SOUTHERN INDIANA GAS AND ELECTRIC COMPA

D/B/A

VECTREN ENERGY DELIVERY OF INDIANA, INC.

CAUSE NO. 45052

VERIFIED (PUBLIC) DIRECT TESTIMONY

OF

DIANE M. FISCHER

CENTRAL REGIONAL AREA DIRECTOR AND ASSOCIATE VICE PRESIDENT

SPONSORING PETITIONER'S EXHIBIT NO. 10,

ATTACHMENTS DMF-1 THROUGH DMF-3 AND DMF-4 (CONFIDENTIAL)

THROUGH DMF-7 (CONFIDENTIAL)

VERIFIED DIRECT TESTIMONY

OF

DIANE M. FISCHER

CENTRAL REGIONAL AREA DIRECTOR and ASSOCIATE VICE PRESIDENT

Q. Please state your name, employer and business address.

A. Diane M. Fischer, Black & Veatch Corporation ("Black & Veatch"), 11401 Lamar Ave., Overland Park, Kansas, 66211.

Q. What position do you hold with Black & Veatch?

A. I am the Central Regional Area Director and Associate Vice President for our Power Generation Services Group.

Q. Please describe your educational background.

A. I received a Bachelor of Science Degree in Mechanical Engineering from Iowa State University in 1992. I am currently licensed as a Professional Engineer in the state of Missouri.

Q. Please describe your professional experience.

A. I have over 25 years of power and/or oil & gas experience acting in roles such as a Project Director, Project Manager, Engineering Manager, Process Engineer, and Design Engineer. My original specialty was air quality control. However, as a project manager and project director, I have been involved in projects that have covered a broad spectrum of technical areas.

Q. What are your duties and responsibilities as a Central Regional Area Director?

A. I am responsible for client satisfaction, project execution, and business capture for the central region of the United States.

For Southern Indiana Gas & Electric Company d/b/a Vectren Energy Delivery of Indiana, Inc.'s ("Vectren South" or the "Company"), I am the Project Director for the Culley ELG Analysis and the AB Brown CCPP Estimate Project. As Project Director I am responsible for overall execution of the project, for ensuring that the project is properly staffed, and that the Vectren South is satisfied with the work performed.

Q. Are you sponsoring any attachments in support of your testimony?

A. Yes. I am sponsoring Petitioner's Attachment No. DMF-1 through DMF-7, including the following:

EXHIBIT NUMBER	DESCRIPTION
Petitioner's Exhibit No. 10, Attachment DMF-1	Black & Veatch's Representative ELG Experience
Petitioner's Exhibit No. 10, Attachment DMF-2	Black & Veatch's Representative Ash Handling Experience
Petitioner's Exhibit No. 10, Attachment DMF-3	Black & Veatch's Representative Combined Cycle Combustion Turbine Experience
Petitioner's Exhibit No. 10, Attachment DMF-4 (CONFIDENTIAL)	FGD Treatment Evaluation Report (CONFIDENTIAL)
Petitioner's Exhibit No. 10, Attachment DMF-5 (CONFIDENTIAL)	Ash Transport Report (CONFIDENTIAL)
Petitioner's Exhibit No. 10, Attachment DMF-6 (CONFIDENTIAL)	EPC Basis of Estimate for the F-Class Configuration (CONFIDENTIAL)
Petitioner's Exhibit No. 10, Attachment DMF-7 (CONFIDENTIAL)	EPC Basis of Estimate for the H-Class Configuration (CONFIDENTIAL)

Q. Were the attachments identified above prepared or assembled by you or under your direction or supervision?

A. Yes, as the Project Director for Black & Veatch on these two projects.

Q. What is the purpose of your Direct Testimony in this proceeding?

A. The purpose of my testimony is to provide information regarding the engineering work completed by Black & Veatch related to Vectren South's proposal to comply with the Effluent Limitation Guidelines (ELG) in 40 CFR 423 that apply to FB Culley Generation Station (Culley) through its renewed NPDES permit and its proposal to install a new combined cycle power plant ("CCPP") on the AB Brown plant site. I will discuss each separately because we handled these activities as two separate projects.

I. Culley Retrofit to Meet ELG Requirements

Q. What are the ELG requirements that Culley Station is subject to?

A. Effluent Limitation Guidelines and standards (ELGs) are established by the Environmental Protection Agency (EPA) under the Clean Water Act (CWA). The CWA requires the EPA to develop the ELGs and enforce under the National Pollutant Discharge Elimination System (NPDES) permitting program. The NPDES permit program controls water pollution by regulating discharge point sources into bodies of water in the United States. Specifically, wastewater discharges from Culley Station are regulated under 40 CFR 423, Steam Electric Power Generating Point Source Category. Existing discharge point sources are required to comply with current wastewater effluent limitation guidelines. The current ELGs for the steam electric power generating existing sources and their applicability to Culley Station are listed in Table DMF-1. Additional details on the regulatory requirements are provided in testimony by Angila Retherford of Vectren South.

TABLE DMF-1
ELG LIMITS

WASTE STREAM/POLLUTANT	EXISTING SOURCE DIRECT DISCHARGE		APPLICABILITY
	BPT[a]	BAT[a]	F. B. CULLEY
All Waste Streams	pH: 6-9 S.U. PCBs[b]: Zero Discharge	PCBs: Zero Discharge	Yes
Low Volume Wastes	TSS: 100 ppm[1] / 30 ppm[2] Oil & Grease: 20 ppm[1] / 15 ppm[2]		Yes
FGD Wastewater	TSS: 100 ppm[1] / 30 ppm[2] Oil & Grease: 20 ppm[1] / 15 ppm[2]	Arsenic: 11 ppb[1] / 8 ppb[2]. Mercury: 788 ppt[1] / 356 ppt[2] Nitrate/nitrite as N: 17 ppm[1] / 4.4 ppm[2]. Selenium: 23 ppb[1] / 12 ppb[2]	Yes
FGMC Wastewater	TSS: 100 ppm[1] / 30 ppm[2] Oil & Grease: 20 ppm[1] / 15 ppm[2]	Zero Discharge	No
Gasification Wastewater	TSS: 100 ppm[1] / 30 ppm[2] Oil & Grease: 20 ppm[1] / 15 ppm[2]	Arsenic: 4 ppb[1]. Mercury: 1.8 ppt[1] / 1.3 ppt[2]. Selenium: 453 ppb[1] / 227 ppb[2] TDS: 38 ppm[1] / 22 ppm[2]	No
Combustion Residual Leachate	TSS: 100 ppm[1] / 30 ppm[2] Oil & Grease: 20 ppm[1] / 15 ppm[2]	TSS: 100 ppm[1] / 30 ppm[2] Oil & Grease: 20 ppm[1] / 15 ppm[2]	No
Fly Ash Transport	TSS: 100 ppm[1] / 30 ppm[2] Oil & Grease: 20 ppm[1] / 15 ppm[2]	Zero Discharge	Yes
Bottom Ash Transport	TSS: 100 ppm[1] / 30 ppm[2] Oil & Grease: 20 ppm[1] / 15 ppm[2]	Zero Discharge	Yes

TABLE DMF-1 ELG LIMITS			
	EXISTING SOURCE DIRECT DISCHARGE		APPLICABILITY
WASTE STREAM/POLLUTANT	BPT[(a)]	BAT[(a)]	F. B. CULLEY
Once-Through Cooling	Free Available Chlorine: 0.5 ppm[(3)] / 0.2 ppm[(4)]	Total Residual Chlorine if ≥25 MW: 0.2 ppm.[(5)] If ≤25 MW: Equal to BPT.	Yes
Cooling Tower Blowdown	Free Available Chlorine: 0.5 ppm[(3)] / 0.2 ppm[(4)]	Free Available Chlorine: 0.5 ppm[(3)] / 0.2 ppm[(4)]. 126 Priority Pollutants: Zero Discharge Except: Chromium: 0.2 ppm[(3)] / 0.2 ppm[(4)]. Zinc: 1.0 ppm[(3)] / 1.0 ppm[(4)].	No
Coal Pile Runoff	TSS: 50 ppm[5]		Yes
Chemical Metal Cleaning Wastes	TSS: 100 ppm[(1)] / 30 ppm[(2)] Oil & Grease: 20 ppm[(1)] / 15 ppm[(2)] Copper, total: 1 ppm[(1)] / 1 ppm[(2)] Iron, total: 1 ppm[(1)] / 1 ppm[(2)]	Copper: 1.0 ppm[(3)] / 1.0ppm[(4)] Iron: 1.0 ppm[(3)] / 1.0ppm[(4)]	Yes

Source: [40 CFR Part 423]

[(1)]Maximum concentration for any one day.

[(2)]Average daily values for 30 consecutive days.

[(3)]Maximum concentration.

[(4)]Average concentration.

[(5)]Instantaneous maximum.

[(a)]The pH of all discharges, except once-through cooling water, shall be within the range of 6.0 – 9.0. For all effluent guidelines, where two or more waste streams are combined, the total pollutant discharge quantity may not exceed the sum of allowable pollutant quantities for each individual waste stream. BAT, best practicable control technology currently available (BPT), and NSPS allow either mass or concentration based limitations.

[(b)]Polychlorinated biphenyl compounds (PCBs) commonly used in transformer fluid.

ppb = Parts per billion

ppt = Parts per trillion

tss = Total Suspended Solids

Q. What was Black & Veatch's role in Vectren South's analysis of the ELG requirements for Culley Station?

A. Vectren South has contracted with Black & Veatch in the evaluation of the ELG requirements for Culley. The focus of the ELG Compliance Program was to identify potential flue gas desulfurization (FGD) discharge water treatment alternatives and ash transport water alternatives that could be implemented at Culley to comply with the updated ELG requirements. The analysis performed by Black & Veatch was reduced into two written reports: one entitled "FGD Treatment Evaluation Report – F.B. Culley Station" (the "Discharge Treatment Report") which is attached hereto as Attachment DMF-4 (CONFIDENTIAL) and the other which is entitled "Bottom Ash Evaluation" (the "Ash Transport Report") which is attached hereto as Attachment DMF-5 (CONFIDENTIAL).

A. FGD Treatment and Discharge

Q. Please describe Black & Veatch and its qualification and experience with performing the work discussed in your testimony for FGD water.

A. Steven Williams is the Project Manager leading the engineering project for Black & Veatch. He is licensed as a Professional Engineer in the state of Indiana and is the responsible engineer. Alec Frank is a licensed Professional Chemical Engineer working under the direct supervision of Steven Williams. They are working under my direction and supervision. A representative list of our experience is provided as Attachment DMF-1.

Q. Please provide an overview of the Discharge Treatment Report.

A. The Discharge Treatment Report first provides a review of the updated ELG regulations, including timing of the respective rules and their application, and their impact on Culley.

The Discharge Treatment Report then discusses the initial screening process used to evaluate potential treatment technology alternatives that could be implemented at Culley to comply with the ELG requirements. The screening process evaluated design concept feasibility, capital expense and operating expense for each of the alternatives assessed. The Discharge Treatment Report next discusses the two main treatment alternatives that were considered in the analysis: (1) FGD treatment and discharge; and (2) zero liquid discharge (ZLD). The Discharge Treatment Report then evaluates three technology types within these two treatment alternatives. For the FGD treatment and discharge option, physical/chemical pretreatment with biological treatment technology was assessed, along with multiple vendors providing such technology. For ZLD, spray dryer evaporator (SDE) and brine concentrator/crystallizer technologies were assessed, along with multiple vendors providing such technologies. Diagrams of all the technologies evaluated can be found in Attachment D of the Discharge Treatment Report.

In addition to the initial technology screening process, the Discharge Treatment Report includes a sensitivity analysis which was conducted for specified technology systems within the two treatment alternatives. Each technology, and subsequent vendor, was evaluated in different operating scenarios to further assess their sensitivity to changes in capital cost, operating and maintenance costs and adaptability to each scenario. In addition, the Discharge Treatment Report includes a comparison amongst the vendors which was performed in order to properly assess the risks associated with each technology system. The Discharge Treatment Report also includes a cost assessment of all alternatives considered within the analysis.

I will provide further detail about each of these sections in the following pages of my testimony.

1. Initial Technology Screening

Q. What was the purpose of the Initial Technology Screening Black & Veatch used to evaluate alternative technologies?

A. As outlined in the Discharge Treatment Report, the purpose of the Initial Technology Screening was to assess potential technologies available for treating FGD wastewater to comply with the ELG requirements. A detailed summary of the initial technology screening is found in the Technology Matrix included within Appendix A of the Discharge Treatment Report.

