate of 18 gallons per square foot per day, which could be considered a typical range, the single module could produce 18,000 gallons per day (GPD) of permeate. Modules of VSEPs can be operated in parallel to meet any flow rate requirements.

Concentration of TSS is not a limiting factor for the VSEP/RO system; however, particle size is. Large particles, those greater than 100 micrometers (µm) in diameter, can cause damage to pumps, valves, and the membrane. Pretreatment of the raw feed water prior to the VSEP/RO technology is necessary for FGD wastewater treatment applications. The raw feed water should be strained or passed through a settling tank to remove grit and large particles, and also treated such that the influent TDS does not exceed 100,000 ppm. As designed, the typical VSEP/RO system includes a basket strainer, but this is not meant as a pretreatment step; it is a secondary measure for large particles or items that may be accidentally dropped (e.g., screwdrivers). It should not be the sole form of pretreatment if the wastewater does contain particles larger than 100 microns. Another pretreatment step that needs to be considered is chemical addition to remove free chlorine and other oxidants. Dechlorination of the feed may be necessary because chlorine damages the polyamide membranes used in the VSEP system, which would result in a lower membrane rejection rate.

Like other membrane systems, the VSEP membranes require periodic flushing and chemical cleanings. These cleanings occur anywhere from once a day to once a month, with once or twice a week being the average. New Logic estimates that the membranes will need to be replaced every one to two years.

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Industry sources report that the VSEP tests summarized in Section 2 demonstrate that anti-fouling technology can enable the use of membrane filtration to treat FGD wastewater and that the VSEP/RO treatment train is effective at removing selenium, arsenic, mercury, and nitrate-nitrite to concentrations well below the ELG limitations. These sources also report that the onsite tests demonstrate that the anti-fouling properties of the VSEP system enable it to treat FGD wastewater without the need for extensive pretreatment. Additionally, the VSEP/RO treatment process has a relatively small footprint and obviates the need for the reaction tanks and much of the other equipment typically included as part of chemical-biological treatment trains. Treating FGD wastewater with the VSEP/RO system can achieve significant volume reduction upstream of thermal or encapsulation zero discharge technologies, thereby reducing the size and cost of the thermal/encapsulation equipment.

The EPA met with representatives from New Logic in support of the 2024 final rule to discuss membrane operations. New Logic confirmed that membrane permeate recovery generally decreases with increased TDS concentrations.

2. Technology Status and Performance

New Logic has conducted several on-site, pilot-scale studies for the treatment of wastewater from power plants using the VSEP system. Table 1 provides a summary of several pilots conducted to treat FGD wastewater and fly ash leachate. With the exception of one pilot study where the wastewater was pretreated by softening with lime and soda ash, New Logic confirmed that there was no pretreatment prior to the VSEP system. New Logic also confirmed that all studies included spiral RO polishing in the treatment train.

Table 1. Summary of New Logic Pilot-Scale Studies

Location	Date	Application	Flux Rate (GFD)	Water Recovery	Feed TDS (mg/L)	Concentrate TDS (mg/L)
Pilot Study #1	6/29/09 - 8/14/09	FGD Wastewater	30.0	67.0%	41,200	93,000
Pilot Study #2	10/16/13 - 1/15/14	FGD Wastewater	25.5	83.2%	17,500	63,500
Pilot Study #3	1/10/15 - 1/20/15	FGD Wastewater	24.8	73.0%	24,600	105,200
Pilot Study #4	6/8/15 - 7/17/15	FGD Wastewater	21.6	75.0%	16,000	59,000
Pilot Study #5	5/17/16 - 6/8/16	FGD Wastewater	24.3	78.8%	4,000	14,200
Pilot Study #6	3/1/18 - 3/15/18	Fly Ash Leachate	27.9	93.0%	7,700	57,000
Pilot Study #7	6/2008 – 10/2008	Surface Impoundment Effluent, including FGD Wastewater	Not reported	75.0%	Not reported	Not reported
Pilot Study #8	9/26/18 - 10/10/18	FGD Wastewater	29.5	55.0%	46,800	75,500
Pilot Study #9	Two years (intermittent)	FGD Wastewater	Flow rate: 50 GPM. Other specific details unknown.			
Pilot Study #10	5/18 – 10/18	FGD Wastewater	Flow rate: 1 GPM. Other specific details unknown.			

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Table 1. Summary of New Logic Pilot-Scale Studies

Location	Date	Application	Flux Rate (GFD)	Water Recovery	Feed TDS (mg/L)	Concentrate TDS (mg/L)
Pilot Study #11	9/20 – Unknown	FGD Wastewater	Flow rate: 50 GPM. Other specific details unknown.			

Abbreviations: GFD (gallons per square foot per day); GPM (gallons per minute).

The EPA has additional details on three of the on-site, pilot-scale studies for the treatment of FGD wastewater listed in Table 1: Pilot Study #2, #4, and #7. New Logic also provided further information on full-scale VSEP systems installed to treat cooling tower blowdown. The details of these three FGD wastewater pilots and cooling tower blowdown applications are presented further in the subsections below.

2.1 Pilot Study #2

A commercial-scale two-stage VSEP/RO system was tested for three months at a coal-fired power plant to treat FGD wastewater. During the study, the VSEP system was operated in both a batch mode and a single-pass mode, with the VSEP system receiving untreated FGD wastewater from the plant's feed tank. The source of wastewater for the feed tank was the plant's FGD settling pond. Other than gravity settling in a surface impoundment, no pretreatment of the wastewater was performed prior to the VSEP system. During batch mode, a finite volume of FGD wastewater is processed through the system. The permeate was transferred away from the system, while the concentrate stream was recycled back to the feed tank for reprocessing. As the batch continued, the feed to the VSEP system became more concentrated and continued operating until a specified end point was reached, such as a target permeate flow rate. Batch operation such as this can be used to maximize the amount of water recovery, which has the effect of minimizing the volume of concentrate requiring disposal or further treatment. During single-pass mode, the feed enters the VSEP system while the concentrate valve is closed. As the permeate is processed through the system, the concentrate valve is opened when the desired permeate volume has been achieved. The concentrated wastewater (membrane reject) is purged from the system when the concentrate valve is opened. During the study, in both modes of operation, the VSEP permeate was transferred to a conventional spiral RO for polishing. Using the combination of VSEP and spiral RO, the treatment train consistently met the discharge limits for FGD wastewater established by the 2015 ELGs (in fact, the effluent concentrations were lower than the limits proposed by the EPA in 2013, which were lower than the limits established by the 2015 ELGs). The pilot test results demonstrated that anti-fouling technology enables the use of membrane filtration to treat FGD wastewater, with no loss of flux and no irreversible fouling or scaling of the membranes over the duration of the study. The pilot test also showed that chemical pretreatment of the wastewater was unnecessary, although addition of anti-scalant can increase water recovery rates. Table 2 presents the average pollutant concentrations in the influent, the VSEP permeate, and the spiral RO permeate when the system was operated in a single-pass mode. Table 3 presents the average pollutant concentrations in the influent, the VSEP permeate, and the spiral RO permeate when the system was operated in a batch mode.

Table 2. Average Pollutant Concentrations for VSEP Pilot Operating in Single-Pass Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Alkalinity (mg/L)	56.3	10.8	10.8
TDS (mg/L)	17,400	813	352
TSS (mg/L)	106	2	< 1
Total Solids (mg/L)	17,600	815	353

Table 2. Average Pollutant Concentrations for VSEP Pilot Operating in Single-Pass Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Fluoride (mg/L)	9.46	< 1.30	< 1.30
Chloride (mg/L)	8,010	254	< 25
Nitrite (mg/L)	4.58	< 1.30	< 1.30
Bromide (mg/L)	61.0	< 3.26	< 3.26
Nitrate (mg/L)	19.2	< 6.51	< 6.51
Nitrate-Nitrite (mg/L)	23.7	0.45	0.07
Phosphate (mg/L)	< 1.30	< 1.30	< 1.30
Sulfate (mg/L)	1,440	< 25	< 25
Beryllium (µg/L)	< 2.5	0.67	< 0.5
Boron (µg/L)	155,000	109,000	81,200
Sodium (µg/L)	52,100	15,900	2,480
Magnesium (µg/L)	646,000	12,500	< 50
Aluminum (µg/L)	< 1,000	< 200	< 200
Silicon (µg/L)	20,900	1,010	< 1,000
Potassium (µg/L)	20,050	10,300	< 2,000
Calcium (µg/L)	2,980,000	72,700	< 2,000
Titanium (µg/L)	21.4	< 2	< 2
Vanadium (µg/L)	< 50	< 10	< 10
Chromium (µg/L)	< 10	< 2	< 2
Manganese (µg/L)	6,430	134	< 4
Iron (µg/L)	< 500	< 100	< 100
Cobalt (µg/L)	34.6	< 0.5	< 0.5
Nickel (µg/L)	178	< 5	< 5
Copper (µg/L)	< 25	< 5	< 5
Zinc (µg/L)	2,010	47.9	< 10
Arsenic (µg/L)	< 5	< 1	< 1
Selenium (µg/L)	191	1.54	< 1
Strontium (µg/L)	912	22.8	< 0.5
Molybdenum (µg/L)	64.6	0.52	< 0.5
Silver (µg/L)	< 2.5	< 0.5	< 0.5
Cadmium (µg/L)	74.2	1.61	< 0.5
Antimony (µg/L)	5.24	< 0.5	< 0.5
Barium (µg/L)	404	11.0	< 0.5
Tungsten (µg/L)	< 2.5	< 0.5	< 0.5
Mercury (ng/L)	1,400	35.4	11.0
Thallium (µg/L)	8.12	9.76	1.19

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Table 2. Average Pollutant Concentrations for VSEP Pilot Operating in Single-Pass Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Lead (µg/L)	< 2.5	< 0.5	< 0.5
Uranium (µg/L)	23.1	< 0.5	< 0.5

Table 3. Average Pollutant Concentrations for VSEP Pilot Operating in Batch Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Alkalinity (mg/L)	55.0	10.0	10.0
TDS (mg/L)	9,820	544	< 1
TSS (mg/L)	58	< 1	< 1
Total Solids (mg/L)	9,880	544	< 1
Fluoride (mg/L)	6.3	< 1.30	< 0.260
Chloride (mg/L)	4,110	183	< 5
Nitrite (mg/L)	< 5.21	< 1.30	0.5
Bromide (mg/L)	23.3	5.8	< 0.651
Nitrate (mg/L)	< 26.0	< 6.51	< 1.30
Nitrate-Nitrite (mg/L)	13.1	0.75	0.04
Phosphate (mg/L)	< 5.21	< 1.30	< 0.260
Sulfate (mg/L)	1,010	< 25	< 5
Ammonium (µg/L)	< 40	< 20	0.109
Beryllium (µg/L)	0.72	< 20	< 0.5
Boron (µg/L)	97,900	< 0.5	32,400
Sodium (µg/L)	24,800	54,100	881
Magnesium (µg/L)	375,000	5,260	139
Aluminum (µg/L)	< 400	14,000	< 400
Silicon (µg/L)	17,400	< 400	< 1,000
Potassium (µg/L)	13,800	1,000	< 2,000
Calcium (µg/L)	2,120,000	4,650	< 2,000
Titanium (µg/L)	6.08	86,100	< 1
Vanadium (µg/L)	< 10	< 1	< 10
Chromium (µg/L)	< 2	16.2	< 2
Manganese (µg/L)	5,110	< 2	< 2
Iron (µg/L)	< 100	181	< 100
Cobalt (µg/L)	36.4	< 100	< 0.5
Nickel (µg/L)	177	1.32	< 5
Copper (µg/L)	10.8	6.61	< 5

Table 3. Average Pollutant Concentrations for VSEP Pilot Operating in Batch Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Zinc (µg/L)	1,160	< 5	< 5
Arsenic (µg/L)	2.03	42.9	< 1
Selenium (µg/L)	267	< 1	< 1
Strontium (µg/L)	633	4.24	< 0.5
Molybdenum (µg/L)	31.3	24.7	< 0.5
Silver (µg/L)	< 0.5	0.54	< 0.5
Cadmium (µg/L)	54.4	< 0.5	< 0.5
Antimony (µg/L)	5.02	1.33	< 0.5
Barium (µg/L)	288	< 0.5	< 1
Tungsten (µg/L)	0.65	11.4	< 0.5
Mercury (ng/L)	833	< 0.5	<10
Thallium (µg/L)	6.20	10.3	0.88
Lead (µg/L)	< 0.5	5.46	< 0.5
Uranium (µg/L)	15.1	< 0.5	< 0.5

2.2 Pilot Study #4

New Logic conducted a pilot study at a coal-fired power plant to test the performance of its VSEP system at treating FGD wastewater at a power plant. During the study, the VSEP system was primarily tested in the single-pass mode, but the percent recovery and the use of an anti-scalant pretreatment were varied to find the optimal performance for the system. Additionally, the VSEP permeate was fed through a spiral-wound RO system to improve the quality of the discharge. Three single-pass runs were conducted at 50 percent recovery, and four single-pass runs were conducted at 75 percent recovery. Initial testing demonstrated that anti-scalant typically increased throughput rates, so the majority of testing was performed with anti-scalant. Results from the 50 percent recovery runs are presented in Table 4, and results from the 75 percent recovery runs are presented in Table 5.

Table 4. Single-Pass Pollutant Concentrations Under 50% Permeate Recovery Rate During Pilot Study #4

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
50	Mercury (total, ng/L)	110	1.7	0.28[a]
	Arsenic (total, µg/L)	2.5[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	ND	ND	ND
	Selenium (total, µg/L)	280	6.3	2.3[a]

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Table 4. Single-Pass Pollutant Concentrations Under 50% Permeate Recovery Rate During Pilot Study #4

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	6.4	0.51	0.02[a]
	TDS (mg/L)	13,000	540	51
	TSS (mg/L)	31	ND	1.6[a]
50	Mercury (total, ng/L)	190	3.5	1.8
	Arsenic (total, µg/L)	2.5[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	2.2[a]	ND	ND
	Selenium (total, µg/L)	340	6.4	2.8[a]
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	6.1	1.3	ND
	TDS (mg/L)	16,000	750	230
	TSS (mg/L)	97	1.6[a]	2[a]
50	Mercury (total, ng/L)	69	1.3	1.9
	Arsenic (total, µg/L)	3[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	1.9[a]	ND	ND
	Selenium (total, µg/L)	240	3.4[a]	1.6[a]
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	17	1	0.18
	TDS (mg/L)	16,000	620	150
	TSS (mg/L)	29	1.6[a]	6.4

a – Measurement below the quantitation limit, but above the method detection limit.

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Table 5. Single-Pass Pollutant Concentrations Under 75% Permeate Recovery Rate During Pilot Study #4

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
75	Mercury (total, ng/L)	150	4.2	0.24[a]
	Arsenic (total, µg/L)	1.9[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	1.4[a]	ND	2.9[a]
	Selenium (total, µg/L)	330	11	3.9[a]
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	15	3.2	0.025[a]
	TDS (mg/L)	16,000	1,000	240
	TSS (mg/L)	63	1.6[a]	ND
75	Mercury (total, ng/L)	180	2.6	0.44[a]
	Arsenic (total, µg/L)	2[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	1.7[a]	ND	ND
	Selenium (total, µg/L)	320	10	5
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	16	2.6	0.06[a]
	TDS (mg/L)	15,000	1,200	260
	TSS (mg/L)	36	3.2[a]	2.8[a]
75	Mercury (total, ng/L)	100	6.5	1.2
	Arsenic (total, µg/L)	1.9[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	ND	ND	1.7[a]
	Selenium (total, µg/L)	250	7.9	5
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	17	1.1	0.13
	TDS (mg/L)	16,000	1,100	100
	TSS (mg/L)	170	5.6	7.6

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Table 5. Single-Pass Pollutant Concentrations Under 75% Permeate Recovery Rate During Pilot Study #4

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
75	Mercury (total, ng/L)	54	2.6	0.82
	Arsenic (total, µg/L)	2.3[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	ND	ND	ND
	Selenium (total, µg/L)	250	10	3.2[a]
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	16	3.7	0.23
	TDS (mg/L)	16,000	2,000	110
	TSS (mg/L)	71	2.8[a]	1.6[a]

a – Measurement below the quantitation limit, but above the method detection limit.

2.3 Pilot Study #7

New Logic conducted a pilot study at a power plant to test the performance of the VSEP system at reducing the volume of water stored in a surface impoundment containing FGD wastewater. The plant operates with zero discharge and its storage ponds were beginning to reach a level that could potentially cause issues at the plant. Therefore, the plant was looking for a technology that would allow them to reuse water internally to reduce the amount of raw water entering the plant and reduce the volume of stored water in the ponds. The tested system incorporated five VSEP nanofiltration membrane modules. The addition of spiral RO treatment downstream of the VSEP modules was not tested as part of the original pilot test but was determined to be a viable option for further polishing monovalent ions. The goal of the study was to identify the optimum system operation that allowed for the highest recovery achievable in which the required cleanings were at least five days apart. The pilot test found that 75 percent recovery at 210 psi reduced the conductivity of the feed water from approximately 5,000 µS/cm to 1,400 µS/cm in the permeate. Concentrate from the system averaged approximately 10,500 µS/cm and was routed to one of the on-site evaporation ponds.

2.4 Cooling Tower Blowdown VSEP Installations

New Logic has installed three full-scale VSEP installations to treat cooling tower blowdown. Table 6 provides a summary of these installations including system design flowrate, permeate destination, and concentration destination.

Table 6. Summary of Cooling Tower Blowdown VSEP Installations

Project	Feed Material	Design Flow Rate (GPM)	Permeate Destination	Concentrate Destination
ExxonMobil King Ranch Gas Plant	Cooling Tower Blowdown	161	Reuse as boiler feed and/or cooling tower makeup	Saltwater disposal

Table 6. Summary of Cooling Tower Blowdown VSEP Installations

Project	Feed Material	Design Flow Rate (GPM)	Permeate Destination	Concentrate Destination
Burney Forest Power	Cooling Tower Blowdown	35	Reuse as cooling tower makeup	Brine hauling
Calpine Pastoria	Cooling Tower Blowdown	60	Reuse as cooling tower makeup	Brine concentrator

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Appendix L – Oasys Forward Osmosis Technology

1. Technology Description

Forward osmosis (FO) is a membrane-based process utilizing a draw solution as a high osmotic potential agent to capture fresh water from a saline or contaminated feed stream. FO is driven by an osmotic pressure gradient across a semi-permeable membrane to attain spontaneous and preferential diffusion of water molecules from a wastewater feed into a draw solution. The draw solution pulls out the clean water from the wastewater feed stream and becomes diluted as it flows through the FO membrane system. The result of the FO separation is a highly concentrated wastestream (i.e., brine stream) and a diluted draw solution stream. The diluted draw solution stream is subsequently processed and recycled to re-concentrate the draw solution to full strength for reuse in the FO system and to recover the final high-quality product water.

