ELIMINATING THE DERATE OF CARBON CAPTURE RETROFITS – REVISION 2

March 31, 2023

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Disclaimer

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TABLE OF CONTENTS

LIST OF EXHIBITS

ACRONYMS AND ABBREVIATIONS

AACE	AACE International (formerly the Association for the Advancement of Cost Engineering)
abs	Absolute
AGR	Acid gas removal
Ar	Argon
Aspen	Aspen Plus®
atm	Atmosphere (14.696 psi)
BEC	Bare erected cost
BFW	Boiler feedwater
BOP	Balance of plant
Btu	British thermal unit
C_2H_6	Ethane
C_3H_8	Propane
C_4H_{10}	Butane
$CaCl_2$	Calcium chloride
CCS	Carbon capture and storage
CF	Capacity factor
CH_4	Methane
CH_4S	Mercaptan
CHP	Combined heat and power
CO_2	Carbon dioxide
CT	Combustion turbine
CTG	Combustion turbine-generator
ELG	Effluent limitation guidelines
Eng'g CM H.O.& Fee	Engineering, construction management, home office and fees
EPC	Engineering, procurement, and construction
FD	Forced draft
FG	Flue gas
FGD	Flue gas desulfurization
ft	Foot, feet
ft^3	Cubic foot
FWH	Feedwater heater
GJ	Gigajoule
gpm	Gallons per minute
gr/100 scf	Grains per one hundred standard cubic feet
H_2	Hydrogen
H_2O	Water
H_2S	Hydrogen sulfide
HCl	Hydrochloric acid
Hg	Mercury
HHV	Higher heating value
hp	Horsepower
HP	High pressure
hr, h	hour
HRCC	Heat rate with carbon capture
HRSG	Heat recovery steam generator
HVAC	Heating, ventilating, and air conditioning
D	Induced draft
IGCC	Integrated Gasification Combined Cycle
IOU	Investor-owned utility
IP	Intermediate pressure
ISO	International Organization for Standardization
kg	Kilogram
kgmol	Kilogram mole
kJ	Kilojoule
KO	Knockout
kW, kWe	Kilowatt electric
kWh	Kilowatt-hour
kWt	Kilowatt thermal
lb	Pound
lb-S	Pound sulfur
lbm	Pound mass
lbmole	Pound mole
LCOE	Levelized cost of electricity
LHV	Lower heating value
LP	Low pressure
m	Meter
m^3	Cubic meter
MATS	Mercury and Air Toxics Standards
mg/Nm^3	Milligrams per normal cubic meter
min	Minute
MISO	Midcontinent Independent System Operator
MJ/scm	Megajoule per standard cubic meter
MM	Million

MPa	Megapascal
MPC	Makeup power cost
MW, MWe	Megawatt electric
MWh	Megawatt-hour
N_2	Nitrogen
N/A	Not applicable
NaCl	Sodium chloride
NaOH	Sodium hydroxide
NETL	National Energy Technology Laboratory
NG	Natural gas
NGCC	Natural gas combined cycle
NGSC	Natural gas simple cycle
NO_X	Oxides of nitrogen
NSPS	New Source Performance Standards
O_2	Oxygen
O&M	Operation and maintenance
O-H	Overhead
PAC	Powdered activated carbon
PC	Pulverized coal
PCC	Post-combustion capture
PM	Particulate matter
ppmv	Parts per million volume
psia	Pound per square inch absolute
psig	Pound per square inch gage
QGESS	Quality Guidelines for Energy System Studies
RDF	Retrofit difficulty factor
scf	Standard cubic foot
SCR	Selective catalytic reduction
SDE	Spray dryer evaporator
SO_2	Sulfur dioxide
SO_3	Sulfur trioxide
ST	Steam turbine
SubC	Subcritical
T&S	Transport and storage
TASC	Total as-spent cost
TBtu	Trillion British thermal units
tonne	Metric ton (1,000 kg)
TOC	Total overnight cost
TPC	Total plant cost
V-L	Vapor liquid portion of stream (excluding solids)
WFGD	Wet flue gas desulfurization
wt%	Weight percent
y, yr	Year
$	U.S. Dollar
°C	Degrees Celsius
°F	Degrees Fahrenheit
%	Percent

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EXECUTIVE SUMMARY

The challenge for the power generation industry continues to face is the need to meet an ever-increasing demand (which requires building new capacity), while simultaneously reducing greenhouse gas emissions from existing sources. Advancements in carbon capture technologies may help increase efficiency and reduce the plant derate experienced when retrofitting existing power plants with amine-based carbon capture and storage (CCS) systems. Even when considering the development of these novel technologies, overcoming logistical and economic challenges of retrofitting the existing fleet is not trivial. Older, higher emitting plants face the prospect of having to add expensive flue gas cleanup equipment or shutting down operations. One of the more significant issues pertains to the reduction in net power output (derate) due to the large parasitic steam and power loads required for appreciable levels of carbon capture. Post-combustion capture has been shown to reduce the net plant efficiency of an equivalent plant without capture by 20 percent or more. Yet, post-combustion amine scrubbing is anticipated to be the most viable near-term technology for reducing carbon dioxide (CO_2) emissions from existing coal plants. This study quantifies options for existing pulverized coal (PC) boilers to reduce the effects caused by steam and power requirements of the CCS systems and the resulting derated output of the existing plant.

In addition to cost and performance concerns, traditional impediments to plant retrofits exist, such as projected plant downtime during construction, plant layout and footprint restrictions, reuse of equipment or resources, and permitting requirements. While individual retrofit projects are highly plant-specific and, therefore, subject to unique optimization pathways, each of the proposed cases in this study attempts to examine the most promising configurations for each option. The study case matrix is presented in Exhibit ES-1. The existing plant was assumed to be the National Energy Technology Laboratory (NETL) Fossil Energy Baseline report series subcritical pulverized coal case, B11A. [1] The results from this study show that combined heat and power (CHP) repowering can make up the lost power due to retrofitting an existing subcritical PC plant with CCS while reducing the overall levelized cost of electricity (LCOE) relative to a CCS-only retrofit at the expense of higher up-front capital charges.

Exhibit ES-1. Study matrix

Plant Configuration	Case	Existing ST Extraction	CO_2 Capture Criteria	Auxiliary Plant Arrangement
Retrofit Baseline	B11A-BR.90	As Required	90% from PC flue gas	N/A
	B11A-BR.95		95% from PC flue gas	
Retrofit with NGSC CHP Repowering	B11A-BRwNGSC.90	None	90% from PC flue gas	NGSC auxiliary plant with a hypothetically sized CT, no carbon capture
	B11A-BRwNGSC.95		95% from PC flue gas	
Retrofit with Natural Gas Boiler	B11A-BRwNGBlr.90	None	90% from PC flue gas	NG boiler providing steam only, no carbon capture
	B11A-BRwNGBlr.95		95% from PC flue gas	

A summary of the performance and environmental results from these cases is presented in Exhibit ES-2 and Exhibit ES-3. A summary of the cost results is presented in Exhibit ES-4 and Exhibit ES-5. The existing plant values and NETL Fossil Energy Baseline report series greenfield subcritical plant with 90 and 95 percent capture, B11B.90 and B11B.95, are included in the tables for comparison. [1] Several study assumptions were established that provide context for the results and conclusions provided in this report. These assumptions include the following:

- The retrofitted CCS facility only treats the flue gas emitted from the PC boiler. CO_2 is not removed from the exhaust gas emitted by the auxiliary natural gas-fired plants. All cases have either a nominal 90 or 95 percent removal rate from the PC plant flue gas based on the total coal feedstock minus unburned carbon in ash.
- The plant is in an area where no regional transmission and distribution restrictions exist that limit the sale of the excess generation.
- The auxiliary natural gas-fired plants are sized such that the entire thermal demand of the retrofitted CCS facility is met by steam raised by the auxiliary plant without duct firing or steam extraction from the existing steam turbine.
- A natural gas simple cycle (NGSC) CHP auxiliary plant is based on a hypothetically sized combustion turbine. It does not represent an “off the shelf,” commercially available model from any specific turbine manufacturer.
- Financing of the CCS facility and the associated auxiliary plants is only applicable to the retrofit equipment and does not include any remaining capital repayment obligations on the existing plant. Retrofit equipment costs are amortized over a three-year construction period and a 30-year plant lifetime.

Contingencies are needed for retrofit capital charges to reflect the added costs associated with any typical retrofit project (limited space resulting in construction premiums, insufficient laydown area, long tie-in connections, etc.) compared to a similar baseline for greenfield costs. These contingencies vary for each capital account as described in the Quality Guidelines for Energy System Studies (QGESS) documents “Carbon Capture Retrofit Studies” and “Estimating Plant Costs Using Retrofit Difficulty Factors.” [2, 3] In this study, the retrofit contingencies were not included in the bare erected costs (BEC) and total plant cost (TPC) estimates for each account. Instead, a retrofit difficulty factor (RDF) of 1.1 was applied to the totals before calculating the total overnight capital (TOC) and the capital component of the LCOE based on the simplified method described in the QGESS. [3] The RDF was calculated as a weighted average of the retrofit total plant cost premiums using the high contingency values applied to greenfield equipment costs scaled for retrofitting to an existing subcritical PC plant. The contingencies are included in the totals summarized in Exhibit ES-4 and Exhibit ES-5.

All cost estimates within this study were scaled from the NETL Fossil Energy Baseline report series cases following the QGESS “Cost Estimation Methodology for NETL Assessments of Power Plant Performance” and “Capital Cost Scaling Methodology: Revision 4a Report.” [4, 5]

Exhibit ES-2. Performance summary and environmental profile for 90% capture rate

Parameter	Combined Plant Performance				
	Existing Plant	Retrofit Baseline	With Auxiliary Plants		Greenfield capture
	Baseline B11A [1]	B11A-BR.90	B11A-BR wNGSC.90	B11A-BR wNGBlr.90	B11B.90 [1]
Gross Steam Turbine Power (MWe)	688	588	688	688	769
Gross Combustion Turbine Power (MWe)	N/A	N/A	274	N/A	N/A
Total Gross Power (MWe)	688	588	962	688	769
Auxiliary Power Requirement (MWe)	38	93	98	97	118
Net Power Output (MWe)	650	495	864	591	650
Coal Flow Rate (lb/hr)	493,115	493,115	493,110	493,110	630,940
Natural Gas Flow Rate (MMBtu/hr)	N/A	N/A	2,657	1,473	N/A
HHV Thermal Input (kWt)	1,685,945	1,685,943	2,464,581	2,117,538	2,157,162
Net Plant HHV Efficiency (%)	38.6%	29.4%	35.1%	27.9%	30.2%
Net Plant HHV Heat Rate (Btu/kWh)	8,849	11,612	9,733	12,230	11,317
Steam Load to Capture System (MMBtu/hr)	N/A	1,132	1,132	1,132	1,448
CO_2 Capture Flow Rate (lb/hr)	N/A	1,047,150	1,047,141	1,047,141	1,339,827
CO_2 Emissions Flow Rate (lb/hr)	1,163,905	116,856	432,027	290,811	149,517
Overall Plant CO_2 Capture (%)	**N/A**	**90%**	**71%**	**78%**	**90%**
Raw Water Withdrawal (gpm)	6,504	7,841	10,048	10,112	9,973
Process Water Discharge (gpm)	1,336	1,997	2,472	2,536	2,542
Raw Water Consumption (gpm)	5,169	5,844	7,576	7,576	7,431
CO_2 Emissions (lb/MMBtu)	202	20	51	40	20
CO_2 Emissions (lb/MWh-gross)	1,693	199	449	423	195
CO_2 Emissions (lb/MWh-net)	1,790	236	500	492	230
SO_2 Emissions (lb/MMBtu)	0.081	0.000	0.000	0.000	0.000
SO_2 Emissions (lb/MWh-gross)	0.675	0.000	0.003	0.002	0.000
NO_X Emissions (lb/MMBtu)	0.084	0.072	0.058	0.067	0.073
NO_X Emissions (lb/MWh-gross)	0.700	0.700	0.510	0.700	0.700
PM Emissions (lb/MMBtu)	0.011	0.009	0.008	0.009	0.009
PM Emissions (lb/MWh-gross)	0.090	0.090	0.070	0.092	0.090
Hg Emissions (lb/TBtu)	0.359	0.307	0.343	0.285	0.313
Hg Emissions (lb/MWh-gross)	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06

Exhibit ES-3. Performance summary and environmental profile for 95% capture rate

Parameter	Combined Plant Performance				
	Existing Plant	Retrofit Baseline	With Auxiliary Plants		Greenfield capture
	Baseline B11A [1]	B11A-BR.95	B11A-BR wNGSC.95	B11A-BR wNGBlr.95	B11B.95 [1]
Gross Steam Turbine Power (MWe)	688	584	688	688	774
Gross Combustion Turbine Power (MWe)	N/A	N/A	290	N/A	N/A
Total Gross Power (MWe)	688	584	977	688	774
Auxiliary Power Requirement (MWe)	38	96	101	100	124
Net Power Output (MWe)	650	488	876	588	650
Coal Flow Rate (lb/hr)	493,115	493,115	493,110	493,110	640,819
Natural Gas Flow Rate (MMBtu/hr)	N/A	N/A	2,803	1,554	N/A
HHV Thermal Input (kWt)	1,685,945	1,685,943	2,507,353	2,141,343	2,190,938
Net Plant HHV Efficiency (%)	38.6%	28.9%	34.9%	27.4%	29.7%
Net Plant HHV Heat Rate (Btu/kWh)	8,849	11,793	9,768	12,434	11,495
Steam Load to Capture System (MMBtu/hr)	N/A	1,194	1,194	1,194	1,552
CO_2 Capture Flow Rate (lb/hr)	N/A	1,105,467	1,105,457	1,105,457	1,436,590
CO_2 Emissions Flow Rate (lb/hr)	1,163,905	58,544	391,029	242,096	76,080
Overall Plant CO_2 Capture (%)	**N/A**	**95%**	**74%**	**82%**	**95%**
Raw Water Withdrawal (gpm)	6,504	7,904	10,233	10,300	10,207
Process Water Discharge (gpm)	1,336	2,026	2,498	2,565	2,618
Raw Water Consumption (gpm)	5,169	5,878	7,735	7,735	7,589
CO_2 Emissions (lb/MMBtu)	202	10	46	33	10
CO_2 Emissions (lb/MWh-gross)	1,693	100	400	352	98
CO_2 Emissions (lb/MWh-net)	1,790	120	446	412	117
SO_2 Emissions (lb/MMBtu)	0.081	0.000	0.000	0.000	0.000
SO_2 Emissions (lb/MWh-gross)	0.675	0.000	0.003	0.002	0.000
NO_X Emissions (lb/MMBtu)	0.084	0.071	0.057	0.066	0.072
NO_X Emissions (lb/MWh-gross)	0.700	0.700	0.503	0.700	0.700
PM Emissions (lb/MMBtu)	0.011	0.009	0.008	0.009	0.009
PM Emissions (lb/MWh-gross)	0.090	0.090	0.069	0.092	0.090
Hg Emissions (lb/TBtu)	0.359	0.304	0.343	0.282	0.311
Hg Emissions (lb/MWh-gross)	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06

Exhibit ES-4. Cost estimation results summary for 90% capture rate

Parameter	Combined Plant Costs[A]					
	Greenfield	Existing Plant	Retrofit Baseline	With Auxiliary Plants		Greenfield capture
	Baseline B11A [1]	B11A	B11A-BR.90	B11A-BR wNGSC.90	B11A-BR wNGBlr.90	Baseline B11B.90 [1]
Total Plant Cost (2018$/kW)	2,015	N/A	1,370	1,093	1,344	3,393
Bare Erected Cost	1,486	N/A	906	743	901	2,408
Home Office Expenses	260	N/A	159	133	159	421
Process Contingency	0	N/A	102	58	85	91
Project Contingency	270	N/A	204	158	198	472
Retrofit Difficulty Contingency	N/A	N/A	137	109	134	N/A
Total Plant Cost with RDF	2,015	N/A	1,507	1,202	1,478	3,393
Total Overnight Cost (2018$MM)	1,615	N/A	904	1,278	1,069	2,709
Total Overnight Cost (2018$/kW)	2,484	N/A	1,825	1,479	1,809	4,165
***Owner's Costs* (2018$/kW)**	468	N/A	318	276	331	772
Total As-Spent Cost (2018$/kW)	2,867	N/A	1,994	1,616	1,977	4,808
LCOE ($/MWh) (excluding T&S)	64.0	36.8	77.0	64.5	80.3	99.1
Capital Costs	27.2	0.0	18.9	15.4	18.8	45.7
Fixed Costs	9.2	9.2	17.5	11.3	15.6	14.6
Variable Costs	7.9	7.9	14.7	9.5	13.3	13.6
Fuel Costs	19.7	19.7	25.9	28.4	32.7	25.2
LCOE ($/MWh) (including T&S)	64.0	36.8	86.6	70.0	88.4	108.4
CO_2 T&S Costs	N/A	N/A	9.6	5.5	8.0	9.3

[A]All costs are on a net output basis ($/kW, $/MWh) representing the costs spread over the combined plant (retrofitted existing plant plus CHP plant if applicable)

Exhibit ES-5. Cost estimation results summary for 95% capture rate

Parameter	Combined Plant Costs[A]					
	Greenfield	Existing Plant	Retrofit Baseline	With Auxiliary Plants		Greenfield capture
	Baseline B11A [1]	B11A	B11A-BR.95	B11A-BR wNGSC.95	B11A-BR wNGBlr.95	Baseline B11B.95 [1]
Total Plant Cost (2018$/kW)	2,015	N/A	1,432	1,111	1,392	3,458
Bare Erected Cost	1,486	N/A	947	755	933	2,453
Home Office Expenses	260	N/A	166	136	165	429
Process Contingency	0	N/A	106	59	88	95
Project Contingency	270	N/A	213	161	205	482
Retrofit Difficulty Contingency	N/A	N/A	143	111	139	N/A
Total Plant Cost with RDF	2,015	N/A	1,575	1,222	1,531	3,458
Total Overnight Cost (2018$MM)	1,615	N/A	930	1,317	1,101	2,761
Total Overnight Cost (2018$/kW)	2,484	N/A	1,907	1,504	1,874	4,245
***Owner's Costs* (2018$/kW)**	468	N/A	332	282	343	787
Total As-Spent Cost (2018$/kW)	2,867	N/A	2,084	1,643	2,048	4,900
LCOE ($/MWh) (excluding T&S)	64.0	36.8	79.0	65.1	82.2	100.9
Capital Costs	27.2	0.0	19.8	15.6	19.5	46.6
Fixed Costs	9.2	9.2	17.9	11.3	15.8	14.9
Variable Costs	7.9	7.9	15.0	9.4	13.5	13.9
Fuel Costs	19.7	19.7	26.3	28.8	33.5	25.6
LCOE ($/MWh) (including T&S)	64.0	36.8	89.3	70.8	90.8	110.9
CO_2 T&S Costs	N/A	N/A	10.3	5.7	8.5	10.0

[A]All costs are on a net output basis ($/kW, $/MWh) representing the costs spread over the combined plant (retrofitted existing plant plus CHP plant if applicable)

EFFECTS ON PERFORMANCE

A greenfield, subcritical PC plant with 90 to 95 percent CO_2 removal technology as part of its original design has a net plant efficiency of about 30 percent on a higher heating value (HHV) basis, approximately 22 to 23 percent less efficient than an analogous non-capture plant having a net plant efficiency of about 39 percent. [1] For cases where CO_2 removal technology is added as a retrofit after the initial power plant design and construction, as is the case in this study, the net output reduction can be even greater depending on how amine regeneration steam is extracted from the existing steam turbine. A 24 to 25 percent reduction from the non-capture plant efficiency is observed in the B11A-BR.90 and B11A-BR.95 cases when extracting steam from the existing steam turbine train. Including an auxiliary CHP plant, as in the B11A-BRwNGSC cases, provides an opportunity to reduce the impact to overall plant efficiency while also allowing for the potential increase of net combined power plant electrical output, beyond that of the 650 MWe existing (non-capture) subcritical PC plant. The B11A-BRwNGBlr cases are a compromise between the two with the steam for the capture system provided by a natural gas-fired boiler, avoiding any derate of the existing steam turbine, but with the auxiliary power requirement provided by the existing plant.

EFFECTS ON COSTS

The simultaneous retrofit of CO_2 removal technology and dedicated auxiliary steam and power generation provides significant additional opportunities to lower costs and increase plant efficiency compared to a stand-alone CO_2 removal retrofit. As a rule, CO_2 capture retrofit of an existing plant will not perform as well as a greenfield plant originally designed to meet the objectives of the retrofit because plant processes cannot be optimized in the same way after the design and construction of the main plant has been completed. Incorporating an auxiliary CHP plant or even just the auxiliary steam boiler into the retrofit design reduces the number and extent of disruptions of (presumably) previously optimized systems of the existing non-capture plant and allows for minimal impact to the performance of the base plant.

All cases in this study assume a fully depreciated base plant, to be representative of the older existing plants in the domestic coal fleet that may be considering such a retrofit. The capital costs of the retrofit, using total overnight cost ($/kW net output of combined plant) as a metric, are shown in Exhibit ES-6 and Exhibit ES-7. The error bars in the chart represent the potential TOC range relative to the maximum and minimum of the capital cost uncertainty range for an AACE International (AACE) Class 4 range of -15 percent/+30 percent. [6]

Exhibit ES-6. Capital costs for 90% capture rate

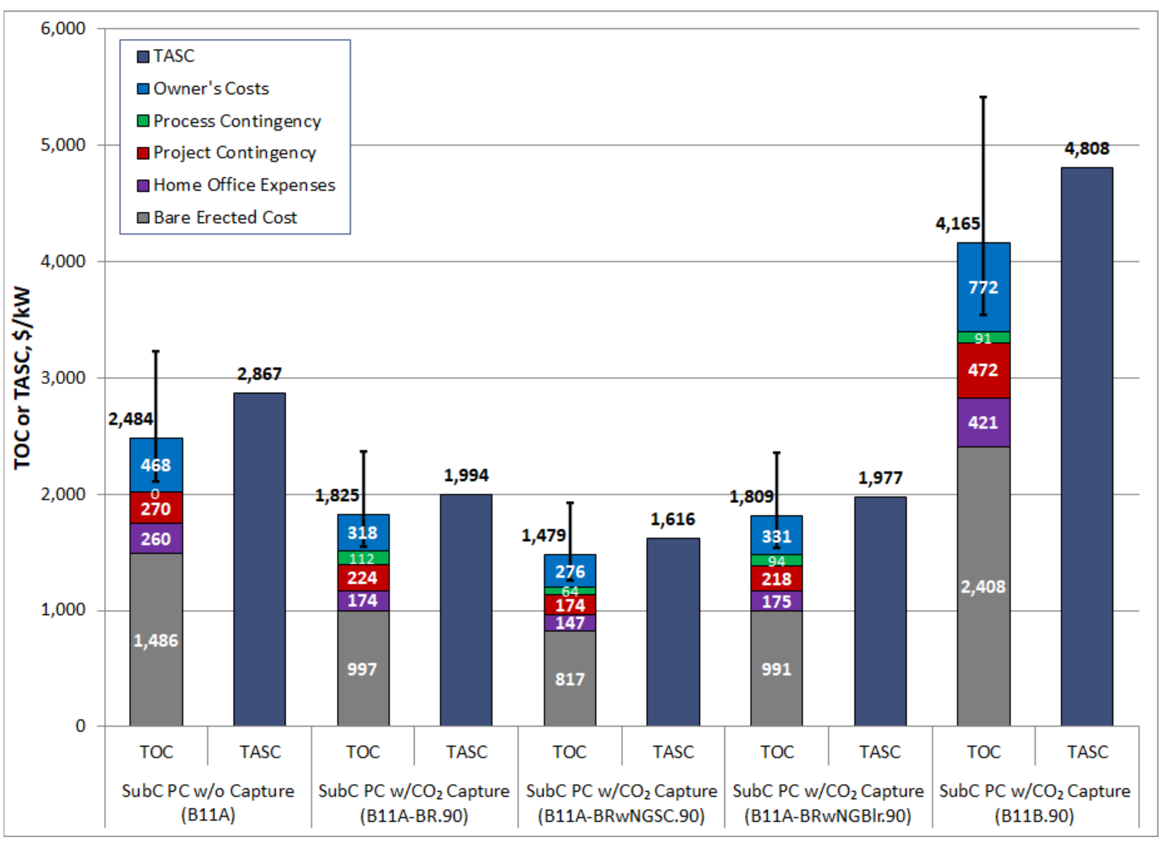
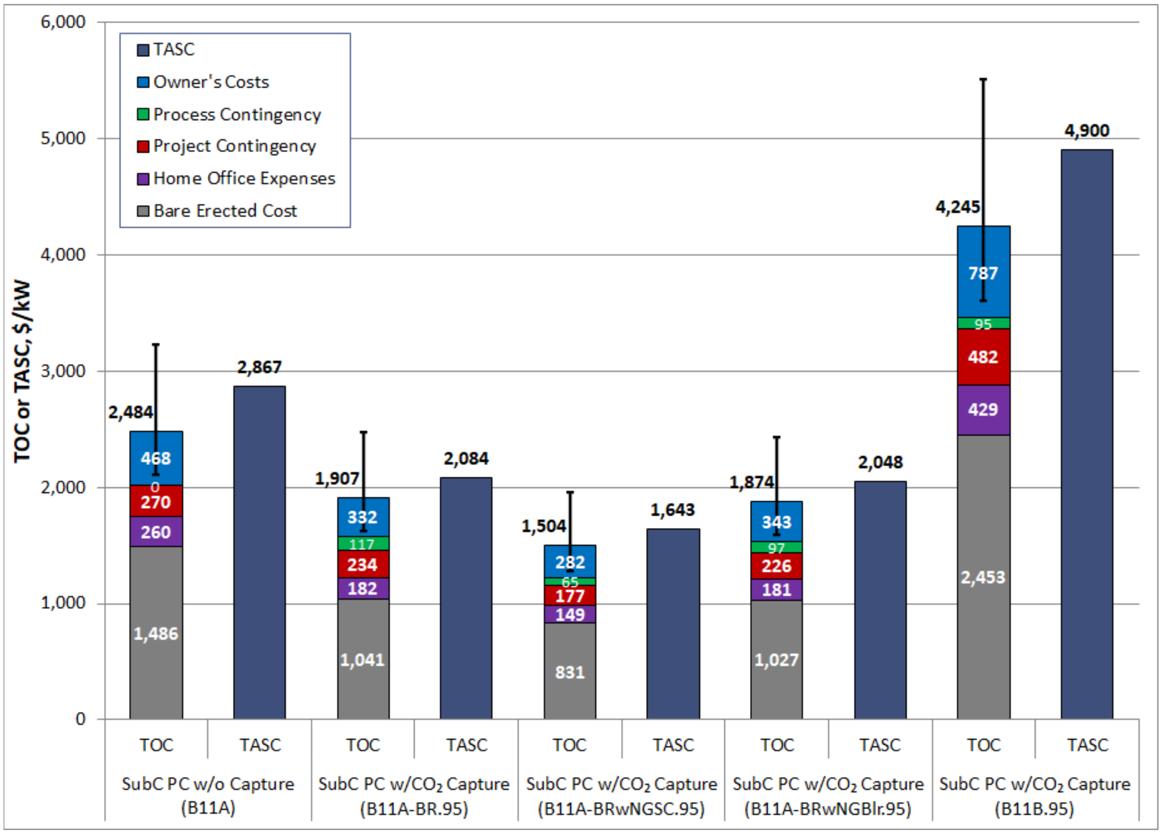


Exhibit ES-7. Capital costs for 95% capture rate



The LCOE for each case is shown in Exhibit ES-8 and Exhibit ES-9. The LCOE is expressed in terms of post-retrofit costs, which include the current plant operation and maintenance (O&M) costs and additional costs associated with the retrofit project (i.e., annualized capital costs plus all fixed and variable operating costs of the CCS equipment, including any fuel costs for operating the auxiliary plants) at the full net output capacity of the combined plant. The LCOE for the existing subcritical PC plant is included for comparison. The LCOE for the retrofit cases include the ongoing O&M costs (i.e., non-capital) associated with the existing, fully depreciated plant.

Exhibit ES-8. LCOE breakdown for 90% capture rate

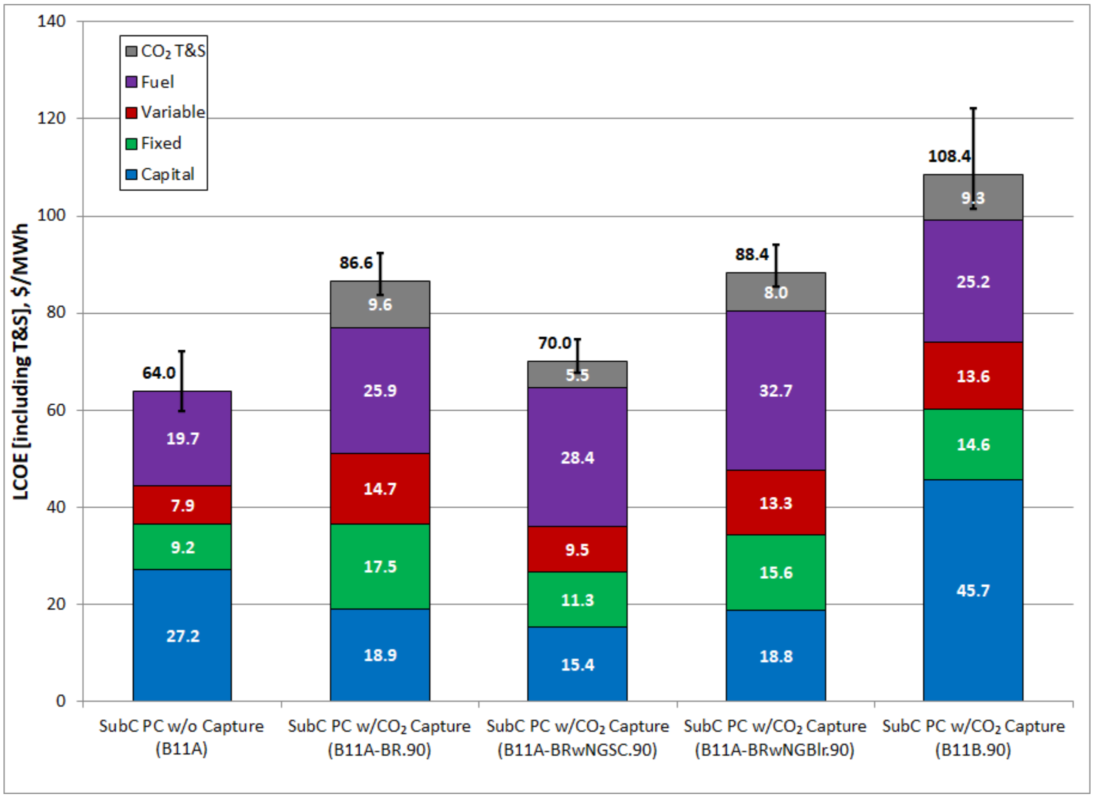
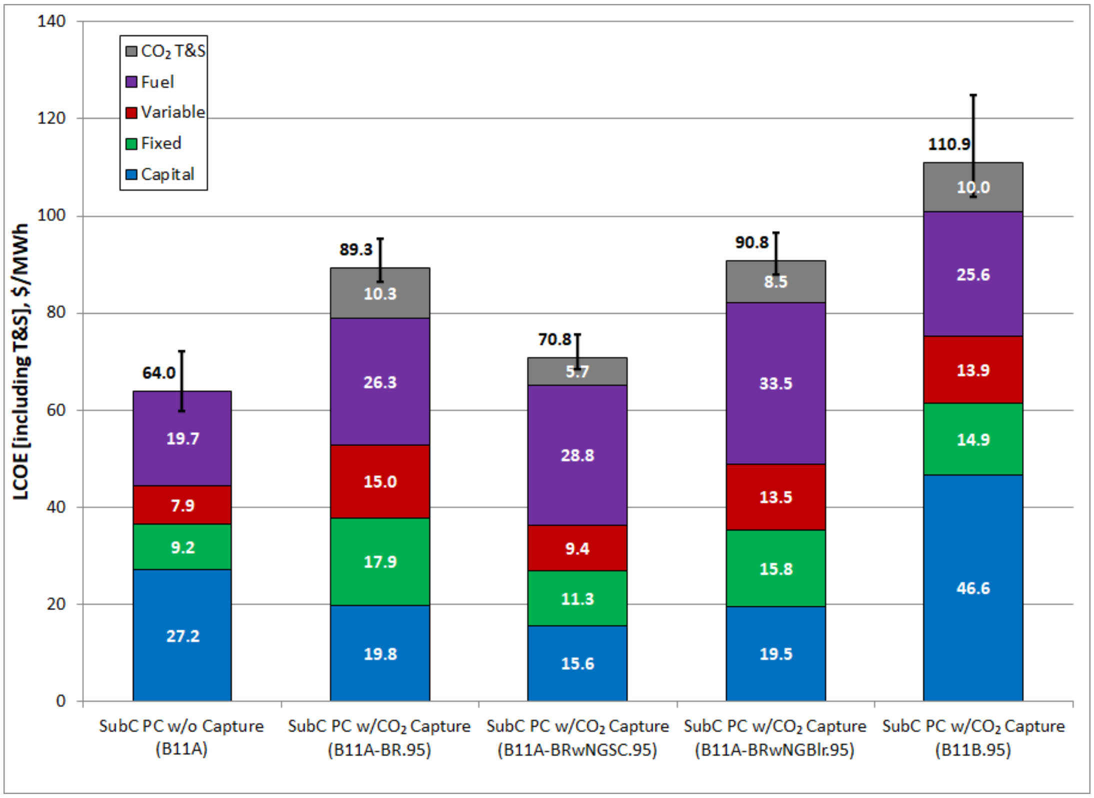


Exhibit ES-9. LCOE breakdown for 95% capture rate



The base case in this study (B11A-BR.90 and B11A-BR.95 – retrofit capture only with derate) shows a post-retrofit LCOE of $87/MWh and $89/MWh and capital cost (using TOC per post-retrofit net kW of generation as a metric) of $1,825/kW and $1,907/kW or a total of $904 and $930 million (MM). The values do not include any costs for lost revenue from reduced power or credit for excess power.

Providing additional capital to replace the lost generation through CHP auxiliary repowering improves the retrofit economics relative to the B11A-BR case. In the B11A-BRwNGSC case, the net electrical generation is greater than the original 650 MW-net. The additional electrical generation acts to dilute the increased capital costs in the LCOE calculation.

The LCOE shown for B11A-BR, B11A-BRwNGSC, and B11A-BRwNGBlr in Exhibit ES-10 and Exhibit ES-11 include retrofit contingencies. These base LCOE are calculated assuming an RDF of 1.1 applied to the TPC before calculating the TOC and the capital component of the cost of electricity. [3] Retrofits with more equipment, complexity, and downtime may be more susceptible to installation or construction problems, so the true price of the retrofit may be better represented by applying a larger retrofit contingency. Each of these cases would have a different configuration and site-specific retrofit contingencies; for example, the cases with no steam extraction from the existing turbine, B11A-BRwNGSC, and B11A-BRwNGBlr, would have lower contingencies compared to the case with the increased complexity of steam extraction (B11A-BR).

Exhibit ES-10. LCOE sensitivity to retrofit difficulty factors for 90% capture rate

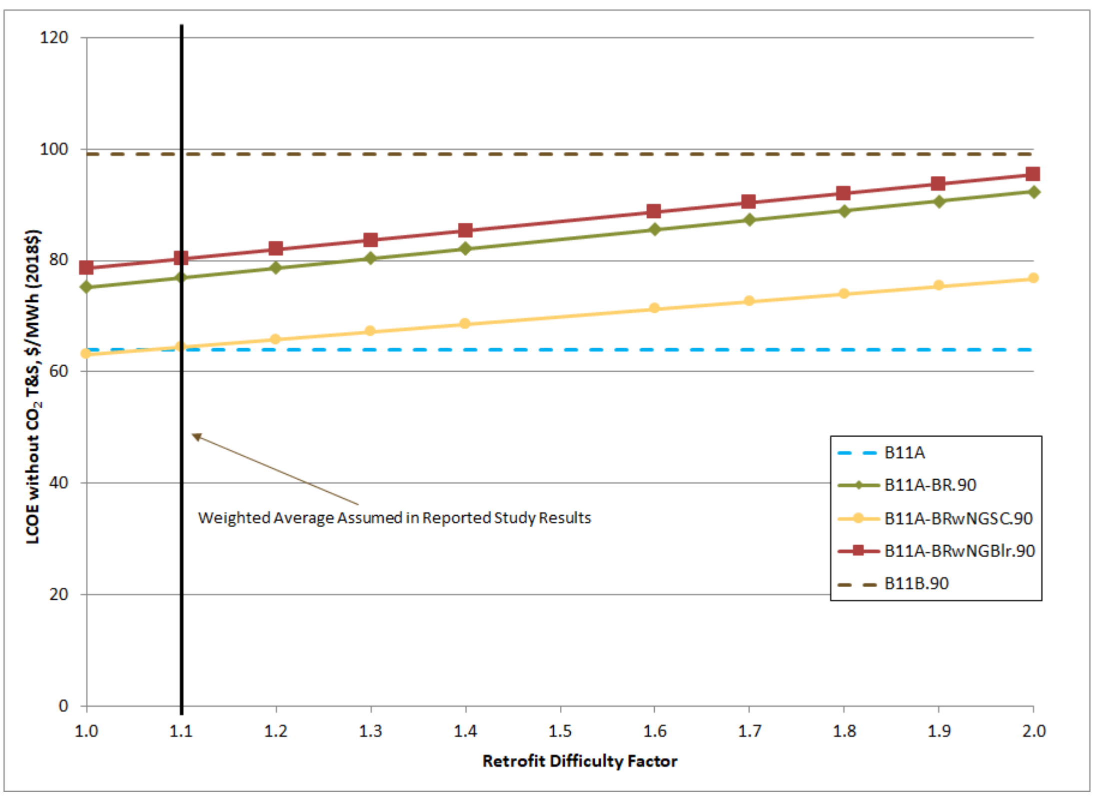
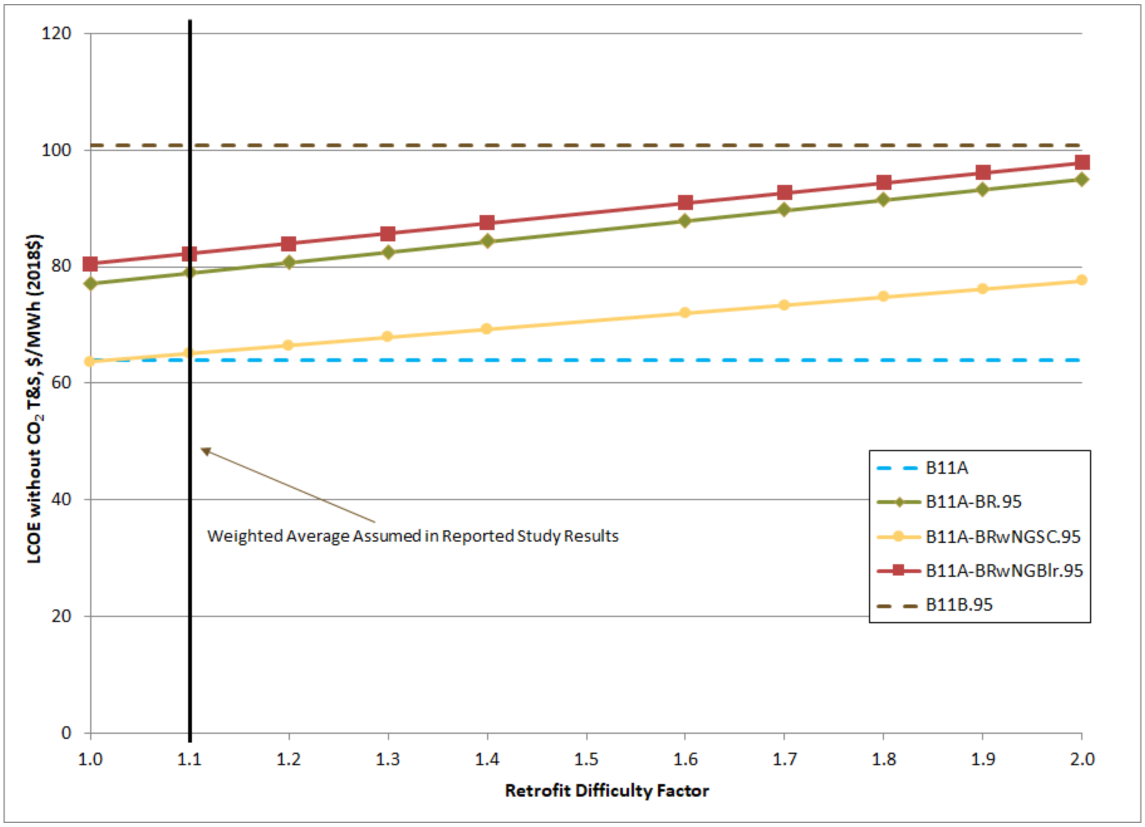


Exhibit ES-11. LCOE sensitivity to retrofit difficulty factors for 95% capture rate



The levelized cost of CO_2 captured and levelized cost of CO_2 avoided relative to a fully depreciated, existing PC plant provide additional insight into the economics of PC retrofits. Exhibit ES-12 and Exhibit ES-13 show these values for each of the PC retrofit scenarios considered as well as the emissions for each case. The values in Exhibit ES-12 and Exhibit ES-13 include an annual charge/credit for the makeup/excess capacity under/over the existing plant net generation in each case at a projected sales price for electricity of $30/MWh. This makeup power cost (MPC) is based on a 2019 approximate average Midcontinent Independent System Operator (MISO) market price with near 10 percent renewable penetration. [7] The B11A-BR cases with the derated existing plant have the lowest emissions, cost of CO_2 captured, and cost of CO_2 avoided of the retrofit cases due to the higher uncontrolled emissions from the natural gas-fired auxiliary plants.

