Pulverized Coal Oxycombustion Power Plants

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Disclaimer

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TABLE OF CONTENTS

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LIST OF ACRONYMS AND ABBREVIATION

AACE	American Association of Cost Engineering
acfm	Actual cubic feet per minute
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASU	Air separation unit
BACT	Best available control technology
BEC	Bare Erected Cost
BFW	Boiler Feed Water
Btu	British thermal unit
CAA	Clean Air Act
CCT	Clean coal technology
CDR	Carbon Dioxide Recovery
CF	Capacity factor
CFB	Circulating Fluidized Bed
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
CGE	Cold gas efficiency
CMB	Circulating Moving Bed
CO_2	Carbon dioxide
COE	Cost of electricity
CRT	Cathode ray tube
CS	Carbon steel
CWT	Cold water temperature
dB	Decibel
DCC	Direct Contact Cooler
DCS	Distributed control system
DOE	Department of Energy
DRB	Dual Register Burner
EDI	Electrodeionization
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
EPC	Engineering, Procurement and Construction
EPCC	Engineering, Procurement and Construction Capital
EPRI	Electric Power Research Institute
ESP	Electrostatic precipitator
ETA	Effective thermal efficiency
EU	European Union
FBHE	Fluidized-bed heat exchanger
FCR	Fixed Charge Rate
FD	Forced draft
FERC	Federal Energy Regulatory Commission
FGD	Flue gas desulfurization
FGR	Flue Gas Recirculation
FOAK	First of a kind
fpm	feet per minute

FRP	Fiberglass-reinforced plastic
GAN	Gaseous Nitrogen
GHG	Greenhouse Gas
GOX	Gaseous Oxygen
gpm	Gallons per minute
GJ	Gigajoule
h, hr	Hour
H_2	Hydrogen
HAP	Hazardous air pollutant
HCl	Hydrochloric acid
HDPE	High density polyethylene
HHV	Higher heating value
hp	Horsepower
HP	High pressure
HRSG	Heat Recovery Steam Generator
HSS	Heat stable salts
HVAC	Heating, ventilating, and air conditioning
HWT	Hot water temperature
Hz	Hertz
IEA	International Energy Agency
in. H_2O	Inches water
in. Hga	Inches mercury (absolute pressure)
in. W.C.	Inches water column
ID	Induced draft
IEEE	Institute of Electrical and Electronics Engineers
IGCC	Integrated gasification combined cycle
IP	Intermediate pressure
IPP	Independent power producer
ISO	International Standards Organization
ITM	Ion Transport Membrane
kPa	Kilopascal absolute
kV	Kilovolt
kW	Kilowatt
kWe	Kilowatts electric
kWh	Kilowatt-hour
kWt	Kilowatts thermal
LAER	Lowest achievable emission rate
LASH	Limestone ash
lb	Pound
lbm	Pound mass
LCOE	Levelized cost of electricity
LHV	Lower heating value
LP	Low pressure
LNB	Low NOx burner
MAC	Main Air Compressor
MAF	Moisture and Ash Free

MCR	Maximum coal burning rate
md	milli-darcy (a measure of permeability)
MEA	Monoethanolamine
MHz	Megahertz
MMBtu	Million British thermal units (also shown as 10^6 Btu)
MMBtu/h	Million British thermal units per hour (also shown as 10^6 Btu/hr)
MPa	Megapascals absolute
MVA	Mega Volt Amp
MW	Molecular weight
MWe	Megawatt electric
MWh	Megawatt-hour
MWt	Megawatt thermal
NETL	National Energy Technology Laboratory
N/A	Not applicable
NAAQS	National Ambient Air Quality Standards
NFPA	National Fire Protection Association
Nm^3	Normal Cubic meter
Nm^3/d	Normal Cubic meter per day
NOx	Oxides of nitrogen
NPSH	Net Positive Suction Head
NSPS	New Source Performance Standards
NSR	New source review
O&M	Operations and maintenance
OD	Outside diameter
OFA	Overfire air
OFO	Overfire Oxygen
OP/VWO	Over pressure/valve wide open
OSHA	Occupational Safety and Health Administration
OTR	Ozone transport region
PA	Primary air
PC	Pulverized coal
PM	Particulate matter
POTW	Publicly owned treatment works
pph	Pounds per hour
ppmvd	Parts per million by volume, dry
PRB	Powder River Basin
PSA	Pressure Swing Adsorption
PSD	Prevention of Significant Deterioration
psia	Pounds per square inch absolute
psid	Pounds per square inch differential
psig	Pounds per square inch gage
RDS	Research and Development Solutions, LLC
rpm	Revolutions per minute
RO	Reverse Osmosis
SC	Supercritical
SCFD	Standard cubic feet per day

scfm	Standard cubic feet per minute
scmh	Standard cubic meter per hour
SCR	Selective catalytic reduction
SIP	State implementation plan
SNCR	Selective non-catalytic reduction
SO_2	Sulfur dioxide
SS	Stainless steel
ST	Steam Turbine
STG	Steam Turbine Generator
TAG	Technical Assessment Guide
TBtu	Trillion (Tera) Btu (10^{12} Btu)
TCR	Total capital requirement
TWh	Trillion (Tera) Watt hour (10^6 MWh)
TPC	Total plant cost
tpd	Tons per day
tph	Tons per hour
TPI	Total plant investment
TPY	Tons per year
ton	2000 pounds
tonne	1000 kg
TSA	temperature swing adsorption
TS&M	Transport, Storage, and Monitoring
USC	Ultra-Supercritical
V-L	Vapor and liquid portion of stream (excluding solids)
WB	Wet bulb
WG	Water gauge
Wt%	Weight percent

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EXECUTIVE SUMMARY

BACKGROUND

As it becomes increasingly likely that future CO_2 emissions will be regulated in some fashion, new processes are being developed to capture CO_2 from the flue gas of fossil fuel-fired power plants. The most studied approach for capturing CO_2 from a conventional pulverized coal-fired boiler is the use of an amine-based solution to absorb CO_2 from the flue gas stream, and its subsequent regeneration of the rich solution to produce a nearly pure product stream. An alternative method to capture CO_2 is to use oxygen rather than air as the oxidant in the combustion process which would yield a flue gas stream comprised primarily of CO_2 and H_2O. By removing the water, a nearly pure CO_2 stream can be produced. This approach, known as oxyfuel or oxycombustion, is the subject of this systems analysis study.

The objective of this report was to establish a cost and performance baseline for the oxycombustion process that can be used as a basis for comparison with past and future studies.

This study consists of twelve plant configurations. In each case, heat and material balances were generated using Aspen Plus, major equipment specifications were developed and capital and operating cost estimates were completed. In all cases, coal feed rate (Illinois No. 6 bituminous coal) was adjusted as necessary to maintain a nominal net plant output of 550 MW.

The work was a collaborative effort with technical and cost information on the oxycombustion boiler provided by Babcock & Wilcox and on the cryogenic distillation process and CO_2 purification and compression process by Air Liquide. The balance of plant costs and cost rollup were done by Research and Development Solutions LLC (RDS), and technical guidance was provided by the Department of Energy's National Energy Technology Laboratory (NETL). In each case a 20-year levelized COE was calculated and is the figure of merit.

The twelve cases examined include four conventional air-based combustion cases for reference (with and without CO_2 control), six oxycombustion cases with O_2 provided by a cryogenic distillation process and two oxycombustion cases with O_2 provided by an ion transport membrane (ITM) process. Both supercritical (SC) 240 bar/600°C/620°C (3,500 psi/1,110°F/1,150°F) and ultra-supercritical (USC) steam cycles 275 bar/730°C/760°C (4000 psi/1350°F/1400°F) were analyzed (see section 2.7 for a discussion of steam conditions). Different levels of oxygen purity and CO_2 purity were also considered. The twelve cases are summarized in Exhibit ES-1.

Among the cryogenic oxygen cases, two levels of oxygen purity are modeled which result in two levels of CO_2 purity. The raw CO_2 can then be further treated, resulting in four options for final CO_2 purity as follows:

- Specification A: Raw product produced using 95% oxygen and dehydrated to 0.015% (by volume) H_2O

- Specification B: Raw product produced using 99% oxygen and dehydrated to 0.015% (by volume) H_2O
- Specification B*: Raw product produced using 95% oxygen and further treated to meet the purity levels of Specification B.
- Specification C: Raw product produced using 95% oxygen, further purified to 0.015% (by volume) H_2O and > 95% CO_2.

Exhibit ES-1 Case Descriptions

Case[2]	Boiler	Steam [3] psig/°F/°F	Oxidant	NOx Control	CO_2 Purity	Intended Storage
1	Wall-fired, PC	3500/1110/1150	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	N/A	N/A
2	Wall-fired PC	4000/1350/1400	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	N/A	N/A
3	Wall-fired [1] PC	3500/1110/1150	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	~100%	Saline Formation
4	Wall-fired [1] PC	4000/1350/1400	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	~100%	
5	Wall-fired PC, FGR	3500/1110/1150	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	Spec. A	
5A	Wall-fired PC, FGR	3500/1110/1150	99 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	Spec. B	
5B	Wall-fired PC, FGR	3500/1110/1150	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	Spec. B*	
5C	Wall-fired PC, FGR	3500/1110/1150	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	Spec. C	
6	Wall-fired PC, FGR	4000/1350/1400	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	Spec. A	
6A	Wall-fired PC, FGR	4000/1350/1400	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	Spec. C	
7	Wall-fired PC, FGR	3500/1110/1150	~100 mol% O_2/ ITM ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	Spec. B	
7A	Wall-fired PC, FGR	3500/1110/1150	~100 mol% O_2/ ITM ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	Spec. C	

[1] Fluor Econamine FG Plus scrubbing for CO_2 capture
[2] Sulfur control with FGD in all cases to 0.1 lb/10^6Btu
[3] The boundary between subcritical and supercritical is well defined because of the critical point of water (3,208 psia and 705°F). The USC boiler conditions in this study (4000psi/1350°F/1400°F) are considered advanced/next generation chosen to be consistent with industry consortiums for advanced material development, including the U.S. Ultra-Supercritical Materials Consortium, to allow for these conditions. (See section 2.7 later in this report) A listing of recent 600°C power plants commissioned by 2002 showed the most aggressive steam conditions to be 4,060 psig/1,121°F/1,135°F for the petroleum coke fired 600 MW Isogo 1 unit in Yogohama, Japan. Source: Bugge et al., "High Efficiency Coal-fired Power Plant Developments and Perspectives," The International Journal of Energy, ISSN: 0360-5442, Volume 31, 2006.

PERFORMANCE

Gross Output

The performance results are presented in Exhibit ES-2 and Exhibit ES-3. Note that the perturbation cases (5A, 5B, 5C, 6A, and 7A) are not significantly different from the respective base cases and are not shown in many of the exhibits that follow. Each case was scaled to maintain a nominal 550 MW net plant output. The gross plant outputs vary from a minimum of 583 MW for the ultra-supercritical, non-CO_2 capture configuration (case 2) to 921 MW for the oxycombustion case with the ITM air separation unit (ASU).

Addition of CO_2 capture to fossil-based power systems results in a substantial auxiliary power load in both conventional air-based amine CO_2 capture cases as well as in oxycombustion cases.

The air-based capture systems (cases 3 and 4) utilize the Fluor Econamine Plus system for CO_2 capture. The Econamine system has significant auxiliary requirements (electricity, steam, and cooling water) necessitating significant increases in gross electrical power output and main steam supply (for both electric power production and amine regeneration) over the equivalent non-CO_2 capture systems (cases 1 and 2). Additionally, the CO_2 compression process creates a significant auxiliary load.

Cases 5 and 6 require significant auxiliary power for the cryogenic ASU, 129 and 118 MW respectively. Additionally, the CO_2 compression costs for cases 5 and 6 are higher than for 3 and 4 because cases 5 and 6 are co-sequestration cases resulting in higher CO_2 removal and a larger relative volume of sequestration gas.

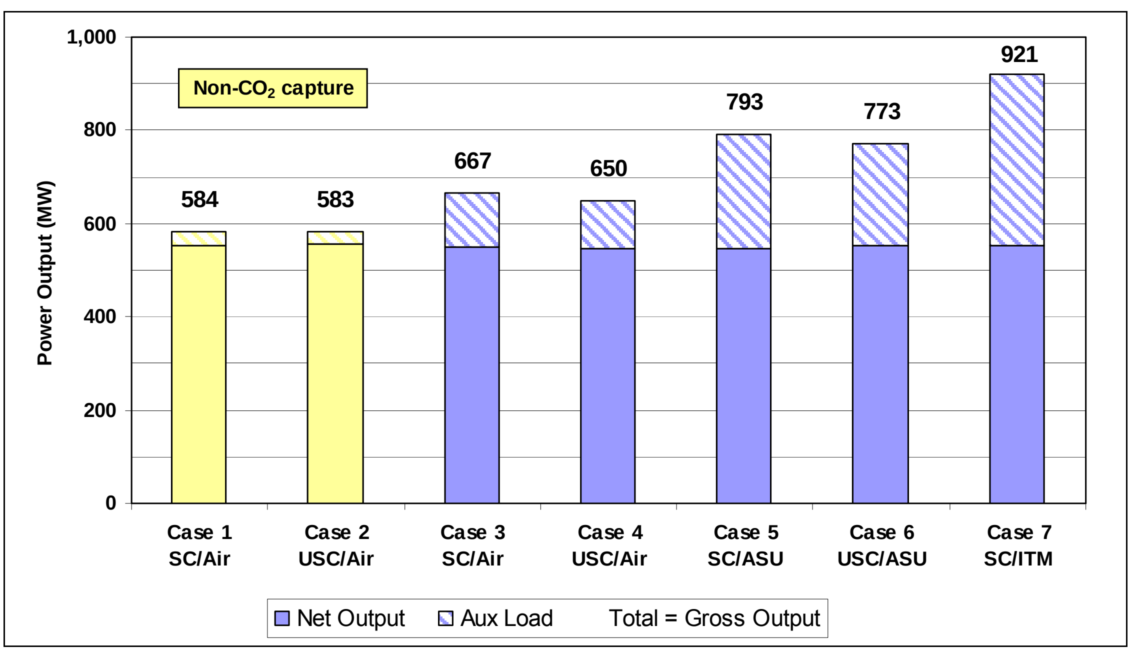
Case 7 is unique with the addition of a warm gas expander to recover a significant quantity (207 MW) of the energy required to operate the ITM. This helps offset a portion of the auxiliary load.

Exhibit ES-2 Performance Summary

		Air-Fired				Oxygen-Fired		
		No Capture		CO_2 Capture		Cryogenic		ITM
		Case 1 SC / Air	Case 2 USC / Air	Case 3 SC / Air	Case 4 USC / Air	Case 5 SC / ASU	Case 6 USC / ASU	Case 7 SC /ITM
Output and Efficiency								
Main Steam Flow	(lbm/hr)	3,581,311	3,100,955	5,113,170	4,217,953	4,968,298	4,193,226	4,419,240
Turbine Heat Rate	(Btu/kWh)	7,604	6,726	10,945	9,282	10,696	9,093	9,427
ITM System Expander	(kW)							206,970
Steam Turbine Generator	(kW)	583,812	582,651	666,626	650,030	792,512	772,611	713,600
Gross Output	(kW)	583,812	582,651	666,626	650,030	792,512	772,611	920,570
Auxiliary Power Summary								
Econamine FG+	(kW)			21,430	18,830			
Air Separation Unit	(kW)					130,270	119,740	268,970
CO_2 Compression	(kW)			47,150	44,192	78,560	67,000	64,950
Base Plant Power	(kW)	30,010	26,770	49,300	41,956	37,490	32,500	34,290
Total Auxiliary Power	(kW)	30,010	26,770	117,880	104,979	246,320	219,240	368,210
Net Plant Output	(kW)	553,802	555,881	548,746	545,051	546,192	553,371	552,360
Boiler Efficiency (HHV)[1]	(fraction)	0.879	0.879	0.873	0.873	0.886	0.880	0.893
Coal Feed Rate	(lbm/hr)	410,563	364,547	589,747	496,764	565,295	490,158	500,000
Coal Heat Input (HHV)	(10^6 Btu/hr)	4,790	4,253	6,880	5,795	6,595	5,718	5,833
Natural Gas Flow	(lbm/hr)							38,831
Natural Gas Heat Input (HHV)[2]	(10^6 Btu/hr)							885
Total Fuel Heat Input (HHV)	(10^6 Btu/hr)	4,790	4,253	6,880	5,795	6,595	5,718	6,718
Net Plant Heat Rate (HHV)	(Btu/kWh)	8,649	7,651	12,538	10,632	12,074	10,333	12,162
Net Plant Thermal Efficiency (HHV)	(%)	39.5	44.6	27.2	32.1	28.3	33.0	28.1
Energy Penalty[3]	(% Net Points	-	-5.1	12.2	7.4	11.2	6.4	11.4

[1]Boiler Heat Input/(Qcoal-HHV + Qcredits)
[2]Required for ITM Cases
[3]Percentage points decrease in efficiency due to CO_2 capture relative to Case 1

Exhibit ES-3 Power Output Summary



Energy Efficiency

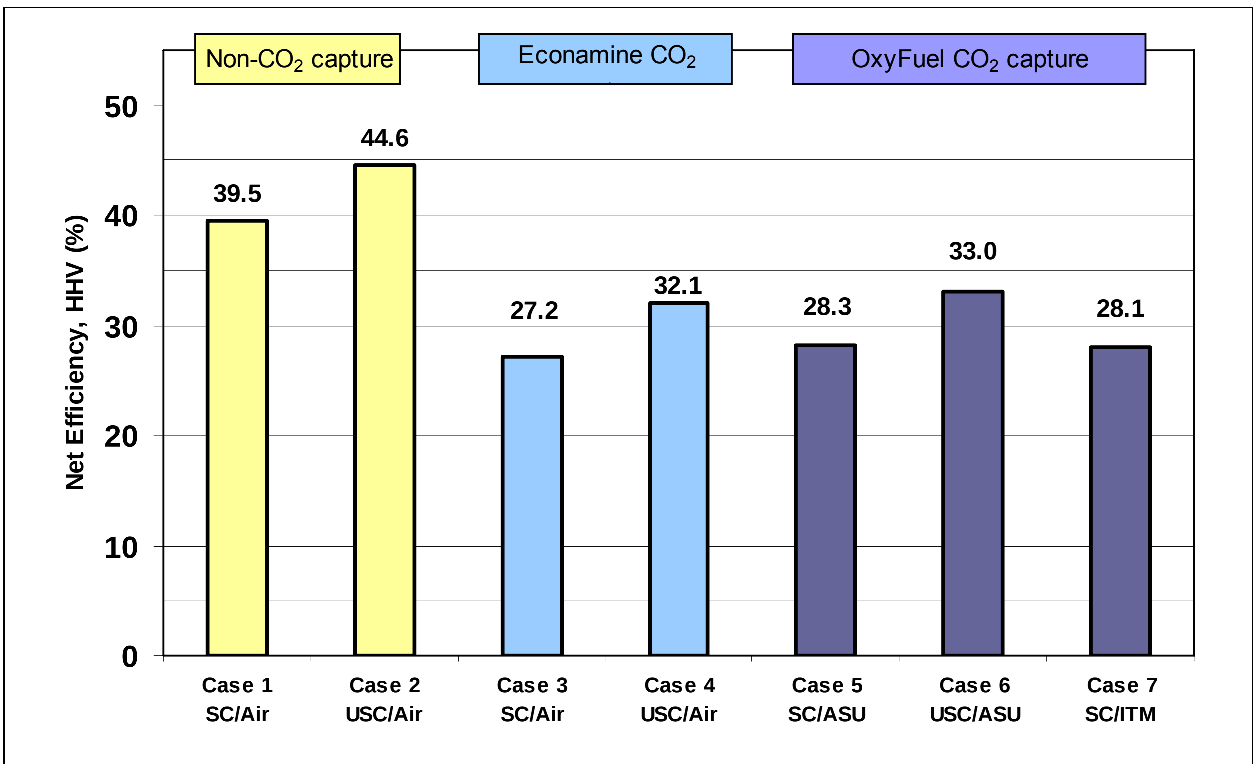
Plant efficiencies are shown in Exhibit ES-4. Case 1 (air-fired supercritical (SC) PC without CO_2 capture) is the reference case to which the others are compared. Case 1 is a commercially available plant configuration. Case 2 with USC steam conditions and no CO_2 capture has a 5.1 percentage point higher efficiency. Case 2 steam conditions are significantly more aggressive than commercially available. These conditions (4000psi/1350°F/1400°F) are considered advanced/next generation and were chosen to be consistent with the goals of an industry consortium for advanced material development (see section 2.7 later in this report).

Adding CO_2 capture using Econamine (cases 3 and 4) results in similar decreases in efficiency (approximately 12 percentage points) compared to the equivalent non-CO_2 capture cases.

Cases 5 and 6 using oxycombustion with a cryogenic ASU for SC and USC steam conditions result in efficiencies approximately 1 percentage point higher than an Econamine based system with the same steam conditions. While the auxiliary load for oxycombustion cases is greater than the Econamine system cases (refer to Exhibit ES-2), the total steam requirement for the Econamine based systems is actually greater because of the large steam demand to regenerate the amine.

Case 7 with SC steam conditions and ITM ASU has an efficiency that is essentially the same as the comparable system with a cryogenic ASU (case 5).

Exhibit ES-4 Plant Efficiency



COST RESULTS

Total Plant Cost

The total plant costs (TPC's) including equipment, materials, construction labor, home office expenses, process contingencies and project contingencies for the seven power plant configurations are shown in Exhibit ES-5 and Exhibit ES-6. The boundary limits for the CO_2 capture cases include compression to 2,200 psia. Transport, storage and monitoring (TS&M) costs are not included in the TPC, but are included in the LCOE calculation as discussed below. All costs are in January 2007 dollars and are for "greenfield" construction located at a generic site in the midwestern U.S.

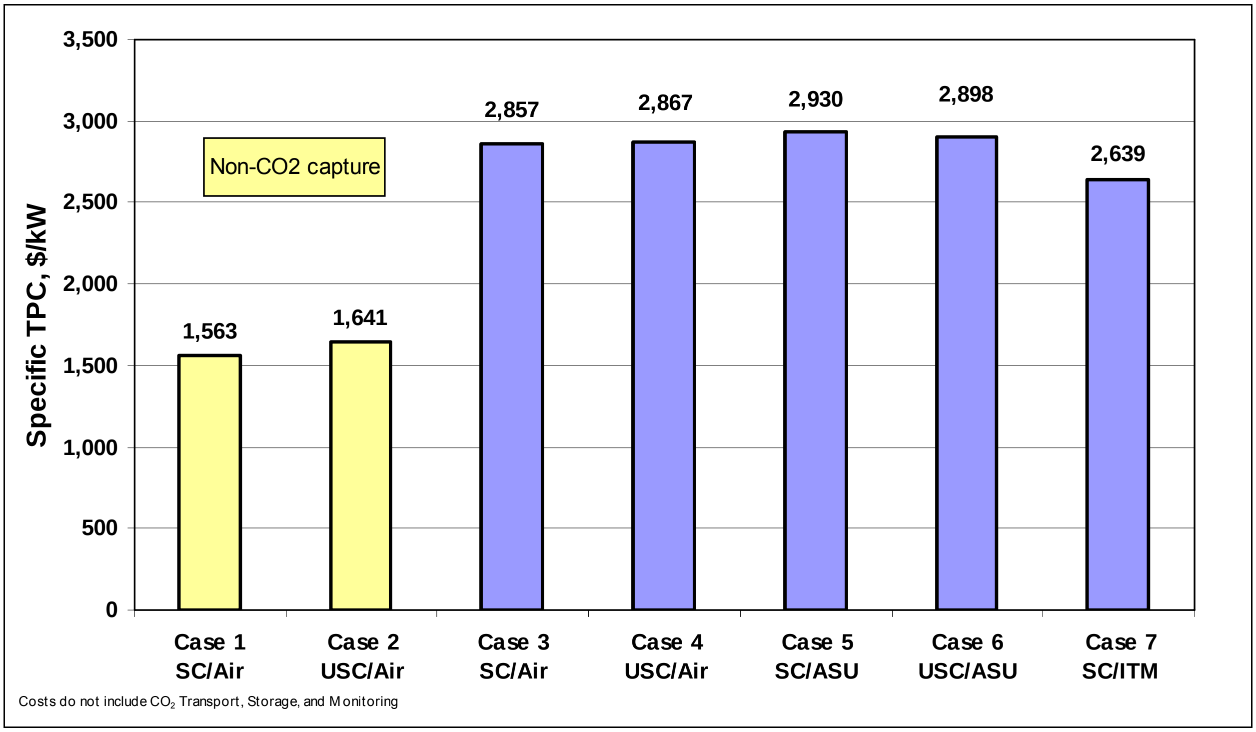
The TPC of a USC PC plant without CO_2 capture (case 2) is $78/kW more than a similar SC PC plant (case 1). When contingencies are removed, the difference is reduced to $25/kW. Higher contingencies are applied to the USC plant because it has not been demonstrated.

The incremental plant cost to include CO_2 capture is greater for the SC steam conditions compared to the USC steam conditions. For example, adding a cryogenic oxycombustion system to a SC PC plant (compare case 1 to case 5) increases the plant cost by $1,367/kW while adding the same technology to an USC PC plant (compare case 2 to case 6) increases the plant cost by $1,257/kW. This is because the higher efficiency of the USC plant results in less baseline CO_2 emissions and therefore less CO_2 to capture.

Exhibit ES-5 Plant Costs

Study Case	Net Plant Output	Total Plant Cost (Including Contingencies)		Total Plant Cost (Excluding Contingencies)	
	kW	1000$	$/kW	1000$	$/kW
Case 1, Air-fired SC w/o CO_2 Capture	553,802	865,818	1,563	773,425	1,397
Case 2, Air-fired USC w/o CO_2 Capture	555,881	912,193	1,641	790,209	1,422
Case 3, Air-fired SC w/Econamine CO_2 Capture	548,746	1,567,622	2,857	1,318,737	2,403
Case 4, Air-fired USC w/Econamine CO_2 Capture	545,051	1,562,511	2,867	1,292,006	2,370
Case 5, O_2-fired SC w/ASU & CO_2 Capture	546,192	1,600,097	2,930	1,381,727	2,530
Case 6, O_2-fired USC w/ASU & CO_2 Capture	553,371	1,603,497	2,898	1,354,040	2,447
Case 7, O_2-fired SC w/ITM & CO_2 Capture	553,360	1,457,596	2,639	1,258,244	2,278

Exhibit ES-6 Total Plant Cost (including contingencies)



Levelized Cost of Electricity (LCOE)

LCOE is calculated for a levelization period of 20 years using the equation:

$$LCOE_P = \frac{(CCF_P)(TPC) + [(LF_{F1})(OC_{F1}) + (LF_{F2})(OC_{F2}) + \ldots] + (CF)[(LF_{V1})(OC_{V1}) + (LF_{V2})(OC_{V2}) + \ldots]}{(CF)(kWh)}$$

where:

$LCOE_P$ =	levelized cost of electricity over P years
P =	levelization period (e.g., 10, 20 or 30 years)
CCF =	capital charge factor for a levelization period of P years
TPC =	total plant cost
LF_{Fn} =	levelization factor for category n fixed operating cost
OC_{Fn} =	category n fixed operating cost for the initial year of operation (but expressed in “first-year-of-construction” year dollars)
CF =	plant capacity factor
LF_{Vn} =	levelization factor for category n variable operating cost
OC_{Vn} =	category n variable operating cost at 100 percent capacity factor for the initial year of operation (but expressed in “first-year-of-construction” year dollars)
kWh =	annual net kilowatt-hours of power generated at 100 percent capacity factor

Values used for the variables in this equation are found in the body of the report.

The LCOE's are shown in Exhibit ES-7 (excluding TS&M costs) and Exhibit ES-9 including a breakdown between capital, fixed operating and maintenance (O&M), variable O&M, and fuel costs.

The LCOE for case 2 is slightly higher than case 1 even though the fuel and variable O&M costs are lower. This is because of the higher capital cost.

The LCOE for USC CO_2 capture cases 4 and 6 are lower than their SC counterparts, cases 3 and 5, by approximately 0.5 ¢/kWh. The cryogenic oxygen cases have the lowest LCOE of CO_2 capture cases for similar steam conditions (compare case 5 to cases 3 and 7, and case 4 to case 6).

The LCOE for the ITM case (case 7) is insignificantly higher than the SC Econamine based system (case 3). The ITM ASU cost is assumed to be 30% less than a conventional cryogenic ASU, because this is the goal of the ITM development program. The fuel cost for case 7 (32% of LCOE) is the highest of any case studied because of the natural gas used in the ITM ASU case.

Exhibit ES-7 Levelized Cost of Electricity for Power Plants

Study Case	**Levelized Cost of Electricity (¢/kWh)**					**Incremental COE[a] (¢/kWh)**	**Increase COE[a] (%)[a]**
	Capital	Fixed O&M	Variable O&M	Fuel	**Total**		
Case 1, Air-fired SC w/o CO_2 Capture	3.44	0.38	0.58	1.89	6.29	-	-
Case 2, Air-fired USC w/o CO_2 Capture	3.86	0.39	0.55	1.66	6.45	0.16	2.5
Case 3, Air-fired SC w/Econamine CO_2 Capture	6.71	0.56	1.05	2.72	11.04	4.75	75.5
Case 4, Air-fired USC w/Econamine CO_2 Capture	6.74	0.56	1.00	2.31	10.60	4.31	68.4
Case 5, O_2-fired SC w/ASU & CO_2 Capture	6.89	0.56	0.84	2.62	10.90	4.61	73.3
Case 6, O_2-fired USC w/ASU & CO_2 Capture	6.81	0.55	0.77	2.24	10.37	4.08	64.8
Case 7, O_2-fired SC w/ITM & CO_2 Capture	6.20	0.53	0.75	3.59	11.07	4.78	75.9

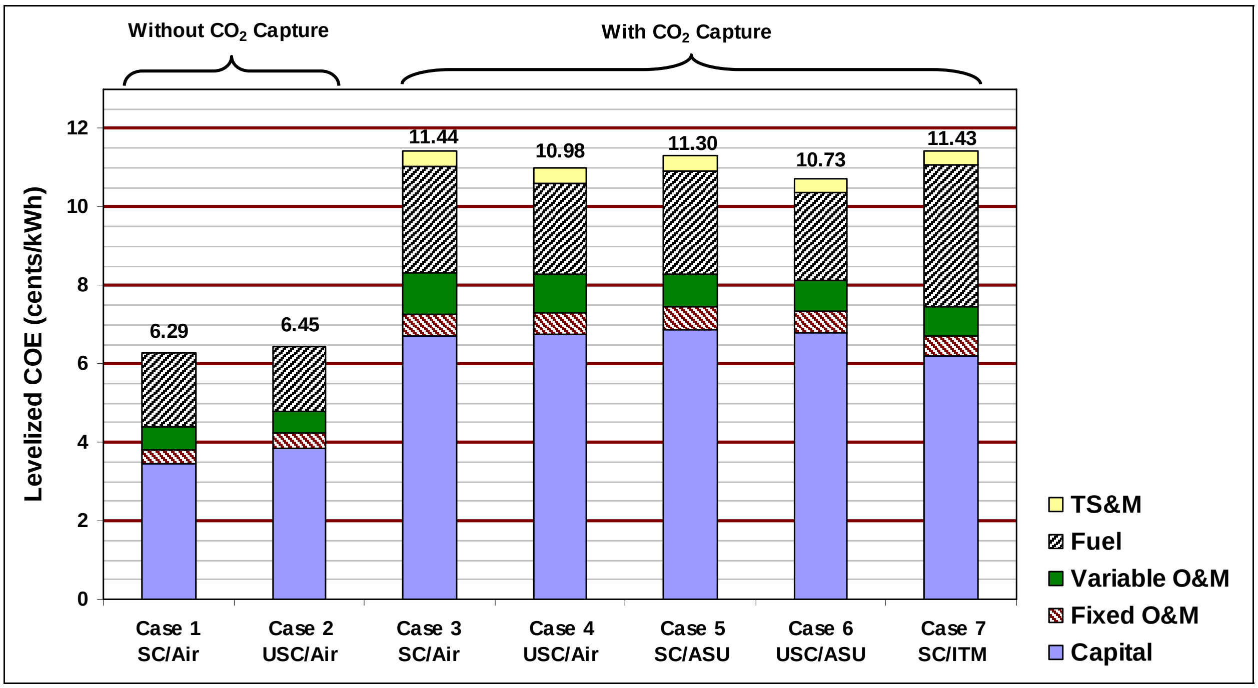
[a] Relative to Case 1 ("Base Case")

The additional cost for CO_2 transport, storage and monitoring (TS&M) in the cases with carbon capture were estimated based on reference data and scaled estimates. The TS&M costs assume the CO_2 is transported 50 miles via pipeline to a geologic sequestration field, injected into a saline formation at a depth of 4,055 ft and monitored for 80 years. These values are shown in Exhibit ES-8. The Total Levelized Costs of Electricity including TS&M are shown in Exhibit ES-9.

Exhibit ES-8 Levelized Cost of Electricity for CO_2 Transport, Storage, and Monitoring

Study Case	20 yr Levelized Costs (¢/kWh)				
	CO_2 Transport	CO_2 Storage	CO_2 Monitoring	LCOE w/o TS&M	**Total LCOE**
Case 3, Air-fired SC w/Econamine CO_2 Capture	0.26	0.04	0.10	11.04	11.44
Case 4, Air-fired USC w/Econamine CO_2 Capture	0.26	0.04	0.08	10.60	10.98
Case 5, O_2-fired SC w/ASU & CO_2 Capture	0.26	0.04	0.10	10.90	11.30
Case 6, O_2-fired USC w/ASU & CO_2 Capture	0.24	0.04	0.08	10.37	10.73
Case 7, O_2-fired SC w/ITM & CO_2 Capture	0.24	0.04	0.08	11.07	11.43

Exhibit ES-9 Levelized Cost of Electricity including CO_2 Transport, Storage, and Monitoring



Cost of CO_2 Removed/Avoided

CO_2 removal costs are calculated using the equation:

$$Removal\ Cost\ \ [\$/ton] = \frac{(LCOE_{with\ removal} - LCOE_{w/o\ removal})\ [\$/MWh]}{CO_2\ \ removed\ [tons/MWh]}$$

CO_2 avoided costs are calculated using the equation:

$$Avoided\ Cost\ [\$/ton] = \frac{(LCOE_{with\ removal} - LCOE_{w/o\ removal})\ [\$/MWh]}{(Emissions_{w/o\ removal} - Emission_{with\ removal})\ [tons/MWh]}$$

Exhibit ES-10 shows the costs for all cases on a \$/ton CO_2 captured and \$/ton CO_2 avoided basis.

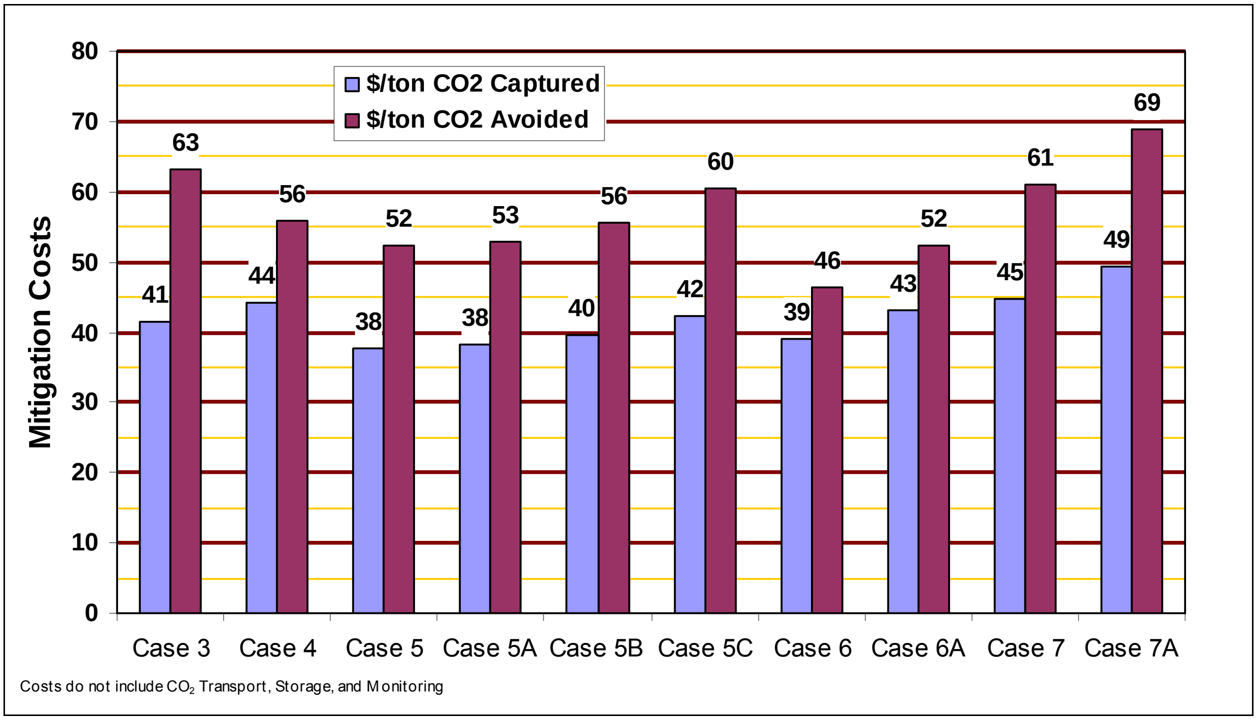
Comparing the SC cases (3, 5, 5A, 5B, 5C, 7, and 7A), it is seen that the cryogenic oxycombustion case 5 has the lowest cost of CO_2 captured and avoided. Case 5A with the higher purity oxygen (99%) has slightly higher costs of CO_2 captured and avoided than case 5.

Comparing cases 5A and 5B, it is clear that if a higher purity CO_2 product is required, the more cost effective approach is to use a higher purity oxygen supply rather than to add a purification process for the CO_2 stream.

Comparing the USC cases (4, 6, and 6A) it is seen that the cost of CO_2 captured and avoided is lower for the oxycombustion cases than for the amine based capture system (case 4).

Comparing cases 5 and 6, it is seen that the cost of CO_2 captured is similar for the SC and USC oxycombustion cases; however the higher efficiency of the USC case results in a lower cost of CO_2 avoided.

Exhibit ES-10 CO_2 Mitigation Costs



ENVIRONMENTAL PERFORMANCE

CO_2 Emissions

The CO_2 capture efficiency design basis for each of the Econamine FG Plus scrubbing cases was set to 90%. Oxycombustion combustion has the opportunity to approach 100% CO_2 capture efficiency. CO_2 production and emissions are tabulated in Exhibit ES-11. Removal efficiencies are shown in Exhibit ES-12**.**

CO_2 capture efficiency is calculated as the quantity of CO_2 captured divided by the quantity of CO_2 produced. Most of the CO_2 produced comes from coal combustion, but a small amount is formed in the flue gas desulfurization (FGD) system. The sum of these two sources is the amount produced.

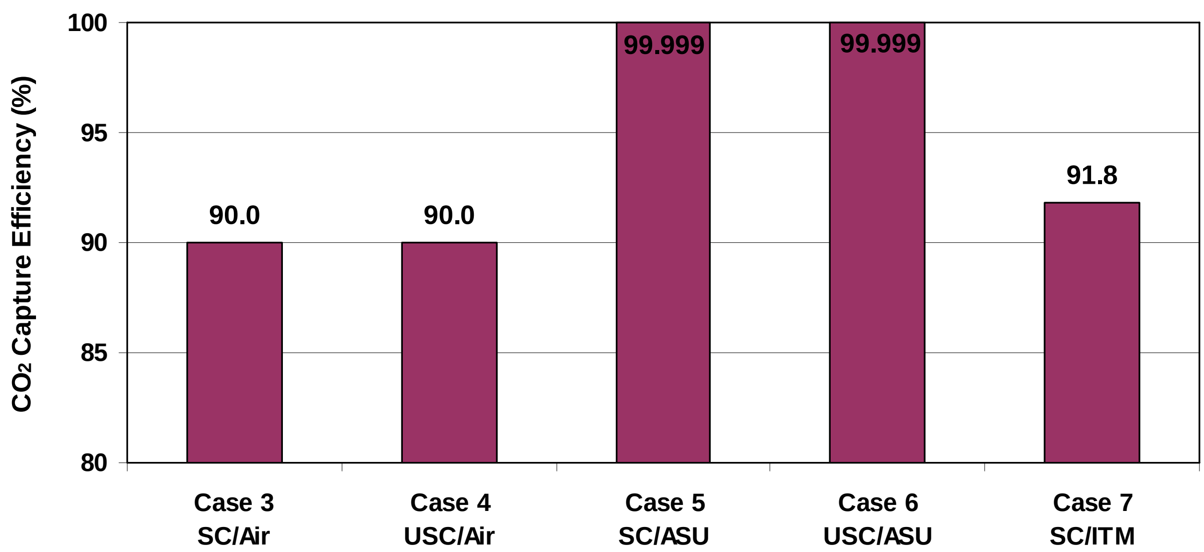
The CO_2 capture efficiency is slightly less than 100% for the cryogenic oxycombustion cases because a small amount of CO_2 is emitted from the CO_2 drying process. The CO_2 capture efficiency is significantly less than 100% for the ITM oxycombustion case because the natural gas fired heater for the ITM has uncontrolled CO_2 emissions.

Exhibit ES-11 CO_2 Emissions

CO_2 Emissions		Air-Fired				Oxygen-Fired		
		No Capture		CO_2 Capture		Cryogenic		ITM
		Case 1 SC	Case 2 USC	Case 3 SC	Case 4 USC	Case 5 SC	Case 6 USC	Case 7 SC
CO_2 Produced	(lbm/h)	973,896	864,812	1,398,563	1,178,242	1,332,902	1,155,546	1,283,134
CO_2 Captured	(lbm/h)	n/a	n/a	1,259,110	1,060,755	1,332,902	1,155,546	1,177,797
CO_2 Capture Efficiency	(%)	n/a	n/a	90.0	90.0	100.000	100.000	91.8
CO_2 Emitted	(lbm/h)	973,896	864,812	139,453	117,486	0	0	105,336
Specific CO_2 Emissions	(lbm/kWh_{net})	1.759	1.556	0.254	0.216	0.000	0.000	0.191
Avoided CO_2 Emissions[1]	(lbm/kWh_{net})	n/a	0.203	1.504	1.543	1.759	1.759	1.568

[1]Relative to Case 1 ("Base Case")

Exhibit ES-12 CO_2 Capture Efficiency



Non-CO_2 Emissions

All twelve cases in this study were designed to meet Best Available Control Technology (BACT) emission limits. The control technologies used are:

- Wet limestone FGD (98% efficient) for SO_2 control. In the air-based cases with CO_2 capture, an SO_2 polishing step reduces the concentration to 10 ppmv and the balance is removed by the amine solution resulting in negligible emissions.
- Low NOx burners (LNBs), overfire air (OFA) and selective catalytic reduction in the air-fired cases and LNBs, overfire oxygen (OFO) and flue gas recirculation (FGR) in

the oxycombustion cases for NOx control. It was assumed that the combination of technologies could achieve 0.07 lb/MMBtu in all cases.

- Fabric filter (99.8% efficient) for particulate control
- Co-benefit capture of mercury (90% efficient) in the fabric filter and FGD units.

The oxycombustion cases with no CO_2 purification have a single gas phase emission point. The flue gas exiting the FGD unit is either recycled to the boiler or sent to the CO_2 drying and compression system. A temperature swing adsorption unit removes water, but remaining SO_2, NO_X, O_2, and Ar are co-sequestered with the CO_2. For this study it was assumed that co-sequestration is possible without requiring special materials or equipment. In the no purification co-sequestration cases (5, 5A, 6 and 7) gas phase emissions of all criteria pollutants are zero.

In oxycombustion cases where the CO_2 product is purified in a series of auto-refrigeration flash steps; there is a vent gas that contains SO_2, NOx, particulate, Hg and CO_2. The balance of the stream not vented is co-sequestered with the CO_2. It was assumed that the non-volatile components (particulate and Hg) were split between the vent stream and sequestration stream in the same proportion as the stream flow rates. The emissions for these cases and the air-based cases are summarized in Exhibit ES-13.

Exhibit ES-13 Air Emission Rates from Air-Based and Oxycombustion Cases

Case (Note 1)	SO_2, lb/MMBtu	NOx, lb/MMBtu	Particulate, lb/MMBtu	Hg, lb/MMBtu	CO_2, lb/MMBtu
BACT Limit	0.100	0.070	0.015	90% Capture	N/A
1	0.085	0.070	0.013	1.14×10^{-6}	203
2	0.085	0.070	0.013	1.14×10^{-6}	203
3	Negligible	0.070	0.013	1.14×10^{-6}	20
4	Negligible	0.070	0.013	1.14×10^{-6}	20
5B	0.003	0.070	0.001	0.07×10^{-6}	6
5C	0.008	0.070	0.002	0.15×10^{-6}	12
6A	0.020	0.070	0.002	0.15×10^{-6}	13
7[2]	Negligible	0.001	Negligible	Negligible	16
7A[2]	0.018	0.062	0.002	0.11×10^{-6}	27

1. Negligible emissions for Cases 5, 5A, and 6
2. Cases 7 and 7A include natural gas combustion for ITM

Based on the results of this study, there is only a nominal difference in cost and performance between the various O_2 and CO_2 purity specifications in the oxycombustion cases. In general there is a very small cost penalty to improve the CO_2 purity, but the penalty is insignificant enough that achieving enhanced purity is easily accomplished and inexpensive.

SENSITIVITY CASES

The DOE goal of 90% CO_2 capture with no more than a 20% increase in LCOE was not achieved for the cases analyzed here. Some barriers to achieving the DOE goal were identified and their impact on LCOE was estimated. The following improvements, if they can be realized, would make progress toward achieving the DOE goal. The sensitivity cases evaluated are:

- Case SA = Case 6, w/o FGD
- Case SB = Case 6, w/o FGD and boiler contingency
- Case SC = Case 6, w/o FGD, w/o boiler contingency, and 55% reduction in ASU Total Plant Cost and Operating costs

Case 1 with a LCOE of 6.29 ¢/kWh (refer to Exhibit ES-14) is the reference case. To achieve the DOE goal, electricity would have to be produced at a maximum cost of 7.55 ¢/kWh.

Eliminate FGD – Case SA

If coal sulfur content is less than 1%, the FGD system can be eliminated for the expense of a condensing heat exchanger which must be capable of handling the volume of flue gas and higher acidity condensate. Eliminating the FGD and associated power and limestone costs reduced the cost of electricity from 10.22 cents/kWh (case 6) to 9.34 cents/kWh (case SA).

Eliminate Boiler Contingency – Case SB

A 15% boiler process contingency was included in the capital costs to account for the lack of commercial scale operating experience with an oxycombustion boiler. As the technology is demonstrated, the process contingency can be eliminated. Eliminating the contingency on the boiler (case SB) further reduces the LCOE to 9.11 cents/kWh.

Reduction in Capital and Operating Cost for the ASU – Case SC

An analysis was performed to determine what reduction in ASU capital and variable operating costs would be required to achieve the DOE LCOE target. Exhibit ES-15 shows a graph with the combination of ASU operating and TPC costs that would satisfy the goal. For example, if the TPC was reduced to 50% of a conventional cryogenic ASU then the operating cost would have to be reduced to 38%.

Assuming the ASU capital and operating costs were reduced by the same fraction; both would have to be 45% of current costs. This is case SC resulting in a LCOE of 7.55 cents/kWh as shown on Exhibit ES-14.

Exhibit ES-14 LCOE for Sensitivity Cases

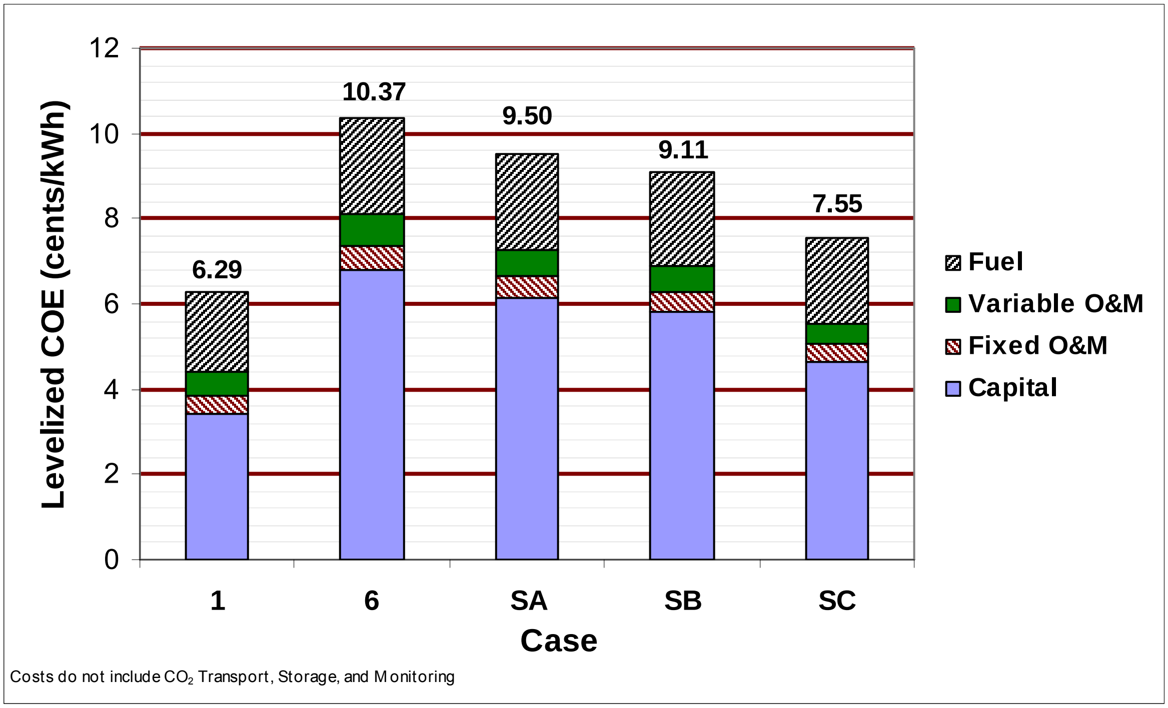
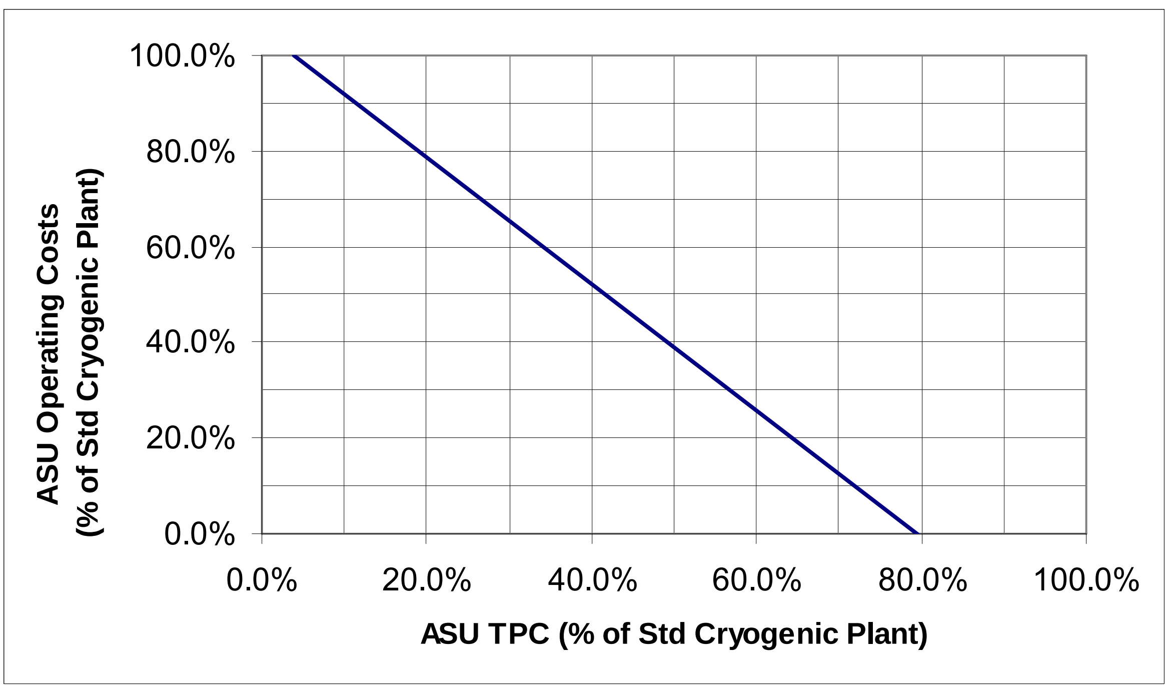


Exhibit ES-15 ASU Capital and Operating Cost Requirements



SUMMARY

- None of the cases analyzed (with the exception of sensitivity case SC) achieves the DOE goal of no more than a 20% increase in LCOE with CO_2 capture.
- Application of current technologies (amine scrubbing) for CO_2 capture results in an increase in LCOE of nearly 80% (comparison of case 3 with case 1 excluding cost of CO_2 transport, storage, and monitoring).
- For the oxycombustion cases studied, the increase in LCOE ranged from a low of 65% for Case 6 to a high of 76% for Case 7 (excluding cost of CO_2 transport, storage, and monitoring).
- Cryogenic oxycombustion has a higher net thermal efficiency (approximately 1%) and a lower LCOE (approximately 0.2 cents/kWh) than an air-fired amine based system for similar steam conditions.
- Cases 5 & 6 have the lowest cost of CO_2 removed.
- Case 6 has the lowest cost of CO_2 avoided.
- The incremental cost of CO_2 capture is less for USC steam conditions because of the initially higher net thermal efficiency.
- One scenario to accomplish the DOE goal of no more than a 20% increase in LCOE is an oxycombustion USC PC boiler without FGD, without boiler contingency, and with ASU capital and operating costs that are 45% of the current market costs of cryogenic ASUs.

1. INTRODUCTION

The rising concentration of carbon dioxide (CO_2) in the environment has been widely documented. Levels of CO_2 in the atmosphere have shown a steady rise from approximately 300 ppm in 1940 to more than 370 ppm today [1]. At the same time, various studies have documented noticeable changes in climate during the recent years and model predictions suggest that CO_2 levels play a role in these climate changes [2]. Given the potential implications surrounding global climate change and increasing concentrations of CO_2 in the atmosphere, technology and policy options are being investigated for mitigating carbon dioxide emissions.

Electric power generation represents one of the largest CO_2 contributors in the United States. Electricity consumption is expected to grow and fossil fuels will continue to be the dominant fuel source. Therefore, fossil fuel based power generation can be expected to provide an even greater CO_2 contribution in the future. Coal fuels more than half of this electric power generation capacity and typically produces the cheapest electricity among all fuel sources. Compared to other fossil fuels, coal suffers inherent CO_2 disadvantages. Coal has higher carbon intensity than natural gas and many coal-fired power plants are older and less efficient than comparable natural gas plants. These disadvantages present a major challenge to coal-based power generation.

The U.S. Department of Energy's Carbon Sequestration Program has adopted a goal of developing technology by 2012 capable of capturing and sequestering 90% of the CO_2 produced in a pulverized coal-fired power plant with an increase in the cost of electricity (COE) of no more than 20% over that for a non-capture based plant. This target was set based on a number of factors, most notably the history of costs associated with implementation of technologies for control of other pollutants, namely NOx, SO_2, and PM. Technologies for control of these criteria pollutants are at a mature stage of development and have resulted in a 10 to 20% increase in COE. It is believed that mature carbon capture technology from PC power plants will follow a similar trend and also result in a 20% increase in COE. In addition, recent systems studies have shown that a 20% increase in COE is a good "stretch goal" that has a reasonable probability of being achieved through a combination of technology advances in oxygen production, advanced boiler materials and design, and co-sequestration.

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1 Karl, T.R., Trenberth, K.E. (2003). Modern Global Climate Change, Science, Vol 302, December 5, 2003, pp. 1719-1723

2 Houghton et al. {Eds} (2001). Climate Change 2001: The Scientific Basis, Cambridge University Press.

Recent analyses carried out by ALSTOM Power [3], Air Liquide [4], IEA GHG [5] and the National Energy Technology Laboratory's (NETL's) Office of Systems Analysis and Planning Group have shown that oxycombustion with CO_2 capture is competitive with conventional air-based combustion and amine scrubbing for CO_2 control. In addition, these studies identified potential areas for process improvements that have the potential to significantly decrease CO_2 mitigation costs compared to amine scrubbing and to approach the DOE Carbon Sequestration Program goal. The focus of the ALSTOM study was on new oxyfired circulating fluidized bed (CFB) and circulating moving bed (CMB) units using both cryogenic and Ion Transport Membrane (ITM) oxygen production approaches. Solids (limestone) were used to control combustion temperature (as well as provide sulfur removal), thereby limiting the amount of CO_2 recycle required. The Air Liquide study [4] focused on subcritical oxyfired pulverized coal (PC) power plants via cryogenic oxygen production, and CO_2 recycle was employed for temperature control.

The main objectives of this study are to (1) provide a cost and performance baseline against which previous and future oxycombustion studies can be compared and (2) identify potential barriers to meeting the DOE goal of no more than a 20% increase in the cost of electricity for 90% CO_2 capture.

OXYCOMBUSTION CONCEPT

The objective of pulverized coal oxygen-fired combustion is to combust coal in an enriched oxygen environment by using pure oxygen diluted with recycled flue gas. In this manner, the flue gas is composed of primarily CO_2 and H_2O, so that a concentrated stream of CO_2 is produced by condensing the water in the exhaust stream. An advantage of oxycombustion is that it provides a high potential for a step-change reduction in CO_2 separation and capture costs because virtually all of the exhaust effluents can be captured and sequestered (co-sequestration). Assuming that trace species such as NOx, CO, unburned hydrocarbons, and SOx do not interfere with the sequestration process and are below certain levels, they do not need to be controlled or scrubbed from the power plant exhaust. Enhanced oil recovery (EOR) has demonstrated successful H_2S/CO_2 injection [6], and the question of how a combination of $SOx/NOx/CO_2$ affects compression, transport and sequestration has been investigated to some extent in a recent study completed by the IEA GHG [7].

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3 Greenhouse Gas Emissions Control by Oxygen Firing in Circulating Fluidized Bed Boilers, Pase 1-A Preliminary Systems Evaluation, ALSTOM Power Inc., Windsor, CT, US DOE NETL, Pittsburgh PA, May 2003

4 Advanced Low/Zero Emission Boiler Design and Operation, Task 3 – Techno-Economic Study, American Air Liquide, Countryside Il, US DOE – NETL, Pittsburgh PA, November 2004, DE-FC26-02NT41586

5 Oxy Combustion Processes for CO_2 Capture from Power Plants, IEA Greenhouse Gas R&D Programme, Prepared by MitsuiBabcock, Report 2005/0, July 2005

6 Moritis, G., (2003). CO_2 Sequestration Adds New Dimension to Oil, Gas Production, Oil and Gas Journal, Vol. 101.9, March 3, 2003. 39-44.

7 Impact of Impurities on CO_2 Capture, Transport and Storage, IEA Greenhouse Gas R&D Programme, Prepared by SNC-Lavalin, Inc., Report Number PH4/32, August 2004

The main benefits of oxycombustion technology with CO_2 capture and sequestration are:

1. Reduction of CO_2 – a greenhouse gas.
2. 60-70% reductions of NOx versus air-fired combustion when using flue gas recycle (FGR). This is mainly due to the FGR, with potential added benefit from reduced thermal NOx levels, resulting from lower available nitrogen in concentrated oxygen used for combustion. Some nitrogen is still available from the coal and from air infiltration.
3. Mercury ionization—potential for enhancement of Hg removal in the baghouse and FGD unit based on B&W data during Small Boiler Simulator (~5 MMBtu/hr) tests which showed an increase in the oxidized Hg/elemental Hg ratio during oxycombustion with PRB coal. Oxidized Hg is more efficiently captured in the baghouse and FGD unit.
4. Additional benefits:
    - The technology can readily be applied to new coal-fired power plants
    - The technology uses conventional equipment already proven in the power generation industry
    - Control during startup, shutdown, load following, and trips is very similar to a conventional PC plant
    - The key process principles have been proven in the past including air separation and flue gas recycle.

The appeal of oxycombustion is tempered by some challenges, as described below:

1. Air infiltration into the boiler is an issue as it dilutes the resulting flue gases. Various options are being investigated to minimize this, including improved boiler materials, sealants, control technologies, and membranes.
2. Combustion of fuels in pure oxygen would occur at temperatures too high for existing boiler or turbine materials. This issue is being addressed by diluting the oxygen using FGR, which results in an increase of the parasitic power load. Further developments aim at reducing or suppressing the flue gas recycle, and are associated with developments of new boiler materials of construction.

All technologies for CO_2 capture from power plants increase the cost of electricity. In the PC-oxycombustion technology, a major part of this cost is due to the air separation plant (capital cost and power consumption). Therefore, all developments that target a decrease of the oxygen cost when supplied in thousands of tons per day will strongly improve the competitiveness of this technology. Such developments include steady improvements of the cryogenic distillation process (leading to a significant cost decrease, even in the past 10 years), as well as investigations of alternative oxygen supply processes such as membranes.

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2. DESIGN BASIS

Eight oxycombustion cases were evaluated and are compared to four reference air-based cases. The eight oxycombustion cases include four supercritical and two ultra-supercritical configurations using cryogenic oxygen and two supercritical configurations using ITM-derived oxygen. The air-based reference cases include two supercritical and two ultra-supercritical configurations, one with CO_2 capture and one without capture for each steam cycle.

Among the cryogenic oxygen cases, two levels of oxygen purity are modeled which result in two levels of CO_2 purity. The raw CO_2 can then be further treated, resulting in four options for final CO_2 purity as follows:

- Specification A: Raw product produced using 95% oxygen and dehydrated to 0.015% (by volume) H_2O
- Specification B: Raw product produced using 99% oxygen and dehydrated to 0.015% (by volume) H_2O
- Specification B*: Raw product produced using 95% oxygen and further treated to meet the purity levels of Specification B.
- Specification C: Raw product produced using 95% oxygen, further purified to 0.015% (by volume) H_2O and > 95% CO_2.

In all oxycombustion cases the captured CO_2 is compressed to a supercritical fluid condition at 2215 psia and 95°F for pipeline transport. In the air-based cases the CO_2 product is compressed to the same pressure, but the temperature ranges from 166-193°F.

The case descriptions are summarized in Exhibit 2-1. The general design basis is described in the following subsections.

Exhibit 2-1 Plant Configuration Summary

Case	Boiler	Steam psig/°F/°F	Oxidant	NOx Control	Sulfur Control	CO_2 Purity	Intended Storage
1	Wall-fired, PC	3500/1110/1150	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	N/A	N/A
2	Wall-fired PC	4000/1350/1400	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	N/A	N/A
3	Wall-fired PC	3500/1110/1150	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	100%	Saline Formation
4	Wall-fired PC	4000/1350/1400	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	100%	
5	Wall-fired PC, FGR	3500/1110/1150	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	Spec. A	
5A	Wall-fired PC, FGR	3500/1110/1150	99 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	Spec. B	
5B	Wall-fired PC, FGR	3500/1110/1150	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	Spec. B*	
5C	Wall-fired PC, FGR	3500/1110/1150	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	Spec. C	
6	Wall-fired PC, FGR	4000/1350/1400	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6Btu	Spec. A	
6A	Wall-fired PC, FGR	4000/1350/1400	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6Btu	Spec. C	
7	Wall-fired PC, FGR	3500/1110/1150	~100 mol% O_2/ ITM ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6Btu	Spec. B	
7A	Wall-fired PC, FGR	3500/1110/1150	~100 mol% O_2/ ITM ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6Btu	Spec. C	

Legend:

LNB - Low NOx burner
OFA - Overfire air
FGD - Flue gas desulfurization
FGR - Flue gas recirculation
ASU- Air Separation Unit
SCR - Selective catalytic reduction
PC - Pulverized coal
OFO - Overfire oxygen
ITM - Ion transfer membrane

2.1 SITE DESCRIPTION

All plants in this study are assumed to be located at a generic Midwestern U.S. plant site, with ambient conditions and site characteristics as presented in Exhibit 2-2 and Exhibit 2-3. The ambient conditions are the same as ISO conditions [8].

Exhibit 2-2 Site Ambient Conditions

Elevation, ft	0
Barometric Pressure, psia	14.696
Design Ambient Temperature, Dry Bulb, °F	59
Design Ambient Temperature, Wet Bulb, °F	51.5
Design Ambient Relative Humidity, %	60

Exhibit 2-3 Site Characteristics

Location	Greenfield, Midwestern USA[1]
Topography	Level
Size, acres	300
Transportation	Rail
Ash Disposal	Off Site
Water	Municipal (50%) / Groundwater (50%)
Access	Land locked, having access by train and highway
CO_2	Compressed to 15.3 MPa (2,215 psia), transported 50 miles and sequestered in a saline formation at a depth of 4,055 feet

[1] Champaign County, Illinois is assumed for assessment of construction costs.

The following design parameters are considered site-specific, and are not quantified for this study. Allowances for normal conditions and construction are included in the cost estimates.

- Flood plain considerations.
- Existing soil/site conditions.
- Water discharges and reuse.
- Rainfall/snowfall criteria.
- Seismic design.
- Buildings/enclosures.

8 Gas turbines – Procurement – Part 2: Standard reference conditions and ratings", ISO 3977-2:1997 and "Gas turbines - Acceptance tests", ISO 2314:1989, Edition 2, International Organization for Standardization, Geneva, Switzerland http://www.iso.org/iso/en/xsite/copyright.html

- Fire protection.
- Local code height requirements.
- Noise regulations – Impact on site and surrounding area.

2.2 COAL CHARACTERISTICS

The design coal characteristics are presented in Exhibit 2-4. All cases in this study were modeled using Illinois No. 6 bituminous coal.

Exhibit 2-4 Design Coal

Coal seam nomenclature	Herrin (No. 6)
Coal name	Illinois No. 6
Mine	Old Ben No. 26
ASTM D388 Rank	High Volatile A Bituminous

Proximate Analysis	**As-Received**	**Dry**
Moisture	11.12%	0.00%
Volatile Matter	34.99%	39.37%
Ash	9.70%	10.91%
Fixed Carbon	44.19%	49.72%
Total	100.00%	100.00%
Ultimate Analysis	**As-Received**	**Dry**
Carbon	63.75%	71.73%
Hydrogen	4.50%	5.06%
Nitrogen	1.25%	1.41%
Sulfur	2.51%	2.82%
Chlorine	0.29%	0.33%
Ash	9.70%	10.91%
Moisture	11.12%	0.00%
Oxygen	6.88%	7.74%
Total	100.00%	100.00%
Reported Heating Value	**As-Received**	**Dry**
HHV (Btu/lb)	11,666	13,126
LHV (Btu/lb)	11,252	12,660
HHV (kJ/kg)	27,135	30,531
LHV (kJ/kg)	26,171	29,447

Exhibit 2-4 Design Coal (Continued)

Typical Ash Mineral Analysis		
Silica	SiO_2	45.0%
Aluminum Oxide	Al_2O_3	18.0%
Titanium Dioxide	TiO_2	1.0%
Iron Oxide	Fe_2O_3	20.0%
Calcium Oxide	CaO	7.0%
Magnesium Oxide	MgO	1.0%
Sodium Oxide	Na_2O	0.6%
Potassium Oxide	K_2O	1.9%
Phosphorus Pentoxide	P_2O_5	0.2%
Sulfur Trioxide	SO_3	3.5%
Undetermined		1.8%
Total		100.0%
Typical Ash Fusion Temperatures (°F)		
Reducing		
Initial – Limited deformation		1950 ºF
Softening	H=W	2030 ºF
Hemispherical	H=1/2W	2140 ºF
Fluid		2150 ºF
Oxidizing		
Initial – Limited deformation		2250 ºF
Softening	H=W	2300 ºF
Hemispherical	H=1/2W	2430 ºF
Fluid		2450 ºF
Hardgrove Grindability Index		60 HGI

Exhibit 2-4 Design Coal (Continued)

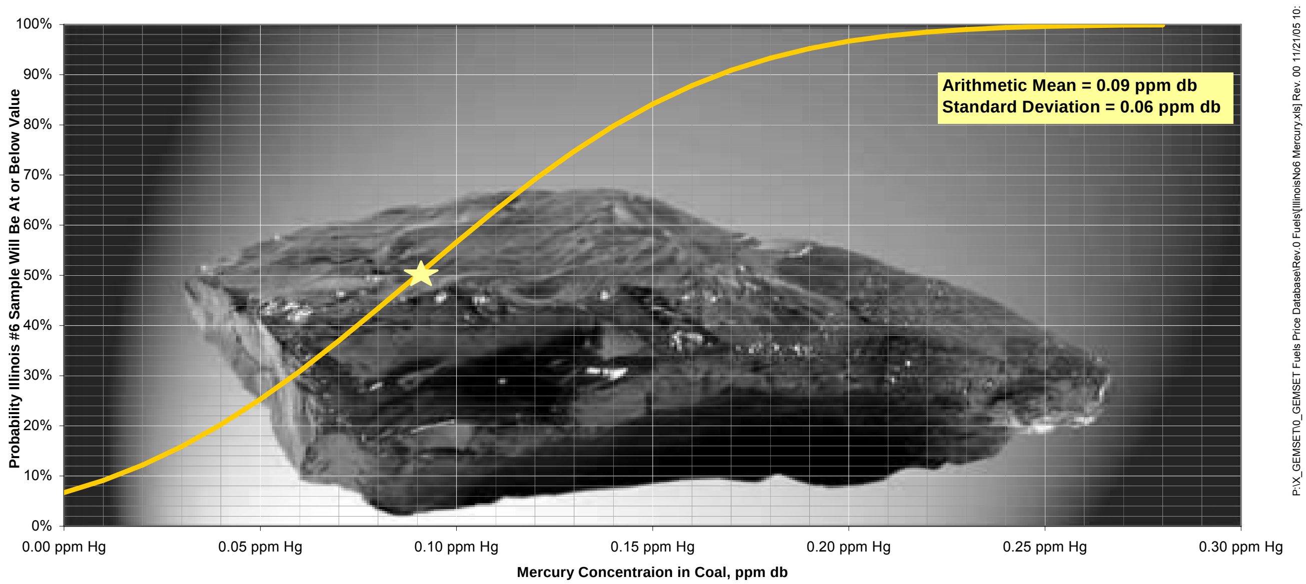
Average Trace Element Composition of Coal Shipped by Illinois Mines, Dry basis, ppm			
Trace Element		**Arithmetic Mean**	**Standard Deviation**
Arsenic	As	7.5	8.1
Boron	B	90	45
Beryllium	Be	1.2	0.7
Cadmium	Cd	0.5	0.9
Chlorine	Cl	1671	1189
Cobalt	Co	3.5	1.3
Chromium	Cr	14	6
Copper	Cu	9.2	2.5
Fluorine	F	93	36
Mercury	Hg	0.09	0.06
Lithium	Li	9.4	7.1
Manganese	Mn	38	32
Molybdenum	Mo	8.4	5.7
Nickel	Ni	14	5
Phosphorus	Ph	87	83
Lead	Pb	24	21
Tin	Sb	0.9	0.7
Selenium	Se	1.9	0.9
Thorium	Th	1.5	0.4
Uranium	Ur	2.2	1.9
Vanadium	V	31	16
Zinc	Zn	84.4	84.2

Note: Average trace element composition of coal shipped by Illinois mines is based on 34 samples, 2004 Keystone Coal Industry Manual [9]

The mercury content in the Illinois No. 6 coal is reported as an arithmetic mean value of 0.09 ppm (dry basis) with standard deviation of 0.06. Hence, as illustrated in Exhibit 2-5, there is a 50% probability that the mercury content in the Illinois No. 6 coal would not exceed 0.09 ppm (dry basis), and 99.9% probability that the mercury content in the Illinois No. 6 coal would not exceed 0.28 ppm (dry basis).

9 2004 Keystone Coal Industry Manual, Published by Coal Age, a Mining Media publication

Exhibit 2-5 Probability Distribution of Mercury Concentration in the Illinois No. 6 Coal



For the cases in this study, coal mercury content was assumed to be equal to the arithmetic mean mercury concentration plus one standard deviation, or 0.15 ppmd. About 84% of the coal samples represented in Exhibit 2-5 have a mercury concentration equal to or less than 0.15 ppmd.

2.3 NATURAL GAS CHARACTERISTICS

Natural gas is required in the ion transport membrane (ITM) cases to heat the air to temperatures in excess of 1470°F. The heat is provided by combusting natural gas in a direct-fired heater. The composition of the design natural gas is presented in Exhibit 2-6. The pipeline natural gas was assumed to be available at the plant battery limit at a pressure of 435 psig.

Exhibit 2-6 Natural Gas Composition

Component		Volume Percentage
Methane	CH_4	93.9
Ethane	C_2H_6	3.2
Propane	C_3H_8	0.7
n-Butane	C_4H_{10}	0.4
Carbon Dioxide	CO_2	1.0
Nitrogen	N_2	0.8
	Total	100.0
	LHV	**HHV**
kJ/kg	47,805	53,015
kJ/scm	35	39
Btu/lb	20,552	22,792
Btu/scf	939	1,040

Note: Fuel composition is normalized and heating values are calculated

2.4 DESIGN SORBENT COMPOSITION

Limestone from Greer Limestone mine in Morgantown, WV is assumed as a design sorbent for this study [10]. Sorbent is delivered to plant storage by truck. Limestone analysis is presented in Exhibit 2-7.

10 Quality Guidelines for Energy System Studies, prepared by DOE NETL Office of Systems and Policy Support, June 4, 2003

Exhibit 2-7 Sorbent Analysis

Supplier	Greer Industries, Inc.	Analysis, %
Calcium Carbonate	$CaCO_3$	80.40
Magnesium Carbonate	$MgCO_3$	3.50
Silica	SiO_2	10.32
Aluminum Oxide	Al_2O_3	3.16
Iron Oxide	Fe_2O_3	1.24
Sodium Oxide	Na_2O	0.23
Potassium Oxide	K_2O	0.72
Balance		0.43
	Total	**100.00**

2.5 ENVIRONMENTAL REQUIREMENTS

The environmental approach for this study was to evaluate each case on the same regulatory design basis. A Best Available Control Technology (BACT) approach was taken and used uniformly throughout the study. The emissions controls employed and the resulting performance are shown in Exhibit 2-8.

Exhibit 2-8 Presumptive BACT Emission Values

Technology	Pulverized Coal Boilers
Sulfur Control Technology	Wet Limestone FGD
Sulfur Limits	98% efficiency or ≤ 0.10 lb $SO_2/10^6$ Btu
NOx Control Technology	LNB w/OFA (or OFO) and SCR in air-based cases
NOx Limits	0.07 lb/10^6 Btu
PM Control Technology	Fabric Filter
PM Limits	99.8% or ≤ 0.015 lb/10^6 Btu
Hg Control Technology	Co-benefit capture
Hg Limits	90% removal

The current regulation governing new fossil-fuel fired power plants is the New Source Performance Standards (NSPS) published in February 2006 and shown in Exhibit 2-9. These NSPS standards superseded the previous NSPS standards that were established in 1978[11]. The

11 40 CFR 60, Subpart Da – Standards of Performance for Electric Utility Steam Generating Units for Which Construction Commenced after September 18, 1978

new standards apply to units with the capacity to generate greater than 73 MW of power by burning fossil fuels, as well as cogeneration units that sell more than 25 MW of power and more than one-third of their potential output capacity to any utility power distribution system. The rule also applies to combined cycle, including IGCC plants, and combined heat and power combustion turbines that burn 75 percent or more synthetic-coal gas.

Other regulations that could affect emissions limits from a new plant include the New Source Review (NSR) permitting process and Prevention of Significant Deterioration (PSD). The NSR process requires installation of emission control technology meeting either BACT determinations for new sources being located in areas meeting ambient air quality standards (attainment areas), or Lowest Achievable Emission Rate (LAER) technology for sources being located in areas not meeting ambient air quality standards (non-attainment areas). Environmental area designation varies by county and can be established only for a specific site location. Based on the EPA Green Book Non-attainment Area Map relatively few areas in the Midwestern U.S. are classified as "non-attainment", and therefore BACT is chosen here rather than LAER [12].

Exhibit 2-9 Standards of Performance for Electric Utility Steam Generating Units Built, Reconstructed, or Modified After February 28, 2005

	New Units		Reconstructed Units		Modified Units	
	Emission Limit	% Reduction	Emission Limit (lb/MMBtu)	% Reduction	Emission Limit (lb/MMBtu)	% Reduction
PM	0.015 lb/MMBtu	99.9	0.015	99.9	0.015	99.8
SO_2	1.4 lb/MWh	95	0.15	95	0.15	90
NOx	1.0 lb/MWh	N/A	0.11	N/A	0.15	N/A

The BACT technologies assumed for this study meet the emission requirements of the 2006 NSPS. It is possible that state and local requirements could supersede NSPS or BACT and impose more stringent requirements. For the purpose of this study, BACT was assumed to be adequate.

2.6 AIR SEPARATION UNIT

Air separation plants have ambient air quality requirements to prevent the build-up of certain components in the cold box. Similarly, the quality of the water used in the direct contact cooler must also meet certain requirements. The ASU design assumes ambient air quality as presented in Exhibit 2-10, and cooling water quality as presented in Exhibit 2-11,

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12 US EPA Green Book Nonattainment Area Map, http://www.epa.gov/oar/oaqps/greenbk/mapnpoll.html

Exhibit 2-10 Ambient Air Quality

Impurities	Chemical Formula	Basis of Design (volume - vapor phase)
Nitrogen	N_2	78.11%
Oxygen	O_2	20.96%
Argon	Ar	0.93%
Carbon Monoxide	CO	< 0.6 ppm
Carbon Dioxide	CO_2	< 480 ppm
Methane	CH_4	< 8 ppm
Ethane	C_2H_6	< 0.1 ppm
Acetylene	C_2H_2	< 0.4 ppm
Ethylene	C_2H_4	< 0.2 ppm
Propylene	C_3H_6	< 0.2 ppm
Propane	C_3H8	< 0.05 ppm
Other Hydrocarbons	C_4+	< 0.05 ppm each
Hydrogen	H_2	< 0.7 ppm
Hydrogen Sulfide	H_2S	< 0.001 ppm
Ammonia	NH_3	< 0.01 ppm
Nitrous Oxide	N_2O	< 0.35 ppm
Nitrogen Oxides	NO_x	< 0.1 ppm
Ozone	O_3	< 0.1 ppm
Sulfur Dioxide	SO_2	< 0.1 ppm
Chloride	Cl	< 0.1 ppm
Total Strong Acid	HCl + HNO_3	< 0.05 ppm
Dust		< 0.2 mg/Nm^3

Exhibit 2-11 Cooling Water Quality

Quality or Impurity	Parameter	Value
pH value		7.6 to 7.8
Carbonate hardness		8 to 10° DH (German degrees)
Carbonic acid	Free	8 to 15 mg/l
	Combined	8 to 15 mg/l
	Corroding	None
Ryznar index*		6.5
Oxygen	At least	4 to 5 mg/l
Chloride ions	Maximum	10 mg/l
Sulphate ions	Maximum	50 mg/l

Quality or Impurity	Parameter	Value
Nitrates and Nitrites	Maximum	10 mg/l
Ammonia	Maximum	10 mg/l
Phosphates and silicates		not significant
Iron and manganese		0.1 to 0.2 mg/l
Suspended solids	Maximum	10 mg/l

Note: The cooling water must be free of living organisms, biological growth, and algae.

* Ryznar index is a modification of the Langelier index used to calculate the degree of calcium carbonate saturation and to predict the likelihood of scale formation from a water supply.

The quality of the low pressure steam used for regeneration of the front end separation of the ASU must meet the specifications shown in Exhibit 2-12.

Exhibit 2-12
Low Pressure Steam Quality

Property	Chemical Formula	Value
Pressure/Temperature		10 bars/(saturated)
pH value		7.0 to 9.5
Conductivity		<0.2 μS/cm
Silicates	SiO_2	<0.02 mg/kg
Iron	Fe	<0.02 mg/kg
Copper	Cu	<0.003 mg/kg
Sodium	Na	<0.01 mg/kg
Organics		<0.2 mg/kg
Calcium + Magnesium	Ca + Mg	<0.05 mg/kg
Oxygen	O_2	<0.25 mg/kg
Chloride ions	Cl^-	<0.1 mg/kg
Bromide ions	Br^-	<0.1 mg/kg
Iodide ions	I^-	<0.1 mg/kg
Fluoride ions	F^-	<0.02 mg/kg
Sulphate ions	SO_4^{2-}	<0.1 mg/kg
Solids		<1.0 mg/kg

2.7 STEAM CONDITIONS

Steam conditions for the Rankine cycle cases were selected based on the NETL Advanced Materials for Supercritical Boilers program. The program is a collaborative effort of NETL, EPRI and Industry Partners (Babcock & Wilcox, Foster Wheeler, Alstom, and Babcock Borsig). The goals of the program dictated the steam conditions selected for the study:

- For supercritical cycle cases – 3500 psig/1110°F/1150°F
- For ultra-supercritical cases – 4000 psig/1350°F/1400°F

In recent years the steam temperature of 1100°F for supercritical units has become common in specifications for new plant design and several units have been built recently. It has also been realized that it is not necessary to increase steam pressure beyond that which is typical for a supercritical unit to achieve high efficiency since increasing pressure has a small impact on heat rate and it proportionately increases the thickness of all pressure parts. This added thickness not only directly increases material cost for the pressure parts, it also produces additional building steel and foundation costs to support the additional weight and causes the surface metal temperatures to increase requiring more costly alloy materials. Thus, the steam pressure should be dictated by the thermodynamic expansion characteristic of the steam turbine given the inlet temperature/flow conditions.

The steam conditions for ultra-supercritical cases (4000 psi/1350°F/1400°F) are currently under development and are expected to be available in the 2015 to 2020 timeframe. The only obstacle to raising steam temperatures to these levels is availability of materials that provide the creep strength, manufacturability, and corrosion resistance to withstand the surface metal temperatures experienced within the final superheater and reheater stages in the boiler. These surface temperatures can be 150°F or more above the steam temperature. Materials must be developed to withstand the higher temperatures while exposed to the flue gases within the boiler.

Three major programs are in progress with the target of developing such materials in the 2015 timeframe: the U.S. Department of Energy's Ultra-Supercritical Materials Program, the Thermie AD700 project and the more recent E-max initiative, both sponsored by the European Union and private industry. The current DOE program for the ultra-supercritical cycle materials development targets cycle conditions of 730ºC/760ºC (1350ºF/1400ºF) at 345 bar (5000 psi) to be available by 2015, and a similar Thermie program in the EU has targeted 700ºC/720ºC (1300ºF/1330ºF) at about 290 bar (4200 psi) [13]. The results of these development efforts will determine what the actual steam temperatures of the future will be. Steam temperature selection for boilers depends upon fuel corrosiveness. There is concern that elevated temperature operation while firing high sulfur coal (such as Illinois No. 6) will result in an exponential increase (with increased temperature) of the material wastage rates of the highest temperature portions of the superheater and reheater due to coal ash corrosion, requiring replacement of the highest temperature portions approximately every 10 or 15 years. This cost may offset the value

13 A Clean and Efficient Supercritical Circulating Fluidized Bed Power Plant, Patrick Laffont, Jacques Bartelemy, Brendon Scarlin, Christian Kervenec, Alstom Power.

of fuel savings and emissions reduction due to the higher efficiency. Availability/reliability of the more exotic materials required to support the elevated temperature environment for high sulfur/chlorine applications, while extensively tested in laboratory [14], has not been commercially demonstrated.

14 Application of High Temperature Countermeasures in High Sulfur Coal-fired boilers, Simon Phillips, Kenji Yamomoto, Noburu Shinotsuka, Yuji Fukuda, Babcock-Hitachi, presented to Electric Power 2003; March 4-6, 2003: Track 11 - Coal Power, New issues for coal and solid fuels, Session 11A – Solid Fuel Fired Technology Updates, www.hitachi.us/power

2.8 BALANCE OF PLANT

Assumed balance of plant requirements are as follows:

Cooling system	Recirculating, Evaporative Cooling Tower
Fuel and Other storage	
Coal	30 days
Ash	30 days
Limestone	30 days
Plant Distribution Voltage	
Motors below 1 hp	110/220 volt
Motors between 1 hp and 250 hp	480 volt
Motors between 250 hp and 5,000 hp	4,160 volt
Motors above 5,000 hp	13,800 volt
Steam and gas turbine generators	24,000 volt
Grid Interconnection voltage	345 kV
Water and Waste Water	
Makeup Water	The water supply is assumed to be 50 percent from a local Publicly Owned Treatment Works (POTW) and 50 percent from groundwater, and is assumed to be in sufficient quantities to meet plant makeup requirements. Makeup for potable, process, and de-ionized (DI) water is drawn from municipal sources.
Process Wastewater	Storm water that contacts equipment surfaces is collected and treated for discharge through a permitted discharge.
Sanitary Waste Disposal	Design includes a packaged domestic sewage treatment plant with effluent discharged to the industrial wastewater treatment system. Sludge is hauled off site. Packaged plant was sized for 5.7 cubic meters per day (1,500 gallons per day).
Water Discharge	Most of the process wastewater is recycled to the cooling tower basin. Blowdown is treated for chloride and metals and discharged.
Solid Waste	Fly ash, bottom ash and scrubber sludge are assumed to be solid wastes that are classified as non-hazardous. Offsite waste disposal sites are assumed to have the capacity to accept waste generated throughout the life of the facility Solid wastes sent to disposal are at an assumed nominal fee per ton, even if the waste is hauled back to the mine. Solid waste generated that can be recycled or reused is assumed at a zero cost to the technology

COST ESTIMATING METHODOLOGY

The estimates in this study carry an accuracy of ±30 percent, consistent with the screening study level of information available for the various power technologies.

The cost estimation methodology is explained in more detail in "Cost and Performance Comparison Baseline for Fossil Energy Power Plants" [15]. This reference is the basis for the costs for the supercritical air-based pulverized coal Rankine cycle cases 1 and 3. Some particulars from the study are described below.

2.8.1 Capital, Operation, and Maintenance Costs

For the cases examined in this study, capital cost, production cost, and levelized cost-of-electricity (LCOE) estimates were developed for each plant based on adjusted vendor-furnished and actual cost data from recent design/build projects, and resulted in determination of a revenue requirement LCOE based on the power plant costs and assumed financing structure. Boiler and ancillary equipment (baghouse, FGD unit, and condensing heat exchanger) cost estimates were provided by B&W. Cryogenic air separation plant cost estimates were provided by Air Liquide. Balance of plant capital cost estimates were based on costs developed independently for prior PC boiler power plants (adjusted for the Midwest site), using a combination of adjusted vendor-furnished cost data and a cost estimating database compiled from recent design/build projects.

The capital costs at the Total Plant Cost (TPC) level include equipment (which includes initial chemical and catalyst loadings), materials, labor, indirect construction costs, engineering, and contingencies. Quantities for major consumables such as fuel and sorbent were taken from technology-specific heat and mass balance diagrams developed for each plant application. Other consumables were evaluated on the basis of the quantity required using reference data. Operation costs were determined on the basis of the number of operators. Maintenance costs were evaluated on the basis of requirements for each major plant section. All capital and O&M costs are presented as "overnight costs" expressed in January 2007 dollars. Specific parameters used are shown with the cost results for each case.

SYSTEM CODE OF ACCOUNTS

The costs are grouped according to a process/system oriented code of accounts. This type of code-of-account structure has the advantage of grouping all reasonably allocable components of a system or process so they are included in the specific system account. This would not be the case had a facility, area, or commodity account structure been chosen instead.