Oasys has developed a high recovery FO technology platform, the MBC system, which combines a specialized draw solution technology, a highly efficient draw recovery system, and a proprietary FO membrane. Oasys has two MBC system technologies, the ClearFlo MBC system and the ClearFlo Edge MBC system. The ClearFlo MBC can treat influent total dissolved solids (TDS) concentrations of up to 150,000 ppm. Oasys manufactures the ClearFlo MBC Edge for smaller desalination applications, with influent streams containing up to 50,000 ppm TDS.

1.1 FGD Wastewater Treatment – ClearFlo MBC

Oasys developed the ClearFlo MBC system by combining optimization of membrane and draw solution interaction, innovation in draw solution recovery, and refinements to system controls architecture to improve process performance and economics. The Oasys FO membrane is a thin-foam composite (TFC) with a thin polyamide backbone. Treatment only requires one pass through the membrane unit. The MBC utilizes a high osmotic draw solution (6,000 psi) that is highly soluble. The solution contains ammonia carbamate, formed by dissolving ammonia and carbon dioxide gases in water.

Two streams are fed into the FO membrane unit: influent wastewater and the concentrated draw solution (CDS) in a countercurrent orientation. Two streams also leave the FO membrane unit: the diluted draw solution (DDS) and the concentrated brine solution. The DDS is sent to a recovery unit where clean water is stripped and discharged for reuse. The draw solution is thermolytic—as heat is added, the ammonia and carbon dioxide evaporate from solution, leaving behind clean water. The ratio of ammonium salts to other components in the dilute and concentrated draw solution naturally buffers the solution and maintains pH between 9.8 and 10.3. No additional pH control by chemical addition is required, other than making sure the salt ratios are in range. The ammonia and carbon dioxide gases formed in the recovery unit are sent to a condenser absorber (a simple distillation column) for recovery.

The ClearFlow MBC system is operated at atmospheric pressure. The difference between the effective feed pressure of the CDS and the effective draw pressure of the DDS is the driving force for FO. Unlike the conventional reverse osmosis (RO) where the differential osmotic pressure generally decreases as the water flows through the membrane column, FO can maintain an approximately constant differential osmotic pressure through the membrane column. The draw solution is concentrated and polarized at the feed and becomes more dilute as water is naturally pulled from the wastewater to the other side of the membrane, thus creating a concentrated brine solution.

The draw solution system is considered a closed loop. A minimal amount of draw solution does pass into the brine. Over time, makeup draw solution is required due to some loss into the brine and losses due to upsets and sample collection. Draw solution that passes into the brine is stripped out in a brine stripper

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column, ensuring that draw solution is lost at a very slow rate. Energy used to heat the thermolytic draw solution can be recovered.

RO is sometimes used to pre-concentrate influent that enters the FO membrane. By pre-concentrating the wastewater, the FO system can be smaller and more economical.

Upon exiting the FO unit, the brine concentrate has a TDS concentration of 250,000 ppm or higher. Brine concentrate may then be fed into a crystallizer, a spray dryer, or mixed with fly ash and lime to manufacture a solid for disposal. Oasys does not provide evaporation, crystallizing, or spray drying equipment.

2. Technology Status and Performance

Oasys has installed two full-scale systems for the treatment of FGD wastewater internationally and has conducted one pilot studies in the U.S.

2.1 Changxing Power Station – China

In 2015, Oasys installed a full-scale treatment system at the coal-fired Huaneng Changxing Power Plant the world's first FO-based ZLD solution. The station includes twin 660 MW steam generators and flue gas pollution controls including wet limestone slurry FGD units by Wuhan Kaidi. The treatment train consists of a solids contact clarifier, filter press, multi-media filtration, and weak acid cation (WAC) ion exchange polishing as pretreatment, then into the ClearFlo MBC system (RO pre-concentration and the FO trains). The concentrated brine is then sent to a crystallizer.

The treatment system is designed to handle approximately 160,000 gallons per day. The incoming FGD wastewater has a TDS concentration of 25,000 ppm. Since operation began, the system has consistently achieved product water with a TDS concentration in the range of 35 to 50 ppm.

The FO system at Changxing was designed to treat wastestreams that were pretreated for mineral hardness removal and concentrated using a RO membrane system. Operations have found the FGD wastewater to be generally at a much lower TDS than the design envelope of 25,000 to 40,000 ppm. The low salinity of the raw water leads to a higher total water recovery through the RO and FO systems. The raw feed is rich in sulfate, which is typical of most FGD blowdown. The combination of these factors requires the removal of mineral hardness for extensive water recovery in the RO and FO systems prior to being fed to the crystallizer. Table 1 presents water quality data for the FO system at Changxing.

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Table 1. Water Quality of Major Streams of the FO System in Changxing, China

Analyte	Raw FGD Wastewater	Pretreated MBC Feed	FO Feed	MBC Brine/ Crystallizer Feed	MBC Product Water
pH	9.4-10.2	9.5-11.0	9.5-11.6	9.5-9.8	9.9-10.9
Na (mg/L)	1,400-2,000	3,460-6,800	14,000-21,000	57,000-85,000	8.7-19.2
Ca (mg/L)	60-600	< 5.0	< 5.0	< 5.0	< 0.05
Mg (mg/L)	150-650	< 5.0	< 5.0	< 5.0	< 0.05
SiO_2 (mg/L)	10-80	5-37	26-137	200-300	< 0.10
Cl (mg/L)	1,700-3,000	2,600-4,800	8,000-16,000	37,000-59,000	5.5-15.2
SO_4 (mg/L)	1,500-3,500	1,500-3,500	8,000-15,000	33,000-45,000	0.3-1.1
HCO_3 (mg/L)	40-120	210-620	1,000-3,300	7,300-20,800	3.0-10.1
CO_3 (mg/L)	15-45	390-805	2,000-4,200	1,300-6,200	5.5-11.0
TDS (mg/L)	6,500-11,500	8,700-16,000	43,000-64,500	155,000-220,000	36-49

Note: Raw water contains 0.0025 mg/L arsenic, 0.044 mg/L selenium, 19.4 mg/L nitrate nitrogen, and 0.1 mg/L nitrite nitrogen. Mercury was not detected, with a detection limit of 0.0002 mg/L. The product water from the RO and system contains < 0.001 mg/L arsenic, 0.0026 mg/L selenium, 7.3 mg/L nitrate nitrogen, and 0.06 mg/L nitrite nitrogen. Mercury was not detected, with a detection limit of 0.0002 mg/L.

2.2 Shanxi Lujin Wangqu Power Station, Lucheng City, China

At the Shanxi Lujin Wangqu Power Plant, Oasys installed a full-scale MBC system to treat FGD wastewater at a feed rate of 79,000 gallons per day. Pretreatment prior to entering the MBC system consists of softening, multimedia filtration, and weak acid cation exchange. The treatment system was installed in mid-2017. The final brine is combined with bottom ash and fly ash for landfill disposal but is not completely encapsulated. Product water is used as make-up water to an offsite denim plant.

2.3 Water Research Center Pilot Study for FGD Wastewater Treatment

Oasys deployed the ClearFlo MBC technology at the Water Research Center (WRC) at Georgia Power's Plant Bowen Power Station from September to October 2016. The two-month pilot study tested a sidestream of FGD pond effluent and verified MBC system performance, reliability, and safety. Oasys operated a 6-9 gallon per minute system consisting of a physical/chemical treatment system to reduce hardness, metals, silica, and solids (pH adjustment, chemical softening, microfiltration, ion exchange, antiscalant) prior to the MBC system (RO, single-pass FO units, and draw recovery system).

The FO units operated as a single-pass operation and did not require cleaning throughout the duration of the study, which totaled more than 300 hours of continuous operation. Untreated FGD wastewater TDS concentrations ranged from 12,000 to 20,000 ppm and 90-95 percent of the raw water was recovered for potential reuse or discharge with a TDS concentration of less than 250 ppm. Brine concentrate had TDS concentrations of up to 300,000 ppm. Table 2 presents performance data from the WRC pilot study.

Table 2. Summary of Performance Data from WRC Pilot Study

Analyte	Raw FGD Water	MBC Feed Water Data Based on Oasys Demonstration Pilot	MBC Product Water Data Based on Oasys Demonstration Pilot
Arsenic (ppb)	33	29	ND (<5)
Mercury (ppt)	2,920	ND (<200)	ND (<200)
Selenium (ppb)	313	250	3.4
Nitrate-Nitrite (ppm-N)	15	13	0.9
TDS (ppm)	13,300	14,600	<250
Boron (ppm)	187	159	4.4

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Appendix M – Purestream Advanced Vapor Recompression

1. Technology Description

Purestream is a water services company formed in 2010 with a specialty in developing brine concentration and desalination technology for water reuse in power plants. Purestream's AVARA uses advanced mechanical vapor recompression to remove pollutants from wastewater and generates a reusable distillate stream and concentrated brine stream from wastewater. It can be used in municipal, commercial, and industrial wastewater treatment systems but is intended for power plant waste streams. It is designed as a modular system that could be used in the field to minimize wastewater, reducing or even eliminating the need to transport, treat, or dispose of wastewater elsewhere.

Each commercial AVARA module has a capacity of 35 gallons per minute (GPM), is skid-mounted (50 feet by 12 feet) and can easily be installed. The modular system, after being purchased or leased from Purestream, can be built in 180 days and is deployable within two days of on-site delivery; assembly only requires electrical and plumbing connections be established. Multiple 35 GPM units can operate together to create a larger capacity system. Each self-contained unit can be placed on-site on individual skids (one unit and ancillary equipment per skid), or equipment can be reconfigured (e.g., all compressors on one skid, all heat exchangers on one skid, etc.) for flexible installation. Purestream asserts that if pH, scaling potential, and solids are monitored and kept within an acceptable range, there are not any additional factors that would preclude installation of the system in any plant design. Influent concentrations are typically monitored and controlled at the feed tank prior to the heat exchanger. Figure 1 shows a process flow diagram for a typical AVARA system.

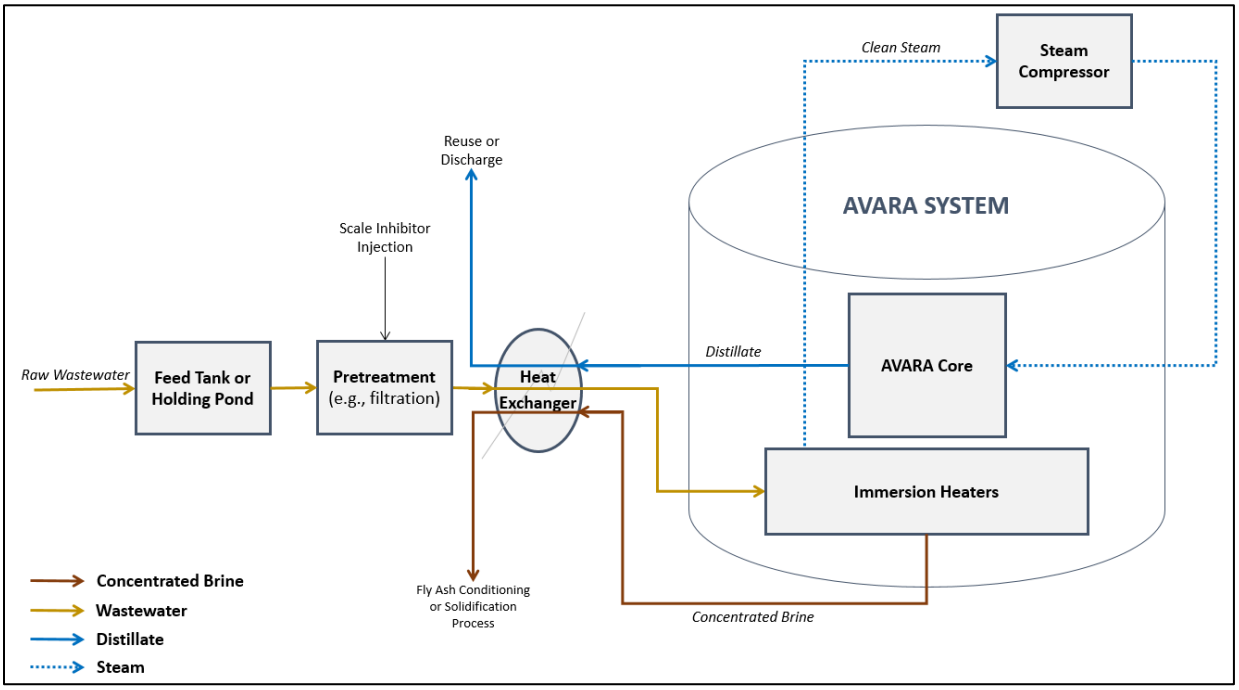


Figure 1. Process Flow Diagram for AVARA Mechanical Vapor Recompression System

FGD wastewater is pumped from a holding pond or tank through an influent filtration system to remove suspended solids; a scale inhibitor is added at the filtration system. To facilitate evaporation, wastewater is initially heated by immersion heaters to the desired temperature. As the wastewater inside the tank boils, steam vents from the top of the tank and passes through a steam compressor, which pushes the steam inside the AVARA cores; the cores are a proprietary design in vertical plate orientation. Heat transfers from steam inside the cores to the brine in the tank, while the steam condenses inside the cores and becomes the "clean" distillate stream. This distillate stream can be discharged or returned to the plant for beneficial reuse; it has a total dissolved solids (TDS) concentration below 300 parts per million (ppm). As wastewater evaporates and steam is generated, the TDS in the brine remaining in the tank becomes concentrated. Once the brine reaches a predetermined TDS set point concentration, not to exceed 200,000 ppm,[3] brine is discharged from the tank in a continuous stream through hydrocyclones. Heat exchangers recover and transfer energy from the hot brine and distillate streams to preheat influent entering the AVARA tank, reducing reliance on the immersion heaters. The concentrated brine may be combined with fly ash for disposal in a landfill or may be used as an ingredient for a solidification process (also referred to as brine encapsulation).

In most FGD wastewater applications, raw FGD wastewater with a total suspended solids (TSS) concentration below 30 ppm can be pumped directly into the AVARA system. Wastewater with higher TSS concentrations may require clarification to lower this influent TSS concentration. However, a settling tank often provides sufficient pretreatment. Chemical addition may also be required to maintain the necessary pH between 5.5 and 6.5. Crystal inhibitors and antiscalants are also added to maintain optimal conditions and to mitigate scaling. The bubbles generated by the boiling liquid create turbulence, which also helps mitigate scaling on the immersed cores. Transducers create ultrasonic bubbles and turbulence in the tank that also prevent scale from building up on the cores. Water circulation within the tank also reduces scaling. The submerged core design leaves little potential for oxidation, so equipment corrosion is typically not an issue.

Conventional reverse osmosis (RO) technology may be used to preconcentrate FGD wastewater prior to the AVARA. This could be a cost-effective zero discharge technology when implemented with brine encapsulation.

The AVARA's modular design allows for simple and quick core replacements and repairs. The cores can be considered akin to cartridges that can be removed and replaced with minimal system downtime. When removed, the cores can be serviced offline (i.e., mechanical or chemical cleaning) without affecting running operation of the system. AVARA can be kept in standby mode during shut-down periods of less than a week. In standby mode, burners are lowered to keep wastewater warm and prevent solids from precipitating. For extended shut-down periods, the system is purged, flushed, and residual steam is blown out. The small volumes of steam released from the vents are not typically scrubbed because this is an infrequent process. The AVARA system is marketed as a turn-key technology that includes operation and service (i.e., Purestream is contracted to operate the system for the facility). The longest system operating in the field has been running intermittently for three years.

The AVARA system typically requires on-site operators, but the system can be managed remotely with proper process controls. One operator can run up to five AVARA modules. When scale builds up and cleaning is required in a multi-unit fleet, one unit can be shut down for cleaning while the others continue operating. Based on a pilot-scale study treating FGD wastewater, Purestream estimates the system can operate a year or more before cleaning to remove scale is required. In testing and full-scale

[3] Above this concentration, the solution becomes saturated, and solids have been observed precipitating out of solution. The system can treat influent with TDS concentrations as high as 120,000 ppm but will see lower recovery rates as the influent TDS concentration approaches the TDS set point.

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implementation to date, cores have been pressure washed to remove scale and have not required chemical cleaning.

2. Technology Status and Performance

In 2015, Purestream, in conjunction with the Electric Power Research Institute (EPRI), began exploring the potential for AVARA to manage wastewater from coal-fired power plants. Since that time, Purestream has been piloting AVARA with EPRI and three coal-fired power plants to treat FGD wastewater and other waste streams. In 2017, Purestream conducted another AVARA pilot-scale study to treat FGD wastewater at a coal-fired power plant in Northern Indiana. Each of these pilot-scale studies is summarized in Table 1.

Table 1. Pilot Scale AVARA Treatment Systems

Pilot Number/Plant Name	Test Duration and/or Test Date	Treatment Train	Treated Water	Recovery Rate
Pilot #1 – Springerville Plant (Arizona)	February – September 2016	Storage pond, settling pits, Induced Gas Flotation (IGF), 35 GPM AVARA	Cooling tower blowdown	86%
Pilot #2 – Plant Bowen (Georgia)	May – October 2016	3-GPM AVARA	FGD wastewater and brine concentrate	-
Pilot #3 – Merom Generating Station (Indiana)	October – December 2016	35-GPM AVARA	FGD wastewater	82.5%
Pilot #4 – Plant in Northern Indiana	July – September 2017	Chemical precipitation (first three quarters of study), 35-GPM AVARA	Pond effluent containing leachate and FGD wastewater	91%

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Appendix N – Saltworks Technologies

1. Technology Description

Headquartered in British Columbia, Canada, Saltworks Technologies (STI) was founded in 2008. STI specializes in technological applications for treating high saline, highly variable wastewater. Specific to FGD wastewater, STI markets two products, the Flex Electrodialysis Reversal (EDR) Selective (previously the Salt Splitter) and SaltMaker™ zero liquid discharge (ZLD) wastewater treatment technologies.

The Flex EDR Selective is a hybrid technology built around two common desalination technologies: electrodialysis (ED) and reverse osmosis (RO). The ED system operates upstream of the RO which improves RO reliability by reducing the scaling potential and allowing the RO to operate at a lower pressure. ED is used to electrochemically soften wastewater. The electrochemical process uses monoselective ion exchange membranes to selectively remove chlorides from wastewater. Compared to the traditional softening processes, which involve addition of soda ash, the Flex EDR Selective achieves lower volumes of brine exiting the RO system.