Exhibit ES-12. Levelized cost of CO_2 captured and avoided for 90% capture rate

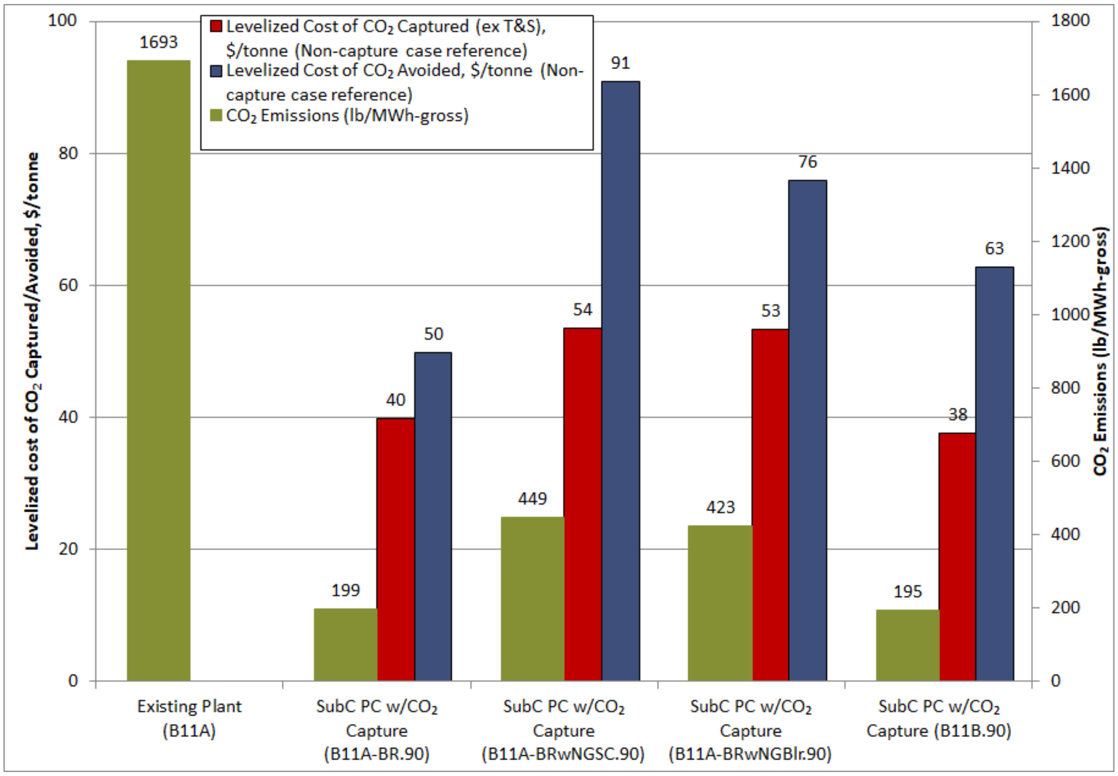
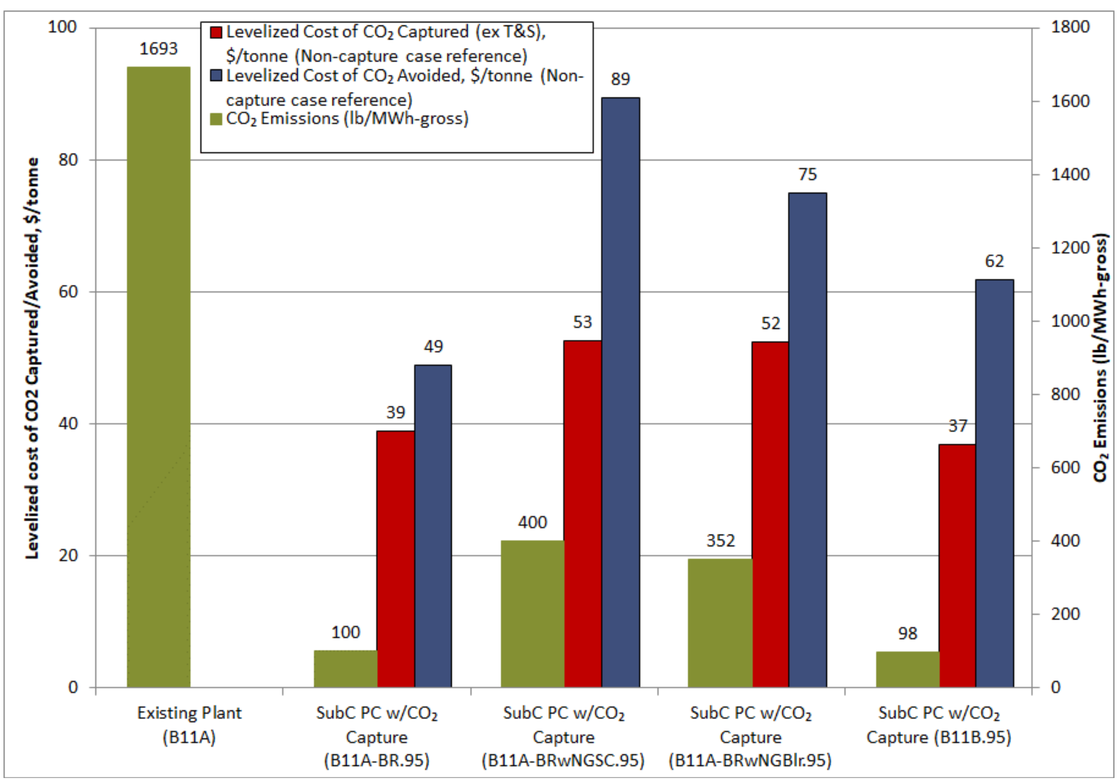


Exhibit ES-13. Levelized cost of CO_2 captured and avoided for 95% capture rate



CONCLUSIONS

The cases presented in this report demonstrate viable opportunities to improve the attractiveness of a CO_2 retrofit by using various alternatives to significantly derating an existing plant while adding carbon capture. Installing alternative sources of steam and power allows for the design to minimize the piping and ducting complexity as well as increase the output of the plant. Under optimal circumstances (i.e., low natural gas prices) these combined retrofits could lower the cost of generating electricity relative to a greenfield plant with CCS.

Specific observations and conclusions from these results include the following:

- Providing the auxiliary steam and power requirements of a retrofitted CCS facility from the existing steam turbine generator is the lowest up-front capital investment option on an absolute dollar TOC basis including retrofit contingency ($904 and $930 MM). However, the performance derate of the steam turbine makes this a less attractive long-term option on a LCOE basis ($87/MWh and $89/MWh).
- Supplying auxiliary electrical power and steam with combustion turbine-based CHP technologies can more than offset the losses in net plant output that would otherwise be incurred. In doing so, the long-term project economics are improved on an LCOE basis at the expense of higher up-front capital investment.
- Implementing 95 percent capture from the PC plant reduces overall emissions with negligible impact on LCOE, cost of CO_2 captured, or cost of CO_2 avoided.

The discrete nature of the choices available for eliminating the derate of carbon capture retrofits requires examination of multiple strategies for each technology option before an optimal configuration can be identified.

CO_2 CAPTURE RATES ABOVE 95 PERCENT

Commercial-scale demonstration of solvent-based post-combustion CO_2 capture systems at power generation facilities (specifically PC plants) has shown the ability to capture 90 percent of the CO_2 in the flue gas stream. Moreover, field-testing of post-combustion CO_2 capture technology as well as vendor and industry feedback on projects currently in the planning stages (including front-end engineering and design projects sponsored by the Department of Energy [DOE]) indicates that capture rates as high as 95 percent are feasible for both coal- and natural gas-fueled electricity generating units. Given the breadth of publicly available information supporting the capability for post-combustion capture systems to remove greater than 90 percent of the CO_2 in the treated stream, cases for 90 percent and 95 percent capture on PC plants are presented in the main body of this report.

It should be emphasized that technology suppliers (as reflected in vendor-supplied information provided to DOE that included cost and performance estimates for >95 percent carbon capture and storage [97 percent for natural gas combined cycle and 99 percent for PC] study cases) as well as subject matter experts acknowledge and support that solvent-based post-combustion CO_2 capture technologies are capable of achieving CO_2 removal rates beyond 95 percent on low-purity streams representative of fossil-fueled combustion. Although techno-economic analyses of deep decarbonization (≥ 99 percent) of combustion flue gas have been published by others, the relatively limited experience with design and operation of capture systems that can routinely, reliably, and economically achieve very high removal rates requires further study. Techno-economic analysis of 99 percent capture cases are included in Appendix A.

1 INTRODUCTION

1.1 STUDY BACKGROUND

The power generation industry has multiple potential carbon mitigation strategies at its disposal, including carbon dioxide (CO_2) utilization/conversion, CO_2 sequestration, increased use of renewable energy, and improved efficiency. Where each strategy is employed will be determined by regulations and plant-specific economics. Furthermore, it is likely that many plants may benefit by employing multiple strategies. For example, a plant may exhaust efficiency improvement options before proceeding to a post-combustion CO_2 capture process. One of the most promising near-term technologies for significant levels of carbon mitigation is amine-based post-combustion capture (PCC).

The existing fleet of coal-fueled power plants represents nearly a century of investment. Options that allow leveraging of these assets so that they may provide cost-effective carbon mitigation are critical. However, retrofitting existing plants with new equipment required for amine-based PCC requires high auxiliary power loads for the carbon capture and compression equipment in addition to steam demands for amine regeneration. Installing amine-based capture equipment on an existing pulverized coal (PC) plant results in a net power deficit that must be overcome. There are several options for replacing this lost power. The purpose of this study is to advance the understanding of how these options compare to one another in terms of thermodynamic performance and economic feasibility. The original publications of this study [8, 9] examined combustion turbine options for meeting the steam and power requirements of the carbon capture and storage (CCS) process. This version of the study includes one such case as well as an option for adding a natural gas-fired boiler to meet the steam requirement. The performance calculations and cost estimates are also updated to match the assumptions and methodologies in Revision 4a of the National Energy Technology Laboratory (NETL) Fossil Energy Baseline report series. [1]

Commercial-scale demonstration of solvent-based post-combustion CO_2 capture systems at power generation facilities (specifically PC plants) has shown the ability to capture 90 percent of the CO_2 in the flue gas stream. Moreover, field-testing of post-combustion CO_2 capture technology as well as vendor and industry feedback on projects currently in the planning stages (including front-end engineering and design projects sponsored by the Department of Energy [DOE]) indicates that capture rates as high as 95 percent are feasible for both coal- and natural gas-fueled electricity generating units. Given the breadth of publicly available information supporting the capability for post-combustion capture systems to remove greater than 90 percent of the CO_2 in the treated stream, cases for 90 percent and 95 percent capture on PC plants are presented in the main body of this report.

It should be emphasized that technology suppliers (as reflected in vendor-supplied information provided to DOE that included cost and performance estimates for >95 percent carbon capture and storage [97 percent for natural gas combined cycle and 99 percent for PC] study cases) as well as subject matter experts acknowledge and support that solvent-based post-combustion CO_2 capture technologies are capable of achieving CO_2 removal rates beyond 95 percent on low-purity streams representative of fossil-fueled combustion. Although techno-economic analyses of deep decarbonization (≥ 99 percent) of combustion flue gas have been published by others, the relatively limited experience with design and operation of capture systems that can routinely, reliably, and economically achieve very high removal rates requires further study. Techno-economic analysis of 99 percent capture cases are included in Appendix A.

In addition to unit-level impacts (e.g., decreased export power available for sale), wide deployment of PCC systems would result in an overall decrease of aggregate capacity capable of supplying power to the grid. It is very likely that in the short term it may be most cost-effective for power generation facilities with lower capacity factors to increase power production to replenish the power lost from the grid due to its use to run CCS equipment at the retrofitted unit. However, increasing the capacity factor of existing plants depends largely on economics and may only provide limited makeup power as CCS retrofits increase to meet applicable carbon regulations.

1.2 Project Objectives

This report examines options to compensate for the auxiliary loads associated with operating a newly installed, amine-based, PCC process that would have otherwise been used to generate power prior to retrofit. The intent of this study is to establish baseline performance and cost estimates incurred because of an integrated (steam and power) retrofit of the amine-based PCC process into the steam cycle of an existing 650 MWe subcritical PC facility and to compare two alternate plant configurations that utilize externally supplied steam to supply the capture system requirements. One of the cases also supplies additional power to meet all capture system auxiliary loads. All cases include retrofitting the existing plant with the Shell's CANSOLV post-combustion capture process and independent CO_2 compression train detailed in Revision 4a of the NETL Fossil Energy Baseline report. [1]

1.3 Study Approach

Three capture system retrofit options were investigated for 90 and 95 percent capture cases as part of this study. One option (Case B11A-BR) is the retrofit of the capture system to an existing PC plant where the capture system is "integrated" into the existing facility. In this option, all energy needs of the capture system (steam and electric power) are supplied by "extraction" from the existing plant (i.e., steam is extracted from the existing steam cycle, electricity that would otherwise be sold as product is diverted from export to the grid). The existing plant is "derated" due to the reduced net plant output and inefficiencies that result from operating the existing steam cycle with different (i.e., lower) energy flows than originally designed. As this option is to serve as the basis for comparison, no attempt is made to mitigate the derate by replacing any of the lost energy streams resulting from the retrofit.

In addition to the integrated retrofit option, two alternative plant configurations were evaluated to minimize the derate of the existing plant by supplying the required steam for the retrofitted capture system with natural gas-fueled plants.

The first of these alternatives (Case B11A-BRwNGSC) represents the addition of a new natural gas simple cycle (NGSC) combined heat and power (CHP) plant where power is provided through a combustion turbine coupled to an electricity generator (combustion turbine-generator (CTG)); the required steam is generated through the recovery of heat from the turbine exhaust. Based on the thermodynamics of the combustion turbine, the CHP system is sized such that steam of the necessary quantities and conditions to satisfy the capture process heat demands is raised in a heat recovery steam generator (HRSG). As a result, the combustion turbine electrical output exceeds the auxiliary load of the capture plant, and it is assumed that excess power can be readily exported to the grid.

The second alternative (Case B11A-BRwNGBlr) represents the addition of a natural gas-fired boiler specifically designed to supply the steam demand of the capture system, but the auxiliary electrical load of the capture plant is supplied by the existing plant power system.

It should be noted that several simplifying assumptions underlie this analysis including but not limited to:

- NGSC plant sized such that all steam requirements could be fully met through heat recovery from the exhaust of a single combustion turbine (without duct-firing) resulting in a "rubber turbine" approach (i.e., the combustion turbine is not considered an "off-the-shelf" unit).
- Excess power generation could be readily accepted by existing transmission and distribution infrastructure at the facility battery limits. New inside battery limits equipment associated with the addition of the NGSC and natural gas-fired boiler are required and included in the respective analyses.
- Capture of 90 percent of the CO_2 in the treated stream of flue gas from the PC plant and no treatment or capture of CO_2 from the exhaust gas from the NGSC and natural gas-fired boiler.

A summary of plant configurations considered in this report is presented in Exhibit 1-1. All cases sequester the CO_2 offsite.

Exhibit 1-1. Study matrix

Plant Configuration	Case	Existing ST Extraction	CO_2 Capture Criteria	Auxiliary Plant Arrangement
Retrofit Baseline	B11A-BR.90	As Required	90% from PC flue gas	N/A
	B11A-BR.90		95% from PC flue gas	
Retrofit with NGSC CHP System	B11A-BRwNGSC.90	None	90% from PC flue gas	NGSC auxiliary plant with a hypothetically sized CT, no carbon capture
	B11A-BRwNGSC.95		95% from PC flue gas	
Retrofit with Natural Gas Boiler	B11A-BRwNGBlr.90	None	90% from PC flue gas	NG boiler providing steam only, no carbon capture
	B11A-BRwNGBlr.95		95% from PC flue gas	

2 General Evaluation Basis

This study is designed to assess technical and economic impacts of offsetting the increased steam and power auxiliaries associated with retrofitting an amine-based, PCC process to an existing PC plant firing Illinois No. 6 coal. For each of the plant configurations analyzed in this report, an Aspen Plus® (Aspen) model was developed and used to generate material and energy balances and plant performance data. The performance data and material balances were used as the basis for generating the capital and operating cost estimates. Performance and process limits were based upon published reports, information obtained from vendors and users of the technology, performance data from design/build utility projects, and/or best engineering judgment. Capital and operating costs were scaled based on NETL Fossil Energy Baseline reports and parameters in the NETL Quality Guidelines for Energy System Studies (QGESS). [1, 5] Ultimately, a levelized cost of electricity (LCOE) was calculated for each of the cases and is reported as the revenue requirement figure-of-merit as described in NETL's retrofit and cost methodology QGESS documents. [3, 4]

The balance of this section discusses the design basis common to all technologies, as well as environmental targets and cost assumptions used in the study. Technology-specific design criteria are covered in subsequent sections.

2.1 Site Characteristics

The existing PC plant considered in this report is assumed to be located at a generic plant site in midwestern United States, with ambient conditions and site characteristics as presented in Exhibit 2-1 and Exhibit 2-2. The ambient conditions are the same as International Organization for Standardization (ISO) conditions. Space for installation of the retrofit systems is assumed to be available in reasonable proximity to the operating plant and clear of any major obstacles to construction. No additional costs were included in the estimates for demolition of existing structures or purchasing of additional land. An 85 percent capacity factor (CF) was selected for all cases. Additional specifications not listed in this report are available in the Fossil Energy Baseline reports. [1]

Exhibit 2-1. Site characteristics

Parameter	Value
Location	Existing plant, Midwestern U.S.
Topography	Level
Transportation	Rail or Highway
Water	50% Municipal and 50% Ground Water

Exhibit 2-2. Site ambient conditions

Parameter	Value
Elevation, m (ft)	0 (0)
Barometric Pressure, MPa (psia)	0.101 (14.696)
Average Ambient Dry Bulb Temperature, °C (°F)	15 (59)
Average Ambient Wet Bulb Temperature, °C (°F)	10.8 (51.5)
Design Ambient Relative Humidity, %	60
Cooling Water Temperature, °C (°F)[A]	15.6 (60)
Air composition based on published psychrometric data, mass %	
N_2	75.055
O_2	22.998
Ar	1.280
H_2O	0.616
CO_2	0.050
Total	100.00

[A]The cooling water temperature is the cooling tower cooling water exit temperature; this is set to 4.8°C (8.5°F) above ambient wet bulb conditions in ISO cases

2.2 Coal Characteristics

The design coal is Illinois No. 6 with characteristics presented in Exhibit 2-3. The coal properties are from the 2019 revision of the QGESS documents "Specification for Selected Feedstocks" and "Detailed Coal Specifications." [10, 11]

Exhibit 2-3. Design coal composition

Rank	Bituminous	
Seam	**Illinois No. 6**	
Proximate Analysis (weight %)[A]		
	As Received	**Dry**
Moisture	11.12	0.00
Ash	9.70	10.91
Volatile Matter	34.99	39.37
Fixed Carbon	44.19	49.72
Total	100.00	100.00
Sulfur	2.51	2.82
HHV, kJ/kg (Btu/lb)	27,113 (11,666)	30,506 (13,126)
LHV, kJ/kg (Btu/lb)	26,151 (11,252)	29,544 (12,712)

Rank	Bituminous	
Seam	Illinois No. 6	
Ultimate Analysis (weight %)		
	As Received	Dry
Moisture	11.12	0.00
Carbon	63.75	71.72
Hydrogen	4.50	5.06
Nitrogen	1.25	1.41
Chlorine	0.15	0.17
Sulfur	2.51	2.82
Ash	9.70	10.91
Oxygen[B]	7.02	7.91
Total	**100.00**	**100.00**

[A]The proximate analysis assumes sulfur as volatile matter
[B]By difference

Fuel costs used in this report are specified according to the 2019 QGESS document "Fuel Prices for Selected Feedstocks in NETL Studies." [12] The current levelized coal price is $2.11/GJ ($2.23/MMBtu) on a higher heating value (HHV) basis for Illinois No. 6 bituminous coal delivered to the Midwest and reported in 2018 dollars. Fuel costs are levelized over an assumed 30-year plant operational period with an assumed on-line year of 2023.

2.3 Natural Gas Characteristics

Natural gas is utilized as an additional fuel in the auxiliary steam supply cases, B11A-BRwNGSC and B11A-BRwNGBlr, and its composition is presented in Exhibit 2-4. The natural gas properties are from the 2019 revision of the QGESS document "Specification for Selected Feedstocks" including the addition of methanethiol (mercaptan). [10, 13]

Exhibit 2-4. Natural gas composition

Component		Volume Percentage	
Methane	CH_4	93.1	
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	1.6	
Methanethiol[A]	CH_4S	5.75×10^{-6}	
	Total	**100.0**	
	LHV	**HHV**	
kJ/kg (Btu/lb)	47,201 (20,293)	52,295 (22,483)	
MJ/scm (Btu/scf)	34.52 (927)	38.25 (1,027)	

[A]The sulfur content of natural gas is primarily composed of added Mercaptan (methanethiol [CH_4S]) with trace levels of hydrogen sulfide (H_2S) [13]
Note: Fuel composition is normalized, and heating values are calculated using Aspen

The current levelized natural gas price is $4.19/GJ ($4.42/MMBtu) on an HHV basis, delivered to the Midwest, as specified according to the 2019 QGESS document "Fuel Prices for Selected Feedstocks in NETL Studies." [12] Fuel costs are levelized over an assumed 30-year plant operational period with an assumed on-line year of 2023.

2.4 Environmental Targets

All emissions values in this study are calculated for baseload operation. Additional specifications not listed in this report, including water quality considerations and environmental targets, are available in the Fossil Energy Baseline reports. [1] All cases in this study are assumed to follow the current utility Mercury and Air Toxics Standards (MATS) and New Source Performance Standards (NSPS) for sulfur dioxide (SO_2), nitrogen oxides (NO_X), particulate matter (PM), mercury (Hg) and hydrochloric acid (HCl) as listed in Exhibit 2-5. [13, 14, 15] In Revision 4a of the NETL Fossil Energy Baseline report, case B11A, defined as the plant for this study, has a CO_2 emission rate of 1,693 lb/MWh-gross. [1]

Exhibit 2-5. MATS and NSPS emission limits for SO_2, NO_X, PM, Hg, and HCl

Pollutant	IGCC (lb/MWh-gross)	PC (lb/MWh-gross)	NGCC (lb/MWh-gross)
SO_2	0.40	1.00	0.90
NO_X	0.70	0.70	0.43
PM (Filterable)	0.07	0.09	N/A
Hg	$3x10^{-6}$	$3x10^{-6}$	N/A
HCl	0.002	0.010	N/A

In Revision 4a of the Fossil Energy Baseline report, only the wet flue gas desulfurization (FGD) wastewater stream required treatment for compliance with the effluent limitation guidelines (ELG) rule. [1] Small volume water streams are not considered, and steam cycle blowdown was assumed compliant. [1] Under these assumptions, natural gas combined cycle (NGCC) cases are compliant with ELG without additional treatment. Based on these assumptions, the cases in this study, including the natural gas-fired auxiliary plants, are assumed to be ELG compliant.

2.5 Capacity Factor Assumptions

Availability is the percent of time during a specific period that a generating unit can produce electricity. This report assumes that the pre-retrofit plant is dispatched any time it is available and can generate the nameplate capacity when online. Therefore, the capacity factor and availability are equal. It is assumed that the retrofitted plant and associated auxiliary plant in each case in this study would be dispatched in the same manner. The operating period selected is also important. The calculations assume that the capacity factor and availability are constant over the life of the plant, but actual operation may require that a plant have a higher peak availability to counter lower availability in the first several years of operation. The Fossil Energy Baseline report series assume an 85 percent capacity factor for all PC and NGCC cases, and that assumption was continued in this study. Natural gas-fired auxiliary plants are assumed to operate with the existing coal plant at the same capacity factor. Additional information behind the assumption is available in the Fossil Energy Baseline reports. [1]

2.6 Raw Water Withdrawal and Consumption

A water balance was performed for each case on the major water consumers in the process. The total water demand for each subsystem was determined and internal recycle water available from various sources like boiler feedwater (BFW) blowdown and condensate from flue gas (in CO_2 capture cases) was applied to offset the water demand. The difference between demand and recycle is raw water withdrawal. Raw water withdrawal is the water removed from the ground or diverted from a municipal source for use in the plant. Raw water consumption is also accounted for as the portion of the raw water withdrawn that is evaporated, transpired, incorporated into products, or otherwise not returned to the water source from which it was withdrawn. Additional details on the calculations and assumptions used in the water balances are available in the Fossil Energy Baseline reports. [1] The water balances presented in subsequent sections are representative of the retrofitted PC plant and auxiliary plant combined. They include the water demand of the major water consumers within the process, the amount provided by internal recycle, the amount of raw water withdrawal by difference, the amount of process water returned to the source, and the raw water consumption, again by difference.

2.7 Cost Estimating Methodology

Detailed information pertaining to topics such as contracting strategy; engineering, procurement, and construction (EPC) contractor services; estimation of capital cost contingencies; owner’s costs; cost estimate scope; economic assumptions; finance structures; and cost of electricity, are available in the February 2021 revision of the QGESS document “Cost Estimation Methodology for NETL Assessment of Power Plant Performance.” [4] 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. The costs for equipment, material, and labor are scaled from values in the Fossil Energy Baseline report series and vendor quotes based on the QGESS document “Capital Cost Scaling Methodology: Revision 4 Report.” [1, 5] The scaled values for equipment, material, and labor costs are added together to generate a bare erected cost (BEC). Engineering, construction management, home office and fees (Eng'g CM H.O.& Fee) costs, process contingencies, and project contingencies are added to the BEC to generate a total plant cost (TPC) based on the factors used in the Fossil Energy Baseline reports for each retrofit cost account. [1]

Additional contingencies are needed for retrofit capital charges to reflect the added costs associated with any typical retrofit project (limited space resulting in construction premiums, insufficient laydown area, long tie-in connections, etc.) compared to a similar baseline for greenfield costs. These contingencies vary for each capital account as described in the QGESS documents “Carbon Capture Retrofit Studies” and the earlier “Estimating Plant Costs Using Retrofit Difficulty Factors.” [2, 3] In this study, the retrofit contingencies were not included in the BEC and total plant cost (TPC) estimates for each account. Instead, a retrofit difficulty factor (RDF) of 1.1 was applied to the TPC before calculating the owner’s costs (pre-production costs, inventory capital, and other costs) to the TPC to calculate the total overnight cost (TOC), total as-spent cost (TASC) and the capital component of the LCOE based on the simplified method described in the QGESS. [3, 4] A benefit of applying the RDF at the TPC level is that it avoids creating a set of accounting rules that can be manipulated to bias the cost estimate. This simplified multiplier compartmentalizes the required cost estimating and engineering judgment knowledge requirements in selecting the most applicable or representative retrofit factor and resulting retrofit costs, but also helps bound the typical effects associated with retrofit construction with minimal additional work. The RDF was calculated as a weighted average of the sub-account level retrofit total plant cost premiums, which vary between 1.0 and 1.3, using the high contingency values applied to greenfield equipment costs scaled for retrofitting to an existing subcritical PC plant.

The total capital estimates reflect an uncertainty range of -15 percent/+30 percent, consistent with AACE International (AACE) Class 4 cost estimates (i.e., feasibility study), based on the level of engineering design performed. [6, 16] In all cases, the report intends to represent the next commercial offering, and relies on vendor cost estimates for component technologies.

The capital cost estimates represent the complete construction and operation of retrofitted CCS and auxiliary facilities for an existing PC power plant located on a generic site. The plant boundary limit is defined as the total plant facility within the fence line including coal receiving and water supply system but terminating at the high voltage side of the main power transformers. For all cases evaluated, it is assumed that the existing plant is fully depreciated and there are no ongoing capital costs for any plant components other than those required to facilitate the retrofit of the different configurations. Systems associated with the existing PC plant that do not require modification are listed in the individual plant cost detail tables but have no associated costs. However, the costs associated with continuing operations of the existing plant (overhead, labor, maintenance materials, consumables, fuels, etc.) are included in developing the LCOE for the retrofitted plant.

The NETL cost estimation methodology for developing Owner's Costs for a PC plant includes costs for inventory capital of chemicals and fuel. In particular, it specifies costs for a 60-day supply of coal to be maintained on site such that fuel supply disruptions, and their impact on the ability of the plant to generate electricity, are mitigated. Retrofit cases where natural gas is used to support capture system operations (B11A-BRwNGSC and B11A-BRwNGBlr) include additional cost in the Inventory Capital section of the Owner's Cost table as a reserve account for acquisition of 60 days of natural gas supply, consistent with the 60-day coal supply.

The prior study/QGESS method had financial structures for low risk (NGCC w/o capture) and high risk (NGCC w/ capture); both were three-year construction periods. [9, 2] The updated three-year construction timeframe/financial structure is used to estimate the capital component of the LCOEs in this update. [3, 4]

A makeup power cost (MPC) of $30/MWh was added to retrofit cases in the levelized cost of CO_2 and CO_2 avoided calculations. The cost is based on a 2019 approximate average Midcontinent Independent System Operator (MISO) market price with near 10 percent renewable penetration. [7] This cost is applied as a debit for cases producing less power than the original existing plant and as a credit for cases producing more power than the original existing plant.

3 PERFORMANCE RESULTS

Steam conditions for the existing PC plant were selected to be subcritical to reflect the prevalence of these units within the existing PC plant fleet. Subcritical with single-reheat steam conditions are 16.5 MPa/566°C/566°C (2,400 psig/1,050°F/1,050°F). The Aspen model for the subcritical PC plant without carbon capture, Case B11A, in Revision 4a of the Fossil Energy Baseline report was used as the existing PC plant model. [1]

Three retrofit options for a generic existing PC-fired Rankine cycle power plant were evaluated:

- Adding CANSOLV CO_2 capture and providing both steam and power required for capture from the existing plant via steam extractions and derate (B11A-BR)
- Adding CANSOLV CO_2 capture and providing both steam and power required for capture from a new NGSC auxiliary CHP plant (B11A-BRwNGSC)
- Adding CANSOLV CO_2 capture and providing steam required for capture from a new natural gas-fired boiler and power required for capture from the existing plant (B11A-BRwNGBlr)

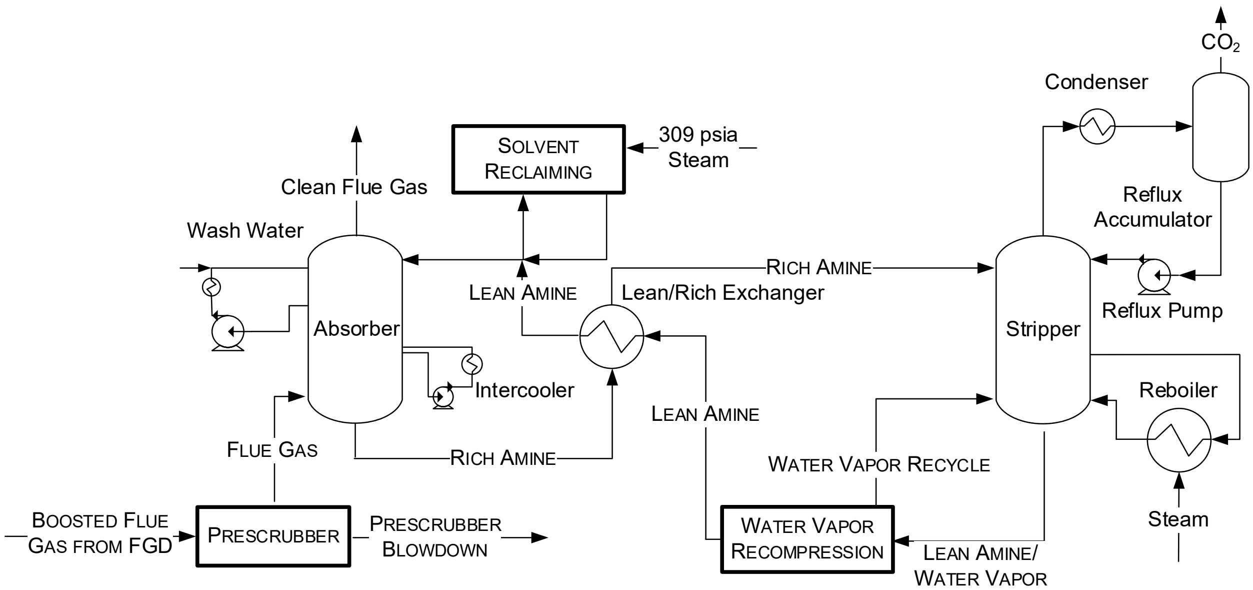
Each of the retrofit cases examined have process areas that are associated with the existing PC plant, such as coal receiving and storage, emissions control technologies, and power generation. Detailed descriptions of these process areas can be found in the process descriptions for Cases B11A and B11B in the Revision 4a of the Fossil Energy Baseline report. [1] Significant changes in aspects and performance features due to retrofitting that are relevant to the individual retrofit cases are discussed in subsections for each case below.

All cases include properly sized carbon capture systems, along with CO_2 compressors and a dryer, retrofitted to the existing plant to capture either 90 or 95 percent of the CO_2 in the flue gas exiting the FGD unit in the existing plant. The facility then purifies it and compresses it for transportation and storage (T&S). The flue gas exiting the FGD unit contains about one percent more CO_2 than the raw flue gas because of the CO_2 liberated from the limestone in the FGD absorber tower. The capture system comprises the pre-scrubber, CO_2 absorber, CO_2 stripper, and solvent reclaiming unit and is based on data provided by Shell on their CANSOLV system in 2021.[a] A typical flowsheet is shown in Exhibit 3-1. This process is designed to recover high-purity CO_2 from low pressure streams that contain O_2, such as flue gas from coal-fired power plants, combustion turbine exhaust gas, and other waste gases. The pre-scrubber step reduces the SO_2 concentration entering the CO_2 absorber column to 0.37 ppmv. The CANSOLV absorber is a single, rectangular, acid resistant, lined concrete structure containing stainless-steel packing. The flue gas enters the absorber and flows counter-current to the CANSOLV solvent. Approximately 90 or 95 percent of the inlet CO_2 is absorbed into the lean solvent, and the remaining CO_2 exits with the remaining flue gas, which is released to the atmosphere after removal of volatiles or entrained amine. The CO_2-rich amine is processed in the amine regeneration stripper, and the recovered CO_2 product gas is separated and sent to the CO_2

[a] Much of the text and descriptions within this section were sourced, with permission, from data provided to NETL by Shell on their CANSOLV system, unless otherwise noted. The information relates to a CO_2 removal system designed by Shell.

compressor at approximately 0.2 MPa (29 psia). The CO_2 compression system is an eight-stage front-loaded integrally geared centrifugal compressor with intercooling for each stage and a triethylene glycol dehydration unit is included between Stages 4 and 5. The CO_2 product enters the transport pipeline as a dense phase liquid at a temperature of 30°C (86°F) and pressure of approximately 15.29 MPa (2,217 psia). Significantly more detail on this system is included in Revision 4a of the Fossil Energy Baseline report. [1]

Exhibit 3-1. CANSOLV CO_2 capture process typical flow diagram for PC



A new circulating water system is constructed, in addition to the existing plant system, in all cases to supply additional cooling water for the retrofitted CO_2 capture facility. The system consists of two 50-percent capacity vertical circulating water pumps, a mechanical draft evaporative cooling tower, and interconnecting piping. The significant quantity of steam turbine extraction in the derated case, B11A-BR, for the capture process stripper reboiler frees up cooling capacity in the existing cooling tower. The newly available capacity can be used to partially supply the additional cooling demands resulting in a smaller additional cooling tower for that case, but modifications to the existing plant circulating water system piping are required and included in the cost estimates.

The flue gas exiting the capture system is returned to the existing stack in all cases. Costs for additional ducting and stack modifications needed to meet velocity and dispersion requirements for the reduced flow of exhaust gas are included in the cost estimates.

3.1 CASE B11A-BR

Case B11A-BR represents a "base case" retrofit of a subcritical PC process with CO_2 capture where the CO_2 capture system is "integrated" into the existing steam cycle to treat 100 percent of the flue gas from an existing subcritical PC boiler plant. The steam and electrical utilities required to operate the CCS facility are supplied by extracting steam from the existing steam cycle and diverting generator output from the grid, effectively reducing the net output available for sale from the existing PC plant. The carbon capture with derate retrofitted plant model (B11A-BR) was created from the Fossil Energy Baseline subcritical PC plant with carbon capture, Case B11B, Aspen model and reducing the plant size to approximately match the coal flow of the B11A case. [1]

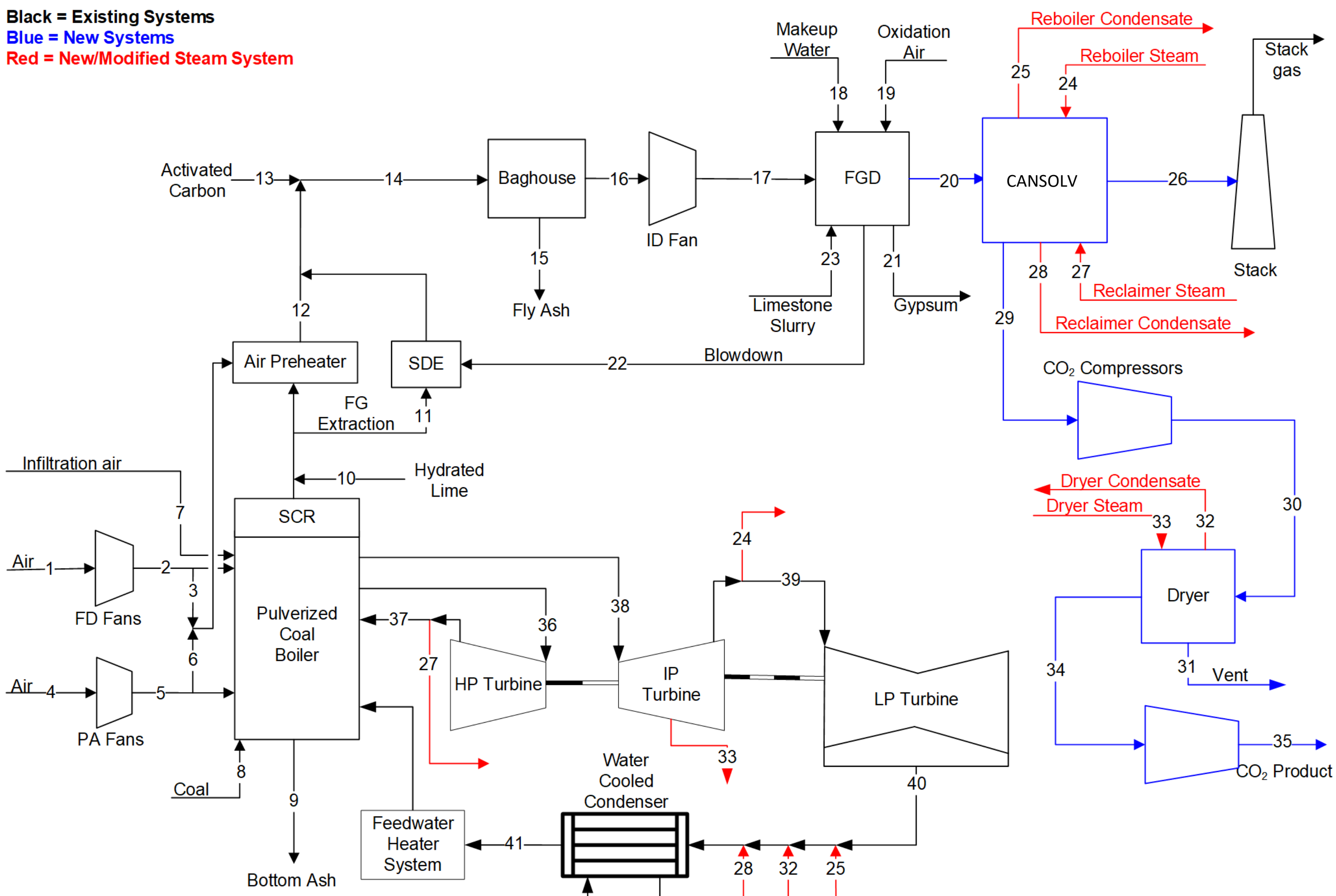
In this retrofit case, the coal feed (and corresponding steam production) is assumed to be essentially unchanged after the retrofit, so the diverted steam and increased auxiliary loads due to CO_2 capture system retrofit reduce both the gross and net plant electricity output. A small reduction in the coal flow rate below that of the existing plant model (B11A) value was required in the model to retain the steam design conditions after the steam diversion.