Q. What was the first step in the process?

A. Before evaluating the technologies available to treat FGD discharge, Black & Veatch first contracted with an outside consultant, [redacted] to identify modifications to the existing FGD blowdown for the purpose of reducing wastewater discharge and optimizing the current system. This evaluation is discussed in Section 5.1 of the Discharge Treatment Report entitled "Water Reduction Opportunities." One of the modifications identified was to modulate/reduce the purge flow to the FGD mercury treatment system and reclaim more blowdown back into the system. The modification is being tested at Culley and, if successful, it is estimated the process would reduce FGD blowdown from 140 gpm to approximately 35 gpm. Vectren South and Black & Veatch used a design point blowdown flow rate of 50 gpm as a starting point for this evaluation, which includes design margin. This section of the Discharge Treatment Report also identifies a number of potential water saving opportunities including: boiler makeup and blowdown, reverse osmosis (RO) design flow rates, river water clarifier, potable water treatment and unit 3 floor drains.

In addition to making the modifications to the FGD blowdown system, the Discharge Treatment Report then evaluated potential FGD treatment and discharge options.

Q. Please discuss the process used for evaluating FGD treatment and discharge options.

A. As discussed in Section 5.2 of the Discharge Treatment Report entitled "FGD Treatment and Discharge" Black & Veatch first evaluated potential additions and modifications to the existing physical/chemical treatment system to treat the FGD wastewater. The Discharge Treatment Report provides more details on the system design and process, as well as the biological treatment system technology used to filter the wastewater. The Discharge Treatment Report also provides an estimated equipment footprint for the FGD treatment and discharge system, as well as an estimated timeline to design, procure, and install the physical/chemical/biological treatment system. The Discharge Treatment Report discusses the efficacy of the system, as well as optimal operational strategies and constraints.

Q. Provide a brief description of the physical/chemical/biological treatment system.

A. Physical/chemical/biological systems use physical tank structures and chemical reactions to reduce suspended solids and heavy metals from the wastewater. Because selenium cannot be effectively removed through physical/chemical means, a bio-filter is added to the system for selenium removal. The bio-filter uses microbes to remove the selenium from the wastewater.

Q. What are the advantages and disadvantages of the physical/chemical treatment system?

A. As discussed in Section 5.2.2 of the Discharge Treatment Report, Black and Veatch identified the following advantages of the physical/chemical treatment system: (1) it is a proven commercial process for FGD wastewater treatment; and (2) the system requires low energy consumption.

With respect to disadvantages of the system, Black & Veatch identified the following: (1) the solution requires operation of a biological system which requires specific personnel and higher O&M costs; (2) the system has little flexibility for changing FGD operation; and (3) the performance of the treatment system can be impacted by varying feed flow and quality.

Q. Besides FGD treatment and discharge, what other alternative did Black & Veatch consider in its analysis?

A. As discussed in Section 5.3 of the Discharge Treatment Report entitled "Zero Liquid Discharge," the other treatment alternative Black & Veatch considered was Zero Liquid Discharge (ZLD). For this option, Black & Veatch analyzed the following two technology types: spray dryer evaporator (SDE) and brine concentrator/crystallizer. With respect to SDE, the Discharge Treatment Report provides more details on the technology, as well as system design and process. The Discharge Treatment Report also provides an overview of the equipment and operational requirements of the system, as well as an estimated timeline for delivery of materials and a timeframe for design, procurement and installation. The Discharge Treatment Report also discusses the efficacy of such system, as well as optimal operational strategies and constraints.

Q. Please describe a spray dryer evaporator.

A. The spray dryer evaporator is an adaption of air quality control technology for use in wastewater control. The spray dryer absorber (evaporator) vessel is placed in the flue gas duct path just before the particulate control device. In the case of Culley, that would be the fabric filter. The wastewater is injected into the spray dryer evaporator where the heat from the flue gas will cause the wastewater to vaporize and exit with the rest of the flue gas through the rest of the flue gas train. The pollutants in the wastewater are now left in particulate form to be collected by the fabric filter and handled with the fly ash.

Q. What are the advantages and disadvantages of the spray dryer evaporator system technology?

As discussed in Section 5.3.2 of the Discharge Treatment Report, Black & Veatch identified the following advantages of the spray dryer evaporator treatment system: (1) it has low operational requirements and, in turn, low O&M costs; (2) there will be no FGD wastewater stream discharging from the site; and (3) the technology has the maximum flexibility to respond to future ELG regulatory updates that could set more stringent limits.

With respect to disadvantages of the system, Black & Veatch identified the following: (1) the system has little flexibility for changing FGD operation and flow rates; (2) the unit must be on line for wastewater to be evaporated; (3) there is zero water recovery to recycle back into the plant; and (4) the system requires high energy consumption.

Q. Please describe the other technology type Black & Veatch analyzed with respect to the Zero Liquid Discharge alternative.

A. As discussed in Section 5.3.3 of the Discharge Treatment Report entitled "Brine Concentrator and Crystallizer System Design," Black & Veatch also analyzed brine concentrator/crystallizer technology as part of its ZLD analysis. The Discharge Treatment Report provides an overview of the technology, as well as system design and process. The Discharge Treatment Report also provides more details on the equipment and utility requirements of the system, as well as an estimated timeframe for design, procurement and installation. The Discharge Treatment Report discusses the efficacy of the system, as well as optimal operational strategies and constraints.

Q. Please describe the brine concentrator and crystallizer system.

A. The brine concentrator/crystallizer system uses heat to concentrate the constituents in the wastewater and allow for their removal. First, a physical/chemical system (discussed earlier) is used for pretreatment. Then, the brine concentrator, which is essentially a water heater, heats the wastewater and boils off a large amount of the water, leaving a water/solids mix, called a slurry, to enter the crystallizer. There, more water is boiled off using plant steam. The remaining solids are dewatered and disposed of as a solid. The wastewater, which has been boiled off throughout the process, is captured and reused in the FGD system. Nutrients such as nitrate and nitrite will also need to be removed by a biological treatment system if high concentration levels are in the FGD blowdown. These nutrients cannot typically be converted in a physical/chemical process.

Q. What are the advantages and disadvantages of the brine concentrator and crystallizer technology?

A. As discussed in Section 5.3.4 of the Discharge Treatment Report, Black & Veatch identified the following advantages of the brine concentrator and crystallizer technology:

(1) it is a proven commercial process for FGD wastewater treatment; (2) there will be no FGD wastewater stream discharging from the site; and (3) the system allows for distillate recovery for plant reuse.

With respect to disadvantages of the system, Black & Veatch identified the following: (1) system maintenance and operations requires higher operating expenses with several unit operations; (2) the salt conversion in the pretreatment system can be prone to upsets; (3) periodic cleanings of the system are required; and (4) the system requires higher energy consumption.

2. Sensitivity Analysis

Q. What was the next step in the analysis performed by Black & Veatch?

A. After performing the initial technology screening process and analyzing the alternatives I just discussed, Black & Veatch conducted a sensitivity analysis for each of the specified technology systems within the two treatment alternatives. The sensitivity analysis is included in Section 6.0 of the Discharge Treatment Report entitled "Sensitivity Analysis;" the full analysis with scenario breakdown is included in Appendix B of the Discharge Treatment Report.

Q. Why did Black & Veatch perform the Sensitivity Analysis?

A. Black & Veatch performed the Sensitivity Analysis after the initial screening evaluation to broaden Vectren South's understanding of the impacts of changes in operation on each of the technologies. They wanted to understand whether or not a different operating scenario would change the preferred solution.

Q. Please describe the sensitivity analysis Black & Veatch conducted.

A. As discussed in Section 6.0 of the Discharge Treatment Report, Black & Veatch evaluated each technology, and subsequent vendor, in different operating scenarios in order to further assess the sensitivity of each technology to changes in capital cost and O&M costs. We also assessed the adaptability of the technologies to operate under changing scenarios. In addition, Black & Veatch performed a comparison amongst the vendors to properly assess the risks associated with each technology and system. This comparison included several site visits to observe the specific technology systems; the details of these site visits are also summarized in Section 6.0 of the Discharge Treatment Report.

Section 6.1 of the Discharge Treatment Report discusses the evaluation parameters and various operating scenarios used to evaluate the three systems. The analysis included seven (7) operating scenarios simulating different variables, including capacity factor and temperature. Scenarios included 80 gpm flowrate, 135 gpm flow rate, high operating capacity (75% annual operation), low operating capacity (15% annual operation), cycling (8-10 hours operation per day), off-line 3-4 months and low ambient temperature operation (-23 deg F). The analysis then modeled the capital costs, O&M costs and treatment capabilities for each system, in each scenario, to determine the impact of the variables and identify the best treatment solution to meet compliance.

Section 6.1 includes a list of the operating scenarios considered, as well as a table of specific vendors and technology types included within the sensitivity analysis.

Q. Does the Discharge Treatment Report include information related to the performance of each technology type in the sensitivity analysis performed by Black & Veatch?

A. Yes. The Discharge Treatment Report provides a detailed discussion regarding how each of the vendor-specific technology types fared within the sensitivity analysis and the various scenarios tested. Section 6.2 of the Discharge Treatment Report discusses the technology types evaluated for the physical/chemical/biological treatment alternative, with Sections 6.2.1 and 6.2.2 providing specific discussions of [redacted] pretreatment technologies. These sections provide an overall evaluation of each technology, including a discussion of how each technology performed in the scenarios, and information gathered during Black & Veatch's observations of the specific technologies.

Section 6.3 of the Discharge Treatment Report discusses the technology types evaluated for the spray dryer ZLD alternative, with Sections 6.3.1, 6.3.2 and 6.3.3 providing specific discussions of the spray dryer technology offerings of [redacted] respectively. These sections provide an overall evaluation of each vendor technology, including a discussion of how each technology performed in the sensitivity analysis scenarios, and information gathered by Black & Veatch during site visits.

Finally, Section 6.4 of the Discharge Treatment Report discusses the technology types evaluated for the brine concentrator/crystallizer ZLD alternative, with Sections 6.4.1, 6.4.2 and 6.4.3 providing specific discussions of [redacted] technology, [redacted] technology and [redacted] technology, respectively. These sections provide an overall evaluation of each vendor technology, including a discussion of how each technology performed in the sensitivity analysis scenarios, and information gathered by Black & Veatch during site visits.

3. Cost Analysis

Q. Did Black & Veatch evaluate the cost of each technology alternative or evaluate other economic criteria in its analysis?

A. Yes. Black & Veatch evaluated the costs estimates and economic criteria associated with each technology type in its analysis. A discussion of this evaluation is included in Section 7.0 of the Discharge Treatment Report entitled "Economic Criteria." In this section, Black & Veatch estimated the various costs associated with each technology alternative and technology type, including total direct costs, indirect costs, owner's cost and escalation, capital investment and annual O&M costs, in order to calculate the total net present value of each alternative. Black & Veatch also performed a capital cost comparison for each of the alternatives, as well as an O&M cost comparison for each of the alternatives in each of the 7 sensitivity analysis scenarios.

Q. How did Black & Veatch prepare the capital cost estimates for the selected technologies for FGD water?

A. Conceptual designs were developed by Black & Veatch to determine the quantities and sizes of equipment needed. Black & Veatch then priced and determined construction needs for that equipment. For the direct capital costs, vendor proposals were evaluated. The indirect and construction/installation costs were determined based on past Black & Veatch experience.

Q. How did B&V develop operation and maintenance ("O&M") cost estimates for FGD water?

A. For the annual O&M costs, each vendor provided cost estimates for maintenance duration and frequency as well as chemical or any other material consumption specific to their technology.

Q. What was the design basis for the cost estimates for FGD water?

A. The design basis for treatment equipment is 50 gallons per minute (gpm) of FGD wastewater. The maximum target for FGD wastewater is 135 gpm.

Q. What does Black & Veatch estimate these FGD water projects will cost?

A. Based on recommended technology, approximately $36M total installed cost (± 30%). A summary of the costs for each of the technologies evaluated is provided as Table DMF-2.

