Advanced Pressurized Fluidized Bed Coal Combustion with Carbon Capture

Pre-FEED Cost Results Report

Concept Area: With Carbon Capture/Carbon Capture Ready

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Acronyms and Abbreviations

AACE	American Association of Cost Engineering
acfm	Actual cubic feet per minute
AC	Alternating Current
AQC	Air Quality Control
Ar	Argon
ASME	American Society of Mechanical Engineers
BEC	Bare erected cost
BFD	Block flow diagram
BOD	Measurement of consumed oxygen by aquatic microorganisms to decompose or oxidize organic matter
BOP	Balance of Plant
Btu	British thermal unit
Btu/h, Btu/hr	British thermal units per hour
Btu/kWh	British thermal units per kilowatt hour
Btu/lb	British thermal units per pound
BTU/scf	British Thermal Unit per standard cubic feet
cf	Cubic feet
cfm	Cubic feet per minute
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Requirement of dissolved oxygen for both the oxidation of organic and inorganic constituents
COE	Cost of electricity
cy/cu yd	Cubic yards
DCS	Distributed Control System
dia	Diameter
DL	Design Load
DOE	Department of Energy
DP	Differential Pressure
EPA	Environmental Protection Agency
EPCM	Engineering, Procurement and Construction Management
FEED	Front-End Engineering Design
FGD	Flue gas desulfurization
FO	Fuel Oil
FO&M	Fixed operations and maintenance
ft	Foot, Feet
FRP	Fiber-reinforced plastic
gal	Gallon
GIS	Gas Insulated Switchgear
GPM	Gallons per minute
h, hr	Hour
H_2	Hydrogen
H_2O	Water
H&MB	Heat and Mass Balance
HAP	Hazardous Air Pollutants
Hg	Mercury
HHV	Higher heating value
hp	Horsepower
HP	High pressure
HRSG	Heat Recovery Steam Generator
HVAC	Heating, Ventilation and Air Conditioning
Hz	Hertz
ID	Interior diameter (of pipe)
in. W.G.	Inch water gauge
IO	input/output
kV	Kilovolt
kVA	Kilovolt-ampere
kW, kWe	Kilowatt electric
kWh	Kilowatt-hour
kWt	Kilowatt thermal
LAER	Lowest Achievable Emission Rate
lb	Pound
lb/ft	
lb/h, lb/hr	Pounds per hour
lb/MMBtu	Pounds per million British thermal units
lb/MWh	Pounds per megawatt hour
LHV	Lower heating value
LNTP	Limited Notice to Proceed
LOI	Loss on ignition
LP	Low pressure
MATS	Mercury and Toxics Standard
MCC	Motor Control Center
mil	One-thousandth of an inch
mm	millimeter
MM	Million
MMBtu	Million British thermal units
MMBtu/h	Million British thermal units per hour
MP	Medium pressure
MVA	Mega volt-ampere
MW, MWe	Megawatt electric

MWh	Megawatt-hour
MW_t	Megawatt thermal
N_2	Nitrogen
N_2O	Nitrous oxide
N/A, NA	Not applicable
NAAQS	National Ambient Air Quality Standard
NESHAP	National Emission Standards for Hazardous Air Pollutants
NETL	National Energy Technology Laboratory
NO_2	Nitrogen Dioxide
NO_X	Oxides of nitrogen
NPDES	National Pollution Discharge Elimination System
NSPS	New Source Performance Standards
NSR	New Source Review
NTP	Notice to Proceed
OEM	Original Equipment Manufacturer
O_2	Oxygen
O_3	Ozone
O&M	Operation and Maintenance
OWS	Operator Work Station
PC	Personal Computer
PFBC	Pressurized Fluid Bed Combustion
PFD	Process flow diagram
pH	potential hydrogen
PLC	Programmable Logic Controller
PM	Particulate matter
POTW	Publicly Owned Treatment Works
ppm	Parts per million
ppmv	Parts per million volume
ppmvd	Parts per million volume, dry
ppmw	Parts per million weight
PSD	Prevention of Significant Deterioration of Air Quality
psf	Pounds per square foot
psi	Pounds per square inch
psia	Pound per square inch absolute
psid	Pound per square inch differential
psig	Pound per square inch gage
Qty	Quantity
RF	Radio Frequency
sbbl	Standard barrel
scf	Standard cubic feet
scf/hr	Standard cubic feet per hour
scfm	Standard cubic feet per minute
SNCR	Selective non-catalytic reduction (NOx control)
SO_2	Sulfur dioxide
SO_3	Sulfur trioxide
SO_X	Oxides of sulfur
SS	Stainless steel
TG	Turbine Generator
mt, tonne	Metric ton (1,000 kg)
TPC	Total plant cost
tph	Tons per hour
tpy	tons per year
TSS	Total suspended solids
$\mu g/m^3$	Micrograms per cubic meter
UPS	Uninterruptible Power Supply
ULSD	Ultra-Low Sulfur Diesel oil
U.S., US	United States
V	Volt
VFD	Variable Frequency Drive
VOC	Volatile Organic Compound
wg	Water gauge
wt%	Weight percent
WWTP	Waste Water Treatment Plant
°C	Degrees Celsius
°F	Degrees Fahrenheit

1 Concept Background

This section presents the concept background including the following:

- Coal-fired power plant scope description
- Plant production/facility capacity
- Plant location consistent with the NETL QGESS
- Business case from conceptual design

We also provide a discussion of the ability to meet specific design criteria and the proposed PFBC target levels of performance to round out this discussion.

1.1 Coal-Fired Power Plant Scope Description

The Advanced PFBC project team has adopted an alternate configuration utilizing an amine-based CO_2 capture system instead of the UOP Benfield capture system utilized in the Conceptual Design Phase (Phase 1) work. As such, with the exception of Section 1.4 (Business Case from Conceptual Design), the plant description and performance and cost results presented in this report are now for an amine-based CO_2 capture configuration.

The proposed Coal-Based Power Plant of the Future concept is based on a pressurized fluidized bubbling bed combustor providing heat of combustion to a gas turbomachine (Brayton Cycle) and a steam generator providing steam to a steam turbine generator (Rankine Cycle) in parallel operation. The plant described is configured to fire Illinois No. 6 coal or fine, wet waste coal derived from CONSOL's bituminous coal mining operations in southwest Pennsylvania. Plant performance and operating characteristics will be evaluated separately for each design fuel, and certain plant components, such as the ash handling system, will be uniquely sized and optimized to accommodate each design fuel.

The offered technology is unique and innovative in this major respect: it has inherent fuel flexibility with the capability of combusting steam coal, waste coal, biomass, and opportunity fuels and has the ability to incorporate carbon capture while maintaining relatively high efficiency. Carbon capture may be added to a capture-ready plant configuration without major rework and with little interruption to the operation of the capture-ready plant. The essential feature of the capture-ready plant is the provision of additional space for housing the additional components, along with space for supporting auxiliaries (electrical cabinets, piping, etc.) The Base Case plant will be designed to fire Illinois No. 6 coal, while the Business Case plant will be designed to fire waste coal while also being fully capable of accommodating typical thermal coal products as well as co-firing up to 10% biomass.

The complete scope of the proposed power plant includes a fuel preparation plant co-located with the power generating plant. The power generation process is described in Section 1.4 and includes all necessary features to receive prepared fuel/sorbent mixture and fire this mixture to generate electricity and carbon dioxide as a co-product. The electric power generated is conveyed on a branch transmission line to the grid. The CO_2 is compressed for pipeline transport for storage or utilization. Both the Illinois No. 6 coal case and the Business Case assume that the CO_2 is compressed to 2215 psi for geologic storage; however, compression to a lower pressure may be possible depending upon the ultimate disposition (i.e., storage or utilization) of the CO_2.

The fuel preparation plant includes coal receiving and storage, limestone sorbent receiving and storage, and, optionally, biomass receiving and storage. Each of these materials are sized and mixed to form a paste with controlled water content (~26%) for firing in the PFBC power generating plant.

The PFBC power generating plant (Base Case-Illinois No. 6 Coal) includes an evaporative cooling tower heat sink, a water treatment facility to prepare several different levels of water quality for use in various parts of the power generating process, a waste water treatment facility to treat waste water streams for beneficial reuse within the complete facility (power generating plant or fuel preparation plant), and necessary administrative and maintenance facilities. The Business Case plant utilizes a dry air-cooled condenser for the steam turbine generator, but also includes a conventional evaporative cooling tower of reduced capacity for other heat loads that are better suited to a lower cooling water temperature. Both configurations include a Zero Liquid Discharge system to eliminate liquid discharges from the plant.

1.2 Plant Production / Facility Capacity

The plant production capacity for the PFBC plant is set primarily by the number of PFBC modules as the PFBC design is essentially fixed. The overall plant production capacity with four (4) PFBC modules firing Illinois No. 6 coal is set at a nominal 404 MWe net without CO_2 capture (but in complete capture ready configuration) and 308 MWe net with CO_2 capture operational at a rate of 97% of all CO_2 produced based on the amine capture system. When operating at this fully-rated capacity (308 MWe) the CO_2 available for delivery at the plant boundary is ~7700 tons/day of pure CO_2 mixed with small amounts of other gases.

The annual production of electricity for delivery to the grid is 2.34 million MWh at 85% capacity factor. The annual production of CO_2 for export at 85% capacity factor is 2.4 million tons/year.

The overall plant production capacity with four (4) PFBC modules firing waste coal and 5% biomass is set at a nominal 280 MWe net with CO_2 capture operational at a rate of 97% of all CO_2 produced based on the amine capture system. When operating at this fully-rated capacity (280 MWe) the CO_2 available for delivery at the plant boundary is ~7900 tons/day of pure CO_2 mixed with small amounts of other gases.

The annual production of electricity for delivery to the grid is 2.08 million MWh at 85% capacity factor. The annual production of CO_2 for export at 85% capacity factor is 2.4 million tons/year.

1.3 Plant Location Consistent with NETL QGESS

As discussed above, the Base Case PFBC plant was designed to fire Illinois No. 6 coal at a Midwestern site. However, the Business Case being considered by the project team would involve firing waste fuel available to CONSOL Energy in southwestern Pennsylvania. As such, we have developed separate designs for these two cases: (1) the Base Case based upon the Midwestern site and Illinois No. 6 coal and (2) the Business Case based upon the southwestern Pennsylvania (or northern West Virginia) site and wet, fine waste coal fuel and biomass. In documenting the site conditions and characteristics for plant location, we have followed the NETL QGESS [**1**] and have presented the site information in Section 3 of the Design Basis Report. Wherever possible, we have utilized available site information in lieu of generic information.

1.4 Business Case from Conceptual Design

The business case and underlying performance estimates and economics presented in this section, Section 1.4, are based on the work performed during the Conceptual Design Study phase of the project, which was completed in April-July 2019 and assumed that the Benfield Process was used for CO_2 capture. The project team has updated this information during the current pre-FEED study to reflect the best overall plant design, which is based on an amine-based CO_2 capture process. The Business Case based on the current pre-FEED study is presented in Section 7 of the Final Report.

This business case presents the following:

- Market Scenario
- Market Advantage of the Concept
- Estimated Cost of Electricity Establishing the Competitiveness of the Concept

1.4.1 Market Scenario

The overall objective of this project is to design an advanced coal-fueled power plant that can be commercially viable in the U.S. power generation market of the future and has the potential to be demonstrated in the next 5-10 years and begin achieving market penetration by 2030. Unlike the current U.S. coal fleet, which was largely installed to provide baseload generation at a time when coal enjoyed a wide cost advantage over competing fuels and when advances in natural gas combined cycle, wind, and solar technologies had not yet materialized, the future U.S. coal fleet must be designed to operate in a much more competitive and dynamic power generation landscape. For example, during 2005-2008, the years leading up to the last wave of new coal-fired capacity additions in the U.S., the average cost of coal delivered to U.S. power plants ($1.77/MMBtu) was $6.05/MMBtu lower than the average cost of natural gas delivered to U.S. power plants ($7.82/MMBtu), and wind and solar accounted for less than 1% of total U.S. power generation. By 2018, the spread between delivered coal and natural gas prices ($2.06 and $3.54/MMBtu, respectively) had narrowed to just $1.48/MMBtu, and renewables penetration had increased to 8% [**2**]. EIA projects that by 2030, the spread between delivered coal and natural gas prices ($2.22/MMBtu and $4.20/MMBtu, respectively, in 2018 dollars) will have widened marginally to $1.98/MMBtu, and wind and solar penetration will have approximately tripled from current levels to 24% [**3**].

In this market scenario, a typical new advanced natural gas combined cycle (NGCC) power plant without carbon dioxide capture would be expected to dispatch with a delivered fuel + variable operating and maintenance (O&M) cost of $28.52/MWh (assuming a 6,300 Btu/kWh HHV heat rate and $2.06/MWh variable cost) and could be built for a total overnight cost of <$1,000/kWe (2018$) [**4**]. By comparison, a new ultra-supercritical pulverized coal-fired power plant would be expected to dispatch at a lower delivered fuel + variable O&M cost of ~$24.14/MWh (assuming an 8,800 Btu/kWh HHV heat rate and $4.60/MWh variable cost), but with a capital cost that is about four times greater than that of the NGCC plant [**5**]. The modest advantage in O&M costs for the coal plant is insufficient to outweigh the large disparity in capital costs vs. the NGCC plant, posing a barrier to market entry for the coal plant. This highlights the need for advanced coal-fueled power generation technologies that can overcome this barrier and enable continued utilization of the nation's valuable coal reserve base to produce affordable, reliable, resilient electricity.

Against this market backdrop, we believe that the commercial viability of any new coal-fueled power generation technology depends strongly upon the following attributes: (1) excellent environmental performance, including very low air, water, and waste emissions (to promote public acceptance and alleviate permitting concerns), (2) lower capital cost relative to other coal technologies (to help narrow the gap between coal and natural gas capex), (3) significantly lower O&M cost relative to natural gas (to help offset the remaining capital cost gap vs. natural gas and ensure that the coal plant is favorably positioned on the dispatch curve across a broad range of natural gas price scenarios), (4) operating flexibility to cycle in a power grid that includes a meaningful share of intermittent renewables (to maximize profitability), and (5) ability to incorporate carbon capture with moderate cost and energy penalties relative to other coal and gas generation technologies (to keep coal as a competitive dispatchable generating resource in a carbon-constrained scenario). These are generally consistent with or enabled by the traits targeted under DOE's Coal-Based Power Plants of the Future program (e.g., high efficiency, modular construction, near-zero emissions, CO_2 capture capability, high ramp rates and turndown capability, minimized water consumption, integration with energy storage and plant value streams), although our view is that the overall cost competitiveness of the plant (capital and O&M) is more important than any single technical performance target. In addition, the technology must have a relatively fast timeline to commercialization, so that new plants can be brought online in time to enable a smooth transition from the existing coal fleet without compromising the sustainability of the coal supply chain.

Pressurized fluidized bed combustion (PFBC) provides a technology platform that is well-suited to meet this combination of attributes. A base version of this technology has already been commercialized, with units currently operated at three locations worldwide: (1) Stockholm, Sweden (135 MWe, 2 x P200, subcritical, 1991 start-up), (2) Cottbus, Germany (80 MWe, 1 x P200, subcritical, 1999 start-up), and (3) Karita, Japan (360 MWe, 1 x P800, supercritical, 2001 start-up). These installations provide proof of certain key features of the technology, including high efficiency (the Karita plant achieved 42.3% net HHV efficiency using a supercritical steam cycle), low emissions (the Vartan plant in Stockholm achieved 98% sulfur capture without a scrubber and 0.05 lb/MMBtu NOx emissions using only SNCR), byproduct reuse (ash from the Karita PFBC is used as aggregate for concrete manufacture), and modular construction. Several of these installations were combined heat and power plants. This also highlights the international as well as domestic market applicability of the technology.

The concept proposed here builds upon the base PFBC platform to create an advanced, state-of-the-art coal-fueled power generation system. Novel aspects of this advanced PFBC technology include: (1) integration of the smaller P200 modules with a supercritical steam cycle to maximize modular construction while maintaining high efficiency, (2) optimizing the steam cycle, turbomachine, and heat integration, and taking advantage of advances in materials and digital control technologies to realize improvements in operating flexibility and efficiency, (3) integrating carbon dioxide capture, and (4) incorporating a new purpose-designed gas turbomachine to replace the earlier ABB (Alstom, Siemens) GT35P machine.

In addition, while performance estimates and economics are presented here for a greenfield Midwestern U.S. plant taking rail delivery of Illinois No. 6 coal, as specified in the Common Design Basis for Conceptual Design Configurations, the most compelling business case for the PFBC technology arises from taking advantage of its tremendous fuel flexibility to use fine, wet waste coal as the fuel source. The waste coal, which is a byproduct of the coal preparation process, can be obtained either by reclaiming tailings from existing slurry impoundments or by diverting the thickener underflow stream (before it is sent for disposal) from actively operating coal preparation plants. It can be transported via pipeline and requires only simple mechanical dewatering to form a paste that can be pumped into the PFBC combustor. There is broad availability of this material, with an estimated 34+ million tons produced each year by currently operating prep plants located in 13 coal-producing states, and hundreds of millions of tons housed in existing slurry impoundments. CONSOL's Bailey Central Preparation Plant in Greene County, PA, alone produces close to 3 million tons/year of fine coal refuse with a higher heating value of ~7,000 Btu/lb (dry basis), which is much more than sufficient to fuel a 300 MW net advanced PFBC power plant with CO_2 capture. This slurry is currently disposed of at a cost. As a result, it has the potential to provide a low- or zero-cost fuel source if it is instead used to fuel an advanced PFBC power plant located in close proximity to the coal preparation plant. Doing so also eliminates an environmental liability (slurry impoundments) associated with the upstream coal production process, improving the sustainability of the overall coal supply chain.

1.4.2 Market Advantage of the Concept

The market advantage of advanced PFBC relative to other coal-fueled generating technologies, then, stems from its unique ability to respond to all five key attributes identified above, while providing a rapid path forward for commercialization. Specifically, based on work performed during the Conceptual Design Phase:

1. Excellent Environmental Performance – The advanced PFBC is able to achieve very low NOx (<0.05 lb/MMBtu) and SO_2 (<0.117 lb/MMBtu) emission rates by simply incorporating selective non-catalytic reduction and limestone injection at pressure within the PFBC vessel itself. After incorporation of an SO_2 polishing step before the CO_2 capture process, the SO_2 emissions will be <0.03 lb/MMBtu or <0.256 lb/MWh. As mentioned above, the PFBC can also significantly improve the environmental footprint of the upstream coal mining process if it uses fine, wet waste coal as a fuel source, and it produces a dry solid byproduct (ash) having potential commercial applications.
2. Low Capital Cost – The advanced PFBC in carbon capture-ready configuration can achieve >40% net HHV efficiency at normal supercritical steam cycle conditions, avoiding the capital expense associated with the exotic materials and thicker walls needed for higher steam temperatures and pressures. Significant capital savings are also realized because NOx and SO_2 emission targets can be achieved without the need for an SCR or FGD. Finally, the P200 is designed for modular construction and replication based on a single, standardized design, enabling further capital cost savings.
3. Low O&M Cost – By fully or partially firing fine, wet waste coal at low-to-zero fuel cost, the advanced PFBC can achieve dramatically lower fuel costs than competing coal and natural gas plants. This is especially meaningful for the commercial competitiveness of the technology, as fuel cost (mine + transportation) accounts for the majority (~2/3) of a typical pulverized coal plant's total O&M cost, and for an even greater amount (>80%) of its variable (dispatch) cost. [**6**]
4. Operating Flexibility – The advanced PFBC plant includes four separate P200 modules that can be run in various combinations to cover a wide range of loads. Each P200 module includes a bed reinjection vessel to provide further load-following capability, enabling an operating range from <20% to 100%. A 4%/minute ramp rate can be achieved using a combination of coal-based energy and natural gas co-firing.
5. Ability to Cost-Effectively Incorporate Carbon Capture – The advanced PFBC produces flue gas at 11 bar, resulting in a greater CO_2 partial pressure and considerably smaller gas volumes relative to atmospheric boilers. The smaller volume results in smaller physical sizes for equipment. The higher partial pressure of CO_2 provides a greater driving force for CO_2 capture and can enable the use of the commercially-available Benfield CO_2 capture process, which has the same working pressure as the PFBC boiler. However, during this pre-FEED study, it was determined that an amine-based system operating at atmospheric pressure to capture CO_2 from the flue gas provides a more cost-effective overall design, even considering the specific process advantages of the Benfield process, due to the unrecoverable losses in temperature and pressure encountered when integrating the Benfield process with the PFBC gas path. In addition, because of the fuel flexibility afforded by the advanced PFBC boiler, there is also an opportunity to co-fire biomass with coal to achieve carbon-neutral operation.

The timeline to commercialization for advanced PFBC is expected to be an advantage relative to other advanced coal technologies because (1) the core P200 module has already been designed and commercially proven and (2) the main technology gaps associated with the advanced PFBC plant, including integration of carbon capture, integration of multiple P200 modules with a supercritical steam cycle, and development of a suitable turbomachine for integration with the PFBC gas path, are considered to be well within the capability of OEMs using existing materials and technology platforms. The concept of firing a PFBC with fine, wet waste coal (thickener underflow) was demonstrated in a 1 MWt pilot unit at CONSOL's former Research & Development facility in South Park, PA, both without CO_2 capture (in 2006-2007) and with potassium carbonate-based CO_2 capture (in 2009-2010), providing evidence of its feasibility. We believe that the first-generation advanced PFBC plant, capable of achieving ≥40% HHV efficiency in CO_2 capture-ready configuration or incorporating 90% CO_2 capture (increased to 97% in the pre-FEED study) and compression with ≤22% energy penalty, would be technically ready for commercial-scale demonstration in the early 2020s. We propose to evaluate CONSOL's Bailey Central Preparation Plant as a potential source of fuel (fine, wet waste coal) and potential location for this demonstration plant. Additional R&D in the areas of process optimization, turbomachine design, and advanced materials could enable a ≥4% efficiency point gain in Nth-of-a-kind plants and an approximately four percentage point improvement in the energy penalty associated with CO_2 capture, although it will likely only make sense to pursue efficiency improvement pathways that can be accomplished while maintaining or reducing plant capital cost.

