Technical Comments on EPA's Final Effluent Limitations Guidelines (ELG) Steam Electric Reconsideration Rule for Coal-Fired Units, October 13, 2020

by

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[1] Resume provided at the end in Attachment B. In addition, documents that are cited in this report that are not already in EPA's record are provided in Attachment C.

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I. Introduction

On October 13, 2020 EPA finalized the Steam Electric Reconsideration Rule ("2020 Rule").[2] I submitted an expert report attached to comments opposing that rule. I stand by the analysis in that report and do not believe EPA adequately considered or responded to the report.

Among other aspects, EPA determined that membrane technologies were not appropriate as the Best Available Technology ("BAT") for treating flue gas desulfurization ("FGD") wastewater and that, instead, they could be considered under the Voluntary Incentives Program ("VIP") should plants wish to do so, with a compliance deadline of December 31, 2028.

If EPA were to properly consider information already in the record of the 2020 Rule, as well as the additional information discussed in this report that would have been available to EPA if it had done sufficient due diligence on membrane systems prior to issuing the 2020 Rule, then EPA would have to determine that membrane technologies are BAT for treatment of FGD wastewater by steam electric power plants. Importantly, membrane technologies that are available to the power industry have demonstrated that not only are they capable of meeting the specified ELG concentrations for arsenic, mercury, selenium and nitrate/nitrites required by the 2020 Rule for FGD wastewaters, they can also achieve zero discharge for such wastewaters, providing recovery of substantial portion of this water along with multiple options to dispose of the remainder of this wastewater ("brine") by multiple means. Achieving zero discharge for FGD wastewater using membranes (plus brine disposal) would eliminate this waste stream's impacts on receiving waters not just for the four named pollutants but also for numerous additional pollutants that are present in this wastewater.

In addition, at the end of this report I also provide brief comments on three other aspects of the final 2020 Rule dealing with: bottom ash transport water ("BATW"); the special carve-out for the TVA Cumberland plant; and EPA's chosen BAT, namely chemical precipitation ("CP") plus Low Residence Time Reduction ("LRTR"). My comments on those issues briefly reiterate the major concerns I raised in my 2020 expert report and emphasize that EPA failed to adequately consider or respond to the issues raised by my 2020 report in finalizing the 2020 Rule.

In developing this report, I have relied on materials in EPA's rulemaking docket and final record, discussions with various vendors, and external research as noted and cited in the report. In order to have candid conversations with various vendors I am unable to disclose specific names. All such conversations were within the last six months.

II. EPA's ELG Limits for FGD Wastewater

For context and reference, on November 3, 2015, EPA finalized[3] the BAT ELG limits for four named pollutants in FGD wastewater for coal-fired units greater than 50 MW in capacity as follows:

[2] EPA, 40 CFR Part 423, Steam Electric Reconsideration Rule, Final Rule, 85 FR 64650-, October 13, 2020.

[3] 80 FR 67895, November 3, 2015. Separate limits applied for units electing to comply under the Voluntary Incentives Program.

Pollutant or pollutant property	BAT Effluent limitations	
	Maximum for any 1 day	Average of daily values for 30 consecutive days shall not exceed
Arsenic, total (ug/L)	11	8
Mercury, total (ng/L)	788	356
Selenium, total (ug/L)	23	12
Nitrate/nitrite as N (mg/L)	17.0	4.4

These final limits were substantially weaker than the limits proposed[4] by EPA for the same four named pollutants in FGD wastewater from coal-fired units greater than 50 MW in 2013:

Pollutant or pollutant property	BAT effluent limitations	
	Maximum for any 1 day	Average of daily values for 30 consecutive days shall not exceed
Arsenic, total (ug/L)	8	6
Mercury, total (ng/L)	242	119
Selenium, total (ug/L)	16	10
Nitrate/nitrate as N (mg/L)	0.17	0.13

I provide these limits in order to facilitate the discussions to follow regarding levels achieved by membrane technologies.

III. EPA's Existing Record, and other Readily Available Information, Supports Reassessing Membranes as BAT for FGD Wastewater

After careful review of EPA's rationale for not concluding that membrane technologies are BAT as discussed in the preamble to the 2020 Rule, I respectfully disagree for the following reasons, which I discuss in greater detail below:

(i) EPA's discussion in the preamble to the 2020 Rule is directly contrary to its discussion of membrane technologies in its own technical assessment document;

(ii) EPA wrongly disregards the full-scale membrane application experience from non-US (i.e., overseas) plants;

(iii) EPA misrepresents the Plant Scherer membrane treatment system as a "long-term pilot," when in fact it is operating at scale and indefinitely;

(iv) EPA minimizes the selection of membranes for FGD wastewater treatment by GenOn;

(v) EPA provides abbreviated and incomplete discussions on the use of membranes to treat wastewaters in other industries, including wastewater more difficult to treat than FGD wastewater; and

4 78 FR 34534, June 7, 2013. Separate limits applied for units electing to comply under the Voluntary Incentives Program.

(vi) EPA makes confusing and contradictory statements on the availability of fly ash for brine disposal and regarding the disposal of encapsulated materials in landfills.

I discuss each of these aspects in the following sections, concluding that EPA's decision to reject membranes as BAT for FGD wastewater was unsupported.

Not only are membranes capable of meeting and exceeding the ELGs for the four named pollutants from FGD wastewater—namely arsenic, mercury, selenium, and nitrate/nitrite—they can also be used in conjunction with complementary technologies such as crystallization and evaporation to achieve zero discharge of such wastewaters, after first allowing for beneficial recovery of a substantial portion of this wastewater.

III.A EPA's Discussion in the Preamble to the 2020 Rule Is Directly Contrary to Its Discussion of Membrane Technologies in Its Own Technical Assessment Document

As part of the record for the 2015 ELG Rule and the 2020 Rule, EPA compiled a summary document of various commercially available technologies from vendors to treat FGD wastewaters. The 2015 summary was updated for the 2020 Rule.[5] The summary consisted of various Appendices, each containing a description of the vendor/technology, followed by application details of that technology as well as performance data, and EPA's conclusions. There were seven membrane-related technologies described in the summary document in the following Appendices:

Appendix B: BKT FMX Membrane Technology
Appendix I: KLeenWater Technology
Appendix K: New Logic Membrane Technology
Appendix L: Oasys Forward Osmosis Technology
Appendix M: Purestream Membrane Technology
Appendix N: Saltworks Technology
Appendix S: DuPont Technology

In Attachment A to this report, I have excerpted these seven Appendices with the exception of the Reference sections in each Appendix in the interest of space. Attachment A also shows underlined emphases as well as highlighted results from numerous pilot studies conducted using one or more of these technologies, showing their ability to not only meet but also exceed the requirements of the 2015 and, in some cases the more-stringent, 2013 proposed ELG requirements for the four named pollutants. In these summaries, EPA's conclusions are uniformly positive about the performance of these technologies and their ability to meet the ELGs and also to meet zero discharge requirements.

Even without zero discharge, EPA's Supplemental Technical Support Document[6] ("Supplemental TSD") for the 2020 Rule clearly recognizes that membrane technologies are superior to EPA's selected BAT, namely CP+LRTR when it discusses pollutants not effectively treated.

[5] EPA-HQ-OW-2009-0819-8890.

[6] Supplemental Technical Development Document for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, EPA-821-R-20-001, August 2020.

For CP+LRTR, the Supplemental TSD admits that “EPA identified seven pollutants which are not reliably removed by CP+LRTR and therefore did not establish CP+LRTR limits for them. These pollutants are: ammonia, boron, bromide, chloride, cyanide, and total dissolved solids (“TDS”). (Supplemental TSD p. 8-4). In contrast, for membranes, EPA states that “[B]ased on process knowledge and performance data for membrane filtration systems, all pollutants known to be present in FGD wastewater would be effectively treated by membrane filtration….” (Supplemental TSD, p. 8-6). Comparing Tables 8-2 and 8-3 in the Supplemental TSD makes the superiority of membranes unequivocally clear.

The summaries in Attachment A also provide details of pilot studies conducted using these technologies. While I strongly recommend that the reader review all of Attachment A, below I provide condensed summaries of the key EPA findings that were evaluated for the first three membrane technologies listed above.

III.A.1 Appendix B (BKT FMX)

Appendix B (BKT FMX) is an advanced membrane filtration system designed for wastewaters containing high total suspended solids (“TSS”) and 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. Depending on the application, microfiltration, ultrafiltration, or nanofiltration membranes can be used in the FMX system. For FGD wastewater applications, nanofiltration membranes are recommended. The FMX system can be operated in conjunction with a downstream conventional reverse osmosis (“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.

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. 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 EPA notes, 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 single-step 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.

EPA discusses 6 pilot studies using the FMX system. I will summarize the results of these pilot projects for the pollutants of concern for FGD wastewater as well as a few additional compounds not addressed in the ELG rule.

Pilot #1 was for three months at a coal-fired power plant. Nanofiltration membranes were used along with a RO membrane. FGD wastewater was fed to the system from the plant's FGD storage tank, a surface impoundment. Concentrate from each batch of wastewater treated was returned to the feed tank until 70-80 percent of the feed volume passed the membranes as permeate. As EPA noted, "[T]he 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 EPA in 2013, which were lower than the limits established by the 2015 ELGs)." Results of this pilot study are shown below and confirm the efficacy of the system.