CO_2 TECHNOLOGY MATURITY

The case estimates provided include technologies at different commercial maturity levels. The estimates for the non-CO_2-capture PC cases represent well-developed, commercial technology or

15 "Cost and Performance Comparison Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity." Final Report No. DOE/NETL-2007/1281, May 2007

"n^{th} plants." The estimates for the CO_2-capture cases represent developing technology, since the post-combustion CO_2 removal technology for the capture cases remains unproven at commercial scale in power generation applications where more then 15,000 tons/day of CO_2 is captured.

CONTINGENCY

Both the project contingency and process contingency costs represent costs that are expected to be spent in the development and execution of the project that are not yet fully reflected in the design. It is industry practice to include project contingency in the TPC to cover project uncertainty and the cost of any additional equipment that would result during detailed design. Likewise, the estimates include process contingency to cover the cost of any additional equipment that would be required as a result of continued technology development.

Project Contingency

Project contingencies were added to each of the capital accounts to cover project uncertainty and the cost of any additional equipment that could result from detailed design. The project contingencies represent costs that are expected to occur. Each bare erected cost account was evaluated against the level of estimate detail, field experience, and the basis for the equipment pricing to define project contingency.

Process Contingency

Process contingency is intended to compensate for uncertainties arising as a result of the state of technology development. Process contingencies have been applied to the estimates as follows:

USC PC Boiler – 10 percent of the total boiler – only the superheater and reheater componenets of the boiler have not been proven commercially at the elevated temperatures.

Oxycombustion – 15 percent of the total boiler (in addition to the USC PC Boiler contingency as appropriate).

ITM ASU – no process contingency is applied to the ITM. The capital cost of the ITM is based off an Nth plant R&D target of 30% less capital cost than a current state-of-the-art cryogenic ASU [16]. This "30% less than cryogenic ASU target" includes all process contingencies associated with the ITM ASU. Therefore, no process contingency is applied to the ITM ASU in Cases 7 and 7A.

Post combustion CO_2 removal system – 20 percent – post-combustion process unproven at commercial scale for power plant applications

AACE International provides standards for process contingency relative to technology status; from commercial technology at 0 to 5 percent to new technology with little or no test data at 40 percent. The process contingencies as applied in this study are consistent with the AACE International standards.

16 "ITM Oxygen for Gasification", Air Products and Chemicals, Inc., Gasification Technologies 2004, Washington, DC, http://www.gasification.org/Docs/2006_Papers/54ARMS.pdf, October 2004

PRICE ESCALATION

A significant change in power plant cost occurred in recent years due to the significant increases in the pricing of equipment and bulk materials. This estimate includes these increases. The price escalation of vendor quotes incorporated a vendor survey of actual and projected pricing increases from 2004 through the third quarter of 2006 that RDS conducted for a recent project. The results of this survey were used to validate/recalibrate the corresponding escalation factors used in the conceptual estimating models.

2.8.2 Levelized Cost of Electricity

The revenue requirement method of performing an economic analysis of a prospective power plant has been widely used in the electric utility industry. This method permits the incorporation of the various dissimilar components for a potential new plant into a single value that can be compared to various alternatives. The revenue requirement figure-of-merit in this report is cost of electricity (COE) levelized over a 20 year period and expressed in mills/kWh (numerically equivalent to $/MWh). The 20-year levelized cost of electricity (LCOE) was calculated using a simplified model derived from the NETL Power Systems Financial Model. [17]

The equation used to calculate LCOE is as follows:

$$LCOE_P = \frac{(CCF_P)(TPC) + [(LF_{F1})(OC_{F1}) + (LF_{F2})(OC_{F2}) + \ldots] + (CF)[(LF_{V1})(OC_{V1}) + (LF_{V2})(OC_{V2}) + \ldots]}{(CF)(kWh)}$$

where

$LCOE_P$ =	levelized cost of electricity over P years
P =	levelization period (e.g., 10, 20 or 30 years)
CCF =	capital charge factor for a levelization period of P years
TPC =	total plant cost
LF_{Fn} =	levelization factor for category n fixed operating cost
OC_{Fn} =	category n fixed operating cost for the initial year of operation (but expressed in "first-year-of-construction" year dollars)
CF =	plant capacity factor
LF_{Vn} =	levelization factor for category n variable operating cost
OC_{Vn} =	category n variable operating cost at 100 percent capacity factor for the initial year of operation (but expressed in "first-year-of-construction" year dollars)
kWh =	annual net kilowatt-hours of power generated at 100 percent capacity factor

All costs are expressed in "first-year-of-construction" year dollars, and the resulting LCOE is also expressed in "first-year-of-construction" year dollars. In this study the first year of plant construction is assumed to be 2007, and the resulting LCOE is expressed in year 2007 dollars.

17 Power Systems Financial Model Version 5.0, September 2006

Although their useful life is usually well in excess of thirty years, a twenty-year levelization period is typically used for large energy conversion plants and is the levelization period used in this study. The economic assumptions used to derive the capital charge factors are shown in Exhibit 2-13.

The technologies modeled in this study were divided into one of two categories for calculating LCOE: investor owned utility (IOU) high risk and IOU low risk. All ultra-supercritical PC cases and cases with CO_2 capture are considered high risk. The non-capture supercritical PC cases are considered low risk. The parameters used are shown in Exhibits following the cost exhibits for each case. The difference between the high risk and low risk categories is manifested in the debt-to-equity ratio and the weighted cost of capital. The values used to generate the capital charge factors and levelization factors in this study are shown in Exhibit 2-14 and Exhibit 2-15.

Exhibit 2-13 Parameter Assumptions for Capital Charge Factors

Parameter	Value
Income Tax Rate	38% Effective (34% Federal, 6% State less 1% Property and 1% Insurance)
Repayment Term of Debt	15 years
Grace Period on Debt Repayment	0 years
Debt Reserve Fund	None
Depreciation	20 years, 150% declining balance
Working Capital	zero for all parameters
Plant Economic Life	30 years
Investment Tax Credit	0%
Tax Holiday	0 years
Start-Up Costs (% of EPC)	2%
All other additional capital costs ($)	0
EPC escalation	0%
Duration of Construction	3 years

Exhibit 2-14
Financial Structure for Investor Owned Utility High and Low Risk Projects

Type of Security	% of Total	Current (Nominal) Dollar Cost	Weighted Current (Nominal) Cost	After Tax Weighted Cost of Capital
Low Risk				
Debt	50	9%	4.5%	2.79%
Equity	50	12%	6%	6%
			11%	8.79%
High Risk				
Debt	45	11%	4.95%	3.07%
Equity	55	12%	6.6%	6.6%
			11.55%	9.67%

Exhibit 2-15 Economic Parameters for LCOE Calculation

	High Risk	Low Risk
Capital Charge Factor	0.175	0.164
Coal Levelization Factor	1.2022	1.2089
Natural Gas Levelization Factor	1.1651	1.1705
General O&M Levelization Factor	1.1568	1.1618

2.8.3 Costs of CO_2 Captured (Removed) and Avoided

Carbon dioxide (CO_2) is not currently regulated. However, the possibility exists that carbon limits will be imposed in the future, and this study examines cases that include a reduction in CO_2 emissions. The cost of CO_2 capture was calculated in two ways, the cost of CO_2 removed and the cost of CO_2 avoided.

The equation used to calculate the **Cost of CO_2 Captured or Removed** is as follows:

$$\text{Removal Cost} = \frac{(\text{LCOE}_{\text{with removal}} - \text{LCOE}_{\text{w/o removal}})}{(\text{CO}_2\ \text{Removed})}$$

where

LCOEp = levelized cost of electricity ($/$MWh_{net}$)
CO_2 Removed = CO_2 captured for case (tonnes/MWh_{net} or tons/MWh_{net})

The equation used to calculate the **Cost of CO_2 Avoided** in $/ton is as follows:

$$\text{Avoided Cost} = \frac{(\text{LCOE}_{\text{with removal}} - \text{LCOE}_{\text{w/o removal}})}{(\text{Emissions}_{\text{w/o removal}} - \text{Emissions}_{\text{with removal}})}$$

where

LCOEp = levelized cost of electricity ($/$MWh_{net}$)
Emissions = CO_2 emissions for case (tonnes/MWh_{net} or tons/MWh_{net})

2.8.4 Costs of CO_2 Transport, Storage and Monitoring

For those cases that feature CO_2 capture, the capital and operating costs for CO_2 transport, storage and monitoring (TS&M) were independently estimated by NETL. Those costs were converted to a levelized cost of electricity (LCOE) and combined with the plant capital and operating costs to produce an overall LCOE. The TS&M costs were levelized over a twenty-year period using the methodology described in the next subsection of this report.

CO_2 TS&M costs were estimated based on the following assumptions:

- CO_2 is supplied to the pipeline at the plant fence line at a pressure of 15.3 MPa (2,215 psia). The CO_2 product gas is composition varies in each case depending on the level of oxygen purity used (95 versus 99% oxygen) and the level of purification required. However, in all cases the CO_2 product stream was dried to <0.015 vol.% water.
- Excess oxygen: The oxygen flow design specification applied to all oxyfuel cases was a 2.7% oxygen flue gas concentration (on a dry basis) at the boiler exit. This study assumes that extensive dehydration of the product stream would minimize pipeline corrosion and allow up to 3% excess oxygen in the CO_2 product stream transported—this is considered a "best-case" or "low-cost" CO_2 purification/compression option. In addition, it was assumed that up to 3% oxygen would not probibit saline formation storage. This assumption is supported by two recently completed IEA Reports titled "Impact of Impurities on CO_2 Capture, Transport and Storage" [18] and "Oxy Combustion Processes for CO_2 Capture from Power Plant" [19]. Additional engineering designs which focus on extensive flue gas purification from oxyfuel processes (such as the multi-pollutant control processes proposed by Air Products) where deep oxygen removal (<100 ppm) is required for enhanced oil recovery applications is beyond the scope of this study.
- The CO_2 is transported 80 kilometers (50 miles) via pipeline to a geologic sequestration field for injection into a saline formation.

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18 "Impact of Impurities on CO_2 Capture, Transport and Storage", IEA GHG Report Number Ph 4-32, August 2004.

19 "Oxy Combustion Processes from Power Plant", IEA GHG Report Number 2005/9, July 2005.

- The CO_2 is transported and injected as a supercritical fluid in order to avoid two-phase flow and achieve maximum efficiency [20]. The pipeline is assumed to have an outlet pressure (above the supercritical pressure) of 10.4 MPa (1,515 psia) with no recompression along the way. Accordingly, CO_2 flow in the pipeline was modeled to determine the pipe diameter that results in a pressure drop of 4.8 MPa (700 psi) over an 80 kilometer (50 mile) pipeline length [21]. (Although not explored in this study, the use of boost compressors and a smaller pipeline diameter could possibly reduce capital costs for sufficiently long pipelines.) The diameter of the injection pipe will be of sufficient size that frictional losses during injection are minimal and no booster compression is required at the well-head in order to achieve an appropriate down-hole pressure.
- The saline formation is at a depth of 1,239 meters (4,055 ft) and has a permeability of 22 millidarcy (a measure of permeability defined as roughly 10^{-3} Darcy) and formation pressure of 8.4 MPa (1,220 psig). [22] This is considered an average storage site and requires roughly one injection well for each 9,360 tonnes (10,320 short tons) of CO_2 injected per day. [22] The assumed formation characteristics are tabulated in Exhibit 2-16.

Exhibit 2-16 Deep Saline Formation Specification

Parameter	Units	Base Case
Pressure	MPa (psi)	8.4 (1,220)
Thickness	m (ft)	161 (530)
Depth	m (ft)	1,236 (4,055)
Permeability	md	22
Pipeline Distance	km (miles)	80 (50)
Injection Rate per Well	tonne (ton) CO_2/day	9,360 (10,320)

20 Smith, Lawrence A., Gupta, Neeraj, Sass, Bruce M. and Bubenik, Thomas A., "Engineering and Economic Assessment of Carbon Dioxide Sequestration in Saline Formations," Battelle Memorial Institute, 2001

21 Ciferno, Jared P. and McIlvried, Howard, "CO_2 Flow Modeling and Pipe Diameter Determination," February, 2003

22 Economic Evaluation of CO_2 Storage and Sink Enhancement Options, Tennessee Valley Authority, NETL and EPRI, December 2002

For CO_2 transport and storage, capital and O&M costs were assessed using metrics from a 2001 Battelle report [23]. These costs were scaled from the 1999-year dollars described in the report to Dec-2006 dollars using U.S. Bureau of Labor Statistics (BLS) Producer Price Indices for the oil and gas industry and the *Chemical Engineering* Plant Cost Index. Project and process contingencies of thirty and twenty percent, respectively, were applied to the Battelle costs to cover additional costs that are expected to arise from: i) developing a more detailed project definition, and ii) using technologies that have not been well-demonstrated to date in a similar commercial application.

For CO_2 monitoring, costs were assessed using metrics for a saline formation "enhanced monitoring package" as reported in a 2004 International Energy Agency (IEA) report [24]. The IEA report presented costs for two types of saline formations: those with low and high residual gas saturations. The reported monitoring costs were higher for saline formations with low residual gas saturation, and those costs were used as the basis for this report. The IEA report calculated the present value of life-cycle monitoring costs using a ten percent discount rate. The present value cost included the initial capital cost for monitoring as well as O&M costs for monitoring over a period of eighty years (a thirty-year injection period followed by fifty years of post-injection monitoring).

For this study, the present value reported in the IEA report was adjusted from Nov-2004 dollars to Dec-2006 dollars using U.S. BLS Producer Price Indices for the oil and gas industry. Project and process contingencies of thirty and thirty-five percent, respectively, were applied to the IEA value to cover additional costs that are expected to arise as described above. The resulting metric used for this report is a present value of $0.176 per metric ton of CO_2 stored over a thirty-year injection period.

In accordance with the IEA's present-value, life-cycle methodology, this report levelized monitoring costs over a twenty-year period by applying a capital charge factor to the present value of life-cycle monitoring costs (10 percent discount rate). This approach is representative of a scenario in which the power plant owner establishes a "CO_2 Monitoring Fund" prior to plant startup that is equal to the present value of life-cycle monitoring costs. Establishing such a fund at the outset could allay concerns about the availability of funds to pay for monitoring during the post-injection period, when the plant is no longer operating. While it is recognized that other, more nuanced, approaches could be taken to levelizing eighty years of monitoring costs over a twenty-year period, the approach applied in this report was chosen because it is simple to describe and should result in a conservative (i.e., higher) estimate of the funds required.

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23 Smith, Lawrence A., Gupta, Neeraj, Sass, Bruce M. and Bubenik, Thomas A., "Engineering and Economic Assessment of Carbon Dioxide Sequestration in Saline Formations," Battelle Memorial Institute, 2001

24 "Overview of Monitoring Requirements for Geologic Storage Projects," International Energy Agency Greenhouse Gas R&D Programme, Report Number PH4/29, November 2004

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3. PROCESS DESCRIPTIONS

The system descriptions are provided in the subsections below. When the description is common to both air-based and oxycombustion cases, a single description is provided. Otherwise, the description distinguishes between the technologies and provides information on each. Differences between supercritical and ultra-supercritical designs are handled in the same manner.

3.1 COAL HANDLING

The function of the coal handling system is the same for all cases. It is to provide the equipment required for unloading, conveying, preparing, and storing the fuel delivered to the plant. The scope of the system is from the delivery point up to the pulverizer fuel inlet. The system is designed to support short-term operation at the 5 percent over pressure/valves wide open (OP/VWO) condition (16 hours) and long-term operation of 90 days or more at the maximum continuous rating (MCR).

The 3" x 0 bituminous Illinois No. 6 coal is delivered to the site by unit trains of 100-ton rail cars. Each unit train consists of 100, 100-ton rail cars. The unloading is done by a trestle bottom dumper, which unloads the coal to two receiving hoppers. Coal from each hopper is fed directly into a vibratory feeder. The 3" x 0 coal from the feeder is discharged onto a belt conveyor (No. 1). The coal is then transferred to a conveyor (No. 2) that transfers the coal to the reclaim area. The conveyor passes under a magnetic plate separator to remove tramp iron, and then to the reclaim pile.

Coal from the reclaim pile is fed by two vibratory feeders, located under the pile, onto a belt conveyor (No. 3), which transfers the coal to the coal surge bin located in the crusher tower. The coal is reduced in size to 1¼" x 0 by the coal crusher. The coal is then transferred by conveyor (No. 4) to the transfer tower. In the transfer tower the coal is routed to the tripper that loads the coal into one of the parallel boiler silos.

3.2 STEAM GENERATOR AND ANCILLARIES

The steam generators for the air-based and oxycombustion cases are very similar and are based on the Babcock & Wilcox supercritical or ultra-supercritical once-through, spiral-wound, Benson-boiler. The air-based system is described first followed by modifications related to the oxycombustion cases.

The steam generator for the air-based reference designs is a once-through, PC wall-fired, balanced draft type unit with a water-cooled dry bottom furnace. It is assumed for the purposes of this study that the power plant is designed to be operated as a base-loaded unit but with some consideration for daily or weekly cycling, as can be cost effectively included in the base design.

3.2.1 Scope and General Arrangement

The steam generator comprises the following:

- Once-through type steam generator
- Low NOx Coal burners and light oil ignitors/ warmup system
- Startup circuit, including integral separators
- Water-cooled furnace, dry bottom
- Soot blower system
- Primary air (PA) fans
- Two-stage superheater
- Air preheaters (Ljungstrom type)
- Induced draft (ID) fans
- Reheater
- Coal feeders and pulverizers
- Forced draft (FD) fans
- Economizer
- Spray type desuperheater
- Overfire air system

The steam generator operates as follows:

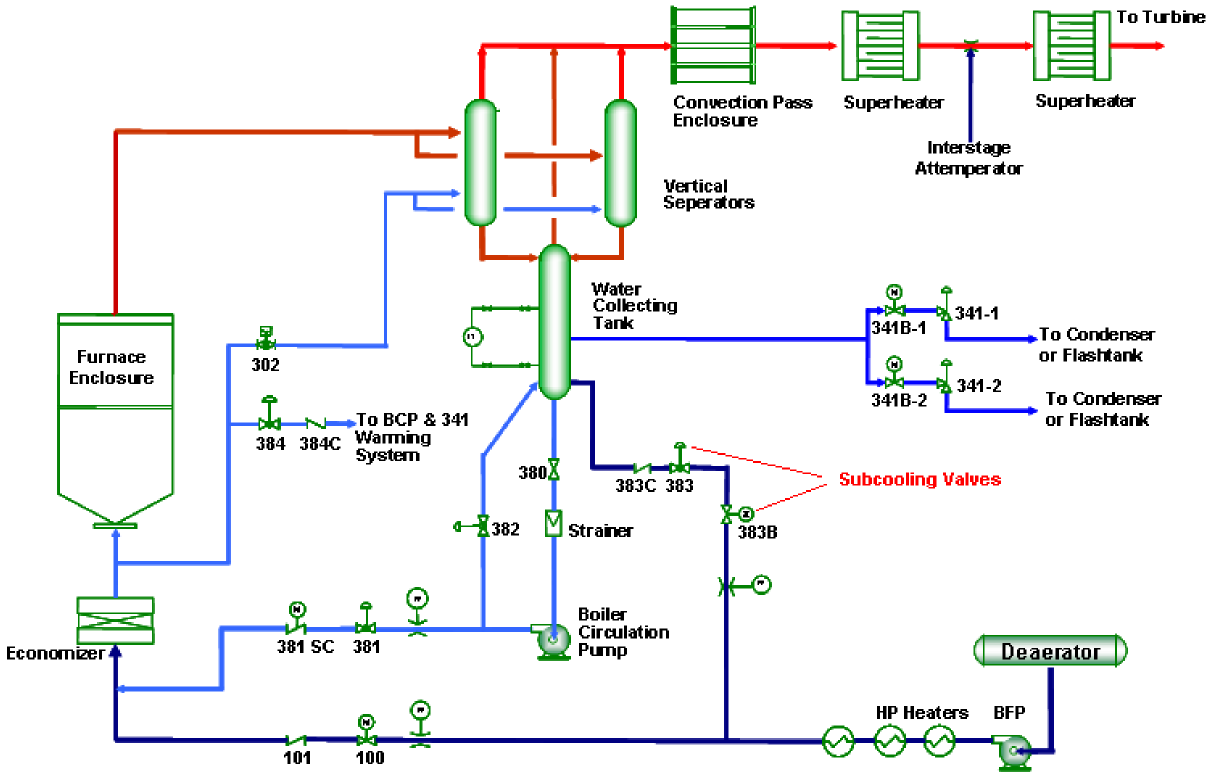
3.2.2 Feedwater and Steam

Feedwater enters the bottom header of the economizer (Exhibit 3-1). Water passes upward through the economizer tube bank and discharges to the economizer outlet headers. From the outlet headers, water flows to the furnace hopper inlet headers via external downcomers. Water then flows upward through the furnace hopper and furnace wall tubes. From the furnace, water flows to the steam water separator. During low load operation (operation below the Benson point), the water from the separator is returned to the economizer inlet with the boiler recirculating pump. Operation at loads above the Benson point is once through.

Steam flows from the separator through the furnace roof to the convection pass enclosure walls, primary superheater, through the first stage of water attemperation, to the furnace platens. From the platens, the steam flows through the second stage of attemperation and then to the intermediate superheater. The steam then flows to the final superheater and on to the outlet pipe terminal. Two stages of spray attemperation are used to provide tight temperature control in all high temperature sections during rapid load changes.

Steam returning from the turbine passes through the primary reheater surface, then through crossover piping containing inter-stage attemperation. The crossover piping feeds the steam to the final reheater banks and then out to the turbine. Inter-stage attemperation is used to provide outlet temperature control during load changes.

Exhibit 3-1
Once Through Variable Pressure Boiler Flow Diagram



Source: B&W Figure

3.2.3 Air and Combusting Products

The steam generator is furnished with vertical-shaft Ljungstrom type air preheaters. These units are driven by electric motors through gear reducers. Two Tri-sector regenerative air heaters are located after the economizer. These air heaters are designed first to deliver heat to the primary stream used to dry and convey the pulverized coal through the pulverizers and second to cool the flue gases leaving the boiler envelope by preheating the stream going to the burners.

Combustion air from the FD fans is heated in air heaters, recovering heat energy from the exhaust gases exiting the boiler. This air is distributed to the burner windbox as secondary air. Air for conveying pulverized coal to the burners is supplied by the PA fans. This air is heated in the air preheaters to permit drying of the pulverized coal, and a portion of the air from the PA fans bypasses the air preheaters to be used for regulating the outlet coal/air temperature leaving the mills.

The pulverized coal and air mixture flows to the coal nozzles at the various elevations of the furnace. The hot combustion products rise to the top of the boiler and pass through the superheater and reheater sections. The gases then pass through the economizer and air preheater. The gases exit the steam generator at this point and flow to the SCR, dust collector, ID fan, FGD system, and stack.

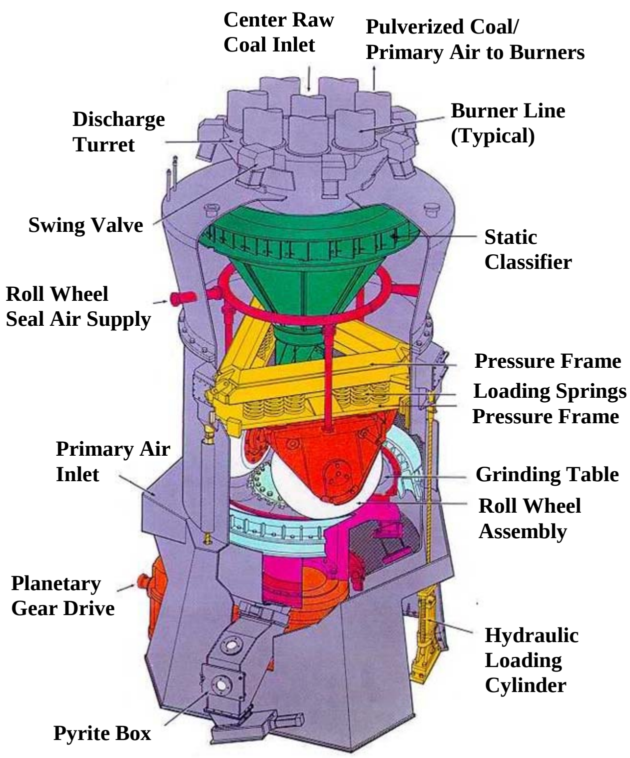
3.2.4 Fuel Feed

B&W 89G pulverizers feed the burners on the front and rear walls (Exhibit 3-2). When firing with air, coal is dried in the pulverizers and conveyed through the burner lines with air. When firing with oxygen, hot recycled gas from the primary airheater is mixed with enough O_2 to have about a 21% oxygen content (by volume dry) flowing to the pulverizers. There were three considerations for determining how much recycle gas to divert to the mills.

- Maintain an equivalent amount of heat in the gas mixture as was used during air firing. This would insure an equal amount of drying and mill outlet temperature.
- Maintain a minimum 27 ft^3 of gas per lb of coal in the mills for fineness and classifier operation.
- Maintain a minimum of 3,000 fpm burner line velocity for coal conveying.

The second and third considerations are the governing criteria since as little recycle gas as possible is needed going through the primary airheater.

Exhibit 3-2
B&W Pulverizer



Source: B&W Figure

3.2.5 Ash Removal

The furnace bottom comprises several hoppers, with a clinker grinder under each hopper. The hoppers are of welded steel construction, lined with 9-inch-thick refractory. The hopper design incorporates a water-filled seal trough around the upper periphery for cooling and sealing. Water and ash discharged from the hopper pass through the clinker grinder to an ash sluice system for conveyance to hydrobins, where the ash is dewatered before it is transferred to trucks for offsite disposal. The description of the balance of the bottom ash handling system is presented in Section 3.8. The steam generator incorporates fly ash hoppers under the economizer outlet and air heater outlet.

3.2.6 Burners

A boiler of this capacity will employ approximately 24 to 36 coal burners arranged in multiple elevations. Each burner is designed as a low-NOx configuration, with staging of the coal combustion to minimize NOx formation. In addition, overfire air nozzles are provided to further stage combustion and thereby minimize NOx formation. See Section 3.2.9 for more detail on NOx control.

Oil-fired pilot torches are provided for each coal burner for ignition, warm-up and flame stabilization at startup and low loads.

3.2.7 Soot Blowers

The soot-blowing system utilizes an array of 50 to 150 retractable nozzles and lances that clean the furnace walls and convection surfaces with jets of high-pressure steam. The blowers are sequenced to provide an effective cleaning cycle depending on the coal quality and design of the furnace and convection surfaces. Electric motors drive the soot blowers through their cycles.

3.2.8 Oxycombustion Modifications

The operation of an oxygen-fired boiler with gas recirculation is essentially the same as an air fired boiler with the exception that recycled flue gas takes the place of the primary and secondary air streams. The oxygen is injected into primary and secondary streams downstream of the airheater. All equipment remains the same except for the gas cooler for condensing water from the gas to be recycled and a gas reheater downstream of the cooler. This gas reheater heats the recycle gas by 10-15°F to vaporize any water droplets before entering the fans.

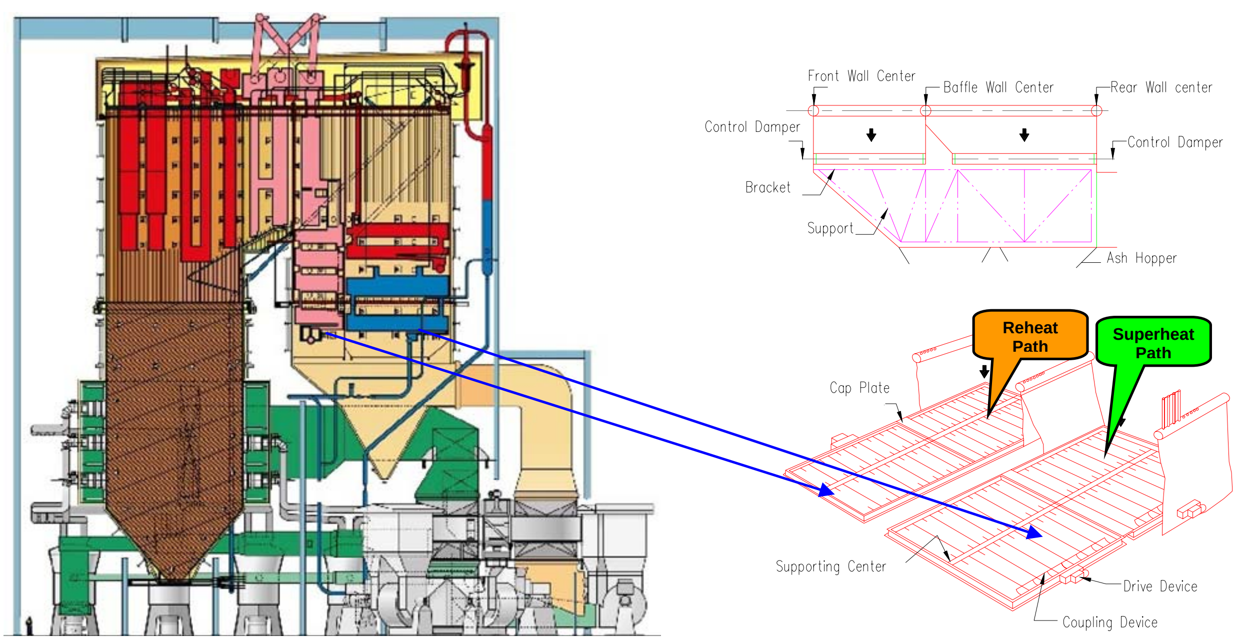
Since the flue gas is recycled and only ‘pure’ oxygen is introduced, the flue gas throughout the system contains a much higher level of CO_2 and very little nitrogen. This in itself does not pose any significant problems or differences from air firing, though it does increase emissivity which is essentially offset, in regard to heat transfer, by the change in density and resulting gas velocity. One other effect is that the concentration of all constituents will increase, relative to an air-fired unit, in the boiler and recycle gas path if not controlled. This is because the amount of oxygen entering the system is about 25% of the mass of air in an air fired unit. When all influences are considered (change in boiler efficiency, air infiltration, etc.), the concentration of the constituents in the flue gas increases by a factor of 3.4 to 3.5 (see section 3.4 Flue Gas Desulfurization for a more detailed explanation). Although this effect occurs in the recycle path, the amount of constituents leaving the system to the CO_2 Compression on a mass basis is the same as the amount of that constituent entering the boiler with the coal or produced during combustion.

The steam generating unit described herein is a Babcock & Wilcox supercritical or ultra-supercritical, once-through, spiral wound, Benson boiler. The boiler was designed to utilize coal as the main fuel. The boiler is a Carolina (two pass) design, with the primary superheater and economizer in one pass and a horizontal reheater in the other (Exhibit 3-3).

Recycled flue gas is fed to the forced draft fans, heated in the tri-sector air heaters, and distributed to the burner windboxes as the secondary air stream. The windboxes are arranged to contain the three elevations of burners and one elevation of over fire oxygen (OFO) ports comprising the advanced OFO system. A portion of the recycled gas is taken by the primary air fans which provide the required static pressure to pass this air through the air heater and pulverizers to the burners. A portion of the air (or oxygen in the oxycombustion cases) from the primary air fans is passed, unheated, around the air heater as tempering primary air. The preheated and tempering primary gas streams are mixed upstream of each pulverizer to obtain the desired fuel-air mixture temperature at the pulverizer outlet.

Within the boiler, hot flue gas from the furnace passes successively across the furnace platens, the secondary superheater and the pendant reheater located in the convection pass as it leaves the high radiant heat transfer zone of the furnace. The flue gas turns downward entering the parallel backend consisting of one flue gas pass with pendant and horizontal reheater and one flue gas pass with primary superheater and economizer surface. After the economizer, the flue gas enters the airheater and is then routed out to the flue gas clean-up equipment. The reheat steam temperature is controlled by flue gas biasing dampers at the outlet of each flue gas pass of the parallel backend. The furnace can be spiral or vertical tube geometry.

Exhibit 3-3
Side View of B&W Once Through Variable Pressure Boiler



Source: B&W Figure

3.2.9 NO_x Control System

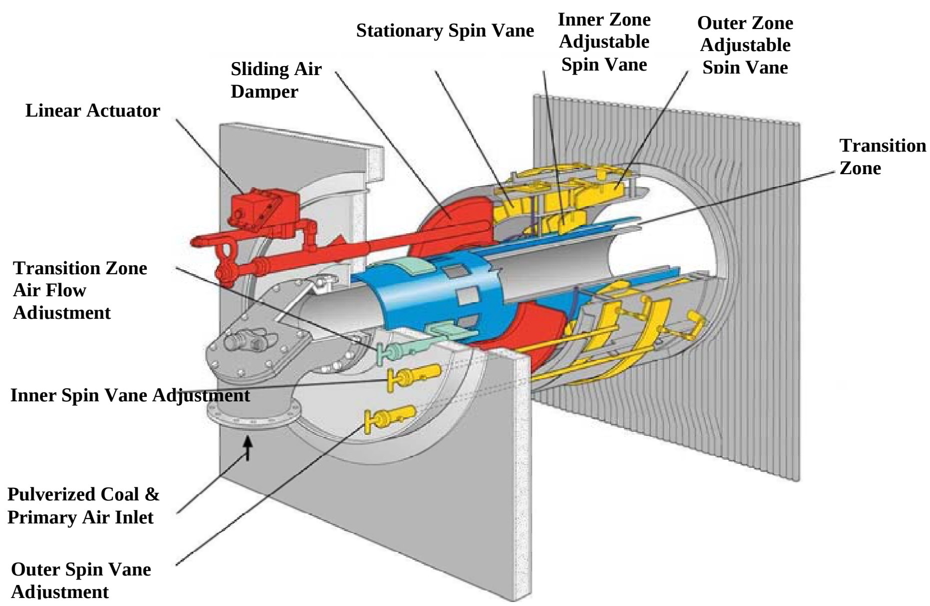
The plants were designed to achieve 0.07 lb/MMBtu NOx emissions. This was accomplished differently in the air-based cases and the oxycombustion cases.

In the air-based cases, three measures are taken to reduce the NOx. The first two are a combination of low-NOx burners and the introduction of staged overfire air in the boiler. The low-NOx burners and overfire air reduce the emissions to about 0.5 lb/MMBtu.

The third measure taken to reduce the NOx emissions is the installation of a selective catalytic reduction (SCR) system prior to the air heater. SCR uses ammonia and a catalyst to reduce NOx to N_2 and H_2O. The SCR system consists of three subsystems: reactor vessel, ammonia storage and injection, and gas flow control. The SCR system was designed for 86 percent NOx reduction while firing medium-sulfur bituminous coal. This along with the low-NOx burners and overfire air achieves the emission limit of 0.07 lb/MMBtu.

In the case of oxycombustion, the burners are B&W DRB-4Z™ low NOx burners with overfire oxygen (OFO) ports on the front and rear walls of the furnace. These state-of-the-art burners in combination with the OFO recycle gas provide the lowest possible NOx leaving the combustion zone. The burners are modified for oxygen service by incorporation of oxygen jets in the upstream ducting and the burner itself in order to deliver the required amount of oxygen to the flame. SCR is not required to meet the NOx emission limit of 0.07 lb/MMBtu in the oxycombustion cases.

Exhibit 3-4
B&W DRB 4Z™ Burner



Source: B&W Figure

3.3 PARTICULATE CONTROL

A bag house comprised of multiple filter bags is located after the air heater. The bag house is designed to achieve 99.8% removal efficiency for both air-based and oxycombustion cases and consists of two separate single-stage, in-line, and 10-compartment units. Each unit is a high air-to-cloth ratio design with a pulse-jet on-line cleaning system. The ash is collected on the outside of the 8 meter long bags, which are supported by steel cages. The dust cake is removed by a pulse of compressed air. The bag material is polyphenylensulfide (PPS) with an intrinsic Teflon (PTFE) coating [25]. Each compartment contains a number of gas passages with filter bags and heated ash hoppers supported by a rigid steel casing. The fabric filter is provided with necessary control devices, inlet gas distribution devices, insulators, inlet and outlet nozzles, expansion joints, and other items as required.

In the air-based cases, the fabric filter reduces particulate loading in the stack gas to below the required levels. It serves the same purpose in the oxycombustion cases, but in addition, the fabric filter reduces the particulate loading in the recycle stream to protect the fans. Also, since the flue gas density is higher during oxycombustion, the flue gas velocities are less than those encountered during air-based combustion, leading to greater residence time during oxycombustion, which should contribute to improving the particulate capture efficiency relative to air firing. Despite this potential improvement, the same removal efficiency was assumed for both oxycombustion and air-based cases. In the oxycombustion case, the dust cake from the bags is removed by pulse jet compressed CO_2 rich recycle gas (taken off after the wet scrubber). One final difference between the two technologies is that in the oxycombustion cases the penthouse volume is sealed with CO_2 in order to prevent air infiltration through roof penetrations. This is to prevent the introduction of nitrogen into the flue gas, which would further dilute the CO_2 product after water condensation.

3.4 FLUE GAS DESULFURIZATION

3.4.1 <u>Wet FGD Process</u>

The FGD system is very similar for both air-based combustion and oxycombustion configurations. The primary difference is that the flue gas after the FGD system in the oxycombustion cases passes through a condensing heat exchanger to remove water and then about 70% is recycled to the boiler. The recycle stream must be reheated by about 10°F to prevent entrained water droplets from passing through the primary and secondary air fans. In the air-based cases no flue gas reheat is required since the gas goes directly to the stack, which is designed to handle the saturated gas condition.

In theory, the oxycombustion cases could be designed without an FGD and the SO_2 would be co-sequestered with the CO_2 and NOx. However, since oxycombustion employs flue gas recycle,

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25 Peter Wieslanger, Fabric Filters for Power Applications, ALSTOM Power Environmental Systems AB, 2000, www.power.alstom.com

the concentrations of the constituents in the flue gas stream increase. The increase in concentration varies slightly depending on boiler efficiency (fuel flow and oxygen flow) and air infiltration, but the factor of increase is generally about 3.4 to 3.5. As a result, unless sulfur is removed from the flue gas leaving the boiler, the sulfur within the boiler and connecting ductwork in the recycle path for a 2.5% sulfur coal is equivalent to the concentration (% by mass) of a coal containing 8.7% sulfur. Since the practical design limit for the boiler materials to avoid excessive corrosion is about a 3.5% sulfur coal, a scrubber would not be required for coals with about 1% sulfur or less.

One additional benefit of the wet scrubber in the oxycombustion cases is that it cools the gas, which enters at about 355°F, to the saturation temperature of about 156°F by evaporation. The flue gas stream is further cooled to 135°F in a gas cooler to reduce moisture content in the recycle gas. A higher level of moisture in the recycle gas could affect the primary gas stream's ability to dry coal without saturating the gas in the pulverizers or burner pipes. A higher level of moisture in the secondary gas stream could inhibit the combustion process. If a scrubber is not employed, the flue gas cooler would be designed to provide recycle gas cooling from 355°F to 135°F. To avoid corrosion in the flues, fan and airheater following the scrubber and cooler, additives are used to remove 90% of the SO_3 and to enhance mercury removal, and the flue gas is reheated 10-15°F after the cooler to maintain gas temperature above the water saturation point.

The following is a general description of the auxiliary systems associated with the wet FGD tower.

3.4.1.1 System Description

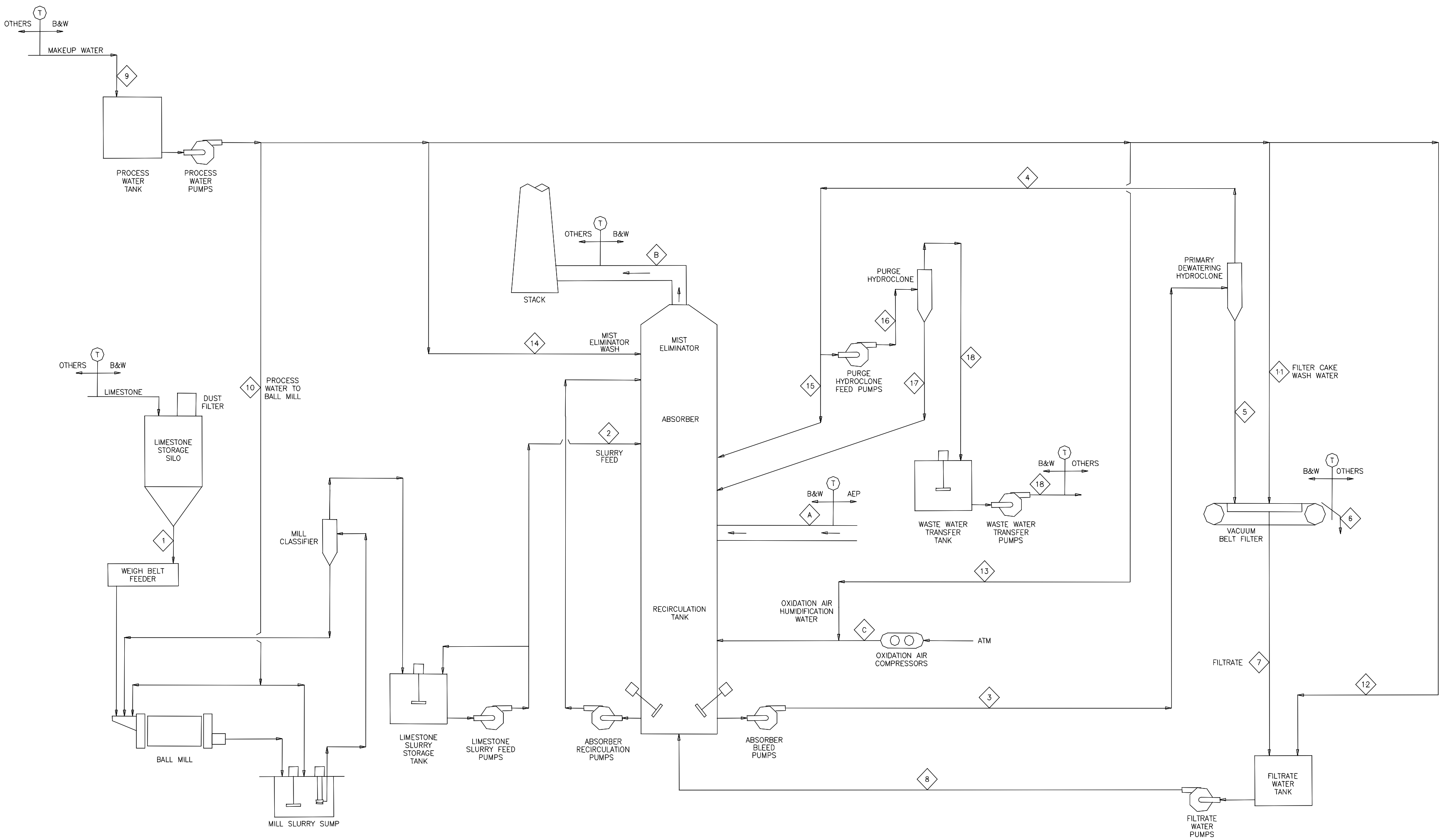
The limestone based, forced oxidation flue gas scrubbing system is designed to remove 98% of the SO_2 from the flue gas. The design incorporates features which have been developed over many years of commercial operation and pilot work in utility flue gas cleaning.

Listed below are the major items that comprise the wet FGD portion of the tower systems.

1. Limestone silos with weigh feeders, capable of supplying the required limestone to the slurry handling systems
2. Limestone preparation systems
3. Absorber
4. Cyclone separators, with spares sufficient to meet the requirements of the FGD absorber systems for gypsum slurry primary dewatering
5. Oxidation air compressors
6. Vacuum filter system

Exhibit 3-5 shows a typical wet FGD process flow diagram.

Exhibit 3-5 Typical B&W Wet FGD Process Flow Diagram



Source: B&W Figure

3.4.1.2 Absorber Tower

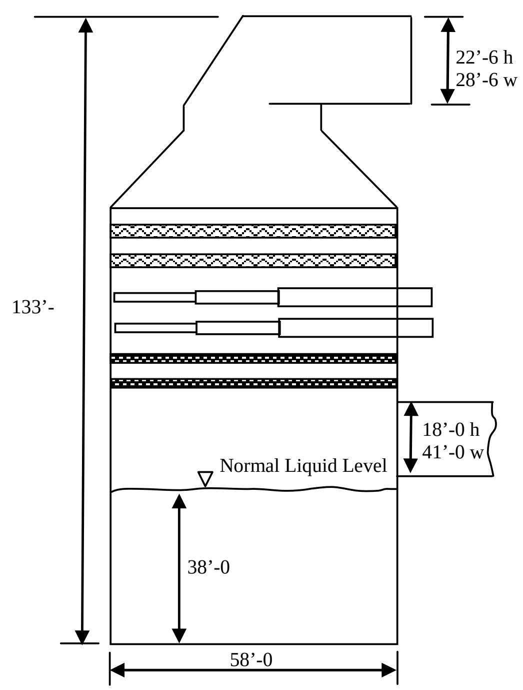
Exhibit 3-6 shows a typical wet scrubber absorber tower arrangement. The absorber tower includes two gas distribution devices (trays), two spray headers of countercurrent absorber sprays, and a two-stage mist eliminator section. As the flue gas enters the absorber, it turns upward and is evenly distributed across the absorber cross-section by the absorber tray. Experience has shown that such a gas distribution device is needed to optimize SO_2 removal. This experience parallels that of the electrostatic precipitator industry and their need for carefully designed gas distribution plates. In addition to providing an even gas flow for the main spray zone, the absorber tray also provides an area of intimate contact between the flue gas and limestone.

The gas leaving the absorber tray passes through several countercurrent spray levels, which are supplied with recirculating slurry from the absorber's reaction tank, and continues through two layers of Chevron type mist eliminators for water droplet removal before exiting the absorber tower through the outlet cone and outlet flue.

The in-situ oxidation system provides air or oxygen to the absorber reaction tank. This oxygen system forces calcium sulfite ($CaSO_3 \cdot ½H_2O$) formed by the SO_2 removal process to be oxidized to calcium sulfate ($CaSO_4 \cdot 2H_2O$). This relatively small amount of oxygen is supplied by an ambient air stream in the air-based cases and from the Air Separation Unit in the oxycombustion cases.

Absorber recirculation pumps mounted on modularized base plates provide assemblies for easy installation. The assemblies can be bolted directly to concrete foundations. Four recirculation pumps are supplied. Three are required for operation at the normal operation design point.

Exhibit 3-6 Wet Scrubber Arrangement



Source: B&W Figure

3.4.2 Limestone Preparation System

The function of the limestone handling and reagent preparation system is to receive, store, convey, and grind the limestone delivered to the plant. The scope of the system is from the storage pile up to the limestone feed system. The system is designed to support continuous baseload operation. Truck roadways, turnarounds, and unloading hoppers are included in this reference plant design.

For the purposes of this conceptual design, limestone is assumed to be delivered to the plant by 25-ton trucks. The limestone is unloaded onto a storage pile located above vibrating feeders. The limestone is fed onto belt conveyors via vibrating feeders and then to day bins equipped with vent filters. Each day bin supplies a 100 percent capacity size ball mill via a weigh feeder. The wet ball mill accepts the limestone and grinds the limestone to 90 to 95 percent passing 325 mesh (44 microns). Water is added at the inlet to the ball mill to create limestone slurry. The reduced limestone slurry is then discharged into a mill slurry tank. Mill recycle pumps, two per tank, pump the limestone water slurry to an assembly of hydrocyclones and distribution boxes. The slurry is classified into several streams, based on suspended solids content and size distribution.

The hydrocyclone underflow with oversized limestone is directed back to the mill for further grinding. The hydrocyclone overflow with correctly sized limestone is routed to a reagent storage tank. Reagent distribution pumps direct slurry from the tank to the absorber module.

3.4.3 Gypsum Dewatering

Gypsum slurry is bled from the absorber by absorber blowdown pumps that feed a primary cyclone separator which concentrates the solids of the gypsum slurry stream. Hydrocyclone overflow is gravity fed to the back to the absorber. Hydrocyclone underflow is gravity fed to the vacuum filters. Each hydrocyclone is supplied with a valve network which can isolate flow to individual hydrocyclones. To reduce the suspended solids in the system, a small volume of the hydrocyclone overflow is pumped by two purge pumps (1 operating, 1 spare) to the wastewater treatment system.

Cyclone separator underflow gravity flows to the belt vacuum filters for further dewatering. The gypsum is dewatered to 90% solids and washed to produce wallboard quality gypsum, which drops from the belt vacuum filters onto a conveying system. The vacuum receiver filtrate pumps pump the filtrate from the belt vacuum filters to the filtrate water tank. The filtrate water is recycled back to the FGD system by means of the filtrate water pumps.

One filtrate water tank is provided with minimum storage capacity of 4 hours of water usage by the absorber at full load normal operation. One wash tank for combined use of the mist eliminator wash system with a minimum storage capacity of 15 minutes is provided.

3.4.4 Mercury Removal

Removal of 90% of the mercury entering with the coal is achieved in a combination of equipment and processes. Since the Illinois No. 6 coal is relatively high in chlorine, most of the mercury entering with the coal will leave the boiler in an oxidized form (85%-90%). In the air-based cases, SCR will further promote the oxidation of Hg. Some additional oxidation will occur in the airheater, and a small portion of the mercury (oxidized and elemental) will be captured with unburned carbon in the baghouse. The majority of the oxidized mercury will be captured in the wet scrubber. An inexpensive additive is injected into the wet scrubber to enhance mercury removal and inhibit any re-emission to achieve the 90% removal rate.

3.5 AIR SEPARATION UNIT

The Air Separation Unit (ASU) is unique to the oxycombustion cases. Two different technologies are investigated: conventional cryogenic distillation producing 95 and 99 mol% oxygen and Ion Transport Membranes (ITM) producing nearly 100% pure oxygen (for this study, oxygen concentration from the ITM unit is modeled as 100%).

3.5.1 Cryogenic Distillation

The cryogenic distillation systems proposed in this study are designed and quoted using today's commercially available technology. Future improvements leading to lower O_2 cost are expected in the 2015-2020 timeframe but have not been included in this study. The ASU system description is based on the referenced Air Liquide Process & Construction, Inc. specification [26]. The equipment identification numbers are referenced to the ASU typical general layout presented in Exhibit 3-7.

3.5.1.1 Air Compression

Atmospheric air is drawn through inlet air filters (F01-1/2) to remove particulate matter. The filtered atmospheric air is then compressed by two main air compressors (C01-1/2) which are driven by electric motors. The heat of compression from the main air compressors is removed in water cooled intercoolers.

3.5.1.2 Air Pre-Cooling

Warm air from the discharge of the main air compressor is cooled in a water-wash tower (E07). Cooling water is pumped by the water wash tower pumps (P60.1/2) into the water-wash tower. Another stream of water is sent to the top of the water chiller tower (E60). In this tower (E60), cooling water is cooled against dry waste nitrogen. The resulting chilled water coming off the bottom of E60 is pumped by the water chiller pumps (P61.1/2) to the water wash tower (E07).

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26 Technical Specification and Cost Estimates, ALPC Reference No. 30258, Revision 1, American Air Liquide, Oxy-combustion Technology for CO_2 Capture in Pulverized Coal-Fired Boilers – DOE Project task 7, 13,745 MT/D Air Separation Unit, February 10, 2006.

Inside E07, warm air from the discharge of the main air compressor is cooled through direct contact with the two water streams. In addition to cooling the water, the water wash tower helps reduce or eliminate some gaseous impurities that may be present in the ambient air.

3.5.1.3 Air Purification

A front-end temperature swing adsorption-type (TSA) purification system is provided for the removal of water and carbon dioxide from the air feed. The system is made up of two radial flow bed vessels (R01/R02) containing activated alumina and molecular sieve adsorbents. By means of a set of automatically controlled switching valves, the compressed air passes alternately through one of the adsorbers or the other. This adsorption process removes moisture, carbon dioxide and some other impurities. The activated alumina removes the moisture and the molecular sieve removes the carbon dioxide contained in the air, as well as some of the other impurities. At the end of every adsorption cycle, the air stream is redirected to the other bed and the vessel containing the adsorbed impurities is regenerated by a stream of dry, heated waste nitrogen (WN2). The waste nitrogen is heated by low-pressure pressure saturated steam in a reactivation heater (E08). After it passes through the bed in regeneration, the gas is vented to the atmosphere. Once the adsorber has been heated for the desired amount of time, the vessel is cooled down and pressurized for the next adsorption phase.

3.5.1.4 Air Refrigeration

Dry compressed air exits the adsorber vessels and is split into two streams. Both enter the main heat exchanger (E01) and are cooled against the waste nitrogen and product streams to near the liquefaction temperature. After exiting the exchanger, one stream is sent directly to the bottom of the high-pressure (HP) column (K01) as feed. The second air stream liquefies against vaporizing GOX product. The liquid air stream is flashed through a valve and the resulting two-phase stream is separated into liquid and vapor streams. The vapor stream enters the LP column (K02). The liquid stream is split into two parts. One part of the stream is sent to the LP column, and the other part is sent to the HP column (K01). The refrigeration necessary for the air liquefaction is obtained by the expansion of a nitrogen stream inside the coldbox. A medium pressure gaseous nitrogen (MP GAN) stream that is extracted from the top of the HP column is sent to the main heat exchanger (E01), extracted from an intermediate location, and subsequently expanded in a nitrogen expander (ET01). This cold nitrogen stream is reintroduced to E01 to provide refrigeration to the air streams. Mechanical power obtained from the turbine is recovered in an electric generator.

3.5.1.5 Cold Production and Distillation

Air sent to the HP column is separated into an oxygen-rich liquid at the bottom and almost pure nitrogen at the top. The separation of the air is carried out in this column, as in any other rectification column, by the interaction of vapor rising with a descending stream of reflux liquid over sections of structured packing materials. The descending liquid gradually becomes rich in oxygen and, at the same time, the vapors passing through the packing lose a corresponding small amount of oxygen at each pack until, when they reach the top pack, almost pure nitrogen is obtained. The gaseous nitrogen at the top of the HP column enters the side of the main vaporizer (E02) where it is condensed by liquid oxygen boiling on the other side of the heat transfer surface. The resulting liquid nitrogen falls by gravity from the top of the HP column where it acts as pure reflux. A liquid nitrogen stream is withdrawn from the top of the HP column and sent to the top of the LP column as reflux. Additionally, rich liquid is withdrawn from the bottom of the HP column and expanded to the LP column as feed. The rectification in the LP column is the same as that in the HP column. Impure liquid nitrogen and oxygen-rich liquids are fed into the appropriate levels of the LP column. Liquid arriving at the bottom is almost entirely oxygen (95% or 99% purity). The reboil duty for the LP column is provided by the main vaporizer, which by vaporizing liquid oxygen condenses the pure nitrogen at the top of the HP column. The main vaporizer is a bath-type vaporizer submerged in liquid oxygen drained from the bottom of the LP column. Liquid oxygen (LOX) is extracted from the bottom of the LP column, vaporized, then warmed in the main heat exchanger (E01) and exits the coldbox as GOX product. Low-pressure waste nitrogen gas (WN2) is extracted at the top of the LP then sent through the main heat exchanger (E01) where it cools down the incoming air. Part of the stream is then used to chill water in the nitrogen chiller tower (E60) while the remaining portion is sent to the steam reactivation heater (E08) and subsequently used to regenerate the adsorbers.

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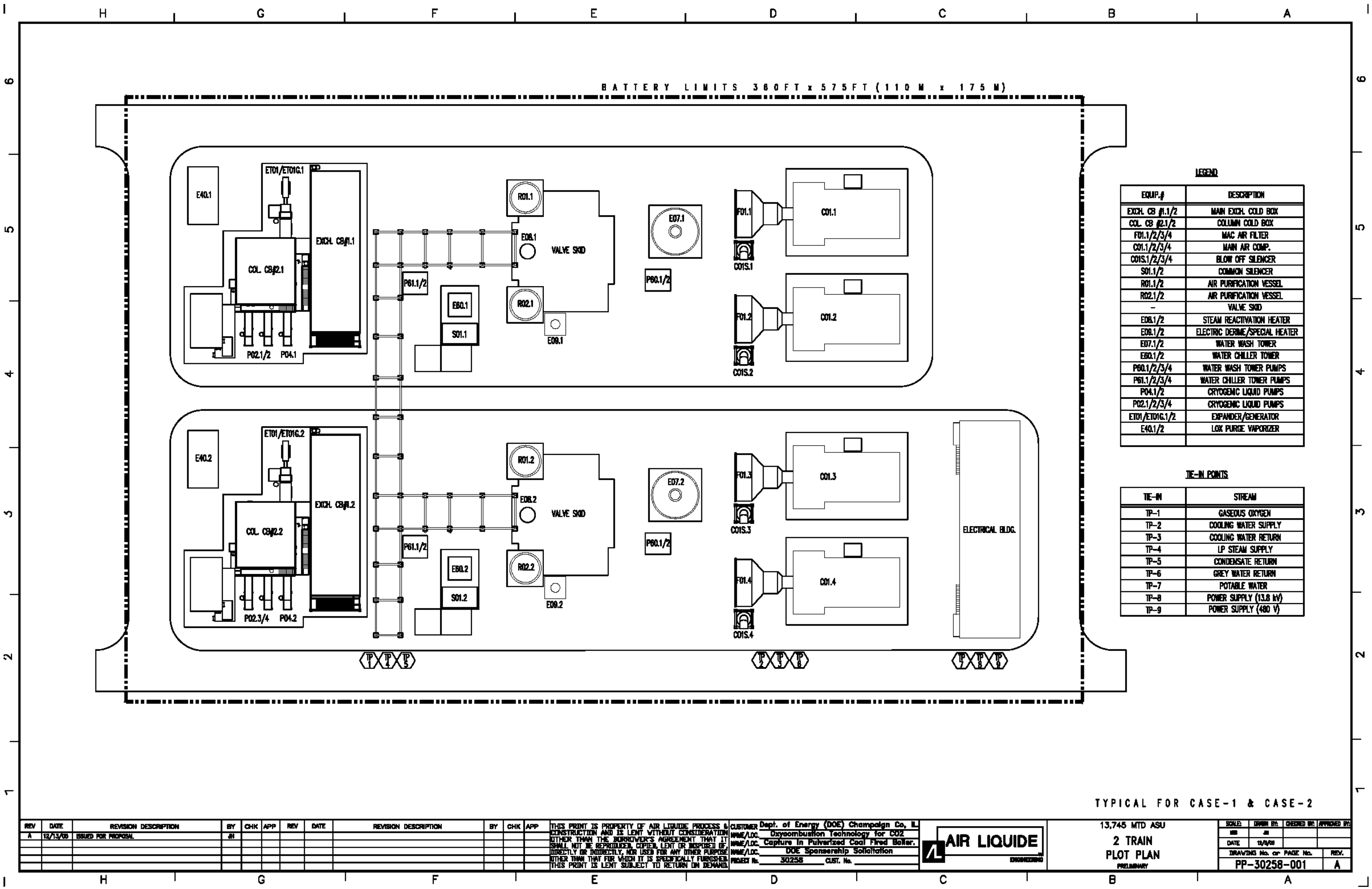
Exhibit 3-7 Air Liquide ASU Typical Plot Plan



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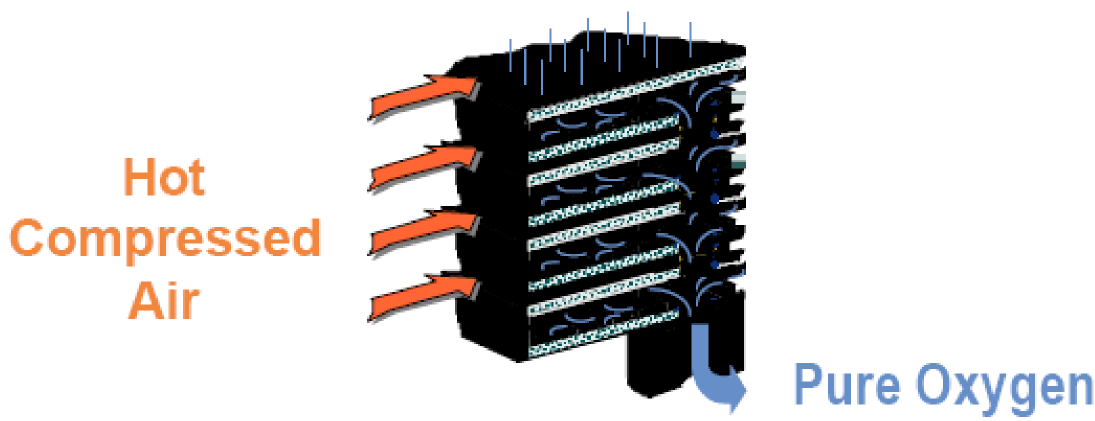
3.5.2 ITM Oxygen Plant

The ITM oxygen process is based on highly selective ceramic membranes. The ceramic materials used for this application have a high flux and selectivity to oxygen. High temperature air (> 1470°F) is introduced into the membrane module (wafer stack), and the oxygen in the air is ionized on the surface of the ceramic and diffuses through the membrane as oxygen ions, forming oxygen molecules on the other side. Impurities, such as nitrogen and argon, are rejected by the membrane. The hot oxygen product stream is nearly 100% pure, and for modeling purposes in this study was assumed to be 100% pure. The remaining gas is a pressurized, oxygen-depleted stream from which significant amounts of energy can be extracted. A conceptual schematic of the ITM membrane is shown in Exhibit 3-8 [27].

Exhibit 3-8 Process Schematic of ITM Oxygen Process



Integration of the ITM oxygen plant is critical to an optimized oxycombustion process. In the cases modeled for this study (Cases 7 and 7A) ambient air is compressed to 200 psia and then preheated to 1060°F in a shell and tube heat exchanger using the oxygen-depleted air from the ITM plant as the heat source. The air stream is further heated to 1475°F using a natural gas-fired direct contact heater. The pure oxygen product is recovered at 1475°F and sub-atmospheric pressure (10 psia). Approximately 70% of the incoming oxygen can be recovered in the ITM process. The vitiated air stream, after being used to preheat the incoming ambient air, is passed through an expansion turbine to recover nearly 200 MW of power and then vented to atmosphere.

The pure oxygen product stream is cooled to 95°F using a direct contact cooler, compressed to 15.2 psia, combined with the flue gas recycle stream and fed to the inlets of the primary and secondary air fans. The oxygen content of the combined oxygen/flue gas recycle stream is nearly 28 mol%.

27 "ITM Oxygen for Gasification", Air Products and Chemicals, Inc., Gasification Technologies 2004, Washington, DC, http://www.gasification.org/Docs/2006_Papers/54ARMS.pdf, October 2004

3.6 CARBON DIOXIDE RECOVERY FACILITY

The CO_2 recovery facility for the air-based systems consists of the Fluor Econamine FG Plus system followed by compression and drying (Cases 3 and 4) and for the oxycombustion configurations consists of condensation, purification (in some cases), drying and compression.

3.6.1 Econamine FG Plus

The Econamine FG Plus technology is designed to remove 90% of the CO_2 in the flue gas exiting the FGD unit, purify it, and compress to a supercritical condition. The carbon dioxide recovery (CDR) unit is comprised of a flue gas supply and cooling system, SO_2 polishing, CO_2 absorption system, solvent stripping and reclaiming system, and CO_2 compression and drying system.

The CO_2 absorption/stripping/solvents reclaim process for the Cases 3 and 4 plant design is based on the Fluor Econamine FG Plus technology [28]. The Econamine FG Plus flow sheet is shown in Exhibit 3-9. The Econamine FG Plus process uses a formulation of monethanolamine (MEA) containing proprietary activators and inhibitors added to improve CO_2 absorption mass transfer and to inhibit corrosion and amine degradation. This process is designed to recover high-purity CO_2 from low-pressure streams that contain oxygen, such as flue gas from coal-fired power plants, gas turbine exhaust gas, and other waste gases.

3.6.1.1 SO_2 Polishing and Flue Gas Cooling and Supply

To prevent the accumulation of heat stable salts, the incoming flue gas must have an SO_2 concentration of 10 ppmv or less. The gas exiting the FGD system passes through an SO_2 polishing step to achieve this objective. The polishing step consists of a non-plugging, low-differential-pressure, spray-baffle-type scrubber using a 20 wt% solution of sodium hydroxide (NaOH). A removal efficiency of about 75 percent is necessary to reduce SO_2 emissions from the FGD outlet to 10 ppmv as required by the Econamine process. The polishing scrubber proposed for this application has been demonstrated in numerous industrial applications throughout the world and can achieve removal efficiencies of over 95 percent if necessary.

The polishing scrubber also serves as the flue gas direct contact cooling system (DCC). Cooling water from the PC plant is used to reduce the temperature and hence moisture content of the saturated flue gas exiting the FGD system. Flue gas is cooled beyond the CO_2 absorption process requirements to 32°C (90°F) to account for the subsequent flue gas temperature increase of about 17°C (30°F) in the flue gas blower. Downstream from the Polishing Scrubber flue gas pressure is boosted in the Flue Gas Blowers by approximately 0.014 MPa (2 psi) to overcome pressure drop in the CO_2 absorber tower.

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28 Improvement in Power Generation with Post-Combustion Capture of CO_2, IEA Greenhouse Gas R&D Programme, Report PH4/33, November 2004

Cooling water is provided from the PC plant circulating water system and returned to the PC plant cooling tower. The CDR facility requires a significant amount of cooling water for flue gas cooling, water wash cooling, absorber intercooling, reflux condenser duty, reclaimer cooling, the lean solvent cooler, and CO_2 compression interstage cooling.

3.6.1.2 CO_2 Absorption

The cooled flue gas enters the bottom of the CO_2 Absorber and flows up the tower countercurrent to a stream of lean MEA-based solvent. Approximately 90% of the CO_2 in the feed gas is absorbed into the lean solvent, and the remaining flue gas leaves the top of the absorber section and flows into the Water Wash section of the tower. The lean solvent enters the top of the absorber, absorbs the CO_2 from the flue gases and leaves the bottom of the absorber with the absorbed CO_2 as the rich amine stream.

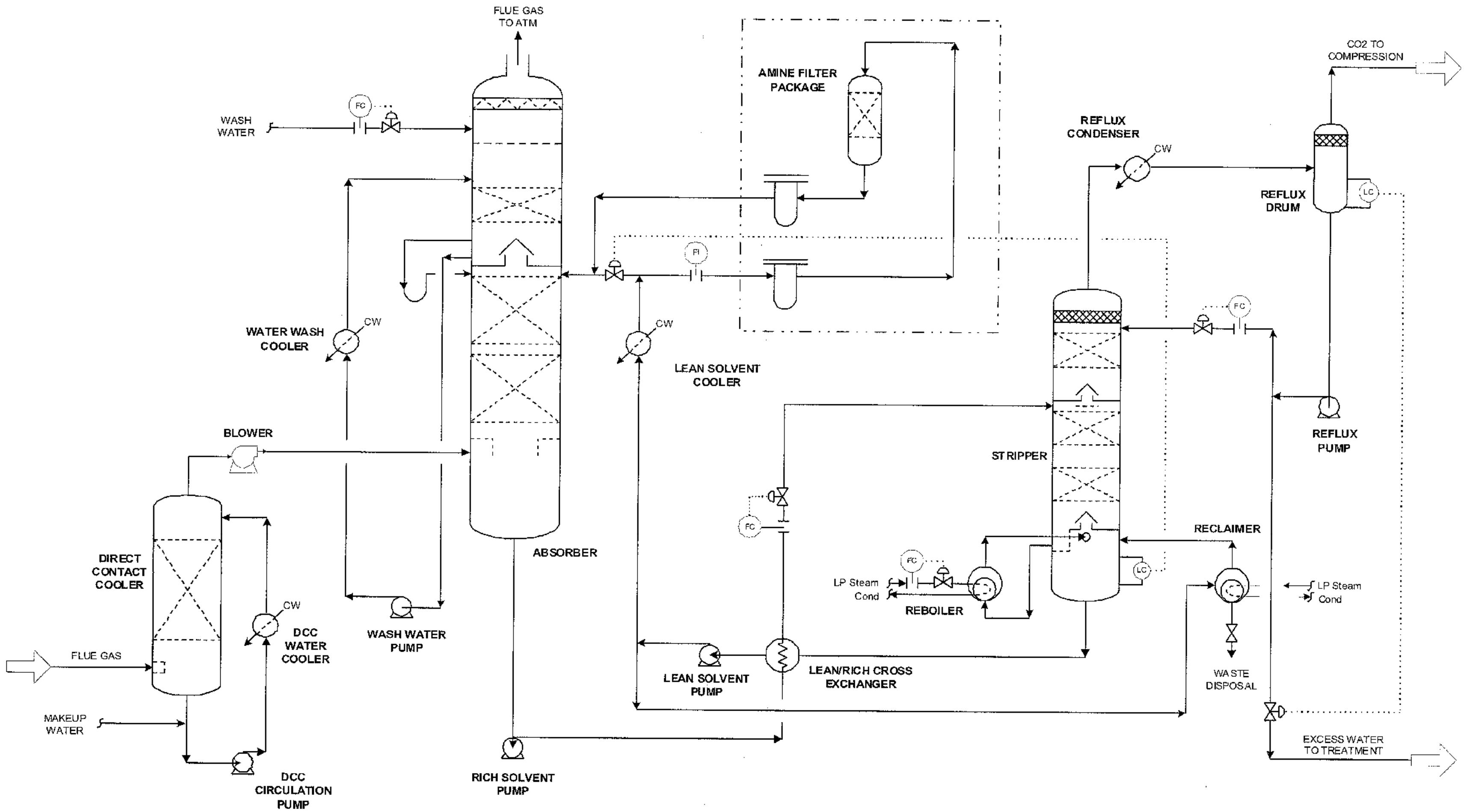
3.6.1.3 Water Wash Section

The purpose of the Water Wash section is to minimize solvent losses due to mechanical entrainment and evaporation. The flue gas from the top of the CO_2 Absorption section is contacted with a re-circulating stream of water for the removal of most of the lean solvent. The scrubbed gases exit the top of the wash section for discharge to the atmosphere via the vent stack. The water stream from the bottom of the wash section is collected on a chimney tray. A portion of the water collected on the chimney tray spills over to the absorber section as water makeup for the amine with the remainder pumped via the Wash Water Pump and cooled by the Wash Water Cooler, and recirculated to the top of the CO_2 Absorber. The wash water level is maintained by water makeup from the Wash Water Makeup Pump.

3.6.1.4 Rich/Lean Amine Heat Exchange System

The rich solvent from the bottom of the CO_2 Absorber is preheated by the lean solvent from the Solvent Stripper in the Rich Lean Solvent Exchanger. The heated rich solvent is routed to the Solvent Stripper for the removal of the absorbed CO_2. The stripped solvent from the bottom of the Solvent Stripper is pumped via the Hot Lean Solvent Pumps through the Rich Lean Exchanger to the Solvent Surge Tank. Prior to entering the Solvent Surge Tank, a slipstream of the lean solvent is pumped via the Solvent Filter Feed Pump through the Solvent Filter Package to prevent buildup of contaminants in the solution. From the Solvent Surge Tank the lean solvent is pumped via the Warm Lean Solvent Pumps to the Lean Solvent Cooler for further cooling, after which the cooled lean solvent is returned to the CO_2 Absorber, completing the circulating solvent circuit

Exhibit 3-9 Fluor Econamine FG Plus Typical Flow Diagram



3.6.1.5 Solvent Stripper

The purpose of the Solvent Stripper is to separate the CO_2 from the rich solvent feed exiting the bottom of the CO_2 Absorber. The rich solvent is collected on a chimney tray below the bottom packed section of the Solvent Stripper and routed to the Solvent Stripper Reboilers where the rich solvent is heated by steam, stripping the CO_2 from the solution. The hot wet vapor from the top of the stripper containing CO_2, steam, and solvent vapor, is partially condensed in the Solvent Stripper Condenser by cross exchanging the hot wet vapor with cooling water. The partially condensed stream then flows to the Solvent Stripper Reflux Drum where the vapor and liquid are separated. The uncondensed CO_2-rich gas is then delivered to the CO_2 product compressor. The condensed liquid from the Solvent Stripper Reflux Drum is pumped via the Solvent Stripper Reflux Pumps where a portion of condensed overhead liquid is used as make-up water for the Water Wash section of the CO_2 Absorber. The rest of the pumped liquid is routed back to the Solvent Stripper as reflux, which aids in limiting the amount of solvent vapors entering the stripper overhead system.

3.6.1.6 Solvent Stripper Reclaimer

A small slipstream of the lean solvent from the Solvent Stripper bottoms is fed to the Solvent Stripper Reclaimer for the removal of high-boiling nonvolatile impurities (heat stable salts - HSS), volatile acids and iron products from the circulating solvent solution. The solvent bound in the HSS is recovered by reaction with caustic and heating with steam. The solvent reclaimer system reduces corrosion, foaming and fouling in the solvent system. The reclaimed solvent is returned to the Solvent Stripper and the spent solvent is pumped via the Solvent Reclaimer Drain Pump to the Solvent Reclaimer Drain Tank.

3.6.1.7 Steam Condensate

Steam condensate from the Solvent Stripper Reclaimer accumulates in the Solvent Reclaimer Condensate Drum and then level controlled to the Solvent Reboiler Condensate Drum. Steam condensate from the Solvent Stripper Reboilers is also collected in the Solvent Reboiler Condensate Drum and pumped to battery limits via the Solvent Reboiler Condensate Pumps.

3.6.1.8 Corrosion Inhibitor System

A proprietary corrosion inhibitor is continuously injected into the CO_2 Absorber rich solvent bottoms outlet line, the Solvent Stripper bottoms outlet line and the Solvent Stripper top tray. This constant injection is to help control the rate of corrosion throughout the CO_2 recovery plant system.

3.6.1.9 Gas Compression and Drying System

In the compression section, the CO_2 is compressed to 15.3 MPa (2215 psia) by multi-stage centrifugal compressors including intercoolers between the compression stages. The discharge pressures of the stages are balanced to give reasonable power distribution and discharge temperatures across the various stages.

Power consumption for this large compressor was estimated assuming an adiabatic efficiency of 75 percent. During compression to 2,220 psia in the multiple-stage, intercooled compressor, the CO_2 stream is dehydrated to a dewpoint of -40°F with triethylene glycol. The virtually moisture-free supercritical CO_2 stream is then ready for pipeline transport.

3.6.2 Oxycombustion CDR System

The flue gas exiting the FGD system in the oxycombustion cases consists of between 88-96% CO_2 and H_2O and the balance is primarily nitrogen, argon and oxygen with smaller amounts of SO_2 and NOx. A portion of the water is condensed from the stream as it is cooled to 135°F, and 28-30% of the remaining gas is sent to CO_2 compression and purification, while the balance of the stream is recycled to the boiler. A small amount of SO_2 exits with the condensate (10-30 lbs/hr), but all of the NOx is assumed to remain in the vapor phase.

The CO_2 compression and purification unit system process design, description and cost information for the oxycombustion cases is based on an American Air Liquide specification [29]. Carbon dioxide compression and purification unit specifications for the study design cases are presented in Exhibit 3-10.

Exhibit 3-10 CO_2 Compression/Purification Unit Specification

Case	Product	Flow (TPD)	Pressure (psia)	Temperature (°F)	CO_2 Purity, (mol%)	CO_2 Recovery Efficiency
5	Supercritical CO_2	18,240	2,215	95	83.6	99.5
5A	Supercritical CO_2	17,577	2,215	95	87.3	99.4
5B	Supercritical CO_2	17,106	2,194	95	87.7	96.9
5C	Supercritical CO_2	15,511	2,200	95	95.8	85.5
6	Supercritical CO_2	15,805	2,200	95	83.6	99.4
6A	Supercritical CO_2	13,463	2,215	95	95.8	93.2
7	Supercritical CO_2	15,369	2,215	95	88.3	99.2
7A	Supercritical CO_2	13,503	2,215	95	97.3	92.9

To meet the above specifications, CO_2 compression and purification units were arranged by case as shown in Exhibit 3-11. Process schematics for the two types of systems (with and without purification) are shown in Exhibit 3-12 and Exhibit 3-13. Only Case 5B utilizes the bypass stream (Stream 2B in Exhibit 3-13) because the purification requirements are the least stringent

29 Technical Specification and Cost Estimates, Revision 1, American Air Liquide, Oxy-combustion Technology for CO_2 Capture in Pulverized Coal-Fired Boilers – DOE Project task 7, CO_2 Compression and Purification Unit, February 16, 2006

for that case and not all of the gas needs to be treated to achieve them. In all other purification cases the entire CO_2 stream is treated.

Exhibit 3-11 CO_2 Compression/Purification Unit Scope by Case

Case	Compression w/ Indirect Water Coolers and Drying Unit	Purification System
5	4 trains in parallel	None
5A	4 trains in parallel	None
5B	4 trains in parallel	Cold box, double-flash auto refrigeration system with bypass
5C	4 trains in parallel	Cold box, double-flash auto refrigeration system
6	3 trains in parallel	None
6A	3 trains in parallel	Cold box, double-flash auto refrigeration system
7	3 trains in parallel	None
7A	3 trains in parallel	Cold box, double flash auto refrigeration system

Exhibit 3-12 Oxycombustion CO_2 Recovery without Purification

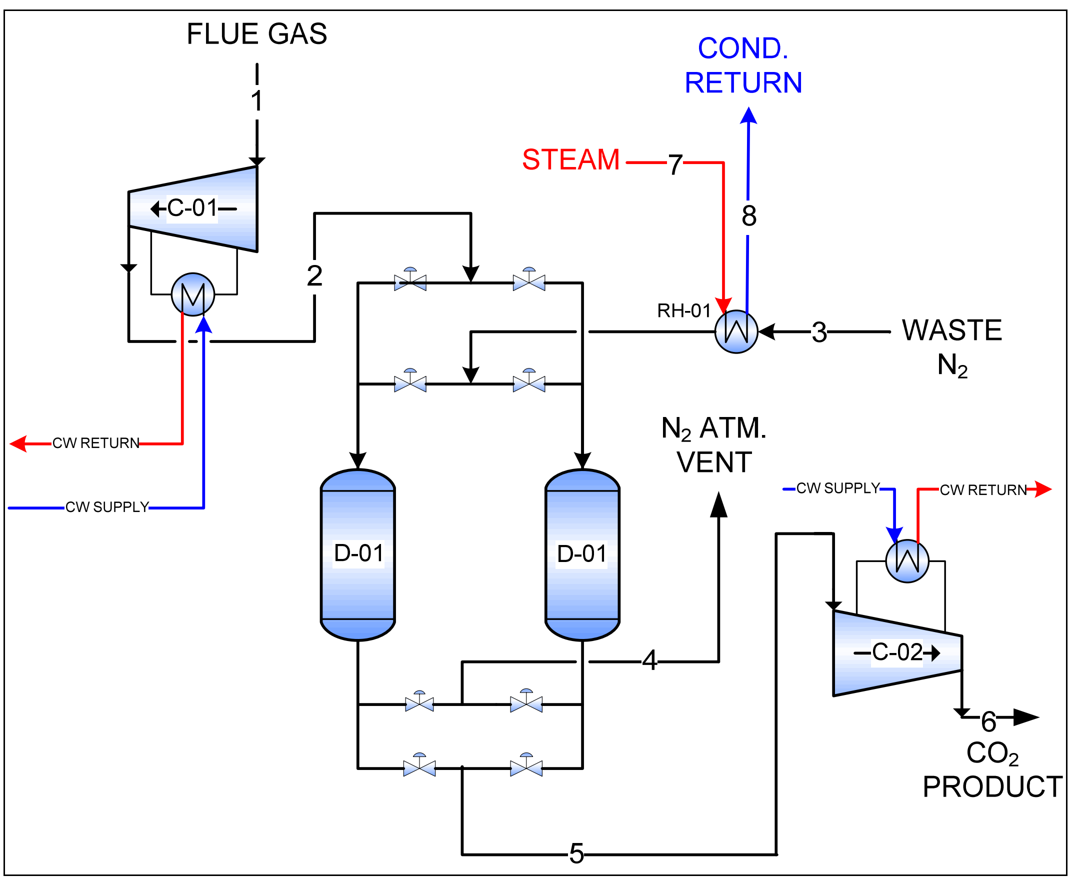
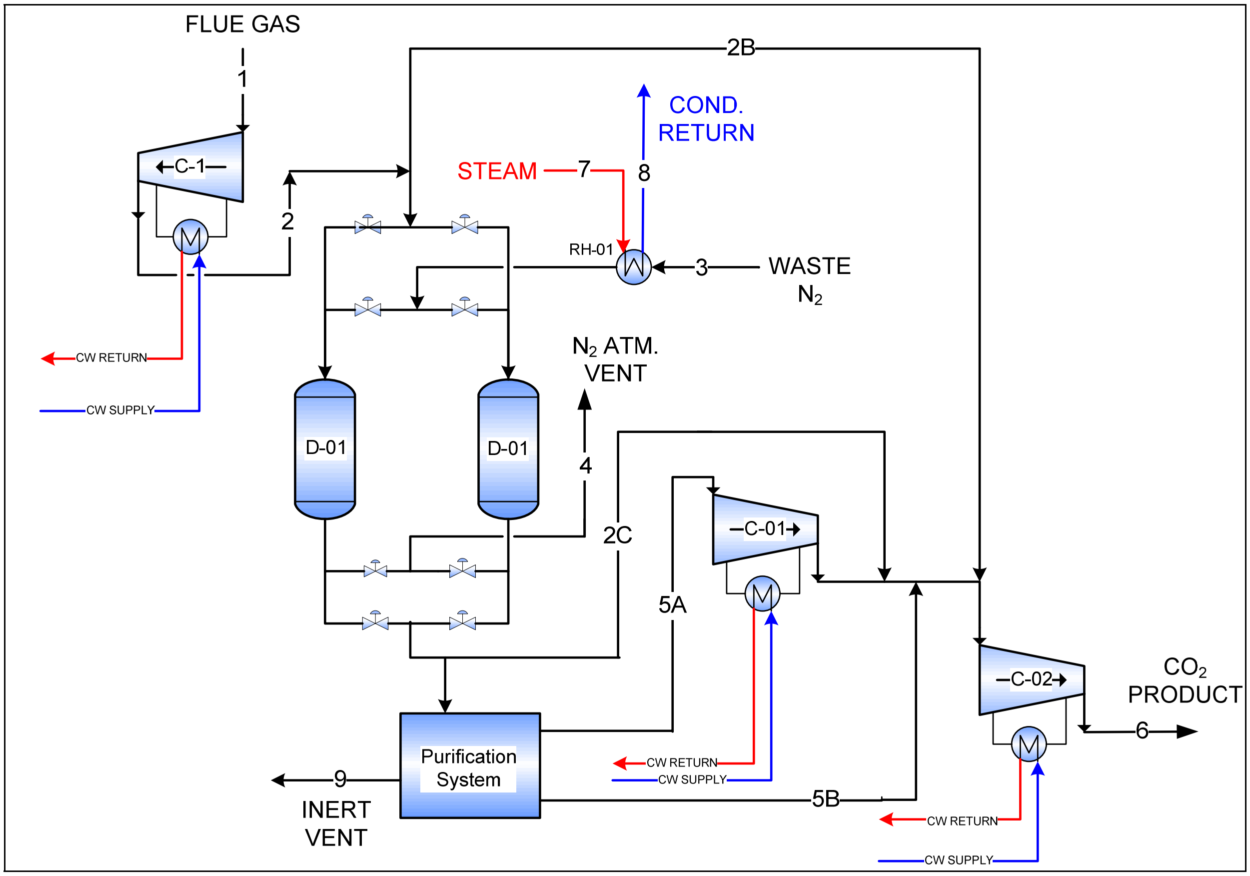


Exhibit 3-13 Oxycombustion CO_2 Recovery with Purification



The Compression/Drying system consists of LP and HP sections, four-stages each, arranged upstream and downstream from the Drying Unit. The centrifugal compressors are driven by electric motors and include intercoolers between the compression stages. The dryer unit utilizes a front end temperature swing adsorption–type (TSA) process and consists of two radial flow bed vessels (D-01) containing activated alumina adsorbents. The drying unit is regenerated by the stream of dry heated waste nitrogen from the ASU.

In cases where additional CO_2 purification is required (Exhibit 3-13) the system separates CO_2 from the inert gases using two heat exchangers operating at different pressures and temperatures. The inert gases along with air pollutants (NOx, SOx, etc.) are vented to the atmosphere. Depending on the pollutant concentrations in the inert vent stream, appropriate pollution control systems could be added if/as required. However, specified BACT emission rates were achieved for these oxycombustion cases without additional vent stream treatment.

For the cases where no additional CO_2 purification was required (Exhibit 3-12), air pollutants such as NOx and SOx were removed and compressed with the CO_2 stream.

3.7 STEAM TURBINE GENERATOR SYSTEM

The steam turbine configuration selected is the same for all supercritical and ultra-supercritical cases and is the same for air-based combustion and oxycombustion cases. Specifically, it is a tandem compound type, utilizing a single flow HP section, and double flow IP section in separate casings. These two high pressure sections are combined with the two double-flow LP sections [30]. The single reheat steam conditions are 3500 psig/1110°F/1150°F for the supercritical models, and 4000 psig/1350°F/1400°F for the ultra-supercritical models [31].

The turbine drives a hydrogen-cooled generator. The turbine has DC motor-operated lube oil pumps, and main lube oil pumps, which are driven off the turbine shaft. The turbine is designed for 582,000 to 792,000 kW (varies among cases) at the generator terminals. The exhaust pressure is 2 inch Hg in the single pressure condenser. The condenser is two-shell, transverse, single pressure with divided waterbox for each shell.

3.7.1.1 Operation Description

Main steam from the boiler passes through the stop valves and control valves and enters the turbine at 3500 psig and 1110ºF for the supercritical cases, and 4000 psig and 1350ºF for the ultra-supercritical cases. The steam initially enters the high-pressure section of the turbine, flows through the turbine, and returns to the boiler for reheating. The reheat steam flows through the reheat stop valves and intercept valves and enters the double-flow IP section at 1150ºF for the supercritical cases and 1400°F for the ultra-supercritical cases. After passing through the IP section, the steam enters crossover piping, which transports the steam to the two LP sections. The steam divides into two paths and flows through the LP sections exhausting downward into the condenser.

Turbine bearings are lubricated by a closed-loop, water-cooled pressurized oil system. Turbine shafts are sealed against air in-leakage or steam blowout using a labyrinth gland arrangement connected to a low-pressure steam seal system. The generator stator is cooled with a closed-loop water system consisting of circulating pumps, shell and tube or plate and frame type heat exchangers, filters, and deionizers, all skid-mounted. The generator rotor is cooled with a hydrogen gas recirculation system using fans mounted on the generator rotor shaft.

The turbine stop valves, control valves, reheat stop valves, and intercept valves are controlled by an electro-hydraulic control system.

3.7.1.2 Supercritical Steam Turbine Cycle

The steam turbine for the supercritical cases is equipped with six non-automatic steam extractions, which along with the HP and IP sections exhausts provide steam for four low

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30 Klaus M. Retzlaff, W. Anthony Ruegger, Steam Turbines for Ultrasupercritical Power Plants, GER-3954A, GE Power Generation, 8/96

31 “Oxyfuel Project Steam Conditions”, NETL e-mail message dated 09/22/2005

pressure feedwater heaters, deaerator and three high pressure feedwater heaters. All feedwater heaters (except the deaerator) are closed type. The condensate drains from the low pressure heater (#1 through #4) are cascaded to the condenser. The condensate drains from the high pressure heaters (#6 through #8) are cascaded to the deaerator. The deaerator storage tank provides suction to the boiler feedwater pumps. The deaerator is assumed to be placed at high elevation to assure sufficient Net Positive Suction Head (NPSH) for the feedwater pumps. Heater #7 is on cold reheat extraction and heater #8 is a heater above the reheat point (HARP).