1.4.3 Estimated Cost of Electricity Establishing the Competitiveness of the Concept

A summary of the estimated COE for the base case advanced PFBC with CO_2 capture is presented in Exhibit 1-1, again based on work performed during the Conceptual Design Study. These estimates are preliminary in nature and will be revised via a much more detailed analysis as part of the pre-FEED study. As discussed above, our base case economic analysis assumes a first-generation advanced PFBC plant constructed on a greenfield Midwestern U.S. site that takes rail delivery of Illinois No. 6 coal, as specified in the Common Design Basis for Conceptual Design Configurations. Capital cost estimates are in mid-2019 dollars and were largely developed by Worley Group, Inc. by scaling and escalating quotes or estimates produced under previous PFBC studies and power plant projects. Costs for coal and other consumables are based on approximate current market prices for the Midwestern U.S.: the delivered coal cost of $50/ton includes an assumed FOB mine price of $40/ton plus a rail delivery charge of $10/ton. For purposes of this conceptual estimate, it was assumed that PFBC bed and fly ash are provided for beneficial reuse at zero net cost/benefit. Also, because our Conceptual Design base plant design includes 90% CO_2 capture, we have assumed that the captured CO_2 is provided for beneficial use or storage at a net credit of $35/ton of CO_2, consistent with the 2024 value of the Section 45Q tax credit for CO_2 that is stored through enhanced oil recovery (EOR) or beneficially reused. Otherwise, the cost estimating methodology used here is largely consistent with that used in DOE's "Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity, Revision 3, July 6, 2015 [**7**][1]." The first-year cost of electricity (COE) values presented in Exhibit 1-1 are based on an 85% capacity factor (see discussion below) and 12.4% capital charge factor (CCF), consistent with the DOE bituminous baseline report assumption for high-risk electric power projects with a 5-year capital expenditure period.

[1] The reference to the 2015 version of the NETL Bituminous Baseline report was the latest version at the time of the Phase I conceptual report. References to the 2019 Bituminous Baseline report are made for the current pre-FEED work.

To better understand the potential competitiveness of the advanced PFBC technology, preliminary estimates for three other cases are also summarized in Exhibit 1-1: (1) a carbon capture-ready PFBC plant based on current technology firing Illinois No. 6 coal, (2) a carbon capture-ready PFBC plant based on advanced technology (4-point efficiency improvement + 15% reduction in capital cost) firing fine, wet waste coal, and (3) a PFBC plant with 90% CO_2 capture based on advanced technology (same as above, plus 4-point reduction in CO_2 capture energy penalty) firing fine, wet waste coal. Use of waste coal in cases (2) and (3) is assumed to result in a fuel cost of $10/ton as compared to $50/ton in the base case. (This cost could be even lower depending on proximity to the waste coal source, commercial considerations, etc.; a revised assumption will be developed as part of the pre-FEED phase.) The improvements in efficiency are assumed to be achieved through process optimization and resolution of the technology gaps identified above and later in this report. The improvements in capital cost are assumed to be achieved through process optimization, adoption of modular construction practices, and learning curve effects.

Exhibit 1-1. Cost of Electricity Projections for Advanced PFBC Plant Cases from Conceptual Design Study – Benfield Process

	Base Case: IL No. 6 coal 90% capture current tech	Case #1 IL No. 6 coal capture-ready current tech	Case #2 fine waste coal capture-ready advanced tech	Case #3 fine waste coal 90% capture advanced tech
Net HHV efficiency	31%	40%	44%	36%
Total Overnight Cost ($/kW)	$5,725	$3,193	$2,466	$4,189
Total Overnight Cost ($/MWh)	$95.33	$53.17	$41.07	$69.76
Fixed O&M Cost ($/MWh)	$24.34	$18.08	$16.44	$20.96
Fuel Cost ($/MWh)	$23.57	$17.93	$3.26	$4.06
CO_2 Credit ($/MWh)	($36.48)	--	--	($31.42)
Variable O&M Cost ($/MWh)	$10.16	$7.73	$7.03	$8.75
TOTAL COE ($/MWh)	$116.92	$96.91	$67.80	$72.12

Note: Data above are based on the Benfield CO_2 capture process, as presented in Conceptual Design Report.

Based on the initial projections from the Conceptual Design Phase in Exhibit 1-1, it is possible to highlight several competitive advantages of the advanced PFBC technology vs. other coal-fueled power generation technologies. First, although capital costs are expected to present a commercial hurdle for all coal-based technologies relative to natural gas-based technologies, the total overnight cost (TOC) range of $2,466/kW to $3,193/kW presented above for a capture-ready PFBC plant compares favorably with the expected TOC of ~$3,600/kW for a less-efficient new supercritical pulverized coal plant [**8**]. Second, the fuel flexibility of the PFBC plant provides an opportunity to use fine, wet waste coal to achieve dispatch costs that are expected to be substantially lower than those of competing coal and natural gas-based plants. As illustrated by Cases #2-3, a PFBC plant firing $10/ton waste coal is expected to achieve total fuel + variable O&M costs of $10-13/MWh, far better than the $24-29/MWh range for ultra-supercritical coal and natural gas combined cycle plants cited in the 2030 market scenario above. This should allow a PFBC plant firing waste coal to dispatch at a very high capacity factor, improving its economic viability. Finally, with a $35/ton credit for CO_2, and assuming a net zero-cost CO_2 offtake opportunity can be identified, the COE for an advanced PFBC plant with 90% CO_2 capture is expected to be reasonably similar to the COE for a capture-ready plant. We anticipate that the economics and performance of a first-generation PFBC plant with 90% CO_2 capture will fall between those presented in the Base Case and Case #3 above. A major objective of the project team moving forward will be to drive down COE through value engineering utilizing a combination of (i) process design and technology optimization and (ii) optimization of fuel sourcing and CO_2 offtake.

1.5 Ability to Meet Specific Design Criteria

The ability of the proposed plant design to meet the specific design criteria (as spelled out on p. 116 of the original Solicitation document) is described below:

- The PFBC plant is capable of meeting a 4% ramp rate using a combination of coal-based energy and co-fired natural gas energy up to 30% of total Btu input. Higher levels of natural gas firing may be feasible and can be evaluated. The PFBC design incorporates a bed reinjection vessel inside the main pressure vessel that stores an inventory of bed material (fuel and ash solids) during steady state operation. When a load increase is called for, this vessel reinjects a portion of its inventory back into the active bed to supplement the bed inventory. Natural gas co-firing using startup lances, over-bed firing, or a combination thereof is used to supplement the energy addition to the fluid bed to support the additional steam generation that supports the increase in power generation during the up-ramp transient. During down-ramp excursions, the bed reinjection vessel can take in some of the bed inventory to assist in maintaining the heat transfer requirements. Coal flow is reduced during a down-ramp transient. Steam bypass to the condenser may also be used in modulating a down-ramp transient.
- The PFBC plant requires 8 hours to start up from cold conditions on coal. Startup from warm conditions requires from 3 to 6 hours, depending on the metal and refractory temperatures existing when a restart order is given. Startup from hot conditions (defined as bed temperature at or near 1500 °F, and main steam pipe temperature above approximately 800 °F) requires less than 2 hours on coal; this time is reduced to approximately 1 to 2 hours with natural gas co-firing. It should be noted that very short startup times are not compatible with use of a supercritical steam cycle with high main and reheat steam design temperatures. There are two compelling factors that work against very fast starts for this type of steam cycle: first are the severe secondary stresses induced in heavy wall piping and valves necessary for supercritical steam conditions. Longer warmup times are necessary to avoid premature material failures and life-limiting changes in the pressure part materials for the piping, valves, and high-pressure turbine components. The second limiting factor on rapid startup times is the feed water chemistry limitation inherent in supercritical steam cycles. After a complete shutdown, condensate and feed water chemistry typically requires some length of time to be returned to specification levels. Assuring long material life and preventing various kinds of corrosion mechanisms from becoming an issue requires that water chemistry be brought to the proper levels prior to proceeding with a full startup from cold, no-flow conditions. Resolution of this entire bundle of issues could be viewed as a

"Technology Gap" of sorts, requiring investigation to determine if realistic, cost-effective remedies can be developed.

- The PFBC can turn down to the required 20% load and below by reducing the number of modules in operation. A 20% power level can be achieved by operating one of four P200 modules at approximately 80% load or two modules at about 40% load each. Operation is expected at full environmental compliance based on known previous operational experience.
- The PFBC technology described employs 97% CO_2 capture, but it can also be offered as fully CO_2 capture-ready without the capture equipment installed. The addition (construction) of the CO_2 capture equipment may be performed while the plant is in operation without interference, and the switch-over to CO_2 capture, after construction is completed, can be made by opening/closing specific valves to make the transition while at power. This is accomplished one PFBC module at a time to minimize any impacts on system operation.
- The proposed PFBC plant will incorporate a Zero Liquid Discharge system. The power plant portion of the facility will be integrated with the fuel preparation portion of the facility to incorporate internal water recycle and to reuse water to the maximum extent. This will minimize the capacity, and thereby the cost, of any required zero liquid discharge (ZLD) system.
- Solids disposal is characterized by two major streams of solids: bed ash and cyclone and filter ash. The ash material has mild pozzolanic properties, and it may be landfilled or used in a beneficial way to fabricate blocks or slabs for landscaping or light-duty architectural applications. The ash products are generally non-leachable as demonstrated by PFBC operations in Sweden and Japan.
- Dry bottom and fly ash discharge: PFBC ash (both bed and fly ash) is dry. Discharge is made through ash coolers that provide some heat recovery into the steam cycle condensate stream. The cooled ash is discharged into ash silos and then off-loaded into closed ash transport trucks for ultimate disposal or transport to a facility for use in manufacture of saleable end products, as noted above.
- Efficiency improvement technologies applicable to the PFBC will include neural network control features and learning models for plant controls balancing air supply against fuel firing rate (excess air), ammonia injection for SNCR, balancing bed performance against the performance of the caustic polishing scrubber for removing sulfur, and other opportunities to optimize overall performance.
- The limitation of air heater outlet temperatures is not applicable to PFBC technology.
- High-efficiency motors will be used for motor-driven equipment when and where applicable. Electric generators will be specified to be constructed to state-of-the-art efficiency standards.
- Excess air levels will be maintained at appropriate levels to optimize the operation of the overall PFBC Brayton and Rankine cycles, and the sulfur capture chemical reactions in the bubbling bed. A 12% excess air limit may or may not be applicable to this technology. Further evaluation is required. The excess air for the base design case is 16%. The PFBC technology does not include any component similar to a PC or CFB boiler air heater. However, attempts will be made to minimize leakage of hot gas that could result in loss of recoverable thermal energy.
- The consideration of sliding pressure vs. partial arc admission at constant throttle pressure will be made during the Phase 3 FEED study.
- A self-cleaning condenser has been employed for the steam cycle of Cases 1A and 1B. This is not applicable to the air cooled condenser used in Cases 2B and 2C. The attainment of consistent 1.5 in Hg backpressure is achievable on an annual average basis for the proposed Midwest site location. However, summer peak backpressures are likely to reach 2.0 inches or

more. This is a consequence of the statistically highly probable occurrence of high ambient wet bulb temperatures above 70 °F. Using aggressive design parameters for the heat sink, including a 5 °F terminal temperature difference for the condenser, a 7 or 8 °F cooling tower approach, and a 17 or 18 °F range for the circulating water system results in a condensing temperature of at least 99 or 100 °F at 70 °F ambient wet bulb temperature, which corresponds to a backpressure of 2.0 in Hga. Therefore, any time ambient wet bulb temperatures exceed 70 °F, the back pressure will exceed 2.0 in Hga. A back pressure of 1.5 in Hga (in the summer above 70 °F wet bulb temperature) might be maintained by use of a sub-dew point cooling tower technology. This is a relatively new innovation that promises to reduce the cooling water temperature produced by an evaporative cooling tower by adding the necessary components of the sub-dew point system to a relatively conventional evaporative cooling tower. Although the efficacy of the system to reduce cold water temperatures produced by an evaporative tower appears theoretically sound, the full economics of employing this type of system remain to be demonstrated in a commercial setting.

- When CO_2 capture is employed, additional sulfur capture is required ahead of the capture process. This additional polishing step reduces sulfur emissions to a level characterized by greater than 99.75% removal.
- Other low-cost solutions are being evaluated as applicable during this pre-FEED study.

1.6 Proposed PFBC Target Level of Performance for the Base Case (Illinois No. 6)

This section presents information on the following topics.

- Expected Plant Efficiency Range at Full and Part Load
- Emissions Control Summary
- CO_2 Control Strategy

1.6.1 Expected Plant Efficiency Range at Full and Part Load

The expected plant efficiency at full load for a CO_2 capture-ready advanced PFBC plant is shown in Exhibit 1-2 as a function of total plant capacity. (Note that information is presented with the amine configuration for various plant sizes, which vary according to the number of P200 modules installed.) The proposed PFBC technology is modular and couples to steam turbine generators of varying size. The efficiency varies with the size of the plant, as the selected steam conditions will vary. For almost a century of progress in the development of steam turbine cycles and equipment, the selected steam turbine throttle and reheat conditions have shown a strong correlation to size, as expressed in the table below. This is based on well-established design principles arrived at by the collective experience of turbine generator manufacturers. The steam temperatures are selected to be somewhat aggressive to maximize efficiency.

Exhibit 1-2. Output and Efficiency for Modular PFBC Designs for Various Installed Capacity Plants (Capture Ready – Amine Configuration)

No. of P200 Modules Installed	Total Installed Unit Output, MWe, net	Efficiency, HHV	Steam Cycle Parameters
1	88	37.0	1600/1025/1025
2	185	39.0	2000/1050/1050
3	285	40.0	2400/1075/1075
4	404	42.5%	3500/1100/1100

Note: The 4-module plant is selected as the case described in the remainder of this report.

Part-load efficiency for the 4 x P200 advanced PFBC plant in CO_2 capture-ready configuration is presented in Exhibit 1-3. The values in the exhibit reflect the PFBC plant operating with the indicated number of P200 modules at the stated load.

Exhibit 1-3. Part Load Efficiency Table for 4 x P200 PFBC Plant (Capture Ready – Amine Configuration)

Percent Load	No. Modules in Operation	MWe, net	Estimated Efficiency %, net, HHV
100	4	404	42.5%
80	4	323	40.7
60	3	242	39.4
40	2	162	37.1
20	1	81	32.0

The reduction in efficiency at part load will vary depending on how the plant is operated. Detailed modeling is required to estimate accurate impacts on thermal efficiency at part load. For example, the impact with 4 x P200 modules operating at 50% load may be different from the result obtained with only 2 x P200 modules operating at 100% load for a total plant output of 50%. Detailed definition of plant performance under these conditions will be evaluated in the Phase 3 FEED study.

For cases involving the addition of CO_2 capture to the completely capture-ready plant, two scenarios are presented below. Exhibit 1-4 shows different levels of CO_2 capture for the 4 x P200 module plant. Each case is based on applying the amine technology at a 97% capture rate to one, two, three, or all four P200 PFBC modules (the Conceptual Design Report used 90% and Benfield technology). These cases are all at full load for each module and for the entire plant.

The first efficiency column ("Current State-of-the-Art") presents estimated efficiency values for the configuration described in the Block Flow Diagram (BFD) in Section 4 of the Final Report. This configuration is based on currently available materials of construction, design experience, and practices. The second efficiency column ("Advanced State-of-the-Art") is based on resolution of the Technology Gap (Final Report Section 6.5.2.2 Improved Steam Cycle Conditions) identified in Section 6.6 "Technology Development Pathway Description" in the Final Report. The principal advance that would contribute to the higher efficiency levels is the use of advanced steam cycle alloys allowing use of the higher steam temperatures, including the use of double reheat.

Exhibit 1-4. Efficiency with CO_2 Capture for 4 x P200 PFBC Plant (Amine Configuration)

No. of Modules with Capture	% Capture, Total Plant	Estimated Efficiency, %, HHV, Current State-of-the-Art	Estimated Efficiency, %, HHV, Advanced State-of-the-Art
0	0	42.5	>44%
1	24.25	40.0	42
2	48.5	37.5	40
3	72.75	34.9	38
4	97.0	32.4	36

1.6.2 Emissions Control Summary

Air emissions for the PFBC technology are dependent on the coal and/or supplementary fuels fired. For the Illinois No. 6 coal, targeted emissions are presented in Exhibit 1-5. For the waste coal/biomass case, targeted emissions are presented in Exhibit 1-6. For different fuels and different sites, which may have widely varying emissions limits, additional measures may be required to meet these more stringent limits. The control of emissions to the limits stated in the DOE solicitation is accomplished as follows.

SO_2 is controlled by capture of sulfur in the pressurized bubbling bed. Limestone sorbent is incorporated in the fuel paste feed. The calcium in the limestone reacts with the sulfur in the coal to form calcium sulfate; the high partial pressure of oxygen in the pressurized bed assures that the material is sulfate (fully oxidized form) instead of sulfite. The design will achieve 90% capture in the bed at a calcium to sulfur (Ca/S) ratio of 2.5. In addition, a polishing step is added to the gas path to achieve a nominal overall 99.8% reduction of sulfur in the gas. The SO_2 reacts with NaOH in the polishing scrubber to form sodium bisulfite ($NaHSO_3$). Some SO_2 can react to form sodium sulfite (Na_2SO_3). This waste stream will be ultimately routed to the ZLD. The addition of the caustic scrubbing polishing step is driven by the limitation of sulfur in the gas feed to the CO_2 capture process as well as for HCl removal in the capture ready case. This has the added advantage of reducing SO_2 in the stack gas which makes the air permitting process easier, and also reduces limestone consumption and costs. The optimal value of total costs for limestone and caustic is expected to be in the range of the parameters described.

Exhibit 1-5. Expected Emissions for P200 Module Firing Illinois No. 6 Coal (Cases 1A / 1B)

Pollutant	DOE Target, lb/MWh	Stack Effluent, lb/MWh	Control Technology / Comments
SO_2	1.00	0.07 (1A) 0.08 (1B)	Target is achievable with 90% capture in-bed and added NaOH polishing step (with 98% removal). No removal by the CO_2 capture system is reflected.
NOx	0.70	0.39 (1A) 0.45 (1B)	Catalyst not required. Target is achievable with SNCR. No removal by the CO_2 capture system is reflected.
PM (filterable)	0.09	0.02	Cyclones and metallic filter will achieve target. Metallic filter is required to protect the turbomachine.
Hg	3×10^{-6}	1.8×10^{-6} (1A) 2×10^{-6} (1B)	Particulate removal and caustic scrubber will meet target. GORE® mercury removal system can be added if required.
HCl	0.010	<0.005	Cl capture of 99.5% plus is required based on the high Illinois No. 6 Cl content. Target is achieved primarily by the caustic scrubber with some Cl retention in the ash.

Exhibit 1-6. Expected Emissions for P200 Module Firing Waste Coal/biomass (Case 2C)

Pollutant	DOE Target, lb/MWh	Stack Effluent, lb/MWh	Control Technology / Comments
SO_2	1.00	0.07	Target is achievable with 90% capture in-bed and added NaOH polishing step (with 98% removal). No removal by the CO_2 capture system is reflected.
NOx	0.70	0.47	Catalyst not required. Target is achievable with SNCR. No removal by the CO_2 capture system is reflected.
PM (filterable)	0.09	0.05	Cyclones and metallic filter will achieve target. Metallic filter is required to protect the turbomachine.
Hg	3×10^{-6}	2.1×10^{-6}	Particulate removal, wet caustic scrubbing and the GORE® mercury removal system will be utilized to meet the target.
HCl	0.010	<0.002	Cl capture of 99.5% plus is required based on the high Illinois No. 6 Cl content. Target is achieved primarily by the caustic scrubber with some Cl retention in the ash.

The bed functions at a constant 1550 °F temperature, a temperature at which the NOx forming reactions are very slow (kinetically) and do not lead to any meaningful thermal NOx production. NOx that is formed is largely a product of fuel-bound nitrogen, as thermal NOx creation is minimized. The use of selective non-catalytic reduction (SNCR) reduces any NOx to very low levels (< 0.05 lb/MM Btu). The small amount of ammonia (NH3) slip from the SNCR will be removed in the NaOH scrubber prior to reaching the amine scrubbing process and/or the plant stack

In this version of the PFBC technology, a metallic filter is used to capture particulate matter (PM). The gas path leaving the PFBC vessel first encounters two stages of cyclones, which remove approximately 98% of the PM. The metallic filter removes over 99.5% of the remaining PM, resulting in very low PM emissions. This also enables the gas to be expanded in conventional gas expanders, and then after heat recovery, to be reacted with CO_2 capture solvent. The use of special expander materials and airfoil profiles is not required.

The fate of Hg and Cl requires detailed evaluation in the Phase 3 FEED study. However, at this time, the following rationale is offered in support of our belief that these elements will be controlled to within regulatory limits particularly for the CO_2 capture-equipped case. A significant portion of the Hg and Cl will be reacted to form a solid compound and will be captured by the two stages of cyclones inside the PFBC vessel and the metallic gas filter (external to the vessel) operating at 99.5% plus efficiency. That leaves Hg and Cl in the vapor phase in solution or as elemental species. The gas will pass in succession through the following:

1. A sulfur polishing stage using an alkaline solvent such as sodium hydroxide
2. A mercury removal system for removal of elemental Hg
3. The CO_2 capture absorber vessel

It is believed that the two stages of scrubbing and the mercury removal system, in series, will capture a very high percentage of the Hg and Cl that remained in the gas after the cyclone/filter stages.

1.6.3 CO_2 Control Strategy

The initial CO_2 capture strategy employed for the proposed advanced PFBC plant was to couple the Benfield process with the P200 gas path to capture CO_2 at elevated pressure and reduced temperature. Regenerative reheating of the gas was utilized to recover most of the thermal energy in the gas to maximize energy recovery and improve thermal efficiency. However, it was determined during the performance results generation process that using an amine-based system operating at 1 atmosphere pressure on the back end of the flue gas path yielded higher plant efficiency with reduced impact on plant capital costs. The CO_2 capture is applied in a modular manner, so that the quantity of CO_2 captured may be tailored to the needs of each specific project. Performance is presented for a 97% capture case (again, the Conceptual Design Report used 90%). For this 97% capture case, each P200 PFBC module is coupled to a separate amine process train for CO_2 capture. The system for CO_2 compression and drying utilizes two 50% capacity (relative to 100% plant capacity) component trains; therefore, each train serves two P200 PFBC modules.

As mentioned above, the project team evaluated a PFBC configuration based on the amine process and has adopted this process for completion of the remaining scope of work.

2 Cost Estimating Methodology and Cost Results

2.1 Capital Costs

2.1.1 General

Capital costs have been developed for a four-module PFBC power plant for each of the pre-FEED study configurations identified in Exhibit 2-1, including:

Case 1A – Illinois No. 6 Coal with 0% CO_2 Capture (Capture-Ready Configuration)

Case 1B – Illinois No. 6 Coal with 97% CO_2 Capture

Case 2B – Waste Coal with 97% CO_2 capture

Case 2C – 95% Waste Coal / 5% Biomass with 97% CO_2 Capture

The capital cost estimates are based on a blend of budget quotations from selected equipment vendors, some targeted material take-off data based on design information developed during the course of the Phase 2 pre-FEED study, and scaled or factored cost information for similar systems and equipment from the Worley experience base.