Pilot Study #1 Results[7]

Pollutant (unit)	Feed	FMX Permeate	RO Permeate	2015 ELG (Max // 30d)
Bromine (mg/L)	59.8	36.2	< 0.283	
Nitrate-Nitrite (mg/L as N)	< 27.3	< 17.6	< 0.234	17 // 4.4
Boron (µg/L)	120,000	106,000	39,900	
Nickel (µg/L)	325	160	< 5	
Zinc (µg/L)	1,740	1,250	12.7	
Arsenic (µg/L)	< 12.7	< 5.35	< 2	11 // 8
Selenium (µg/L)	219	55.4	< 1	23 // 12
Molybdenum (µg/L)	62.6	15.4	< 0.5	
Cadmium (µg/L)	72.7	56.3	< 0.75	
Mercury (µg/L)	2,030	94.7	< 5	0.788 // 0.356

Pilot #2 was also at a coal-fired power plant, using two different nanofiltration membranes. Permeate generated from the FMX system was further treated by a conventional RO system. The goal of the study was to determine if injected polymers affected the performance of the system. Results from this study are shown in the table below.

Pilot Study #2 Results

Pollutant (unit)	Feed	FMX Permeate	RO Permeate	2015 ELG (Max // 30d)
Arsenic (Total, µg/L)	2.21	1.14	0.673	11 // 8
Mercury (Total, ng/L)	77.4	7.18	0.81	788 // 356
Selenium (Total, µg/L)	275	96.7	2.13	23 // 12

Pilot #3 was an 8-month pilot test 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

[7] In this table and the tables that follow, the yellow highlighted rows show the pollutants of interest for the FGD wastewater ELGs and the rows highlighted in blue show other pollutants which are also toxic but not included in the ELG rule.

used in this test to further treat the FMX permeate. Per EPA, plant staff reported that the 80 percent recovered permeate from the FMX nanofiltration system was pure enough for reuse in the FGD system. In this pilot, the FMX concentrate was collected so that it could be used to evaluate encapsulation processes. The table below shows the results. Since a polishing RO unit was not included during this test, the data in the table below does not show the effluent quality following combined FMX and RO treatment.

Pilot Study #3 Results

Pollutant (unit)	Feed	FMX Permeate	2015 ELG (Max // 30d)
Arsenic (Total, µg/L)	10	2	11 // 8
Mercury (Total, ng/L)	50	3	788 // 356
Selenium (Total, µg/L)	200	69	23 // 12

Like Pilot #3 above, Pilot #4 used nanofiltration membranes at a coal plant for over a year to treat FGD wastewater without an RO system. 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 clean-in-place procedure was performed once per month using the FMX system permeate. The table below shows the results for a period of approximately six months, per EPA.

Pilot Study #4 Results

Pollutant (unit)	Feed	FMX Permeate	2015 ELG (Max // 30d)
Bromide (mg/L)	73	15	
Nitrate (as N, mg/L)	27.8	6	17 // 4.4
Arsenic (Total, µg/L)	<5.5	<5.5	11 // 8
Mercury (Total, ng/L)	1,610	334	788 // 356
Selenium (Total, µg/L)	423	30.4	23 // 12

In Pilot #5, 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. The table below shows the results.

Pilot Study #5 Results

Pollutant (unit)	Feed	FMX Permeate	RO Permeate	2015 ELG (Max // 30d)
Arsenic (Total), ug/L	11.1	8.46	6.09	11 // 8
Mercury (Total), ng/L	240	16.6	< 5	788 // 356
Selenium (Total), ug/L	1,930	726	6.84	23 // 12
Nitrate-Nitrite (as N, mg/L)	5.6	5.6	1.25	17 // 4.4

Finally in a sixth pilot study, a 400 gpm FMX system was installed in 2018 at a large coal-fired power plant in the Southeastern U.S for two months. 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. The system was tested in both batch and continuous modes. It was found that operating in batch mode results in the lowest operating and maintenance costs, as compared to continuous, single-pass operation. Results are shown in the table below.

Pilot #6 Results

Pollutant (unit)	Feed	FMX Permeate	RO Permeate	2015 ELG (Max // 30d)
Arsenic (µg/L)	≤ 8.1	≤ 6.69	≤ 5.73	11 // 8
Selenium (µg/L)	2,062	974	8.44	23 // 12
NO_2+NO_3 as N (mg/L)	5.54	5.66	1.17	17 // 4.4
Total Mercury (ng/L)	151	≤ 10.2	≤ 12.3	788 // 356

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

It is clear that in each instance when the FMX system was used with the polishing RO system the combined system was able to meet the FGD ELG requirements in every instance. It is my opinion that EPA did not adequately consider the clear, successful results demonstrated by the six pilot studies above when it rejected membranes as BAT.

III.A.2 Appendix I (KLeeNwater)

KLeeNwater offers technologies for FGD wastewater treatment applications: I-MICRO, I-PRO, and B-PRO. I-MICRO is a microfiltration membrane with chemical addition, and I-PRO and B-PRO are RO membranes. The typical application for FGD wastewater treatment consists of pretreatment to reduce the amount of 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. EPA acknowledged that this system was tested at 23 laboratory-scale studies treating FGD wastewater from coal-fired power plants. In addition, there were three pilot studies conducted, whose results I summarize below. In its review of these pilot studies, EPA notes that each showed "…pollutant concentrations in the membrane permeate lower than the limits established by the 2015 ELGs…."

In Pilot Study #1, a five-week study, the treatment system included physical/chemical treatment, I-MICRO, I-PRO, and B-PRO. EPA noted that "[T]he effluent from the pilot system consistently met ELG and state regulations and the permeate was considered suitable for re-use within the plant or discharge. The encapsulation tests also met regulatory requirements for leachability." Results are shown in the table below.

Pilot Test #1 Results

Pollutant (unit)	FGD Purge	Final Effluent	2015 ELG (Max // 30d)
Arsenic (µg/L)	14.5	1.2	11 // 8
Nitrate-Nitrite as N (mg/L)	70.4	0.16	17 // 4.4
Selenium (µg/L)	563	2.7	23 // 12

A second study (Pilot Study #2) was conducted to validate the results of the first pilot study above and to refine the pretreatment process. It successfully validated the results of the first study and further optimized the system's pretreatment in the second study.

In Pilot Study #3, a six-week study at a coal-fired power plant treating FGD wastewater, the system successfully handled load cycling of the unit. The system achieved an average water recovery of greater than 90 percent. The results of this study are shown below.

Pilot Test #3 Results

Pollutant (unit)	Pretreatment Influent	Final Effluent	2015 ELG (Max // 30d)
Arsenic (µg/L)	158	5.0	11 // 8
Mercury (ng/L)	53,900	9.7	788 // 356
Nitrate-Nitrite as N (mg/L)	5.15	0.40	17 // 4.4
Selenium (µg/L)	809	9.5	23 // 12

In Pilot Study #4, which was conducted for 10 weeks at a coal-fired power plant to treat its FGD wastewater, the test objectives, per EPA's summary "… 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 programs, and demonstrate long-term feasibility of the technology." The treatment train consisted of chemical pretreatment followed by clarification, I-MICRO, and a two-stage I-PRO/B-PRO system. It yielded, on average, 85.4 percent recovery. As with the pilots above, the discharge consistently met ELG regulations and the permeate was of sufficient quality for reuse as scrubber make-up water. Results are shown below.

Pilot Test #4 Results

Pollutant (unit)	Feed Tank Influent	Final Effluent	2015 ELG (Max // 30d)
Arsenic (µg/L)	18.5	5.0	11 // 8
Mercury (ng/L)	636	0.5	788 // 356
Nitrate-Nitrite as N (mg/L)	294	1.19	17 // 4.4
Selenium (µg/L)	561	5.0	23 // 12

To reiterate, as shown in the results' tables above, this vendor's membrane technology clearly demonstrated the ability to successfully meet the 2015 FGD ELG requirements. In fact, in later discussion, I note that GenOn selected this technology to treat its FGD wastewater for its Dickerson, Chalk Point, and Morgantown plants.

Finally, KLeeNwater also investigated a variety of approaches including thermal or brine solidification processes to treat the brine from the membranes to achieve zero liquid discharge. KLeeNwater tested different mixtures (e.g., fly ash, lime, superabsorbent polymer) to achieve encapsulation of the brine. EPA noted that based on the results of the pilot studies, the treatment technology produced a concentrate that can be successfully encapsulated using these different approaches.

III.A.3 Appendix K (New Logic VSEP)

Next, I summarize below the results from studies conducted using membranes from yet another vendor, New Logic, using its VSEP technology. EPA noted that this "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." Table 1 in the EPA's technology summary document, Appendix K, lists six pilot studies using this technology on treating FGD wastewaters. EPA summarizes the results of two of these studies, which I excerpt below, using the same numbering system as EPA, for consistency.

In 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 FGD settling pond. As EPA confirms, "[O]ther 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. During single-pass mode, the feed entered the VSEP system while the concentrate valve was closed. As the permeate was processed through the system, the concentrate valve was opened when the desired permeate volume was been achieved. In either mode of operation, the VSEP permeate was transferred to a conventional spiral RO for polishing. The two tables below show the results in this pilot study for both modes of operation, as noted.

Crucially, EPA correctly noted that "[U]sing 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 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."