TABLE DMF-2
COST OF FGD WATER ELG COMPLIANCE OPTIONS

COSTS	ALTERNATIVE 1 PHYSICAL/CHEMICAL/ BIOLOGICAL TREATMENT[1] (CLASS 3)	ALTERNATIVE 2 SPRAY DRYER EVAPORATOR[2] (CLASS 3)	ALTERNATIVE 3 BRINE CONCENTRATOR/ CRYSTALLIZER[3] (CLASS 5)
Total Direct Costs	$15,972,920	$16,279,794	$23,275,000
Total Indirect Costs	$19,681,720	$20,180,330	$31,646,863
Total Capital Investment for System	**$35,654,641**	**$36,460,124**	**$54,921,863**
Total Annual O&M Costs	$1,039,349	$610,176	$1,599,586
Net Present Value[4]	**($18,858,186)**	**($15,854,086)**	**($44,599,658)**
Pilot Testing	**$370,000 for 6 months**	**Pilot Not Feasible**	**~$250,000 per month**

[redacted] year life. No taxes or escalation included.

Q. What costs are included in this estimate?

A. The following items are included in the cost estimate:

- Major equipment costs are based on in-house pricing.
- Direct costs include the costs associated with the purchase of equipment, erection, and all contractor services.
- General indirect costs include all necessary services required for checkouts, testing services, and commissioning.
- Insurance, including builder's risk and general liability.
- Field construction management services, including field management staff, supporting staff personnel, field contract administration, field inspection/quality assurance, and project controls.
- Technical direction and management of startup and testing, cleanup expense for the portion not included in the direct cost construction contracts, safety and medical services, guards and other security services, insurance premiums, performance bond, and liability insurance for equipment and tools.
- Transportation costs for equipment and materials delivery to the jobsite.
- Construction contractor contingency costs.
- Construction contractor typical profit margin.

We have not included owner's costs, which are estimated by other witnesses.

Q. What level of accuracy would you estimate these cost estimates represent?

A. The estimate is consistent with an AACE Class 3 cost estimate. Conceptual design up to 40% project definition for the purpose of budget and authorization. Expected cost estimate accuracy is +/- 30%.

4. Overall Recommendation

Q. Based on the initial technology assessment, the sensitivity analysis and the economic analysis performed, did Black & Veatch provide a final overall assessment or recommendation related to each technology?

A. Yes. Black & Veatch provided a final overall assessment of each technology and vendor offering based on its analysis and the following attributes: (1) start-up/ramp up reliability; (2) technology readiness risk; (3) adaptability to sensitivity analysis scenarios; (4) operation and control risk; (5) heat rate impact risk; (6) number of operators; (7) capital and annual O&M costs, including energy consumptions; (8) susceptibility to future environmental regulations; (9) overall financial stability and credit rating. This evaluation is included in Section 8.0 of the Discharge Treatment Report entitled "Final Assessment." Black & Veatch divided these attributes into "technical" and "commercial" and provided each technology a technical and commercial ranking. Black & Veatch then used these rankings to complete an "Attribute Assessment Matrix" comparing all of the technologies. This Matrix was then used to provide an overall of assessment of the technologies. It is included in Table 8-3 of the Discharge Treatment Report.

Q. What is Black & Veatch's overall assessment of the technology alternatives and types?

A. As discussed in Section 8.3 of the Discharge Treatment Report, the two treatment technologies that meet the highest ranked quality attributes are the [redacted] system and the SDE. However, given the relatively low capital and O&M costs and its high treatment readiness ranking, the SDE (Spray Dryer Evaporator) system (Alternative 2) ranked highest on the assessment. The one drawback of this system is its lack of adaptability to handle increased FGD wastewater flow rates. As shown in the Discharge

Treatment Report and throughout the assessment, 80 gpm is the preliminary design maximum FGD treatment flow rate for the SDE technology.

Q. What technology does Black & Veatch recommend for compliance with the ELG requirements for FGD water at Culley Station?

A. It is recommended that Vectren moves forward to a detailed engineering phase with SDE type technology if the maximum FGD wastewater flow rate of between 50 and 80 gpm is achieved through future testing and operations.

It should be noted that this recommendation will require that Vectren South continue to operate their newest throttling valve to reduce wastewater flow to between 50 and 80 gpm. This gives a reasonable margin on the design blowdown rate of 50 gpm.

Q. Why does Black & Veatch make this recommendation?

A. The SDE solution ranks the highest among all technologies based on the quality attributes discussed earlier. This solution is economically viable and provides a zero discharge solution if the minimum FGD wastewater flow rate of between 50 and 80 gpm is achieved. This solution is economically viable and provides a zero discharge solution if the maximum FGD wastewater flow rate of 80 gpm is achieved. The conceptual design evaluation indicated the SDE can be feasibly located and tied into the existing equipment at Culley. This ZLD solution also provides certainty that any future change in EPA regulations, such as reducing discharge limitations or adding new parameters, would not apply at Culley since there would be no discharge of FGD wastewater.

The conceptual design evaluation indicated the SDE can be feasibly located and tied into the existing equipment at Culley.

B. Ash Transport

Q. Please describe Black & Veatch and its qualification and experience with performing the work related to ash transport.

A. Steven Williams is the Project Manager leading the engineering project for Black & Veatch. He is licensed as a Professional Engineer in the state of Indiana and is the responsible engineer. Kyle Kropf is a licensed Professional Mechanical Engineer working under the direct supervision of Steven Williams. They are working under my direction and supervision. A representative list of our corporate experience is provided as Attachment DMF-2.

Q. What was the purpose of the analysis performed by Black & Veatch with respect to ash transport at Culley Station?

A. The purpose of the analysis was to identify alternative ash transport solutions that could be implemented at Culley to comply with ELG requirements. The evaluation performed by Black & Veatch focused specifically on identifying options for removal and dewatering of bottom ash from the Culley Unit 3 boiler with truck transport and disposal of the dry material at an off-site location. Unit 2 bottom ash options were not included in the evaluation, as Vectren has announced plans to retire the unit by December 31, 2023. As I testified previously, our analysis was reduced into a written report which I refer to as the Ash Transport Report. It is attached hereto as Attachment DMF-5 (CONFIDENTIAL).

Q. Please provide an overview of the Ash Transport Report.

A. The Ash Transport Report first provides a review of the updated environmental requirements, including ELG and CCR regulations, as well as their impact on Culley and the timing of the respective rules and application. The Ash Transport Report then discusses the evaluation Black & Veatch conducted with respect to the available ash transport alternatives. In its evaluation, Black & Veatch evaluated two categories of technologies: (1) dry conversion of the bottom ash system and (2) closed loop wet sluicing system. For the dry conversion system, Black & Veatch evaluated a submerged chain conveyor under the existing bottom ash hopper. For the closed loop wet sluicing system, Black & Veatch evaluated both a dewatering bunker and a remote submerged chain conveyor. The Ash Transport Report provides an overview and analysis of each of the alternatives considered, as well as a summary of the cost estimates for each alternative. The Ash Transport Report concludes with an overall recommendation of which alternative Black & Veatch believes Vectren should consider for further investigation and cost estimate refinement.

Q. Can you briefly describe what you mean by dry conversion and closed loop wet sluicing?

A "Dry conversion" means that the ash is being conveyed without the use of water. "Closed loop wet sluicing" means that the water used to convey the ash is reused over and over again by the system, in a loop. After the ash is conveyed out to its final destination for storage, the water is pumped back to the starting point to be used again.

Q. How did Black & Veatch decide what technologies to consider for addressing ash transport water?

A. An attribute assessment matrix was used to compare all technologies based on a set of quality attributes to select the preferred treatment for Culley Station. Quality attributes included:

- Technical Feasibility
- Total Installed Cost

- Operating and Maintenance Cost
- Estimated Additional Manpower (FTE)
- Estimated Footprint
- Major Equipment
- Advantages
- Disadvantages
- Reliability

Q. Please discuss the first alternative considered for Culley Unit 3.

A. As discussed in Section 4.1.2 of the Ash Transport Report, the first design concept Black & Veatch considered in its analysis consists of a new submerged chain conveyor. The submerged chain conveyor system would consist of a water filled lower trough with submerged drag chain flights attached to two chains to transport the ash. An inclined conveyor section would dewater the ash and discharge it directly into a dump truck, or three-sided concrete storage bunker for later loading into a dump truck, which would then haul the dewatered ash to an off-site location for disposal or recycling. The Ash Transport Report provides an overview of the conceptual design and major equipment required for this alternative, as well as the estimated time frame to design, procure, install, start up, test and commission the system.

Q. What are the advantages and disadvantages of this alternative?

A. As further discussed in Section 4.1.2 of the Ash Transport Report, the advantages of the submerged chain conveyor are as follows: (1) the system allows for the continued use of the existing bottom ash hopper and grinders; and (2) the system requires comparatively minimal new equipment. The disadvantages include: (1) the system requires truck operators throughout the day or a three-sides concrete bunker with front-end loaders; (2)

the system requires the installation of an additional weather structure over the exterior storage pile/truck loading platform; and (3) the system requires modification of the existing concrete foundation to provide clearances for the new submerged chain conveyor.

Q. Please discuss the second alternative considered for Culley Unit 3.

A. As discussed in Section 4.1.3 of the Ash Transport Report, the second design concept Black & Veatch considered in its analysis is a dewatering bunker. With this system, bottom ash is transferred from the existing bottom ash hoppers to a new bottom ash transfer tank using fast moving water under vacuum. From the transfer tank, ash is transferred by water to the dewatering bunker. A dewatering bunker is a square vessel sized for one day of ash storage that is designed to allow water to drain from the ash before it is loaded onto trucks for disposal. The Ash Transport Report provides an overview of the conceptual design and major equipment required for this alternative, as well as the estimated time frame to design, procure, install, start up, test and commission the system.

Q. What are the advantages and disadvantages of this alternative?

A. As further discussed in Section 4.1.3 of the Ash Transport Report, the advantages of the dewatering bunker are as follows: (1) the system allows for the continued use of the existing bottom ash hoppers, grinders and sluice pumps; and (2) the system requires minimal outage time for modifications to the existing boiler. The disadvantages include: (1) the system requires pumps, tanks and concrete structures and thus a large site area is needed; (2) the system requires numerous pieces of new equipment; (3) the system requires a significant amount of sluice piping to deliver the ash to the remote location for the new bunker; (4) the system requires front-end loaders with support crews; and (5) the system requires that ash sluicing water be maintained in a close loop.

Q. Please discuss the third alternative considered for Culley Unit 3.

A. As discussed in Section 4.1.4 of the Ash Transport Report, the third design concept Black & Veatch considered in its analysis is a remote submerged drag chain conveyor positioned outside of the existing Boiler Building. In this system, the existing bottom ash hopper and sluicing pump would deliver the ash to a new remote submerged drag chain conveyor that would dewater and deliver the ash to a three-sided concrete storage bunker for later loading into a dump truck, which would haul the ash to an off-site location for disposal or recycling. The Ash Transport Report provides an overview of the conceptual design and major equipment required for this alternative, as well as the estimated time frame to design, procure, install, start up, test and commission the system.

Q. What are the advantages and disadvantages of this alternative?

A. As further discussed in Section 4.1.4 of the Ash Transport Report, the general advantage of the remote submerged drag chain conveyor system is the system requires minimal outage time for modification to the existing boiler. The disadvantages include: (1) the system requires a new foundational support for the remote equipment; (2) the system requires weather protection for the remote collection trough; (3) the system requires a weather protection structure to control the ash in the three-sided bunker; (4) the system requires freeze protection for winter operation; (5) the system requires an additional booster pump to deliver the wet ash to the remote conveyor; and (6) the system requires that ash sluicing water be maintained in a close loop.

Q. Did Black & Veatch develop cost estimates for all technologies considered for addressing ash transport water?

A. Yes, as outlined in Section 5.0 of the Ash Transport Report, cost estimates were developed for all technologies considered.

Q. How did Black & Veatch prepare the capital cost estimates for the selected technologies for addressing ash transport water?

A. For the direct capital costs, vendor proposals were evaluated. The indirect and construction/installation costs were determined based on past Black & Veatch experience. In addition, the conceptual designs developed by Black & Veatch were used to determine the quantities and sizes of equipment needed. We then priced that equipment and determined construction needs for that equipment.

Q. How did Black & Veatch develop the ash disposal costs?

A. Onsite handling costs were estimated using RSMeans Heavy Construction Cost data book. This is an industry recognized, published source of cost data for the engineering and construction industry. Ash disposal costs were based on estimates from local disposal providers Charah and Solar Sources Mining.

Q. What was the design basis for the cost estimates for addressing ash transport water?

A. Ash production design basis was calculated based on historical unit operating data and defined capacity factor provided by Vectren South. The design basis for total bottom ash production for Unit 3 was [redacted] tons per year assuming a [redacted] percent unit capacity factor. An ash production rate of [redacted] pounds per hour was calculated by Black & Veatch using a heat rate of [redacted]

[redacted]

Q. What does Black & Veatch estimate these projects will cost?

A. Based on recommended technology, approximately $11M total installed cost (± 30%). A summary of the costs for each of the technologies evaluated is provided as Table DMF-3. Our recommendation is Alternative 1.