3.7.1.3 Ultra-supercritical Steam Turbine Cycle

The steam turbine for the ultra-supercritical cases is equipped with seven non-automatic steam extractions, which along with the HP and IP sections exhausts provide steam for five low pressure feedwater heaters, deaerator, three high pressure feedwater heaters and a topping desuperheater. The condensate drain flow from the feedwater heater #1 is cascaded back to the condenser. Feedwater heater #2 has a heater drip pump to push the drain flow into the condensate to the heater #3, while condensate drip flow from the heater #3 is cascaded to the heater #2. Feedwater heater #4 is an open type heater and supplies the booster pump suction. Heater #5 is after the booster pump and its drains are cascaded to heater #4. Heater #6 is the deaerator operating at 170 psig. The boiler feedwater pumps are before the heater #7. Heater #8 is on cold reheat extraction, and heater #9 is a heater above reheat point (HARP). The topping desuperheater (#10) is a non-condensing steam to water heat exchanger. It is installed in the main feedwater line downstream of the highest pressure feedwater heater (#9). Extraction steam from the first extraction of the IP turbine is routed to this desuperheater, and steam leaving the desuperheater is fed to the feedwater heater #7.

3.8 BALANCE OF PLANT

3.8.1 Condensate

The function of the condensate system is to pump condensate from the condenser hotwell to the deaerator, through the gland steam condenser and the LP feedwater heaters. Condensate system for supercritical designs consists of one main condenser; two 50 percent capacity, variable speed electric motor-driven vertical condensate pumps; one gland steam condenser; four LP heaters; and one deaerator with storage tank. Condensate system for the ultra-supercritical designs consists of one main condenser; two 50 percent capacity, variable speed electric motor-driven vertical condensate pumps; one gland steam condenser; five LP heaters (four closed type and one - #4 open type); condensate booster pumps, heater drip pumps and one deaerator with storage tank.

In the supercritical designs condensate is delivered to a common discharge header through two separate pump discharge lines, each with a check valve and a gate valve. A common minimum flow recirculation line discharging to the condenser is provided downstream of the gland steam condenser to maintain minimum flow requirements for the gland steam condenser and the condensate pumps.

LP feedwater heaters 1 through 4 are 50 percent capacity, parallel flow, and are located in the condenser neck. All remaining feedwater heaters are 100 percent capacity shell and U-tube heat exchangers. Each LP feedwater heater is provided with inlet/outlet isolation valves and a full capacity bypass. LP feedwater heater drains cascade down to the next lowest extraction pressure heater and finally discharge into the condenser. Pneumatic level control valves control normal drain levels in the heaters. High heater level dump lines discharging to the condenser are provided for each heater for turbine water induction protection. Pneumatic level control valves control dump line flow.

The ultra-supercritical designs are similar to the supercritical designs, except the feedwater heater #2 has a heater drip pump to push the drain flow into the condensate to the heater #3, and the feedwater heater #4 is an open type heater that supplies the booster pump suction.

3.8.2 Feedwater

The function of the feedwater system is to pump the feedwater from the deaerator storage tank through the HP feedwater heaters to the boiler economizer. One turbine-driven boiler feed pump sized at 100 percent capacity is provided to pump feedwater through the HP feedwater heaters. One 30 percent motor-driven boiler feed pump is provided for startup. The pumps are provided with inlet and outlet isolation valves, and individual minimum flow recirculation lines discharging back to the deaerator storage tank. The recirculation flow is controlled by automatic recirculation valves, which are a combination check valve in the main line and in the bypass, bypass control valve, and flow sensing element. The suction of the boiler feed pump is equipped with startup strainers, which are utilized during initial startup and following major outages or system maintenance.

Each HP feedwater heater is provided with inlet/outlet isolation valves and a full capacity bypass. Feedwater heater drains cascade down to the next lowest extraction pressure heater and finally discharge into the deaerator. Pneumatic level control valves control normal drain level in the heaters. High heater level dump lines discharging to the condenser are provided for each heater for turbine water induction protection. Dump line flow is controlled by pneumatic level control valves.

The ultra-supercritical designs are equipped with a topping desuperheater. Its purpose is to improve cycle heat rate and reduce the thermal impact on the lower stage high pressure feedwater heater. The topping desuperheater is a dry non-condensing type steam to water heat exchanger. Steam exiting the topping desuperheater is used in the lower stage feedwater heating. The topping desuperheater and its lower stage feedwater heater are designed to operate together and need no additional controls or valves [32].

The deaerator is a horizontal, spray tray type with internal direct contact stainless steel vent condenser and storage tank. The boiler feed pump turbine is driven by main steam up to 60 percent plant load. Above 60 percent load, extraction from the IP turbine exhaust provides steam to the boiler feed pump steam turbine.

32 R.D. Hottenstine, N.A. Phillips, and R.L. Dail, Development Plan for Advanced Fossil Fuel Plants, prepared by Gilbert Associates, Inc. for EPRI, EPRI CS-4029, Final report, May 1985.

3.8.3 Main and Reheat Steam

The function of the main steam system is to convey main steam from the boiler superheater outlet to the HP turbine stop valves. The function of the reheat system is to convey steam from the HP turbine exhaust to the boiler reheater and from the boiler reheater outlet to the IP turbine stop valves.

Main steam exits the boiler superheater through a motor-operated stop/check valve and a motor-operated gate valve, and is routed in a single line feeding the HP turbine. A branch line off the IP turbine exhaust feeds the boiler feed water pump turbine during unit operation starting at approximately 60 percent load.

Cold reheat steam exits the HP turbine, flows through a motor-operated isolation gate valve and a flow control valve, and enters the boiler reheater. Hot reheat steam exits the boiler reheater through a motor-operated gate valve and is routed to the IP turbine.

3.8.4 Extraction Steam

The function of the extraction steam system is to convey steam from turbine extraction points to the feedwater heaters.

The turbine is protected from overspeed on turbine trip, from flash steam reverse flow from the heaters through the extraction piping to the turbine. This protection is provided by positive closing, balanced disc non-return valves located in all extraction lines except the lines to the LP feedwater heaters in the condenser neck. The extraction non-return valves are located only in horizontal runs of piping and as close to the turbine as possible.

The turbine trip signal automatically trips the non-return valves through relay dumps. The remote manual control for each heater level control system is used to release the non-return valves to normal check valve service when required to restart the system.

3.8.5 Circulating Water System

It is assumed that the plant is serviced by a public water facility and has access to groundwater for use as makeup cooling water with minimal pretreatment. All filtration and treatment of the circulating water are conducted on site. A mechanical draft, counter-flow cooling tower is provided for the circulating water heat sink. Two 50 percent circulating water pumps are provided. The circulating water system provides cooling water to the condenser, the Econamine process (cases 3 and 4) and the auxiliary cooling water system.

The auxiliary cooling water system is a closed-loop system. Plate and frame heat exchangers with circulating water as the cooling medium are provided. This system provides cooling water to the lube oil coolers, turbine generator, boiler feed pumps, etc. All pumps, vacuum breakers, air release valves, instruments, controls, etc. are included for a complete operable system.

3.8.6 Ash Handling System

The function of the ash handling system is to provide the equipment required for conveying, preparing, storing, and disposing of the fly ash and bottom ash produced on a daily basis by the boiler. The scope of the system is from the bag house hoppers, air heater hopper collectors, and bottom ash hoppers to the hydrobins (for bottom ash) and truck filling stations (for fly ash). The system is designed to support short-term operation at the 5 percent OP/VWO condition (16 hours) and long-term operation at the 100 percent guarantee point (90 days or more).

The fly ash collected in the bag house and in the air heaters is conveyed to the fly ash storage silo. A pneumatic transport system using low-pressure air from a blower provides the transport mechanism for the fly ash. Fly ash is discharged through a wet unloader, which conditions the fly ash and conveys it through a telescopic unloading chute into a truck for disposal.

The bottom ash from the boiler is fed into a clinker grinder. The clinker grinder is provided to break up any clinkers that may form. From the clinker grinders the bottom ash is sluiced to hydrobins for dewatering and offsite removal by truck.

Ash from the economizer hoppers and pyrites (rejected from the coal pulverizers) is conveyed by hydraulic means (water) to the economizer/pyrites transfer tank. This material is then sluiced, on a periodic basis, to the hydrobins.

3.8.7 Ducting and Stack

One stack is provided with a single fiberglass-reinforced plastic (FRP) liner. The stack is constructed of reinforced concrete. For the air-based cases, the stack is 500 feet high for adequate particulate dispersion. It has one FRP stack liner that is 17 to 19 feet in diameter. For the oxycombustion with CO_2 capture cases, the stack size is reduced to 150 feet high and 10 to 11 feet in diameter. The stack for the oxycombustion with CO_2 capture cases is needed for startup and venting of gases released in the CO_2 purification process.

3.8.8 Waste Treatment/Miscellaneous Systems

An onsite water treatment facility will treat all runoff, cleaning wastes, blowdown, and backwash to within the U.S. Environmental Protection Agency (EPA) standards for suspended solids, oil and grease, pH, and miscellaneous metals. Waste treatment equipment is housed in a separate building. The waste treatment system consists of a water collection basin, three raw waste pumps, an acid neutralization system, an oxidation system, flocculation, clarification/thickening, and sludge dewatering. The water collection basin is a synthetic-membrane-lined earthen basin, which collects rainfall runoff, maintenance cleaning wastes, and backwash flows.

The raw waste is pumped to the treatment system at a controlled rate by the raw waste pumps. The neutralization system neutralizes the acidic wastewater with hydrated lime in a two-stage system, consisting of a lime storage silo/lime slurry makeup system with 50-ton lime silo, 0 to 1,000 lb/h dry lime feeder, 5,000-gallon lime slurry tank, slurry tank mixer, and 25 gpm lime slurry feed pumps.

The oxidation system consists of a 50 scfm air compressor, which injects air through a sparger pipe into the second-stage neutralization tank. The flocculation tank is fiberglass with a variable speed agitator. A polymer dilution and feed system is also provided for flocculation. The clarifier is a plate-type, with the sludge pumped to the dewatering system. The sludge is dewatered in filter presses and disposed offsite. Trucking and disposal costs are included in the cost estimate. The filtrate from the sludge dewatering is returned to the raw waste sump.

Miscellaneous systems consisting of fuel oil, service air, instrument air, and service water are provided. A 300,000-gallon storage tank provides a supply of No. 2 fuel oil used for startup and for a small auxiliary boiler. Fuel oil is delivered by truck. All truck roadways and unloading stations inside the fence area are provided.

3.8.9 Buildings and Structures

A soil-bearing load of 5,000 lb/ft^2 is used for foundation design. Foundations are provided for the support structures, pumps, tanks, and other plant components. The following buildings are included in the design basis:

- Steam turbine building
- Boiler building
- Administration and service building
- Makeup water and pretreatment building
- Fuel oil pump house
- Coal crusher building
- Continuous emissions monitoring building
- Pump house and electrical equipment building
- Guard house
- Runoff water pump house
- Industrial waste treatment building
- FGD system buildings

3.8.10 Accessory Electric Plant

The accessory electric plant is the same for all cases and consists of switchgear and control equipment, generator equipment, station service equipment, conduit and cable trays, and wire and cable. It also includes the main power transformer, required foundations, and standby equipment.

3.8.11 Instrumentation and Control

An integrated plant-wide control and monitoring distributed control system (DCS) is provided for all cases. The DCS is a redundant microprocessor-based, functionally distributed system. The control room houses an array of multiple video monitor and keyboard units. The monitor/keyboard units are the primary interface between the generating process and operations personnel. The DCS incorporates plant monitoring and control functions for all the major plant equipment. The DCS is designed to provide 99.5 percent availability. The plant equipment and the DCS are designed for automatic response to load changes from minimum load to 100 percent. Startup and shutdown routines are implemented as supervised manual, with operator selection of modular automation routines available.

4. AIR-BASED PULVERIZED COAL RANKINE CYCLE PLANTS

The four air-based pulverized coal (PC)-fired plants described in this section are reference cases for comparison to the oxycombustion cases presented in Sections 5 and 6. The four cases are:

Case 1 – Supercritical PC without CO_2 capture

Case 2 – Ultra-supercritical PC without CO_2 capture

Case 3 – Supercritical PC with amine scrubbing CO_2 capture

Case 4 – Ultra-supercritical PC with amine scrubbing CO_2 capture

4.1 PLANT CONFIGURATION SUMMARY

Four PC Rankine cycle power plant configurations were evaluated and are presented in this section. Two of the cases are supercritical PC-fired plants, one with CO_2 capture and one without. The second two cases are identical except that an ultra-supercritical steam cycle is utilized.

The evaluation scope included developing heat and mass balances and estimating plant performance on a common a 550 MWe net output basis while firing bituminous Illinois No. 6 coal. Equipment lists were developed for each design to support plant capital and operating costs estimates. A summary of the cases evaluated in this section is presented in Exhibit 4-1.

Exhibit 4-1 PC Plant Configuration Summary

Case	Boiler	Steam psig/°F/°F	Oxidant	NOx Control	Sulfur Control	CO_2 Purity	Intended Storage
1	Wall-fired, PC	3500/1110/1150	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	N/A	N/A
2	Wall-fired PC	4000/1350/1400	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	N/A	N/A
3	Wall-fired PC	3500/1110/1150	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	100%	Saline Formation
4	Wall-fired PC	4000/1350/1400	Air	LNB/OFA/SCR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	100%	Saline Formation

Legend:

LNB - Low NOx burner

OFA - Overfire air

FGD - Flue gas desulfurization

SCR - Selective catalytic reduction

PC - Pulverized coal

Air-based PC plants are assumed to be built on a "green-field" site and utilize recirculating evaporative cooling systems for cycle heat rejection. Major systems for each plant (described in Section 3) include:

1. Steam Generator
2. Steam Turbine/Generator
3. Particulate control system
4. FGD system
5. SCR system
6. CO_2 Recovery (Cases 3 and 4 only)
7. Balance of Plant

Support facilities include coal handling (receiving, crushing, storing, and drying), limestone handling (including receiving, crushing, storing, and feeding), solid waste disposal, circulating water system with evaporative mechanical draft cooling towers, wastewater treatment, and other ancillary systems equipment necessary for an efficient, highly available, and completely operable facility.

The plant designs are based on using components suitable for a 30-year life, with provision for periodic maintenance and replacement of critical parts. All equipment is based on compliance with the latest applicable codes and standards. ASME, ANSI, IEEE, NFPA, CAA, state regulations, and OSHA codes are all adhered to in the design approach.

4.2 MATERIAL AND ENERGY BALANCES

The modeling assumptions that were used to generate the air-based PC case material and energy balances are summarized in Exhibit 4-2.

Material and energy balance information, environmental performance and a major equipment list for the two non-CO_2 capture cases are summarized in Section 4.2.1. Similar information for the two cases with CO_2 capture is summarized in Section 4.2.2.

Exhibit 4-2 Air-Based Combustion Configuration Modeling Assumptions

	Case 1	Case 2	Case 3	Case 4
Throttle pressure, psig	3500	4000	3500	4000
Throttle temperature, ºF	1110	1350	1110	1350
Reheat temperature, ºF	1150	1400	1150	1400
Condenser pressure, in Hg	2	2	2	2
Cooling water to condenser, ºF	60	60	60	60
Cooling water from condenser, ºF	80	80	80	80
Stack temperature	saturation	saturation	saturation	saturation
Coal HHV (Illinois No. 6), Btu/lb	11,666	11,666	11,666	11,666
FGD efficiency	98%	98%	98%	98%
SOx emissions, lb/MMBtu	0.1	0.1	0.1	0.1
SCR efficiency	86%	86%	86%	86%
NOx emissions, lb/MMBtu	0.07	0.07	0.07	0.07
Ammonia slip (end of catalyst life), ppm	2	2	2	2
Baghouse efficiency	99.8%	99.8%	99.8%	99.8%
Particulate emissions PM/PM_{10}, lb/MMBtu	0.015	0.015	0.015	0.015
Mercury removal, %	90	90	90	90
CO_2 Capture Efficiency*, %	N/A	N/A	90	90
Product CO_2 Condition, psia/°F	N/A	N/A	2215/95	2215/95

* Percentage of CO_2 in flue gas

4.2.1 Air-Fired Cases without CO_2 Capture Performance Results

A process block flow diagram for Cases 1 and 2 is shown in Exhibit 4-3 and the corresponding stream tables are contained in Exhibit 4-4 and Exhibit 4-5. The heat and mass balance diagrams, including the steam cycle, are shown in Exhibit 4-6 and Exhibit 4-7. These two cases represent air-based supercritical and ultra-supercritical steam cycles with no CO_2 capture.

Overall performance for Cases 1 and 2 is summarized in Exhibit 4-8 which includes auxiliary power requirements.

4.2.1.1 Environmental Performance for Cases 1 and 2

Each case was designed to meet presumptive BACT standards utilizing the emissions control processes described in Section 2.5. A summary of plant air emissions is presented in Exhibit 4-9.

SO_2 emissions are controlled using a wet limestone forced oxidation scrubber that achieves a removal efficiency of 98%. The byproduct calcium sulfate is dewatered and stored on site. The wallboard grade material can potentially be marketed and sold, but since it is highly dependent on local market conditions, no byproduct credit was taken. The saturated flue gas exiting the scrubber is vented through the plant stack.

NOx emissions are controlled to about 0.5 lb/10^6 Btu through the use of LNBs and OFA. An SCR unit then further reduces the NOx concentration by 86% to 0.07 lb/10^6 Btu.

Particulate emissions are controlled using a pulse jet fabric filter (baghouse) which operates at an efficiency of 99.8%. It was assumed that 20% of the ash exits the boiler as bottom ash and the remaining 80% exits the boiler in the flue gas [33].

Co-benefit capture of Hg in the fabric filter and FGD system was assumed to achieve a 90% capture rate [34]. The high chlorine content of the Illinois No. 6 coal and the SCR system will convert most of the Hg in the system to an oxidized state [35]. The addition of an inexpensive additive to the FGD system can be used to promote Hg capture if necessary, but was not included in this study.

33 Coal Utilization By Products - Clean Coal Technologies Topical Report Number 24, page 8, http://www.netl.doe.gov/technologies/coalpower/cctc/topicalreports/pdfs/Topical24.pdf, August 2006.

34 Enhancing Mercury Control on Coal-Fired Boilers with SCR, Oxidation Catalyst, and FGD, Institute of Clean Air Companies (ICAC), www.icac.com.

35 Standalone Documentation for EPA Base Case 2004 (V.2.1.9) Using the Integrated Planning Model, page 5-11, EPA 430-R-05-011, September 2005.

Exhibit 4-3 Cases 1 and 2 Process Block Flow Diagram, Air-Based PC without CO_2 Capture

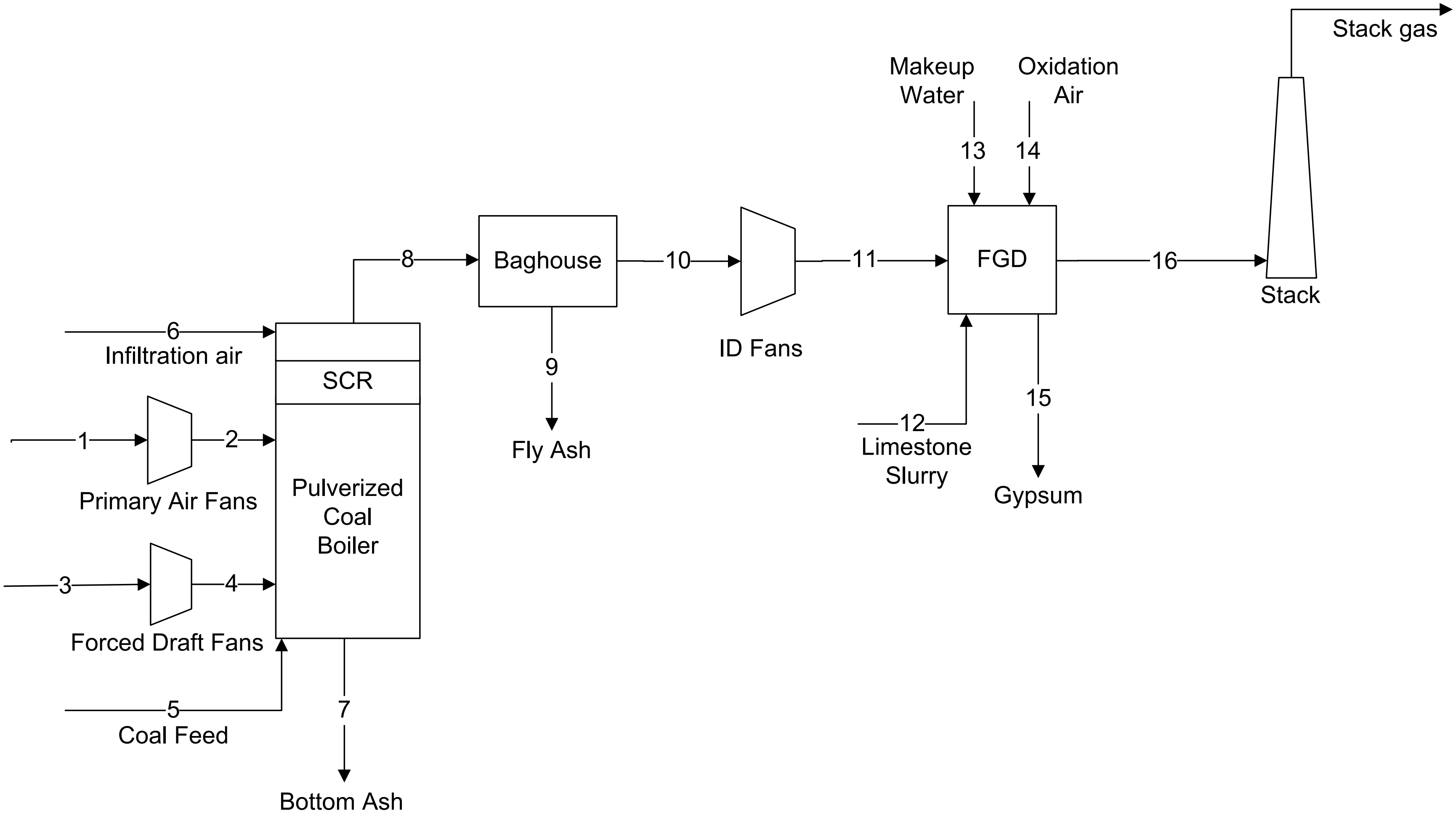

Exhibit 4-4 Case 1 Stream Table, Air-Based Supercritical PC without CO_2 Capture

	1	2	3	4	5	6	7	8
V-L Mole Fractions								
Ar	0.0092	0.0092	0.0092	0.0092	0.0000	0.0092	0.0000	0.0087
CO_2	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0000	0.1450
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0099	0.0099	0.0099	0.0099	0.0000	0.0099	0.0000	0.0870
N_2	0.7732	0.7732	0.7732	0.7732	0.0000	0.7732	0.0000	0.7324
O_2	0.2074	0.2074	0.2074	0.2074	0.0000	0.2074	0.0000	0.0247
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021
Total	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000
V-L Flow (lb_{mol}/hr)	32,868	32,868	106,995	106,995	0	2,473	0	150,560
V-L Flow (lb/hr)	948,464	948,464	3,087,550	3,087,550	0	71,355	0	4,478,120
Solids Flowrate	0	0	0	0	410,563	0	7,962	31,849
Temperature (°F)	59	78	59	66	59	59	350	350
Pressure (psia)	14.70	16.14	14.70	15.25	14.70	14.70	14.40	14.40
Enthalpy (Btu/lb)	13.13	17.66	13.13	14.90	--	13.13	--	135.64
Density (lb/ft^3)	0.076	0.081	0.076	0.078	--	0.076	--	0.049
Avg. Molecular Weight	28.86	28.86	28.86	28.86	--	28.86	--	29.74

	9	10	11	12	13	14	15	16
V-L Mole Fractions								
Ar	0.0000	0.0087	0.0087	0.0000	0.0000	0.0092	0.0000	0.0080
CO_2	0.0000	0.1450	0.1450	0.0000	0.0000	0.0003	0.0016	0.1326
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0000	0.0870	0.0870	1.0000	1.0000	0.0099	0.9976	0.1669
N_2	0.0000	0.7324	0.7324	0.0000	0.0000	0.7732	0.0008	0.6690
O_2	0.0000	0.0247	0.0247	0.0000	0.0000	0.2074	0.0000	0.0235
SO_2	0.0000	0.0021	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	0	150,560	150,560	5,236	24,211	1,779	14,115	166,886
V-L Flow (lb/hr)	0	4,478,120	4,478,120	94,335	436,167	51,348	254,984	4,782,320
Solids Flowrate	31,849	0	0	40,748	0	0	63,419	0
Temperature (°F)	350	350	370	59	59	59	134	134
Pressure (psia)	14.20	14.20	15.26	14.70	14.70	14.70	14.70	14.70
Enthalpy (Btu/lb)	--	136.24	141.47	--	32.36	13.13	86.96	138.12
Density (lb/ft^3)	--	0.049	0.051	62.622	62.622	0.076	36.294	0.066
Avg. Molecular Weight	--	29.74	29.74	18.02	18.02	28.86	18.06	28.66

Exhibit 4-5 Case 2 Stream Table, Air-Based Ultra-Supercritical PC without CO_2 Capture

	1	2	3	4	5	6	7	8
V-L Mole Fractions								
Ar	0.0092	0.0092	0.0092	0.0092	0.0000	0.0092	0.0000	0.0087
CO_2	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0000	0.1449
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0099	0.0099	0.0099	0.0099	0.0000	0.0099	0.0000	0.0869
N_2	0.7732	0.7732	0.7732	0.7732	0.0000	0.7732	0.0000	0.7325
O_2	0.2074	0.2074	0.2074	0.2074	0.0000	0.2074	0.0000	0.0248
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021
Total	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000
V-L Flow (lb_{mol}/hr)	29,204	29,204	95,070	95,070	0	2,196	0	133,772
V-L Flow (lb/hr)	842,751	842,751	2,743,420	2,743,420	0	63,357	0	3,978,730
Solids Flowrate	0	0	0	0	364,547	0	7,070	28,280
Temperature (°F)	59	78	59	66	59	59	350	350
Pressure (psia)	14.70	16.14	14.70	15.25	14.70	14.70	14.40	14.40
Enthalpy (Btu/lb)	13.13	17.66	13.13	14.90	--	13.13	--	135.61
Density (lb/ft^3)	0.076	0.081	0.076	0.078	--	0.076	--	0.049
Avg. Molecular Weight	28.86	28.86	28.86	28.86	--	28.86	--	29.74

	9	10	11	12	13	14	15	16
V-L Mole Fractions								
Ar	0.0000	0.0087	0.0087	0.0000	0.0000	0.0092	0.0000	0.0080
CO_2	0.0000	0.1449	0.1449	0.0000	0.0000	0.0003	0.0014	0.1324
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0000	0.0869	0.0869	1.0000	1.0000	0.0099	0.9978	0.1673
N_2	0.0000	0.7325	0.7325	0.0000	0.0000	0.7732	0.0007	0.6686
O_2	0.0000	0.0248	0.0248	0.0000	0.0000	0.2074	0.0000	0.0236
SO_2	0.0000	0.0021	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	0	133,772	133,772	4,596	21,602	1,582	12,485	148,369
V-L Flow (lb/hr)	0	3,978,730	3,978,730	82,793	389,172	45,659	225,497	4,250,730
Solids Flowrate	28,280	0	0	35,979	0	0	56,108	0
Temperature (°F)	350	350	370	59	60	59	134	134
Pressure (psia)	14.20	14.20	15.26	14.70	14.70	14.70	14.70	14.70
Enthalpy (Btu/lb)	--	136.21	141.44	--	33.26	13.13	85.10	138.48
Density (lb/ft^3)	--	0.049	0.051	62.622	62.589	0.076	40.538	0.066
Avg. Molecular Weight	--	29.74	29.74	18.02	18.02	28.86	18.06	28.65

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Exhibit 4-6 Case 1 Heat and Mass Balance, Supercritical PC Boiler without CO_2 Capture

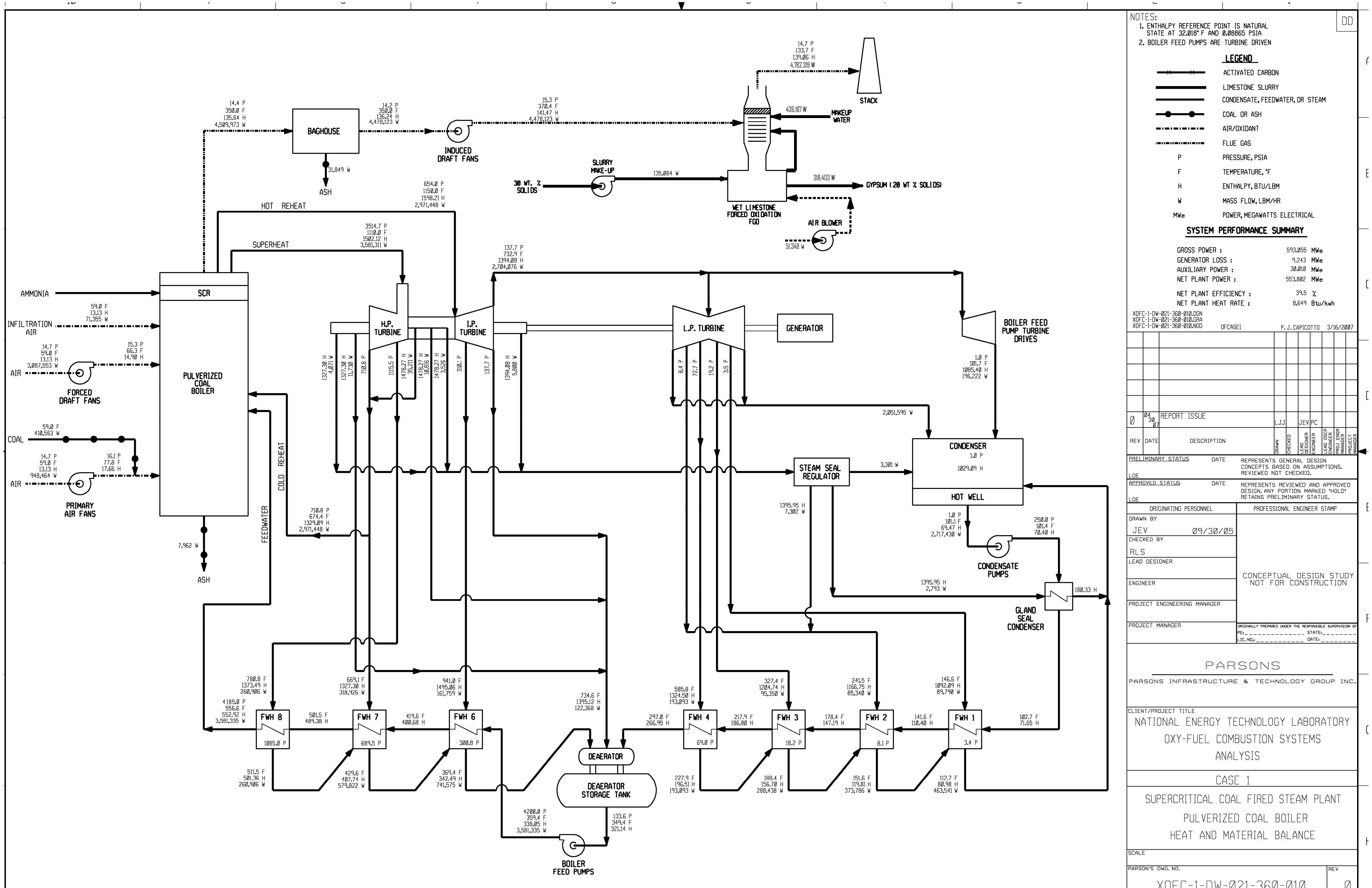

Exhibit 4-7 Case 2 Heat and Mass Balance, Ultra-Supercritical PC Boiler without CO_2 Capture

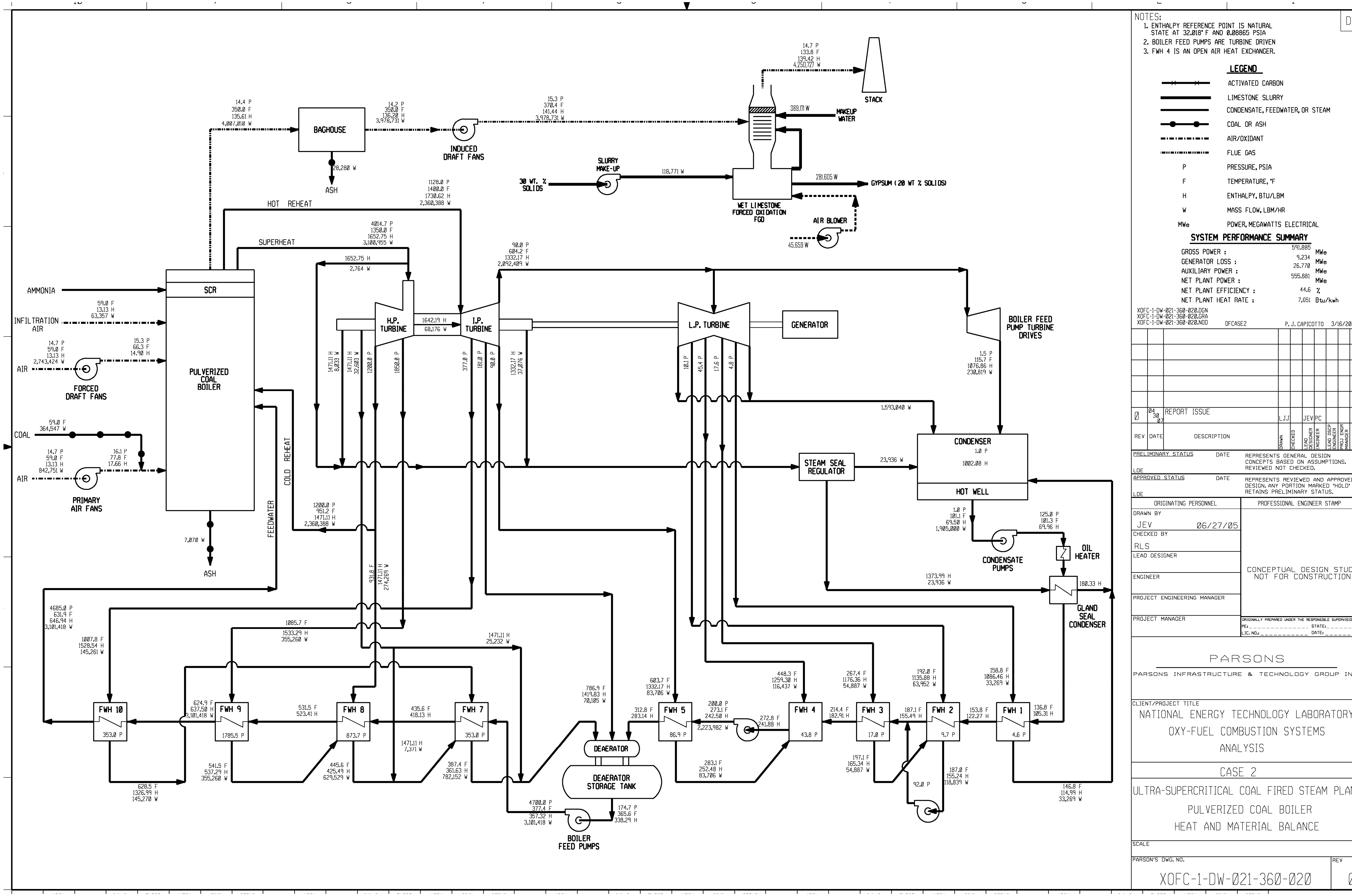

Exhibit 4-8 Performance Modeling Results for Cases 1 and 2

	Case 1 (SC)	Case 2 (USC)
Gross Power at Generator Terminals, kWe	**583,812**	**582,651**
AUXILIARY LOAD SUMMARY, kWe		
Coal Handling and Conveying	410	400
Limestone Handling & Reagent Preparation	890	790
Pulverizers	2,790	2,480
Ash Handling	530	470
Primary Air Fans	1,310	1,160
Forced Draft Fans	1,660	1,470
Induced Draft Fans	7,120	6,330
SCR	50	50
Baghouse	100	100
FGD Pumps and Agitators	2,970	2,640
Condensate Pumps	780	270
Condensate Booster pump	0	430
Miscellaneous Balance of Plant (Note 2)	2,000	2,000
Steam Turbine Auxiliaries	400	400
Circulating Water Pumps	4,730	3,990
Cooling Tower Fans	2,440	1,990
Transformer Loss	1,830	1,800
TOTAL AUXILIARIES, kWe	30,010	26,770
NET POWER, kWe	**553,802**	**555,881**
Net Plant Efficiency (HHV)	39.5%	44.6%
Net Plant Heat Rate (Btu/kWh)	8,649	7,651
Condenser Cooling Duty, MMBtu/hr	**2,178**	**1,885**
CONSUMABLES		
As-Received Coal Feed, lb/hr (Note 3)	410,563	364,547
Thermal Input, kW_{th}	1,403,702	1,246,375
Limestone Sorbent Feed, lb/hr	40,748	35,979
Anhydrous Ammonia Feed (19% solution), lb/h	1,167	1,036
Raw Water Usage, gpm	5,443	4,720

Notes:
1. Boiler feed pumps are turbine driven
2. Includes plant control systems, lighting, HVAC, etc
3. As-received coal heating value: 11,666 Btu/lb (HHV)

Exhibit 4-9 Estimated Air Emission Rates for Cases 1 and 2

Pollutant	lb/ MMBtu Fuel In		Tons/year, CF 85%		lb/MWh_{net}	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
SO_2	0.085	0.085	1,511	1,343	0.733	0.649
NOx	0.070	0.070	1,248	1,108	0.605	0.536
Particulates	0.013	0.013	232	206	0.112	0.099
CO_2	203	203	3,625,814	3,219,694	1,759	1,556
Hg	$1.14x10^{-6}$	$1.14x10^{-6}$	0.020	0.018	$9.9x10^{-6}$	$8.7x10^{-6}$

4.2.1.2 Major Equipment List for Cases 1 and 2

ACCOUNT 1 FUEL AND SORBENT HANDLING

Equipment No.	Description	Type	Design Condition		Qty.
			Case 1	Case 2	
1	Bottom Trestle Dumper with Receiving Hoppers	N/A	200 tph	200 tph	2
2	Feeder	Belt	630 tph	630 tph	2
3	Conveyor No. 1	Belt	1,250 tph	1,250 tph	1
4	Transfer Tower No. 1	Enclosed	N/A	N/A	1
5	Conveyor No. 2	Belt	1,250 tph	1,250 tph	1
4	As-Received Coal Sampling System	Two-stage	N/A	N/A	1
6	Stacker/Reclaim	Traveling Linear	1,250 tph	1,250 tph	1
7	Reclaim Hopper	N/A	40 ton	40 ton	3
8	Feeder	Vibratory	170 tph	150 tph	3
9	Conveyor No. 3	Belt w/tripper	340 tph	300 tph	1
10	Crusher Tower	N/A	N/A	N/A	1
11	Coal Surge Bin w/ Vent Filter	Dual Outlet	170 ton	150 ton	2
12	Crusher	Impactor reduction	3"x0 - 1.25"x0	3"x0 – 1.25"x0	2
13	As-Fired Coal Sampling System	Swing Hammer	N/A	N/A	2
14	Conveyor No. 4	Belt w/tripper	340 tph	300 tph	1
15	Transfer Tower No. 2	Enclosed	N/A	N/A	1
16	Conveyor No. 5	Belt w/tripper	340 tph	300 tph	1
17	Coal Silo w/ Vent Filter and Slide Gates	Field Erected	800 tph	700 tph	3
18	Limestone Truck Unloading Hopper	N/A	40 ton	40 ton	1
19	Limestone Feeder	Belt	90 tph	80 tph	1
20	Limestone Conveyor No. 1	Belt	90 tph	80 tph	1
21	Limestone Reclaim Hopper	N/A	20 tph	10 tph	1
22	Limestone Reclaim Feeder	Belt	70 tph	60 tph	1
23	Limestone Conveyor No. 1	Belt	70 tph	60 tph	1
24	Limestone Day Bin	w/ actuator	270 ton	240 ton	2

ACCOUNT 2 COAL AND SORBENT PREPARATION AND FEED

Equipment No.	Description	Type	Design Condition		Qty.
			Case 1	Case 2	
1	Coal Feeder	Gravimetric	40 tph	30 tph	6
2	Coal Pulverizer	Ball type or eq.	40 tph	30 tph	6
3	Limestone Weigh Feeder	Gravimetric	22 tph	20 tph	2
4	Limestone Ball Mill	Rotary	22 tph	20 tph	2
5	Mill Slurry Tank with Agitator	N/A	20,000 gal	18,000 gal	2
6	Mill Recycle Pumps	Horizontal centrifugal	340 gpm @40 ft H_2O	300 gpm @40 ft H_2O	2
7	Hydroclone Classifier	4 active cyclones in a 5 cyclone bank	90 gpm per cyclone	80 gpm per cyclone	2
8	Distribution Box	2-way	N/A	N/A	2
9	Reagent Storage Tank with Agitator	Field erected	116,000 gal	103,000 gal	2
10	Reagent Distribution Pumps	Horizontal centrifugal	240 gpm @30 ft H_2O	210 gpm @30 ft H_2O	2

ACCOUNT 3 FEEDWATER AND MISCELLANEOUS SYSTEMS AND EQUIPMENT

Equipment No.	Description	Type	Design Condition		Qty.
			Case 1	Case 2	
1	Demineralized Water Storage Tank	Vertical, cylindrical, outdoor	283,000 gal	245,000 gal	2
2	Condensate Pumps	Vertical canned	6,000gpm @ 700 ft H_2O	4,200gpm @ 300 ft H_2O	2
3	Deaerator and Storage Tank	Horizontal spray type	3,939,000 lb/h, 5 min tank	3,412,000 lb/h 5 min tank	1
4	Boiler Feed Pump/ Turbine driven	Barrel type, multi-staged, centrifugal	7,900 gpm @ 11,400 ft H_2O	6,900 gpm @ 12,600 ft H_2O	2
5	Startup Boiler Feed Pump, Electric. motor driven	Barrel type, multi-stage, centrifugal	2,400 gpm @ 11,400 ft H_2O	2,000 gpm @ 12,600 ft H_2O	1
6	LP Feedwater Heater 1A/1B	Horizontal U tube	1,490,000 lb/h	1,100,000 lb/h	2
7	LP Feedwater Heater 2A/2B	Horizontal U tube	1,490,000 lb/h	1,100,000 lb/h	2

Equipment No.	Description	Type	Design Condition		Qty.
			Case 1	Case 2	
8	LP Feedwater Heater 3A/3B	Horizontal U tube	1,490,000 lb/h	1,100,000 lb/h	2
9	LP Feedwater Heater 4A/4B	Horizontal U tube	1,490,000 lb/h	1,100,000 lb/h	2
10	HP Feedwater Heater 6	Horizontal U tube	3,490,000 lb/h	3,410,000 lb/h	1
11	HP Feedwater Heater 7	Horizontal U tube	3,490,000 lb/h	3,410,000 lb/h	1
12	HP Feedwater Heater 8	Horizontal U tube	3,490,000 lb/h	--	1
13	Auxiliary Boiler	Shop fabricated, water-tube	400 psig, 650°F, 40,000 lb/h	400 psig, 650°F, 40,000 lb/h	1
14	Fuel Oil System	No. 2 for light off	300,000 gal	300,000 gal	1
15	Service Air Compressors	Flooded screw	100 psig, 1,000 cfm	100 psig, 1,000 cfm	3
16	Inst. Air Dryers	Duplex, regenerative	1,000 scfm	1,000 scfm	3
17	Closed Cycle Cooling Heat Exch.	Shell & tube	50 MMBtu/h each	50 MMBtu/h each	2
18	Closed Cycle Cooling Water Pumps	Horizontal centrifugal	5,500gpm @ 100 ft H_2O	5,500gpm @ 100 ft H_2O	3
19	Fire Service Booster Pump	Two-stage centrifugal	700gpm @ 210 ft H_2O	700gpm @ 210 ft H_2O	2
20	Engine-Driven Fire Pump	Vert. turbine, diesel engine	1,000gpm @ 290 ft H_2O	1,000gpm @ 290 ft H_2O	2
21	Raw Water Pumps	SS, single suction	3,030gpm @ 140 ft H_2O	2,480gpm @ 140 ft H_2O	3
22	Filtered Water Pumps	SS, single suction	400gpm @ 160 ft H_2O	340gpm @ 160 ft H_2O	3
23	Filtered Water Tank	Vertical, cylindrical	385,000 gal	322,000 gal	1
24	Makeup Demineralizer	Anion, cation, and mixed bed	160 gpm	140 gpm	2
25	Liquid Waste Treatment System	--	10 years, 24-hour storm	10 years, 24-hour storm	1

ACCOUNT 4 BOILER AND ACCESSORIES

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
1	Boiler	wall-fired, low NOx burners, overfire air	Supercritical drum-type 3,940,000 lb/h at 3500 psig/ 1110ºF/1150ºF	Ultra Supercritical drum-type 3,410,000 lb/h at 4000 psig/ 1350ºF/1400ºF	1
2	Primary Air Fan	Centrifugal	522,000 lb/h, 114,400 acfm, @ 48" WG	464,000 lb/h, 101,600 acfm @ 48" WG	2

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
3	Forced Draft Fan	Centrifugal	1,698,000 lb/h, 330,9000 acfm @ 19" WG	1,509,000 lb/h, 330,900 acfm @ 19" WG	2
4	Induced Draft Fan	Centrifugal	2,463,000 lb/h, 744,300 acfm @ 35" WG	2,188,000 lb/h, 744,300 acfm @ 36" WG	2
5	SCR Reactor Vessel	Space for spare layer	4,930,000 lb/h	4,380,000 lb/h	2
6	SCR Catalyst	---	---	---	3
7	Dilution Air Blower	Centrifugal	4,700 scfm @ 42" WG	4,200 scfm @ 42" WG	2
8	Ammonia Storage	Horizontal tank	39,000 gal	34,000 gal	5
9	Ammonia Feed Pump	Centrifugal	7 scfm @ 300 ft H_2O	7 scfm @ 300 ft H_2O	2

ACCOUNT 5 FLUE GAS CLEANUP

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
1	Fabric bag filter	Single-stage, high-ratio with pulse-jet on-line cleaning system.	2,480,000 lb/h, 99.8% efficiency	2,204,000 lb/h, 99.8% efficiency	2
2	Absorber Module	Counter-current Open spray	1,330,000 acfm	1,179,000 acfm	1
3	Recirculation Pumps	Horizontal centrifugal	35,000 gpm @ 210 ft H_2O	31,000 gpm @ 210 ft H_2O	6
4	Bleed Pumps	Horizontal centrifugal	1,060 gpm 20% solids	930 gpm 20% solids	3
5	Oxidation Air Blowers	Centrifugal	5,620 scfm @ 37 psia	5,000 scfm @ 37 psia	3
6	Agitators	Side entering	50 hp motor	50 hp motor	6
7	Dewatering Hydrocyclones	Radial assembly (5 units EA)	270 gpm	230 gpm	2
8	Vacuum Filter Belt	Horizontal belt	35 tph 50 wt% solids slurry	31 tph 50 wt% solids slurry	3
9	Filtrate Water Return Pumps	Horizontal centrifugal	160 gpm @ 40 ft H_2O	140 gpm @ 40 ft H_2O	2
10	Filtrate Water Return Storage Tank	Vertical, lined	110,000 gal	90,000 gal	1
11	Process Water Recirculation Pumps	Horizontal centrifugal	640 gpm @ 70 ft H_2O	540 gpm @ 70 ft H_2O	2

ACCOUNT 6 COMBUSTION TURBINE/ACCESSORIES

N/A

ACCOUNT 7 DUCTING AND STACK

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
1	Stack	Reinforced concrete with FRP liner	500 ft high x 19 ft diameter	500 ft high x 18 ft diameter	1

ACCOUNT 8 STEAM TURBINE GENERATOR

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
1	Steam Turbine Generator	Case 1 - Commercially available, advanced Case 2 - Advanced (not yet developed)	610 MW, 3500 psig/ 1110°F /1150°F	610 MW, 4000 psig/ 1350°F /1400°F	1
2	Steam Turbine Generator	Hydrogen cooled, static excitation	680 MVA @ 0.9 p.f., 24 kV, 60 Hz	680 MVA @ 0.9 p.f., 24 kV, 60 Hz	1
3	Surface Condenser	Single pass, divided waterbox including vacuum pumps	2,530 MMBtu/h, Inlet water 60ºF rise 20ºF	1,930 MMBtu/h, Inlet water 60ºF rise 20ºF	1

ACCOUNT 9 COOLING WATER SYSTEM

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
1	Cooling Tower	Evaporative, mechanical draft, multi-cell	11°C (51.5°F) wet bulb / 16°C (60°F) CWT / 27°C (80°F) HWT 2,646 MMkJ/h (2,510 MMBtu/h) heat load	11°C (51.5°F) wet bulb / 16°C (60°F) CWT / 27°C (80°F) HWT 2,151 MMkJ/h (2,040 MMBtu/h) heat load	1
2	Circ. Water Pumps	Vertical, wet pit	125,000 gpm @ 100 ft	102,000 gpm @ 100 ft,	3

ACCOUNT 10 ASH/SPENT SORBENT RECOVERY AND HANDLING

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
1	Economizer Hopper (part of boiler scope of supply)	--	--	--	4
2	Bottom Ash Hopper (part of boiler scope of supply)	--	--	--	2
3	Clinker Grinder	--	4 tph	4 tph	2
4	Pyrites Hopper (part of pulverizer scope of supply included with boiler)	--	--	--	6
5	Hydroejectors	--	--	--	12
6	Economizer/Pyrites Transfer Tank	--	--	--	2
7	Ash Sluice Pumps	Vertical, wet pit	40 gpm @ 56 ft H_2O	40 gpm @ 56 ft H_2O	2
8	Ash Seal Water Pumps	Vertical, wet pit	2,000 gpm @ 28 ft H_2O	2,000 gpm @ 28 ft H_2O	2
9	Hydrobins	--	40 gpm	40 gpm	2
10	Baghouse Hopper (part of baghouse scope of supply)	--	--	--	24
11	Air Heater Hopper (part of boiler scope of supply)	--	--	--	10
12	Air Blower	--	510 scfm @ 24 psi	460 scfm @ 24 psi	2
13	Fly Ash Silo	Reinforced concrete	1,100 tons	900 tons	2
14	Slide Gate Valves	--	--	--	2
15	Unloader	--	100 tph	90 tph	1
16	Telescoping Unloading Chute	--	--	--	1

ACCOUNT 11 ACCESSORY ELECTRIC PLANT

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
1	STG Transformer	Oil-filled	24 kV/345 kV, 680 MVA, 3-ph, 60 Hz	24 kV/345 kV, 680 MVA, 3-ph, 60 Hz	1
2	Auxiliary Transformer	Oil-filled	24 kV/ 4.16 kV, 33 MVA, 3-ph, 60 Hz	24 kV/ 4.16 kV, 30 MVA, 3-ph, 60 Hz	2
3	LV Transformer	Dry ventilated	4.16 kV /480 V, 5 MVA, 3-ph, 60 Hz	4.16 kV /480 V, 4 MVA, 3-ph, 60 Hz	2
4	STG Isolated Phase Bus Duct and Tap Bus	Aluminum, self-cooled	24 kV, 3-ph, 60 Hz	24 kV, 3-ph, 60 Hz	1
5	Medium Voltage Switchgear	Metal Clad	4.16 kV, 3-ph, 60 Hz	4.16 kV, 3-ph, 60 Hz	2
6	Low Voltage Switchgear	Metal Enclosed	480 V, 3-ph, 60 Hz	480 V, 3-ph, 60 Hz	2
7	Emergency Diesel Generator	Sized for emergency shutdown	750 kW, 480 V, 3-ph, 60 Hz	750 kW, 480 V, 3-ph, 60 Hz	1

ACCOUNT 12 INSTRUMENTATION AND CONTROL

Equipment No.	Description	Type	Design Condition		Qty
			Case 1	Case 2	
1	DCS - Main Control	Monitor/keyboard; Operator printer – laser color; Eng. Printer – laser B&W	Operator Stations/Printers and Engineering Stations/Printers	Operator Stations/Printers and Engineering Stations/Printers	1
2	DCS - Processor	Microprocessor with Redundant Input/Output	N/A	N/A	1
3	DCS - Data Highway	Fiber optic	Fully redundant, 25% spare	Fully redundant, 25% spare	1

4.2.2 Air-Fired Cases with CO_2 Capture Performance Results

A process block flow diagram for Cases 3 and 4 is shown in Exhibit 4-10 and the corresponding stream tables are contained in Exhibit 4-11 and Exhibit 4-12. The heat and mass balance diagrams, including the steam cycle, are shown in Exhibit 4-13 and Exhibit 4-14. These two cases represent air-based supercritical and ultra-supercritical steam cycles with CO_2 capture using the Econamine FG Plus process.

Overall performance for Cases 3 and 4 is summarized in Exhibit 4-15 which includes auxiliary power requirements.

4.2.2.1 Environmental Performance for Cases 3 and 4

Each case was designed to meet presumptive BACT standards utilizing the emissions control processes described in Section 2.5. A summary of plant air emissions is presented in Exhibit 4-16.

SO_2 emissions are controlled using a wet limestone forced oxidation scrubber that achieves a removal efficiency of 98%. To avoid the formation of heat stable salts in the Econamine process, sulfur must be reduced to 10 ppm prior to the CO_2 absorber. An SO_2 polishing step is included as part of the Econamine process to achieve the necessary SO_2 reduction, and the balance of the SO_2 is absorbed by the amine solution resulting in negligible stack emissions. The byproduct calcium sulfate is dewatered and stored on site. The wallboard grade material can potentially be marketed and sold, but since it is highly dependent on local market conditions, no byproduct credit was taken. The saturated flue gas exiting the scrubber is vented through the plant stack.

NOx emissions are controlled to about 0.5 lb/10^6 Btu through the use of LNBs and OFA. An SCR unit then further reduces the NOx concentration by 86% to 0.07 lb/10^6 Btu.

Particulate emissions are controlled using a pulse jet fabric filter (baghouse) which operates at an efficiency of 99.8%. It was assumed that 20% of the ash exits the boiler as bottom ash and the remaining 80% exits the boiler in the flue gas [36].

Co-benefit capture of Hg in the fabric filter and FGD system was assumed to achieve a 90% capture rate [37]. The high chlorine content of the Illinois No. 6 coal and the SCR system will convert most of the Hg in the system to an oxidized state [38]. The addition of an inexpensive additive to the FGD system can be used to promote Hg capture if necessary, but was not included in this study.

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36 Coal Utilization By Products - Clean Coal Technologies Topical Report Number 24, page 8, http://www.netl.doe.gov/technologies/coalpower/cctc/topicalreports/pdfs/Topical24.pdf, August 2006.

37 Enhancing Mercury Control on Coal-Fired Boilers with SCR, Oxidation Catalyst, and FGD, Institute of Clean Air Companies (ICAC), www.icac.com.

38 Standalone Documentation for EPA Base Case 2004 (V.2.1.9) Using the Integrated Planning Model, page 5-11, EPA 430-R-05-011, September 2005.

Exhibit 4-10 Cases 3 and 4 Process Block Flow Diagram, Air-Based PC with CO_2 Capture

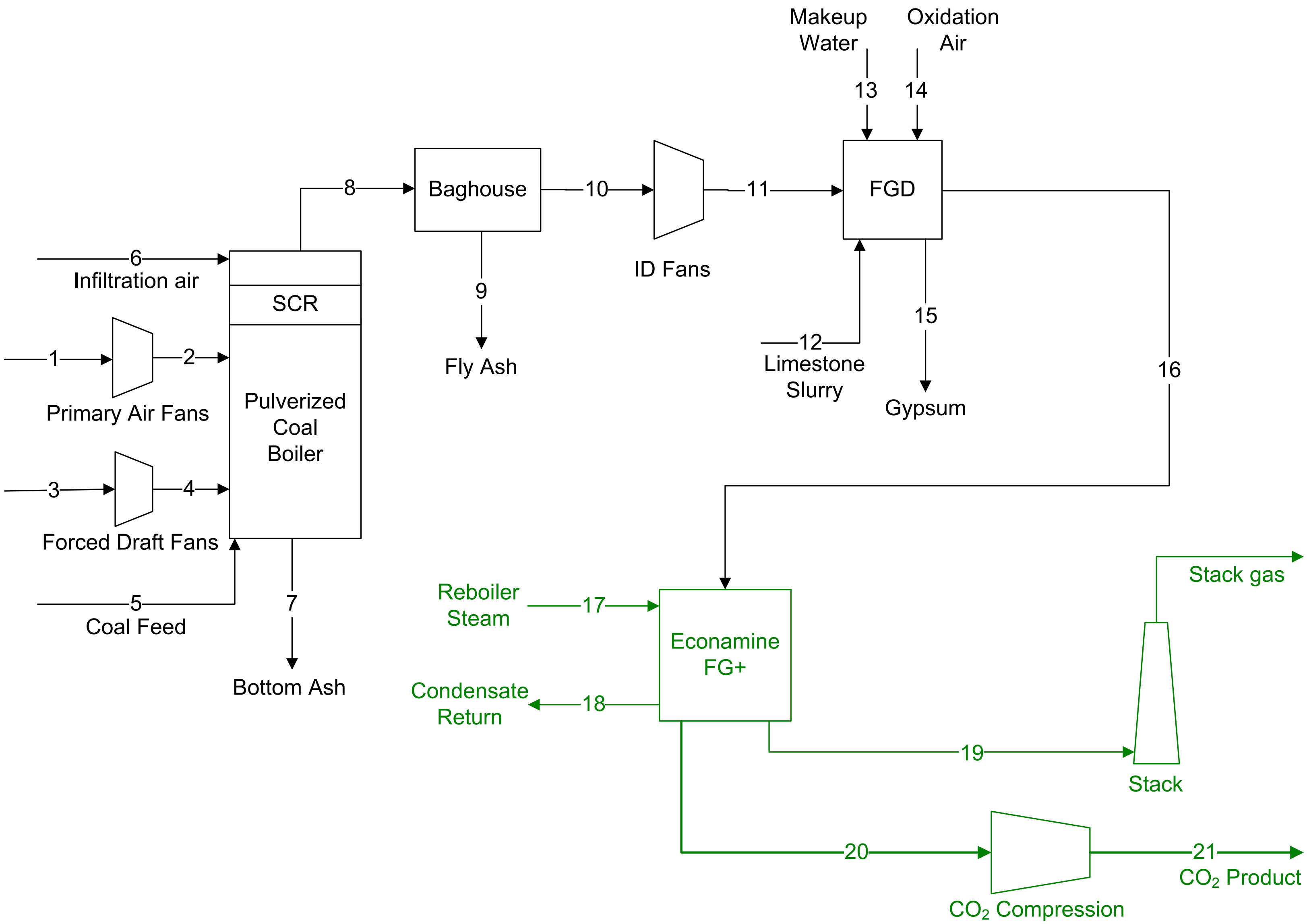

Exhibit 4-11 Case 3 Stream Table, Air-Based Supercritical PC with CO_2 Capture

	1	2	3	4	5	6	7	8	9	10	11
V-L Mole Fraction											
Ar	0.0092	0.0092	0.0092	0.0092	0.0000	0.0092	0.0000	0.0087	0.0000	0.0087	0.0087
CO_2	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0000	0.1452	0.0000	0.1452	0.1452
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0099	0.0099	0.0099	0.0099	0.0000	0.0099	0.0000	0.0871	0.0000	0.0871	0.0871
N_2	0.7732	0.7732	0.7732	0.7732	0.0000	0.7732	0.0000	0.7324	0.0000	0.7324	0.7324
O_2	0.2074	0.2074	0.2074	0.2074	0.0000	0.2074	0.0000	0.0244	0.0000	0.0244	0.0244
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000	0.0021	0.0021
Total	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (lb_{mol}/hr)	47,141	47,141	153,458	153,458	0	3,552	0	215,964	0	215,964	215,964
V-L Flowrate (lb/hr)	1,360,330	1,360,330	4,428,320	4,428,320	0	102,496	0	6,423,700	0	6,423,700	6,423,700
Solids Flowrate (lb/hr)	0	0	0	0	589,745	0	11,437	45,749	45,749	0	0
Temperature (°F)	59	78	59	66	59	59	350	350	350	350	370
Pressure (psia)	14.7	16.1	14.7	15.3	14.7	14.7	14.4	14.4	14.2	14.2	15.3
Enthalpy (Btu/lb)	13.13	17.66	13.13	14.90	--	13.13	--	135.69	--	136.29	141.53
Density (lb/ft^3)	0.08	0.08	0.08	0.08	--	0.08	--	0.05	--	0.05	0.05
Molecular Weight	28.86	28.86	28.86	28.86	--	28.86	--	29.74	--	29.74	29.74

	12	13	14	15	16	17	18	19	20	21
V-L Mole Fraction										
Ar	0.0000	0.0000	0.0092	0.0000	0.0080	0.0000	0.0000	0.0109	0.0000	0.0000
CO_2	0.0000	0.0000	0.0003	0.0014	0.1330	0.0000	0.0000	0.0181	0.9863	1.0000
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	1.0000	1.0000	0.0099	0.9978	0.1663	1.0000	1.0000	0.0281	0.0137	0.0000
N_2	0.0000	0.0000	0.7732	0.0007	0.6694	0.0000	0.0000	0.9113	0.0000	0.0000
O_2	0.0000	0.0000	0.2074	0.0000	0.0232	0.0000	0.0000	0.0316	0.0000	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flowrate (lb_{mol}/hr)	7,526	34,770	2,401	20,514	239,017	99,451	99,451	175,544	29,007	28,610
V-L Flowrate (lb/hr)	135,589	626,384	69,283	370,511	6,851,890	1,791,630	1,791,630	4,964,060	1,266,270	1,259,100
Solids Flowrate (lb/hr)	59,623	0	0	92,188	0	0	0	0	0	0
Temperature (°F)	59	59	59	135	135	731	348	74	69	124
Pressure (psia)	14.7	14.7	14.7	15.2	15.2	130.9	130.9	14.7	23.5	2,215.0
Enthalpy (Btu/lb)	--	32.36	13.13	94.40	138.07	1,393.66	319.48	29.51	11.38	-70.79
Density (lb/ft^3)	62.62	62.62	0.08	41.89	0.07	0.19	55.67	0.07	0.18	40.76
Molecular Weight	18.02	18.02	28.86	18.06	28.67	18.02	18.02	28.28	43.65	44.01

Exhibit 4-12 Case 4 Stream Table, Air-Based Ultra-Supercritical PC with CO_2 Capture

	1	2	3	4	5	6	7	8	9	10	11
V-L Mole Fractions											
Ar	0.0092	0.0092	0.0092	0.0092	0.0000	0.0092	0.0000	0.0087	0.0000	0.0087	0.0087
CO_2	0.0003	0.0003	0.0003	0.0003	0.0000	0.0003	0.0000	0.1450	0.0000	0.1450	0.1450
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0099	0.0099	0.0099	0.0099	0.0000	0.0099	0.0000	0.0870	0.0000	0.0870	0.0870
N_2	0.7732	0.7732	0.7732	0.7732	0.0000	0.7732	0.0000	0.7324	0.0000	0.7324	0.7324
O_2	0.2074	0.2074	0.2074	0.2074	0.0000	0.2074	0.0000	0.0248	0.0000	0.0248	0.0248
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000	0.0021	0.0021
Total	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	39,798	39,798	129,554	129,554	0	2,992	0	182,297	0	182,297	182,297
V-L Flow (lb/hr)	1,148,440	1,148,440	3,738,540	3,738,540	0	86,351	0	5,422,000	0	5,422,000	5,422,000
Solids Flowrate	0	0	0	0	496,851	0	9,636	38,543	38,543	0	0
Temperature (°F)	59	78	59	66	59	59	350	350	350	350	370
Pressure (psia)	14.70	16.14	14.70	15.25	14.70	14.70	14.40	14.40	14.20	14.20	15.26
Enthalpy (Btu/lb)	13.13	17.66	13.13	14.90	--	13.13	--	135.57	--	136.17	141.40
Density (lb/ft^3)	0.076	0.081	0.076	0.078	--	0.076	--	0.049	--	0.049	0.051
Avg. Molecular Weight	28.86	28.86	28.86	28.86	--	28.86	--	29.74	--	29.74	29.74

	12	13	14	15	16	17	18	19	20	21
V-L Mole Fractions										
Ar	0.0000	0.0000	0.0092	0.0000	0.0080	0.0000	0.0000	0.0109	0.0000	0.0000
CO_2	0.0000	0.0000	0.0003	0.0014	0.1325	0.0000	0.0000	0.0180	0.9862	1.0000
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	1.0000	1.0000	0.0099	0.9978	0.1673	1.0000	1.0000	0.0281	0.0138	0.0000
N_2	0.0000	0.0000	0.7732	0.0007	0.6686	0.0000	0.0000	0.9108	0.0000	0.0000
O_2	0.0000	0.0000	0.2074	0.0000	0.0236	0.0000	0.0000	0.0322	0.0000	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	6,344	29,471	2,164	17,130	202,195	86,445	86,445	148,385	24,442	24,103
V-L Flow (lb/hr)	114,297	530,926	62,435	309,375	5,792,850	1,557,330	1,557,330	4,196,340	1,066,900	1,060,750
Solids Flowrate	49,545	0	0	76,980	0	0	0	0	0	0
Temperature (°F)	59	60	59	134	134	603	320	74	69	183
Pressure (psia)	14.70	14.70	14.70	14.70	14.70	90.00	90.00	14.70	23.52	2215.00
Enthalpy (Btu/lb)	--	33.26	13.13	88.76	138.44	1,331.35	290.71	29.44	11.37	31.24
Density (lb/ft^3)	62.622	62.589	0.076	40.856	0.066	0.144	56.629	0.073	0.183	14.128
Avg. Molecular Weight	18.02	18.02	28.86	18.06	28.65	18.02	18.02	28.28	43.65	44.01

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Exhibit 4-13 Case 3 Heat and Mass Balance, Supercritical PC Boiler with CO_2 Capture

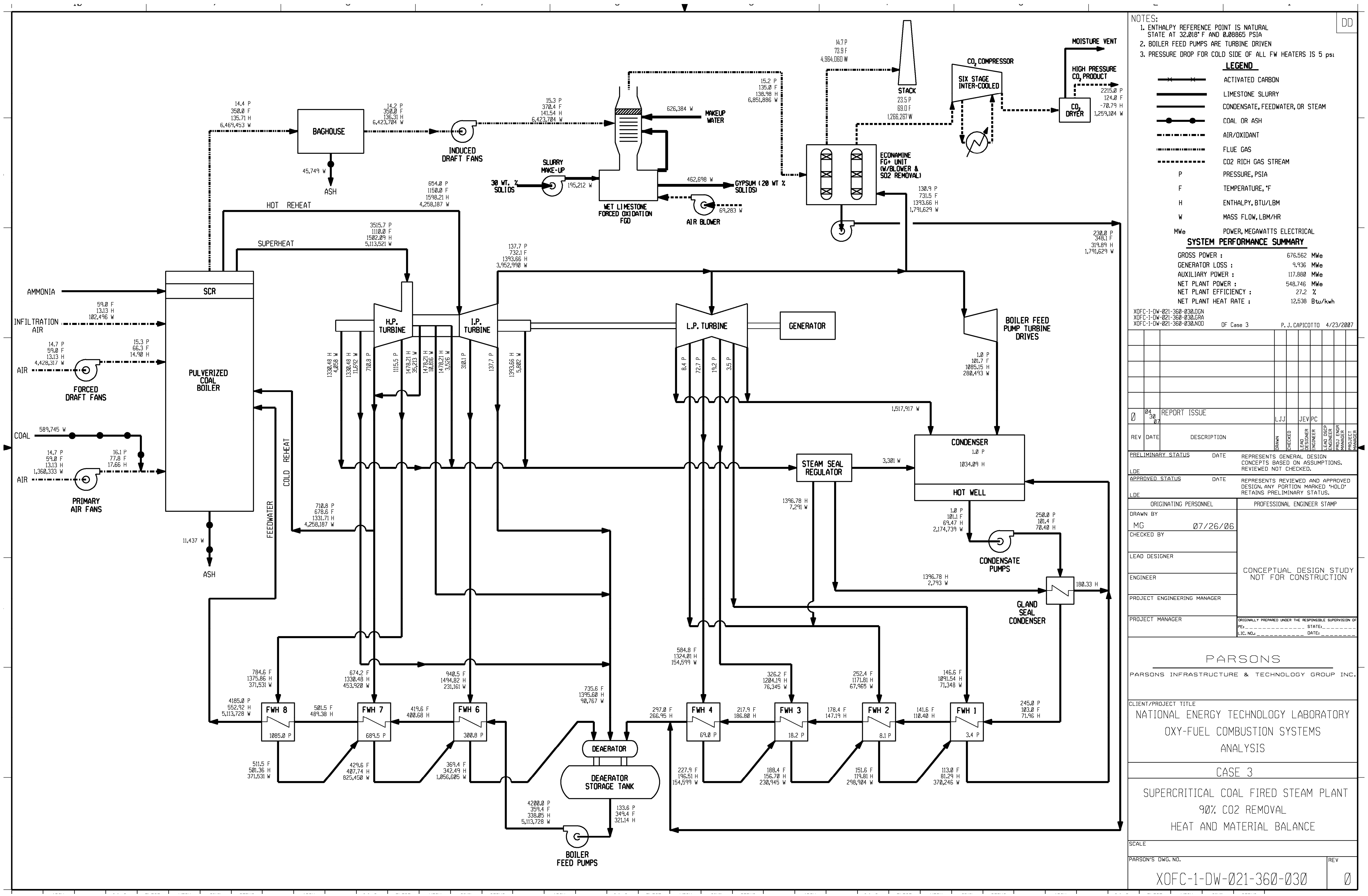

Exhibit 4-14 Case 4 Heat and Mass Balance, Ultra-Supercritical PC Boiler with CO_2 Capture

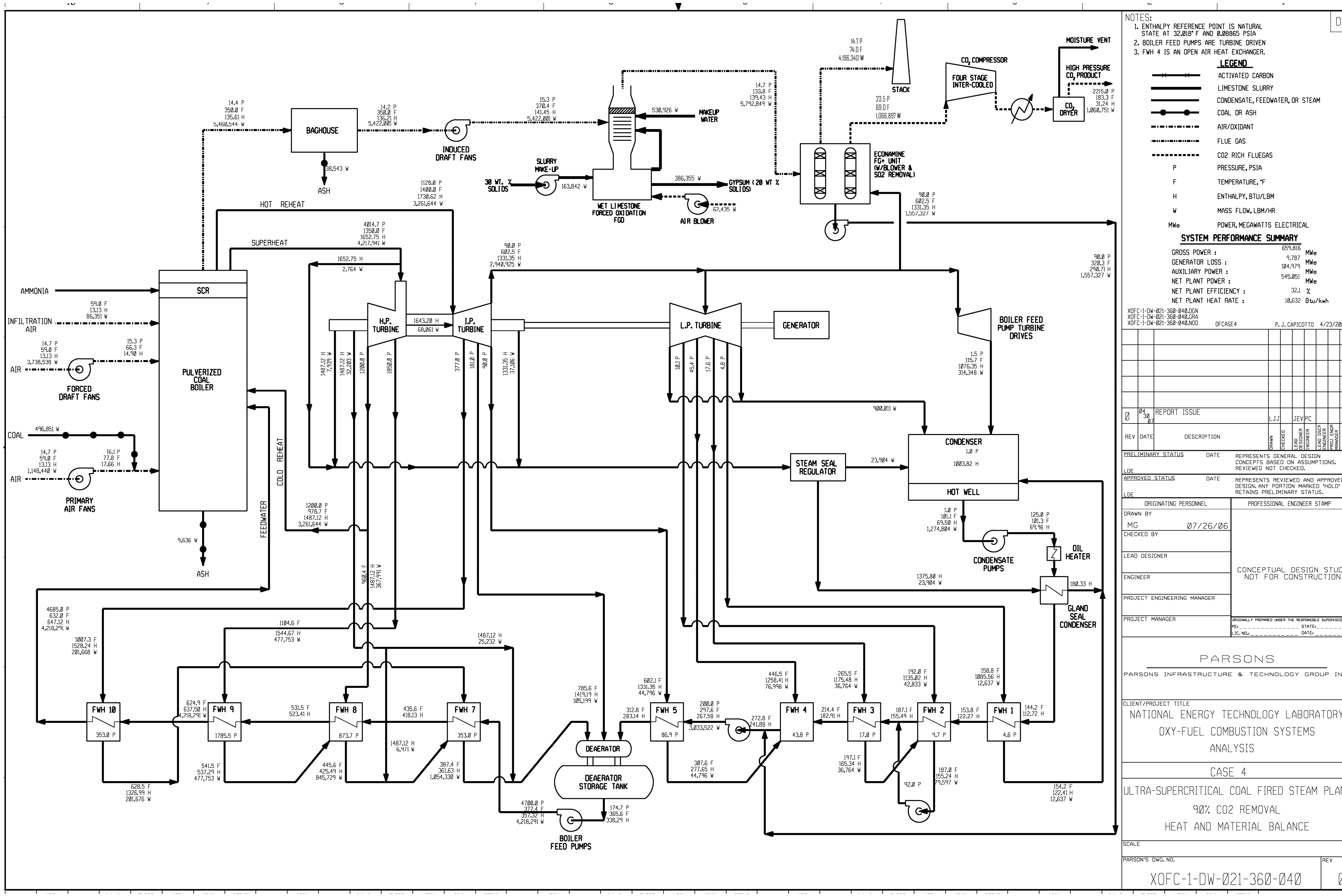

Exhibit 4-15 Performance Modeling Results for Cases 3 and 4

	Case 3 (SC)	Case 4 (USC)
Gross Power at Generator Terminals, kWe	**666,626**	**650,030**
AUXILIARY LOAD SUMMARY, kWe		
Coal Handling and Conveying	470	460
Limestone Handling & Reagent Preparation	1,300	1,080
Pulverizers	4,010	3,380
Ash Handling	770	650
Primary Air Fans	1,870	1,580
Forced Draft Fans	2,380	2,007
Induced Draft Fans	10,160	8,618
SCR	70	60
Baghouse	100	100
FGD Pumps and Agitators	4,270	3,600
Econamine FG Plus Auxiliaries	21,430	18,830
CO_2 Compression	47,150	44,192
Miscellaneous Balance of Plant (Note 2)	2,000	2,000
Steam Turbine Auxiliaries	400	400
Condensate Pumps	620	182
Boiler Feedwater Booster Pumps	---	589
Circulating Water Pumps	12,230	10,000
Cooling Tower Fans	6,330	5,020
Transformer Loss	2,320	2,230
TOTAL AUXILIARIES, kWe	117,880	104,978
NET POWER, kWe	**548,746**	**545,052**
Net Plant Efficiency (HHV)	27.2%	32.1%
Net Plant Heat Rate (Btu/kWh)	12,538	10,632
Condenser Cooling Duty, MMBtu/hr	**1,758**	**1,190**
CONSUMABLES		
As-Received Coal Feed, lb/hr (Note 3)	589,747	496,764
Thermal Input, kW_{th}	2,016,327	1,698,421
Limestone Sorbent Feed, lb/hr	59,623	49,548
Anhydrous Ammonia Feed (19% solution), lb/h	1,676	1,405
Raw Water Usage, gpm	12,130	9,640

Notes:
1. Boiler feed pumps are turbine driven
2. Includes plant control systems, lighting, HVAC, etc
3. As-received coal heating value: 11,666 Btu/lb (HHV)

Exhibit 4-16 Estimated Air Emission Rates for Cases 3 and 4

Pollutant	lb/ MMBtu		Tons/year, CF 85%		lb/MWh_{net}	
	Case 3	Case 4	Case 3	Case 4	Case 3	Case 4
SO_2	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
NOx	0.070	0.070	1,793	1,510	0.878	0.744
Particulates	0.013	0.013	333	280	0.163	0.138
CO_2	20	20	519,185	437,401	254	216
Hg	$1.14x10^{-6}$	$1.14x10^{-6}$	0.029	0.025	$14.3x10^{-6}$	$12.2x10^{-6}$

4.2.2.2 Major Equipment List for Cases 3 and 4

ACCOUNT 1 FUEL AND SORBENT HANDLING

Equipment No.	Description	Type	Design Condition		Qty.
			Case 3	Case 4	
1	Bottom Trestle Dumper with Receiving Hoppers	N/A	200 tph	200 tph	2
2	Feeder	Belt	630 tph	630 tph	2
3	Conveyor No. 1	Belt	1,250 tph	1,250 tph	1
4	Transfer Tower No. 1	Enclosed	N/A	N/A	1
5	Conveyor No. 2	Belt	1,250 tph	1,250 tph	1
4	As-Received Coal Sampling System	Two-stage	N/A	N/A	1
6	Stacker/Reclaim	Traveling Linear	1,250 tph	1,250 tph	1
7	Reclaim Hopper	N/A	60 ton	50 ton	3
8	Feeder	Vibratory	240 tph	200 tph	3
9	Conveyor No. 3	Belt w/tripper	490 tph	410 tph	1
10	Crusher Tower	N/A	N/A	N/A	1
11	Coal Surge Bin w/ Vent Filter	Dual Outlet	240 ton	200 ton	2
12	Crusher	Impactor reduction	3"x0 - 1.25"x0	3"x0 – 1.25"x0	2
13	As-Fired Coal Sampling System	Swing Hammer	N/A	N/A	2
14	Conveyor No. 4	Belt w/tripper	490 tph	410 tph	1
15	Transfer Tower No. 2	Enclosed	N/A	N/A	1
16	Conveyor No. 5	Belt w/tripper	490 tph	410 tph	1
17	Coal Silo w/ Vent Filter and Slide Gates	Field Erected	1,100 tph	900 tph	3
18	Limestone Truck Unloading Hopper	N/A	40 ton	40 ton	1
19	Limestone Feeder	Belt	130 tph	100 tph	1
20	Limestone Conveyor No. 1	Belt	130 tph	100 tph	1
21	Limestone Reclaim Hopper	N/A	20 tph	20 tph	1
22	Limestone Reclaim Feeder	Belt	100 tph	80 tph	1
23	Limestone Conveyor No. 1	Belt	100 tph	80 tph	1
24	Limestone Day Bin	w/ actuator	390 ton	330 ton	2

ACCOUNT 2 COAL AND SORBENT PREPARATION AND FEED

Equipment No.	Description	Type	Design Condition		Qty.
			Case 3	Case 4	
1	Coal Feeder	Gravimetric	50 tph	50 tph	6
2	Coal Pulverizer	Ball type or eq.	50 tph	50 tph	6
3	Limestone Weigh Feeder	Gravimetric	33 tph	27 tph	2
4	Limestone Ball Mill	Rotary	33 tph	27 tph	2
5	Mill Slurry Tank with Agitator	N/A	30,000 gal	25,000 gal	2
6	Mill Recycle Pumps	Horizontal centrifugal	500 gpm @40 ft H_2O	410 gpm @40 ft H_2O	2
7	Hydroclone Classifier	4 active cyclones in a 5 cyclone bank	130 gpm per cyclone	100 gpm per cyclone	2
8	Distribution Box	2-way	N/A	N/A	2
9	Reagent Storage Tank with Agitator	Field erected	170,000 gal	141,000 gal	2
10	Reagent Distribution Pumps	Horizontal centrifugal	350 gpm @30 ft H_2O	290 gpm @30 ft H_2O	2

ACCOUNT 3 FEEDWATER AND MISCELLANEOUS SYSTEMS AND EQUIPMENT

Equipment No.	Description	Type	Design Condition		Qty.
			Case 3	Case 4	
1	Demineralized Water Storage Tank	Vertical, cylindrical, outdoor	405,000 gal	334,000 gal	2
2	Condensate Pumps	Vertical canned	4,800gpm @ 700 ft H_2O	2,800gpm @ 300 ft H_2O	2
3	Deaerator and Storage Tank	Horizontal spray type	5,625,000 lb/h, 5 min tank	4,639,000 lb/h 5 min tank	1
4	Boiler Feed Pump/ Turbine driven	Barrel type, multi-staged, centrifugal	11,400 gpm @ 11,400 ft H_2O	9,300 gpm @ 12,600 ft H_2O	2
5	Startup Boiler Feed Pump, Electric. motor driven	Barrel type, multi-stage, centrifugal	3,400 gpm @ 11,400 ft H_2O	2,800 gpm @ 12,600 ft H_2O	1
6	LP Feedwater Heater 1A/1B	Horizontal U tube	1,200,000 lb/h	700,000 lb/h	2
7	LP Feedwater Heater 2A/2B	Horizontal U tube	1,200,000 lb/h	700,000 lb/h	2

Equipment No.	Description	Type	Design Condition		Qty.
			Case 3	Case 4	
8	LP Feedwater Heater 3A/3B	Horizontal U tube	1,200,000 lb/h	700,000 lb/h	2
9	LP Feedwater Heater 4A/4B	Horizontal U tube	1,200,000 lb/h	700,000 lb/h	2
10	HP Feedwater Heater 6	Horizontal U tube	5,620,000 lb/h	4,640,000 lb/h	1
11	HP Feedwater Heater 7	Horizontal U tube	5,620,000 lb/h	4,640,000 lb/h	1
12	HP Feedwater Heater 8	Horizontal U tube	5,620,000 lb/h	4,640,000 lb/h	1
13	Auxiliary Boiler	Shop fabricated, water-tube	400 psig, 650°F, 40,000 lb/h	400 psig, 650°F, 40,000 lb/h	1
14	Fuel Oil System	No. 2 for light off	300,000 gal	300,000 gal	1
15	Service Air Compressors	Flooded screw	100 psig, 1,000 cfm	100 psig, 1,000 cfm	3
16	Inst. Air Dryers	Duplex, regenerative	1,000 scfm	1,000 scfm	3
17	Closed Cycle Cooling Heat Exch.	Shell & tube	50 MMBtu/h each	50 MMBtu/h each	2
18	Closed Cycle Cooling Water Pumps	Horizontal centrifugal	5,500gpm @ 100 ft H_2O	5,500gpm @ 100 ft H_2O	3
19	Fire Service Booster Pump	Two-stage centrifugal	700gpm @ 210 ft H_2O	700gpm @ 210 ft H_2O	2
20	Engine-Driven Fire Pump	Vert. turbine, diesel engine	1,000gpm @ 290 ft H_2O	1,000gpm @ 290 ft H_2O	2
21	Raw Water Pumps	SS, single suction	6,730gpm @ 140 ft H_2O	5,350gpm @ 140 ft H_2O	3
22	Filtered Water Pumps	SS, single suction	560gpm @ 160 ft H_2O	470gpm @ 160 ft H_2O	3
23	Filtered Water Tank	Vertical, cylindrical	533,000 gal	454,000 gal	1
24	Makeup Demineralizer	Anion, cation, and mixed bed	270 gpm	220 gpm	2
25	Liquid Waste Treatment System	--	10 years, 24-hour storm	10 years, 24-hour storm	1

ACCOUNT 4 BOILER AND ACCESSORIES

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	Boiler	wall-fired, low NOx burners, overfire air	Supercritical drum-type, 5,620,000 lb/h at 3500 psig/ 1110ºF/1150ºF	Ultra Supercritical drum-type, 4,640,000 lb/h at 4000 psig/ 1350ºF/1400ºF	1
2	Primary Air Fan	Centrifugal	748,000 lb/h, 164,100 acfm, @ 48" WG	632,000 lb/h, 138,500 acfm @ 48" WG	2

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
3	Forced Draft Fan	Centrifugal	2,436,000 lb/h, 534,100 acfm @ 19" WG	2,056,000 lb/h, 450,800 acfm @ 19" WG	2
4	Induced Draft Fan	Centrifugal	3,533,000 lb/h, 1,211,300 acfm @ 35" WG	2,981,000 lb/h, 1,014,100 acfm @ 36" WG	2
5	SCR Reactor Vessel	Space for spare layer	7,070,000 lb/h	5,960,000 lb/h	2
6	SCR Catalyst	---	---	---	3
7	Dilution Air Blower	Centrifugal	6,700 scfm @ 42" WG	5,700 scfm @ 42" WG	2
8	Ammonia Storage	Horizontal tank	56,000 gal	47,000 gal	5
9	Ammonia Feed Pump	Centrifugal	11 scfm @ 300 ft H_2O	9 scfm @ 300 ft H_2O	2

ACCOUNT 5 FLUE GAS CLEANUP

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	Fabric bag filter	Single-stage, high-ratio with pulse-jet on-line cleaning system.	3,558,000 lb/h, 99.8% efficiency	3,003,000 lb/h, 99.8% efficiency	2
2	Absorber Module	Counter-current Open spray	1,832,000 acfm	1,607,000 acfm	1
3	Recirculation Pumps	Horizontal centrifugal	48,000 gpm @ 210 ft H_2O	42,000 gpm @ 210 ft H_2O	6
4	Bleed Pumps	Horizontal centrifugal	1,530 gpm 20% solids	1,280 gpm 20% solids	3
5	Oxidation Air Blowers	Centrifugal	7,580 scfm @ 42 psia	6,830 scfm @ 42 psia	3
6	Agitators	Side entering	50 hp motor	50 hp motor	6
7	Dewatering Hydrocyclones	Radial assembly (5 units EA)	380 gpm	320 gpm	2
8	Vacuum Filter Belt	Horizontal belt	51 tph 50 wt% solids slurry	42 tph 50 wt% solids slurry	3
9	Filtrate Water Return Pumps	Horizontal centrifugal	230 gpm @ 40 ft H_2O	200 gpm @ 40 ft H_2O	2
10	Filtrate Water Return Storage Tank	Vertical, lined	150,000 gal	130,000 gal	1
11	Process Water Recirculation Pumps	Horizontal centrifugal	850 gpm @ 70 ft H_2O	730 gpm @ 70 ft H_2O	2

ACCOUNT 5B CARBON DIOXIDE RECOVERY

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	Econamine FG Plus	Amine-based CO_2 capture technology	1,707,777 kg/h (3,765,000 lb/h) 20.4 wt % CO2 concentration	1,443,333 kg/h (3,182,000 lb/h) 20.4 wt % CO2 concentration	2
2	CO_2 Compressor	Integrally geared, multistage centrifugal with indirect water intercoolers	314,113 kg/h @ 15.3 MPa (692,501 lb/h @ 2,215 psia)	264,598 kg/h @15.3 MPa (583,338 lb/h @ 2,215 psia)	2

ACCOUNT 6 COMBUSTION TURBINE/ACCESSORIES

N/A

ACCOUNT 7 DUCTING AND STACK

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	Stack	Reinforced concrete with FRP liner	500 ft high x 18 ft diameter	500 ft high x 17 ft diameter	1

ACCOUNT 8 STEAM TURBINE GENERATOR

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	Steam Turbine Generator	Case 3 - Commercially available, advanced Case 4 - Advanced (not yet developed)	710 MW, 3500 psig/ 1110°F /1150°F	680 MW, 4000 psig/ 1350°F /1400°F	1
2	Steam Turbine Generator	Hydrogen cooled, static excitation	790 MVA @ 0.9 p.f., 24 kV, 60 Hz	760 MVA @ 0.9 p.f., 24 kV, 60 Hz	1
3	Surface Condenser	Single pass, divided waterbox including vacuum pumps	2,045 MMBtu/h, Inlet water 60ºF rise 20ºF	1,310 MMBtu/h, Inlet water 60ºF rise 20ºF	1

ACCOUNT 9 COOLING WATER SYSTEM

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	Cooling Tower	Evaporative, mechanical draft, multi-cell	11°C (51.5°F) wet bulb / 16°C (60°F) CWT / 27°C (80°F) HWT 5,903 MMkJ/h (5,600 MMBtu/h) heat load	11°C (51.5°F) wet bulb / 16°C (60°F) CWT / 27°C (80°F) HWT 4,659 MMkJ/h (4,420 MMBtu/h) heat load	1
2	Circ. Water Pumps	Vertical, wet pit	125,000 gpm @ 100 ft	129,000 gpm @ 100 ft	3

ACCOUNT 10 ASH/SPENT SORBENT RECOVERY AND HANDLING

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	Economizer Hopper (part of boiler scope of supply)	--	--	--	4
2	Bottom Ash Hopper (part of boiler scope of supply)	--	--	--	2
3	Clinker Grinder	--	5.4 tph	4.5 tph	2
4	Pyrites Hopper (part of pulverizer scope of supply included with boiler)	--	--	--	6
5	Hydroejectors	--	--	--	12
6	Economizer/Pyrites Transfer Tank	--	--	--	2
7	Ash Sluice Pumps	Vertical, wet pit	60 gpm @ 56 ft H_2O	50 gpm @ 56 ft H_2O	2
8	Ash Seal Water Pumps	Vertical, wet pit	2,000 gpm@ 28 ft H_2O	2,000 gpm @ 28 ft H_2O	2
9	Hydrobins	--	60 gpm	50 gpm	2
10	Baghouse Hopper (part of baghouse scope of supply)	--	--	--	24
11	Air Heater Hopper (part of boiler scope of supply)	--	--	--	10
12	Air Blower	--	740 scfm @ 24 psi	620 scfm @ 24 psi	2
13	Fly Ash Silo	Reinforced concrete	1,500 tons	1,300 tons	2
14	Slide Gate Valves	--	--	--	2

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
15	Unloader	--	140 tph	120 tph	1
16	Telescoping Unloading Chute	--	--	--	1

ACCOUNT 11 ACCESSORY ELECTRIC PLANT

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	STG Transformer	Oil-filled	24 kV/345 kV, 790 MVA, 3-ph, 60 Hz	24 kV/345 kV, 760 MVA, 3-ph, 60 Hz	1
2	Auxiliary Transformer	Oil-filled	24 kV/ 4.16 kV, 131 MVA, 3-ph, 60 Hz	24 kV/ 4.16 kV, 114 MVA, 3-ph, 60 Hz	2
3	LV Transformer	Dry ventilated	4.16 kV /480 V, 20 MVA, 3-ph, 60 Hz	4.16 kV /480 V, 17 MVA, 3-ph, 60 Hz	2
4	STG Isolated Phase Bus Duct and Tap Bus	Aluminum, self-cooled	24 kV, 3-ph, 60 Hz	24 kV, 3-ph, 60 Hz	1
5	Medium Voltage Switchgear	Metal Clad	4.16 kV, 3-ph, 60 Hz	4.16 kV, 3-ph, 60 Hz	2
6	Low Voltage Switchgear	Metal Enclosed	480 V, 3-ph, 60 Hz	480 V, 3-ph, 60 Hz	2
7	Emergency Diesel Generator	Sized for emergency shutdown	750 kW, 480 V, 3-ph, 60 Hz	750 kW, 480 V, 3-ph, 60 Hz	1

ACCOUNT 12 INSTRUMENTATION AND CONTROL

Equipment No.	Description	Type	Design Condition		Qty
			Case 3	Case 4	
1	DCS - Main Control	Monitor/keyboard; Operator printer – laser color; Eng. Printer – laser B&W	Operator Stations/Printers and Engineering Stations/Printers	Operator Stations/Printers and Engineering Stations/Printers	1
2	DCS - Processor	Microprocessor with Redundant Input/Output	N/A	N/A	1
3	DCS - Data Highway	Fiber optic	Fully redundant, 25% spare	Fully redundant, 25% spare	1

4.3 ECONOMIC ANALYSIS FOR AIR-FIRED CASES 1 THROUGH 4

The capital and operating costs for Cases 1 and 2 are presented in Section 4.3.1 and for Cases 3 and 4 in Section 4.3.2. A cost and performance summary table for all four cases is shown in Section 4.3.3. Additional cost detail sheets for all four cases are contained in Section 4.3.4.