When retrofitting a PC plant with a CO_2 capture process and extracting the required steam from an existing steam cycle, such as in Case B11A-BR, alterations to the steam turbine must be made to accommodate these demands. The modifications may include a throttled intermediate pressure (IP)-low pressure (LP) crossover extraction scheme, where a throttling valve, along with the associated flanges, spool pieces, and piping, is installed to extract the desired steam. The IP/LP crossover point assumed in this study is more representative of "capture ready" systems and additional derate may be applicable based on the actual plant IP/LP crossover steam conditions. The LP turbine section may also need to have the turbine blades and casing replaced to accommodate the reduced flow, but specific steam turbine modifications were not included in the cost estimates for this study. A derate factor (0.0202) times the steam turbine gross power output after steam extractions was included to reflect expected performance impacts resulting from steam turbine modifications for off-design operation in this base case as in the previous study. [1, 9, 17]

The plant configuration for Case B11A-BR is illustrated in the block flow diagram in Exhibit 3-2 and the material and energy data are presented in the stream tables in Exhibit 3-3 and Exhibit 3-4.

Overall performance for the plant is summarized in Exhibit 3-5 and Exhibit 3-6. Exhibit 3-7 and Exhibit 3-8 provide a detailed breakdown of the auxiliary power requirements. The existing plant, B11A, data are included for comparison. [1] The plant retrofitted with 90 percent capture produces a net output of 495 MWe at a net plant efficiency of 29.4 percent (HHV basis). The plant retrofitted with 95 percent capture produces a net output of 488 MWe at a net plant efficiency of 28.9 percent (HHV basis). This is a decrease of 155 to 162 MWe over the existing plant net capacity and a decrease of 9.2 to 9.6 percentage points from the existing plant efficiency due to the steam turbine derate, 93 to 96 MWe_{gross}, resulting from reduced steam flow and off-design operation, and additional auxiliary load for the capture systems.

Exhibit 3-2. Case B11A-BR block flow diagram



Note: Block Flow Diagram is not intended to represent a complete material balance. Only major process streams and equipment are shown.

Exhibit 3-3. Case B11A-BR.90 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	0.0000
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	60,980	60,980	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,516	0	86,214	5
V-L Flowrate (kg/hr)	1,759,696	1,759,696	52,120	540,560	540,560	74,394	38,896	0	0	12	119,507	2,420,548	0	2,552,646	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,673	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)[B]	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,066.21
Density (kg/m³)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.897
V-L Flowrate (lb_{mol}/hr)	134,438	134,438	3,982	41,298	41,298	5,684	2,972	0	0	2	8,858	179,711	0	190,070	12
V-L Flowrate (lb/hr)	3,879,466	3,879,466	114,905	1,191,732	1,191,732	164,011	85,750	0	0	27	263,467	5,336,395	0	5,627,620	1,218
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,115	9,940	2,687	2,128	40,848	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)[A]	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)[B]	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.4
Density (lb/ft³)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-3. Case B11A-BR.90 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0101	0.0000	0.0000	0.0000	0.0000
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0156	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0807	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8483	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0453	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,209	86,209	5,036	3,609	96,375	203	681	2,805	27,718	25,387	77,287	310	310	11,031	10,818
V-L Flowrate (kg/hr)	2,552,080	2,552,080	90,745	104,139	2,769,826	3,656	12,591	50,543	499,356	457,357	2,145,279	5,585	5,585	479,248	475,418
Solids Flowrate (kg/hr)	0	0	0	0	0	32,887	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	266	105	45	355	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.12	0.10	4.28	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.58	302.09	-47.80	30.23	297.00	---	---	---	2,994.07	439.34	178.41	3,098.44	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,495.73	-14,994.25	-12,986.23	-15,540.95	-903.21	-12,881.86	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.5	1,003.7	2.0	954.9	1.1	16.0	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.495	18.019	18.015	18.015	27.757	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,059	190,059	11,103	7,956	212,470	447	1,501	6,184	61,109	55,969	170,389	683	683	24,319	23,851
V-L Flowrate (lb/hr)	5,626,373	5,626,373	200,059	229,586	6,106,421	8,060	27,759	111,429	1,100,891	1,008,300	4,729,531	12,313	12,313	1,056,560	1,048,116
Solids Flowrate (lb/hr)	0	0	0	0	0	72,504	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	511	221	113	671	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	17.4	14.8	620.5	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,287.2	188.9	76.7	1,332.1	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.0	-6,446.4	-5,583.1	-6,681.4	-388.3	-5,538.2	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.147	62.658	0.123	59.612	0.067	1.000	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-3. Case B11A-BR.90 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41
V-L Mole Fraction											
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	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
H_2O	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
HCl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	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	0.0000
SO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NaCl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	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
V-L Flowrate (kg_{mol}/hr)	23	14	14	10,796	10,796	103,950	96,714	96,714	81,220	40,525	57,095
V-L Flowrate (kg/hr)	438	250	250	474,979	474,979	1,872,688	1,742,337	1,742,337	1,463,199	730,075	1,028,586
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	476	29	30	566	355	566	267	38	39
Pressure (MPa, abs)	2.81	1.64	2.42	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32
Steam Table Enthalpy (kJ/kg)^A	137.94	863.65	3,408.95	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43
AspenPlus Enthalpy (kJ/kg)^B	-15,225.22	-15,116.65	-12,571.34	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	-12,986.23	-13,640.29	-15,817.87
Density (kg/m^3)	351.5	861.8	7.1	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015
V-L Flowrate (lb_{mol}/hr)	50	31	31	23,801	23,801	229,170	213,219	213,219	179,059	89,343	125,873
V-L Flowrate (lb/hr)	966	552	552	1,047,150	1,047,150	4,128,570	3,841,196	3,841,196	3,225,802	1,609,540	2,267,645
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	888	85	86	1,050	671	1,050	512	101	101
Pressure (psia)	407.6	237.4	350.5	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7
Steam Table Enthalpy (Btu/lb)^A	59.3	371.3	1,465.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8
AspenPlus Enthalpy (Btu/lb)^B	-6,545.7	-6,499.0	-5,404.7	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5
Density (lb/ft^3)	21.943	53.801	0.446	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010

^{A}Steam table reference conditions are 32.02°F & 0.089 psia

^{B}Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-4. Case B11A-BR.95 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	0.0000
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	60,980	60,980	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,515	0	86,214	5
V-L Flowrate (kg/hr)	1,759,696	1,759,696	52,120	540,560	540,560	74,394	38,896	0	0	12	119,514	2,420,540	0	2,552,645	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,673	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)[B]	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,065.97
Density (kg/m³)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.898
V-L Flowrate (lb_{mol}/hr)	134,438	134,438	3,982	41,298	41,298	5,684	2,972	0	0	2	8,859	179,710	0	190,070	12
V-L Flowrate (lb/hr)	3,879,466	3,879,466	114,905	1,191,731	1,191,731	164,011	85,750	0	0	27	263,484	5,336,376	0	5,627,619	1,216
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,115	9,940	2,687	2,128	40,847	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)[A]	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)[B]	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.3
Density (lb/ft³)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-4. Case B11A-BR.95 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0102	0.0000	0.0000	0.0000	0.0000
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0079	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0807	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8555	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0457	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,209	86,209	5,037	3,609	96,375	203	681	2,805	29,262	26,801	76,633	310	310	11,645	11,421
V-L Flowrate (kg/hr)	2,552,080	2,552,080	90,758	104,139	2,769,825	3,656	12,591	50,543	527,172	482,834	2,117,876	5,586	5,586	505,938	501,894
Solids Flowrate (kg/hr)	0	0	0	0	0	32,887	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	266	105	45	355	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.12	0.10	4.28	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.59	302.09	-47.80	30.23	297.00	---	---	---	2,994.07	439.34	179.09	3,098.44	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,496.19	-14,994.25	-12,986.23	-15,540.95	-797.41	-12,881.86	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.4	1,003.7	2.0	954.9	1.1	16.0	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.494	18.019	18.015	18.015	27.637	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,059	190,059	11,105	7,956	212,470	447	1,501	6,184	64,513	59,087	168,947	684	684	25,674	25,179
V-L Flowrate (lb/hr)	5,626,374	5,626,374	200,087	229,586	6,106,420	8,060	27,759	111,429	1,162,215	1,064,466	4,669,117	12,314	12,314	1,115,401	1,106,487
Solids Flowrate (lb/hr)	0	0	0	0	0	72,504	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	511	221	113	671	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	17.4	14.8	620.5	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,287.2	188.9	77.0	1,332.1	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.2	-6,446.4	-5,583.1	-6,681.4	-342.8	-5,538.2	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.145	62.658	0.123	59.612	0.066	1.000	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-4. Case B11A-BR.95 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41
V-L Mole Fraction											
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	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
H_2O	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
HCl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	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	0.0000
SO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NaCl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	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
V-L Flowrate (kg_{mol}/hr)	24	15	15	11,397	11,397	103,950	96,714	96,714	81,186	39,180	55,647
V-L Flowrate (kg/hr)	463	264	264	501,431	501,431	1,872,689	1,742,338	1,742,338	1,462,582	705,836	1,002,490
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	476	29	30	566	355	566	267	38	39
Pressure (MPa, abs)	2.81	1.64	2.42	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32
Steam Table Enthalpy (kJ/kg)[A]	137.94	863.65	3,408.95	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43
AspenPlus Enthalpy (kJ/kg)[B]	-15,225.22	-15,116.65	-12,571.34	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	-12,986.23	-13,640.29	-15,817.87
Density (kg/m³)	351.5	861.8	7.1	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015
V-L Flowrate (lb_{mol}/hr)	53	32	32	25,126	25,126	229,171	213,219	213,219	178,984	86,377	122,680
V-L Flowrate (lb/hr)	1,020	581	581	1,105,467	1,105,467	4,128,573	3,841,197	3,841,197	3,224,441	1,556,102	2,210,111
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	888	85	86	1,050	671	1,050	512	101	101
Pressure (psia)	407.6	237.4	350.5	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7
Steam Table Enthalpy (Btu/lb)[A]	59.3	371.3	1,465.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8
AspenPlus Enthalpy (Btu/lb)[B]	-6,545.7	-6,499.0	-5,404.7	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5
Density (lb/ft³)	21.943	53.801	0.446	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-5. Case B11A-BR.90 plant performance summary for 90% capture rate

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BR.90)
Steam Turbine Power, MWe	688	588
Total Gross Power, MWe	**688**	**588**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	14,700
CO_2 Compression, kWe	N/A	38,030
Balance of Plant, kWe	37,520	40,250
Total Auxiliaries, MWe	**38**	**93**
Net Power, MWe	**650**	**495**
HHV Net Plant Efficiency, %	38.6%	29.4%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	12,251 (11,612)
LHV Net Plant Efficiency, %	40.0%	30.5%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	11,816 (11,200)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	54.0%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	6,667 (6,319)
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	1,807 (1,713)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,690 (1,602)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,673 (493,115)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,943
Coal LHV Thermal Input, kWt	1,626,114	1,626,113
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.060 (15.8)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.045 (11.8)

Exhibit 3-6. Case B11A-BR.95 plant performance summary for 95% capture rate

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BR.95)
Steam Turbine Power, MWe	688	584
Total Gross Power, MWe	**688**	**584**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	15,500
CO_2 Compression, kWe	N/A	40,150
Balance of Plant, kWe	37,520	40,350
Total Auxiliaries, MWe	**38**	**96**
Net Power, MWe	**650**	**488**
HHV Net Plant Efficiency, %	38.6%	28.9%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	12,442 (11,793)
LHV Net Plant Efficiency, %	40.0%	30.0%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	12,001 (11,375)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	54.7%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	6,585 (6,242)
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	1,752 (1,661)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,761 (1,669)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,673 (493,115)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,943
Coal LHV Thermal Input, kWt	1,626,114	1,626,113
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.061 (16.2)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.046 (12.1)

Exhibit 3-7. Case B11A-BR.90 plant power summary for 90% capture rate

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BR.90)
Steam Turbine Power, MWe	688	588
Total Gross Power, MWe	**688**	**588**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	730
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	7,600
CO_2 Capture/Removal Auxiliaries, kWe	N/A	14,700
CO_2 Compression, kWe	N/A	38,030
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	560
Cooling Tower Fans, kWe	2,950	3,930
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	710
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	40
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
Transformer Losses, kWe	2,160	2,050
Total Auxiliaries, MWe	**38**	**93**
Net Power, MWe	**650**	**495**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

Exhibit 3-8. Case B11A-BR.95 plant power summary for 95% capture rate

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BR.95)
Steam Turbine Power, MWe	688	584
Total Gross Power, MWe	**688**	**584**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	730
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	7,660
CO_2 Capture/Removal Auxiliaries, kWe	N/A	15,500
CO_2 Compression, kWe	N/A	40,150
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	550
Cooling Tower Fans, kWe	2,950	3,970
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	720
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	40
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
Transformer Losses, kWe	2,160	2,050
Total Auxiliaries, MWe	**38**	**96**
Net Power, MWe	**650**	**488**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

The environmental targets for emissions of Hg, NO_X, SO_2, and PM are presented in Exhibit 2-5. A summary of the plant air emissions for Case B11A-BR is presented in Exhibit 3-9 and Exhibit 3-10. SO_2 emissions are utilized as a surrogate for HCl emissions; therefore, HCl is not reported.

Exhibit 3-9. Case B11A-BR.90 air emissions

	kg/GJ (lb/MMBtu)	tonne/y (ton/y)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	0 (0)	0.000 (0.000)
NO_X	0.031 (0.072)	1,391 (1,533)	0.318 (0.700)
Particulate	0.004 (0.009)	179 (197)	0.041 (0.090)
Hg	1.32E-7 (3.07E-7)	0.006 (0.007)	1.36E-6 (3.00E-6)
CO_2	9 (20)	394,675 (435,055)	90 (199)
CO_2[C]	-	-	107 (236)
		mg/Nm³	
Particulate Concentration[D,E]		12.44	

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

Exhibit 3-10. Case B11A-BR.95 air emissions

	kg/GJ (lb/MMBtu)	tonne/year (ton/year)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	0 (0)	0.000 (0.000)
NO_X	0.031 (0.071)	1,380 (1,521)	0.318 (0.700)
Particulate	0.004 (0.009)	177 (196)	0.041 (0.090)
Hg	1.31E-7 (3.04E-7)	0.006 (0.007)	1.36E-6 (3.00E-6)
CO_2	4 (10)	197,731 (217,961)	45 (100)
CO_2[C]	-	-	54 (120)
		mg/Nm³	
Particulate Concentration[D,E]		12.34	

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

SO_2 emissions are controlled in the existing plant using a wet limestone forced oxidation scrubber that achieves a removal efficiency of 98 percent. They are further reduced to 0.37 ppmv using a sodium hydroxide (NaOH)-based polishing scrubber in the CO_2 capture process. The remaining low concentration of SO_2 is essentially completely removed in the absorber vessel resulting in very low SO_2 emissions (reported as zero here).

The NO_X produced in the existing plant boiler remains constant, but the gross power is reduced, which would result in an increase in normalized NO_X emissions. Additional selective catalytic reduction (SCR) ammonia is included in the cost estimates such that the plant still complies with the 0.7 lb/MWh-gross emissions limit, even with the lower gross plant output for the derated case. The SCR reactor for case B11A in Revision 4a of the Fossil Energy Baseline report, which serves as the existing plant for this study, was equipped with space for installation of an additional catalyst layer if needed, which is assumed to be standard design practice, and no modifications to the SCR were included in the cost estimates for the retrofit cases in this study. [1]

This retrofit study does not address any measures to control particulate or mercury emissions beyond those included in the existing plant.

CO_2 emissions represent controlled emissions from the retrofitted CO_2 capture facility.

The carbon balance for the plant is shown in Exhibit 3-11 and Exhibit 3-12. The carbon input to the plant consists of carbon in the coal, carbon in the air, powdered activated carbon (PAC) used for mercury control in the existing plant, and carbon in the limestone reagent used in the FGD absorber. Carbon leaves the plant mostly as CO_2 product from the CO_2 compression train; however, some CO_2 exits through the stack, the PAC is captured in the fabric filter, unburned carbon remains in the bottom ash, and some leaves as gypsum. The carbon capture efficiency is defined as one minus the amount of carbon in the stack gas relative to the total carbon in, represented by the following fraction for Case B11A-BR.90:

$$\frac{Carbon\ in\ Stack}{(Total\ Carbon\ In)} = \left(1 - \left(\frac{31{,}892}{320{,}015}\right)\right) * 100 = 90.0\%$$

Exhibit 3-11. Case B11A-BR.90 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		**kg/hr (lb/hr)**
Coal	142,580 (314,335)	Stack Gas	14,466 (31,892)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
		CO_2 Product	129,603 (285,726)
		CO_2 Dryer Vent	14 (30)
		CO_2 Knockout	0.4 (0.8)
Total	**145,157 (320,015)**	**Total**	**145,157 (320,015)**

Exhibit 3-12. Case B11A-BR.95 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	142,580 (314,335)	Stack Gas	7,247 (15,978)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
		CO_2 Product	136,821 (301,638)
		CO_2 Dryer Vent	14 (32)
		CO_2 Knockout	0.4 (0.9)
Total	**145,157 (320,015)**	**Total**	**145,157 (320,015)**

Exhibit 3-13 and Exhibit 3-14 show the sulfur balance for the cases. Sulfur input comes solely from the sulfur in the coal. Sulfur output includes the sulfur recovered from the FGD as gypsum, sulfur removed in the polishing scrubber, and sulfur removed in the baghouse.

Exhibit 3-13. Case B11A-BR.90 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,360)	FGD Product	5,271 (11,620)
		Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
Total	**5,606 (12,360)**	**Total**	**5,606 (12,360)**

Exhibit 3-14. Case B11A-BR.95 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,360)	FGD Product	5,271 (11,620)
		Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
Total	**5,606 (12,360)**	**Total**	**5,606 (12,360)**

Exhibit 3-15 and Exhibit 3-16 show the overall water balance for the plant. With CO_2 capture cases, a significant amount of water is recovered from the initial capture process cooling step. This water would otherwise be discharged; however, it is suitable to be used as FGD makeup. The balance of the water from the capture process is sent to discharge.

Exhibit 3-15. Case B11A-BR.90 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (1.9)	0.0 (-1.9)
CO_2 Capture Recovery	–	–	–	0.8 (202)	-0.8 (-202)
CO_2 Compression KO	–	–	–	0.1 (17)	-0.1 (-17)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**30 (7,824)**	**0.3 (84)**	**29 (7,741)**	**6.7 (1,760)**	**23 (5,981)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**32 (8,548)**	**2.7 (707)**	**30 (7,841)**	**7.6 (1,997)**	**22 (5,844)**

Exhibit 3-16. Case B11A-BR.95 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (2.0)	0.0 (-2.0)
CO_2 Capture Recovery	–	–	–	0.8 (215)	-0.8 (-215)
CO_2 Compression KO	–	–	–	0.1 (18)	-0.1 (-18)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**30 (7,887)**	**0.3 (84)**	**30 (7,803)**	**6.7 (1,774)**	**23 (6,030)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**33 (8,610)**	**2.7 (707)**	**30 (7,904)**	**7.7 (2,026)**	**22 (5,878)**

Energy and mass balance diagrams are shown for PC boiler and gas cleanup systems in Exhibit 3-17 and Exhibit 3-19, and the PC plant steam cycle in Exhibit 3-18 and Exhibit 3-20. An overall plant energy balance is provided in tabular form in Exhibit 3-21 and Exhibit 3-22. The power out is the steam turbine power after derating. The cooling tower load is the combined duty of the existing cooling tower plus the additional tower sized for the capture process heat rejected to cooling water, the CO_2 compressor intercooler load, and other miscellaneous cooling loads.

Exhibit 3-17. Case B11A-BR.90 energy and mass balance, subcritical PC boiler with CO_2 capture

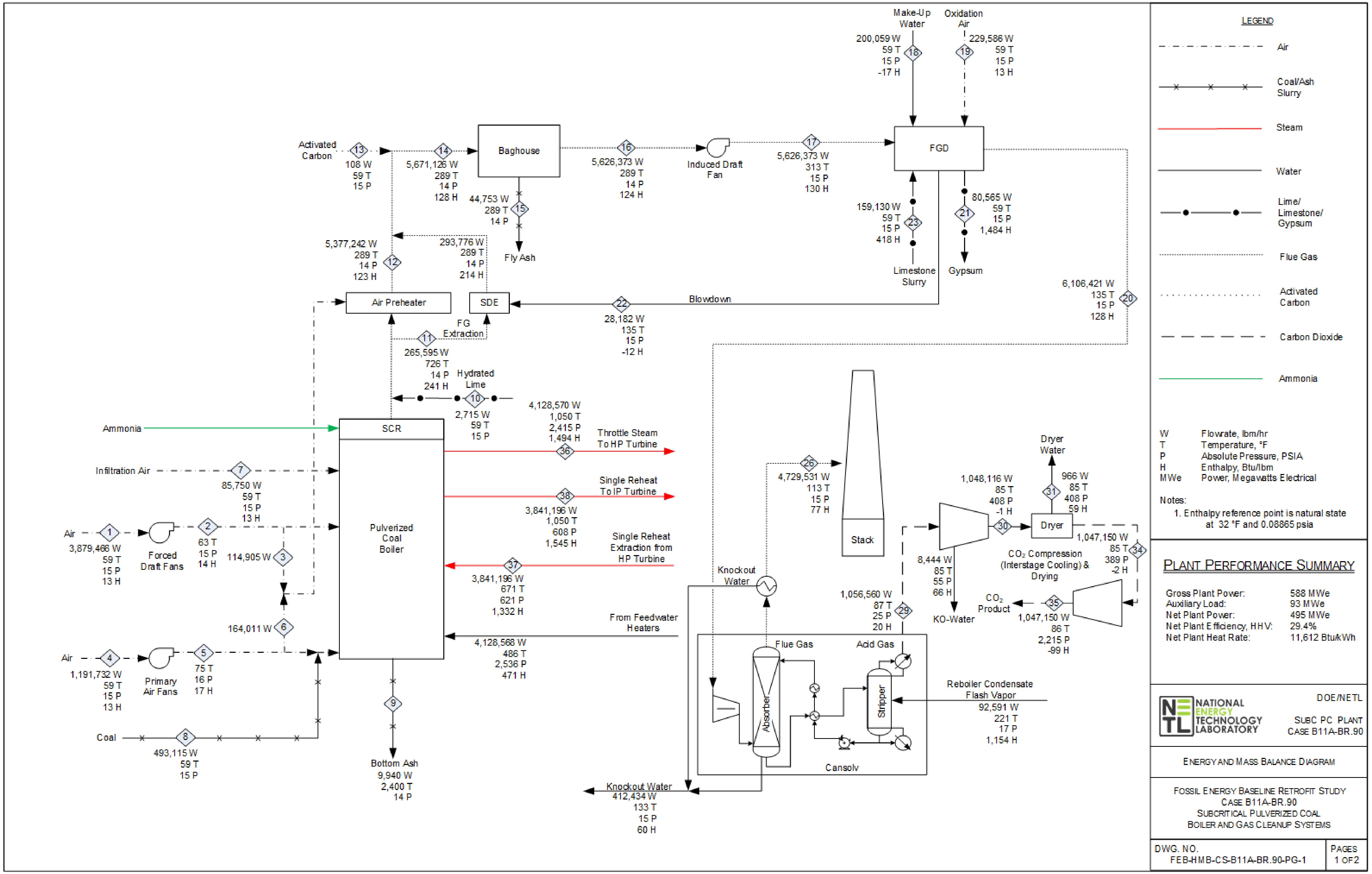


Exhibit 3-18. Case B11A-BR.90 energy and mass balance, subcritical steam cycle

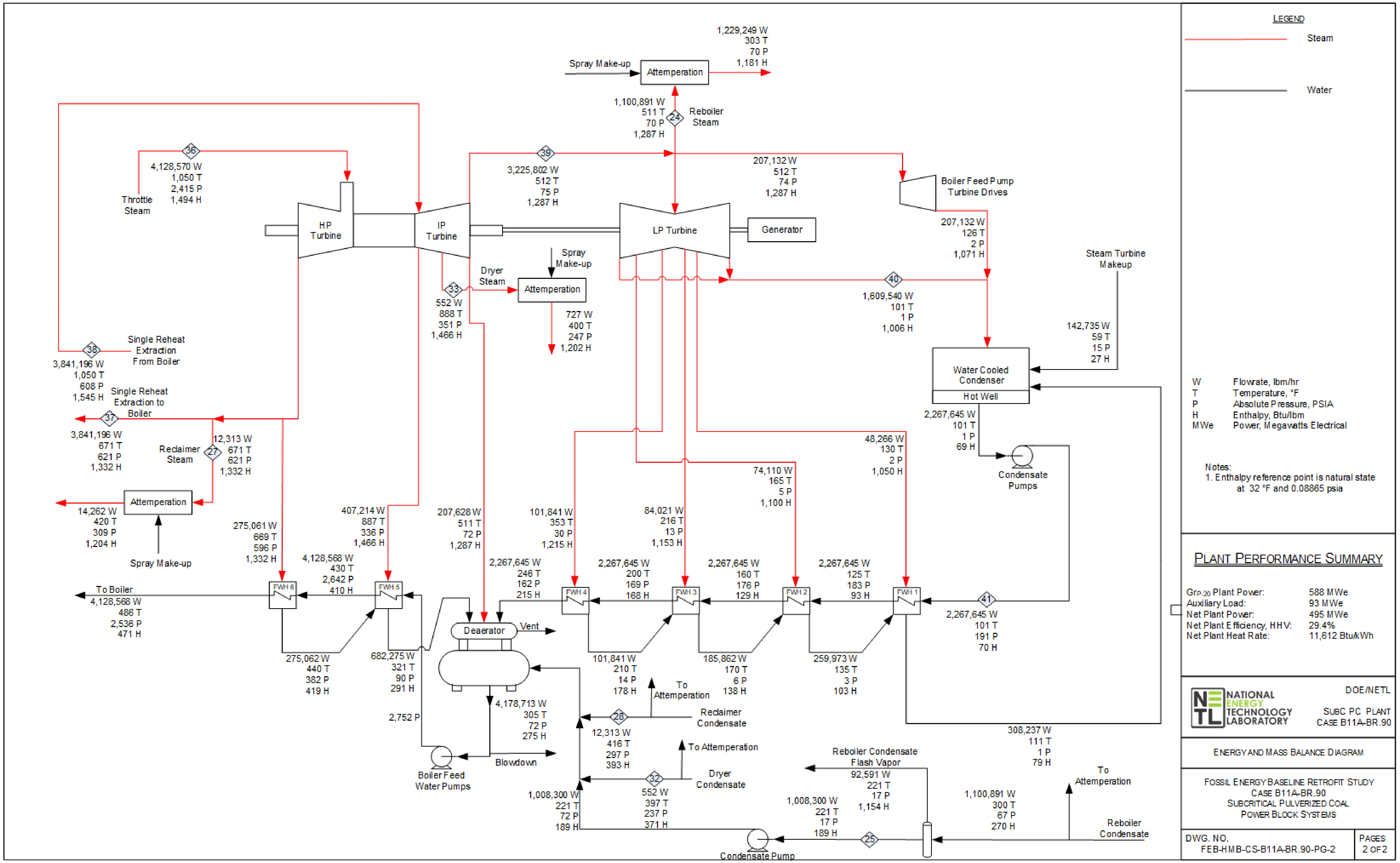


Exhibit 3-19. Case B11A-BR.95 energy and mass balance, subcritical PC boiler with CO_2 capture

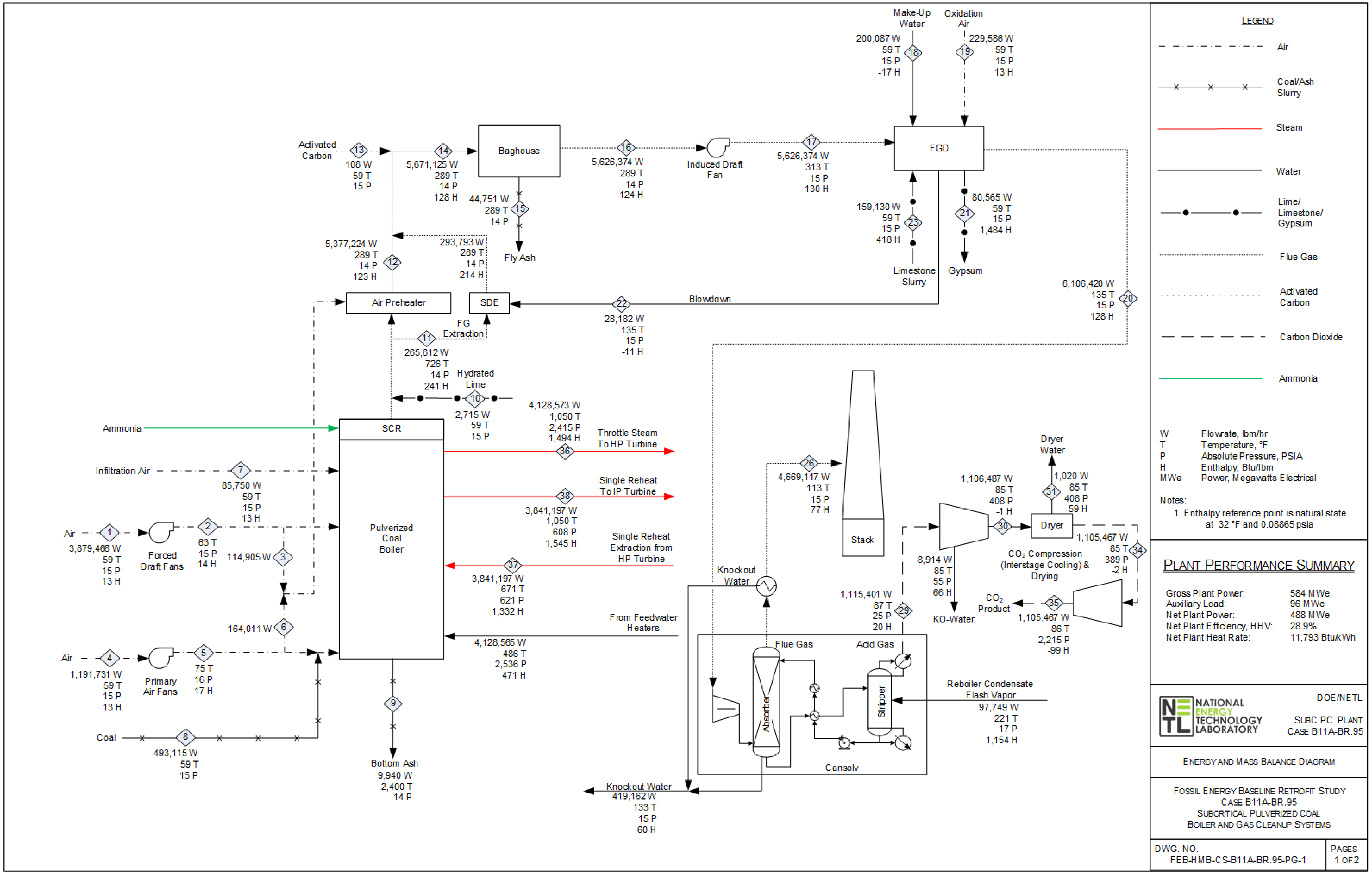


Exhibit 3-20. Case B11A-BR.95 energy and mass balance, subcritical steam cycle

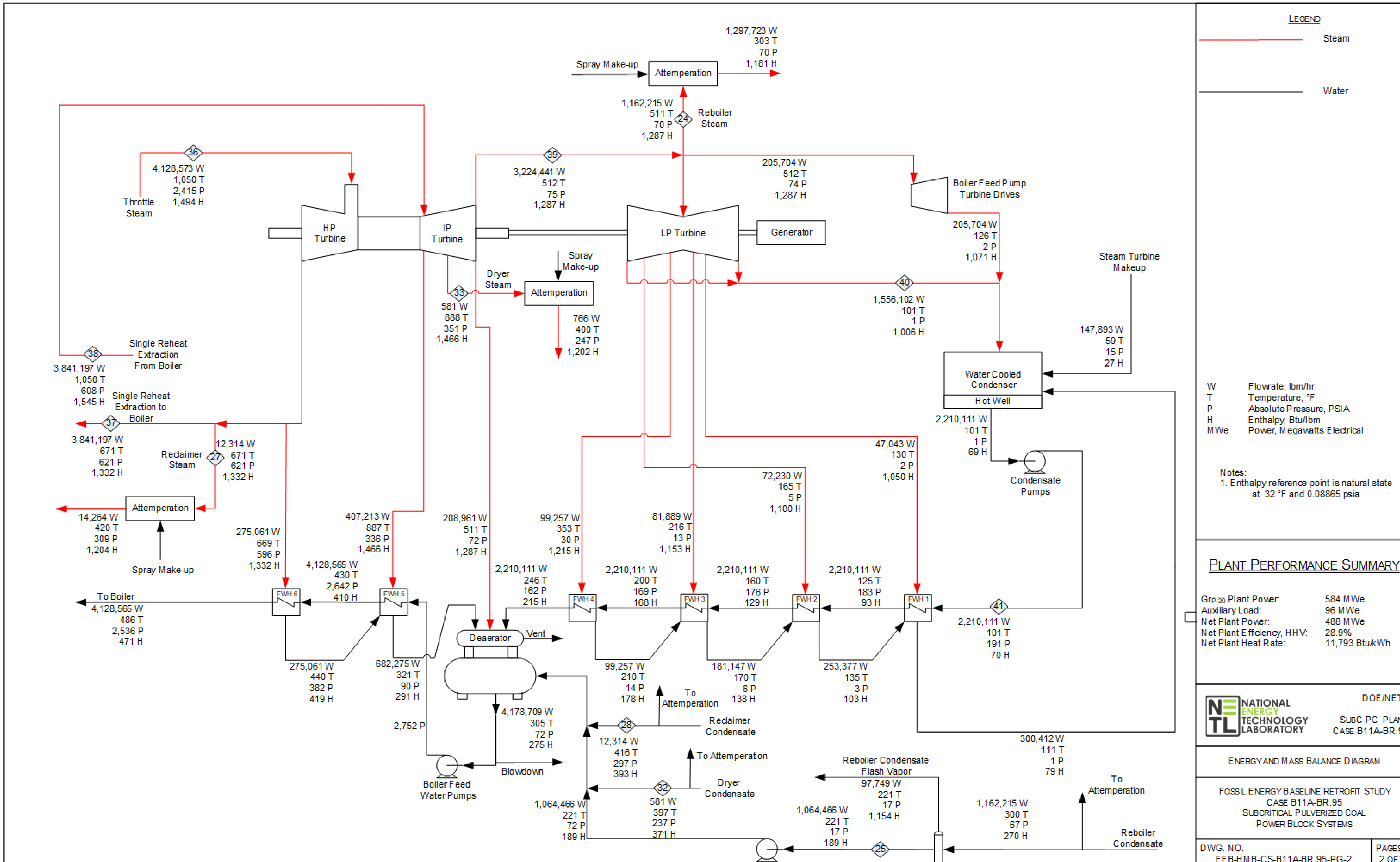


Exhibit 3-21. Case B11A-BR.90 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Raw Water Makeup	–	112 (106)	–	112 (106)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	335 (317)	335 (317)
TOTAL	**6,069 (5,753)**	**188 (178)**	**335 (317)**	**6,592 (6,248)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	383 (363)	–	383 (363)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	39 (37)	39 (37)
Cooling Tower Load[A]	–	3,868 (3,666)	–	3,868 (3,666)
CO_2 Product Stream	–	-110 (-104)	–	-110 (-104)
AGR Effluent	–	44 (42)	–	44 (42)
Blowdown Streams and Deaerator Vent	–	14 (14)	–	14 (14)
Ambient Losses[B]	–	144 (137)	–	144 (137)
Power	–	–	2,118 (2,008)	2,118 (2,008)
TOTAL	**2.0 (1.9)**	**4,353 (4,126)**	**2,157 (2,045)**	**6,512 (6,173)**
Unaccounted Energy[C]	–	*80 (75)*	–	*80 (75)*

[A]Includes condenser, AGR, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

Exhibit 3-22. Case B11A-BR.95 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Raw Water Makeup	–	112 (107)	–	112 (107)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	346 (328)	346 (328)
TOTAL	**6,069 (5,753)**	**189 (179)**	**346 (328)**	**6,604 (6,259)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	379 (360)	–	379 (360)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	39 (37)	39 (37)
Cooling Tower Load[A]	–	3,899 (3,695)	–	3,899 (3,695)
CO_2 Product Stream	–	-116 (-110)	–	-116 (-110)
AGR Effluent	–	44 (42)	–	44 (42)
Blowdown Streams and Deaerator Vent	–	14 (14)	–	14 (14)
Ambient Losses[B]	–	144 (137)	–	144 (137)
Power	–	–	2,102 (1,992)	2,102 (1,992)
TOTAL	**2.0 (1.9)**	**4,375 (4,147)**	**2,141 (2,029)**	**6,518 (6,178)**
Unaccounted Energy[C]	–	*86 (81)*	–	*86 (81)*

[A]Includes condenser, AGR, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

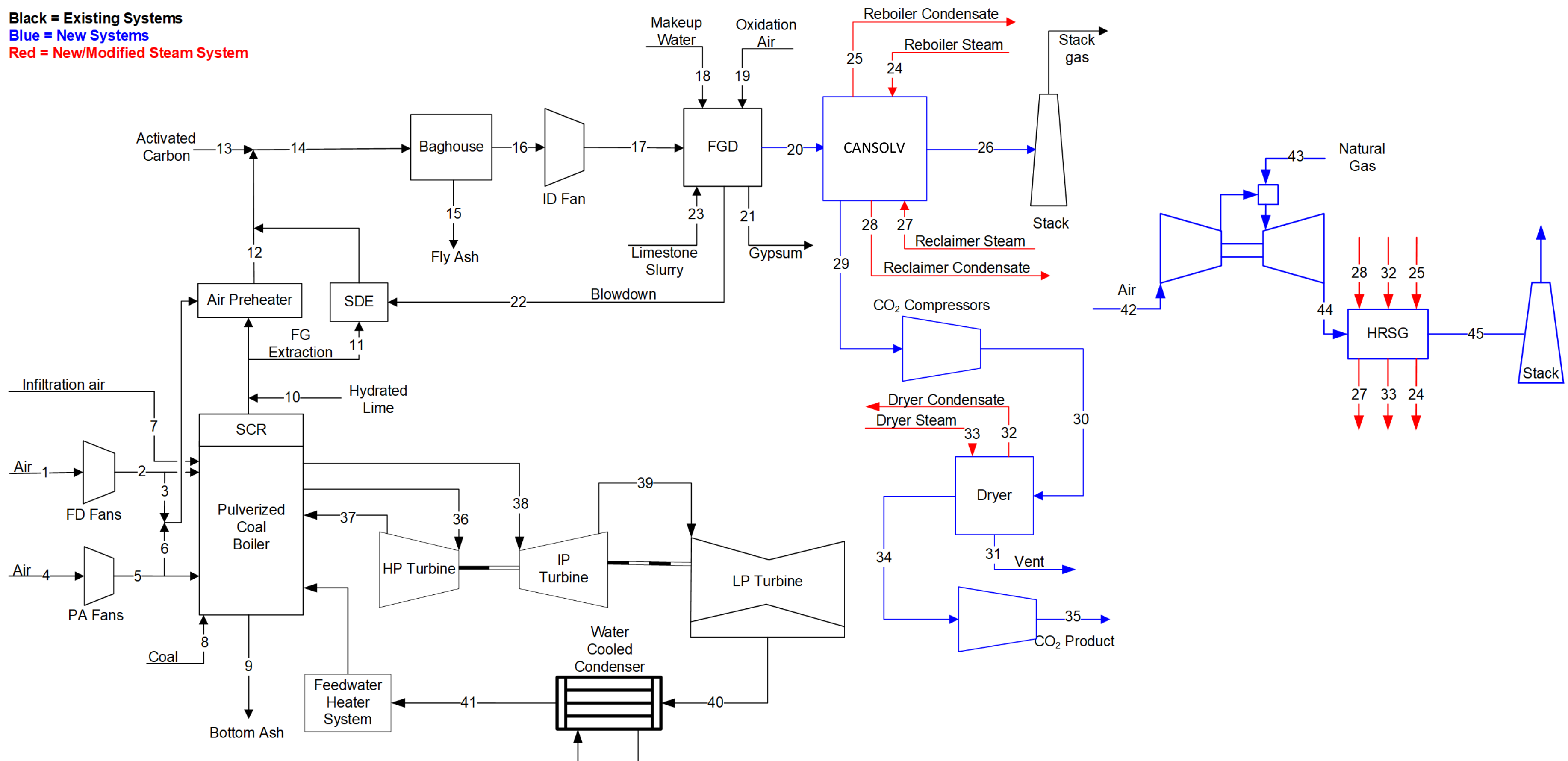
3.2 Case B11A-BRwNGSC

Case B11A-BRwNGSC includes the addition of the carbon capture systems to treat 100 percent of the flue gas from an existing subcritical PC boiler plant without integrating it to the existing steam cycle. Instead of integrating systems, the steam and electrical utilities required to operate the CCS facility are supplied by a NGSC. The size of the combustion turbine was determined by the amount of steam required for the capture process and not based on a commercially available turbine. The hypothetically sized turbine is approximately 1.15 to 1.22 times the capacity of the F-class turbine in cases B31A and B31B in Revision 4a of the Fossil Energy Baseline report. [1] The Aspen model for this case was created from the B11A-BR model by removing the steam extractions and turbine derate then adding the original NGSC model from the previous study updated to match Revision 4a Fossil Energy Baseline report assumptions as needed. [9]

The plant configuration for Case B11A-BRwNGSC is illustrated in the block flow diagram Exhibit 3-23 and the material and energy data are presented in the stream tables in Exhibit 3-24 and Exhibit 3-25.