TABLE DMF-3
COST OF ASH TRANSPORT WATER COMPLIANCE OPTIONS

COSTS	ALTERNATIVE 1 SUBMERGED CHAIN CONVEYOR (CLASS 3)	ALTERNATIVE 2 DEWATERING BUNKER (CLASS 5)	ALTERNATIVE 3 REMOTE SUBMERGED CHAIN CONVEYOR (CLASS 5)
Total Direct Costs	$4,514,000	$8,226,000	$12,975,000
Total Indirect Costs	$6,437,600	$11,484,800	$17,942,050
Total Capital Investment for System	**$10,951,600**	**$19,710,800**	**$30,917,050**
Total Annual O&M Costs	$870,280	$1,217,520	$1,109,500
Total Levelized Annual Costs	$2,107,000	$3,371,900	$4,289,100

Q. What costs are included in this estimate?

B. The following items are included in the cost estimate:

- Major equipment costs are based on in-house pricing.
- Direct costs include the costs associated with the purchase of equipment, erection, and all contractor services.
- General indirect costs include all necessary services required for checkouts, testing services, and commissioning.
- Insurance, including builder's risk and general liability.

- Field construction management services, including field management staff, supporting staff personnel, field contract administration, field inspection/quality assurance, and project controls.
- Technical direction and management of startup and testing, cleanup expense for the portion not included in the direct cost construction contracts, safety and medical services, guards and other security services, insurance premiums, performance bond, and liability insurance for equipment and tools.
- Transportation costs for equipment and materials delivery to the jobsite.
- Construction contractor contingency costs.
- Construction contractor typical profit margin.

We did not include owner's costs, which are estimated by other witnesses.

Q. How would you characterize the level of accuracy of the cost estimates?

A. The estimate is consistent with an AACE Class 3 cost estimate for Alternative 1 Submerged Chain Conveyor and AACE Class 5 cost estimate for Alternative 2 Dewatering Bunker and Alternative 3 Remote Submerged Chain Conveyor. For Alternative 1, Black & Veatch completed conceptual design up to 40 percent project definition for the purpose of budget and authorization.

Q. What technology does Black & Veatch ultimately recommend for compliance with the ELG requirements to address ash transport water at Culley Station?

A. As discussed in Section 6.0 of the Ash Transport Report, for Unit 3, Black & Veatch recommends Alternative 1, Submerged Chain Conveyor.

Q. Why does Black & Veatch make this recommendation?

A. The Submerged Chain Conveyor provides the lowest installed cost solution and provides the commonly used technical solution to meet the ash transport water compliance required by the ELG requirements. Alternatives 2 and 3, the Dewatering Bunker and Remote Submerged Chain Conveyor, respectively, are not recommended for further investigation because of the complexity of design and comparatively higher installed cost to Alternative 1.

II. Estimate for a New Combined Cycle Power Plant (CCPP) at AB Brown Station

Q. How has Black & Veatch assisted in Vectren South's assessment of installing a new combined cycle power plant at AB Brown Station?

A. Black & Veatch assisted Vectren by developing conceptual designs and detailed cost estimates for installing several different options for a new combined cycle power plant on the AB Brown Station Site.

Q. Please describe Black & Veatch's qualification and experience with performing the work discussed in your testimony.

A. Steven Williams is the Project Manager leading the engineering project for Black & Veatch. He is licensed as a Professional Engineer in the state of Indiana and is the responsible engineer. Nathan Mentzer is the Engineering Manager and is a licensed Professional Mechanical Engineer working under the direct supervision of Steven Williams. They are working under my direction and supervision. A representative list of our corporate experience is provided as Attachment DMF-3.

Q. Describe the work performed by Black & Veatch.

A. Black & Veatch's work included three key activities:

- Development of a design basis

- Development of a conceptual design
- Development of a cost estimate

Q. Describe the work performed by Black & Veatch to develop a design basis.

A. Black & Veatch performed various design evaluations to provide Vectren South with the information needed to make decisions on the plant design and features. Some of the evaluations performed are as follows:

- **Reuse of Existing Utilities –** This study analyzed the potential for existing equipment to be reused for the new combined cycle.
- **Gas Bypass –** This evaluation studied the advantages and disadvantages of adding a flue gas bypass on each Combustion Turbine.
- **Redundant Equipment** – This evaluation of equipment redundancy examined the base system to determine the desired plant reliability. The results of this study were used as a basis of our cost estimates.
- **Ramp Rate –** This evaluation investigated the start-up and operational ramp rate (MW/min) of Combustion Turbine Generators (CTG) being considered for this project and their impact on the plant systems and major equipment including HRSG and Steam Turbine generator.
- **Start-up/Fast Start** – This evaluation examined designing the CCPP with "fast start" capabilities for start-up between ignition and minimum emission compliance levels.

- **Simultaneous vs. Sequential Starting** – This evaluation studied auxiliary electrical system design analysis impacts due to starting the CTGs at the same time or starting the CTGs one after the other.
- **Cooling Towers** (use of existing vs. new) – This study analyzed the design impacts and cost comparison of using one or both existing cooling towers and circulating water pipe for the new CCPP.
- **Water Makeup, Demin and Wastewater Systems** – The existing makeup water, demin and wastewater systems were evaluated to determine adequacy for the permanent installation of the new combined cycle.
- **Auxiliary Boiler** – This evaluation examined adding an auxiliary boiler and associated interconnecting piping to generate sparging steam for the HRSG and condenser and seal steam for the steam turbine to maintain temperatures and condenser vacuum while the unit is offline to enable desired Startup capabilities.
- **Level 2 Schedule** - Black & Veatch created a level 2 schedule based on the scope of work outlined in the Project Execution phase.
- **Labor and Construction Market Study** – Black & Veatch performed a Labor and Construction Market study regarding the anticipated labor market and the prices that may be required to attract and retain construction field professionals in the Evansville Area. This labor study was performed by surveying the area for other projects that may require the same skills to obtain an estimate of the going rate for the same type of field professionals.

- **2023 Sequence Scheduling** – This study reviewed coordination and various limitations due to simultaneous operations that will occur during the transition from the existing coal plant to the new CCPP.

There are individual reports in my workpapers supporting and describing every one of these evaluations.

Q. Describe the work performed by Black & Veatch to develop a conceptual design.

A. In order to support the viability of the project cost estimate, several conceptual designs for the new CCPP were developed. For each design, Black & Veatch developed the following design documents:

- Process Flow Diagrams
- Heat Balances
- Water Balance (including makeup water treatment and wastewater treatment)
- Equipment Lists
- Site Arrangement
- Geotechnical Investigation
- One-Lines
- Load List
- Communications Networking Diagram
- Construction Plan
- Commission/Startup Plan
- Schedule - Level 2
- Bill-of-Quantities

These documents are also included in my workpapers.

Q. After preparing the conceptual design, what work was next?

A. For purposes of preliminary design, we identified 10 plant alternatives for purposes of estimating costs, and those 10 alternatives fall into three classes of CCCP: F Class 2x1; H Class 2x1; and H Class 1x1. The 10 plants are identified in Attachment DMF-6 (CONFIDENTIAL) – EPC Cost-Basis of Estimate ("Basis of Estimate"). After the conceptual design, we eliminated the H Class 1x1 alternative. This left 7 alternatives for detailed costing.

Q. Why did you eliminate the H Class 1 x 1 alternative?

A. The H Class 1 x 1 alternative did not produce the amount of power (in megawatts) to meet Vectren South's capacity needs.

Q. Describe the work performed by Black & Veatch to develop cost estimates.

A. This is further explained in the Basis of Estimate. For each cost estimate, Black & Veatch developed specifications, issued equipment RFPs, evaluated bids, and obtained competitive pricing for all aspects of the designs.

Black & Veatch performed internal construction cost estimates and obtained competitive pricing from local construction and erection contractors.

Bids were obtained for the following equipment and materials:

- Combustion Turbines
- Steam Turbine
- Heat Recovery Steam Generators
- Cooling Tower
- Surface Condenser
- Generator Step-Up Transformers

- Circulating Water Pumps
- Boiler Feed Pumps
- Condensate Pumps
- Closed Cooling Water Pumps and Heat Exchangers
- Fuel Gas Supply and Regulating Equipment
- Cycle Chemical Feed Equipment
- Unit Aux Transformers (UATs)
- Auxiliary Boiler
- Structural Steel

Q. What technologies were evaluated by Black & Veatch?

A. Detailed cost estimates were finalized for two plant configurations alternatives. Those configurations are as follows:

- 2 x 1 F- Class Option, With Duct Burners, EPC Contract Basis
- 2 x 1 H-Class Option, Without Duct Firing, EPC Contract Basis

Q. How did you arrive at two plant configuration alternatives from the seven that were included in your conceptual design phase?

A. The final two were selected based on evaluating the following criteria:

- Operations and maintenance costs
- Plant efficiency and heat rate vs. capital costs
- Plant output versus Vectren South's target generation needs

The two selected configurations were identified as best balancing Vectren South's needs.

Q. What does "EPC Contract Basis" mean?

A. "EPC" stands for "Engineer", "Procure", and "Construct". The contractor, known as the "EPC Contractor", would be responsible for obtaining all specified equipment, designing the plant, constructing the plant, and assuming the project cost and schedule risk associated with completing the plant.

This contracting basis is different than the other typical method of completing a project, which is called a "multiple lump sum basis". In this method, the Owner would be responsible for obtaining all the individual contracts to complete the project.

Q. How did Black & Veatch decide which technologies to consider?

A. We first learned from discussions with Vectren South the generation and capacity needs. From that, Black & Veatch was able to recommend options that would meet those needs. Vectren South has determined their generation and capacity needs through their generation system modeling and Integrated Resource Plan, which is being addressed by a separate consultant. A detailed discussion of how Vectren South determined their need can be found in the direct testimony of Mr. Wayne Games. Vectren South's generation need is outside the scope of what I did.

Q. Explain the components of the capital cost estimates.

A. Black & Veatch developed capital cost estimates for items in the following cost categories:

- Direct Costs – costs for equipment, commodities, labor, engineering, transportation, and services associated with building the new facility.
- Indirect costs – this includes costs for construction management, site development, site services (trash removal, port-a-johns, construction trailers, etc.), cranes, testing services, site utilities, and other costs that are not

directly attributable to the construction of the facility but are needed to complete the project.

- G&A Costs – General and accounting – this is the overhead costs for the contractor to complete the project
- Contingency – this is the EPC contractor's allocation to account for the unknown costs associated with the project
- Profit – this accounts for the EPC contractor's profits on the project
- Escalation – this accounts for the cost required to present the price in 2023 dollars instead of 2017 dollars (estimate year).

Q. How were these cost estimates determined?

A. Based on the conceptual design developed by Black & Veatch, we solicited and evaluated competitive bids for all equipment and construction for both technologies.

Because Black & Veatch is an EPC contractor, we are aware of the drivers for the remaining costs that make up the total EPC cost (such as indirects, contingency, overhead, and profit). Based upon our experience with responding to such RFPs, we have been able to build the estimates of these components into our total estimate.

Q. Indiana Code § 8-1-8.5-6(e) requires that for a proposal to construct a generating facility of this size, the estimated costs must, to the extent commercially practicable, be the result of competitively bid engineering, procurement or construction contracts, as applicable. Does your estimate satisfy this?

A. Yes. First, I would note that engineering, procurement "or" construction contracts is not the same thing as an EPC contract. An EPC contract is engineering, procurement "and" construction. With that said, Black & Veatch's cost estimate is based on competitively bid pricing for procurement (Equipment) and construction contracts. We did not competitively bid engineering because it is not commercially practicable to do so.

Q. Why is it not commercially practicable to competitively bid engineering contracts?

A. Black & Veatch is an engineering firm. Our competitors are not going to provide us their bids for engineering services. Because we are an engineering firm, we are fully capable of providing reliable estimates for those contracts and our estimate is within the ± 10% range.

Q. What level of accuracy would you estimate these cost estimates represent?

A. The cost estimate for the project represents a +/- 10% estimate for equipment and a +/- 10% estimate for construction.