4.3.1 Cost Estimate Results for Cases 1 and 2

The capital and operating costs for Case 1 are shown in Exhibit 4-17 and Exhibit 4-19 and the corresponding costs for Case 2 are shown in Exhibit 4-20 and Exhibit 4-21. The economic estimate basis and criteria are shown in Exhibit 4-22. Capital and operating cost estimating methodology is explained in Section 2.8.

Exhibit 4-17 Case 1 Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 1 - Air Fired Super-Critical PC w/o CO2 Capture
Plant Size: **553.80** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING	15,481	4,183	9,376	0	**29,040**	2,602	0	4,746	**$36,389**	$66
2	COAL & SORBENT PREP & FEED	10,405	603	2,638	0	**13,646**	1,196	0	2,226	**$17,068**	$31
3	FEEDWATER & MISC. BOP SYSTEMS	40,107	0	18,856	0	**58,963**	5,369	0	10,462	**$74,795**	$135
4	PC BOILER										
4.1	PC Boiler & Accessories	148,766	0	83,888	0	**232,654**	22,535	0	25,519	**$280,708**	$507
4.2	SCR (w/4.1)	0	0	0	0	**0**	0	0	0	**$0**	$0
4.3-4.9	Other Boiler Equipment	0	0	0	0	**0**	0	0	0	**$0**	$0
	Subtotal 4	148,766	0	83,888	0	**232,654**	22,535	0	25,519	**$280,708**	$507
5	FLUE GAS CLEANUP	78,075	0	26,700	0	**104,775**	9,955	0	11,473	**$126,203**	$228
5B	CO2 REMOVAL & COMPRESSION	0	0	0	0	**0**	0	0	0	**$0**	$0
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0	0	**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	N/A	0	N/A	0	**0**	0	0	0	**$0**	
7.2-7.9	Ductwork and Stack	16,653	959	11,402	0	**29,013**	2,656	0	4,132	**$35,801**	$65
	Subtotal 7	16,653	959	11,402	0	**29,013**	2,656	0	4,132	**$35,801**	$65
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	48,728	0	6,532	0	**55,260**	5,291	0	6,055	**$66,606**	$120
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	23,094	1,042	12,656	0	**36,792**	3,213	0	5,619	**$45,625**	$82
	Subtotal 8	71,822	1,042	19,188	0	**92,052**	8,504	0	11,675	**$112,231**	$203
9	COOLING WATER SYSTEM	11,274	6,553	11,673	0	**29,500**	2,759	0	4,450	**$36,709**	$66
10	ASH/SPENT SORBENT HANDLING SYS	4,232	133	5,628	0	**9,992**	951	0	1,126	**$12,069**	$22
11	ACCESSORY ELECTRIC PLANT	15,533	5,832	17,190	0	**38,556**	3,411	0	5,217	**$47,183**	$85
12	INSTRUMENTATION & CONTROL	8,069	0	8,480	0	**16,549**	1,515	0	2,222	**$20,285**	$37
13	IMPROVEMENTS TO SITE	2,827	1,625	5,741	0	**10,194**	1,001	0	2,239	**$13,434**	$24
14	BUILDINGS & STRUCTURES	0	21,560	20,672	0	**42,232**	3,805	0	6,906	**$52,943**	$96
	TOTAL COST	**$423,244**	**$42,490**	**$241,430**	**$0**	**$707,164**	**$66,260**	**$0**	**$92,393**	**$865,818**	**$1,563**

Exhibit 4-18 Case 1 Capital Investment and Operating Cost Summary

TITLE/DEFINITION

Case:	**Case 1 - Air Fired Super-Critical PC w/o CO2 Capture**				
Plant Size:	**553.80**	**(MW,net)**	**Heat Rate**	**8,649**	**Btu/kWh**
Fuel(type):	**Illinois #6**		**Fuel Cost:**	**1.80**	**($/MMBtu)**
Design/Construction:	**3**	**(years)**	**BookLife:**	**30**	**(years)**
TPC(Plant Cost) Year:	**2007**	**(Jan)**	**Startup Year:**	**2010**	
Capacity Factor:	**85.0%**		**CO_2 Catured**	**0**	**(TPD)**

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	707,164	1,276.9
Engineering(incl.C.M.,H.O.& Fee)	66,260	119.6
Process Contingency	0	0.0
Project Contingency	92,393	166.8
TOTAL PLANT COST(TPC)	**865,818**	**1,563.4**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	5,261	9.5
Maintenance Labor	5,817	10.5
Maintenance Material	8,725	15.8
Administrative & Support Labor	2,570	4.6
TOTAL OPERATION & MAINTENANCE	$22,373	40.4
FIXED O & M (2007)	$13,648	24.6
VARIABLE O & M	$8,725	15.8

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	2,505	0.06
Chemicals	6,983	0.17
Other Consumables	0	0.00
Waste Disposal	2,290	0.06
TOTAL CONSUMABLES	$11,778	0.29
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$64,366	1.56

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.38
Variable O & M	1.16	0.25
Consumables	1.16	0.33
By-product Credit	1.16	0.00
Fuel	1.21	1.89
TOTAL PRODUCTION COST		2.85
2007 CARRYING CHARGES (Capital)		3.44
CCF for a 20-Year Levelization Period - IOU - Lower-Risk	**16.4**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		6.29

Exhibit 4-19 Case 1 Estimate Basis /Economic Criteria Summary

Case Title:	**Case 1 - Air Fired Super-Critical PC w/o CO2 Capture**		
Unit Size:/Plant Size:		**553.80**	**MW,net**
Location:	**Midwestern, USA**		
Fuel: Coal/Secondary	**Illinois #6**		
Plant Heat Rate:		**8,649**	**Btu/kWh**
Levelized Capacity Factor:		**85.0%**	
Capital Cost Year Dollars:		**2007**	**(Jan)**
Delivered Cost of Coal /Primary Fuel		**1.80**	**$/MMBtu**
Delivered Cost of Natural Gas//Secondary Fuel		**6.75**	**$/MMBtu**
Design/Construction Period:		**3**	**years**
Plant Startup Date(year):		**2010**	**(January)**
FINANCIAL CRITERIA	IOU Low Risk		
Project Book Life:		**30**	**years**
Book Salvage Value:		**0.0**	**%**
Project Tax Life:		**20**	**years**
Tax Depreciation Method:	**20 years, 150% declining balance**		
Property Tax Rate:		**1.0**	**% per year**
Insurance Tax Rate:		**1.0**	**% per year**
Federal Income Tax Rate:		**34.0**	**%**
State Income Tax Rate:		**6.0**	**%**
Investment Tax Credit/% Eligible		**0.0**	**%**
Economic Basis:	**20th Year Current Dollars**		

		% of Total	**Cost(%)**
Capital Structure			
	Common Equity	**50.00**	**12.00**
	Tax Free Municipal Bonds	**0.00**	**0.00**
	Debt	**50.00**	**9.00**
Weighted Cost of Capital:(after tax)		**8.79 %**	

		2010 - 2030	
Escalation Rates			
	General	**1.9**	**% per year**
	Coal Price	**2.348**	**% per year**
	Secondary Fuel:	**1.955**	**% per year**

Exhibit 4-20 Case 2 Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture
Plant Size: **555.88** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING	14,208	3,808	8,426		**26,442**	2,369	0	4,322	**$33,133**	$60
2	COAL & SORBENT PREP & FEED	9,516	548	2,371		**12,435**	1,090	0	2,029	**$15,554**	$28
3	FEEDWATER & MISC. BOP SYSTEMS	47,256	0	21,402		**68,658**	6,295	0	12,601	**$87,554**	$158
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	157,011	0	88,537		**245,547**	23,784	26,933	26,933	**$323,197**	$581
4.2	Open	0	0	0		**0**	0	0	0	**$0**	$0
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	157,011	0	88,537		**245,547**	23,784	26,933	26,933	**$323,197**	$581
5	FLUE GAS CLEANUP	70,521	0	23,570		**94,091**	8,940	0	10,303	**$113,334**	$204
5B	CO2 REMOVAL & COMPRESSION	0	0	0		**0**	0	0	0	**$0**	$0
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0		**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	0	0	0		**0**	0	0	0	**$0**	
7.2-7.9	Ductwork and Stack	16,281	937	11,147		**28,365**	2,596	0	4,040	**$35,001**	$63
	Subtotal 7	16,281	937	11,147		**28,365**	2,596	0	4,040	**$35,001**	$63
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	54,474	0	7,302		**61,776**	5,915	0	6,769	**$74,461**	$134
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	25,817	1,165	14,149		**41,131**	3,592	0	6,282	**$51,005**	$92
	Subtotal 8	80,292	1,165	21,451		**102,908**	9,507	0	13,051	**$125,466**	$226
9	COOLING WATER SYSTEM	9,982	5,802	10,335		**26,120**	2,443	0	3,940	**$32,503**	$58
10	ASH/SPENT SORBENT HANDLING SYS	3,912	122	5,094		**9,128**	869	0	1,029	**$11,025**	$20
11	ACCESSORY ELECTRIC PLANT	14,570	5,966	16,852		**37,388**	3,310	0	5,104	**$45,802**	$82
12	INSTRUMENTATION & CONTROL	9,464	0	9,738		**19,202**	1,758	0	2,577	**$23,537**	$42
13	IMPROVEMENTS TO SITE	2,940	1,686	5,882		**10,508**	1,032	0	2,308	**$13,848**	$25
14	BUILDINGS & STRUCTURES	0	21,358	20,312		**41,670**	3,755	0	6,814	**$52,238**	$94
	TOTAL COST	**$435,953**	**$41,392**	**$245,117**	**$0**	**$722,462**	**$67,747**	**$26,933**	**$95,050**	**$912,193**	**$1,641**

Exhibit 4-21 Case 2 Capital Investment and Operating Cost Summary

TITLE/DEFINITION

Case:	**Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture**			
Plant Size:	**555.88 (MW,net)**	**Heat Rate**	**7,651**	**Btu/kWh**
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**	
Capacity Factor:	**85.0%**	**CO_2 Catured**	**0**	**(TPD)**

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	722,462	1,299.7
Engineering(incl.C.M.,H.O.& Fee)	67,747	121.9
Process Contingency	26,933	48.5
Project Contingency	95,050	171.0
TOTAL PLANT COST(TPC)	**912,193**	**1,641.0**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	5,261	9.5
Maintenance Labor	6,128	11.0
Maintenance Material	9,193	16.5
Administrative & Support Labor	2,570	4.6
TOTAL OPERATION & MAINTENANCE	$23,152	41.6
FIXED O & M (2007)	$13,959	25.1
VARIABLE O & M	$9,193	16.5

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	2,172	0.05
Chemicals	6,144	0.15
Other Consumables	0	0.00
Waste Disposal	2,035	0.05
TOTAL CONSUMABLES	$10,351	0.25
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$57,152	1.38

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.39
Variable O & M	1.16	0.26
Consumables	1.16	0.29
By-product Credit	1.16	0.00
Fuel	1.20	1.66
TOTAL PRODUCTION COST		2.60
2007 CARRYING CHARGES (Capital)		3.86
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		6.45

Exhibit 4-22 Case 2 Estimate Basis /Economic Criteria Summary

Case Title:	**Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture**		
Unit Size:/Plant Size:		**555.88**	**MW,net**
Location:		**Midwestern, USA**	
Fuel: Coal/Secondary		**Illinois #6**	
Plant Heat Rate:		**7,651**	**Btu/kWh**
Levelized Capacity Factor:		**85.0%**	
Capital Cost Year Dollars:		**2007**	**(Jan)**
Delivered Cost of Coal /Primary Fuel		**1.80**	**$/MMBtu**
Delivered Cost of Natural Gas//Secondary Fuel		**6.75**	**$/MMBtu**
Design/Construction Period:		**3**	**years**
Plant Startup Date(year):		**2010**	**(January)**
FINANCIAL CRITERIA		IOU High Risk	
Project Book Life:		**30**	**years**
Book Salvage Value:		**0.0**	**%**
Project Tax Life:		**20**	**years**
Tax Depreciation Method:		**20 years, 150% declining balance**	
Property Tax Rate:		**1.0**	**% per year**
Insurance Tax Rate:		**1.0**	**% per year**
Federal Income Tax Rate:		**34.0**	**%**
State Income Tax Rate:		**6.0**	**%**
Investment Tax Credit/% Eligible		**0.0**	**%**
Economic Basis:		**20th Year Current Dollars**	

		% of Total	**Cost(%)**
Capital Structure			
	Common Equity	**55.00**	**12.00**
	Tax Free Municipal Bonds	**0.00**	**0.00**
	Debt	**45.00**	**11.00**
Weighted Cost of Capital:(after tax)		**9.67 %**	

		2010 - 2030	
Escalation Rates			
	General	**1.9**	**% per year**
	Coal Price	**2.348**	**% per year**
	Secondary Fuel:	**1.955**	**% per year**

4.3.2 Cost Estimate Results for Cases 3 and 4

The capital and operating costs for Case 3 are shown in Exhibit 4-23 and Exhibit 4-24 and the corresponding costs for Case 4 are shown in Exhibit 4-25 and Exhibit 4-26. The economic estimate basis and criteria are shown in Exhibit 4-27. Capital and operating cost estimating methodology is explained in Section 2.8.

Exhibit 4-23 Case 3 Total Plant Costs

	Client:	U.S. DOE / NETL							**Report Date:**	28-Aug-07		
	Project:	Oxy-Fuel Combustion Systems Analysis										
					TOTAL PLANT COST SUMMARY							
	Case:	Case 3 Air-Fired Supercritical Boiler with CO2 Capture										
	Plant Size:	**548.75** MW,net		**Estimate Type:**	Conceptual			**Cost Base (Jan)** 2007		$x1000		
Acct		**Equipment**	**Material**	**Labor**		**Bare Erected**	**Eng'g CM**	**Contingencies**		**TOT. PLANT COST**		
No.	**Item/Description**	**Cost**	**Cost**	**Direct**	**Indirect**	**Cost $**	**H.O.& Fee**	**Process**	**Project**	**$**	**$/kW**	
1	COAL & SORBENT HANDLING	19,316	5,215	11,691	0	**36,222**	3,246	0	5,920	**$45,389**	$83	
2	COAL & SORBENT PREP & FEED	13,126	758	3,326	0	**17,210**	1,508	0	2,808	**$21,527**	$39	
3	FEEDWATER & MISC. BOP SYSTEMS	54,477	0	25,648	0	**80,126**	7,317	0	14,428	**$101,870**	$186	
4	PC BOILER & ACCESSORIES											
4.1	PC Boiler & Accessories	191,692	0	108,093	0	**299,785**	29,037	0	32,882	**$361,705**	$659	
4.2	SCR (w/4.1)	0	0	0	0	**0**	0	0	0	**$0**	$0	
4.3-4.9	Other Boiler Equipment	0	0	0	0	**0**	0	0	0	**$0**	$0	
	Subtotal 4	191,692	0	108,093	0	**299,785**	29,037	0	32,882	**$361,705**	$659	
5	FLUE GAS CLEANUP	101,747	0	34,963	0	**136,710**	12,990	0	14,970	**$164,670**	$300	
5B	CO2 REMOVAL & COMPRESSION	229,832	0	69,851	0	**299,683**	28,443	52,879	76,201	**$457,207**	$833	
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0	0	**0**	0	0	0	**$0**	$0	
7	DUCTING & STACK											
7.1	Flue Gas Recycle Heat Exchanger	N/A	0	N/A	0	**0**	0	0	0	**$0**	$0	
7.2-7.9	Ductwork and Stack	17,839	1,027	12,214	0	**31,080**	2,845	0	4,426	**$38,351**	$70	
	Subtotal 7	17,839	1,027	12,214	0	**31,080**	2,845	0	4,426	**$38,351**	$70	
8	STEAM TURBINE GENERATOR											
8.1	Steam TG & Accessories	55,126	0	7,389	0	**62,515**	5,986	0	6,850	**$75,351**	$137	
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	26,126	1,179	14,318	0	**41,623**	3,635	0	6,357	**$51,615**	$94	
	Subtotal 8	81,252	1,179	21,707	0	**104,138**	9,621	0	13,207	**$126,966**	$231	
9	COOLING WATER SYSTEM	19,756	11,482	20,455	0	**51,693**	4,835	0	7,799	**$64,327**	$117	
10	ASH/SPENT SORBENT HANDLING SYS	5,154	162	6,854	0	**12,169**	1,158	0	1,371	**$14,699**	$27	
11	ACCESSORY ELECTRIC PLANT	20,251	10,240	29,301	0	**59,792**	5,338	0	8,295	**$73,425**	$134	
12	INSTRUMENTATION & CONTROL	9,195	0	9,662	0	**18,857**	1,726	943	2,648	**$24,174**	$44	
13	IMPROVEMENTS TO SITE	3,162	1,818	6,421	0	**11,402**	1,120	0	2,504	**$15,026**	$27	
14	BUILDINGS & STRUCTURES	0	23,760	22,735	0	**46,495**	4,189	0	7,603	**$58,287**	$106	
	TOTAL COST	**$766,801**	**$55,641**	**$382,922**	**$0**	**$1,205,363**	**$113,373**	**$53,822**	**$195,063**	**$1,567,622**	**$2,857**	

Exhibit 4-24 Case 3 Capital Investment and Operating Cost Summary

TITLE/DEFINITION				
Case:	**Case 3 Air-Fired Supercritical Boiler with CO2 Capture**			
Plant Size:	**548.75 (MW,net)**	**Heat Rate**	**12,538**	**Btu/kWh**
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**	
Capacity Factor:	**85.0%**	**CO_2 Catured**	**15,109**	**(TPD)**

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	1,205,363	2,196.6
Engineering(incl.C.M.,H.O.& Fee)	113,373	206.6
Process Contingency	53,822	98.1
Project Contingency	195,063	355.5
TOTAL PLANT COST(TPC)	**1,567,622**	**2,856.7**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	6,126	11.2
Maintenance Labor	10,532	19.2
Maintenance Material	15,798	28.8
Administrative & Support Labor	2,992	5.5
TOTAL OPERATION & MAINTENANCE	$35,447	64.6
FIXED O & M (2007)	$19,649	35.8
VARIABLE O & M	$15,798	28.8

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	5,582	0.14
Chemicals	12,570	0.31
Other Consumables	0	0.00
Waste Disposal	3,289	0.08
TOTAL CONSUMABLES	$21,441	0.52
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$92,458	2.26

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.56
Variable O & M	1.16	0.45
Consumables	1.16	0.61
By-product Credit	1.16	0.00
Fuel	1.20	2.72
TOTAL PRODUCTION COST		4.33
2007 CARRYING CHARGES (Capital)		6.71
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		11.04

Exhibit 4-25 Case 4 Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 4 - Air Fired Ultra-Super-Critical PC with CO2 Capture
Plant Size: **545.05** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies		TOT. PLANT COST	
				Direct	Indirect			Process	Project	$	$/kW
1	COAL & SORBENT HANDLING	18,673	5,007	11,080		**34,760**	3,115	0	5,681	**$43,556**	$80
2	COAL & SORBENT PREP & FEED	12,506	721	3,117		**16,344**	1,432	0	2,666	**$20,443**	$38
3	FEEDWATER & MISC. BOP SYSTEMS	62,114	0	28,133		**90,247**	8,274	0	16,563	**$115,085**	$211
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	194,987	0	109,951		**304,939**	29,537	33,448	33,448	**$401,370**	$736
4.2	Open	0	0	0		**0**	0	0	0	**$0**	$0
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	194,987	0	109,951		**304,939**	29,537	33,448	33,448	**$401,370**	$736
5	FLUE GAS CLEANUP	92,698	0	30,982		**123,680**	11,751	0	13,543	**$148,974**	$273
5B	CO2 REMOVAL & COMPRESSION	205,225	0	62,372		**267,597**	25,398	47,218	68,043	**$408,256**	$749
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0		**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	0	0	0		**0**	0	0	0	**$0**	
7.2-7.9	Ductwork and Stack	17,267	994	11,822		**30,083**	2,754	0	4,284	**$37,121**	$68
	Subtotal 7	17,267	994	11,822		**30,083**	2,754	0	4,284	**$37,121**	$68
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	60,310	0	8,084		**68,394**	6,549	0	7,494	**$82,437**	$151
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	28,583	1,290	15,665		**45,537**	3,977	0	6,955	**$56,470**	$104
	Subtotal 8	88,893	1,290	23,749		**113,932**	10,526	0	14,450	**$138,907**	$255
9	COOLING WATER SYSTEM	17,274	10,040	17,885		**45,199**	4,228	0	6,819	**$56,245**	$103
10	ASH/SPENT SORBENT HANDLING SYS	5,142	156	6,697		**11,995**	1,142	0	1,351	**$14,488**	$27
11	ACCESSORY ELECTRIC PLANT	20,432	10,256	29,076		**59,764**	5,325	0	8,304	**$73,393**	$135
12	INSTRUMENTATION & CONTROL	11,074	0	11,826		**22,900**	2,096	1,145	3,217	**$29,358**	$54
13	IMPROVEMENTS TO SITE	2,940	1,686	5,882		**10,508**	1,032	0	2,308	**$13,848**	$25
14	BUILDINGS & STRUCTURES	0	24,726	24,305		**49,031**	4,419	0	8,017	**$61,467**	$113
	TOTAL COST	**$749,225**	**$54,875**	**$376,878**	**$0**	**$1,180,979**	**$111,027**	**$81,810**	**$188,694**	**$1,562,511**	**$2,867**

Exhibit 4-26 Case 4 Capital Investment and Operating Cost Summary

TITLE/DEFINITION

Case:	**Case 4 - Air Fired Ultra-Super-Critical PC with CO2 Capture**				
Plant Size:	**545.05 (MW,net)**	**Heat Rate**	**10,632**	**Btu/kWh**	
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**	
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**	
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**		
Capacity Factor:	**85.0%**	**CO_2 Catured**	**12,729**	**(TPD)**	

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	1,180,979	2,166.7
Engineering(incl.C.M.,H.O.& Fee)	111,027	203.7
Process Contingency	81,810	150.1
Project Contingency	188,694	346.2
TOTAL PLANT COST(TPC)	**1,562,511**	**2,866.7**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	6,126	11.2
Maintenance Labor	10,497	19.3
Maintenance Material	15,746	28.9
Administrative & Support Labor	2,992	5.5
TOTAL OPERATION & MAINTENANCE	$35,361	64.9
FIXED O & M (2007)	$19,615	36.0
VARIABLE O & M	$15,746	28.9

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	4,436	0.11
Chemicals	11,990	0.30
Other Consumables	0	0.00
Waste Disposal	2,756	0.07
TOTAL CONSUMABLES	$19,182	0.47
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$77,881	1.92

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.56
Variable O & M	1.16	0.45
Consumables	1.16	0.55
By-product Credit	1.16	0.00
Fuel	1.20	2.31
TOTAL PRODUCTION COST		3.86
2007 CARRYING CHARGES (Capital)		6.74
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		10.60

Exhibit 4-27 Case 3 & 4 Estimate Basis /Economic Criteria Summary

Location:	**Midwestern, USA**		
Fuel: Coal/Secondary	**Illinois #6**		
Levelized Capacity Factor:	**85.0%**		
Capital Cost Year Dollars:	**2007**	**(Jan)**	
Delivered Cost of Coal /Primary Fuel	**1.80**	**$/MMBtu**	
Delivered Cost of Natural Gas//Secondary Fuel	**6.75**	**$/MMBtu**	
Design/Construction Period:	**3**	**years**	
Plant Startup Date(year):	**2010**	**(January)**	
FINANCIAL CRITERIA	IOU High Risk		
Project Book Life:	**30**	**years**	
Book Salvage Value:	**0.0**	**%**	
Project Tax Life:	**20**	**years**	
Tax Depreciation Method:	**20 years, 150% declining balance**		
Property Tax Rate:	**1.0**	**% per year**	
Insurance Tax Rate:	**1.0**	**% per year**	
Federal Income Tax Rate:	**34.0**	**%**	
State Income Tax Rate:	**6.0**	**%**	
Investment Tax Credit/% Eligible	**0.0**	**%**	
Economic Basis:	**20th Year Current Dollars**		
	% of Total		**Cost(%)**
Capital Structure			
Common Equity	**55.00**		**12.00**
Tax Free Municipal Bonds	**0.00**		**0.00**
Debt	**45.00**		**11.00**
Weighted Cost of Capital:(after tax)	**9.67**	**%**	
Escalation Rates	**2010 - 2030**		
General	**1.9**	**% per year**	
Coal Price	**2.348**	**% per year**	
Secondary Fuel:	**1.955**	**% per year**	

4.3.3 Cost Estimate and Performance Summary for Air-Based Cases

A summary of plant costs and performance are shown in Exhibit 4-28.

Exhibit 4-28 Cost and Performance Results for Cases 1 through 4

Case	1	2	3	4
Gross Power Output, MW_e	583.8	582.7	666.6	650.0
Net Power Output, MW_e	553.8	555.8	548.7	545.1
Net Plant Efficiency, % (HHV)	39.5	44.6	27.2	32.1
Net Plant Heat Rate, Btu/kWh (HHV)	8,649	7,651	12,538	10,632
Total Plant Cost, $x1000	865,818	912,193	1,567,622	1,562,511
Total Plant Cost, $/kW	1,563	1,641	2,857	2,867
CO_2 Capital Cost Penalty[a], $/kW	-	78	1,293	1,303
Levelized Cost of Electricity, ¢/kWh (85% Capacity Factor)	6.29	6.45	11.04	10.60
Levelized COE CO_2 Penalty[b], ¢/kWh (85% Capacity Factor)	-	0.16	4.75	4.31
Percent increase in COE[c], (85% Capacity Factor)	-	2.6%	76%	68%
Total CO_2 Emitted, lb/MWh_{net}	1,759	1,556	254	216
Cost of CO_2 Avoided[d,f], $/ton	-	16	63	62
Total CO_2 Captured, lb/MWh_{net}	-	-	2,295	1,946
Cost of CO_2 Captured[e], $/ton	-	-	41	43

a. CO_2 Capital Cost Penalty = TPC with capture – TPC case 1 air-fired without capture
b. CO_2 LCOE Cost Penalty = LCOE with capture – LCOE case 1 air-fired without capture
c. Relative to Case 1 ("Base Case")
d. CO_2 Cost Avoided = (COE with capture – COE without capture)/(Emissions without capture – Emissions with capture)
e. CO_2 Cost Captured (or Removal) = (COE with capture – COE without capture)/(CO_2 Captured)
Costs do not include CO_2 Transport, Storage, and Monitoring

f. CO_2 Cost Avoided for Case 2 based on higher net plant efficiency as compared to Case 1

4.3.4 Cost Estimate Details for Air-Based Cases

Additional cost estimating details are provided for the four air-based PC cases in the following subsections:

Section 4.3.4.1: Case 1 – Supercritical PC without CO_2 capture

Section 4.3.4.2: Case 2 – Ultra-supercritical PC without CO_2 capture

Section 4.3.4.3: Case 3 – Supercritical PC with CO_2 capture

Section 4.3.4.4: Case 4 – Ultra-supercritical with CO_2 capture

4.3.4.1 Case 1 – Supercritical PC without CO_2 capture

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Case 1 - Air Fired Super-Critical PC w/o CO2 Capture

TOTAL PLANT COST SUMMARY

Case: Case 1 - Air Fired Super-Critical PC w/o CO2 Capture
Plant Size: 553.80 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	3,183	0	1,469		$4,652	415	0	760	**$5,827**	$11
1.2	Coal Stackout & Reclaim	4,113	0	942		$5,055	442	0	825	**$6,322**	$11
1.3	Coal Conveyors	3,824	0	932		$4,756	417	0	776	**$5,949**	$11
1.4	Other Coal Handling	1,001	0	216		$1,216	106	0	198	**$1,521**	$3
1.5	Sorbent Receive & Unload	127	0	39		$166	15	0	27	**$208**	$0
1.6	Sorbent Stackout & Reclaim	2,056	0.00	381		$2,437	212	0	397	**$3,047**	$6
1.7	Sorbent Conveyors	734	158	182		$1,073	93	0	175	**$1,341**	$2
1.8	Other Sorbent Handling	443	103	235		$781	69	0	128	**$978**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	3,922	4,982		$8,904	832	0	1,460	**$11,197**	$20
	SUBTOTAL 1.	**$15,481**	**$4,183**	**$9,376**		**$29,040**	**$2,602**	**$0**	**$4,746**	**$36,389**	$66
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	1,823	0	359		$2,182	190	0	356	**$2,728**	$5
2.2	Coal Conveyor to Storage	4,668	0	1,030		$5,698	498	0	929	**$7,125**	$13
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	3,493	150	733		$4,376	381	0	714	**$5,470**	$10
2.6	Sorbent Storage & Feed	421	0	163		$584	52	0	95	**$731**	$1
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	453	353		$807	74	0	132	**$1,013**	$2
	SUBTOTAL 2.	**$10,405**	**$603**	**$2,638**		**$13,646**	**$1,196**	**$0**	**$2,226**	**$17,068**	$31
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	FeedwaterSystem	17,490	0	5,725		$23,214	2,033	0	3,787	**$29,034**	$52
3.2	Water Makeup & Pretreating	4,278	0	1,376		$5,654	530	0	1,237	**$7,420**	$13
3.3	Other Feedwater Subsystems	5,404	0	2,293		$7,697	686	0	1,257	**$9,641**	$17
3.4	Service Water Systems	844	0	456		$1,300	121	0	284	**$1,705**	$3
3.5	Other Boiler Plant Systems	6,403	0	6,264		$12,667	1,188	0	2,078	**$15,933**	$29
3.6	FO Supply Sys & Nat Gas	247	0	304		$551	51	0	90	**$692**	$1
3.7	Waste Treatment Equipment	2,883	0	1,652		$4,535	439	0	995	**$5,969**	$11
3.8	Misc. Equip.(cranes,AirComp.,Comm.)	2,558	0	788		$3,346	321	0	733	**$4,400**	$8
	SUBTOTAL 3.	**$40,107**	**$0**	**$18,856**		**$58,963**	**$5,369**	**$0**	**$10,462**	**$74,795**	$135
4	PC BOILER										
4.1	PC Boiler & Accessories	148,766	0	83,888		$232,654	22,535	0	25,519	**$280,708**	$507
4.2	SCR (w/4.1)	0	0	0		$0	0	0	0	**$0**	$0
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BoP (w/ ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	w/4.1	0	w/4.1		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	w/4.1	0	w/4.1		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	w/4.1	w/4.1		$0	0	0	0	**$0**	$0
4.9	Boiler Foundations	0	w/14.1	w/14.1		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$148,766**	**$0**	**$83,888**		**$232,654**	**$22,535**	**$0**	**$25,519**	**$280,708**	$507

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 1 - Air Fired Super-Critical PC w/o CO2 Capture
Plant Size: 553.80 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	54,227	0	11,683		$65,910	6,238	0	7,215	**$79,363**	$143
5.2	Other FGD	2,830	0	3,209		$6,039	582	0	662	**$7,283**	$13
5.3	Bag House & Accessories	15,654	0	9,942		$25,596	2,448	0	2,804	**$30,849**	$56
5.4	Other Particulate Removal Materials	1,059	0	1,134		$2,194	211	0	241	**$2,646**	$5
5.5	Gypsum Dewatering System	4,304	0	732		$5,036	476	0	551	**$6,063**	$11
5.6	Mercury Removal System	0	0	0		$0	0	0	0	**$0**	$0
5.7	Open					$0	0	0	0	**$0**	$0
5.9	Open					$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$78,075**	**$0**	**$26,700**		**$104,775**	**$9,955**	**$0**	**$11,473**	**$126,203**	$228
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	0	0	0		$0	0	0	0	**$0**	**$0**
	SUBTOTAL 5B.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator	N/A	0	N/A		$0	0	0	0	**$0**	**$0**
6.2	Open	0	0	0		$0	0	0	0	**$0**	**$0**
6.3	Compressed Air Piping	0.00	0	0		$0	0	0	0	**$0**	**$0**
6.9	Combustion Turbine Foundations	0	0	0		$0	0	0	0	**$0**	**$0**
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	DUCTING & STACK										
7.1	N/A	N/A	0	N/A		$0	0	0	0	**$0**	$0
7.2	N/A	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	8,242	0	5,379		$13,621	1,190	0	2,222	**$17,033**	$31
7.4	Stack	8,411	0	4,925		$13,336	1,274	0	1,461	**$16,071**	$29
7.9	Duct & Stack Foundations	0	959	1,097		$2,056	192	0	449	**$2,697**	$5
	SUBTOTAL 7.	**$16,653**	**$959**	**$11,402**		**$29,013**	**$2,656**	**$0**	**$4,132**	**$35,801**	$65
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	48,728	0	6,532		$55,260	5,291	0	6,055	**$66,606**	$120
8.2	Turbine Plant Auxiliaries	334	0	716		$1,050	102	0	115	**$1,268**	$2
8.3	Condenser & Auxiliaries	6,405	0	2,204		$8,610	818	0	943	**$10,370**	$19
8.4	Steam Piping	16,354	0	8,078		$24,433	2,039	0	3,971	**$30,443**	$55
8.9	TG Foundations	0	1,042	1,658		$2,699	254	0	591	**$3,544**	$6
	SUBTOTAL 8.	**$71,822**	**$1,042**	**$19,188**		**$92,052**	**$8,504**	**$0**	**$11,675**	**$112,231**	$203
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	8,669	0	2,702		$11,371	1,079	0	1,245	**$13,695**	$25
9.2	Circulating Water Pumps	1,223	0	171		$1,394	120	0	151	**$1,666**	$3
9.3	Circ.Water System Auxiliaries	515	0	69		$583	55	0	64	**$702**	$1
9.4	Circ.Water Piping	0	4,150	3,958		$8,108	747	0	1,328	**$10,183**	$18
9.5	Make-up Water System	457	0	605		$1,062	101	0	174	**$1,337**	$2
9.6	Component Cooling Water Sys	411	0	324		$735	69	0	121	**$924**	$2
9.9	Circ.Water System Foundations& Structures	0	2,403	3,844		$6,247	588	0	1,367	**$8,202**	$15
	SUBTOTAL 9.	**$11,274**	**$6,553**	**$11,673**		**$29,500**	**$2,759**	**$0**	**$4,450**	**$36,709**	$66

Client: U.S. DOE / NETL — **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 1 - Air Fired Super-Critical PC w/o CO2 Capture
Plant Size: 553.80 MW,net — **Estimate Type:** — **Cost Base (Jan)** 2007 — $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	563	0	1,735		$2,298	224	0	252	**$2,774**	$5
10.7	Ash Transport & Feed Equipment	3,669	0	3,735		$7,403	700	0	810	**$8,914**	$16
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundation	0	133	158		$291	27	0	64	**$381**	$1
	SUBTOTAL 10.	**$4,232**	**$133**	**$5,628**		**$9,992**	**$951**	**$0**	**$1,126**	**$12,069**	$22
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	1,524	0	249		$1,773	164	0	145	**$2,083**	$4
11.2	Station Service Equipment	2,578	0	882		$3,460	331	0	284	**$4,075**	$7
11.3	Switchgear & Motor Control	3,063	0	525		$3,588	332	0	392	**$4,312**	$8
11.4	Conduit & Cable Tray	0	1,967	6,693		$8,660	829	0	1,423	**$10,913**	$20
11.5	Wire & Cable	0	3,568	7,051		$10,619	895	0	1,727	**$13,241**	$24
11.6	Protective Equipment	243	0	861		$1,104	108	0	121	**$1,333**	$2
11.7	Standby Equipment	1,176	0	28		$1,204	114	0	132	**$1,450**	$3
11.8	Main Power Transformers	6,950	0	165		$7,116	541	0	766	**$8,422**	$15
11.9	Electrical Foundations	0	297	735		$1,032	98	0	226	**$1,356**	$2
	SUBTOTAL 11.	**$15,533**	**$5,832**	**$17,190**		**$38,556**	**$3,411**	**$0**	**$5,217**	**$47,183**	$85
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	w/12.7	0	w/12.7		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	N/A	0	N/A		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	w/8.1	0	w/8.1		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	W/12.7	0	w/12.7		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	413	0	258		$671	65	0	110	**$846**	$2
12.7	Distributed Control System Equipment	4,172	0	760		$4,932	470	0	540	**$5,942**	$11
12.8	Instrument Wiring & Tubing	2,305	0	4,674		$6,979	594	0	1,136	**$8,710**	$16
12.9	Other I & C Equipment	1,179	0	2,787		$3,966	386	0	435	**$4,788**	$9
	SUBTOTAL 12.	**$8,069**	**$0**	**$8,480**		**$16,549**	**$1,515**	**$0**	**$2,222**	**$20,285**	$37

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 1 - Air Fired Super-Critical PC w/o CO2 Capture
Plant Size: 553.80 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	48	958		$1,005	99	0	221	**$1,325**	$2
13.2	Site Improvements	0	1,578	1,974		$3,552	349	0	780	**$4,681**	$8
13.3	Site Facilities	2,827	0	2,809		$5,637	553	0	1,238	**$7,428**	$13
	SUBTOTAL 13.	**$2,827**	**$1,625**	**$5,741**		**$10,194**	**$1,001**	**$0**	**$2,239**	**$13,434**	$24
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	7,843	6,990		$14,833	1,332	0	2,425	**$18,590**	$34
14.2	Turbine Building	0	11,220	10,597		$21,817	1,964	0	3,567	**$27,348**	$49
14.3	Administration Building	0	554	594		$1,147	104	0	188	**$1,439**	$3
14.4	Circulation Water Pumphouse	0	159	128		$286	26	0	47	**$359**	$1
14.5	Water Treatment Buildings	0	565	471		$1,036	93	0	169	**$1,299**	$2
14.6	Machine Shop	0	370	252		$623	55	0	102	**$780**	$1
14.7	Warehouse	0	251	255		$506	46	0	83	**$635**	$1
14.8	Other Buildings & Structures	0	205	177		$382	34	0	62	**$479**	$1
14.9	Waste Treating Building & Str.	0	393	1,208		$1,601	151	0	263	**$2,015**	$4
	SUBTOTAL 14.	**$0**	**$21,560**	**$20,672**		**$42,232**	**$3,805**	**$0**	**$6,906**	**$52,943**	$96
	TOTAL COST	**$423,244**	**$42,490**	**$241,430**		**$707,164**	**$66,260**	**$0**	**$92,393**	**$865,818**	$1,563

INITIAL & ANNUAL O&M EXPENSES			25-Apr-2007		Cost Base:	Jan 2007 dollars
Case 1 - Air Fired Super-Critical PC w/o CO2 Capture					Heat Rate-net(Btu/kWh)	8,649
Plant Output: Carbon Dioxide(tpd): 0					Mwe-net:	553.80
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00 $/hour					
Operating Labor Burden:	30.00 % of base					
Labor O-H Charge Rate:	25.00 % of Labor					
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	9.0	9.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	14.0	14.0				
					Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$5,261,256	9.50
Maintenance Labor Cost					$5,816,841	10.50
Administrative & Support Labor					$2,569,677	4.64
TOTAL FIXED OPERATING COSTS					**$13,647,773**	**24.64**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$8,725,262	0.0021
Consumables	Initial	/Day	Unit Cost	Initial Cost		
Water(/1000 gallons)		7,838	$1.03	$0	$2,504,666	0.0006
Chemicals						
MU & WT Chem.(lbs)	265,584	37,941	$0.16	$43,768	$1,939,871	0.0005
Limestone (Tons)	3,423	489.0	$20.60	$70,510	$3,125,119	0.0008
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	0	0.0	$2,142.40	$0	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	350	50.0	$123.60	$43,272	$1,917,893	0.0005
Subtotal Chemicals				$157,551	$6,982,883	0.0017
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		382	$15.45		$1,831,979	0.0004
Bottom Ash (tons)		96	$15.45		$457,995	0.0001
Subtotal-Waste Disposal					$2,289,974	0.0006
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$20,502,784**	0.0050
Fuel - Coal (Tons)	147,803	4,927	$42.11	$6,223,980	**$64,366,324**	0.0156

4.3.4.2 Case 2 – Ultra-supercritical PC without CO_2 capture

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture

TOTAL PLANT COST SUMMARY

Case: Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture
Plant Size: 555.88 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	2,924	0	1,321		$4,245	379	0	694	**$5,318**	$10
1.2	Coal Stackout & Reclaim	3,777	0	847		$4,624	405	0	754	**$5,783**	$10
1.3	Coal Conveyors & Yard Breaker	3,513	0	838		$4,351	381	0	710	**$5,442**	$10
1.4	Other Coal Handling	920	0	193		$1,113	97	0	182	**$1,392**	$3
1.5	Sorbent Receive & Unload	116	0	35		$151	13	0	25	**$189**	$0
1.6	Sorbent Stackout & Reclaim	1,881	0	341		$2,222	194	0	362	**$2,778**	$5
1.7	Sorbent Conveyors	671	143	163		$977	85	0	159	**$1,221**	$2
1.8	Other Sorbent Handling	406	93	211		$710	63	0	116	**$889**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	3,572	4,477		$8,049	752	0	1,320	**$10,122**	$18
	SUBTOTAL 1.	**$14,208**	**$3,808**	**$8,426**		**$26,442**	**$2,369**	**$0**	**$4,322**	**$33,133**	$60
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	1,669	0	321		$1,990	174	0	325	**$2,488**	$4
2.2	Coal Conveyor to Storage	4,269	0	922		$5,191	454	0	847	**$6,492**	$12
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	3,193	135	656		$3,984	347	0	650	**$4,981**	$9
2.6	Sorbent Storage & Feed	385	0	146		$531	47	0	87	**$665**	$1
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	413	326		$739	68	0	121	**$928**	$2
	SUBTOTAL 2.	**$9,516**	**$548**	**$2,371**		**$12,435**	**$1,090**	**$0**	**$2,029**	**$15,554**	$28
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	17,261	0	5,236		$22,497	1,970	0	3,670	**$28,137**	$51
3.2	Water Makeup & Pretreating	8,078	0	2,541		$10,619	996	0	2,323	**$13,937**	$25
3.3	Other Feedwater Subsystems	5,294	0	2,130		$7,424	662	0	1,213	**$9,298**	$17
3.4	Service Water Systems	1,596	0	843		$2,439	226	0	533	**$3,198**	$6
3.5	Other Boiler Plant Systems	6,846	0	6,555		$13,401	1,257	0	2,199	**$16,857**	$30
3.6	FO Supply Sys & Nat Gas	241	0	291		$532	49	0	87	**$669**	$1
3.7	Waste Treatment Equipment	5,442	0	3,052		$8,494	823	0	1,863	**$11,180**	$20
3.8	Misc. Power Plant Equipment	2,498	0	754		$3,252	312	0	713	**$4,277**	$8
	SUBTOTAL 3.	**$47,256**	**$0**	**$21,402**		**$68,658**	**$6,295**	**$0**	**$12,601**	**$87,554**	$158
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	157,011	0	88,537		$245,547	23,784	26,933	26,933	**$323,197**	$581
4.2	Open	0	0	0		$0	0	0	0	**$0**	$0
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$157,011**	**$0**	**$88,537**		**$245,547**	**$23,784**	**$26,933**	**$26,933**	**$323,197**	$581

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture
Plant Size: 555.88 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	48,924	0	10,320		$59,244	5,607	0	6,485	**$71,336**	$128
5.2	Other FGD	2,553	0	2,835		$5,389	519	0	591	**$6,498**	$12
5.3	Baghouse & Accessories	14,065	0	8,747		$22,812	2,182	0	2,499	**$27,493**	$49
5.4	Other Particulate Removal Materials	952	0	998		$1,950	188	0	214	**$2,351**	$4
5.5	Gypsum Dewatering System	4,027	0	670		$4,697	444	0	514	**$5,655**	$10
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$70,521**	**$0**	**$23,570**		**$94,091**	**$8,940**	**$0**	**$10,303**	**$113,334**	$204
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System					$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying					$0	0	0	0	**$0**	**$0**
	SUBTOTAL 5B.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator						0	0	0	**$0**	$0
6.2	Combustion Turbine Accessories						0	0	0	**$0**	$0
6.3	Compressed Air Piping						0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations						0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	DUCTING & STACK										
7.1	N/A	0	0	0		$0	0	0	0	**$0**	$0
7.2	N/A	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	8,058	0	5,259		$13,317	1,163	0	2,172	**$16,652**	$30
7.4	Stack	8,223	0	4,815		$13,038	1,246	0	1,428	**$15,712**	$28
7.9	Duct & Stack Foundations	0	937	1,072		$2,010	187	0	439	**$2,636**	$5
	SUBTOTAL 7.	**$16,281**	**$937**	**$11,147**		**$28,365**	**$2,596**	**$0**	**$4,040**	**$35,001**	$63
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	54,474	0	7,302		$61,776	5,915	0	6,769	**$74,461**	$134
8.2	Turbine Plant Auxiliaries	374	0	801		$1,174	114	0	129	**$1,417**	$3
8.3	Condenser & Auxiliaries	7,161	0	2,464		$9,625	915	0	1,054	**$11,593**	$21
8.4	Steam Piping	18,283	0	9,031		$27,314	2,280	0	4,439	**$34,033**	$61
8.9	TG Foundations	0	1,165	1,853		$3,018	284	0	660	**$3,962**	$7
	SUBTOTAL 8.	**$80,292**	**$1,165**	**$21,451**		**$102,908**	**$9,507**	**$0**	**$13,051**	**$125,466**	$226
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	7,676	0	2,392		$10,068	956	0	1,102	**$12,126**	$22
9.2	Circulating Water Pumps	1,083	0	151		$1,234	107	0	134	**$1,475**	$3
9.3	Circ.Water System Auxiliaries	456	0	61		$517	49	0	57	**$622**	$1
9.4	Circ.Water Piping	0	3,675	3,504		$7,179	661	0	1,176	**$9,016**	$16
9.5	Make-up Water System	404	0	536		$940	89	0	154	**$1,184**	$2
9.6	Component Cooling Water Sys	364	0	287		$651	61	0	107	**$818**	$1
9.9	Circ.Water System Foundations	0	2,127	3,404		$5,531	521	0	1,210	**$7,262**	$13
	SUBTOTAL 9.	**$9,982**	**$5,802**	**$10,335**		**$26,120**	**$2,443**	**$0**	**$3,940**	**$32,503**	$58

	Client:	U.S. DOE / NETL						**Report Date:**	23-Apr-07		
	Project:	Oxy-Fuel Combustion Systems Analysis									
					TOTAL PLANT COST SUMMARY						
	Case:	Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture									
	Plant Size:	555.88 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000	

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	520	0	1,570		$2,090	204	0	229	**$2,523**	$5
10.7	Ash Transport & Feed Equipment	3,392	0	3,381		$6,773	641	0	741	**$8,155**	$15
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	122	143		$265	25	0	58	**$348**	$1
	SUBTOTAL 10.	**$3,912**	**$122**	**$5,094**		**$9,128**	**$869**	**$0**	**$1,029**	**$11,025**	$20
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	1,528	0	245		$1,773	164	0	145	**$2,083**	$4
11.2	Station Service Equipment	2,454	0	840		$3,294	315	0	271	**$3,880**	$7
11.3	Switchgear & Motor Control	2,916	0	500		$3,416	316	0	373	**$4,106**	$7
11.4	Conduit & Cable Tray	0	2,017	6,732		$8,749	837	0	1,438	**$11,024**	$20
11.5	Wire & Cable	0	3,658	7,093		$10,751	906	0	1,749	**$13,405**	$24
11.6	Protective Equipment	153	0	532		$685	67	0	75	**$827**	$1
11.7	Standby Equipment	1,180	0	27		$1,207	114	0	132	**$1,453**	$3
11.8	Main Power Transformers	6,339	0	162		$6,501	494	0	699	**$7,694**	$14
11.9	Electrical Foundations	0	291	721		$1,012	96	0	222	**$1,330**	$2
	SUBTOTAL 11.	**$14,570**	**$5,966**	**$16,852**		**$37,388**	**$3,310**	**$0**	**$5,104**	**$45,802**	$82
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	485	0	295		$780	75	0	128	**$983**	$2
12.7	Computer & Accessories	4,893	0	873		$5,766	549	0	632	**$6,947**	$12
12.8	Instrument Wiring & Tubing	2,703	0	5,369		$8,072	688	0	1,314	**$10,074**	$18
12.9	Other I & C Equipment	1,383	0	3,201		$4,584	446	0	503	**$5,534**	$10
	SUBTOTAL 12.	**$9,464**	**$0**	**$9,738**		**$19,202**	**$1,758**	**$0**	**$2,577**	**$23,537**	$42

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture
Plant Size: 555.88 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	50	981		$1,031	102	0	227	**$1,359**	$2
13.2	Site Improvements	0	1,636	2,023		$3,659	359	0	804	**$4,822**	$9
13.3	Site Facilities	2,940	0	2,878		$5,818	571	0	1,278	**$7,667**	$14
	SUBTOTAL 13.	**$2,940**	**$1,686**	**$5,882**		**$10,508**	**$1,032**	**$0**	**$2,308**	**$13,848**	$25
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	7,512	6,612		$14,124	1,268	0	2,309	**$17,701**	$32
14.2	Turbine Building	0	11,053	10,311		$21,364	1,924	0	3,493	**$26,781**	$48
14.3	Administration Building	0	574	607		$1,181	107	0	193	**$1,481**	$3
14.4	Circulation Water Pumphouse	0	264	209		$473	42	0	77	**$593**	$1
14.5	Water Treatment Buildings	0	943	778		$1,721	154	0	281	**$2,156**	$4
14.6	Machine Shop	0	377	264		$641	57	0	105	**$803**	$1
14.7	Warehouse	0	108	177		$285	26	0	47	**$357**	$1
14.8	Other Buildings & Structures	0	120	118		$238	21	0	39	**$298**	$1
14.9	Waste Treating Building & Str.	0	407	1,236		$1,643	155	0	270	**$2,068**	$4
	SUBTOTAL 14.	**$0**	**$21,358**	**$20,312**		**$41,670**	**$3,755**	**$0**	**$6,814**	**$52,238**	$94
	TOTAL COST	**$435,953**	**$41,392**	**$245,117**		**$722,462**	**$67,747**	**$26,933**	**$95,050**	**$912,193**	$1,641

INITIAL & ANNUAL O&M EXPENSES			25-Apr-2007		Cost Base:	Jan 2007 dollars
Case 2 - Air Fired Ultra-Super-Critical PC w/o CO2 Capture					Heat Rate-net(Btu/kWh)	7,651
Plant Output: Carbon Dioxide(tpd): 0					Mwe-net:	555.88
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00 $/hour					
Operating Labor Burden:	30.00 % of base					
Labor O-H Charge Rate:	25.00 % of Labor					
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	9.0	9.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	14.0	14.0				
					Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$5,261,256	9.46
Maintenance Labor Cost					$6,128,403	11.02
Administrative & Support Labor					$2,569,677	4.62
TOTAL FIXED OPERATING COSTS					**$13,959,335**	**25.11**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$9,192,604	0.0022
Consumables	Initial	/Day	Unit Cost	Initial Cost		
Water(/1000 gallons)		6,797	$1.03	$0	$2,171,968	0.0005
Chemicals						
MU & WT Chem.(lbs)	230,306	32,901	$0.16	$37,954	$1,682,195	0.0004
Limestone (Tons)	3,022	431.7	$20.60	$62,258	$2,759,366	0.0007
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	0	0.0	$2,142.40	$0	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	311	44.4	$123.60	$38,415	$1,702,602	0.0004
Subtotal Chemicals				$138,627	$6,144,164	0.0015
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		340	$15.45		$1,627,827	0.0004
Bottom Ash (tons)		85	$15.45		$406,957	0.0001
Subtotal-Waste Disposal					$2,034,784	0.0005
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$19,543,520**	0.0047
Fuel - Coal (Tons)	131,237	4,375	$42.11	$5,526,395	**$57,152,131**	0.0138

4.3.4.3 Case 3 – Supercritical PC with CO_2 capture

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Case 3 Air-Fired Supercritical Boiler with CO2 Capture

TOTAL PLANT COST DETAIL

Case: Case 3 Air-Fired Supercritical Boiler with CO2 Capture
Plant Size: 548.75 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	3,967	0	1,831		$5,797	518	0	947	**$7,262**	$13
1.2	Coal Stackout & Reclaim	5,126	0	1,174		$6,300	551	0	1,028	**$7,879**	$14
1.3	Coal Conveyors	4,766	0	1,161		$5,927	520	0	967	**$7,414**	$14
1.4	Other Coal Handling	1,247	0	269		$1,516	132	0	247	**$1,895**	$3
1.5	Sorbent Receive & Unload	160	0	49		$208	18	0	34	**$260**	$0
1.6	Sorbent Stackout & Reclaim	2,576	0	477		$3,053	266	0	498	**$3,817**	$7
1.7	Sorbent Conveyors	919	198	228		$1,345	116	0	219	**$1,680**	$3
1.8	Other Sorbent Handling	555	129	294		$979	87	0	160	**$1,225**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	4,888	6,210		$11,097	1,037	0	1,820	**$13,955**	$25
	SUBTOTAL 1.	**$19,316**	**$5,215**	**$11,691**		**$36,222**	**$3,246**	**$0**	**$5,920**	**$45,389**	$83
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,305	0	454		$2,759	241	0	450	**$3,449**	$6
2.2	Coal Conveyor to Storage	5,901	0	1,301		$7,203	630	0	1,175	**$9,007**	$16
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	4,391	188	922		$5,501	479	0	897	**$6,878**	$13
2.6	Sorbent Storage & Feed	529	0	205		$734	65	0	120	**$919**	$2
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	570	444		$1,014	93	0	166	**$1,274**	$2
	SUBTOTAL 2.	**$13,126**	**$758**	**$3,326**		**$17,210**	**$1,508**	**$0**	**$2,808**	**$21,527**	$39
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	FeedwaterSystem	22,090	0	7,230		$29,320	2,567	0	4,783	**$36,670**	$67
3.2	Water Makeup & Pretreating	7,572	0	2,435		$10,007	938	0	2,189	**$13,134**	$24
3.3	Other Feedwater Subsystems	6,826	0	2,896		$9,722	866	0	1,588	**$12,176**	$22
3.4	Service Water Systems	1,495	0	807		$2,301	214	0	503	**$3,018**	$5
3.5	Other Boiler Plant Systems	8,357	0	8,175		$16,533	1,551	0	2,713	**$20,796**	$38
3.6	FO Supply Sys & Nat Gas	267	0	329		$596	55	0	98	**$749**	$1
3.7	Waste Treatment Equipment	5,103	0	2,923		$8,027	778	0	1,761	**$10,565**	$19
3.8	Misc. Equip.(cranes,AirComp.,Comm.)	2,768	0	853		$3,621	348	0	794	**$4,762**	$9
	SUBTOTAL 3.	**$54,477**	**$0**	**$25,648**		**$80,126**	**$7,317**	**$0**	**$14,428**	**$101,870**	$186
4	PC BOILER & ACCESSORIES										
4.1	PC Boiler & Accessories	191,692	0	108,093		$299,785	29,037	0	32,882	**$361,705**	$659
4.2	SCR (w/4.1)	0	0	0		$0	0	0	0	**$0**	$0
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BoP (w/ ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	w/4.1	0	w/4.1		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	w/4.1	0	w/4.1		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	w/4.1	w/4.1		$0	0	0	0	**$0**	$0
4.9	Boiler Foundations	0	w/14.1	w/14.1		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$191,692**	**$0**	**$108,093**		**$299,785**	**$29,037**	**$0**	**$32,882**	**$361,705**	$659

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST DETAIL

Case: Case 3 Air-Fired Supercritical Boiler with CO2 Capture
Plant Size: 548.75 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	70,491	0	15,186		$85,677	8,109	0	9,379	**$103,165**	$188
5.2	Other FGD	3,679	0	4,172		$7,850	756	0	861	**$9,467**	$17
5.3	Bag House & Accessories	20,751	0	13,179		$33,931	3,245	0	3,718	**$40,894**	$75
5.4	Other Particulate Removal Materials	1,404	0	1,504		$2,908	280	0	319	**$3,507**	$6
5.5	Gypsum Dewatering System	5,422	0	922		$6,344	599	0	694	**$7,638**	$14
5.6	Mercury Removal System	0	0	0		$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$101,747**	**$0**	**$34,963**		**$136,710**	**$12,990**	**$0**	**$14,970**	**$164,670**	$300
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	202,944	0	61,453		$264,397	25,093	52,879	68,474	**$410,843**	**$749**
5B.2	CO2 Compression & Drying	26,888	0	8,398		$35,286	3,350	0	7,727	**$46,363**	**$84**
	SUBTOTAL 5B.	**$229,832**	**$0**	**$69,851**		**$299,683**	**$28,443**	**$52,879**	**$76,201**	**$457,207**	**$833**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator	N/A	0	N/A		$0	0	0	0	**$0**	$0
6.2	Open	0	0	0		$0	0	0	0	**$0**	$0
6.3	Compressed Air Piping	0.00	0	0		$0	0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	DUCTING & STACK										
7.1	N/A	N/A	0	N/A		$0	0	0	0	**$0**	$0
7.2	N/A	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	8,829	0	5,763		$14,592	1,274	0	2,380	**$18,246**	$33
7.4	Stack	9,010	0	5,276		$14,286	1,365	0	1,565	**$17,216**	$31
7.9	Duct & Stack Foundations	0	1,027	1,175		$2,202	205	0	481	**$2,889**	$5
	SUBTOTAL 7.	**$17,839**	**$1,027**	**$12,214**		**$31,080**	**$2,845**	**$0**	**$4,426**	**$38,351**	$70
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	55,126	0	7,389		$62,515	5,986	0	6,850	**$75,351**	$137
8.2	Turbine Plant Auxiliaries	378	0	810		$1,188	115	0	130	**$1,434**	$3
8.3	Condenser & Auxiliaries	7,246	0	2,494		$9,740	926	0	1,067	**$11,732**	$21
8.4	Steam Piping	18,502	0	9,139		$27,641	2,307	0	4,492	**$34,440**	$63
8.9	TG Foundations	0	1,179	1,875		$3,054	287	0	668	**$4,010**	$7
	SUBTOTAL 8.	**$81,252**	**$1,179**	**$21,707**		**$104,138**	**$9,621**	**$0**	**$13,207**	**$126,966**	$231
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	15,191	0	4,734		$19,925	1,892	0	2,182	**$23,999**	$44
9.2	Circulating Water Pumps	2,144	0	299		$2,443	211	0	265	**$2,919**	$5
9.3	Circ.Water System Auxiliaries	902	0	120		$1,022	96	0	112	**$1,231**	$2
9.4	Circ.Water Piping	0	7,272	6,936		$14,208	1,309	0	2,328	**$17,844**	$33
9.5	Make-up Water System	800	0	1,060		$1,861	176	0	306	**$2,342**	$4
9.6	Component Cooling Water Sys	720	0	568		$1,288	121	0	211	**$1,620**	$3
9.9	Circ.Water System Foundations& Structures	0	4,210	6,736		$10,946	1,030	0	2,395	**$14,372**	$26
	SUBTOTAL 9.	**$19,756**	**$11,482**	**$20,455**		**$51,693**	**$4,835**	**$0**	**$7,799**	**$64,327**	$117

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST DETAIL

Case: Case 3 Air-Fired Supercritical Boiler with CO2 Capture
Plant Size: 548.75 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	N/A	0	N/A		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	685	0	2,113		$2,799	273	0	307	**$3,379**	$6
10.7	Ash Transport & Feed Equipment	4,468	0	4,548		$9,016	853	0	987	**$10,856**	$20
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundation	0	162	192		$354	33	0	77	**$464**	$1
	SUBTOTAL 10.	**$5,154**	**$162**	**$6,854**		**$12,169**	**$1,158**	**$0**	**$1,371**	**$14,699**	$27
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	1,647	0	270		$1,917	178	0	157	**$2,251**	$4
11.2	Station Service Equipment	4,642	0	1,589		$6,231	596	0	512	**$7,339**	$13
11.3	Switchgear & Motor Control	5,517	0	945		$6,462	598	0	706	**$7,766**	$14
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$36
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$43
11.6	Protective Equipment	243	0	861		$1,104	108	0	121	**$1,333**	$2
11.7	Standby Equipment	1,253	0	30		$1,282	121	0	140	**$1,544**	$3
11.8	Main Power Transformers	6,950	0	182		$7,132	542	0	767	**$8,441**	$15
11.9	Electrical Foundations	0	326	806		$1,133	108	0	248	**$1,488**	$3
	SUBTOTAL 11.	**$20,251**	**$10,240**	**$29,301**		**$59,792**	**$5,338**	**$0**	**$8,295**	**$73,425**	$134
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	w/12.7	0	w/12.7		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	N/A	0	N/A		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	w/8.1	0	w/8.1		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	W/12.7	0	w/12.7		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	471	0	294		$765	74	38	131	**$1,008**	$2
12.7	Distributed Control System Equipment	4,754	0	866		$5,620	535	281	644	**$7,080**	$13
12.8	Instrument Wiring & Tubing	2,626	0	5,327		$7,953	677	398	1,354	**$10,382**	$19
12.9	Other I & C Equipment	1,343	0	3,176		$4,520	440	226	519	**$5,704**	$10
	SUBTOTAL 12.	**$9,195**	**$0**	**$9,662**		**$18,857**	**$1,726**	**$943**	**$2,648**	**$24,174**	$44

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST DETAIL

Case: Case 3 Air-Fired Supercritical Boiler with CO2 Capture
Plant Size: 548.75 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	53	1,071		$1,124	111	0	247	**$1,482**	$3
13.2	Site Improvements	0	1,765	2,208		$3,973	390	0	873	**$5,236**	$10
13.3	Site Facilities	3,162	0	3,142		$6,305	619	0	1,385	**$8,308**	$15
	SUBTOTAL 13.	**$3,162**	**$1,818**	**$6,421**		**$11,402**	**$1,120**	**$0**	**$2,504**	**$15,026**	$27
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	8,384	7,472		$15,857	1,424	0	2,592	**$19,873**	$36
14.2	Turbine Building	0	12,152	11,477		$23,629	2,128	0	3,864	**$29,621**	$54
14.3	Administration Building	0	608	651		$1,259	114	0	206	**$1,579**	$3
14.4	Circulation Water Pumphouse	0	279	225		$503	45	0	82	**$631**	$1
14.5	Water Treatment Buildings	0	999	834		$1,833	164	0	300	**$2,297**	$4
14.6	Machine Shop	0	406	277		$683	61	0	112	**$855**	$2
14.7	Warehouse	0	275	280		$555	50	0	91	**$696**	$1
14.8	Other Buildings & Structures	0	225	194		$419	38	0	69	**$525**	$1
14.9	Waste Treating Building & Str.	0	431	1,325		$1,756	166	0	288	**$2,210**	$4
	SUBTOTAL 14.	**$0**	**$23,760**	**$22,735**		**$46,495**	**$4,189**	**$0**	**$7,603**	**$58,287**	$106
	TOTAL COST	**$766,801**	**$55,641**	**$382,922**		**$1,205,363**	**$113,373**	**$53,822**	**$195,063**	**$1,567,622**	$2,857

INITIAL & ANNUAL O&M EXPENSES			28-Aug-2007		Cost Base:	Jan 2007 dollars
Case 3 Air-Fired Supercritical Boiler with CO2 Capture					Heat Rate-net(Btu/kWh)	12,538
Plant Output: Carbon Dioxide(tpd): 15,109					Mwe-net:	548.75
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00 $/hour					
Operating Labor Burden:	30.00 % of base					
Labor O-H Charge Rate:	25.00 % of Labor					
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.3	11.3				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.3	16.3				
					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$6,125,605	11.16
Maintenance Labor Cost					$10,531,786	19.19
Administrative & Support Labor					$2,991,838	5.45
TOTAL FIXED OPERATING COSTS					**$19,649,229**	**35.81**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$15,797,679	0.0039
Consumables	Initial	/Day	Unit Cost	Initial Cost		
Water(/1000 gallons)		17,467	$1.03	$0	$5,581,775	0.0014
Chemicals						
MU & WT Chem.(lbs)	591,867	84,552	$0.16	$97,540	$4,323,100	0.0011
Limestone (Tons)	5,008	715.5	$20.60	$103,172	$4,572,714	0.0011
Carbon (lbs)	0	1815.0	$1.00	$0	$563,089	0.0001
MEA Solvent (Ton)	1,070	1.5	$2,142.40	$2,292,800	$1,008,358	0.0002
Sulfuric Acid (Ton)	50.49	7.21	$132.15	$6,672	$295,722	0.0001
Caustic Soda (Ton)	56.57	8.08	$412.96	$23,362	$1,035,449	0.0003
Ammonia (28% NH3) ton	141	20.1	$123.60	$17,398	$771,125	0.0002
Subtotal Chemicals				$2,540,945	$12,569,557	0.0031
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		549	$15.45		$2,631,444	0.0006
Bottom Ash (tons)		137	$15.45		$657,861	0.0002
Subtotal-Waste Disposal					$3,289,306	0.0008
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$37,238,316**	0.0091
Fuel - Coal (Tons)	212,309	7,077	$42.11	$8,940,341	**$92,458,031**	0.0226
Fuel - Natural Gas (Mscf)	0	0	$6.93	$0	**$0**	0.0000

4.3.4.4 Case 4 – Ultra-supercritical PC with CO_2 capture

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Case 4 - Air Fired Ultra-Super-Critical PC with CO2 Capture

TOTAL PLANT COST SUMMARY

Case: Case 4 - Air Fired Ultra-Super-Critical PC with CO2 Capture
Plant Size: 545.05 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	3,841	0	1,739		$5,580	498	0	912	$6,990	$13
1.2	Coal Stackout & Reclaim	4,965	0	1,113		$6,078	532	0	992	$7,602	$14
1.3	Coal Conveyors & Yard Breaker	4,617	0	1,102		$5,719	501	0	933	$7,153	$13
1.4	Other Coal Handling	1,209	0	253		$1,462	128	0	238	$1,828	$3
1.5	Sorbent Receive & Unload	153	0	47		$200	18	0	33	$250	$0
1.6	Sorbent Stackout & Reclaim	2,473	0	448		$2,921	255	0	476	$3,652	$7
1.7	Sorbent Conveyors	882	188	215		$1,285	111	0	209	$1,606	$3
1.8	Other Sorbent Handling	533	123	277		$933	82	0	152	$1,168	$2
1.9	Coal & Sorbent Hnd.Foundations	0	4,696	5,886		$10,582	989	0	1,736	$13,307	$24
	SUBTOTAL 1.	**$18,673**	**$5,007**	**$11,080**		**$34,760**	**$3,115**	**$0**	**$5,681**	**$43,556**	$80
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,193	0	422		$2,615	228	0	426	$3,270	$6
2.2	Coal Conveyor to Storage	5,611	0	1,213		$6,824	597	0	1,113	$8,534	$16
2.3	Coal Injection System	0	0	0		$0	0	0	0	$0	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	$0	$0
2.5	Sorbent Prep Equipment	4,196	178	863		$5,237	456	0	854	$6,547	$12
2.6	Sorbent Storage & Feed	506	0	192		$698	62	0	114	$874	$2
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	$0	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	$0	$0
2.9	Coal & Sorbent Feed Foundation	0	543	427		$970	89	0	159	$1,218	$2
	SUBTOTAL 2.	**$12,506**	**$721**	**$3,117**		**$16,344**	**$1,432**	**$0**	**$2,666**	**$20,443**	$38
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	22,688	0	6,883		$29,571	2,589	0	4,824	$36,984	$68
3.2	Water Makeup & Pretreating	10,619	0	3,340		$13,959	1,309	0	3,054	$18,321	$34
3.3	Other Feedwater Subsystems	6,958	0	2,799		$9,757	870	0	1,594	$12,221	$22
3.4	Service Water Systems	2,098	0	1,108		$3,206	298	0	701	$4,204	$8
3.5	Other Boiler Plant Systems	8,998	0	8,618		$17,616	1,652	0	2,890	$22,159	$41
3.6	FO Supply Sys & Nat Gas	317	0	382		$699	65	0	115	$879	$2
3.7	Waste Treatment Equipment	7,152	0	4,012		$11,164	1,081	0	2,449	$14,695	$27
3.8	Misc. Power Plant Equipment	3,284	0	991		$4,275	410	0	937	$5,623	$10
	SUBTOTAL 3.	**$62,114**	**$0**	**$28,133**		**$90,247**	**$8,274**	**$0**	**$16,563**	**$115,085**	$211
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	194,987	0	109,951		$304,939	29,537	33,448	33,448	$401,370	$736
4.2	Open	0	0	0		$0	0	0	0	$0	$0
4.3	Open	0	0	0		$0	0	0	0	$0	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	$0	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	$0	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	$0	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	$0	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	$0	$0
	SUBTOTAL 4.	**$194,987**	**$0**	**$109,951**		**$304,939**	**$29,537**	**$33,448**	**$33,448**	**$401,370**	$736

	Client:	U.S. DOE / NETL							Report Date:	23-Apr-07	
	Project:	Oxy-Fuel Combustion Systems Analysis									
					TOTAL PLANT COST SUMMARY						
	Case:	Case 4 - Air Fired Ultra-Super-Critical PC with CO2 Capture									
	Plant Size:	545.05 MW,net		Estimate Type:				Cost Base (Jan)	2007	$x1000	
Acct		Equipment	Material	Labor		Bare Erected	Eng'g CM	Contingencies		TOT. PLANT COST	
No.	Item/Description	Cost	Cost	Direct	Indirect	Cost $	H.O.& Fee	Process	Project	$	$/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	64,308	0	13,565		$77,873	7,370	0	8,524	**$93,768**	$172
5.2	Other FGD	3,356	0	3,727		$7,083	682	0	776	**$8,541**	$16
5.3	Baghouse & Accessories	18,488	0	11,497		$29,985	2,868	0	3,285	**$36,139**	$66
5.4	Other Particulate Removal Materials	1,252	0	1,312		$2,564	247	0	281	**$3,092**	$6
5.5	Gypsum Dewatering System	5,294	0	881		$6,175	584	0	676	**$7,435**	$14
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$92,698**	**$0**	**$30,982**		**$123,680**	**$11,751**	**$0**	**$13,543**	**$148,974**	$273
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	181,216	0	54,874		$236,089	22,407	47,218	61,143	**$366,856**	**$673**
5B.2	CO2 Compression & Drying	24,010	0	7,499		$31,508	2,991	0	6,900	**$41,399**	**$76**
	SUBTOTAL 5B.	**$205,225**	**$0**	**$62,372**		**$267,597**	**$25,398**	**$47,218**	**$68,043**	**$408,256**	**$749**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator						0	0	0	**$0**	$0
6.2	Combustion Turbine Accessories						0	0	0	**$0**	$0
6.3	Compressed Air Piping						0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations						0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	DUCTING & STACK										
7.1	N/A	0	0	0		$0	0	0	0	**$0**	$0
7.2	N/A	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	8,546	0	5,578		$14,124	1,234	0	2,304	**$17,661**	$32
7.4	Stack	8,721	0	5,107		$13,827	1,321	0	1,515	**$16,664**	$31
7.9	Duct & Stack Foundations	0	994	1,137		$2,131	199	0	466	**$2,796**	$5
	SUBTOTAL 7.	**$17,267**	**$994**	**$11,822**		**$30,083**	**$2,754**	**$0**	**$4,284**	**$37,121**	$68
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	60,310	0	8,084		$68,394	6,549	0	7,494	**$82,437**	$151
8.2	Turbine Plant Auxiliaries	414	0	887		$1,300	126	0	143	**$1,569**	$3
8.3	Condenser & Auxiliaries	7,928	0	2,728		$10,656	1,013	0	1,167	**$12,836**	$24
8.4	Steam Piping	20,242	0	9,999		$30,240	2,524	0	4,915	**$37,679**	$69
8.9	TG Foundations	0	1,290	2,052		$3,341	314	0	731	**$4,387**	$8
	SUBTOTAL 8.	**$88,893**	**$1,290**	**$23,749**		**$113,932**	**$10,526**	**$0**	**$14,450**	**$138,907**	$255
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	13,282	0	4,140		$17,422	1,654	0	1,908	**$20,984**	$38
9.2	Circulating Water Pumps	1,874	0	262		$2,136	184	0	232	**$2,552**	$5
9.3	Circ.Water System Auxiliaries	789	0	105		$894	84	0	98	**$1,076**	$2
9.4	Circ.Water Piping	0	6,359	6,064		$12,423	1,144	0	2,035	**$15,602**	$29
9.5	Make-up Water System	700	0	927		$1,627	154	0	267	**$2,048**	$4
9.6	Component Cooling Water Sys	629	0	497		$1,126	106	0	185	**$1,416**	$3
9.9	Circ.Water System Foundations	0	3,681	5,890		$9,571	901	0	2,094	**$12,566**	$23
	SUBTOTAL 9.	**$17,274**	**$10,040**	**$17,885**		**$45,199**	**$4,228**	**$0**	**$6,819**	**$56,245**	$103

Client: U.S. DOE / NETL **Report Date:** 23-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 4 - Air Fired Ultra-Super-Critical PC with CO2 Capture
Plant Size: 545.05 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	684	0	2,064		$2,748	268	0	302	**$3,317**	$6
10.7	Ash Transport & Feed Equipment	4,458	0	4,445		$8,903	842	0	974	**$10,719**	$20
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	156	188		$344	32	0	75	**$451**	$1
	SUBTOTAL 10.	**$5,142**	**$156**	**$6,697**		**$11,995**	**$1,142**	**$0**	**$1,351**	**$14,488**	$27
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	1,788	0	297		$2,085	193	0	171	**$2,449**	$4
11.2	Station Service Equipment	4,416	0	1,512		$5,928	567	0	487	**$6,982**	$13
11.3	Switchgear & Motor Control	5,248	0	899		$6,148	569	0	672	**$7,388**	$14
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$36
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$44
11.6	Protective Equipment	179	0	645		$824	81	0	90	**$995**	$2
11.7	Standby Equipment	1,381	0	33		$1,414	134	0	155	**$1,703**	$3
11.8	Main Power Transformers	7,419	0	197		$7,616	579	0	819	**$9,014**	$17
11.9	Electrical Foundations	0	342	875		$1,217	116	0	267	**$1,599**	$3
	SUBTOTAL 11.	**$20,432**	**$10,256**	**$29,076**		**$59,764**	**$5,325**	**$0**	**$8,304**	**$73,393**	$135
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	566	0	359		$925	89	46	159	**$1,219**	$2
12.7	Computer & Accessories	5,727	0	1,060		$6,787	646	339	777	**$8,550**	$16
12.8	Instrument Wiring & Tubing	3,164	0	6,520		$9,684	825	484	1,649	**$12,642**	$23
12.9	Other I & C Equipment	1,617	0	3,887		$5,504	536	275	632	**$6,947**	$13
	SUBTOTAL 12.	**$11,074**	**$0**	**$11,826**		**$22,900**	**$2,096**	**$1,145**	**$3,217**	**$29,358**	$54

	Client: U.S. DOE / NETL								**Report Date:** 23-Apr-07		
	Project: Oxy-Fuel Combustion Systems Analysis										
	TOTAL PLANT COST SUMMARY										
	Case: Case 4 - Air Fired Ultra-Super-Critical PC with CO2 Capture										
	Plant Size: 545.05 MW,net			**Estimate Type:**					**Cost Base (Jan)** 2007	$x1000	
Acct No.	**Item/Description**	**Equipment Cost**	**Material Cost**	**Labor Direct**	**Labor Indirect**	**Bare Erected Cost $**	**Eng'g CM H.O.& Fee**	**Contingencies Process**	**Contingencies Project**	**TOT. PLANT COST $**	**TOT. PLANT COST $/kW**
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	50	981		$1,031	102	0	227	**$1,359**	$2
13.2	Site Improvements	0	1,636	2,023		$3,659	359	0	804	**$4,822**	$9
13.3	Site Facilities	2,940	0	2,878		$5,818	571	0	1,278	**$7,667**	$14
	SUBTOTAL 13.	**$2,940**	**$1,686**	**$5,882**		**$10,508**	**$1,032**	**$0**	**$2,308**	**$13,848**	$25
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	9,921	9,019		$18,940	1,701	0	3,096	**$23,737**	$44
14.2	Turbine Building	0	11,853	11,418		$23,271	2,095	0	3,805	**$29,171**	$54
14.3	Administration Building	0	574	607		$1,181	107	0	193	**$1,481**	$3
14.4	Circulation Water Pumphouse	0	292	238		$530	47	0	87	**$664**	$1
14.5	Water Treatment Buildings	0	943	778		$1,721	154	0	281	**$2,156**	$4
14.6	Machine Shop	0	377	264		$641	57	0	105	**$803**	$1
14.7	Warehouse	0	108	177		$285	26	0	47	**$357**	$1
14.8	Other Buildings & Structures	0	120	118		$238	21	0	39	**$298**	$1
14.9	Waste Treating Building & Str.	0	538	1,686		$2,224	210	0	365	**$2,799**	$5
	SUBTOTAL 14.	**$0**	**$24,726**	**$24,305**		**$49,031**	**$4,419**	**$0**	**$8,017**	**$61,467**	$113
	TOTAL COST	**$749,225**	**$54,875**	**$376,878**		**$1,180,979**	**$111,027**	**$81,810**	**$188,694**	**$1,562,511**	$2,867

INITIAL & ANNUAL O&M EXPENSES	16-Jul-2007	Cost Base:	Jan 2007 dollars
Case 4 - Air Fired Ultra-Super-Critical PC with CO2 Capture		Heat Rate-net(Btu/kWh)	10,632
Plant Output: Carbon Dioxide(tpd): 12,729		Mwe-net:	545.05
		Capacity Factor: (%):	85.0%

OPERATING & MAINTENANCE LABOR

Operating Labor

Operating Labor Rate(base):	33.00	$/hour
Operating Labor Burden:	30.00	% of base
Labor O-H Charge Rate:	25.00	% of Labor

Operating Labor Requirements(O.J.)per Shift:

	Per unit	Total Plant
Skilled Operator	2.0	2.0
Operator	11.3	11.3
Foreman	1.0	1.0
Lab Tech's, etc.	2.0	2.0
TOTAL -O.J.'s	16.3	16.3

	Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost	$6,125,605	11.24
Maintenance Labor Cost	$10,497,449	19.26
Administrative & Support Labor	$2,991,838	5.49
TOTAL FIXED OPERATING COSTS	**$19,614,892**	**35.99**

VARIABLE OPERATING COSTS

	Initial	/Day	Unit Cost	Initial Cost	Annual Cost	$/kWH-net
Maintenance Material Cost					$15,746,174	0.0039
Consumables						
Water(/1000 gallons)		13,882	$1.03	$0	$4,435,969	0.0011
Chemicals						
MU & WT Chem.(lbs)	470,371	67,196	$0.16	$77,517	$3,435,670	0.0008
Limestone (Tons)	4,162	594.6	$20.60	$85,738	$3,800,024	0.0009
Carbon (lbs)	0	1529.0	$1.00	$0	$474,383	0.0001
MEA Solvent (Ton)	902	1.3	$2,142.40	$1,931,603	$849,505	0.0002
Sulfuric Acid (Ton)	42.54	6.08	$132.15	$5,621	$249,135	0.0001
Caustic Soda (Ton)	47.66	6.81	$412.96	$19,682	$872,329	0.0002
Ammonia (28% NH3) ton	422	60.2	$123.60	$52,097	$2,309,031	0.0006
Subtotal Chemicals				$2,172,258	$11,990,078	0.0030
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		460	$15.45		$2,205,108	0.0005
Bottom Ash (tons)		115	$15.45		$551,277	0.0001
Subtotal-Waste Disposal					$2,756,384	0.0007
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$34,928,606**	0.0086
Fuel - Coal (Tons)	178,835	5,961	$42.11	$7,530,754	**$77,880,551**	0.0192

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5. OXYGEN-FIRED PULVERIZED COAL RANKINE CYCLE PLANTS USING CRYOGENIC AIR SEPARATION UNIT

Six pulverized coal (PC)-fired Rankine cycle oxycombustion power plant configurations were evaluated and are presented in this section. All plant designs employ a cryogenic distillation air separation unit to generate the oxygen. Four cases utilize a supercritical steam cycle and two cases an ultra-supercritical cycle. Performance and cost results are for the cryogenic distillation oxycombustion cases are presented below. The six cases are:

Case 5 – Oxycombustion Supercritical PC with CO_2 capture

Case 5A – Oxycombustion Supercritical PC with CO_2 capture

Case 5B – Oxycombustion Supercritical PC with CO_2 capture

Case 5C – Oxycombustion Supercritical PC with CO_2 capture

Case 6 – Oxycombustion Ultra-supercritical PC with CO_2 capture

Case 6A – Oxycombustion Ultra-supercritical PC with CO_2 capture

The oxycombustion process utilizing oxygen from a cryogenic distillation ASU is similar to air-based combustion with the exception that flue gas is recycled to the boiler to reduce the inlet oxygen concentration and moderate temperature. The use of low-NOx burners, overfire oxygen and flue gas recirculation limits NOx outlet concentration to 0.07 lb/MMBtu and eliminates the need for an SCR unit. The remaining downstream processes are the same, namely a baghouse for particulate control and an FGD unit for SO_2 control. Instead of venting the flue gas to a stack after the FGD unit, water is partially condensed from the stream and about 70% is recycled to the boiler and the remaining 30% is sent to the CO_2 compression, drying and purification process. The flue gas recycled to the boiler is reheated to prevent the introduction of liquid water into the primary and secondary fans.

5.1 PLANT CONFIGURATION SUMMARY

Four designs (Cases 5, 5A, 5B and 5C) employ a supercritical single-reheat 3500 psig/1110°F/1150°F Rankine cycle comprised of a state-of-the art pulverized coal steam generator firing bituminous Illinois No. 6 coal and a steam turbine. The two remaining cases (Cases 6 and 6A) utilize an ultra-supercritical single-reheat 4000 psig/1350°F/1400°F cycle. In all cases CO_2 was captured and compressed to 2215 psia. A summary of the cases evaluated in this section is presented in Exhibit 5-1.

The evaluation scope included developing heat and mass balances and estimating plant performance on a common 550 MWe net output basis. Equipment lists were developed for each design to support plant capital and operating costs estimates.

Exhibit 5-1 Plant Configuration Summary for Cryogenic Oxygen Oxycombustion Plants

Case	Boiler	Oxidant	NOx Control	Sulfur Control	Product CO_2	
5	Wall-fired SC, FGR	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6 Btu	CO_2 2215 psia/95ºF	Spec. A
5A	Wall-fired SC, FGR	99 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6 Btu	CO_2 2215 psia/95ºF	Spec. B
5B	Wall-fired SC, FGR	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6 Btu	CO_2 2215 psia/95ºF	Spec. B*
5C	Wall-fired SC, FGR	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6 Btu	CO_2 2215 psia/95ºF	Spec. C
6	Wall-fired USC, FGR	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6 Btu	CO_2 2215 psia/95ºF	Spec. A
6A	Wall-fired USC, FGR	95 mol% O_2/ Cryogenic ASU	LNB/OFO/FGR/ 0.07 lb/10^6Btu	FGD, 0.1 lb/10^6 Btu	CO_2 2215 psia/95ºF	Spec. C

Legend:

LNB -	Low NOx burner	ASU	Air separation unit
OFO -	Overfire oxygen	PC -	Pulverized coal
FGD -	Flue gas desulfurization	SC -	Supercritical
FGR -	Flue gas recycle	USC-	Ultra Supercritical

The four cases using a supercritical steam cycle were configured with different oxygen purities and different CO_2 product specifications. The CO_2 product purity specifications were defined previously in Section 2, but are repeated here for ease of reference.

- Specification A: Raw product produced using 95% oxygen and dehydrated to 0.015% (by volume) H_2O
- Specification B: Raw product produced using 99% oxygen and dehydrated to 0.015% (by volume) H_2O
- Specification B*: Raw product produced using 95% oxygen and further treated to meet the purity levels of Specification B.
- Specification C: Raw product produced using 95% oxygen, further purified to 0.015% (by volume) H_2O and > 95% CO_2

All oxycombustion plants are assumed to be built on a greenfield site and utilize recirculating evaporative cooling systems for cycle heat rejection. The oxycombustion cases were evaluated on a common thermal input basis, while generating approximately 550 MWe net. The CO_2

purity specifications also vary between cases as described above. Major systems for each plant are described in Section 3 and include:

1. Steam Generator
2. Steam Turbine/Generator
3. Particulate control system
4. FGD system
5. CO_2 Recovery
6. Balance of Plant

Support facilities include coal handling (receiving, crushing, storing, and drying), limestone handling (including receiving, crushing, storing, and feeding), solid waste disposal, circulating water system with evaporative mechanical draft cooling towers, wastewater treatment, and other ancillary systems equipment necessary for an efficient, highly available, and completely operable facility.