Pilot Study #2 Results (Single-Pass Mode)

Pollutant (unit)	Feed	VSEP Permeate	RO Permeate	2015 ELG (Max // 30d)
Nitrate-Nitrite (mg/L)	23.7	0.45	0.07	17 // 4.4
Boron (µg/L)	155,000	109,000	81,200	
Cobalt (µg/L)	34.6	< 0.5	< 0.5	
Nickel (µg/L)	178	< 5	< 5	
Arsenic (µg/L)	< 5	< 1	< 1	11 // 8
Selenium (µg/L)	191	1.54	< 1	23 // 12
Mercury (ng/L)	1,400	35.4	11.0	788 // 356

Pilot Study #2 Results (Batch Mode)

Pollutant (unit)	Feed	VSEP Permeate	RO Permeate	2015 ELG (Max // 30d)
Nitrate-Nitrite (mg/L)	13.1	0.75	0.04	17 // 4.4
Boron (µg/L)	97,900	< 0.5	32,400	
Cobalt (µg/L)	36.4	< 100	< 0.5	
Nickel (µg/L)	177	1.32	< 5	
Arsenic (µg/L)	2.03	42.9	<1	11 // 8
Selenium (µg/L)	267	<1	<1	23 // 12
Mercury (ng/L)	833	<0.5	<10	788 // 356

In Pilot Study #4, also conducted at a coal-fired power plant, the VSEP system was 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. The VSEP permeate was fed through a spiral-wound RO system. Three single-pass runs were conducted at 50 percent recovery, and four single-pass runs were conducted at 75 percent recovery. The majority of test runs used anti-scalant. The results are shown in the two tables.

Pilot Study #4 (Single-Pass, 50% Permeate Recovery)

Permeate Recovery Rate, Run	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
50, Run 1	Mercury (total, ng/L)	110	1.7	0.28[a]
	Arsenic (total, µg/L)	2.5[a]	ND	ND
	Selenium (total, µg/L)	280	6.3	2.3[a]
50, Run 2	Mercury (total, ng/L)	190	3.5	1.8
	Arsenic (total, µg/L)	2.5[a]	ND	ND
	Selenium (total, µg/L)	340	6.4	2.8[a]
50, Run 3	Mercury (total, ng/L)	69	1.3	1.9
	Arsenic (total, µg/L)	3[a]	ND	ND
	Selenium (total, µg/L)	240	3.4[a]	1.6[a]

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

Pilot Study #4 (Single-Pass, 75% Permeate Recovery)

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
75, Run 1	Mercury (total, ng/L)	150	4.2	0.24[a]
	Arsenic (total, µg/L)	1.9[a]	ND	ND
	Selenium (total, µg/L)	330	11	3.9[a]
75, Run 2	Mercury (total, ng/L)	180	2.6	0.44[a]
	Arsenic (total, µg/L)	2[a]	ND	ND
	Selenium (total, µg/L)	320	10	5
75, Run 3	Mercury (total, ng/L)	100	6.5	1.2
	Arsenic (total, µg/L)	1.9[a]	ND	ND
	Selenium (total, µg/L)	250	7.9	5
75, Run 4	Mercury (total, ng/L)	54	2.6	0.82
	Arsenic (total, µg/L)	2.3a	ND	ND
	Selenium (total, µg/L)	250	10	3.2a

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

It is clear from the results shown above that, like the results from the various pilot studies from the two other vendors summarized above, these pilot studies successfully demonstrated that the VSEP membrane technology could easily meet the 2015 ELG limits.

All three of the vendors whose pilot studies are summarized above are active and present commercially today. Attachment A also contains EPA's summaries of the four other vendors with membrane technologies, including Oasys (whose US-based) technology was selected by Chinese plants, as I will discuss later; Purestream; Saltworks; and DuPont, which EPA noted "…has installed nine MLD-ZLD systems for FGD wastewater treatment at power plants in China since 2015."

III.A.4 Summary

It should be clear from the excerpts above that there has been extensive testing and validation of multiple membrane technologies, individually and in combination, both with and without pre-treatment in both pilot as well as full-scale applications to treat FGD wastewater. Arguably, from a technology standpoint, this is one of the most tested pollution control technologies in a wide range of applications compared to many others in any media.

Yet, in spite of this extensive record, EPA dismisses the efficacy of membranes in its 2020 Rule preamble:

> "With respect to pilots, EPA is aware of at least 19 previous or ongoing domestic pilot studies and one foreign pilot study of FGD wastewater treatment using four different membrane filtration technologies. All of these technologies first used some

> form of suspended solids removal, such as microfiltration or chemical precipitation. This pretreated FGD wastewater was then fed into either nanofiltration, reverse osmosis, or EDR membrane filtration systems. For several of the pilot studies, the resultant brines were mixed with [fly ash] FA and/or lime to test the potential for encapsulation of the concentrated brine wastestream."[8]

As should be clear, this is misleading in several respects. There are arguably seven and not "four" membrane filtration technologies. Also, as is clear in EPA's own summaries as I have excerpted them above, several of the pilot studies achieved compliance with the 2015 ELG limits without any pretreatment – i.e., taking the FGD wastewater from an impoundment where the only "pretreatment" was some prior settling of solids. So, EPA's statement above that "[A]ll….used some form of suspended solids removal, such as microfiltration or chemical precipitation…" is incorrect.

EPA also inaccurately portrays the numerous studies discussed above and in Attachment A in an attempt to discredit the extensive record it has relating to the efficacy of membranes to treat FGD wastewater. For example, EPA claims that:

> "…critical uncertainties remain…" and states that "[W]ith respect to data from the pilot studies, these studies focused on membrane technologies intended to remove dissolved pollutants. Several studies of the technologies designed to remove dissolved pollutants either did not include a second stage of membrane filtration (*i.e.*, a reverse osmosis polishing stage, which electric utilities and vendors indicated would need to be part of any potential future membrane filtration system that they would consider installing to operate with a discharge) or provided only summaries of effluent data because of nondisclosure agreements between EPRI, treatment technology vendors, and/or the plant operators."[9] (emphasis added)

As I have summarized above, EPA's statement that several studies "did not include a second stage….(i.e., reverse osmosis)"[10] is inaccurate because many of the pilot studies did, in fact, include this second stage, along with results from such pilot studies as I have excerpted from EPA's own compilations above.

As to EPA's criticism that only "summaries of effluent data"[11] were provided for membranes, I find it notable that EPA did not criticize similar pilot data from its recommended BAT (i.e., CP+LRTR) that it had available.[12] I did not see the "individual daily samples"[13] that EPA claims were lacking for the membrane pilots for the CP+LRTR pilots either. Summary data of the type provided for CP+LRTR and membranes should be adequate for selecting either technology as BAT. EPA cannot

[8] 85 FR 64666.
[9] 85 FR 64667.
[10] 85 FR 64667.
[11] 85 FR 64667.
[12] Supplemental Technical Development Document for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, EPA-821-R-20-001, August 2020 (hereafter "Supplemental TSD"), p. 8-12. In FN59, EPA admits that it did not have any data for the full-scale plants that are using CP+LRTR.
[13] 85 FR 64667.

hold evidence supporting membrane technology to a higher standard than evidence supporting other technologies such as CP+LRTR.

As to its inability to obtain data due to non-disclosure agreements, that is simply not credible because EPA has the ability to obtain this information using its statutory authority under Clean Water Act Section 308. The docket for this rulemaking contains numerous EPRI and industry documents that EPA received under confidential terms. So, nothing prevented EPA from similarly receiving membrane test data from any pilot study that it needed for its evaluation. There is nothing in the record to indicate that EPA made credible attempts to obtain such data and was rebuffed.

In summary, and based on this extensive demonstration of consistent performance in meeting the 2015 FGD ELG limits – i.e., multiple vendors, with numerous pilot studies, including optimization studies, there is simply no basis for EPA to have concluded that membrane technologies are not mature enough to be BAT today. And, importantly, the studies demonstrate that they are not only effective in meeting the 2015 ELG limits for the four named pollutants, but that they can dramatically reduce additional pollutants such as boron, bromide, cobalt, nickel, molybdenum, etc. and, with brine encapsulation, can achieve zero liquid discharge, eliminating all flows to receiving waters while recovering a large percentage of the wastewater for beneficial reuse within the plant.

III.B EPA Wrongly Disregards Global Full-Scale Membrane Application Experience

In the preamble to the 2020 Rule, EPA noted that there were multiple full-scale installations of membrane technologies to treat FGD wastewater. Yet, it chose to disregard all of this experience.

Frankly, it appears that EPA made very little effort to obtain and review information from numerous power plants operating overseas that use membrane technologies to treat FGD wastewater.[14] There is

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[14] Regarding the plants in China, EPA makes the following statements as to its inability to consider membrane applications at these full-scale units. It is my opinion that EPA did not make a reasonable effort to obtain additional information on these applications, some of which is available in the open literature, as summarized in this section. Additionally, it is unknown to what extent EPA exerted itself in obtaining information it claims it needed to evaluate membranes since not having such information allowed EPA to conveniently deem membranes not to be BAT.