Q. What was the design basis for the cost estimates?

A. Table DMF-4 Is the design basis for our conceptual design.

TABLE DMF-4
DESIGN BASIS

ITEM	DESCRIPTION
Nominal Plant Capacity (F-Class Design)	~850 MW net
Nominal Plant Capacity (H-Class Design)	~ 1050 MW net
Configuration	2x1 Combined Cycle
Project Location	Posey County, Indiana Coordinates (Google Earth): 37°54'18.17"N 87°42'55.54"W
Unit Number	Unit 5 (South CTG), Unit 6 (North CTG), Unit 7 (STG)
Operation Mode	Daily Cycling
Design Life	30 years
Yearly Operating Hours	Up to 8,760

TABLE DMF-4 DESIGN BASIS	
ITEM	**DESCRIPTION**
Annual Capacity Factor	45% to 100%
Total Starts Per Combustion Turbine	<310
Fuel	
Primary Fuel	Natural Gas
General Design Data:	
Building Code	2014 Indiana Building Code (IBC 2012)
Risk Category	III
Site Elevation (Mean Sea Level), ft	415
Wind Design Data:	
Ultimate Design Wind Speed, Vult, Nominal 3 second gust wind speed at 33 ft above ground for Exposure C category, mph	120
Exposure Category	C
Topographic Factor, Kzt	1.0
Snow Design Data:	
Ground Snow Load, Pg, lb/ft2	20
Importance Factor (Snow Loads), I	1.1
Seismic Design Data:	
Short Period Mapped Spectral Acceleration, Ss	0.616g
One Second Period Mapped Spectral Acceleration, S1	0.213g
Site Class	D
Design Spectral Response Acceleration Parameter, SDS	0.537g
Design Spectral Response Acceleration Parameter, SD1	0.280g
Seismic Design Category	D
Importance Factor (Seismic Loads), I	1.25

Q. What does Black & Veatch estimate the project will cost?

A. Table DMF-5 (confidential) below presents the EPC costs for the new combustion turbines combined cycle project. Costs shown are for the F-Class configuration and for the H-Class configuration. Table DMF-5 (public) is a public version of the more detailed and confidential estimate.

Table DMF-5 (CONFIDENTIAL) Capital Costs for a New Combined Cycle Project		
Description	**2 x 1 F-Class**	**2 x 1 H-Class**
Direct Costs		
Sitework	[redacted]	[redacted]
Foundations & Concrete	[redacted]	[redacted]
Buildings	[redacted]	[redacted]
Steel	[redacted]	[redacted]
Mechanical Equipment	[redacted]	[redacted]
Piping	[redacted]	[redacted]
Electrical Equipment	[redacted]	[redacted]
Electrical Bulks	[redacted]	[redacted]
Instrument Equipment	[redacted]	[redacted]
Instrument Bulks	[redacted]	[redacted]
Insulation	[redacted]	[redacted]
Painting	[redacted]	[redacted]
Switchyard	[redacted]	[redacted]
Construction Management and Indirects	[redacted]	[redacted]
Engineering	[redacted]	[redacted]
Project Indirects	[redacted]	[redacted]
EPC Contingency	[redacted]	[redacted]
EPC Overhead & Profit	[redacted]	[redacted]
EPC Overhead and Profit Revisions for	[redacted]	[redacted]

Table DMF-5 (CONFIDENTIAL) Capital Costs for a New Combined Cycle Project		
Description	**2 x 1 F-Class**	**2 x 1 H-Class**
Direct Costs		
Owner Procuring Power Island		
Subtotal	**$549,000,000**	**$696,000,000**
EPC Project Costs Escalation	**$33,000,000**	**$43,000,000**
Total EPC Project Costs (Excluding Owner Costs)	**$582,000,000**	**$739,000,000**

Q. Did Black & Veatch include escalation in your estimate?

A. Yes, Black & Veatch included escalation provided by Vectren South.

Table DMF-5 (PUBLIC) Capital Costs for a New Combined Cycle Project		
Description	**2 x 1 F-Class**	**2 x 1 H-Class**
Direct Project Costs	$424,000,000	$589,000,000
Indirect Project Costs	$126,000,000	$150,000,000
Total Project Costs	**$582,000,000**	**$739,000,000**

Q. What does Black & Veatch estimate the operating characteristics for this project to be?

A. The table below presents the operating characteristics for the two configurations evaluated by Black & Veatch.

Table DMF-6 Operating Characteristics for the New Combined Cycle Project		
Description	**2 x 1 F-Class**	**2 x 1 H-Class**
Fuel Gas Flow, lbs/hr	275,000	306,000

Table DMF-6 Operating Characteristics for the New Combined Cycle Project		
Description	**2 x 1 F-Class**	**2 x 1 H-Class**
Estimated Heat Rate/Efficiency at full load without Duct Firing, (Btu/kWh, HHV)	6,540	6,220
Estimated Heat Rate/Efficiency at full load fully fired, (Btu/kWh, HHV)	6,885	N/A

III. Conclusion

Q. Does this conclude your prepared direct testimony?

A. Yes, at this time.

VERIFICATION

The undersigned affirms under the penalties for perjury that the foregoing testimony is true to the best of her knowledge, information and belief.

Diane M. Fischer

ATTACHMENT NO. DMF-1
REPRESENTATIVE ELG EXPERIENCE

The following are several recent projects of the more than 300 industrial water and wastewater projects Black &Veatch has executed. These projects have been selected to highlight our wide experience in delivering integrated water and wastewater treatment solutions in the Energy sector.

Ameren Missouri
Labadie, Rush Island and Sioux Station ELG Wastewater Treatment Detailed Design
2014 - Present
Black & Veatch is providing engineering services for the detailed design of the new wastewater treatment systems to be installed at the three power stations to facilitate closure of the ash impoundments. These treatment systems include low volume wastewater solids settling systems, neutralization systems, and storm water management systems.

Kansas City Power & Light
Iatan Station FGD Wastewater Spray Drier Installation
2014 – Present
Black & Veatch is providing engineering services for the detailed design and installation of a new spray drier evaporator to treat FGD wastewater. The spray drier is being installed as part of the flue gas train and represents the first such treatment installation in this configuration in North America.

Southern Company
Plant Barry Wastewater Management Project
2016 – Present
Black & Veatch is providing engineering services for the detailed design and installation of FGD wastewater, low volume wastewater, coal pile runoff, and miscellaneous plant modifications to implement ELG compliance solution for Plant Barry.

Gulf Power Company
Plant Crist Scrubber Addition
2006-2011
Black & Veatch provided engineering, procurement support and construction support services for the balance of plant design for the Plant Crist scrubber project. The balance of plant design included the water supply, wastewater collection, and wastewater treatment systems as well as coordination and design of interfaces within the existing facility.
The wastewater treatment system consisted of physical/chemical treatment, including two 115 gpm trains to reduce suspended solids and heavy metals in the scrubber bleed stream. Each train consisted of a desaturation tank, coagulation tank, clarifier, neutralization tank, gravity filter, filter press, and associated chemical feed equipment.

Orlando Utilities Commission (OUC)
Stanton Energy Center Demineralizer and Brine Plant Expansion
2007-2011
Black & Veatch has provided extensive engineering services at the OUC Stanton Energy Center. Most recently, Black & Veatch provided engineering, procurement and construction support services to support replacement of the Unit 1 brine concentrator/crystallizer treatment equipment with a new, 600 gpm brine concentrator/crystallizer

Prior to this, Black & Veatch provided engineering, procurement support and construction support services for an addition to the existing station demineralizer and zero liquid discharge brine plant as part of an expansion of the Stanton Site power generation capabilities. The addition included both the water/wastewater treatment systems as well as building additions and modifications necessary to house the new systems and coordination and design of all interfaces with the existing facility.

The demineralizer addition consisted of three 300 gpm multimedia pressure filters, a 300 gpm four bed demineralizer (strong acid cation, weak based anion, strong base anion, mixed bed) with a vacuum degasifier, and onsite regeneration equipment. The demineralizer was located in an expansion of the existing water treatment building. The new demineralizer utilized some existing equipment for regeneration.

The brine plant addition consisted of one 600 gpm brine concentrator/crystallizer train with associated balance of plant equipment. The brine plant addition was located in an expansion of the existing wastewater treatment building.

Black & Veatch provided engineering, procurement and construction management services for the construction of the pulverized coal Units 1 and 2 at this site, including the brine concentrators/crystallizers provided to support the zero liquid discharge water management approach at the plant.

Sandy Creek Services
Sandy Creek Power Station
2009-2013

Black & Veatch, in a joint venture with its construction partners, is providing EPC for Sandy Creek Power Station, a 900 MW supercritical pulverized coal unit in Riesel, Texas.
Makeup water is treated water from the City of Waco Municipal treatment plant. A 10,000 gpm lime softener/filtration system pretreats the water for use as cooling tower makeup and plant service/fire water. The demineralizer consists of two 200 gpm RO units, and two 165 gpm mixed beds with onsite regeneration equipment. Wastewater from the coal pile runoff pond is treated for solids reduction prior to discharge, with the majority of the plant wastewater to the Brazos River.

ATTACHMENT NO. DMF-2
Black & Veatch's Representative Ash Handling Experience

Client / Plant Name	Unit	Location	Capacity MW	Year Complete
Kansas City Board of Public Utilities, Nearman Creek Power Station	Unit 1	USA, Kansas	235MW	2014-Ongoing
Confidential Client	Unit 1, 2 and 3	USA	550 (plant)	2016-Ongoing
Westar Energy, Jeffrey and Lawrence Energy Center	Unit 1-3 Unit 4 & 5	USA, Kansas	3 x 720, 114 & 403	2016
ACWA, Khanyisa Station	Unit 1 &2	South Africa, Witbank	2 x 153	2016
SaskPower, Shand Station	Unit 1	Canada, Province of Saskatchewan, City of Estevan	300	2014-2015
Confidential Client	Unit 1-3	United Kingdom, Lynemouth	3 x 140	2015
Seminole Electric Cooperative (SECI) / Seminole Generating Station (SGS)	Units 1 & 2	Florida, Putnam	2 x 715	2011-2012
City of Ames, City of Ames Plant	7 and 8	USA Iowa	38, 71	2012
American Natural Gas Association (ANGA)	Numerous	Entire US	Various	2010
Confidential Client		USA Kentucky	4 x 480 MW	2010
Suncor, Inc. - CPU Power Canada, Ltd. / Three Roses Power Project	-----	-----	270	Cancelled
Confidential Client	-----	USA, Kentucky	4 x 480	2010
Jacksonville Electric Authority / Northside	Unit 1 and 2	Florida,	2 x 275	2001
Iowa State University / Utility Heating Plant	Units 1 - 7	Iowa	175k #/hr.	1999
Moapa Energy Ltd. Partnership / Moapa Generation Station	-----	-----	53	1997
Black Hills Power & Light / Neil Simpson	Unit 2	Wyoming, Gillette	80	1996

ATTACHMENT NO. DMF-2
Black & Veatch's Representative Ash Handling Experience

Client / Plant Name	Unit	Location	Capacity MW	Year Complete
US Generating Company / Cedar Bay	Unit 1	Jacksonville, Florida	250	1994
AES Barbers Point, Inc.	Unit 1	Hawaii, Honolulu	180	1993
AES Thames, Inc.	Unit 1	Connecticut, Thames	180	1990
Jackson County Resource Recovery Facility	Unit 1	Jackson, Michigan	4	1987
Electricity Generating Authority of Thailand	-----	Map Ta Phut, Thailand	-----	-----
Montana-Dakota Utilities	-----	-----	-----	-----

ATTACHMENT NO. DMF-3

BLACK & VEATCH'S REPRESENTATIVE CONCEPTUAL DESIGN AND COST ESTIMATE EXPERIENCE FOR COMBINED CYCLE COMBUSTION TURBINE PROJECTS