Capital costs are presented at the Bare Erected Cost (BEC), Total Plant Cost (TPC), Total Overnight Cost (TOC), and Total As-Spent Capital (TASC) levels. BEC includes the cost of equipment, construction materials, and associated installation labor (both direct and indirect). TPC includes BEC plus the cost of engineering, design, and construction management services and associated fees, as well as both process and project contingencies. TOC includes the TPC plus all other overnight costs, including pre-production costs, inventory capital, financing costs, and other owner's costs. TASC represents the total of all capital expenditures incurred during the capital expenditure period, including both escalation and interest during construction. TOC and TASC were estimated using the methodology set forth in the *Quality Guidelines for Energy System Studies: Cost Estimation Methodology for NETL Assessments of Power Plant Performance* [**9**].

Additional details of the capital costing approach are listed below.

- The estimates are based on an engineer, procure and construction management (EPCM) contracting approach, utilizing multiple subcontracts.
- All costs are presented in U.S. dollars and represent "overnight" costs for late 2019/early 2020. Forward escalation over the period of performance through FEED and Design and Construction to Commercial Operation is excluded.
- The estimated boundary limit is defined as the total plant facility within the "fence line," including fuel (Illinois No. 6 or waste coal and biomass) and limestone sorbent receiving and preparation to form the fuel/sorbent paste that is fed to the PFBC boiler. CO_2 compression and pipeline within the fence line are also included.
- A new switchyard is required, and an allowance for a 4-breaker ring bus configuration to connect to an existing transmission line (345 kV for Case 1 and 500 kV for Case 2) crossing the intended site has been included.
- The project site will be furnished in a clean, level condition.

- Costs are grouped according to a system-oriented code of accounts; all reasonably allocable components of a system or process are included in the specific system account in contrast to a facility, area, or commodity account structure.

2.1.2 Equipment and Material Pricing

Vendor quotations were solicited and received for the following major subsystems and components:

• PFBC Vessels and Internals	Nooter/Eriksen
• CO_2 Capture System	BASF-Linde
• Hot Gas Filters	Mott Corporation and Pall Corp. (subsidiary of Danaher Corp.)
• Steam Turbine Generator	General Electric and Siemens
• Gas Turbomachines	Baker Hughes
• Fuel and Sorbent Prep and Feed	Farnham & Pfile

The above were supplemented by a limited number of project-specific quotations for some of the more minor equipment items as well as from Worley's database of quotations for similar equipment and systems from other recent or ongoing projects. All database quotations were scaled to reflect the project-specific design parameters and escalated as appropriate.

All quotations were adjusted as required to include freight to site, vendor technical direction during installation, incomplete or missing scope items, and/or changes in capacity, as well as conversion to U.S. dollars.

Where specifically identified, contingency was removed from the quotations and applied in a consistent manner in the cost summaries presented later in this section.

2.1.3 Labor Pricing

Installation labor costs for the Illinois No. 6 coal-fired cases (Cases 1A and 1B) are based on merit-shop rates for a Midwest U.S. location. Labor costs for the waste coal-fired Business Cases located in southwest Pennsylvania (Cases 2B and 2C) are based on union shop rates and associated productivities. All cases are based on a competitive bidding environment, with adequate skilled craft labor available locally to staff the projects.

Labor is based on a 50-hour workweek (5-10s). No additional incentives such as per-diems or bonuses have been included to attract craft labor.

The labor cost is considered all-inclusive and includes the following:

- Craft wages
- Burdens and benefits
- Payroll taxes and insurance
- Supervision, indirect craft, scaffolding
- Temporary facilities and utilities
- Field office
- Small tools and consumables
- Safety
- Mobilization/demobilization

- Construction rental equipment (with associated fuel, oil, and maintenance)
- Contractor's labor-related overhead and profit

2.1.4 Engineering

Engineering, procurement and construction management costs were generally estimated at 10 percent of the BEC. These costs included all home office engineering, design, and procurement services as well as field construction management staff. Site staffing generally included a construction manager, resident engineers, scheduling, project controls, document control, materials management, site safety, and field inspection.

The furnish and erect quotation for the PFBC vessels and the furnish and erect estimate for the complete fuel and sorbent preparation and feed system each included all required costs for design, engineering, procurement, and site supervision. As such, the engineering costs for these items were estimated at a reduced value of 3.5 percent to reflect the reduced scope of work for the project EPCM contractor.

2.1.5 Contingency

Contingencies are included in the estimate to account for unknown costs that are omitted or unforeseen due to a lack of complete project definition and engineering. Experience has shown that such costs are likely and expected to be incurred even though they cannot be explicitly determined at the time the estimate is prepared. It is expected that by the end of the project the entire contingency will be spent on either direct or indirect costs.

Process contingency is intended to compensate for uncertainty in cost estimates caused by performance and technology integration uncertainties associated with the development status of a particular system. While the overall project is in essence a first-of-a-kind plant, it is comprised of equipment and processes that are, in most cases, representative of mature commercial technologies. As such, process contingency has been applied to only two accounts:

- Turbomachines: 20% process contingency to address a custom design for this application
- Instrumentation and Controls: 15% process contingency to address integration issues

Project contingency has generally been applied at 15 percent of the sum of BEC, EPCM, and process contingency. This is based on the current level of design development and definition. Contingency has been reduced to 10% on the furnish and erect values for the fuel and sorbent preparation and feed system and the PFBC vessels. This is consistent with the estimate development process for these packages.

2.1.6 Exclusions

The following items are excluded from the capital cost estimate:

- Demolition/removal of existing facilities/structures
- Removal/remediation of hazardous or contaminated materials
- Removal/relocation of underground obstructions
- Infrastructure external to plant boundary (e.g. CO_2 pipeline)
- All taxes, with the exception of payroll and property taxes (property taxes are included with the fixed O&M costs)

2.1.7 Estimate Accuracy

AACE International estimate classifications identify both the level of project definition and the estimate approach associated with various degrees of estimate accuracy; the better the accuracy, the more stringent the requirements. However, estimate accuracy is somewhat subjective as it is a function of numerous variables. These include the level of project definition, the estimate approach, the extent and quality of supporting quotations, estimate preparation time, etc. A further consideration is maturity of the technologies and their integration into a process. In setting estimate accuracy, each of these must be taken into account and the associated risk evaluated.

Some key considerations regarding this estimate include:

- Project definition is currently in the very early stages; estimated to be in the range of 1% of total engineering and design definition.
- While the individual project components are mostly considered to be mature technologies, the overall plant is essentially a first-of-a-kind.
- Project-specific quotations were limited to individual equipment items or processes and likely do not reflect the full extent of the overall project process integration requirements.

Based on the level of design definition and the estimate methodology, the current estimate is best classified as falling between AACE Class 3 and Class 4.

2.2 Capital Cost Saving Concepts for FEED Study Implementation

The design configuration presented in the Phase 2 pre-FEED Study Final Report is comprised of 4 x P200 PFBC modules operating at nominal 12 bar pressure connected in parallel to a single supercritical steam turbine generator. The flue gas path employs CO_2 capture at low pressure and temperature, after expansion through the turbomachine and all economically feasible energy recovery from the gas have been completed.

This configuration is significantly different from what was employed at the beginning of the pre-FEED study. That configuration employed a reduction in gas temperature prior to gas filtration, followed by further gas cooling in a regenerative heat transfer arrangement, CO_2 capture at elevated pressure (nominal 12 bar) using the Benfield process, and reheating of the CO_2-lean gas in the regenerative heat transfer system prior to expansion through the turbomachine.

Thermodynamic cycle studies were performed to evaluate alternative arrangements, based on the somewhat disappointing performance results from the original configuration. These studies revealed that there were unrecoverable losses due to the following:

- Pressure drops on the gas side in the heat transfer processes, leading to loss of expander power,
- Reduction in final temperature at the gas expander inlet, due to realistic and finite approach temperatures in the various heat exchangers employed. This reduction in temperature also reduces available power generation, and
- Loss of expansion power from the CO_2 gas component of the total gas stream. Although the CO_2 is captured at pressure in the original configuration, it is stripped and released from the Benfield solvent at between 1 and 2 bar. This then requires recompression to the final desired pressure (2215 psi or 153 bar).

These cumulative losses do not compensate for the reduced parasitic loads incurred in operation of the Benfield CO_2 capture system (lower steam requirement for CO_2 stripping and lower auxiliary electrical loads) relative to the amine-based CO_2 capture process selected for inclusion in the final design configuration. It is likely that prior evaluations of the application of the Benfield process to CO_2 capture in a PFBC did not fully account for or underestimated the losses involved.

At the conclusion of the Phase 2 pre-FEED study, a review was conducted to identify further changes to the advanced PFBC concept that hold promise for further reducing costs and increasing efficiency. These modifications are described below; they may be evaluated separately in parallel and then combined for a final system evaluation. The potential cost savings may not be linearly additive, as there may be interactions between these proposed changes that are synergistic (cumulative effects may be greater than the simple sum); or, conversely, the net combined sum of the changes may be less than the total linear superposition sum.

The first initiative to be evaluated is to increase the operating pressure of each PFBC module from 12 bar to 16 bar. In theory, this can allow three PFBC modules operating at 16 bar to accomplish the same thermal duty and power generation as four modules operating at 12 bar. This is precisely what the Karita P800 design in Japan has accomplished (though in that case the three higher-pressure PFBC boilers are integrated into a single large pressure vessel, resulting in a less modular design). The increased pressure allows higher mass flow and heat transfer to occur at the same volumetric flow.

This concept requires modifications to the PFBC pressure vessel, gas piping, gas filters, and gas turbomachines. Other ancillary equipment is also impacted, and the combustor building can be redesigned with a smaller footprint. The net cost savings that may accrue from this change in operating pressure can range up to $100 MM or more on a bare erected overnight construction cost basis. Other projected cost savings presented below are also on the same overnight BEC basis.

The second initiative to reduce overall costs is to select a power plant site with direct river access. This will allow complete fabrication of the PFBC vessels at a favorable site with regard to labor costs and productivity. With the current inland site, significant additional disassembly and reassembly work and non-destructive examination (radiography of welds, possible post-weld heat treatment) is required. Net cost savings from this change can be in the range of $30 to 50 MM.

Another potential cost saving modification to the Business Case plant documented in the Phase 2 Pre-FEED Study Final Report is to perform additional pre-processing of the waste coal to be fired. Based on extensive modeling of the PFBC system with Thermoflex, it is known that power output and thermal efficiency (on an HHV basis) are impacted by the ash content of the as-fired fuel. More ash requires more water for transport into the PFBC boilers. The resulting increase in vapor phase water occupies volume inside the PFBC gas flow passages and impacts the gas velocity throughout the system. As gas velocity is limited through the fluidized bubbling bed, this constraint limits fuel input and, therefore, power output. This change by itself will not reduce PFBC module costs but can reduce some ancillary system costs such as ash handling system costs. It is expected that some or all of these cost savings may be offset by increased costs in the fuel preparation area to cover the costs of the additional coal processing. However, the primary capital cost benefit to be gained by this modification is that, by increasing net power output, it will reduce costs on a $/kWe basis. The difference in ash content and power output can be gauged roughly by comparing the Illinois No. 6 case with the waste coal case (assuming the same steam turbine conditions). This implies an increase in net output of about 28 MWe for a decrease in ash content from nominal 33% by weight for waste coal to 10% by weight for Illinois No. 6 coal, as well as an approximately 2+ percentage point increase in net plant HHV efficiency. Pilot testing conducted by OMNIS Bailey, LLC using the thickener underflow stream from CONSOL's Bailey Central Preparation Plant has demonstrated that the ash content of the waste coal stream can be reduced to even lower levels than this and that the resulting separated mineral matter stream (which is not ash because it has been separated from the fuel prior to combustion) may have applicability as a soil amendment in agricultural applications [**10**]. OMNIS is now building the first commercial-scale module at Bailey to process thickener underflow [**11**]; this option will be explored in depth as part of the FEED study.

Again, cost savings may be realized by subjecting the design of the entire PFBC power plant to a disciplined Value Engineering process. This process evaluates functions of the various systems and components, reliability and availability relative to the installed capacity of components (i.e., sparing and capacity selections - for example, two pumps at 100% vs. three pumps at 50%), mean time to failure and mean time to repair for essential components, materials of construction for all systems and components, selection of appropriate design codes and design margins, etc. The general arrangement drawings of the plant and the footprint of the major buildings and structures show potential for reduction in size and cost. There was insufficient time during the pre-FEED study to fully evaluate these measures. It is difficult to put a number on the potential savings that can be achieved by a disciplined, structured Value Engineering process. For the purposes of this narrative, it is suggested that a range of 3% to 6% of bare erected cost be used; therefore, a reduction in bare erected cost of between $45 to $90 MM can be assumed.

Another avenue of possible capital cost reduction is a reduction in the size of the ZLD system and the costs associated with it. The present configuration includes systems sized assuming the use of evaporative cooling towers for the Illinois No. 6 case (i.e., Case 1), and a smaller evaporative cooling tower for the waste coal-fired Business Case (i.e., Case 2, which uses a dry air-cooled condenser for the steam turbine generator).

Some of the remaining heat loads, in addition to the steam turbine condenser, can be cooled by a closed loop cooling system using a dry fin fan cooler. By further reducing the cooling tower duty, and thus reducing the evaporation and blowdown rates, the ZLD system size and cost can be reduced. This will be evaluated in the Phase 3 FEED study, with estimated savings of $5 to $10 million.

Yet another area of review for potential cost savings is the CO_2 capture and compression system. The cost for this system in the current estimate is based on a quote from a single vendor. (A total of five vendors were solicited for quotes. Four of the five declined to provide any information within the timeframe and scope of the pre-FEED study but noted that they would be more forthcoming in an actual procurement process). Besides competitive bidding, some reconfiguration of the system might be possible based on inputs from qualified vendors, leading to potential cost reductions. Cost reductions of 5% to 10% can be assumed as a placeholder for the purposes of this narrative. Therefore, cost savings of $ 10MM to $ 20MM are possible.

As more detailed analyses and design proceed during the Phase 3 FEED study, other potential initiatives to reduce costs may be revealed. The simple linear superposition of the initiatives described in this narrative total to a sum between $190 MM to $ 270 MM in bare erected cost. In addition, a gain in net power for sale on the order of 30 MWe may be achieved for the Business Case (Case 2) plant.

The net impact of successfully implementing the initiatives described above can produce a reduction in plant capital costs ranging from 20% to 30% on a $/kWe (net) basis. This represents a very significant improvement in the potential plant economic basis. These initiatives are very credible and can be implemented with a good likelihood of success. All will be pursued and fully vetted during the initial design studies planned for the first seven months of the Phase 3 FEED study.

2.3 Operation and Maintenance Costs

Operation and Maintenance (O&M) costs were estimated on a late-2019/early 2020 “overnight” cost basis consistent with the capital costs. The costs are presented on an average annual basis and do not include initial start-up costs. The O&M costs are split into two components: fixed and variable. Fixed costs are independent of capacity factor, while variable costs are proportional to the plant capacity factor. Annual costs for property taxes & insurance have been included at two percent of the TPC.

Operating labor cost was based on the anticipated staffing, by area, required to operate the plant. The corresponding hours were converted to equivalent around-the-clock (24/7) operating jobs.

Maintenance cost was evaluated on the basis of relationships of maintenance cost to initial capital cost for similar equipment items and processes. This represents a weighted analysis in which the individual cost relationships were considered for each major plant component or section.

Fuel costs for Illinois No. 6 coal and biomass were based on the assumptions set forth in the Final Report Sections 3.2.1 and 3.2.2, respectively. Waste coal for the Business Case (Case 2) was assumed to be supplied to the power plant gate at zero net cost, as this material is a waste stream having no current value (it is actually being disposed of at cost), and the cost to pump it via slurry pipeline to the assumed power plant site (within the footprint of the Bailey Central Preparation Plant Site) was estimated to be approximately the same as the current cost to pump it via slurry pipeline for disposal in slurry impoundments located within that same footprint.

Costs for consumables (water, chemicals, and supplemental fuels) were determined on the basis of individual rates of consumption, the unit cost of each consumable, and the plant annual operating hours. The quantities for initial fills and daily consumables were calculated on a 100 percent operating capacity basis. The annual cost for the daily consumables was then adjusted to incorporate the annual plant operating basis, or capacity factor.

Similarly, waste disposal costs were determined on the basis of individual consumption / production rates, the unit costs for each item, and the plant annual operating hours. For purposes of this initial estimate, and based on the success achieved with beneficially utilizing PFBC ash produced at the Karita plant, it was assumed that PFBC bed and fly ash are provided for beneficial reuse at zero net cost/benefit.

Also, for those cases including CO_2 capture, we assumed that the captured CO_2 is injected for storage in a deep geologic formation in the vicinity of the plant. CO_2 that has been verified as geologically sequestered was assumed to have a credit value of $50/ton for the life of the plant, consistent with the value currently specified under Section 45Q of the U.S. tax code. DOE-NETL estimated the costs for CO_2 transport and storage to be approximately $10/tonne ($9/ton) of CO_2 in the midwestern U.S. [**12**]. As such, all of the costs presented in this report assume that any captured CO_2 was credited at a value of $41/ton ($50/ton value of 45Q credit less $9/ton for transport and storage) at the power plant gate.

2.4 Cost Results

The capital and O&M cost results for the analyzed cases are presented in the following Exhibits:

Exhibit 2-1. Total Plant Cost Summary – Case 1A (Illinois No. 6 - Capture Ready)

Exhibit 2-2. Owner's Costs – Case 1A (Illinois No. 6 - Capture Ready)

Exhibit 2-3. Initial and Annual O&M Expenses – Case 1A (Illinois No. 6 - Capture Ready)

Exhibit 2-4. Total Plant Cost Summary – Case 1B (Illinois No. 6 - Capture Equipped)

Exhibit 2-5. Owner's Costs – Case 1B (Illinois No. 6 - Capture Equipped)

Exhibit 2-6. Initial and Annual O&M Expenses – Case 1B (Illinois No. 6 - Capture Equipped)

Exhibit 2-7. Total Plant Cost Summary – Case 2B (Waste Coal - Capture Equipped)

Exhibit 2-8. Owner's Costs – Case 2B (Waste Coal - Capture Equipped)

Exhibit 2-9. Initial and Annual O&M Expenses – Case 2B (Waste Coal - Capture Equipped)

Exhibit 2-10. Total Plant Cost Summary – Case 2C (Waste Coal & Biomass - Capture Equipped)

Exhibit 2-11. Owner's Costs – Case 2C (Waste Coal & Biomass - Capture Equipped)

Exhibit 2-12. Initial and Annual O&M Expenses – Case 2C (Waste Coal & Biomass - Capture Equipped)

Exhibit 2-1. Total Plant Cost Summary – Case 1A (Illinois No. 6 - Capture Ready)

Client: Consol
Project: Case 1A - PFBC Illinois Coal Based Power Plant **no** CO2 Capture
Report Date: 2020 May 04

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual
Plant Size: 404.0 MW,net
Labor Basis mid-West US - merit
Cost Base Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	FUEL PREP & FEED	$88,700	$0	**$88,700**	$3,105	$0	$9,180	**$100,985**	$250
2	OPEN	$0	$0	**$0**	$0	$0	$0	**$0**	$0
3	FEEDWATER & MISC. BOP SYSTEMS	$97,276	$55,122	**$152,398**	$15,240	$0	$25,146	**$192,784**	$477
4	PFBC								
4.1	PFBC - furnish & erect	$326,500	$0	**$326,500**	$11,428	$0	$33,793	**$371,720**	$920
4.2-4.9	Other	$3,774	$4,976	**$8,750**	$875	$0	$1,444	**$11,069**	$0
	SUBTOTAL 4	**$330,274**	**$4,976**	**$335,250**	**$12,303**	**$0**	**$35,237**	**$382,790**	**$947**
5	FLUE GAS CLEANUP	$78,111	$16,466	**$94,577**	$9,458	$0	$15,605	**$119,639**	$296
5B	CO2 REMOVAL & COMPRESSION	$0	$0	**$0**	$0	$0	$0	**$0**	$0
6	TURBO MACHINES								
6.1	Turbo Machines	$54,192	$6,143	**$60,335**	$6,034	$12,067	$11,765	**$90,201**	$223
6.2-6.9	Other	$361	$949	**$1,311**	$131	$0	$216	**$1,658**	$4
	SUBTOTAL 6	**$54,553**	**$7,093**	**$61,646**	**$6,165**	**$12,067**	**$11,982**	**$91,859**	**$227**
7	DUCTING & STACK								
7.1	open	$0	$0	**$0**	$0	$0	$0	**$0**	$0
7.2-7.9	Ductwork and Stack	$28,941	$2,034	**$30,975**	$3,097	$0	$5,111	**$39,183**	$97
	SUBTOTAL 7	**$28,941**	**$2,034**	**$30,975**	**$3,097**	**$0**	**$5,111**	**$39,183**	**$97**
8	STEAM TURBINE GENERATOR								
8.1	Steam TG & Accessories	$36,060	$5,728	**$41,788**	$4,179	$0	$6,895	**$52,862**	$131
8.2-8.9	Turbine Plant Auxiliaries and Steam Piping	$29,796	$18,251	**$48,047**	$4,805	$0	$7,928	**$60,779**	$150
	SUBTOTAL 8	**$65,856**	**$23,979**	**$89,835**	**$8,983**	**$0**	**$14,823**	**$113,641**	**$281**
9	COOLING WATER SYSTEM	$16,631	$12,292	**$28,922**	$2,892	$0	$4,772	**$36,587**	$91
10	ASH HANDLING SYSTEM	$28,785	$4,844	**$33,629**	$3,363	$0	$5,549	**$42,540**	$105
11	ACCESSORY ELECTRIC PLANT	$41,230	$32,908	**$74,138**	$7,414	$0	$12,233	**$93,784**	$232
12	INSTRUMENTATION & CONTROL	$10,583	$948	**$11,531**	$1,153	$1,730	$2,162	**$16,575**	$41
13	IMPROVEMENTS TO SITE	$2,175	$4,595	**$6,770**	$677	$0	$1,117	**$8,564**	$21
14	BUILDINGS & STRUCTURES	$52,735	$31,498	**$84,233**	$8,423	$0	$13,898	**$106,554**	$264
	TOTAL COST	**$895,849**	**$196,753**	**$1,092,602**	**$82,272**	**$13,797**	**$156,814**	**$1,345,485**	**$3,330**

Client: Consol
Project: Case 1A - PFBC Illinois Coal Based Power Plant **no** CO2 Capture
Report Date: 2020 May 04