> "Regarding the plants in China, EPA is generally aware that two of the plants employ pretreatment and a combination of reverse osmosis and forward osmosis. <u>But EPA was not able to obtain further information about the specific configurations, maintenance, or long-term performance of these two systems. EPA also has no information about how the resultant brine is being managed or disposed of.</u> Furthermore, the company that sold these two systems has since ceased commercial operations. EPA is aware that two other plants operating in China employ pretreatment followed by nanofiltration and reverse osmosis. As with the systems above, <u>the vendors declined to provide plant operation, maintenance, or performance information to EPA.</u> The remaining Chinese systems were developed by DuPont, which met with EPA after proposal to provide what limited information was available. While DuPont has sold six systems to Chinese plants to treat FGD wastewater, the company did not have access to operation, maintenance, or performance data for these systems.
>
> <u>Due to travel restrictions in place during the COVID–19 pandemic</u> in spring and summer 2020, EPA representatives were unable to travel abroad to visit these plants. Because the vendor companies either ceased operations or declined to provide EPA with information about the operation,

no reason EPA could not follow up with the operators of these full-scale systems in China, Korea, and Finland, to satisfy itself that membrane technologies are effective in these applications. EPA should explore additional data collection for the four named pollutants to the extent such data may not be readily available, for these plants.

There is nothing unique about the US coal-plant fleet, its FGD systems or the makeup of its FGD wastewater (which is quite diverse across the US plant fleet) that would render non-US experience irrelevant, as EPA has erroneously chosen to do in the 2020 Rule.

Information about non-US membrane applications is noted in the record and also in the open literature for EPA to evaluate. To that extent, I provide some details of example Chinese plants and their membrane applications below, as available in the open literature.

III.B.1 General Electric/Jingneng Zhouzhou plant

This is an example of GE providing membrane and brine concentration technologies to a China plant, not considered by EPA. The following information is provided:

> GE today announced that it will supply its advanced wastewater treatment equipment for the Jingneng Zhuozhou coal-red power plant in Zhuozhou City, 60 kilometers south of Beijing, in Hebei Province, China. GE will provide its membrane and brine concentration technologies followed by crystallization to produce pure NaCl salt (sodium chloride). GE's zero liquid discharge (ZLD) technology will treat flue gas desulfurization (FGD) wastewater to meet Chinese emissions and discharge limitations for new thermal power plants and enable the reuse of 99 percent of the FGD blowdown wastewater at the plant. The power plant's wastewater will be recycled and used as makeup water.[15]

III.B.2 Huaneng Changxing Station

Although this plant and its membrane application is briefly described in the EPA summary (and in my excerpt, under Oasys and DuPont earlier), additional technical detail from the open literature is also available that EPA should consider in any reevaluation. The following is taken from a technical article.[16]

> "With China's new air pollution and water intake/outflow requirements under consideration, for its Changxing units, Huaneng…committed to install a new

maintenance, or performance of their membrane filtration products, and EPA's lack of regulatory authority to compel the production of information from foreign plants, EPA's record has significant information gaps on the operation and performance of membranes used to treat FGD wastewater." (emphasis added) 85 FR 64666.

[15] GE to Provide Water Recycling Technology for Chinese Coal-Fired Power Plant August 15, 2016, available at https://www.power-eng.com/emissions/ge-to-provide-water-recycling-technology-for-chinese-coal-fired-power-plant/#gref.

[16] Huaneng Power's Changxing Station ZLD Project, China, Power, August 1, 2016, available at https://www.powermag.com/huaneng-powers-changxing-station-zld-project-china/.

wastewater treatment plant to treat a combined waste stream, including the FGD blowdown wastewater stream and cooling water blowdown—and to make it a zero liquid discharge (ZLD) system, with recovered water being recycled in the boiler feedwater loop. In a world first, the system was also designed to use forward osmosis (FO) technology as the brine concentration technology for the ZLD train….Huaneng considered various project proposals for the novel plant application, eventually selecting Boston, Mass.–based Oasys Water Inc. and its Chinese partner, Beijing Woteer, to deliver the world's first commercial application of FO–based ZLD. Oasys Water, a company founded in 2008, provided its patented and trademarked ClearFlo membrane brine concentrator (MBC) system with pre-concentrating reverse osmosis (RO), while Beijing Woteer supplied physical-chemical filtration, ion exchange pretreatment, and a crystallizer package. According to Oasys, the guiding philosophy in designing the ZLD process flow for Changxing was for the pretreatment and MBC sections of the system to be able to absorb the "wide swings" in wastewater flow and water quality arising from variations in the FGD scrubber process. "Because the wastewater treatment plant was built with the new facility and not a retrofit, the ZLD process flow was designed based on projected water quality data. Ability to treat a variety of waters across a wide range of hardness, alkalinity, and total dissolved solids [TDS] was therefore planned for in the design of the system," a company spokesman said. The company also said that several important design decisions were made to optimize the system for stable performance over the expected wide range of water quality and flow conditions. They included:

■ Complete softening of the FGD wastewater was required due to the high concentration factor required for ZLD, in order to minimize opportunities for scaling in the pre-concentrating RO system and for premature saturation of minerals in the crystallizer. Stoichiometric softening in a contact clarifier was combined with weak acid cation ion exchange polishing.

■ MBC process flexibility was maximized so that the wide range of feed flow and water quality could be managed. To accomplish this, the team defined four design cases for flow and incoming TDS. The RO and FO components of the MBC were then designed to produce stable brine TDS, allowing flow and overall recovery to float as necessary.

■ To maximize turndown ratio, the FO component of the MBC was split into three parallel trains (Figure in original), a configuration that allows operation of the MBC at flows from 60% to 110% of design maximum.

…The Changxing zero liquid discharge (ZLD) flue gas desulfurization (FGD) water treatment process is designed for flexibility. Blowdown water from the FGD scrubber is pretreated via contact clarifier with rapid mixing of soda ash and lime to remove the typical 8,000 to 15,000 milligrams per liter of hardness (as calcium carbonate). The softened wastewater is then filtered and polished using weak acid cation ion exchange (CAC IX) beds to reduce hardness to single-digit levels. Reverse osmosis (RO) then concentrates the stream from approximately 20,000 parts per million (ppm) of total dissolved solids to 60,000 ppm. The membrane brine concentration (MBC) forward osmosis system used for brine concentration is designed as three parallel trains supported by a single draw solution recovery system. This allows flexibility to handle a flow range of 30% to 110% of design flow, while the system provides consistent quality of feed to the final ZLD step of crystallization.

…the FO MBC concentrates wastewater dissolved solids from approximately 60,000 milligrams per liter (mg/l) in the RO concentrate to 220,000 mg/l or higher. “The MBC does the brine concentration work of a thermal or mechanical evaporator with the simplicity and modularity of a membrane system, while consuming a fraction of the energy,” it explained.

…The FO trains are driven by an osmotic pressure gradient created across a semi-permeable membrane to achieve spontaneous and preferential diffusion of water molecules from a saline feed into a proprietary draw solution. As water crosses the FO membrane, it dilutes the draw solution. At the draw solution exit of the FO array (Figure in original), it has extracted the prescribed amount of clean water from the wastewater stream and a separation process must be performed to reconcentrate the draw solution and to separate the clean water stream for reuse….To reconcentrate the draw solution, it must be heated to between 45C and 65C above the inlet dilute draw solution temperature to volatilize and subsequently recondense and absorb ammonia and carbon dioxide. For the Changxing system, the energy requirement is less than 90 kWth/m3 of wastewater processed, Oasys Water said. The draw solution recovery was designed to use steam as the energy source for volatilization and water cooling for condensation, but the company noted that mechanical vapor recompression system designs are also an option. The freshwater stream exiting the MBC draw solution recovery loop combines with the pretreated wastewater stream and passes through the RO system. It leaves the system in the second-pass RO permeate stream with TDS of less than 100 mg/l. It is then stored in the product water tank and is reused in the power plant’s boiler makeup water system. The MBC system is designed to recover up to 23 m3/hour—or up to 87% recovery—but it is actually performing at more than 90% in operation thus far, said Oasys Water. Notably, the salt byproduct from the process is also collected and sold. Concentrated brine exiting the MBC system feeds a two-stage crystallizer at a target TDS concentration of 220,000 mg/l or higher. Currently, the crystallizer processes 2.5 m3/hour of brine, operates at pH 8.0–8.5, and concentrates the brine to saturation. A pusher centrifuge and hot air dryer system then remove remaining water to less than 0.5%. Finally, produced mixed salt crystals of more than 95% (NaCl + Na2SO4) are bagged and palletized for sale to chemical manufacturers in the region.

The Changxing Power Station Units 7 and 8 were new builds that came online in late 2014, which meant there was “no actual water analysis on which to base the design of the ZLD process train to treat FGD blowdown wastewater,” noted Oasys Water. “This fact guided the design team to conservatively design the pretreatment and the FO brine concentrator as described,” it said, noting that since startup, the flow per day to the plant has been in range of the design basis, but TDS levels have been lower than expected (see table in original). This has resulted in lower flow to the MBC system and overall higher recovery prior to the ZLD crystallizer.

> …Oasys and Chinese partner Beijing Woteer, which have since secured three additional projects in China. They include another coal power FGD wastewater project and two projects for ZLD treatment of streams at coal-to-chemical process complexes."