BLACK & VEATCH - COMBUSTION TURBINE EXPERIENCE					
CLIENT	PLANT AND LOCATION	REGION	SIZE MW	COMBUSTION TURBINE	YEAR COMPLETE
GAMA Power Systems	Hamitabat Project; Turkey	EMEIA	1200	1 x 1 (2); Siemen SGT5-8000H (SS)	2018
SK E&S	Jangmoon Combined Cycle Power Plant; Paju City, South Korea	Asia	1820	2 x 1 (2); Siemens SGT6-8000H+	2017
GAMA Power Systems	Kazanskaya Project; Russia	EMEIA	390	1 x 1; General Electric 9H	2017
Tampa Electric Company	Polk County Combined Cycle Conversion; Florida	Americas	460	4 x 1; General Electric 7FA	2017
Exelon	Project Phoenix; Texas	Americas	2000	2 x 1 (2); General Electric 7HA.02	2017
Grand River Dam Authority	GREC Unit 3; Oklahoma	Americas	495	1 X 1; Mitsubishi 501J (SS)	2017
Portland General Electric	Carty Generating Station Unit 1	Americas	440	1 x 1; Mitsubishi Heavy Industries 501GAC	2013
IRPC Public Company Limited	PMC for Two SPP Projects	Asia	120	2 x 1; Siemens SGT5-8000H	2012
Reliance Energy	Samalkot Power Plant; India	EMEIA	2500	2 x 1 (3); General Electric 9FA	2012
Sunrise Power Company (Chevron Texaco/Edison Mission)	Sunrise Power (Simple Cycle Conversion to Combined Cycle); California	Americas	570	2 x 1; General Electric 7FA	2003
Florida Power & Light Co. (FPL)	Sanford Repowering; Florida	Americas	2020	4 x 1 (2); General Electric 7FA	2002
Kissimmee Utility Authority / Florida Municipal Power Agency	Kissimmee Cane Island Unit 3; Florida	Americas	250	1 x 1; General Electric 7FA	2002
Florida Power & Light Co. (FPL)	Fort Myers Repowering; Florida	Americas	1530	6 x 2; General Electric 7FA	2002
Tuas Power Ltd.	Tuas Project; Singapore	Asia	720	1 x 1 (2); Mitsubishi Heavy Industries	2001

BLACK & VEATCH - COMBUSTION TURBINE EXPERIENCE					
CLIENT	**PLANT AND LOCATION**	**REGION**	**SIZE MW**	**COMBUSTION TURBINE**	**YEAR COMPLETE**
				701F (SS)	
CheveronTexaco / Edison Mission Energy	Sunrise Power Project; California	Americas	570	2 x 2; General Electric 7FA	2003
Empire District Electric Company	State Line Combined Cycle Project; Missouri	Americas	504	2 x 1; Siemens Westinghouse 501F	2001
Milford Power Company LLC	Milford Power Project; Connecticut	Americas	544	2 x 1; ABB GT24N	2001
City of Klamath Falls	Klamath Cogeneration Project; Oregon	Americas	500	2 x 1; Siemens Westinghouse 501F	2001
PP&L Global and Duke Energy	Griffith Energy Project; Arizona	Americas	500	2 x 1; General Electric 7FA	2001
Tenaska Frontier Partners Ltd.	Frontier Generating Station; Grimes County, Texas	Americas	830	3 x 1; General Electric 7FA	2000
City Public Service (CPS) of San Antonio	CPS Combined Cycle Unit; Texas	Americas	500	2 x 1; General Electric 7FA	2000

REV. F DRAFT

FGD TREATMENT EVALUATION REPORT

F.B. Culley Station

BLACK & VEATCH PROJECT NO. 190507
BLACK & VEATCH FILE NO. 41.4200

PREPARED FOR

Vectren Corporation

MARCH 16, 2018

BLACK & VEATCH

Reviewed by: 3/16/18

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1.0 Executive Summary

Southern Indiana Gas and Electric Company d/b/a Vectren Power Supply, Inc. (Company) has contracted with Black & Veatch Corporation (Consultant) in the evaluation of effluent limitation guideline (ELG) requirements for F.B. Culley (FBC) Power Station.

The focus of the ELG Compliance Program was to identify potential flue gas desulfurization (FGD) discharge water treatment alternatives that could be implemented at FBC to comply with the updated ELG regulations. This report provides a review of the updated ELG requirements and their impact on FBC, including timing of the respective rules and application. An initial screening evaluation of treatment technology alternatives with respect to the updated ELG rulings, including design concepts feasibility and capital and operating expenses for each alternative assessed, is also included. Appendix A contains the initial technology screening matrix. Two main treatment alternatives are considered in this study: (1) FGD treatment and discharge and (2) zero liquid discharge (ZLD). Within these two treatment alternatives, three technology types with multiple vendors were evaluated: physical/chemical pretreatment with biological treatment, and for ZLD, the spray dryer evaporator (SDE) and brine concentrator/crystallizer.

In addition to the initial technology screening, a sensitivity analysis was conducted for specified technology systems of the two treatment alternatives. Each technology, and subsequent vendor, was evaluated at different operating scenarios to further assess their sensitivity to changes in capital cost, operating and maintenance (O&M) costs, and adaptability to these scenarios. In addition, a comparison amongst the vendors was performed to properly assess the risks associated with each system. Several site visits occurred to observe specific technology systems. Appendix B contains the Sensitivity Analysis Matrix.

A cost comparison is provided in Table 1-1. As indicated in Table 1-1, Class 3 cost estimates were developed for the Physical/Chemical/Biological Treatment (Alternative 1) and the Spray Dryer Evaporator (Alternative 2). A Class 5 estimate was developed for the Brine Concentrator/ Crystallizer (Alternative 3). Appendix C contains the list of assumptions Black & Veatch used to complete the cost assessment for all alternatives. Appendix B contains the Sensitivity Analysis Matrix that further details the costs associated with each alternative and each vendor.

Table 1-1 Cost Assessment Summary (50 gpm Treatment Flow Rate)

COSTS	ALTERNATIVE 1 PHYSICAL/CHEMICAL/ BIOLOGICAL TREATMENT[1] (CLASS 3)	ALTERNATIVE 2 SPRAY DRYER EVAPORATOR[2] (CLASS 3)	ALTERNATIVE 3 BRINE CONCENTRATOR/ CRYSTALLIZER[3] (CLASS 5)
Total Direct Costs	$15,972,920	$16,279,794	$23,275,000
Total Indirect Costs	$13,576,982	$13,932,430	$19,783,750
Owner's Cost, Escalation, and Pilot Testing	$6,104,738	$6,247,900	$11,863,113
Total Capital Investment	**$35,654,641**	**$36,460,124**	**$54,921,863**
Total Annual O&M Costs	$1,039,349	$610,176	$1,599,586
Net Present Value[4]	**($18,858,186)**	**($15,854,086)**	**($44,599,658)**
Pilot Testing	**$370,000 for 6 months**	**Pilot not Feasible**	**~$250,000 per month**

[redacted]

4. Six percent discount rate at 20 year life. No taxes or escalation included.

An Attribute Assessment Matrix was created to compare each of the technologies with a list of quality attributes of a technology system. An abbreviated Attribute Assessment Matrix is shown in Table 1-2. This matrix compared the top vendor of each technology type with the top attributes ranked by importance. A higher total number equates to a better overall ranking. The full Attribute Assessment Matrix and an explanation for how the score total numbers were determined can be found in Section 8.0 of this report.

Table 1-2 Attribute Assessment Matrix (Abbreviated)

TECHNOLOGY	VENDOR	ASSESSMENT SCORE
Physical/Chemical and Biological	[redacted]	146
	[redacted]	127
ZLD - SDE	[redacted]	154
	[redacted]	145
	[redacted]	147
ZLD - Brine Concentrator	[redacted]	106
	[redacted]	94

As shown in Table 1-2, the SDE [redacted] ranks the highest among all technologies and vendors. The SDE can be feasibly located and tied into the existing equipment at FBC. In addition, [redacted] SDE has low O&M costs, demanding the least manpower for operations. With the SDE, however, FBC may face heat rate and fly ash impacts. At a treatment flow rate of 80 gallons per minute (gpm) at full load, FBC would lose nearly 170 British thermal units per kilowatt-hour (Btu/kWh) with an auxiliary power loss of nearly 330 kilowatts (kW). The fly ash is predicted to still be of quality to sell; however, more analysis and confirmation shall take place on the fuel source and required quality of the fly ash. Additional details on the heat rate and fly ash impacts can be found in Appendix D.

Throughout the course of the ELG evaluation and sensitivity analysis, it has been assumed that FBC will achieve the target treatment flow rate of 50 gpm. FBC is working with [redacted] to throttle the flow rate lower through testing and analysis. As discussions have taken place during this evaluation period, it was noted that the flow rate has been successfully throttled to approximately 100 gpm to120 gpm thus far. It is assumed that the flow rate will continue to decrease before installation of the FGD wastewater treatment system; however, further analysis will need to be conducted if the flow rate is unable to throttle below 80 gpm due to failure of the SDE to feasibly operate above this flow rate. Further explanations and detailed cost comparisons are shown in the Sensitivity Analysis Matrix in Appendix B.

Vectren also contracted with Black & Veatch in the evaluation of alternative bottom ash designs for FBC Power Station and summarized its analysis findings in a subsequent Bottom Ash Evaluation report. The Unit 2 bottom ash evaluation information was excluded from this Bottom Ash report and subsequent sensitivity analysis in November 2016 based on the Integrated Resource Plan (IRP) preferred case. Appendix H includes information which represents the evaluation at that time but should not be considered a final analysis of the FBC Unit 2 bottom ash alternative design.

2.0 Introduction

2.1 GENERAL FACILITY OVERVIEW

FBC is a two unit, 360 megawatt (MW) coal fired electricity generating power facility located on the northern bank of the Ohio River, southeast of Newburgh, Indiana. Two units are in operation at FBC: a 90 MW Unit 2 and a 270 MW Unit 3.

FBC receives water for cooling from a combination of two sources: the Ohio River and from water wells. Well water is used for makeup to the potable water pretreatment system. For heat rejection, the condenser cooling system is a closed cycle system utilizing water from the river as makeup. The river also provides makeup to the FGD system.

Plant wastewater is currently routed to a single outfall, Outfall 001, for discharge into the Ohio River.

2.2 EVALUATION OBJECTIVE

The focus of the ELG Compliance Program for FBC was to identify FGD wastewater treatment technologies, as well as any water reclamation or elimination options for each stream that discharges into the east ash pond that could be implemented at FBC to comply with coal combustion residual (CCR) regulations and 40 Code of Federal Regulations (CFR) 423 ELG regulations. Black & Veatch's evaluation was completed in two parts. The initial evaluation included a review of the water material balance (WMB), the water quality data, and an assessment of the technologies that would be applicable to treating FGD wastewater to comply with new ELG regulations. For the second part, Black & Veatch evaluated each technology for sensitivity to various operating scenarios.

This evaluation accomplished the following:

- Summarized the O&M costs and treatment capabilities under different operating scenarios to determine the impact of these inputted variables and the best treatment solution to meet compliance.
- Summarized the key takeaways from site visits to various operating systems.
- Reported the estimated impacts to the heat rate at FBC utilizing an SDE technology.
- Provided an overall assessment and final recommendation based on several technical and commercial factors.

3.0 Project Timeline

This section summarizes the steps that have been taken during the course of this Project to determine the most cost-effective approach to meeting the ELG requirements. Table 3-1 provides a timeline of the relevant major events that played a role in selecting technologies for FBC.

Table 3-1 Major Events in Technology Selection

DATE	ACTIVITY	DESCRIPTION
August 27, 2015	CCR Compliance Evaluation for FBC	Burns & McDonnell evaluated CCR compliance options for FBC.
December 18, 2015	CCR Compliance Cost Estimate	AECOM provided a Class 3 cost estimate for closure options at FBC.
January 8, 2016	FBC CCR Compliance Analysis - Wastewater Treatment and Reduction Study	AECOM conducted a review of the plant water balance and the effect of ash pond closures on wastewater treatment at FBC. Wastewater treatment options were presented.
January 2016	Technology Selection	Black & Veatch evaluated technology options and costs to comply with ELG and CCR regulations at FBC.
July 2016	Water Balance and Treatment Evaluation Summary	Black & Veatch evaluated technology options with high-level costs associated with the technologies capable of treating FGD wastewater to comply with updated ELG regulations.
November 2016	Review of FGD Treatment Options	Black & Veatch evaluated chemical/biological treatment and discharge and ZLD technologies along with a detailed cost analysis to provide a recommendation for the most suitable FGD wastewater treatment.
June 2017	Completion of Sensitivity Analysis	Black & Veatch evaluated several vendors for the chemical/biological treatment and discharge and the ZLD technologies against several operating scenarios to provide a recommendation for the most feasible FGD wastewater treatment.

4.0 Effluent Limitation Guidelines

4.1 BACKGROUND

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating discharge point sources into bodies of water in the United States. Wastewater discharges from FBC are regulated under 40 CFR 423, Steam Electric Power Generating Point Source Category.

Existing discharge point sources are required to comply with current wastewater effluent limits representing the degree of effluent reduction by application of best available technology economically achievable (BAT). New discharge point sources are required to comply with the current effluent limits as well as new source performance standards (NSPS). In addition, existing and new sources that introduce pollutants into a publicly owned treatment works (POTWs) must achieve the applicable pretreatment standards for existing sources (PSES) and/or pretreatment standards for new sources (PSNS). Local and state wastewater effluent standards may also apply in addition to federal standards.