The Flex EDR Selective converts calcium sulfate ($CaSO_4$) to non-scaling sodium sulfate (Na_2SO_4) and calcium chloride ($CaCl_2$). Sodium sulfate and calcium chloride are much more soluble in water than calcium sulfate. Sodium chloride (NaCl) must be added to some FGD wastewater to prevent scaling and allow the ED process to function as designed and maintain the chemistry charge balance in the water. The amount of NaCl required varies by influent chemistry and depends on the concentrations of calcium, sulfate, sodium, and chloride. The Flex EDR Selective technology generates a RO permeate stream, which can be discharged or reused, and two concentrated brine streams, one rich in sodium sulfate and another rich in calcium chloride. Lower TDS concentrations in the untreated wastewater result in higher recovery of water in the RO permeate. The two brine streams can achieve a TDS concentration of 200,000 milligrams per liter (mg/L). Reject from the RO system is recycled back to the Flex EDR Selective feed and reprocessed through the system. Sulfates and multi-valent anions do not pass through the Flex EDR Selective ion exchange membranes and thus are recycled back to the FGD scrubber. Arsenate and selenite also do not pass through the ion exchange membranes.

FGD wastewater requires additional treatment to remove heavy metals and silica. For these pollutants, which cannot be effectively removed by the RO, the pH of the incoming wastewater is raised to 10.5 in order to precipitate out these pollutants prior to the Flex EDR Selective system. When treating FGD wastewater, the treated chloride-reduced wastewater is recycled back to the FGD scrubber. The technology also produces a non-scaling brine, predominantly calcium, sodium, and chloride.

The concentrated brine streams can be sent to a traditional crystallizer, to produce solids that can be landfilled as part of a ZLD configuration, or to STI's SaltMaker™ technology. STI markets their SaltMaker™ technology as an alternative to traditional crystallizers or vapor compression systems. It uses humidification and dehumidification systems to evaporate the water. The technology can produce more concentrated brine streams or achieve true ZLD and generate solids. SaltMaker™ technology operates at temperatures below 95 degrees Celsius and can use low-pressure steam as the thermal energy source. Because the system reuses thermal energy, it uses 20-25% of the energy of typical single effect evaporation systems that are open to atmosphere. In part, due to its self-cleaning functionalities, STI claims their SaltMaker™ technology is more robust, is less likely to foul, and experience lower rates of shutdown as compared to traditional vapor compression systems. The SaltMaker™ is currently operated at full-scale at mining, landfills, smelters, and waste to energy facilities.

Pilot-scale and bench-scale testing has shown the system can successfully treat FGD wastewater. In 2017, a pilot-scale demonstration in China operated for 90 days and treated 50 gallons of wastewater per day. The system included pretreatment to removed silica, transitional metals and ultra/microfiltration. The incoming FGD wastewater had a total dissolved solids concentration of 19,300 mg/l and the system

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achieved a RO recovery rate of approximately 91-92%; brine (combined flow of both streams) volume was around 8-9%.

From March 24th to May 24th, 2019 , STI also conducted a second pilot study in collaboration with the United States Department of Energy, the Electric Power Research Institute, and Southern Company. The pilot study's goal was to selectively remove chlorides so the FGD wastewater could be reused within the FGD scrubber system. The pilot treated FGD wastewater continuously for 61 days with an average recovery of 93 percent. Influent TDS to the Flex EDR Selective ranged from 7,860 mg/L when the feedwater was untreated FGD wastewater to 35,300 mg/L when the feedwater was membrane filtration reject. Pretreatment consisted of lime and sulfuric acid addition to prevent scaling. The chemicals used during the Flex EDR Selective operation included sodium chloride and sodium sulfate to protect against electrode fouling; and biocide to inhibit biological growth.

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Appendix O – SUEZ ABMet Biological Treatment Technology

1. Technology Description

The ABMet™ technology utilizes a packed bed, fixed-film biological filter, consisting of anoxic, granular activated carbon (GAC) media bioreactors. The GAC media is inoculated with microorganisms that grow within the GAC bed to create a fixed-film that retains the microorganisms and precipitates solids within the bioreactor. The system uses microorganisms chosen specifically for use in FGD systems because of their hardiness in the extreme water chemistry as well as selenium respiration and reduction abilities. The ABMet™ system is classified as high residence time biological reduction (HRTR); the bioreactor stage is typically designed for a residence time on the order of 10-16 hours or more. The long hydraulic residence time of the HRTR process results in a relatively large footprint for tanks and other equipment. However, SUEZ has stated that their ABMet™ technology can be designed and sized for a continuum of residence times, including shorter than 10 hours.

The ABMet™ system is designed as a plug-flow system to ensure the feed water is evenly distributed and has maximum contact with the microorganisms in the fixed-film. The bioreactor allows for oxidation-reduction potential (ORP) gradational zones in the bioreactors to facilitate denitrification, reduction of selenium to its elemental form, and sulfur reduction, eventually precipitating trace metals. The system maintains a pH level in the bioreactor between 6.0 and 9.0 S.U. because extreme high or low pH levels could affect the performance of the microbes and potentially allow undesirable microbes to propagate.

Figure 1 presents a typical process flow diagram for an anoxic/anaerobic biological treatment system with two stages of bioreactor cells in series. Both stages of bioreactors contain multiple cells in parallel. Plants usually employ multiple bioreactors to provide the necessary residence time to achieve the specified removals.

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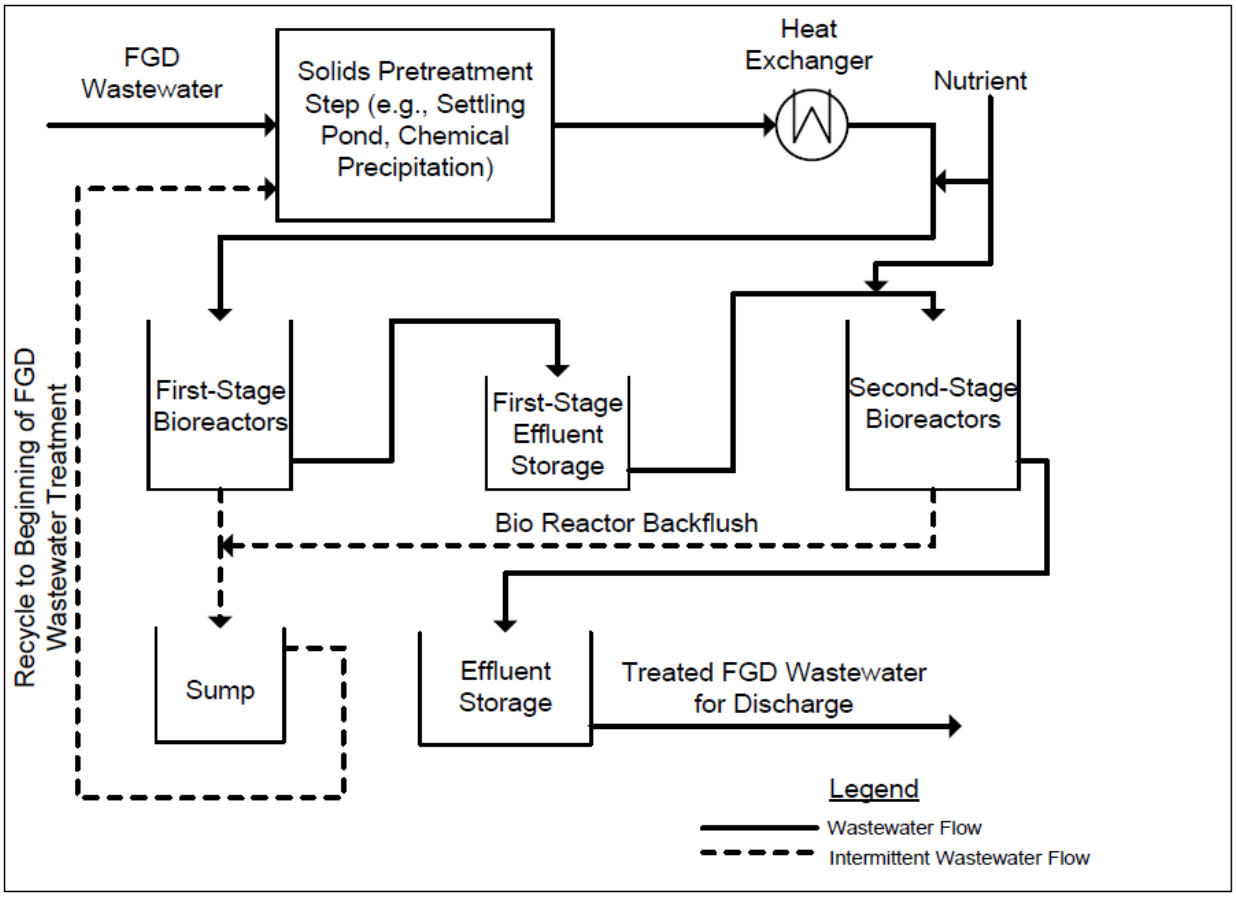


Figure 1. Process Flow Diagram for a Typical Downflow Packed Bed Anoxic/Anaerobic Biological Treatment System

Management of ORP in the bioreactor is important for optimizing removal of nitrate-nitrite and selenium. Nitrate-nitrite and selenium removals are optimized when ORP in the reactor is in range of -300 to -150 mV. These levels are achieved by adding organic carbon to feed microbial growth and sodium bisulfite as needed to reduce free oxidants, and encouraging sequential reduction of oxygen, nitrate, selenate, and sulfate. High concentrations of oxidants have the potential to inhibit the growth and activity of the microorganisms that reduce nitrate-nitrite and selenium. At one pilot test site, the plant was experiencing degraded pollutant removal performance that was determined to be associated with high ORP of the wastewater. The site added reducing agents to remove the oxidants and the wastewater was then able to support microbial growth and activity. The site found that by monitoring the ORP in the wastewater, optimizing pretreatment with chemical precipitation including the addition of reducing agents to pretreat the wastewater, the issues related to the increased ORP levels can be controlled and the biological treatment system is able to function as expected.

The microorganisms in this system are susceptible to temperatures in excess of 105ºF. Because of this susceptibility, some plants cool the FGD wastewater before it enters the biological system using heat exchangers. Based on data from the EPA sampling episodes, these plants generally are in geographic regions with sustained periods of maximum ambient temperatures greater than 90ºF.

When gases or solids build-up in the media, they are periodically backwashed from the system using permeate from the biofilter, effectively removing nitrogen gas, selenium, and other pollutants. Waste

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solids are collected near the top of the biofilter and flow by gravity to a storage tank, pond, or solids handling system. Some plants send the backflush water to the beginning of the chemical precipitation wastewater treatment system so that the system can remove the solids (and adhered selenium) within the clarifier. Other plants have transferred the backflush water to a surface impoundment where the solids (and adhered selenium) settle out.

2. Technology Status and Performance

As of 2015, full-scale ABMet™ treatment systems were being used to treat gold mining wastewater, coal mining wastewater, precious metal recycling wastewater, FGD wastewater from power plants, and ash leachate from power plants. See the *Statistical Support Document: Effluent Limitations for FGD Wastewater, Gasification Wastewater, and Combustion Residual Leachate for the Final Steam Electric Power Generating Effluent Limitations Guidelines and Standards* (DCN SE05733) for detailed information regarding the pollutant removal efficacy of this treatment technology.

Through communication with GE Water, Suez, and power companies, the EPA is aware of at least 5 full-scale installations of ABMet™ for treating FGD wastewater at coal-fired power plants. These systems were designed to treat either FGD wastewater alone or a combination of FGD wastewater and other wastewater streams (e.g., landfill leachate). Table 1 includes a list of the locations of these full-scale installations.

Table 1. Full Scale ABMet™ FGD Wastewater Treatment Systems

Plant Name	State	Treatment Configuration Notes
Allen Steam Station	North Carolina	Chemical precipitation followed by ABMet™.
Belews Creek Steam Station	North Carolina	Chemical precipitation followed by ABMet™.
Roxboro Steam Plant	North Carolina	Original configuration was pond followed by ABMet™. System has since been upgraded to chemical precipitation followed by ABMet™.
Mayo Electric Generating Plant	North Carolina	Original system was pond followed by ABMet™. Treatment system has since been replaced by a thermal evaporation system.
Mountaineer Plant	West Virginia	Chemical precipitation followed by ABMet™. ABMet™ system treats FGD wastewater and landfill leachate.

The systems operated at Duke Energy Carolinas' Allen Steam Station and Belews Creek Steam Station have two stages of bioreactor cells in series, as shown in Figure 1, but both stages of bioreactors contain multiple cells in parallel. Data from both treatment systems were used to establish the 2015 effluent guidelines for FGD wastewater.

Table 2 includes a listing of the pilot demonstrations of the ABMet™ system on FGD wastewater.

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Table 2. Pilot Scale ABMet™ FGD Wastewater Treatment Systems

Pilot Number/Plant Name	Test Duration and/or Test Date
Pilot #1 – North Carolina	2007
Pilot #2 – North Carolina	2007
Pilot #3 – West Virginia	2008
Pilot #4 – Belgium	2009
Pilot #5 – North Carolina (Cliffside)	2011-2012
Pilot #6 – Indiana	2013
Pilot #7 – South Carolina	8 Months (2013-2014)
Pilot #8 – Georgia	2014-2015
Pilot #9 – Wisconsin (Pleasant Prairie)	6 Months (2015-2016)
Pilot #10 – South Carolina (Winyah)	87 Days (2016-2017)
Pilot #11 – Ohio (Cardinal)	5 Months (2017)

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Appendix P – SUEZ Thermal Technology

1. Technology Description

SUEZ offers a brine concentration treatment option consisting of a vertical tube falling film evaporator and mechanical vapor compressor. SUEZ recommends pretreatment upstream of the brine concentration system to achieve desaturation and solids removal. Depending on the FGD wastewater characteristics, pretreatment may include organosulfide, ferric chloride, and polymer addition, followed by clarification and filtration (in certain cases), for increased metals removal.

The brine concentration technology can recover up to 95 percent of industrial wastewater as high purity distillate that can be used for other plant processes. The remaining five percent is a slurry concentrate. The technology uses a calcium sulfate seeded slurry process to concentrate wastewater and prevent scaling inside the system. Seeds are added at startup, then continuously produced as the system operates. The slurry has the lowest solubility at the heat transfer surface on the evaporator to ensure calcium sulfate precipitates on circulating seed material.

SUEZ doses anti-scaling solution in the brine concentration system feed tank and the system runs at a pH between 5.5 and 6.0 and dissolved oxygen levels less than 50 parts per billion (ppb) to prevent stress corrosion cracking. To bring the brine concentration system online for initial use, an operator seeds the evaporator and circulates the slurry between eight and twelve hours. To put the evaporator offline, an operator enables a “hot standby” where the recirculation pump is running, but no heat input is needed due to the high level of insulation in the system. The brine concentration system can be on standby indefinitely and the only cost incurred during this time is for energy associated with the recirculation pump. After a standby period, the evaporator can be brought back online in about 15 minutes and no re-seeding is needed. This mode of operation is beneficial for peaking plants that only operate between 12 and 14 hours per day. The brine concentration system needs to be brought completely offline for cleaning once per year for a period of three to five days.

To operate the system with no discharge, the brine concentration system can be combined with mixed salt crystallization or pozzolanic solidification/encapsulation. Mixed salt crystallization can reduce brine concentrate to a dry solid. Recovered water can be recycled back to plant processes, while the dry solids produced through the crystallization process can be disposed in a landfill. In the case of mixed salt crystallization, softening pretreatment is required to remove calcium and magnesium sulfates. These compounds are converted to a sodium sulfate and calcium chloride solution exiting the crystallizer, which must be disposed in a landfill.

To create the final pozzolan for disposal, brine, Portland cement, fly ash, and water are combined in a ribbon mixer. Additional lime may be added to the mixture to facilitate partial encapsulation, if desired. The final pozzolan is less permeable and is less likely to leach when disposed in a landfill, compared with the mixed salt crystallization products. SUEZ has conducted both bench-scale and pilot-scale testing to optimize encapsulation mixtures.

If a plant has Class F fly ash, soluble calcium will not be in the brine solution; therefore, more calcium addition would be required for pozzolanic encapsulation, compared to a plant with Class C fly ash. The evaporator concentrate may have considerable concentrations of free calcium. A greater amount of fly ash (per unit of product) is needed to perform fly ash wetting than for a pozzolanic reaction and final disposal.

SUEZ also offers spray dryer evaporator (SDE) with brine concentration as a thermal treatment option. The SDE uses flue gas upstream of an electrostatic precipitator (ESP) or baghouse system to evaporate FGD blowdown. Spray drying without brine concentration is more expensive than spray drying with brine concentration. If a plant has a single power block and a small wastewater flow rate, SUEZ recommends the implementation of an SDE to achieve ZLD. However, for plants with multiple power blocks that are

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not close in proximity, an SDE may not be an ideal option because the flue gas ducting may not be easily combined.

In addition, SUEZ has examined lime softening plus ultrafiltration followed by crystallization as a zero-discharge option; however, SUEZ emphasized that their falling film evaporator combined with brine encapsulation is a more cost-effective treatment option for FGD wastewater. SUEZ has found that life cycle costs of the crystallizer are typically higher due to high electricity costs.

2. Technology Status and Performance

In the power industry, SUEZ has over 65 full-scale installations of their brine concentration system. There are approximately six installed brine concentration systems treating FGD wastewater alone, including one installed at the Indianapolis Power and Light (IPL) Petersburg Generating Station, or combined with other waste streams. SUEZ plans to install one system in South Africa, two systems in Korea, and is in talks with plants in China and India.