Overall performance for the plant is summarized in Exhibit 3-26 and Exhibit 3-27. Exhibit 3-28 and Exhibit 3-29 provide a detailed breakdown of the auxiliary power requirements. The existing plant, B11A, data are included for comparison. [1] The retrofitted plant with NGSC and 90 percent capture produces a net output of 864 MWe at an overall net plant efficiency of 35.1 percent (HHV basis). The retrofitted plant with NGSC and 95 percent capture produces a net output of 876 MWe at an overall net plant efficiency of 34.9 percent (HHV basis). This is 369 to 388 MWe higher net capacity than the corresponding B11A-BR base case and 5.7 to 6.0 percentage points higher in efficiency due to the addition of the NGSC and elimination of the steam turbine derating. It is an increase of 214 to 226 MWe over the existing plant net capacity due to the generation capacity of a combustion turbine sized for the capture system steam requirement producing excess power. It is a decrease of 3.6 to 3.7 percentage points from the existing plant efficiency due to the additional fuel consumption in the NGSC and additional auxiliary load for the capture system.

Exhibit 3-23. Case B11A-BRwNGSC block flow diagram



Note: Block Flow Diagram is not intended to represent a complete material balance. Only major process streams and equipment are shown.

Exhibit 3-24. Case B11A-BRwNGSC.90 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	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
CH_4S	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
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
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
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg$_{mol}$/hr)	60,979	60,979	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,515	0	86,214	5
V-L Flowrate (kg/hr)	1,759,681	1,759,681	52,119	540,556	540,556	74,394	38,895	0	0	12	119,510	2,420,522	0	2,552,623	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,671	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)[B]	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,066.03
Density (kg/m³)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.899
V-L Flowrate (lb$_{mol}$/hr)	134,437	134,437	3,982	41,298	41,298	5,684	2,972	0	0	2	8,859	179,709	0	190,069	12
V-L Flowrate (lb/hr)	3,879,432	3,879,432	114,904	1,191,721	1,191,721	164,010	85,749	0	0	27	263,473	5,336,338	0	5,627,570	1,217
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,110	9,940	2,687	2,128	40,847	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)[A]	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)[B]	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.3
Density (lb/ft³)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-24. Case B11A-BRwNGSC.90 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0101	0.0000	0.0000	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
CH_4S	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
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
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
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0156	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0807	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8483	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0453	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,208	86,208	5,036	3,609	96,374	203	681	2,805	30,950	30,950	77,286	359	359	11,031	10,818
V-L Flowrate (kg/hr)	2,552,058	2,552,058	90,749	104,138	2,769,801	3,656	12,591	50,543	557,573	557,573	2,145,261	6,469	6,469	479,243	475,413
Solids Flowrate (kg/hr)	0	0	0	0	0	32,887	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	151	149	45	216	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.46	0.10	2.13	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.59	302.09	-47.80	30.23	297.00	---	---	---	2,747.01	628.07	178.41	2,799.90	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,496.04	-14,994.25	-13,233.28	-15,352.23	-903.21	-13,180.40	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.5	1,003.7	2.6	918.0	1.1	10.7	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.495	18.019	18.015	18.015	27.757	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,057	190,057	11,103	7,956	212,468	447	1,501	6,184	68,233	68,233	170,387	792	792	24,319	23,850
V-L Flowrate (lb/hr)	5,626,324	5,626,324	200,067	229,584	6,106,367	8,060	27,759	111,428	1,229,238	1,229,238	4,729,491	14,262	14,262	1,056,551	1,048,107
Solids Flowrate (lb/hr)	0	0	0	0	0	72,504	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	303	300	113	420	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	67.2	14.8	308.9	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,181.0	270.0	76.7	1,203.7	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.1	-6,446.4	-5,689.3	-6,600.3	-388.3	-5,666.6	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.146	62.658	0.161	57.307	0.067	0.667	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-24. Case B11A-BRwNGSC.90 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
V-L Mole Fraction															
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0000	0.0089	0.0089
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	0.9310	0.0000	0.0000
CH_4S	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	0.0320	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	0.0070	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	0.0040	0.0000	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0100	0.0408	0.0408
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	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0099	0.0000	0.0875	0.0875
HCl	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
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7732	0.0160	0.7428	0.7428
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2074	0.0000	0.1200	0.1200
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	0.0000	0.0000
SO_3	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
NaCl	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
$CaCl_2$	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
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 Flowrate (kg_{mol}/hr)	23	18	18	10,796	10,796	103,895	96,973	96,973	82,051	65,522	83,313	76,388	3,093	79,571	79,571
V-L Flowrate (kg/hr)	438	329	329	474,975	474,975	1,871,696	1,746,997	1,746,997	1,478,180	1,180,395	1,500,904	2,204,312	53,603	2,257,915	2,257,915
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	204	29	30	566	355	566	267	38	39	15	27	625	104
Pressure (MPa, abs)	2.81	1.64	1.71	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32	0.10	2.96	0.11	0.11
Steam Table Enthalpy (kJ/kg)[A]	137.94	863.65	2,795.02	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43	30.23	22.04	832.59	248.38
AspenPlus Enthalpy (kJ/kg)[B]	-15,225.22	-15,116.65	-13,185.27	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	-12,986.23	-13,640.29	-15,817.87	-97.58	-4,487.18	-644.02	-1,228.22
Density (kg/m³)	351.5	861.8	8.6	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3	1.2	22.1	0.4	1.0
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015	28.857	17.328	28.376	28.376
V-L Flowrate (lb_{mol}/hr)	50	40	40	23,800	23,800	229,049	213,789	213,789	180,893	144,451	183,673	168,406	6,820	175,423	175,423
V-L Flowrate (lb/hr)	966	726	726	1,047,141	1,047,141	4,126,384	3,851,468	3,851,468	3,258,830	2,602,326	3,308,928	4,859,676	118,174	4,977,850	4,977,850
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	400	85	86	1,050	671	1,050	512	101	101	59	80	1,156	220
Pressure (psia)	407.6	237.4	247.3	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7	14.7	430.0	15.5	15.5
Steam Table Enthalpy (Btu/lb)[A]	59.3	371.3	1,201.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8	13.0	9.5	357.9	106.8
AspenPlus Enthalpy (Btu/lb)[B]	-6,545.7	-6,499.0	-5,668.6	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5	-42.0	-1,929.1	-276.9	-528.0
Density (lb/ft³)	21.943	53.801	0.537	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010	0.076	1.380	0.025	0.060

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-25. Case B11A-BRwNGSC.95 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	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
CH_4S	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
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
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
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	60,979	60,979	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,515	0	86,214	5
V-L Flowrate (kg/hr)	1,759,681	1,759,681	52,119	540,556	540,556	74,394	38,895	0	0	12	119,510	2,420,522	0	2,552,623	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,671	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)[B]	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,066.03
Density (kg/m^3)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.899
V-L Flowrate (lb_{mol}/hr)	134,437	134,437	3,982	41,298	41,298	5,684	2,972	0	0	2	8,859	179,709	0	190,069	12
V-L Flowrate (lb/hr)	3,879,432	3,879,432	114,904	1,191,721	1,191,721	164,010	85,749	0	0	27	263,473	5,336,338	0	5,627,570	1,217
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,110	9,940	2,687	2,128	40,847	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)[A]	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)[B]	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.3
Density (lb/ft^3)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-25. Case B11A-BRwNGSC.95 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0102	0.0000	0.0000	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
CH_4S	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
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
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
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0078	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0851	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8514	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0455	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,208	86,208	5,036	3,609	96,374	203	681	2,805	32,674	32,674	77,002	359	359	11,645	11,421
V-L Flowrate (kg/hr)	2,552,058	2,552,058	90,749	104,138	2,769,801	3,656	12,591	50,543	588,636	588,636	2,124,510	6,470	6,470	505,933	501,890
Solids Flowrate (kg/hr)	0	0	0	0	0	32,887	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	151	149	46	216	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.46	0.10	2.13	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.59	302.09	-47.80	30.23	297.00	---	---	---	2,747.01	628.07	187.69	2,799.90	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,496.04	-14,994.25	-13,233.28	-15,352.23	-835.76	-13,180.40	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.5	1,003.7	2.6	918.0	1.1	10.7	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.495	18.019	18.015	18.015	27.590	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,057	190,057	11,103	7,956	212,468	447	1,501	6,184	72,034	72,034	169,760	792	792	25,673	25,179
V-L Flowrate (lb/hr)	5,626,324	5,626,324	200,067	229,584	6,106,367	8,060	27,759	111,428	1,297,720	1,297,720	4,683,742	14,264	14,264	1,115,392	1,106,478
Solids Flowrate (lb/hr)	0	0	0	0	0	72,504	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	303	300	115	420	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	67.2	14.8	308.9	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,181.0	270.0	80.7	1,203.7	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.1	-6,446.4	-5,689.3	-6,600.3	-359.3	-5,666.6	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.146	62.658	0.161	57.307	0.066	0.667	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-25. Case B11A-BRwNGSC.95 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
V-L Mole Fraction															
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0000	0.0089	0.0089
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	0.9310	0.0000	0.0000
CH_4S	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	0.0320	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	0.0070	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	0.0040	0.0000	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0100	0.0408	0.0408
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	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0099	0.0000	0.0875	0.0875
HCl	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
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7732	0.0160	0.7428	0.7428
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2074	0.0000	0.1200	0.1200
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	0.0000	0.0000
SO_3	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
NaCl	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
$CaCl_2$	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
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 Flowrate (kg_{mol}/hr)	24	19	19	11,397	11,397	103,895	96,973	96,973	82,051	65,522	83,313	80,595	3,263	83,953	83,953
V-L Flowrate (kg/hr)	463	348	348	501,427	501,427	1,871,696	1,746,997	1,746,997	1,478,180	1,180,395	1,500,904	2,325,718	56,547	2,382,265	2,382,265
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	204	29	30	566	355	566	267	38	39	15	27	625	104
Pressure (MPa, abs)	2.81	1.64	1.71	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32	0.10	2.96	0.11	0.11
Steam Table Enthalpy (kJ/kg)[A]	137.94	863.65	2,795.02	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43	30.23	22.04	832.56	248.29
AspenPlus Enthalpy (kJ/kg)[B]	-15,225.22	-15,116.65	-13,185.27	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	-12,986.23	-13,640.29	-15,817.87	-97.58	-4,487.18	-643.86	-1,228.14
Density (kg/m³)	351.5	861.8	8.6	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3	1.2	22.1	0.4	1.0
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015	28.857	17.328	28.376	28.376
V-L Flowrate (lb_{mol}/hr)	53	43	43	25,126	25,126	229,049	213,789	213,789	180,893	144,451	183,673	177,681	7,195	185,084	185,084
V-L Flowrate (lb/hr)	1,020	767	767	1,105,457	1,105,457	4,126,384	3,851,468	3,851,468	3,258,830	2,602,326	3,308,928	5,127,331	124,665	5,251,996	5,251,996
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	400	85	86	1,050	671	1,050	512	101	101	59	80	1,156	219
Pressure (psia)	407.6	237.4	247.3	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7	14.7	430.0	15.5	15.5
Steam Table Enthalpy (Btu/lb)[A]	59.3	371.3	1,201.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8	13.0	9.5	357.9	106.7
AspenPlus Enthalpy (Btu/lb)[B]	-6,545.7	-6,499.0	-5,668.6	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5	-42.0	-1,929.1	-276.8	-528.0
Density (lb/ft³)	21.943	53.801	0.537	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010	0.076	1.380	0.025	0.060

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-26. Case B11A-BRwNGSC.90 plant performance summary

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGSC.90)
Combustion Turbine Power, MWe	N/A	274
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**962**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	14,700
CO_2 Compression, kWe	N/A	38,030
Balance of Plant, kWe	37,520	45,280
Total Auxiliaries, MWe	**38**	**98**
Net Power, MWe	**650**	**864**
HHV Net Plant Efficiency, %	38.6%	35.1%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	10,269 (9,733)
LHV Net Plant Efficiency, %	40.0%	37.1%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	9,704 (9,198)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	46.3%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	7,770 (7,364)
HHV Combustion Turbine Cycle Efficiency, %	N/A	35.2%
LHV Steam Turbine Cycle Efficiency, %	N/A	39.0%
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	2,793 (2,648)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,690 (1,602)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,671 (493,110)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,928
Coal LHV Thermal Input, kWt	1,626,114	1,626,099
Natural Gas Feed, kg/hr (lb/hr)	N/A	53,603 (118,174)
NG HHV Thermal Input, kWt	N/A	778,652
NG LHV Thermal Input, kWt	N/A	702,811
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.044 (11.6)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.033 (8.8)

Exhibit 3-27. Case B11A-BRwNGSC.95 plant performance summary

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGSC.95)
Combustion Turbine Power, MWe	N/A	290
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**977**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	15,500
CO_2 Compression, kWe	N/A	40,150
Balance of Plant, kWe	37,520	45,620
Total Auxiliaries, MWe	**38**	**101**
Net Power, MWe	**650**	**876**
HHV Net Plant Efficiency, %	38.6%	34.9%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	10,306 (9,768)
LHV Net Plant Efficiency, %	40.0%	37.0%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	9,731 (9,224)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	46.3%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	7,770 (7,364)
HHV Combustion Turbine Cycle Efficiency, %	N/A	35.2%
LHV Steam Turbine Cycle Efficiency, %	N/A	39.0%
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	2,793 (2,648)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,761 (1,669)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,671 (493,110)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,928
Coal LHV Thermal Input, kWt	1,626,114	1,626,099
Natural Gas Feed, kg/hr (lb/hr)	N/A	56,547 (124,665)
NG HHV Thermal Input, kWt	N/A	821,424
NG LHV Thermal Input, kWt	N/A	741,417
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.044 (11.7)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.033 (8.8)

Exhibit 3-28. Case B11A-BRwNGSC.90 plant power summary

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGSC.90)
Combustion Turbine Power, MWe	N/A	274
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**962**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	720
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	9,540
CO_2 Capture/Removal Auxiliaries, kWe	N/A	14,700
CO_2 Compression, kWe	N/A	38,030
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	720
NGSC Condensate Pumps, kWe	N/A	80
Cooling Tower Fans, kWe	2,950	4,940
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	910
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	50
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
Combustion Turbine Auxiliaries, kWe	N/A	510
Transformer Losses, kWe	2,160	3,180
Total Auxiliaries, MWe	**38**	**98**
Net Power, MWe	**650**	**864**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

Exhibit 3-29. Case B11A-BRwNGSC.95 plant power summary

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGSC.95)
Combustion Turbine Power, MWe	N/A	290
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**977**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	720
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	9,710
CO_2 Capture/Removal Auxiliaries, kWe	N/A	15,500
CO_2 Compression, kWe	N/A	40,150
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	720
NGSC Condensate Pumps, kWe	N/A	90
Cooling Tower Fans, kWe	2,950	5,020
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	930
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	50
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
Combustion Turbine Auxiliaries, kWe	N/A	510
Transformer Losses, kWe	2,160	3,240
Total Auxiliaries, MWe	**38**	**101**
Net Power, MWe	**650**	**876**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

The environmental targets for emissions of Hg, NO_X, SO_2, and PM are presented in Exhibit 2-5. A summary of the plant air emissions for Case B11A-BRwNGSC is presented in Exhibit 3-30 and Exhibit 3-31. The NGSC design and cost estimate includes a separate stack for the flue gas exiting the HRSG. The values in the tables are combined totals for the existing plant retrofitted with capture plus the NGSC.

Exhibit 3-30. Case B11A-BRwNGSC.90 air emissions

	kg/GJ (lb/MMBtu)	tonne/year (ton/year)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	8 (9)	0.001 (0.003)
NO_X	0.025 (0.058)	1,658 (1,827)	0.231 (0.510)
Particulate	0.003 (0.008)	226 (249)	0.032 (0.070)
Hg	1.05E-7 (2.45E-7)	0.007 (0.008)	1.36E-6 (3.00E-6)
CO	0.000 (0.001)	17 (18)	0.002 (0.005)
CO_2	22 (51)	1,459,149 (1,608,436)	204 (449)
CO_2[C]	-	-	227 (500)
	mg/Nm^3		
Particulate Concentration[D,E]	15.70		

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

Exhibit 3-31. Case B11A-BRwNGSC.95 air emissions

	kg/GJ (lb/MMBtu)	tonne/year (ton/year)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	9 (10)	0.001 (0.003)
NO_X	0.025 (0.057)	1,659 (1,829)	0.228 (0.503)
Particulate	0.003 (0.008)	227 (250)	0.031 (0.069)
Hg	1.04E-7 (2.41E-7)	0.007 (0.008)	1.36E-6 (3.00E-6)
CO	0.000 (0.001)	18 (19)	0.002 (0.005)
CO_2	20 (46)	1,320,680 (1,455,801)	182 (400)
CO_2[C]	-	-	203 (446)
	mg/Nm^3		
Particulate Concentration[D,E]	15.77		

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

SO_2 emissions from the existing plant are reduced to 0.37 ppmv using a NaOH-based polishing scrubber in the CO_2 capture process. The remaining low concentration of SO_2 is essentially completely removed in the absorber vessel resulting in very low SO_2 emissions. The natural gas burned in the NGSC was assumed to contain the domestic average value of total sulfur of 0.34 gr/100 scf (4.71×10^{-4} lb-S/MMBtu). [13] It was also assumed that the added CH_4S was the sole contributor of sulfur to the natural gas. No sulfur capture systems are required on the NGSC flue gas resulting in a low but non-zero value for the B11A-BRwNGSC case.

The NGSC is equipped with low NO_X burners and an SCR to minimize NO_X emissions. The increase in gross power for the total plant reduces the overall NO_X emissions per MWh_{gross}, so the SCR catalyst and ammonia quantities treating the PC flue gas do not need to be increased to maintain compliance.

This retrofit study does not address any measures to control particulate or mercury emissions beyond those included in the existing plant.

CO_2 emissions represent controlled emissions from the retrofitted CO_2 capture facility and the uncontrolled emissions from the NGSC, combined.

The carbon balance for the plant is shown in Exhibit 3-32 and Exhibit 3-33. The carbon input to the existing plant consists of carbon in the coal, carbon in the air, PAC used for mercury control in the existing plant, and carbon in the limestone reagent used in the FGD absorber. Additional carbon input for the B11A-BRwNGSC case is from the natural gas and air inputs to the NGSC. Carbon leaves the plant mostly as CO_2 product from the CO_2 compression train; however, some CO_2 exits through the stacks, the PAC is captured in the fabric filter, unburned carbon remains in the bottom ash, and some leaves as gypsum. While the capture system is designed for 90 or 95 percent capture from the PC plant flue gas, the addition of the uncaptured CO_2 from the NGSC stack decreases the overall carbon capture efficiency for the retrofitted plant. For the 90 percent capture case the capture efficiency is represented by the following fraction:

$$\frac{Carbon\ in\ Stacks}{(Total\ Carbon\ In)} = \left(1 - \left(\frac{31{,}892 + 86{,}016}{406{,}028}\right)\right) * 100 = 71.0\%$$

Exhibit 3-32. Case B11A-BRwNGSC.90 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	142,579 (314,332)	Stack Gas	14,466 (31,892)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
Natural Gas	38,716 (85,355)	CO_2 Product	129,602 (285,723)
NGSC Air (CO_2)	300 (661)	CO_2 Dryer Vent	14 (30)
		CO_2 Knockout	0.4 (0.8)
		NGSC Stack Gas	39,016 (86,016)
Total	**184,171 (406,028)**	**Total**	**184,171 (406,028)**

Exhibit 3-33. Case B11A-BRwNGSC.95 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	142,579 (314,332)	Stack Gas	7,247 (15,978)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
Natural Gas	40,843 (90,043)	CO_2 Product	136,820 (301,636)
NGSC Air (CO_2)	316 (697)	CO_2 Dryer Vent	14 (32)
		CO_2 Knockout	0.4 (0.9)
		NGSC Stack Gas	41,159 (90,741)
Total	**186,315 (410,753)**	**Total**	**186,315 (410,753)**

Exhibit 3-34 and Exhibit 3-35 show the sulfur balance for the plants. Sulfur input comes from the sulfur in the coal and natural gas. Sulfur output includes the sulfur recovered from the FGD as gypsum, sulfur removed in the polishing scrubber, and sulfur removed in the baghouse and sulfur in the NGSC flue gas.

Exhibit 3-34. Case B11A-BRwNGSC.90 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,359)	FGD Product	5,271 (11,620)
Natural Gas	0.6 (1.3)	Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
		NGSC Stack Gas	0.6 (1.3)
Total	**5,607 (12,361)**	**Total**	**5,607 (12,361)**

Exhibit 3-35. Case B11A-BRwNGSC.95 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,359)	FGD Product	5,271 (11,620)
Natural Gas	0.6 (1.3)	Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
		NGSC Stack Gas	0.6 (1.3)
Total	**5,607 (12,361)**	**Total**	**5,607 (12,361)**

Exhibit 3-36 and Exhibit 3-37 show the overall water balance for the plants. With CO_2 capture cases, a significant amount of water is recovered from the initial capture process cooling step. This water would otherwise be discharged; however, it is suitable to be used as FGD makeup. Additional water is used in the NGSC HRSG. The balance of the water from the capture process is sent to discharge.

Exhibit 3-36. Case B11A-BRwNGSC.90 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (1.9)	0.0 (-1.9)
CO_2 Capture Recovery	–	–	–	0.8 (223)	-0.8 (-223)
CO_2 Compression KO	–	–	–	0.1 (17)	-0.1 (-17)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
NGSC HRSG	9.4 (2,488)	8.6 (2,282)	0.8 (211)	0.0 (4.6)	0.8 (207)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**37 (9,820)**	**0.3 (84)**	**37 (9,737)**	**8.4 (2,208)**	**28 (7,528)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**49 (13,032)**	**11 (2,988)**	**38 (10,048)**	**9.4 (2,472)**	**29 (7,576)**

Exhibit 3-37. Case B11A-BRwNGSC.95 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (2.0)	0.0 (-2.0)
CO_2 Capture Recovery	–	–	–	0.8 (209)	-0.8 (-209)
CO_2 Compression KO	–	–	–	0.1 (18)	-0.1 (-18)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
NGSC HRSG	9.9 (2,626)	9.1 (2,407)	0.8 (223)	0.0 (4.8)	0.8 (218)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**38 (9,993)**	**0.3 (84)**	**38 (9,910)**	**8.5 (2,247)**	**29 (7,662)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**51 (13,342)**	**12 (3,114)**	**39 (10,233)**	**9.5 (2,498)**	**29 (7,735)**

Energy and mass balance diagrams are shown for PC boiler, NGSC, and gas cleanup systems in Exhibit 3-38 and Exhibit 3-40, and the PC plant steam cycle in Exhibit 3-39 and Exhibit 3-41. An overall plant energy balance is provided in tabular form in Exhibit 3-42 and Exhibit 3-43. The total power out is from the gas turbine generator as well as the steam turbine generator. The cooling tower load is the combined duty of the existing cooling tower plus the additional tower sized for the capture process heat rejected to cooling water, the CO_2 compressor intercooler load, and other miscellaneous cooling loads.

Exhibit 3-38. Case B11A-BRwNGSC.90 energy and mass balance, subcritical PC boiler with CO_2 capture and NGSC

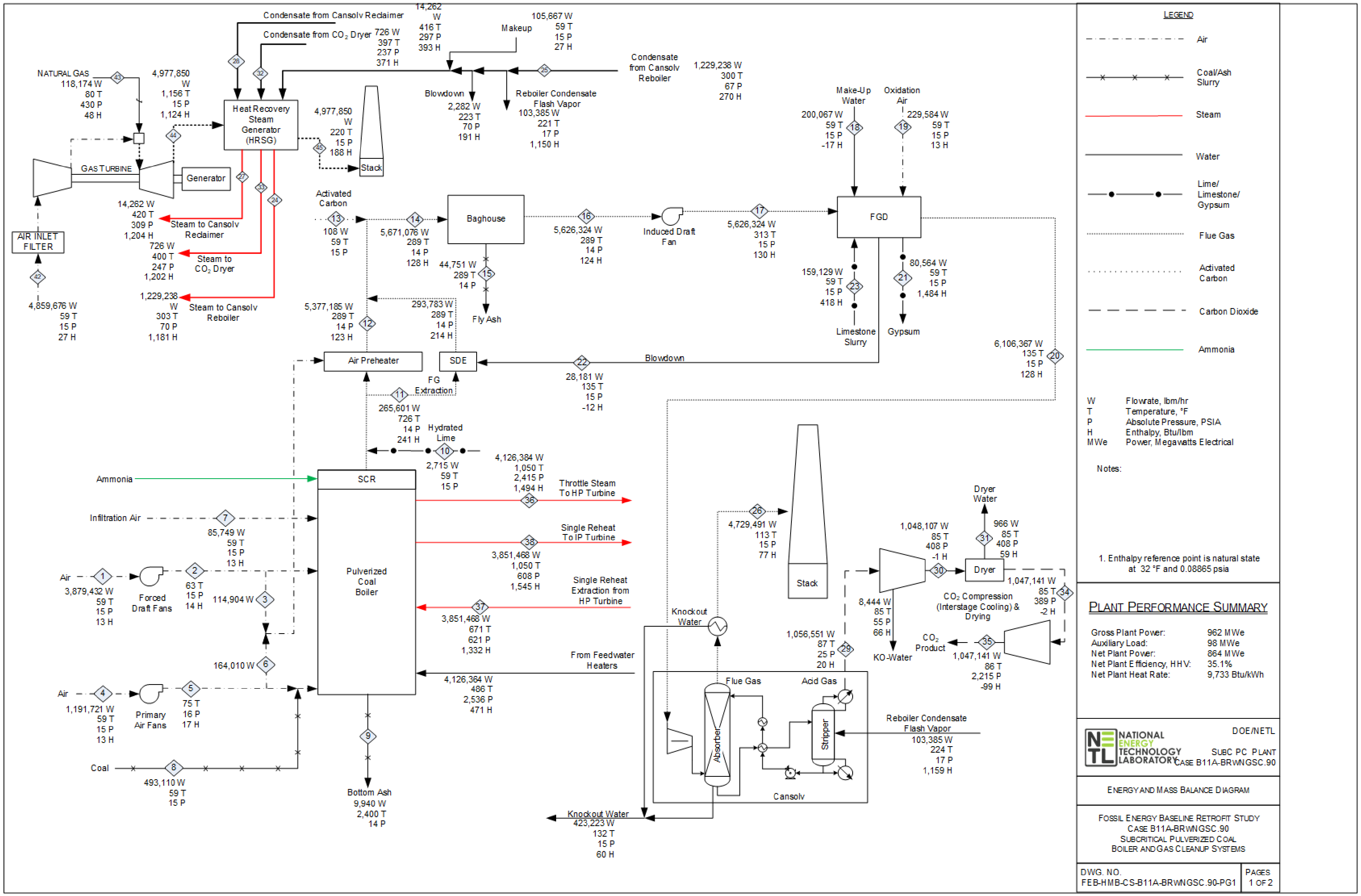


Exhibit 3-39. Case B11A-BRwNGSC.90 energy and mass balance, subcritical steam cycle

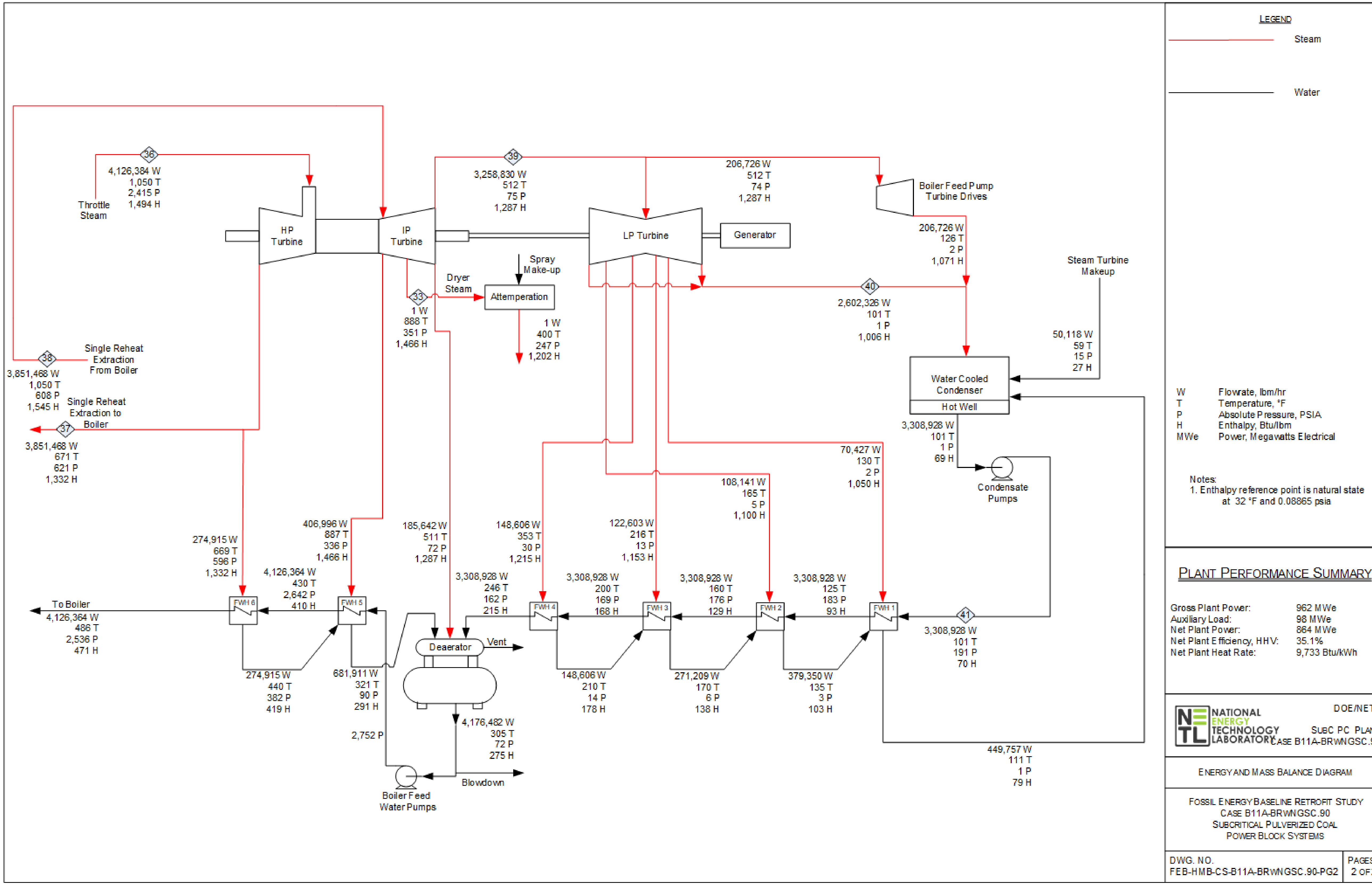


Exhibit 3-40. Case B11A-BRwNGSC.95 energy and mass balance, subcritical PC boiler with CO_2 capture and NGSC

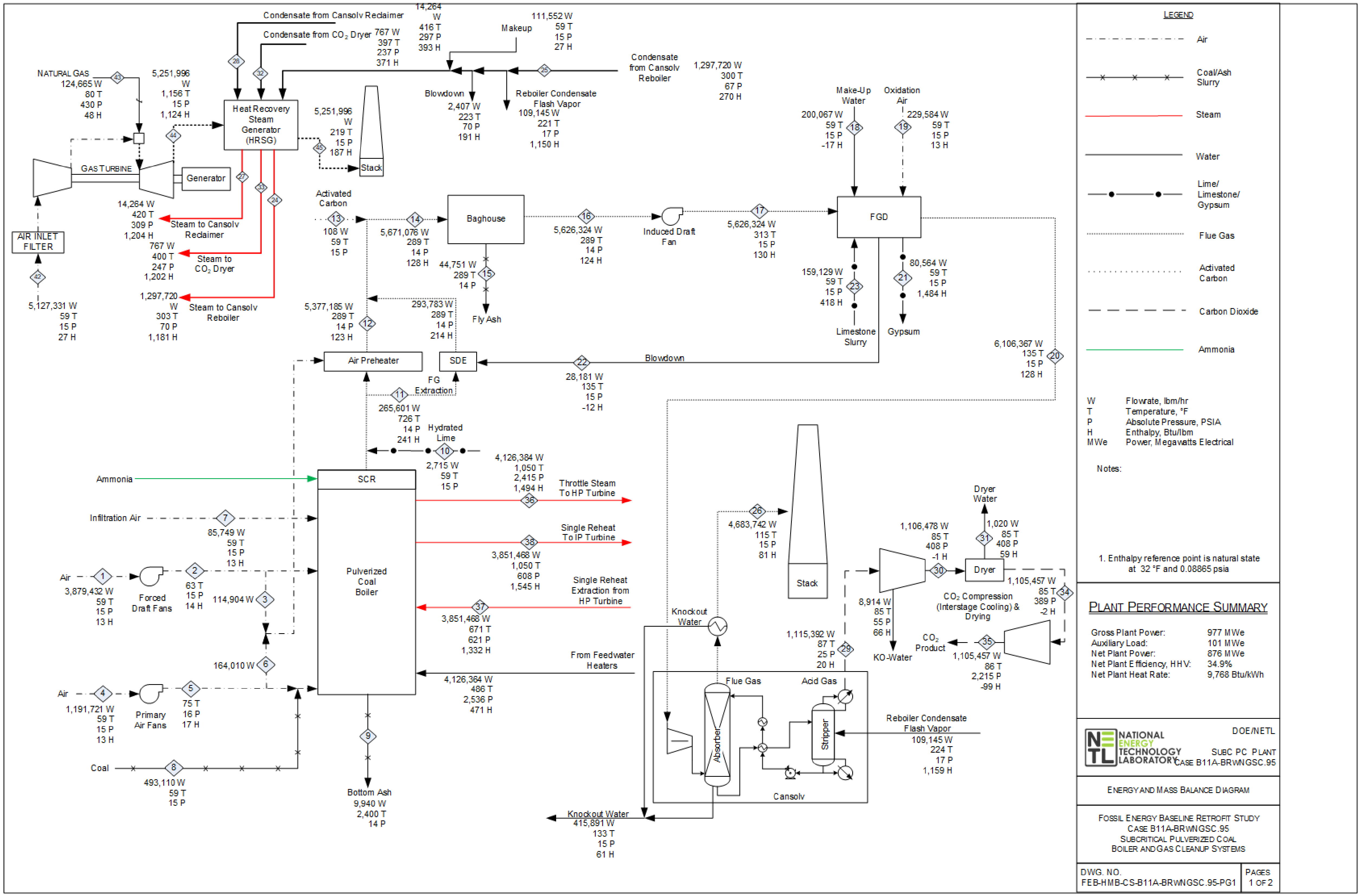


Exhibit 3-41. Case B11A-BRwNGSC.95 energy and mass balance, subcritical steam cycle

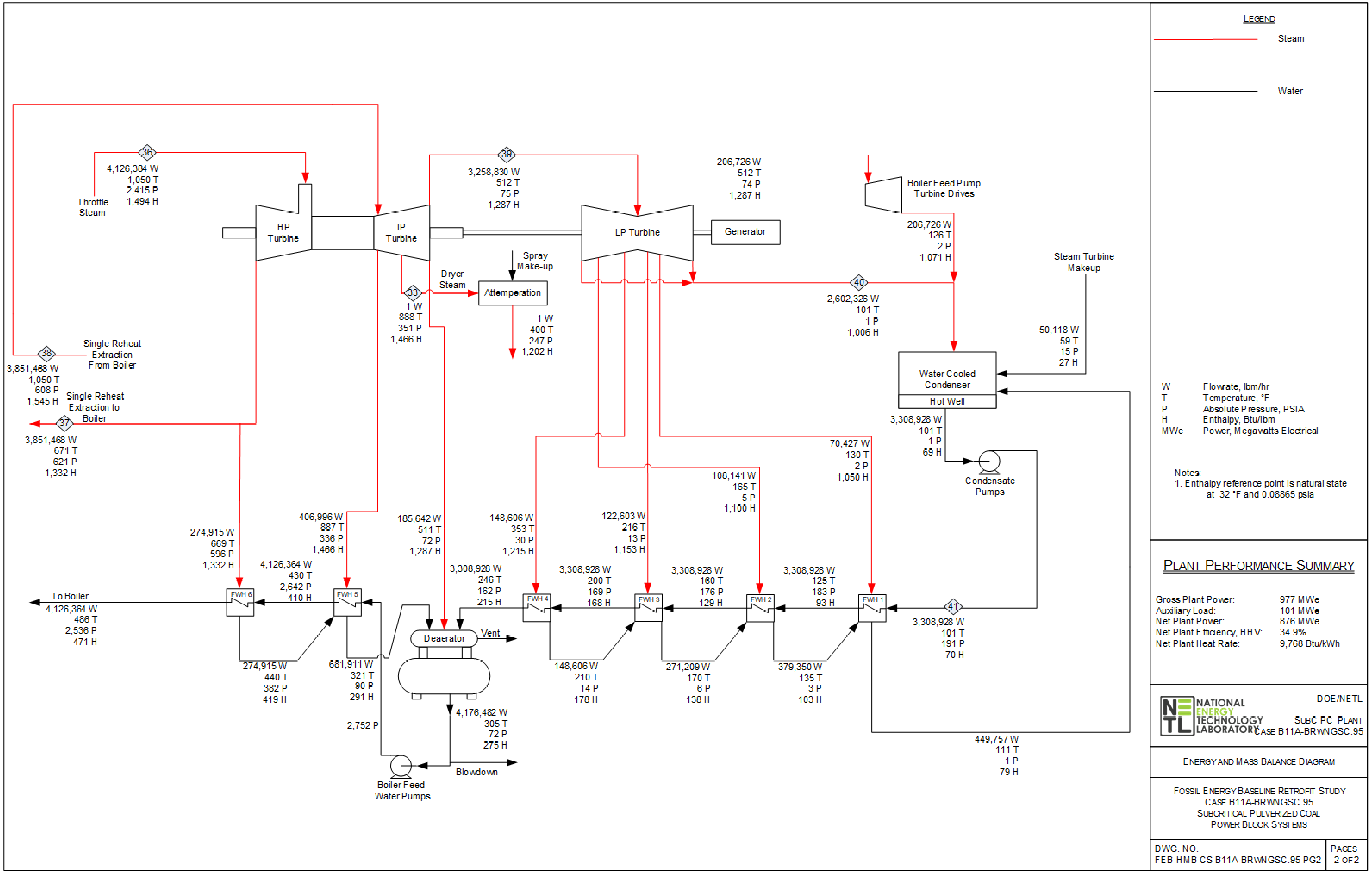


Exhibit 3-42. Case B11A-BRwNGSC.90 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Natural Gas	2,803 (2,657)	1.9 (1.8)	–	2,805 (2,659)
CT Air	–	67 (63)	–	67 (63)
Raw Water Makeup	–	143 (136)	–	143 (136)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	353 (334)	353 (334)
TOTAL	**8,872 (8,409)**	**288 (273)**	**353 (334)**	**9,513 (9,017)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	383 (363)	–	383 (363)
CT Stack Gas	–	561 (532)	–	561 (532)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	68 (64)	68 (64)
Cooling Tower Load[A]	–	4,854 (4,601)	–	4,854 (4,601)
CO_2 Product Stream	–	-110 (-104)	–	-110 (-104)
AGR Effluent	–	45 (42)	–	45 (42)
Blowdown Streams and Deaerator Vent	–	15 (14)	–	15 (14)
Ambient Losses[B]	–	161 (153)	–	161 (153)
Power	–	–	3,463 (3,282)	3,463 (3,282)
TOTAL	**2.0 (1.9)**	**5,919 (5,611)**	**3,531 (3,347)**	**9,452 (8,959)**
Unaccounted Energy[C]	–	*61 (58)*	–	*61 (58)*