The Environmental Protection Agency (EPA) released the final update to the rule on September 30, 2015. The final rule strengthens the technology-based ELGs by introducing more stringent discharge restrictions on toxic pollutants. The updated rule focuses on heavy metals reduction, i.e., mercury, arsenic, and selenium, as well as any waste streams that come in contact with combustion materials. Changes include new standards for FGD, flue gas mercury control (FGMC), gasification, landfill leachate, and CCR waste streams that were previously included under low-volume wastes. In addition, fly and bottom ash transport waste streams are zero discharge for both new and existing point sources. The final rule did not include any changes to the previously specified cooling tower blowdown, once-through cooling, or coal pile runoff effluent standards.

4.2 FINAL RULE REVIEW

For the first time, the final rule establishes separate definitions and categories for FGD wastewater, FGMC wastewater, gasification wastewater, nonchemical metal cleaning wastes, and combustion residual leachate, which were previously considered low-volume waste sources.

The EPA's rulemaking sets forth technology-based effluent standards for discharges from these new wastewater streams to surface waters and publically owned treatment works sewer systems. NPDES permitting authorities (Indiana Department of Environmental Management [IDEM]) must incorporate these new ELG standards, as applicable, into the next renewal issuance of each existing facility's NPDES permit.

4.2.1 Timing

The final ELG rule requires that permits issued after the rule's January 4, 2016, effective date must incorporate the applicable new ELGs; however, the permitting authority is allowed to designate the date when the limitations will apply to each discharger and waste stream. In an attempt to account for the magnitude and complexity of process changes and new equipment installations that would be required at facilities to meet the new rulemaking requirements, all new ELG limits will not apply until a date determined by the permitting authority to be "as soon as possible" beginning November 1, 2018 (approximately 3 years following promulgation of this rule), but no later than December 31, 2023 (approximately 8 years following promulgation).

4.2.2 Regulatory Compliance Options

The EPA outlined six technology-based options considered in the development of the new ELG rulemaking. Ultimately, the EPA established the same basis for BAT and PSES standards for existing facilities, and the same basis for NSPS and PSNS standards for new steam electric power plants. The technology bases for these new ELGs are shown in Table 4-1. The current ELGs for the steam electric power generating existing sources and their applicability to FBC are shown in Appendix E. The ELG final rule, as applicable to FBC, establishes separate definitions and categories for FGD wastewater, which was previously considered a low-volume waste source.

Table 4-1 Technology Basis for the Existing BAT and PSES and New NSPS and PSNS ELGs

WASTE STREAMS	EXISTING BAT AND PSES	NEW NSPS AND PSNS
Wet FGD Wastewater	Chemical Precipitation and Biological Treatment	Evaporation
Fly Ash Transport Water	Dry Handling	Dry Handling
Bottom Ash Transport Water	Dry Handling/Closed Loop	Dry Handling/Closed Loop
FGMC Wastewater	Dry Handling	Dry Handling
Gasification Wastewater	Vapor Compression Evaporation	Evaporation
Combustion Residual Leachate	Gravity Settling Impoundment	Chemical Precipitation

The EPA established numerical effluent limits that would correspond to the level of treatment that could be achieved by applying these treatment technologies. After these new ELG limits are incorporated by IDEM into the next NPDES permit issued to FBC, the facility will need to achieve these discharge limits. The ELGs do not specifically require installation of the BAT treatment technologies, but each facility will nevertheless need to undertake whatever measures or upgrades may be needed to meet the new NPDES permit limits.

The ELG rule identifies the BAT for control of pollutants discharged in FGD wastewater as chemical precipitation followed by biological treatment. More specifically, the technology basis for BAT is a chemical precipitation system that employs hydroxide precipitation, sulfide precipitation (organosulfide), and iron coprecipitation, followed by anoxic/anaerobic fixed-film biological treatment designed to remove heavy metals, selenium, and nitrates.

Many plants that do not use chemical precipitation followed by a biological treatment system employ FGD wastewater management approaches that eliminate the discharge of FGD wastewater. A variety of approaches that depend on plant-specific conditions are used to achieve zero pollutant discharge at these plants, including evaporation ponds, complete recycle, and processes that combine the FGD wastewater with other materials for landfill disposal. Although these technologies as well as others currently used for achieving zero pollutant discharge may be available for some plants with FGD wastewater, the EPA determined that they are not available nationally. For example, evaporation ponds are only available in certain climates, and complete recycle is only available at plants with appropriate FGD metallurgy.

The ELG rule identifies dry handling or closed-loop systems as the BAT for control of pollutants in bottom ash transport water. More specifically, the first technology basis for BAT is a system in which bottom ash is collected in a quench water bath and a drag chain conveyor (mechanical drag system) then pulls the bottom ash out of the water bath on an incline to dewater it. The second technology basis for BAT is a system in which the bottom ash is transported using the same processes as a wet-sluicing system, but instead of going to an impoundment, the bottom ash is sluiced to a remote mechanical drag system. Once there, a drag chain conveyor pulls the bottom ash out of the water on an incline to dewater it, and the transport (sluice) water is then recycled back to the bottom ash collection system.

The EPA did not identify surface impoundments as BAT for bottom ash transport water for the same reasons that it did not identify surface impoundments as BAT for FGD wastewater.

4.3 F.B. CULLEY FGD EFFLUENT EVALUATION

FBC currently utilizes a chemical-precipitation treatment system to remove mercury from the FGD blowdown. The system uses ferric chloride, organosulfide, and a polymer to facilitate settling in the east ash pond. The FGD blowdown constituents of concern, according to the ELG rule, are mercury, arsenic, nitrate/nitrite, and selenium. The numerical limits for these constituents can be found in Table 4-2 and in Appendix E. Samples collected from Outfall 301 spanning the months of October 2015 to August 2016 were analyzed to find the plant maximum value of the constituents of concern. The maximum value in this time period of the four FGD blowdown constituents of concern are summarized in Table 4-2.

Table 4-2 F.B. Culley FGD Effluent Data Summary

CONSTITUENT	PLANT DATA (MAX)	ELG LIMIT (MAX)
Mercury (ng/L)	34,900	788
Arsenic (μg/L)	495	11
Selenium (μg/L)	2,740	23
Nitrate/Nitrite as N (mg/L)	55	17
ng/L = nanogram per liter μg/L = microgram per liter mg/L = milligram per liter		

Two methods were reviewed to upgrade FBC to be compliant with future regulations for FGD wastewater: (1) enhance the wastewater treatment system to discharge the effluent or (2) provide a means to utilize ZLD. Section 5.0 includes an evaluation of acceptable treatment methods.

5.0 Initial Technology Screening

This section summarizes the initial technology assessment for the ELG Program for FBC. This assessment focuses on an overview of the technologies available for treating FGD wastewater to comply with ELG regulations. A summary of the initial technology screening is found in the Technology Matrix in Appendix A.

5.1 WATER REDUCTION OPPORTUNITIES

After reviewing the capabilities of the existing plant wastewater systems, another consultant working for the Company, [redacted], identified modifications to the existing FGD blowdown system to reduce wastewater discharge and optimize the system. One of the modifications was to modulate/reduce the purge flow to the FGD mercury treatment system and reclaim more blowdown back into the system. This would increase the cycles of concentration of the constituent levels, particularly chlorides, from 4,800 parts per million (ppm) to approximately 13,000 ppm. This modification is being tested at the plant but has only recently begun to be operated. It is estimated that, if successful, the process would reduce FGD blowdown from 140 gpm to approximately 35 gpm. For the purpose of this evaluation, Vectren South and Black & Veatch both decided on a conservative FGD blowdown flow rate out of the system of approximately 50 gpm.

Black & Veatch has identified a number of potential water saving opportunities or instances where the water balance may need to be updated or reconfirmed (refer to Appendix F, Attachment A):

Boiler Makeup and Blowdown--The water balance indicates identical flow rates for both boiler makeup and the recoverable blowdown. The accuracy of these flows will need to be investigated. The balance does not account for the nonrecoverable portion because it is assumed that all feedwater makeup is recovered.

Reverse Osmosis (RO) Design Flow Rates--When comparing the RO reject flow to the permeate sent to condensate storage, Black & Veatch finds that the RO recovery is close to 56 percent. Black & Veatch would expect the RO recovery to be closer to 75 percent. The accuracy of the RO reject design flow rate will need to be investigated.

River Water Clarifier--The water balance indicates that wastewater from the clarifier is going to the east ash pond. What this stream is and its quality will need to be investigated.

Potable Water Treatment--Flow rates indicate water effluent recovery is close to 46 percent. The accuracy of the reject design flow rate will need to be investigated.

Unit 3 Floor Drains--Performing a balance around the Unit 3 floor drains and all wastewater flows going to this box and, ultimately, the east yard sump indicates almost 243 gpm from the Unit 3 floor drains. The accuracy of this flow will need to be investigated or clarified to determine what flows are going to this Unit 3 floor drain.

5.2 FGD TREATMENT AND DISCHARGE

5.2.1 Physical/Chemical Treatment System Design

The proposed addition to the physical/chemical precipitation treatment system would receive the FGD blowdown from the existing mercury treatment system. The FGD wastewater would be sent through reaction tanks and clarifiers to reduce suspended solids and any remaining heavy metals, including arsenic. Because of the nature of selenium in FGD blowdown, the physical/chemical process is not capable of reducing selenium to low enough concentrations to meet the ELG discharge limits. Therefore, a biological process is required downstream of the secondary physical/chemical treatment system to reduce selenium concentration to the target effluent concentration listed in Appendix E. Nutrients such as nitrate/nitrite will also need to be removed by a biological treatment system if high concentration levels are in the FGD blowdown; these nutrients cannot typically be converted in a physical/chemical process.

Figure D-1 in Appendix F, Attachment D, shows a simplified flow diagram for the physical/chemical pretreatment process. The FGD blowdown would be pumped to a new sulfide reaction tank followed by a coagulation tank that would allow for the chemical addition of sulfide and ferric chloride. The reaction tanks are sized to allow sufficient reaction time for the chemical precipitation reactions to occur. The coagulation reaction tanks feed clarifiers where polymer is added to increase the particle size of the insoluble particles to allow inerts and unreacted limestone to be removed with traditional clarification techniques. Settled solids from the clarifiers would be directed to dewatering equipment.

The sludge produced in the clarifying process will be dewatered prior to disposal using filter presses with additional polymer feed. The dewatered solids will be sent for off-site disposal and the filtrate will be collected and recycled back to the front end of the physical/chemical treatment system in the sulfide reaction tank. Solids production rate is estimated to be approximately 4 tons per day of sludge.

The system would also include miscellaneous feed pumps, valves, instrumentation, and controls. The filter presses, electrical gear, and control system would be located inside a new wastewater treatment building.

To enhance selenium and nitrate/nitrite reduction for ELGs, effluent from the physical/chemical treatment system would be fed into a biological treatment system. The [redacted] biological treatment system consists of a membrane bioreactor (MBR) pretreatment followed by the [redacted] system. The MBR system would be necessary because of the high concentration of nitrate in the influent. The MBR utilizes an anoxic tank to convert nitrate into nitrogen gas. The [redacted] system further treats the water with a series of fixed-film biofilters that contain a specially engineered blend of microbes that form an attached growth on a granular activated carbon substrate. A flow diagram of the [redacted] biological system is included on Figure D-2 in Appendix F, Attachment D.

The MBR equipment consists of membrane blowers, tanks, and pumps. The [redacted] equipment consists of feed tanks and pumps, a nutrient addition system, biofilters, an effluent storage system, and a waste storage system.

Considering the design water quality and flow rate, two stages of biofilters will be required. Wastewater flows downward through the first stage of biofilters to a second stage feed tank by gravity. Wastewater from the tank is pumped to the second stage of biofilters for additional treatment and collected in an effluent tank that discharges to a sedimentation pond. Water that discharges from the sedimentation pond must meet the new ELG discharge limits as described in Appendix E.

As the wastewater passes through the biofilters, nitrate and nitrite are first reduced to nitrogen gas (denitrification) followed by selenium reduction. A nutrient (carbon source) is fed to the inlet of the biofilters for the microorganisms to control the oxidation-reduction potential within the bioreactor within a range that is ideal for selenium reduction.