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Appendix Q – Sylvan Source

1. Technology Description

The SSI Core technology is a system that combines three different treatment technologies into a single thermal evaporation system to boil wastewater and then condense the steam to create clean water. Figure 1 presents a schematic of the SSI Core technology. The SSI Core combines the following three wastewater treatment technologies:

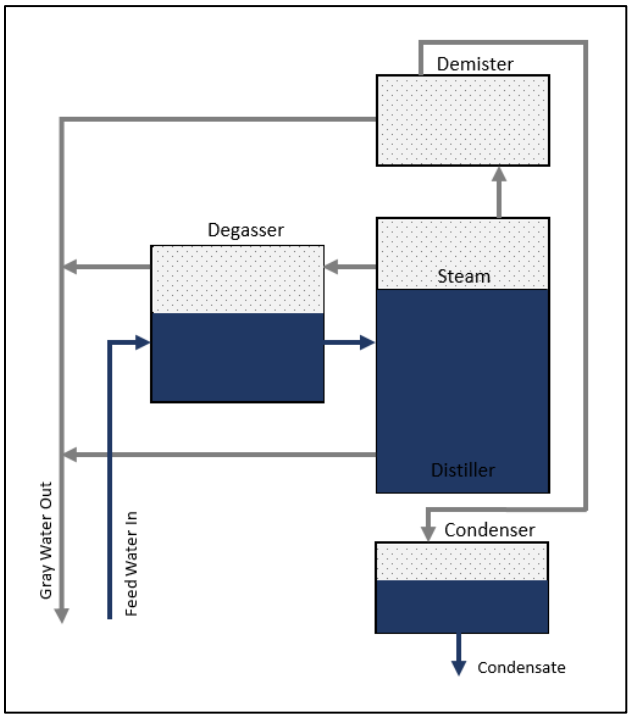


Figure 1. SSI Core Technology Schematic

- Degassing: The wastewater is first sent to a degasser where it is heated to near boiling by the steam leaving the distiller. This allows the dissolved gases and organics to vaporize out of the wastestream and into counterflowing steam from the distiller. The steam, dissolved gases, and organics leave the degasser as a gas and are referred to as "gray steam."
- Distillation: The water stream leaving the degasser flows into the distiller where it is converted to steam. The concentrated brine created in the distiller is removed from the bottom of the vessel and combined with the "gray steam" from the degasser. Some of the steam from distiller flows through the degasser to remove the dissolved gases and organics. The remainder of the steam rises to the demister. The SSI Core operates close to atmospheric pressure, but it is possible to configure with vacuum.
- Demisting: The steam from the distiller enters the demister where SSI's patent-pending process separates the steam from the mist droplets. The droplets are removed from the demister and combined with the "gray steam" and concentrated brine. These combined contaminated streams are condensed and prepared for disposal. The steam, on the other hand, passes through the demister and is then condensed and can be reused or discharged.

The SSI Core system can be operated in multiple stages. For multiple stage operation, the energy to drive the first system can come from a variety of sources, including steam, flue gas, and other forms of waste heat. But for all the subsequent stages, the energy to drive the system comes primarily from the heat of condensation of the steam created in the previous stage.

The SSI Core is capable of concentrating waste streams to a heavy brine that crystallizes when cooled. However, the SSI Core does require the feed water to be pretreated to reduce the magnesium concentration to enable crystallization. A range of standard pretreatment technologies, including ion exchange, pH adjustment, and precipitation, can be used to optimize the SSI Core.

SSI has conducted several pilot studies on various power plant wastewaters, including one pilot-scale study of FGD wastewater from a coal-fired power plant. In 2013, FGD wastewater from a coal-fired power plant was transported to SSI in San Carlos, CA for treatment through their SSI System Pilot Unit. Table 1

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presents the FGD feedwater and product water (following proprietary pretreatment and SSI Core system treatment) concentrations for a subset of pollutant.

Table 1. Sample Test Results from 2013 SSI System Pilot Unit Study Using Power Plant FGD Wastewater

Parameter	FGD Feedwater	SSI Product Water
Arsenic	<2 ppb	ND
Mercury	15 ppb	0.086 ppb
Selenium, total	1,221 ppb	ND
TDS	13,200 ppm	33 ppm

2. References

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Appendix R – Vacom Technology

1. Technology Description

The Vacom VCC One-Step™ Process combines an evaporator and a crystallizer into a single system. Additionally, the process uses turbulent flows to minimize fouling and scaling on the equipment. Figure 1 presents a process flow diagram of the VCC One-Step™ Process.

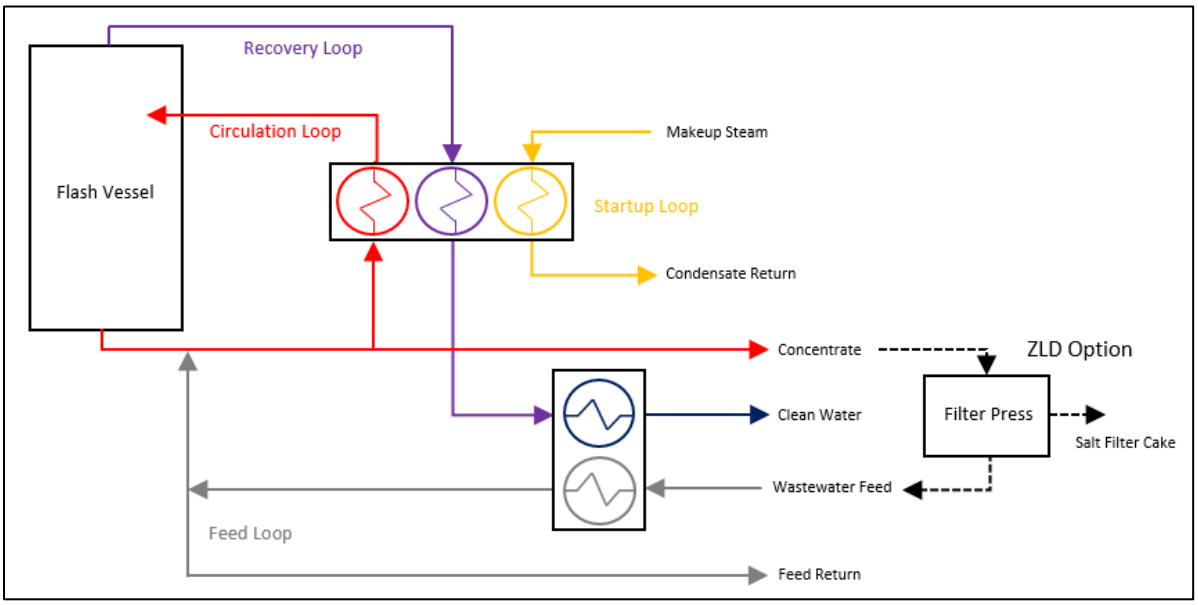


Figure 1. Process Flow Diagram for the Vacom VCC One-Step™ Process

As shown in Figure 1, there are four interconnected loops in the system:

1. The feed loop;
2. The circulation loop;
3. The recovery loop; and
4. The startup loop.

In the feed loop, the raw wastewater entering the VCC One-Step™ Process first passes through a heat exchanger where the heat from the clean distillate stream is used to preheat the feed water. This preheated feed water is then mixed in-line with the circulation loop.

In the circulation loop, the concentrated wastestream leaving the bottom of the flash vessel is mixed with the preheated feed water and circulated back to the flash vessel. But prior to reaching the flash vessel, the wastewater is pumped at high velocities through the primary heat exchanger to heat the wastewater to its boiling point using the heat from the steam generated and removed from the flash vessel. The high velocity of the wastewater in combination with the salt crystals generated in the flash vessel act as scouring agents in the heat exchanger help to clean the tubing and prevent scaling and fouling. The wastewater in the circulation loop is maintained at a temperature and pressure such that evaporation does not occur in the loop, but rather, only occurs in the flash vessel. Once the wastewater reaches the flash vessel, the water is evaporated, exits the vessel through the top and enters the recovery loop. The salts remaining in the vessel are pulled from the bottom of the vessel and enter the circulation loop again.

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There is a bleed stream from the circulation loop, referred to as the concentrate, which needs to be disposed.

The steam generated in the flash vessel is removed using a blower that increases the temperature and pressure of the steam. This higher-pressure steam then passes through the primary heat exchanger to heat the circulation loop prior to it entering the flash vessel. Additionally, this condenses the steam in the recovery loop into water. The condensed water then passes through another heat exchanger to heat the raw wastewater feed, which also helps cool the distillate stream.

The start-up loop consists of make up steam that is used in the primary heat exchanger to heat the circulation loop to get the process started. This is necessary because when the process initially begins, there is not any steam generated in the recovery loop that can heat up the circulation loop. Therefore, another source of heat is needed until the process gets started.

As for the concentrate (i.e., salt slurry) generated through the VCC One-Step™ Process, the plant can dewater the salt slurry to generate a dry haulable salt. Potential dewatering devices may include a rotary drum filter or a filter press. Any water removed from the dewatering process would then be combined with the raw wastewater feed and reprocessed in the system.

Vacom has conducted at least one onsite pilot study for the treatment of FGD wastewater from a coal-fired power plant using the VCC One-Step™ Process. The pilot test was conducted at the Water Research Center located at Georgia Power's Plant Bowen. Over a period of approximately 42 days, the pilot system was tested using the following three different variations of FGD wastewater:

1. Chemical precipitation effluent;
2. Raw FGD pond effluent; and
3. Concentrated effluent from a pilot-scale vibratory shear enhanced process membrane provided by New Logic Research, Inc.

2. Technology Status and Performance

Two steam electric power plants in China are using the VCC One-Step™ Process to treat FGD wastewater. The first system, installed in December 2017, treats 100 gallons per minute from four coal-fired generating units. Treatment includes clarifiers to remove suspended calcium sulfate followed by the One-Step™ Process. When the system was designed, the plant had planned to beneficially reuse or sell the calcium sulfate removed in pretreatment, and sodium chloride filtered from the concentrate stream, but has since abandoned these plans due to high costs of chemical addition required for pretreatment (sodium sulfate). Instead, the plant stabilizes the concentrate and disposes of it in a landfill. The second installation in China is identical to the first but included disposal of stabilized concentrate in its original design.

Vacom has also participated in a series of pilot and long-term testing of FGD wastewater treatment at the Water Research Center with the Electric Power Research Institute (EPRI). The testing used the One-Step™ Process in combination with other FGD wastewater treatment technologies, including other membrane filtration technologies.

Vacom also piloted its One-Step™ Process for treatment of municipal landfill leachate in China. This pilot system used a reverse osmosis (RO) membrane with concentrate from the RO membrane further treated using the One-Step™ Process.

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3. References

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2. EPRI. 2017. Electric Power Research Institute. Thermal Evaporation Technologies for Treating Power Plant Wastewater: A Review of Six Technologies. 3002011665. Palo Alto, CA. (September).
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Appendix S – DuPont Technologies

1. Technology Description

DuPont markets a combination of two technologies to treat FGD wastewater: minimal liquid discharge (MLD) membrane filtration and zero liquid discharge (ZLD) thermal treatment.

- MLD – Includes chemical precipitation, ultrafiltration, ion exchange softening, and combinations of reverse osmosis (RO), forward osmosis (FO), and/or nanofiltration (NF).
- ZLD – Includes pretreatment, which could be MLD, followed by a brine concentrator and crystallizer.

When combined with a ZLD thermal treatment technology, MLD systems can be more affordable and reduce landfill waste. The MLD-ZLD water reuse process begins with pretreatment using UF to remove suspended solids followed by ion exchange or nanofiltration softening to remove scaling potential. After pretreatment, a combination of primary RO, secondary RO, ultra-high-pressure RO or FO, and/or selective NF generates permeate and a purified sodium chloride brine. The brine is further treated through the ZLD portion of the system, using the brine concentrator and crystallizer. Permeate from the MLD system can be reused.

Pretreatment requirements vary based on the wastewater influent quality. In general, system operation increases in efficiency with greater softening. With DuPont's RO systems, it is ideal to remove close to 100 percent of hardness prior to RO. Instead of a secondary or more robust precipitation softening step, weak acid cation (WAC) exchange is used to ensure a plant can achieve the desired recovery level. The ion exchange regeneration waste can be sent back to a lime and soda softening process for further treatment.

RO treatment is limited by osmotic pressure of the water and the designed pressure limits of the RO system and membrane module. Standard RO systems can be operated up to 1,200 pounds per square inch (psi). When applying 1,200 psi pressure to an RO membrane, water will stop permeating through the membrane when the water osmotic strength approaches 1,200 psi. Depending on the compositions of salts, the maximum concentration of salt achieved by a system operating at 1,200 psi will be approximately eight to 10 percent. Ultra-high-pressure RO systems are designed to operate up to 1,740 psi, producing salt concentrations between 10 to 20 percent depending on the salt composition.

A four-stage, single-pass RO system, using an ultra-high-pressure RO as the final stage, can achieve up to 95 percent water recovery, with booster pumps used between stages to increase pressure. DuPont recommends operating membranes below 35 degrees Celsius to optimize permeate quality such that permeate is suitable for reuse without needing a second pass of RO treatment.

2. Technology Status and Performance

DuPont has installed nine MLD-ZLD systems for FGD wastewater treatment at power plants in China since 2015, shown in Table 1. Detailed information on two of these installations were provided by DuPont, described in Sections 2.1 and 2.2 below.

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Table 1. DuPont MLD-ZLD Installations in China

Plant Number	Commission Date	Capacity (cubic meters per hour)
Plant #1	2015	22
Plant #2	2017	36
Plant #3	2018	25
Plant #4	2018	10
Plant #5	2018	15
Plant #6	2018	40
Plant #7	2018	40
Plant #8	2018	6
Plant #9	2019	100

2.1 Changxing Power Plant – China

The ZLD water treatment system at the Changxing Power Plant in Zhejiang Province, China treats FGD wastewater and cooling tower blowdown using lime soda softening to remove most of the hardness, WAC exchange to remove any remaining hardness, two-pass RO to preconcentrate the brine, FO, and a brine concentrator/crystallizer. Recovered water from the treatment train is reused as boiler make-up water. Since operation began in May 2015, the plant has achieved between 70 to 75 percent water recovery. This plant uses two seawater RO systems that produce a concentrate TDS of 60,000 mg/L. Salts generated by the crystallizer, up to 10,000 metric tons per year, are sold to the local chemical industry.

2.2 Hanchuan Power Plant – China

At the Hanchuan Power Plant in Hubei Province, China, DuPont implemented an FGD wastewater treatment system consisting of tubular microfiltration (MF) softening, NF, two-pass RO (seawater and brackish water systems, SWRO and BWRO, respectively), high-pressure RO, and ZLD technologies that generate industrial grade salt, shown in Figure 1 below. Final disposal of the salt product is unknown. Laboratory studies have demonstrated that NF concentrate contains sodium sulfate with some sodium chloride, and the permeate mostly consists of sodium chloride (98.5 percent). This treatment train was originally a pilot study that experienced stable operation for over two months and led to full scale implementation, beginning operation in late 2016.

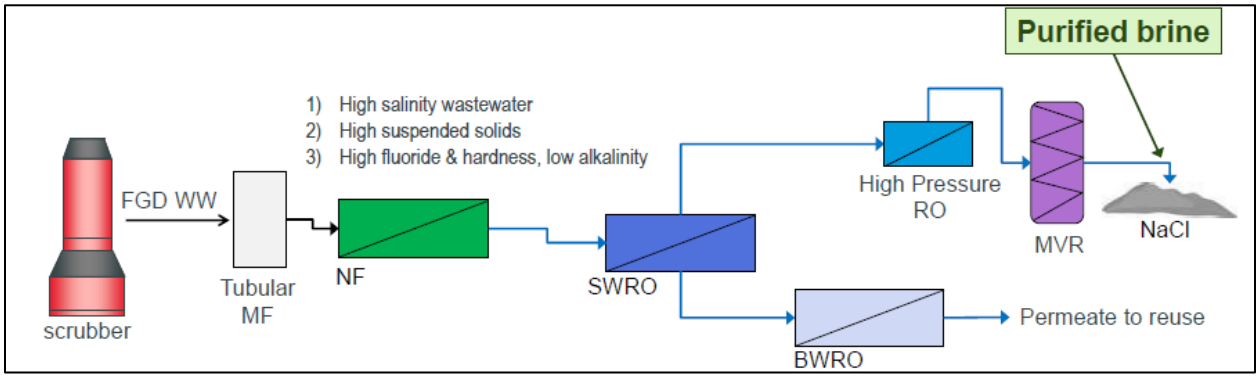


Figure 1. Hanchuan Power Plant FGD Wastewater Treatment System

2.3 Treatment of Landfill Leachate

Dupont noted experience treating leachate from municipal landfills in both Mexico and China. Treatment consists of membrane filtration. Permeate is typically discharged and reject is disposed of in the landfill. Dupont noted, in China, landfill leachate has strict requirements for chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), nitrogen, and color. Typical treatment needed to meet requirements include biological treatment (anaerobic or aerobic) then a membrane bioreactor (typically a tube configuration) followed by a combination of nanofiltration and reverse osmosis.

3. References

1. Dow Water and Process Solutions. 2017. DuPont Notes Appendix C: Case Studies & Analysis of Reverse Osmosis to Treat Flue Gas Desulfurization Wastewater. (November). IWC 17-74. DCN SE08618A3.
2. DuPont. 2020a. Notes from Meeting with DuPont Appendix A: DuPont Presentation to EPA. (15 April). SE08618A1.
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Appendix T – Ljungström Technology

1. Technology Description

The Ljungström AdvX®-ZLD Technology consists of three major components:

1. Spray dryer evaporator (SDE),
2. Sulfur trioxide (SO_3) control upstream of the air pre-heater, and
3. AdvX® Air preheater upgrade.

Ljungström markets the technology as a potential zero liquid discharge (ZLD) evaporation treatment alternative for the power generation industry. The technology routes a slipstream of flue gas around the boiler air preheater. The hot flue gas is used to evaporate wastewater. In the case of steam electric plants, flue gas desulfurization (FGD) wastewater or other wastestreams are sprayed into the evaporation vessel and mixed with the hot gas. Liquid is evaporated, generating a gas stream and a solid byproduct. The gas stream is reintroduced to the flue gas downstream of the air preheater, which allows entrained solids to be collected via an existing particulate control device, along with fly ash. Ljungström offers a proprietary AdvX® Air preheater upgrade. This upgrade recovers the heat rate loss associated with the flue gas bypass duct around the air preheater, thus reducing or eliminating the corresponding energy cost.

The Ljungström technology is not sensitive to water quality and does not require pretreatment of wastewater. Water quality (such as high chlorides) may require different materials of construction for wastewater holding tanks or piping. Wastewater does not come into contact with the evaporator vessel; therefore, wastewater characteristics do not impact those materials of construction.

There is a practical limit for the flow rate that can be evaporated in the flue gas using this type of technology. Wastewater can only be evaporated until the flue gas reaches saturation. The treatment flow rate threshold is plant specific based on flue gas saturation and/or acid dewpoint and flue gas temperature. The largest system Ljungström has quoted to date is 125 gallons per minute (gpm) per unit; however, it is concievable that AdvX®-ZLD can accommodate higher flow rates.

Operation and maintenance requirements for the Ljungström system include energy, instrument air, water, and spare parts. Power requirements are higher without the AdvX® upgrade to compensate for the higher heat rate loss. No chemicals are needed for the technology, and no additional labor is needed operation and maintenance of the system.

2. Technology Status and Performance

The Ljungström AdvX®-ZLD Technology is used to treat FGD wastewater internationally, at two power plants in Asia.

3. References

1. Ljungström. 2021. CBI Vendor Cost Data for Ljungström. (07 October). DCN SE10370.
2. US EPA. 2022. US Environmental Protection Agency. *Notes from Vendor Call with Ljungström on September 17, 2021*. (02 September). DCN SE10377.