The plant designs are based on using components suitable for a 30-year life, with provision for periodic maintenance and replacement of critical parts. All equipment is based on compliance with the latest applicable codes and standards. ASME, ANSI, IEEE, NFPA, CAA, state regulations, and OSHA codes are all adhered to in the design approach.

5.2 MATERIAL AND ENERGY BALANCES

The modeling assumptions that were used to generate the cryogenic oxygen oxycombustion material and energy balances are summarized in Exhibit 5-2.

Material and energy balance information, environmental performance and a major equipment list is provided for the four supercritical cryogenic oxycombustion cases in Section 5.2.1 and for the two ultra-supercritical cryogenic oxycombustion cases in Section 5.2.2.

Exhibit 5-2 Supercritical Cryogenic Oxycombustion Cases Modeling Assumptions

	Supercritical Cases				Ultra-Supercritical Cases	
	Case 5	Case 5A	Case 5B	Case 5C	Case 6	Case 6A
Throttle pressure, psig	3500	3500	3500	3500	4000	4000
Throttle temperature, ºF	1110	1100	1110	1110	1350	1350
Reheat temperature, ºF	1150	1150	1150	1150	1400	1400
Condenser pressure, in Hg	2	2	2	2	2	2
Cooling water to condenser, ºF	60	60	60	60	60	60
Cooling water from condenser, ºF	80	80	80	80	80	80
CO_2 Purifier Vent temperature, °F	N/A	N/A	48	48	N/A	48
Coal HHV (Illinois No. 6), Btu/lb	11,666	11,666	11,666	11,666	11,666	11,666
FGD efficiency, %	98	98	98	98	98	98
SOx emissions, lb/MMBtu	0.1	0.1	0.1	0.1	0.1	0.1
NOx emissions, lb/MMBtu	0.07	0.07	0.07	0.07	0.07	0.07
Baghouse efficiency, %	99.8	99.8	99.8	99.8	99.8	99.8
Particulate emissions PM/PM_{10}, lb/MMBtu	0.015	0.015	0.015	0.015	0.015	0.015
Mercury removal, %	90	90	90	90	90	90
ASU Oxygen Purity, %	95	99	95	95	95	95
CO_2 Capture Efficiency, %*	99.5	99.4	96.9	85.5	99.4	93.2
Product CO_2 Condition, psia/°F	2215/95	2215/95	2215/95	2215/95	2215/95	2215/95
Product CO_2 Specification	A	B	B*	C	A	C

* Percentage of CO_2 in flue gas

5.2.1 Performance Results for Supercritical Cryogenic Oxycombustion Cases

A process block flow diagram for the supercritical cases (5, 5A, 5B and 5C) is shown in Exhibit 5-3 and the corresponding stream tables for each are shown in Exhibit 5-4 through Exhibit 5-7. The heat and mass balance diagrams, including the steam cycle, are shown in Exhibit 5-8 through Exhibit 5-11.

Overall performance for the supercritical cryogenic oxycombustion cases is summarized in Exhibit 5-12 which includes auxiliary power requirements.

Exhibit 5-3 Process Block Flow Diagram for Cryogenic Oxycombustion Cases 5, 5A, 5B, and 5C

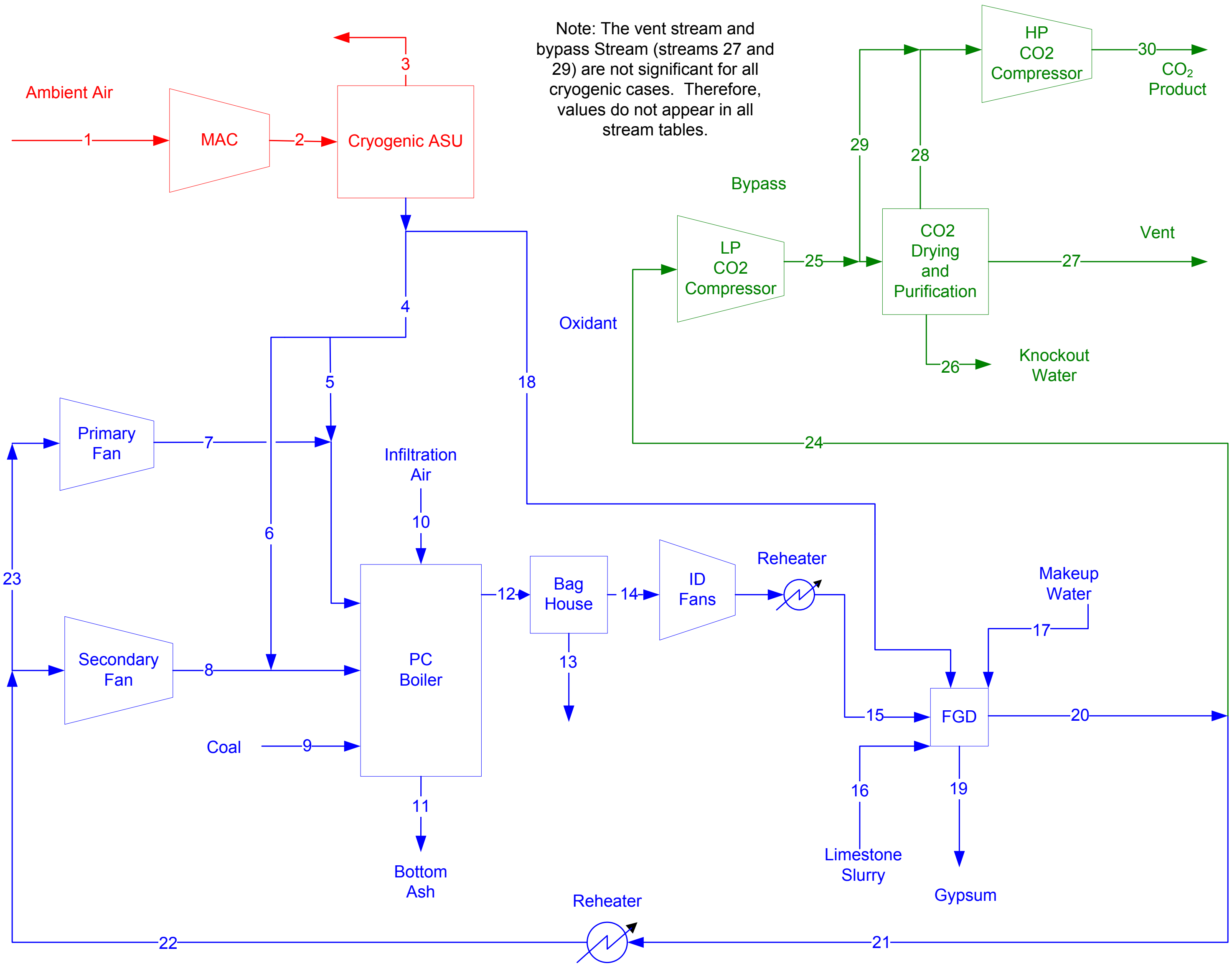

Exhibit 5-4 Case 5 Stream Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fractions															
Ar	0.0092	0.0092	0.0024	0.0340	0.0340	0.0340	0.0305	0.0305	0.0000	0.0092	0.0000	0.0288	0.0000	0.0288	0.0288
CO_2	0.0005	0.0005	0.0006	0.0000	0.0000	0.0000	0.6968	0.6968	0.0000	0.0003	0.0000	0.6578	0.0000	0.6578	0.6578
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0101	0.0101	0.0128	0.0000	0.0000	0.0000	0.1661	0.1661	0.0000	0.0099	0.0000	0.2116	0.0000	0.2116	0.2116
N_2	0.7729	0.7729	0.9778	0.0162	0.0162	0.0162	0.0819	0.0819	0.0000	0.7732	0.0000	0.0775	0.0000	0.0775	0.0775
O_2	0.2074	0.2074	0.0063	0.9498	0.9498	0.9498	0.0246	0.0246	0.0000	0.2074	0.0000	0.0216	0.0000	0.0216	0.0216
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0027	0.0000	0.0027	0.0027
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	178,446	178,446	140,412	37,502	8,813	28,689	26,266	85,503	0	3,405	0	163,999	0	163,999	163,999
V-L Flow (lb/hr)	5,149,230	5,149,230	3,924,360	1,207,750	283,821	923,928	997,117	3,245,940	0	98,262	0	6,059,540	0	6,059,540	6,059,540
Solids Flowrate	0	0	0	0	0	0	0	0	565,295	0	10,963	43,852	43,852	0	0
Temperature (°F)	59	250	63	55	55	55	163	152	59	59	350	350	350	350	360
Pressure (psia)	14.70	86.62	14.70	23.20	23.20	23.20	16.70	15.80	16.10	16.10	14.40	14.40	14.20	14.20	15.25
Enthalpy (Btu/lb)	13.14	59.04	16.61	4.94	4.94	4.94	114.09	111.71	--	13.13	--	186.30	--	187.27	189.83
Density (lb/ft^3)	0.076	0.328	0.073	0.135	0.135	0.135	0.095	0.091	--	0.083	--	0.061	--	0.060	0.064
Avg. Molecular Weight	28.86	28.86	27.95	32.20	32.20	32.20	37.96	37.96	--	28.86	--	36.95	--	36.95	36.95

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fractions															
Ar	0.0000	0.0000	0.0340	0.0000	0.0305	0.0305	0.0305	0.0305	0.0305	0.0364	0.0000	0.0000	0.0366	0.0000	0.0366
CO_2	0.0000	0.0000	0.0000	0.0080	0.6968	0.6968	0.6968	0.6968	0.6968	0.8319	0.0000	0.0000	0.8356	0.0000	0.8356
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	1.0000	1.0000	0.0000	0.9918	0.1661	0.1661	0.1661	0.1661	0.1661	0.0045	1.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0162	0.0001	0.0819	0.0819	0.0819	0.0819	0.0819	0.0978	0.0000	0.0000	0.0982	0.0000	0.0982
O_2	0.0000	0.0000	0.9498	0.0000	0.0246	0.0246	0.0246	0.0246	0.0246	0.0294	0.0000	0.0000	0.0296	0.0000	0.0296
SO_2	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0000	0.0001
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000
V-L Flow (lb_{mol}/hr)	7,109	4,515	532	19,822	155,235	111,769	111,769	26,266	43,466	36,408	163	--	36,244	--	36,244
V-L Flow (lb/hr)	128,077	81,337	17,122	361,288	5,893,130	4,243,050	4,243,050	997,117	1,650,080	1,522,920	2,942	--	1,519,970	--	1,519,970
Solids Flowrate	56,878	0	0	88,541	0	0	0	0	0	0	0	--	0	--	0
Temperature (°F)	59	59	55	135	135	135	145	145	135	247	100	--	247	--	95
Pressure (psia)	14.70	14.70	23.20	15.20	15.20	15.20	15.20	15.20	15.20	498.66	14.70	--	498.26	--	2214.70
Enthalpy (Btu/lb)	--	32.36	4.94	87.22	107.74	107.74	110.06	110.06	107.74	39.70	24.63	--	37.60	--	-63.45
Density (lb/ft^3)	62.622	62.622	0.135	15.677	0.090	0.090	0.089	0.089	0.090	2.920	61.249	--	2.923	--	35.419
Avg. Molecular Weight	18.02	18.02	32.20	18.23	37.96	37.96	37.96	37.96	37.96	41.83	18.02	--	41.94	--	41.94

Exhibit 5-5 Case 5A Stream Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fractions															
Ar	0.0092	0.0092	0.0090	0.0100	0.0100	0.0100	0.0096	0.0096	0.0000	0.0092	0.0000	0.0090	0.0000	0.0090	0.0090
CO_2	0.0005	0.0005	0.0006	0.0000	0.0000	0.0000	0.7282	0.7282	0.0000	0.0003	0.0000	0.6844	0.0000	0.6844	0.6844
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0101	0.0101	0.0127	0.0000	0.0000	0.0000	0.1661	0.1661	0.0000	0.0099	0.0000	0.2151	0.0000	0.2151	0.2151
N_2	0.7729	0.7729	0.9703	0.0000	0.0000	0.0000	0.0708	0.0708	0.0000	0.7732	0.0000	0.0667	0.0000	0.0667	0.0667
O_2	0.2074	0.2074	0.0075	0.9900	0.9900	0.9900	0.0253	0.0253	0.0000	0.2074	0.0000	0.0220	0.0000	0.0220	0.0220
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0028	0.0000	0.0028	0.0028
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	179,245	179,245	142,776	35,959	8,450	27,508	25,126	81,794	0	3,405	0	157,607	0	157,607	157,607
V-L Flow (lb/hr)	5,172,290	5,172,290	4,002,420	1,153,510	271,074	882,433	960,301	3,126,090	0	98,264	0	5,848,650	0	5,848,650	5,848,650
Solids Flowrate	0	0	0	0	0	0	0	0	565,310	0	10,963	43,854	43,854	0	0
Temperature (°F)	59	250	63	55	55	55	162	152	59	59	350	350	350	350	360
Pressure (psia)	14.70	86.62	14.70	23.20	23.20	23.20	16.70	15.80	16.10	16.10	14.40	14.40	14.20	14.20	15.25
Enthalpy (Btu/lb)	13.14	59.04	16.44	4.99	4.99	4.99	113.54	111.17	--	13.13	--	188.20	--	189.23	191.81
Density (lb/ft^3)	0.076	0.328	0.073	0.135	0.135	0.135	0.096	0.092	--	0.083	--	0.062	--	0.061	0.064
Avg. Molecular Weight	28.86	28.86	28.03	32.08	32.08	32.08	38.22	38.22	--	28.86	--	37.11	--	37.11	37.11

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fractions															
Ar	0.0000	0.0000	0.0100	0.0000	0.0096	0.0096	0.0096	0.0096	0.0096	0.0114	0.0000	0.0000	0.0115	0.0000	0.0115
CO_2	0.0000	0.0000	0.0000	0.0084	0.7282	0.7282	0.7282	0.7282	0.7282	0.8694	0.0000	0.0000	0.8733	0.0000	0.8733
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	1.0000	1.0000	0.0000	0.9915	0.1661	0.1661	0.1661	0.1661	0.1661	0.0045	1.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0000	0.0001	0.0708	0.0708	0.0708	0.0708	0.0708	0.0845	0.0000	0.0000	0.0849	0.0000	0.0849
O_2	0.0000	0.0000	0.9900	0.0000	0.0253	0.0253	0.0253	0.0253	0.0253	0.0301	0.0000	0.0000	0.0303	0.0000	0.0303
SO_2	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0000	0.0001
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000
V-L Flow (lb_{mol}/hr)	7,390	3,892	510	19,800	148,500	106,920	106,920	25,126	41,580	34,830	156	--	34,674	--	34,674
V-L Flow (lb/hr)	133,127	70,115	16,369	361,063	5,675,540	4,086,390	4,086,390	960,301	1,589,150	1,467,540	2,818	--	1,464,720	--	1,464,720
Solids Flowrate	56,754	0	0	88,417	0	0	0	0	0	0	0	--	0	--	0
Temperature (°F)	59	59	55	135	135	135	145	145	135	245	100	--	245	--	95
Pressure (psia)	14.70	14.70	23.20	15.20	15.20	15.20	15.20	15.20	15.20	498.66	14.70	--	498.26	--	2214.70
Enthalpy (Btu/lb)	--	32.36	4.99	86.46	107.28	107.28	109.54	109.54	107.28	39.23	24.63	--	37.14	--	-69.94
Density (lb/ft^3)	62.622	62.622	0.135	14.512	0.091	0.091	0.090	0.090	0.091	2.963	61.249	--	2.967	--	38.379
Avg. Molecular Weight	18.02	18.02	32.08	18.24	38.22	38.22	38.22	38.22	38.22	42.13	18.02	--	42.24	--	42.24

Exhibit 5-6 Stream Table Case 5B

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fractions															
Ar	0.0092	0.0092	0.0024	0.0340	0.0340	0.0340	0.0305	0.0305	0.0000	0.0092	0.0000	0.0287	0.0000	0.0287	0.0287
CO_2	0.0005	0.0005	0.0006	0.0000	0.0000	0.0000	0.6963	0.6963	0.0000	0.0003	0.0000	0.6574	0.0000	0.6574	0.6574
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0101	0.0101	0.0128	0.0000	0.0000	0.0000	0.1661	0.1661	0.0000	0.0099	0.0000	0.2115	0.0000	0.2115	0.2115
N_2	0.7729	0.7729	0.9778	0.0162	0.0162	0.0162	0.0818	0.0818	0.0000	0.7732	0.0000	0.0774	0.0000	0.0774	0.0774
O_2	0.2074	0.2074	0.0063	0.9498	0.9498	0.9498	0.0253	0.0253	0.0000	0.2074	0.0000	0.0222	0.0000	0.0222	0.0222
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0027	0.0000	0.0027	0.0027
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	178,584	178,584	140,521	37,531	8,820	28,712	26,286	85,570	0	3,405	0	164,116	0	164,116	164,116
V-L Flow (lb/hr)	5,153,230	5,153,230	3,927,410	1,208,690	284,043	924,651	997,740	3,247,960	0	98,264	0	6,063,150	0	6,063,150	6,063,150
Solids Flowrate	0	0	0	0	0	0	0	0	565,310	0	10,963	43,854	43,854	0	0
Temperature (°F)	59	250	63	55	55	55	163	152	59	59	350	350	350	350	360
Pressure (psia)	14.70	86.62	14.70	23.20	23.20	23.20	16.70	15.80	16.10	16.10	14.40	14.40	14.20	14.20	15.25
Enthalpy (Btu/lb)	13.14	59.04	16.61	4.94	4.94	4.94	114.11	111.73	--	13.13	--	186.28	--	187.26	189.81
Density (lb/ft^3)	0.076	0.328	0.073	0.135	0.135	0.135	0.095	0.091	--	0.083	--	0.061	--	0.060	0.064
Avg. Molecular Weight	28.86	28.86	27.95	32.20	32.20	32.20	37.96	37.96	--	28.86	--	36.94	--	36.94	36.94

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fractions															
Ar	0.0000	0.0000	0.0340	0.0000	0.0305	0.0305	0.0305	0.0305	0.0305	0.0364	0.0000	0.1930	0.0000	0.0366	0.0240
CO_2	0.0000	0.0000	0.0000	0.0080	0.6963	0.6963	0.6963	0.6963	0.6963	0.8312	0.0000	0.3096	0.9578	0.8350	0.8771
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	1.0000	1.0000	0.0000	0.9918	0.1661	0.1661	0.1661	0.1661	0.1661	0.0045	1.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0162	0.0001	0.0818	0.0818	0.0818	0.0818	0.0818	0.0977	0.0000	0.4557	0.0145	0.0981	0.0695
O_2	0.0000	0.0000	0.9498	0.0000	0.0253	0.0253	0.0253	0.0253	0.0253	0.0301	0.0000	0.0416	0.0276	0.0303	0.0294
SO_2	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	7,390	4,216	532	19,798	155,358	111,858	111,857	26,286	43,500	36,436	163	2,691	11,515	22,067	33,582
V-L Flow (lb/hr)	133,127	75,955	17,129	360,852	5,896,850	4,245,730	4,245,700	997,740	1,651,120	1,523,860	2,944	95,373	500,270	925,268	1,425,540
Solids Flowrate	56,769	0	0	88,433	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	59	59	55	135	135	135	145	145	136	247	152	48	97	212	95
Pressure (psia)	14.70	14.70	23.20	15.20	15.20	15.20	15.20	15.20	15.20	498.66	14.70	467.75	355.30	498.66	2194.09
Enthalpy (Btu/lb)	--	32.36	4.94	86.55	107.76	107.76	110.08	110.08	107.99	39.71	120.80	--	12.97	--	-70.58
Density (lb/ft^3)	62.622	62.622	0.135	15.631	0.090	0.090	0.089	0.089	0.090	2.919	59.447	3.041	2.586	2.900	38.897
Avg. Molecular Weight	18.02	18.02	32.20	18.23	37.96	37.96	37.96	37.96	37.96	41.82	18.02	35.44	43.45	41.93	42.45

Exhibit 5-7 Stream Table Case 5C

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fractions															
Ar	0.0092	0.0092	0.0024	0.0340	0.0340	0.0340	0.0305	0.0305	0.0000	0.0092	0.0000	0.0287	0.0000	0.0287	0.0287
CO_2	0.0005	0.0005	0.0006	0.0000	0.0000	0.0000	0.6963	0.6963	0.0000	0.0003	0.0000	0.6574	0.0000	0.6574	0.6574
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0101	0.0101	0.0128	0.0000	0.0000	0.0000	0.1661	0.1661	0.0000	0.0099	0.0000	0.2115	0.0000	0.2115	0.2115
N_2	0.7729	0.7729	0.9778	0.0162	0.0162	0.0162	0.0818	0.0818	0.0000	0.7732	0.0000	0.0774	0.0000	0.0774	0.0774
O_2	0.2074	0.2074	0.0063	0.9498	0.9498	0.9498	0.0253	0.0253	0.0000	0.2074	0.0000	0.0222	0.0000	0.0222	0.0222
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0027	0.0000	0.0027	0.0027
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	178,584	178,584	140,521	37,531	8,820	28,712	26,286	85,570	0	3,405	0	164,116	0	164,116	164,116
V-L Flow (lb/hr)	5,153,230	5,153,230	3,927,410	1,208,690	284,043	924,651	997,740	3,247,960	0	98,264	0	6,063,150	0	6,063,150	6,063,150
Solids Flowrate	0	0	0	0	0	0	0	0	565,310	0	10,963	43,854	43,854	0	0
Temperature (°F)	59	250	63	55	55	55	163	152	59	59	350	350	350	350	360
Pressure (psia)	14.70	86.62	14.70	23.20	23.20	23.20	16.70	15.80	16.10	16.10	14.40	14.40	14.20	14.20	15.25
Enthalpy (Btu/lb)	13.14	59.04	16.61	4.94	4.94	4.94	114.11	111.73	--	13.13	--	186.28	--	187.26	189.81
Density (lb/ft^3)	0.076	0.328	0.073	0.135	0.135	0.135	0.095	0.091	--	0.083	--	0.061	--	0.060	0.064
Avg. Molecular Weight	28.86	28.86	27.95	32.20	32.20	32.20	37.96	37.96	--	28.86	--	36.94	--	36.94	36.94

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fractions															
Ar	0.0000	0.0000	0.0340	0.0000	0.0305	0.0305	0.0305	0.0305	0.0305	0.0364	0.0000	0.2032	0.0000	0.0000	0.0000
CO_2	0.0000	0.0000	0.0000	0.0080	0.6963	0.6963	0.6963	0.6963	0.6963	0.8312	0.0000	0.2730	0.9583	0.0000	0.9583
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	1.0000	1.0000	0.0000	0.9918	0.1661	0.1661	0.1661	0.1661	0.1661	0.0045	1.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0162	0.0001	0.0818	0.0818	0.0818	0.0818	0.0818	0.0977	0.0000	0.4799	0.0144	0.0000	0.0144
O_2	0.0000	0.0000	0.9498	0.0000	0.0253	0.0253	0.0253	0.0253	0.0253	0.0301	0.0000	0.0438	0.0273	0.0000	0.0273
SO_2	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0000	0.0001
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000
V-L Flow (lb_{mol}/hr)	7,390	4,216	532	19,798	155,358	111,858	111,857	26,286	43,500	36,436	163	6,526	29,747	--	29,747
V-L Flow (lb/hr)	133,127	75,955	17,129	360,852	5,896,850	4,245,730	4,245,700	997,740	1,651,120	1,523,860	2,944	228,298	1,292,610	--	1,292,610
Solids Flowrate	56,769	0	0	88,433	0	0	0	0	0	0	0	0	0	--	0
Temperature (°F)	59	59	55	135	135	135	145	145	136	247	100	48	96	--	95
Pressure (psia)	14.70	14.70	23.20	15.20	15.20	15.20	15.20	15.20	15.20	498.66	14.70	467.75	355.30	--	2200.00
Enthalpy (Btu/lb)	--	32.36	4.94	86.55	107.76	107.76	110.08	110.08	107.99	39.71	24.63	--	12.86	--	-85.04
Density (lb/ft^3)	62.622	62.622	0.135	15.631	0.090	0.090	0.089	0.089	0.090	2.919	61.249	3.002	2.589	--	46.317
Avg. Molecular Weight	18.02	18.02	32.20	18.23	37.96	37.96	37.96	37.96	37.96	41.82	18.02	34.98	43.45	--	43.45

Exhibit 5-8 Case 5 Heat and Mass Balance Diagram

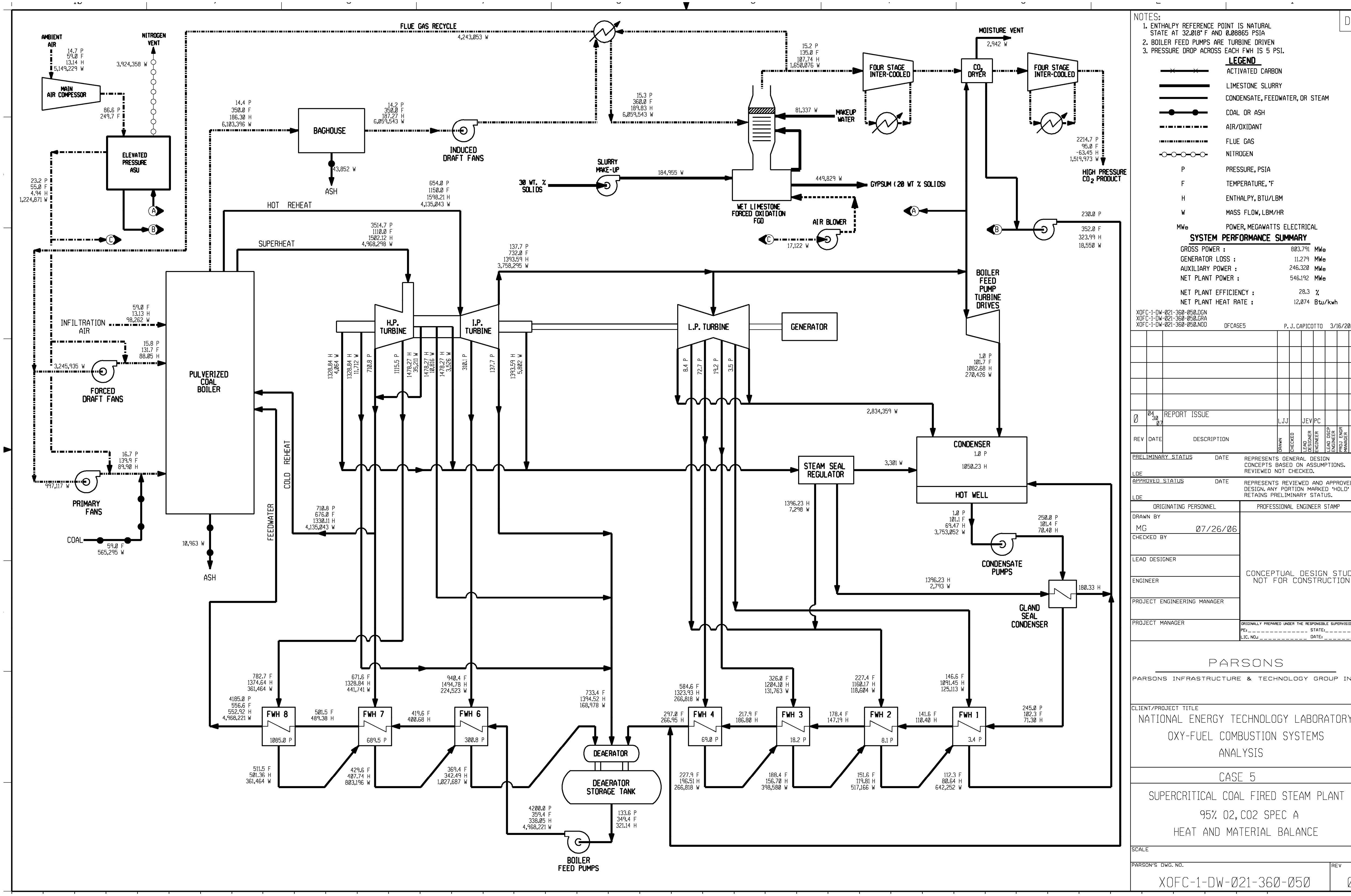

Exhibit 5-9 Case 5A Heat and Mass Balance Diagram

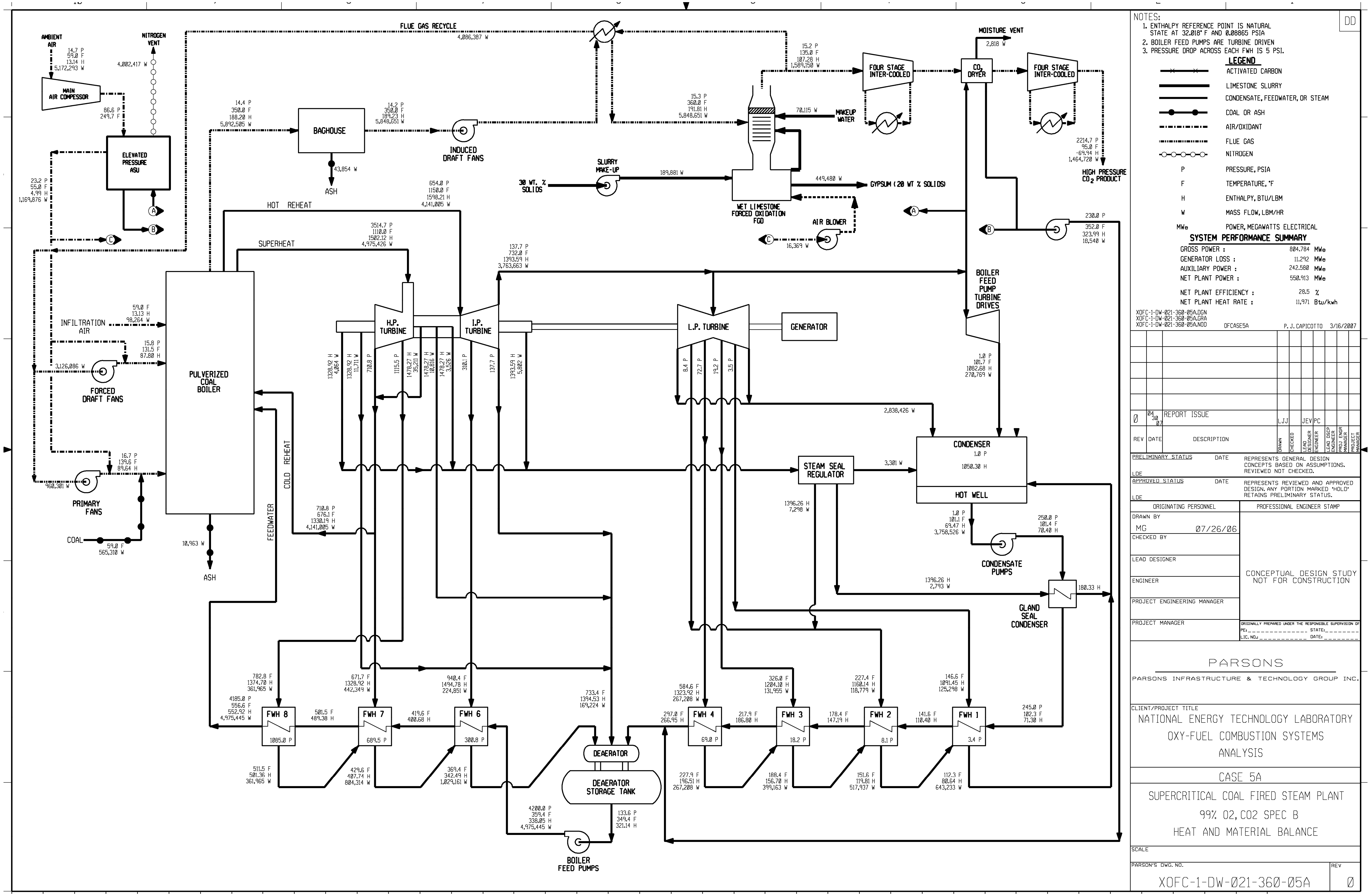

Exhibit 5-10 Case 5B Heat and Mass Balance Diagram

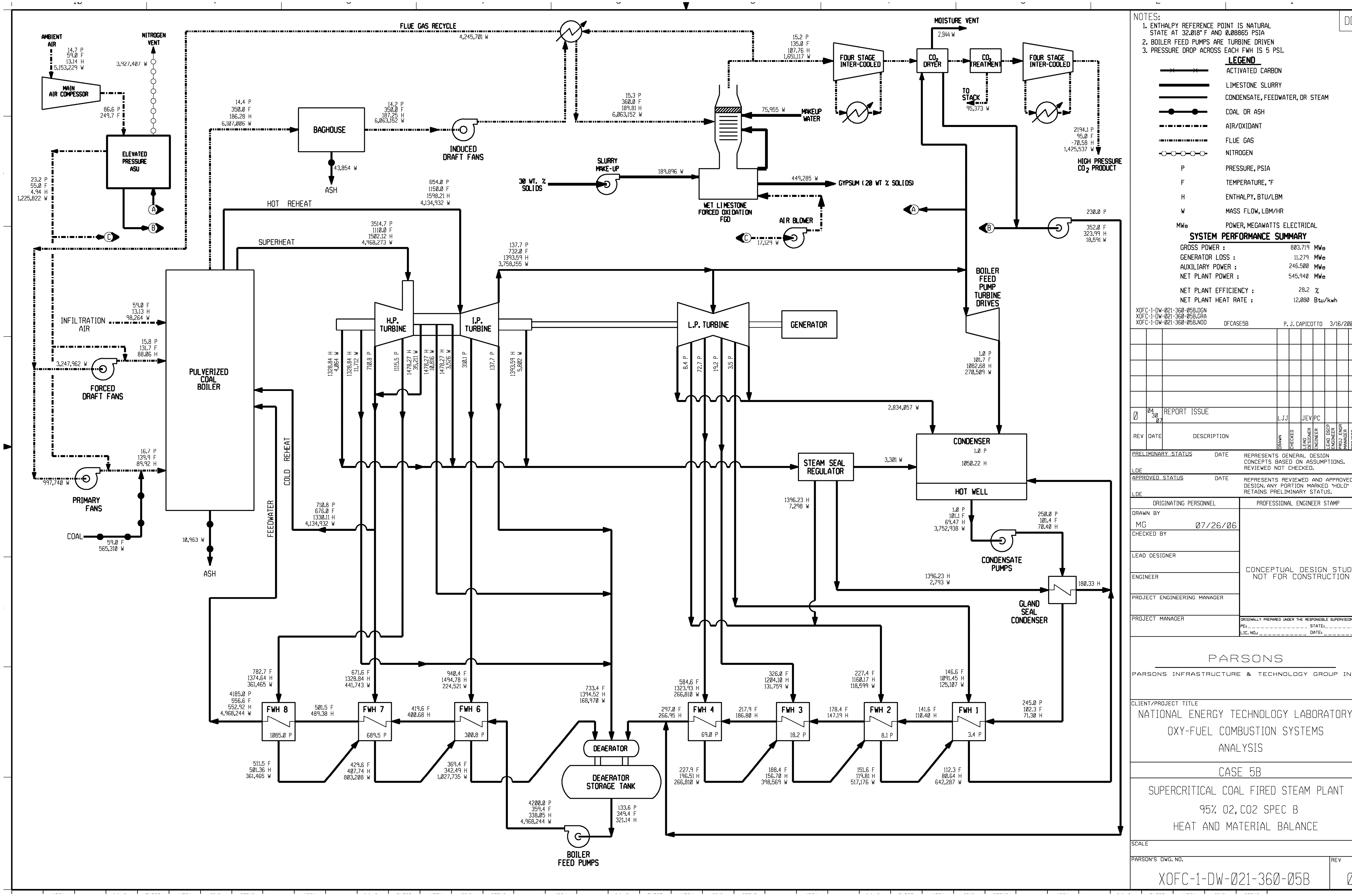

Exhibit 5-11 Case 5C Heat and Mass Balance Diagram

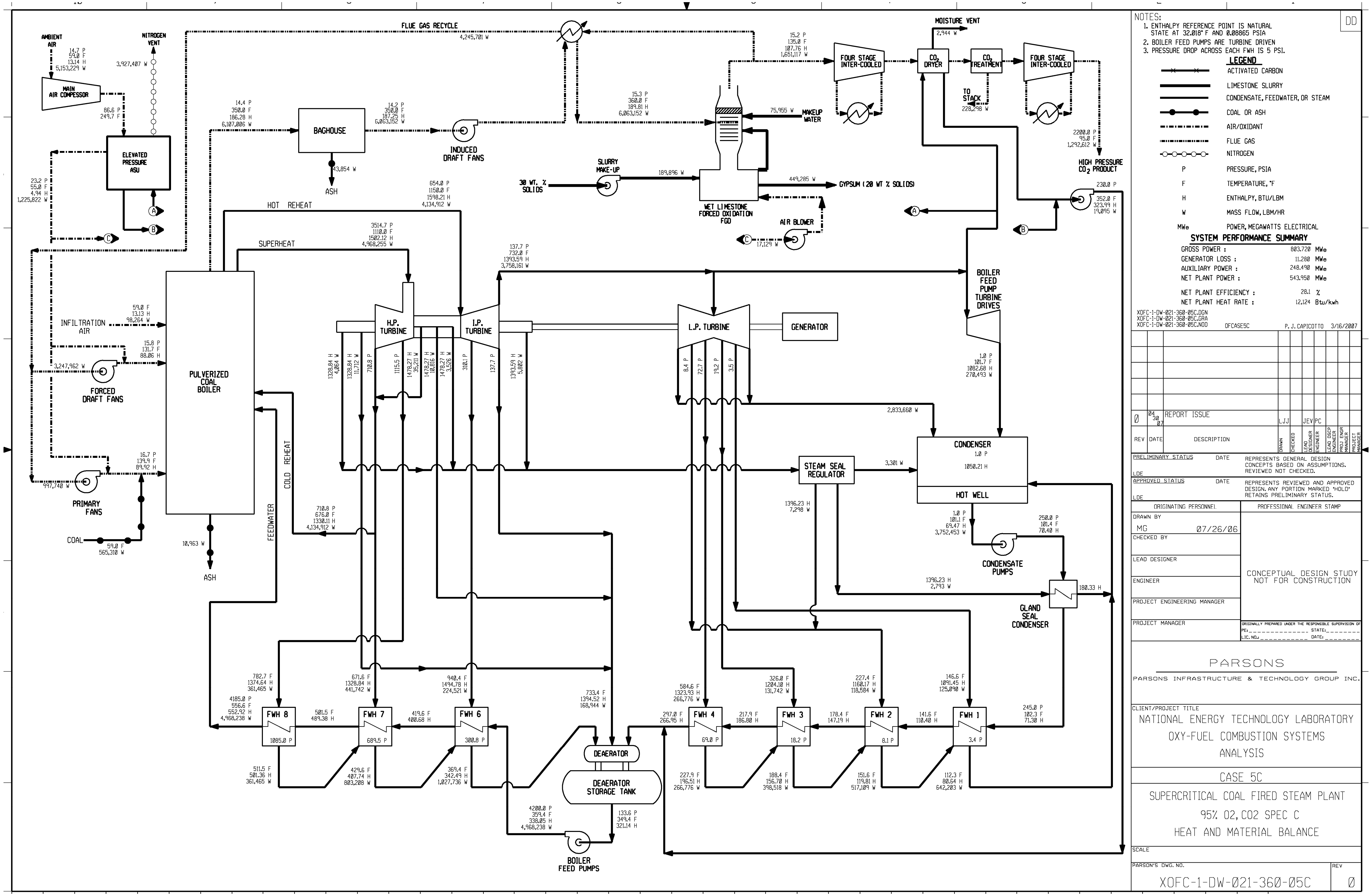

Exhibit 5-12 Supercritical Cryogenic Oxycombustion Cases Modeling Results Summary

	Supercritical Cases			
	5	5A	5B	5C
Gross Plant Power, kWe	**792,512**	**793,493**	**792,440**	**792,440**
AUXILIARY LOAD SUMMARY, kWe				
Coal Handling and Conveying	480	480	480	480
Limestone Handling & Reagent Preparation	1,240	1,240	1,240	1,240
Pulverizers	3,840	3,840	3,840	3,840
Ash Handling	730	730	730	730
Primary Fans	1,220	1,170	1,220	1,220
Forced Air Fans	1,620	1,550	1,620	1,620
Induced Air Fans	7,690	7,390	7,700	7,700
Air Separation Unit Main Air Compressor	129,270	129,980	129,500	129,500
Air Separation Unit Auxiliaries	1,000	1,000	1,000	1,000
SCR	N/A	N/A	N/A	N/A
Baghouse	100	100	100	100
FGD Pumps and Agitators	4,100	4,100	4,100	4,100
CO_2 Compression	78,560	74,530	78,500	80,490
Condensate Pumps	1,060	1,060	1,060	1,060
Miscellaneous Balance of Plant (Note 2)	2,000	2,000	2,000	2,000
Steam Turbine Auxiliaries	400	400	400	400
Circulating Water Pumps	6,570	6,580	6,570	6,570
Cooling Tower Fans	3,400	3,400	3,400	3,400
Transformer Loss	3,040	3,030	3,040	3,040
Total	246,320	242,580	246,500	248,490
NET PLANT POWER, kWe	**546,192**	**550,913**	**545,940**	**543,950**
PLANT PERFORMANCE				
Net Plant Efficiency (HHV)	28.3%	28.5%	28.2%	28.1%
Net Plant Heat Rate (Btu/kWh, HHV)	12,074	11,971	12,080	12,124
Condenser Cooling Duty, MMBtu/hr	**3,066**	**3,070**	**3,065**	**3,065**
CONSUMABLES				
As-Received Coal Feed, lb/hr (Note 3)	565,295	565,310	565,310	565,310
Thermal Input, kWth	1,932,726	1,932,777	1,932,777	1,932,777
Limestone Sorbent Feed, lb/hr	56,878	56,755	56,770	56,770
Raw Water Usage, gpm	7,206	7,213	7,205	7,205

Notes:
1. Boiler feed pumps are turbine driven
2. Includes plant control systems, lighting, HVAC, etc
3. As-received coal heating value: 11,666 Btu/lb (HHV)

5.2.1.1 Environmental Performance for Cases 5, 5A, 5B and 5C

Each case was designed to meet presumptive BACT standards utilizing the emissions control processes described in Section 2.5. A summary of plant air emissions is presented in Exhibit 5-13. In the no purification co-sequestration cases (5 and 5A) gas phase emissions of all criteria pollutants are zero.

SO_2 emissions are controlled using a wet limestone forced oxidation scrubber that achieves a removal efficiency of 98%. The byproduct calcium sulfate is dewatered and stored on site. The wallboard grade material can potentially be marketed and sold, but since it is highly dependent on local market conditions, no byproduct credit was taken. The saturated flue gas exiting the scrubber is vented through the plant stack.

NOx emissions are controlled to 0.07 lb/10^6 Btu through the use of LNBs, OFO and FGR.

Particulate emissions are controlled using a pulse jet fabric filter (baghouse) which operates at an efficiency of 99.8%. It was assumed that 20% of the ash exits the boiler as bottom ash and the remaining 80% exits the boiler in the flue gas [39].

Co-benefit capture of Hg in the fabric filter and FGD system was assumed to achieve a 90% capture rate [40]. The addition of an inexpensive additive to the FGD system can be used to promote Hg capture if necessary, but was not included in this study.

In Cases 5 and 5A there is no CO_2 purification step and therefore there are no air emission points. Flue gas from the FGD unit, after water is condensed, is either recycled to the boiler or sent to CO_2 compression and drying. Any pollutants in the gas stream sent to the CO_2 system will be co-sequestered with the CO_2. A small amount of SO_2 will be knocked out in the condenser after the FGD unit, but this sour water stream will be neutralized and disposed of and will not lead to any air emissions.

In Cases 5B and 5C the raw CO_2 product stream is further purified through a series of refrigerated flash steps and the vent stream contains SO_2, NOx, CO_2, Ar, N_2 and O_2. The components of the vent stream represent the only air emissions from these cases. These emissions are at levels that meet design emissions limits.

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39 Coal Utilization By Products - Clean Coal Technologies Topical Report Number 24, page 8, http://www.netl.doe.gov/technologies/coalpower/cctc/topicalreports/pdfs/Topical24.pdf, August 2006.

40 Enhancing Mercury Control on Coal-Fired Boilers with SCR, Oxidation Catalyst, and FGD, Institute of Clean Air Companies (ICAC), www.icac.com.

Exhibit 5-13 Estimated Air Emission Rates for Cases 5, 5A, 5B, and 5C

Pollutant	lb/MMBtu				Tons/yr, 85% CF				lb/MWh_{net}			
	Case 5	Case 5A	Case 5B	Case 5C	Case 5	Case 5A	Case 5B	Case 5C	Case 5	Case 5A	Case 5B	Case 5C
SO_2	0	0	0.003	0.008	0	0	78	200	0	0	0.038	0.099
NOx	0	0	0.070	0.070	0	0	1,719	1,719	0	0	0.846	0.849
Particulate	0	0	0.001	0.002	0	0	19	42	0	0	0.009	0.021
CO_2	0	0	6	12	0	0	136,524	291,909	0	0	67	144
Hg	0	0	0.07×10^{-6}	0.15×10^{-6}	0	0	0.002	0.004	0	0	0.81×10^{-6}	1.81×10^{-6}

5.2.1.2 Major Equipment List for Cases 5, 5A, 5B and 5C

ACCOUNT 1 FUEL AND SORBENT HANDLING

Equipment No.	Description	Type	Design Condition				Qty.
			Case 5	Case 5A	Case 5B	Case 5C	
1	Bottom Trestle Dumper with Receiving Hoppers	N/A	200 tph	200 tph	200 tph	200 tph	2
2	Feeder	Belt	630 tph	630 tph	630 tph	630 tph	2
3	Conveyor No. 1	Belt	1,250 tph	1,250 tph	1,250 tph	1,250 tph	1
4	Transfer Tower No. 1	Enclosed	N/A	N/A	N/A	N/A	1
5	Conveyor No. 2	Belt	1,250 tph	1,250 tph	1,250 tph	1,250 tph	1
4	As-Received Coal Sampling System	Two-stage	N/A	N/A	N/A	N/A	1
6	Stacker/Reclaim	Traveling Linear	1,250 tph	1,250 tph	1,250 tph	1,250 tph	1
7	Reclaim Hopper	N/A	60 ton	60 ton	60 ton	60 ton	3
8	Feeder	Vibratory	230 tph	230 tph	230 tph	230 tph	3
9	Conveyor No. 3	Belt w/tripper	470 tph	470 tph	470 tph	470 tph	1
10	Crusher Tower	N/A	N/A	N/A	N/A	N/A	1
11	Coal Surge Bin w/ Vent Filter	Dual Outlet	230 ton	230 ton	230 ton	230 ton	2
12	Crusher	Impactor reduction	3"x0 - 1.25"x0	3"x0 – 1.25"x0	3"x0 - 1.25"x0	3"x0 – 1.25"x0	2
13	As-Fired Coal Sampling System	Swing Hammer	N/A	N/A	N/A	N/A	2
14	Conveyor No. 4	Belt w/tripper	470 tph	470 tph	470 tph	470 tph	1
15	Transfer Tower No. 2	Enclosed	N/A	N/A	N/A	N/A	1
16	Conveyor No. 5	Belt w/tripper	470 tph	470 tph	470 tph	470 tph	1
17	Coal Silo w/ Vent Filter and Slide Gates	Field Erected	1,000 tph	1,000 tph	1,000 tph	1,000 tph	3

Equipment No.	Description	Type	Design Condition				Qty.
			Case 5	Case 5A	Case 5B	Case 5C	
18	Limestone Truck Unloading Hopper	N/A	40 ton	40 ton	40 ton	40 ton	1
19	Limestone Feeder	Belt	120 tph	120 tph	120 tph	120 tph	1
20	Limestone Conveyor No. 1	Belt	120 tph	120 tph	120 tph	120 tph	1
21	Limestone Reclaim Hopper	N/A	20 tph	20 tph	20 tph	20 tph	1
22	Limestone Reclaim Feeder	Belt	90 tph	90 tph	90 tph	90 tph	1
23	Limestone Conveyor No. 2	Belt	90 tph	90 tph	90 tph	90 tph	1
24	Limestone Day Bin	w/ actuator	380 ton	370 ton	370 ton	370 ton	2

ACCOUNT 2 COAL AND SORBENT PREPARATION AND FEED

Equipment No.	Description	Type	Design Condition				Qty.
			Case 5	Case 5A	Case 5B	Case 5C	
1	Coal Feeder	Gravimetric	50 tph	50 tph	50 tph	50 tph	6
2	Coal Pulverizer	Ball type or eq.	50 tph	50 tph	50 tph	50 tph	6
3	Limestone Weigh Feeder	Gravimetric	31 tph	31 tph	31 tph	31 tph	2
4	Limestone Ball Mill	Rotary	31 tph	31 tph	31 tph	31 tph	2
5	Mill Slurry Tank with Agitator	N/A	29,000 gal	29,000 gal	29,000 gal	29,000 gal	2
6	Mill Recycle Pumps	Horizontal centrifugal	490 gpm @40 ft H_2O	490 gpm @40 ft H_2O	490 gpm @40 ft H_2O	490 gpm @40 ft H_2O	2
7	Hydroclone Classifier	4 active cyclones in a 5 cyclone bank	120 gpm per cyclone	120 gpm per cyclone	120 gpm per cyclone	120 gpm per cyclone	2
8	Distribution Box	2-way	N/A	N/A	N/A	N/A	2
9	Limestone Slurry Tank with Agitator	Field erected	162,000 gal	162,000 gal	162,000 gal	162,000 gal	2

Equipment No.	Description	Type	Design Condition				Qty.
			Case 5	Case 5A	Case 5B	Case 5C	
10	Limestone Slurry Feed Pumps	Horizontal centrifugal	340 gpm @30 ft H_2O	340 gpm @30 ft H_2O	340 gpm @30 ft H_2O	340 gpm @30 ft H_2O	2

ACCOUNT 3 FEEDWATER AND MISCELLANEOUS SYSTEMS AND EQUIPMENT

Equipment No.	Description	Type	Design Condition				Qty.
			Case 5	Case 5A	Case 5B	Case 5C	
1	Demineralized Water Storage Tank	Vertical, cylindrical, outdoor	393,000 gal	394,000 gal	393,000 gal	393,000 gal	2
2	Condensate Pumps	Vertical canned	8,300gpm @ 700 ft H_2O	8,300gpm @ 700 ft H_2O	8,300gpm @ 700 ft H_2O	8,300gpm @ 700 ft H_2O	2
3	Deaerator and Storage Tank	Horizontal spray type	5,465,000 lb/h, 5 min tank	5,473,000 lb/h, 5 min tank	5,465,000 lb/h, 5 min tank	5,465,000 lb/h, 5 min tank	1
4	Boiler Feed Pump/ Turbine driven	Barrel type, multi-staged, centrifugal	11,000 gpm @ 11,400 ft H_2O	11,000 gpm @ 11,400 ft H_2O	11,000 gpm @ 11,400 ft H_2O	11,000 gpm @ 11,400 ft H_2O	2
5	Startup Boiler Feed Pump, Electric. motor driven	Barrel type, multi-stage, centrifugal	3,000 gpm @ 11,400 ft H_2O	3,300 gpm @ 11,400 ft H_2O	3,300 gpm @ 11,400 ft H_2O	3,300 gpm @ 11,400 ft H_2O	1
6	LP Feedwater Heater 1A/1B	Horizontal U tube	2,060,000 lb/h	2,070,000 lb/h	2,060,000 lb/h	2,060,000 lb/h	2
7	LP Feedwater Heater 2A/2B	Horizontal U tube	2,060,000 lb/h	2,070,000 lb/h	2,060,000 lb/h	2,060,000 lb/h	2
8	LP Feedwater Heater 3A/3B	Horizontal U tube	2,060,000 lb/h	2,070,000 lb/h	2,060,000 lb/h	2,060,000 lb/h	2
9	LP Feedwater Heater 4A/4B	Horizontal U tube	2,060,000 lb/h	2,070,000 lb/h	2,060,000 lb/h	2,060,000 lb/h	2
10	HP Feedwater Heater 6	Horizontal U tube	5,470,000 lb/h	5,470,000 lb/h	5,470,000 lb/h	5,470,000 lb/h	1
11	HP Feedwater Heater 7	Horizontal U tube	5,470,000 lb/h	5,470,000 lb/h	5,470,000 lb/h	5,470,000 lb/h	1

Equipment No.	Description	Type	Design Condition				Qty.
			Case 5	Case 5A	Case 5B	Case 5C	
12	HP Feedwater Heater 8	Horizontal U tube	5,470,000 lb/h	5,470,000 lb/h	5,470,000 lb/h	5,470,000 lb/h	1
13	Auxiliary Boiler	Shop fabricated, water-tube	400 psig, 650°F, 40,000 lb/h	400 psig, 650°F, 40,000 lb/h	400 psig, 650°F, 40,000 lb/h	400 psig, 650°F, 40,000 lb/h	1
14	Fuel Oil System	No. 2 for light off	300,000 gal	300,000 gal	300,000 gal	300,000 gal	1
15	Service Air Compressors	Flooded screw	100 psig, 1,000 scfm	100 psig, 1,000 scfm	100 psig, 1,000 scfm	100 psig, 1,000 scfm	3
16	Inst. Air Dryers	Duplex, regenerative	1,000 scfm	1,000 scfm	1,000 scfm	1,000 scfm	3
17	Closed Cycle Cooling Heat Exch.	Shell & tube	50 MMBtu/h each	50 MMBtu/h each	50 MMBtu/h each	50 MMBtu/h each	2
18	Closed Cycle Cooling Water Pumps	Horizontal centrifugal	5,500gpm @ 100 ft H_2O	5,500gpm @ 100 ft H_2O	5,500gpm @ 100 ft H_2O	5,500gpm @ 100 ft H_2O	3
19	Fire Service Booster Pump	Two-stage centrifugal	700gpm @ 210 ft H_2O	700gpm @ 210 ft H_2O	700gpm @ 210 ft H_2O	700gpm @ 210 ft H_2O	2
20	Engine-Driven Fire Pump	Vert. turbine, diesel engine	1,000gpm @ 290 ft H_2O	1,000gpm @ 290 ft H_2O	1,000gpm @ 290 ft H_2O	1,000gpm @ 290 ft H_2O	2
21	Raw Water Pumps	SS, single suction	4,020gpm @ 140 ft H_2O	4,110gpm @ 140 ft H_2O	4,020gpm @ 140 ft H_2O	4,020gpm @ 140 ft H_2O	3
22	Filtered Water Pumps	SS, single suction	500gpm @ 160 ft H_2O	580gpm @ 160 ft H_2O	500gpm @ 160 ft H_2O	500gpm @ 160 ft H_2O	3
23	Filtered Water Tank	Vertical, cylindrical	480,000 gal	560,000 gal	480,000 gal	480,000 gal	1
24	Makeup Demineralizer	Anion, cation, and mixed bed	220 gpm	220 gpm	220 gpm	220 gpm	2
25	Liquid Waste Treatment System	--	10 years, 24-hour storm	10 years, 24-hour storm	10 years, 24-hour storm	10 years, 24-hour storm	1

ACCOUNT 4 BOILER AND ACCESSORIES

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	Boiler with superheater	Supercritical, drum-type, wall-fired, low NOx burners, overfire oxygen	5,470,000 lb/h, 3,500 psig/ 1110°F/1150°F	5,470,000 lb/h, 3,500 psig/ 1110°F/1150°F	5,470,000 lb/h, 3,500 psig/ 1110°F/1150°F	5,470,000 lb/h, 3,500 psig/ 1110°F/1150°F	1
2	Primary Fan	Centrifugal	548,000 lb/h, 102,600 acfm @ 50 in WG	528,000 lb/h, 97,800 acfm @ 50 in WG	549,000 lb/h, 102,800 acfm @ 50 in WG	549,000 lb/h, 102,800 acfm @ 50 in WG	2
3	Forced Draft Fan	Centrifugal	1,784,000 lb/h, 334,000 acfm @ 20 in WG	1,719,000 lb/h, 318,400 acfm @ 20 in WG	1,786,000 lb/h, 334,500 acfm @ 20 in WG	1,786,000 lb/h, 334,500 acfm @ 20 in WG	2
4	Induced Draft Fan	Centrifugal	3,330,00 lb/h, 925,100 acfm, 35 in WG	3,217,00 lb/h, 878,900 acfm, 35 in WG	3,330500 lb/h, 926,300 acfm, 35 in WG	3,335,00 lb/h, 926,300 acfm, 35 in WG	2
5	Air Separation Unit	Cryogenic	8,080 tpd 95 vol% O_2 purity	7,720 tpd 99 vol% O_2 purity	8,090 tpd 95 vol% O_2 purity	8,090 tpd 95 vol% O_2 purity	2

ACCOUNT 5 FLUE GAS CLEANUP

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	Fabric Filter	Single stage, high-ratio with pulse-jet online cleaning system	3,330,000 lb/h, 99.8% efficiency	3,217,000 lb/h, 99.8% efficiency	3,335,000 lb/h, 99.8% efficiency	3,335,000 lb/h, 99.8% efficiency	2
2	Absorber module	Tray type with concurrent spray	1,484,000 acfm	1,417,000 acfm	1,486,000 acfm	1,486,000 acfm	1
3	Recirculation pumps	Horizontal centrifugal	39,000 gpm @210 ft H_2O	37,000 gpm @210 ft H_2O	39,000 gpm @210 ft H_2O	39,000 gpm @210 ft H_2O	6
4	Bleed pumps	Horizontal centrifugal	1,470 gpm, 20% solids	1,470 gpm, 20% solids	1,470 gpm, 20% solids	1,470 gpm, 20% solids	3

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
5	Oxidation Blowers	Centrifugal	1,160 acfm @ 26 psia	1,110 acfm @ 26 psia	1,160 acfm @ 26 psia	1,160 acfm @ 26 psia	3
6	Agitators	Side entering	50 hp	50 hp	50 hp	50 hp	6
7	Dewatering Hydrocyclones	Radial assembly, 5 units each	370 gpm per cyclone	370 gpm per cyclone	370 gpm per cyclone	370 gpm per cyclone	2
8	Vacuum Belt Filter	Horizontal Belt	49 tph, 50% wt. solids, Slurry flow	49 tph, 50% wt. solids, Slurry flow	49 tph, 50% wt. solids, Slurry flow	49 tph, 50% wt. solids, Slurry flow	3
9	Filtrate Water Return Pumps	Horizontal Centrifugal	220 gpm @40 ft H_2O	220 gpm @40 ft H_2O	220 gpm @40 ft H_2O	220 gpm @40 ft H_2O	2
10	Filtrate Water Storage tank	Vertical lined	150,000 gal	150,000 gal	150,000 gal	150,000 gal	1
11	Process Water Recirculating Pumps	Horizontal Centrifugal	780 gpm @70 ft H_2O	940 gpm @70 ft H_2O	780 gpm @70 ft H_2O	780 gpm @70 ft H_2O	2

ACCOUNT 5B CARBON DIOXIDE RECOVERY

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	CO_2 Compression and Purification unit	Integrally geared, multistage centrifugal with indirect water intercoolers	835,000 lb/h, 2,215 psia, 83.6 mol% CO_2 product conc.	806,000 lb/h, 2,215 psia, 87.3 mol% CO_2 product conc.	784,000 lb/h, 2,215 psia, 87.7 mol% CO_2 product conc.	711,000 lb/h, 2,215 psia, 95.9 mol% CO_2 product conc.	2
2	Condensing Heat Exchanger	Shell and Tube, Alloy Steel Construction	7,120,000 lb/h @ 158 °F	6,890,000 lb/h @ 158 °F	7,130,000 lb/h @ 158 °F	7,130,000 lb/h @ 158 °F	1

ACCOUNT 6 COMBUSTION TURBINE/ACCESSORIES

N/A

ACCOUNT 7 DUCTING & STACK

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	Stack	Reinforced concrete w/ FRP liner	150 ft high x 11 ft diameter	150 ft high x 10 ft diameter	150 ft high x 11 ft diameter	150 ft high x 11 ft diameter	1

ACCOUNT 8 STEAM TURBINE GENERATOR AND AUXILIARIES

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	Steam Turbine	Commercially available advanced steam turbine	830 MW, 3500 psig/ 1110°F/1150°F	840 MW, 3500 psig/ 1110°F/1150°F	830 MW, 3500 psig/ 1110°F/1150°F	830 MW, 3500 psig/ 1110°F/1150°F	1
2	Steam Turbine Generator	Hydrogen cooled, static excitation	920 MVA, 0.9 PF 24 kV	920 MVA, 0.9 PF 24 kV	920 MVA, 0.9 PF 24 kV	920 MVA, 0.9 PF 24 kV	1
3	Surface Condenser	Single pass, divided waterbox including vacuum pumps	3,370 MMBtu/h, Inlet water Temp 16ºC (60ºF), Water temp rise 11ºC (20ºF)	3,380 MMBtu/h, Inlet water Temp 16ºC (60ºF), Water temp rise 11ºC (20ºF)	3,370 MMBtu/h, Inlet water Temp 16ºC (60ºF), Water temp rise 11ºC (20ºF)	3,370 MMBtu/h, Inlet water Temp 16ºC (60ºF), Water temp rise 11ºC (20ºF)	1

ACCOUNT 9 COOLING WATER SYSTEM

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	Cooling Tower	Evaporative, mechanical draft, multi-cell	51.5°F WB/ 60ºF CW /80°F HW 3,480 10^6 Btu/h	51.5°FWB/ 60°F CW /80°F HW 3,490 10^6 Btu/h	51.5°FWB/ 60ºF CW /80°F HW 3,480 10^6 Btu/h	51.5°FWB/ 60ºF CW /80°F HW 3,480 10^6 Btu/h	1
2	Circ. Water Pumps	Vertical, wet pit	87,000 gpm @ 100 ft WG	87,000 gpm @ 100 ft WG	87,000 gpm @ 100 ft WG	87,000 gpm @ 100 ft WG	2

ACCOUNT 10 ASH/SPENT SORBENT RECOVERY AND HANDLING

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	Economizer Hopper (part of boiler scope of supply)	--	--	--	--	--	4
2	Bottom Ash Hopper (part of boiler scope of supply)	--	--	--	--	--	2
3	Clinker Grinder	--	5.4 tph	5.4 tph	5.4 tph	5.4 tph	2
4	Pyrites Hopper (part of pulverizer scope of supply included with boiler)	--	--	--	--	--	6
5	Hydroejectors	--	--	--	--	--	12
6	Economizer/Pyrites Transfer Tank	--	--	--	--	--	1
7	Ash Sluice Pumps	Vertical, wet pit	60 gpm @ 56 ft H_2O	60 gpm @ 56 ft H_2O	60 gpm @ 56 ft H_2O	60 gpm @ 56 ft H_2O	2
8	Ash Seal Water Pumps	Vertical, wet pit	2,000 gpm @ 28 ft H_2O	2,000 gpm @ 28 ft H_2O	2,000 gpm @ 28 ft H_2O	2,000 gpm @ 28 ft H_2O	2
9	Hydrobins	--	60 gpm	60 gpm	60 gpm	60 gpm	2
10	Baghouse Hopper (part of baghouse scope of supply)	--	--	--	--	--	24
11	Air Heater Hopper (part of boiler scope of supply)	--	--	--	--	--	10
12	Air Blower	--	710 scfm @ 24 psi	710 scfm @ 24 psi	710 scfm @ 24 psi	710 scfm @ 24 psi	2
13	Fly Ash Silo	Reinforced concrete	1,400 tons	1,400 tons	1,400 tons	1,400 tons	1

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
14	Slide Gate Valves	--	--	--	--	--	2
15	Unloader	--	--	--	--	--	1
16	Telescoping Unloading Chute	--	140 tph	140 tph	140 tph	140 tph	1

ACCOUNT 11 ACCESSORY ELECTRIC PLANT

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	STG Transformer	Oil-filled	24 kV/345 kV, 930 MVA, 3-ph, 60 Hz	24 kV/345 kV, 930 MVA, 3-ph, 60 Hz	24 kV/345 kV, 930 MVA, 3-ph, 60 Hz	24 kV/345 kV, 930 MVA, 3-ph, 60 Hz	1
2	Auxiliary Transformer	Oil-filled	24 kV/ 4.16 kV, 270 MVA, 3-ph, 60Hz	24 kV/ 4.16 kV, 270 MVA, 3-ph, 60Hz	24 kV/ 4.16 kV, 270 MVA, 3-ph, 60Hz	24 kV/ 4.16 kV, 270 MVA, 3-ph, 60Hz	2
3	LV Transformer	Dry ventilated	4.16 kV /480 V, 41 MVA, 3-ph, 60 Hz	4.16 kV /480 V, 41 MVA, 3-ph, 60 Hz	4.16 kV /480 V, 41 MVA, 3-ph, 60 Hz	4.16 kV /480 V, 41 MVA, 3-ph, 60 Hz	2
4	STG Isolated Phase Bus Duct and Tap Bus	Aluminum, self-cooled	24 kV, 3-ph, 60 Hz	24 kV, 3-ph, 60 Hz	24 kV, 3-ph, 60 Hz	24 kV, 3-ph, 60 Hz	1
5	Medium Voltage Switchgear	Metal Clad	4.16 kV, 3-ph, 60 Hz,	4.16 kV, 3-ph, 60 Hz,	4.16 kV, 3-ph, 60 Hz,	4.16 kV, 3-ph, 60 Hz,	2
6	Low Voltage Switchgear	Metal Enclosed	480 V, 3-ph, 60 Hz	480 V, 3-ph, 60 Hz	480 V, 3-ph, 60 Hz	480 V, 3-ph, 60 Hz	2
7	Emergency Diesel Generator	Sized for emergency shutdown	750 kW, 480 V, 3-ph, 60 Hz	750 kW, 480 V, 3-ph, 60 Hz	750 kW, 480 V, 3-ph, 60 Hz	750 kW, 480 V, 3-ph, 60 Hz	1

ACCOUNT 12 INSTRUMENTATION AND CONTROL

Equipment No.	Description	Type	Design Condition				Qty
			Case 5	Case 5A	Case 5B	Case 5C	
1	DCS - Main Control	Monitor/keyboard; Operator printer – laser color; Eng. Printer – laser B&W	Operator Stations/Printers and Engineering. Stations/Printers	Operator Stations/Printers and Engineering. Stations/Printers	Operator Stations/Printers and Engineering. Stations/Printers	Operator Stations/Printers and Engineering. Stations/Printers	1
2	DCS - Processor	Microprocessor with Redundant Input/Output	N/A	N/A	N/A	N/A	1
3	DCS - Data Highway	Fiber optic	Fully redundant, 25% spare	Fully redundant, 25% spare	Fully redundant, 25% spare	Fully redundant, 25% spare	1

5.2.2 Performance Results for Ultra-Supercritical Cryogenic Oxycombustion Cases

Cases 6 and 6A are analogous to Cases 5 and 5C with the exception that 6 and 6A use an ultra-supercritcal steam cycle instead of a supercritical cycle. In all cases 95% oxygen is produced from the ASU. In Case 6, the CO_2 product is not further purified. In Case 6A the raw CO_2 product stream is purified to <0.015% (by volume) H2O and purity specification of greater than 95% CO_2.

A process block flow diagram for the ultra-supercritical cases 6 and 6A is shown in Exhibit 5-14 and the corresponding stream tables for each are shown in Exhibit 5-15 and Exhibit 5-16. The heat and mass balance diagrams, including the steam cycle, are shown in Exhibit 5-17 and Exhibit 5-18.

Overall performance for the ultra-supercritical cryogenic oxycombustion cases is summarized in Exhibit 5-19 which includes auxiliary power requirements.

Exhibit 5-14 Process Block Flow Diagram for Cryogenic Oxycombustion Cases 6, and 6A

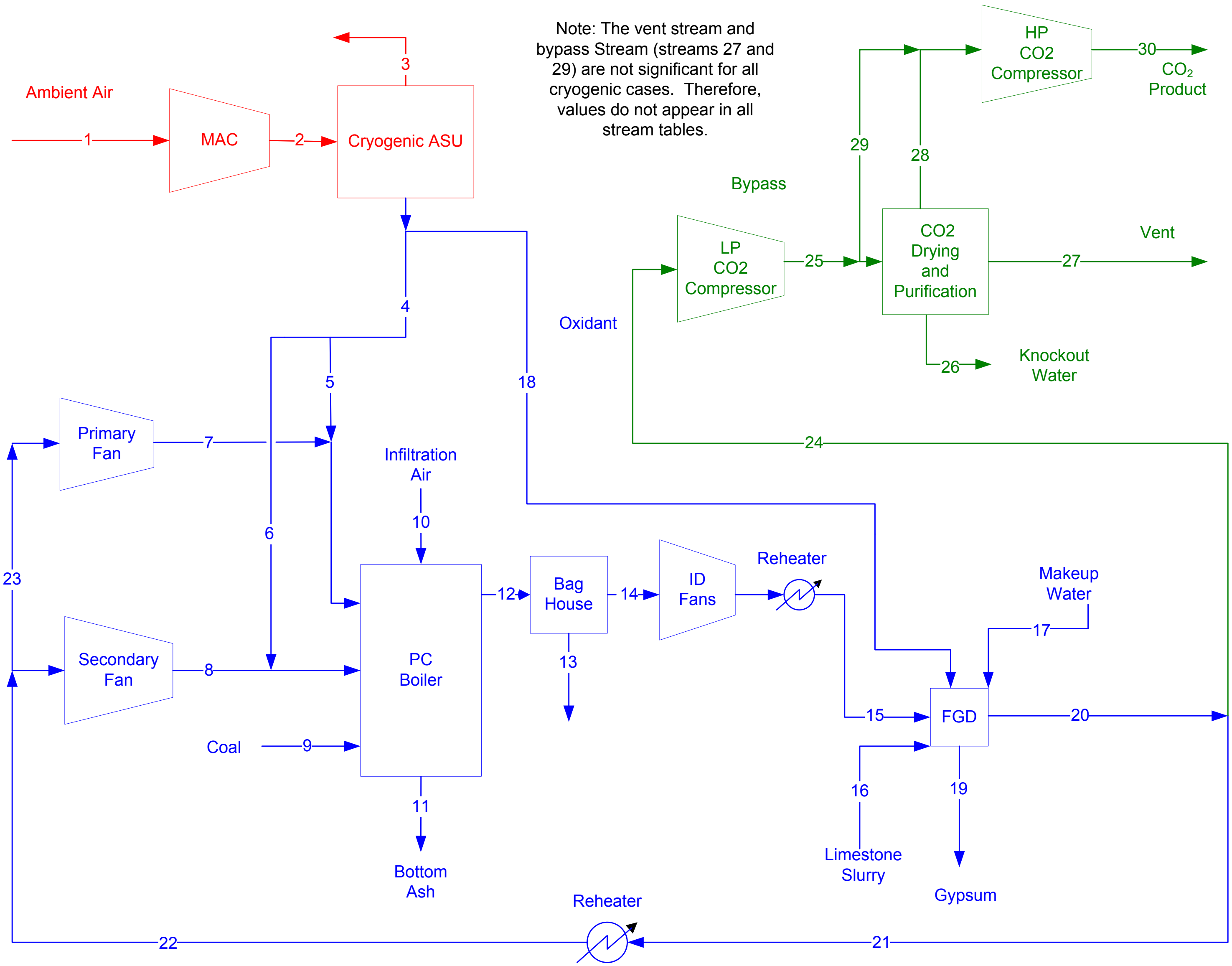

Exhibit 5-15 Case 6 Stream Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fractions															
Ar	0.0092	0.0092	0.0025	0.0339	0.0339	0.0339	0.0303	0.0303	0.0000	0.0092	0.0000	0.0286	0.0000	0.0286	0.0286
CO_2	0.0005	0.0005	0.0006	0.0000	0.0000	0.0000	0.6976	0.6976	0.0000	0.0003	0.0000	0.6585	0.0000	0.6585	0.6585
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0101	0.0101	0.0128	0.0000	0.0000	0.0000	0.1656	0.1656	0.0000	0.0099	0.0000	0.2114	0.0000	0.2114	0.2114
N_2	0.7729	0.7729	0.9781	0.0161	0.0161	0.0161	0.0819	0.0819	0.0000	0.7732	0.0000	0.0774	0.0000	0.0774	0.0774
O_2	0.2074	0.2074	0.0060	0.9501	0.9501	0.9501	0.0245	0.0245	0.0000	0.2074	0.0000	0.0214	0.0000	0.0214	0.0214
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0027	0.0000	0.0027	0.0027
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	154,470	154,470	121,516	32,485	7,634	24,851	22,744	74,039	0	2,953	0	142,039	0	142,039	142,039
V-L Flow (lb/hr)	4,457,390	4,457,390	3,396,150	1,046,140	245,843	800,298	863,777	2,811,870	0	85,201	0	5,249,620	0	5,249,620	5,249,620
Solids Flowrate	0	0	0	0	0	0	0	0	490,158	0	9,506	38,024	38,024	0	0
Temperature (°F)	59	267	63	55	55	55	162	152	59	59	350	350	350	350	360
Pressure (psia)	14.70	86.60	14.70	23.20	23.20	23.20	16.70	15.80	16.10	16.10	14.40	14.40	14.20	14.20	15.26
Enthalpy (Btu/lb)	13.14	63.35	16.62	4.94	4.94	4.94	113.70	111.32	--	13.13	--	186.13	--	187.10	189.66
Density (lb/ft^3)	0.076	0.320	0.073	0.135	0.135	0.135	0.095	0.091	--	0.083	--	0.061	--	0.060	0.064
Avg. Molecular Weight	28.86	28.86	27.95	32.20	32.20	32.20	37.98	37.98	--	28.86	--	36.96	--	36.96	36.96

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fractions															
Ar	0.0000	0.0000	0.0339	0.0000	0.0303	0.0303	0.0303	0.0303	0.0303	0.0362	0.0000	0.0000	0.0364	0.0000	0.0364
CO_2	0.0000	0.0000	0.0000	0.0081	0.6976	0.6976	0.6976	0.6976	0.6976	0.8324	0.0000	0.0000	0.8361	0.0000	0.8361
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	1.0000	1.0000	0.0000	0.9917	0.1656	0.1656	0.1656	0.1656	0.1656	0.0045	1.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0161	0.0001	0.0819	0.0819	0.0819	0.0819	0.0819	0.0977	0.0000	0.0000	0.0981	0.0000	0.0981
O_2	0.0000	0.0000	0.9501	0.0000	0.0245	0.0245	0.0245	0.0245	0.0245	0.0292	0.0000	0.0000	0.0293	0.0000	0.0293
SO_2	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0000	0.0001
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000
V-L Flow (lb_{mol}/hr)	6,382	3,641	469	17,159	134,420	96,782	96,782	22,744	37,638	31,544	141	--	31,403	--	31,403
V-L Flow (lb/hr)	114,968	65,596	15,100	312,769	5,105,060	3,675,640	3,675,650	863,777	1,429,420	1,319,640	2,543	--	1,317,090	--	1,317,090
Solids Flowrate	49,186	0	0	76,640	0	0	0	0	0	0	0	--	0	--	0
Temperature (°F)	59	59	55	135	135	135	145	145	136	247	100	--	72	--	95
Pressure (psia)	14.70	14.70	23.20	15.25	15.25	15.25	15.25	15.25	15.24	500.00	14.70	--	499.60	--	2200.00
Enthalpy (Btu/lb)	--	32.36	4.94	86.30	107.45	107.45	109.80	109.80	107.68	39.67	24.63	--	-5.90	--	12.64
Density (lb/ft^3)	62.622	62.622	0.135	15.545	0.091	0.091	0.089	0.089	0.091	2.929	61.249	--	4.420	--	24.400
Avg. Molecular Weight	18.02	18.02	32.20	18.23	37.98	37.98	37.98	37.98	37.98	41.83	18.02	--	41.94	--	41.94

Exhibit 5-16 Case 6A Stream Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fractions															
Ar	0.0092	0.0092	0.0025	0.0339	0.0339	0.0339	0.0303	0.0303	0.0000	0.0092	0.0000	0.0286	0.0000	0.0286	0.0286
CO_2	0.0005	0.0005	0.0006	0.0000	0.0000	0.0000	0.6976	0.6976	0.0000	0.0003	0.0000	0.6585	0.0000	0.6585	0.6585
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0101	0.0101	0.0128	0.0000	0.0000	0.0000	0.1656	0.1656	0.0000	0.0099	0.0000	0.2114	0.0000	0.2114	0.2114
N_2	0.7729	0.7729	0.9781	0.0161	0.0161	0.0161	0.0819	0.0819	0.0000	0.7732	0.0000	0.0774	0.0000	0.0774	0.0774
O_2	0.2074	0.2074	0.0060	0.9501	0.9501	0.9501	0.0244	0.0244	0.0000	0.2074	0.0000	0.0213	0.0000	0.0213	0.0213
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0027	0.0000	0.0027	0.0027
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	154,856	154,856	121,819	32,566	7,653	24,913	22,801	74,223	0	2,960	0	142,394	0	142,394	142,394
V-L Flow (lb/hr)	4,468,520	4,468,520	3,404,620	1,048,750	246,456	802,293	865,936	2,818,900	0	85,415	0	5,262,740	0	5,262,740	5,262,740
Solids Flowrate	0	0	0	0	0	0	0	0	491,390	0	9,530	38,119	38,119	0	0
Temperature (°F)	59	267	63	55	55	55	162	152	59	59	350	350	350	350	360
Pressure (psia)	14.70	86.60	14.70	23.20	23.20	23.20	16.70	15.80	16.10	16.10	14.40	14.40	14.20	14.20	15.26
Enthalpy (Btu/lb)	13.14	63.35	16.62	4.94	4.94	4.94	113.70	111.32	--	13.13	--	186.13	--	187.11	189.66
Density (lb/ft^3)	0.076	0.320	0.073	0.135	0.135	0.135	0.095	0.091	--	0.083	--	0.061	--	0.060	0.064
Avg. Molecular Weight	28.86	28.86	27.95	32.20	32.20	32.20	37.98	37.98	--	28.86	--	36.96	--	36.96	36.96

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fractions															
Ar	0.0000	0.0000	0.0339	0.0000	0.0303	0.0303	0.0303	0.0303	0.0303	0.0362	0.0000	0.1451	0.0123	0.0000	0.0123
CO_2	0.0000	0.0000	0.0000	0.0081	0.6976	0.6976	0.6976	0.6976	0.6976	0.8324	0.0000	0.2860	0.9579	0.0000	0.9579
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	1.0000	1.0000	0.0000	0.9917	0.1656	0.1656	0.1656	0.1656	0.1656	0.0045	1.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0161	0.0001	0.0819	0.0819	0.0819	0.0819	0.0819	0.0977	0.0000	0.4538	0.0194	0.0000	0.0194
O_2	0.0000	0.0000	0.9501	0.0000	0.0244	0.0244	0.0244	0.0244	0.0244	0.0292	0.0000	0.1148	0.0104	0.0000	0.0104
SO_2	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0003	0.0000	0.0000	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000
V-L Flow (lb_{mol}/hr)	6,276	3,775	470	17,204	134,755	97,024	97,024	22,801	37,732	31,623	142	5,706	25,776	--	25,776
V-L Flow (lb/hr)	113,062	68,002	15,142	313,604	5,117,820	3,684,830	3,684,830	865,936	1,432,990	1,322,940	2,550	198,494	1,121,890	--	1,121,890
Solids Flowrate	49,322	0	0	76,845	0	0	0	0	0	0	0	0	0	--	0
Temperature (°F)	59	59	55	135	135	135	145	145	136	247	100	48	107	--	95
Pressure (psia)	14.70	14.70	23.20	15.25	15.25	15.25	15.25	15.25	15.24	500.00	14.70	467.75	355.30	--	2214.70
Enthalpy (Btu/lb)	--	32.36	4.94	86.38	107.45	107.45	109.80	109.80	107.68	39.67	24.63	3.33	15.10	--	12.59
Density (lb/ft^3)	62.622	62.622	0.135	15.553	0.091	0.091	0.089	0.089	0.091	2.929	61.249	2.986	2.542	--	16.194
Avg. Molecular Weight	18.02	18.02	32.20	18.23	37.98	37.98	37.98	37.98	37.98	41.83	18.02	34.79	43.52	--	43.52

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Exhibit 5-17 Case 6 Heat and Mass Balance Diagram

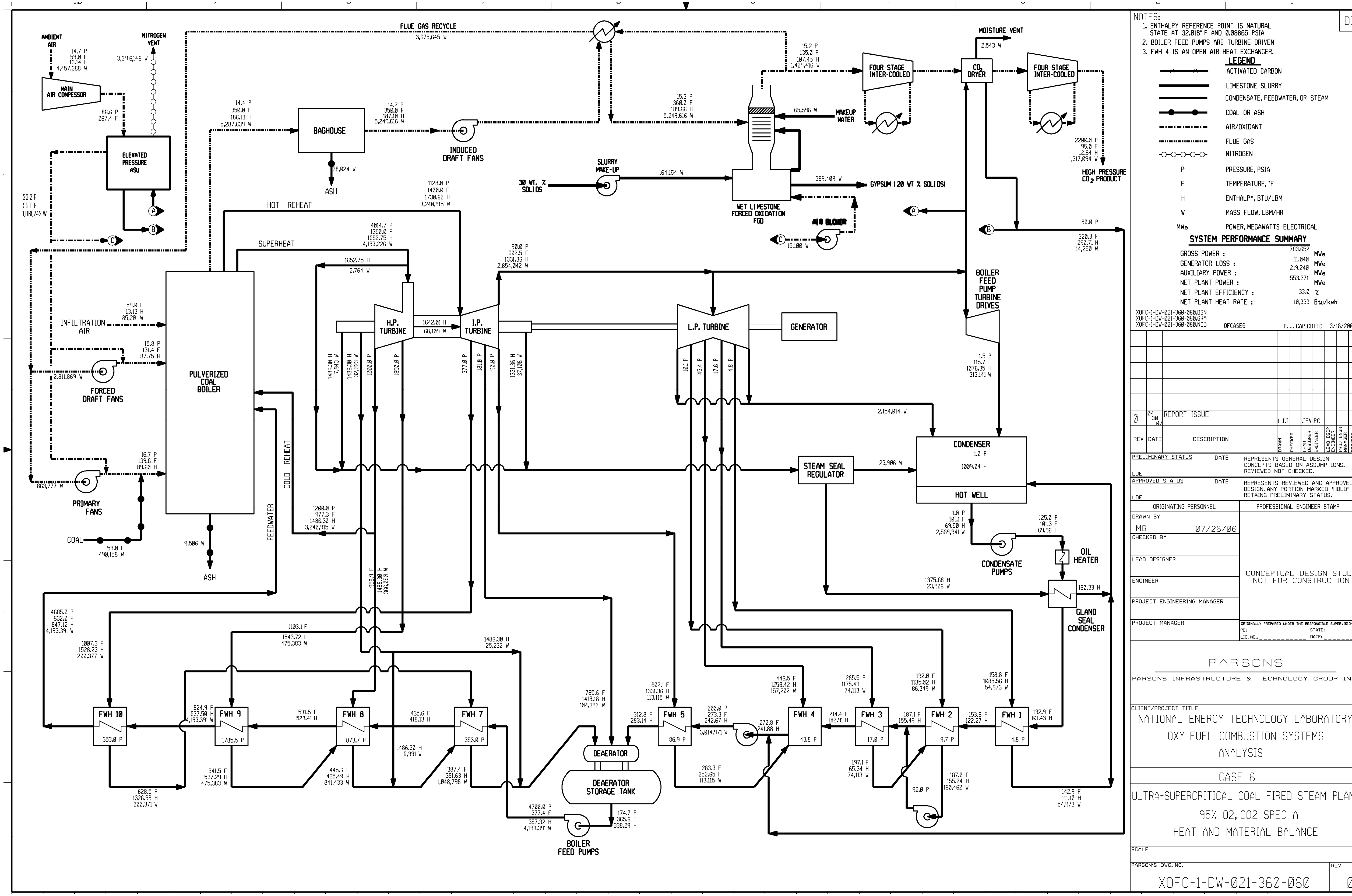

Exhibit 5-18 Case 6A Heat and Mass Balance Diagram

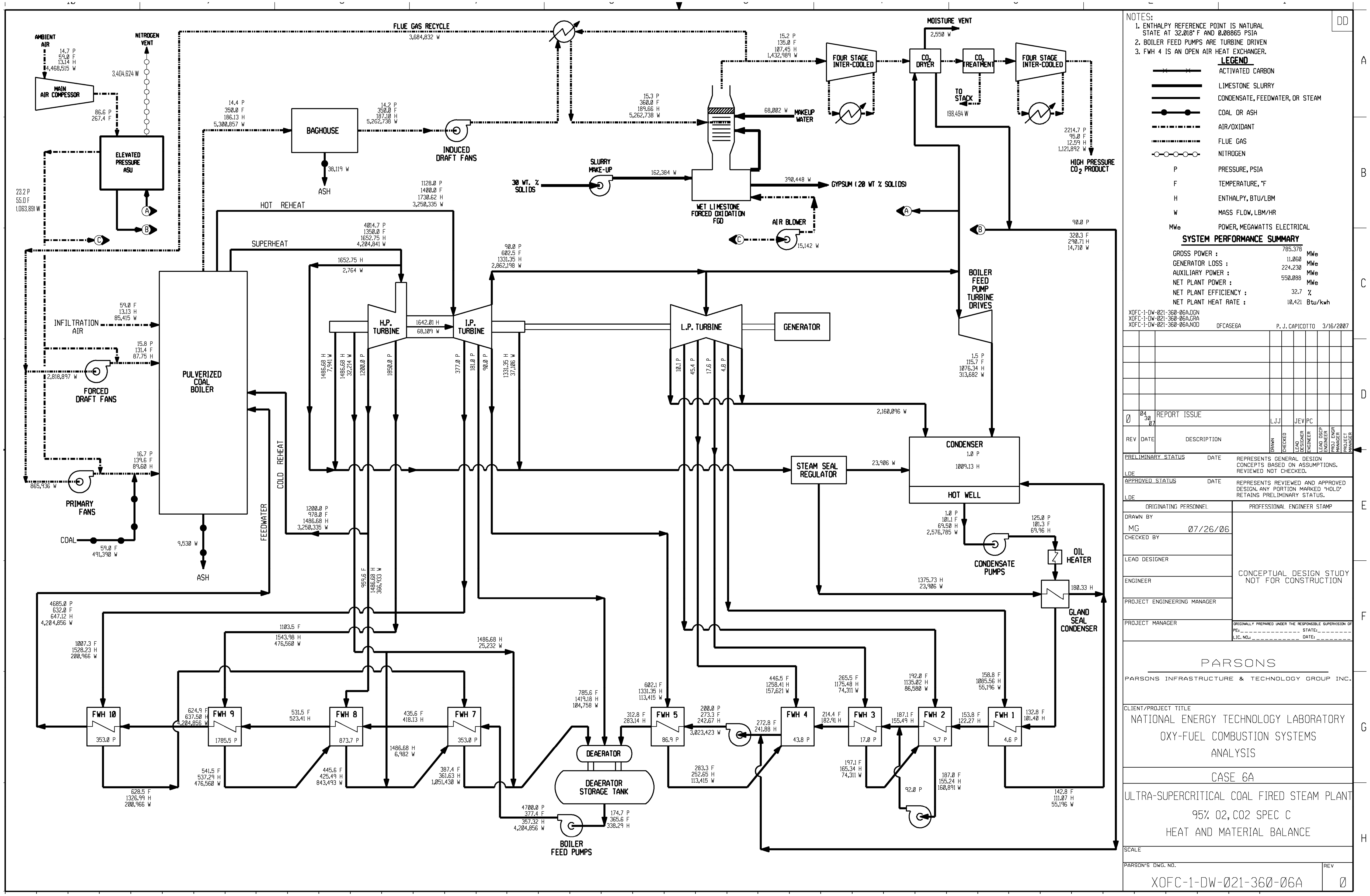

Exhibit 5-19 Ultra-Supercritical Cryogenic Oxycombustion Cases Modeling Results Summary

	Ultra-Supercritical Cases	
	6	**6A**
Gross Plant Power, kWe	**772,611**	**774,318**
AUXILIARY LOAD SUMMARY, kWe		
Coal Handling and Conveying	460	460
Limestone Handling & Reagent Preparation	1,080	1,080
Pulverizer	3,340	3,340
Ash Handling	640	640
Primary Fans	1,030	1,030
Forced Draft Fans	1,300	1,300
Induced Draft Fan	6,700	6,720
Air Separation Unit Main Air Compressor	118,740	119,040
Air Separation Unit Auxiliaries	1,000	1,000
SCR	N/A	N/A
Baghouse	100	100
FGD Pumps and Agitators	3,550	3,560
CO_2 Compression	67,000	71,910
Condensate Pumps	370	380
Boiler Feedwater Booster Pumps	520	520
Miscellaneous Balance of Plant (Note 2)	2,000	2,000
Steam Turbine Auxiliaries	400	400
Circulating Water Pumps	5,330	5,150
Cooling Tower Fans	2,760	2,660
Transformer Loss	2,920	2,940
Total	219,240	224,230
NET PLANT POWER, kWe	**553,371**	**550,088**
PLANT PERFORMANCE		
Net Plant Efficiency (%, HHV)	33.0%	32.7%
Net Plant Heat Rate (Btu/kWh, HHV)	10,333	10,421
Condenser Cooling Duty, MMBtu/hr	**2,375**	**2,554**
CONSUMABLES		
As-Received Coal Feed, lb/hr (Note 3)	490,158	491,390
Thermal Input, kW_{th}	1,675,835	1,680,047
Limestone Sorbent Feed, lb/hr	49,86	49,330
Raw Water Usage, gpm	5,690	5,688

Notes:
1. Boiler feed pumps are turbine driven
2. Includes plant control systems, lighting, HVAC, etc
3. As-received coal heating value: 11,666 Btu/lb (HHV)

5.2.2.1 Environmental Performance for Cases 6 and 6A

Estimated emission rates and annual emissions based on 85% capacity factor are presented in Exhibit 5-20. In the no purification co-sequestration Case 6, gas phase emissions of all criteria pollutants are zero.