[A]Includes condenser, capture system, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

Exhibit 3-43. Case B11A-BRwNGSC.95 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Natural Gas	2,957 (2,803)	2.0 (1.9)	–	2,959 (2,805)
CT Air	–	70 (67)	–	70 (67)
Raw Water Makeup	–	146 (138)	–	146 (138)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	365 (346)	365 (346)
TOTAL	**9,026 (8,555)**	**294 (279)**	**365 (346)**	**9,685 (9,180)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	399 (378)	–	399 (378)
CT Stack Gas	–	591 (561)	–	591 (561)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	69 (66)	69 (66)
Cooling Tower Load[A]	–	4,940 (4,682)	–	4,940 (4,682)
CO_2 Product Stream	–	-116 (-110)	–	-116 (-110)
AGR Effluent	–	44 (42)	–	44 (42)
Blowdown Streams and Deaerator Vent	–	15 (14)	–	15 (14)
Ambient Losses[B]	–	162 (154)	–	162 (154)
Power	–	–	3,518 (3,334)	3,518 (3,334)
TOTAL	**2.0 (1.9)**	**6,046 (5,730)**	**3,587 (3,400)**	**9,635 (9,132)**
Unaccounted Energy[C]	–	*51 (48)*	–	*51 (48)*

[A]Includes condenser, capture system, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

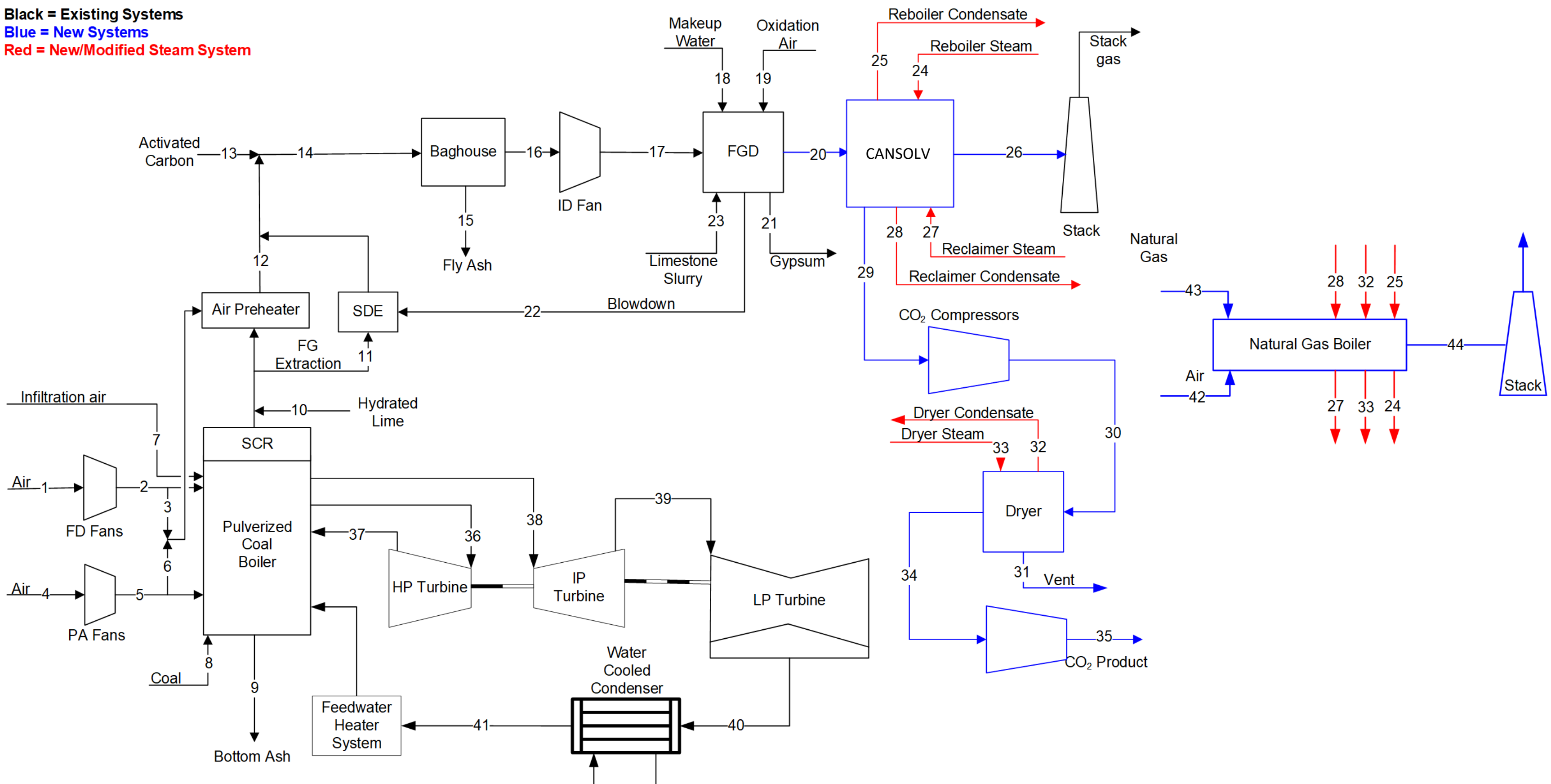
3.3 CASE B11A-BRWNGBLR

Case B11A-BRwNGBlr includes the addition of 90 and 95 percent carbon capture systems to treat 100 percent of the flue gas from an existing subcritical PC boiler plant without integrating it to the existing steam cycle. Instead of integrating all systems, the steam required to operate the CCS facility is supplied by a natural gas-fired boiler. The electrical utilities required to operate the CCS facility are supplied by the existing plant power system. The natural gas-fired boiler performance and costs are based on a quote from CleaverBrooks for 2×500,000 lb/hr package boilers and scaled by the amount of steam required for the capture process based on NETL cost scaling methodology. [5, 18] The Aspen model for this case was created from the B11A-BR model by removing the steam extractions and turbine derate then adding a natural gas-fired boiler model based on the vendor quote. [9]

The plant configuration for Case B11A-BRwNGBlr is illustrated in the block flow diagram Exhibit 3-44 and the material and energy data are presented in the stream tables in Exhibit 3-45 and Exhibit 3-46.

Overall performance for the plant is summarized in Exhibit 3-47 and Exhibit 3-48. Exhibit 3-49 and Exhibit 3-50 provide a detailed breakdown of the auxiliary power requirements. The existing plant, B11A, data are included for comparison. [1] The retrofitted plant with the natural gas-fired boiler and 90 percent capture produces a net output of 591 MWe at a net plant efficiency of 27.9 percent (HHV basis). The retrofitted plant with the natural gas-fired boiler and 95 percent capture produces a net output of 588 MWe at a net plant efficiency of 27.4 percent (HHV basis). This is 95 to 100 MWe higher net capacity than the corresponding B11A-BR base case due to the elimination of the steam turbine derating and a decrease of 1.5 percentage points in the efficiency due to the additional fuel consumption in the natural gas-fired boiler. It is a decrease of 59 to 62 MWe over the existing plant net capacity due to the additional auxiliary load for the capture system and 10.7 to 11.2 percentage points decrease in the efficiency due to the additional fuel consumption in the natural gas-fired boiler.

Exhibit 3-44. Case B11A-BRwNGBlr block flow diagram



Note: Block Flow Diagram is not intended to represent a complete material balance. Only major process streams and equipment are shown.

Exhibit 3-45. Case B11A-BRwNGBlr.90 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	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
CH_4S	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
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
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
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	60,979	60,979	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,515	0	86,214	5
V-L Flowrate (kg/hr)	1,759,681	1,759,681	52,119	540,556	540,556	74,394	38,895	0	0	12	119,510	2,420,522	0	2,552,623	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,671	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)[B]	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,066.03
Density (kg/m^3)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.899
V-L Flowrate (lb_{mol}/hr)	134,437	134,437	3,982	41,298	41,298	5,684	2,972	0	0	2	8,859	179,709	0	190,069	12
V-L Flowrate (lb/hr)	3,879,432	3,879,432	114,904	1,191,721	1,191,721	164,010	85,749	0	0	27	263,473	5,336,338	0	5,627,570	1,217
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,110	9,940	2,687	2,128	40,847	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)[A]	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)[B]	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.3
Density (lb/ft^3)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-45. Case B11A-BRwNGBlr.90 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0101	0.0000	0.0000	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
CH_4S	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
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
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
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0156	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0807	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8483	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0453	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,208	86,208	5,036	3,609	96,374	203	681	2,805	30,950	30,950	77,286	359	359	11,031	10,818
V-L Flowrate (kg/hr)	2,552,058	2,552,058	90,749	104,138	2,769,801	3,656	12,591	50,543	557,573	557,573	2,145,261	6,469	6,469	479,243	475,413
Solids Flowrate (kg/hr)	0	0	0	0	0	32,887	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	151	149	45	216	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.46	0.10	2.13	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.59	302.09	-47.80	30.23	297.00	---	---	---	2,747.01	628.07	178.41	2,799.89	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,496.04	-14,994.25	-13,233.28	-15,352.23	-903.21	-13,180.40	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.5	1,003.7	2.6	918.0	1.1	10.7	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.495	18.019	18.015	18.015	27.757	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,057	190,057	11,103	7,956	212,468	447	1,501	6,184	68,233	68,233	170,387	792	792	24,319	23,850
V-L Flowrate (lb/hr)	5,626,324	5,626,324	200,067	229,584	6,106,367	8,060	27,759	111,428	1,229,238	1,229,238	4,729,491	14,263	14,263	1,056,551	1,048,107
Solids Flowrate (lb/hr)	0	0	0	0	0	72,504	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	303	300	113	420	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	67.2	14.8	308.9	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,181.0	270.0	76.7	1,203.7	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.1	-6,446.4	-5,689.3	-6,600.3	-388.3	-5,666.6	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.146	62.658	0.161	57.307	0.067	0.667	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-45. Case B11A-BRwNGBlr.90 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44
V-L Mole Fraction														
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0000	0.0085
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	0.9310	0.0000
CH_4S	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	0.0320	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	0.0070	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	0.0040	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0100	0.0869
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
H_2O	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0099	0.0000	0.1758
HCl	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
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7732	0.0160	0.7083
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2074	0.0000	0.0205
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	0.0000
SO_3	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
NaCl	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
$CaCl_2$	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
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
V-L Flowrate (kg_{mol}/hr)	23	18	18	10,796	10,796	103,895	96,973	96,973	82,051	65,522	83,313	18,858	1,715	20,623
V-L Flowrate (kg/hr)	438	330	330	474,975	474,975	1,871,696	1,746,997	1,746,997	1,478,180	1,180,395	1,500,904	544,194	29,712	573,906
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	204	29	30	566	355	566	267	38	39	15	27	102
Pressure (MPa, abs)	2.81	1.64	1.71	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	137.94	863.65	2,795.02	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43	30.23	54.60	396.64
AspenPlus Enthalpy (kJ/kg)[B]	-15,225.22	-15,116.65	-13,185.27	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	-12,986.23	-13,640.29	-15,817.87	-97.58	-4,454.63	-2,672.62
Density (kg/m³)	351.5	861.8	8.6	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3	1.2	0.7	0.9
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015	28.857	17.328	27.829
V-L Flowrate (lb_{mol}/hr)	50	40	40	23,800	23,800	229,049	213,789	213,789	180,893	144,451	183,673	41,576	3,780	45,465
V-L Flowrate (lb/hr)	966	727	727	1,047,141	1,047,141	4,126,384	3,851,468	3,851,468	3,258,830	2,602,326	3,308,928	1,199,742	65,504	1,265,247
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	400	85	86	1,050	671	1,050	512	101	101	59	80	215
Pressure (psia)	407.6	237.4	247.3	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7	14.7	14.7	14.7
Steam Table Enthalpy (Btu/lb)[A]	59.3	371.3	1,201.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8	13.0	23.5	170.5
AspenPlus Enthalpy (Btu/lb)[B]	-6,545.7	-6,499.0	-5,668.6	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5	-42.0	-1,915.1	-1,149.0
Density (lb/ft³)	21.943	53.801	0.537	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010	0.076	0.044	0.057

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-46. Case B11A-BRwNGBlr.95 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	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
CH_4S	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
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
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
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	60,979	60,979	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,515	0	86,214	5
V-L Flowrate (kg/hr)	1,759,681	1,759,681	52,119	540,556	540,556	74,394	38,895	0	0	12	119,510	2,420,522	0	2,552,623	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,671	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)^A	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)^B	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,066.03
Density (kg/m³)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.899
V-L Flowrate (lb_{mol}/hr)	134,437	134,437	3,982	41,298	41,298	5,684	2,972	0	0	2	8,859	179,709	0	190,069	12
V-L Flowrate (lb/hr)	3,879,432	3,879,432	114,904	1,191,721	1,191,721	164,010	85,749	0	0	27	263,473	5,336,338	0	5,627,570	1,217
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,110	9,940	2,687	2,128	40,847	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)^A	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)^B	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.3
Density (lb/ft³)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

^{A}Steam table reference conditions are 32.02°F & 0.089 psia

^{B}Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-46. Case B11A-BRwNGBlr.95 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0102	0.0000	0.0000	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
CH_4S	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
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
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
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0078	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0851	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8514	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0455	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,208	86,208	5,036	3,609	96,374	203	681	2,805	32,674	32,674	77,002	359	359	11,645	11,421
V-L Flowrate (kg/hr)	2,552,058	2,552,058	90,749	104,138	2,769,801	3,656	12,591	50,543	588,636	588,636	2,124,510	6,470	6,470	505,933	501,890
Solids Flowrate (kg/hr)	0	0	0	0	0	32,887	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	151	149	46	216	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.46	0.10	2.13	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.59	302.09	-47.80	30.23	297.00	---	---	---	2,747.01	628.07	187.69	2,799.89	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,496.04	-14,994.25	-13,233.28	-15,352.23	-835.76	-13,180.40	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.5	1,003.7	2.6	918.0	1.1	10.7	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.495	18.019	18.015	18.015	27.590	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,057	190,057	11,103	7,956	212,468	447	1,501	6,184	72,034	72,034	169,760	792	792	25,673	25,179
V-L Flowrate (lb/hr)	5,626,324	5,626,324	200,067	229,584	6,106,367	8,060	27,759	111,428	1,297,720	1,297,720	4,683,742	14,264	14,264	1,115,392	1,106,478
Solids Flowrate (lb/hr)	0	0	0	0	0	72,504	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	303	300	115	420	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	67.2	14.8	308.9	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,181.0	270.0	80.7	1,203.7	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.1	-6,446.4	-5,689.3	-6,600.3	-359.3	-5,666.6	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.146	62.658	0.161	57.307	0.066	0.667	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-46. Case B11A-BRwNGBlr.95 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44
V-L Mole Fraction														
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0000	0.0085
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	0.9310	0.0000
CH_4S	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	0.0320	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	0.0070	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	0.0040	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0100	0.0869
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
H_2O	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0099	0.0000	0.1758
HCl	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
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7732	0.0160	0.7083
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2074	0.0000	0.0205
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	0.0000
SO_3	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
NaCl	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
$CaCl_2$	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
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
V-L Flowrate (kg_{mol}/hr)	24	19	19	11,397	11,397	103,895	96,973	96,973	82,051	65,522	83,313	19,898	1,809	21,760
V-L Flowrate (kg/hr)	463	348	348	501,427	501,427	1,871,696	1,746,997	1,746,997	1,478,180	1,180,395	1,500,904	574,209	31,351	605,565
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	204	29	30	566	355	566	267	38	39	15	27	102
Pressure (MPa, abs)	2.81	1.64	1.71	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	137.94	863.65	2,795.02	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43	30.23	54.60	396.56
AspenPlus Enthalpy (kJ/kg)[B]	-15,225.22	-15,116.65	-13,185.27	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	-12,986.23	-13,640.29	-15,817.87	-97.58	-4,454.63	-2,672.70
Density (kg/m^3)	351.5	861.8	8.6	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3	1.2	0.7	0.9
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015	28.857	17.328	27.829
V-L Flowrate (lb_{mol}/hr)	53	43	43	25,126	25,126	229,049	213,789	213,789	180,893	144,451	183,673	43,869	3,989	47,973
V-L Flowrate (lb/hr)	1,020	767	767	1,105,457	1,105,457	4,126,384	3,851,468	3,851,468	3,258,830	2,602,326	3,308,928	1,265,914	69,117	1,335,042
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	400	85	86	1,050	671	1,050	512	101	101	59	80	215
Pressure (psia)	407.6	237.4	247.3	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7	14.7	14.7	14.7
Steam Table Enthalpy (Btu/lb)[A]	59.3	371.3	1,201.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8	13.0	23.5	170.5
AspenPlus Enthalpy (Btu/lb)[B]	-6,545.7	-6,499.0	-5,668.6	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5	-42.0	-1,915.1	-1,149.1
Density (lb/ft^3)	21.943	53.801	0.537	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010	0.076	0.044	0.057

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit 3-47. Case B11A-BRwNGBlr.90 plant performance summary

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGBlr.90)
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**688**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	14,700
CO_2 Compression, kWe	N/A	38,030
Balance of Plant, kWe	37,520	44,060
Total Auxiliaries, MWe	**38**	**97**
Net Power, MWe	**650**	**591**
HHV Net Plant Efficiency, %	38.6%	27.9%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	12,903 (12,230)
LHV Net Plant Efficiency, %	40.0%	29.3%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	12,282 (11,641)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	46.3%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	7,770 (7,364)
HHV NG Boiler Efficiency, %	N/A	77.6%
LHV NG Boiler Efficiency, %	N/A	86.0%
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	2,793 (2,648)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,690 (1,602)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,671 (493,110)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,928
Coal LHV Thermal Input, kWt	1,626,114	1,626,099
Natural Gas Feed, kg/hr (lb/hr)	N/A	29,712 (65,504)
NG HHV Thermal Input, kWt	N/A	431,610
NG LHV Thermal Input, kWt	N/A	389,570
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.065 (17.1)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.049 (12.8)

Exhibit 3-48. Case B11A-BRwNGBlr.95 plant performance summary

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGBlr.95)
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**688**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	15,500
CO_2 Compression, kWe	N/A	40,150
Balance of Plant, kWe	37,520	44,340
Total Auxiliaries, MWe	**38**	**100**
Net Power, MWe	**650**	**588**
HHV Net Plant Efficiency, %	38.6%	27.4%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	13,119 (12,434)
LHV Net Plant Efficiency, %	40.0%	28.8%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	12,481 (11,829)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	46.3%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	7,770 (7,364)
HHV NG Boiler Efficiency, %	N/A	77.6%
LHV NG Boiler Efficiency, %	N/A	86.0%
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	2,793 (2,648)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,761 (1,669)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,671 (493,110)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,928
Coal LHV Thermal Input, kWt	1,626,114	1,626,099
Natural Gas Feed, kg/hr (lb/hr)	N/A	31,351 (69,117)
NG HHV Thermal Input, kWt	N/A	455,415
NG LHV Thermal Input, kWt	N/A	411,057
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.066 (17.5)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.050 (13.2)

Exhibit 3-49. Case B11A-BRwNGBlr.90 plant power summary

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwBlr.90)
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**688**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	720
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	9,540
CO_2 Capture/Removal Auxiliaries, kWe	N/A	14,700
CO_2 Compression, kWe	N/A	38,030
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	720
NG Boiler Condensate Pumps, kWe	N/A	80
Cooling Tower Fans, kWe	2,950	4,940
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	920
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	50
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
NG Boiler Auxiliaries, kWe	N/A	100
Transformer Losses, kWe	2,160	2,360
Total Auxiliaries, MWe	**38**	**97**
Net Power, MWe	**650**	**591**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

Exhibit 3-50. Case B11A-BRwNGBlr.95 plant power summary

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwBlr.95)
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**688**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	720
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	9,710
CO_2 Capture/Removal Auxiliaries, kWe	N/A	15,500
CO_2 Compression, kWe	N/A	40,150
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	720
NG Boiler Condensate Pumps, kWe	N/A	90
Cooling Tower Fans, kWe	2,950	5,020
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	930
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	50
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
NG Boiler Auxiliaries, kWe	N/A	100
Transformer Losses, kWe	2,160	2,370
Total Auxiliaries, MWe	**38**	**100**
Net Power, MWe	**650**	**588**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

The environmental targets for emissions of Hg, NO_X, SO_2, and PM are presented in Exhibit 2-5. Summaries of the plant air emissions for case B11A-BRwNGBlr are presented in Exhibit 3-51 and Exhibit 3-52. The natural gas-fired boiler system design and cost estimate includes a separate stack for the flue gas exiting the boilers. The values in the table are combined totals for the existing plant retrofitted with capture plus the natural gas-fired boiler.

Exhibit 3-51. Case B11A-BRwNGBlr.90 air emissions

	kg/GJ (lb/MMBtu)	tonne/year (ton/year)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	5 (5)	0.001 (0.002)
NO_X	0.029 (0.067)	1,626 (1,792)	0.318 (0.700)
Particulate	0.004 (0.009)	213 (235)	0.042 (0.092)
Hg	1.23E-7 (2.85E-7)	0.007 (0.008)	1.36E-6 (3.00E-6)
CO_2	17 (40)	982,200 (1,082,691)	192 (423)
CO_2[C]	-	-	223 (492)
	mg/Nm³		
Particulate Concentration[D,E]	14.83		

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

Exhibit 3-52. Case B11A-BRwNGBlr.95 air emissions

	kg/GJ (lb/MMBtu)	tonne/year (ton/year)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	5 (5)	0.001 (0.002)
NO_X	0.028 (0.066)	1,626 (1,792)	0.318 (0.700)
Particulate	0.004 (0.009)	214 (235)	0.042 (0.092)
Hg	1.21E-7 (2.82E-7)	0.007 (0.008)	1.36E-6 (3.00E-6)
CO_2	14 (33)	817,668 (901,325)	160 (352)
CO_2[C]	-	-	187 (412)
	mg/Nm³		
Particulate Concentration[D,E]	14.85		

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

SO_2 emissions from the existing plant are reduced to 0.37 ppmv using a NaOH-based polishing scrubber in the CO_2 capture process. The remaining low concentration of SO_2 is essentially completely removed in the absorber vessel resulting in very low SO_2 emissions. The natural gas burned in the auxiliary boiler was assumed to contain the domestic average value of total sulfur of 0.34 g/100 scf (4.71×10^{-4} lb-S/MMBtu). [13] It was also assumed that the added CH_4S was the sole contributor of sulfur to the natural gas. No sulfur capture systems are required on the boiler flue gas resulting in a low but non-zero value for the B11A-BRwNGBlr case.

The natural gas-fired boiler is equipped with low NO_X burners to minimize NO_X emissions. The NO_X produced in the existing plant boiler remains constant, but the gross power is reduced, which would result in an increase in normalized NO_X emissions. Additional selective catalytic reduction (SCR) ammonia is included in the cost estimates such that the plant still complies with the 0.7 lb/MWh-gross emissions limit, even with the lower gross plant output. The SCR reactor for case B11A in Revision 4a of the Fossil Energy Baseline report, which serves as the existing plant for this study, was equipped with space for installation of an additional catalyst layer if needed, which is assumed to be standard design practice, and no modifications to the SCR were included in the cost estimates for the retrofit cases in this study. [1]

This retrofit study does not address any measures to control particulate or mercury emissions beyond those included in the existing plant.

CO_2 emissions represent controlled emissions from the retrofitted CO_2 capture facility and the uncontrolled emissions from the natural gas-fired boiler, combined.

The carbon balance for the plant is shown in Exhibit 3-53 and Exhibit 3-54. The carbon input to the existing plant consists of carbon in the coal, carbon in the air, PAC used for mercury control in the existing plant, and carbon in the limestone reagent used in the FGD absorber. Additional carbon input for the B11A-BRwNGBlr case is from the natural gas and air inputs to the natural gas-fired boiler. Carbon leaves the plant mostly as CO_2 product from the CO_2 compression train; however, some CO_2 exits through the stacks, the PAC is captured in the fabric filter, unburned carbon remains in the bottom ash, and some leaves as gypsum. While the capture system is designed for 90 or 95 percent capture from the PC plant flue gas, the addition of the uncaptured CO_2 from the natural gas-fired boiler stack decreases the overall carbon capture efficiency for the retrofitted plant. The capture efficiency for the 90 percent capture case is represented by the following fraction:

$$\frac{Carbon\ in\ Stacks}{(Total\ Carbon\ In)} = \left(1 - \left(\frac{31{,}892 + 47{,}476}{367{,}488}\right)\right) * 100 = 78.4\%$$

Exhibit 3-53. Case B11A-BRwNGBlr.90 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	142,579 (314,332)	Stack Gas	14,466 (31,892)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
Natural Gas	21,461 (47,312)	CO_2 Product	129,602 (285,723)
NG Boiler Air (CO_2)	74 (163)	CO_2 Dryer Vent	14 (30)
		CO_2 Knockout	0.4 (0.8)
		NG Boiler Stack Gas	21,535 (47,476)
Total	**166,690 (367,488)**	**Total**	**166,690 (367,488)**

Exhibit 3-54. Case B11A-BRwNGBlr.95 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	142,579 (314,332)	Stack Gas	7,247 (15,978)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
Natural Gas	22,644 (49,922)	CO_2 Product	136,820 (301,636)
NG Boiler Air (CO_2)	78 (172)	CO_2 Dryer Vent	14 (32)
		CO_2 Knockout	0.4 (0.9)
		NG Boiler Stack Gas	22,722 (50,094)
Total	**167,878 (370,107)**	**Total**	**167,878 (370,107)**

Exhibit 3-55 and Exhibit 3-56 show the sulfur balance for the plant. Sulfur input comes from the sulfur in the coal and natural gas. Sulfur output includes the sulfur recovered from the FGD as gypsum, sulfur removed in the polishing scrubber, and sulfur removed in the baghouse and sulfur in the natural gas-fired boiler flue gas.

Exhibit 3-55. Case B11A-BRwNGBlr.90 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,359)	FGD Product	5,271 (11,620)
Natural Gas	0.3 (0.7)	Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
		NG Boiler Stack Gas	0.3 (0.7)
Total	**5,606 (12,360)**	**Total**	**5,606 (12,360)**

Exhibit 3-56. Case B11A-BRwNGBlr.95 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,359)	FGD Product	5,271 (11,620)
Natural Gas	0.3 (0.7)	Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
		NG Boiler Stack Gas	0.3 (0.7)
Total	**5,606 (12,360)**	**Total**	**5,606 (12,360)**

Exhibit 3-57 and Exhibit 3-58 show the overall water balance for the plant. With CO_2 capture cases, a significant amount of water is recovered from the initial capture process cooling step. This water would otherwise be discharged; however, it is suitable to be used as FGD makeup. Additional water is used in the natural gas-fired boiler. The balance of the water from the capture process is sent to discharge.

Exhibit 3-57. Case B11A-BRwNGBlr.90 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (1.9)	0.0 (-1.9)
CO_2 Capture Recovery	–	–	–	0.8 (223)	-0.8 (-223)
CO_2 Compression KO	–	–	–	0.1 (17)	-0.1 (-17)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
Natural Gas Boiler	9.4 (2,488)	8.6 (2,282)	1.0 (275)	0.3 (68)	0.8 (207)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**37 (9,820)**	**0.3 (84)**	**37 (9,737)**	**8.4 (2,208)**	**28 (7,528)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**49 (13,032)**	**11 (2,988)**	**38 (10,112)**	**9.6 (2,536)**	**29 (7,576)**

Exhibit 3-58. Case B11A-BRwNGBlr.95 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (2.0)	0.0 (-2.0)
CO_2 Capture Recovery	–	–	–	0.8 (209)	-0.8 (-209)
CO_2 Compression KO	–	–	–	0.1 (18)	-0.1 (-18)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
Natural Gas Boiler	9.9 (2,626)	9.1 (2,407)	1.1 (291)	0.3 (72)	0.8 (218)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**38 (9,993)**	**0.3 (84)**	**38 (9,910)**	**8.5 (2,247)**	**29 (7,662)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**51 (13,342)**	**12 (3,114)**	**39 (10,300)**	**9.7 (2,565)**	**29 (7,735)**

Energy and mass balance diagrams are shown for PC boiler, natural gas-fired boiler, and gas cleanup systems in Exhibit 3-59 and Exhibit 3-61, and the PC plant steam cycle in Exhibit 3-60 and Exhibit 3-62. An overall plant energy balance is provided in tabular form in Exhibit 3-63 and Exhibit 3-64. The total power out is from the steam turbine generator. The cooling tower load is the combined duty of the existing cooling tower plus the additional tower sized for the capture process heat rejected to cooling water, the CO_2 compressor intercooler load, and other miscellaneous cooling loads.

Exhibit 3-59. Case B11A-BRwNGBlr.90 energy and mass balance, subcritical PC boiler with CO_2 capture and NG boiler

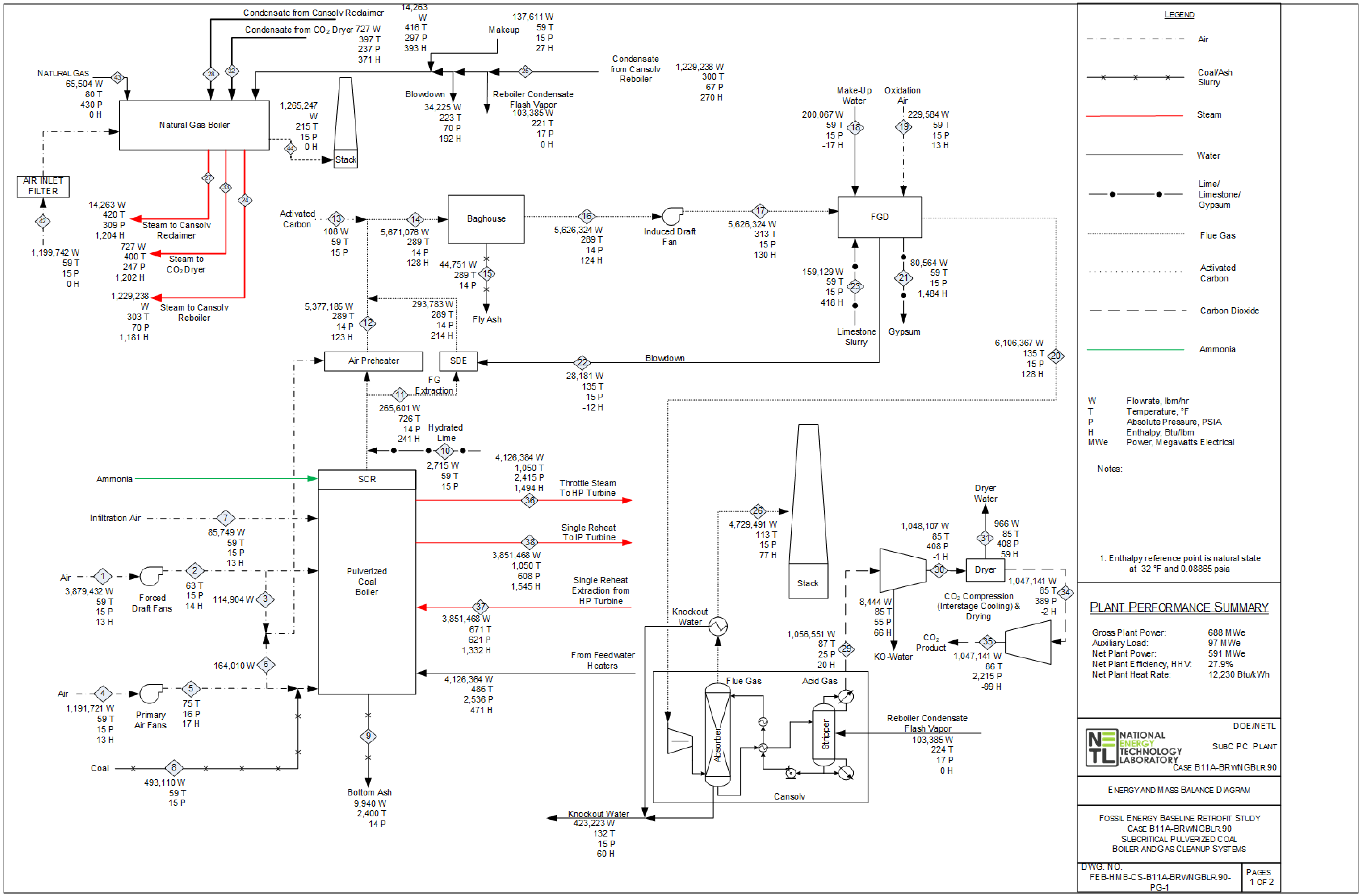


Exhibit 3-60. Case B11A-BRwNGBlr.90 energy and mass balance, subcritical steam cycle

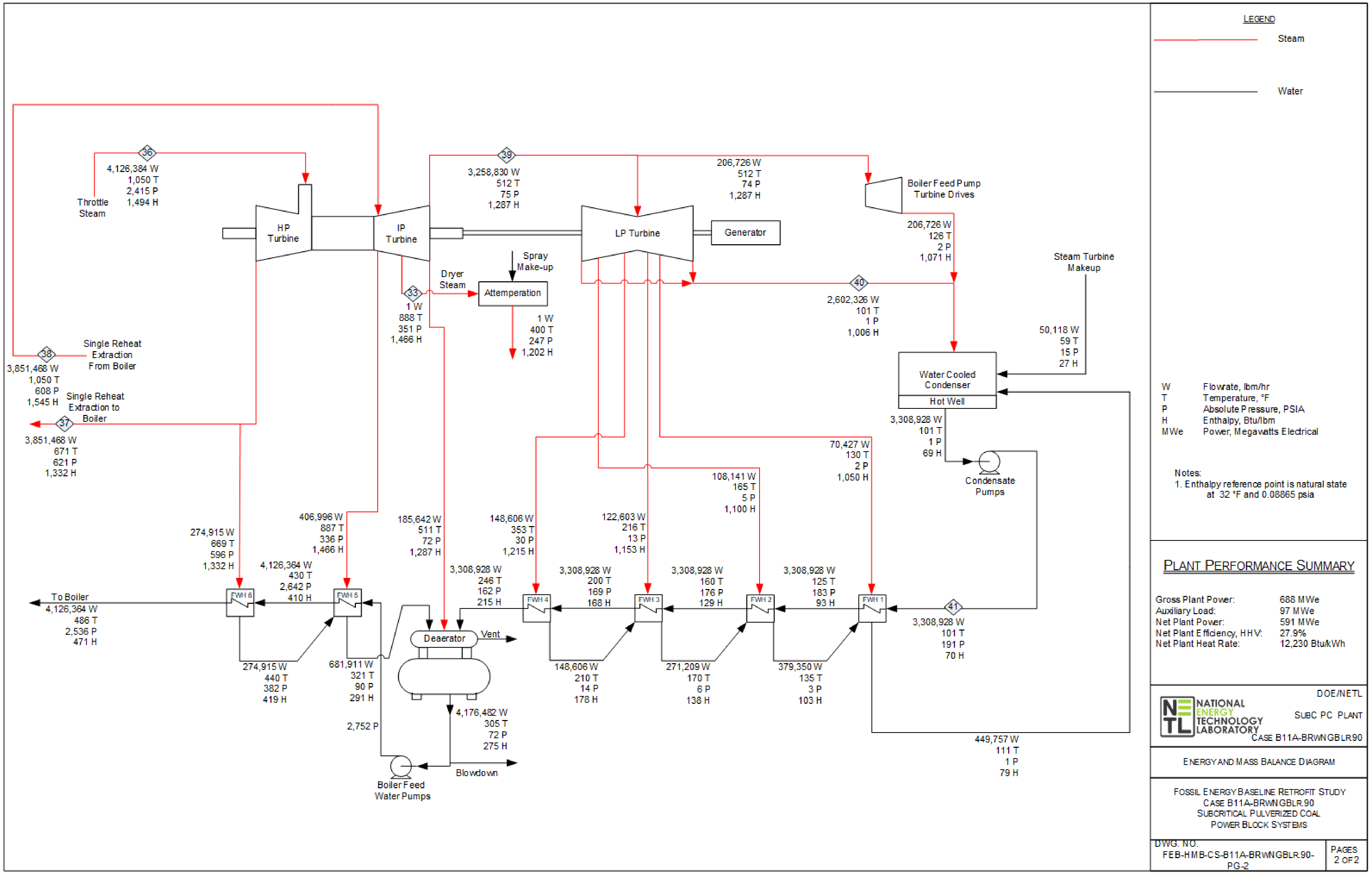


Exhibit 3-61. Case B11A-BRwNGBlr.95 energy and mass balance, subcritical PC boiler with CO_2 capture and NG boiler

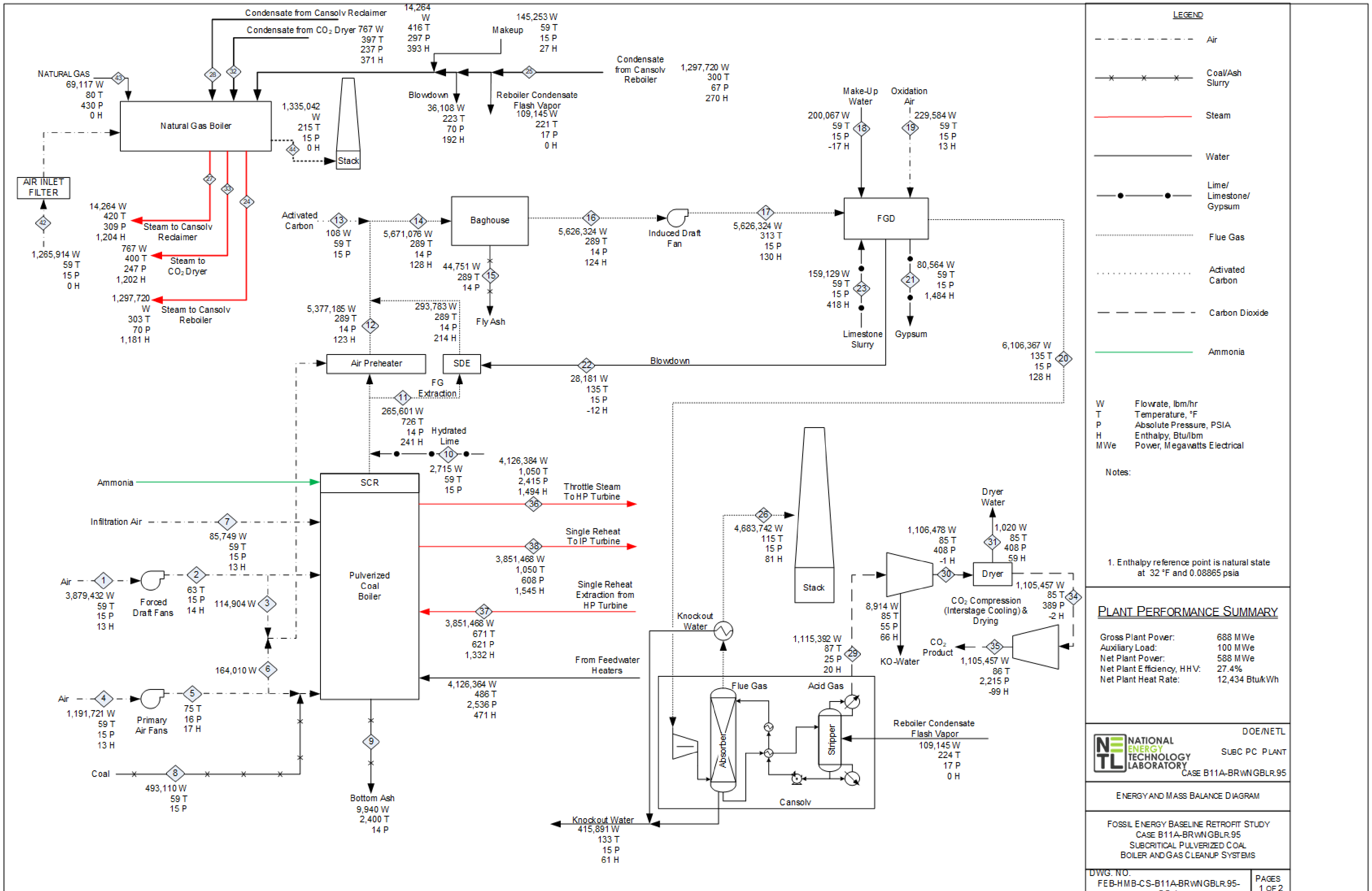


Exhibit 3-62. Case B11A-BRwNGBlr.95 energy and mass balance, subcritical steam cycle