Appendix U – Membrane Development Specialists (MDS) Technology

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1. Technology Description

Membrane Development Specialists (MDS) has been developing membrane technologies for industrial applications since 1980. Over the last several years, MDS has developed pilot systems and full-scale installations within various industries, including flue gas desulfurization (FGD) wastewater reuse, cooling tower blowdown, mine wastewater, and municipal landfill leachate.

A typical treatment train for treatment of FGD wastewater using an MDS system includes pretreatment to precipitate gypsum followed by ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), if needed. Permeate is recycled as scrubber make up water. Concentrate can be managed by an evaporation pond or small evaporators. The hollow fiber UF membranes remove bacteria and suspended solids but are less expensive over time than comparable sand filters. NF removes divalent cations and anions.

The NF portion of the system is considered the most vulnerable. Since this membrane is exposed to saturated sulfates, frequent replacement is required due to fouling from precipitates. However, quality pretreatment can extend the life of the membranes. MDS estimates that with pretreatment, on average, the lifespan of UF, NF, and RO membranes are less than 2 years, 3-5 years, and over 3 years, respectively. The membranes require a suite of pretreatment chemicals to remove fouling.

Typical system monitoring parameters include conductivity, oxidation reduction potential (ORP), pH, temperature, and pressure drop across the membranes. Monitoring for scale forming ions is also important as temperature and pH may impact their solubility.

MDS has partnered with Purestream to test management of membrane concentrate using evaporation. Since the cost of evaporators can drive the cost of overall treatment, plants can alternatively dispose of concentrate as a hazardous waste.

2. Technology Status and Performance

MDS is currently working with a coal-fired power plant in Pennsylvania to consider membranes as an option for treating FGD wastewater.

MDS has worked with European municipal landfills to treat landfill leachate, which can have high concentrations of biochemical oxygen demand (BOD) and TDS, to meet limits acceptable for surface discharge. Some of these landfills use small membrane bioreactors (MBR) following the MDS system to remove organics. Concentrate from these treatment systems is typically disposed of in a hazardous landfill.

MDS is also assisting with projects in Nevada and South America to capture and treat wastewater from mines.

The EPA met with MDS in support of the 2024 final rule to discuss their experience treating wastewaters with similar characteristics to FGD wastewater. The following topics were discussed:

- MDS's timeline to design, build, and commission a 100-gpm treatment system is approximately eight to 12 months.
- Their experience with acid mine drainage is analogous to FGD wastewater, as there is high TDS concentrations and low pH, but with higher concentrations of heavy metals.

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3. References

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Appendix V – Slurry Management Systems, LLC (SMS) Technology

1. Technology Description

The Slurry Management Systems, LLC (SMS) technology is a mobile dewatering system. Wastewater from a holding area (e.g., pit, pond, collection tank) is pumped through a filter press to generate a filter cake and filtrate. A shaker screen may be used as pretreatment to remove larger particles prior to the filter press. The shaker screen, feed pumps, controls, holding tank, and filter press are self-contained on a trailer, which can be hauled directly to any site. Automated plate shifters on the filter press allow solids to drop from the end of the trailer directly into a loader or truck. The capacity of a single mobile system is 100-150 gallons per minute (gpm).

The SMS technology is targeted for multiple industries, including concrete plants, oil and gas facilities, ash and flue gas desulfurization (FGD) ponds, mining, and construction.

SMS currently applies their dewatering technology at a wash sand plant where two temporary systems are used to handle wastewater while a site-specific SMS system is designed and installed.

2. References

1. ERG. 2022. Eastern Research Group, Inc. *Notes from Vendor Call with Slurry Management Systems, LLC on November 19, 2021.* (22 December). DCN SE10379.

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EXHIBIT 32

Georgia Power

Environmental Affairs
241 Ralph McGill Blvd, NE
Atlanta, Georgia 30308-3374

October 12, 2023
ELECTRONIC MAIL

Ms. Whitney Fenwick, Manager
Wastewater Regulatory Program
Georgia Environmental Protection Division
2 Martin Luther King, Jr. Drive S.W., Suite 1152
Atlanta, GA 30334

Re: NPDES Permit No. GA0035564 – Plant Scherer
2023 ELG Annual Progress Report

Dear Ms. Fenwick:

Georgia Power is providing this Annual Progress Report for Plant Scherer, consistent with 40 C.F.R. § 423.19 (f)(3) and the 2020 Steam Electric Effluent Limitations Guidelines. The attached Annual Progress Report provides the status for each generating unit and the associated high-level milestones.

If you need additional information or have questions regarding this matter, please contact Jean Brown at 404-506-6360.

Sincerely,

Dominic Weatherill
Environmental Affairs Supervisor

Cc: Sarita Banjade - EPD

Georgia Power

Plant Scherer – NPDES Permit No. GA0035564

ELG Progress Report – October 12, 2023

Summary

Georgia Power Company ("the Company") Plant Scherer remains on track to meet the Flue Gas Desulfurization Wastewater ("FGDW") compliance deadlines in the 2020 Effluent Limitations Guidelines ("ELG") Rule.

The Company's ELG compliance strategy for Plant Scherer continues to incorporate the Integrated Resource Planning ("IRP") process with the Georgia Public Service Commission ("PSC"), necessary coordination with Plant Scherer co-owners, while also acknowledging the continued regulatory uncertainty resulting from the U.S Environmental Protection Agency's ("EPA's") on-going rulemaking efforts.

This report summarizes progress at Plant Scherer in meeting the E*ffluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* for FGDW. The report describes early steps completed to meet the Voluntary Incentive Program ("VIP") effluent limits for FGDW provided in 40 C.F.R. § 423.13(g)(3)(i); and information regarding the subcategory for Permanent Cessation of Coal Combustion as provided in 40 C.F.R. § 423.13(g)(2)(i). The details provided herein conform with the annual reporting requirements in 40 C.F.R. § 423.19(f) and 40 C.F.R. § 423.19(h).

Units 3 and 4

On October 13, 2021, pursuant to 40 C.F.R. § 423.19(f) the Company submitted to EPD a Notice of Planned Participation ("NOPP") for Unit 3 and a separate NOPP for Unit 4 at Plant Scherer. The NOPP's informed EPD of the plan to permanently cease coal combustion for Units 3 and 4 by no later than December 31, 2028, and January 31, 2022, respectively, and notified EPD that these units are eligible for the alternative limits at 40 C.F.R. § 423.13(g)(2)(i).

For Unit 3, following the 2022 IRP, the PSC issued a Final Order approving the December 31, 2028, retirement. No updates to this plan have occurred.

For Unit 4, the Company previously notified EPD that Unit 4 was retired by Florida Power & Light on December 31, 2021.

However, and as previously noted, the electric generating status of Units 3 and 4 does not impact the overall FGDW compliance strategy at Plant Scherer as the FGDW system is a common environmental control for all four generating units.

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Plant Scherer – NPDES Permit No. GA0035564

ELG Progress Report – October 12, 2023

Units 1 and 2

On October 13, 2021, pursuant to 40 C.F.R. § 423.19(h) the Company submitted a NOPP for Units 1 and 2 informing EPD of the Company's plan to participate in the VIP, and notified EPD that these units are eligible for the alternative limits at 40 C.F.R. § 423.19(g)(3)(i). As required, the NOPP also included an engineering dependency chart ("schedule") that was subsequently updated and provided to EPD as part of the 2022 ELG Progress Report.

The Company continues to work with WesTech as the supporting engineering firm and has since further refined and updated the schedule as provided below. This schedule is subject to further revisions that will be disclosed in future annual progress reports.

The updated schedule reflects the current implementation of the ELG pilot study, which will further inform the technical capabilities for management of the membrane concentrate (brine). The updated schedule also illustrates an approximate 3–5-month extension in each of the major schedule components (engineering, procurement, construction, and commissioning). This revision is in response to delays in contract execution and terms, which is not uncommon for projects of this scale and complexity. The schedule still supports a June 2026 thru June 2027 commissioning period, which is well in advance of the statutory applicability date of 12/31/2028.

The Company continues in its pursuit of a leading-edge and full-scale membrane based FGDW treatment system, afforded by the unique FGDW conditions present at Plant Scherer.

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Plant Scherer – FGDW VIP Schedule

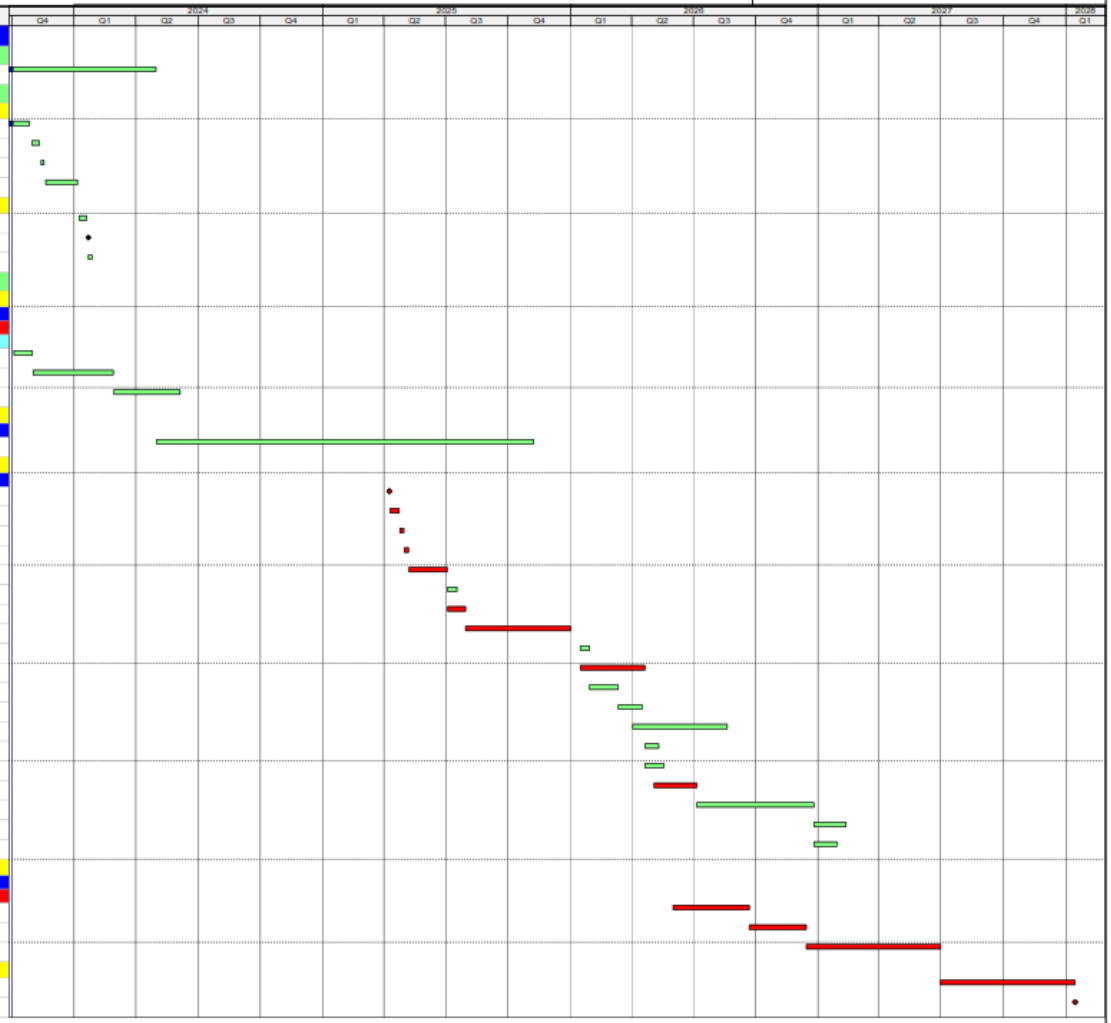
Project Filename: Scherer ELG Water Treatment

Project ID: SCH-ELG-WT

Scherer ELG Water Treatment
Scherer ELG WT - GPC EA

Page 1 of 1
Data Date: 02-Oct-2023
Run Date: 09-Oct-2023 09:28

Activity ID	Activity Name	Remaining Duration	Start	Finish	Expected Finish
Scherer ELG Water Treatment		1103	07-Mar-2023 A	14-Jan-2028	30-Apr-2024
FGDW Rule Modifications		147	07-Mar-2023 A	30-Apr-2024	30-Apr-2024
A1330	FGDW Rule Modification Prediction (Final)	147	07-Mar-2023 A	30-Apr-2024	30-Apr-2024
ELG Pilot Study		80	25-Sep-2023 A	26-Jan-2024	27-Oct-2023
Test Plan		65	25-Sep-2023 A	05-Jan-2024	27-Oct-2023
TP1020	Avara Brine Study	20	25-Sep-2023 A	27-Oct-2023	27-Oct-2023
TP1040	2 Weeks Continuous Avara Operation	10	30-Oct-2023	10-Nov-2023	
TP1050	Brine Production	5	13-Nov-2023	17-Nov-2023	
TP1060	Aged Brine Study	30	20-Nov-2023	05-Jan-2024	
Test Results and Final Reports		15	08-Jan-2024	26-Jan-2024	
TR2000	WesTech Develop & Evaluate Pilot Study Reports	10	08-Jan-2024	19-Jan-2024	
TR2010	WesTech Submit Pilot Study Reports to SCS	0	22-Jan-2024		
TR2020	SCS Review Pilot Study Reports	5	22-Jan-2024	26-Jan-2024	
ELG Water Treatment Project		1101	04-Oct-2023	14-Jan-2028	
Engineering		170	04-Oct-2023	04-Jun-2024	
Westech		170	04-Oct-2023	04-Jun-2024	
WesTech PO		170	04-Oct-2023	04-Jun-2024	
WesTech Engineering		170	04-Oct-2023	04-Jun-2024	
A1020	Scope Development - WesTech	20	04-Oct-2023	31-Oct-2023	
A1030	Project Definition - WesTech	80	01-Nov-2023	27-Feb-2024	
A1050	Detailed Design - WesTech	70	28-Feb-2024	04-Jun-2024	
Procurement		392	01-May-2024	07-Nov-2025	
WesTech Procurement		392	01-May-2024	07-Nov-2025	
A1110	Equipment Procurement	392	01-May-2024	07-Nov-2025	
CONSTRUCTION		475	09-Apr-2025	11-Feb-2027	
ELG Water Treatment System		475	09-Apr-2025	11-Feb-2027	
A1485	Mobilization Complete	0		09-Apr-2025	
A1140	Install Erosion Control Measures	10	10-Apr-2025	23-Apr-2025	
A1150	Install Site Grading	5	24-Apr-2025	30-Apr-2025	
A1170	Establish Laydown & Trailer Access	5	01-May-2025	07-May-2025	
A1160	Excavation for Foundations	41	08-May-2025	03-Jul-2025	
A1180	Install Underground Utilities	10	04-Jul-2025	17-Jul-2025	
A1190	Install Grounding	19	04-Jul-2025	30-Jul-2025	
A1200	Form/Set Rebar/Place Concrete	105	30-Jul-2025	01-Jan-2026	
A1210	Backfill and Final Grade	10	15-Jan-2026	29-Jan-2026	
A1240	Erect PEMB & OH Gantry Crane System	67	15-Jan-2026	20-Apr-2026	
A1220	Concrete Floor & Curb Coating - Chemcial Area & Equipment Pads	30	29-Jan-2026	12-Mar-2026	
A1280	Install Electrical Equipment	25	12-Mar-2026	16-Apr-2026	
A1290	Install Raceways, Wiring, & Misc Systems	100	02-Apr-2026	20-Aug-2026	
A1250	Install Asphalt Roadway & Paved Areas	15	20-Apr-2026	11-May-2026	
A1260	Interior Offices and Finishes	20	20-Apr-2026	18-May-2026	
A1270	Set Process Equipment	45	04-May-2026	06-Jul-2026	
A1300	Install Interconnecting Piping	124	06-Jul-2026	25-Dec-2026	
A1230	Concrete Floor & Curb Coating - Final Coat Balance of Plant Area	34	25-Dec-2026	11-Feb-2027	
A1310	Test Piping	24	25-Dec-2026	28-Jan-2027	
Startup & Commissioning		282	01-Jun-2026	30-Jun-2027	
ELG Water Treatment System including BOP		282	01-Jun-2026	30-Jun-2027	
ELG Water Treatment System including BOP Commissioning		282	01-Jun-2026	30-Jun-2027	
A1440	Functional Testing	80	01-Jun-2026	21-Sep-2026	
A1450	System Testing	60	21-Sep-2026	14-Dec-2026	
A1460	Operational Testing	142	14-Dec-2026	30-Jun-2027	
Project Closeout		142	30-Jun-2027	14-Jan-2028	
A1480	Project Closeout	142	30-Jun-2027	14-Jan-2028	
A1470	ELG Water Treatment Project Complete	0		14-Jan-2028	



Remaining LOE
Actual LOE
Actual Work
Remaining Work
Critical Remaining Work
Milestone
Critical Milestone

Scherer ELG WT - GPC EA

Southern Company

EXHIBIT 33

Santee Cooper - Cross Generating Station

Notice of Planned Participation - Annual Report of Progress

(40 CFR Part 423 Section 19, Paragraph (h)(3) and (h)(4))

Date Submitted: October 10, 2023

Prepared by: Lauren B. Fennell, P.E.



Santee Cooper's Cross Generating Station (Cross) is a four-unit, coal-fired electric generating station located in Pineville, South Carolina. Cross is subject to EPA's Effluent Limit Guidelines (ELGs) under 40 CFR 423: Steam Electric Power Generating Point Source. Revised ELGs under the Steam Electric Reconsideration Rule were published on October 13, 2020 and included new requirements for flue gas desulfurization (FGD) wastewater (WW) discharges. Santee Cooper submitted a Notice of Planned Participation (NOPP) for Cross on a contingent basis, on October 13, 2021 to SCDHEC Water Facility Permitting Division, noting the potential for Cross to establish effluent discharge limitations set by the Voluntary Incentives Program (VIP) under 40 CFR Part 423 Section 13 Paragraph g3i.

The purpose of this document is to provide a progress report to DHEC regarding Cross's contingent election to comply with the voluntary incentive plan (VIP) requirements for FGD wastewater treatment required by 40 CFR Part 423 Section 19, Paragraph h3 and h4.