Exhibit 5-20 Estimated Air Emission Rates for Cases 6 and 6A

Pollutant	$lb/10^6$ Btu		Tons/year, CF 85%		lb/MWh_{net}	
	Case 6	Case 6A	Case 6	Case 6A	Case 6	Case 6A
SO_2	0	0.020	0	437	0	0.213
NOx	0	0.070	0	1,494	0	0.729
Particulates	0	0.002	0	36	0	0.018
CO_2	0	13	0	267,401	0	131
Hg	0	0.15×10^{-6}	0	0.003	0	1.6×10^{-6}

SO_2 emissions are controlled using a wet limestone forced oxidation scrubber that achieves a removal efficiency of 98%. The byproduct calcium sulfate is dewatered and stored on site. The wallboard grade material can potentially be marketed and sold, but since it is highly dependent on local market conditions, no byproduct credit was taken. The saturated flue gas exiting the scrubber is vented through the plant stack.

NOx emissions are controlled to 0.07 $lb/10^6$ Btu through the use of LNBs, OFO and FGR.

Particulate emissions are controlled using a pulse jet fabric filter (baghouse) which operates at an efficiency of 99.8%. It was assumed that 20% of the ash exits the boiler as bottom ash and the remaining 80% exits the boiler in the flue gas [41].

Co-benefit capture of Hg in the fabric filter and FGD system was assumed to achieve a 90% capture rate [42]. The addition of an inexpensive additive to the FGD system can be used to promote Hg capture if necessary, but was not included in this study.

In Case 6 there is no CO_2 purification step and therefore there are no air emission points. Flue gas from the FGD unit, after water is condensed, is either recycled to the boiler or sent to CO_2 compression and drying. Any pollutants in the gas stream sent to the CO_2 system will be co-sequestered with the CO_2. A small amount of SO_2 will be knocked out in the condenser after the

41 Coal Utilization By Products - Clean Coal Technologies Topical Report Number 24, page 8, http://www.netl.doe.gov/technologies/coalpower/cctc/topicalreports/pdfs/Topical24.pdf, August 2006.

42 Enhancing Mercury Control on Coal-Fired Boilers with SCR, Oxidation Catalyst, and FGD, Institute of Clean Air Companies (ICAC), www.icac.com.

FGD unit, but this sour water stream will be neutralized and disposed of and will not lead to any air emissions.

In Cases 6A the raw CO_2 product stream is further purified through a series of refrigerated flash steps and the vent stream contains SO_2, NOx, CO_2, Ar, N_2 and O_2. The components of the vent stream represent the only air emissions from these cases. These emissions are at levels that meet design emissions limits.

5.2.2.2 Major Equipment List for Cases 6 and 6A

ACCOUNT 1 FUEL AND SORBENT HANDLING

Equipment No.	Description	Type	Design Condition		Qty.
			Case 6	Case 6A	
1	Bottom Trestle Dumper with Receiving Hoppers	N/A	200 tph	200 tph	2
2	Feeder	Belt	630 tph	630 tph	2
3	Conveyor No. 1	Belt	1,250 tph	1,250 tph	1
4	Transfer Tower No. 1	Enclosed	N/A	N/A	1
5	Conveyor No. 2	Belt	1,250 tph	1,250 tph	1
4	As-Received Coal Sampling System	Two-stage	N/A	N/A	1
6	Stacker/Reclaim	Traveling Linear	1,250 tph	1,250 tph	1
7	Reclaim Hopper	N/A	50 ton	50 ton	3
8	Feeder	Vibratory	200 tph	200 tph	3
9	Conveyor No. 3	Belt w/tripper	400 tph	410 tph	1
10	Crusher Tower	N/A	N/A	N/A	1
11	Coal Surge Bin w/ Vent Filter	Dual Outlet	200 ton	200 ton	2
12	Crusher	Impactor reduction	3"x0 - 1.25"x0	3"x0 – 1.25"x0	2
13	As-Fired Coal Sampling System	Swing Hammer	N/A	N/A	2
14	Conveyor No. 4	Belt w/tripper	400 tph	410 tph	1
15	Transfer Tower No. 2	Enclosed	N/A	N/A	1
16	Conveyor No. 5	Belt w/tripper	400 tph	410 tph	1
17	Coal Silo w/ Vent Filter and Slide Gates	Field Erected	900 tph	900 tph	3
18	Limestone Truck Unloading Hopper	N/A	40 ton	40 ton	1
19	Limestone Feeder	Belt	100 tph	100 tph	1
20	Limestone Conveyor No. 1	Belt	100 tph	100 tph	1
21	Limestone Reclaim Hopper	N/A	20 tph	20 tph	1
22	Limestone Reclaim Feeder	Belt	80 tph	80 tph	1
23	Limestone Conveyor No. 1	Belt	80 tph	80 tph	1
24	Limestone Day Bin	w/ actuator	320 ton	330 ton	2

ACCOUNT 2 COAL AND SORBENT PREPARATION AND FEED

Equipment No.	Description	Type	Design Condition		Qty.
			Case 6	Case 6A	
1	Coal Feeder	Gravimetric	40 tph	50 tph	6
2	Coal Pulverizer	Ball type or eq.	40 tph	50 tph	6
3	Limestone Weigh Feeder	Gravimetric	27 tph	27 tph	2
4	Limestone Ball Mill	Rotary	27 tph	27 tph	2
5	Mill Slurry Tank with Agitator	N/A	25,000 gal	25,000 gal	2
6	Mill Recycle Pumps	Horizontal centrifugal	410 gpm @40 ft H_2O	410 gpm @40 ft H_2O	2
7	Hydroclone Classifier	4 active cyclones in a 5 cyclone bank	100 gpm per cyclone	100 gpm per cyclone	2
8	Distribution Box	2-way	N/A	N/A	2
9	Reagent Storage Tank with Agitator	Field erected	140,000 gal	141,000 gal	2
10	Reagent Distribution Pumps	Horizontal centrifugal	290 gpm @30 ft H_2O	290 gpm @30 ft H_2O	2

ACCOUNT 3 FEEDWATER AND MISCELLANEOUS SYSTEMS AND EQUIPMENT

Equipment No.	Description	Type	Design Condition		Qty.
			Case 6	Case 6A	
1	Demineralized Water Storage Tank	Vertical, cylindrical, outdoor	332,000 gal	333,000 gal	2
2	Condensate Pumps	Vertical canned	5,700gpm @ 700 ft H_2O	5,700gpm @ 300 ft H_2O	2
3	Deaerator and Storage Tank	Horizontal spray type	4,613,000 lb/h, 5 min tank	4,625,000 lb/h 5 min tank	1
4	Boiler Feed Pump/ Turbine driven	Barrel type, multi-staged, centrifugal	9,300 gpm @ 12,600 ft H_2O	9,300 gpm @ 12,600 ft H_2O	2
5	Startup Boiler Feed Pump, Electric. motor driven	Barrel type, multi-stage, centrifugal	2,800 gpm @ 12,600 ft H_2O	2,800 gpm @ 12,600 ft H_2O	1
6	LP Feedwater Heater 1A/1B	Horizontal U tube	1,410,000 lb/h	1,420,000 lb/h	2
7	LP Feedwater Heater 2A/2B	Horizontal U tube	1,410,000 lb/h	1,420,000 lb/h	2

Equipment No.	Description	Type	Design Condition		Qty.
			Case 6	Case 6A	
8	LP Feedwater Heater 3A/3B	Horizontal U tube	1,410,000 lb/h	1,420,000 lb/h	2
9	LP Feedwater Heater 4A/4B	Horizontal U tube	1,410,000 lb/h	1,420,000 lb/h	2
10	HP Feedwater Heater 6	Horizontal U tube	4,610,000 lb/h	4,630,000 lb/h	1
11	HP Feedwater Heater 7	Horizontal U tube	4,610,000 lb/h	4,630,000 lb/h	1
12	HP Feedwater Heater 8	Horizontal U tube	4,610,000 lb/h	4,630,000 lb/h	1
13	Auxiliary Boiler	Shop fabricated, water-tube	400 psig, 650°F, 40,000 lb/h	400 psig, 650°F, 40,000 lb/h	1
14	Fuel Oil System	No. 2 for light off	300,000 gal	300,000 gal	1
15	Service Air Compressors	Flooded screw	100 psig, 1,000 cfm	100 psig, 1,000 cfm	3
16	Inst. Air Dryers	Duplex, regenerative	1,000 scfm	1,000 scfm	3
17	Closed Cycle Cooling Heat Exch.	Shell & tube	50 MMBtu/h each	50 MMBtu/h each	2
18	Closed Cycle Cooling Water Pumps	Horizontal centrifugal	5,500gpm @ 100 ft H_2O	5,500gpm @ 100 ft H_2O	3
19	Fire Service Booster Pump	Two-stage centrifugal	700gpm @ 210 ft H_2O	700gpm @ 210 ft H_2O	2
20	Engine-Driven Fire Pump	Vert. turbine, diesel engine	1,000gpm @ 290 ft H_2O	1,000gpm @ 290 ft H_2O	2
21	Raw Water Pumps	SS, single suction	3,180gpm @ 140 ft H_2O	3,170gpm @ 140 ft H_2O	3
22	Filtered Water Pumps	SS, single suction	440gpm @ 160 ft H_2O	430gpm @ 160 ft H_2O	3
23	Filtered Water Tank	Vertical, cylindrical	422,000 gal	412,000 gal	1
24	Makeup Demineralizer	Anion, cation, and mixed bed	180 gpm	180 gpm	2
25	Liquid Waste Treatment System	--	10 years, 24-hour storm	10 years, 24-hour storm	1

ACCOUNT 4 BOILER AND ACCESSORIES

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	Boiler	Ultra Supercritical drum-type, wall-fired, low NOx burners, overfire air	4,610,000 lb/h at 4000 psig/ 1350ºF/1400ºF	4,630,000 lb/h at 4000 psig/ 1350ºF/1400ºF	1
2	Primary Fan	Centrifugal	475,000 lb/h, 87,000 acfm, @ 50" WG	476,000 lb/h, 89,200 acfm @ 50" WG	2
3	Forced Draft Fan	Centrifugal	1,547,000 lb/h, 283,200 acfm @ 20" WG	1,550,000 lb/h, 290,300 acfm @ 20" WG	2
4	Induced Draft Fan	Centrifugal	2,887,000 lb/h, 802,000 acfm @ 35" WG	2,895,000 lb/h, 804,000 acfm @ 35" WG	2
5	Air Separation Unit	Cryogenic	7,000 tpd @ 95 vol% O_2	7,020 tpd @ 95 vol% O_2	2

ACCOUNT 5 FLUE GAS CLEANUP

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	Fabric bag filter	Single-stage, high-ratio with pulse-jet on-line cleaning system.	2,908,000 lb/h, 99.8% efficiency	2,895,000 lb/h, 99.8% efficiency	2
2	Absorber Module	Tray type with concurrent spray	1,287,000 acfm	1,287,000 acfm	1
3	Recirculation Pumps	Horizontal centrifugal	33,000 gpm @ 210 ft H_2O	34,000 gpm @ 210 ft H_2O	6
4	Bleed Pumps	Horizontal centrifugal	1,280 gpm 20% solids	1,280 gpm 20% solids	3
5	Oxidation Air Blowers	Centrifugal	1,030 scfm @ 26 psia	1,030 scfm @ 26 psia	3
6	Agitators	Side entering	50 hp	50 hp	6
7	Dewatering Hydrocyclones	Radial assembly (5 units EA)	320 gpm per cyclone	320 gpm per cyclone	2
8	Vacuum Filter Belt	Horizontal belt	42 tph 50 wt% solids slurry	42 tph 50 wt% solids slurry	3
9	Filtrate Water Return Pumps	Horizontal centrifugal	190 gpm @ 40 ft H_2O	190 gpm @ 40 ft H_2O	2
10	Filtrate Water Return Storage Tank	Vertical, lined	130,000 gal	139,0000 gal	1
11	Process Water Recirculation Pumps	Horizontal centrifugal	690 gpm @ 70 ft H_2O	680 gpm @ 70 ft H_2O	2

ACCOUNT 5B CARBON DIOXIDE RECOVERY

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	CO_2 Compression and Purification Unit	Integrally geared, multistage centrifugal with indirect water intercoolers	726,000 lb/h @ 2215 psia 83.6 wt % CO_2 concentration	788,000 lb/h @ 2215 psia 95.6 mol% CO_2 concentration	2
2	Condensing Heat Exchanger	Shell and tube, alloy steel construction	2,803,204 kg/h @ 70.0 °C (6,180,000 lb/h @ 158 °F)	2,807,740 kg/h @ 70.0 °C (6,190,000 lb/h @ 158 °F)	2

ACCOUNT 6 COMBUSTION TURBINE/ACCESSORIES

N/A

ACCOUNT 7 DUCTING AND STACK

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	Stack	Reinforced concrete with FRP liner	150 ft high x 10 ft diameter	150 ft high x 10 ft diameter	1

ACCOUNT 8 STEAM TURBINE GENERATOR

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	Steam Turbine Generator	Advanced (not yet demonstrated)	810 MW, 4000 psig/ 1350°F /1400°F	820 MW, 4000 psig/ 1350°F /1400°F	1
2	Steam Turbine Generator	Hydrogen cooled, static excitation	900 MVA @ 0.9 p.f., 24 kV, 60 Hz	910 MVA @ 0.9 p.f., 24 kV, 60 Hz	1
3	Surface Condenser	Single pass, divided waterbox including vacuum pumps	2,610 MMBtu/h, Inlet water 60ºF rise 20ºF	2,620 MMBtu/h, Inlet water 60ºF rise 20ºF	1

ACCOUNT 9 COOLING WATER SYSTEM

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	Cooling Tower	Evaporative, mechanical draft, multi-cell	11°C (51.5°F) wet bulb / 16°C (60°F) CWT / 27°C (80°F) HWT 2,867 MMkJ/h (2,720 MMBtu/h) heat load	11°C (51.5°F) wet bulb / 16°C (60°F) CWT / 27°C (80°F) HWT 2,878 MMkJ/h (2,730 MMBtu/h) heat load	1
2	Circ. Water Pumps	Vertical, wet pit	68,000 gpm @ 100 ft	68,000 gpm @ 100 ft,	3

ACCOUNT 10 ASH/SPENT SORBENT RECOVERY AND HANDLING

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	Economizer Hopper (part of boiler scope of supply)	--	--	--	4
2	Bottom Ash Hopper (part of boiler scope of supply)	--	--	--	2
3	Clinker Grinder	--	4.5 tph	4.5 tph	2
4	Pyrites Hopper (part of pulverizer scope of supply included with boiler)	--	--	--	6
5	Hydroejectors	--	--	--	12
6	Economizer/Pyrites Transfer Tank	--	--	--	2
7	Ash Sluice Pumps	Vertical, wet pit	50 gpm @ 56 ft H_2O	50 gpm @ 56 ft H_2O	2
8	Ash Seal Water Pumps	Vertical, wet pit	2,000 gpm@ 28 ft H_2O	2,000 gpm @ 28 ft H_2O	2
9	Hydrobins	--	50 gpm	50 gpm	2
10	Baghouse Hopper (part of baghouse scope of supply)	--	--	--	24
11	Air Heater Hopper (part of boiler scope of supply)	--	--	--	10
12	Air Blower	--	610 scfm @ 24 psi	610 scfm @ 24 psi	2
13	Fly Ash Silo	Reinforced concrete	1,300 tons	1,300 tons	2
14	Slide Gate Valves	--	--	--	2

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
15	Unloader	--	120 tph	120 tph	1
16	Telescoping Unloading Chute	--	--	--	1

ACCOUNT 11 ACCESSORY ELECTRIC PLANT

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	STG Transformer	Oil-filled	24 kV/345 kV, 900 MVA, 3-ph, 60 Hz	24 kV/345 kV, 910 MVA, 3-ph, 60 Hz	1
2	Auxiliary Transformer	Oil-filled	24 kV/ 4.16 kV, 244 MVA, 3-ph, 60 Hz	24 kV/ 4.16 kV, 249 MVA, 3-ph, 60 Hz	2
3	LV Transformer	Dry ventilated	4.16 kV /480 V, 37 MVA, 3-ph, 60 Hz	4.16 kV /480 V, 37 MVA, 3-ph, 60 Hz	2
4	STG Isolated Phase Bus Duct and Tap Bus	Aluminum, self-cooled	24 kV, 3-ph, 60 Hz	24 kV, 3-ph, 60 Hz	1
5	Medium Voltage Switchgear	Metal Clad	4.16 kV, 3-ph, 60 Hz	4.16 kV, 3-ph, 60 Hz	2
6	Low Voltage Switchgear	Metal Enclosed	480 V, 3-ph, 60 Hz	480 V, 3-ph, 60 Hz	2
7	Emergency Diesel Generator	Sized for emergency shutdown	750 kW, 480 V, 3-ph, 60 Hz	750 kW, 480 V, 3-ph, 60 Hz	1

ACCOUNT 12 INSTRUMENTATION AND CONTROL

Equipment No.	Description	Type	Design Condition		Qty
			Case 6	Case 6A	
1	DCS - Main Control	Monitor/keyboard; Operator printer – laser color; Eng. Printer – laser B&W	Operator Stations/Printers and Engineering Stations/Printers	Operator Stations/Printers and Engineering Stations/Printers	1
2	DCS - Processor	Microprocessor with Redundant Input/Output	N/A	N/A	1
3	DCS - Data Highway	Fiber optic	Fully redundant, 25% spare	Fully redundant, 25% spare	1

5.3 ECONOMIC ANALYSIS FOR CRYOGENIC OXYCOMBUSTION CASES

Capital and operating costs for the supercritical oxycombustion cases are presented in Section 5.3.1 and for the ultra-supercritical cases in Section 5.3.2. A cost and performance summary table for all six cases is given in Section 5.3.3 and additional cost detail sheets for all cases are contained in Section 5.3.4.

5.3.1 Cost Estimate Results for Cases 5, 5A, 5B and 5C

The capital and operating costs for Cases 5 through 5C are shown in Exhibit 5-21 through Exhibit 5-28. The economic estimate basis and criteria are shown in Exhibit 5-29. Capital and operating cost methodology is explained in Section 2.8.

Exhibit 5-21 Case 5 Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 26-Jul-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5 - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: **546.19** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING	20,015	5,362	11,872		**37,249**	3,337	0	6,088	**$46,674**	$85
2	COAL & SORBENT PREP & FEED	13,456	775	3,354		**17,585**	1,541	0	2,869	**$21,995**	$40
3	FEEDWATER & MISC. BOP SYSTEMS	63,766	0	28,976		**92,742**	8,506	0	17,118	**$118,366**	$217
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	186,093	0	104,936		**291,029**	28,189	47,883	31,922	**$399,023**	$731
4.2	ASU/Oxidant Compression	126,630	0	103,606		**230,236**	22,301	0	25,254	**$277,790**	$509
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	312,723	0	208,542		**521,265**	50,490	47,883	57,176	**$676,814**	$1,239
5	FLUE GAS CLEANUP	71,413	0	72,849		**144,262**	13,699	0	15,796	**$173,756**	$318
5B	CO2 REMOVAL & COMPRESSION	50,673	0	36,694		**87,367**	8,294	0	19,132	**$114,793**	$210
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0		**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	9,174	0	766		**9,940**	950	0	1,089	**$11,979**	$22
7.2-7.9	Ductwork and Stack	11,182	622	8,015		**19,819**	1,766	0	3,131	**$24,716**	$45
	Subtotal 7	20,356	622	8,781		**29,759**	2,716	0	4,220	**$36,695**	$67
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	64,747	0	8,679		**73,426**	7,030	0	8,046	**$88,502**	$162
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	30,686	1,384	16,817		**48,888**	4,270	0	7,467	**$60,624**	$111
	Subtotal 8	95,433	1,384	25,496		**122,314**	11,300	0	15,513	**$149,126**	$273
9	COOLING WATER SYSTEM	13,690	7,957	14,174		**35,820**	3,350	0	5,404	**$44,575**	$82
10	ASH/SPENT SORBENT HANDLING SYS	5,473	172	7,128		**12,773**	1,216	0	1,440	**$15,428**	$28
11	ACCESSORY ELECTRIC PLANT	27,864	10,354	30,669		**68,886**	6,144	0	9,244	**$84,274**	$154
12	INSTRUMENTATION & CONTROL	14,031	0	14,436		**28,467**	2,606	1,423	3,995	**$36,492**	$67
13	IMPROVEMENTS TO SITE	2,808	1,619	5,828		**10,255**	1,007	0	2,252	**$13,514**	$25
14	BUILDINGS & STRUCTURES	0	27,599	26,319		**53,918**	4,858	0	8,816	**$67,593**	$124
	TOTAL COST	**$711,701**	**$55,844**	**$495,117**	**$0**	**$1,262,662**	**$119,065**	**$49,306**	**$169,063**	**$1,600,097**	**$2,930**

Exhibit 5-22 Case 5 Capital Investment and Operating Cost Summary

TITLE/DEFINITION					
Case:	**Case 5 - Oxy-Fuel Super-Critical PC w/ CO2 Capture**				
Plant Size:	**546.19 (MW,net)**	**Heat Rate**	**12,074**	**Btu/kWh**	
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**	
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**	
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**		
Capacity Factor:	**85.0%**	**CO2 Catured**	**15,995**	**(TPD)**	

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	1,262,662	2,311.8
Engineering(incl.C.M.,H.O.& Fee)	119,065	218.0
Process Contingency	49,306	90.3
Project Contingency	169,063	309.5
TOTAL PLANT COST(TPC)	**1,600,097**	**2,929.5**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	6,013	11.0
Maintenance Labor	10,750	19.7
Maintenance Material	16,125	29.5
Administrative & Support Labor	2,937	5.4
TOTAL OPERATION & MAINTENANCE	$35,825	65.6
FIXED O & M (2007)	$19,700	36.1
VARIABLE O & M	$16,125	29.5

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	3,316	0.08
Chemicals	6,930	0.17
Other Consumables	0	0.00
Waste Disposal	3,153	0.08
TOTAL CONSUMABLES	$13,399	0.33
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$88,625	2.18

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.56
Variable O & M	1.16	0.46
Consumables	1.16	0.38
By-product Credit	1.16	0.00
Fuel	1.20	2.62
TOTAL PRODUCTION COST		4.02
2007 CARRYING CHARGES (Capital)		6.89
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		10.90

Exhibit 5-23 Case 5A Total Plant Costs

Client: U.S. DOE / NETL
Report Date: 26-Jul-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5A - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: **550.91** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING	20,015	5,362	11,872		**37,249**	3,337	0	6,088	**$46,674**	$85
2	COAL & SORBENT PREP & FEED	13,456	775	3,354		**17,585**	1,541	0	2,869	**$21,995**	$40
3	FEEDWATER & MISC. BOP SYSTEMS	63,766	0	28,976		**92,742**	8,506	0	17,118	**$118,366**	$215
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	186,097	0	104,938		**291,035**	28,190	47,884	31,922	**$399,031**	$724
4.2	ASU/Oxidant Compression	139,292	0	113,967		**253,259**	24,531	0	27,779	**$305,569**	$555
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	325,389	0	218,905		**544,294**	52,721	47,884	59,701	**$704,599**	$1,279
5	FLUE GAS CLEANUP	71,413	0	72,849		**144,262**	13,699	0	15,796	**$173,756**	$315
5B	CO2 REMOVAL & COMPRESSION	49,554	0	35,884		**85,438**	8,111	0	18,710	**$112,259**	$204
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0		**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	9,174	0	766		**9,940**	950	0	1,089	**$11,979**	$22
7.2-7.9	Ductwork and Stack	11,182	622	8,015		**19,819**	1,766	0	3,131	**$24,716**	$45
	Subtotal 7	20,356	622	8,781		**29,759**	2,716	0	4,220	**$36,695**	$67
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	64,822	0	8,689		**73,511**	7,038	0	8,055	**$88,604**	$161
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	30,721	1,386	16,837		**48,944**	4,275	0	7,475	**$60,694**	$110
	Subtotal 8	95,543	1,386	25,525		**122,454**	11,313	0	15,530	**$149,298**	$271
9	COOLING WATER SYSTEM	13,701	7,963	14,186		**35,850**	3,353	0	5,408	**$44,611**	$81
10	ASH/SPENT SORBENT HANDLING SYS	5,473	172	7,128		**12,773**	1,216	0	1,440	**$15,428**	$28
11	ACCESSORY ELECTRIC PLANT	27,772	10,354	30,646		**68,772**	6,133	0	9,233	**$84,138**	$153
12	INSTRUMENTATION & CONTROL	14,031	0	14,436		**28,467**	2,606	1,423	3,995	**$36,492**	$66
13	IMPROVEMENTS TO SITE	2,808	1,619	5,828		**10,255**	1,007	0	2,252	**$13,514**	$25
14	BUILDINGS & STRUCTURES	0	27,599	26,319		**53,918**	4,858	0	8,816	**$67,593**	$123
	TOTAL COST	**$723,277**	**$55,852**	**$504,689**	**$0**	**$1,283,817**	**$121,118**	**$49,307**	**$171,178**	**$1,625,420**	**$2,950**

Exhibit 5-24 Case 5A Capital Investment and Operating Cost Summary

TITLE/DEFINITION

Case:	**Case 5A - Oxy-Fuel Super-Critical PC w/ CO2 Capture**			
Plant Size:	**550.91 (MW,net)**	**Heat Rate**	**11,971**	**Btu/kWh**
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**	
Capacity Factor:	**85.0%**	**CO_2 Catured**	**15,992**	**(TPD)**

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	1,283,817	2,330.3
Engineering(incl.C.M.,H.O.& Fee)	121,118	219.8
Process Contingency	49,307	89.5
Project Contingency	171,178	310.7
TOTAL PLANT COST(TPC)	**1,625,420**	**2,950.4**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	6,013	10.9
Maintenance Labor	10,920	19.8
Maintenance Material	16,380	29.7
Administrative & Support Labor	2,937	5.3
TOTAL OPERATION & MAINTENANCE	$36,250	65.8
FIXED O & M (2007)	$19,870	36.1
VARIABLE O & M	$16,380	29.7

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	3,319	0.08
Chemicals	6,923	0.17
Other Consumables	0	0.00
Waste Disposal	3,153	0.08
TOTAL CONSUMABLES	$13,396	0.33
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$88,627	2.16

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.56
Variable O & M	1.16	0.46
Consumables	1.16	0.38
By-product Credit	1.16	0.00
Fuel	1.20	2.60
TOTAL PRODUCTION COST		4.00
2007 CARRYING CHARGES (Capital)		6.93
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		10.93

Exhibit 5-25 Case 5B Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 26-Jul-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5B - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: **545.94** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING	20,015	5,362	11,872		**37,249**	3,337	0	6,088	**$46,674**	$85
2	COAL & SORBENT PREP & FEED	13,456	775	3,354		**17,585**	1,541	0	2,869	**$21,995**	$40
3	FEEDWATER & MISC. BOP SYSTEMS	63,766	0	28,976		**92,742**	8,506	0	17,118	**$118,366**	$217
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	186,097	0	104,938		**291,035**	28,190	47,884	31,922	**$399,031**	$731
4.2	ASU/Oxidant Compression	126,630	0	103,606		**230,236**	22,301	0	25,254	**$277,790**	$509
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	312,727	0	208,544		**521,271**	50,491	47,884	57,176	**$676,821**	$1,240
5	FLUE GAS CLEANUP	71,413	0	72,849		**144,262**	13,699	0	15,796	**$173,756**	$318
5B	CO2 REMOVAL & COMPRESSION	56,287	0	40,759		**97,046**	9,213	0	21,252	**$127,511**	$234
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0		**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	11,008	0	2,752		**13,760**	1,315	0	1,507	**$16,582**	$30
7.2-7.9	Ductwork and Stack	11,182	622	8,015		**19,819**	1,766	0	3,131	**$24,716**	$45
	Subtotal 7	22,190	622	10,767		**33,579**	3,081	0	4,639	**$41,299**	$76
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	64,742	0	8,678		**73,420**	7,030	0	8,045	**$88,495**	$162
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	30,683	1,384	16,816		**48,883**	4,269	0	7,466	**$60,619**	$111
	Subtotal 8	95,425	1,384	25,494		**122,303**	11,299	0	15,511	**$149,114**	$273
9	COOLING WATER SYSTEM	13,689	7,956	14,173		**35,818**	3,350	0	5,404	**$44,571**	$82
10	ASH/SPENT SORBENT HANDLING SYS	5,473	172	7,128		**12,773**	1,216	0	1,440	**$15,428**	$28
11	ACCESSORY ELECTRIC PLANT	27,868	10,354	30,670		**68,891**	6,145	0	9,245	**$84,280**	$154
12	INSTRUMENTATION & CONTROL	14,031	0	14,436		**28,467**	2,606	1,423	3,995	**$36,492**	$67
13	IMPROVEMENTS TO SITE	2,808	1,619	5,828		**10,255**	1,007	0	2,252	**$13,514**	$25
14	BUILDINGS & STRUCTURES	0	27,599	26,319		**53,918**	4,858	0	8,816	**$67,593**	$124
	TOTAL COST	**$719,147**	**$55,843**	**$501,168**	**$0**	**$1,276,159**	**$120,349**	**$49,307**	**$171,601**	**$1,617,416**	**$2,963**

Exhibit 5-26 Case 5B Capital Investment and Operating Cost Summary

TITLE/DEFINITION					
Case:	**Case 5B - Oxy-Fuel Super-Critical PC w/ CO2 Capture**				
Plant Size:	**545.94 (MW,net)**	**Heat Rate**		**12,080 Btu/kWh**	
Fuel(type):	**Illinois #6**	**Fuel Cost:**		**1.80 ($/MMBtu)**	
Design/Construction:	**3 (years)**	**BookLife:**		**30 (years)**	
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**		**2010**	
Capacity Factor:	**85.0%**	**CO_2 Catured**		**15,555 (TPD)**	

CAPITAL INVESTMENT		**$x1000**	**$/kW**
Process Capital & Facilities		1,276,159	2,337.5
Engineering(incl.C.M.,H.O.& Fee)		120,349	220.4
Process Contingency		49,307	90.3
Project Contingency		171,601	314.3
	TOTAL PLANT COST(TPC)	**1,617,416**	**2,962.6**
OPERATING & MAINTENANCE COSTS(2007)		**$x1000**	**$/kW-yr**
Operating Labor		6,013	11.0
Maintenance Labor		10,866	19.9
Maintenance Material		16,299	29.9
Administrative & Support Labor		2,937	5.4
	TOTAL OPERATION & MAINTENANCE	$36,115	66.2
	FIXED O & M (2007)	$19,816	36.3
	VARIABLE O & M	$16,299	29.9
CONSUMABLE OPERATING COSTS, LESS FUEL		**$x1000**	**¢/kWh**
Water		3,315	0.08
Chemicals		6,922	0.17
Other Consumables		0	0.00
Waste Disposal		3,153	0.08
	TOTAL CONSUMABLES	$13,390	0.33
BY-PRODUCT CREDITS		$0	0.00
FUEL COST		$88,627	2.18

			Levelized Costs
PRODUCTION COST SUMMARY		**LF**	**¢/kWh**
Fixed O & M		1.16	0.56
Variable O & M		1.16	0.46
Consumables		1.16	0.38
By-product Credit		1.16	0.00
Fuel		1.20	2.62
	TOTAL PRODUCTION COST		4.03
2007 CARRYING CHARGES (Capital)			6.96
CCF for a 20-Year Levelization Period - IOU - Higher-Risk		**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER			10.99

Exhibit 5-27 Case 5C Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 26-Jul-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5C - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: **543.95** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct		Equipment	Material	Labor		Bare Erected	Eng'g CM	Contingencies		TOT. PLANT COST	
No.	Item/Description	Cost	Cost	Direct	Indirect	Cost $	H.O.& Fee	Process	Project	$	$/kW
1	COAL & SORBENT HANDLING	20,015	5,362	11,872		**37,249**	3,337	0	6,088	**$46,674**	$86
2	COAL & SORBENT PREP & FEED	13,456	775	3,354		**17,585**	1,541	0	2,869	**$21,995**	$40
3	FEEDWATER & MISC. BOP SYSTEMS	63,766	0	28,976		**92,742**	8,506	0	17,118	**$118,366**	$218
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	186,097	0	104,938		**291,035**	28,190	47,884	31,922	**$399,031**	$734
4.2	ASU/Oxidant Compression	126,630	0	103,606		**230,236**	22,301	0	25,254	**$277,790**	$511
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	312,727	0	208,544		**521,271**	50,491	47,884	57,176	**$676,821**	$1,244
5	FLUE GAS CLEANUP	71,413	0	72,849		**144,262**	13,699	0	15,796	**$173,756**	$319
5B	CO2 REMOVAL & COMPRESSION	67,684	0	49,013		**116,697**	11,079	0	25,555	**$153,331**	$282
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0		**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	13,761	0	1,149		**14,910**	1,425	0	1,633	**$17,968**	$33
7.2-7.9	Ductwork and Stack	11,182	622	8,015		**19,819**	1,766	0	3,131	**$24,716**	$45
	Subtotal 7	24,943	622	9,164		**34,729**	3,191	0	4,765	**$42,685**	$78
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	64,742	0	8,678		**73,420**	7,030	0	8,045	**$88,495**	$163
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	30,683	1,384	16,816		**48,883**	4,269	0	7,466	**$60,619**	$111
	Subtotal 8	95,425	1,384	25,494		**122,303**	11,299	0	15,511	**$149,114**	$274
9	COOLING WATER SYSTEM	13,688	7,955	14,172		**35,815**	3,350	0	5,403	**$44,568**	$82
10	ASH/SPENT SORBENT HANDLING SYS	5,473	172	7,128		**12,773**	1,216	0	1,440	**$15,428**	$28
11	ACCESSORY ELECTRIC PLANT	27,916	10,354	30,682		**68,952**	6,150	0	9,250	**$84,352**	$155
12	INSTRUMENTATION & CONTROL	14,031	0	14,436		**28,467**	2,606	1,423	3,995	**$36,492**	$67
13	IMPROVEMENTS TO SITE	2,808	1,619	5,828		**10,255**	1,007	0	2,252	**$13,514**	$25
14	BUILDINGS & STRUCTURES	0	27,599	26,319		**53,918**	4,858	0	8,816	**$67,593**	$124
	TOTAL COST	**$733,345**	**$55,842**	**$507,830**	**$0**	**$1,297,017**	**$122,330**	**$49,307**	**$176,036**	**$1,644,690**	**$3,024**

Exhibit 5-28 Case 5C Capital Investment and Operating Cost Summary

TITLE/DEFINITION

Case:	**Case 5C - Oxy-Fuel Super-Critical PC w/ CO2 Capture**				
Plant Size:	**543.95 (MW,net)**	**Heat Rate**	**12,124**	**Btu/kWh**	
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**	
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**	
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**		
Capacity Factor:	**85.0%**	**CO_2 Catured**	**15,054**	**(TPD)**	

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	1,297,017	2,384.4
Engineering(incl.C.M.,H.O.& Fee)	122,330	224.9
Process Contingency	49,307	90.6
Project Contingency	176,036	323.6
TOTAL PLANT COST(TPC)	**1,644,690**	**3,023.6**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	6,013	11.1
Maintenance Labor	11,050	20.3
Maintenance Material	16,574	30.5
Administrative & Support Labor	2,937	5.4
TOTAL OPERATION & MAINTENANCE	$36,574	67.2
FIXED O & M (2007)	$19,999	36.8
VARIABLE O & M	$16,574	30.5

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	3,315	0.08
Chemicals	6,922	0.17
Other Consumables	0	0.00
Waste Disposal	3,153	0.08
TOTAL CONSUMABLES	$13,390	0.33
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$88,627	2.19

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.57
Variable O & M	1.16	0.47
Consumables	1.16	0.38
By-product Credit	1.16	0.00
Fuel	1.20	2.63
TOTAL PRODUCTION COST		4.06
2007 CARRYING CHARGES (Capital)		7.11
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		11.16

Exhibit 5-29 Cases 5, 5A, 5B, and 5C Estimate Basis /Economic Criteria Summary

Location:	**Midwestern, USA**	
Fuel: Coal/Secondary	**Illinois #6**	
Levelized Capacity Factor:	**85.0%**	
Capital Cost Year Dollars:	**2007**	**(Jan)**
Delivered Cost of Coal /Primary Fuel	**1.80**	**$/MMBtu**
Delivered Cost of Natural Gas//Secondary Fuel	**6.75**	**$/MMBtu**
Design/Construction Period:	**3**	**years**
Plant Startup Date(year):	**2010**	**(January)**
FINANCIAL CRITERIA	IOU High Risk	
Project Book Life:	**30**	**years**
Book Salvage Value:	**0.0**	**%**
Project Tax Life:	**20**	**years**
Tax Depreciation Method:	**20 years, 150% declining balance**	
Property Tax Rate:	**1.0**	**% per year**
Insurance Tax Rate:	**1.0**	**% per year**
Federal Income Tax Rate:	**34.0**	**%**
State Income Tax Rate:	**6.0**	**%**
Investment Tax Credit/% Eligible	**0.0**	**%**
Economic Basis:	**20th Year Current Dollars**	

	% of Total	Cost(%)
Capital Structure		
Common Equity	**55.00**	**12.00**
Tax Free Municipal Bonds	**0.00**	**0.00**
Debt	**45.00**	**11.00**
Weighted Cost of Capital:(after tax)	**9.67 %**	

Escalation Rates	**2010 - 2030**	
General	**1.9**	**% per year**
Coal Price	**2.348**	**% per year**
Secondary Fuel:	**1.955**	**% per year**

5.3.2 Cost Estimate Results for Cases 6 and 6A

The capital and operating costs for Cases 6 and 6A are shown in Exhibit 5-30 through Exhibit 5-33. The economic estimate basis and criteria are the same as for the supercritical cases and were presented in Exhibit 5-34. Capital and operating cost methodology is explained in Section 0.

Exhibit 5-30 Case 6 Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 6 -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture
Plant Size: **553.37** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING	18,048	4,838	10,707		**33,593**	3,010	0	5,490	**$42,093**	$76
2	COAL & SORBENT PREP & FEED	12,088	696	3,011		**15,795**	1,384	0	2,577	**$19,756**	$36
3	FEEDWATER & MISC. BOP SYSTEMS	60,509	0	27,410		**87,919**	8,061	0	16,136	**$112,116**	$203
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	193,169	0	108,926		**302,095**	29,261	82,839	33,136	**$447,330**	$808
4.2	ASU/Oxidant Compression	119,049	0	97,403		**216,452**	20,966	0	23,742	**$261,159**	$472
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	312,218	0	206,329		**518,547**	50,227	82,839	56,877	**$708,489**	$1,280
5	FLUE GAS CLEANUP	66,848	0	67,126		**133,974**	12,719	0	14,669	**$161,362**	$292
5B	CO2 REMOVAL & COMPRESSION	48,094	0	34,827		**82,921**	7,872	0	18,159	**$108,952**	$197
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0		**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	7,890	0	659		**8,549**	817	0	937	**$10,303**	$19
7.2-7.9	Ductwork and Stack	10,600	622	7,619		**18,841**	1,683	0	2,957	**$23,481**	$42
	Subtotal 7	18,490	622	8,278		**27,390**	2,500	0	3,894	**$33,784**	$61
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	70,822	0	9,493		**80,315**	7,690	0	8,800	**$96,805**	$175
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	33,565	1,514	18,395		**53,474**	4,670	0	8,167	**$66,312**	$120
	Subtotal 8	104,387	1,514	27,888		**133,789**	12,360	0	16,968	**$163,117**	$295
9	COOLING WATER SYSTEM	11,840	6,881	12,258		**30,979**	2,898	0	4,674	**$38,551**	$70
10	ASH/SPENT SORBENT HANDLING SYS	5,010	157	6,524		**11,691**	1,113	0	1,318	**$14,121**	$26
11	ACCESSORY ELECTRIC PLANT	26,656	10,337	30,381		**67,374**	6,008	0	9,087	**$82,469**	$149
12	INSTRUMENTATION & CONTROL	13,774	0	14,174		**27,948**	2,559	1,397	3,922	**$35,827**	$65
13	IMPROVEMENTS TO SITE	3,764	2,159	7,531		**13,454**	1,321	0	2,955	**$17,730**	$32
14	BUILDINGS & STRUCTURES	0	26,586	25,367		**51,953**	4,681	0	8,495	**$65,130**	$118
	TOTAL COST	**$701,726**	**$53,790**	**$481,811**	**$0**	**$1,237,327**	**$116,713**	**$84,236**	**$165,221**	**$1,603,497**	**$2,898**

Exhibit 5-31 Case 6 Capital Investment and Operating Cost Summary

TITLE/DEFINITION				
Case:	**Case 6 -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture**			
Plant Size:	**553.37 (MW,net)**	**Heat Rate**	**10,333**	**Btu/kWh**
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**	
Capacity Factor:	**85.0%**	**CO_2 Catured**	**13,867**	**(TPD)**

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	1,237,327	2,236.0
Engineering(incl.C.M.,H.O.& Fee)	116,713	210.9
Process Contingency	84,236	152.2
Project Contingency	165,221	298.6
TOTAL PLANT COST(TPC)	**1,603,497**	**2,897.7**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	6,013	10.9
Maintenance Labor	10,773	19.5
Maintenance Material	16,159	29.2
Administrative & Support Labor	2,937	5.3
TOTAL OPERATION & MAINTENANCE	$35,882	64.8
FIXED O & M (2007)	$19,722	35.6
VARIABLE O & M	$16,159	29.2

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	2,618	0.06
Chemicals	5,800	0.14
Other Consumables	0	0.00
Waste Disposal	2,741	0.07
TOTAL CONSUMABLES	$11,159	0.27
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$76,845	1.86

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.55
Variable O & M	1.16	0.45
Consumables	1.16	0.31
By-product Credit	1.16	0.00
Fuel	1.20	2.24
TOTAL PRODUCTION COST		3.56
2007 CARRYING CHARGES (Capital)		6.81
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		10.37

Exhibit 5-32 Case 6A Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 6A -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture
Plant Size: **550.09** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies		TOT. PLANT COST	
				Direct	Indirect			Process	Project	$	$/kW
1	COAL & SORBENT HANDLING	18,048	4,838	10,707		**33,593**	3,010	0	5,490	**$42,093**	$77
2	COAL & SORBENT PREP & FEED	12,088	696	3,011		**15,795**	1,384	0	2,577	**$19,756**	$36
3	FEEDWATER & MISC. BOP SYSTEMS	60,509	0	27,410		**87,919**	8,061	0	16,136	**$112,116**	$204
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	193,508	0	109,117		**302,626**	29,313	82,985	33,194	**$448,117**	$815
4.2	ASU/Oxidant Compression	119,049	0	97,403		**216,452**	20,966	0	23,742	**$261,159**	$475
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	312,557	0	206,520		**519,078**	50,278	82,985	56,936	**$709,276**	$1,289
5	FLUE GAS CLEANUP	66,848	0	67,126		**133,974**	12,719	0	14,669	**$161,362**	$293
5B	CO2 REMOVAL & COMPRESSION	58,287	0	42,208		**100,495**	9,540	0	22,007	**$132,042**	$240
6	COMBUSTION TURBINE/ACCESSORIES	0	0	0		**0**	0	0	0	**$0**	$0
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	7,890	0	659		**8,549**	817	0	937	**$10,303**	$19
7.2-7.9	Ductwork and Stack	10,600	622	7,619		**18,841**	1,683	0	2,957	**$23,481**	$43
	Subtotal 7	18,490	622	8,278		**27,390**	2,500	0	3,894	**$33,784**	$61
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	70,967	0	9,513		**80,480**	7,706	0	8,819	**$97,004**	$176
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	33,634	1,517	18,433		**53,584**	4,680	0	8,184	**$66,448**	$121
	Subtotal 8	104,601	1,517	27,945		**134,064**	12,386	0	17,003	**$163,452**	$297
9	COOLING WATER SYSTEM	11,858	6,892	12,277		**31,027**	2,902	0	4,681	**$38,610**	$70
10	ASH/SPENT SORBENT HANDLING SYS	5,010	157	6,524		**11,691**	1,113	0	1,318	**$14,121**	$26
11	ACCESSORY ELECTRIC PLANT	26,785	10,337	30,413		**67,535**	6,023	0	9,102	**$82,661**	$150
12	INSTRUMENTATION & CONTROL	13,774	0	14,174		**27,948**	2,559	1,397	3,922	**$35,827**	$65
13	IMPROVEMENTS TO SITE	3,764	2,159	7,531		**13,454**	1,321	0	2,955	**$17,730**	$32
14	BUILDINGS & STRUCTURES	0	26,586	25,367		**51,953**	4,681	0	8,495	**$65,130**	$118
	TOTAL COST	**$712,620**	**$53,804**	**$489,492**	**$0**	**$1,255,916**	**$118,478**	**$84,382**	**$169,185**	**$1,627,961**	**$2,959**

Exhibit 5-33 Case 6A Capital Investment and Operating Cost Summary

TITLE/DEFINITION					
Case:	**Case 6A -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture**				
Plant Size:	**550.09 (MW,net)**	**Heat Rate**	**10,421 Btu/kWh**		
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80 ($/MMBtu)**		
Design/Construction:	**3 (years)**	**BookLife:**	**30 (years)**		
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**		
Capacity Factor:	**85.0%**	**CO2 Catured**	**13,040 (TPD)**		

CAPITAL INVESTMENT		**$x1000**	**$/kW**
Process Capital & Facilities		1,255,916	2,283.1
Engineering(incl.C.M.,H.O.& Fee)		118,478	215.4
Process Contingency		84,382	153.4
Project Contingency		169,185	307.6
	TOTAL PLANT COST(TPC)	**1,627,961**	**2,959.5**
OPERATING & MAINTENANCE COSTS(2007)		**$x1000**	**$/kW-yr**
Operating Labor		6,013	10.9
Maintenance Labor		10,937	19.9
Maintenance Material		16,406	29.8
Administrative & Support Labor		2,937	5.3
	TOTAL OPERATION & MAINTENANCE	$36,293	66.0
	FIXED O & M (2007)	$19,887	36.2
	VARIABLE O & M	$16,406	29.8
CONSUMABLE OPERATING COSTS, LESS FUEL		**$x1000**	**¢/kWh**
Water		2,617	0.06
Chemicals		5,811	0.14
Other Consumables		0	0.00
Waste Disposal		2,741	0.07
	TOTAL CONSUMABLES	$11,169	0.27
BY-PRODUCT CREDITS		$0	0.00
FUEL COST		$77,038	1.88

PRODUCTION COST SUMMARY		**LF**	**Levelized Costs ¢/kWh**
Fixed O & M		1.16	0.56
Variable O & M		1.16	0.46
Consumables		1.16	0.32
By-product Credit		1.16	0.00
Fuel		1.20	2.26
	TOTAL PRODUCTION COST		3.60
2007 CARRYING CHARGES (Capital)			6.96
CCF for a 20-Year Levelization Period - IOU - Higher-Risk		**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER			10.56

Exhibit 5-34 Cases 6 and 6A Estimate Basis /Economic Criteria Summary

Location:	**Midwestern, USA**	
Fuel: Coal/Secondary	**Illinois #6**	
Levelized Capacity Factor:	**85.0%**	
Capital Cost Year Dollars:	**2007**	**(Jan)**
Delivered Cost of Coal /Primary Fuel	**1.80**	**$/MMBtu**
Delivered Cost of Natural Gas//Secondary Fuel	**6.75**	**$/MMBtu**
Design/Construction Period:	**3**	**years**
Plant Startup Date(year):	**2010**	**(January)**
FINANCIAL CRITERIA	IOU High Risk	
Project Book Life:	**30**	**years**
Book Salvage Value:	**0.0**	**%**
Project Tax Life:	**20**	**years**
Tax Depreciation Method:	**20 years, 150% declining balance**	
Property Tax Rate:	**1.0**	**% per year**
Insurance Tax Rate:	**1.0**	**% per year**
Federal Income Tax Rate:	**34.0**	**%**
State Income Tax Rate:	**6.0**	**%**
Investment Tax Credit/% Eligible	**0.0**	**%**
Economic Basis:	**20th Year Current Dollars**	

		% of Total	Cost(%)
Capital Structure			
	Common Equity	**55.00**	**12.00**
	Tax Free Municipal Bonds	**0.00**	**0.00**
	Debt	**45.00**	**11.00**
Weighted Cost of Capital:(after tax)		**9.67 %**	

		2010 - 2030	
Escalation Rates			
	General	**1.9**	**% per year**
	Coal Price	**2.348**	**% per year**
	Secondary Fuel:	**1.955**	**% per year**

5.3.3 Cost Estimate and Performance Summary for all Cryogenic Oxycombustion Cases

A summary of plant costs and performance for all of the cryogenic oxycombustion cases is shown in Exhibit 5-35.

Exhibit 5-35 Cost and Performance Results for Cryogenic Oxycombustion Cases

Case	5	5A	5B	5C	6	6A
Gross Power Output, MW_e	792.5	793.5	792.4	792.4	772.6	774.3
Net Power Output, MW_e	546.2	550.9	545.9	543.9	553.4	550.1
Net Plant Efficiency, % (HHV)	28.3	28.5	28.2	28.1	33.0	32.7
Net Plant Heat Rate, Btu/kWh (HHV)	12,074	11,971	12,080	12,124	10,333	10,421
Total Plant Cost, $x1000	1,600,097	1,625,420	1,617,416	1,644,690	1,603,497	1,627,961
Total Plant Cost, $/kW	2,930	2,950	2,963	3,024	2,898	2,959
CO_2 Capital Cost Penalty[a], $/kW	1,367	1,387	1,400	1,461	1,334	1,396
Levelized Cost of Electricity, ¢/kWh (85% Capacity Factor)	10.90	10.93	10.99	11.16	10.37	10.56
Levelized COE CO_2 Penalty[b], ¢/kWh (85% Capacity Factor)	4.61	4.64	4.70	4.87	4.08	4.26
Percent increase in COE[c], (85% Capacity Factor)	73%	74%	75%	77%	65%	68%
Total CO_2 Emitted, lb/MWh_{net}	0	0	67	144	0	131
Cost of CO_2 Avoided[d], $/ton	52	53	56	60	50	58
Total CO_2Captured, lb/MWh_{net}	2,440	2,419	2,375	2,306	2,088	1,975
Cost of CO_2 Captured[e], $/ton	38	38	40	42	38	42

a. CO_2 Capital Cost Penalty = TPC with capture – TPC case 1 air-fired without capture
b. CO_2 LCOE Cost Penalty = LCOE with capture – LCOE case 1 air-fired without capture
c. Relative to Case 1 ("Base Case")
d. CO_2 Cost Avoided = (COE with capture – COE without capture)/(Emissions without capture – Emissions with capture)
e. CO_2 Cost Captured (or Removal) = (COE with capture – COE without capture)/(CO_2 Captured)
Costs do not include CO_2 Transport, Storage, and Monitoring

5.3.4 Cost Estimate Details for Cryogenic Oxycombustion Cases

Additional cost estimating details are provided for the cryogenic oxycombustion cases in the following subsections:

Section 5.3.4.1: Case 5 – Oxycombustion Supercritical PC with CO_2 capture

Section 5.3.4.2: Case 5A – Oxycombustion Supercritical PC with CO_2 capture

Section 5.3.4.3: Case 5B – Oxycombustion Supercritical PC with CO_2 capture

Section 5.3.4.4: Case 5C – Oxycombustion Supercritical PC with CO_2 capture

Section 5.3.4.5: Case 6 – Oxycombustion Ultra-supercritical PC with CO_2 capture

Section 5.3.4.6: Case 6A – Oxycombustion Ultra-supercritical PC with CO_2 capture

5.3.4.1 Case 5 – Oxycombustion Supercritical PC with CO_2 capture

	Client:	U.S. DOE / NETL								Report Date:	24-Apr-07	
	Project:	Case 5 - Oxy-Fuel Super-Critical PC w/ CO2 Capture										
		TOTAL PLANT COST SUMMARY										
	Case:	Case 5 - Oxy-Fuel Super-Critical PC w/ CO2 Capture										
	Plant Size:	546.19 MW,net		Estimate Type:				Cost Base (Jan) 2007			$x1000	
Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	4,112	0	1,861		$5,973	533	0	976	**$7,482**	$14
1.2	Coal Stackout & Reclaim	5,320	0	1,191		$6,511	570	0	1,062	**$8,143**	$15
1.3	Coal Conveyors & Yard Breaker	4,947	0	1,180		$6,127	537	0	1,000	**$7,664**	$14
1.4	Other Coal Handling	1,295	0	272		$1,567	137	0	256	**$1,960**	$4
1.5	Sorbent Receive & Unload	164	0	49		$213	19	0	35	**$267**	$0
1.6	Sorbent Stackout & Reclaim	2,656	0	482		$3,138	273	0	512	**$3,923**	$7
1.7	Sorbent Conveyors	948	202	231		$1,381	120	0	225	**$1,726**	$3
1.8	Other Sorbent Handling	573	131	296		$1,000	88	0	163	**$1,252**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	5,029	6,310		$11,339	1,060	0	1,860	**$14,259**	$26
	SUBTOTAL 1.	**$20,015**	**$5,362**	**$11,872**		**$37,249**	**$3,337**	**$0**	**$6,088**	**$46,674**	$85
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,359	0	455		$2,814	245	0	459	**$3,518**	$6
2.2	Coal Conveyor to Storage	6,042	0	1,306		$7,348	643	0	1,199	**$9,189**	$17
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	4,511	192	927		$5,630	490	0	918	**$7,038**	$13
2.6	Sorbent Storage & Feed	544	0	206		$750	67	0	122	**$939**	$2
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	583	460		$1,043	96	0	171	**$1,310**	$2
	SUBTOTAL 2.	**$13,456**	**$775**	**$3,354**		**$17,585**	**$1,541**	**$0**	**$2,869**	**$21,995**	$40
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	22,926	0	7,346		$30,272	2,651	0	4,938	**$37,861**	$69
3.2	Water Makeup & Pretreating	11,613	0	3,653		$15,266	1,431	0	3,339	**$20,037**	$37
3.3	Other Feedwater Subsystems	7,085	0	2,942		$10,027	894	0	1,638	**$12,559**	$23
3.4	Service Water Systems	2,291	0	1,211		$3,502	325	0	765	**$4,592**	$8
3.5	Other Boiler Plant Systems	8,413	0	8,056		$16,469	1,545	0	2,702	**$20,716**	$38
3.6	FO Supply Sys & Nat Gas	318	0	383		$701	65	0	115	**$881**	$2
3.7	Waste Treatment Equipment	7,823	0	4,389		$12,212	1,183	0	2,679	**$16,074**	$29
3.8	Misc. Power Plant Equipment	3,297	0	996		$4,293	412	0	941	**$5,646**	$10
	SUBTOTAL 3.	**$63,766**	**$0**	**$28,976**		**$92,742**	**$8,506**	**$0**	**$17,118**	**$118,366**	$217
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	186,093	0	104,936		$291,029	28,189	47,883	31,922	**$399,023**	$731
4.2	ASU/Oxidant Compression	126,630	0	103,606		$230,236	22,301	0	25,254	**$277,790**	$509
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$312,723**	**$0**	**$208,542**		**$521,265**	**$50,490**	**$47,883**	**$57,176**	**$676,814**	$1,239

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5 - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 546.19 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	28,556	0	33,972		$62,528	5,918	0	6,845	**$75,290**	$138
5.2	Other FGD	2,728	0	3,142		$5,870	566	0	644	**$7,080**	$13
5.3	Baghouse & Accessories	21,284	0	15,816		$37,100	3,549	0	4,065	**$44,714**	$82
5.4	Other Particulate Removal Materials	1,018	0	1,109		$2,127	205	0	233	**$2,565**	$5
5.5	Gypsum Dewatering System	17,827	0	18,809		$36,636	3,462	0	4,010	**$44,107**	$81
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$71,413**	**$0**	**$72,849**		**$144,262**	**$13,699**	**$0**	**$15,796**	**$173,756**	$318
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	50,673	0	36,694		$87,367	8,294	0	19,132	**$114,793**	**$210**
	SUBTOTAL 5B.	**$50,673**	**$0**	**$36,694**		**$87,367**	**$8,294**	**$0**	**$19,132**	**$114,793**	**$210**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator						0	0	0	**$0**	$0
6.2	Combustion Turbine Accessories						0	0	0	**$0**	$0
6.3	Compressed Air Piping						0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations						0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	HR, DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	9,174	0	766		$9,940	950	0	1,089	**$11,979**	$22
7.2	SCR System	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	9,101	0	6,027		$15,128	1,321	0	2,467	**$18,917**	$35
7.4	Stack	2,081	0	1,236		$3,317	317	0	363	**$3,997**	$7
7.9	Duct & Stack Foundations	0	622	752		$1,374	128	0	300	**$1,802**	$3
	SUBTOTAL 7.	**$20,356**	**$622**	**$8,781**		**$29,759**	**$2,716**	**$0**	**$4,220**	**$36,695**	$67
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	64,747	0	8,679		$73,426	7,030	0	8,046	**$88,502**	$162
8.2	Turbine Plant Auxiliaries	444	0	952		$1,396	135	0	153	**$1,684**	$3
8.3	Condenser & Auxiliaries	8,511	0	2,929		$11,440	1,087	0	1,253	**$13,780**	$25
8.4	Steam Piping	21,731	0	10,734		$32,465	2,709	0	5,276	**$40,450**	$74
8.9	TG Foundations	0	1,384	2,203		$3,587	338	0	785	**$4,709**	$9
	SUBTOTAL 8.	**$95,433**	**$1,384**	**$25,496**		**$122,314**	**$11,300**	**$0**	**$15,513**	**$149,126**	$273
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	10,526	0	3,281		$13,807	1,311	0	1,512	**$16,630**	$30
9.2	Circulating Water Pumps	1,485	0	207		$1,693	146	0	184	**$2,023**	$4
9.3	Circ.Water System Auxiliaries	625	0	83		$708	67	0	78	**$853**	$2
9.4	Circ.Water Piping	0	5,039	4,806		$9,845	907	0	1,613	**$12,365**	$23
9.5	Make-up Water System	554	0	735		$1,289	122	0	212	**$1,623**	$3
9.6	Component Cooling Water Sys	499	0	394		$892	84	0	146	**$1,122**	$2
9.9	Circ.Water System Foundations	0	2,917	4,668		$7,585	714	0	1,660	**$9,959**	$18
	SUBTOTAL 9.	**$13,690**	**$7,957**	**$14,174**		**$35,820**	**$3,350**	**$0**	**$5,404**	**$44,575**	$82

Client: U.S. DOE / NETL | **Report Date:** 24-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5 - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 546.19 MW,net | **Estimate Type:** | **Cost Base (Jan)** 2007 | $x1000

Acct		Equipment	Material	Labor		Bare Erected	Eng'g CM	Contingencies		TOT. PLANT COST	
No.	Item/Description	Cost	Cost	Direct	Indirect	Cost $	H.O.& Fee	Process	Project	$	$/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	728	0	2,198		$2,926	285	0	321	**$3,532**	$6
10.7	Ash Transport & Feed Equipment	4,745	0	4,730		$9,475	896	0	1,037	**$11,408**	$21
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	172	200		$372	35	0	81	**$488**	$1
	SUBTOTAL 10.	**$5,473**	**$172**	**$7,128**		**$12,773**	**$1,216**	**$0**	**$1,440**	**$15,428**	$28
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	2,309	0	369		$2,678	248	0	219	**$3,145**	$6
11.2	Station Service Equipment	6,373	0	2,182		$8,555	818	0	703	**$10,076**	$18
11.3	Switchgear & Motor Control	7,574	0	1,298		$8,871	821	0	969	**$10,662**	$20
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$36
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$43
11.6	Protective Equipment	238	0	826		$1,064	104	0	117	**$1,285**	$2
11.7	Standby Equipment	1,782	0	41		$1,823	173	0	200	**$2,195**	$4
11.8	Main Power Transformers	9,588	0	245		$9,833	748	0	1,058	**$11,639**	$21
11.9	Electrical Foundations	0	440	1,090		$1,530	145	0	335	**$2,010**	$4
	SUBTOTAL 11.	**$27,864**	**$10,354**	**$30,669**		**$68,886**	**$6,144**	**$0**	**$9,244**	**$84,274**	$154
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	718	0	439		$1,157	111	58	199	**$1,525**	$3
12.7	Computer & Accessories	7,255	0	1,293		$8,548	814	427	979	**$10,768**	$20
12.8	Instrument Wiring & Tubing	4,008	0	7,959		$11,967	1,019	598	2,038	**$15,622**	$29
12.9	Other I & C Equipment	2,050	0	4,745		$6,795	662	340	780	**$8,576**	$16
	SUBTOTAL 12.	**$14,031**	**$0**	**$14,436**		**$28,467**	**$2,606**	**$1,423**	**$3,995**	**$36,492**	$67

	Client:	U.S. DOE / NETL							**Report Date:**	24-Apr-07	
	Project:	Oxy-Fuel Combustion Systems Analysis									
					TOTAL PLANT COST SUMMARY						
	Case:	Case 5 - Oxy-Fuel Super-Critical PC w/ CO2 Capture									
	Plant Size:	546.19 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000	
Acct		**Equipment**	**Material**	**Labor**		**Bare Erected**	**Eng'g CM**	**Contingencies**		**TOT. PLANT COST**	
No.	**Item/Description**	**Cost**	**Cost**	**Direct**	**Indirect**	**Cost $**	**H.O.& Fee**	**Process**	**Project**	**$**	**$/kW**
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	48	972		$1,020	100	0	224	**$1,345**	$2
13.2	Site Improvements	0	1,571	2,004		$3,575	351	0	785	**$4,711**	$9
13.3	Site Facilities	2,808	0	2,852		$5,660	556	0	1,243	**$7,459**	$14
	SUBTOTAL 13.	**$2,808**	**$1,619**	**$5,828**		**$10,255**	**$1,007**	**$0**	**$2,252**	**$13,514**	$25
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	9,901	8,713		$18,614	1,672	0	3,043	**$23,328**	$43
14.2	Turbine Building	0	14,783	13,791		$28,574	2,573	0	4,672	**$35,819**	$66
14.3	Administration Building	0	550	602		$1,152	104	0	188	**$1,445**	$3
14.4	Circulation Water Pumphouse	0	349	276		$625	56	0	102	**$783**	$1
14.5	Water Treatment Buildings	0	904	770		$1,674	150	0	274	**$2,097**	$4
14.6	Machine Shop	0	363	261		$624	55	0	102	**$781**	$1
14.7	Warehouse	0	103	176		$279	25	0	46	**$350**	$1
14.8	Other Buildings & Structures	0	115	117		$232	21	0	38	**$291**	$1
14.9	Waste Treating Building & Str.	0	531	1,613		$2,144	203	0	352	**$2,699**	$5
	SUBTOTAL 14.	**$0**	**$27,599**	**$26,319**		**$53,918**	**$4,858**	**$0**	**$8,816**	**$67,593**	$124
	TOTAL COST	**$711,701**	**$55,844**	**$495,117**		**$1,262,662**	**$119,065**	**$49,306**	**$169,063**	**$1,600,097**	$2,930

INITIAL & ANNUAL O&M EXPENSES			25-Apr-2007		Cost Base:	Jan 2007 dollars
Case 5 - Oxy-Fuel Super-Critical PC w/ CO2 Capture					Heat Rate-net(Btu/kWh)	12,074
Plant Output: Carbon Dioxide(tpd): 15,995					Mwe-net:	546.19
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of Labor				
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.0	11.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.0	16.0				
					Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$6,012,864	11.01
Maintenance Labor Cost					$10,749,963	19.68
Administrative & Support Labor					$2,936,773	5.38
TOTAL FIXED OPERATING COSTS					**$19,699,600**	**36.07**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$16,124,945	0.0040
Consumables	Initial	/Day	Unit Cost	Initial Cost		
Water(/1000 gallons)		10,377	$1.03	$0	$3,315,933	0.0008
Chemicals						
MU & WT Chem.(lbs)	351,607	50,230	$0.16	$57,945	$2,568,199	0.0006
Limestone (Tons)	4,778	682.5	$20.60	$98,422	$4,362,190	0.0011
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	1,133	0.0	$2,142.40	$2,427,173	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	0	0.0	$123.60	$0	$0	0.0000
Subtotal Chemicals				$2,583,540	$6,930,389	0.0017
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		526	$15.45		$2,522,482	0.0006
Bottom Ash (tons)		132	$15.45		$630,620	0.0002
Subtotal-Waste Disposal					$3,153,103	0.0008
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$29,524,370**	0.0073
Fuel - Coal (Tons)	203,506	6,784	$42.11	$8,569,658	**$88,624,550**	0.0218

5.3.4.2 Case 5A – Oxycombustion Supercritical PC with CO_2 capture

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07
Project: Case 5A - Oxy-Fuel Super-Critical PC w/ CO2 Capture

TOTAL PLANT COST SUMMARY

Case: Case 5A - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 550.91 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	4,112	0	1,861		$5,973	533	0	976	**$7,482**	$14
1.2	Coal Stackout & Reclaim	5,320	0	1,191		$6,511	570	0	1,062	**$8,143**	$15
1.3	Coal Conveyors & Yard Breaker	4,947	0	1,180		$6,127	537	0	1,000	**$7,664**	$14
1.4	Other Coal Handling	1,295	0	272		$1,567	137	0	256	**$1,960**	$4
1.5	Sorbent Receive & Unload	164	0	49		$213	19	0	35	**$267**	$0
1.6	Sorbent Stackout & Reclaim	2,656	0	482		$3,138	273	0	512	**$3,923**	$7
1.7	Sorbent Conveyors	948	202	231		$1,381	120	0	225	**$1,726**	$3
1.8	Other Sorbent Handling	573	131	296		$1,000	88	0	163	**$1,252**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	5,029	6,310		$11,339	1,060	0	1,860	**$14,259**	$26
	SUBTOTAL 1.	**$20,015**	**$5,362**	**$11,872**		**$37,249**	**$3,337**	**$0**	**$6,088**	**$46,674**	$85
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,359	0	455		$2,814	245	0	459	**$3,518**	$6
2.2	Coal Conveyor to Storage	6,042	0	1,306		$7,348	643	0	1,199	**$9,189**	$17
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	4,511	192	927		$5,630	490	0	918	**$7,038**	$13
2.6	Sorbent Storage & Feed	544	0	206		$750	67	0	122	**$939**	$2
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	583	460		$1,043	96	0	171	**$1,310**	$2
	SUBTOTAL 2.	**$13,456**	**$775**	**$3,354**		**$17,585**	**$1,541**	**$0**	**$2,869**	**$21,995**	$40
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	22,926	0	7,346		$30,272	2,651	0	4,938	**$37,861**	$69
3.2	Water Makeup & Pretreating	11,613	0	3,653		$15,266	1,431	0	3,339	**$20,037**	$36
3.3	Other Feedwater Subsystems	7,085	0	2,942		$10,027	894	0	1,638	**$12,559**	$23
3.4	Service Water Systems	2,291	0	1,211		$3,502	325	0	765	**$4,592**	$8
3.5	Other Boiler Plant Systems	8,413	0	8,056		$16,469	1,545	0	2,702	**$20,716**	$38
3.6	FO Supply Sys & Nat Gas	318	0	383		$701	65	0	115	**$881**	$2
3.7	Waste Treatment Equipment	7,823	0	4,389		$12,212	1,183	0	2,679	**$16,074**	$29
3.8	Misc. Power Plant Equipment	3,297	0	996		$4,293	412	0	941	**$5,646**	$10
	SUBTOTAL 3.	**$63,766**	**$0**	**$28,976**		**$92,742**	**$8,506**	**$0**	**$17,118**	**$118,366**	$215
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	186,097	0	104,938		$291,035	28,190	47,884	31,922	**$399,031**	$724
4.2	ASU/Oxidant Compression	139,292	0	113,967		$253,259	24,531	0	27,779	**$305,569**	$555
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$325,389**	**$0**	**$218,905**		**$544,294**	**$52,721**	**$47,884**	**$59,701**	**$704,599**	$1,279

	Client:	U.S. DOE / NETL							**Report Date:**	24-Apr-07		
	Project:	Oxy-Fuel Combustion Systems Analysis										
					TOTAL PLANT COST SUMMARY							
	Case:	Case 5A - Oxy-Fuel Super-Critical PC w/ CO2 Capture										
	Plant Size:	550.91 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000		

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	28,556	0	33,972		$62,528	5,918	0	6,845	**$75,290**	$137
5.2	Other FGD	2,728	0	3,142		$5,870	566	0	644	**$7,080**	$13
5.3	Baghouse & Accessories	21,284	0	15,816		$37,100	3,549	0	4,065	**$44,714**	$81
5.4	Other Particulate Removal Materials	1,018	0	1,109		$2,127	205	0	233	**$2,565**	$5
5.5	Gypsum Dewatering System	17,827	0	18,809		$36,636	3,462	0	4,010	**$44,107**	$80
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$71,413**	**$0**	**$72,849**		**$144,262**	**$13,699**	**$0**	**$15,796**	**$173,756**	$315
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	49,554	0	35,884		$85,438	8,111	0	18,710	**$112,259**	**$204**
	SUBTOTAL 5B.	**$49,554**	**$0**	**$35,884**		**$85,438**	**$8,111**	**$0**	**$18,710**	**$112,259**	**$204**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator						0	0	0	**$0**	$0
6.2	Combustion Turbine Accessories						0	0	0	**$0**	$0
6.3	Compressed Air Piping						0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations						0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	HR, DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	9,174	0	766		$9,940	950	0	1,089	**$11,979**	$22
7.2	SCR System	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	9,101	0	6,027		$15,128	1,321	0	2,467	**$18,917**	$34
7.4	Stack	2,081	0	1,236		$3,317	317	0	363	**$3,997**	$7
7.9	Duct & Stack Foundations	0	622	752		$1,374	128	0	300	**$1,802**	$3
	SUBTOTAL 7.	**$20,356**	**$622**	**$8,781**		**$29,759**	**$2,716**	**$0**	**$4,220**	**$36,695**	$67
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	64,822	0	8,689		$73,511	7,038	0	8,055	**$88,604**	$161
8.2	Turbine Plant Auxiliaries	444	0	953		$1,397	136	0	153	**$1,686**	$3
8.3	Condenser & Auxiliaries	8,521	0	2,932		$11,453	1,089	0	1,254	**$13,796**	$25
8.4	Steam Piping	21,756	0	10,747		$32,502	2,713	0	5,282	**$40,497**	$74
8.9	TG Foundations	0	1,386	2,205		$3,591	338	0	786	**$4,715**	$9
	SUBTOTAL 8.	**$95,543**	**$1,386**	**$25,525**		**$122,454**	**$11,313**	**$0**	**$15,530**	**$149,298**	$271
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	10,535	0	3,283		$13,818	1,312	0	1,513	**$16,643**	$30
9.2	Circulating Water Pumps	1,487	0	208		$1,694	146	0	184	**$2,024**	$4
9.3	Circ.Water System Auxiliaries	626	0	83		$709	67	0	78	**$854**	$2
9.4	Circ.Water Piping	0	5,043	4,810		$9,853	908	0	1,614	**$12,375**	$22
9.5	Make-up Water System	555	0	735		$1,290	122	0	212	**$1,624**	$3
9.6	Component Cooling Water Sys	499	0	394		$893	84	0	147	**$1,123**	$2
9.9	Circ.Water System Foundations	0	2,920	4,672		$7,591	715	0	1,661	**$9,967**	$18
	SUBTOTAL 9.	**$13,701**	**$7,963**	**$14,186**		**$35,850**	**$3,353**	**$0**	**$5,408**	**$44,611**	$81

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5A - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 550.91 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	728	0	2,198		$2,926	285	0	321	**$3,532**	$6
10.7	Ash Transport & Feed Equipment	4,745	0	4,730		$9,475	896	0	1,037	**$11,408**	$21
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	172	200		$372	35	0	81	**$488**	$1
	SUBTOTAL 10.	**$5,473**	**$172**	**$7,128**		**$12,773**	**$1,216**	**$0**	**$1,440**	**$15,428**	$28
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	2,309	0	369		$2,678	248	0	219	**$3,145**	$6
11.2	Station Service Equipment	6,331	0	2,167		$8,499	813	0	698	**$10,010**	$18
11.3	Switchgear & Motor Control	7,524	0	1,289		$8,813	816	0	963	**$10,592**	$19
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$35
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$43
11.6	Protective Equipment	238	0	826		$1,064	104	0	117	**$1,285**	$2
11.7	Standby Equipment	1,782	0	41		$1,823	173	0	200	**$2,195**	$4
11.8	Main Power Transformers	9,588	0	245		$9,833	748	0	1,058	**$11,639**	$21
11.9	Electrical Foundations	0	440	1,090		$1,530	145	0	335	**$2,010**	$4
	SUBTOTAL 11.	**$27,772**	**$10,354**	**$30,646**		**$68,772**	**$6,133**	**$0**	**$9,233**	**$84,138**	$153
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	718	0	439		$1,157	111	58	199	**$1,525**	$3
12.7	Computer & Accessories	7,255	0	1,293		$8,548	814	427	979	**$10,768**	$20
12.8	Instrument Wiring & Tubing	4,008	0	7,959		$11,967	1,019	598	2,038	**$15,622**	$28
12.9	Other I & C Equipment	2,050	0	4,745		$6,795	662	340	780	**$8,576**	$16
	SUBTOTAL 12.	**$14,031**	**$0**	**$14,436**		**$28,467**	**$2,606**	**$1,423**	**$3,995**	**$36,492**	$66

	Client: U.S. DOE / NETL							**Report Date:** 24-Apr-07			
	Project: Oxy-Fuel Combustion Systems Analysis										
	TOTAL PLANT COST SUMMARY										
	Case: Case 5A - Oxy-Fuel Super-Critical PC w/ CO2 Capture										
	Plant Size: 550.91 MW,net		**Estimate Type:**					**Cost Base (Jan)** 2007		$x1000	
Acct No.	**Item/Description**	**Equipment Cost**	**Material Cost**	**Labor Direct**	**Labor Indirect**	**Bare Erected Cost $**	**Eng'g CM H.O.& Fee**	**Contingencies Process**	**Contingencies Project**	**TOT. PLANT COST $**	**TOT. PLANT COST $/kW**
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	48	972		$1,020	100	0	224	**$1,345**	$2
13.2	Site Improvements	0	1,571	2,004		$3,575	351	0	785	**$4,711**	$9
13.3	Site Facilities	2,808	0	2,852		$5,660	556	0	1,243	**$7,459**	$14
	SUBTOTAL 13.	**$2,808**	**$1,619**	**$5,828**		**$10,255**	**$1,007**	**$0**	**$2,252**	**$13,514**	$25
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	9,901	8,713		$18,614	1,672	0	3,043	**$23,328**	$42
14.2	Turbine Building	0	14,783	13,791		$28,574	2,573	0	4,672	**$35,819**	$65
14.3	Administration Building	0	550	602		$1,152	104	0	188	**$1,445**	$3
14.4	Circulation Water Pumphouse	0	349	276		$625	56	0	102	**$783**	$1
14.5	Water Treatment Buildings	0	904	770		$1,674	150	0	274	**$2,097**	$4
14.6	Machine Shop	0	363	261		$624	55	0	102	**$781**	$1
14.7	Warehouse	0	103	176		$279	25	0	46	**$350**	$1
14.8	Other Buildings & Structures	0	115	117		$232	21	0	38	**$291**	$1
14.9	Waste Treating Building & Str.	0	531	1,613		$2,144	203	0	352	**$2,699**	$5
	SUBTOTAL 14.	**$0**	**$27,599**	**$26,319**		**$53,918**	**$4,858**	**$0**	**$8,816**	**$67,593**	$123
	TOTAL COST	**$723,277**	**$55,852**	**$504,689**		**$1,283,817**	**$121,118**	**$49,307**	**$171,178**	**$1,625,420**	$2,950

INITIAL & ANNUAL O&M EXPENSES			25-Apr-2007		Cost Base:	Jan 2007 dollars
Case 5A - Oxy-Fuel Super-Critical PC w/ CO2 Capture					Heat Rate-net(Btu/kWh)	11,971
Plant Output: Carbon Dioxide(tpd): 15,992					Mwe-net:	550.91
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00 $/hour					
Operating Labor Burden:	30.00 % of base					
Labor O-H Charge Rate:	25.00 % of Labor					
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.0	11.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.0	16.0				
					Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$6,012,864	10.91
Maintenance Labor Cost					$10,920,093	19.82
Administrative & Support Labor					$2,936,773	5.33
TOTAL FIXED OPERATING COSTS					**$19,869,730**	**36.07**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$16,380,140	0.0040
Consumables	Initial	/Day	Unit Cost	Initial Cost		
Water(/1000 gallons)		10,387	$1.03	$0	$3,319,154	0.0008
Chemicals						
MU & WT Chem.(lbs)	351,949	50,278	$0.16	$58,001	$2,570,694	0.0006
Limestone (Tons)	4,767	681.1	$20.60	$98,209	$4,352,757	0.0011
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	1,133	0.0	$2,142.40	$2,426,686	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	0	0.0	$123.60	$0	$0	0.0000
Subtotal Chemicals				$2,582,896	$6,923,451	0.0017
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		526	$15.45		$2,522,476	0.0006
Bottom Ash (tons)		132	$15.45		$630,619	0.0002
Subtotal-Waste Disposal					$3,153,095	0.0008
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$29,775,840**	0.0073
Fuel - Coal (Tons)	203,512	6,784	$42.11	$8,569,886	**$88,626,902**	0.0216

5.3.4.3 Case 5B – Oxycombustion Supercritical PC with CO_2 capture

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07
Project: Case 5B - Oxy-Fuel Super-Critical PC w/ CO2 Capture

TOTAL PLANT COST SUMMARY

Case: Case 5B - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 545.94 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct		Equipment	Material	Labor		Bare Erected	Eng'g CM	Contingencies		TOT. PLANT COST	
No.	Item/Description	Cost	Cost	Direct	Indirect	Cost $	H.O.& Fee	Process	Project	$	$/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	4,112	0	1,861		$5,973	533	0	976	**$7,482**	$14
1.2	Coal Stackout & Reclaim	5,320	0	1,191		$6,511	570	0	1,062	**$8,143**	$15
1.3	Coal Conveyors & Yard Breaker	4,947	0	1,180		$6,127	537	0	1,000	**$7,664**	$14
1.4	Other Coal Handling	1,295	0	272		$1,567	137	0	256	**$1,960**	$4
1.5	Sorbent Receive & Unload	164	0	49		$213	19	0	35	**$267**	$0
1.6	Sorbent Stackout & Reclaim	2,656	0	482		$3,138	273	0	512	**$3,923**	$7
1.7	Sorbent Conveyors	948	202	231		$1,381	120	0	225	**$1,726**	$3
1.8	Other Sorbent Handling	573	131	296		$1,000	88	0	163	**$1,252**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	5,029	6,310		$11,339	1,060	0	1,860	**$14,259**	$26
	SUBTOTAL 1.	**$20,015**	**$5,362**	**$11,872**		**$37,249**	**$3,337**	**$0**	**$6,088**	**$46,674**	$85
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,359	0	455		$2,814	245	0	459	**$3,518**	$6
2.2	Coal Conveyor to Storage	6,042	0	1,306		$7,348	643	0	1,199	**$9,189**	$17
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	4,511	192	927		$5,630	490	0	918	**$7,038**	$13
2.6	Sorbent Storage & Feed	544	0	206		$750	67	0	122	**$939**	$2
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	583	460		$1,043	96	0	171	**$1,310**	$2
	SUBTOTAL 2.	**$13,456**	**$775**	**$3,354**		**$17,585**	**$1,541**	**$0**	**$2,869**	**$21,995**	$40
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	22,926	0	7,346		$30,272	2,651	0	4,938	**$37,861**	$69
3.2	Water Makeup & Pretreating	11,613	0	3,653		$15,266	1,431	0	3,339	**$20,037**	$37
3.3	Other Feedwater Subsystems	7,085	0	2,942		$10,027	894	0	1,638	**$12,559**	$23
3.4	Service Water Systems	2,291	0	1,211		$3,502	325	0	765	**$4,592**	$8
3.5	Other Boiler Plant Systems	8,413	0	8,056		$16,469	1,545	0	2,702	**$20,716**	$38
3.6	FO Supply Sys & Nat Gas	318	0	383		$701	65	0	115	**$881**	$2
3.7	Waste Treatment Equipment	7,823	0	4,389		$12,212	1,183	0	2,679	**$16,074**	$29
3.8	Misc. Power Plant Equipment	3,297	0	996		$4,293	412	0	941	**$5,646**	$10
	SUBTOTAL 3.	**$63,766**	**$0**	**$28,976**		**$92,742**	**$8,506**	**$0**	**$17,118**	**$118,366**	$217
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	186,097	0	104,938		$291,035	28,190	47,884	31,922	**$399,031**	$731
4.2	ASU/Oxidant Compression	126,630	0	103,606		$230,236	22,301	0	25,254	**$277,790**	$509
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$312,727**	**$0**	**$208,544**		**$521,271**	**$50,491**	**$47,884**	**$57,176**	**$676,821**	$1,240

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5B - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 545.94 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	28,556	0	33,972		$62,528	5,918	0	6,845	**$75,290**	$138
5.2	Other FGD	2,728	0	3,142		$5,870	566	0	644	**$7,080**	$13
5.3	Baghouse & Accessories	21,284	0	15,816		$37,100	3,549	0	4,065	**$44,714**	$82
5.4	Other Particulate Removal Materials	1,018	0	1,109		$2,127	205	0	233	**$2,565**	$5
5.5	Gypsum Dewatering System	17,827	0	18,809		$36,636	3,462	0	4,010	**$44,107**	$81
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$71,413**	**$0**	**$72,849**		**$144,262**	**$13,699**	**$0**	**$15,796**	**$173,756**	$318
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	56,287	0	40,759		$97,046	9,213	0	21,252	**$127,511**	**$234**
	SUBTOTAL 5B.	**$56,287**	**$0**	**$40,759**		**$97,046**	**$9,213**	**$0**	**$21,252**	**$127,511**	**$234**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator						0	0	0	**$0**	$0
6.2	Combustion Turbine Accessories						0	0	0	**$0**	$0
6.3	Compressed Air Piping						0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations						0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	HR, DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	11,008	0	2,752		$13,760	1,315	0	1,507	**$16,582**	$30
7.2	SCR System	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	9,101	0	6,027		$15,128	1,321	0	2,467	**$18,917**	$35
7.4	Stack	2,081	0	1,236		$3,317	317	0	363	**$3,997**	$7
7.9	Duct & Stack Foundations	0	622	752		$1,374	128	0	300	**$1,802**	$3
	SUBTOTAL 7.	**$22,190**	**$622**	**$10,767**		**$33,579**	**$3,081**	**$0**	**$4,639**	**$41,299**	$76
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	64,742	0	8,678		$73,420	7,030	0	8,045	**$88,495**	$162
8.2	Turbine Plant Auxiliaries	444	0	952		$1,396	135	0	153	**$1,684**	$3
8.3	Condenser & Auxiliaries	8,511	0	2,928		$11,439	1,087	0	1,253	**$13,779**	$25
8.4	Steam Piping	21,729	0	10,733		$32,462	2,709	0	5,276	**$40,447**	$74
8.9	TG Foundations	0	1,384	2,202		$3,587	338	0	785	**$4,709**	$9
	SUBTOTAL 8.	**$95,425**	**$1,384**	**$25,494**		**$122,303**	**$11,299**	**$0**	**$15,511**	**$149,114**	$273
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	10,526	0	3,280		$13,806	1,311	0	1,512	**$16,628**	$30
9.2	Circulating Water Pumps	1,485	0	207		$1,693	146	0	184	**$2,023**	$4
9.3	Circ.Water System Auxiliaries	625	0	83		$708	67	0	78	**$853**	$2
9.4	Circ.Water Piping	0	5,039	4,806		$9,845	907	0	1,613	**$12,364**	$23
9.5	Make-up Water System	554	0	735		$1,289	122	0	212	**$1,623**	$3
9.6	Component Cooling Water Sys	499	0	394		$892	84	0	146	**$1,122**	$2
9.9	Circ.Water System Foundations	0	2,917	4,667		$7,585	714	0	1,660	**$9,958**	$18
	SUBTOTAL 9.	**$13,689**	**$7,956**	**$14,173**		**$35,818**	**$3,350**	**$0**	**$5,404**	**$44,571**	$82

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5B - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 545.94 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	728	0	2,198		$2,926	285	0	321	**$3,532**	$6
10.7	Ash Transport & Feed Equipment	4,745	0	4,730		$9,475	896	0	1,037	**$11,408**	$21
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	172	200		$372	35	0	81	**$488**	$1
	SUBTOTAL 10.	**$5,473**	**$172**	**$7,128**		**$12,773**	**$1,216**	**$0**	**$1,440**	**$15,428**	$28
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	2,309	0	369		$2,678	248	0	219	**$3,145**	$6
11.2	Station Service Equipment	6,375	0	2,182		$8,557	818	0	703	**$10,079**	$18
11.3	Switchgear & Motor Control	7,576	0	1,298		$8,874	822	0	970	**$10,665**	$20
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$36
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$43
11.6	Protective Equipment	238	0	826		$1,064	104	0	117	**$1,285**	$2
11.7	Standby Equipment	1,782	0	41		$1,823	173	0	200	**$2,195**	$4
11.8	Main Power Transformers	9,588	0	245		$9,833	748	0	1,058	**$11,639**	$21
11.9	Electrical Foundations	0	440	1,090		$1,530	145	0	335	**$2,010**	$4
	SUBTOTAL 11.	**$27,868**	**$10,354**	**$30,670**		**$68,891**	**$6,145**	**$0**	**$9,245**	**$84,280**	$154
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	718	0	439		$1,157	111	58	199	**$1,525**	$3
12.7	Computer & Accessories	7,255	0	1,293		$8,548	814	427	979	**$10,768**	$20
12.8	Instrument Wiring & Tubing	4,008	0	7,959		$11,967	1,019	598	2,038	**$15,622**	$29
12.9	Other I & C Equipment	2,050	0	4,745		$6,795	662	340	780	**$8,576**	$16
	SUBTOTAL 12.	**$14,031**	**$0**	**$14,436**		**$28,467**	**$2,606**	**$1,423**	**$3,995**	**$36,492**	$67