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual
Plant Size: 404.0 MW,net
Labor Basis mid-West US - merit
Cost Base Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	FUEL PREP & FEED								
1.1	Fuel Prep & Feed System - complete plant	$88,700	$0	$88,700	$3,105	$0	$9,180	$100,985	$250
1.8	Fuel Prep & Feed Buildings - incl with system costs	$0	$0	$0	$0	$0	$0	$0	$0
1.9	Fuel Prep & Feed Foundations - incl with system costs	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 1.	**$88,700**	**$0**	**$88,700**	**$3,105**	**$0**	**$9,180**	**$100,985**	**$250**
2	OPEN								
2.1	open	$0	$0	$0	$0	$0	$0	$0	$0
2.9	open	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 2.	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	FEEDWATER & MISC. BOP SYSTEMS								
3.1	Feedwater System	$16,192	$6,471	$22,662	$2,266	$0	$3,739	$28,668	$71
3.2	Water Makeup & Pretreating - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.3	Other Feedwater Subsystems - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.4	Service Water Systems - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.5	Other Plant Systems	$43,780	$26,975	$70,755	$7,076	$0	$11,675	$89,505	$222
3.6	FO Supply System - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.7	Zero Liquid Discharge System	$36,250	$19,281	$55,531	$5,553	$0	$9,163	$70,247	$174
3.8	Misc. Equip.(cranes,AirComp.,Comm.) - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.8	BOP Foundations	$1,054	$2,396	$3,450	$345	$0	$569	$4,364	$11
	SUBTOTAL 3.	**$97,276**	**$55,122**	**$152,398**	**$15,240**	**$0**	**$25,146**	**$192,784**	**$477**
4	PFBC								
4.1	PFBC - furnish & erect	$326,500	$0	$326,500	$11,428	$0	$33,793	$371,720	$920
4.2	PFBC Auxilliary Systems	$252	$703	$955	$95	$0	$158	$1,208	$3
4.3	Open	$0	$0	$0	$0	$0	$0	$0	$0
4.4	Boiler BoP (w/ ID Fans)	$0	$0	$0	$0	$0	$0	$0	$0
4.5	Primary Air System	$0	$0	$0	$0	$0	$0	$0	$0
4.6	Secondary Air System	$0	$0	$0	$0	$0	$0	$0	$0
4.8	Major Component Rigging	$0	$0	$0	$0	$0	$0	$0	$0
4.9	PFBC Foundations	$3,522	$4,273	$7,796	$780	$0	$1,286	$9,861	$24
	SUBTOTAL 4.	**$330,274**	**$4,976**	**$335,250**	**$12,303**	**$0**	**$35,237**	**$382,790**	**$947**

Client: Consol
Project: Case 1A - PFBC Illinois Coal Based Power Plant **no** CO2 Capture
Report Date: 2020 May 04

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual
Plant Size: 404.0 MW,net
Labor Basis mid-West US - merit
Cost Base Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
5	FLUE GAS CLEANUP								
5.1	Gas Heating & Cooling	$0	$0	$0	$0	$0	$0	$0	$0
5.2	Gas Filtration	$68,040	$9,277	$77,317	$7,732	$0	$12,757	$97,806	$242
5.3	SO2 Removal	$6,000	$3,369	$9,369	$937	$0	$1,546	$11,851	$29
5.4	Mercury removal	$0	$0	$0	$0	$0	$0	$0	$0
5.5	Flue Gas Piping	$3,051	$3,531	$6,582	$658	$0	$1,086	$8,327	$21
5.6	CEMs	$1,020	$289	$1,309	$131	$0	$216	$1,656	$4
5.9	open	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 5.	**$78,111**	**$16,466**	**$94,577**	**$9,458**	**$0**	**$15,605**	**$119,639**	**$296**
5B	CO2 REMOVAL & COMPRESSION								
5B.1	CO2 Removal System	$0	$0	$0	$0	$0	$0	$0	$0
5B.2	CO2 Compression	$0	$0	$0	$0	$0	$0	$0	$0
5B.9	CO2 Removal & Compression Foundations	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 5B.	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
6	TURBO MACHINES								
6.1	Turbo Machines	$54,192	$6,143	$60,335	$6,034	$12,067	$11,765	$90,201	$223
6.2	Intercooler for PFBC	$0	$0	$0	$0	$0	$0	$0	$0
6.3	Open	$0	$0	$0	$0	$0	$0	$0	$0
6.9	Turbo Machines Foundations	$361	$949	$1,311	$131	$0	$216	$1,658	$4
	SUBTOTAL 6.	**$54,553**	**$7,093**	**$61,646**	**$6,165**	**$12,067**	**$11,982**	**$91,859**	**$227**
7	DUCTING & STACK								
7.1	open	$0	$0	$0	$0	$0	$0	$0	$0
7.3	Ductwork	$561	$994	$1,555	$156	$0	$257	$1,967	$5
7.4	Stack - furnish and erect	$27,600	$0	$27,600	$2,760	$0	$4,554	$34,914	$86
7.9	Duct & Stack Foundations	$780	$1,040	$1,820	$182	$0	$300	$2,302	$6
	SUBTOTAL 7.	**$28,941**	**$2,034**	**$30,975**	**$3,097**	**$0**	**$5,111**	**$39,183**	**$97**
8	STEAM TURBINE GENERATOR								
8.1	Steam TG & Accessories	$36,060	$5,728	$41,788	$4,179	$0	$6,895	$52,862	$131
8.2	Turbine Plant Auxiliaries	$1,955	$2,435	$4,390	$439	$0	$724	$5,553	$14
8.3	Condenser & Auxiliaries	$5,990	$2,493	$8,483	$848	$0	$1,400	$10,732	$27
8.4	Steam Piping	$19,933	$9,645	$29,578	$2,958	$0	$4,880	$37,417	$93
8.9	STG Foundations	$1,917	$3,678	$5,595	$559	$0	$923	$7,077	$18
	SUBTOTAL 8.	**$65,856**	**$23,979**	**$89,835**	**$8,983**	**$0**	**$14,823**	**$113,641**	**$281**
9	COOLING WATER SYSTEM								
9.1	Cooling Towers - furnish & erect	$6,720	$0	$6,720	$672	$0	$1,109	$8,501	$21
9.2	Circulating Water Pumps	$1,200	$104	$1,304	$130	$0	$215	$1,649	$4
9.3	Circ.Water System Auxiliaries	$194	$119	$313	$31	$0	$52	$396	$1
9.4	Circ.Water Piping	$5,435	$7,083	$12,518	$1,252	$0	$2,065	$15,835	$39
9.5	Make-up Water System	$0	$0	$0	$0	$0	$0	$0	$0
9.6	Component Cooling Water Sys	$657	$588	$1,245	$125	$0	$205	$1,575	$4
9.9	Circ.Water System Foundations & Structures	$2,425	$4,398	$6,822	$682	$0	$1,126	$8,630	$21
	SUBTOTAL 9.	**$16,631**	**$12,292**	**$28,922**	**$2,892**	**$0**	**$4,772**	**$36,587**	**$91**

Client: Consol **Report Date:** 2020 May 04
Project: Case 1A - PFBC Illinois Coal Based Power Plant **no** CO2 Capture

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual **Labor Basis** mid-West US - merit
Plant Size: 404.0 MW,net **Cost Base** Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
10	ASH HANDLING SYSTEM								
10.1	Ash Handling System	$18,115	$2,620	$20,735	$2,073	$0	$3,421	$26,230	$65
10.2	Ash Silos - furnish & erect	$8,920	$0	$8,920	$892	$0	$1,472	$11,284	$28
10.8	Misc. Ash Handling Equipment	$0	$0	$0	$0	$0	$0	$0	$0
10.9	Ash System Foundations	$1,750	$2,224	$3,974	$397	$0	$656	$5,027	$12
	SUBTOTAL 10.	**$28,785**	**$4,844**	**$33,629**	**$3,363**	**$0**	**$5,549**	**$42,540**	**$105**
11	ACCESSORY ELECTRIC PLANT								
11.1	Electrical Equipment	$25,225	$4,324	$29,549	$2,955	$0	$4,876	$37,380	$93
11.2	open	$0	$0	$0	$0	$0	$0	$0	$0
11.3	open	$0	$0	$0	$0	$0	$0	$0	$0
11.4	Raceway, wire & cable	$9,545	$23,496	$33,041	$3,304	$0	$5,452	$41,797	$103
11.5	open	$0	$0	$0	$0	$0	$0	$0	$0
11.6	Switchyard	$5,680	$3,131	$8,811	$881	$0	$1,454	$11,146	$28
11.7	open	$0	$0	$0	$0	$0	$0	$0	$0
11.8	open	$0	$0	$0	$0	$0	$0	$0	$0
11.9	Electrical Foundations	$780	$1,956	$2,736	$274	$0	$451	$3,461	$9
	SUBTOTAL 11.	**$41,230**	**$32,908**	**$74,138**	**$7,414**	**$0**	**$12,233**	**$93,784**	**$232**
12	INSTRUMENTATION & CONTROL								
12.1	PFBC Control Equipment - with PFBC	$0	$0	$0	$0	$0	$0	$0	$0
12.2	Turbo Machine Control - with Turbo Machine	$0	$0	$0	$0	$0	$0	$0	$0
12.3	Steam Turbine Control - with Steam Turbine	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control - with equipment	$0	$0	$0	$0	$0	$0	$0	$0
12.5	open	$0	$0	$0	$0	$0	$0	$0	$0
12.6	open	$0	$0	$0	$0	$0	$0	$0	$0
12.7	Distributed Control System Equipment	$10,000	w/ mat'l	$10,000	$1,000	$1,500	$1,875	$14,375	$36
12.8	Instrument Wiring & Tubing - with electrical	$0	$0	$0	$0	$0	$0	$0	$0
12.9	Other I & C Equipment	$583	$948	$1,531	$153	$230	$287	$2,200	$5
	SUBTOTAL 12.	**$10,583**	**$948**	**$11,531**	**$1,153**	**$1,730**	**$2,162**	**$16,575**	**$41**
13	IMPROVEMENTS TO SITE								
13.1	Site Preparation	$0	$0	$0	$0	$0	$0	$0	$0
13.2	Site Improvements	$2,175	$4,595	$6,770	$677	$0	$1,117	$8,564	$21
13.3	Site Facilities	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 13.	**$2,175**	**$4,595**	**$6,770**	**$677**	**$0**	**$1,117**	**$8,564**	**$21**
14	BUILDINGS & STRUCTURES								
14.1	Combustion Building	$25,894	$19,006	$44,900	$4,490	$0	$7,409	$56,799	$141
14.2	Turbine Building	$12,255	$10,302	$22,556	$2,256	$0	$3,722	$28,534	$71
14.3	Administration Building	$2,101	$175	$2,275	$228	$0	$375	$2,878	$7
14.4	Water Treatment Building	$2,694	$471	$3,166	$317	$0	$522	$4,004	$10
14.5	CO2 Regeneration & Compression Buildings	$9,028	$1,341	$10,369	$1,037	$0	$1,711	$13,116	$32
14.6	open	$0	$0	$0	$0	$0	$0	$0	$0
14.7	open	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$764	$203	$967	$97	$0	$160	$1,223	$3
	SUBTOTAL 14.	**$52,735**	**$31,498**	**$84,233**	**$8,423**	**$0**	**$13,898**	**$106,554**	**$264**
	TOTAL COST	**$895,849**	**$196,753**	**$1,092,602**	**$82,272**	**$13,797**	**$156,814**	**$1,345,485**	**$3,330**

Exhibit 2-2. Owner's Costs – Case 1A (Illinois No. 6 - Capture Ready)

Owner's Costs

Case 1A - PFBC Illinois Coal Based Power Plant no CO2 Capture

Description	$ x 1,000	$.kW
TPC	$1,345,485	$3,330
Pre-production		
6 Months All Labor	$9,764	$24
1 Month Maintenance Materials	$1,147	$3
1 Month Non-Fuel Consumables	$1,532	$4
1 Month Waste Disposal	$0	$0
25% of 1 Month's Fuel at 100% CF	$5,274	$13
2% of TPC	$26,910	$67
Total Preproduction	**$44,627**	$110
Inventory Capital		
60 Day Supply Fuel & Consumables at 100% CF	$13,426	$33
0.5% of TPC (spare parts)	$6,727	$17
Total Inventory Capital	**$20,153**	$50
Other Costs		
Initial Cost for Catalysts & Chemicals	$693	$2
Land	$900	$2
Finanacing Costs	$36,328	$90
Owner's Costs	$201,823	$500
Total Other Costs	**$239,744**	$593
Total OverNight Cost (TOC)	**$1,650,009**	$4,084
TASC Multiplier (IOU, 35 year)	1.154	
Total As-Spent Capital(TASC)	**$1,904,110**	$4,713

Exhibit 2-3. Initial and Annual O&M Expenses – Case 1A (Illinois No. 6 - Capture Ready)

INITIAL & ANNUAL O&M EXPENSES					Cost Basis:	Dec 2019
Case 1A - PFBC Illinois Coal Based Power Plant					Heat Rate-net (Btu/kWh):	8,030
4 x 1 P200 **no** CO_2 capture					MWe-net:	404.0
					Capacity Factor (%):	85
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate (base):	38.50	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of labor				
Total Operators & Lab Techs (equivalent 24/7 positions)	15					
					Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$6,445,039	$15.953
Maintenance Labor Cost					$9,177,858	$22.717
Administrative & Support Labor					$3,905,724	$9.668
Property Taxes and Insurance					$26,909,703	$66.608
TOTAL FIXED OPERATING COSTS					**$46,438,324**	**$114.946**
VARIABLE OPERATING COSTS						$/kWh-net
Maintenance Material Cost					**$13,766,788**	**$0.00458**
Consumables	Consumption Initial Fill	Consumption /Day	Unit Cost	Initial Fill Cost		
Water (/1000 gallons)	-	3,593	1.90	$0	$2,117,984	$0.00070
Chemicals						
MU & WT Chem.(lbs)	121,747	8,696	0.28	$33,480	$741,950	$0.00025
Limestone (ton)	11,368	812	24.25	$275,674	$6,109,133	$0.00203
Activated Carbon (ton)	-	-	1,600.00	$0	$0	$0.00000
Mercury Removal Filter Modules	w/ capital	-	10,000.00	$0	$0	$0.00000
Ammonia (19% NH_3) ton	81	5.8	300.00	$24,402	$540,766	$0.00018
NaOH - 50% (ton) for causitc scrubber	329	23.5	600.00	$197,568	$4,378,248	$0.00146
Amine Solvent (gal) - $ incl w/ CO_2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO_2 NaOH - 20% (gal) - $ incl w/ CO_2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO_2 Capture Solvents - proprietary	w/ capital	-	-	$0	$0	$0.00000
Triethylene Glycol (gal)	w/ capital	-	6.80	$0	$0	$0.00000
Ion Exchange Resin (ft3) for demin/condensate	w/ capital	1	285.00	$0	$53,295	$0.00002
NaOH - 50% (ton) for demin/condensate	10	0.7	600.00	$6,266	$138,864	$0.00005
H_2SO_4 - 93% (ton) for demin/condensate	14	1.0	205.00	$2,937	$65,095	$0.00002
NaOH - 50% (ton) for ZLD	54	3.8	600.00	$32,227	$714,172	$0.00024
H_2SO_4 - 93% (ton) for ZLD	55	3.9	205.00	$11,243	$249,146	$0.00008
Anti-scale (ton) for ZLD	2	0.2	5,900.00	$14,233	$315,405	$0.00010
Anti-coagulant (ton) for ZLD	46	3	2,050.00	$94,655	$2,097,618	$0.00070
Subtotal Chemicals				**$692,685**	**$15,403,691**	**$0.00512**
Other						
Supplemental Fuel #2 Oil (MMBtu)	7,000	12	15.00	$105,000	$55,845	$0.00002
Natural Gas for start-up (MMBtu)	-	164	3.35	$0	$170,850	$0.00006
Gases, N2 etc. (/100scf)	-	-	-	$0	$0	$0.00000
Subtotal Other				**$105,000**	**$226,695**	**$0.00008**
Waste Disposal						
Fly Ash (ton)	-	-	38.00	$0	$0	$0.00000
Bed Ash (ton)	-	-	38.00	$0	$0	$0.00000
Triethylene Glycol (gal)	-	-	0.35	$0	$0	$0.00000
Subtotal-Waste Disposal				**$0**	**$0**	**$0.00000**
By-products & Emissions						
CO_2 (ton)	-	-	41.00	$0	$0	$0.00000
Subtotal By-Products				**$0**	**$0**	**$0.00000**
TOTAL VARIABLE OPERATING COSTS				**$797,685**	**$31,515,157**	**$0.01048**
Fuel - Coal (ton)	46,715	3,337	51.96	$2,427,299	$53,790,669	$0.01788
Fuel - Biomass (ton)	0	0	50.00	$0	$0	$0.00000
TOTAL FUEL COSTS				**$2,427,299**	**$53,790,669**	**$0.01788**

Exhibit 2-4. Total Plant Cost Summary – Case 1B (Illinois No. 6 - Capture Equipped)

Client: Consol **Report Date:** 2020 May 04
Project: Case 1B - PFBC Illinois Coal Based Power Plant with CO2 Capture

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual mid-West US - merit
Plant Size: 307.7 MW,net Dec 2019 ($x1000) ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	FUEL PREP & FEED	$88,700	$0	**$88,700**	$3,105	$0	$9,180	**$100,985**	$328
2	OPEN	$0	$0	**$0**	$0	$0	$0	**$0**	$0
3	FEEDWATER & MISC. BOP SYSTEMS	$93,790	$53,854	**$147,644**	$14,764	$0	$24,361	**$186,769**	$607
4	PFBC								
4.1	PFBC - furnish & erect	$326,500	$0	**$326,500**	$11,428	$0	$33,793	**$371,720**	$1,208
4.2-4.9	Other	$3,774	$4,976	**$8,750**	$875	$0	$1,444	**$11,069**	$0
	SUBTOTAL 4	**$330,274**	**$4,976**	**$335,250**	**$12,303**	**$0**	**$35,237**	**$382,790**	**$1,244**
5	FLUE GAS CLEANUP	$82,707	$17,646	**$100,353**	$10,035	$0	$16,558	**$126,947**	$413
5B	CO2 REMOVAL & COMPRESSION	$140,091	$88,071	**$228,161**	$22,816	$0	$37,647	**$288,624**	$938
6	TURBO MACHINES								
6.1	Turbo Machines	$53,012	$6,001	**$59,013**	$5,901	$11,803	$11,508	**$88,225**	$287
6.2-6.9	Other	$361	$949	**$1,311**	$131	$0	$216	**$1,658**	$5
	SUBTOTAL 6	**$53,373**	**$6,951**	**$60,324**	**$6,032**	**$11,803**	**$11,724**	**$89,883**	**$292**
7	DUCTING & STACK								
7.1	open	$0	$0	**$0**	$0	$0	$0	**$0**	$0
7.2-7.9	Ductwork and Stack	$25,341	$2,034	**$27,375**	$2,737	$0	$4,517	**$34,629**	$113
	SUBTOTAL 7	**$25,341**	**$2,034**	**$27,375**	**$2,737**	**$0**	**$4,517**	**$34,629**	**$113**
8	STEAM TURBINE GENERATOR								
8.1	Steam TG & Accessories	$32,250	$5,113	**$37,363**	$3,736	$0	$6,165	**$47,264**	$154
8.2-8.9	Turbine Plant Auxiliaries and Steam Piping	$26,063	$16,214	**$42,277**	$4,228	$0	$6,976	**$53,481**	$174
	SUBTOTAL 8	**$58,313**	**$21,327**	**$79,640**	**$7,964**	**$0**	**$13,141**	**$100,744**	**$327**
9	COOLING WATER SYSTEM	$15,740	$11,917	**$27,657**	$2,766	$0	$4,563	**$34,986**	$114
10	ASH HANDLING SYSTEM	$28,785	$4,844	**$33,629**	$3,363	$0	$5,549	**$42,540**	$138
11	ACCESSORY ELECTRIC PLANT	$41,230	$32,908	**$74,138**	$7,414	$0	$12,233	**$93,784**	$305
12	INSTRUMENTATION & CONTROL	$10,583	$948	**$11,531**	$1,153	$1,730	$2,162	**$16,575**	$54
13	IMPROVEMENTS TO SITE	$2,175	$4,595	**$6,770**	$677	$0	$1,117	**$8,564**	$28
14	BUILDINGS & STRUCTURES	$52,735	$31,498	**$84,233**	$8,423	$0	$13,898	**$106,554**	$346
	TOTAL COST	**$1,023,837**	**$281,567**	**$1,305,404**	**$103,552**	**$13,532**	**$191,887**	**$1,614,375**	**$5,247**

Client: Consol
Project: Case 1B - PFBC Illinois Coal Based Power Plant **with** CO2 Capture
Report Date: 2020 May 04

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual — mid-West US - merit
Plant Size: 307.7 MW,net — Dec 2019 ($x1000) ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	FUEL PREP & FEED								
1.1	Fuel Prep & Feed System - complete plant	$88,700	$0	$88,700	$3,105	$0	$9,180	$100,985	$328
1.8	Fuel Prep & Feed Buildings - incl with system costs	$0	$0	$0	$0	$0	$0	$0	$0
1.9	Fuel Prep & Feed Foundations - incl with system costs	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 1.	**$88,700**	**$0**	**$88,700**	**$3,105**	**$0**	**$9,180**	**$100,985**	**$328**
2	OPEN								
2.1	open	$0	$0	$0	$0	$0	$0	$0	$0
2.9	open	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 2.	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	FEEDWATER & MISC. BOP SYSTEMS								
3.1	Feedwater System	$14,694	$6,216	$20,910	$2,091	$0	$3,450	$26,451	$86
3.2	Water Makeup & Pretreating - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.3	Other Feedwater Subsystems - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.4	Service Water Systems - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.5	Other Plant Systems	$43,462	$26,842	$70,304	$7,030	$0	$11,600	$88,935	$289
3.6	FO Supply System - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.7	Zero Liquid Discharge System	$34,581	$18,399	$52,980	$5,298	$0	$8,742	$67,019	$218
3.8	Misc. Equip.(cranes,AirComp.,Comm.) - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.8	BOP Foundations	$1,054	$2,396	$3,450	$345	$0	$569	$4,364	$14
	SUBTOTAL 3.	**$93,790**	**$53,854**	**$147,644**	**$14,764**	**$0**	**$24,361**	**$186,769**	**$607**
4	PFBC								
4.1	PFBC - furnish & erect	$326,500	$0	$326,500	$11,428	$0	$33,793	$371,720	$1,208
4.2	PFBC Auxilliary Systems	$252	$703	$955	$95	$0	$158	$1,208	$4
4.3	Open	$0	$0	$0	$0	$0	$0	$0	$0
4.4	Boiler BoP (w/ ID Fans)	$0	$0	$0	$0	$0	$0	$0	$0
4.5	Primary Air System	$0	$0	$0	$0	$0	$0	$0	$0
4.6	Secondary Air System	$0	$0	$0	$0	$0	$0	$0	$0
4.8	Major Component Rigging	$0	$0	$0	$0	$0	$0	$0	$0
4.9	PFBC Foundations	$3,522	$4,273	$7,796	$780	$0	$1,286	$9,861	$32
	SUBTOTAL 4.	**$330,274**	**$4,976**	**$335,250**	**$12,303**	**$0**	**$35,237**	**$382,790**	**$1,244**