> *40 CFR Part 423.19.h(3) Annual progress report. After submission of the Notice of Planned Participation in paragraph (h)(1), a progress report shall be filed with the permitting authority, or control authority in the case of an indirect discharger.*
>
> *40 CFR Part 423.19.h (4) Contents. An Annual Progress Report shall detail the completion of interim milestones presented in the engineering dependency chart from the Notice of Planned Participation since the previous progress report, provide a narrative discussion of completed, missed, or delayed milestones, and provide updated milestones.*

Membrane Treatment (VIP) Milestone Progress

The October 2021 NOPP was submitted to retain the VIP alternative as an option while biological treatment systems pilots for BAT continued, and additional data and cost were evaluated. Since submission of the October 2022 NOPP annual update, Santee Cooper completed evaluation of both VIP and BAT options. A summary of each alternative evaluated and the ranking methodology was included in the Preliminary Engineering Report submitted to DHEC on March 12, 2023 and approved on May 5, 2023 under LOA-006636. Ultimately, Santee Cooper elected to proceed with EPA's BAT of physical-chemical and biological treatment with Ultrafiltration based on the ranking methodology presented in the March 2023 PER. Though Santee Cooper retains the VIP alternative given the regulatory uncertainty.

Biological Treatment (BAT) Status

Santee Cooper also provided SCDHEC with a proposed schedule for compliance with the 2020 ELG Rule generally applicable limitations for Cross Generating Station on March 2, 2021. Since the October 2022 Annual NOPP Report, pilot study results and multiple alternative technologies were evaluated to address the ELG requirements and identify the recommended treatment approach. Santee Cooper selected EPA's BAT of Physical-Chemical and Biological Treatment with Ultrafiltration based on the ranking methodology presented in the March 2023 PER. As of the date of this report, Santee Cooper has selected a technology provider of the treatment solution and a majority of the engineering design has

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been completed. A Final Engineering Report and application for Wastewater Treatment Construction was submitted to DHEC Bureau of Water (BOW) on September 7, 2023, with construction planned to begin January 2024.

Projected Milestone Delays

Announcement and delay of the proposed ELG revised rule along with finalization of the Cross NPDES permit delayed final decisions regarding the technology path to proceed with. On November 19, 2021, Santee Cooper requested that DHEC include provisions similar to Plant Bowen in Georgia, allowing BAT and VIP in the Cross NPDES permit. The regulatory uncertainty delayed both the BAT and VIP option schedules, as strategic decisions on current technology proposals were placed on hold until the fall of 2022 in expectation that a draft ELG Revised Rule might provide additional certainty.

In the absence of a draft ELG Rule – and in recognition that a final rule may look very different from early agency drafts - Santee Cooper made the decision to proceed with the generally applicable BAT standard treatment approach from the 2020 ELG Rule. As the 2020 ELG rule is the only rule in force and as EPA has indicated that utilities should continue to follow it, Santee Cooper selected EPA's BAT of physical-chemical and biological treatment with Ultrafiltration based on the ranking methodology presented in the March 2023 PER (LOA-006636). The draft ELG Revised Rule was published in the Federal Register March 29, 2023.

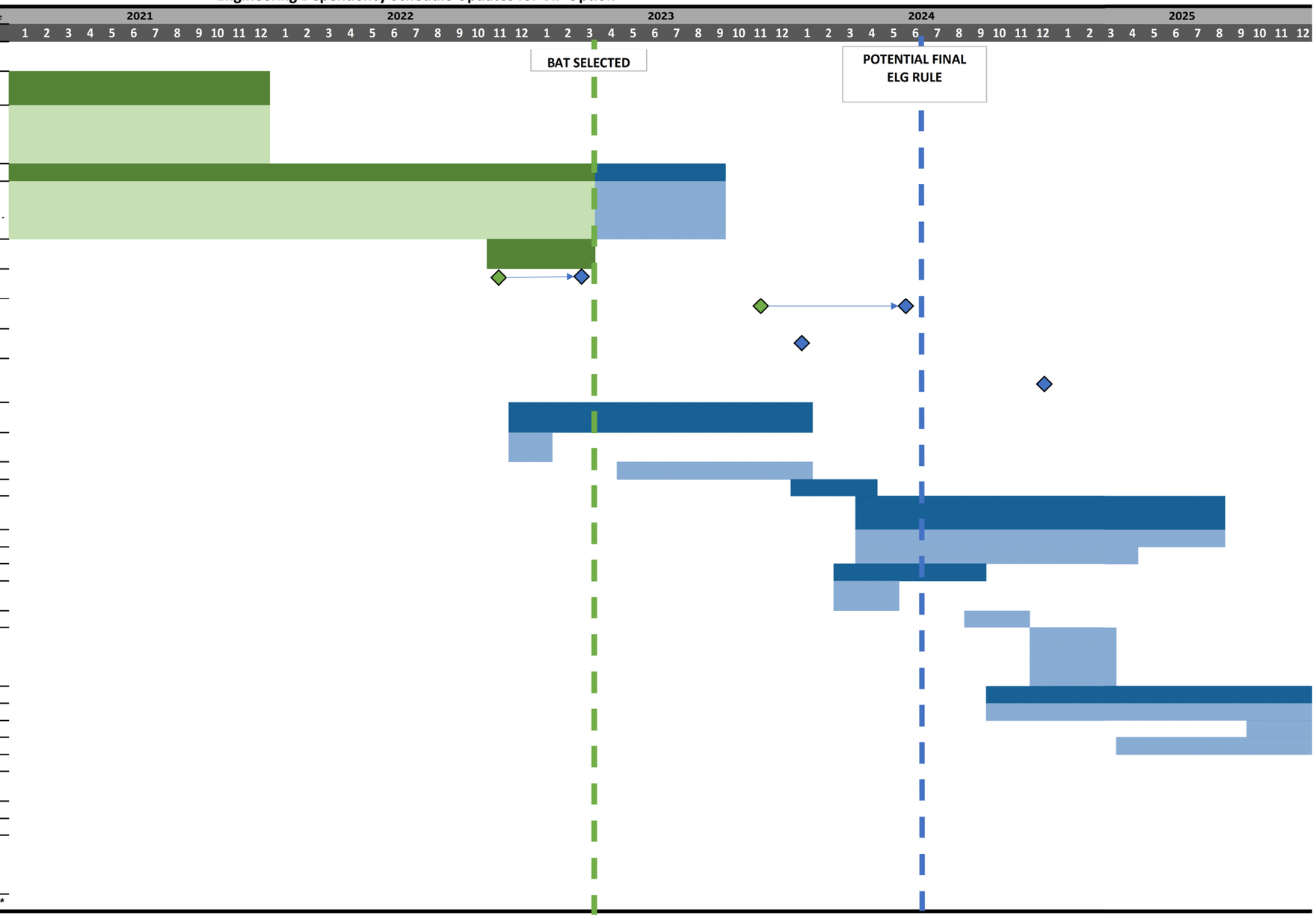
Waiting on a final rule is not an option in this case, because EPA has not granted enough time for this. In other words, we cannot be sure EPA won't revert to the 2020 rule anyway, so waiting to get started constructing the new treatment system would make complying with the 2020 rule impossible, since EPA has not chosen to stay it or delay compliance dates while they write a new rule. At this time it seems unlikely that EPA will have a final rule before summer of 2024.

Santee Cooper also worked with DHEC Bureau of Water (BOW) to add language to the Cross NPDES permit providing an option to transfer to comply with the VIP option. The current draft NPDES permit for Cross Station requires Santee Cooper to notify DHEC BOW by December 31, 2024 if the facility will implement the generally applicable effluent guidelines (BAT) or chose to activate the NOPP to implement the voluntary incentives program (VIP).

The preliminary milestones and engineering dependency chart previously provided in October of 2021 for compliance with VIP limitations has been further expanded and updated based on the information provided above and included in Attachment 1. Activity has not proceeded with the VIP option as indicated by the green vertical line in the Schedule Summary (Attachment 1); should EPA require a transition in technology, significant schedule delays would result from shifting project paths to comply with the VIP subcategory or any possible new similar zero discharge category.

Engineering Dependency Schedule Updates for VIP Option

	Task Name	2022 Baseline*		2023 Update
	Santee Cooper Cross Station FGD VIP Engineering Dependency Chart			
Define Phase	**FGD WW Treatment Project Initiation**			
	Engineering contractor selected, project kickoff, compliance strategy, FGD characterization, develop FGD water balance			***Complete***
	FGD WW Pilot Testing	1/1/2021	9/28/2023	***TBD***
	Provide FGD characterization data, develop specifications, provide bulk volumes for bench testing w/ vendors, obtain pilot approval, conduct pilots	1/1/2021	9/28/2023	***Not complete - TBD***
	BAT and VIP Bid Evaluations and Alternative Analysis			***3/30/2023***
	EPA Steam Effluent ELG Rule Draft Release		11/1/2022	***3/29/2023***
	EPA Steam Effluent ELG Final Rule Expected		11/1/2023	***6/1/2024***
	Cross NPDES Permit Final - Date Needed to Proceed		10/1/2024	***1/1/2024***
	Accept BAT Limits or Activate NOPP (VIP) - Per Cross Draft NPDES - Schedule of Compliance			***12/31/2024***
	Finalize FGD WW Treatment Specifications	11/1/2022	1/24/2024	***TBD***
	Finalize Engineering Procurement Construction Contract	10/31/2022	11/29/2022	***TBD***
	Preliminary Engineering - Fixation	5/23/2023	1/24/2024	***TBD***
	Obtain Funding	1/26/2024	4/19/2024	***TBD***
Execution Phase	**Complete Detailed Engineering Design**	4/22/2024	10/20/2025	***TBD***
	VIP Engineering	4/22/2024	10/20/2025	***TBD***
	Fixation Engineering	4/22/2024	4/22/2025	***TBD***
	Permitting	3/1/2024	4/1/2025	***TBD***
	Preliminary Engineering Report (PER) for Wastewater Construction Permitting	3/1/2024	5/30/2024	***TBD***
	Permit Application Preparation	9/1/2024	12/30/2024	***TBD***
	Submit Request/Obtain Approval to Construct from DHEC (some parallel activities with detailed design); obtain permits	12/1/2024	4/1/2025	***TBD***
	Construction	10/10/2024	4/28/2027	***TBD***
	Procurement & Delivery Equipment	10/10/2024	5/13/2026	***TBD***
	VIP Construction	10/21/2025	4/28/2027	***TBD***
	Fixation Construction	4/23/2025	6/18/2026	***TBD***
	Commissioning	6/19/2026	4/25/2028	***TBD***
	Membrane system testing & commissioning	4/29/2027	4/25/2028	***TBD***
	Fixaxtion Testing & Commissioning	6/19/2026	9/25/2026	***TBD***
	Approval to Operate - Discharge (DHEC)			***TBD***
	Develop bring solidification formula (if selected), finalize thermal evaporative system tie ins, overall system commissioning			***TBD***
	ELG Applicability Date		12/31/2028	***12/31/2029****



*Baseline updated with 2022 Report on 10/10/2022

** 2023 EPA Draft ELG Rule noted 12/31/2029 Compliance Date

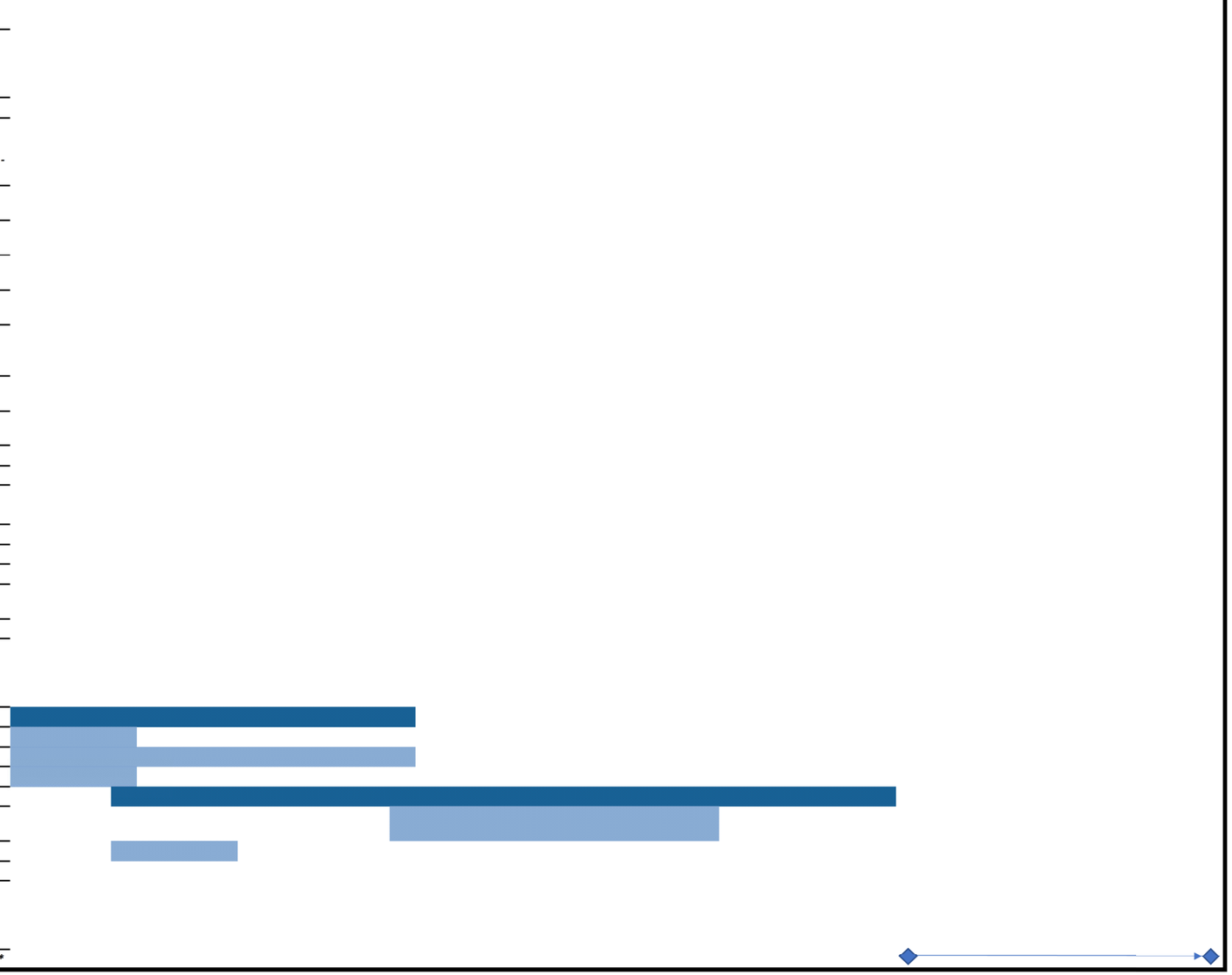
KEY:

Completed

To Be Determined - Not Complete

Engineering Dependency Schedule Updates for VIP Option

		2022 Baseline*		2023 Update
	Task Name			
	Santee Cooper Cross Station FGD VIP Engineering Dependency Chart			
Define Phase	**FGD WW Treatment Project Initiation**			
	Engineering contractor selected, project kickoff, compliance strategy, FGD characterization, develop FGD water balance			***Complete***
	FGD WW Pilot Testing	1/1/2021	9/28/2023	***TBD***
	Provide FGD characterization data, develop specifications, provide bulk volumes for bench testing w/ vendors, obtain pilot approval, conduct pilots	1/1/2021	9/28/2023	***Not complete - TBD***
	BAT and VIP Bid Evaluations and Alternative Analysis			***3/30/2023***
	EPA Steam Effluent ELG Rule Draft Release		11/1/2022	***3/29/2023***
	EPA Steam Effluent ELG Final Rule Expected		11/1/2023	***6/1/2024***
	Cross NPDES Permit Final - Date Needed to Proceed		10/1/2024	***1/1/2024***
	Accept BAT Limits or Activate NOPP (VIP) - Per Cross Draft NPDES - Schedule of Compliance			***12/31/2024***
	Finalize FGD WW Treatment Specifications	11/1/2022	1/24/2024	***TBD***
	Finalize Engineering Procurement Construction Contract	10/31/2022	11/29/2022	***TBD***
	Preliminary Engineering - Fixation	5/23/2023	1/24/2024	***TBD***
	Obtain Funding	1/26/2024	4/19/2024	***TBD***
Execution Phase	**Complete Detailed Engineering Design**	4/22/2024	10/20/2025	***TBD***
	VIP Engineering	4/22/2024	10/20/2025	***TBD***
	Fixation Engineering	4/22/2024	4/22/2025	***TBD***
	Permitting	3/1/2024	4/1/2025	***TBD***
	Preliminary Engineering Report (PER) for Wastewater Construction Permitting	3/1/2024	5/30/2024	***TBD***
	Permit Application Preparation	9/1/2024	12/30/2024	***TBD***
	Submit Request/Obtain Approval to Construct from DHEC (some parallel activities with detailed design); obtain permits	12/1/2024	4/1/2025	***TBD***
	Construction	10/10/2024	4/28/2027	***TBD***
	Procurement & Delivery Equipment	10/10/2024	5/13/2026	***TBD***
	VIP Construction	10/21/2025	4/28/2027	***TBD***
	Fixation Construction	4/23/2025	6/18/2026	***TBD***
	Commissioning	6/19/2026	4/25/2028	***TBD***
	Membrane system testing & commissioning	4/29/2027	4/25/2028	***TBD***
	Fixaxtion Testing & Commissioning	6/19/2026	9/25/2026	***TBD***
	Approval to Operate - Discharge (DHEC)			***TBD***
	Develop bring solidification formula (if selected), finalize thermal evaporative system tie ins, overall system commissioning			***TBD***
	ELG Applicability Date		12/31/2028	***12/31/2029****



*Baseline updated with 2022 Report on 10/10/2022
** 2023 EPA Draft ELG Rule noted 12/31/2029 Compliance Date

KEY:

Completed

To Be Determined - Not Complete

EXHIBIT 34

May 30, 2023

Submitted via www.regulations.gov

U.S. Environmental Protection Agency
EPA Docket Center
Docket ID No. EPA-HQ-OW-2009-0819
1200 Pennsylvania Avenue N.W.
Washington, D.C. 20460

Re: Santee Cooper Comments on the Proposed Rule to Revise the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Source Category
Docket ID No. EPA-HQ-OW-2009-0819

Dear Sir or Madam:

The South Carolina Public Service Authority, also known as Santee Cooper, respectfully submits the following comments on the proposed rule that the Environmental Protection Agency (EPA or Agency) issued to revise the current Effluent Limitations Guidelines (ELGs) for the steam electric power generating source category.[1]

The mission of Santee Cooper is to be the state's leading resource for improving the quality of life for the people of South Carolina. Santee Cooper is South Carolina's state-owned, public-power provider and source of electricity for approximately 2 million people in all 46 counties of South Carolina. Santee Cooper serves more than 193,000 residential and commercial customers directly in Berkeley, Georgetown, and Horry counties. It also supplies electricity to the state's 20 electric cooperatives, the cities of Bamberg and Georgetown, and 27 large industrial customers. Santee Cooper was the 5th largest public power utility in the United States, by generation (specifically, net generation in megawatt-hours) in 2018. Santee Cooper also provides wholesale water to more than 200,000 people throughout South Carolina.