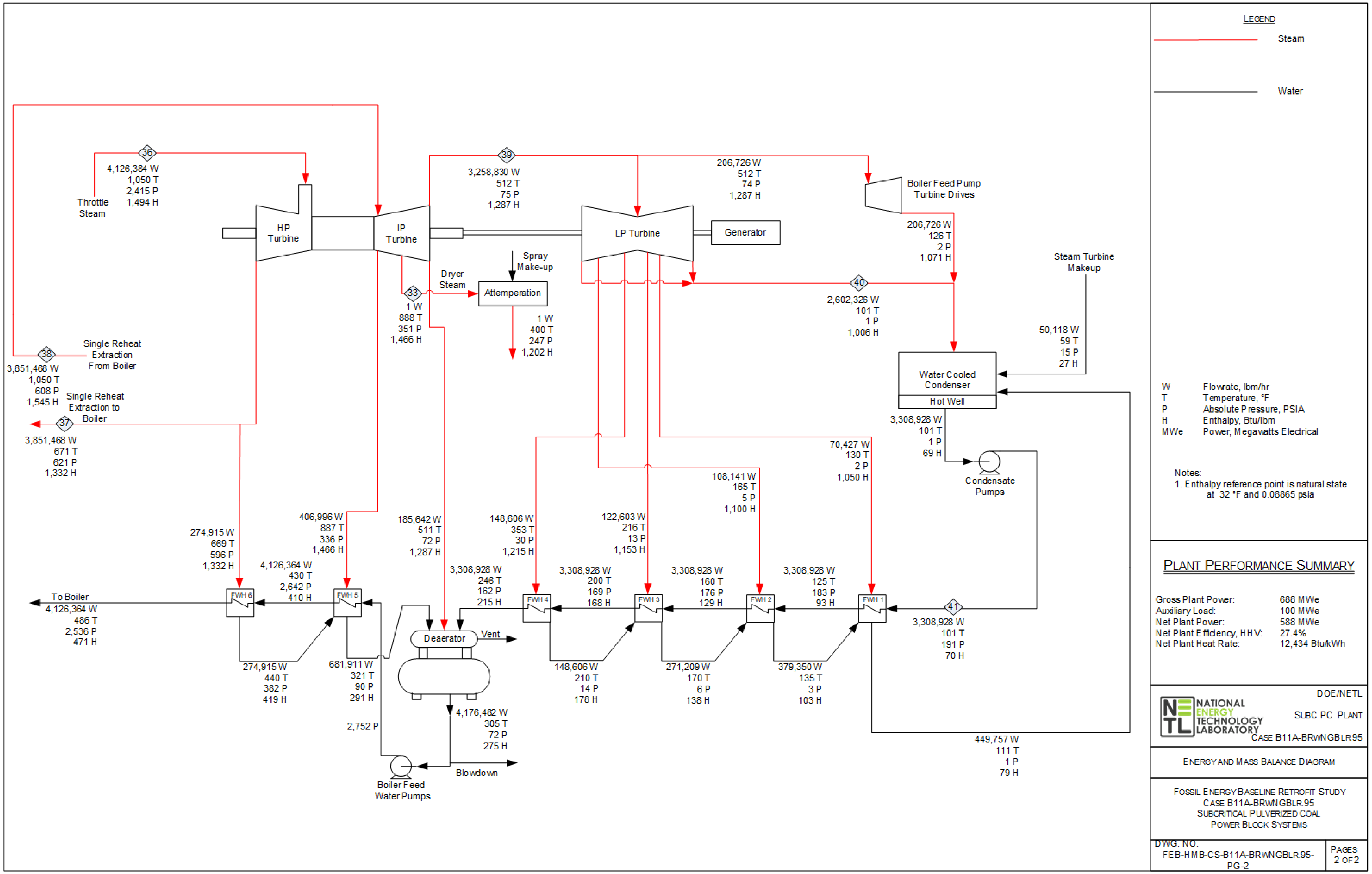


Exhibit 3-63. Case B11A-BRwNGBlr.90 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Natural Gas	1,554 (1,473)	1.0 (1.0)	–	1,555 (1,474)
NG Boiler Air	–	16 (16)	–	16 (16)
Raw Water Makeup	–	144 (136)	–	144 (136)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	348 (330)	348 (330)
TOTAL	**7,623 (7,225)**	**238 (225)**	**348 (330)**	**8,209 (7,781)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	383 (363)	–	383 (363)
NG Boiler Stack Gas	–	228 (216)	–	228 (216)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	45 (42)	45 (42)
Cooling Tower Load[A]	–	4,854 (4,601)	–	4,854 (4,601)
CO_2 Product Stream	–	-110 (-104)	–	-110 (-104)
AGR Effluent	–	45 (42)	–	45 (42)
Blowdown Streams and Deaerator Vent	–	24 (23)	–	24 (23)
Ambient Losses[B]	–	175 (166)	–	175 (166)
Power	–	–	2,475 (2,346)	2,475 (2,346)
TOTAL	**2.0 (1.9)**	**5,609 (5,316)**	**2,520 (2,389)**	**8,131 (7,707)**
Unaccounted Energy[C]	–	*78 (74)*	–	*78 (74)*

[A]Includes condenser, capture system, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

Exhibit 3-64. Case B11A-BRwNGBlr.95 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Natural Gas	1,639 (1,554)	1.1 (1.0)	–	1,641 (1,555)
NG Boiler Air	–	17 (16)	–	17 (16)
Raw Water Makeup	–	147 (139)	–	147 (139)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	360 (341)	360 (341)
TOTAL	**7,709 (7,307)**	**241 (229)**	**360 (341)**	**8,310 (7,876)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	399 (378)	–	399 (378)
NG Boiler Stack Gas	–	240 (228)	–	240 (228)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	45 (43)	45 (43)
Cooling Tower Load[A]	–	4,940 (4,682)	–	4,940 (4,682)
CO_2 Product Stream	–	-116 (-110)	–	-116 (-110)
AGR Effluent	–	44 (42)	–	44 (42)
Blowdown Streams and Deaerator Vent	–	25 (24)	–	25 (24)
Ambient Losses[B]	–	176 (167)	–	176 (167)
Power	–	–	2,475 (2,346)	2,475 (2,346)
TOTAL	**2.0 (1.9)**	**5,719 (5,420)**	**2,520 (2,389)**	**8,241 (7,811)**
Unaccounted Energy[C]	–	*69 (65)*	–	*69 (65)*

[A]Includes condenser, capture system, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

3.4 Performance Summary

The existing plant, B11A, and the NETL Fossil Energy Baseline report series greenfield subcritical plant with capture, B11B, values are included in the charts in this section for comparison. [1]

A graph of the net plant efficiency (HHV basis) is provided in Exhibit 3-65 and Exhibit 3-66. The increased generation from the NGSC improves overall efficiency of the B11A-BRwNGSC cases over the derate, B11A-BR case, but not enough to restore it to the pre-retrofit value. The additional natural gas usage in the natural gas-fired boiler without additional power generation reduces overall efficiency for the B11A-BRwNGBlr cases.

Exhibit 3-65. Efficiency comparison for 90% capture rate

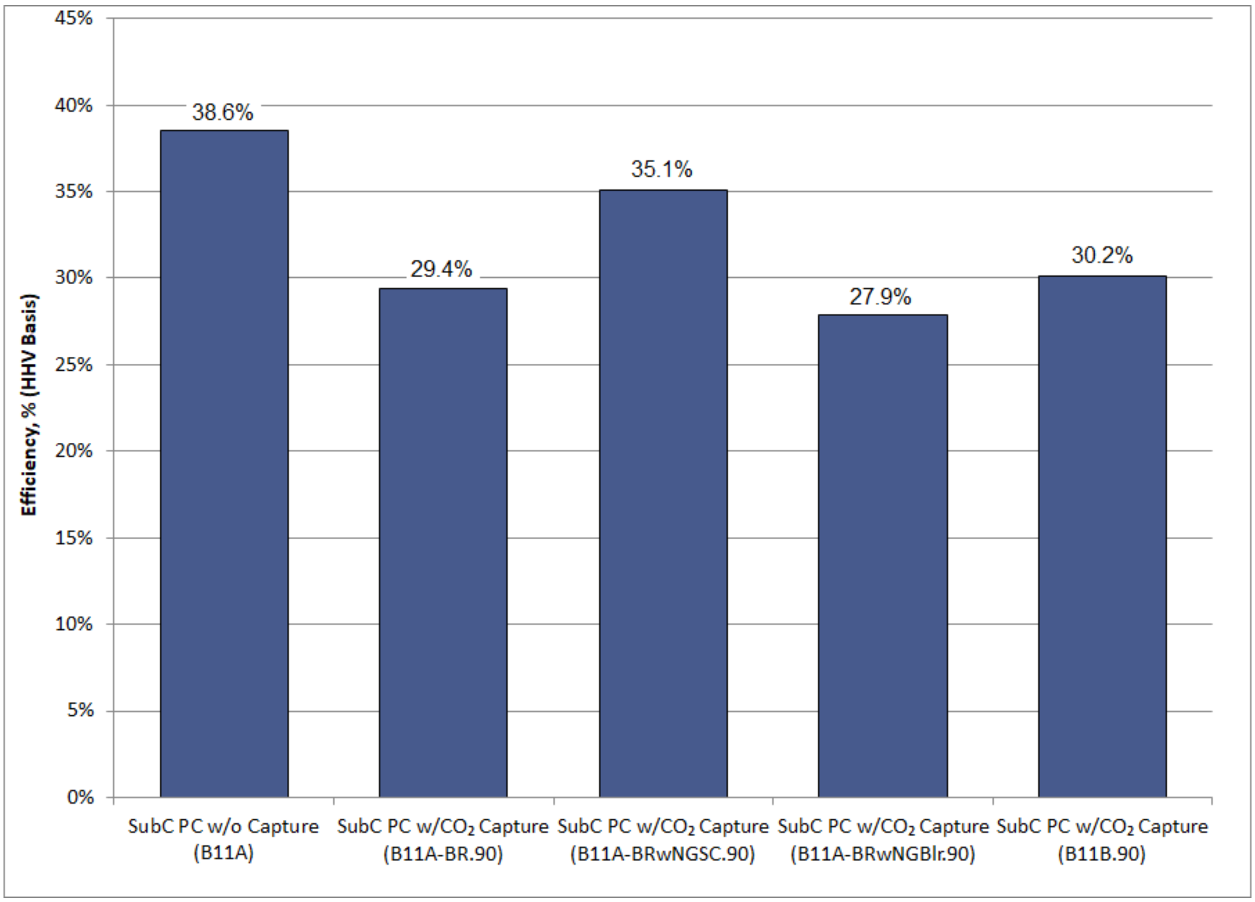
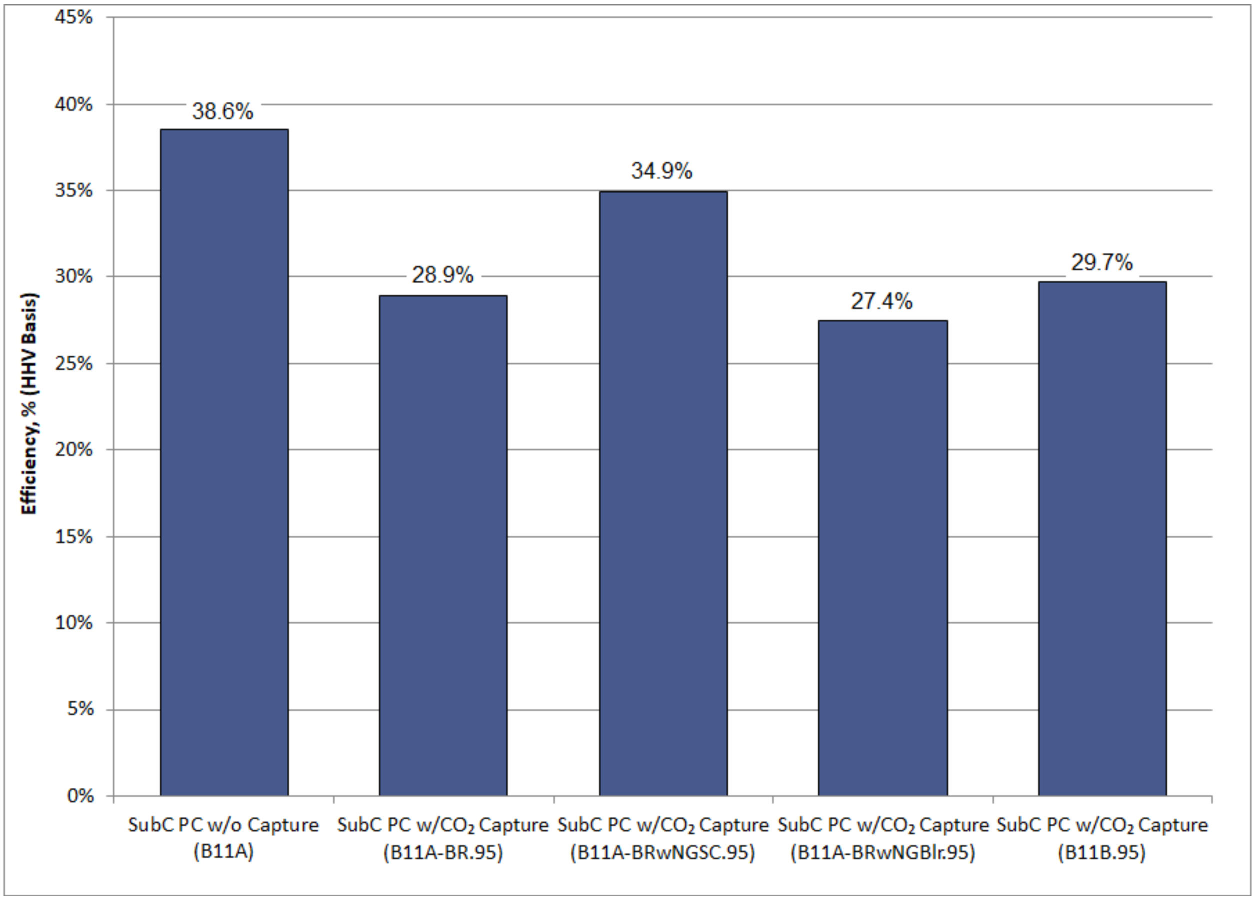


Exhibit 3-66. Efficiency comparison for 95% capture rate



Graphs of the SO_2, NO_X, and PM emissions are provided in Exhibit 3-67 and Exhibit 3-68. All emissions are estimated based on vendor specifications and assumptions. Actual emissions are not modeled. The sulfur polisher in the CANSOLV capture system reduces the SO_2 from coal to below detection levels. SO_2 emissions in B11A-BRwNGSC and B11A-BRwNGBlr are from natural gas firing. NO_X produced from the boiler remains constant, but the gross power is reduced, which would result in an increase in normalized NO_X emissions. However, SCR capacity was added such that the plant still complies with the 0.7 lb/MWh-gross emissions limit, even with the lower gross plant output for the derated and natural gas-fired boiler cases. Reductions in NO_X and particulate intensity in the NGSC case are attributed to additional power generation.

Exhibit 3-67. SO_2, NO_X, and PM emissions comparison for 90% capture rate

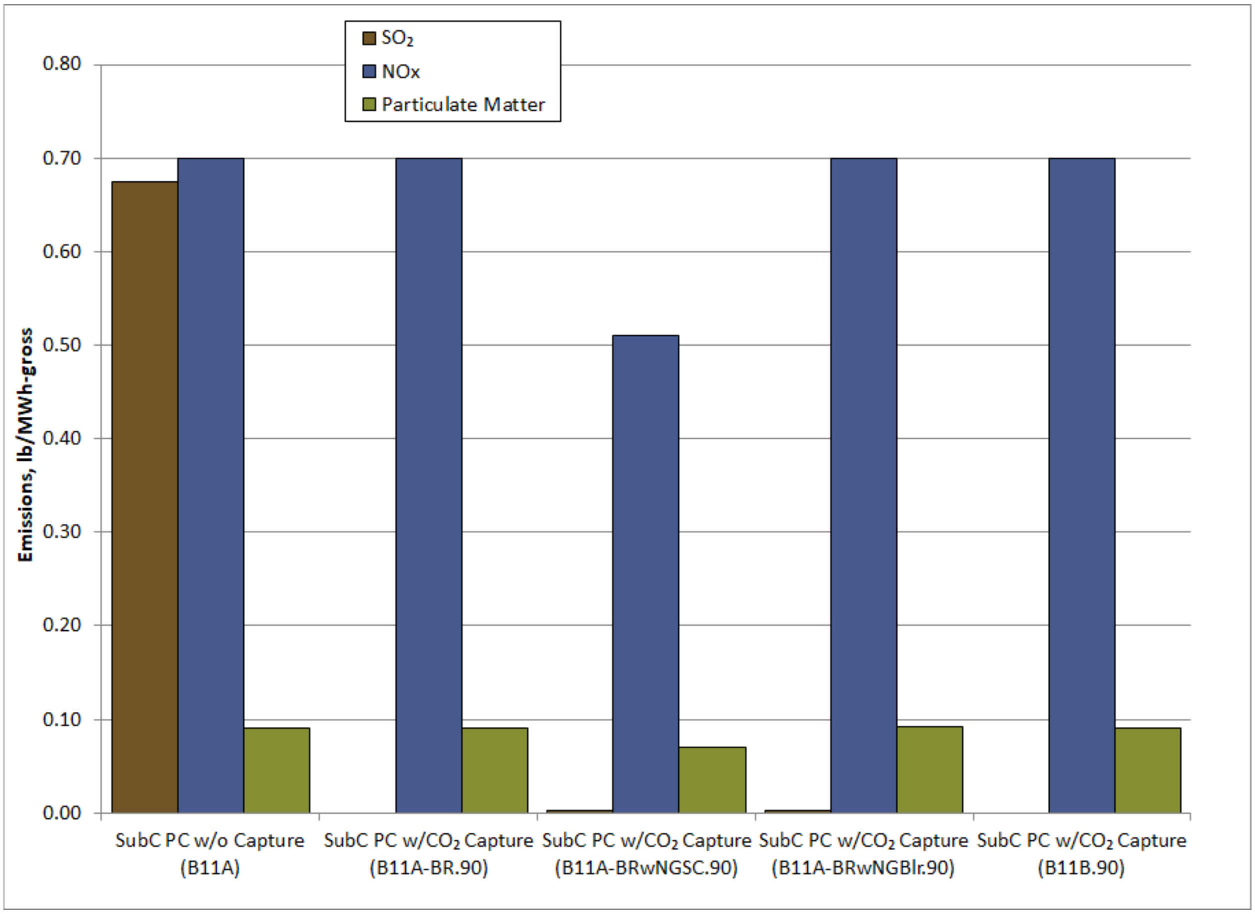
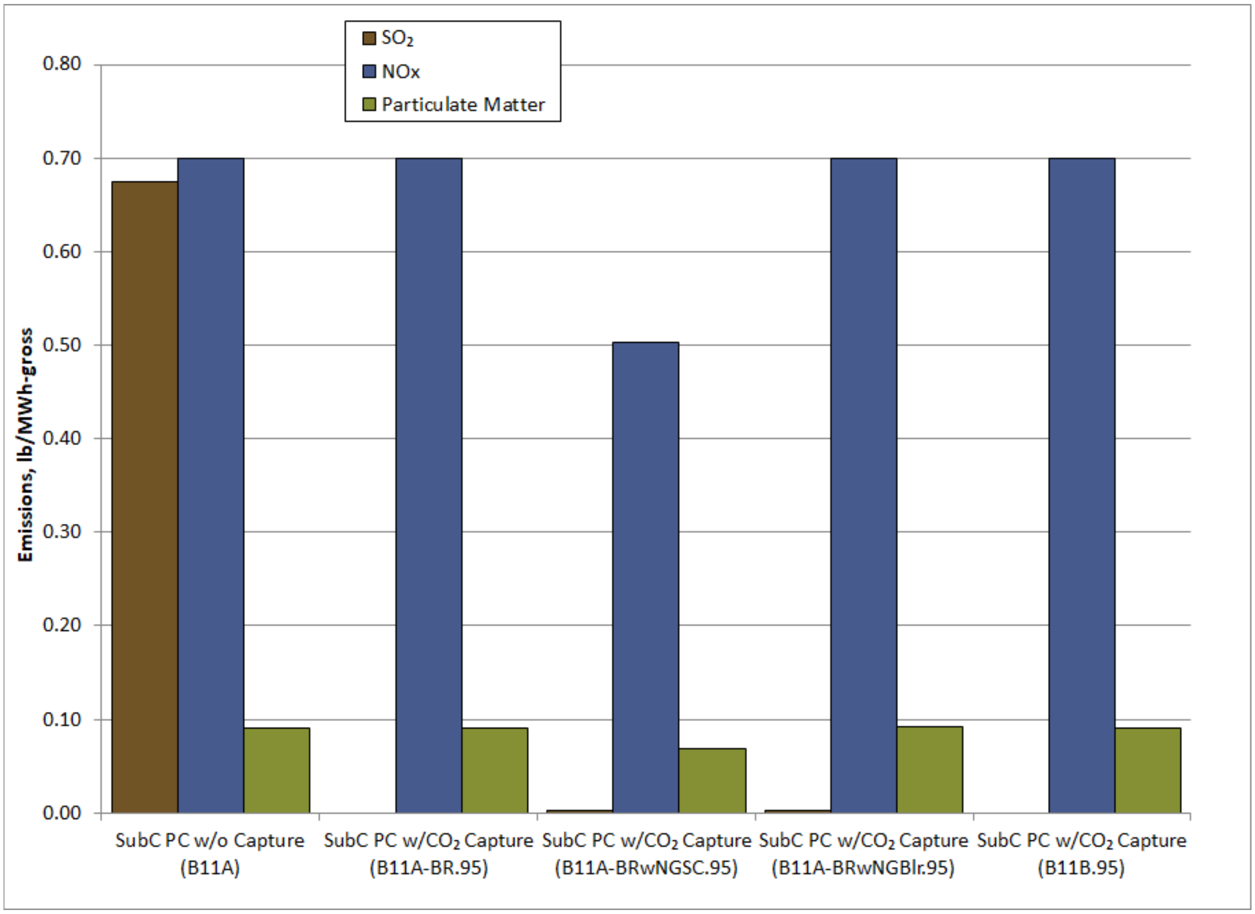


Exhibit 3-68. SO_2, NO_X, and PM emissions comparison for 95% capture rate



A graph of the CO_2 emissions is provided in Exhibit 3-69 and Exhibit 3-70. All cases include 90 or 95 percent capture of CO_2 in the flue gas from the existing PC plant. While the annual CO_2 emissions are lower than the existing plant for all cases, the total plant CO_2 intensity increases as the amount of natural gas burned in the auxiliary plants, without capture, increases.

Exhibit 3-69. CO_2 emissions comparison for 90% capture rate

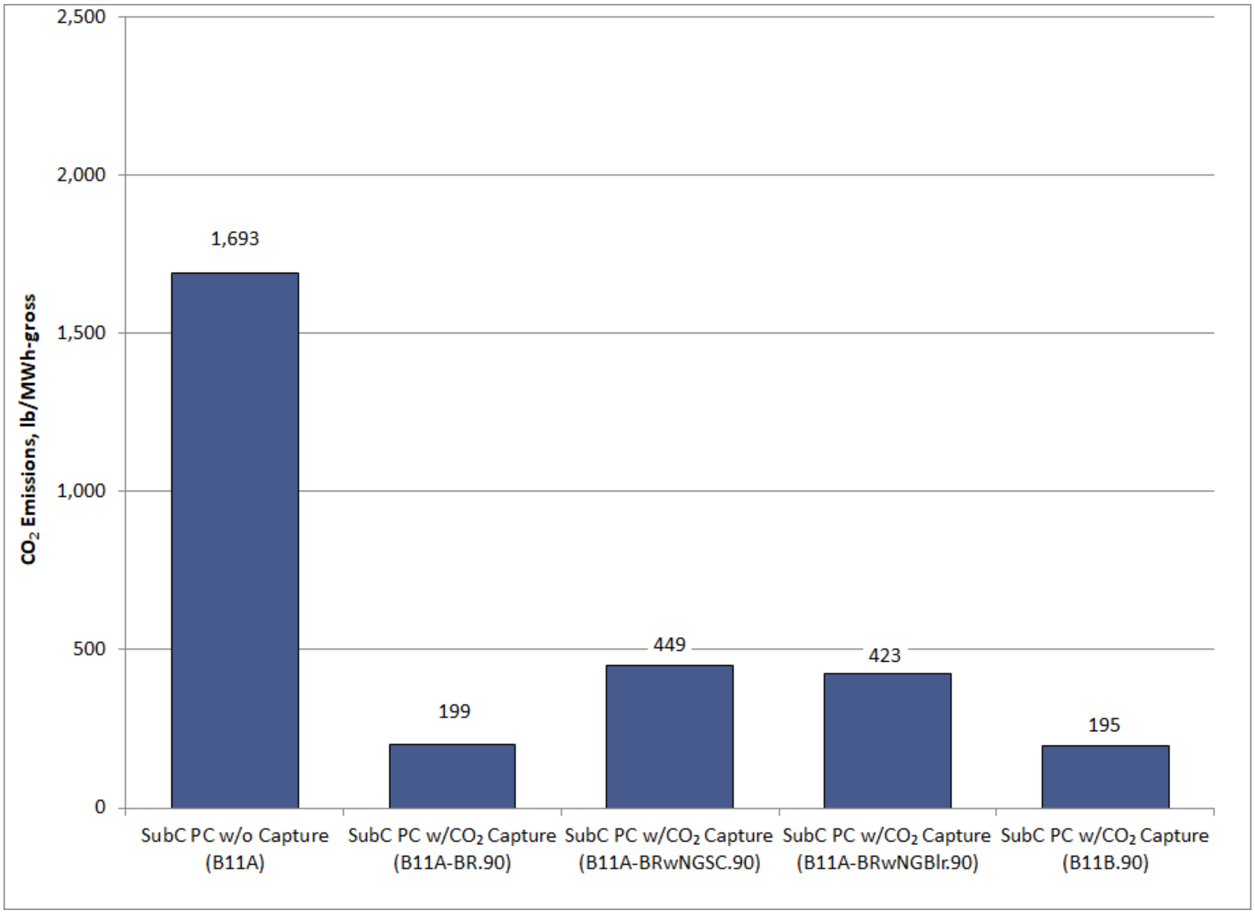
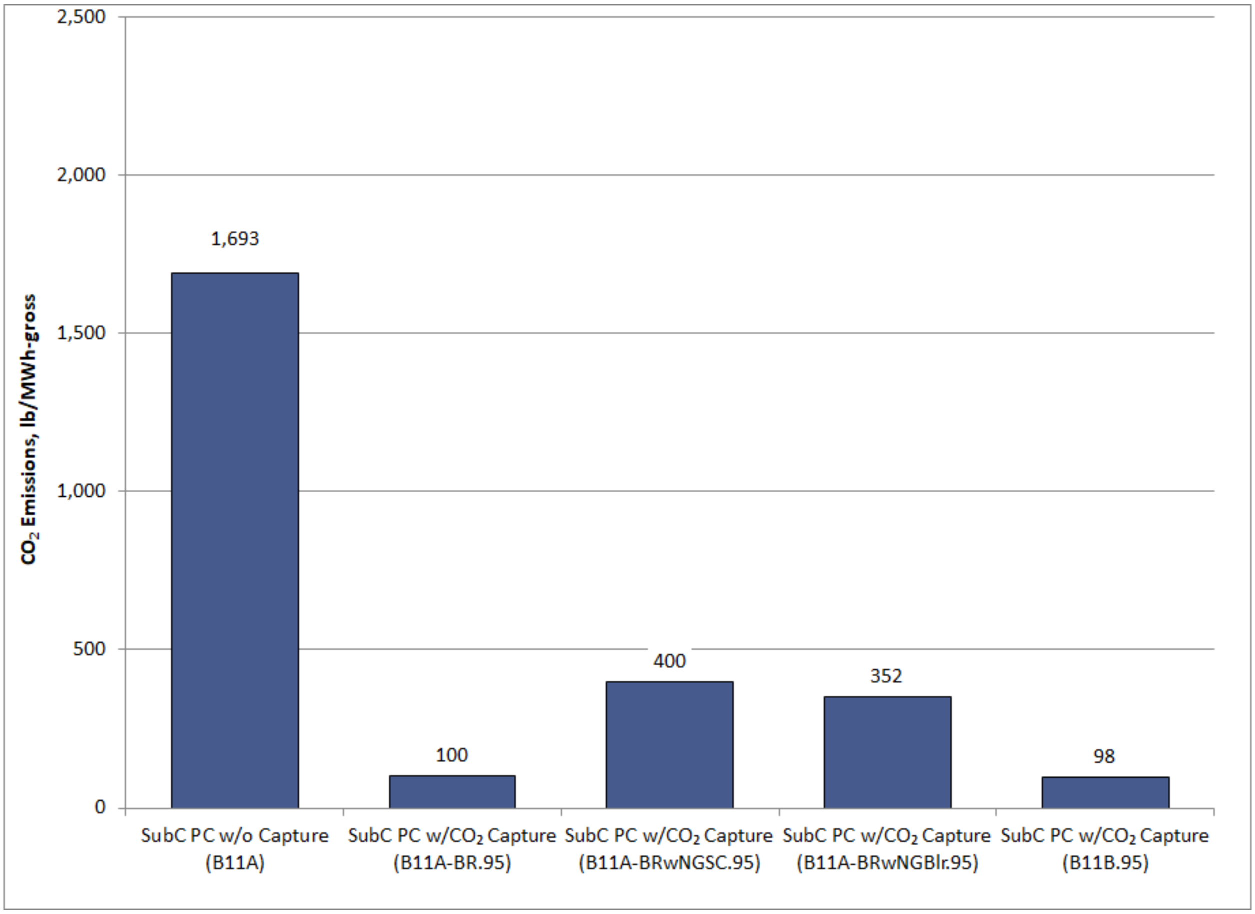


Exhibit 3-70. CO_2 emissions comparison for 95% capture rate



The retrofitted case water metrics, shown in Exhibit 3-71 and Exhibit 3-72, are higher than the existing plant values primarily due to increases in cooling water demands for the capture system. Reductions in the normalized water metrics for the B11A-BRwNGSC cases compared to the other cases are due to the additional power generation in the denominators of the metrics.

Exhibit 3-71. Water metric comparison for 90% capture rate

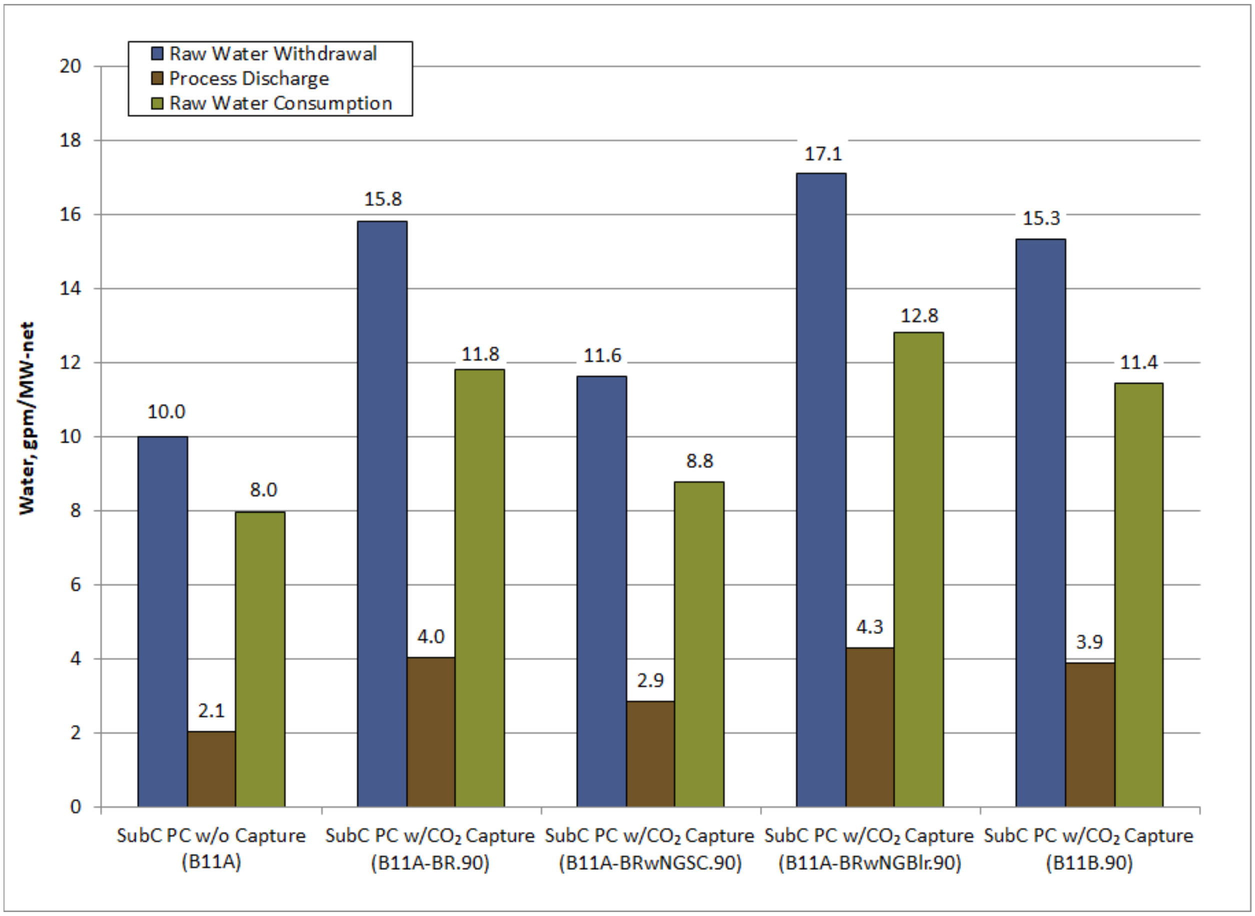
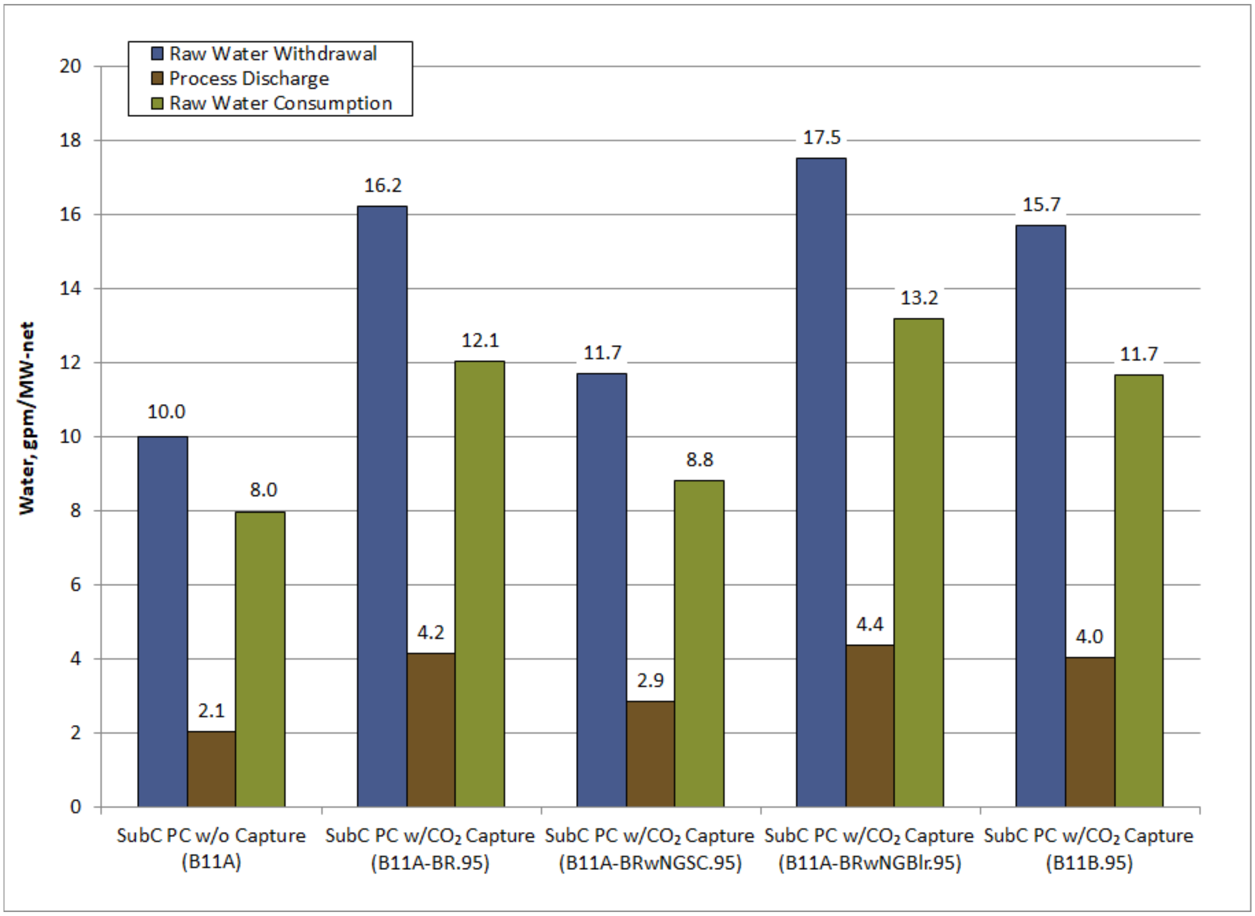


Exhibit 3-72. Water metric comparison for 95% capture rate



The energy penalty for retrofitting the existing non-capture PC plant (B11A) with CO_2 capture can be quantified. A useful metric for quantifying the impact to electrical output to capture each pound of CO_2 under each capture system retrofit scenario is the energy penalty, as defined below:

$$\text{Energy Penalty}\left(\frac{\text{kWh}}{\text{lb CO}_2}\right) = \frac{\left(\frac{1}{\text{HRNC}} - \frac{1}{\text{HRCC}}\right)}{\text{Capture Rate} \ast \text{CO}_2\text{ Emissions Factor}}$$

Where:

$$\text{HRNC}\left(\frac{\text{Btu}}{\text{kWh}}\right) = \text{Heat rate of the existing plant}$$

$$\text{HRCC}\left(\frac{\text{Btu}}{\text{kWh}}\right) = \text{Overall heat rate of the retrofitted + auxiliary plants}$$

$$\text{Capture Rate (\%)} = \text{Overall capture rate of the retrofitted + auxiliary plants}$$

$$\text{CO}_2\text{ Emissions Factor}\left(\frac{\text{lb CO}_2}{\text{MMBtu}}\right) = \text{Weighted average for fuels}$$

Using Case B11A from Revision 4a of the Fossil Energy Baseline report as the existing plant reference, the energy penalty calculated for each case is shown in Exhibit 3-73 and Exhibit 3-74.

The addition of CHP auxiliary repowering in the B11A-BRwNGSC cases acts to offset the efficiency penalty that adding capture creates. The addition of auxiliary steam generation in case B11A-BRwNGBlr is not enough to offset the efficiency penalty created by adding capture.