Client:	Consol	**Report Date:** 2020 May 04
Project:	Case 1B - PFBC Illinois Coal Based Power Plant **with** CO2 Capture	

TOTAL PLANT COST SUMMARY

Estimate Type:	Conceptual	mid-West US - merit
Plant Size:	307.7 MW,net	Dec 2019 ($x1000) ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
5	FLUE GAS CLEANUP								
5.1	Gas Heating & Cooling	$4,596	$1,180	$5,777	$578	$0	$953	$7,307	$24
5.2	Gas Filtration	$68,040	$9,277	$77,317	$7,732	$0	$12,757	$97,806	$318
5.3	SO2 Removal	$6,000	$3,369	$9,369	$937	$0	$1,546	$11,851	$39
5.4	Mercury removal	$0	$0	$0	$0	$0	$0	$0	$0
5.5	Flue Gas Piping	$3,051	$3,531	$6,582	$658	$0	$1,086	$8,327	$27
5.6	CEMs	$1,020	$289	$1,309	$131	$0	$216	$1,656	$5
5.9	open	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 5.	**$82,707**	**$17,646**	**$100,353**	**$10,035**	**$0**	**$16,558**	**$126,947**	**$413**
5B	CO2 REMOVAL & COMPRESSION								
5B.1	CO2 Removal System	$110,000	$80,977	$190,977	$19,098	$0	$31,511	$241,585	$785
5B.2	CO2 Compression	$29,160	$5,105	$34,265	$3,426	$0	$5,654	$43,345	$141
5B.9	CO2 Removal & Compression Foundations	$931	$1,990	$2,920	$292	$0	$482	$3,694	$12
	SUBTOTAL 5B.	**$140,091**	**$88,071**	**$228,161**	**$22,816**	**$0**	**$37,647**	**$288,624**	**$938**
6	TURBO MACHINES								
6.1	Turbo Machines	$53,012	$6,001	$59,013	$5,901	$11,803	$11,508	$88,225	$287
6.2	Intercooler for PFBC	$0	$0	$0	$0	$0	$0	$0	$0
6.3	Open	$0	$0	$0	$0	$0	$0	$0	$0
6.9	Turbo Machines Foundations	$361	$949	$1,311	$131	$0	$216	$1,658	$5
	SUBTOTAL 6.	**$53,373**	**$6,951**	**$60,324**	**$6,032**	**$11,803**	**$11,724**	**$89,883**	**$292**
7	DUCTING & STACK								
7.1	open	$0	$0	$0	$0	$0	$0	$0	$0
7.3	Ductwork	$561	$994	$1,555	$156	$0	$257	$1,967	$6
7.4	Stack - furnish and erect	$24,000	$0	$24,000	$2,400	$0	$3,960	$30,360	$99
7.9	Duct & Stack Foundations	$780	$1,040	$1,820	$182	$0	$300	$2,302	$7
	SUBTOTAL 7.	**$25,341**	**$2,034**	**$27,375**	**$2,737**	**$0**	**$4,517**	**$34,629**	**$113**
8	STEAM TURBINE GENERATOR								
8.1	Steam TG & Accessories	$32,250	$5,113	$37,363	$3,736	$0	$6,165	$47,264	$154
8.2	Turbine Plant Auxiliaries	$1,944	$2,433	$4,377	$438	$0	$722	$5,537	$18
8.3	Condenser & Auxiliaries	$4,633	$1,878	$6,511	$651	$0	$1,074	$8,236	$27
8.4	Steam Piping	$17,766	$8,594	$26,360	$2,636	$0	$4,349	$33,345	$108
8.9	STG Foundations	$1,721	$3,309	$5,030	$503	$0	$830	$6,363	$21
	SUBTOTAL 8.	**$58,313**	**$21,327**	**$79,640**	**$7,964**	**$0**	**$13,141**	**$100,744**	**$327**
9	COOLING WATER SYSTEM								
9.1	Cooling Towers - furnish & erect	$6,000	$0	$6,000	$600	$0	$990	$7,590	$25
9.2	Circulating Water Pumps	$1,200	$104	$1,304	$130	$0	$215	$1,649	$5
9.3	Circ.Water System Auxiliaries	$194	$119	$313	$31	$0	$52	$396	$1
9.4	Circ.Water Piping	$5,435	$7,083	$12,518	$1,252	$0	$2,065	$15,835	$51
9.5	Make-up Water System	$0	$0	$0	$0	$0	$0	$0	$0
9.6	Component Cooling Water Sys	$737	$666	$1,403	$140	$0	$231	$1,774	$6
9.9	Circ.Water System Foundations & Structures	$2,175	$3,945	$6,120	$612	$0	$1,010	$7,741	$25
	SUBTOTAL 9.	**$15,740**	**$11,917**	**$27,657**	**$2,766**	**$0**	**$4,563**	**$34,986**	**$114**

Client: Consol **Report Date:** 2020 May 04
Project: Case 1B - PFBC Illinois Coal Based Power Plant **with** CO2 Capture

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual mid-West US - merit
Plant Size: 307.7 MW,net Dec 2019 ($x1000) ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
10	ASH HANDLING SYSTEM								
10.1	Ash Handling System	$18,115	$2,620	$20,735	$2,073	$0	$3,421	$26,230	$85
10.2	Ash Silos - furnish & erect	$8,920	$0	$8,920	$892	$0	$1,472	$11,284	$37
10.8	Misc. Ash Handling Equipment	$0	$0	$0	$0	$0	$0	$0	$0
10.9	Ash System Foundations	$1,750	$2,224	$3,974	$397	$0	$656	$5,027	$16
	SUBTOTAL 10.	**$28,785**	**$4,844**	**$33,629**	**$3,363**	**$0**	**$5,549**	**$42,540**	**$138**
11	ACCESSORY ELECTRIC PLANT								
11.1	Electrical Equipment	$25,225	$4,324	$29,549	$2,955	$0	$4,876	$37,380	$121
11.2	open	$0	$0	$0	$0	$0	$0	$0	$0
11.3	open	$0	$0	$0	$0	$0	$0	$0	$0
11.4	Raceway, wire & cable	$9,545	$23,496	$33,041	$3,304	$0	$5,452	$41,797	$136
11.5	open	$0	$0	$0	$0	$0	$0	$0	$0
11.6	Switchyard	$5,680	$3,131	$8,811	$881	$0	$1,454	$11,146	$36
11.7	open	$0	$0	$0	$0	$0	$0	$0	$0
11.8	open	$0	$0	$0	$0	$0	$0	$0	$0
11.9	Electrical Foundations	$780	$1,956	$2,736	$274	$0	$451	$3,461	$11
	SUBTOTAL 11.	**$41,230**	**$32,908**	**$74,138**	**$7,414**	**$0**	**$12,233**	**$93,784**	**$305**
12	INSTRUMENTATION & CONTROL								
12.1	PFBC Control Equipment - with PFBC	$0	$0	$0	$0	$0	$0	$0	$0
12.2	Turbo Machine Control - with Turbo Machine	$0	$0	$0	$0	$0	$0	$0	$0
12.3	Steam Turbine Control - with Steam Turbine	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control - with equipment	$0	$0	$0	$0	$0	$0	$0	$0
12.5	open	$0	$0	$0	$0	$0	$0	$0	$0
12.6	open	$0	$0	$0	$0	$0	$0	$0	$0
12.7	Distributed Control System Equipment	$10,000	w/ mat'l	$10,000	$1,000	$1,500	$1,875	$14,375	$47
12.8	Instrument Wiring & Tubing - with electrical	$0	$0	$0	$0	$0	$0	$0	$0
12.9	Other I & C Equipment	$583	$948	$1,531	$153	$230	$287	$2,200	$7
	SUBTOTAL 12.	**$10,583**	**$948**	**$11,531**	**$1,153**	**$1,730**	**$2,162**	**$16,575**	**$54**
13	IMPROVEMENTS TO SITE								
13.1	Site Preparation	$0	$0	$0	$0	$0	$0	$0	$0
13.2	Site Improvements	$2,175	$4,595	$6,770	$677	$0	$1,117	$8,564	$28
13.3	Site Facilities	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 13.	**$2,175**	**$4,595**	**$6,770**	**$677**	**$0**	**$1,117**	**$8,564**	**$28**
14	BUILDINGS & STRUCTURES								
14.1	Combustion Building	$25,894	$19,006	$44,900	$4,490	$0	$7,409	$56,799	$185
14.2	Turbine Building	$12,255	$10,302	$22,556	$2,256	$0	$3,722	$28,534	$93
14.3	Administration Building	$2,101	$175	$2,275	$228	$0	$375	$2,878	$9
14.4	Water Treatment Building	$2,694	$471	$3,166	$317	$0	$522	$4,004	$13
14.5	CO2 Regeneration & Compression Buildings	$9,028	$1,341	$10,369	$1,037	$0	$1,711	$13,116	$43
14.6	open	$0	$0	$0	$0	$0	$0	$0	$0
14.7	open	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$764	$203	$967	$97	$0	$160	$1,223	$4
	SUBTOTAL 14.	**$52,735**	**$31,498**	**$84,233**	**$8,423**	**$0**	**$13,898**	**$106,554**	**$346**
	TOTAL COST	**$1,023,837**	**$281,567**	**$1,305,404**	**$103,552**	**$13,532**	**$191,887**	**$1,614,375**	**$5,247**

Exhibit 2-5. Owner's Costs – Case 1B (Illinois No. 6 - Capture Equipped)

Owner's Costs
Case 1B - PFBC Illinois Coal Based Power Plant with CO2 Capture

Description	$ x 1,000	$.kW
TPC	$1,614,375	$5,247
Pre-production		
6 Months All Labor	$11,512	$37
1 Month Maintenance Materials	$1,371	$4
1 Month Non-Fuel Consumables	$2,026	$7
1 Month Waste Disposal	$3	$0
25% of 1 Month's Fuel at 100% CF	$5,274	$17
2% of TPC	$32,287	$105
Total Preproduction	**$52,473**	$171
Inventory Capital		
60 Day Supply Fuel & Consumables at 100% CF	$14,400	$47
0.5% of TPC (spare parts)	$8,072	$26
Total Inventory Capital	**$22,471**	$73
Other Costs		
Initial Cost for Catalysts & Chemicals	$686	$2
Land	$900	$3
Finanacing Costs	$43,588	$142
Owner's Costs	$242,156	$787
Total Other Costs	**$287,330**	$934
Total OverNight Cost (TOC)	**$1,976,649**	$6,424
TASC Multiplier (IOU, 35 year)	1.154	
Total As-Spent Capital(TASC)	**$2,281,053**	$7,413

Exhibit 2-6. Initial and Annual O&M Expenses – Case 1B (Illinois No. 6 - Capture Equipped)

INITIAL & ANNUAL O&M EXPENSES						Cost Basis:	Dec 2019
Case 1B - PFBC Illinois Coal Based Power Plant						Heat Rate-net (Btu/kWh):	10,542
4 x 1 P200 with CO2 capture						MWe-net:	307.7
						Capacity Factor (%):	85
OPERATING & MAINTENANCE LABOR							
Operating Labor							
Operating Labor Rate (base):	38.50	$/hour					
Operating Labor Burden:	30.00	% of base					
Labor O-H Charge Rate:	25.00	% of labor					
Total Operators & Lab Techs	17						
(equivalent 24/7 positions)						Annual Cost	Annual Unit Cost
						$	$/kW-net
Annual Operating Labor Cost						$7,453,446	$24.223
Maintenance Labor Cost						$10,965,390	$35.637
Administrative & Support Labor						$4,604,709	$14.965
Property Taxes and Insurance						$32,287,497	$104.932
TOTAL FIXED OPERATING COSTS						**$55,311,043**	**$179.756**
VARIABLE OPERATING COSTS							
							$/kWh-net
Maintenance Material Cost						**$16,448,085**	**$0.00718**
Consumables	Consumption		Unit	Initial Fill			
	Initial Fill	/Day	Cost	Cost			
Water (/1000 gallons)	-	4,228	1.90	$0		$2,492,300	$0.00109
Chemicals							
MU & WT Chem.(lbs)	143,264	10,233	0.28	$39,397		$873,076	$0.00038
Limestone (ton)	11,368	812	24.25	$275,674		$6,109,133	$0.00267
Activated Carbon (ton)	-	-	1,600.00	$0		$0	$0.00000
Mercury Removal Filter Modules	w/ capital	-	10,000.00	$0		$0	$0.00000
Ammonia (19% NH3) ton	81	5.8	300.00	$24,402		$540,766	$0.00024
NaOH - 50% (ton) for causitc scrubber	329	23.5	600.00	$197,568		$4,378,248	$0.00191
Amine Solvent (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0		$0	$0.00000
CO2 NaOH - 20% (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0		$0	$0.00000
CO2 Capture Solvents - proprietary	w/ capital	-	-	$0		$4,613,800	$0.00201
Triethylene Glycol (gal)	w/ capital	273	6.80	$0		$575,948	$0.00025
Ion Exchange Resin (ft3) for demin/condensate	w/ capital	1	285.00	$0		$46,633	$0.00002
NaOH - 50% (ton) for demin/condensate	9	0.6	600.00	$5,146		$114,047	$0.00005
H2SO4 - 93% (ton) for demin/condensate	12	0.8	205.00	$2,412		$53,462	$0.00002
NaOH - 50% (ton) for ZLD	50	3.6	600.00	$29,925		$663,159	$0.00029
H2SO4 - 93% (ton) for ZLD	51	3.6	205.00	$10,440		$231,350	$0.00010
Anti-scale (ton) for ZLD	2	0.2	5,900.00	$13,216		$292,876	$0.00013
Anti-coagulant (ton) for ZLD	43	3	2,050.00	$87,894		$1,947,788	$0.00085
Subtotal Chemicals				**$686,075**		**$20,440,287**	**$0.00892**
Other							
Supplemental Fuel #2 Oil (MBtu)	7,000	12	15.00	$105,000		$55,845	$0.00002
Natural Gas for start-up (MMBtu)	-	164	3.35	$0		$170,850	$0.00007
Gases, N2 etc. (/100scf)	-	-	-	$0		$0	$0.00000
Subtotal Other				**$105,000**		**$226,695**	**$0.00010**
Waste Disposal							
Fly Ash (ton)	-	-	38.00	$0		$0	$0.00000
Bed Ash (ton)	-	-	38.00	$0		$0	$0.00000
Triethylene Glycol (gal)	-	273	0.35	$0		$29,644	$0.00001
Subtotal-Waste Disposal				**$0**		**$29,644**	**$0.00001**
By-products & Emissions							
CO2 (ton)	-	7,694	41.00	$0		-$97,869,604	-$0.04272
Subtotal By-Products				**$0**		**-$97,869,604**	**-$0.04272**
TOTAL VARIABLE OPERATING COSTS				**$791,075**		**-$58,232,592**	**-$0.02542**
Fuel - Coal (ton)	46,715	3,337	51.96	$2,427,299		$53,790,669	$0.02348
Fuel - Biomass (ton)	0	0	50.00	$0		$0	$0.00000
TOTAL FUEL COSTS				**$2,427,299**		**$53,790,669**	**$0.02348**

Exhibit 2-7. Total Plant Cost Summary – Case 2B (Waste Coal - Capture Equipped)

Client: Consol
Project: Case 2B - PFBC Waste Coal Based Power Plant with CO2 Capture
Report Date: 2020 May 04

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual
Plant Size: 279.6 MW,net
Labor Basis Southeast, PA - union
Cost Base Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	FUEL PREP & FEED	$136,350	$0	**$136,350**	$4,772	$0	$14,112	**$155,234**	$555
2	OPEN	$0	$0	**$0**	$0	$0	$0	**$0**	$0
3	FEEDWATER & MISC. BOP SYSTEMS	$71,433	$56,421	**$127,854**	$12,785	$0	$21,096	**$161,735**	$578
4	PFBC								
4.1	PFBC - furnish & erect	$326,500	$0	**$326,500**	$11,428	$0	$33,793	**$371,720**	$1,329
4.2-4.9	Other	$3,774	$6,591	**$10,365**	$1,036	$0	$1,710	**$13,111**	$0
	SUBTOTAL 4	**$330,274**	**$6,591**	**$336,865**	**$12,464**	**$0**	**$35,503**	**$384,831**	**$1,376**
5	FLUE GAS CLEANUP	$88,767	$22,500	**$111,267**	$11,127	$0	$18,359	**$140,753**	$503
5B	CO2 REMOVAL & COMPRESSION	$140,091	$117,806	**$257,897**	$25,790	$0	$42,553	**$326,239**	$1,167
6	TURBO MACHINES								
6.1	Turbo Machines	$53,012	$8,191	**$61,203**	$6,120	$12,241	$11,935	**$91,498**	$327
6.2-6.9	Other	$361	$1,234	**$1,595**	$159	$0	$263	**$2,017**	$7
	SUBTOTAL 6	**$53,373**	**$9,424**	**$62,798**	**$6,280**	**$12,241**	**$12,198**	**$93,516**	**$334**
7	DUCTING & STACK								
7.1	open	$0	$0	**$0**	$0	$0	$0	**$0**	$0
7.2-7.9	Ductwork and Stack	$15,268	$2,531	**$17,799**	$1,780	$0	$2,937	**$22,516**	$81
	SUBTOTAL 7	**$15,268**	**$2,531**	**$17,799**	**$1,780**	**$0**	**$2,937**	**$22,516**	**$81**
8	STEAM TURBINE GENERATOR								
8.1	Steam TG & Accessories	$29,900	$6,583	**$36,483**	$3,648	$0	$6,020	**$46,151**	$165
8.2-8.9	Turbine Plant Auxiliaries and Steam Piping	$40,006	$27,202	**$67,208**	$6,721	$0	$11,089	**$85,018**	$304
	SUBTOTAL 8	**$69,906**	**$33,786**	**$103,692**	**$10,369**	**$0**	**$17,109**	**$131,170**	**$469**
9	COOLING WATER SYSTEM	$11,359	$10,911	**$22,269**	$2,227	$0	$3,674	**$28,171**	$101
10	ASH HANDLING SYSTEM	$35,265	$6,780	**$42,045**	$4,205	$0	$6,937	**$53,187**	$190
11	ACCESSORY ELECTRIC PLANT	$41,230	$45,343	**$86,573**	$8,657	$0	$14,284	**$109,514**	$392
12	INSTRUMENTATION & CONTROL	$10,583	$1,383	**$11,966**	$1,197	$1,795	$2,244	**$17,201**	$62
13	IMPROVEMENTS TO SITE	$2,175	$5,532	**$7,707**	$771	$0	$1,272	**$9,749**	$35
14	BUILDINGS & STRUCTURES	$52,735	$41,142	**$93,876**	$9,388	$0	$15,490	**$118,753**	$425
	TOTAL COST	**$1,058,808**	**$360,149**	**$1,418,957**	**$111,810**	**$14,035**	**$207,768**	**$1,752,570**	**$6,268**

Client: Consol **Report Date:** 2020 May 04
Project: Case 2B - PFBC Waste Coal Based Power Plant with CO2 Capture

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual **Labor Basis** Southeast, PA - union
Plant Size: 279.6 MW,net **Cost Base** Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies		TOTAL PLANT COST	
						Process	Project	$	$/kW
1	FUEL PREP & FEED								
1.1	Fuel Prep & Feed System - complete plant	$136,350	$0	$136,350	$4,772	$0	$14,112	$155,234	$555
1.8	Fuel Prep & Feed Buildings - incl with system costs	$0	$0	$0	$0	$0	$0	$0	$0
1.9	Fuel Prep & Feed Foundations - incl with system costs	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 1.	**$136,350**	**$0**	**$136,350**	**$4,772**	**$0**	**$14,112**	**$155,234**	**$555**
2	OPEN								
2.1	open	$0	$0	$0	$0	$0	$0	$0	$0
2.9	open	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 2.	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	FEEDWATER & MISC. BOP SYSTEMS								
3.1	Feedwater System	$12,858	$7,887	$20,745	$2,075	$0	$3,423	$26,242	$94
3.2	Water Makeup & Pretreating - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.3	Other Feedwater Subsystems - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.4	Service Water Systems - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.5	Other Plant Systems	$42,165	$34,160	$76,326	$7,633	$0	$12,594	$96,552	$345
3.6	FO Supply System - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.7	Zero Liquid Discharge System	$15,355	$11,298	$26,653	$2,665	$0	$4,398	$33,716	$121
3.8	Misc. Equip.(cranes,AirComp.,Comm.) - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.8	BOP Foundations	$1,054	$3,077	$4,130	$413	$0	$682	$5,225	$19
	SUBTOTAL 3.	**$71,433**	**$56,421**	**$127,854**	**$12,785**	**$0**	**$21,096**	**$161,735**	**$578**
4	PFBC								
4.1	PFBC - furnish & erect	$326,500	$0	$326,500	$11,428	$0	$33,793	$371,720	$1,329
4.2	PFBC Auxilliary Systems	$252	$998	$1,250	$125	$0	$206	$1,581	$6
4.3	Open	$0	$0	$0	$0	$0	$0	$0	$0
4.4	Boiler BoP (w/ ID Fans)	$0	$0	$0	$0	$0	$0	$0	$0
4.5	Primary Air System	$0	$0	$0	$0	$0	$0	$0	$0
4.6	Secondary Air System	$0	$0	$0	$0	$0	$0	$0	$0
4.8	Major Component Rigging	$0	$0	$0	$0	$0	$0	$0	$0
4.9	PFBC Foundations	$3,522	$5,593	$9,115	$912	$0	$1,504	$11,530	$41
	SUBTOTAL 4.	**$330,274**	**$6,591**	**$336,865**	**$12,464**	**$0**	**$35,503**	**$384,831**	**$1,376**

Client: Consol
Project: Case 2B - PFBC Waste Coal Based Power Plant with CO2 Capture
Report Date: 2020 May 04