[1] 88 Fed. Reg. 18,824 (Mar. 29, 2023), or "Proposed ELG Rule."

Summary

The proposed rule is the third time that EPA has sought to revise the ELG regulations applicable to coal-fired steam electric generating units in recent years. Previously the Agency has issued rules to update and tighten the ELG regulations in 2015[3] and then again to revise those regulations slightly in 2020.[4] With this proposal, EPA has initiated for a third time within an eight-year period a rulemaking to revise the applicable effluent discharge limitations and other requirements applicable to affected steam electric generating units. Among other things, the proposed rule seeks to significantly tighten the stringency of the effluent discharge limitations for flue gas desulfurization wastewater (FGD WW) and bottom ash transport water (BATW).

Santee Cooper believes that major revisions to the 2015 Rule and 2020 Reconsideration Rule are generally not needed, and will significantly increase customer costs without achieving a commensurate improvement to the environment and water quality. However, if the proposed changes to the rule are made, consideration should be given to those electric utilities that have spent considerable money and resources to comply with the prior rules and are on track to have treatment systems online by the applicable compliance date or dates set in the 2020 rule. Santee Cooper, like many other public-power utilities, has already expended substantial resources that are necessary for designing and procuring the capital investments required to comply with the existing rules. Santee Cooper's current plans to comply with the 2020 ELGs for FGD WW are to construct biological treatment systems which comply with the 2020 rule's standards based on best available technology economically achievable (BAT) at the Cross and Winyah Generating Stations. The Agency's proposed revisions to greatly increase the stringency of the current effluent limitations for controlling FGD WW, while compliance efforts are underway – and indeed are required by the Agency – will lead to abandoned equipment and wasteful expense of capital.

If, however, EPA elects to move forward with the current pending ELG rulemaking, Santee Cooper offers the following suggestions that the Agency should consider taking to ensure that a revised Final Rule is technically attainable and economically feasible.

- Santee Cooper supports the compliance options and subcategorizations provided under the 2020 rule to accommodate different situations for FGD wastewater treatment and requests that rule revisions made by EPA do not remove the current compliance options before the payback period of capital investments nor removal of the compliance option for the cessation of coal combustion.

[3] 80 Fed. Reg. 67,838 (November 3, 2015) or "2015 Rule."
[4] 85 Fed. Reg. 64,650 (October 13, 2020) or "2020 Reconsideration Rule."

Appellate Case: 24-2123 Page: 3 Date Filed: 09/04/2024 Entry ID: 5432163

- Santee Cooper is concerned about key elements of the 2023 proposed rule, including the early adopter subcategory and the requirement of zero discharge for FGD wastewater for the newly proposed BAT.
- Santee Cooper requests that EPA reconsider its evaluation of the economic impact to customers, including accurate system costs and the increased costs due to abandoned equipment and wasteful expense of capital.
- Santee Cooper requests consideration be given for handling both combustion residual leachate and legacy wastewater as low volume waste subject to state water quality standards, owing to the short-term nature of these waste streams' discharge.
- The stringent "Voluntary Incentive Program" (VIP) discharge limitations for FGD wastewater adopted by the Agency in the final 2020 ELG rule should remain a valid compliance pathway for affected power plants under the proposed rule given that—
    - the VIP limitations were set based on the same state-of-the-art BAT controls (*i.e.*, chemical precipitation plus membrane filtration) that the Agency is now proposing to use in setting new generally applicable requirements that would prohibit the discharge of any FGD wastewater by December 31, 2029; and
    - the proposed rule has not indicated – either explicitly or implicitly – an intent to repeal, revise, or otherwise change the VIP discharge limitations adopted in the ELG rule.
- The "transfer" provisions that EPA established in the 2020 ELG rule and which are now codified at 40 C.F.R. §423.13(o) should remain in effect and, therefore, continue to allow owners or operators of affected power plants to switch between available compliance options for which they have filed a timely "notice of planned participation" with their permitting authority, in the event they choose to make a future election to automatically transfer between applicable effluent discharge limitations through their NPDES permits.
- Santee Cooper requests consideration be given for the need for Clean Water Act rule stability and consistency, and adequate time for response from the regulated community.
- Santee Cooper requests adequate consideration for grid stability and comprehensive environmental impacts of fuel switching, and cumulative costs to consumers.
- Given the short 60-day comment period, we are only able to address a few of EPA's 120 or more unique requests for comment in detail, as EPA has requested. Attachment 1 contains brief comments on the entire set of unique requests, and Attachment 2 contains a non-exhaustive list of probable errors we noticed while preparing these targeted comments.

Santee Cooper endorses the UWAG, USWAG, EPRI, and APPA comments for all issues we are unable to address in detail herein.

Santee Cooper's Areas of Concern

1. **EPA's apparent understanding that coal-fired generation is not cost-competitive[7] is currently incorrect, at least in our case.**

This misunderstanding endangers those who depend upon us for electricity to serve vital human necessities. Even given costly and dramatic environmental improvements over the last fifteen years, coal remains cost competitive. Santee Cooper's 2023 Integrated Resource Plan (IRP), filed with the Public Service Commission of South Carolina on May 15, 2023, demonstrates that in the current environment, maintaining an existing low-cost coal plant (Cross Generating Station) within our fleet is the most economical option available to us. As part of IRP preparation, a sensitivity analysis involving retirement of this facility in 2029, 2034, and 2039 was compared with an economically-optimized scenario. This exercise determined that maintaining Cross as an available, existing resource under the current regulatory regime and with current cost and load assumptions would likely cost more than $1 billion less over the 2023-2052 study period versus any scenario involving retirement (Table 1), because of the avoided costs which would be associated with replacing the assets at Cross. In fact, in reviewing the three years studied for retirement (through 2039), the longer retirement was delayed, the more cost effective our portfolio became.[8]

Table 1. Cross Retirement Timing Sensitivity Analysis.

Portfolio	Reference Case ($B)
Economically Optimized – Cross Not Retired	$23.5
Cross Retirement – 2029	$25.9
Cross Retirement – 2034	$25.3
Cross Retirement – 2039	$24.7

2. **Santee Cooper is concerned that 2020 subcategories be maintained, that costs for FGD zero liquid discharge (ZLD) systems be correctly estimated, and that the cessation of coal combustion (2020 rule) and early adopter (2023 proposal) subcategories be adjusted to avoid waste of financial resources as stranded capital investments.**

[7] 88 Fed. Reg. 118826 (Mar. 29, 2023)
[8] Santee Cooper (May 15, 2023). *2023 Integrated Resource Plan*. https://www.santeecooper.com/About/Integrated-Resource-Plan/Reports-and-Materials/Santee-Cooper-2023-Integrated-Resource-Plan_Final-Rev_01.pdf, accessed May 16, 2023.

a. EPA's Cost Estimates and Pollutant Removal Estimates for the 2023 proposal's FGD Wastewater BAT are Inaccurate and Do Not Provide Technical Grounds for Setting a Zero-Liquid Discharge Limitation (ZLD) for FGD WW.

As part of its efforts to comply with the 2020 rule, Santee Cooper bid out both biological treatment (2020 BAT) and zero liquid discharge systems (2023 proposed BAT), competitively against one another. Santee Cooper is currently following through on plans to construct 900 gpm physical-chemical and biological treatment systems for FGD wastewater at its Cross and Winyah generating stations in compliance with the 2020 rule. After a competitively bid process, the final estimate of $138 million in terms of initial capital expense at each plant far outpaces our initial budget estimates of $45 and then $100 million, not to mention the unrealistically low pricing estimates that EPA used in 2020 and 2023 ELG rulemakings, and which we provided as a handout in our discussion with the Office of Management and Budget on February 16, 2023. Given EPA's announcement of its intent to rewrite the rule while leaving the 2020 rule in place and resulting uncertainty, Santee Cooper also bid out a zero-discharge membrane system with spray dryers. We received only one bid in response to multiple vendor solicitations. That detailed bid response indicates that the costs of this treatment system would be $298 million in initial capital costs at both facilities, along with an ongoing excess power cost of more than $4 million per year and an additional $1 million per year in landfill costs. Assuming financing at a rate of 5% over 20 years, and not adjusting for inflation, total customer costs are included in Table 2 below for a single facility. In our case, this would likely be doubled given our plans for an identical installation at the Winyah Generating Station.

Table 2. Total Per-Facility Costs to Customers for Biological and Zero Liquid Discharge FGD Wastewater Treatment Systems Based on Competitive Bidding.

	Estimated Capital Cost Per Facility†	Estimated Annual O&M Cost Per Facility†	Annual Cost Per Facility	Total Cost Per Facility
Biological	$138,300,000	$5,199,021	$18,107,301	$362,146,020
ZLD/Membrane	$298,000,000	$10,500,000	$38,235,879	$764,717,580

† Anonymized, round figures based on competitive bidding.

These high costs point to major flaws and deficiencies in the methodology that EPA used in calculating costs, and they underscore our concern that vendors may provide overly-optimistic estimates of costs to the agency that are not reflective of what they are likely to bid. Unfortunately, EPA in recent years has often dramatically underestimated such costs. As an example, we note that EPA's April 2013

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summary of incremental costs[9] - while not providing unit-level cost estimates in the public docket – did provide summed industry-wide costs of implementation in Table 11-3. The capital costs for regulatory option 4, the option most like the final rule, was estimated to cost $8,011,000,000 across 277 plants, for an average cost of $28,920,578. Actual costs for only conversion to dry bottom ash handling at our Cross facility, for dry bottom ash and fly ash handling conversions at our Winyah facility, and for various improvements in preparation for an FGD wastewater treatment system at both facilities came to $352,109,532 and $231,506,580, respectively. As to the current proposed rule, we will discuss EPA's estimates of rate impact in a later section on customer impacts, so here (Table 3) we will merely present a comparison of the bid costs we developed for biological treatment and EPA's estimate from the 2020 rule, along with the bid costs for ZLD and EPA's estimate from the 2023 proposal.

Table 3. Total Per-Facility Cost Estimates from Santee Cooper (2022) and EPA (2020 and 2023).

	Santee Cooper Estimate (2022)	EPA Estimate (2020) Cross Generating Station†	EPA Estimate (2023) Cross Generating Station‡
Biological Capital	$138,300,000	$5,971,518	-
Biological O&M	$5,199,021	$448,708	-
ZLD/Membrane Capital	$298,000,000	$14,579,112	$41,837,107
ZLD/Membrane O&M	$10,500,000	$1,415,785	$3,243,908

† Technical development document (TDD) costs here are the sum of the unit costs for regulatory options A (Table 4) and C (Table 6) for Cross Generating Station as provided by ERG in their August 31, 2020 memo in support of the 2020 rulemaking.
‡ *Generating Unit Level Costs and Loadings Estimates for 2023 Rule*, US E.P.A. memo of February 28, 2023, from Table 4. We presume an error in Table 4, that costs for the four Cross units are shifted up one row; otherwise the costs shown for Cross Unit 4 are zero, which is obviously incorrect. We have also summed EPA's estimate of capital and one-time costs as capital costs here. Additionally, we note that this document indicates that most coal facilities use bromide additives. That is no longer true, so EPA has dramatically underestimated costs while overestimating benefits.

Table 3 demonstrates that EPA has dramatically underestimated costs of the ZLD option for the 2023 rule, just as it did for biological treatment in the 2020 rule. We note that the figures for the Santee Cooper estimate include up to $100 million for physical-chemical pretreatment, which EPA would treat as a baseline cost. Nonetheless, even deducting this amount per facility would indicate that EPA's estimate is only about 20% of an estimate based on competitive bidding. When the Agency's overestimate of pollutant removal is considered (based on the misunderstanding that bromide additives are still in use), it is clear that the Agency's figures must lead to dramatic underestimates of the cost per pound of pollutant removal. Elsewhere the Agency indicated that membrane treatment systems would also be effective at removing PFAS chemicals. However, the only significant source of PFAS at steam

[9] U.S. EPA. *Incremental Costs and Pollutant Removals for the Proposed Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*, April 2013. EPA-HQ-OW-2009-0819-2256.

electric facilities is likely to be the intake water which is used within the plant and then discharged, cycled up in closed-cycle cooling systems by a factor of three or more, as required by federal regulation. The FGD system is a relatively small waste stream compared to other sources and is not a source of PFAS chemicals. EPA has acknowledged this in two places of which we are aware. First, the lack of power plant contribution was noted in the Agency's December 2022 guidance document which did not include electric utilities as an industrial category likely to discharge PFAS.[10] Secondly, the ELG proposal itself correctly notes that "the steam electric power sector was not identified as one of the top PFAS dischargers" while stating that "PFAS may nevertheless be present in steam electric discharges" citing use of firefighting foam in particular[11] – Santee Cooper does not use PFAS-containing firefighting foam. Finally, FGD system blowdown is already a relatively small percentage of total power plant discharge, so PFAS removal from this waste stream is unlikely to be significant. Collectively, this indicates that regulation of PFAS from power plants is best left to the states that can use standard reasonable potential calculations and, in so doing, account for the background level of PFAS in intake water.

Santee Cooper is very confident in its cost estimates, which are based on N+1 redundancy and a competitively-bid process. While we note that EPA did not incorporate spray dryers in its estimate, spray dryers or crystallizers will be necessary for those electric utilities who may need to install membrane treatment systems outside of arid regions in order to facilitate the management of brine.

Brine is the concentrated liquid leftover when the wastewater passes through the filtering membrane. In the case of Santee Cooper, spray dryers or crystallizers are essential components of an effective membrane treatment system because brine encapsulation is not a viable option. This is due to the fact that most coal-fired power plants currently do not generate enough coal ash to fixate the brine leftover from the filtration process. In addition, sufficient quantities of coal ash cannot be bought or otherwise secured to fixate the brine from other electric utilities because of the closure and reduced utilization of other coal plants. As the handout we provided at our OMB meeting on February 23, 2023 indicates (Attachment 3), without spray dryers, Cross Generating Station would require 170 tons per hour of fly ash in order to fixate the brine stream. Neither the station nor surrounding stations would be able to meet this requirement given existing contracts with cement manufacturers. Even if this amount of fly ash could be physically delivered to the station, the costs would be astronomical. We estimate this scenario would cost over $146 million annually for brine fixation alone, which includes more than $36 million in landfill costs. In the case of spray dryer use, some amount of ash will still be necessary. We estimate

[10] Fox, Radhika, Memo *Addressing PFAS Discharges in NPDES Permits and Through the Pretreatment Program and Monitoring Programs.* https://www.epa.gov/system/files/documents/2022-12/NPDES_PFAS_State%20Memo_December_2022.pdf, accessed May 13, 2023.
[11] 88 Fed. Reg. 118892 (Mar. 29, 2023)

31,000 tons per year will be required, which at an average cost of $8.50 per ton, will impose additional costs of additional $263,328 annually. This will then cost more than $2 million annually in landfill disposal costs. These costs, of course, would roughly double providing an identical installation at Winyah. An additional section concerning impacts to the beneficial use market – beyond Santee Cooper's direct costs – follows.[12]

A major cost of the membrane treatment process is related to increased operational costs associated with loss of productivity from the units associated with reducing the volume of brine. This sums to about $4.3 million per year in lost revenue due to parasitic power consumption and lost heat rate, which does not seem to have been adequately captured in cost estimates generated by EPA in support of the 2020 rule. Further, this loss of marketable power represents an additional hurdle against reliability for an electric power industry already struggling with the transition to renewable sources of energy. Without the evaporator technology, brine fixation would cost an additional $19.2-$146 million annually depending on water quality and required flow rates.

b. Santee Cooper's Bidding Process Raises Major Questions Regarding the Achievability of EPA's Proposed Limits (2020 BAT) and the Availability of ZLD Treatment (2023 Proposed BAT) for FGD WW.

Like other electric utilities, Santee Cooper requires a performance guarantee from vendors in order to award a bid. Our competitive bidding process yielded just three biological bids. Of these, one vendor bid was incomplete and another bid did not guarantee a fixed cost while continuously adding new influent constraints. The third vendor initially refused to provide a performance guarantee but later provided a sliding-scale guarantee. We understand that our FGD WW has higher chlorides and more-reduced forms of the limited metals than EPA assumed, related to our MATS compliance strategy of oxidation-reduction potential (ORP) control. This complicated our ability to obtain performance guarantees from biological treatment vendors. For our facility, an additional oxidation step will likely be required, increasing costs in order to comply with the 2020 rule limits. Each of the bids received for biological treatment included this additional oxidation step.

Santee Cooper received a single bid for membrane treatment with spray dryers. No compliant bids were received that involved crystallizers. The high costs of ZLD, coupled with the lack of interested vendors, indicates that this treatment system may not be as available domestically as EPA supposes. Our

[12] U.S. EPA. Memo, *2023 Steam Electric Supplemental Proposed Rule: Fly Ash Availability – DCN SE10242*, February 27. 2023. It is unclear how EPA arrived at its estimates of required fly ash, but we note it differs from EPRI's estimates and likely from ours. Further, EPA admits that its estimates are solely based on information from vendors.

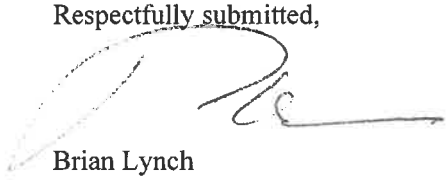
unusual step of failing to provide a 90-day comment period, opening the agency to the charge of filibustering the regulated community. To address this concern, we request that EPA remain open to receiving comments after the public comment period closes as new information emerges. Santee Cooper is committed to an open dialogue and to working collaboratively with the agency at its convenience.

Finally, we are concerned with whether final rule provisions can be written based on requests for comment which appear only in the preamble. For instance, EPA does not establish new requirements for bottom ash contact water in the text of the rule, but in the preamble (page 18847) requests comment on whether a new category should be created, and what sort of standards should apply if so. Elsewhere the preamble requests comment on whether to maintain or eliminate the cessation of coal combustion subcategory. In such cases, EPA should publish a new proposed rule for these particular provisions if the agency receives comments that suggest the need for regulation beyond the current proposed rule text. To do otherwise would be to treat a proposed rule like an advanced notice of proposed rulemaking and then to leap to a final rule, a particularly troubling approach given the short timeframe for public comment and an inadequate amount of time to generate analytical data related to the request for comment.