Exhibit 3-73. Retrofit energy penalty comparison for 90% capture rate

Parameter	Case B11A	Case B11A-BR.90	Case B11A-BR wNGSC.90	Case B11A-BR wNGBlr.90	Case B11B.90
Overall HHV Heat Rate, Btu/kWh	8,849	11,612	9,733	12,230	11,317
Overall CO_2 Emissions Factor, lb CO_2/MMBtu of Fuel	204	204	177	186	204
Overall CO_2 Capture Rate, %	N/A	90.0%	70.8%	78.3%	90.0%
Energy Penalty, kWh/lb CO_2	N/A	0.146	0.082	0.214	0.134

Exhibit 3-74. Retrofit energy penalty comparison for 95% capture rate

Parameter	Case B11A	Case B11A-BR.95	Case B11A-BR wNGSC.95	Case B11A-BR wNGBlr.95	Case B11B.95
Overall HHV Heat Rate, Btu/kWh	8,849	11,793	9,768	12,434	11,495
Overall CO_2 Emissions Factor, lb CO_2/MMBtu of Fuel	204	204	176	186	204
Overall CO_2 Capture Rate, %	N/A	95.0%	73.9%	82.0%	95.0%
Energy Penalty, kWh/lb CO_2	N/A	0.146	0.082	0.214	0.134

4 COST ESTIMATION RESULTS

All cost estimates within this study were scaled from the NETL Fossil Energy Baseline report series cases following the QGESS "Cost Estimation Methodology for NETL Assessments of Power Plant Performance" and "Capital Cost Scaling Methodology: Revision 4 Report." [1, 4, 5] The capital cost estimates documented in this report reflect an uncertainty range of -15 percent/+30 percent, or AACE class 4 estimates as specified in the Fossil Energy Baseline reports, based on the level of engineering design performed and given recent experience with coal plants. [1, 16, 6] More detail on the cost estimating methodology is described in the Fossil Energy Baseline reports as well as the cost estimation QGESS. [1, 4]

The capital cost estimates represent the complete construction and operation of retrofitted CCS and auxiliary facilities for an existing PC power plant located on a generic site. For all cases evaluated, it is assumed that the existing plant is fully depreciated and there are no ongoing capital costs for any plant components other than those required to facilitate the retrofit of the different configurations. Systems associated with the existing PC plant that do not require modification are listed in the individual plant cost detail tables below but have no associated costs. However, the costs associated with continuing operations of the existing plant (overhead, labor, maintenance materials, consumables, fuels, etc.) are included in developing operation and maintenance (O&M) costs for each retrofitted case and included in the LCOE for the retrofitted plant. The retrofitted plant is assumed to operate at an 85 percent capacity factor in all cases for the operating cost and LCOE calculations.

In all cases, a new cooling tower and circulating water system to supply additional cooling water for the retrofitted CO_2 capture facility is included in the cost estimates. If cooling capacity is available at an actual plant, then these costs could be reduced or eliminated, but such availability is dependent on the specific plant design and operation and not assumed to exist in this study.

The previous study included a new stack for the retrofitted capture system. This update only includes modifications to the existing stack to meet velocity and dispersion requirements for the reduced flow of exhaust gas. A new stack would allow for a single, less complex tie-in point to the existing flue gas duct work and reduce the facility downtime during construction, but the benefits of the design are very dependent on the existing plant layout and operation, so it was not included in any cases in this study.

The NETL cost estimation methodology for developing Owner's Costs for a PC plant includes costs for inventory capital of chemicals and fuel. In particular, it specifies costs for a 60-day supply of coal to be maintained on site such that fuel supply disruptions, and their impact on the ability of the plant to generate electricity, are mitigated. Retrofit cases where natural gas is used to support capture system operations (B11A-BRwNGSC and B11A-BRwNGBlr) include additional cost in the Inventory Capital section of the Owner's Cost table as a reserve account for acquisition of 60 days of natural gas supply, consistent with the 60-day coal supply.

Additional contingencies are needed for retrofit capital charges to reflect the added costs associated with any typical retrofit project (limited space resulting in construction premiums, insufficient laydown area, long tie-in connections, etc.) compared to a similar baseline for greenfield costs. In this study, the retrofit contingencies were not included in the BEC and TPC estimates for each account. An RDF of 1.1 was applied to the TPC and included in the TOC, TASC, and the capital component of the LCOE based on the simplified method described in the QGESS. [3, 4] The RDF was calculated as a weighted average of the sub-account level retrofit total plant cost premiums, which vary between 1.0 and 1.3, using the high contingency values applied to greenfield equipment costs scaled for retrofitting to an existing subcritical PC plant. [3]

CO_2 T&S costs of $10/tonne are added to the LCOE, as specified according to the 2019 QGESS document "Carbon Dioxide Transport and Storage Costs in NETL Studies." [19]

A makeup power cost (MPC) of $30/MWh was added to retrofit cases in the levelized cost of CO_2 captured and CO_2 avoided calculations. The cost is based on a 2019 approximate average MISO market price with near 10 percent renewable penetration. [7] This cost is applied as a debit for cases producing less power than the original existing plant and as a credit for cases producing more power than the original existing plant.

4.1 CASE B11A-BR

Costs for the retrofitted capture system, modified ductwork, modified steam piping, etc. were scaled from the Case B11B cost estimates using the scaling QGESS methodology as in previous study based on the performance data reported in the previous section of this report. [1, 9, 3, 5]

The significant quantity of steam turbine extraction for the capture process stripper reboiler in these derated cases reduces condenser duty and frees up cooling capacity in the existing cooling tower. The available capacity is used to partially supply the additional cooling demands resulting in a smaller sized additional cooling tower for these cases, but modifications to the existing plant circulating water system piping are included in the estimate.

NO_X produced from the boiler remains constant, but SCR catalyst and ammonia are added such that the plant remains compliant with the 0.7 lb/MWh-gross emissions limit, even with the lower gross plant output for the derated and natural gas-fired boiler cases. It was assumed that space is available in the existing SCR to handle an additional catalyst layer and no modification costs are included in the estimate.

Exhibit 4-1 and Exhibit 4-2 show a detailed breakdown of the capital costs including the major equipment items as well as other capital expenditures required to facilitate the retrofit. Exhibit 4-3 and Exhibit 4-4 identify owner's costs, along with the TOC and TASC. Exhibit 4-5 and Exhibit 4-6 show the initial and annual O&M costs, and Exhibit 4-7 and Exhibit 4-8 show the LCOE breakdown. The estimated bare erected cost and total plant costs of retrofitting the subcritical PC boiler plant with 90 percent CO_2 capture are $906/kW and $1,370/kW, respectively, before adding retrofit contingencies. Using a retrofit difficulty factor of 1.1 adds a 10 percent retrofit contingency to the TPC for a total value of $746,741,000 or $1,507/kW. The total overnight cost is estimated at $904,197,000 or $1,825/kW, and the LCOE is $77.0/MWh excluding T&S. The estimated bare erected cost and total plant costs of retrofitting the subcritical PC boiler plant with 95 percent CO_2 capture are $947/kW and $1,432/kW, respectively, before adding retrofit contingencies. Using a retrofit difficulty factor of 1.1 adds a 10 percent retrofit contingency to the TPC for a total value of $7680,346,000 or $1,575/kW. The total overnight cost is estimated at $930,327,000 or $1,907/kW, and the LCOE is $79.0/MWh excluding T&S.

Exhibit 4-1. Case B11A-BR.90 retrofit plant cost details

	Case:	B11A-BR.90	– Retrofit Subcritical PC w/ CO_2				Estimate Type:			Conceptual	
	Plant Size (MW, net):	495					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
1	Coal & Sorbent Handling										
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
2	Coal & Sorbent Preparation & Feed										
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	Feedwater & Miscellaneous BOP Systems										
3.1	Feedwater System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.2	Water Makeup & Pretreating	$1,837	$184	$1,041	$0	$3,062	$536	$0	$720	$4,317	$9
3.3	Other Feedwater Subsystems	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.4	Service Water Systems	$529	$1,009	$3,268	$0	$4,806	$841	$0	$1,129	$6,776	$14
3.5	Other Boiler Plant Systems	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.6	Natural Gas Pipeline and Start-Up System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.7	Wastewater Treatment Equipment	$5,131	$0	$3,145	$0	$8,276	$1,448	$0	$1,945	$11,669	$24
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$7,497**	**$1,193**	**$7,454**	**$0**	**$16,144**	**$2,825**	**$0**	**$3,794**	**$22,763**	**$46**
4	Pulverized Coal Boiler & Accessories										
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
5	Flue Gas Cleanup										
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$124,107	$55,204	$115,929	$0	$295,240	$51,667	$50,191	$69,492	$466,591	$942
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$37,816	$5,673	$12,451	$0	$55,940	$9,789	$0	$13,146	$78,875	$159
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$395	$63	$169	$0	$627	$110	$0	$147	$884	$2
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.12	Gas Cleanup Foundations	$0	$133	$117	$0	$250	$44	$0	$44	$338	$1
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$162,318**	**$61,073**	**$128,666**	**$0**	**$352,057**	**$61,610**	**$50,191**	**$82,829**	**$546,687**	**$1,103**

Case:		B11A-BR.90	– Retrofit Subcritical PC w/ CO_2				Estimate Type:			Conceptual	
Plant Size (MW, net):		495					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
7	Ductwork & Stack										
7.3	Ductwork	$0	$745	$518	$0	$1,263	$221	$0	$223	$1,707	$3
7.4	Stack	$885	$0	$514	$0	$1,399	$245	$0	$246	$1,890	$4
7.5	Duct & Stack Foundations	$0	$207	$246	$0	$454	$79	$0	$107	$640	$1
	Subtotal	**$885**	**$953**	**$1,278**	**$0**	**$3,116**	**$545**	**$0**	**$576**	**$4,237**	**$9**
8	Steam Turbine & Accessories										
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$345	$0	$734	$0	$1,079	$189	$0	$190	$1,457	$3
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$12,803	$0	$5,189	$0	$17,992	$3,149	$0	$3,171	$24,312	$49
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$13,148**	**$0**	**$5,923**	**$0**	**$19,070**	**$3,337**	**$0**	**$3,361**	**$25,769**	**$52**
9	Cooling Water System										
9.1	Cooling Towers	$5,861	$0	$1,813	$0	$7,674	$1,343	$0	$1,353	$10,370	$21
9.2	Circulating Water Pumps	$710	$0	$50	$0	$760	$133	$0	$134	$1,027	$2
9.3	Circulating Water System Auxiliaries	$6,014	$0	$796	$0	$6,810	$1,192	$0	$1,200	$9,201	$19
9.4	Circulating Water Piping	$0	$2,781	$2,519	$0	$5,299	$927	$0	$934	$7,161	$14
9.5	Makeup Water System	$485	$0	$623	$0	$1,108	$194	$0	$195	$1,497	$3
9.6	Component Cooling Water System	$433	$0	$333	$0	$766	$134	$0	$135	$1,035	$2
9.7	Circulating Water System Foundations	$0	$280	$466	$0	$746	$131	$0	$175	$1,052	$2
	Subtotal	**$13,504**	**$3,061**	**$6,598**	**$0**	**$23,163**	**$4,054**	**$0**	**$4,126**	**$31,343**	**$63**
10	Ash & Spent Sorbent Handling Systems										
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
11	Accessory Electric Plant										
11.1	Generator Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.2	Station Service Equipment	$5,536	$0	$475	$0	$6,011	$1,052	$0	$1,059	$8,123	$16
11.3	Switchgear & Motor Control	$8,594	$0	$1,491	$0	$10,085	$1,765	$0	$1,778	$13,628	$28
11.4	Conduit & Cable Tray	$0	$1,117	$3,220	$0	$4,337	$759	$0	$764	$5,860	$12
11.5	Wire & Cable	$0	$2,959	$5,289	$0	$8,247	$1,443	$0	$1,454	$11,144	$22
11.6	Protective Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.7	Standby Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.8	Main Power Transformers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.9	Electrical Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,131**	**$4,076**	**$10,474**	**$0**	**$28,681**	**$5,019**	**$0**	**$5,055**	**$38,755**	**$78**

	Case:	B11A-BR.90	– Retrofit Subcritical PC w/ CO_2				Estimate Type:			Conceptual	
	Plant Size (MW, net):	495					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
	12				Instrumentation & Control						
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.3	Steam Turbine Control Equipment	$553	$0	$63	$0	$616	$108	$0	$109	$833	$2
12.5	Signal Processing Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.6	Control Boards, Panels & Racks	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.7	Distributed Control System Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.8	Instrument Wiring & Tubing	$502	$402	$1,607	$0	$2,511	$439	$126	$461	$3,538	$7
12.9	Other Instrumentation & Controls Equipment	$617	$0	$1,430	$0	$2,047	$358	$102	$376	$2,884	$6
	Subtotal	**$1,673**	**$402**	**$3,100**	**$0**	**$5,175**	**$906**	**$228**	**$946**	**$7,254**	**$15**
	13				Improvements to Site						
13.1	Site Preparation	$0	$31	$611	$0	$642	$112	$0	$151	$905	$2
13.2	Site Improvements	$0	$143	$189	$0	$332	$58	$0	$78	$467	$1
13.3	Site Facilities	$163	$0	$171	$0	$334	$59	$0	$79	$471	$1
	Subtotal	**$163**	**$173**	**$972**	**$0**	**$1,308**	**$229**	**$0**	**$307**	**$1,844**	**$4**
	14				Buildings & Structures						
14.2.	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$27	$21	$0	$47	$8	$0	$8	$64	$0
14.6	Water Treatment Buildings	$0	$38	$35	$0	$73	$13	$0	$13	$98	$0
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$7	$23	$0	$30	$5	$0	$5	$41	$0
	Subtotal	**$0**	**$72**	**$79**	**$0**	**$150**	**$26**	**$0**	**$26**	**$203**	**$0**
	Total	**$213,317**	**$71,003**	**$164,544**	**$0**	**$448,864**	**$78,551**	**$50,419**	**$101,022**	**$678,856**	**$1,370**
	Retrofit Difficulty Allowance	**$21,332**	**$7,100**	**$16,454**	**$0**	**$44,886**	**$7,855**	**$5,042**	**$10,102**	**$67,886**	**$137**
	Total (Including Retrofit Difficulty Factor)	**$234,649**	**$78,103**	**$180,999**	**$0**	**$493,751**	**$86,406**	**$55,461**	**$111,124**	**$746,741**	**$1,507**

Exhibit 4-2. Case B11A-BR.95 retrofit plant cost details

	Case:	B11A-BR.95	– Retrofit Subcritical PC w/ CO_2					Estimate Type:		Conceptual	
	Plant Size (MW, net):	488						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
1	Coal & Sorbent Handling										
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
2	Coal & Sorbent Preparation & Feed										
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	Feedwater & Miscellaneous BOP Systems										
3.1	Feedwater System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.2	Water Makeup & Pretreating	$1,901	$190	$1,077	$0	$3,169	$555	$0	$745	$4,468	$9
3.3	Other Feedwater Subsystems	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.4	Service Water Systems	$548	$1,047	$3,390	$0	$4,985	$872	$0	$1,171	$7,029	$14
3.5	Other Boiler Plant Systems	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.6	Natural Gas Pipeline and Start-Up System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.7	Wastewater Treatment Equipment	$5,292	$0	$3,243	$0	$8,535	$1,494	$0	$2,006	$12,034	$25
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$7,741**	**$1,237**	**$7,711**	**$0**	**$16,689**	**$2,921**	**$0**	**$3,922**	**$23,531**	**$48**
4	Pulverized Coal Boiler & Accessories										
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
5	Flue Gas Cleanup										
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$128,021	$56,698	$119,065	$0	$303,783	$53,162	$51,643	$71,503	$480,091	$984
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$39,088	$5,863	$12,870	$0	$57,822	$10,119	$0	$13,588	$81,529	$167
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$413	$66	$177	$0	$656	$115	$0	$154	$925	$2
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.12	Gas Cleanup Foundations	$0	$134	$117	$0	$251	$44	$0	$44	$340	$1
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$167,522**	**$62,761**	**$132,230**	**$0**	**$362,512**	**$63,440**	**$51,643**	**$85,290**	**$562,885**	**$1,154**
7	Ductwork & Stack										
7.3	Ductwork	$0	$748	$520	$0	$1,268	$222	$0	$223	$1,713	$4

	Case:	B11A-BR.95	– Retrofit Subcritical PC w/ CO_2				Estimate Type:			Conceptual	
	Plant Size (MW, net):	488					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
7.4	Stack	$885	$0	$514	$0	$1,399	$245	$0	$246	$1,890	$4
7.5	Duct & Stack Foundations	$0	$207	$246	$0	$454	$79	$0	$107	$640	$1
	Subtotal	**$885**	**$956**	**$1,280**	**$0**	**$3,120**	**$546**	**$0**	**$577**	**$4,243**	**$9**
8	**Steam Turbine & Accessories**										
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$356	$0	$758	$0	$1,114	$195	$0	$196	$1,505	$3
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$13,293	$0	$5,388	$0	$18,680	$3,269	$0	$3,292	$25,241	$52
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$13,649**	**$0**	**$6,145**	**$0**	**$19,794**	**$3,464**	**$0**	**$3,489**	**$26,747**	**$55**
9	**Cooling Water System**										
9.1	Cooling Towers	$6,003	$0	$1,857	$0	$7,860	$1,375	$0	$1,385	$10,620	$22
9.2	Circulating Water Pumps	$729	$0	$52	$0	$781	$137	$0	$138	$1,055	$2
9.3	Circulating Water System Auxiliaries	$6,134	$0	$812	$0	$6,946	$1,216	$0	$1,224	$9,385	$19
9.4	Circulating Water Piping	$0	$2,837	$2,569	$0	$5,405	$946	$0	$953	$7,304	$15
9.5	Makeup Water System	$496	$0	$637	$0	$1,133	$198	$0	$200	$1,531	$3
9.6	Component Cooling Water System	$442	$0	$339	$0	$781	$137	$0	$138	$1,055	$2
9.7	Circulating Water System Foundations	$0	$286	$474	$0	$760	$133	$0	$179	$1,071	$2
	Subtotal	**$13,805**	**$3,122**	**$6,739**	**$0**	**$23,666**	**$4,142**	**$0**	**$4,216**	**$32,023**	**$66**
10	**Ash & Spent Sorbent Handling Systems**										
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
11	**Accessory Electric Plant**										
11.1	Generator Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.2	Station Service Equipment	$5,664	$0	$486	$0	$6,150	$1,076	$0	$1,084	$8,310	$17
11.3	Switchgear & Motor Control	$8,793	$0	$1,525	$0	$10,318	$1,806	$0	$1,819	$13,942	$29
11.4	Conduit & Cable Tray	$0	$1,143	$3,294	$0	$4,437	$776	$0	$782	$5,995	$12
11.5	Wire & Cable	$0	$3,027	$5,411	$0	$8,438	$1,477	$0	$1,487	$11,401	$23
11.6	Protective Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.7	Standby Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.8	Main Power Transformers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.9	Electrical Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,456**	**$4,170**	**$10,716**	**$0**	**$29,342**	**$5,135**	**$0**	**$5,172**	**$39,649**	**$81**
12	**Instrumentation & Control**										
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.3	Steam Turbine Control Equipment	$559	$0	$64	$0	$623	$109	$0	$110	$842	$2

Case:		B11A-BR.95	– Retrofit Subcritical PC w/ CO_2						Estimate Type:		Conceptual	
Plant Size (MW, net):		488							Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
12.5	Signal Processing Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.6	Control Boards, Panels & Racks	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.7	Distributed Control System Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.8	Instrument Wiring & Tubing	$506	$405	$1,618	$0	$2,529	$443	$126	$465	$3,562	$7
12.9	Other Instrumentation & Controls Equipment	$622	$0	$1,440	$0	$2,061	$361	$103	$379	$2,904	$6
	Subtotal	**$1,687**	**$405**	**$3,122**	**$0**	**$5,213**	**$912**	**$229**	**$953**	**$7,308**	**$15**
13						**Improvements to Site**					
13.1	Site Preparation	$0	$32	$630	$0	$661	$116	$0	$155	$933	$2
13.2	Site Improvements	$0	$147	$195	$0	$342	$60	$0	$80	$482	$1
13.3	Site Facilities	$168	$0	$176	$0	$344	$60	$0	$81	$486	$1
	Subtotal	**$168**	**$178**	**$1,001**	**$0**	**$1,347**	**$236**	**$0**	**$317**	**$1,900**	**$4**
14						**Buildings & Structures**					
14.2.	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$27	$21	$0	$49	$9	$0	$9	$66	$0
14.6	Water Treatment Buildings	$0	$39	$37	$0	$76	$13	$0	$13	$103	$0
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$8	$23	$0	$31	$5	$0	$5	$42	$0
	Subtotal	**$0**	**$74**	**$81**	**$0**	**$156**	**$27**	**$0**	**$27**	**$211**	**$0**
	Total	**$219,913**	**$72,903**	**$169,025**	**$0**	**$461,840**	**$80,822**	**$51,873**	**$103,961**	**$698,496**	**$1,432**
	Retrofit Difficulty Allowance	**$21,991**	**$7,290**	**$16,902**	**$0**	**$46,184**	**$8,082**	**$5,187**	**$10,396**	**$69,850**	**$143**
	Total (Including Retrofit Difficulty Factor)	**$241,904**	**$80,193**	**$185,927**	**$0**	**$508,024**	**$88,904**	**$57,060**	**$114,358**	**$768,346**	**$1,575**

Exhibit 4-3. Case B11A-BR.90 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$3,355	$7
1 Month Maintenance Materials	$639	$1
1 Month Non-Fuel Consumables	$906	$2
1 Month Waste Disposal	$13	$0
25% of 1 Months Fuel Cost at 100% CF	$0	$0
2% of TPC	$14,935	$30
Total	**$19,847**	**$40**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$1,701	$3
0.5% of TPC (spare parts)	$3,734	$8
Total	**$5,435**	**$11**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$0	$0
Other Owner's Costs	$112,011	$226
Financing Costs	$20,162	$41
Total Overnight Costs (TOC)	**$904,197**	**$1,825**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$987,968**	**$1,994**

Exhibit 4-4. Case B11A-BR.95 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$3,433	$7
1 Month Maintenance Materials	$657	$1
1 Month Non-Fuel Consumables	$929	$2
1 Month Waste Disposal	$13	$0
25% of 1 Months Fuel Cost at 100% CF	$0	$0
2% of TPC	$15,367	$32
Total	**$20,400**	**$42**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$1,742	$4
0.5% of TPC (spare parts)	$3,842	$8
Total	**$5,584**	**$11**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$0	$0
Other Owner's Costs	$115,252	$236
Financing Costs	$20,745	$43
Total Overnight Costs (TOC)	**$930,327**	**$1,907**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$1,016,519**	**$2,084**

Exhibit 4-5. Case B11A-BR.90 initial and annual operating and maintenance costs

Case:	**B11A-BR.90**	**– Retrofit Subcritical PC w/ CO_2**			**Cost Base:**	**Dec 2018**
Plant Size (MW, net):	**495**	**Heat Rate-net (Btu/kWh):**		**11,621**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:		2.0
Operating Labor Burden:		30.00	**% of base**	Operator:		11.3
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:		1.0
				Lab Techs, etc.:		2.0
				Total:		**16.3**
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,161,008	$14.45
Maintenance Labor:					$12,729,557	$25.69
Administrative & Support Labor:					$4,972,641	$10.04
Property Taxes and Insurance:					$39,779,865	$80.30
Total:					**$64,643,070**	**$130.48**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$19,094,335	$5.18
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	5,646	$1.90	$0	$3,327,925	$0.90
Makeup and Wastewater Treatment Chemicals (ton):	0	16.8	$550.00	$0	$2,869,675	$0.78
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,679	$0.17
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,547	$0.66
Limestone (ton):	0	572	$22.00	$0	$3,906,996	$1.06
Ammonia (19 wt%, ton):	0	57.4	$300.00	$0	$5,343,460	$1.45
SCR Catalyst (ft^3):	14,235	13.0	$150.00	$2,135,240	$604,985	$0.16
CO_2 Capture System Chemicals[A]	Proprietary				$6,922,845	$1.88
Triethylene Glycol (gal):	w/equip.	489	$6.80	$0	$1,032,653	$0.28
Subtotal:				**$2,135,240**	**$27,076,765**	**$7.34**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,383	$1.72
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,320	$0.38
SCR Catalyst (ft^3):	0	13.0	$2.50	$0	$10,083	$0.00
Triethylene Glycol (gal):	0	489	$0.35	$0	$53,151	$0.01
Thermal Reclaimer Unit Waste (ton)	0	6.30	$38.00	$0	$74,324	$0.02
Subtotal:				**$0**	**$7,875,261**	**$2.13**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,135,240**	**$54,046,361**	**$14.65**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,388,011	$25.86
Total:				**$0**	**$95,388,011**	**$25.86**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

Exhibit 4-6. Case B11A-BR.95 initial and annual operating and maintenance costs

Case:	B11A-BR.95	– Retrofit Subcritical PC w/ CO_2			Cost Base:	Dec 2018
Plant Size (MW, net):	**488**	**Heat Rate-net (Btu/kWh):**		**11,793**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:		2.0
Operating Labor Burden:		30.00	**% of base**	Operator:		11.3
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:		1.0
				Lab Techs, etc.:		2.0
				Total:		**16.3**
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,161,008	$14.68
Maintenance Labor:					$12,855,254	$26.35
Administrative & Support Labor:					$5,004,065	$10.26
Property Taxes and Insurance:					$40,172,668	$82.35
Total:					**$65,192,994**	**$133.65**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$19,282,880	$5.31
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	5,691	$1.90	$0	$3,354,483	$0.92
Makeup and Wastewater Treatment Chemicals (ton):	0	17.0	$550.00	$0	$2,892,576	$0.80
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,680	$0.18
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,546	$0.67
Limestone (ton):	0	572	$22.00	$0	$3,906,995	$1.08
Ammonia (19 wt%, ton):	0	57.5	$300.00	$0	$5,354,201	$1.47
SCR Catalyst (ft^3):	14,235	13.0	$150.00	$2,135,239	$604,985	$0.17
CO_2 Capture System Chemicals[A]	Proprietary				$7,041,964	$1.94
Triethylene Glycol (gal):	w/equip.	517	$6.80	$0	$1,090,163	$0.30
Subtotal:				**$2,135,239**	**$27,313,593**	**$7.52**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,155	$1.74
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,319	$0.39
SCR Catalyst (ft^3):	0	13.0	$2.50	$0	$10,083	$0.00
Triethylene Glycol (gal):	0	517	$0.35	$0	$56,111	$0.02
Thermal Reclaimer Unit Waste (ton)	0	6.42	$38.00	$0	$75,731	$0.02
Subtotal:				**$0**	**$7,879,399**	**$2.17**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,135,239**	**$54,475,873**	**$15.00**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,387,987	$26.26
Total:				**$0**	**$95,387,987**	**$26.26**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

Exhibit 4-7. Case B11A-BR.90 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	18.9	22%
Fixed	17.5	20%
Variable	14.7	17%
Fuel	25.9	30%
Total (Excluding T&S)	**77.0**	89%
CO_2 T&S	9.6	11%
Total (Including T&S)	**86.6**	100%

Exhibit 4-8. Case B11A-BR.95 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	19.8	22%
Fixed	17.9	20%
Variable	15.0	17%
Fuel	26.3	29%
Total (Excluding T&S)	**79.0**	88%
CO_2 T&S	10.3	12%
Total (Including T&S)	**89.3**	100%

4.2 CASE B11A-BRWNGSC

Costs for the retrofitted capture system, modified ductwork, modified steam piping, etc., were scaled from the Case B11B cost estimates using the scaling QGESS methodology as in the previous study based on the performance data reported in the previous section of this report. [1, 9, 3, 5] While cost estimates for combustion turbines are typically provided by vendors for specific models with defined performance characteristics, costs for the hypothetically-sized turbine in this case were scaled based on cost estimates for the F-class turbine in Revision 4a of the Fossil Energy Baseline report at approximately 25 percent more than a single F-class turbine. [1] The NGSC was assumed to include low NO_X burners, an SCR, an emergency dump condenser, and a separate stack.

Exhibit 4-9 and Exhibit 4-10 show a detailed breakdown of the capital costs including the major equipment items as well as other capital expenditures required to facilitate the retrofit. Exhibit 4-11 and Exhibit 4-12 identify owner's costs, along with the TOC and TASC. Exhibit 4-13 and Exhibit 4-14 show the initial and annual O&M costs and Exhibit 4-15 and Exhibit 4-16 show the LCOE breakdown. The estimated bare erected cost and total plant costs of retrofitting the subcritical PC boiler plant with 90 percent CO_2 capture and an auxiliary NGSC CHP plant are $743/kW and $1,093/kW, respectively, before adding retrofit contingencies. The retrofit difficulty factor of 1.1 adds 10 percent retrofit contingency to the TPC for a total value of $1,038,760,000 or $1,202/kW. The total overnight cost is $1,277,630,000 or $1,479/kW, and the LCOE is $64.5/MWh excluding T&S. The estimated bare erected cost and total plant costs of retrofitting the subcritical PC boiler plant with 95 percent CO_2 capture and an auxiliary NGSC CHP plant are $755/kW and $1,111/kW, respectively, before adding retrofit contingencies. The retrofit difficulty factor of 1.1 adds 10 percent retrofit contingency to the TPC for a total value of $1,070,679,000 or $1,222/kW. The total overnight cost is $1,317,350,000 or $1,504/kW, and the LCOE is $65.1/MWh excluding T&S.

Exhibit 4-9. Case B11A-BRwNGSC.90 retrofit plant cost details

	Case:	B11A-BR wNGSC.90	– Retrofit Subcritical PC w/ CO_2 with NGSC						Estimate Type:	Conceptual	
	Plant Size (MW, net):	864							Cost Base:	Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
	1					Coal & Sorbent Handling					
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	2					Coal & Sorbent Preparation & Feed					
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	3					Feedwater & Miscellaneous BOP Systems					
3.1	Feedwater System	$1,890	$3,240	$1,620	$0	$6,749	$1,350	$0	$1,215	$9,314	$11
3.2	Water Makeup & Pretreating	$3,817	$382	$2,163	$0	$6,361	$1,113	$0	$1,495	$8,969	$10
3.3	Other Feedwater Subsystems	$1,075	$352	$335	$0	$1,762	$352	$0	$317	$2,432	$3
3.4	Service Water Systems	$1,153	$2,201	$7,129	$0	$10,483	$1,835	$0	$2,464	$14,781	$17
3.5	Other Boiler Plant Systems	$263	$96	$239	$0	$598	$120	$0	$108	$825	$1
3.6	Natural Gas Pipeline and Start-Up System	$5,347	$230	$172	$0	$5,750	$1,150	$0	$1,035	$7,935	$9
3.7	Wastewater Treatment Equipment	$7,617	$0	$4,668	$0	$12,285	$2,150	$0	$2,887	$17,322	$20
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$176	$23	$90	$0	$289	$51	$0	$68	$407	$0
	Subtotal	**$21,338**	**$6,524**	**$16,416**	**$0**	**$44,278**	**$8,120**	**$0**	**$9,588**	**$61,986**	**$72**
	4					Pulverized Coal Boiler & Accessories					
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	5					Flue Gas Cleanup					
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$124,106	$55,204	$115,928	$0	$295,239	$51,667	$50,191	$69,492	$466,588	$540
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$37,816	$5,673	$12,451	$0	$55,940	$9,789	$0	$13,146	$78,875	$91
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$395	$63	$169	$0	$627	$110	$0	$147	$884	$1
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.12	Gas Cleanup Foundations	$0	$133	$117	$0	$250	$44	$0	$44	$338	$0

	Case:	B11A-BR wNGSC.90	– Retrofit Subcritical PC w/ CO_2 with NGSC					Estimate Type:		Conceptual	
	Plant Size (MW, net):	864						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$162,317**	**$61,072**	**$128,666**	**$0**	**$352,056**	**$61,610**	**$50,191**	**$82,829**	**$546,685**	**$633**
	6	Combustion Turbine & Accessories									
6.1	Combustion Turbine Generator	$46,383	$0	$2,823	$0	$49,205	$9,841	$0	$8,857	$67,903	$79
6.2	Emergency / Startup / Dump Condenser	$3,975	$0	$1,601	$0	$5,577	$1,115	$0	$1,004	$7,696	$9
6.3	Combustion Turbine Accessories	$1,884	$0	$115	$0	$1,999	$400	$0	$360	$2,758	$3
6.4	Compressed Air Piping	$0	$622	$141	$0	$763	$153	$0	$137	$1,053	$1
6.5	Combustion Turbine Foundations	$0	$650	$702	$0	$1,352	$270	$0	$324	$1,947	$2
	Subtotal	**$52,242**	**$1,272**	**$5,382**	**$0**	**$58,896**	**$11,779**	**$0**	**$10,682**	**$81,357**	**$94**
	7	Ductwork & Stack									
7.1	Heat Recovery Steam Generator	$25,300	$0	$6,325	$0	$31,625	$6,325	$0	$5,693	$43,643	$51
7.2	Heat Recovery Steam Generator Accessories + Foundations	$10,963	$407	$2,417	$0	$13,787	$2,369	$0	$2,082	$18,238	$21
7.3	Ductwork	$0	$1,702	$967	$0	$2,669	$467	$0	$470	$3,606	$4
7.4	Stack(s)	$7,557	$0	$1,749	$0	$9,306	$1,629	$0	$1,640	$12,575	$15
7.5	Duct & Stack Foundations	$0	$1,269	$731	$0	$1,999	$350	$0	$470	$2,819	$3
7.6	Selective Catalytic Reduction System	$1,000	$420	$586	$0	$2,006	$401	$0	$361	$2,769	$3
	Subtotal	**$44,821**	**$3,797**	**$12,774**	**$0**	**$61,392**	**$11,541**	**$0**	**$10,716**	**$83,649**	**$97**
	8	Steam Turbine & Accessories									
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$13,835	$0	$5,607	$0	$19,443	$3,402	$0	$3,427	$26,272	$30
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$13,835**	**$0**	**$5,607**	**$0**	**$19,443**	**$3,402**	**$0**	**$3,427**	**$26,272**	**$30**
	9	Cooling Water System									
9.1	Cooling Towers	$9,995	$0	$3,091	$0	$13,086	$2,290	$0	$2,306	$17,683	$20
9.2	Circulating Water Pumps	$1,298	$0	$92	$0	$1,390	$243	$0	$245	$1,878	$2
9.3	Circulating Water System Auxiliaries	$9,360	$0	$1,238	$0	$10,599	$1,855	$0	$1,868	$14,322	$17
9.4	Circulating Water Piping	$0	$4,328	$3,920	$0	$8,248	$1,443	$0	$1,454	$11,146	$13
9.5	Makeup Water System	$782	$0	$1,005	$0	$1,787	$313	$0	$315	$2,414	$3
9.6	Component Cooling Water System	$674	$0	$518	$0	$1,192	$209	$0	$210	$1,611	$2

	Case:	B11A-BR wNGSC.90	– Retrofit Subcritical PC w/ CO_2 with NGSC						Estimate Type:	Conceptual	
	Plant Size (MW, net):	864							Cost Base:	Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
9.7	Circulating Water System Foundations	$0	$421	$700	$0	$1,121	$196	$0	$263	$1,581	$2
	Subtotal	**$22,110**	**$4,750**	**$10,563**	**$0**	**$37,423**	**$6,549**	**$0**	**$6,662**	**$50,634**	**$59**
	10	**Ash & Spent Sorbent Handling Systems**									
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	11	**Accessory Electric Plant**									
11.1	Generator Equipment	$1,860	$0	$1,403	$0	$3,263	$653	$0	$587	$4,503	$5
11.2	Station Service Equipment	$5,747	$0	$493	$0	$6,240	$1,092	$0	$1,100	$8,432	$10
11.3	Switchgear & Motor Control	$8,921	$0	$1,548	$0	$10,469	$1,832	$0	$1,845	$14,146	$16
11.4	Conduit & Cable Tray	$0	$1,160	$3,342	$0	$4,502	$788	$0	$793	$6,083	$7
11.5	Wire & Cable	$0	$3,071	$5,490	$0	$8,561	$1,498	$0	$1,509	$11,568	$13
11.6	Protective Equipment	$32	$0	$110	$0	$141	$25	$0	$25	$191	$0
11.7	Standby Equipment	$495	$0	$457	$0	$952	$167	$0	$168	$1,287	$1
11.8	Main Power Transformers	$2,000	$0	$41	$0	$2,040	$357	$0	$360	$2,757	$3
11.9	Electrical Foundations	$0	$103	$263	$0	$366	$64	$0	$86	$516	$1
	Subtotal	**$19,055**	**$4,334**	**$13,146**	**$0**	**$36,535**	**$6,475**	**$0**	**$6,473**	**$49,483**	**$57**
	12	**Instrumentation & Control**									
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.2	NGSC Control + Combustion Turbine Equipment	$559	$0	$356	$0	$915	$183	$0	$165	$1,262	$1
12.3	Steam Turbine Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control Equipment	$608	$0	$387	$0	$995	$199	$0	$179	$1,373	$2
12.5	Signal Processing Equipment	$423	$0	$13	$0	$436	$87	$0	$78	$601	$1
12.6	Control Boards, Panels & Racks	$112	$0	$68	$0	$180	$36	$0	$32	$249	$0
12.7	Distributed Control System Equipment	$6,215	$0	$189	$0	$6,404	$1,281	$0	$1,153	$8,837	$10
12.8	Instrument Wiring & Tubing	$508	$406	$1,625	$0	$2,540	$444	$127	$467	$3,578	$4
12.9	Other Instrumentation & Controls Equipment	$624	$0	$1,446	$0	$2,070	$362	$104	$380	$2,916	$3
	Subtotal	**$9,049**	**$406**	**$4,085**	**$0**	**$13,540**	**$2,593**	**$231**	**$2,454**	**$18,817**	**$22**
	13	**Improvements to Site**									
13.1	Site Preparation	$0	$402	$8,483	$0	$8,885	$1,555	$0	$2,088	$12,527	$14
13.2	Site Improvements	$0	$1,335	$1,764	$0	$3,100	$542	$0	$728	$4,371	$5
13.3	Site Facilities	$1,308	$0	$1,372	$0	$2,679	$469	$0	$630	$3,778	$4
	Subtotal	**$1,308**	**$1,737**	**$11,619**	**$0**	**$14,664**	**$2,566**	**$0**	**$3,446**	**$20,676**	**$24**

	Case:	B11A-BR wNGSC.90	– Retrofit Subcritical PC w/ CO_2 with NGSC					Estimate Type:		Conceptual	
	Plant Size (MW, net):	864						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
	14					Buildings & Structures					
14.1	Combustion Turbine Building	$0	$199	$105	$0	$304	$61	$0	$55	$419	$0
14.2	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$111	$88	$0	$199	$35	$0	$35	$269	$0
14.6	Water Treatment Buildings	$0	$287	$262	$0	$550	$96	$0	$97	$743	$1
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$612	$1,857	$0	$2,469	$432	$0	$435	$3,336	$4
	Subtotal	**$0**	**$1,209**	**$2,312**	**$0**	**$3,522**	**$624**	**$0**	**$622**	**$4,768**	**$6**
	Total	**$346,075**	**$85,102**	**$210,570**	**$0**	**$641,748**	**$115,259**	**$50,421**	**$136,899**	**$944,328**	**$1,093**
	Retrofit Difficulty Allowance	**$34,608**	**$8,510**	**$21,057**	**$0**	**$64,175**	**$11,526**	**$5,042**	**$13,690**	**$94,433**	**$109**
	Total (Including Retrofit Difficulty Factor)	**$380,683**	**$93,613**	**$231,628**	**$0**	**$705,923**	**$126,785**	**$55,463**	**$150,589**	**$1,038,760**	**$1,202**

Exhibit 4-10. Case B11A-BRwNGSC.95 retrofit plant cost details

	Case:	B11A-BR wNGSC.95	– Retrofit Subcritical PC w/ CO_2 with NGSC					Estimate Type:		Conceptual	
	Plant Size (MW, net):	876						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
1	Coal & Sorbent Handling										
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
2	Coal & Sorbent Preparation & Feed										
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	Feedwater & Miscellaneous BOP Systems										
3.1	Feedwater System	$1,964	$3,367	$1,684	$0	$7,015	$1,403	$0	$1,263	$9,681	$11
3.2	Water Makeup & Pretreating	$3,965	$397	$2,247	$0	$6,609	$1,157	$0	$1,553	$9,318	$11
3.3	Other Feedwater Subsystems	$1,117	$366	$348	$0	$1,832	$366	$0	$330	$2,528	$3
3.4	Service Water Systems	$1,201	$2,293	$7,425	$0	$10,919	$1,911	$0	$2,566	$15,395	$18
3.5	Other Boiler Plant Systems	$276	$100	$251	$0	$628	$126	$0	$113	$866	$1
3.6	Natural Gas Pipeline and Start-Up System	$5,641	$243	$182	$0	$6,066	$1,213	$0	$1,092	$8,370	$10
3.7	Wastewater Treatment Equipment	$7,742	$0	$4,745	$0	$12,487	$2,185	$0	$2,934	$17,606	$20
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$179	$24	$91	$0	$294	$51	$0	$69	$414	$0
	Subtotal	**$22,086**	**$6,789**	**$16,972**	**$0**	**$45,847**	**$8,412**	**$0**	**$9,919**	**$64,179**	**$73**
4	Pulverized Coal Boiler & Accessories										
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
5	Flue Gas Cleanup										
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$128,020	$56,697	$119,064	$0	$303,782	$53,162	$51,643	$71,503	$480,089	$548
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$39,088	$5,863	$12,870	$0	$57,822	$10,119	$0	$13,588	$81,529	$93
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$413	$66	$177	$0	$656	$115	$0	$154	$925	$1
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.12	Gas Cleanup Foundations	$0	$134	$117	$0	$251	$44	$0	$44	$340	$0
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$167,521**	**$62,760**	**$132,229**	**$0**	**$362,511**	**$63,439**	**$51,643**	**$85,289**	**$562,882**	**$643**
6	Combustion Turbine & Accessories										
6.1	Combustion Turbine Generator	$48,414	$0	$2,946	$0	$51,360	$10,272	$0	$9,245	$70,877	$81
6.2	Emergency / Startup / Dump Condenser	$4,163	$0	$1,677	$0	$5,841	$1,168	$0	$1,051	$8,060	$9