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual
Plant Size: 279.6 MW,net
Labor Basis Southeast, PA - union
Cost Base Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
5	FLUE GAS CLEANUP								
5.1	Gas Heating & Cooling	$4,596	$1,750	$6,346	$635	$0	$1,047	$8,028	$29
5.2	Gas Filtration	$59,440	$10,823	$70,263	$7,026	$0	$11,593	$88,882	$318
5.3	SO2 Removal	$6,000	$4,509	$10,509	$1,051	$0	$1,734	$13,294	$48
5.4	Mercury removal	$14,660	$0	$14,660	$1,466	$0	$2,419	$18,545	$66
5.5	Flue Gas Piping	$3,051	$5,011	$8,062	$806	$0	$1,330	$10,198	$36
5.6	CEMs	$1,020	$407	$1,427	$143	$0	$235	$1,805	$6
5.9	open	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 5.	**$88,767**	**$22,500**	**$111,267**	**$11,127**	**$0**	**$18,359**	**$140,753**	**$503**
5B	CO2 REMOVAL & COMPRESSION								
5B.1	CO2 Removal System	$110,000	$108,398	$218,398	$21,840	$0	$36,036	$276,274	$988
5B.2	CO2 Compression	$29,160	$6,833	$35,993	$3,599	$0	$5,939	$45,532	$163
5B.9	CO2 Removal & Compression Foundations	$931	$2,575	$3,505	$351	$0	$578	$4,434	$16
	SUBTOTAL 5B.	**$140,091**	**$117,806**	**$257,897**	**$25,790**	**$0**	**$42,553**	**$326,239**	**$1,167**
6	TURBO MACHINES								
6.1	Turbo Machines	$53,012	$8,191	$61,203	$6,120	$12,241	$11,935	$91,498	$327
6.2	Intercooler for PFBC	$0	$0	$0	$0	$0	$0	$0	$0
6.3	Open	$0	$0	$0	$0	$0	$0	$0	$0
6.9	Turbo Machines Foundations	$361	$1,234	$1,595	$159	$0	$263	$2,017	$7
	SUBTOTAL 6.	**$53,373**	**$9,424**	**$62,798**	**$6,280**	**$12,241**	**$12,198**	**$93,516**	**$334**
7	DUCTING & STACK								
7.1	open	$0	$0	$0	$0	$0	$0	$0	$0
7.3	Ductwork	$561	$1,318	$1,879	$188	$0	$310	$2,376	$8
7.4	Stack - furnish and erect	$14,000	$0	$14,000	$1,400	$0	$2,310	$17,710	$63
7.9	Duct & Stack Foundations	$707	$1,214	$1,921	$192	$0	$317	$2,430	$9
	SUBTOTAL 7.	**$15,268**	**$2,531**	**$17,799**	**$1,780**	**$0**	**$2,937**	**$22,516**	**$81**
8	STEAM TURBINE GENERATOR								
8.1	Steam TG & Accessories	$29,900	$6,583	$36,483	$3,648	$0	$6,020	$46,151	$165
8.2	Turbine Plant Auxiliaries	$1,940	$3,446	$5,386	$539	$0	$889	$6,813	$24
8.3	Condenser & Auxiliaries	$20,052	$8,382	$28,434	$2,843	$0	$4,692	$35,969	$129
8.4	Steam Piping	$16,401	$11,258	$27,660	$2,766	$0	$4,564	$34,990	$125
8.9	STG Foundations	$1,612	$4,116	$5,729	$573	$0	$945	$7,247	$26
	SUBTOTAL 8.	**$69,906**	**$33,786**	**$103,692**	**$10,369**	**$0**	**$17,109**	**$131,170**	**$469**
9	COOLING WATER SYSTEM								
9.1	Cooling Towers - furnish & erect	$3,960	$0	$3,960	$396	$0	$653	$5,009	$18
9.2	Circulating Water Pumps	$1,200	$139	$1,339	$134	$0	$221	$1,694	$6
9.3	Circ.Water System Auxiliaries	$194	$166	$360	$36	$0	$59	$455	$2
9.4	Circ.Water Piping	$4,119	$6,960	$11,079	$1,108	$0	$1,828	$14,015	$50
9.5	Make-up Water System	$0	$0	$0	$0	$0	$0	$0	$0
9.6	Component Cooling Water Sys	$737	$897	$1,634	$163	$0	$270	$2,067	$7
9.9	Circ.Water System Foundations & Structures	$1,149	$2,749	$3,898	$390	$0	$643	$4,930	$18
	SUBTOTAL 9.	**$11,359**	**$10,911**	**$22,269**	**$2,227**	**$0**	**$3,674**	**$28,171**	**$101**

Client: Consol
Project: Case 2B - PFBC Waste Coal Based Power Plant with CO2 Capture
Report Date: 2020 May 04

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual
Plant Size: 279.6 MW,net
Labor Basis Southeast, PA - union
Cost Base Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
10	ASH HANDLING SYSTEM								
10.1	Ash Handling System	$19,915	$3,870	$23,785	$2,378	$0	$3,925	$30,088	$108
10.2	Ash Silos - furnish & erect	$13,600	$0	$13,600	$1,360	$0	$2,244	$17,204	$62
10.8	Misc. Ash Handling Equipment	$0	$0	$0	$0	$0	$0	$0	$0
10.9	Ash System Foundations	$1,750	$2,910	$4,660	$466	$0	$769	$5,895	$21
	SUBTOTAL 10.	**$35,265**	**$6,780**	**$42,045**	**$4,205**	**$0**	**$6,937**	**$53,187**	**$190**
11	ACCESSORY ELECTRIC PLANT								
11.1	Electrical Equipment	$25,225	$6,089	$31,314	$3,131	$0	$5,167	$39,612	$142
11.2	open	$0	$0	$0	$0	$0	$0	$0	$0
11.3	open	$0	$0	$0	$0	$0	$0	$0	$0
11.4	Raceway, wire & cable	$9,545	$32,298	$41,843	$4,184	$0	$6,904	$52,932	$189
11.5	open	$0	$0	$0	$0	$0	$0	$0	$0
11.6	Switchyard	$5,680	$4,411	$10,091	$1,009	$0	$1,665	$12,765	$46
11.7	open	$0	$0	$0	$0	$0	$0	$0	$0
11.8	open	$0	$0	$0	$0	$0	$0	$0	$0
11.9	Electrical Foundations	$780	$2,544	$3,324	$332	$0	$548	$4,205	$15
	SUBTOTAL 11.	**$41,230**	**$45,343**	**$86,573**	**$8,657**	**$0**	**$14,284**	**$109,514**	**$392**
12	INSTRUMENTATION & CONTROL								
12.1	PFBC Control Equipment - with PFBC	$0	$0	$0	$0	$0	$0	$0	$0
12.2	Turbo Machine Control - with Turbo Machine	$0	$0	$0	$0	$0	$0	$0	$0
12.3	Steam Turbine Control - with Steam Turbine	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control - with equipment	$0	$0	$0	$0	$0	$0	$0	$0
12.5	open	$0	$0	$0	$0	$0	$0	$0	$0
12.6	open	$0	$0	$0	$0	$0	$0	$0	$0
12.7	Distributed Control System Equipment	$10,000	w/ mat'l	$10,000	$1,000	$1,500	$1,875	$14,375	$51
12.8	Instrument Wiring & Tubing - with electrical	$0	$0	$0	$0	$0	$0	$0	$0
12.9	Other I & C Equipment	$583	$1,383	$1,966	$197	$295	$369	$2,826	$10
	SUBTOTAL 12.	**$10,583**	**$1,383**	**$11,966**	**$1,197**	**$1,795**	**$2,244**	**$17,201**	**$62**
13	IMPROVEMENTS TO SITE								
13.1	Site Preparation	$0	$0	$0	$0	$0	$0	$0	$0
13.2	Site Improvements	$2,175	$5,532	$7,707	$771	$0	$1,272	$9,749	$35
13.3	Site Facilities	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 13.	**$2,175**	**$5,532**	**$7,707**	**$771**	**$0**	**$1,272**	**$9,749**	**$35**
14	BUILDINGS & STRUCTURES								
14.1	Combustion Building	$25,894	$24,866	$50,760	$5,076	$0	$8,375	$64,211	$230
14.2	Turbine Building	$12,255	$13,441	$25,696	$2,570	$0	$4,240	$32,506	$116
14.3	Administration Building	$2,101	$225	$2,326	$233	$0	$384	$2,942	$11
14.4	Water Treatment Building	$2,694	$611	$3,305	$331	$0	$545	$4,181	$15
14.5	CO2 Regeneration & Compression Buildings	$9,028	$1,737	$10,764	$1,076	$0	$1,776	$13,617	$49
14.6	open	$0	$0	$0	$0	$0	$0	$0	$0
14.7	open	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$764	$262	$1,025	$103	$0	$169	$1,297	$5
	SUBTOTAL 14.	**$52,735**	**$41,142**	**$93,876**	**$9,388**	**$0**	**$15,490**	**$118,753**	**$425**
	TOTAL COST	**$1,058,808**	**$360,149**	**$1,418,957**	**$111,810**	**$14,035**	**$207,768**	**$1,752,570**	**$6,268**

Exhibit 2-8. Owner's Costs – Case 2B (Waste Coal - Capture Equipped)

Owner's Costs
Case 2B - PFBC Waste Coal Based Power Plant with CO2 Capture

Description	Case 2B $ x 1,000	$.kW
TPC	$1,752,570	$6,268
Pre-production		
6 Months All Labor	$12,894	$46
1 Month Maintenance Materials	$1,490	$5
1 Month Non-Fuel Consumables	$1,836	$7
1 Month Waste Disposal	$0	$0
25% of 1 Month's Fuel at 100% CF	$0	$0
2% of TPC	$35,051	$125
Total Preproduction	**$51,272**	$183
Inventory Capital		
60 Day Supply Fuel & Consumables at 100% CF	$3,621	$13
0.5% of TPC (spare parts)	$8,763	$31
Total Inventory Capital	**$12,384**	$44
Other Costs		
Initial Cost for Catalysts & Chemicals	$540	$2
Land	$900	$3
Finanacing Costs	$47,319	$169
Owner's Costs	$262,886	$940
Total Other Costs	**$311,645**	$1,115
Total OverNight Cost (TOC)	**$2,127,871**	$7,610
TASC Multiplier (IOU, 35 year)	1.154	
Total As-Spent Capital(TASC)	**$2,455,563**	$8,782

Exhibit 2-9. Initial and Annual O&M Expenses – Case 2B (Waste Coal - Capture Equipped)

INITIAL & ANNUAL O&M EXPENSES					Cost Basis:	Dec 2019
Case 2B - PFBC Waste Coal Based Power Plant					Heat Rate-net (Btu/kWh):	11,275
4 x 1 P200 with CO2 capture					MWe-net:	279.6
					Capacity Factor (%):	85
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate (base):	45.00	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of labor				
Total Operators & Lab Techs	17					
(equivalent 24/7 positions)					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$8,711,820	$31.158
Maintenance Labor Cost					$11,919,235	$42.630
Administrative & Support Labor					$5,157,764	$18.447
Property Taxes and Insurance					$35,051,406	$125.363
TOTAL FIXED OPERATING COSTS					**$60,840,226**	**$217.597**
VARIABLE OPERATING COSTS						
						$/kWh-net
Maintenance Material Cost					**$17,878,853**	**$0.00859**
Consumables	Consumption Initial Fill	Consumption /Day	Unit Cost	Initial Fill Cost		
Water (/1000 gallons)	-	1,992	1.90	$0	$1,174,234	$0.00056
Chemicals						
MU & WT Chem.(lbs)	67,498	4,821	0.28	$18,562	$411,345	$0.00020
Limestone (ton)	10,416	744	24.25	$252,588	$5,597,531	$0.00269
Activated Carbon (ton)	-	-	1,600.00	$0	$0	$0.00000
Mercury Removal Filter Modules	w/ capital	0.4	10,000.00	$0	$1,224,000	$0.00059
Ammonia (19% NH3) ton	79	5.7	300.00	$23,730	$525,874	$0.00025
NaOH - 50% (ton) for causitc scrubber	302	21.5	600.00	$180,936	$4,009,671	$0.00193
Amine Solvent (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 NaOH - 20% (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 Capture Solvents - proprietary	w/ capital	-	-	$0	$4,688,600	$0.00225
Triethylene Glycol (gal)	w/ capital	277	6.80	$0	$584,387	$0.00028
Ion Exchange Resin (ft3) for demin/condensate	w/ capital	0	285.00	$0	$43,605	$0.00002
NaOH - 50% (ton) for demin/condensate	8	0.6	600.00	$4,922	$109,084	$0.00005
H2SO4 - 93% (ton) for demin/condensate	11	0.8	205.00	$2,307	$51,135	$0.00002
NaOH - 50% (ton) for ZLD	20	1.4	600.00	$11,970	$265,264	$0.00013
H2SO4 - 93% (ton) for ZLD	20	1.5	205.00	$4,176	$92,540	$0.00004
Anti-scale (ton) for ZLD	1	0.1	5,900.00	$5,286	$117,150	$0.00006
Anti-coagulant (ton) for ZLD	17	1	2,050.00	$35,158	$779,115	$0.00037
Subtotal Chemicals				**$539,636**	**$18,499,301**	**$0.00889**
Other						
Supplemental Fuel #2 Oil (MBtu)	7,000	12	15.00	$105,000	$55,845	$0.00003
Natural Gas for start-up (MMBtu)	-	164	3.35	$0	$170,850	$0.00008
Gases, N2 etc. (/100scf)	-	-	-	$0	$0	$0.00000
Subtotal Other				**$105,000**	**$226,695**	**$0.00011**
Waste Disposal						
Fly Ash (ton)	-	-	38.00	$0	$0	$0.00000
Bed Ash (ton)	-	-	38.00	$0	$0	$0.00000
Triethylene Glycol (gal)	-	-	0.35	$0	$0	$0.00000
Subtotal-Waste Disposal				**$0**	**$0**	**$0.00000**
By-products & Emissions						
CO2 (ton)	-	7,819	41.00	$0	-$99,459,635	-$0.04777
Subtotal By-Products				**$0**	**-$99,459,635**	**-$0.04777**
TOTAL VARIABLE OPERATING COSTS				**$644,636**	**-$61,680,551**	**-$0.02963**
Fuel - Coal (ton)	90,509	6,465	0.00	$0	$0	$0.00000
Fuel - Biomass (ton)	0	0	50.00	$0	$0	$0.00000
TOTAL FUEL COSTS				**$0**	**$0**	**$0.00000**

Exhibit 2-10. Total Plant Cost Summary – Case 2C (Waste Coal & Biomass - Capture Equipped)

Client: Consol
Project: Case 2C - PFBC Waste Coal & Biomass Based Power Plant with CO2 Capture
Report Date: 2020 May 04

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual
Plant Size: 279.4 MW,net
Labor Basis Southeast, PA - union
Cost Base Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	FUEL PREP & FEED	$136,350	$0	**$136,350**	$4,772	$0	$14,112	**$155,234**	$556
2	OPEN	$0	$0	**$0**	$0	$0	$0	**$0**	$0
3	FEEDWATER & MISC. BOP SYSTEMS	$71,433	$56,421	**$127,854**	$12,785	$0	$21,096	**$161,735**	$579
4	PFBC								
4.1	PFBC - furnish & erect	$326,500	$0	**$326,500**	$11,428	$0	$33,793	**$371,720**	$1,330
4.2-4.9	Other	$3,774	$6,591	**$10,365**	$1,036	$0	$1,710	**$13,111**	$0
	SUBTOTAL 4	**$330,274**	**$6,591**	**$336,865**	**$12,464**	**$0**	**$35,503**	**$384,831**	**$1,377**
5	FLUE GAS CLEANUP	$88,767	$22,500	**$111,267**	$11,127	$0	$18,359	**$140,753**	$504
5B	CO2 REMOVAL & COMPRESSION	$140,091	$117,806	**$257,897**	$25,790	$0	$42,553	**$326,239**	$1,168
6	TURBO MACHINES								
6.1	Turbo Machines	$53,012	$8,191	**$61,203**	$6,120	$12,241	$11,935	**$91,498**	$327
6.2-6.9	Other	$361	$1,234	**$1,595**	$159	$0	$263	**$2,017**	$7
	SUBTOTAL 6	**$53,373**	**$9,424**	**$62,798**	**$6,280**	**$12,241**	**$12,198**	**$93,516**	**$335**
7	DUCTING & STACK								
7.1	open	$0	$0	**$0**	$0	$0	$0	**$0**	$0
7.2-7.9	Ductwork and Stack	$15,268	$2,531	**$17,799**	$1,780	$0	$2,937	**$22,516**	$81
	SUBTOTAL 7	**$15,268**	**$2,531**	**$17,799**	**$1,780**	**$0**	**$2,937**	**$22,516**	**$81**
8	STEAM TURBINE GENERATOR								
8.1	Steam TG & Accessories	$29,900	$6,583	**$36,483**	$3,648	$0	$6,020	**$46,151**	$165
8.2-8.9	Turbine Plant Auxiliaries and Steam Piping	$40,006	$27,202	**$67,208**	$6,721	$0	$11,089	**$85,018**	$304
	SUBTOTAL 8	**$69,906**	**$33,786**	**$103,692**	**$10,369**	**$0**	**$17,109**	**$131,170**	**$469**
9	COOLING WATER SYSTEM	$11,359	$10,911	**$22,269**	$2,227	$0	$3,674	**$28,171**	$101
10	ASH HANDLING SYSTEM	$35,265	$6,780	**$42,045**	$4,205	$0	$6,937	**$53,187**	$190
11	ACCESSORY ELECTRIC PLANT	$41,230	$45,343	**$86,573**	$8,657	$0	$14,284	**$109,514**	$392
12	INSTRUMENTATION & CONTROL	$10,583	$1,383	**$11,966**	$1,197	$1,795	$2,244	**$17,201**	$62
13	IMPROVEMENTS TO SITE	$2,175	$5,532	**$7,707**	$771	$0	$1,272	**$9,749**	$35
14	BUILDINGS & STRUCTURES	$52,735	$41,142	**$93,876**	$9,388	$0	$15,490	**$118,753**	$425
	TOTAL COST	**$1,058,808**	**$360,149**	**$1,418,957**	**$111,810**	**$14,035**	**$207,768**	**$1,752,570**	**$6,273**

Client: Consol **Report Date:** 2020 May 04
Project: Case 2C - PFBC Waste Coal & Biomass Based Power Plant with CO2 Capture

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual **Labor Basis** Southeast, PA - union
Plant Size: 279.4 MW,net **Cost Base** Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	FUEL PREP & FEED								
1.1	Fuel Prep & Feed System - complete plant	$136,350	$0	$136,350	$4,772	$0	$14,112	$155,234	$556
1.8	Fuel Prep & Feed Buildings - incl with system costs	$0	$0	$0	$0	$0	$0	$0	$0
1.9	Fuel Prep & Feed Foundations - incl with system costs	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 1.	**$136,350**	**$0**	**$136,350**	**$4,772**	**$0**	**$14,112**	**$155,234**	**$556**
2	OPEN								
2.1	open	$0	$0	$0	$0	$0	$0	$0	$0
2.9	open	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 2.	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	FEEDWATER & MISC. BOP SYSTEMS								
3.1	Feedwater System	$12,858	$7,887	$20,745	$2,075	$0	$3,423	$26,242	$94
3.2	Water Makeup & Pretreating - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.3	Other Feedwater Subsystems - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.4	Service Water Systems - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.5	Other Plant Systems	$42,165	$34,160	$76,326	$7,633	$0	$12,594	$96,552	$346
3.6	FO Supply System - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.7	Zero Liquid Discharge System	$15,355	$11,298	$26,653	$2,665	$0	$4,398	$33,716	$121
3.8	Misc. Equip.(cranes,AirComp.,Comm.) - incl with other	$0	$0	$0	$0	$0	$0	$0	$0
3.8	BOP Foundations	$1,054	$3,077	$4,130	$413	$0	$682	$5,225	$19
	SUBTOTAL 3.	**$71,433**	**$56,421**	**$127,854**	**$12,785**	**$0**	**$21,096**	**$161,735**	**$579**
4	PFBC								
4.1	PFBC - furnish & erect	$326,500	$0	$326,500	$11,428	$0	$33,793	$371,720	$1,330
4.2	PFBC Auxilliary Systems	$252	$998	$1,250	$125	$0	$206	$1,581	$6
4.3	Open	$0	$0	$0	$0	$0	$0	$0	$0
4.4	Boiler BoP (w/ ID Fans)	$0	$0	$0	$0	$0	$0	$0	$0
4.5	Primary Air System	$0	$0	$0	$0	$0	$0	$0	$0
4.6	Secondary Air System	$0	$0	$0	$0	$0	$0	$0	$0
4.8	Major Component Rigging	$0	$0	$0	$0	$0	$0	$0	$0
4.9	PFBC Foundations	$3,522	$5,593	$9,115	$912	$0	$1,504	$11,530	$41
	SUBTOTAL 4.	**$330,274**	**$6,591**	**$336,865**	**$12,464**	**$0**	**$35,503**	**$384,831**	**$1,377**

Client: Consol — **Report Date:** 2020 May 04
Project: Case 2C - PFBC Waste Coal & Biomass Based Power Plant with CO2 Capture