Additional process details on this application are also available in the open literature.[17]

III.B.3 Hanchuan Plant, DOW FilmTec

Although briefly discussed by EPA (see DuPont discussion in Attachment A, Appendix S, and as excerpted earlier), additional details on the membranes themselves are available in the open literature, as noted below:

> "…As the general EPC (Engineering Procurement Construction) contractor for Guodian Hanchuan power plant's FGD wastewater ZLD project, Beijing Lucency enviro-tech Co. Ltd, Nanjing branch was one of the pioneers to investigate the ZLD treatment process of such high salinity challenging wastewater. This FGD wastewater treatment plant is the first to employ ZLD for China's 1000 MW power unit level. It is also the first coal-fired power plant to employ ion separation technology in the wastewater treatment to provide salt recovery for reuse. It showcases the ability to successfully achieve ZLD when treating FGD wastewater and also to minimize the solid wastes residue left by the ZLD process. Before the industrial project started-up, Dow Water & Process Solution closely collaborated with Nanjing Lucency to conduct on site pilot trials in order to determine which product were best suited for the application. From the pilot demonstration, the decision was made to install the following elements in the commercial process: DOW FILMTEC FORTILIFETM XC-N nanofiltration elements for ion separation of the FGD wastewater; DOW FILMTEC FORTILIFETM XC80 reverse osmosis elements for salt concentration and volume reduction of FGD wastewater; and DOW FILMTECTM BW30-400 for permeate water polishing. Not only was the power plant able to benefit from the reusable water, but the purity of crystallized salt from wastewater ZLD process achieved engineering design expectations and was more than 98.5%."[18]

In addition to the plants in China discussed above, there is at least one plant in South Korea which is using membrane technology to treat FGD wastewater. As announced in the press a few years ago, Doosan's ZLD technology will be used at the Yeongheung power plant:

> "Doosan's zero liquid discharge (ZLD) system treats flue gas desulfurization (FGD) wastewater of thermal power plants by combining its advanced membrane solutions, such as reverse osmosis (RO), and thermal processes involving evaporators and crystallizers. The company's advanced wastewater treatment technology helps remove not only industrial liquid waste, such as mercury, which could be removed using

[17] https://www.wateronline.com/doc/changxing-power-plant-debuts-the-world-s-first-forward-osmosis-based-zero-liquid-discharge-application-0001.

[18] DOW Tech Fact, DOW FILMTEC™ membranes, available at https://www.dupont.com/content/dam/dupont/amer/us/en/water-solutions/public/documents/en/45-D01758-en.pdf.

> existing wastewater treatment solutions, but it also eliminates nitrate and selenium…The company will be in charge of the entire project including the design, manufacturing and commissioning processes of the Yeongheung Thermal Power Plant, which is scheduled to be completed by August 2018. Once completed, the plant will be capable of recycling 1250 m^3 of FGD wastewater daily."[19]

Finally, there is at least one announced FGD wastewater treatment using RO membranes in Finland as announced by Lenntech, the vendor:

> "Flue Gas Desulfurization Treatment, Finland, Flow 42 m^3/hour…Lenntech has engineered, installed and commissioned a double pass RO system, first pass is a high recovery CCRO system (93%) followed by a conventional RO system (95%) for a boiler feed water application in Finland. The treated water is used as make-up water for the boiler line…"[20]

It is clear that there are numerous full-scale and operating membrane applications overseas that EPA did not thoroughly assess and therefore inappropriately dismissed when evaluating membranes as BAT for FGD wastewater treatment. For this reason, EPA should reassess these applications and reassess membranes as BAT.

I note that in the case of the China plants, these foreign installations are using technology from US providers like Oasys (from Boston) who could not find similar markets at home at least in part as a result of EPA's own actions. Since this was US technology, EPA should have been able to fully evaluate it and did not do so. EPA cites Oasys's exit from the marketplace as an excuse for not evaluating its technology being used abroad, but fails to acknowledge EPA's own delay of effluent guidelines and reconsideration rulemaking focused on weakening the guidelines likely played a major role in Oasys' challenges finding domestic customers.

III.C EPA Misrepresents the Plant Scherer Full Scale Membrane Treatment System as a Pilot

As noted previously, EPA repeatedly asserts that one of its reasons not to deem membranes BAT is because there are no domestic (i.e., US) plants that are using a full-scale version of this technology to treat FGD waste water.

First, as noted in the previous discussion, there is no technical reason why full-scale implementation in the US should be a prerequisite to deeming a technology BAT. After all, EPA did not point to anything specific or unique (nor can it) about US domestic coal plants and their FGD systems/wastewater that would render non-US experience - often with technology from American vendors - irrelevant. In other words, full-scale applications elsewhere in the world, which EPA has acknowledged only to dismiss such as in China, Korea, Finland, etc. should be directly relevant for membrane technology assessment.

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[19] https://www.doosan.com/en/media-center/press-release_view?id=14170&page=5&.
[20] https://www.lenntech.com/Data-sheets/2019-Flue-Gas-Desulfurization-Treatment-Finland.pdf.

Even setting that aside for the moment, it was pointed out in comments that Plant Scherer has a full-scale membrane treatment system.[21] EPA disputes this and calls this a "long-term pilot" instead.[22] First, this system is treating a substantial quantity of FGD wastewater at Plant Scherer, based on my discussions with vendors. Second, a "long-term" pilot is an oxymoron. There is simply no such thing as a long-term pilot. Pilot plants are designed to prove a concept at scale before "full-scale" application. EPA does not dispute that the Plant Scherer membrane application (using New Logic's VSEP technology, per industry contacts) is a full-scale application. In fact, sources have confirmed that this system treats a substantial portion of the plant's FGD wastewater and has been successfully doing so for some time now (well over a year). Instead EPA has adopted the term "long-term pilot" to characterize optimization studies that are continuing at this plant for brine disposal. It is not uncommon for optimization to continue for a long time or, indeed, forever at fully operating plants. Optimization, by definition, does not have an end point – it can continue indefinitely. That does not mean, however, that the application is a "pilot."

EPA's mischaracterization of Plant Scherer as a "long-term pilot" is incorrect. This is yet another reason for EPA to reassess membranes as BAT for FGD wastewater treatment.

III.D EPA Minimizes the Selection of Membranes for FGD Wastewater Treatment by GenOn

In addition to the long-term operating New Logic membrane technology at Plant Scherer noted above, EPA discredits the selection of membrane technology for FGD wastewater by GenOn for its power plants in Maryland (Dickerson, Chalk Point, and Morgantown[23]):

> "…The State of Maryland also informed EPA that three GenOn plants planned to install technologies to meet the 2015 rule VIP effluent limitations. In a teleconference call held to learn more about these plans, GenOn staff stated that one of these plants (Dickerson) had announced its retirement, but confirmed that the other two (Chalk Point and Morgantown) are currently considering reverse osmosis systems (see DCN SE08614). <u>EPA views GenOn's consideration of membrane technology similarly to the bids and engineering reports for full-scale systems that the agency was aware of at proposal.</u> As discussed at proposal, the sources of the

[21] EPA-HQ-OW-2008-0819-8179. Email from Mr. Greg Johnson of New Logic to EPA, dated June 22, 2019.

> "Regarding our system that was installed at the research center in Atlanta, I can confirm that it is being moved to the new location and that it will be a permanent installation to treat about 50 gm of FGD effluent. This is the total flow that they have and this is not intended to be a pilot, it is a final treatment plant that will be permanent." (emphasis added)

[22] "A vendor email cited by some commenters erroneously asserted that a full-scale installation of such a technology had begun at Georgia Power's Plant Scherer. Follow-up discussions with staff working on that project revealed that the plant is not installing a permanent full-scale membrane technology to treat FGD wastewater, but <u>is performing a long-term pilot</u> of both membrane filtration and biological treatment systems…" 85 FR 64665 (emphasis added) I have quoted from the referenced vendor email in the previous footnote. EPA states that the vendor's email is erroneous without any specific facts other than that someone from EPA (unspecified) had (unspecified) follow-up discussions with (unspecified) "staff working on that project." This is not a sufficient basis to refute the vendor statement, especially when EPA is apparently relying on the lack of a full-scale operating system of this type to reject membrane technologies as BAT.

[23] That GenOn has subsequently decided to shutdown Dickerson and Chalk Point is irrelevant to their choice of membrane technology for FGD wastewater treatment. There is no indication that their selection of membranes was in any way related to the plant shutdown decision.

bids and engineering reports expressed concerns about operating a technology on this wastewater that would be the first of its kind in the U.S."[24] (emphasis added)

First, EPA did not appear to gather any of the data collected by GenOn during its evaluation of membrane technologies, at any of the named GenOn plants. This is an omission in the record.

Second, it is not clear what EPA means by "similarly to bids and engineering reports" but it is misleading for EPA to misrepresent GenOn's selection of membrane technology for its plants in Maryland, after extensive evaluations, as some sort of speculative bidding exercise. I discuss the timeline of GenOn's membrane evaluations in some detail later in this section.

In any case, EPA's dismissal of GenOn's selection of membranes was inappropriate. Below, I show a series of actions GenOn has publicly stated with regards to its efforts on considering membranes for FGD wastewater treatment, culminating in its selection of this technology:[25]

"•In Q2 2015, GenOn commissioned a study and provided FGD water samples from Chalk Point that were tested in a pilot scale laboratory. The goals established and evaluated in the off-site pilot study included:

o Determining if a Reverse Osmosis (RO) system could replace the existing sequencing batch reactors (SBRs) to meet the then proposed ELG regulations.

o Determining if the RO system could polish the water from the SBR to meet the then proposed ELG regulations.

• In Q3 2017, GenOn commissioned a 5 gallon per minute pilot treatment system study at the Conemaugh Generating Station. The pilot was designed to treat FGD wastewater and consisted of a conventional wastewater precipitation system, microfilter system, and an industrial high-pressure RO system. The performance of chemical additives was evaluated to prevent carbonate and sulfate fouling and to prevent microbiological growth of the membrane surfaces prior to feeding to the RO membrane system. The concentrates from the pilot were transferred to a pilot solids concentration system that utilized fly ash, cement and/or stabilizer to provide a solid substance for disposal.