Conclusion

Santee Cooper appreciates the opportunity to provide comments for EPA's consideration of a new ELG rule. We believe the information we have provided here, along with our comments of March 29, 2022 and our February 23, 2023 OMB meeting handout will be helpful to the agency in developing a final rule that is durable, achievable, and that maintains a reliable supply of reasonably-priced electricity for ratepayers. We look forward to discussing this information further at the agency's convenience. Please contact me by telephone at (843) 761-8000, ext. 4620 or by email at brian.lynch@santeecooper .com if you have any questions.

Respectfully submitted,



Brian Lynch
Director
Environmental Services

Attachment 1: Brief Responses to EPA Requests for Comment
Attachment 2: Errata
Attachment 3: Santee Cooper Demonstrations from OMB Meeting of February 23, 2023
Attachment 4: Santee Cooper Metals Data During Unit Dewatering
Attachment 5 (CBI): Santee Cooper Rate Calculation – Estimated Impact of Proposed Rule

ec: Mr. Richard Benware
Engineering and Analysis Division
Office of Water, (4303T)
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460
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EXHIBIT 35

DTE

December 21, 2023

Ms. Tiffany Myers, District Supervisor
Water Resources Division
Michigan Department of Environment, Great Lakes and Energy (EGLE)
Jackson District Office
301 E. Louis B. Glick Highway - 4th Floor
Jackson, Michigan 49201

Re: Flue Gas Desulfurization Wastewater (FGD) Voluntary Incentive Program (VIP)/
Cessation of Coal Combustion (COCC) 2023 Annual Progress Reports
DTE – Monroe Plt
NPDES Permit No. MI0001848

Dear Ms. Myers,

This submittal is the follow-up annual progress report per 40 CFR 423.19(h)(3), and per Permit Section I.A.16.c. The following enclosures provide the updates as required by 40 CFR 423.19(h)(4).

On October 13, 2021, DTE Electric Company (DTE) submitted a Notice of Planned Participation (NOPP) for the Flue Gas Desulfurization Wastewater Voluntary Incentive Program per 40 CFR 423.19(h)(1). The following enclosures provide the information necessary for the annual progress report as required by 40 CFR 423.19(h)(3) and 40 CFR 423.19(h)(4).

On October 13, 2020, the Environmental Protection Agency (EPA) released the final version of the Effluent Limit Guidelines (ELG) Reconsideration Rule (2020 Rule) which updated the 2015 ELG Rule (2015 Rule). This 2020 Rule is the product of the EPA's "Reconsideration" of certain portions of the 2015 Rule, specifically addressing bottom ash transport water (BATW) and flue gas desulfurization wastewater (FGD WW).

The 2020 Rule established Best Available Technology (BAT) standard discharge limits for FGD WW discharges, and further, finalized the Voluntary Incentive Program (VIP) for FGD WW. Under the VIP, companies may choose to meet more stringent effluent limits established by EPA based on the model technology of membrane filtration or zero-liquid discharge. If a company chooses the VIP option, then the applicability date for FGD WW compliance will be December 31, 2028. The extended compliance deadline allows for additional time to design, pilot, procure, and install VIP compliant technologies since they are currently not as common and economically viable compared to physical and chemical plus biological treatment systems.

On July 26, 2023 the Michigan Public Service Commission (MPSC) approved DTE's Integrated Resource Plan (IRP). In this plan DTE is committed to retire two of the four Monroe units by December 31, 2028. Also in 2023, EPA issued a Direct to Final Rule that allows facilities planning to cease coal combustion operation by this date to submit a NOPP until June 27, 2023 if the facilities fulfill certain requirements regarding the proper submittal of a NOPP and subsequent annual reports. DTE submitted the Cessation of Coal NOPP for Monroe Power

Plant (MONPP) Units 3 and 4 on April 28, 2023 in accordance with 40 CFR 423.19(f)(1). For these reasons, Units 3 & 4 will follow the Cessation of Coal Combustion (COCC) pathway as submitted in the COCC NOPP on April 28, 2023.

If you have any questions relative to this submittal, please contact Marcela Orlandea at (248) 207-7768 or via e-mail at marcela.orlandea@dteenergy.com.

Sincerely,

Daniel Casey
Plant Manager
Monroe Power Plant
Energy Supply - DTE Electric Company
734-384-2203
Enclosures

Cc: Alexandria Seeger - EGLE, Jackson District Office
Gerald Chilson, Jr – DTE EM&S, Monroe Power Plant
Christopher Paquette – DTE EM&S
Barry Marietta – DTE EM&S
Marcela Orlandea – DTE EM&S
Lisa Lockwood – DTE EM&S

Enclosure 1

Flue Gas Desulfurization Wastewater (FGD) Voluntary Incentive Program (VIP)
2023 Annual Progress Report

Facility Identification

Monroe Power Plant is located at 3500 East Front Street, Monroe, Michigan. MONPP consists of four B&W supercritical wall-fired boilers firing a blend of subbituminous coal, bituminous coal and petroleum coke and is rated for a maximum gross output of 3,280 MW. The units started commercial operation from 1971 to 1974. This flue gas desulfurization wastewater (FGD WW) NOPP annual progress report applies to all operational units at MONPP for both the VIP NOPP and the COCC NOPP.

Technology Projected to be Utilized for VIP Compliance

DTE has evaluated of a suite of technologies for FGD WW treatment that would qualify for VIP compliance. These technologies included but were not limited to membrane treatment, thermal reduction (such as crystallization), encapsulation, and spray dryer evaporators.

In 2022, DTE selected spray dryer evaporators as the primary option to comply with VIP technology requirements for Units 1 and 2. A waste heat or bypass spray dryer is another form of an evaporative solution that can process the FGD wastewater and achieve 2020 Rule VIP compliance limits. The bypass spray dryer takes a small portion of the flue gas and routes it around the air preheater to a spray dryer vessel where the FGD WW is injected. The heat from the flue gas evaporates the wastewater leaving behind residual solids and fly ash from the flue gas. These solids are captured in the existing particulate collection device or a small fabric filter and landfilled. All the FGD wastewater is converted into a solid that is landfilled, eliminating any need to discharge FGD WW and achieving 2020 Rule VIP compliance.

DTE's IRP was filed in November of 2022 and received Commission approval on July 26, 2023, which included the future operation of Belle River Power Plant and Monroe Power Plant. The IRP moves up the retirement date for MONPP Units 1 and 2 to 2032 from 2035. This commitment to retire 3 years earlier prompted DTE to reevaluate it's VIP technology compliance options in order to provide a more economical solution for our customers. DTE is currently evaluating a suite of options that include lower cost technology options and changes in operation that will achieve VIP technology compliance standards.

Engineering Dependency Charts

Enclosure 2 includes a schedule that shows the amount of time required for the installation of a VIP technology for FGD WW treatment system that is capable of achieving compliance with the revised 2020 Rule, such as spray dryer evaporators at Monroe Power Plant Units 1 and 2.

The draft schedule in Enclosure 1a allows appropriate project execution time to implement a VIP technology that would meet the VIP limits. DTE must progress through a preliminary design phase to develop an overall cost estimate. Once the preliminary design phase is completed, the development of cost estimates required to establish overall project cost and obtain approvals by DTE leadership to move into the final design phase of project

development can begin. Following final cost estimate, detailed engineering can begin with finalization of the project design basis and overall scope of work.

Updates to Initial NOPP

The information presented in this annual progress report represents the best information available to meet the contents of the annual progress report as specified in 40 CFR 423.19(h)(4). DTE has identified the following factors that could result in modifications of information submitted in this NOPP annual progress report:

1. Other Regulatory Filings – The approved 2022 IRP, Case number U-21193, provides a plan in which DTE will provide affordable and reliable electricity to its customers. However, many of the projects that will be required to achieve compliance with the 2020 Rule will need to be approved within other future DTE regulatory filings, including electric rate cases. The outcome of future regulatory matters regarding future projects may result in additional modifications to the initial NOPP.
2. Regulatory Changes / Rule Modifications – On August 3, 2021, EPA initiated a new rulemaking to revise the 2020 Rule for certain wastewater discharge limits. The proposed rulemaking or other potential future regulatory changes could impact DTE's ELG compliance strategy including the use of the VIP compliance subcategory and associated NOPP process.
3. Other Factors to Be Determined – Other factors including, but not limited to, legal challenges of EPA's ELG rules or rulemakings conducted by future federal administrations.

DTE will continue to comply with the initial Notice of Planned Participation for Units 1 and 2 at Monroe Power Plant as submitted on October 13, 2021.

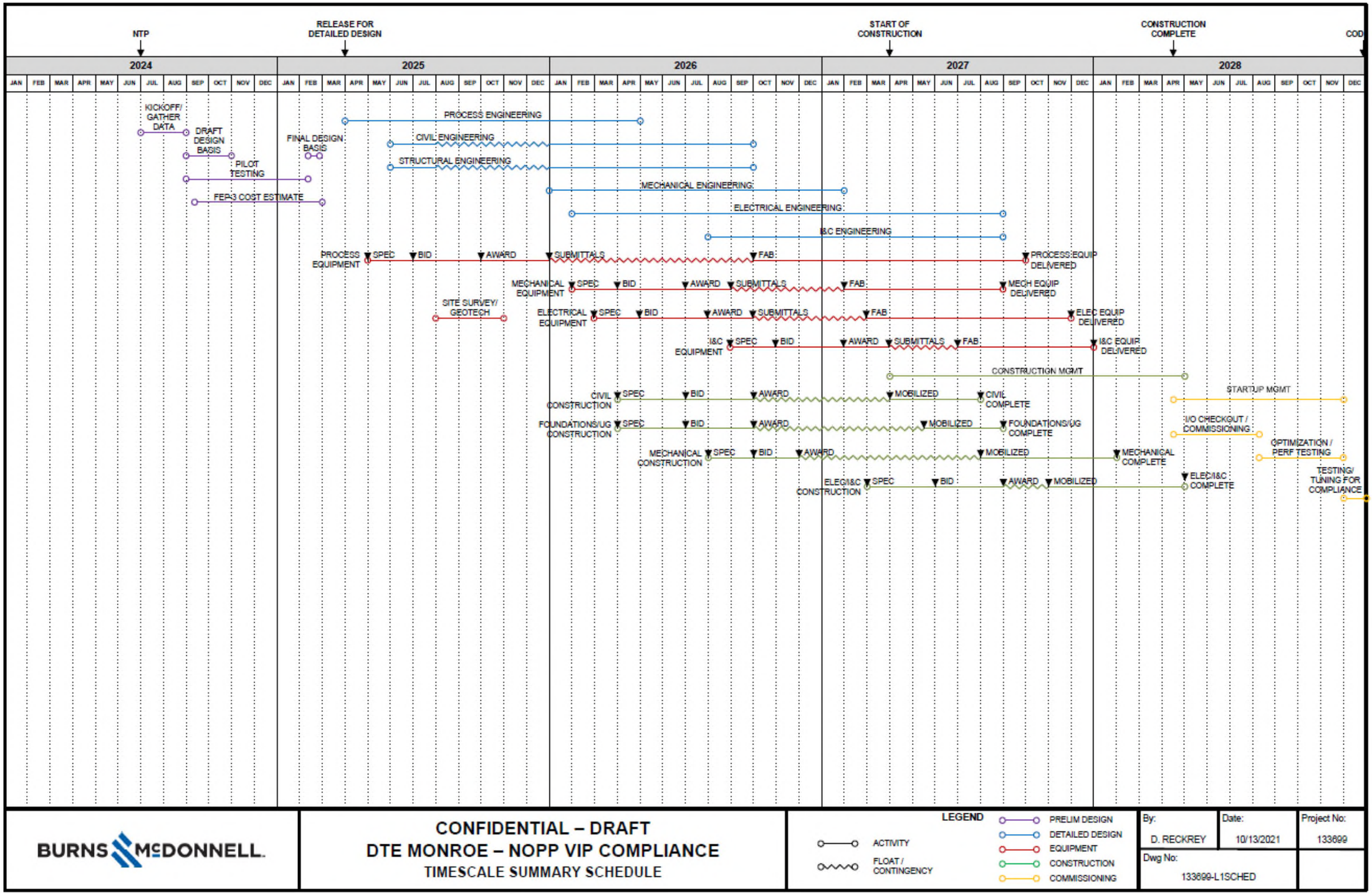
DTE has selected to comply with the cessation of coal combustion NOPP submitted in April 2023 for Monroe Power Plant Units 3 and 4. This updates serves as notification that DTE has elected to transfer to the cessation of coal combustion pathway for MONPP Units 3 and 4 for FGD Wastewater Treatment discharge as described in 40 CFR 423.13(g)(2)(i). See Enclosure 2 for more details related to COCC NOPP annual update.

During 2024, DTE will proceed with activities necessary to obtain a cost estimate, as well as continue to develop the scope and feasibility of any necessary pilot testing of a selected VIP technology.

Enclosure 1a

VIP Implementation Schedule

The overall schedule follows a traditional general / multiple contractor approach. Following completion of the cost estimate, detailed engineering can begin with finalization of the project design basis and overall scope of work. A site survey and geotechnical report are developed for the project and the design basis is updated with this additional information. Procurement packages are developed for long lead equipment and the major process equipment. Submittal drawings and information are needed from the major process equipment for the balance of the detailed engineering activities to commence. The engineering deliverables involve development of process flow diagrams, piping & instrumentation diagrams, general arrangement drawings, one-line diagrams, lists, 3D models, isometric drawings, cable schedules, control narratives, etc. Procurement packages are developed for other balance of plant commodities. Major procurement activities include development of technical specifications, issuing packages to bid, evaluating bids received, negotiating and awarding contracts, receipt of submittals, review of submittal information, release of manufacturing to fabricate, fabrication of equipment / components, and delivery to site.


NTP
RELEASE FOR DETAILED DESIGN
START OF CONSTRUCTION
CONSTRUCTION COMPLETE
COD
2024
2025
2026
2027
2028
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
KICKOFF/ GATHER DATA
DRAFT DESIGN BASIS
PILOT TESTING
FEP-3 COST ESTIMATE
FINAL DESIGN BASIS
PROCESS ENGINEERING
CIVIL ENGINEERING
STRUCTURAL ENGINEERING
MECHANICAL ENGINEERING
ELECTRICAL ENGINEERING
I&C ENGINEERING
PROCESS EQUIPMENT SPEC BID AWARD SUBMITTALS FAB PROCESS EQUIP DELIVERED
MECHANICAL EQUIPMENT SPEC BID AWARD SUBMITTALS FAB MECH EQUIP DELIVERED
SITE SURVEY/ GEOTECH
ELECTRICAL EQUIPMENT SPEC BID AWARD SUBMITTALS FAB ELEC EQUIP DELIVERED
I&C EQUIPMENT SPEC BID AWARD SUBMITTALS FAB I&C EQUIP DELIVERED
CONSTRUCTION MGMT
CIVIL CONSTRUCTION SPEC BID AWARD MOBILIZED CIVIL COMPLETE
FOUNDATIONS/UG CONSTRUCTION SPEC BID AWARD MOBILIZED FOUNDATIONS/UG COMPLETE
MECHANICAL CONSTRUCTION SPEC BID AWARD MOBILIZED MECHANICAL COMPLETE
ELEC/I&C CONSTRUCTION SPEC BID AWARD MOBILIZED ELEC/I&C COMPLETE
STARTUP MGMT
I/O CHECKOUT / COMMISSIONING
OPTIMIZATION / PERF TESTING
TESTING/ TUNING FOR COMPLIANCE
BURNS McDONNELL
CONFIDENTIAL – DRAFT
DTE MONROE – NOPP VIP COMPLIANCE
TIMESCALE SUMMARY SCHEDULE
LEGEND
ACTIVITY
FLOAT / CONTINGENCY
PRELIM DESIGN
DETAILED DESIGN
EQUIPMENT
CONSTRUCTION
COMMISSIONING
By: D. RECKREY
Date: 10/13/2021
Project No: 133699
Dwg No: 133699-L1SCHED

Enclosure 2

Cessation of Coal – 2023 Annual Progress Report
Content Requirements

Facility Identification

Monroe Power Plant (MONPP) is located at 3500 East Front Street, Monroe, Michigan. MONPP consists of four B&W supercritical wall-fired boilers firing a blend of subbituminous coal, bituminous coal and petroleum coke rated for a maximum gross output of 3,280 MW. The units started commercial operation from 1971 to 1974. This section of the annual progress report to cease coal burning generation activities by December 31, 2028 applies to Units 3 and 4 at MONPP.

Expected Date of Coal Cessation

Since the release of the 2023 Direct to Final Rule, DTE has evaluated the feasibility of coal cessation on Units 3 and 4 at MONPP. DTE submits this 2023 Annual Progress Report maintaining the commitment to cease burning coal at MONPP Units 3 and 4 by December 31, 2028.

Method for Cessation of Coal Burning Activities

DTE's current Integrated Resource Plan (IRP) was approved on July 26, 2023 and included a planned retirement for MONPP Units 3 and 4 by December 31, 2028. The 2020 Rule details that the cessation of coal could occur by either unit retirement or repowering to another fuel source. The option to retire generation units is the option DTE has considered for two of the MONPP units.

Regulatory Approval of Coal Cessation

The NOPP submitted in April 2023 represents the first formal submittal to a regulatory body regarding DTE's intentions to meet the 2020 Rule's cessation of coal compliance subcategory. In the preamble of the 2020 Rule, EPA acknowledges that a company may submit a cessation of coal NOPP and may not receive regulatory approval of those actions until a later date.

DTE's IRP was approved by the Michigan Public Service Commission (MPSC) on July 26, 2023 and qualifies as the regulatory approval identified by the 2020 Rule for the cessation of coal compliance subcategory.

Supporting Documentation of Coal Cessation Commitment

This 2023 Annual Progress Report documents DTE's commitment regarding its intentions to utilize the 2020 Rule's cessation of coal compliance subcategory. The finalized IRP settlement can be found on the Michigan Public Service Commission (MPSC) website under Filing: U-21193-0527 (site.com). Any future regulatory filings, if and when they become available, may be provided as additional documentation in support to achieve compliance with ELG requirements.

Timeline for Achieving Coal Cessation

MonroeUnits 3 and 4 are expected to cease operation of coal burning activities by December 31, 2028.

Risks/ Milestone Delays

The information presented in this annual progress report represents the best information available to meet the requirements of NPDES Permit MI0001848 I.A.15.a. DTE has identified the following factors that could result in modifications of information submitted in this NOPP:

1. Regulatory Changes / Rule Modifications – On July 26, 2021, the EPA announced that it will initiate a new rulemaking to revise the 2020 ELG Rule for certain wastewater discharge limits.
2. Other Factors to Be Determined – Other factors include long lead material construction and delivery delays, outage schedule changes as well as legal challenges of EPA's ELG rules or rulemakings conducted by future federal administrations.