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual — **Labor Basis** Southeast, PA - union
Plant Size: 279.4 MW,net — **Cost Base** Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies: Process	Contingencies: Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
5	FLUE GAS CLEANUP								
5.1	Gas Heating & Cooling	$4,596	$1,750	$6,346	$635	$0	$1,047	$8,028	$29
5.2	Gas Filtration	$59,440	$10,823	$70,263	$7,026	$0	$11,593	$88,882	$318
5.3	SO2 Removal	$6,000	$4,509	$10,509	$1,051	$0	$1,734	$13,294	$48
5.4	Mercury removal	$14,660	$0	$14,660	$1,466	$0	$2,419	$18,545	$66
5.5	Flue Gas Piping	$3,051	$5,011	$8,062	$806	$0	$1,330	$10,198	$37
5.6	CEMs	$1,020	$407	$1,427	$143	$0	$235	$1,805	$6
5.9	open	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 5.	**$88,767**	**$22,500**	**$111,267**	**$11,127**	**$0**	**$18,359**	**$140,753**	**$504**
5B	CO2 REMOVAL & COMPRESSION								
5B.1	CO2 Removal System	$110,000	$108,398	$218,398	$21,840	$0	$36,036	$276,274	$989
5B.2	CO2 Compression	$29,160	$6,833	$35,993	$3,599	$0	$5,939	$45,532	$163
5B.9	CO2 Removal & Compression Foundations	$931	$2,575	$3,505	$351	$0	$578	$4,434	$16
	SUBTOTAL 5B.	**$140,091**	**$117,806**	**$257,897**	**$25,790**	**$0**	**$42,553**	**$326,239**	**$1,168**
6	TURBO MACHINES								
6.1	Turbo Machines	$53,012	$8,191	$61,203	$6,120	$12,241	$11,935	$91,498	$327
6.2	Intercooler for PFBC	$0	$0	$0	$0	$0	$0	$0	$0
6.3	Open	$0	$0	$0	$0	$0	$0	$0	$0
6.9	Turbo Machines Foundations	$361	$1,234	$1,595	$159	$0	$263	$2,017	$7
	SUBTOTAL 6.	**$53,373**	**$9,424**	**$62,798**	**$6,280**	**$12,241**	**$12,198**	**$93,516**	**$335**
7	DUCTING & STACK								
7.1	open	$0	$0	$0	$0	$0	$0	$0	$0
7.3	Ductwork	$561	$1,318	$1,879	$188	$0	$310	$2,376	$9
7.4	Stack - furnish and erect	$14,000	$0	$14,000	$1,400	$0	$2,310	$17,710	$63
7.9	Duct & Stack Foundations	$707	$1,214	$1,921	$192	$0	$317	$2,430	$9
	SUBTOTAL 7.	**$15,268**	**$2,531**	**$17,799**	**$1,780**	**$0**	**$2,937**	**$22,516**	**$81**
8	STEAM TURBINE GENERATOR								
8.1	Steam TG & Accessories	$29,900	$6,583	$36,483	$3,648	$0	$6,020	$46,151	$165
8.2	Turbine Plant Auxiliaries	$1,940	$3,446	$5,386	$539	$0	$889	$6,813	$24
8.3	Condenser & Auxiliaries	$20,052	$8,382	$28,434	$2,843	$0	$4,692	$35,969	$129
8.4	Steam Piping	$16,401	$11,258	$27,660	$2,766	$0	$4,564	$34,990	$125
8.9	STG Foundations	$1,612	$4,116	$5,729	$573	$0	$945	$7,247	$26
	SUBTOTAL 8.	**$69,906**	**$33,786**	**$103,692**	**$10,369**	**$0**	**$17,109**	**$131,170**	**$469**
9	COOLING WATER SYSTEM								
9.1	Cooling Towers - furnish & erect	$3,960	$0	$3,960	$396	$0	$653	$5,009	$18
9.2	Circulating Water Pumps	$1,200	$139	$1,339	$134	$0	$221	$1,694	$6
9.3	Circ.Water System Auxiliaries	$194	$166	$360	$36	$0	$59	$455	$2
9.4	Circ.Water Piping	$4,119	$6,960	$11,079	$1,108	$0	$1,828	$14,015	$50
9.5	Make-up Water System	$0	$0	$0	$0	$0	$0	$0	$0
9.6	Component Cooling Water Sys	$737	$897	$1,634	$163	$0	$270	$2,067	$7
9.9	Circ.Water System Foundations & Structures	$1,149	$2,749	$3,898	$390	$0	$643	$4,930	$18
	SUBTOTAL 9.	**$11,359**	**$10,911**	**$22,269**	**$2,227**	**$0**	**$3,674**	**$28,171**	**$101**

Client: Consol **Report Date:** 2020 May 04
Project: Case 2C - PFBC Waste Coal & Biomass Based Power Plant with CO2 Capture

TOTAL PLANT COST SUMMARY

Estimate Type: Conceptual **Labor Basis** Southeast, PA - union
Plant Size: 279.4 MW,net **Cost Base** Dec 2019 ($x1000)

Acct No.	Item/Description	Equipment & Material Cost	Labor Cost	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
10	ASH HANDLING SYSTEM								
10.1	Ash Handling System	$19,915	$3,870	$23,785	$2,378	$0	$3,925	$30,088	$108
10.2	Ash Silos - furnish & erect	$13,600	$0	$13,600	$1,360	$0	$2,244	$17,204	$62
10.8	Misc. Ash Handling Equipment	$0	$0	$0	$0	$0	$0	$0	$0
10.9	Ash System Foundations	$1,750	$2,910	$4,660	$466	$0	$769	$5,895	$21
	SUBTOTAL 10.	**$35,265**	**$6,780**	**$42,045**	**$4,205**	**$0**	**$6,937**	**$53,187**	**$190**
11	ACCESSORY ELECTRIC PLANT								
11.1	Electrical Equipment	$25,225	$6,089	$31,314	$3,131	$0	$5,167	$39,612	$142
11.2	open	$0	$0	$0	$0	$0	$0	$0	$0
11.3	open	$0	$0	$0	$0	$0	$0	$0	$0
11.4	Raceway, wire & cable	$9,545	$32,298	$41,843	$4,184	$0	$6,904	$52,932	$189
11.5	open	$0	$0	$0	$0	$0	$0	$0	$0
11.6	Switchyard	$5,680	$4,411	$10,091	$1,009	$0	$1,665	$12,765	$46
11.7	open	$0	$0	$0	$0	$0	$0	$0	$0
11.8	open	$0	$0	$0	$0	$0	$0	$0	$0
11.9	Electrical Foundations	$780	$2,544	$3,324	$332	$0	$548	$4,205	$15
	SUBTOTAL 11.	**$41,230**	**$45,343**	**$86,573**	**$8,657**	**$0**	**$14,284**	**$109,514**	**$392**
12	INSTRUMENTATION & CONTROL								
12.1	PFBC Control Equipment - with PFBC	$0	$0	$0	$0	$0	$0	$0	$0
12.2	Turbo Machine Control - with Turbo Machine	$0	$0	$0	$0	$0	$0	$0	$0
12.3	Steam Turbine Control - with Steam Turbine	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control - with equipment	$0	$0	$0	$0	$0	$0	$0	$0
12.5	open	$0	$0	$0	$0	$0	$0	$0	$0
12.6	open	$0	$0	$0	$0	$0	$0	$0	$0
12.7	Distributed Control System Equipment	$10,000	w/ mat'l	$10,000	$1,000	$1,500	$1,875	$14,375	$51
12.8	Instrument Wiring & Tubing - with electrical	$0	$0	$0	$0	$0	$0	$0	$0
12.9	Other I & C Equipment	$583	$1,383	$1,966	$197	$295	$369	$2,826	$10
	SUBTOTAL 12.	**$10,583**	**$1,383**	**$11,966**	**$1,197**	**$1,795**	**$2,244**	**$17,201**	**$62**
13	IMPROVEMENTS TO SITE								
13.1	Site Preparation	$0	$0	$0	$0	$0	$0	$0	$0
13.2	Site Improvements	$2,175	$5,532	$7,707	$771	$0	$1,272	$9,749	$35
13.3	Site Facilities	$0	$0	$0	$0	$0	$0	$0	$0
	SUBTOTAL 13.	**$2,175**	**$5,532**	**$7,707**	**$771**	**$0**	**$1,272**	**$9,749**	**$35**
14	BUILDINGS & STRUCTURES								
14.1	Combustion Building	$25,894	$24,866	$50,760	$5,076	$0	$8,375	$64,211	$230
14.2	Turbine Building	$12,255	$13,441	$25,696	$2,570	$0	$4,240	$32,506	$116
14.3	Administration Building	$2,101	$225	$2,326	$233	$0	$384	$2,942	$11
14.4	Water Treatment Building	$2,694	$611	$3,305	$331	$0	$545	$4,181	$15
14.5	CO2 Regeneration & Compression Buildings	$9,028	$1,737	$10,764	$1,076	$0	$1,776	$13,617	$49
14.6	open	$0	$0	$0	$0	$0	$0	$0	$0
14.7	open	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$764	$262	$1,025	$103	$0	$169	$1,297	$5
	SUBTOTAL 14.	**$52,735**	**$41,142**	**$93,876**	**$9,388**	**$0**	**$15,490**	**$118,753**	**$425**
	TOTAL COST	**$1,058,808**	**$360,149**	**$1,418,957**	**$111,810**	**$14,035**	**$207,768**	**$1,752,570**	**$6,273**

Exhibit 2-11. Owner's Costs – Case 2C (Waste Coal & Biomass - Capture Equipped)

Owner's Costs
Case 2C - PFBC Waste Coal & Biomass Based Power Plant with CO2 Capture

Description	$ x 1,000	$.kW
TPC	$1,752,570	$6,273
Pre-production		
6 Months All Labor	$12,894	$46
1 Month Maintenance Materials	$1,490	$5
1 Month Non-Fuel Consumables	$1,836	$7
1 Month Waste Disposal	$0	$0
25% of 1 Month's Fuel at 100% CF	$447	$2
2% of TPC	$35,051	$125
Total Preproduction	**$51,719**	$185
Inventory Capital		
60 Day Supply Fuel & Consumables at 100% CF	$4,504	$16
0.5% of TPC (spare parts)	$8,763	$31
Total Inventory Capital	**$13,266**	$47
Other Costs		
Initial Cost for Catalysts & Chemicals	$540	$2
Land	$900	$3
Finanacing Costs	$47,319	$169
Owner's Costs	$262,886	$941
Total Other Costs	**$311,645**	$1,115
Total OverNight Cost (TOC)	**$2,129,200**	$7,621
TASC Multiplier (IOU, 35 year)	1.154	
Total As-Spent Capital(TASC)	**$2,457,097**	$8,794

Exhibit 2-12. Initial and Annual O&M Expenses – Case 2C (Waste Coal & Biomass - Capture Equipped)

INITIAL & ANNUAL O&M EXPENSES					Cost Basis:	Dec 2019
Case 2C - PFBC Waste Coal & Biomass Based Power Plant					Heat Rate-net (Btu/kWh):	11,290
4 x 1 P200 with CO2 capture					MWe-net:	279.4
					Capacity Factor (%):	85
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate (base):	45.00 $/hour					
Operating Labor Burden:	30.00 % of base					
Labor O-H Charge Rate:	25.00 % of labor					
Total Operators & Lab Techs	17					
(equivalent 24/7 positions)					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$8,711,820	$31.180
Maintenance Labor Cost					$11,919,235	$42.660
Administrative & Support Labor					$5,157,764	$18.460
Property Taxes and Insurance					$35,051,406	$125.452
TOTAL FIXED OPERATING COSTS					**$60,840,226**	**$217.753**
VARIABLE OPERATING COSTS						
						$/kWh-net
Maintenance Material Cost					**$17,878,853**	**$0.00859**
Consumables	Consumption: Initial Fill	Consumption: /Day	Unit Cost	Initial Fill Cost		
Water (/1000 gallons)	-	1,992	1.90	$0	$1,174,234	$0.00056
Chemicals						
MU & WT Chem.(lbs)	67,498	4,821	0.28	$18,562	$411,345	$0.00020
Limestone (ton)	10,416	744	24.25	$252,588	$5,597,531	$0.00269
Activated Carbon (ton)	-	-	1,600.00	$0	$0	$0.00000
Mercury Removal Filter Modules	w/ capital	0.4	10,000.00	$0	$1,224,000	$0.00059
Ammonia (19% NH3) ton	79	5.7	300.00	$23,730	$525,874	$0.00025
NaOH - 50% (ton) for causitc scrubber	302	21.5	600.00	$180,936	$4,009,671	$0.00193
Amine Solvent (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 NaOH - 20% (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 Capture Solvents - proprietary	w/ capital	-	-	$0	$4,688,600	$0.00225
Triethylene Glycol (gal)	w/ capital	277	6.80	$0	$584,387	$0.00028
Ion Exchange Resin (ft3) for demin/condensate	w/ capital	0	285.00	$0	$43,605	$0.00002
NaOH - 50% (ton) for demin/condensate	8	0.6	600.00	$4,922	$109,084	$0.00005
H2SO4 - 93% (ton) for demin/condensate	11	0.8	205.00	$2,307	$51,135	$0.00002
NaOH - 50% (ton) for ZLD	20	1.4	600.00	$11,970	$265,264	$0.00013
H2SO4 - 93% (ton) for ZLD	20	1.5	205.00	$4,176	$92,540	$0.00004
Anti-scale (ton) for ZLD	1	0.1	5,900.00	$5,286	$117,150	$0.00006
Anti-coagulant (ton) for ZLD	17	1	2,050.00	$35,158	$779,115	$0.00037
Subtotal Chemicals				**$539,636**	**$18,499,301**	**$0.00889**
Other						
Supplemental Fuel #2 Oil (MBtu)	7,000	12	15.00	$105,000	$55,845	$0.00003
Natural Gas for start-up (MMBtu)	-	164	3.35	$0	$170,850	$0.00008
Gases, N2 etc. (/100scf)	-	-	-	$0	$0	$0.00000
Subtotal Other				**$105,000**	**$226,695**	**$0.00011**
Waste Disposal						
Fly Ash (ton)	-	-	38.00	$0	$0	$0.00000
Bed Ash (ton)	-	-	38.00	$0	$0	$0.00000
Triethylene Glycol (gal)	-	-	0.35	$0	$0	$0.00000
Subtotal-Waste Disposal				**$0**	**$0**	**$0.00000**
By-products & Emissions						
CO2 (ton)	-	7,819	41.00	$0	-$99,459,635	-$0.04781
Subtotal By-Products				**$0**	**-$99,459,635**	**-$0.04781**
TOTAL VARIABLE OPERATING COSTS				**$644,636**	**-$61,680,551**	**-$0.02965**
Fuel - Coal (ton)	86,116	6,151	0.00	$0	$0	$0.00000
Fuel - Biomass (ton)	4,116	294	50.00	$205,817	$4,561,047	$0.00219
TOTAL FUEL COSTS				**$205,817**	**$4,561,047**	**$0.00219**

2.5 O&M Expenses Sensitivity to Operational Flexibility

In Section 2.4, the O&M Expenses were developed at an 85% capacity factor and a load point of 100%. In this section we present O&M expenses for the alternate capacity factor and load point combinations presented per Exhibit 2-13 to illustrate the impact of the plant's operational flexibility.

Exhibit 2-13. O&M Expenses for Alternate Operating Parameters

Case Identifier	Capacity Factor	Load Point	Exhibit No.
Case 1B	85%	100%	Exhibit 2-6
Case 1B – Alt 1	75%	90%	Exhibit 2-14
Case 1B – Alt 2	65%	90%	Exhibit 2-15
Case 2B	85%	100%	Exhibit 2-9
Case 2B – Alt 1	75%	90%	Exhibit 2-16
Case 2B – Alt 2	65%	90%	Exhibit 2-17

Exhibit 2-14. Initial and Annual O&M Expenses – Case 1B Alt 1 (Illinois No. 6 - Capture Equipped, 75% Capacity Factor, 90% Load Point)

INITIAL & ANNUAL O&M EXPENSES					Cost Basis:	Dec 2019
Case 1B - PFBC Illinois Coal Based Power Plant					Heat Rate-net (Btu/kWh):	10,616
4 x 1 P200 with CO2 capture					MWe-net:	278.1
		Load Factor (%):	90		Capacity Factor (%):	75
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate (base):	38.50	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of labor				
Total Operators & Lab Techs (equivalent 24/7 positions)	17					
					Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$7,453,446	$26.801
Maintenance Labor Cost					$10,965,390	$39.430
Administrative & Support Labor					$4,604,709	$16.558
Property Taxes and Insurance					$32,287,497	$116.100
TOTAL FIXED OPERATING COSTS					**$55,311,043**	**$198.889**
VARIABLE OPERATING COSTS						
						$/kWh-net
Maintenance Material Cost					**$16,448,085**	**$0.00814**
Consumables	Consumption Initial Fill	Consumption /Day	Unit Cost	Initial Fill Cost		
Water (/1000 gallons)	-	3,932	1.90	$0	$2,262,831	$0.00112
Chemicals						
MU & WT Chem.(lbs)	143,264	9,313	0.28	$39,397	$775,711	$0.00038
Limestone (ton)	11,368	739	24.25	$275,674	$5,427,841	$0.00268
Activated Carbon (ton)	-	-	1,600.00	$0	$0	$0.00000
Mercury Removal Filter Modules	w/ capital	-	10,000.00	$0	$0	$0.00000
Ammonia (19% NH3) ton	81	5.3	300.00	$24,402	$480,459	$0.00024
NaOH - 50% (ton) for causitc scrubber	329	21.4	600.00	$197,568	$3,889,985	$0.00192
Amine Solvent (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 NaOH - 20% (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 Capture Solvents - proprietary	w/ capital	-	-	$0	$4,099,268	$0.00203
Triethylene Glycol (gal)	w/ capital	248	6.80	$0	$511,718	$0.00025
Ion Exchange Resin (ft3) for demin/condensate	w/ capital	0	285.00	$0	$41,433	$0.00002
NaOH - 50% (ton) for demin/condensate	9	0.6	600.00	$5,146	$101,329	$0.00005
H2SO4 - 93% (ton) for demin/condensate	12	0.8	205.00	$2,412	$47,500	$0.00002
NaOH - 50% (ton) for ZLD	50	3.2	600.00	$29,925	$589,204	$0.00029
H2SO4 - 93% (ton) for ZLD	51	3.3	205.00	$10,440	$205,549	$0.00010
Anti-scale (ton) for ZLD	2	0.1	5,900.00	$13,216	$260,214	$0.00013
Anti-coagulant (ton) for ZLD	43	3	2,050.00	$87,894	$1,730,571	$0.00086
Subtotal Chemicals				**$686,075**	**$18,160,783**	**$0.00994**
Other						
Supplemental Fuel #2 Oil (MBtu)	7,000	11	15.00	$105,000	$49,617	$0.00002
Natural Gas for start-up (MMBtu)	-	164	3.35	$0	$170,850	$0.00008
Gases, N2 etc. (/100scf)	-	-	-	$0	$0	$0.00000
Subtotal Other				**$105,000**	**$220,467**	**$0.00011**
Waste Disposal						
Fly Ash (ton)	-	-	38.00	$0	$0	$0.00000
Bed Ash (ton)	-	-	38.00	$0	$0	$0.00000
Triethylene Glycol (gal)	-	248	0.35	$0	$26,338	$0.00001
Subtotal-Waste Disposal				**$0**	**$26,338**	**$0.00001**
By-products & Emissions						
CO2 (ton)	-	7,002	41.00	$0	-$86,955,171	-$0.04301
Subtotal By-Products				**$0**	**-$86,955,171**	**-$0.04301**
TOTAL VARIABLE OPERATING COSTS				**$791,075**	**-$49,836,666**	**-$0.02369**
Fuel - Coal (ton)	42,514	3,037	51.96	$2,209,032	$43,194,457	$0.02364
Fuel - Biomass (ton)	0	0	50.00	$0	$0	$0.00000
TOTAL FUEL COSTS				**$2,209,032**	**$43,194,457**	**$0.02364**

Exhibit 2-15. Initial and Annual O&M Expenses – Case 1B Alt 2 (Illinois No. 6 - Capture Equipped, 65% Capacity Factor, 90% Load Point)

INITIAL & ANNUAL O&M EXPENSES						
					Cost Basis:	Dec 2019
Case 1B - PFBC Illinois Coal Based Power Plant					Heat Rate-net (Btu/kWh):	10,616
4 x 1 P200 with CO2 capture					MWe-net:	278.1
		Load Factor (%):	90		Capacity Factor (%):	65
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate (base):	38.50	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of labor				
Total Operators & Lab Techs (equivalent 24/7 positions)	17				Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$7,453,446	$26.801
Maintenance Labor Cost					$10,965,390	$39.430
Administrative & Support Labor					$4,604,709	$16.558
Property Taxes and Insurance					$32,287,497	$116.100
TOTAL FIXED OPERATING COSTS					**$55,311,043**	**$198.889**
VARIABLE OPERATING COSTS						
						$/kWh-net
Maintenance Material Cost					**$16,448,085**	**$0.00939**
Consumables	Consumption Initial Fill	Consumption /Day	Unit Cost	Initial Fill Cost		
Water (/1000 gallons)	-	3,932	1.90	$0	$1,961,120	$0.00112
Chemicals						
MU & WT Chem.(lbs)	143,264	9,313	0.28	$39,397	$672,283	$0.00038
Limestone (ton)	11,368	739	24.25	$275,674	$4,704,129	$0.00268
Activated Carbon (ton)	-	-	1,600.00	$0	$0	$0.00000
Mercury Removal Filter Modules	w/ capital	-	10,000.00	$0	$0	$0.00000
Ammonia (19% NH3) ton	81	5.3	300.00	$24,402	$416,398	$0.00024
NaOH - 50% (ton) for causitc scrubber	329	21.4	600.00	$197,568	$3,371,320	$0.00192
Amine Solvent (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 NaOH - 20% (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 Capture Solvents - proprietary	w/ capital	-	-	$0	$3,552,699	$0.00203
Triethylene Glycol (gal)	w/ capital	248	6.80	$0	$443,489	$0.00025
Ion Exchange Resin (ft3) for demin/condensate	w/ capital	0	285.00	$0	$35,908	$0.00002
NaOH - 50% (ton) for demin/condensate	9	0.6	600.00	$5,146	$87,818	$0.00005
H2SO4 - 93% (ton) for demin/condensate	12	0.8	205.00	$2,412	$41,167	$0.00002
NaOH - 50% (ton) for ZLD	50	3.2	600.00	$29,925	$510,643	$0.00029
H2SO4 - 93% (ton) for ZLD	51	3.3	205.00	$10,440	$178,143	$0.00010
Anti-scale (ton) for ZLD	2	0.1	5,900.00	$13,216	$225,519	$0.00013
Anti-coagulant (ton) for ZLD	43	3	2,050.00	$87,894	$1,499,828	$0.00086
Subtotal Chemicals				**$686,075**	**$15,739,345**	**$0.00994**
Other						
Supplemental Fuel #2 Oil (MBtu)	7,000	11	15.00	$105,000	$43,002	$0.00002
Natural Gas for start-up (MMBtu)	-	164	3.35	$0	$170,850	$0.00010
Gases, N2 etc. (/100scf)	-	-	-	$0	$0	$0.00000
Subtotal Other				**$105,000**	**$213,852**	**$0.00012**
Waste Disposal						
Fly Ash (ton)	-	-	38.00	$0	$0	$0.00000
Bed Ash (ton)	-	-	38.00	$0	$0	$0.00000
Triethylene Glycol (gal)	-	248	0.35	$0	$22,827	$0.00001
Subtotal-Waste Disposal				**$0**	**$22,827**	**$0.00001**
By-products & Emissions						
CO2 (ton)	-	7,002	41.00	$0	-$75,361,148	-$0.04301
Subtotal By-Products				**$0**	**-$75,361,148**	**-$0.04301**
TOTAL VARIABLE OPERATING COSTS				**$791,075**	**-$40,975,919**	**-$0.02243**
Fuel - Coal (ton)	42,514	3,037	51.96	$2,209,032	$37,435,196	$0.02364
Fuel - Biomass (ton)	0	0	50.00	$0	$0	$0.00000
TOTAL FUEL COSTS				**$2,209,032**	**$37,435,196**	**$0.02364**