• On September 21, 2018, GenOn received business confidential budgetary proposals for Morgantown and Dickerson for industrial high-pressure RO technology that were designed to treat FGD wastewater to achieve compliance and high recovery.

• On May 17, 2019, GenOn commissioned a business confidential study at Dickerson that utilizes industrial high-pressure RO technology that was designed to treat FGD wastewater to achieve compliance and high recovery.

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[24] 85 FR 64666.

[25] Letter from Mr. Stephen Frank, GenOn to Mr. Jonathan Rice, Maryland Department of the Environment (MDE), August 31, 2020 regarding ELG Progress Report for Morgantown Generating Station, Permit No. 14-DP-0841 (MD0002674); Chalk Point Generating Station, Permit No. 14-DP-0627 (MD0002658); Dickerson Generating Station, Permit No. 14-DP-0048 (MD0002640).

• On August 22, 2019, ERG released a Memorandum with the subject: Notes from Meeting with KLeeNwater. This was in response to a meeting held between EPA and KLeeNwater on September 27, 2017.

• Beginning on September 13, 2019, GenOn commissioned and completed off-site laboratory RO performance testing using a tote of FGD wastewater from Dickerson achieving the goal of 90% recovery.

• On November 11, 2019, GenOn commissioned a business confidential engineering evaluation of the May 2019 Study of industrial high-pressure RO technology that was designed to treat FGD wastewater to achieve compliance and high recovery.

• On November 22, 2019, EPA published proposed ELG standards. The proposed ELG standards included two additional FGD wastewater treatment technologies among the suite of regulatory options that were not evaluated as main regulatory options in the 2015 rule: Low Hydraulic Residence Time Biological Reduction (LRTR) and membrane filtration system designed specifically for high TDS and TSS waste streams. Because few if any are currently used for FGD treatment in the industry, EPA's addition of membrane filtration for FGD wastewater treatment provided additional assurance for GenOn.

• On May 22, 2020, EPA conducted a call with GenOn to discuss the 2019 proposed revisions to the Steam Electric Rulemaking and GenOn's recent certification to MDE to comply with the 2015 voluntary effluent limitation guidelines in 40 CFR 423.13(g)(3)(i). When EPA inquired about our plans, we stated that for both Morgantown and Chalk Point, GenOn is planning to install RO systems. The expectation is that permeate will be recycled back to the absorber and brine (or salt crystals) will be disposed of offsite.

• On May 26, 2020, GenOn completed a zero-liquid discharge evaluation for FGD wastewater at Chalk Point. This report presents business confidential information that includes a RO summary memorandum for how the technology can be applied at Chalk Point Station, budgetary proposals from RO vendors, and an engineer's estimate of probable costs.

• On June 10, 2020, Morgantown collected FGD water representing one boiler in operation for parameters specific to the operation of RO systems. The analytical report was received on June 23, 2020.

• On June 12, 2020, Chalk Point collected FGD water representing one boiler in intermittent operation for parameters specific to the operation of RO systems. The analytical report was received on July 27, 2020.

• On June 16, 2020, a request to bid on supplying GenOn's Morgantown Plant with a RO System to meet the ELGs was sent to multiple vendors. Bids were received on or before August 24th and will be evaluated through Q3 and Q4 of 2020.

• Beginning July 2020, GenOn commissioned and completed off-site laboratory RO performance testing using a tote of FGD wastewater from Morgantown achieving the goal of greater than 90% recovery. The full results of testing are pending as of August 31.

• On July 22, 2020, Morgantown collected FGD water representative of two boilers in operation for parameters specific to the operation of RO systems. The analytical report was received on August 4, 2020 and provided to vendors to support their bids.

GenOn will provide a response by September 15 to MDE's August 3, 2020 reopener request to support the evaluation of "legacy" FGD wastewater to determine if additional limitations or enforceable milestones are appropriate. We will provide a summary of the activities and schedule for complying with the December 31, 2023 compliance deadline for meeting the VIP requirements. Note that GenOn is not proposing to use evaporative technologies for FGD wastewater as suggested in the reopener letter and, at this time, is preparing to use membrane technologies. The use of membrane technologies is anticipated to have zero discharges of FGD wastewater during routine operations, but may have limited treated discharges during absorber maintenance, high water level conditions in the FGD absorber, and/or at retirement of the station."[26] (emphasis added)

Note the role that EPA's November 2019 proposal played in providing GenOn with "additional assurance" to proceed with its selection of the KLeeNwater technology as noted above. Note also how GenOn corrected Maryland regulators that it is not "proposing" to use evaporative technologies and that it is "preparing" to use membrane technologies instead.[27] Nothing in the summary above suggests remotely that GenOn was engaged in a speculative "bid and engineering report" exercise as implied by EPA in the preamble noted above.

Further confirming its selection, GenOn subsequently sent another letter to the Maryland regulators, portions of which I have excerpted below:

"As further detailed below, GenOn is not planning to use evaporative technologies. GenOn is tentatively planning on utilizing industrial high-pressure reverse osmosis (RO) membrane filtration technology preceded by pretreatment (i.e., chemical precipitation) and an optional brackish water RO technology for polishing. GenOn is also evaluating use of ion selective Electrodialysis Reversal (EDR) technology preceded by pretreatment with or without RO membrane filtration technology."[28]

"The anticipated system will be installed following the existing FGD wastewater treatment system clarifier that will be used to pretreat the FGD water. The existing

[26] Letter from Mr. Stephen Frank, GenOn to Mr. Jonathan Rice, Maryland Department of the Environment (MDE), August 31, 2020 regarding ELG Progress Report for Morgantown Generating Station, Permit No. 14-DP-0841 (MD0002674); Chalk Point Generating Station, Permit No. 14-DP-0627 (MD0002658); Dickerson Generating Station, Permit No. 14-DP-0048 (MD0002640).

[27] On May 4, 2020, GenOn sent letters to MDE electing to use membrane technologies under the VIP program.

[28] Letter from Stephen M. Frank, GenOn to Mr. Jonathan Rice, Maryland Department of the Environment, September 15, 2020.

> biological treatment components will be removed from service and may be repurposed in the new system design. Pretreated FGD water will be collected in an existing feed tank. FGD water will be pumped from this feed tank through new sand filters then cartridge filters and may be injected with anti-scalant and microbiocide to prevent silica and sulfate fouling and microbiological growth on the membrane surfaces, respectively. Acidic chemistry may also be injected in the cartridge filter effluent. Cartridge filter effluent will be pumped through the first stage of the RO system. The concentrate from the RO system will be recirculated through the RO system until a predetermined solids concentration is achieved. At that point, high TDS concentrate will be directed to a Concentrate Tank followed by two existing Brine Storage Tanks (e.g., repurposed biological tanks).
>
> Permeate from the first stage RO system will be directed to the optional Polish RO Feed Tank or to the Treated Water Lift Tank. Water will be pumped from the feed tank through cartridge filters and may be injected with anti-scalant and microbiocide to prevent silica and sulfate fouling and microbiological growth on the Polish RO membrane surfaces, respectively. Cartridge filter effluent will be pumped through the Polish RO system. Concentrate from this Polish RO system will be directed the Polish RO feed tank for retreatment or to the first stage RO feed tank for retreatment. Permeate will be collected in the Treated Water Lift Tank, from which it will be transferred to an existing tank that will be re-purposed for permeate storage in advance of its use as makeup water in the existing FGD absorber or discharge to IMP 801."[29]

Again, it is clear that GenOn was not engaged in a cursory "bid and engineering report" exercise that EPA mischaracterized in the preamble. Given this mischaracterization and the fact that EPA has failed to gather information about GenOn's tests as part of the 2020 Rule, this is yet another reason for EPA to revisit the choice of membranes as BAT for FGD wastewater.

III.E EPA Provides Incomplete Discussion on the Use of Membranes to Treat Wastewaters in Other Industries

After making the unsupported or poorly supported determinations that: (i) overseas installations of membrane technologies for FGD wastewater treatment could not be evaluated; (ii) there are no full-scale installations in the US (i.e., mischaracterizing Plant Scherer's application as a "long-term pilot"); and (iii) misleadingly dismissing GenOn's selection of membranes, in the preamble EPA makes a half-hearted attempt to show that while membranes have been used to treat wastewaters from other industries, that experience is not applicable. EPA states:

> "With respect to the use of membrane filtration in other industries and in connection with non-FGD power plant wastestreams, given what is known about FGD wastewater, EPA focused its evaluation on the more challenging wastewaters in other industries. In the mining industry, reverse osmosis is employed to treat <u>mine-influenced</u> water. For example, since 2006, the Bingham Canyon Water Treatment Plant (BCWTP) at the Kennecott South Superfund site treats 3,200 gallons per minute of mine-influenced water and has maintained a TDS removal efficiency of

[29] *Ibid*.