	Client:	U.S. DOE / NETL							**Report Date:**	24-Apr-07		
	Project:	Oxy-Fuel Combustion Systems Analysis										
					TOTAL PLANT COST SUMMARY							
	Case:	Case 5B - Oxy-Fuel Super-Critical PC w/ CO2 Capture										
	Plant Size:	545.94 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000		
Acct		**Equipment**	**Material**	**Labor**		**Bare Erected**	**Eng'g CM**	**Contingencies**		**TOT. PLANT COST**		
No.	**Item/Description**	**Cost**	**Cost**	**Direct**	**Indirect**	**Cost $**	**H.O.& Fee**	**Process**	**Project**	**$**	**$/kW**	
13	IMPROVEMENTS TO SITE											
13.1	Site Preparation	0	48	972		$1,020	100	0	224	**$1,345**	$2	
13.2	Site Improvements	0	1,571	2,004		$3,575	351	0	785	**$4,711**	$9	
13.3	Site Facilities	2,808	0	2,852		$5,660	556	0	1,243	**$7,459**	$14	
	SUBTOTAL 13.	**$2,808**	**$1,619**	**$5,828**		**$10,255**	**$1,007**	**$0**	**$2,252**	**$13,514**	$25	
14	BUILDINGS & STRUCTURES											
14.1	Boiler Building	0	9,901	8,713		$18,614	1,672	0	3,043	**$23,328**	$43	
14.2	Turbine Building	0	14,783	13,791		$28,574	2,573	0	4,672	**$35,819**	$66	
14.3	Administration Building	0	550	602		$1,152	104	0	188	**$1,445**	$3	
14.4	Circulation Water Pumphouse	0	349	276		$625	56	0	102	**$783**	$1	
14.5	Water Treatment Buildings	0	904	770		$1,674	150	0	274	**$2,097**	$4	
14.6	Machine Shop	0	363	261		$624	55	0	102	**$781**	$1	
14.7	Warehouse	0	103	176		$279	25	0	46	**$350**	$1	
14.8	Other Buildings & Structures	0	115	117		$232	21	0	38	**$291**	$1	
14.9	Waste Treating Building & Str.	0	531	1,613		$2,144	203	0	352	**$2,699**	$5	
	SUBTOTAL 14.	**$0**	**$27,599**	**$26,319**		**$53,918**	**$4,858**	**$0**	**$8,816**	**$67,593**	$124	
	TOTAL COST	**$719,147**	**$55,843**	**$501,168**		**$1,276,159**	**$120,349**	**$49,307**	**$171,601**	**$1,617,416**	$2,963	

INITIAL & ANNUAL O&M EXPENSES			25-Apr-2007		Cost Base:	Jan 2007 dollars
Case 5B - Oxy-Fuel Super-Critical PC w/ CO2 Capture					Heat Rate-net(Btu/kWh)	12,080
Plant Output: Carbon Dioxide(tpd): 15,555					Mwe-net:	545.94
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of Labor				
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.0	11.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.0	16.0				
					Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$6,012,864	11.01
Maintenance Labor Cost					$10,866,317	19.90
Administrative & Support Labor					$2,936,773	5.38
TOTAL FIXED OPERATING COSTS					**$19,815,954**	**36.30**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$16,299,476	0.0040
Consumables	Initial	/Day	Unit Cost	Initial Cost		
Water(/1000 gallons)		10,375	$1.03	$0	$3,315,473	0.0008
Chemicals						
MU & WT Chem.(lbs)	351,558	50,223	$0.16	$57,937	$2,567,843	0.0006
Limestone (Tons)	4,769	681.2	$20.60	$98,235	$4,353,907	0.0011
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	1,102	0.0	$2,142.40	$2,360,470	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	0	0.0	$123.60	$0	$0	0.0000
Subtotal Chemicals				$2,516,641	$6,921,750	0.0017
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		526	$15.45		$2,522,476	0.0006
Bottom Ash (tons)		132	$15.45		$630,619	0.0002
Subtotal-Waste Disposal					$3,153,095	0.0008
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$29,689,794**	0.0073
Fuel - Coal (Tons)	203,512	6,784	$42.11	$8,569,886	**$88,626,902**	0.0218

5.3.4.4 Case 5C – Oxycombustion Supercritical PC with CO_2 capture

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07
Project: Case 5C - Oxy-Fuel Super-Critical PC w/ CO2 Capture

TOTAL PLANT COST SUMMARY

Case: Case 5C - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 543.95 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct		Equipment	Material	Labor		Bare Erected	Eng'g CM	Contingencies		TOT. PLANT COST	
No.	Item/Description	Cost	Cost	Direct	Indirect	Cost $	H.O.& Fee	Process	Project	$	$/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	4,112	0	1,861		$5,973	533	0	976	**$7,482**	$14
1.2	Coal Stackout & Reclaim	5,320	0	1,191		$6,511	570	0	1,062	**$8,143**	$15
1.3	Coal Conveyors & Yard Breaker	4,947	0	1,180		$6,127	537	0	1,000	**$7,664**	$14
1.4	Other Coal Handling	1,295	0	272		$1,567	137	0	256	**$1,960**	$4
1.5	Sorbent Receive & Unload	164	0	49		$213	19	0	35	**$267**	$0
1.6	Sorbent Stackout & Reclaim	2,656	0	482		$3,138	273	0	512	**$3,923**	$7
1.7	Sorbent Conveyors	948	202	231		$1,381	120	0	225	**$1,726**	$3
1.8	Other Sorbent Handling	573	131	296		$1,000	88	0	163	**$1,252**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	5,029	6,310		$11,339	1,060	0	1,860	**$14,259**	$26
	SUBTOTAL 1.	**$20,015**	**$5,362**	**$11,872**		**$37,249**	**$3,337**	**$0**	**$6,088**	**$46,674**	$86
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,359	0	455		$2,814	245	0	459	**$3,518**	$6
2.2	Coal Conveyor to Storage	6,042	0	1,306		$7,348	643	0	1,199	**$9,189**	$17
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	4,511	192	927		$5,630	490	0	918	**$7,038**	$13
2.6	Sorbent Storage & Feed	544	0	206		$750	67	0	122	**$939**	$2
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	583	460		$1,043	96	0	171	**$1,310**	$2
	SUBTOTAL 2.	**$13,456**	**$775**	**$3,354**		**$17,585**	**$1,541**	**$0**	**$2,869**	**$21,995**	$40
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	22,926	0	7,346		$30,272	2,651	0	4,938	**$37,861**	$70
3.2	Water Makeup & Pretreating	11,613	0	3,653		$15,266	1,431	0	3,339	**$20,037**	$37
3.3	Other Feedwater Subsystems	7,085	0	2,942		$10,027	894	0	1,638	**$12,559**	$23
3.4	Service Water Systems	2,291	0	1,211		$3,502	325	0	765	**$4,592**	$8
3.5	Other Boiler Plant Systems	8,413	0	8,056		$16,469	1,545	0	2,702	**$20,716**	$38
3.6	FO Supply Sys & Nat Gas	318	0	383		$701	65	0	115	**$881**	$2
3.7	Waste Treatment Equipment	7,823	0	4,389		$12,212	1,183	0	2,679	**$16,074**	$30
3.8	Misc. Power Plant Equipment	3,297	0	996		$4,293	412	0	941	**$5,646**	$10
	SUBTOTAL 3.	**$63,766**	**$0**	**$28,976**		**$92,742**	**$8,506**	**$0**	**$17,118**	**$118,366**	$218
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	186,097	0	104,938		$291,035	28,190	47,884	31,922	**$399,031**	$734
4.2	ASU/Oxidant Compression	126,630	0	103,606		$230,236	22,301	0	25,254	**$277,790**	$511
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$312,727**	**$0**	**$208,544**		**$521,271**	**$50,491**	**$47,884**	**$57,176**	**$676,821**	$1,244

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07

Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5C - Oxy-Fuel Super-Critical PC w/ CO2 Capture

Plant Size: 543.95 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	28,556	0	33,972		$62,528	5,918	0	6,845	**$75,290**	$138
5.2	Other FGD	2,728	0	3,142		$5,870	566	0	644	**$7,080**	$13
5.3	Baghouse & Accessories	21,284	0	15,816		$37,100	3,549	0	4,065	**$44,714**	$82
5.4	Other Particulate Removal Materials	1,018	0	1,109		$2,127	205	0	233	**$2,565**	$5
5.5	Gypsum Dewatering System	17,827	0	18,809		$36,636	3,462	0	4,010	**$44,107**	$81
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$71,413**	**$0**	**$72,849**		**$144,262**	**$13,699**	**$0**	**$15,796**	**$173,756**	$319
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	67,684	0	49,013		$116,697	11,079	0	25,555	**$153,331**	**$282**
	SUBTOTAL 5B.	**$67,684**	**$0**	**$49,013**		**$116,697**	**$11,079**	**$0**	**$25,555**	**$153,331**	**$282**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator						0	0	0	**$0**	$0
6.2	Combustion Turbine Accessories						0	0	0	**$0**	$0
6.3	Compressed Air Piping						0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations						0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	HR, DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	13,761	0	1,149		$14,910	1,425	0	1,633	**$17,968**	$33
7.2	SCR System	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	9,101	0	6,027		$15,128	1,321	0	2,467	**$18,917**	$35
7.4	Stack	2,081	0	1,236		$3,317	317	0	363	**$3,997**	$7
7.9	Duct & Stack Foundations	0	622	752		$1,374	128	0	300	**$1,802**	$3
	SUBTOTAL 7.	**$24,943**	**$622**	**$9,164**		**$34,729**	**$3,191**	**$0**	**$4,765**	**$42,685**	$78
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	64,742	0	8,678		$73,420	7,030	0	8,045	**$88,495**	$163
8.2	Turbine Plant Auxiliaries	444	0	952		$1,396	135	0	153	**$1,684**	$3
8.3	Condenser & Auxiliaries	8,511	0	2,928		$11,439	1,087	0	1,253	**$13,779**	$25
8.4	Steam Piping	21,729	0	10,733		$32,462	2,709	0	5,276	**$40,447**	$74
8.9	TG Foundations	0	1,384	2,202		$3,587	338	0	785	**$4,709**	$9
	SUBTOTAL 8.	**$95,425**	**$1,384**	**$25,494**		**$122,303**	**$11,299**	**$0**	**$15,511**	**$149,114**	$274
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	10,525	0	3,280		$13,805	1,311	0	1,512	**$16,627**	$31
9.2	Circulating Water Pumps	1,485	0	207		$1,693	146	0	184	**$2,022**	$4
9.3	Circ.Water System Auxiliaries	625	0	83		$708	67	0	78	**$853**	$2
9.4	Circ.Water Piping	0	5,038	4,805		$9,844	907	0	1,613	**$12,363**	$23
9.5	Make-up Water System	554	0	735		$1,289	122	0	212	**$1,623**	$3
9.6	Component Cooling Water Sys	499	0	394		$892	84	0	146	**$1,122**	$2
9.9	Circ.Water System Foundations	0	2,917	4,667		$7,584	714	0	1,660	**$9,957**	$18
	SUBTOTAL 9.	**$13,688**	**$7,955**	**$14,172**		**$35,815**	**$3,350**	**$0**	**$5,403**	**$44,568**	$82

Client: U.S. DOE / NETL **Report Date:** 24-Apr-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 5C - Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 543.95 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	728	0	2,198		$2,926	285	0	321	**$3,532**	$6
10.7	Ash Transport & Feed Equipment	4,745	0	4,730		$9,475	896	0	1,037	**$11,408**	$21
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	172	200		$372	35	0	81	**$488**	$1
	SUBTOTAL 10.	**$5,473**	**$172**	**$7,128**		**$12,773**	**$1,216**	**$0**	**$1,440**	**$15,428**	$28
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	2,309	0	369		$2,678	248	0	219	**$3,145**	$6
11.2	Station Service Equipment	6,397	0	2,190		$8,587	821	0	706	**$10,114**	$19
11.3	Switchgear & Motor Control	7,602	0	1,302		$8,905	824	0	973	**$10,702**	$20
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$36
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$44
11.6	Protective Equipment	238	0	826		$1,064	104	0	117	**$1,285**	$2
11.7	Standby Equipment	1,782	0	41		$1,823	173	0	200	**$2,195**	$4
11.8	Main Power Transformers	9,588	0	245		$9,833	748	0	1,058	**$11,639**	$21
11.9	Electrical Foundations	0	440	1,090		$1,530	145	0	335	**$2,010**	$4
	SUBTOTAL 11.	**$27,916**	**$10,354**	**$30,682**		**$68,952**	**$6,150**	**$0**	**$9,250**	**$84,352**	$155
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	718	0	439		$1,157	111	58	199	**$1,525**	$3
12.7	Computer & Accessories	7,255	0	1,293		$8,548	814	427	979	**$10,768**	$20
12.8	Instrument Wiring & Tubing	4,008	0	7,959		$11,967	1,019	598	2,038	**$15,622**	$29
12.9	Other I & C Equipment	2,050	0	4,745		$6,795	662	340	780	**$8,576**	$16
	SUBTOTAL 12.	**$14,031**	**$0**	**$14,436**		**$28,467**	**$2,606**	**$1,423**	**$3,995**	**$36,492**	$67

	Client: U.S. DOE / NETL									**Report Date:** 24-Apr-07		
	Project: Oxy-Fuel Combustion Systems Analysis											
	TOTAL PLANT COST SUMMARY											
	Case: Case 5C - Oxy-Fuel Super-Critical PC w/ CO2 Capture											
	Plant Size: 543.95 MW,net			**Estimate Type:**					**Cost Base (Jan)** 2007		$x1000	
Acct No.	**Item/Description**	**Equipment Cost**	**Material Cost**	**Labor**		**Bare Erected Cost $**	**Eng'g CM H.O.& Fee**	**Contingencies**		**TOT. PLANT COST**		
				Direct	**Indirect**			**Process**	**Project**	**$**	**$/kW**	
13	IMPROVEMENTS TO SITE											
13.1	Site Preparation	0	48	972		$1,020	100	0	224	**$1,345**	$2	
13.2	Site Improvements	0	1,571	2,004		$3,575	351	0	785	**$4,711**	$9	
13.3	Site Facilities	2,808	0	2,852		$5,660	556	0	1,243	**$7,459**	$14	
	SUBTOTAL 13.	**$2,808**	**$1,619**	**$5,828**		**$10,255**	**$1,007**	**$0**	**$2,252**	**$13,514**	$25	
14	BUILDINGS & STRUCTURES											
14.1	Boiler Building	0	9,901	8,713		$18,614	1,672	0	3,043	**$23,328**	$43	
14.2	Turbine Building	0	14,783	13,791		$28,574	2,573	0	4,672	**$35,819**	$66	
14.3	Administration Building	0	550	602		$1,152	104	0	188	**$1,445**	$3	
14.4	Circulation Water Pumphouse	0	349	276		$625	56	0	102	**$783**	$1	
14.5	Water Treatment Buildings	0	904	770		$1,674	150	0	274	**$2,097**	$4	
14.6	Machine Shop	0	363	261		$624	55	0	102	**$781**	$1	
14.7	Warehouse	0	103	176		$279	25	0	46	**$350**	$1	
14.8	Other Buildings & Structures	0	115	117		$232	21	0	38	**$291**	$1	
14.9	Waste Treating Building & Str.	0	531	1,613		$2,144	203	0	352	**$2,699**	$5	
	SUBTOTAL 14.	**$0**	**$27,599**	**$26,319**		**$53,918**	**$4,858**	**$0**	**$8,816**	**$67,593**	$124	
	TOTAL COST	**$733,345**	**$55,842**	**$507,830**		**$1,297,017**	**$122,330**	**$49,307**	**$176,036**	**$1,644,690**	$3,024	

INITIAL & ANNUAL O&M EXPENSES			25-Apr-2007		Cost Base:	Jan 2007 dollars
Case 5C - Oxy-Fuel Super-Critical PC w/ CO2 Capture					Heat Rate-net(Btu/kWh)	12,124
Plant Output: Carbon Dioxide(tpd): 15,054					Mwe-net:	543.95
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of Labor				
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.0	11.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.0	16.0				
					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$6,012,864	11.05
Maintenance Labor Cost					$11,049,555	20.31
Administrative & Support Labor					$2,936,773	5.40
TOTAL FIXED OPERATING COSTS					**$19,999,192**	**36.77**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$16,574,332	0.0041
Consumables	Initial	/Day	Unit Cost	Initial Cost		
Water(/1000 gallons)		10,375	$1.03	$0	$3,315,473	0.0008
Chemicals						
MU & WT Chem.(lbs)	351,558	50,223	$0.16	$57,937	$2,567,843	0.0006
Limestone (Tons)	4,769	681.2	$20.60	$98,235	$4,353,907	0.0011
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	1,066	0.0	$2,142.40	$2,284,470	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	0	0.0	$123.60	$0	$0	0.0000
Subtotal Chemicals				$2,440,641	$6,921,750	0.0017
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		526	$15.45		$2,522,476	0.0006
Bottom Ash (tons)		132	$15.45		$630,619	0.0002
Subtotal-Waste Disposal					$3,153,095	0.0008
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$29,964,650**	0.0074
Fuel - Coal (Tons)	203,512	6,784	$42.11	$8,569,886	**$88,626,902**	0.0219

5.3.4.5 Case 6 – Oxycombustion Ultra-supercritical PC with CO_2 capture

Client: U.S. DOE / NETL | **Report Date:** 28-Aug-07
Project: Case 6 -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture
TOTAL PLANT COST DETAIL
Case: Case 6 -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture
Plant Size: 553.37 MW,net | **Estimate Type:** | **Cost Base (Jan)** 2007 | $x1000

Acct		Equipment	Material	Labor		Bare Erected	Eng'g CM	Contingencies		TOT. PLANT COST	
No.	Item/Description	Cost	Cost	Direct	Indirect	Cost $	H.O.& Fee	Process	Project	$	$/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	3,712	0	1,681		$5,393	482	0	881	**$6,756**	$12
1.2	Coal Stackout & Reclaim	4,798	0	1,076		$5,874	514	0	958	**$7,346**	$13
1.3	Coal Conveyors & Yard Breaker	4,463	0	1,065		$5,528	485	0	902	**$6,915**	$12
1.4	Other Coal Handling	1,169	0	245		$1,414	124	0	231	**$1,768**	$3
1.5	Sorbent Receive & Unload	148	0	45		$193	17	0	32	**$242**	$0
1.6	Sorbent Stackout & Reclaim	2,390	0	432		$2,822	246	0	460	**$3,528**	$6
1.7	Sorbent Conveyors	852	182	207		$1,241	107	0	202	**$1,551**	$3
1.8	Other Sorbent Handling	516	119	268		$903	80	0	147	**$1,130**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	4,537	5,688		$10,225	956	0	1,677	**$12,858**	$23
	SUBTOTAL 1.	**$18,048**	**$4,838**	**$10,707**		**$33,593**	**$3,010**	**$0**	**$5,490**	**$42,093**	$76
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,119	0	408		$2,527	220	0	412	**$3,160**	$6
2.2	Coal Conveyor to Storage	5,424	0	1,172		$6,596	577	0	1,076	**$8,249**	$15
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	4,056	172	833		$5,061	441	0	825	**$6,327**	$11
2.6	Sorbent Storage & Feed	489	0	185		$674	60	0	110	**$844**	$2
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	524	413		$937	86	0	153	**$1,177**	$2
	SUBTOTAL 2.	**$12,088**	**$696**	**$3,011**		**$15,795**	**$1,384**	**$0**	**$2,577**	**$19,756**	$36
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	22,103	0	6,705		$28,808	2,522	0	4,700	**$36,030**	$65
3.2	Water Makeup & Pretreating	10,345	0	3,256		$13,601	1,275	0	2,975	**$17,851**	$32
3.3	Other Feedwater Subsystems	6,779	0	2,727		$9,506	847	0	1,553	**$11,906**	$22
3.4	Service Water Systems	2,042	0	1,079		$3,121	290	0	682	**$4,093**	$7
3.5	Other Boiler Plant Systems	8,766	0	8,396		$17,162	1,610	0	2,816	**$21,588**	$39
3.6	FO Supply Sys & Nat Gas	308	0	372		$680	63	0	111	**$855**	$2
3.7	Waste Treatment Equipment	6,967	0	3,909		$10,876	1,054	0	2,386	**$14,315**	$26
3.8	Misc. Power Plant Equipment	3,199	0	966		$4,165	400	0	913	**$5,478**	$10
	SUBTOTAL 3.	**$60,509**	**$0**	**$27,410**		**$87,919**	**$8,061**	**$0**	**$16,136**	**$112,116**	$203
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	193,169	0	108,926		$302,095	29,261	82,839	33,136	**$447,330**	$808
4.2	ASU/Oxidant Compression	119,049	0	97,403		$216,452	20,966	0	23,742	**$261,159**	$472
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$312,218**	**$0**	**$206,329**		**$518,547**	**$50,227**	**$82,839**	**$56,877**	**$708,489**	$1,280

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST DETAIL

Case: Case 6 -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture
Plant Size: 553.37 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	28,600	0	31,421		$60,021	5,681	0	6,570	**$72,272**	$131
5.2	Other FGD	2,487	0	2,866		$5,353	516	0	587	**$6,456**	$12
5.3	Baghouse & Accessories	18,127	0	13,471		$31,598	3,022	0	3,462	**$38,082**	$69
5.4	Other Particulate Removal Materials	928	0	1,009		$1,937	186	0	212	**$2,336**	$4
5.5	Gypsum Dewatering System	16,706	0	18,359		$35,065	3,313	0	3,838	**$42,216**	$76
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$66,848**	**$0**	**$67,126**		**$133,974**	**$12,719**	**$0**	**$14,669**	**$161,362**	$292
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	48,094	0	34,827		$82,921	7,872	0	18,159	**$108,952**	**$197**
	SUBTOTAL 5B.	**$48,094**	**$0**	**$34,827**		**$82,921**	**$7,872**	**$0**	**$18,159**	**$108,952**	**$197**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator						0	0	0	**$0**	$0
6.2	Combustion Turbine Accessories						0	0	0	**$0**	$0
6.3	Compressed Air Piping						0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations						0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	HR, DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	7,890	0	659		$8,549	817	0	937	**$10,303**	$19
7.2	SCR System	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	8,349	0	5,529		$13,878	1,212	0	2,264	**$17,354**	$31
7.4	Stack	2,251	0	1,338		$3,589	343	0	393	**$4,325**	$8
7.9	Duct & Stack Foundations	0	622	752		$1,374	128	0	300	**$1,802**	$3
	SUBTOTAL 7.	**$18,490**	**$622**	**$8,278**		**$27,390**	**$2,500**	**$0**	**$3,894**	**$33,784**	$61
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	70,822	0	9,493		$80,315	7,690	0	8,800	**$96,805**	$175
8.2	Turbine Plant Auxiliaries	486	0	1,041		$1,527	148	0	167	**$1,842**	$3
8.3	Condenser & Auxiliaries	9,310	0	3,204		$12,513	1,189	0	1,370	**$15,073**	$27
8.4	Steam Piping	23,769	0	11,741		$35,511	2,964	0	5,771	**$44,246**	$80
8.9	TG Foundations	0	1,514	2,409		$3,923	369	0	859	**$5,151**	$9
	SUBTOTAL 8.	**$104,387**	**$1,514**	**$27,888**		**$133,789**	**$12,360**	**$0**	**$16,968**	**$163,117**	$295
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	9,104	0	2,837		$11,941	1,134	0	1,307	**$14,382**	$26
9.2	Circulating Water Pumps	1,285	0	179		$1,464	126	0	159	**$1,749**	$3
9.3	Circ.Water System Auxiliaries	541	0	72		$613	58	0	67	**$738**	$1
9.4	Circ.Water Piping	0	4,358	4,157		$8,515	784	0	1,395	**$10,694**	$19
9.5	Make-up Water System	480	0	635		$1,115	106	0	183	**$1,404**	$3
9.6	Component Cooling Water Sys	431	0	341		$772	72	0	127	**$971**	$2
9.9	Circ.Water System Foundations	0	2,523	4,037		$6,560	617	0	1,436	**$8,613**	$16
	SUBTOTAL 9.	**$11,840**	**$6,881**	**$12,258**		**$30,979**	**$2,898**	**$0**	**$4,674**	**$38,551**	$70

	Client:	U.S. DOE / NETL							**Report Date:**	28-Aug-07	
	Project:	Oxy-Fuel Combustion Systems Analysis									
					TOTAL PLANT COST DETAIL						
	Case:	Case 6 -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture									
	Plant Size:	553.37 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000	

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	667	0	2,011		$2,678	261	0	294	**$3,233**	$6
10.7	Ash Transport & Feed Equipment	4,343	0	4,330		$8,673	820	0	949	**$10,443**	$19
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	157	183		$340	32	0	74	**$446**	$1
	SUBTOTAL 10.	**$5,010**	**$157**	**$6,524**		**$11,691**	**$1,113**	**$0**	**$1,318**	**$14,121**	$26
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	2,223	0	356		$2,579	239	0	211	**$3,029**	$5
11.2	Station Service Equipment	6,062	0	2,075		$8,137	778	0	669	**$9,584**	$17
11.3	Switchgear & Motor Control	7,204	0	1,234		$8,438	781	0	922	**$10,141**	$18
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$35
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$43
11.6	Protective Equipment	222	0	773		$995	97	0	109	**$1,201**	$2
11.7	Standby Equipment	1,718	0	39		$1,757	166	0	192	**$2,116**	$4
11.8	Main Power Transformers	9,228	0	236		$9,464	719	0	1,018	**$11,202**	$20
11.9	Electrical Foundations	0	423	1,049		$1,472	140	0	322	**$1,934**	$3
	SUBTOTAL 11.	**$26,656**	**$10,337**	**$30,381**		**$67,374**	**$6,008**	**$0**	**$9,087**	**$82,469**	$149
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	705	0	430		$1,135	109	57	195	**$1,496**	$3
12.7	Computer & Accessories	7,122	0	1,270		$8,392	799	420	961	**$10,572**	$19
12.8	Instrument Wiring & Tubing	3,935	0	7,815		$11,750	1,001	588	2,001	**$15,339**	$28
12.9	Other I & C Equipment	2,012	0	4,659		$6,671	650	334	765	**$8,420**	$15
	SUBTOTAL 12.	**$13,774**	**$0**	**$14,174**		**$27,948**	**$2,559**	**$1,397**	**$3,922**	**$35,827**	$65

	Client:	U.S. DOE / NETL							**Report Date:**	28-Aug-07		
	Project:	Oxy-Fuel Combustion Systems Analysis										
					TOTAL PLANT COST DETAIL							
	Case:	Case 6 -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture										
	Plant Size:	553.37 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000		
Acct		**Equipment**	**Material**	**Labor**		**Bare Erected**	**Eng'g CM**	**Contingencies**		**TOT. PLANT COST**		
No.	**Item/Description**	**Cost**	**Cost**	**Direct**	**Indirect**	**Cost $**	**H.O.& Fee**	**Process**	**Project**	**$**	**$/kW**	
13	IMPROVEMENTS TO SITE											
13.1	Site Preparation	0	64	1,255		$1,319	130	0	290	**$1,739**	$3	
13.2	Site Improvements	0	2,095	2,590		$4,685	460	0	1,029	**$6,174**	$11	
13.3	Site Facilities	3,764	0	3,686		$7,450	731	0	1,636	**$9,817**	$18	
	SUBTOTAL 13.	**$3,764**	**$2,159**	**$7,531**		**$13,454**	**$1,321**	**$0**	**$2,955**	**$17,730**	$32	
14	BUILDINGS & STRUCTURES											
14.1	Boiler Building	0	9,543	8,401		$17,944	1,611	0	2,933	**$22,489**	$41	
14.2	Turbine Building	0	14,154	13,205		$27,359	2,463	0	4,473	**$34,296**	$62	
14.3	Administration Building	0	550	601		$1,151	104	0	188	**$1,444**	$3	
14.4	Circulation Water Pumphouse	0	339	267		$606	54	0	99	**$759**	$1	
14.5	Water Treatment Buildings	0	904	770		$1,674	150	0	274	**$2,097**	$4	
14.6	Machine Shop	0	362	261		$623	55	0	102	**$780**	$1	
14.7	Warehouse	0	103	175		$278	25	0	45	**$349**	$1	
14.8	Other Buildings & Structures	0	114	117		$231	21	0	38	**$289**	$1	
14.9	Waste Treating Building & Str.	0	517	1,570		$2,087	197	0	343	**$2,627**	$5	
	SUBTOTAL 14.	**$0**	**$26,586**	**$25,367**		**$51,953**	**$4,681**	**$0**	**$8,495**	**$65,130**	$118	
	TOTAL COST	**$701,726**	**$53,790**	**$481,811**		**$1,237,327**	**$116,713**	**$84,236**	**$165,221**	**$1,603,497**	$2,898	

INITIAL & ANNUAL O&M EXPENSES			28-Aug-2007		Cost Base:	Jan 2007 dollars
Case 6 -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture					Heat Rate-net(Btu/kWh)	10,333
Plant Output: Carbon Dioxide(tpd): 13,867					Mwe-net:	553.37
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00 $/hour					
Operating Labor Burden:	30.00 % of base					
Labor O-H Charge Rate:	25.00 % of Labor					
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.0	11.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.0	16.0				
					Annual Cost $	Annual Unit Cost $/kW-net
Annual Operating Labor Cost					$6,012,864	10.87
Maintenance Labor Cost					$10,772,809	19.47
Administrative & Support Labor					$2,936,773	5.31
TOTAL FIXED OPERATING COSTS					**$19,722,446**	**35.64**

VARIABLE OPERATING COSTS	Initial	/Day	Unit Cost	Initial Cost	Annual Cost	$/kWH-net
Maintenance Material Cost					$16,159,213	0.0039
Consumables						
Water(/1000 gallons)		8,193	$1.03	$0	$2,618,143	0.0006
Chemicals						
MU & WT Chem.(lbs)	277,617	39,660	$0.16	$45,751	$2,027,759	0.0005
Limestone (Tons)	4,132	590.2	$20.60	$85,111	$3,772,261	0.0009
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	982	0.0	$2,142.40	$2,104,214	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	0	0.0	$123.60	$0	$0	0.0000
Subtotal Chemicals				$2,235,077	$5,800,021	0.0014
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		457	$15.45		$2,192,619	0.0005
Bottom Ash (tons)		114	$15.45		$548,155	0.0001
Subtotal-Waste Disposal					$2,740,774	0.0007
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$27,318,151**	0.0066
Fuel - Coal (Tons)	176,457	5,882	$42.11	$7,430,610	**$76,844,890**	0.0186

5.3.4.6 Case 6A – Oxycombustion Ultra-supercritical PC with CO_2 capture

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Case 6A -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture

TOTAL PLANT COST DETAIL

Case: Case 6A -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture
Plant Size: 550.09 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct		Equipment	Material	Labor		Bare Erected	Eng'g CM	Contingencies		TOT. PLANT COST	
No.	Item/Description	Cost	Cost	Direct	Indirect	Cost $	H.O.& Fee	Process	Project	$	$/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	3,712	0	1,681		$5,393	482	0	881	**$6,756**	$12
1.2	Coal Stackout & Reclaim	4,798	0	1,076		$5,874	514	0	958	**$7,346**	$13
1.3	Coal Conveyors & Yard Breaker	4,463	0	1,065		$5,528	485	0	902	**$6,915**	$13
1.4	Other Coal Handling	1,169	0	245		$1,414	124	0	231	**$1,768**	$3
1.5	Sorbent Receive & Unload	148	0	45		$193	17	0	32	**$242**	$0
1.6	Sorbent Stackout & Reclaim	2,390	0	432		$2,822	246	0	460	**$3,528**	$6
1.7	Sorbent Conveyors	852	182	207		$1,241	107	0	202	**$1,551**	$3
1.8	Other Sorbent Handling	516	119	268		$903	80	0	147	**$1,130**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	4,537	5,688		$10,225	956	0	1,677	**$12,858**	$23
	SUBTOTAL 1.	**$18,048**	**$4,838**	**$10,707**		**$33,593**	**$3,010**	**$0**	**$5,490**	**$42,093**	$77
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,119	0	408		$2,527	220	0	412	**$3,160**	$6
2.2	Coal Conveyor to Storage	5,424	0	1,172		$6,596	577	0	1,076	**$8,249**	$15
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	4,056	172	833		$5,061	441	0	825	**$6,327**	$12
2.6	Sorbent Storage & Feed	489	0	185		$674	60	0	110	**$844**	$2
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	524	413		$937	86	0	153	**$1,177**	$2
	SUBTOTAL 2.	**$12,088**	**$696**	**$3,011**		**$15,795**	**$1,384**	**$0**	**$2,577**	**$19,756**	$36
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	22,103	0	6,705		$28,808	2,522	0	4,700	**$36,030**	$65
3.2	Water Makeup & Pretreating	10,345	0	3,256		$13,601	1,275	0	2,975	**$17,851**	$32
3.3	Other Feedwater Subsystems	6,779	0	2,727		$9,506	847	0	1,553	**$11,906**	$22
3.4	Service Water Systems	2,042	0	1,079		$3,121	290	0	682	**$4,093**	$7
3.5	Other Boiler Plant Systems	8,766	0	8,396		$17,162	1,610	0	2,816	**$21,588**	$39
3.6	FO Supply Sys & Nat Gas	308	0	372		$680	63	0	111	**$855**	$2
3.7	Waste Treatment Equipment	6,967	0	3,909		$10,876	1,054	0	2,386	**$14,315**	$26
3.8	Misc. Power Plant Equipment	3,199	0	966		$4,165	400	0	913	**$5,478**	$10
	SUBTOTAL 3.	**$60,509**	**$0**	**$27,410**		**$87,919**	**$8,061**	**$0**	**$16,136**	**$112,116**	$204
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	193,508	0	109,117		$302,626	29,313	82,985	33,194	**$448,117**	$815
4.2	ASU/Oxidant Compression	119,049	0	97,403		$216,452	20,966	0	23,742	**$261,159**	$475
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$312,557**	**$0**	**$206,520**		**$519,078**	**$50,278**	**$82,985**	**$56,936**	**$709,276**	$1,289

	Client:	U.S. DOE / NETL							**Report Date:**	28-Aug-07		
	Project:	Oxy-Fuel Combustion Systems Analysis										
				TOTAL PLANT COST DETAIL								
	Case:	Case 6A -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture										
	Plant Size:	550.09 MW,net		**Estimate Type:**					**Cost Base (Jan)** 2007		$x1000	

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	28,600	0	31,421		$60,021	5,681	0	6,570	**$72,272**	$131
5.2	Other FGD	2,487	0	2,866		$5,353	516	0	587	**$6,456**	$12
5.3	Baghouse & Accessories	18,127	0	13,471		$31,598	3,022	0	3,462	**$38,082**	$69
5.4	Other Particulate Removal Materials	928	0	1,009		$1,937	186	0	212	**$2,336**	$4
5.5	Gypsum Dewatering System	16,706	0	18,359		$35,065	3,313	0	3,838	**$42,216**	$77
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$66,848**	**$0**	**$67,126**		**$133,974**	**$12,719**	**$0**	**$14,669**	**$161,362**	$293
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	58,287	0	42,208		$100,495	9,540	0	22,007	**$132,042**	**$240**
	SUBTOTAL 5B.	**$58,287**	**$0**	**$42,208**		**$100,495**	**$9,540**	**$0**	**$22,007**	**$132,042**	**$240**
6	COMBUSTION TURBINE/ACCESSORIES										
6.1	Combustion Turbine Generator						0	0	0	**$0**	$0
6.2	Combustion Turbine Accessories						0	0	0	**$0**	$0
6.3	Compressed Air Piping						0	0	0	**$0**	$0
6.9	Combustion Turbine Foundations						0	0	0	**$0**	$0
	SUBTOTAL 6.	**$0**	**$0**	**$0**		**$0**	**$0**	**$0**	**$0**	**$0**	$0
7	HR, DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	7,890	0	659		$8,549	817	0	937	**$10,303**	$19
7.2	SCR System	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	8,349	0	5,529		$13,878	1,212	0	2,264	**$17,354**	$32
7.4	Stack	2,251	0	1,338		$3,589	343	0	393	**$4,325**	$8
7.9	Duct & Stack Foundations	0	622	752		$1,374	128	0	300	**$1,802**	$3
	SUBTOTAL 7.	**$18,490**	**$622**	**$8,278**		**$27,390**	**$2,500**	**$0**	**$3,894**	**$33,784**	$61
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	70,967	0	9,513		$80,480	7,706	0	8,819	**$97,004**	$176
8.2	Turbine Plant Auxiliaries	487	0	1,043		$1,530	148	0	168	**$1,846**	$3
8.3	Condenser & Auxiliaries	9,329	0	3,210		$12,539	1,192	0	1,373	**$15,104**	$27
8.4	Steam Piping	23,818	0	11,765		$35,584	2,970	0	5,783	**$44,336**	$81
8.9	TG Foundations	0	1,517	2,414		$3,932	370	0	860	**$5,162**	$9
	SUBTOTAL 8.	**$104,601**	**$1,517**	**$27,945**		**$134,064**	**$12,386**	**$0**	**$17,003**	**$163,452**	$297
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	9,118	0	2,842		$11,960	1,135	0	1,310	**$14,405**	$26
9.2	Circulating Water Pumps	1,287	0	180		$1,466	126	0	159	**$1,752**	$3
9.3	Circ.Water System Auxiliaries	541	0	72		$614	58	0	67	**$739**	$1
9.4	Circ.Water Piping	0	4,365	4,163		$8,528	786	0	1,397	**$10,711**	$19
9.5	Make-up Water System	480	0	636		$1,117	106	0	183	**$1,406**	$3
9.6	Component Cooling Water Sys	432	0	341		$773	73	0	127	**$972**	$2
9.9	Circ.Water System Foundations	0	2,527	4,043		$6,570	618	0	1,438	**$8,626**	$16
	SUBTOTAL 9.	**$11,858**	**$6,892**	**$12,277**		**$31,027**	**$2,902**	**$0**	**$4,681**	**$38,610**	$70

	Client:	U.S. DOE / NETL							**Report Date:**	28-Aug-07		
	Project:	Oxy-Fuel Combustion Systems Analysis										
					TOTAL PLANT COST DETAIL							
	Case:	Case 6A -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture										
	Plant Size:	550.09 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000		
Acct No.	**Item/Description**	**Equipment Cost**	**Material Cost**	**Labor Direct**	**Labor Indirect**	**Bare Erected Cost $**	**Eng'g CM H.O.& Fee**	**Contingencies Process**	**Contingencies Project**	**TOT. PLANT COST $**	**TOT. PLANT COST $/kW**	
10	ASH/SPENT SORBENT HANDLING SYS											
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0	
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0	
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0	
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0	
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0	
10.6	Ash Storage Silos	667	0	2,011		$2,678	261	0	294	**$3,233**	$6	
10.7	Ash Transport & Feed Equipment	4,343	0	4,330		$8,673	820	0	949	**$10,443**	$19	
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0	
10.9	Ash/Spent Sorbent Foundations	0	157	183		$340	32	0	74	**$446**	$1	
	SUBTOTAL 10.	**$5,010**	**$157**	**$6,524**		**$11,691**	**$1,113**	**$0**	**$1,318**	**$14,121**	$26	
11	ACCESSORY ELECTRIC PLANT											
11.1	Generator Equipment	2,223	0	356		$2,579	239	0	211	**$3,029**	$6	
11.2	Station Service Equipment	6,121	0	2,095		$8,216	786	0	675	**$9,677**	$18	
11.3	Switchgear & Motor Control	7,274	0	1,246		$8,520	789	0	931	**$10,239**	$19	
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$36	
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$43	
11.6	Protective Equipment	222	0	773		$995	97	0	109	**$1,201**	$2	
11.7	Standby Equipment	1,718	0	39		$1,757	166	0	192	**$2,116**	$4	
11.8	Main Power Transformers	9,228	0	236		$9,464	719	0	1,018	**$11,202**	$20	
11.9	Electrical Foundations	0	423	1,049		$1,472	140	0	322	**$1,934**	$4	
	SUBTOTAL 11.	**$26,785**	**$10,337**	**$30,413**		**$67,535**	**$6,023**	**$0**	**$9,102**	**$82,661**	$150	
12	INSTRUMENTATION & CONTROL											
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0	
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0	
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0	
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0	
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0	
12.6	Control Boards,Panels & Racks	705	0	430		$1,135	109	57	195	**$1,496**	$3	
12.7	Computer & Accessories	7,122	0	1,270		$8,392	799	420	961	**$10,572**	$19	
12.8	Instrument Wiring & Tubing	3,935	0	7,815		$11,750	1,001	588	2,001	**$15,339**	$28	
12.9	Other I & C Equipment	2,012	0	4,659		$6,671	650	334	765	**$8,420**	$15	
	SUBTOTAL 12.	**$13,774**	**$0**	**$14,174**		**$27,948**	**$2,559**	**$1,397**	**$3,922**	**$35,827**	$65	

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST DETAIL

Case: Case 6A -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture
Plant Size: 550.09 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	64	1,255		$1,319	130	0	290	**$1,739**	$3
13.2	Site Improvements	0	2,095	2,590		$4,685	460	0	1,029	**$6,174**	$11
13.3	Site Facilities	3,764	0	3,686		$7,450	731	0	1,636	**$9,817**	$18
	SUBTOTAL 13.	**$3,764**	**$2,159**	**$7,531**		**$13,454**	**$1,321**	**$0**	**$2,955**	**$17,730**	$32
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	9,543	8,401		$17,944	1,611	0	2,933	**$22,489**	$41
14.2	Turbine Building	0	14,154	13,205		$27,359	2,463	0	4,473	**$34,296**	$62
14.3	Administration Building	0	550	601		$1,151	104	0	188	**$1,444**	$3
14.4	Circulation Water Pumphouse	0	339	267		$606	54	0	99	**$759**	$1
14.5	Water Treatment Buildings	0	904	770		$1,674	150	0	274	**$2,097**	$4
14.6	Machine Shop	0	362	261		$623	55	0	102	**$780**	$1
14.7	Warehouse	0	103	175		$278	25	0	45	**$349**	$1
14.8	Other Buildings & Structures	0	114	117		$231	21	0	38	**$289**	$1
14.9	Waste Treating Building & Str.	0	517	1,570		$2,087	197	0	343	**$2,627**	$5
	SUBTOTAL 14.	**$0**	**$26,586**	**$25,367**		**$51,953**	**$4,681**	**$0**	**$8,495**	**$65,130**	$118
	TOTAL COST	**$712,620**	**$53,804**	**$489,492**		**$1,255,916**	**$118,478**	**$84,382**	**$169,185**	**$1,627,961**	$2,959

INITIAL & ANNUAL O&M EXPENSES			28-Aug-2007		Cost Base:	Jan 2007 dollars
Case 6A -Oxy-Fuel Ultra-Super-Critical PC w/ CO2 Capture					Heat Rate-net(Btu/kWh)	10,421
Plant Output: Carbon Dioxide(tpd): 13,040					Mwe-net:	550.09
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of Labor				
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.0	11.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.0	16.0				
					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$6,012,864	10.93
Maintenance Labor Cost					$10,937,166	19.88
Administrative & Support Labor					$2,936,773	5.34
TOTAL FIXED OPERATING COSTS					**$19,886,803**	**36.15**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$16,405,749	0.0040
Consumables			Unit	Initial		
	Initial	/Day	Cost	Cost		
Water(/1000 gallons)		8,191	$1.03	$0	$2,617,476	0.0006
Chemicals						
MU & WT Chem.(lbs)	277,546	39,649	$0.16	$45,740	$2,027,242	0.0005
Limestone (Tons)	4,144	592.0	$20.60	$85,361	$3,783,305	0.0009
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	924	0.0	$2,142.40	$1,978,715	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	0	0.0	$123.60	$0	$0	0.0000
Subtotal Chemicals				$2,109,815	$5,810,547	0.0014
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		457	$15.45		$2,192,637	0.0005
Bottom Ash (tons)		114	$15.45		$548,159	0.0001
Subtotal-Waste Disposal					$2,740,796	0.0007
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$27,574,568**	0.0067
Fuel - Coal (Tons)	176,900	5,897	$42.11	$7,449,287	**$77,038,038**	0.0188

6. OXYGEN-FIRED PULVERIZED COAL RANKINE PLANTS USING ION TRANSPORT MEMBRANE (ITM)

The two cases presented in this section use nearly pure oxygen generated from an ITM process that was described in Section 3.5.2. The two cases are:

Case 7 – Supercritical ITM oxycombustion with no CO_2 purification

Case 7A – Supercritical ITM oxycombustion with CO_2 purification

For modeling purposes, the outlet oxygen concentration was assumed to be 100%. Cases 7 and 7A also utilize the same supercritical steam cycle described for Cases 5-5C (3500 psig/1110°F/1150°F). The only significant difference between cases is in the CO_2 product specification. In Case 7, the CO_2 product was compressed and dried with no further treatment while in Case 7A the raw CO_2 product was further purified to a concentration of over 95 mol%.

6.1 PLANT CONFIGURATION SUMMARY

The evaluation scope included developing heat and mass balances and estimating plant performance on a common 550 MWe net output basis while firing bituminous Illinois No. 6 coal. Equipment lists were developed for each design to support plant capital and operating costs estimates. A summary of the cases evaluated in this section is presented in Exhibit 6-1.

Exhibit 6-1 ITM Oxycombustion Plant Configuration Summary

Case	Boiler	Steam psig/°F/°F	Oxidant	NOx Control	Sulfur Control	CO_2 Purity	Intended Storage
7	Wall-fired, PC, FGR	3500/1110/1150	100 mol% O_2/ ITM ASU	LNB/OFO/FGR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	Spec. B	Saline Formation
7A	Wall-fired PC, FGR	3500/1100/1150	100 mol% O_2/ ITM ASU	LNB/OFO/FGR 0.07 lb/10^6Btu	FGD 0.1 lb/10^6Btu	Spec. C	

Legend:

LNB -	Low NOx burner	PC -	Pulverized Coal
OFO -	Overfire oxygen	ITM ASU	Ion Transport Membrane Air Separation Unit
FGR-	Flue Gas Recycle	Spec. B	Raw product produced using ITM (100%) oxygen
FGD -	Flue gas desulfurization	Spec. C	Raw product produced using ITM oxygen, further purified to > 95% CO_2

ITM oxycombustion plants are assumed to be built on a “greenfield” site and utilize recirculating evaporative cooling systems for cycle heat rejection. Major systems for each plant (described in Section 3) include:

1. Steam generator
2. Steam turbine/generator
3. ITM oxygen plant

4. Particulate control system
5. FGD system
6. CO_2 recovery
7. Balance of plant

Support facilities include coal handling (receiving, crushing, storing, and drying), limestone handling (including receiving, crushing, storing, and feeding), solid waste disposal, circulating water system with evaporative mechanical draft cooling towers, wastewater treatment, and other ancillary systems equipment necessary for an efficient, highly available, and completely operable facility.

The plant designs are based on using components suitable for a 30-year life, with provision for periodic maintenance and replacement of critical parts. All equipment is based on compliance with the latest applicable codes and standards. ASME, ANSI, IEEE, NFPA, CAA, state regulations, and OSHA codes are all adhered to in the design approach.

6.2 MATERIAL AND ENERGY BALANCES

The modeling assumptions that were used to generate the ITM oxycombustion case material and energy balances are summarized in Exhibit 6-2.

Exhibit 6-2 ITM Oxycombustion Configuration Modeling Assumptions

	Case 7	Case 7A
Throttle pressure, psig	3500	3500
Throttle temperature, ºF	1110	1110
Reheat temperature, ºF	1150	1150
Condenser pressure, in Hg	2	2
Cooling water to condenser, ºF	60	60
Cooling water from condenser, ºF	80	80
CO_2 Purifier Vent temperature, ºF	N/A	48°F
Coal HHV (Illinois No. 6), Btu/lb	11,666	11,666
FGD efficiency	98%	98%
SOx emissions, lb/MMBtu	0.1	0.1
NOx emissions, lb/MMBtu	0.07	0.07
Baghouse efficiency	99.8%	99.8%
Particulate emissions PM/PM_{10}, lb/MMBtu	0.015	0.015
Mercury removal, %	90	90
CO_2 Capture Efficiency, %*	99.2	92.9
Product CO_2 Condition, psia/°F	2215/95	2215/95

* Percentage of CO_2 in flue gas

6.2.1 Performance Results for ITM Oxycombustion Cases

A process block flow diagram for Cases 7 and 7A is shown in Exhibit 6-3 and the corresponding stream tables are contained in Exhibit 6-4 and Exhibit 6-5. The heat and mass balance diagram for Case 7 excluding the steam cycle is shown in Exhibit 6-6 and the steam cycle is shown in Exhibit 6-7. The same two drawings for Case 7A are shown in Exhibit 6-8 and Exhibit 6-9. These two cases represent supercritical ITM oxycombustion cases with CO_2 capture and, in the case of Case 7A, CO_2 purification [43].

Overall performance for Cases 7 and 7A is summarized in Exhibit 6-10 which includes auxiliary power requirements.

43 "ITM Oxygen for Gasification", Air Products and Chemicals, Inc., Gasification Technologies 2004, Washington, DC, http://www.gasification.org/Docs/2006_Papers/54ARMS.pdf, October 2004

Exhibit 6-3 Process Block Flow Diagram for Cases 7 and 7A

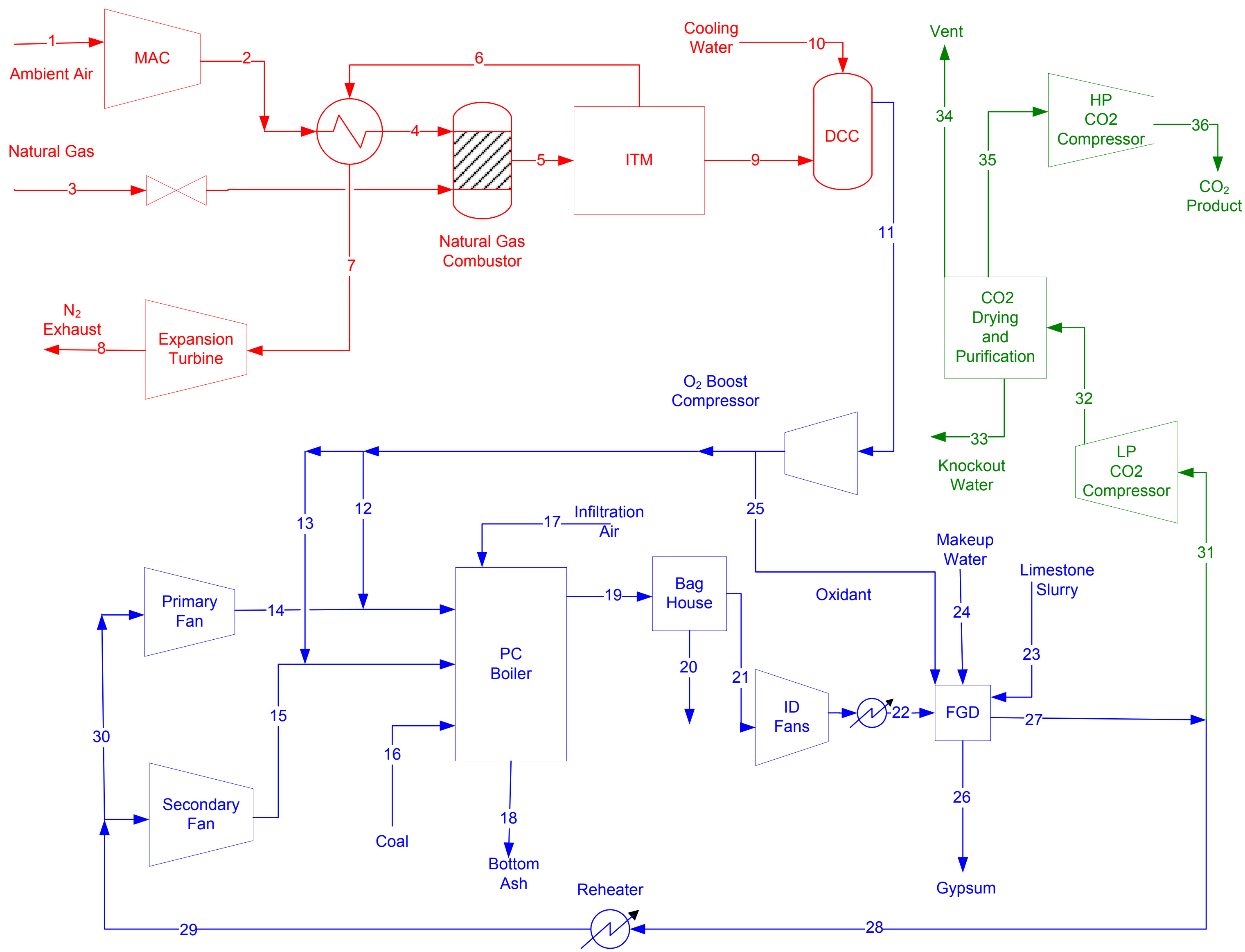

Exhibit 6-4 Case 7 Stream Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
V-L Mole Fractions																		
Ar	0.0092	0.0092	0.0000	0.0092	0.0092	0.0105	0.0105	0.0105	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0008	0.0000	0.0092	0.0000
CO_2	0.0003	0.0003	0.0038	0.0003	0.0100	0.0115	0.0115	0.0115	0.0000	0.0000	0.0000	0.0000	0.0000	0.7367	0.7367	0.0000	0.0003	0.0000
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0099	0.0099	0.0000	0.0099	0.0288	0.0331	0.0331	0.0331	0.0000	1.0000	0.0816	0.0816	0.0816	0.1661	0.1661	0.0000	0.0099	0.0000
N_2	0.7732	0.7732	0.0047	0.7732	0.7658	0.8806	0.8806	0.8806	0.0000	0.0000	0.0000	0.0000	0.0000	0.0717	0.0717	0.0000	0.7732	0.0000
O_2	0.2074	0.2074	0.0000	0.2074	0.1863	0.0643	0.0643	0.0643	1.0000	0.0000	0.9184	0.9184	0.9184	0.0248	0.0248	0.0000	0.2074	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000
CH_4	0.0000	0.0000	0.9701	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_2H_6	0.0000	0.0000	0.0176	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_3H_8	0.0000	0.0000	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_4H_{10}	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000
V-L Flow (lb_{mol}/hr)	245,053	245,053	2,343	245,053	247,427	215,166	215,166	215,166	32,260	2,835	34,738	8,049	26,202	21,953	71,464	0	3,012	0
V-L Flow (lb/hr)	7,071,480	7,071,480	38,831	7,071,480	7,110,320	6,078,020	6,078,020	6,078,020	1,032,290	51,067	1,071,930	248,376	808,543	839,637	2,733,290	0	86,912	0
Solids Flowrate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500,000	0	9,697
Temperature (°F)	59	227	95	1076	1475	1475	549	79	1475	59	95	211	211	162	152	59	59	350
Pressure (psia)	14.70	200.00	400.00	200.00	200.00	195.00	195.00	14.70	10.00	14.70	10.00	16.70	16.70	16.70	15.80	16.10	16.10	14.40
Enthalpy (Btu/lb)	13.00	53.88	21.48	269.30	395.36	403.07	152.43	34.47	349.99	32.36	65.71	92.59	92.59	113.59	111.22	--	13.13	--
Density (lb/ft^3)	0.076	0.783	1.114	0.350	0.277	0.265	0.509	0.072	0.015	62.622	0.052	0.072	0.072	0.096	0.092	--	0.083	--
Avg. Molecular Weight	28.86	28.86	16.57	28.86	28.74	28.25	28.25	28.25	32.00	18.02	30.86	30.86	30.86	38.25	38.25	--	28.86	--

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
V-L Mole Fractions																		
Ar	0.0007	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0008	0.0008	0.0008	0.0008	0.0008	0.0009	0.0000	0.0000	0.0009	0.0009
CO_2	0.6778	0.0000	0.6778	0.6778	0.0000	0.0000	0.0000	0.0095	0.7367	0.7367	0.7367	0.7367	0.7367	0.8794	0.0000	0.0000	0.8834	0.8834
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.2316	0.0000	0.2316	0.2316	1.0000	1.0000	0.0816	0.9904	0.1661	0.1661	0.1661	0.1661	0.1661	0.0045	1.0000	0.0000	0.0000	0.0000
N_2	0.0661	0.0000	0.0661	0.0661	0.0000	0.0000	0.0000	0.0001	0.0717	0.0717	0.0717	0.0717	0.0717	0.0855	0.0000	0.0000	0.0859	0.0859
O_2	0.0211	0.0000	0.0211	0.0211	0.0000	0.0000	0.9184	0.0000	0.0248	0.0248	0.0248	0.0248	0.0248	0.0296	0.0000	0.0000	0.0297	0.0297
SO_2	0.0028	0.0000	0.0028	0.0028	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001
CH_4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_2H_6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_3H_8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_4H_{10}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	140,695	0	140,695	140,695	6,695	396	486	17,555	129,746	93,417	93,417	21,953	36,329	30,432	137	--	30,295	30,295
V-L Flow (lb/hr)	5,168,270	0	5,168,270	5,168,270	120,604	7,142	15,011	320,631	4,962,390	3,572,920	3,572,920	839,637	1,389,470	1,283,220	2,463	--	1,280,760	1,280,760
Solids Flowrate	38,787	38,787	0	0	50,298	0	0	78,302	0	0	0	0	0	0	0	--	0	0
Temperature (°F)	350	350	350	360	59	59	211	135	135	135	145	145	136	244	100	--	244	95
Pressure (psia)	14.40	14.20	14.20	15.25	14.70	14.70	16.70	15.20	15.20	15.20	15.20	15.20	15.20	498.66	14.70	--	498.26	2214.70
Enthalpy (Btu/lb)	198.93	--	200.03	202.64	--	32.36	92.59	87.18	107.29	107.29	109.59	109.59	107.52	39.16	24.63	--	37.07	-71.56
Density (lb/ft^3)	0.061	--	0.060	0.064	62.622	62.622	0.072	10.224	0.091	0.091	0.090	0.090	0.091	2.972	61.249	--	2.975	39.026
Avg. Molecular Weight	36.73	--	36.73	36.73	18.02	18.02	30.86	18.26	38.25	38.25	38.25	38.25	38.25	42.17	18.02	--	42.28	42.28

Exhibit 6-5 Case 7A Stream Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
V-L Mole Fractions																		
Ar	0.0092	0.0092	0.0000	0.0092	0.0092	0.0105	0.0105	0.0105	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0008	0.0000	0.0092	0.0000
CO_2	0.0003	0.0003	0.0038	0.0003	0.0100	0.0115	0.0115	0.0115	0.0000	0.0000	0.0000	0.0000	0.0000	0.7371	0.7371	0.0000	0.0003	0.0000
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.0099	0.0099	0.0000	0.0099	0.0288	0.0331	0.0331	0.0331	0.0000	1.0000	0.0816	0.0816	0.0816	0.1655	0.1655	0.0000	0.0099	0.0000
N_2	0.7732	0.7732	0.0047	0.7732	0.7658	0.8806	0.8806	0.8806	0.0000	0.0000	0.0000	0.0000	0.0000	0.0717	0.0717	0.0000	0.7732	0.0000
O_2	0.2074	0.2074	0.0000	0.2074	0.1863	0.0643	0.0643	0.0643	1.0000	0.0000	0.9184	0.9184	0.9184	0.0248	0.0248	0.0000	0.2074	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000
CH_4	0.0000	0.0000	0.9701	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_2H_6	0.0000	0.0000	0.0176	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_3H_8	0.0000	0.0000	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_4H_{10}	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000
V-L Flow (lb_{mol}/hr)	245,053	245,053	2,343	245,053	247,427	215,166	215,166	215,166	32,260	2,835	34,738	8,049	26,202	21,938	71,415	0	3,012	0
V-L Flow (lb/hr)	7,071,480	7,071,480	38,831	7,071,480	7,110,310	6,078,020	6,078,020	6,078,020	1,032,290	51,067	1,071,930	248,376	808,543	839,355	2,732,370	0	86,912	0
Solids Flowrate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500,000	0	9,697
Temperature (°F)	59	227	95	1076	1475	1475	549	79	1475	59	95	211	211	161	151	59	59	350
Pressure (psia)	14.70	200.00	400.00	200.00	200.00	195.00	195.00	14.70	10.00	14.70	10.00	16.70	16.70	16.70	15.80	16.10	16.10	14.40
Enthalpy (Btu/lb)	13.00	53.88	21.48	269.30	395.36	403.07	152.43	34.47	349.99	32.36	65.71	92.59	92.59	113.13	110.77	--	13.13	--
Density (lb/ft^3)	0.076	0.783	1.114	0.350	0.277	0.265	0.509	0.072	0.015	62.622	0.052	0.072	0.072	0.096	0.092	--	0.083	--
Avg. Molecular Weight	28.86	28.86	16.57	28.86	28.74	28.25	28.25	28.25	32.00	18.02	30.86	30.86	30.86	38.26	38.26	--	28.86	--

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
V-L Mole Fractions																		
Ar	0.0007	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0008	0.0008	0.0008	0.0008	0.0008	0.0009	0.0000	0.0045	0.0003	0.0003
CO_2	0.6781	0.0000	0.6781	0.6781	0.0000	0.0000	0.0000	0.0095	0.7371	0.7371	0.7371	0.7371	0.7371	0.8794	0.0000	0.3686	0.9732	0.9732
H_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H_2O	0.2312	0.0000	0.2312	0.2312	1.0000	1.0000	0.0816	0.9903	0.1655	0.1655	0.1655	0.1655	0.1655	0.0045	1.0000	0.0000	0.0000	0.0000
N_2	0.0661	0.0000	0.0661	0.0661	0.0000	0.0000	0.0000	0.0001	0.0717	0.0717	0.0717	0.0717	0.0717	0.0855	0.0000	0.4846	0.0163	0.0163
O_2	0.0211	0.0000	0.0211	0.0211	0.0000	0.0000	0.9184	0.0000	0.0248	0.0248	0.0248	0.0248	0.0248	0.0296	0.0000	0.1419	0.0101	0.0101
SO_2	0.0028	0.0000	0.0028	0.0028	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0004	0.0000	0.0000
CH_4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_2H_6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_3H_8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C_4H_{10}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	1.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flow (lb_{mol}/hr)	140,631	0	140,631	140,631	6,695	372	486	17,556	129,658	93,354	93,354	21,938	36,304	30,431	136	4,501	25,793	25,793
V-L Flow (lb/hr)	5,167,070	0	5,167,070	5,167,070	120,604	6,708	15,011	320,663	4,960,730	3,571,720	3,571,720	839,355	1,389,000	1,283,180	2,456	155,496	1,125,230	1,125,230
Solids Flowrate	38,787	38,787	0	0	50,298	0	0	78,302	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	350	350	350	360	59	59	211	135	135	135	145	145	136	244	100	48	54	95
Pressure (psia)	14.40	14.20	14.20	15.25	14.70	14.70	16.70	15.25	15.25	15.25	15.25	15.25	15.25	500.34	14.70	467.75	355.30	2214.70
Enthalpy (Btu/lb)	198.71	--	199.82	202.43	--	32.36	92.59	87.17	106.97	106.97	109.28	109.28	107.21	39.13	24.63	--	4.36	-87.15
Density (lb/ft^3)	0.061	--	0.060	0.064	62.622	62.622	0.072	10.213	0.091	0.091	0.090	0.090	0.091	2.982	61.249	3.201	2.811	47.384
Avg. Molecular Weight	36.74	--	36.74	36.74	18.02	18.02	30.86	18.27	38.26	38.26	38.26	38.26	38.26	42.17	18.02	34.54	43.63	43.63

Exhibit 6-6 Case 7 Heat and Mass Balance Diagram Excluding the Steam Cycle

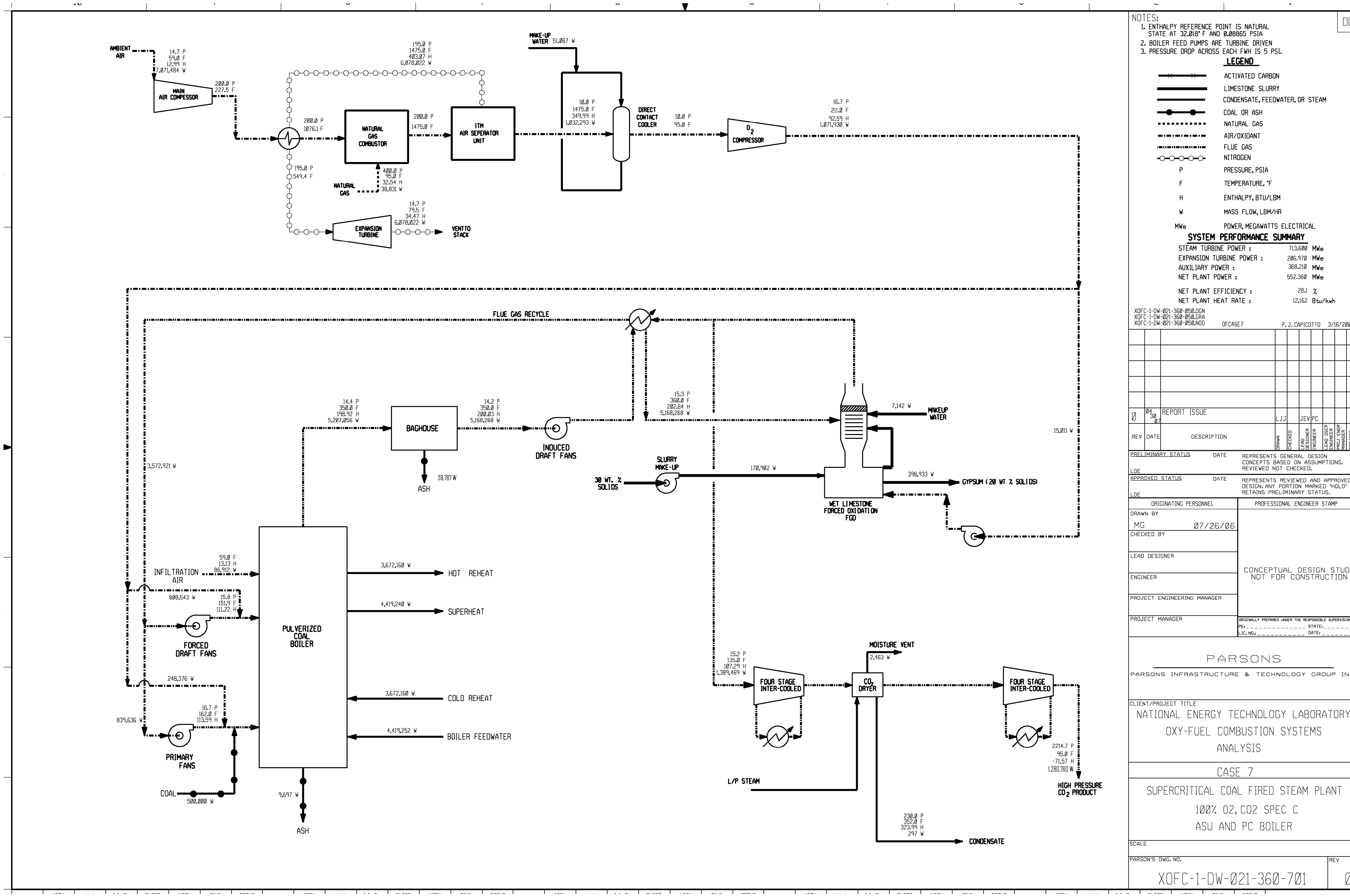

Exhibit 6-7 Case 7 Steam Cycle Heat and Mass Balance Diagram

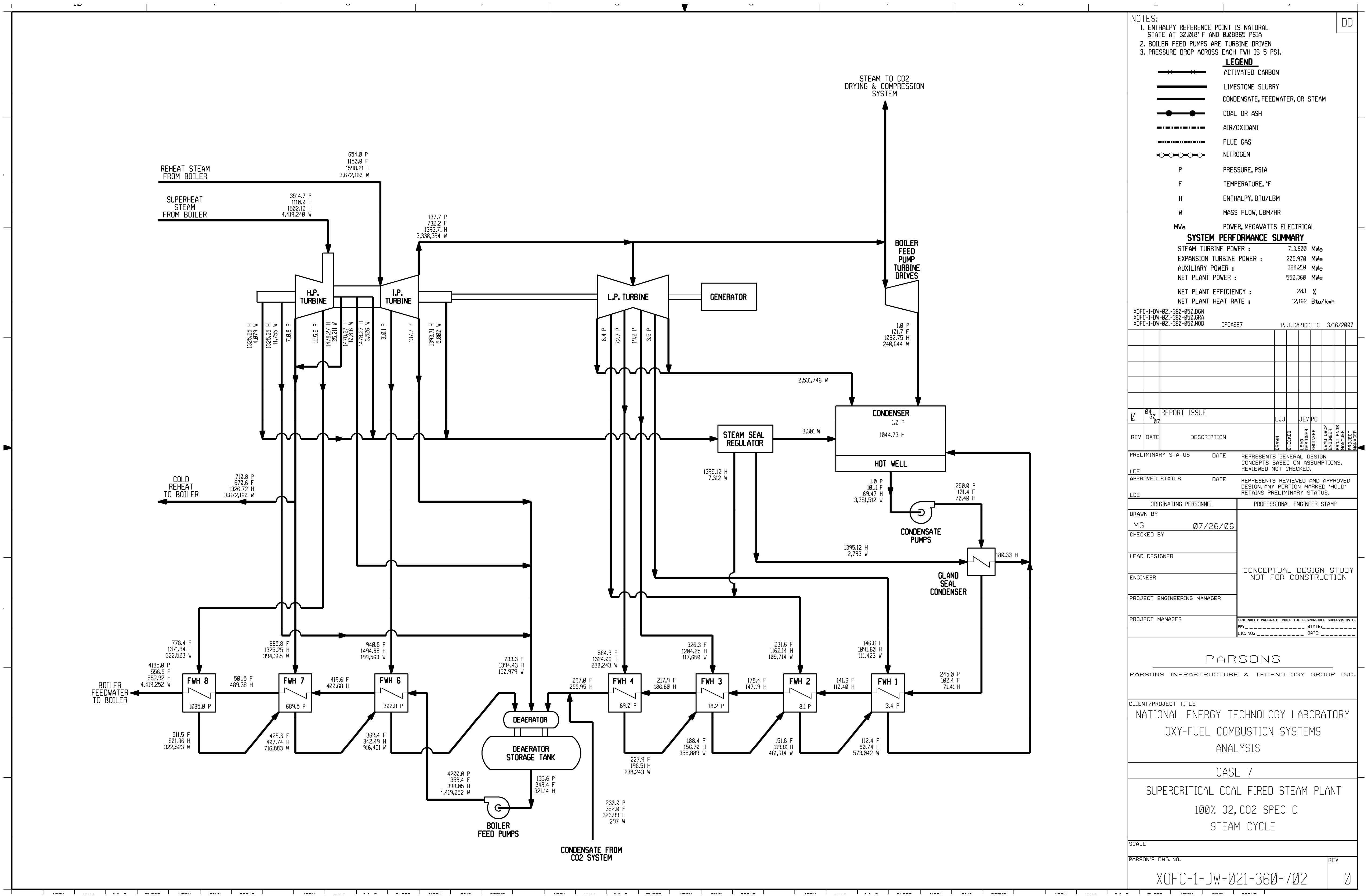

Exhibit 6-8 Case 7A Heat and Mass Balance Diagram Excluding the Steam Cycle

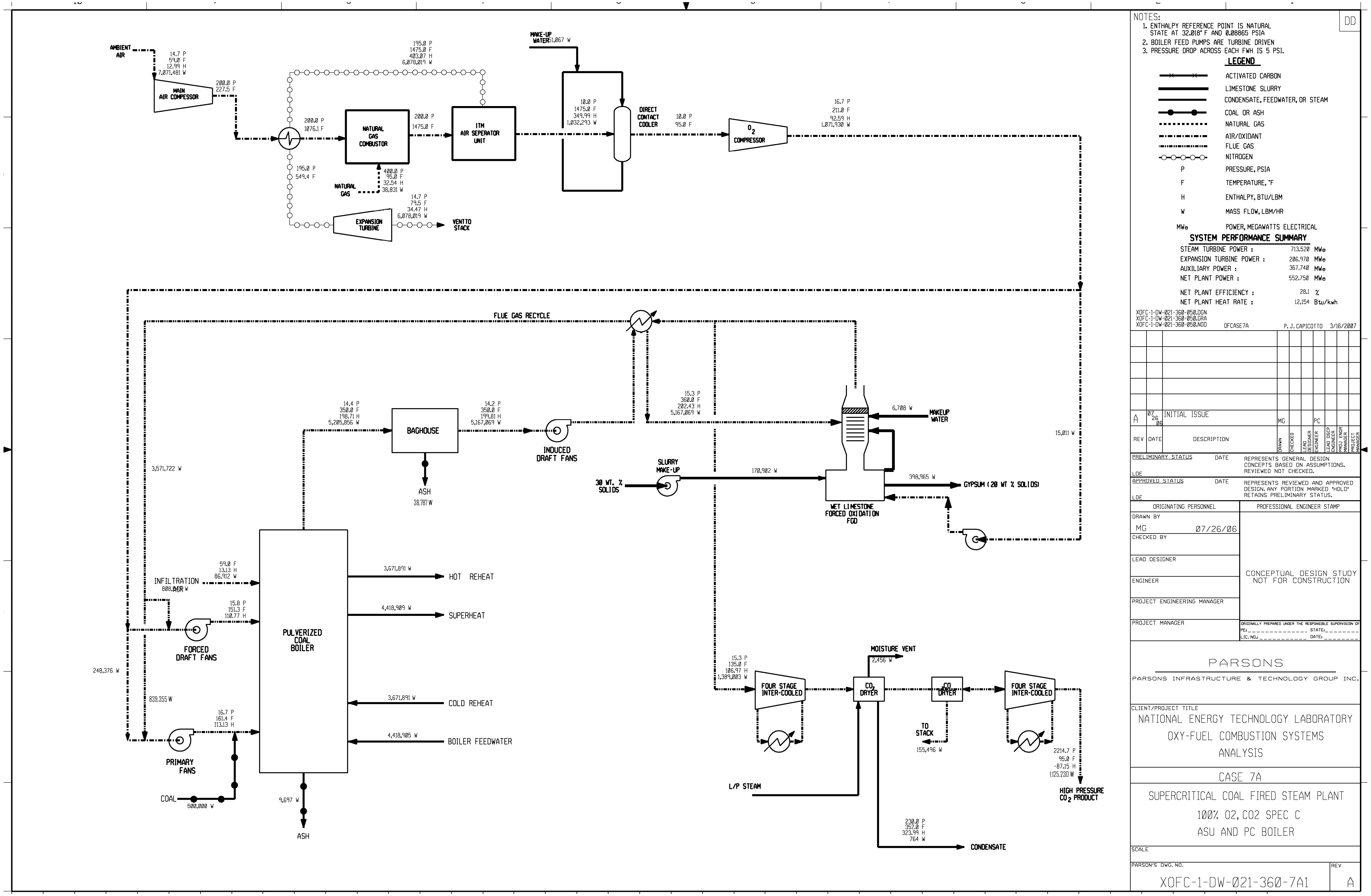

Exhibit 6-9 Case 7A Steam Cycle Heat and Mass Balance Diagram

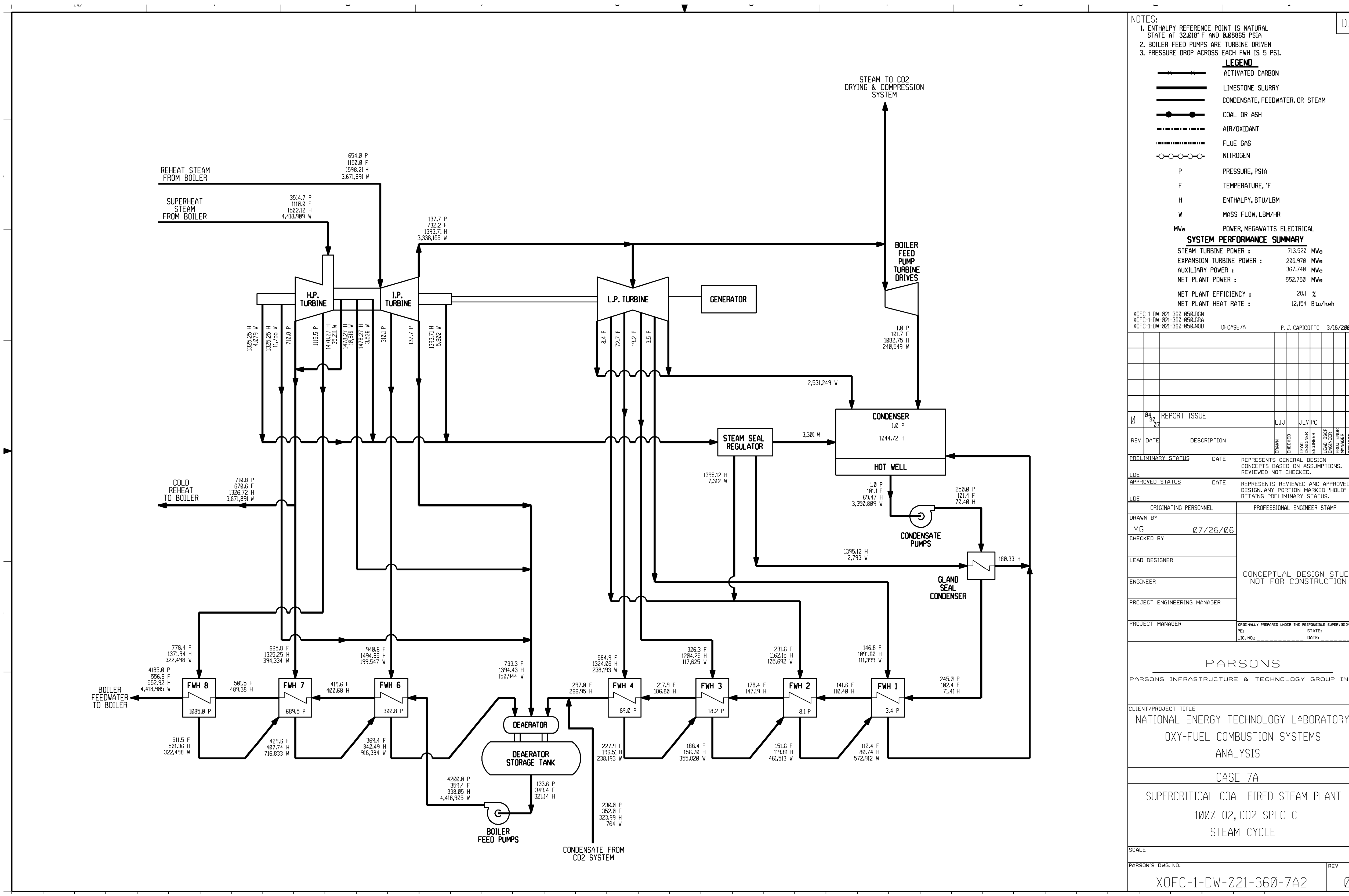

Exhibit 6-10 Performance Modeling Results for Cases 7 and 7A

	ITM Oxycombustion Cases	
	7	7A
Gross Plant Power, kWe	**713,600**	**713,520**
AUXILIARY LOAD SUMMARY, kWe		
Coal Handling and Conveying	460	460
Limestone Handling & Reagent Preparation	1,100	1,100
Pulverizer	3,400	3,400
Ash Handling	650	650
Primary Fans	1,020	1,000
Forced Draft Fans	1,350	1,240
Induced Draft Fan	6,600	6,600
Net ITM ASU	62,000	62,000
Baghouse	100	100
FGD Pumps and Agitators	3,620	3,620
CO_2 Compression	64,950	64,620
Condensate Pumps	960	960
Miscellaneous Balance of Plant (Note 2)	2,000	2,000
Steam Turbine Auxiliaries	400	400
Circulating Water Pumps	5,850	5,850
Cooling Tower Fans	3,030	3,030
Transformer Loss	3,750	3,740
Total	161,240	160,770
NET PLANT POWER, kWe	**552,360**	**552,750**
PLANT PERFORMANCE		
Net Plant Efficiency (%, HHV)	28.1%	28.1%
Net Plant Heat Rate (Btu/kWh, HHV)	12,162	12,154
Condenser Cooling Duty, MMBtu/hr	**2,724**	**2,724**
CONSUMABLES		
As-Received Coal Feed, lb/hr (Note 3)	500,000	500,000
Natural Gas, lb/hr (Note 4)	38,831	38,831
Coal Thermal Input, kW_{th}	1,709,484	1,709,484
Natural Gas Thermal Input, kW_{th}	259,379	259,379
Total Thermal Input, kW_{th} (Coal+Natural Gas)	1,968,863	1,968,863
Limestone Sorbent Feed, lb/hr	50,298	50,298
Raw Water Usage, gpm	6,503	6,502

Notes:
1. Boiler feed pumps are turbine driven
2. Includes plant control systems, lighting, HVAC, etc
3. As-received coal heating value: 11,666 Btu/lb (HHV)
4. Heating value (HHV) of natural gas is 22,792 Btu/lb

6.2.1.1 Environmental Performance for Cases 7 and 7A

Each case was designed to meet presumptive BACT standards utilizing the emissions control processes described in Section 2.5. A summary of plant air emissions is presented in Exhibit 6-11.

SO_2 emissions are controlled using a wet limestone forced oxidation scrubber that achieves a removal efficiency of 98%. The byproduct calcium sulfate is dewatered and stored on site. The wallboard grade material can potentially be marketed and sold, but since it is highly dependent on local market conditions, no byproduct credit was taken. The saturated flue gas exiting the scrubber is vented through the plant stack.

NOx emissions are controlled to 0.07 lb/10^6 Btu exiting the boiler through the use of LNBs, OFO and FGR. Only a fraction of the NOx is vented to the atmosphere as determined by the percentage of the flue gas sent to the CO_2 recovery process and the percentage of the NOx that ends up in the vent stream.

Particulate emissions are controlled using a pulse jet fabric filter (baghouse) which operates at an efficiency of 99.8%. It was assumed that 20% of the ash exits the boiler as bottom ash and the remaining 80% exits the boiler in the flue gas [44].

Co-benefit capture of Hg in the fabric filter and FGD system was assumed to achieve a 90% capture rate [45]. The addition of an inexpensive additive to the FGD system can be used to promote Hg capture if necessary, but was not included in this study.

In Case 7 there is no CO_2 purification step and therefore there are no air emission points. Flue gas from the FGD unit, after water is condensed, is either recycled to the boiler or sent to CO_2 compression and drying. Any pollutants in the gas stream sent to the CO_2 system will be co-sequestered with the CO_2. A small amount of SO_2 will be knocked out in the condenser after the FGD unit, but this sour water stream will be neutralized and disposed of and will not lead to an air emission.

In Case 7A the raw CO_2 product stream is further purified through a series of refrigerated flash steps and the vent stream contains SO_2, NOx, CO_2, Ar, N_2 and O_2. The components of the vent stream represent the only air emissions from this case.

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44 Coal Utilization By Products - Clean Coal Technologies Topical Report Number 24, page 8, http://www.netl.doe.gov/technologies/coalpower/cctc/topicalreports/pdfs/Topical24.pdf, August 2006.

45 Enhancing Mercury Control on Coal-Fired Boilers with SCR, Oxidation Catalyst, and FGD, Institute of Clean Air Companies (ICAC), www.icac.com.