Entrained solids and gasses need to be removed with a backwash process every 2 to 6 weeks. To backwash, treated effluent is used as a counterflow wash to remove entrained solids and gases from the biofilter substrate. Backwash wastewater is allowed to degas and is recycled to the inlet of the secondary pretreatment system where the solids are settled in the clarifier and dewatered with the pretreatment sludge. Waste testing of existing installations has shown that the solids produced can be disposed of as nonhazardous waste.

The biological treatment system is sized according to the hydraulic retention time in the reactors. Water quality can significantly impact the reactor size and hydraulic retention time, especially for constituents such as nitrates and selenium.

The estimated equipment footprint for the FGD treatment and discharge system is detailed in the Sensitivity Analysis Matrix in Appendix B.

Biological treatment has been proven effective in treating FGD wastewater to low levels as required by ELG regulations. GE currently has five operating power plant FGD installations in the United States using the [redacted] process. The estimated time frame to design, procure, and install the physical/chemical and biological treatment system is less than 2 years. It is recommended that the FGD wastewater at FBC be tested prior to system design with a 6 month pilot test. Pilot testing is typically required for system suppliers to provide effluent guarantees.

5.2.2 Physical/Chemical Treatment System Operation Strategies and Constraints

For optimal treatment capability, the flow, temperature, and constituent concentrations should remain fairly constant or in a steady state. Upsetting the biomass in the reactors will result in reduced treatment capabilities. The following should be considered:

Each biological treatment system will include equipment with holding tanks for flow equalization and recirculation during low flow situations. Larger upfront holding tanks may be warranted for FBC because of the anticipated low capacity factors (10 to 60 percent).

High levels of influent dissolved solids (chlorides) reduce the rate of reaction. Increasing the FGD blowdown flow rate (reduced chloride cycles of concentration) will benefit the biological reactors. This is slightly counterintuitive because the FGD blowdown is currently being retrofitted to reduce flow and increase concentrations. Once the final FGD blowdown flow rate is optimized, an updated water quality sample would be required to confirm if the physical/chemical and biological treatment system is sized accordingly.

Near complete denitrification is necessary to achieve selenium reduction. Denitrification is dependent on consistent chemical oxygen demand (COD) and temperature. A consistent COD source (nutrient food) and warm temperature is necessary for the biological process to work. The anaerobic process ensures a suitable temperature for denitrification, but during low flow scenarios, it will be necessary to recirculate the wastewater within the system and continuously feed the nutrient for biomass stabilization. The nutrient feed operation and wastewater flow would need to continue during outages and off-line scenarios.

The following are advantages of the physical/chemical treatment system:

- Proven commercial process for FGD wastewater treatment.
- Reduced solids discharge.
- Low energy consumption.

The following are disadvantages of the physical/chemical treatment system:

- Operation of biological treatment system that requires specific personnel and high O&M costs.
- Limited flexibility for changing FGD operation.
- Varying feed flow and quality can affect the performance of the treatment system.

5.3 ZERO LIQUID DISCHARGE

5.3.1 Spray Dryer Evaporator System Design

Spray dryers or dry scrubbers have been used successfully in the power industry utilizing hydrated lime for sulfur dioxide capture. While the use of FGD blowdown as the reagent in slipstream is a fairly new concept, the use of the flue gas stream for drying is not and has been proven in the industry. The equipment and design associated with this alternative provides a reliable, proven technology. However, there is only one installation (with a second under way) where this has been used to treat FGD wastewater. Because this is an evaporation technology for treating FGD wastewater, it would qualify under the voluntary incentives program to push the required compliance date back until December 31, 2023.

The spray dryer alternative has minimal operational requirements and produces no wastewater. In addition, implementing a ZLD approach will allow for an extension to meet the new ELG regulations.

Figure D-3 in Appendix F, Attachment D, shows a simplified flow diagram for the spray dryer process. The FGD blowdown would be pumped to a new wastewater tank that would buffer the treatment system against variations in wastewater flow. Wastewater from the wastewater tank would be pumped into the spray dryer.

The spray dryer will utilize rotary atomizers or dual fluid nozzles to distribute the wastewater into the dryer. The wastewater is evaporated utilizing a hot flue gas slipstream extracted upstream of the Unit 3 air heater to produce a humidified gas stream. The flue gas exits the spray dryer through the cone bottom and recombines with the main flue stream upstream of the existing baghouse. Typically, the dried solids would be collected in the existing baghouse; this will increase the concentration of chlorides and other contaminants in the fly ash, potentially causing it to no longer meet quality requirements for sale. An electrostatic precipitator (ESP) shall be installed downstream of the spray dryer to collect solids from the spray dryer, if necessary. From the ESP, the flue gas slip stream will be returned to the main flue gas duct upstream of the existing bag house. Because of the large footprint of the ESP, a location has not yet been determined.

The system would also include additional structural steel, ductwork, dampers, seal air fans, seal air heaters, expansion joints, piping, valves, instrumentation, and controls.

To minimize ductwork modifications, the spray dryer should be located near the air heater unit. The spray dryer would be installed above ground level to accommodate the roadway underneath. The FGD wastewater storage tank would be approximately 25,000 gallons. The estimated footprints for this equipment are detailed in the Sensitivity Analysis Matrix in Appendix B.

This system requires very little operator attention, does not need any pretreatment of the FGD wastewater, and could use existing equipment for solids capture. The major tie-in work would primarily involve the ductwork around the air heater.

Utility requirements are moderately high for the spray dryer system. It is assumed that the existing fly ash equipment and fabric filters would be able to handle the additional solids loading. The relatively large size of the spray dryer and the amount of flue gas required to evaporate the wastewater would cause an approximate 3 MW impact to the heat rate. The solids production rate is estimated to be approximately 15 tons per day.

The estimated time frame for delivery of materials is 12 months from purchase order issue, including time for document review. An estimated time frame to design, procure, and install this treatment system is 3 years. An estimated outage time of 4 to 8 weeks, depending on access difficulties, is required to make the needed tie-ins.

5.3.2 Spray Dryer Evaporator System Operating Strategies and Constraints

For optimal treatment and cost effectiveness, the wastewater flow should remain low and fairly consistent:

- Reducing FGD blowdown is already being implemented at FBC. After an optimal flow rate and chemistry in the scrubber has been reached, water sample analyses should be taken.
- A unit must be on line for the system to operate. During outages and off-line scenarios, larger upfront holding tanks may be warranted because of the anticipated low capacity factors (60 percent). Residual FGD wastewater would have to be circulated in an SDE feed tank as wastewater is still generated after system shutdown.
- Captured FGD waste solids in the existing fabric filter may affect fly ash sales. A secondary fabric filter/ESP for the dry scrubber waste slipstream shall be included to remove solids prior to existing particulate control device to preserve fly ash consistency.

The following are advantages of the spray dryer evaporator treatment system:

- Low operations requirements that lead to low O&M costs.
- No FGD wastewater stream discharging from the site.
- The technology has the maximum flexibility to respond to future ELG regulatory updates that could set more stringent limits.

The following are disadvantages of the spray dryer evaporator treatment system:

- Limited flexibility for changing FGD operation and flow rates.
- A unit must be on line for wastewater to be evaporated.
- Zero water recovery to recycle back into the plant.
- High energy usage.

5.3.3 Brine Concentrator and Crystallizer System Design

Brine concentrator/crystallizer technology has been used successfully at power generation facilities operating with ZLD waste to treat cooling tower blowdown. There are, however, only two brine concentrator/crystallizer systems at power generation facilities in the United States treating FGD blowdown. Because of the expensive materials required for the brine concentrator and crystallizer, the equipment costs tend to be high. For these reasons, reduction and minimization of FGD wastewater streams is critical in reducing the costs of this alternative.

Evaporated water from both the brine concentrator and crystallizer is condensed and returned to the plant for reuse. This is a high quality water source that would slightly reduce the overall water requirements for the plant. Concentrated brine from the brine concentrator is sent to the crystallizer. Solids from the crystallizer are dewatered and disposed of in an off-site landfill. The solids production rate is estimated to be approximately 15 tons per day of solids.

A pretreatment system is required prior to feeding the brine concentrator/crystallizer to convert mostly calcium chloride and magnesium chloride based salts in the FGD wastewater to sodium chloride based salts. Calcium chloride and magnesium chloride based salts are highly soluble, corresponding to a high boiling point. The high boiling point makes it difficult to evaporate to a solid state due to equipment constraints and uneconomical equipment design. Sodium chloride salts have a lower boiling point and are more suitable for evaporation. The required pretreatment system shown on Figure D-4 in Appendix F, Attachment D is similar to the pretreatment system required for the biological treatment system (Figure D-1).

The FGD blowdown would similarly be collected in a new continuously mixed equalization tank. The wastewater would flow from the tank into clarifiers where lime and soda ash would be fed to remove calcium and magnesium. In addition, coagulant and polymer would be added to increase the particle size of the insoluble particles to allow settling within the clarifier. Suspended solids from the FGD system would be removed with traditional clarification techniques and directed to dewatering equipment. The sludge produced in the clarifying process must be dewatered prior to disposal. Plate and frame filter presses would be used with the dewatered solids sent for off-site disposal and the filtrate would be collected and recycled back to the front end of the pretreatment system.

The pretreatment effluent is concentrated using a thin film brine concentrator. The flow diagram for this system is shown on Figure D-5 in Appendix F, Attachment D. Pretreatment effluent passes through an inlet heat exchanger to bring the feed temperature near its atmospheric boiling point by recovering heat from the brine concentrator distillate. From the heat exchanger, the feed is deaerated, enters the bottom portion of the brine concentrator, and is mixed with concentrated slurry. The concentrated slurry is continuously pumped via recirculation pumps to the top of the brine concentrator where it is distributed as a thin film to the inside wall of a vertical tube heat exchanger. As the thin film of slurry passes down the tube, water is evaporated. The remaining slurry is collected at the bottom sump within the brine concentrator and again recirculated via the recirculation pump. The evaporated water is collected and sent to the vapor compressor, to increase its pressure and condensation temperature, and then used as the heating medium on the shell side of the vertical heat exchanger. The vapor condenses, is pumped through the inlet heat exchanger, and can then be collected for plant use.

A slip stream from the recirculating brine slurry is blown down to the crystallizer feed tank. From the crystallizer feed tank, brine is pumped to the forced circulation crystallizer, which uses energy in the form of plant steam. Slurry in the crystallizer is continuously recirculated through an external shell and tube heat exchanger where the slurry is heated past its atmospheric boiler temperature by steam from the plant. Once heated, the slurry is fed into the crystallizer where it flashes, and the evaporated water from the crystallizer is scrubbed and condensed into distillate. A blowdown brine stream from the recirculation pump is sent to either a belt press or centrifuge for dewatering.

The system would also include chemical dosing systems, miscellaneous feed pumps, valves, instrumentation, and controls. The chemical dosing systems, dewatering equipment, electrical gear, and controls systems would be located inside a new wastewater treatment building.

Utility requirements are much higher for the brine concentrator system than the physical/chemical and biological treatment. Plant steam would also be required as the heat source for the vaporizer which would result in approximately 0.5 MW of heat rate impact. Mechanical evaporation and crystallization are the most frequently utilized ZLD type technologies in the power industry.

Because this is an evaporation technology for treating FGD wastewater, it would qualify under the ELG voluntary incentives program to push the required compliance date back until December 31, 2023. The estimated time frame to design, procure, and install the brine concentrator/crystallizer system is 3 years. A long lead time is required for the crystallizer materials and construction.

5.3.4 Brine Concentrator and Crystallizer System Operating Strategies and Constraints

For optimal treatment and cost-effectiveness, the wastewater flow should remain low and fairly consistent.

- Reducing FGD blowdown is already being implemented at FBC. Once an optimal flow rate and chemistry in the scrubber has been reached, water sample analyses should be taken.
- The pretreatment process is sensitive to upsets and requires intensive monitoring and sampling. A large amount of chemical is required for the salt conversion process, which leads to a large amount of solids generation.
- Unit must be on line in order for system to operate. During outages and off-line scenarios, larger upfront holding tanks may be warranted due to the anticipated low capacity factors. Wastewater would have to be circulated in a feed tank.

The following are advantages of the brine concentrator and crystallizer treatment system:

- Proven commercial process for FGD wastewater treatment.
- Reduced solids and load on the CWTS.
- No FGD wastewater stream discharging from the site.
- Distillate recovery for plant reuse.

The following are disadvantages of the brine concentrator and crystallizer treatment system:

- High operating expenses with several unit operations to maintain and operate.
- The salt conversion in pretreatment is prone to upsets.
- Periodic cleanings are required.
- High energy consumption.