> 98.9 percent, given an expected influent TDS of approximately 2,000 mg/L. Mining wastewaters demonstrate some similar challenges seen in FGD wastewaters, but there are also differences in the two wastestreams. For example, both are highly scaling in gypsum, but as the BCWTP example demonstrates, mining influent TDS concentrations can be an order of magnitude (or more) lower than the TDS concentrations found in some FGD wastewater streams. In the mining industry, brine generated by reverse osmosis is typically disposed of through evaporation, deep well injection, or ocean discharge.
>
> In the oil and gas industry, there are several applications and opportunities for membrane filtration, recently summarized by Adham et al. (2018). For example, nanofiltration is used worldwide for sulfate removal in offshore oil and gas operations. Reverse osmosis is the standard treatment for coal seam gas water in Australia, where regulations restrict underground….."[30]

As the discussion above shows, EPA looked at applications of membranes for wastewater treatment in just two non-power plant industries, namely, to treat "mine-influenced" wastewater and in the oil and gas industry. While there are no doubt applications in these industries, EPA's discussion is misleadingly light.

In fact, as review of readily available public information shows, there are membrane applications[31] for treating wastewaters from a wide range of industries. These include:

Acid Mine Drainage (noted by EPA);
Algae Dewatering;
Beer Recovery from Spent Yeast;
Biogas Effluent;
Black Liquor;
Boiler Feed Water;
Bottled Water;
Box and Bag Plant Effluent;
Carbon Black;
Colloidal Silica;
Coolant Recovery;
Cooling Tower Blowdown (noted by EPA for power plant applications)
Desalter Effluent;
Drinking Water;
Ethanol Production;

Fuel Storage Tank Bottom Water;
Herbicide Wastewater;
Industrial Laundries;
Landfill Leachate;
Latex Emulsion Concentration;

[30] 85 FR 64666.
[31] https://www.vsep.com/downloads/case-studies-application-notes/.

Medium Density Fiberboard;
Manure Slurry Filtration;
Metal Hydroxide Treatment;
Metal Plating;
Oily Wastewater;
Organic and Inorganic Pigment Washing;
Paper Coating Effluent;
Polymer Diafiltration;
Phosphate Filtration;
Precious Metals Recovery;
Tannery Wastewater;
Waste Oil Recycling;
Whey Concentration; and
Winery Wastewater.

As examples, I highlight a couple of these wastewaters. First, while EPA discusses mine drainage, it states that this wastewater is not as challenging as FGD wastewater because it has a TDS content of 2000 mg/L. This is misleading. I provide, just as an example, the analysis for an acid mine site[32] below with a TDS value substantially greater (i.e., 10,000 ppm or mg/L). Thus, EPA's characterization that these wastewaters are not as challenging is erroneous.

Table 1: Acid Mine Drainage Sample Analysis

	Untreated	Limed	V✧SEP*
TDS	10,000 ppm	3,000 ppm	240 ppm
pH	2.7	8.5	8.5
Calcium, Ca	490 ppm	600 ppm	36 ppm
Magnesium, Mg	420 ppm	350 ppm	18 ppm
Sodium, Na	70 ppm	70 ppm	6 ppm
Iron, Fe	1,100 ppm	0.1 ppm	<0.1 ppm
Manganese, Mn	182 ppm	3.6 ppm	<0.1 ppm
Copper, Cu	186 ppm	<0.1 ppm	<0.1 ppm
Zinc, Zn	550 ppm	<0.1 ppm	<0.1 ppm
Sulphate, SO4	8,000 ppm	2,000 ppm	100 ppm

*40ºC, 85% Recovery, 450 psi

Next, I show below, a sample from landfill leachate,[33] likely among the more challenging wastewaters to treat, based on my conversations with several of the membrane vendors.

32 https://www.vsep.com/pdf/AcidMineDrainage.pdf.
33 https://www.vsep.com/pdf/LandfillLeachate.pdf.

Leachate Treatment Technology Comparisons

		Initial Raw Feed	Precipitation plus Biotower	Sequence Batch Reactor	Activated Sludge	2 Stage RO Membrane
		ppm (mg/l)	4626	4721	4759	4687
Arsenic	As	584		223	312	2
Barium	Ba	280	3			1
Chromium	Cr	415	123	222	82	2
Copper	Cu	139		54	76	1
Molybdenum	Mo	13,260		13,260	13,127	27
Nickle	Ni	2,060		1,976	1,879	10
Selenium	Se	178		138	178	0
Tin	Sn	908		886	723	5
Titanium	Ti	23	738	2	2	0
Zinc	Zn	126	11	42	47	1
Boron	Bo	1,808	1,220	1,728	1,540	101
Cyanide	Cn	3,990			271	20
Lithium	Li	266		266	239	1
Silicon	Si	4,362	3,677	3,969	4,362	353
Strontium	Sr	1,406	39	1,232	467	14
Ammonia	NH4	58,480	351	234		292
Total Nitrogen	TKN	209,400			155,584	1,047
Total Suspended Solids	TSS	171,800	3,436	47,932	126,101	2
Total Dissolved Solids	TDS	2,478,000		2,438,352	2,373,924	9,912
Biological Oxygen Demand	BOD	1,182,000	41,370	62,646	28,368	5,910
Chemical Oxygen Demand	COD	1,526,000	61,040	424,228	360,136	10,682
Total Organic Carbon	TOC	642,600		216,556	101,531	3,213
Oil and Grease	O&G	37,333		5,563	9,333	37
Benzoic Acid		7,685	23	69	8	38
P-Cresol		797		37	2	4
Pheonol		1,262	19	8	3	6
Tolulene		376	3	3	28	2

Note the extremely high levels of TDS, TSS, BOD, COD, organic carbon as well as numerous metals and other organics in this wastewater as shown in the raw feed column. Not only does it present significantly more challenges than FGD wastewater, note the reported reductions in all of the contaminants using membranes in the last column.

EPA's previous analysis fails to give substantial weight to the long history, maturity and track record of this technology for treating not only a wide range of wastewaters but also significantly more challenging wastewaters.

III.F EPA Makes Inconsistent and Unsupported Statements on the Availability of Fly Ash for Brine Disposal and Regarding Disposal of Encapsulated Materials in Landfills

One of the more inadequately supported reasons that EPA proffers in rejecting membranes as BAT is the supposed lack of options to properly deal with the brine concentrates that result from the use of membranes. As I have previously noted, pilot-scale evaluations have used a variety of potential disposal options, including mixing with fly ash – which is generated at every single coal-fired power plant – to form solid matrices which can be disposed of in landfills (including onsite landfills in many power plants) or as pastes (which EPA itself discusses but calls a "developing" technology in the preamble).[34] Other options include crystallization of the brine or evaporation, such as noted for some of the plants in China and in South Korea. EPA did not, to my knowledge, provide any indication in the record that it had evaluated brine disposal options in use when membranes are used in other industries.

Focusing on the most likely disposal option, i.e., using fly ash to stabilize the brine, given that fly ash is generated at each and every power plant, EPA attempts to demonstrate that sufficient fly ash may not be available at some plants since they sell all of their fly ash, making this disposal option therefore not available. The relevant discussion in the preamble is as follows:

> "When asked about the availability of FA for sale, one of the three plants indicated that its particular market for FA is flush, and that plant was no longer able to maintain contracts for the sale of its FA, which would make it available for the plant to use to encapsulate the thermal system brine. In contrast, two of the plants with which EPA discussed possible future installations of membrane filtration systems stated that they sell 100 percent of the FA generated for beneficial reuse. Although some commenters suggested that there is more than sufficient FA available for reuse, the EPA's rulemaking record contains information to the contrary. According to 2017 and 2018 EIA data, the median percentage of FA that was sold for beneficial use by plants with wet FGD systems was approximately 14 percent, with some plants selling all of their fly ash and some plants selling none. Furthermore, these EIA estimates may be low, as one plant's staff represented that they were beneficially using 100 percent of their FA rather than the amount reported in the EIA data. A quantitative comparison of EIA data for plants with FGD wastewater indicates that if plants currently disposing of their FA installed membrane filtration, they may have enough FA to encapsulate the quantities of brine produced by membrane filtration…..Thus, while EPA's assumption of a typical blend is reasonable for a nationwide assessment, the Agency anticipates that there will be sites where non-water quality environmental impacts are particularly unacceptable."[35] (emphasis added)

EPA's reasoning is strained and inconsistent with the record. I note that EPA bases its conclusion that fly ash may not be available on discussions with three plants, two of which stated that they sell all of their fly ash while the third indicated that it had enough fly ash. Three plants is hardly

[34] 85 FR 64676.
[35] 85 FR 64668.

representative of the industry. In fact, as the record clearly notes, EPA's broader survey of fly ash availability states that overall, there is more than sufficient fly ash available for stabilizing brine:

> "…over 82 percent of the plants have enough fly ash for EPA's estimated brine encapsulation without considering the amount of fly ash sold. After factoring in fly ash sales, ERG estimates that about 70 percent of the plants still have enough fly ash to encapsulate brine generated from membrane filtration with no impact on the revenue generated from selling ash…."[36]

EPA's analysis of fly ash requirements assumed that only fly ash would be used for encapsulation of brine,[37] and in this case approximately 5.63 million tons of fly ash would be required (sum of column titled "EPA FA Required (tons)." In the same analysis EPA also estimated the total amounts of surplus fly ash – i.e., considering fly ash generated, but not sold or potentially used for encapsulation – for each plant. In most cases there was a net surplus of fly ash (i.e., generation minus sales minus potential use for encapsulation was positive) in each year. Fleetwide, the net surplus for 2017 was 4.01 million tons and for 2018 it was 4.03 million tons. This shows that there is likely to be more than enough surplus fly ash fleetwide, and even though a few plants may be short they can and should be able to obtain surplus fly ash from others if needed.