Exhibit 2-16. Initial and Annual O&M Expenses – Case 2B Alt 1 (Waste Coal - Capture Equipped, 75% Capacity Factor, 90% Load Point)

INITIAL & ANNUAL O&M EXPENSES					Cost Basis:	Dec 2019
Case 2B - PFBC Waste Coal Based Power Plant					Heat Rate-net (Btu/kWh):	11,383
4 x 1 P200 with CO2 capture					MWe-net:	252.2
		Load Factor (%):	90		Capacity Factor (%):	75
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate (base):	45.00	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of labor				
Total Operators & Lab Techs	17					
(equivalent 24/7 positions)					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$8,711,820	$34.543
Maintenance Labor Cost					$11,919,235	$47.261
Administrative & Support Labor					$5,157,764	$20.451
Property Taxes and Insurance					$35,051,406	$138.983
TOTAL FIXED OPERATING COSTS					**$60,840,226**	**$241.238**
VARIABLE OPERATING COSTS						
						$/kWh-net
Maintenance Material Cost					**$17,878,853**	**$0.00973**
Consumables	Consumption		Unit	Initial Fill		
	Initial Fill	/Day	Cost	Cost		
Water (/1000 gallons)	-	1,838	1.90	$0	$1,059,878	$0.00058
Chemicals						
MU & WT Chem.(lbs)	67,498	4,449	0.28	$18,562	$371,285	$0.00020
Limestone (ton)	10,416	686	24.25	$252,588	$5,052,399	$0.00275
Activated Carbon (ton)	-	-	1,600.00	$0	$0	$0.00000
Mercury Removal Filter Modules	w/ capital	0.4	10,000.00	$0	$1,104,797	$0.00060
Ammonia (19% NH3) ton	79	5.2	300.00	$23,730	$474,660	$0.00026
NaOH - 50% (ton) for causitc scrubber	302	19.9	600.00	$180,936	$3,619,178	$0.00197
Amine Solvent (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 NaOH - 20% (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 Capture Solvents - proprietary	w/ capital	-	-	$0	$4,231,987	$0.00230
Triethylene Glycol (gal)	w/ capital	256	6.80	$0	$527,475	$0.00029
Ion Exchange Resin (ft3) for demin/condensate	w/ capital	0	285.00	$0	$39,358	$0.00002
NaOH - 50% (ton) for demin/condensate	8	0.5	600.00	$4,922	$98,460	$0.00005
H2SO4 - 93% (ton) for demin/condensate	11	0.7	205.00	$2,307	$46,155	$0.00003
NaOH - 50% (ton) for ZLD	20	1.3	600.00	$11,970	$239,430	$0.00013
H2SO4 - 93% (ton) for ZLD	20	1.3	205.00	$4,176	$83,528	$0.00005
Anti-scale (ton) for ZLD	1	0.1	5,900.00	$5,286	$105,741	$0.00006
Anti-coagulant (ton) for ZLD	17	1	2,050.00	$35,158	$703,239	$0.00038
Subtotal Chemicals				**$539,636**	**$16,697,694**	**$0.01007734**
Other						
Supplemental Fuel #2 Oil (MBtu)	7,000	11	15.00	$105,000	$50,406	$0.00003
Natural Gas for start-up (MMBtu)	-	164	3.35	$0	$170,850	$0.00009
Gases, N2 etc. (/100scf)	-	-	-	$0	$0	$0.00000
Subtotal Other				**$105,000**	**$221,256**	**$0.00012**
Waste Disposal						
Fly Ash (ton)	-	-	38.00	$0	$0	$0.00000
Bed Ash (ton)	-	-	38.00	$0	$0	$0.00000
Triethylene Glycol (gal)	-	-	0.35	$0	$0	$0.00000
Subtotal-Waste Disposal				**$0**	**$0**	**$0.00000**
By-products & Emissions						
CO2 (ton)	-	7,215	41.00	$0	-$89,773,477	-$0.04887
Subtotal By-Products				**$0**	**-$89,773,477**	**-$0.04887**
TOTAL VARIABLE OPERATING COSTS				**$644,636**	**-$53,915,795**	**-$0.02836**
Fuel - Coal (ton)	83,514	5,965	0.00	$0	$0	$0.00000
Fuel - Biomass (ton)	0	0	50.00	$0	$0	$0.00000
TOTAL FUEL COSTS				**$0**	**$0**	**$0.00000**

Exhibit 2-17. Initial and Annual O&M Expenses – Case 2B Alt 2 (Waste Coal - Capture Equipped, 65% Capacity Factor, 90% Load Point)

INITIAL & ANNUAL O&M EXPENSES					Cost Basis:	Dec 2019
Case 2B - PFBC Waste Coal Based Power Plant					Heat Rate-net (Btu/kWh):	11,383
4 x 1 P200 with CO2 capture					MWe-net:	252.2
		Load Factor (%):	90		Capacity Factor (%):	65
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate (base):	45.00	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of labor				
Total Operators & Lab Techs	17					
(equivalent 24/7 positions)					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$8,711,820	$34.543
Maintenance Labor Cost					$11,919,235	$47.261
Administrative & Support Labor					$5,157,764	$20.451
Property Taxes and Insurance					$35,051,406	$138.983
TOTAL FIXED OPERATING COSTS					**$60,840,226**	**$241.238**
VARIABLE OPERATING COSTS						
						$/kWh-net
Maintenance Material Cost					**$17,878,853**	**$0.01123**
Consumables	Consumption		Unit	Initial Fill		
	Initial Fill	/Day	Cost	Cost		
Water (/1000 gallons)	-	1,838	1.90	$0	$918,561	$0.00058
Chemicals						
MU & WT Chem.(lbs)	67,498	4,449	0.28	$18,562	$321,781	$0.00020
Limestone (ton)	10,416	686	24.25	$252,588	$4,378,746	$0.00275
Activated Carbon (ton)	-	-	1,600.00	$0	$0	$0.00000
Mercury Removal Filter Modules	w/ capital	0.4	10,000.00	$0	$957,491	$0.00060
Ammonia (19% NH3) ton	79	5.2	300.00	$23,730	$411,372	$0.00026
NaOH - 50% (ton) for causitc scrubber	302	19.9	600.00	$180,936	$3,136,621	$0.00197
Amine Solvent (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 NaOH - 20% (gal) - $ incl w/ CO2 Capture Solvents	-	-	-	$0	$0	$0.00000
CO2 Capture Solvents - proprietary	w/ capital	-	-	$0	$3,667,722	$0.00230
Triethylene Glycol (gal)	w/ capital	256	6.80	$0	$457,145	$0.00029
Ion Exchange Resin (ft3) for demin/condensate	w/ capital	0	285.00	$0	$34,111	$0.00002
NaOH - 50% (ton) for demin/condensate	8	0.5	600.00	$4,922	$85,332	$0.00005
H2SO4 - 93% (ton) for demin/condensate	11	0.7	205.00	$2,307	$40,001	$0.00003
NaOH - 50% (ton) for ZLD	20	1.3	600.00	$11,970	$207,506	$0.00013
H2SO4 - 93% (ton) for ZLD	20	1.3	205.00	$4,176	$72,391	$0.00005
Anti-scale (ton) for ZLD	1	0.1	5,900.00	$5,286	$91,643	$0.00006
Anti-coagulant (ton) for ZLD	17	1	2,050.00	$35,158	$609,474	$0.00038
Subtotal Chemicals				**$539,636**	**$14,471,335**	**$0.01008**
Other						
Supplemental Fuel #2 Oil (MBtu)	7,000	11	15.00	$105,000	$43,686	$0.00003
Natural Gas for start-up (MMBtu)	-	164	3.35	$0	$170,850	$0.00011
Gases, N2 etc. (/100scf)	-	-	-	$0	$0	$0.00000
Subtotal Other				**$105,000**	**$214,536**	**$0.00013**
Waste Disposal						
Fly Ash (ton)	-	-	38.00	$0	$0	$0.00000
Bed Ash (ton)	-	-	38.00	$0	$0	$0.00000
Triethylene Glycol (gal)	-	-	0.35	$0	$0	$0.00000
Subtotal-Waste Disposal				**$0**	**$0**	**$0.00000**
By-products & Emissions						
CO2 (ton)	-	7,215	41.00	$0	-$77,803,680	-$0.04887
Subtotal By-Products				**$0**	**-$77,803,680**	**-$0.04887**
TOTAL VARIABLE OPERATING COSTS				**$644,636**	**-$44,320,395**	**-$0.02685**
Fuel - Coal (ton)	83,514	5,965	0.00	$0	$0	$0.00000
Fuel - Biomass (ton)	0	0	50.00	$0	$0	$0.00000
TOTAL FUEL COSTS				**$0**	**$0**	**$0.00000**

2.6 COE Results and Sensitivities

The first year COE for the four cases is presented in Exhibit 2-18.

Exhibit 2-18. First Year COE for Cases 1A, 1B, 2B, 2C

Parameter / Case	Case 1A	Case 1B	Case 2B	Case 2C
COE ($/MWh)	88.55	92.59	82.99	85.29

Sensitivity analyses were performed for several parameters of interest for the various PFBC configurations described in this report. These analyses evaluated the Cost of Electricity (COE) as the principal result using DOE methodology as prescribed in the September 2019 Quality Guidelines for Energy System Studies-Cost Estimation Methodology for NETL Assessments of Power Plant Performance [**9**].

With reference to Section 3.4.1 of the above referenced DOE Quality Guidelines, the COE has been calculated for ranges of variation for the following parameters of interest:

- **Cost of Fuel (Coal)**: this cost was varied between zero and $80.00/ton. The zero lower bound was used because the waste coal-fired Business Cases (Cases 2B and 2C in this report) will fire waste coal that is produced and owned by CONSOL and is likely to be available to the plant at zero net cost. (Exhibit 2-19)
- **Capital Cost** (expressed as Total Plant Cost): the capital cost was varied over a range from 80 to 120% of nominal. (Exhibit 2-20)
- **Capacity Factor**: this parameter was varied from a low of 60% to a high of 90%. It was expected that the various cases described in this report, especially waste coal-fired cases 2B and 2C, will be operated as baseload plants, with high-priority dispatch. This assumption was based on their status as potentially very low-cost marginal producers of electricity, derived by firing very low-cost fuel and, therefore, being very high in the dispatch order. The very low or slightly negative carbon footprint will contribute to their high dispatch potential. (Exhibit 2-21)
- **CO_2 Credit Value**: this factor varied from zero to a maximum value of $50/ton of CO_2 captured. The CO_2 will be sequestered to capture the section 45Q tax credit or other credits as long as they are available or sold for beneficial end use. (Exhibit 2-22)

The results of the various sensitivity analyses are presented in the Exhibits below.

Exhibit 2-19. First Year COE vs Coal Cost Sensitivity

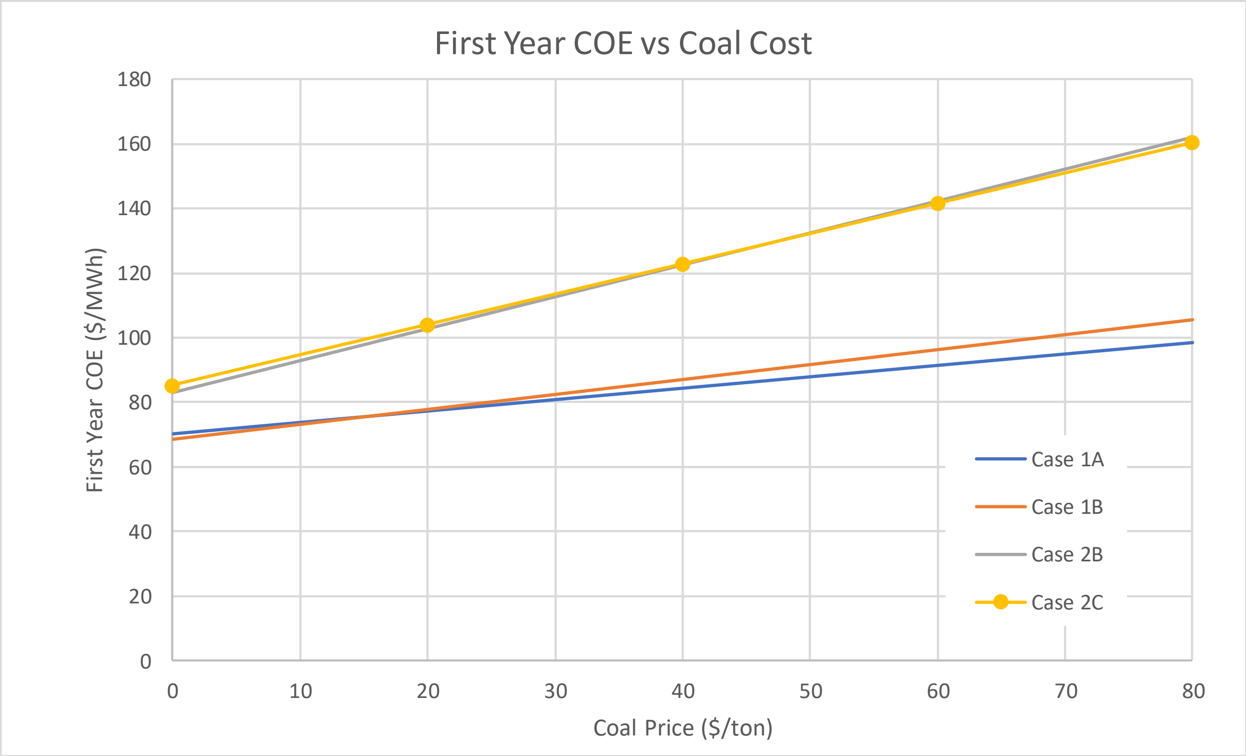


Exhibit 2-20. First Year COE vs TPC Sensitivity

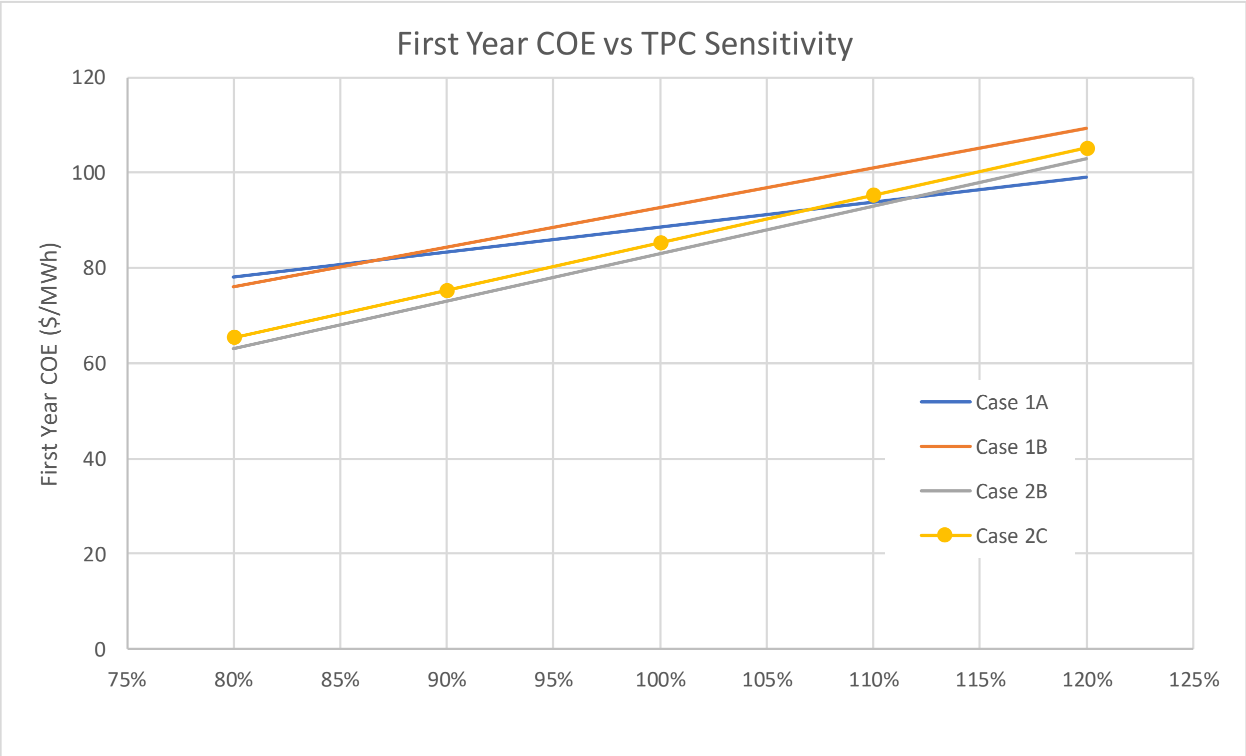


Exhibit 2-21. First Year COE vs Capacity Factor Sensitivity

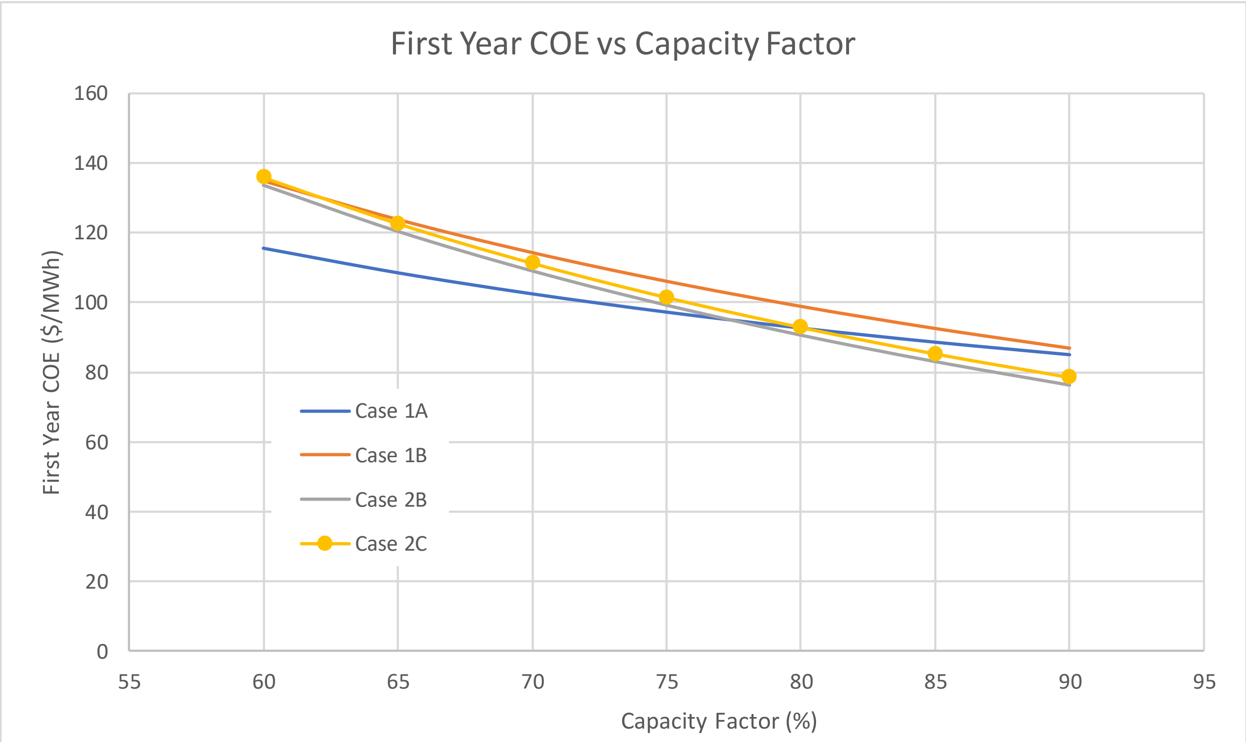
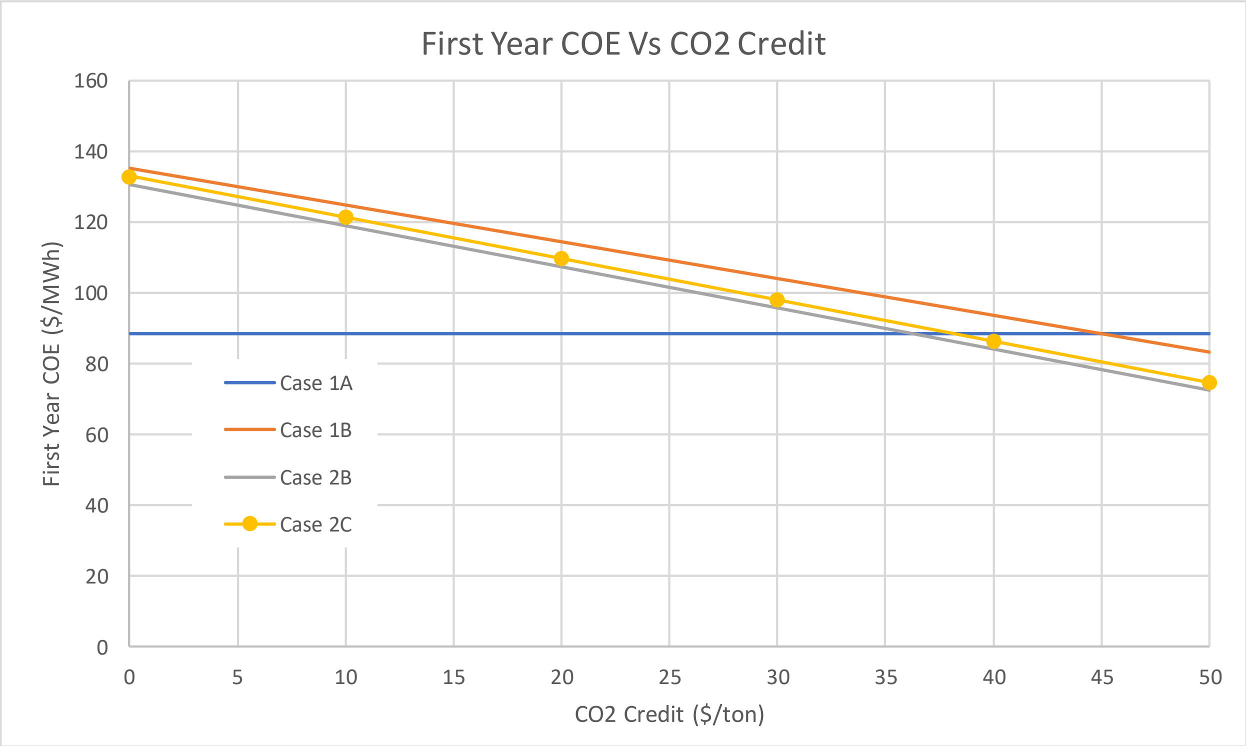


Exhibit 2-22. First Year COE vs CO_2 Credit Sensitivity



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