Exhibit 6-11 Estimated Air Emission Rates for Cases 7 and 7A

Pollutant	$lb/10^6$ Btu		Tons/year, CF 85%		lb/MWh_{net}	
	Case 7	Case 7A	Case 7	Case 7A	Case 7	Case 7A
SO_2	0	0.018	0	443	0	0.215
NOx	0.001	0.062	26	1,346	0.013	0.654
Particulates	0	0.001	0	31	0	0.015
CO_2	16	27	392,167	664,025	191	323
Hg	0	0.11×10^{-6}	0	0.003	0	1.30×10^{-6}

Note – CO_2 and NOx include emissions from natural gas combustion in ITM system

6.2.1.2 Major Equipment List for Cases 7 and 7A

ACCOUNT 1 FUEL AND SORBENT HANDLING

Equipment No.	Description	Type	Design Condition		Qty.
			Case 7	Case 7A	
1	Bottom Trestle Dumper with Receiving Hoppers	N/A	200 tph	200 tph	2
2	Feeder	Belt	630 tph	630 tph	2
3	Conveyor No. 1	Belt	1,250 tph	1,250 tph	1
4	Transfer Tower No. 1	Enclosed	N/A	N/A	1
5	Conveyor No. 2	Belt	1,250 tph	1,250 tph	1
4	As-Received Coal Sampling System	Two-stage	N/A	N/A	1
6	Stacker/Reclaim	Traveling Linear	1,250 tph	1,250 tph	1
7	Reclaim Hopper	N/A	50 ton	50 ton	3
8	Feeder	Vibratory	210 tph	210 tph	3
9	Conveyor No. 3	Belt w/tripper	410 tph	410 tph	1
10	Crusher Tower	N/A	N/A	N/A	1
11	Coal Surge Bin w/ Vent Filter	Dual Outlet	210 ton	210 ton	2
12	Crusher	Impactor reduction	3"x0 - 1.25"x0	3"x0 – 1.25"x0	2
13	As-Fired Coal Sampling System	Swing Hammer	N/A	N/A	2
14	Conveyor No. 4	Belt w/tripper	410 tph	410 tph	1
15	Transfer Tower No. 2	Enclosed	N/A	N/A	1
16	Conveyor No. 5	Belt w/tripper	410 tph	410 tph	1
17	Coal Silo w/ Vent Filter and Slide Gates	Field Erected	900 tph	900 tph	3
18	Gas Pipeline	Underground, coated carbon steel, wrapped cathodic protection	16 m3/min @ 1.4 MPa (568 acfm @ 210 psia) 25 cm (10 in) standard wall pipe	16 m3/min @ 1.4 MPa (568 acfm @ 210 psia) 25 cm (10 in) standard wall pipe	10 mile
19	Gas Metering Station	---	16 m3/min (568 acfm)	16 m3/min (568 acfm)	1
20	Limestone Truck Unloading Hopper	N/A	36 ton	36 ton	1
21	Limestone Feeder	Belt	110 tph	110 tph	1
22	Limestone Conveyor No. 1	Belt	110 tph	110 tph	1

Equipment No.	Description	Type	Design Condition		Qty.
			Case 7	Case 7A	
23	Limestone Reclaim Hopper	N/A	20 tph	20 tph	1
25	Limestone Reclaim Feeder	Belt	80 tph	80 tph	1
26	Limestone Conveyor No. 1	Belt	80 tph	80 tph	1
27	Limestone Day Bin	w/ actuator	330 ton	330 ton	2

ACCOUNT 2 COAL AND SORBENT PREPARATION AND FEED

Equipment No.	Description	Type	Design Condition		Qty.
			Case 7	Case 7A	
1	Coal Feeder	Gravimetric	50 tph	50 tph	6
2	Coal Pulverizer	Ball type or eq.	50 tph	50 tph	6
3	Limestone Weigh Feeder	Gravimetric	28 tph	28 tph	2
4	Limestone Ball Mill	Rotary	28 tph	28 tph	2
5	Mill Slurry Tank with Agitator	N/A	26,000 gal	26,000 gal	2
6	Mill Recycle Pumps	Horizontal centrifugal	430 gpm @40 ft H_2O	430 gpm @40 ft H_2O	2
7	Hydroclone Classifier	4 active cyclones in a 5 cyclone bank	110 gpm per cyclone	110 gpm per cyclone	2
8	Distribution Box	2-way	N/A	N/A	2
9	Reagent Storage Tank with Agitator	Field erected	143,000 gal	143,000 gal	2
10	Reagent Distribution Pumps	Horizontal centrifugal	300 gpm @30 ft H_2O	300 gpm @30 ft H_2O	2

ACCOUNT 3 FEEDWATER AND MISCELLANEOUS SYSTEMS AND EQUIPMENT

Equipment No.	Description	Type	Design Condition		Qty.
			Case 7	Case 7A	
1	Demineralized Water Storage Tank	Vertical, cylindrical, outdoor	349,000 gal	349,000 gal	2
2	Condensate Pumps	Vertical canned	7,400gpm @ 700 ft H_2O	7,400gpm @ 300 ft H_2O	2

Equipment No.	Description	Type	Design Condition		Qty.
			Case 7	Case 7A	
3	Deaerator and Storage Tank	Horizontal spray type	4,856,000 lb/h, 5 min tank	4,856,000 lb/h 5 min tank	1
4	Boiler Feed Pump/ Turbine driven	Barrel type, multi-staged, centrifugal	9,800 gpm @ 11,400 ft H_2O	9,800 gpm @ 11,400 ft H_2O	2
5	Startup Boiler Feed Pump, Electric. motor driven	Barrel type, multi-stage, centrifugal	2,900 gpm @ 12400 ft H_2O	2,900 gpm @ 11,400 ft H_2O	1
6	LP Feedwater Heater 1A/1B	Horizontal U tube	1,840,000 lb/h	1,840,000 lb/h	2
7	LP Feedwater Heater 2A/2B	Horizontal U tube	1,840,000 lb/h	1,840,000 lb/h	2
8	LP Feedwater Heater 3A/3B	Horizontal U tube	1,840,000 lb/h	1,840,000 lb/h	2
9	LP Feedwater Heater 4A/4B	Horizontal U tube	1,840,000 lb/h	1,840,000 lb/h	2
10	HP Feedwater Heater 6	Horizontal U tube	4,860,000 lb/h	4,860,000 lb/h	1
11	HP Feedwater Heater 7	Horizontal U tube	4,860,000 lb/h	4,860,000 lb/h	1
12	HP Feedwater Heater 8	Horizontal U tube	4,860,000 lb/h	4,860,000 lb/h	1
13	Auxiliary Boiler	Shop fabricated, water-tube	400 psig, 650°F, 40,000 lb/h	400 psig, 650°F, 40,000 lb/h	1
14	Fuel Oil System	No. 2 for light off	300,000 gal	300,000 gal	1
15	Service Air Compressors	Flooded screw	100 psig, 1,000 cfm	100 psig, 1,000 cfm	3
16	Inst. Air Dryers	Duplex, regenerative	1,000 scfm	1,000 scfm	3
17	Closed Cycle Cooling Heat Exch.	Shell & tube	50 MMBtu/h each	50 MMBtu/h each	2
18	Closed Cycle Cooling Water Pumps	Horizontal centrifugal	5,500gpm @ 100 ft H_2O	5,500gpm @ 100 ft H_2O	3
19	Fire Service Booster Pump	Two-stage centrifugal	700gpm @ 210 ft H_2O	700gpm @ 210 ft H_2O	2
20	Engine-Driven Fire Pump	Vert. turbine, diesel engine	1,000gpm @ 290 ft H_2O	1,000gpm @ 290 ft H_2O	2
21	Raw Water Pumps	SS, single suction	3,580gpm @ 140 ft H_2O	3,580gpm @ 140 ft H_2O	3
22	Filtered Water Pumps	SS, single suction	440gpm @ 160 ft H_2O	440gpm @ 160 ft H_2O	3
23	Filtered Water Tank	Vertical, cylindrical	422,000 gal	422,000 gal	1
24	Makeup Demineralizer	Anion, cation, and mixed bed	180 gpm	190 gpm	2
25	Liquid Waste Treatment System	--	10 years, 24-hour storm	10 years, 24-hour storm	1

ACCOUNT 4 BOILER AND ACCESSORIES

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	Boiler	Supercritical drum-type, wall-fired, low NOx burners, overfire air	4,860,000 lb/h at 3500 psig/ 1110ºF/1150ºF	4,860,000 lb/h at 3500 psig/ 1110ºF/1150ºF	1
2	Primary Fan	Centrifugal	462,000 lb/h, 85,500 acfm, @ 50" WG	462,000 lb/h, 85,500 acfm, @ 50" WG	2
3	Forced Draft Fan	Centrifugal	1,503,000 lb/h, 278,400 acfm @ 20" WG	1.503,000 lb/h, 278,400 acfm @ 20" WG	2
4	Induced Draft Fan	Centrifugal	2,843,000 lb/h, 789,600 acfm @ 35" WG	2,842,000 lb/h, 789,600 acfm @ 35" WG	2
5	Air Separation Unit	ITM	6,810 tpd @ 100 vol% O_2	6,810 tpd @ 100 vol% O_2	2

ACCOUNT 5 FLUE GAS CLEANUP

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	Fabric filter	Single-stage, high-ratio with pulse-jet on-line cleaning system.	2,843,000 lb/h, 99.9% efficiency	2,842,000 lb/h, 99.9% efficiency	2
2	Absorber Module	Tray type with concurrent spray	1,285,000 acfm	1,268,000 acfm	1
3	Recirculation Pumps	Horizontal centrifugal	33,000 gpm @ 210 ft H_2O	33,000 gpm @ 210 ft H_2O	6
4	Bleed Pumps	Horizontal centrifugal	1,300 gpm 20% solids	1,300 gpm 20% solids	3
5	Oxidation Blowers	Centrifugal	1,020 scfm @ 26 psia	1,020 scfm @ 26 psia	3
6	Agitators	Side entering	50 hp	50 hp	6
7	Dewatering Hydrocyclones	Radial assembly (5 units EA)	330 gpm per cyclone	330 gpm per cyclone	2
8	Vacuum Filter Belt	Horizontal belt	43 tph 50 wt% solids slurry	43 tph 50 wt% solids slurry	3
9	Filtrate Water Return Pumps	Horizontal centrifugal	200 gpm @ 40 ft H_2O	200 gpm @ 40 ft H_2O	2
10	Filtrate Water Return Storage Tank	Vertical, lined	130,000 gal	130,000 gal	1
11	Process Water Recirculation Pumps	Horizontal centrifugal	680 gpm @ 70 ft H_2O	680 gpm @ 70 ft H_2O	2

ACCOUNT 5B CARBON DIOXIDE RECOVERY

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	CO_2 Compression and Purification Unit	Integrally geared, multistage centrifugal with indirect water intercoolers	704,000 lb/h @ 2215psia 88.3 wt % CO_2 concentration	619,000 lb/h @ 2215psia 97.3 wt % CO_2 concentration	2
2	Condensing Heat Exchanger	Shell and tube, alloy steel construction	2,762,381 kg/h @ 71.1 °C (6,090,000 lb/h @ 160 °F)	2,762,381 kg/h @ 71.1 °C (6,090,000 lb/h @ 160 °F)	2

ACCOUNT 6 NITROGEN EXPANDER GENERATOR

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	Dual End Generator w/ Two Nitrogen Expander / Generators	Expander/ Generator	1,011,059 kg/h (2,229,000 lb/h) N_2 per train, 76 MW output/generator	1,011,059 kg/h (2,229,000 lb/h) N_2 per train, 76 MW output/generator	3

ACCOUNT 7 DUCTING AND STACK

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	Stack	Reinforced concrete with FRP liner	150 ft high x 10 ft diameter	150 ft high x 10 ft diameter	1
2	Flue Gas Reheater	Gas-gas heat exchanger	9.0 MMBtu/h	9.0 MMBtu/h	1

ACCOUNT 8 STEAM TURBINE GENERATOR

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	Steam Turbine Generator	Commercially available advanced steam turbine	750 MW, 3500 psig/ 1110°F /1150°F	750 MW, 3500 psig/ 1110°F /1150°F	1

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
2	Steam Turbine Generator	Hydrogen cooled, static excitation	830 MVA @ 0.9 p.f., 24 kV, 60 Hz	830 MVA @ 0.9 p.f., 24 kV, 60 Hz	1
3	Surface Condenser	Single pass, divided waterbox including vacuum pumps	2,990 MMBtu/h, Inlet water 60ºF rise 20ºF	2,990 MMBtu/h, Inlet water 60ºF rise 20ºF	1

ACCOUNT 9 COOLING WATER SYSTEM

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	Cooling Tower	Evaporative, mechanical draft, multi-cell	11°C (51.5°F) wet bulb / 16°C (60°F) CWT / 27°C (80°F) HWT 3,268 MMkJ/h (3,100 MMBtu/h) heat load	11°C (51.5°F) wet bulb / 16°C (60°F) CWT / 27°C (80°F) HWT 3,268 MMkJ/h (3,100 MMBtu/h) heat load	1
2	Circ. Water Pumps	Vertical, wet pit	78,000 gpm @ 100 ft	78,000 gpm @ 100 ft,	6

ACCOUNT 10 ASH/SPENT SORBENT RECOVERY AND HANDLING

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	Economizer Hopper (part of boiler scope of supply)	--	--	--	4
2	Bottom Ash Hopper (part of boiler scope of supply)	--	--	--	2
3	Clinker Grinder	--	4.5 tph	4.5 tph	2
4	Pyrites Hopper (part of pulverizer scope of supply included with boiler)	--	--	--	6
5	Hydroejectors	--	--	--	12
6	Economizer/Pyrites Transfer Tank	--	--	--	2
7	Ash Sluice Pumps	Vertical, wet pit	50 gpm @ 56 ft H_2O	50 gpm @ 56 ft H_2O	2
8	Ash Seal Water Pumps	Vertical, wet pit	2,000 gpm@ 28 ft H_2O	2,000 gpm @ 28 ft H_2O	2

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
9	Hydrobins	--	50 gpm	50 gpm	2
10	Baghouse Hopper (part of baghouse scope of supply)	--	--	--	24
11	Air Heater Hopper (part of boiler scope of supply)	--	--	--	10
12	Air Blower	--	620 scfm @ 24 psi	620 scfm @ 24 psi	2
13	Fly Ash Silo	Reinforced concrete	1,300 tons	1,300 tons	2
14	Slide Gate Valves	--	--	--	2
15	Unloader	--	120 tph	120 tph	1
16	Telescoping Unloading Chute	--	--	--	1

ACCOUNT 11 ACCESSORY ELECTRIC PLANT

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	STG Transformer	Oil-filled	24 kV/345 kV, 830 MVA, 3-ph, 60 Hz	24 kV/345 kV, 910 MVA, 3-ph, 60 Hz	1
2	Auxiliary Transformer	Oil-filled	24 kV/ 4.16 kV, 403 MVA, 3-ph, 60 Hz	24 kV/ 4.16 kV, 403 MVA, 3-ph, 60 Hz	2
3	LV Transformer	Dry ventilated	4.16 kV /480 V, 60 MVA, 3-ph, 60 Hz	4.16 kV /480 V, 60 MVA, 3-ph, 60 Hz	2
4	STG Isolated Phase Bus Duct and Tap Bus	Aluminum, self-cooled	24 kV, 3-ph, 60 Hz	24 kV, 3-ph, 60 Hz	1
5	Medium Voltage Switchgear	Metal Clad	4.16 kV, 3-ph, 60 Hz	4.16 kV, 3-ph, 60 Hz	2
6	Low Voltage Switchgear	Metal Enclosed	480 V, 3-ph, 60 Hz	480 V, 3-ph, 60 Hz	2
7	Emergency Diesel Generator	Sized for emergency shutdown	750 kW, 480 V, 3-ph, 60 Hz	750 kW, 480 V, 3-ph, 60 Hz	1

ACCOUNT 12 INSTRUMENTATION AND CONTROL

Equipment No.	Description	Type	Design Condition		Qty
			Case 7	Case 7A	
1	DCS - Main Control	Monitor/keyboard; Operator printer – laser color; Eng. Printer – laser B&W	Operator Stations/Printers and Engineering Stations/Printers	Operator Stations/Printers and Engineering Stations/Printers	1
2	DCS - Processor	Microprocessor with Redundant Input/Output	N/A	N/A	1
3	DCS - Data Highway	Fiber optic	Fully redundant, 25% spare	Fully redundant, 25% spare	1

6.3 ECONOMIC ANALYSIS FOR ITM OXYCOMBUSTION CASES

Capital and operating costs for the ITM oxycombustion cases are presented in Section 6.3.1. A cost and performance summary table for both cases is given in Section 6.3.2 and additional cost detail sheets for both cases are contained in Section 6.3.3.

6.3.1 Cost Estimate Results for Cases 7 and 7A

The capital and operating costs for Cases 7 and 7A are shown in Exhibit 6-12 through Exhibit 6-15. The economic estimate basis and criteria are shown in Exhibit 6-16. Capital and operating cost methodology is explained in Section 2.8. A summary of plant costs and performance for all of the ITM oxycombustion cases is shown in Exhibit 6-17. Additional cost detail sheets for all cases are contained in Section 6.3.3.

The ITM ASU cost is assumed to be 30% less than a conventional cryogenic ASU, consistent with the announced goals of the ITM program [46].

46 "ITM Oxygen for Gasification", Air Products and Chemicals, Inc., Gasification Technologies 2004, Washington, DC, http://www.gasification.org/Docs/2006_Papers/54ARMS.pdf, October 2004

Exhibit 6-12 Case 7 Total Plant Costs

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST SUMMARY

Case: Case 7 - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: **552.36** MW,net **Estimate Type:** Conceptual **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING	17,590	4,711	10,434		**32,735**	2,933	0	5,350	**$41,018**	$74
2	COAL & SORBENT PREP & FEED	11,828	681	2,946		**15,455**	1,355	0	2,521	**$19,331**	$35
3	FEEDWATER & MISC. BOP SYSTEMS	56,041	0	25,469		**81,510**	7,476	0	15,045	**$104,031**	$188
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	170,772	0	96,297		**267,069**	25,868	43,941	29,294	**$366,172**	$663
4.2	ASU/Oxidant Compression	88,641	0	72,524		**161,165**	15,611	0	17,678	**$194,453**	$352
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0
	Subtotal 4	259,413	0	168,821		**428,234**	41,479	43,941	46,971	**$560,625**	$1,015
5	FLUE GAS CLEANUP	62,763	0	64,024		**126,786**	12,039	0	13,883	**$152,708**	$276
5B	CO2 REMOVAL & COMPRESSION	44,509	0	32,231		**76,740**	7,285	0	16,805	**$100,830**	$183
6	NITROGEN EXPANDER/GENERATOR	38,289	0	3,105		**41,394**	4,139	0	4,553	**$50,087**	$91
7	DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	9,027	0	919		**9,946**	950	0	1,090	**$11,986**	$22
7.2-7.9	Ductwork and Stack	10,249	622	7,386		**18,257**	1,632	0	2,862	**$22,751**	$41
	Subtotal 7	19,276	622	8,305		**28,203**	2,583	0	3,952	**$34,737**	$63
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	58,730	0	7,872		**66,602**	6,377	0	7,298	**$80,277**	$145
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	27,834	1,256	15,254		**44,344**	3,873	0	6,773	**$54,990**	$100
	Subtotal 8	86,564	1,256	23,127		**110,946**	10,250	0	14,071	**$135,267**	$245
9	COOLING WATER SYSTEM	12,790	7,433	13,242		**33,465**	3,130	0	5,049	**$41,644**	$75
10	ASH/SPENT SORBENT HANDLING SYS	4,810	151	6,264		**11,225**	1,068	0	1,265	**$13,558**	$25
11	ACCESSORY ELECTRIC PLANT	31,594	10,388	31,528		**73,509**	6,565	0	9,712	**$89,786**	$163
12	INSTRUMENTATION & CONTROL	15,138	0	15,578		**30,716**	2,812	1,536	4,311	**$39,375**	$71
13	IMPROVEMENTS TO SITE	2,808	1,619	5,828		**10,255**	1,007	0	2,252	**$13,514**	$24
14	BUILDINGS & STRUCTURES	0	24,796	23,775		**48,571**	4,378	0	7,942	**$60,891**	$110
	TOTAL COST	**$663,412**	**$51,657**	**$434,676**	**$0**	**$1,149,745**	**$108,499**	**$45,476**	**$153,682**	**$1,457,403**	**$2,639**

Exhibit 6-13 Case 7 Capital Investment and Operating Cost Summary

TITLE/DEFINITION

Case:	**Case 7 - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture**			
Plant Size:	**552.36 (MW,net)**	**Heat Rate**	**12,162**	**Btu/kWh**
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**	
Capacity Factor:	**85.0%**	**CO_2 Catured**	**14,134**	**(TPD)**

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	1,149,745	2,081.5
Engineering(incl.C.M.,H.O.& Fee)	108,499	196.4
Process Contingency	45,476	82.3
Project Contingency	153,682	278.2
TOTAL PLANT COST(TPC)	**1,457,403**	**2,638.5**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	6,013	10.9
Maintenance Labor	9,791	17.7
Maintenance Material	14,687	26.6
Administrative & Support Labor	2,937	5.3
TOTAL OPERATION & MAINTENANCE	$33,428	60.5
FIXED O & M (2007)	$18,741	33.9
VARIABLE O & M	$14,687	26.6

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	2,992	0.07
Chemicals	6,175	0.15
Other Consumables	0	0.00
Waste Disposal	2,789	0.07
TOTAL CONSUMABLES	$11,956	0.29
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$122,870	2.99

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.53
Variable O & M	1.16	0.41
Consumables	1.16	0.34
By-product Credit	1.16	0.00
Fuel	1.20	3.59
TOTAL PRODUCTION COST		4.87
2007 CARRYING CHARGES (Capital)		6.20
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		11.07

Exhibit 6-14 Case 7A Total Plant Costs

	Client:	U.S. DOE / NETL							**Report Date:**	28-Aug-07		
	Project:	Oxy-Fuel Combustion Systems Analysis										
					TOTAL PLANT COST SUMMARY							
	Case:	Case 7A - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture										
	Plant Size:	**552.75** MW,net		**Estimate Type:**	Conceptual		**Cost Base (Jan)** 2007			$x1000		
Acct No.	**Item/Description**	**Equipment Cost**	**Material Cost**	**Labor Direct**	**Labor Indirect**	**Bare Erected Cost $**	**Eng'g CM H.O.& Fee**	**Contingencies Process**	**Contingencies Project**	**TOT. PLANT COST $**	**TOT. PLANT COST $/kW**	
1	COAL & SORBENT HANDLING	17,590	4,711	10,434		**32,735**	2,933	0	5,350	**$41,018**	$74	
2	COAL & SORBENT PREP & FEED	11,828	681	2,946		**15,455**	1,355	0	2,521	**$19,331**	$35	
3	FEEDWATER & MISC. BOP SYSTEMS	56,041	0	25,469		**81,510**	7,476	0	15,045	**$104,031**	$188	
4	PC BOILER & ACCESSORIES											
4.1	PC BOILER	170,772	0	96,297		**267,069**	25,868	43,941	29,294	**$366,172**	$662	
4.2	ASU/Oxidant Compression	88,641	0	72,524		**161,165**	15,611	0	17,678	**$194,453**	$352	
4.3-4.9	Other Boiler Equipment	0	0	0		**0**	0	0	0	**$0**	$0	
	Subtotal 4	259,413	0	168,821		**428,234**	41,479	43,941	46,971	**$560,625**	$1,014	
5	FLUE GAS CLEANUP	62,763	0	64,024		**126,786**	12,039	0	13,883	**$152,708**	$276	
5B	CO2 REMOVAL & COMPRESSION	60,577	0	43,866		**104,443**	9,915	0	22,872	**$137,230**	$248	
6	NITROGEN EXPANDER/GENERATOR	38,289	0	3,105		**41,394**	4,139	0	4,553	**$50,087**	$91	
7	DUCTING & STACK											
7.1	Flue Gas Recycle Heat Exchanger	9,022	0	919		**9,941**	950	0	1,089	**$11,980**	$22	
7.2-7.9	Ductwork and Stack	10,249	622	7,386		**18,257**	1,632	0	2,862	**$22,751**	$41	
	Subtotal 7	19,271	622	8,305		**28,198**	2,582	0	3,951	**$34,731**	$63	
8	STEAM TURBINE GENERATOR											
8.1	Steam TG & Accessories	58,724	0	7,872		**66,595**	6,376	0	7,297	**$80,269**	$145	
8.2-8.9	Turbine Plant Auxiliaries & Steam Piping	27,831	1,256	15,253		**44,339**	3,872	0	6,772	**$54,984**	$99	
	Subtotal 8	86,555	1,256	23,124		**110,935**	10,249	0	14,069	**$135,253**	$245	
9	COOLING WATER SYSTEM	12,788	7,432	13,240		**33,461**	3,130	0	5,048	**$41,639**	$75	
10	ASH/SPENT SORBENT HANDLING SYS	4,810	151	6,264		**11,225**	1,068	0	1,265	**$13,558**	$25	
11	ACCESSORY ELECTRIC PLANT	31,584	10,388	31,526		**73,498**	6,564	0	9,711	**$89,773**	$162	
12	INSTRUMENTATION & CONTROL	15,138	0	15,578		**30,716**	2,812	1,536	4,311	**$39,375**	$71	
13	IMPROVEMENTS TO SITE	2,808	1,619	5,828		**10,255**	1,007	0	2,252	**$13,514**	$24	
14	BUILDINGS & STRUCTURES	0	24,796	23,775		**48,571**	4,378	0	7,942	**$60,891**	$110	
	TOTAL COST	**$679,456**	**$51,656**	**$446,304**	**$0**	**$1,177,416**	**$111,126**	**$45,476**	**$159,745**	**$1,493,763**	**$2,702**	

Exhibit 6-15 Case 7A Capital Investment and Operating Cost Summary

TITLE/DEFINITION				
Case:	**Case 7A - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture**			
Plant Size:	**552.75 (MW,net)**	**Heat Rate**	**12,154**	**Btu/kWh**
Fuel(type):	**Illinois #6**	**Fuel Cost:**	**1.80**	**($/MMBtu)**
Design/Construction:	**3 (years)**	**BookLife:**	**30**	**(years)**
TPC(Plant Cost) Year:	**2007 (Jan)**	**Startup Year:**	**2010**	
Capacity Factor:	**85.0%**	**CO_2 Catured**	**13,257**	**(TPD)**

CAPITAL INVESTMENT	**$x1000**	**$/kW**
Process Capital & Facilities	1,177,416	2,130.1
Engineering(incl.C.M.,H.O.& Fee)	111,126	201.0
Process Contingency	45,476	82.3
Project Contingency	159,745	289.0
TOTAL PLANT COST(TPC)	**1,493,763**	**2,702.4**

OPERATING & MAINTENANCE COSTS(2007)	**$x1000**	**$/kW-yr**
Operating Labor	6,013	10.9
Maintenance Labor	10,036	18.2
Maintenance Material	15,053	27.2
Administrative & Support Labor	2,937	5.3
TOTAL OPERATION & MAINTENANCE	$34,039	61.6
FIXED O & M (2007)	$18,985	34.3
VARIABLE O & M	$15,053	27.2

CONSUMABLE OPERATING COSTS, LESS FUEL	**$x1000**	**¢/kWh**
Water	2,992	0.07
Chemicals	6,175	0.15
Other Consumables	0	0.00
Waste Disposal	2,789	0.07
TOTAL CONSUMABLES	$11,956	0.29
BY-PRODUCT CREDITS	$0	0.00
FUEL COST	$122,870	2.99

PRODUCTION COST SUMMARY	**LF**	**Levelized Costs ¢/kWh**
Fixed O & M	1.16	0.53
Variable O & M	1.16	0.42
Consumables	1.16	0.34
By-product Credit	1.16	0.00
Fuel	1.20	3.59
TOTAL PRODUCTION COST		4.88
2007 CARRYING CHARGES (Capital)		6.35
CCF for a 20-Year Levelization Period - IOU - Higher-Risk	**17.5**	
20 YEAR LEVELIZED BUSBAR COST OF POWER		11.23

Exhibit 6-16 Cases 7 and 7A Estimate Basis /Economic Criteria Summary

Location:	**Midwestern, USA**	
Fuel: Coal/Secondary	**Illinois #6**	
Levelized Capacity Factor:	**85.0%**	
Capital Cost Year Dollars:	**2007**	**(Jan)**
Delivered Cost of Coal /Primary Fuel	**1.80**	**$/MMBtu**
Delivered Cost of Natural Gas//Secondary Fuel	**6.75**	**$/MMBtu**
Design/Construction Period:	**3**	**years**
Plant Startup Date(year):	**2010**	**(January)**
FINANCIAL CRITERIA	IOU High Risk	
Project Book Life:	**30**	**years**
Book Salvage Value:	**0.0**	**%**
Project Tax Life:	**20**	**years**
Tax Depreciation Method:	**20 years, 150% declining balance**	
Property Tax Rate:	**1.0**	**% per year**
Insurance Tax Rate:	**1.0**	**% per year**
Federal Income Tax Rate:	**34.0**	**%**
State Income Tax Rate:	**6.0**	**%**
Investment Tax Credit/% Eligible	**0.0**	**%**
Economic Basis:	**20th Year Current Dollars**	

		% of Total	**Cost(%)**
Capital Structure			
	Common Equity	**55.00**	**12.00**
	Tax Free Municipal Bonds	**0.00**	**0.00**
	Debt	**45.00**	**11.00**
Weighted Cost of Capital:(after tax)		**9.67 %**	

		2010 - 2030	
Escalation Rates			
	General	**1.9**	**% per year**
	Coal Price	**2.348**	**% per year**
	Secondary Fuel:	**1.955**	**% per year**

6.3.2 Cost Estimate and Performance Summary for ITM Oxycombustion Cases

A summary of plant costs and performance for all of the cryogenic oxycombustion cases is shown in Exhibit 6-17.

Exhibit 6-17 Cost and Performance Results for ITM Oxycombustion Cases

Case	7	7A
Gross Power Output, MW_e	920.6	920.5
Net Power Output, MW_e	552.4	552.8
Net Plant Efficiency, % (HHV)	28.1	28.1
Net Plant Heat Rate, Btu/kWh (HHV)	12,162	12,154
Total Plant Cost, $x1000	1,457,403	1,493,763
Total Plant Cost, $/kW	2,639	2,702
CO_2 Capital Cost Penalty[a], $/kW	1,075	1,139
Levelized Cost of Electricity, ¢/kWh (85% Capacity Factor)	11.07	11.23
Levelized COE CO_2 Penalty[b], ¢/kWh (85% Capacity Factor)	4.78	4.94
Percent increase in COE[c], (85% Capacity Factor)	76%	79%
Total CO_2 Emitted, lb/MWh_{net}	191	323
Cost of CO_2 Avoided[d], $/ton	60.93	68.81
Total CO_2 Captured, lb/MWh_{net}	2,132	1,999
Cost of CO_2 Captured[e], $/ton	44.80	49.44

a. CO_2 Capital Cost Penalty = TPC with capture – TPC case 1 air-fired without capture
b. CO_2 LCOE Cost Penalty = LCOE with capture – LCOE case 1 air-fired without capture
c. Relative to Case 1 ("Base Case")
d. CO_2 Cost Avoided = (COE with capture – COE without capture)/(Emissions without capture – Emissions with capture)
e. CO_2 Cost Captured (or Removal) = (COE with capture – COE without capture)/(CO_2 Captured)
Costs do not include CO_2 Transport, Storage, and Monitoring

6.3.3 Cost Estimate Details for ITM Oxycombustion Cases

Additional cost estimating details are provided for the four air-based PC cases in the following subsections:

Section 6.3.3.1: Case 7 – Supercritical ITM oxycombustion with no CO_2 purification

Section 6.3.3.2: Case 7A – Supercritical ITM oxycombustion with CO_2 purification

6.3.3.1 Case 7 – Supercritical ITM Oxycombustion with No CO_2 Purification

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Case 7 - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture

TOTAL PLANT COST DETAIL

Case: Case 7 - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 552.36 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
1	COAL & SORBENT HANDLING										
1.1	Coal Receive & Unload	3,613	0	1,637		$5,250	469	0	858	**$6,577**	$12
1.2	Coal Stackout & Reclaim	4,675	0	1,047		$5,722	501	0	933	**$7,156**	$13
1.3	Coal Conveyors & Yard Breaker	4,348	0	1,037		$5,385	472	0	879	**$6,736**	$12
1.4	Other Coal Handling	1,138	0	239		$1,377	120	0	225	**$1,722**	$3
1.5	Sorbent Receive & Unload	145	0	43		$188	17	0	31	**$235**	$0
1.6	Sorbent Stackout & Reclaim	2,334	0	423		$2,757	240	0	450	**$3,447**	$6
1.7	Sorbent Conveyors	833	177	202		$1,212	105	0	198	**$1,514**	$3
1.8	Other Sorbent Handling	504	116	261		$881	78	0	144	**$1,103**	$2
1.9	Coal & Sorbent Hnd.Foundations	0	4,418	5,545		$9,963	931	0	1,634	**$12,528**	$23
	SUBTOTAL 1.	**$17,590**	**$4,711**	**$10,434**		**$32,735**	**$2,933**	**$0**	**$5,350**	**$41,018**	$74
2	COAL & SORBENT PREP & FEED										
2.1	Coal Crushing & Drying	2,074	0	400		$2,474	216	0	403	**$3,093**	$6
2.2	Coal Conveyor to Storage	5,310	0	1,147		$6,457	565	0	1,053	**$8,075**	$15
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0
2.5	Sorbent Prep Equipment	3,965	169	814		$4,948	431	0	807	**$6,186**	$11
2.6	Sorbent Storage & Feed	479	0	181		$660	59	0	108	**$826**	$1
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0
2.9	Coal & Sorbent Feed Foundation	0	512	404		$916	84	0	150	**$1,150**	$2
	SUBTOTAL 2.	**$11,828**	**$681**	**$2,946**		**$15,455**	**$1,355**	**$0**	**$2,521**	**$19,331**	$35
3	FEEDWATER & MISC. BOP SYSTEMS										
3.1	Feedwater System	20,148	0	6,456		$26,604	2,329	0	4,340	**$33,273**	$60
3.2	Water Makeup & Pretreating	10,207	0	3,211		$13,418	1,258	0	2,935	**$17,611**	$32
3.3	Other Feedwater Subsystems	6,227	0	2,585		$8,812	785	0	1,440	**$11,037**	$20
3.4	Service Water Systems	2,013	0	1,066		$3,079	286	0	673	**$4,038**	$7
3.5	Other Boiler Plant Systems	7,394	0	7,080		$14,474	1,358	0	2,375	**$18,206**	$33
3.6	FO Supply Sys & Nat Gas	279	0	337		$616	57	0	101	**$774**	$1
3.7	Waste Treatment Equipment	6,876	0	3,859		$10,735	1,040	0	2,355	**$14,130**	$26
3.8	Misc. Power Plant Equipment	2,897	0	875		$3,772	362	0	827	**$4,961**	$9
	SUBTOTAL 3.	**$56,041**	**$0**	**$25,469**		**$81,510**	**$7,476**	**$0**	**$15,045**	**$104,031**	$188
4	PC BOILER & ACCESSORIES										
4.1	PC BOILER	170,772	0	96,297		$267,069	25,868	43,941	29,294	**$366,172**	$663
4.2	ASU/Oxidant Compression	88,641	0	72,524		$161,165	15,611	0	17,678	**$194,453**	$352
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 4.	**$259,413**	**$0**	**$168,821**		**$428,234**	**$41,479**	**$43,941**	**$46,971**	**$560,625**	$1,015

Client: U.S. DOE / NETL **Report Date:** 28-Aug-07
Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST DETAIL

Case: Case 7 - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture
Plant Size: 552.36 MW,net **Estimate Type:** **Cost Base (Jan)** 2007 $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	25,097	0	29,857		$54,954	5,201	0	6,015	**$66,170**	$120
5.2	Other FGD	2,398	0	2,762		$5,160	497	0	566	**$6,223**	$11
5.3	Baghouse & Accessories	18,706	0	13,900		$32,606	3,119	0	3,572	**$39,297**	$71
5.4	Other Particulate Removal Materials	895	0	975		$1,870	180	0	205	**$2,255**	$4
5.5	Gypsum Dewatering System	15,667	0	16,531		$32,198	3,042	0	3,524	**$38,764**	$70
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$62,763**	**$0**	**$64,024**		**$126,786**	**$12,039**	**$0**	**$13,883**	**$152,708**	$276
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	44,509	0	32,231		$76,740	7,285	0	16,805	**$100,830**	**$183**
	SUBTOTAL 5B.	**$44,509**	**$0**	**$32,231**		**$76,740**	**$7,285**	**$0**	**$16,805**	**$100,830**	**$183**
6	NITROGEN EXPANDER GENERATOR										
6.1	Nitrogen Expander Generator	38,289		3,105		$41,394	4,139	0	4,553	**$50,087**	**$91**
6.2	Nitrogen Expander Generator Accessories					$0	0	0	0	**$0**	**$0**
6.3	Compressed Air Piping					$0	0	0	0	**$0**	**$0**
6.9	Nitrogen Expander Generator Foundations					$0	0	0	0	**$0**	**$0**
	SUBTOTAL 6.	**$38,289**	**$0**	**$3,105**		**$41,394**	**$4,139**	**$0**	**$4,553**	**$50,087**	$91
7	HR, DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	9,027	0	919		$9,946	950	0	1,090	**$11,986**	$22
7.2	SCR System	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	7,998	0	5,296		$13,294	1,161	0	2,168	**$16,623**	$30
7.4	Stack	2,251	0	1,338		$3,589	343	0	393	**$4,325**	$8
7.9	Duct & Stack Foundations	0	622	752		$1,374	128	0	300	**$1,802**	$3
	SUBTOTAL 7.	**$19,276**	**$622**	**$8,305**		**$28,203**	**$2,583**	**$0**	**$3,952**	**$34,737**	$63
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	58,730	0	7,872		$66,602	6,377	0	7,298	**$80,277**	$145
8.2	Turbine Plant Auxiliaries	403	0	863		$1,266	123	0	139	**$1,528**	$3
8.3	Condenser & Auxiliaries	7,720	0	2,657		$10,377	986	0	1,136	**$12,499**	$23
8.4	Steam Piping	19,711	0	9,737		$29,448	2,458	0	4,786	**$36,691**	$66
8.9	TG Foundations	0	1,256	1,998		$3,254	306	0	712	**$4,272**	$8
	SUBTOTAL 8.	**$86,564**	**$1,256**	**$23,127**		**$110,946**	**$10,250**	**$0**	**$14,071**	**$135,267**	$245
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	9,834	0	3,065		$12,899	1,225	0	1,412	**$15,536**	$28
9.2	Circulating Water Pumps	1,388	0	194		$1,581	136	0	172	**$1,890**	$3
9.3	Circ.Water System Auxiliaries	584	0	78		$662	62	0	72	**$797**	$1
9.4	Circ.Water Piping	0	4,708	4,490		$9,198	847	0	1,507	**$11,552**	$21
9.5	Make-up Water System	518	0	686		$1,204	114	0	198	**$1,516**	$3
9.6	Component Cooling Water Sys	466	0	368		$834	78	0	137	**$1,049**	$2
9.9	Circ.Water System Foundations	0	2,725	4,361		$7,086	667	0	1,551	**$9,304**	$17
	SUBTOTAL 9.	**$12,790**	**$7,433**	**$13,242**		**$33,465**	**$3,130**	**$0**	**$5,049**	**$41,644**	$75

	Client:	U.S. DOE / NETL						**Report Date:**	28-Aug-07		
	Project:	Oxy-Fuel Combustion Systems Analysis									
					TOTAL PLANT COST DETAIL						
	Case:	Case 7 - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture									
	Plant Size:	552.36 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000	

Acct No.	**Item/Description**	**Equipment Cost**	**Material Cost**	**Labor Direct**	**Labor Indirect**	**Bare Erected Cost $**	**Eng'g CM H.O.& Fee**	**Contingencies Process**	**Contingencies Project**	**TOT. PLANT COST $**	**TOT. PLANT COST $/kW**
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	640	0	1,931		$2,571	250	0	282	**$3,104**	$6
10.7	Ash Transport & Feed Equipment	4,170	0	4,157		$8,327	787	0	911	**$10,026**	$18
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	151	176		$327	31	0	72	**$429**	$1
	SUBTOTAL 10.	**$4,810**	**$151**	**$6,264**		**$11,225**	**$1,068**	**$0**	**$1,265**	**$13,558**	$25
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	2,491	0	399		$2,890	268	0	237	**$3,394**	$6
11.2	Station Service Equipment	7,576	0	2,593		$10,169	972	0	836	**$11,977**	$22
11.3	Switchgear & Motor Control	9,003	0	1,542		$10,545	976	0	1,152	**$12,674**	$23
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$35
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$43
11.6	Protective Equipment	256	0	891		$1,147	112	0	126	**$1,385**	$3
11.7	Standby Equipment	1,923	0	44		$1,967	186	0	215	**$2,369**	$4
11.8	Main Power Transformers	10,345	0	264		$10,609	807	0	1,142	**$12,557**	$23
11.9	Electrical Foundations	0	474	1,176		$1,650	157	0	361	**$2,168**	$4
	SUBTOTAL 11.	**$31,594**	**$10,388**	**$31,528**		**$73,509**	**$6,565**	**$0**	**$9,712**	**$89,786**	$163
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	775	0	473		$1,248	120	62	215	**$1,645**	$3
12.7	Computer & Accessories	7,828	0	1,396		$9,224	878	461	1,056	**$11,620**	$21
12.8	Instrument Wiring & Tubing	4,324	0	8,588		$12,912	1,100	646	2,199	**$16,856**	$31
12.9	Other I & C Equipment	2,211	0	5,121		$7,332	714	367	841	**$9,254**	$17
	SUBTOTAL 12.	**$15,138**	**$0**	**$15,578**		**$30,716**	**$2,812**	**$1,536**	**$4,311**	**$39,375**	$71

	Client:	U.S. DOE / NETL							**Report Date:**	28-Aug-07		
	Project:	Oxy-Fuel Combustion Systems Analysis										
					TOTAL PLANT COST DETAIL							
	Case:	Case 7 - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture										
	Plant Size:	552.36 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000		
Acct No.	**Item/Description**	**Equipment Cost**	**Material Cost**	**Labor Direct**	**Labor Indirect**	**Bare Erected Cost $**	**Eng'g CM H.O.& Fee**	**Contingencies Process**	**Contingencies Project**	**TOT. PLANT COST $**	**TOT. PLANT COST $/kW**
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	48	972		$1,020	100	0	224	**$1,345**	$2
13.2	Site Improvements	0	1,571	2,004		$3,575	351	0	785	**$4,711**	$9
13.3	Site Facilities	2,808	0	2,852		$5,660	556	0	1,243	**$7,459**	$14
	SUBTOTAL 13.	**$2,808**	**$1,619**	**$5,828**		**$10,255**	**$1,007**	**$0**	**$2,252**	**$13,514**	$24
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	8,701	7,658		$16,359	1,469	0	2,674	**$20,502**	$37
14.2	Turbine Building	0	13,212	12,326		$25,538	2,299	0	4,176	**$32,013**	$58
14.3	Administration Building	0	550	602		$1,152	104	0	188	**$1,445**	$3
14.4	Circulation Water Pumphouse	0	317	252		$569	51	0	93	**$713**	$1
14.5	Water Treatment Buildings	0	904	770		$1,674	150	0	274	**$2,097**	$4
14.6	Machine Shop	0	363	261		$624	55	0	102	**$781**	$1
14.7	Warehouse	0	103	176		$279	25	0	46	**$350**	$1
14.8	Other Buildings & Structures	0	115	117		$232	21	0	38	**$291**	$1
14.9	Waste Treating Building & Str.	0	531	1,613		$2,144	203	0	352	**$2,699**	$5
	SUBTOTAL 14.	**$0**	**$24,796**	**$23,775**		**$48,571**	**$4,378**	**$0**	**$7,942**	**$60,891**	$110
	TOTAL COST	**$663,412**	**$51,657**	**$434,676**		**$1,149,745**	**$108,499**	**$45,476**	**$153,682**	**$1,457,403**	$2,639

INITIAL & ANNUAL O&M EXPENSES			28-Aug-2007		Cost Base:	Jan 2007 dollars
Case 7 - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture					Heat Rate-net(Btu/kWh)	12,162
Plant Output: Carbon Dioxide(tpd): 14,134					Mwe-net:	552.36
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00	$/hour				
Operating Labor Burden:	30.00	% of base				
Labor O-H Charge Rate:	25.00	% of Labor				
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.0	11.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.0	16.0				
					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$6,012,864	10.89
Maintenance Labor Cost					$9,791,297	17.73
Administrative & Support Labor					$2,936,773	5.32
TOTAL FIXED OPERATING COSTS					**$18,740,934**	**33.93**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$14,686,946	0.0036
Consumables			Unit	Initial		
	Initial	/Day	Cost	Cost		
Water(/1000 gallons)		9,364	$1.03	$0	$2,992,439	0.0007
Chemicals						
MU & WT Chem.(lbs)	317,305	45,329	$0.16	$52,292	$2,317,652	0.0006
Limestone (Tons)	4,225	603.6	$20.60	$87,036	$3,857,545	0.0009
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	1,001	0.0	$2,142.40	$2,144,733	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	0	0.0	$123.60	$0	$0	0.0000
Subtotal Chemicals				$2,284,060	$6,175,197	0.0015
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		465	$15.45		$2,231,055	0.0005
Bottom Ash (tons)		116	$15.45		$557,764	0.0001
Subtotal-Waste Disposal					$2,788,819	0.0007
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$26,643,400**	0.0065
Fuel - Coal (Tons)	180,000	6,000	$42.11	$7,579,811	**$78,387,877**	0.0191
Fuel - Natural Gas (Mscf)	620,473	20,682	$6.93	$4,301,276	**$44,482,360**	0.0108

6.3.3.2 Case 7A – Supercritical ITM Oxycombustion with CO_2 Purification

	Client:	U.S. DOE / NETL								**Report Date:**	28-Aug-07		
	Project:	Case 7A - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture											
		TOTAL PLANT COST DETAIL											
	Case:	Case 7A - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture											
	Plant Size:	552.75 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007			$x1000		
Acct No.	**Item/Description**	**Equipment Cost**	**Material Cost**	**Labor**		**Bare Erected Cost $**	**Eng'g CM H.O.& Fee**	**Contingencies**		**TOT. PLANT COST**			
				Direct	**Indirect**			**Process**	**Project**	**$**	**$/kW**		
1	COAL & SORBENT HANDLING												
1.1	Coal Receive & Unload	3,613	0	1,637		$5,250	469	0	858	**$6,577**	$12		
1.2	Coal Stackout & Reclaim	4,675	0	1,047		$5,722	501	0	933	**$7,156**	$13		
1.3	Coal Conveyors & Yard Breaker	4,348	0	1,037		$5,385	472	0	879	**$6,736**	$12		
1.4	Other Coal Handling	1,138	0	239		$1,377	120	0	225	**$1,722**	$3		
1.5	Sorbent Receive & Unload	145	0	43		$188	17	0	31	**$235**	$0		
1.6	Sorbent Stackout & Reclaim	2,334	0	423		$2,757	240	0	450	**$3,447**	$6		
1.7	Sorbent Conveyors	833	177	202		$1,212	105	0	198	**$1,514**	$3		
1.8	Other Sorbent Handling	504	116	261		$881	78	0	144	**$1,103**	$2		
1.9	Coal & Sorbent Hnd.Foundations	0	4,418	5,545		$9,963	931	0	1,634	**$12,528**	$23		
	SUBTOTAL 1.	**$17,590**	**$4,711**	**$10,434**		**$32,735**	**$2,933**	**$0**	**$5,350**	**$41,018**	$74		
2	COAL & SORBENT PREP & FEED												
2.1	Coal Crushing & Drying	2,074	0	400		$2,474	216	0	403	**$3,093**	$6		
2.2	Coal Conveyor to Storage	5,310	0	1,147		$6,457	565	0	1,053	**$8,075**	$15		
2.3	Coal Injection System	0	0	0		$0	0	0	0	**$0**	$0		
2.4	Misc.Coal Prep & Feed	0	0	0		$0	0	0	0	**$0**	$0		
2.5	Sorbent Prep Equipment	3,965	169	814		$4,948	431	0	807	**$6,186**	$11		
2.6	Sorbent Storage & Feed	479	0	181		$660	59	0	108	**$826**	$1		
2.7	Sorbent Injection System	0	0	0		$0	0	0	0	**$0**	$0		
2.8	Booster Air Supply System	0	0	0		$0	0	0	0	**$0**	$0		
2.9	Coal & Sorbent Feed Foundation	0	512	404		$916	84	0	150	**$1,150**	$2		
	SUBTOTAL 2.	**$11,828**	**$681**	**$2,946**		**$15,455**	**$1,355**	**$0**	**$2,521**	**$19,331**	$35		
3	FEEDWATER & MISC. BOP SYSTEMS												
3.1	Feedwater System	20,148	0	6,456		$26,604	2,329	0	4,340	**$33,273**	$60		
3.2	Water Makeup & Pretreating	10,207	0	3,211		$13,418	1,258	0	2,935	**$17,611**	$32		
3.3	Other Feedwater Subsystems	6,227	0	2,585		$8,812	785	0	1,440	**$11,037**	$20		
3.4	Service Water Systems	2,013	0	1,066		$3,079	286	0	673	**$4,038**	$7		
3.5	Other Boiler Plant Systems	7,394	0	7,080		$14,474	1,358	0	2,375	**$18,206**	$33		
3.6	FO Supply Sys & Nat Gas	279	0	337		$616	57	0	101	**$774**	$1		
3.7	Waste Treatment Equipment	6,876	0	3,859		$10,735	1,040	0	2,355	**$14,130**	$26		
3.8	Misc. Power Plant Equipment	2,897	0	875		$3,772	362	0	827	**$4,961**	$9		
	SUBTOTAL 3.	**$56,041**	**$0**	**$25,469**		**$81,510**	**$7,476**	**$0**	**$15,045**	**$104,031**	$188		
4	PC BOILER & ACCESSORIES												
4.1	PC BOILER	170,772	0	96,297		$267,069	25,868	43,941	29,294	**$366,172**	$662		
4.2	ASU/Oxidant Compression	88,641	0	72,524		$161,165	15,611	0	17,678	**$194,453**	$352		
4.3	Open	0	0	0		$0	0	0	0	**$0**	$0		
4.4	Boiler BOP (w/ID Fans)	0	0	0		$0	0	0	0	**$0**	$0		
4.5	Primary Air System	0	0	0		$0	0	0	0	**$0**	$0		
4.6	Secondary Air System	0	0	0		$0	0	0	0	**$0**	$0		
4.8	Major Component Rigging	0	0	0		$0	0	0	0	**$0**	$0		
4.9	PC Foundations	0	0	0		$0	0	0	0	**$0**	$0		
	SUBTOTAL 4.	**$259,413**	**$0**	**$168,821**		**$428,234**	**$41,479**	**$43,941**	**$46,971**	**$560,625**	$1,014		

Client: U.S. DOE / NETL | **Report Date:** 28-Aug-07

Project: Oxy-Fuel Combustion Systems Analysis

TOTAL PLANT COST DETAIL

Case: Case 7A - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture

Plant Size: 552.75 MW,net | **Estimate Type:** | **Cost Base (Jan)** 2007 | $x1000

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
5.0	FLUE GAS CLEANUP										
5.1	Absorber Vessels & Accessories	25,097	0	29,857		$54,954	5,201	0	6,015	**$66,170**	$120
5.2	Other FGD	2,398	0	2,762		$5,160	497	0	566	**$6,223**	$11
5.3	Baghouse & Accessories	18,706	0	13,900		$32,606	3,119	0	3,572	**$39,297**	$71
5.4	Other Particulate Removal Materials	895	0	975		$1,870	180	0	205	**$2,255**	$4
5.5	Gypsum Dewatering System	15,667	0	16,531		$32,198	3,042	0	3,524	**$38,764**	$70
5.6	Mercury Removal System		0			$0	0	0	0	**$0**	$0
5.7	Open	0	0	0		$0	0	0	0	**$0**	$0
5.9	Open	0	0	0		$0	0	0	0	**$0**	$0
	SUBTOTAL 5.	**$62,763**	**$0**	**$64,024**		**$126,786**	**$12,039**	**$0**	**$13,883**	**$152,708**	$276
5B	CO2 REMOVAL & COMPRESSION										
5B.1	CO2 Removal System	0	0	0		$0	0	0	0	**$0**	**$0**
5B.2	CO2 Compression & Drying	60,577	0	43,866		$104,443	9,915	0	22,872	**$137,230**	**$248**
	SUBTOTAL 5B.	**$60,577**	**$0**	**$43,866**		**$104,443**	**$9,915**	**$0**	**$22,872**	**$137,230**	**$248**
6	NITROGEN EXPANDER GENERATOR										
6.1	Nitrogen Expander Generator	38,289		3,105		$41,394	4,139	0	4,553	**$50,087**	**$91**
6.2	Nitrogen Expander Generator Accessories					$0	0	0	0	**$0**	**$0**
6.3	Compressed Air Piping					$0	0	0	0	**$0**	**$0**
6.9	Nitrogen Expander Generator Foundations					$0	0	0	0	**$0**	**$0**
	SUBTOTAL 6.	**$38,289**	**$0**	**$3,105**		**$41,394**	**$4,139**	**$0**	**$4,553**	**$50,087**	$91
7	HR, DUCTING & STACK										
7.1	Flue Gas Recycle Heat Exchanger	9,022	0	919		$9,941	950	0	1,089	**$11,980**	$22
7.2	SCR System	0	0	0		$0	0	0	0	**$0**	$0
7.3	Ductwork	7,998	0	5,296		$13,294	1,161	0	2,168	**$16,623**	$30
7.4	Stack	2,251	0	1,338		$3,589	343	0	393	**$4,325**	$8
7.9	Duct & Stack Foundations	0	622	752		$1,374	128	0	300	**$1,802**	$3
	SUBTOTAL 7.	**$19,271**	**$622**	**$8,305**		**$28,198**	**$2,582**	**$0**	**$3,951**	**$34,731**	$63
8	STEAM TURBINE GENERATOR										
8.1	Steam TG & Accessories	58,724	0	7,872		$66,595	6,376	0	7,297	**$80,269**	$145
8.2	Turbine Plant Auxiliaries	403	0	863		$1,266	123	0	139	**$1,528**	$3
8.3	Condenser & Auxiliaries	7,719	0	2,656		$10,376	986	0	1,136	**$12,498**	$23
8.4	Steam Piping	19,709	0	9,736		$29,445	2,457	0	4,785	**$36,687**	$66
8.9	TG Foundations	0	1,256	1,998		$3,253	306	0	712	**$4,271**	$8
	SUBTOTAL 8.	**$86,555**	**$1,256**	**$23,124**		**$110,935**	**$10,249**	**$0**	**$14,069**	**$135,253**	$245
9	COOLING WATER SYSTEM										
9.1	Cooling Towers	9,833	0	3,065		$12,898	1,224	0	1,412	**$15,534**	$28
9.2	Circulating Water Pumps	1,388	0	194		$1,581	136	0	172	**$1,889**	$3
9.3	Circ.Water System Auxiliaries	584	0	78		$662	62	0	72	**$797**	$1
9.4	Circ.Water Piping	0	4,707	4,489		$9,197	847	0	1,507	**$11,551**	$21
9.5	Make-up Water System	518	0	686		$1,204	114	0	198	**$1,516**	$3
9.6	Component Cooling Water Sys	466	0	368		$834	78	0	137	**$1,049**	$2
9.9	Circ.Water System Foundations	0	2,725	4,360		$7,086	667	0	1,550	**$9,303**	$17
	SUBTOTAL 9.	**$12,788**	**$7,432**	**$13,240**		**$33,461**	**$3,130**	**$0**	**$5,048**	**$41,639**	$75

	Client:	U.S. DOE / NETL						**Report Date:**	28-Aug-07		
	Project:	Oxy-Fuel Combustion Systems Analysis									
				TOTAL PLANT COST DETAIL							
	Case:	Case 7A - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture									
	Plant Size:	552.75 MW,net		**Estimate Type:**				**Cost Base (Jan)** 2007		$x1000	

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost $	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	TOT. PLANT COST $	TOT. PLANT COST $/kW
10	ASH/SPENT SORBENT HANDLING SYS										
10.1	Ash Coolers	0	0	0		$0	0	0	0	**$0**	$0
10.2	Cyclone Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.3	HGCU Ash Letdown	0	0	0		$0	0	0	0	**$0**	$0
10.4	High Temperature Ash Piping	0	0	0		$0	0	0	0	**$0**	$0
10.5	Other Ash Recovery Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.6	Ash Storage Silos	640	0	1,931		$2,571	250	0	282	**$3,104**	$6
10.7	Ash Transport & Feed Equipment	4,170	0	4,157		$8,327	787	0	911	**$10,026**	$18
10.8	Misc. Ash Handling Equipment	0	0	0		$0	0	0	0	**$0**	$0
10.9	Ash/Spent Sorbent Foundations	0	151	176		$327	31	0	72	**$429**	$1
	SUBTOTAL 10.	**$4,810**	**$151**	**$6,264**		**$11,225**	**$1,068**	**$0**	**$1,265**	**$13,558**	$25
11	ACCESSORY ELECTRIC PLANT										
11.1	Generator Equipment	2,491	0	399		$2,890	268	0	237	**$3,394**	$6
11.2	Station Service Equipment	7,571	0	2,592		$10,163	972	0	835	**$11,971**	$22
11.3	Switchgear & Motor Control	8,998	0	1,542		$10,539	976	0	1,152	**$12,667**	$23
11.4	Conduit & Cable Tray	0	3,523	11,989		$15,512	1,485	0	2,549	**$19,546**	$35
11.5	Wire & Cable	0	6,390	12,630		$19,020	1,603	0	3,093	**$23,716**	$43
11.6	Protective Equipment	256	0	891		$1,147	112	0	126	**$1,385**	$3
11.7	Standby Equipment	1,923	0	44		$1,967	186	0	215	**$2,369**	$4
11.8	Main Power Transformers	10,345	0	264		$10,609	807	0	1,142	**$12,557**	$23
11.9	Electrical Foundations	0	474	1,176		$1,650	157	0	361	**$2,168**	$4
	SUBTOTAL 11.	**$31,584**	**$10,388**	**$31,526**		**$73,498**	**$6,564**	**$0**	**$9,711**	**$89,773**	$162
12	INSTRUMENTATION & CONTROL										
12.1	PC Control Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.2	Combustion Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.3	Steam Turbine Control	0	0	0		$0	0	0	0	**$0**	$0
12.4	Other Major Component Control	0	0	0		$0	0	0	0	**$0**	$0
12.5	Signal Processing Equipment	0	0	0		$0	0	0	0	**$0**	$0
12.6	Control Boards,Panels & Racks	775	0	473		$1,248	120	62	215	**$1,645**	$3
12.7	Computer & Accessories	7,828	0	1,396		$9,224	878	461	1,056	**$11,620**	$21
12.8	Instrument Wiring & Tubing	4,324	0	8,588		$12,912	1,100	646	2,199	**$16,856**	$30
12.9	Other I & C Equipment	2,211	0	5,121		$7,332	714	367	841	**$9,254**	$17
	SUBTOTAL 12.	**$15,138**	**$0**	**$15,578**		**$30,716**	**$2,812**	**$1,536**	**$4,311**	**$39,375**	$71

	Client: U.S. DOE / NETL							**Report Date:** 28-Aug-07			
	Project: Oxy-Fuel Combustion Systems Analysis										
	TOTAL PLANT COST DETAIL										
	Case: Case 7A - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture										
	Plant Size: 552.75 MW,net		**Estimate Type:**					**Cost Base (Jan)** 2007		$x1000	
Acct		**Equipment**	**Material**	**Labor**		**Bare Erected**	**Eng'g CM**	**Contingencies**		**TOT. PLANT COST**	
No.	**Item/Description**	**Cost**	**Cost**	**Direct**	**Indirect**	**Cost $**	**H.O.& Fee**	**Process**	**Project**	**$**	**$/kW**
13	IMPROVEMENTS TO SITE										
13.1	Site Preparation	0	48	972		$1,020	100	0	224	**$1,345**	$2
13.2	Site Improvements	0	1,571	2,004		$3,575	351	0	785	**$4,711**	$9
13.3	Site Facilities	2,808	0	2,852		$5,660	556	0	1,243	**$7,459**	$13
	SUBTOTAL 13.	**$2,808**	**$1,619**	**$5,828**		**$10,255**	**$1,007**	**$0**	**$2,252**	**$13,514**	$24
14	BUILDINGS & STRUCTURES										
14.1	Boiler Building	0	8,701	7,658		$16,359	1,469	0	2,674	**$20,502**	$37
14.2	Turbine Building	0	13,212	12,326		$25,538	2,299	0	4,176	**$32,013**	$58
14.3	Administration Building	0	550	602		$1,152	104	0	188	**$1,445**	$3
14.4	Circulation Water Pumphouse	0	317	252		$569	51	0	93	**$713**	$1
14.5	Water Treatment Buildings	0	904	770		$1,674	150	0	274	**$2,097**	$4
14.6	Machine Shop	0	363	261		$624	55	0	102	**$781**	$1
14.7	Warehouse	0	103	176		$279	25	0	46	**$350**	$1
14.8	Other Buildings & Structures	0	115	117		$232	21	0	38	**$291**	$1
14.9	Waste Treating Building & Str.	0	531	1,613		$2,144	203	0	352	**$2,699**	$5
	SUBTOTAL 14.	**$0**	**$24,796**	**$23,775**		**$48,571**	**$4,378**	**$0**	**$7,942**	**$60,891**	$110
	TOTAL COST	**$679,456**	**$51,656**	**$446,304**		**$1,177,416**	**$111,126**	**$45,476**	**$159,745**	**$1,493,763**	$2,702

INITIAL & ANNUAL O&M EXPENSES			28-Aug-2007		Cost Base:	Jan 2007 dollars
Case 7A - ITM Oxy-Fuel Super-Critical PC w/ CO2 Capture					Heat Rate-net(Btu/kWh)	12,154
Plant Output: Carbon Dioxide(tpd): 13,257					Mwe-net:	552.75
					Capacity Factor: (%):	85.0%
OPERATING & MAINTENANCE LABOR						
Operating Labor						
Operating Labor Rate(base):	33.00 $/hour					
Operating Labor Burden:	30.00 % of base					
Labor O-H Charge Rate:	25.00 % of Labor					
Operating Labor Requirements(O.J.)per Shift:						
	Per unit	Total Plant				
Skilled Operator	2.0	2.0				
Operator	11.0	11.0				
Foreman	1.0	1.0				
Lab Tech's, etc.	2.0	2.0				
TOTAL -O.J.'s	16.0	16.0				
					Annual Cost	Annual Unit Cost
					$	$/kW-net
Annual Operating Labor Cost					$6,012,864	10.88
Maintenance Labor Cost					$10,035,580	18.16
Administrative & Support Labor					$2,936,773	5.31
TOTAL FIXED OPERATING COSTS					**$18,985,217**	**34.35**
VARIABLE OPERATING COSTS						
						$/kWH-net
Maintenance Material Cost					$15,053,370	0.0037
Consumables	Initial	/Day	Unit Cost	Initial Cost		
Water(/1000 gallons)		9,363	$1.03	$0	$2,991,979	0.0007
Chemicals						
MU & WT Chem.(lbs)	317,256	45,322	$0.16	$52,284	$2,317,296	0.0006
Limestone (Tons)	4,225	603.6	$20.60	$87,036	$3,857,545	0.0009
Carbon (lbs)	0	0.0	$1.00	$0	$0	0.0000
MEA Solvent (Ton)	939	0.0	$2,142.40	$2,011,703	$0	0.0000
Sulfuric Acid (Ton)	0.00	0.00	$132.15	$0	$0	0.0000
Caustic Soda (Ton)	0.00	0.00	$412.96	$0	$0	0.0000
Ammonia (28% NH3) ton	0	0.0	$123.60	$0	$0	0.0000
Subtotal Chemicals				$2,151,023	$6,174,840	0.0015
Other						
Subtotal Other					$0	0.0000
Waste Disposal						
Flyash (tons)		465	$15.45		$2,231,055	0.0005
Bottom Ash (tons)		116	$15.45		$557,764	0.0001
Subtotal-Waste Disposal					$2,788,819	0.0007
Byproducts & Emissions						
Gypsum (Tons)		0	$0.00		$0	0.0000
Subtotal Byproducts						
TOTAL VARIABLE OPERATING COSTS					**$27,009,007**	0.0066
Fuel - Coal (Tons)	180,000	6,000	$42.11	$7,579,811	**$78,387,877**	0.0190
Fuel - Natural Gas (Mscf)	620,473	20,682	$6.93	$4,301,276	**$44,482,360**	0.0108

7. RESULTS AND RECOMMENDATIONS

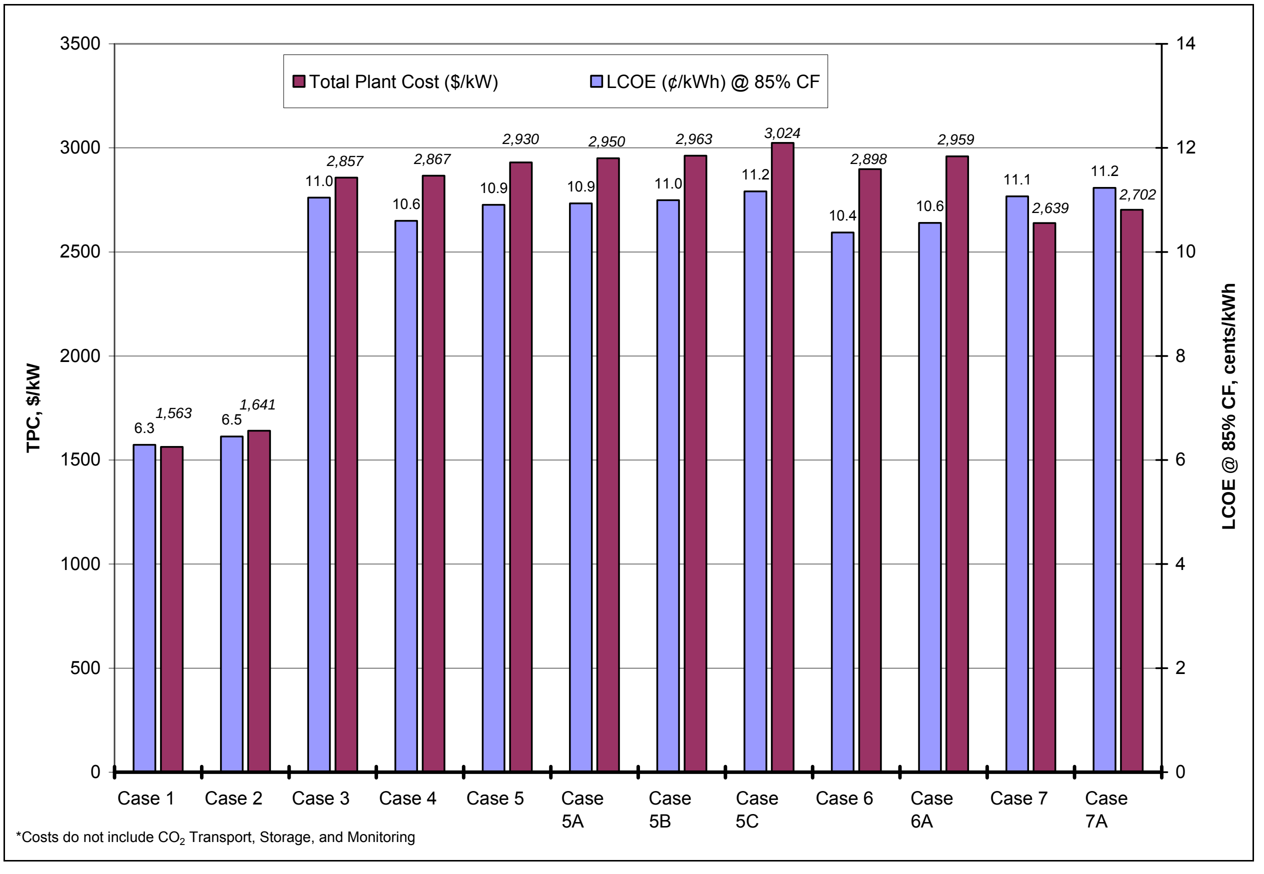
The results of this systems analysis study are discussed below in relation to the two main objectives set forth in the statement of work.

7.1 COST AND PERFORMANCE BASELINE

The eight oxycombustion cases presented in this report cover a range of oxygen purities, oxygen production technologies, CO_2 product purities and advanced steam cycles. The combination of parameters studied provides a sound basis for comparing previous and future oxycombustion cases. The design and costing basis in these studies is well-defined which allows for an "apples-to-apples" comparison of cases in this report. Furthermore, the results presented here can be compared to other references as long as the reference study provides a like amount of detail.

The total plant costs and LCOE's for all 12 cases are shown in Exhibit 7-1.

Exhibit 7-1 Total Plant Cost and LCOE for All Cases



The LCOE tracks capital cost fairly well except for the two ITM cases (7 and 7A). The ITM cases have several cost trade-offs and the end result is a slightly higher LCOE than the cryogenic oxycombustion cases. First, according to the ITM process developers the process itself has a capital cost that is about 30% less than a cryogenic plant producing the same amount of oxygen.

(ITM technology has not been demonstrated at the scale shown in this report). The main capital cost savings realized by the ITM process comes from the smaller boiler and downstream equipment that is required because of less power required from the steam turbine. Less power is required from the steam turbine because the vitiated gas stream exiting the ITM process, after being used to preheat the incoming air, provides an additional 207 MW of power by passing through parallel expansion turbines. The result is a higher gross power output (over 900 MW) than the other oxycombustion cases. The ITM cases use about 120 MW more auxiliary power than the comparable cryogenic cases (primarily because the air is compressed to 200 psia in the ITM cases but only 86 psia in the cryogenic cases), but the ITM steam turbine still generates 80 MW less power than the cryogenic cases to maintain a net output of 550 MW. The reduction in cost of the boiler and related equipment more than offsets the capital cost of the expansion turbine/generator. The LCOE of the ITM process, however, is still higher than the cryogenic cases because of the natural gas required to heat the air from 1060°F to 1475°F. The coal plus natural gas in the ITM cases contributes 3.59 ¢/kWh to the COE, while the coal only in the cryogenic cases contributes 2.24 to 2.62 ¢/kWh. The fuel cost increase more than offsets the capital cost decrease.

The LCOE for air-based cases without CO_2 capture is 6.29 ¢/kWh for supercritical steam conditions and 6.45 ¢/kWh for ultra-supercritical conditions. Adding amine-based CO_2 capture to the air-based cases increases the COE to 11.04 and 10.60 ¢/kWh for supercritical and ultra-supercritical conditions respectively, an average increase of about 70%.

For the cryogenic supercritical oxycombustion cases, changing the O_2 purity and CO_2 purity requirements has only a minimal impact on the COE with a range of 10.90-11.16 ¢/kWh. The average increase in LCOE over the air-based supercritical case with no CO_2 capture is 75%, which is slightly lower than the 78% increase for the amine-based capture process. The ultra-supercritical cases have an average LCOE of 10.46 ¢/kWh with a range of 10.37-10.56 ¢/kWh for the range of CO_2 purities required. The average LCOE increase for an oxycombustion ultra-supercritical boiler over the reference air-based case with no capture is 65%.

The additional cost for CO_2 transporting, storing and monitoring (TS&M) in the cases with carbon capture, was also estimated based on reference data and scaled estimates (see Section 2.8.4). These values, shown in Exhibit 7-2, increase the LCOE for each CO_2 capture case by approximately 3.5%. This additional cost was not included in the sensitivity calculations.

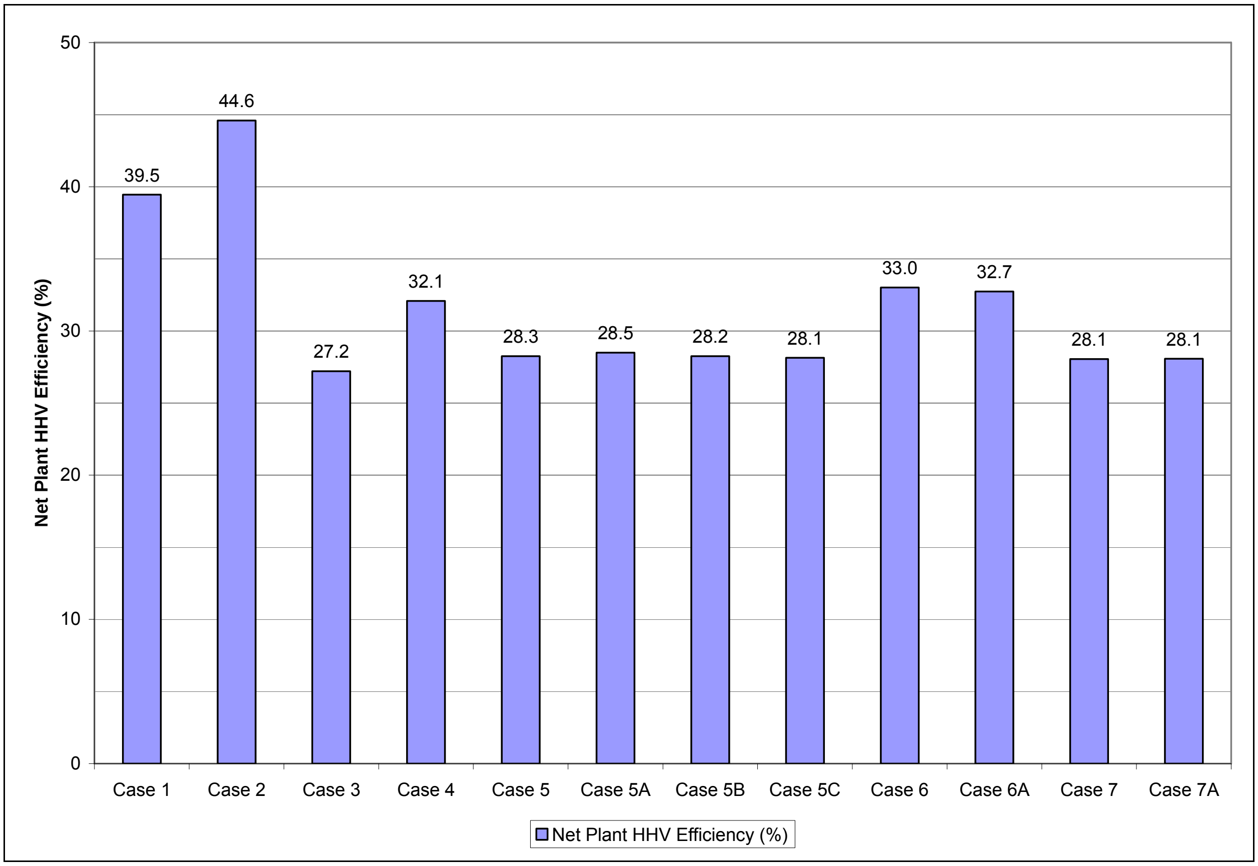
Exhibit 7-2 Levelized Cost of Electricity for CO_2 Transport, Storage, and Monitoring

Study Case	**20 yr Levelized Costs (¢/kWh)**				
	CO_2 Transport	CO_2 Storage	CO_2 Monitoring	LCOE w/o TS&M	**Total LCOE**
Case 3, Air-fired SC w/Econamine CO_2 Capture	0.26	0.04	0.10	11.04	11.44
Case 4, Air-fired USC w/Econamine CO_2 Capture	0.26	0.04	0.08	10.60	10.98
Case 5, O_2-fired SC w/ASU & CO_2 Capture	0.26	0.04	0.10	10.90	11.30
Case 6, O_2-fired USC w/ASU & CO_2 Capture	0.24	0.04	0.08	10.37	10.73
Case 7, O_2-fired SC w/ITM & CO_2 Capture	0.24	0.04	0.08	11.07	11.43

Net plant efficiency is negatively impacted by the high auxiliary loads imposed by CO_2 capture and compression systems whether through an amine system for air-based combustion or through the oxycombustion system. Exhibit 7-3 shows the net plant efficiency for all 12 cases.

The ultra-supercritical steam cycle has the most impact on net efficiency. In the air-based non-CO_2 capture cases, the ultra-supercritical efficiency is 44.6% compared to the supercritical efficiency of 39.5%. For cases with CO_2 capture, the highest efficiencies are for the three ultra-supercritical cases (4, 6 and 6A). The air-based amine CO_2 capture system has a net efficiency of 32.1% while the two ultra-supercritical oxycombustion systems have net efficiencies of 33.0 and 32.7%. The lowest net efficiency is for the air-based supercritical case with CO_2 capture at 27.2%. The four supercritical cryogenic oxycombustion cases have nearly identical efficiencies (28.1-28.5%). Just as oxygen and CO_2 purity level had little impact on LCOE, likewise they have little impact on plant efficiency. The two supercritical ITM cases have efficiencies equal to the supercritical cryogenic cases (28.1%).

Exhibit 7-3 Net Plant Efficiency for All Study Cases



All cases were designed to meet BACT standards as defined in Section 2.5. The oxycombustion cases far exceed the BACT standards, and in cases with no additional CO_2 purification, there are zero air emissions. The control measures taken for each pollutant are defined below:

- Wet limestone FGD (98% efficient) for SO_2 control. In the air-based cases with CO_2 capture, an SO_2 polishing step reduces the concentration to 10 ppmv and the balance is removed by the amine solution resulting in negligible emissions.
- LNBs, OFA and SCR for NOx control in the air-based cases and LNBs, OFO and FGR in the oxycombustion cases. It was assumed that the combination of technologies could achieve 0.07 lb/MMBtu exiting the boiler in all cases.
- Fabric filter (99.8% efficient) for particulate control.
- Co-benefit capture of mercury (90% efficient) in the fabric filter and FGD units.

The co-benefit capture of mercury is predicated on the relatively high chlorine content of the Illinois No. 6 coal which will promote oxidation of the elemental mercury, and in the air-based cases the SCR unit will also promote Hg oxidation. The oxidized Hg will then be removed in the baghouse and in the FGD process. B&W has limited data to support the increased Hg oxidation in an oxycombustion boiler.

The oxycombustion cases with no CO_2 purification have a single gas phase emission point. The flue gas exiting the FGD unit is either recycled to the boiler or sent to the CO_2 drying and compression system. A temperature swing absorption unit in the CO_2 process removes water, but remaining SO_2, NOx, O_2, and Ar are co-sequestered with the CO_2. For this study it was assumed that co-sequestration is possible without requiring special materials or equipment. In the no purification co-sequestration cases (5, 5A, 6 and 7) gas phase emissions of all criteria pollutants are zero.

In cases where the CO_2 is further purified through a series of auto-refrigeration flash steps; there is a single gas phase emission point. A portion of the CO_2 is lost to the vent stream along with some SO_2 and NOx. The non-volatile components (Hg and particulate) were assumed to split between the vent stream and product stream in the same ratio as the total flow rates. Emissions for each case are shown in Exhibit 7-4.

The general trend for oxycombustion emissions is that as CO_2 purity increases so do air emissions. The purification process requires that volatile components like SO_2 and NOx be separated from the main product stream; and as greater purity is required, more of the non-CO_2 components must be separated. In the process some CO_2 is also vented thus increasing CO_2 emissions. However, even in the cases with the greatest CO_2 purity (5C, 6A and 7A), the air emissions are still well below BACT standards.

While the air-based cases also meet BACT standards, the emissions are significantly greater than for the oxycombustion cases. If co-sequestration is proven economically feasible and CO_2 purity is not an issue, the oxycombustion cases result in near zero emissions.

Exhibit 7-4 Air Emissions for All Cases

Pollutant	Case 1	Case 2	Case 3	Case 4	Case 5	Case 5A	Case 5B	Case 5C	Case 6	Case 6A	Case 7	Case 7A
SO_2, lb/MMBtu	0.085	0.085	Neg.	Neg.	0	0	0.003	0.008	0	0.020	0	0.018
SO_2, lb/MWh	0.733	0.649	Neg.	Neg.	0	0	0.038	0.099	0	0.213	0	0.215
SO_2, TPY	1,511	1,343	Neg.	Neg.	0	0	78	200	0	437	0	443
NOx, lb/MMBtu	0.070	0.070	0.070	0.070	0	0	0.070	0.070	0	0.070	0.001	0.062
NOx, lb/MWh	0.605	0.536	0.878	0.744	0	0	0.846	0.849	0	0.729	0.013	0.654
NOx, TPY	1,248	1,108	1,793	1,510	0	0	1,719	1,719	0	1,494	26	1,346
Particulate, lb/MMBtu	0.013	0.013	0.013	0.013	0	0	0.001	0.002	0	0.002	0	0.002
Particulate, lb/MWh	0.112	0.099	0.163	0.138	0	0	0.009	0.021	0	0.018	0	0.015
Particulate, TPY	232	206	333	280	0	0	19	42	0	36	0	31
CO_2, lb/MMBtu	203	203	20	20	0	0	6	12	0	13	16	27
CO_2, lb/MWh	1,759	1,556	254	216	0	0	67	144	0	131	191	323
CO_2, TPY	3,625,814	3,219,694	519,185	437,401	0	0	136,524	291,909	0	267,401	392,167	664,025
Hg, lb/TBtu	1.14	1.14	1.14	1.14	0	0	0.07	0.15	0	0.15	0	0.11
Hg, lb/TWh	9.88	8.74	14.30	12.20	0	0	0.81	1.81	0	1.55	0	1.30
Hg, TPY	0.020	0.018	0.029	0.025	0	0	0.002	0.004	0	0.003	0	0.003

Neg. = Negligible

7.2 BARRIERS TO ACHIEVING DOE'S ECONOMIC GOAL

The results of the system studies presented in this report indicate that the baseline oxycombustion concepts currently do not reach DOE's goal of no more than a 20% increase in the cost of electricity for 90% CO_2 capture relative to a non-capture configuration. There are, however, a number of possibilities that could help to approach this goal.

7.2.1 Eliminate FGD

In theory, the oxycombustion cases don't require FGD and the SO_2 could be co-sequestered with the CO_2 and NOx. However, since oxycombustion employs flue gas recycle, the concentrations of constituents in the flue gas stream increase. This increase varies slightly depending on boiler efficiency (fuel flow and oxygen flow) and air infiltration, but the concentrations of the constituents in the flue gas increase by a factor of 3.4 to 3.5. As a result, unless sulfur is removed from the flue gas leaving the boiler, the sulfur within the boiler and connecting ductwork in the recycle path for a 2.5% sulfur coal is equivalent to the concentration of a coal containing 8.7% sulfur. Since the practical design limit for boiler materials to avoid excessive corrosion is about a 3.5% sulfur coal, a scrubber would not be required for coals with about 1% sulfur or less. Thus, when burning a low sulfur coal (< 1%), the FGD system could be eliminated.

Eliminating SO_2 control eliminates the capital cost of the FGD unit, the gypsum dewatering system, limestone receiving and handling, and limestone feed preparation. There is also a reduction in operating cost, primarily due to the elimination of the limestone and the reduction in auxiliary power load.

Meeting the coal sulfur requirement of < 1 wt% most likely would require Powder River Basin (PRB) coal. The higher moisture content and lower heating value of PRB coal could translate to lower efficiency. For the purpose of this study, it was assumed that these issues could be handled without an increase in plant capital cost.

The impact in LCOE from eliminating the FGD (case SA) is shown in Exhibit 7-5. LCOE is reduced from 10.37 cents/kWh for case 6 to 9.50 cents/kWh, a reduction of 8.5%, but still 51% higher than the reference case (case 1).

7.2.2 Eliminate Boiler Contingency

A 15% boiler process contingency was included in the capital costs to account for the lack of commercial scale operating experience with an oxycombustion boiler. Am additional 10% boiler process contingency was added for the ultrasupercritical cases. If the technology is demonstrated at the estimated cost, the process contingencies can be eliminated. Eliminating the contingency on the boiler (case SB) further reduces the LCOE to 9.11 cents/kWh or an additional 4% reduction, but still 45% higher than case 1.

7.2.3 Reduction in Capital and Operating Cost for the ASU

An analysis was performed to determine what reduction in ASU capital and variable operating costs would be required to achieve the DOE LCOE target. Exhibit 7-6 shows a graph with the combination of ASU operating and TPC costs that would satisfy the goal. For example, if the TPC was reduced to 50% of a conventional cryogenic ASU then the operating cost would have to be reduced to 38%.

Assuming the capital and operating cost were reduced by the same fraction, reductions of 55% would be required. This is case SC resulting in a LCOE of 7.55 cents/kWh, as shown in Exhibit 7-5.

Exhibit 7-5 LCOE for Sensitivity Cases

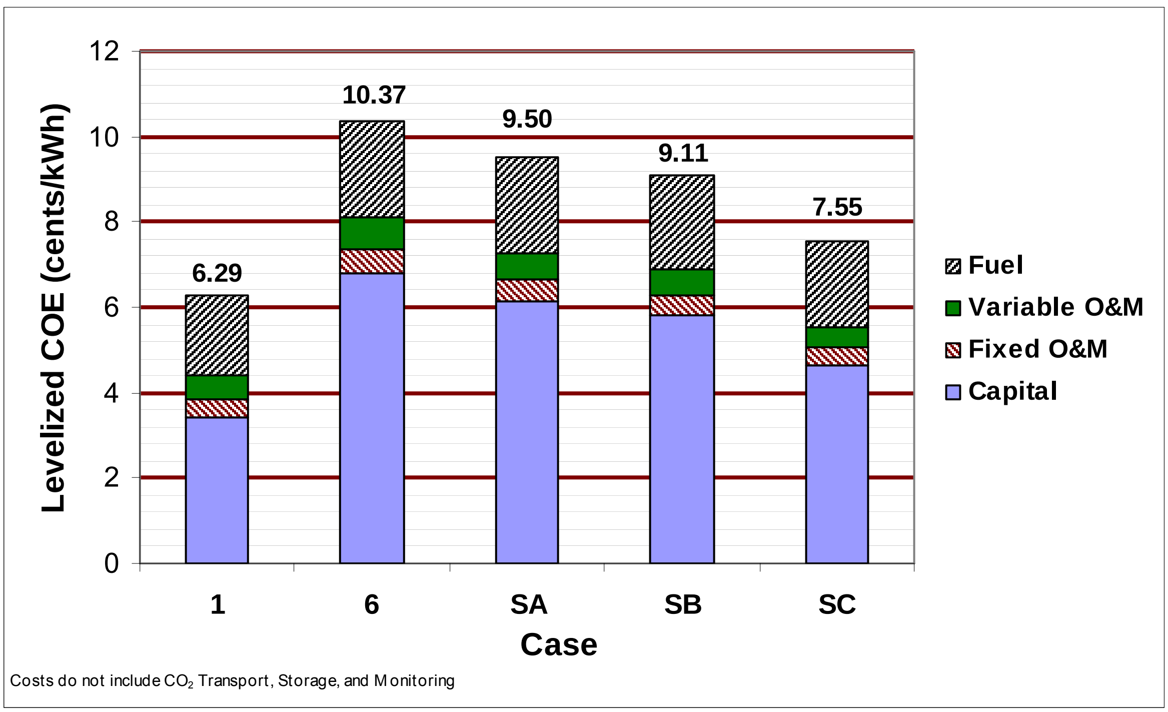
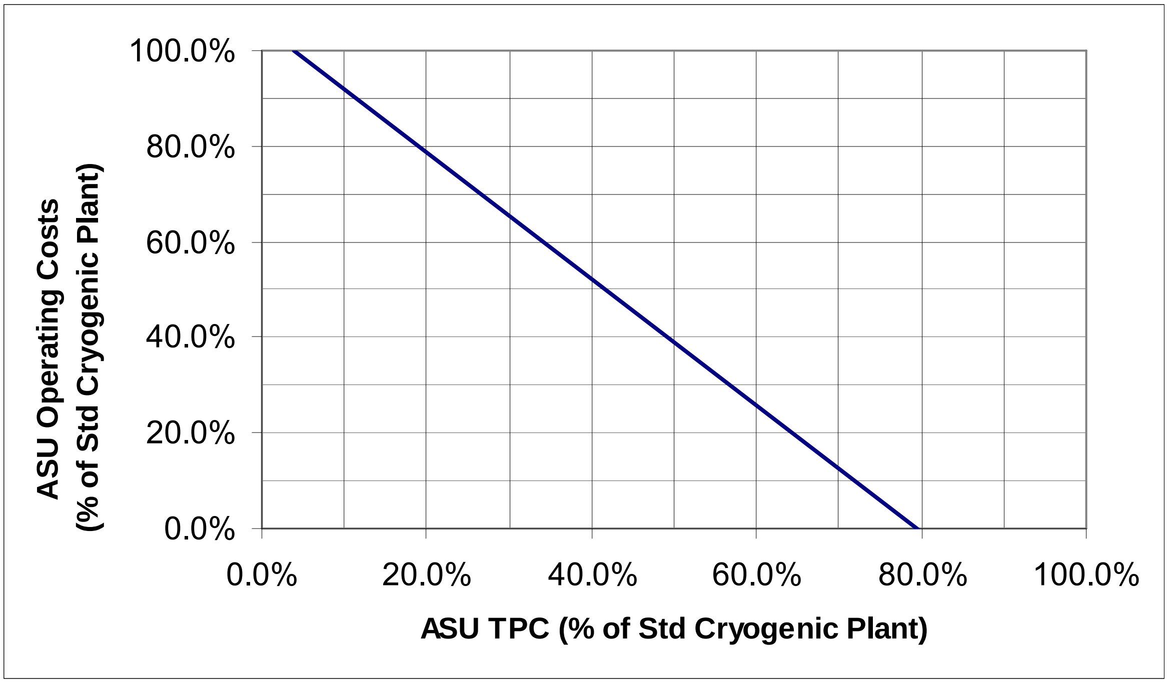


Exhibit 7-6 ASU Capital and Operating Cost Requirements



7.2.4 Additional Considerations

In addition to the potential improvements that could lower oxycombustion costs, there are some potential challenges to overcome, including:

- Air infiltration into the boiler dilutes the resulting flue gas making CO_2 capture and purification more expensive. Various options are being investigated to minimize infiltration, including improved boiler materials, sealants, control technologies, and membranes.

- Combustion of fuels in pure oxygen occurs at temperatures too high for existing boiler or turbine materials. This issue is being addressed by diluting the oxygen using FGR, which results in a slight increase of the parasitic power load. However, this load could be reduced or eliminated, if new materials are developed that can handle higher combustion temperatures.

- FGR results in concentrating flue gas components by a factor of 3.4-3.5. It will be necessary to demonstrate that there are no detrimental impacts to the boiler because of trace components not removed by the FGD system as concentrations increase by this factor.

7.3 RECOMMENDATIONS FOR FUTURE WORK

DOE's goal of 90% CO_2 capture with a LCOE increase of no more than 20% was not achieved in the cases examined in this systems analysis study. Some suggestions for future work that may help achieve DOE's goal include:

- Determine the minimum pressure to which the CO_2 must be compressed for various applications (EOR or sequestration) and re-run the cases at the lower pressure to determine the impact on LCOE.

- Determine if there is a LCOE benefit to reducing CO_2 capture requirements to less than 90%.

- Investigate alternate methods to heat the incoming air in the ITM oxygen cases to reduce the cost penalty imposed by the high price of natural gas. For example, the ITM air heater heat transfer surfaces could potentially be incorporated into the oxycombustion boiler design.

- Perform a full systems analysis study of a PRB based system (< 1 wt% sulfur) to quantify the impacts on the boiler and downstream equipment.