Confirming this, EPA states above that "the median percentage of FA that was sold for beneficial use by plants with wet FGD systems was approximately 14 percent…" Thus, lack of fly ash in general should not be an issue.

In addition, the fact that a particular plant is selling all of its fly ash presently is also not an availability factor but rather one of cost – i.e., should such a plant choose to use fly ash to encapsulate brine or make a paste etc., it may, at best, lose some revenue. For such plants, other options can be considered such as crystallization or evaporation, if these turn out to be better from an economic standpoint. For the same reasons, EPA's statement that "there will be sites" where non-water quality impacts are particularly unacceptable is wholly speculative and merits no rebuttal.

It is also worth noting that EPA's evaluation of fly ash availability did not substantiate industry claims:

> "<u>EIA data are not consistent with claims raised by EPRI in public comments</u> and indicates that for the set of plants discharging FGD wastewater, a much smaller amount of fly ash is sold on average. Additionally, the amount, and percentage, of fly ash sold year to year is not limited by the amount of fly ash generated in a single year because fly ash can be stored on a short- or longterm basis."[38]

Perhaps realizing that its argument about brine disposal (and therefore membrane availability as BAT) is weak, EPA speculates about potential problems of disposing of the encapsulated brine in landfills, pointing to the fact that commingling such solids with other landfill refuse "could result in a leachate blowout"[39] citing to a King County Virginia case where improper placement of materials resulted in

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[36] EPA-HQ-OW-2009-0819-8963 (DCN SE09070).
[37] *Ibid*, Table A-2.
[38] *Ibid*., p. 3.
[39] 85 FR 64669.

a blowout. Again, EPA reaches for extreme examples that "could" happen while not discussing the norm – which is that thousands of wastes of varying characteristics, including differential infiltration rates, are disposed of in municipal and industrial landfills every year in this country, with rare leachate blowouts. To suggest that encapsulated brine is so unique that it alone would cause such blowouts and therefore would need to be disposed of in "dedicated landfill cells"[40] which would "require time to permit and construct"[41] – therefore making membranes unsuitable as BAT at the present – is unjustifiable.[42]

For all of the reasons discussed, it is my opinion that EPA should revisit and reassess its wrong decision to reject membranes as BAT.

III.G Summary

Membrane technology has been in use overseas and in this country in a wide range of applications, many of which are far more challenging than FGD wastewater. The record before the EPA including its own technology summaries as well as the discussions on membranes and their effectiveness in its own Supplemental TSD make it clear that membrane technologies are available today and ready to be deemed BAT. In fact, by providing a clear path towards zero discharge, eliminating not just the impacts of the four named ELG pollutants from FGD wastewater (i.e., arsenic, mercury, selenium, and nitrate/nitrite) but all others, membranes are far superior to the combination of CP+LRTR that EPA has selected as BAT.

IV. Other Issues

IV.A Bottom Ash Transport Water (BATW)

I have reviewed EPA's revisions weakening the zero-discharge ELG for BATW to allow "high-recycle rate" systems (which it describes as "partially closed loop" allowing a purge stream for various reasons including maintenance and storm events) and disagree with EPA's reasoning and unsupported basis for the change. In fact, EPA did not respond in any factual and meaningful way to numerous technical comments from myself and others on this issue.

My opinions have not changed on this issue. It is more likely than not that this change will be used as a loophole by operators to "purge" BATW without treatment, adding unnecessarily to pollutant

[40] 85 FR 64669.
[41] 85 FR 64669.
[42] I note that using fly ash in combination with brine for disposal in a landfill is not new. Duke Energy Progress has been doing that since 2015. See North Carolina DEQ/DWR Fact Sheet for NPDES Permit Development, NPDES No. NC0038377:

> "Duke Energy Progress treats the FGD blowdown via VCE (vapor compression evaporator) whose purpose is to evaporate the majority of the waste water produced from the FGD scrubber system. The VCE became operational in February, 2015. It produces two waste streams, both are utilized in the plant processes. The concentrated wastewater is used for moisture conditioning of fly ash prior to sending to the landfill. The second stream is a clean distillate that is utilized to partially replace water withdrawal from Mayo Reservoir."

burdens on receiving waters. EPA's change is inadequately supported, as EPA itself acknowledges that closed-loop systems are available and economically achievable. And, even if it were true that closed-loop systems could not achieve zero discharge, BAT should still be set at zero discharge due to dry handling systems being available and achievable for bottom ash. And, for the reasons stated in the comments, EPA has simply not justified that a purge allowance of any amount reflects the performance of the best-performing plant. Nor does EPA's allowance in the final rule for permitting authorities to set a lower site-specific purge limit justify EPA's failure to set BAT standards based on the technologies used by the best-performing plants.

IV.B High Flow Carve-Out (Cumberland)

In the 2020 Rule, EPA has carved out a high FGD flow subcategory ("High Flow Subcategory"), which would establish BAT based on chemical precipitation alone for facilities with purge flows greater than four million gallons per day. As it turns out, this subcategory would apply only to the Cumberland Fossil Plant ("Cumberland Plant"), a coal plant owned and operated by the Tennessee Valley Authority ("TVA"), the nation's largest publicly owned utility.

In 1994, TVA chose to install a cheaper scrubber design knowing that it would discharge large volumes of FGD wastewater, premised on the fact that it did not have to meet any effluent limitations on metals. TVA has since argued that Cumberland could not achieve the ELGs because its cheap FGD system, due to its metallurgy, would corrode if it recycled the FGD wastewater. And TVA claimed that modifying Cumberland's scrubber material to something more corrosion resistant, or simply complying without recirculation, would be too expensive.

In the 2015 ELG Rule, EPA rejected these claims and denied TVA's request for a special subcategory. Yet, in the 2020 Rule, EPA reversed its position and justified the High Flow Subcategory based only on compliance costs, but the agency significantly overestimates those costs, as was pointed out in comments on the proposed rule.

EPA did not address the comments in any meaningful way. I stand by my previous analysis arguing that EPA should not create this one-plant subcategory.

IV.C EPA's Selected BAT, CP+LRTR, Is Less Effective Than Membranes

In a report at the proposal stage, I opined that the switch from HRTR to LRTR was unsupported and that while LRTR is not different technology than HRTR, the shorter residence time in LRTR can, not unexpectedly, result in higher long-term average concentrations of pollutants in the effluent as compared to HRTR systems, and that EPA's assertions to the contrary were unsupported. For short-term average concentrations, EPA had acknowledged that effluent from LRTR showed more variability than effluent from HRTR, which is to be expected given the lower residence time for treatment in the former. In other words residence time matters and longer the residence time, lower the long-term average concentrations and lower the short-term variability. The data confirm this. EPA's own data showed that LRTR was not the best-performing technology.

I stand behind my previous report because nothing in EPA's 2020 Rule addresses the deficiencies of LRTR as compared to HRTR systems. EPA did not provide an adequate response to my prior report on this issue.

It is also useful to point out that EPA's selected BAT, namely CP+LRTR, is demonstrably inferior to membranes, using EPA's own analysis of data presented in its Supplemental TSD for the 2020 Rule,[43] shown below.

Table 8-9. Long-Term Averages and Effluent Limitations for FGD Wastewater

Treatment Technology Basis	Pollutant	Long-Term Average	Daily Maximum Limitation	Monthly Average Limitation
CP+LRTR[a]	Arsenic (µg/L)	4.98	18	8
	Mercury (ng/L)	13.48	103	34
	Nitrate-nitrite as N (mg/L)	2.14	3.7	2.6
	Selenium (µg/L)	15.87	70	29
Membrane Filtration (VIP)	Arsenic (µg/L)	5.0 [b]	5 [c]	--- [d]
	Mercury (ng/L)	5.44	23	10
	Nitrate-nitrite as N (mg/L)	0.89	2.0	1.2
	Selenium (µg/L)	7.35	10[c]	--- [d]
	Bromide (mg/L)	0.200	0.2	--- [d]
	TDS (mg/L)	86.06	306	149
Chemical Precipitation (High Flow and Low Utilization Subcategories)	Arsenic (µg/L)	5.98	11	8
	Mercury (ng/L)	159	788	356

a – The CP+LRTR effluent limitations would apply to all plants not in the Voluntary Incentives Program, high flow plants, low utilization EGUs, or those units ceasing coal combustion by 2028.
b – Long-term average is the arithmetic mean of the quantitation limitations since all observations were not detected.
c – Limitation is set equal to the highest quantitation limit for the evaluated data set(s).
d – EPA is not establishing monthly average limitations when the daily maximum limitation is based on the quantitation limit.

The Long-Term Average values, which EPA recommends that plants be designed and operated to meet,[44] make clear that the use of membranes results in lower concentrations for every pollutant rather than using CP+LRTR, with the exception of arsenic, for which the two are comparable (approximately 5 ug/L).[45]

[43] Supplemental Technical Development Document for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, EPA-821-R-20-001, August 2020, Table 8-9.
[44] For the rationale provided by EPA, see Supplemental TSD, p. 8-4.
[45] As noted in previous discussion, EPA's analysis shown above was from pilot plant data for both membranes as well as CP+LRTR and no full-scale plant data was used for the CP+LRTR technology combination, as EPA admits in the Supplemental TSD. In other words EPA used currently available pilot plant data in both instances but arbitrarily only deemed this to be an issue for membranes and not for CP+LRTR.