	Case:	B11A-BR wNGSC.95	– Retrofit Subcritical PC w/ CO_2 with NGSC				Estimate Type:			Conceptual	
	Plant Size (MW, net):	876					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies Process	Contingencies Project	Total Plant Cost $/1,000	Total Plant Cost $/kW
6.3	Combustion Turbine Accessories	$1,946	$0	$118	$0	$2,064	$413	$0	$372	$2,848	$3
6.4	Compressed Air Piping	$0	$642	$145	$0	$788	$158	$0	$142	$1,087	$1
6.5	Combustion Turbine Foundations	$0	$671	$725	$0	$1,396	$279	$0	$335	$2,010	$2
	Subtotal	**$54,523**	**$1,313**	**$5,612**	**$0**	**$61,448**	**$12,290**	**$0**	**$11,144**	**$84,882**	**$97**
	7					Ductwork & Stack					
7.1	Heat Recovery Steam Generator	$26,270	$0	$6,567	$0	$32,837	$6,567	$0	$5,911	$45,315	$52
7.2	Heat Recovery Steam Generator Accessories + Foundations	$11,383	$422	$2,509	$0	$14,315	$2,460	$0	$2,162	$18,937	$22
7.3	Ductwork	$0	$1,727	$985	$0	$2,712	$475	$0	$478	$3,665	$4
7.4	Stack(s)	$7,812	$0	$1,796	$0	$9,607	$1,681	$0	$1,693	$12,982	$15
7.5	Duct & Stack Foundations	$0	$1,288	$749	$0	$2,037	$356	$0	$479	$2,872	$3
7.6	Selective Catalytic Reduction System	$1,038	$436	$608	$0	$2,082	$416	$0	$375	$2,873	$3
	Subtotal	**$46,502**	**$3,873**	**$13,215**	**$0**	**$63,591**	**$11,956**	**$0**	**$11,097**	**$86,644**	**$99**
	8					Steam Turbine & Accessories					
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$14,364	$0	$5,822	$0	$20,186	$3,533	$0	$3,558	$27,276	$31
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,364**	**$0**	**$5,822**	**$0**	**$20,186**	**$3,533**	**$0**	**$3,558**	**$27,276**	**$31**
	9					Cooling Water System					
9.1	Cooling Towers	$10,326	$0	$3,193	$0	$13,519	$2,366	$0	$2,383	$18,268	$21
9.2	Circulating Water Pumps	$1,347	$0	$95	$0	$1,442	$252	$0	$254	$1,949	$2
9.3	Circulating Water System Auxiliaries	$9,616	$0	$1,272	$0	$10,889	$1,906	$0	$1,919	$14,713	$17
9.4	Circulating Water Piping	$0	$4,447	$4,027	$0	$8,474	$1,483	$0	$1,494	$11,451	$13
9.5	Makeup Water System	$802	$0	$1,030	$0	$1,832	$321	$0	$323	$2,475	$3
9.6	Component Cooling Water System	$693	$0	$532	$0	$1,225	$214	$0	$216	$1,655	$2
9.7	Circulating Water System Foundations	$0	$432	$717	$0	$1,149	$201	$0	$270	$1,621	$2
	Subtotal	**$22,784**	**$4,879**	**$10,867**	**$0**	**$38,530**	**$6,743**	**$0**	**$6,858**	**$52,131**	**$60**
	10					Ash & Spent Sorbent Handling Systems					
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	11					Accessory Electric Plant					
11.1	Generator Equipment	$1,920	$0	$1,448	$0	$3,368	$674	$0	$606	$4,648	$5
11.2	Station Service Equipment	$5,878	$0	$504	$0	$6,382	$1,117	$0	$1,125	$8,624	$10
11.3	Switchgear & Motor Control	$9,125	$0	$1,583	$0	$10,708	$1,874	$0	$1,887	$14,469	$17
11.4	Conduit & Cable Tray	$0	$1,186	$3,418	$0	$4,605	$806	$0	$812	$6,222	$7
11.5	Wire & Cable	$0	$3,141	$5,615	$0	$8,757	$1,532	$0	$1,543	$11,832	$14
11.6	Protective Equipment	$33	$0	$116	$0	$149	$26	$0	$26	$201	$0

	Case:	B11A-BR wNGSC.95	– Retrofit Subcritical PC w/ CO_2 with NGSC				Estimate Type:			Conceptual	
	Plant Size (MW, net):	876					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
11.7	Standby Equipment	$509	$0	$470	$0	$979	$171	$0	$173	$1,324	$2
11.8	Main Power Transformers	$2,102	$0	$43	$0	$2,145	$375	$0	$378	$2,898	$3
11.9	Electrical Foundations	$0	$108	$274	$0	$382	$67	$0	$90	$538	$1
	Subtotal	**$19,567**	**$4,435**	**$13,472**	**$0**	**$37,475**	**$6,642**	**$0**	**$6,640**	**$50,757**	**$58**
	12					Instrumentation & Control					
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.2	NGSC Control + Combustion Turbine Equipment	$563	$0	$358	$0	$921	$184	$0	$166	$1,271	$1
12.3	Steam Turbine Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control Equipment	$607	$0	$387	$0	$994	$199	$0	$179	$1,372	$2
12.5	Signal Processing Equipment	$423	$0	$13	$0	$436	$87	$0	$78	$602	$1
12.6	Control Boards, Panels & Racks	$112	$0	$68	$0	$180	$36	$0	$32	$249	$0
12.7	Distributed Control System Equipment	$6,219	$0	$189	$0	$6,408	$1,282	$0	$1,153	$8,843	$10
12.8	Instrument Wiring & Tubing	$511	$409	$1,637	$0	$2,557	$448	$128	$470	$3,602	$4
12.9	Other Instrumentation & Controls Equipment	$629	$0	$1,456	$0	$2,084	$365	$104	$383	$2,936	$3
	Subtotal	**$9,064**	**$409**	**$4,108**	**$0**	**$13,581**	**$2,600**	**$232**	**$2,462**	**$18,876**	**$22**
	13					Improvements to Site					
13.1	Site Preparation	$0	$406	$8,569	$0	$8,974	$1,570	$0	$2,109	$12,654	$14
13.2	Site Improvements	$0	$1,350	$1,783	$0	$3,133	$548	$0	$736	$4,418	$5
13.3	Site Facilities	$1,322	$0	$1,387	$0	$2,710	$474	$0	$637	$3,820	$4
	Subtotal	**$1,322**	**$1,755**	**$11,739**	**$0**	**$14,817**	**$2,593**	**$0**	**$3,482**	**$20,892**	**$24**
	14					Buildings & Structures					
14.1	Combustion Turbine Building	$0	$210	$111	$0	$321	$64	$0	$58	$442	$1
14.2	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$114	$90	$0	$204	$36	$0	$36	$276	$0
14.6	Water Treatment Buildings	$0	$295	$269	$0	$564	$99	$0	$99	$762	$1
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$613	$1,862	$0	$2,475	$433	$0	$436	$3,345	$4
	Subtotal	**$0**	**$1,232**	**$2,332**	**$0**	**$3,564**	**$632**	**$0**	**$629**	**$4,825**	**$6**
	Total	**$357,735**	**$87,447**	**$216,368**	**$0**	**$661,550**	**$118,839**	**$51,875**	**$141,080**	**$973,345**	**$1,111**
	Retrofit Difficulty Allowance	**$35,773**	**$8,745**	**$21,637**	**$0**	**$66,155**	**$11,884**	**$5,187**	**$14,108**	**$97,334**	**$111**
	Total (Including Retrofit Difficulty Factor)	**$393,508**	**$96,192**	**$238,005**	**$0**	**$727,706**	**$130,723**	**$57,062**	**$155,188**	**$1,070,679**	**$1,222**

Exhibit 4-11. Case B11A-BRwNGSC.90 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$4,691	$5
1 Month Maintenance Materials	$889	$1
1 Month Non-Fuel Consumables	$1,322	$2
1 Month Waste Disposal	$13	$0
25% of 1 Months Fuel Cost at 100% CF	$2,143	$2
2% of TPC	$20,775	$24
Total	**$29,833**	**$35**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$19,495	$23
0.5% of TPC (spare parts)	$5,194	$6
Total	**$24,689**	**$29**
Other Costs		
Initial Cost for Catalyst and Chemicals	$487	$1
Land	$0	$0
Other Owner's Costs	$155,814	$180
Financing Costs	$28,047	$32
Total Overnight Costs (TOC)	**$1,277,630**	**$1,479**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$1,395,998**	**$1,616**

Exhibit 4-12. Case B11A-BRwNGSC.95 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$4,807	$5
1 Month Maintenance Materials	$916	$1
1 Month Non-Fuel Consumables	$1,368	$2
1 Month Waste Disposal	$13	$0
25% of 1 Months Fuel Cost at 100% CF	$2,261	$3
2% of TPC	$21,414	$24
Total	**$30,779**	**$35**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$20,514	$23
0.5% of TPC (spare parts)	$5,353	$6
Total	**$25,868**	**$30**
Other Costs		
Initial Cost for Catalyst and Chemicals	$514	$1
Land	$0	$0
Other Owner's Costs	$160,602	$183
Financing Costs	$28,908	$33
Total Overnight Costs (TOC)	**$1,317,350**	**$1,504**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$1,439,398**	**$1,643**

Exhibit 4-13. Case B11A-BRwNGSC.90 initial and annual operating and maintenance costs

Case:	**B11A-BR wNGSC.90**	**– Retrofit Subcritical PC w/ CO_2 with NGSC**			**Cost Base:**	**Dec 2018**
Plant Size (MW, net):	**864**	**Heat Rate-net (Btu/kWh):**		**9,733**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:		2.0
Operating Labor Burden:		30.00	**% of base**	Operator:		12.3
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:		1.0
				Lab Techs, etc.:		2.0
				Total:		**17.3**
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,599,446	$8.80
Maintenance Labor:					$14,428,576	$16.70
Administrative & Support Labor:					$5,507,005	$6.37
Property Taxes and Insurance:					$45,089,300	$52.19
Total:					**$72,624,328**	**$84.06**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$21,642,864	$3.36
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	7,235	$1.90	$0	$4,264,645	$0.66
Makeup and Wastewater Treatment Chemicals (ton):	0	21.6	$550.00	$0	$3,677,410	$0.57
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,674	$0.10
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,525	$0.38
Limestone (ton):	0	572	$22.00	$0	$3,906,961	$0.61
Ammonia (19 wt%, ton):	0	83.4	$300.00	$0	$7,757,841	$1.21
SCR Catalyst (ft^3):	17,482	14.8	$150.00	$2,622,342	$687,790	$0.11
CO_2 Capture System Chemicals[A]	Proprietary				$6,922,752	$1.08
Triethylene Glycol (gal):	w/equip.	489	$6.80	$0	$1,032,644	$0.16
Subtotal:				**$2,622,342**	**$31,318,242**	**$4.87**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,167	$0.98
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,307	$0.22
SCR Catalyst (ft^3):	0	14.8	$2.50	$0	$11,463	$0.00
Triethylene Glycol (gal):	0	489	$0.35	$0	$53,151	$0.01
Thermal Reclaimer Unit Waste (ton)	0	6.30	$38.00	$0	$74,324	$0.01
Subtotal:				**$0**	**$7,876,412**	**$1.22**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,622,342**	**$60,837,518**	**$9.46**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,387,161	$14.83
Natural Gas (MMBtu):	0	63,765	$4.42	$0	$87,445,113	$13.59
Total:				**$0**	**$182,832,273**	**$28.42**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

Exhibit 4-14. Case B11A-BRwNGSC.95 initial and annual operating and maintenance costs

Case:	**B11A-BR wNGSC.95**	**– Retrofit Subcritical PC w/ CO_2 with NGSC**			**Cost Base:**	**Dec 2018**
Plant Size (MW, net):	**876**	**Heat Rate-net (Btu/kWh):**		**9,768**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:		2.0
Operating Labor Burden:		30.00	**% of base**	Operator:		12.3
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:		1.0
				Lab Techs, etc.:		2.0
				Total:		**17.3**
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,599,446	$8.68
Maintenance Labor:					$14,614,285	$16.69
Administrative & Support Labor:					$5,553,433	$6.34
Property Taxes and Insurance:					$45,669,640	$52.14
Total:					**$73,436,803**	**$83.85**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$21,921,427	$3.36
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	7,368	$1.90	$0	$4,343,116	$0.67
Makeup and Wastewater Treatment Chemicals (ton):	0	21.9	$550.00	$0	$3,745,075	$0.57
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,674	$0.10
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,525	$0.37
Limestone (ton):	0	572	$22.00	$0	$3,906,961	$0.60
Ammonia (19 wt%, ton):	0	84.9	$300.00	$0	$7,903,131	$1.21
SCR Catalyst (ft^3):	17,661	14.9	$150.00	$2,649,168	$692,350	$0.11
CO_2 Capture System Chemicals[A]		Proprietary			$7,041,904	$1.08
Triethylene Glycol (gal):	w/equip.	517	$6.80	$0	$1,090,154	$0.17
Subtotal:				**$2,649,168**	**$31,790,889**	**$4.87**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,167	$0.97
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,307	$0.22
SCR Catalyst (ft^3):	0	14.9	$2.50	$0	$11,539	$0.00
Triethylene Glycol (gal):	0	517	$0.35	$0	$56,111	$0.01
Thermal Reclaimer Unit Waste (ton)	0	6.42	$38.00	$0	$75,731	$0.01
Subtotal:				**$0**	**$7,880,855**	**$1.21**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,649,168**	**$61,593,171**	**$9.44**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,387,161	$14.63
Natural Gas (MMBtu):	0	67,268	$4.42	$0	$92,248,562	$14.15
Total:				**$0**	**$187,635,723**	**$28.77**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

Exhibit 4-15. Case B11A-BRwNGSC.90 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	15.4	22%
Fixed	11.3	16%
Variable	9.5	14%
Fuel	28.4	41%
Total (Excluding T&S)	**64.5**	92%
CO_2 T&S	5.5	8%
Total (Including T&S)	**70.0**	100%

Exhibit 4-16. Case B11A-BRwNGSC.95 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	15.6	22%
Fixed	11.3	16%
Variable	9.4	13%
Fuel	28.8	41%
Total (Excluding T&S)	**65.1**	92%
CO_2 T&S	5.7	8%
Total (Including T&S)	**70.8**	100%

4.3 CASE B11A-BRWNGBLR

Costs for the retrofitted capture system, modified ductwork, modified steam piping, etc., were scaled from the Case B11B cost estimates using the scaling QGESS methodology as in the previous study. [1, 9, 3, 5] The natural gas-fired boiler costs are based on a quote from CleaverBrooks for 2×500,000 lb/hr package boilers and scaled by the amount of steam required for the capture process based on NETL cost scaling methodology. [5, 18] The natural gas-fired boiler includes low NO_X burners and a separate stack.

NO_X produced from the existing plant PC boiler remains constant, but SCR catalyst and ammonia are added such that the plant remains compliant with the 0.7 lb/MWh-gross emissions limit, even with the lower gross plant output due to the auxiliary load of the capture system in this case. It was assumed that space is available in the existing SCR to handle an additional catalyst layer and no modification costs are included in the estimate.

Exhibit 4-17 and Exhibit 4-18 show a detailed breakdown of the capital costs including the major equipment items as well as other capital expenditures required to facilitate the retrofit. Exhibit 4-19 and Exhibit 4-20 identify owner's costs, along with the TOC and TASC. Exhibit 4-21 and Exhibit 4-22 show the initial and annual O&M costs and Exhibit 4-23 and Exhibit 4-24 show the LCOE breakdown. The estimated bare erected cost and total plant costs of retrofitting the subcritical PC boiler plant with 90 percent CO_2 capture and an auxiliary natural gas-fired boiler are $901/kW and $1,344/kW, respectively, before adding retrofit contingencies. The retrofit difficulty factor of 1.1 adds 10 percent retrofit contingency to the TPC for a total value of $873,505,000 or $1,478/kW. The total overnight cost is $1,068,879,000 or $1,809/kW, and the LCOE is $80.3/MWh excluding T&S. The estimated bare erected cost and total plant costs of retrofitting the subcritical PC boiler plant with 95 percent CO_2 capture and an auxiliary natural gas-fired boiler are $934/kW and $1,392/kW, respectively, before adding retrofit contingencies. The retrofit difficulty factor of 1.1 adds 10 percent retrofit contingency to the TPC for a total value of $899,825,000 or $1,531/kW. The total overnight cost is $1,101,332,000 or $1,874/kW, and the LCOE is $82.2/MWh excluding T&S.

Exhibit 4-17. Case B11A-BRwNGBlr.90 retrofit plant cost details

	Case:	B11A-BR wNGBlr.90	– Retrofit Subcritical PC w/ CO_2 with NG Boiler					Estimate Type:		Conceptual	
	Plant Size (MW, net):	591						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
1					Coal & Sorbent Handling						
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
2					Coal & Sorbent Preparation & Feed						
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3					Feedwater & Miscellaneous BOP Systems						
3.1	Feedwater System	$1,890	$3,240	$1,620	$0	$6,749	$1,350	$0	$1,215	$9,314	$16
3.2	Water Makeup & Pretreating	$3,868	$387	$2,192	$0	$6,447	$1,128	$0	$1,515	$9,090	$15
3.3	Other Feedwater Subsystems	$1,075	$352	$335	$0	$1,762	$352	$0	$317	$2,432	$4
3.4	Service Water Systems	$1,170	$2,233	$7,231	$0	$10,634	$1,861	$0	$2,499	$14,994	$25
3.5	Other Boiler Plant Systems	$263	$96	$239	$0	$598	$120	$0	$108	$825	$1
3.6	Natural Gas Pipeline and Start-Up System	$2,964	$127	$96	$0	$3,187	$637	$0	$574	$4,398	$7
3.7	Wastewater Treatment Equipment	$7,927	$0	$4,859	$0	$12,786	$2,238	$0	$3,005	$18,028	$31
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$152	$20	$77	$0	$249	$44	$0	$59	$351	$1
	Subtotal	**$19,309**	**$6,455**	**$16,649**	**$0**	**$42,413**	**$7,730**	**$0**	**$9,291**	**$59,434**	**$101**
4					Pulverized Coal Boiler & Accessories						
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
5					Flue Gas Cleanup						
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$124,106	$55,204	$115,928	$0	$295,239	$51,667	$50,191	$69,492	$466,588	$790
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$37,816	$5,673	$12,451	$0	$55,940	$9,789	$0	$13,146	$78,875	$134
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$395	$63	$169	$0	$627	$110	$0	$147	$884	$1
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.12	Gas Cleanup Foundations	$0	$133	$117	$0	$250	$44	$0	$44	$338	$1
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$162,317**	**$61,072**	**$128,666**	**$0**	**$352,056**	**$61,610**	**$50,191**	**$82,829**	**$546,685**	**$925**
6					Combustion Turbine & Accessories						
6.1 – 6.5	Combustion Turbine & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	Case:	B11A-BR wNGBlr.90	– Retrofit Subcritical PC w/ CO_2 with NG Boiler						Estimate Type:	Conceptual	
	Plant Size (MW, net):	591							Cost Base:	Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
	Subtotal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7						**Ductwork & Stack**					
7.1	NG Package Boiler w Stack	$11,700	$0	$7,641	$0	$19,341	$3,868	$0	$3,481	$26,691	$45
7.2	NG Steam Boiler Accessories + Foundations	$5,070	$188	$1,118	$0	$6,376	$1,096	$0	$963	$8,434	$14
7.3	Ductwork	$0	$745	$518	$0	$1,263	$221	$0	$223	$1,707	$3
7.4	Stack	$885	$0	$514	$0	$1,399	$245	$0	$246	$1,890	$3
7.5	Duct & Stack Foundations	$0	$207	$246	$0	$454	$79	$0	$107	$640	$1
	Subtotal	**$17,655**	**$1,141**	**$10,037**	**$0**	**$28,833**	**$5,509**	**$0**	**$5,020**	**$39,362**	**$67**
8						**Steam Turbine & Accessories**					
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$13,835	$0	$5,607	$0	$19,443	$3,402	$0	$3,427	$26,272	$44
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$13,835**	**$0**	**$5,607**	**$0**	**$19,443**	**$3,402**	**$0**	**$3,427**	**$26,272**	**$44**
9						**Cooling Water System**					
9.1	Cooling Towers	$9,995	$0	$3,091	$0	$13,086	$2,290	$0	$2,306	$17,683	$30
9.2	Circulating Water Pumps	$1,298	$0	$92	$0	$1,390	$243	$0	$245	$1,878	$3
9.3	Circulating Water System Auxiliaries	$9,360	$0	$1,238	$0	$10,599	$1,855	$0	$1,868	$14,322	$24
9.4	Circulating Water Piping	$0	$4,328	$3,920	$0	$8,248	$1,443	$0	$1,454	$11,146	$19
9.5	Makeup Water System	$789	$0	$1,013	$0	$1,802	$315	$0	$318	$2,435	$4
9.6	Component Cooling Water System	$674	$0	$518	$0	$1,192	$209	$0	$210	$1,611	$3
9.7	Circulating Water System Foundations	$0	$421	$700	$0	$1,121	$196	$0	$263	$1,581	$3
	Subtotal	**$22,117**	**$4,750**	**$10,572**	**$0**	**$37,439**	**$6,552**	**$0**	**$6,665**	**$50,655**	**$86**
10						**Ash & Spent Sorbent Handling Systems**					
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
11						**Accessory Electric Plant**					
11.1	Generator Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.2	Station Service Equipment	$5,697	$0	$489	$0	$6,185	$1,082	$0	$1,090	$8,358	$14
11.3	Switchgear & Motor Control	$8,843	$0	$1,534	$0	$10,378	$1,816	$0	$1,829	$14,023	$24
11.4	Conduit & Cable Tray	$0	$1,150	$3,313	$0	$4,463	$781	$0	$787	$6,030	$10
11.5	Wire & Cable	$0	$3,045	$5,442	$0	$8,486	$1,485	$0	$1,496	$11,467	$19
11.6	Protective Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.7	Standby Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.8	Main Power Transformers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Case:		B11A-BR wNGBlr.90	– Retrofit Subcritical PC w/ CO₂ with NG Boiler				Estimate Type:			Conceptual	
Plant Size (MW, net):		591					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
11.9	Electrical Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,540**	**$4,194**	**$10,778**	**$0**	**$29,512**	**$5,165**	**$0**	**$5,202**	**$39,878**	**$67**
12	**Instrumentation & Control**										
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.2	NG Boiler Control Equipment	$361	$0	$230	$0	$591	$118	$0	$106	$815	$1
12.3	Steam Turbine Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control Equipment	$506	$0	$322	$0	$828	$166	$0	$149	$1,142	$2
12.5	Signal Processing Equipment	$422	$0	$13	$0	$435	$87	$0	$78	$600	$1
12.6	Control Boards, Panels & Racks	$112	$0	$68	$0	$180	$36	$0	$32	$248	$0
12.7	Distributed Control System Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.8	Instrument Wiring & Tubing	$507	$405	$1,621	$0	$2,533	$443	$127	$465	$3,569	$6
12.9	Other Instrumentation & Controls Equipment	$623	$0	$1,442	$0	$2,065	$361	$103	$379	$2,909	$5
	Subtotal	**$2,530**	**$405**	**$3,696**	**$0**	**$6,631**	**$1,211**	**$230**	**$1,211**	**$9,283**	**$16**
13	**Improvements to Site**										
13.1	Site Preparation	$0	$345	$7,281	$0	$7,626	$1,335	$0	$1,792	$10,753	$18
13.2	Site Improvements	$0	$1,153	$1,524	$0	$2,677	$468	$0	$629	$3,775	$6
13.3	Site Facilities	$1,133	$0	$1,189	$0	$2,321	$406	$0	$546	$3,273	$6
	Subtotal	**$1,133**	**$1,498**	**$9,993**	**$0**	**$12,624**	**$2,209**	**$0**	**$2,967**	**$17,800**	**$30**
14	**Buildings & Structures**										
14.1	NG Boiler Building	$0	$175	$92	$0	$267	$53	$0	$48	$369	$1
14.2	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$111	$88	$0	$199	$35	$0	$35	$269	$0
14.6	Water Treatment Buildings	$0	$290	$264	$0	$555	$97	$0	$98	$749	$1
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$612	$1,859	$0	$2,471	$432	$0	$436	$3,339	$6
	Subtotal	**$0**	**$1,188**	**$2,304**	**$0**	**$3,492**	**$618**	**$0**	**$617**	**$4,727**	**$8**
	Total	**$253,437**	**$80,705**	**$198,301**	**$0**	**$532,443**	**$94,006**	**$50,420**	**$117,227**	**$794,096**	**$1,344**
	Retrofit Difficulty Allowance	**$25,344**	**$8,070**	**$19,830**	**$0**	**$53,244**	**$9,401**	**$5,042**	**$11,723**	**$79,410**	**$134**
	Total (Including Retrofit Difficulty Factor)	**$278,780**	**$88,775**	**$218,132**	**$0**	**$585,687**	**$103,406**	**$55,463**	**$128,949**	**$873,505**	**$1,478**

Exhibit 4-18. Case B11A-BRwNGBlr.95 retrofit plant cost details

	Case:	B11A-BR wNGBlr.95	– Retrofit Subcritical PC w/ CO_2 with NG Boiler					Estimate Type:		Conceptual	
	Plant Size (MW, net):	588						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
1	Coal & Sorbent Handling										
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
2	Coal & Sorbent Preparation & Feed										
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	Feedwater & Miscellaneous BOP Systems										
3.1	Feedwater System	$1,964	$3,367	$1,684	$0	$7,015	$1,403	$0	$1,263	$9,681	$16
3.2	Water Makeup & Pretreating	$4,019	$402	$2,277	$0	$6,698	$1,172	$0	$1,574	$9,444	$16
3.3	Other Feedwater Subsystems	$1,117	$366	$348	$0	$1,832	$366	$0	$330	$2,528	$4
3.4	Service Water Systems	$1,218	$2,326	$7,532	$0	$11,076	$1,938	$0	$2,603	$15,617	$27
3.5	Other Boiler Plant Systems	$276	$100	$251	$0	$628	$126	$0	$113	$866	$1
3.6	Natural Gas Pipeline and Start-Up System	$3,127	$135	$101	$0	$3,363	$673	$0	$605	$4,641	$8
3.7	Wastewater Treatment Equipment	$8,067	$0	$4,944	$0	$13,011	$2,277	$0	$3,058	$18,346	$31
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$155	$20	$79	$0	$254	$44	$0	$60	$358	$1
	Subtotal	**$19,944**	**$6,717**	**$17,216**	**$0**	**$43,876**	**$7,999**	**$0**	**$9,605**	**$61,480**	**$105**
4	Pulverized Coal Boiler & Accessories										
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
5	Flue Gas Cleanup										
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$128,020	$56,697	$119,064	$0	$303,782	$53,162	$51,643	$71,503	$480,089	$817
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$39,088	$5,863	$12,870	$0	$57,822	$10,119	$0	$13,588	$81,529	$139
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$413	$66	$177	$0	$656	$115	$0	$154	$925	$2
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.12	Gas Cleanup Foundations	$0	$134	$117	$0	$251	$44	$0	$44	$340	$1
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$167,521**	**$62,760**	**$132,229**	**$0**	**$362,511**	**$63,439**	**$51,643**	**$85,289**	**$562,882**	**$958**
6	Combustion Turbine & Accessories										
6.1 – 6.5	Combustion Turbine & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	Case:	B11A-BR wNGBlr.95	– Retrofit Subcritical PC w/ CO_2 with NG Boiler				Estimate Type:			Conceptual	
	Plant Size (MW, net):	588					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
7	Ductwork & Stack										
7.1	NG Package Boiler w Stack	$12,345	$0	$8,062	$0	$20,406	$4,081	$0	$3,673	$28,161	$48
7.2	NG Steam Boiler Accessories + Foundations	$5,349	$198	$1,179	$0	$6,727	$1,156	$0	$1,016	$8,899	$15
7.3	Ductwork	$0	$748	$520	$0	$1,268	$222	$0	$223	$1,713	$3
7.4	Stack	$885	$0	$514	$0	$1,399	$245	$0	$246	$1,890	$3
7.5	Duct & Stack Foundations	$0	$207	$246	$0	$454	$79	$0	$107	$640	$1
	Subtotal	**$18,578**	**$1,154**	**$10,521**	**$0**	**$30,254**	**$5,783**	**$0**	**$5,266**	**$41,302**	**$70**
8	Steam Turbine & Accessories										
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$14,364	$0	$5,822	$0	$20,186	$3,533	$0	$3,558	$27,276	$46
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,364**	**$0**	**$5,822**	**$0**	**$20,186**	**$3,533**	**$0**	**$3,558**	**$27,276**	**$46**
9	Cooling Water System										
9.1	Cooling Towers	$10,326	$0	$3,193	$0	$13,519	$2,366	$0	$2,383	$18,268	$31
9.2	Circulating Water Pumps	$1,347	$0	$95	$0	$1,442	$252	$0	$254	$1,949	$3
9.3	Circulating Water System Auxiliaries	$9,616	$0	$1,272	$0	$10,889	$1,906	$0	$1,919	$14,713	$25
9.4	Circulating Water Piping	$0	$4,447	$4,027	$0	$8,474	$1,483	$0	$1,494	$11,451	$19
9.5	Makeup Water System	$809	$0	$1,039	$0	$1,848	$323	$0	$326	$2,497	$4
9.6	Component Cooling Water System	$693	$0	$532	$0	$1,225	$214	$0	$216	$1,655	$3
9.7	Circulating Water System Foundations	$0	$432	$717	$0	$1,149	$201	$0	$270	$1,621	$3
	Subtotal	**$22,791**	**$4,879**	**$10,876**	**$0**	**$38,546**	**$6,746**	**$0**	**$6,861**	**$52,153**	**$89**
10	Ash & Spent Sorbent Handling Systems										
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
11	Accessory Electric Plant										
11.1	Generator Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.2	Station Service Equipment	$5,827	$0	$500	$0	$6,327	$1,107	$0	$1,115	$8,549	$15
11.3	Switchgear & Motor Control	$9,046	$0	$1,569	$0	$10,615	$1,858	$0	$1,871	$14,344	$24
11.4	Conduit & Cable Tray	$0	$1,176	$3,389	$0	$4,565	$799	$0	$805	$6,168	$10
11.5	Wire & Cable	$0	$3,114	$5,566	$0	$8,681	$1,519	$0	$1,530	$11,730	$20
11.6	Protective Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.7	Standby Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.8	Main Power Transformers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	Case:	B11A-BR wNGBlr.95	– Retrofit Subcritical PC w/ CO_2 with NG Boiler					Estimate Type:		Conceptual	
	Plant Size (MW, net):	588						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
11.9	Electrical Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,873**	**$4,290**	**$11,024**	**$0**	**$30,187**	**$5,283**	**$0**	**$5,320**	**$40,790**	**$69**
12	Instrumentation & Control										
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.2	NG Boiler Control Equipment	$361	$0	$230	$0	$591	$118	$0	$106	$816	$1
12.3	Steam Turbine Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control Equipment	$506	$0	$322	$0	$828	$166	$0	$149	$1,143	$2
12.5	Signal Processing Equipment	$422	$0	$13	$0	$435	$87	$0	$78	$600	$1
12.6	Control Boards, Panels & Racks	$112	$0	$68	$0	$180	$36	$0	$32	$248	$0
12.7	Distributed Control System Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.8	Instrument Wiring & Tubing	$510	$408	$1,632	$0	$2,550	$446	$128	$469	$3,593	$6
12.9	Other Instrumentation & Controls Equipment	$627	$0	$1,452	$0	$2,079	$364	$104	$382	$2,929	$5
	Subtotal	**$2,538**	**$408**	**$3,717**	**$0**	**$6,664**	**$1,217**	**$231**	**$1,217**	**$9,329**	**$16**
13	Improvements to Site										
13.1	Site Preparation	$0	$349	$7,371	$0	$7,721	$1,351	$0	$1,814	$10,886	$19
13.2	Site Improvements	$0	$1,168	$1,544	$0	$2,712	$475	$0	$637	$3,824	$7
13.3	Site Facilities	$1,148	$0	$1,205	$0	$2,353	$412	$0	$553	$3,317	$6
	Subtotal	**$1,148**	**$1,518**	**$10,120**	**$0**	**$12,786**	**$2,237**	**$0**	**$3,005**	**$18,028**	**$31**
14	Buildings & Structures										
14.1	NG Boiler Building	$0	$184	$97	$0	$282	$56	$0	$51	$389	$1
14.2	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$114	$90	$0	$204	$36	$0	$36	$276	$0
14.6	Water Treatment Buildings	$0	$298	$271	$0	$569	$100	$0	$100	$769	$1
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$614	$1,864	$0	$2,477	$434	$0	$437	$3,348	$6
	Subtotal	**$0**	**$1,210**	**$2,323**	**$0**	**$3,533**	**$625**	**$0**	**$624**	**$4,782**	**$8**
	Total	**$261,758**	**$82,936**	**$203,848**	**$0**	**$548,542**	**$96,862**	**$51,874**	**$120,744**	**$818,023**	**$1,392**
	Retrofit Difficulty Allowance	**$26,176**	**$8,294**	**$20,385**	**$0**	**$54,854**	**$9,686**	**$5,187**	**$12,074**	**$81,802**	**$139**
	Total (Including Retrofit Difficulty Factor)	**$287,934**	**$91,229**	**$224,233**	**$0**	**$603,396**	**$106,549**	**$57,062**	**$132,819**	**$899,825**	**$1,531**

Exhibit 4-19. Case B11A-BRwNGBlr.90 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$4,090	$7
1 Month Maintenance Materials	$747	$1
1 Month Non-Fuel Consumables	$1,228	$2
1 Month Waste Disposal	$12	$0
25% of 1 Months Fuel Cost at 100% CF	$1,188	$2
2% of TPC	$17,470	$30
Total	**$24,736**	**$42**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$11,660	$20
0.5% of TPC (spare parts)	$4,368	$7
Total	**$16,027**	**$27**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$0	$0
Other Owner's Costs	$131,026	$222
Financing Costs	$23,585	$40
Total Overnight Costs (TOC)	**$1,068,879**	**$1,809**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$1,167,907**	**$1,977**

Exhibit 4-20. Case B11A-BRwNGBlr.95 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$4,185	$7
1 Month Maintenance Materials	$770	$1
1 Month Non-Fuel Consumables	$1,269	$2
1 Month Waste Disposal	$13	$0
25% of 1 Months Fuel Cost at 100% CF	$1,254	$2
2% of TPC	$17,997	$31
Total	**$25,488**	**$43**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$12,251	$21
0.5% of TPC (spare parts)	$4,499	$8
Total	**$16,750**	**$29**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$0	$0
Other Owner's Costs	$134,974	$230
Financing Costs	$24,295	$41
Total Overnight Costs (TOC)	**$1,101,332**	**$1,874**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$1,203,367**	**$2,048**

Exhibit 4-21. Case B11A-BRwNGBlr.90 initial and annual operating and maintenance costs

Case:	B11A-BR wNGBlr.90	– Retrofit Subcritical PC w/ CO_2 with NG Boiler			Cost Base:	Dec 2018
Plant Size (MW, net):	**591**	**Heat Rate-net (Btu/kWh):**		**12,230**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:		2.0
Operating Labor Burden:		30.00	**% of base**	Operator:		12.3
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:		1.0
				Lab Techs, etc.:		2.0
				Total:		**17.3**
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,599,446	$12.86
Maintenance Labor:					$13,467,090	$22.79
Administrative & Support Labor:					$5,266,634	$8.91
Property Taxes and Insurance:					$42,084,658	$71.23
Total:					**$68,417,828**	**$115.80**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$20,200,636	$4.59
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	7,281	$1.90	$0	$4,291,761	$0.98
Makeup and Wastewater Treatment Chemicals (ton):	0	21.7	$550.00	$0	$3,700,791	$0.84
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,674	$0.15
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,525	$0.55
Limestone (ton):	0	572	$22.00	$0	$3,906,961	$0.89
Ammonia (19 wt%, ton):	0	73.4	$300.00	$0	$6,831,473	$1.55
SCR Catalyst (ft³):	14,235	13.0	$150.00	$2,135,221	$604,979	$0.14
CO_2 Capture System Chemicals[A]		Proprietary			$6,922,752	$1.57
Triethylene Glycol (gal):	w/equip.	489	$6.80	$0	$1,032,644	$0.23
Subtotal:				**$2,135,221**	**$30,359,560**	**$6.90**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,167	$1.44
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,307	$0.32
SCR Catalyst (ft³):	0	13.0	$2.50	$0	$10,083	$0.00
Triethylene Glycol (gal):	0	489	$0.35	$0	$53,151	$0.01
Thermal Reclaimer Unit Waste (ton)	0	6.30	$38.00	$0	$74,324	$0.02
Subtotal:				**$0**	**$7,875,032**	**$1.79**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,135,221**	**$58,435,228**	**$13.28**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,387,161	$21.68
Natural Gas (MMBtu):	0	35,345	$4.42	$0	$48,471,124	$11.02
Total:				**$0**	**$143,858,285**	**$32.70**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

Exhibit 4-22. Case B11A-BRwNGBlr.95 initial and annual operating and maintenance costs

Case:	**B11A-BR wNGBlr.95**	**– Retrofit Subcritical PC w/ CO_2 with NG Boiler**			**Cost Base:**	**Dec 2018**
Plant Size (MW, net):	**588**	**Heat Rate-net (Btu/kWh):**		**12,434**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:	2.0	
Operating Labor Burden:		30.00	**% of base**	Operator:	12.3	
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:	1.0	
				Lab Techs, etc.:	2.0	
				Total:	**17.3**	
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,599,446	$12.93
Maintenance Labor:					$13,620,225	$23.18
Administrative & Support Labor:					$5,304,918	$9.03
Property Taxes and Insurance:					$42,563,204	$72.43
Total:					**$69,087,792**	**$117.57**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$20,430,338	$4.67
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	7,416	$1.90	$0	$4,371,723	$1.00
Makeup and Wastewater Treatment Chemicals (ton):	0	22.1	$550.00	$0	$3,769,742	$0.86
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,674	$0.15
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,525	$0.55
Limestone (ton):	0	572	$22.00	$0	$3,906,961	$0.89
Ammonia (19 wt%, ton):	0	74.4	$300.00	$0	$6,926,325	$1.58
SCR Catalyst (ft^3):	14,235	13.0	$150.00	$2,135,221	$604,979	$0.14
CO_2 Capture System Chemicals[A]	Proprietary				$7,041,904	$1.61
Triethylene Glycol (gal):	w/equip.	517	$6.80	$0	$1,090,154	$0.25
Subtotal:				**$2,135,221**	**$30,779,987**	**$7.03**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,167	$1.45
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,307	$0.32
SCR Catalyst (ft^3):	0	13.0	$2.50	$0	$10,083	$0.00
Triethylene Glycol (gal):	0	517	$0.35	$0	$56,111	$0.01
Thermal Reclaimer Unit Waste (ton)	0	6.42	$38.00	$0	$75,731	$0.02
Subtotal:				**$0**	**$7,879,399**	**$1.80**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,135,221**	**$59,089,723**	**$13.51**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,387,161	$21.80
Natural Gas (MMBtu):	0	37,295	$4.42	$0	$51,144,528	$11.69
Total:				**$0**	**$146,531,688**	**$33.49**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

Exhibit 4-23. Case B11A-BRwNGBlr.90 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	18.8	21%
Fixed	15.6	18%
Variable	13.3	15%
Fuel	32.7	37%
Total (Excluding T&S)	**80.3**	91%
CO_2 T&S	8.0	9%
Total (Including T&S)	**88.4**	100%

Exhibit 4-24. Case B11A-BRwNGBlr.95 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	19.5	21%
Fixed	15.8	17%
Variable	13.5	15%
Fuel	33.5	37%
Total (Excluding T&S)	**82.2**	91%
CO_2 T&S	8.5	9%
Total (Including T&S)	**90.8**	100%

4.4 Cost Estimation Summary

The existing plant, B11A, and NETL Fossil Energy Baseline report series greenfield subcritical plant with capture, B11B, values are included in the charts in this section for comparison. [1]

Summary graphs of total overnight and total as-spent capital costs are shown in Exhibit 4-25 and Exhibit 4-26, and the breakdown of the LCOE for each case is presented in Exhibit 4-27 and Exhibit 4-28. The error bars represent the potential TOC range relative to the maximum and minimum of the capital cost uncertainty range for an AACE Class 4 range of -15 percent/+30 percent.

Exhibit 4-25. TOC and TASC comparison for 90% capture rate

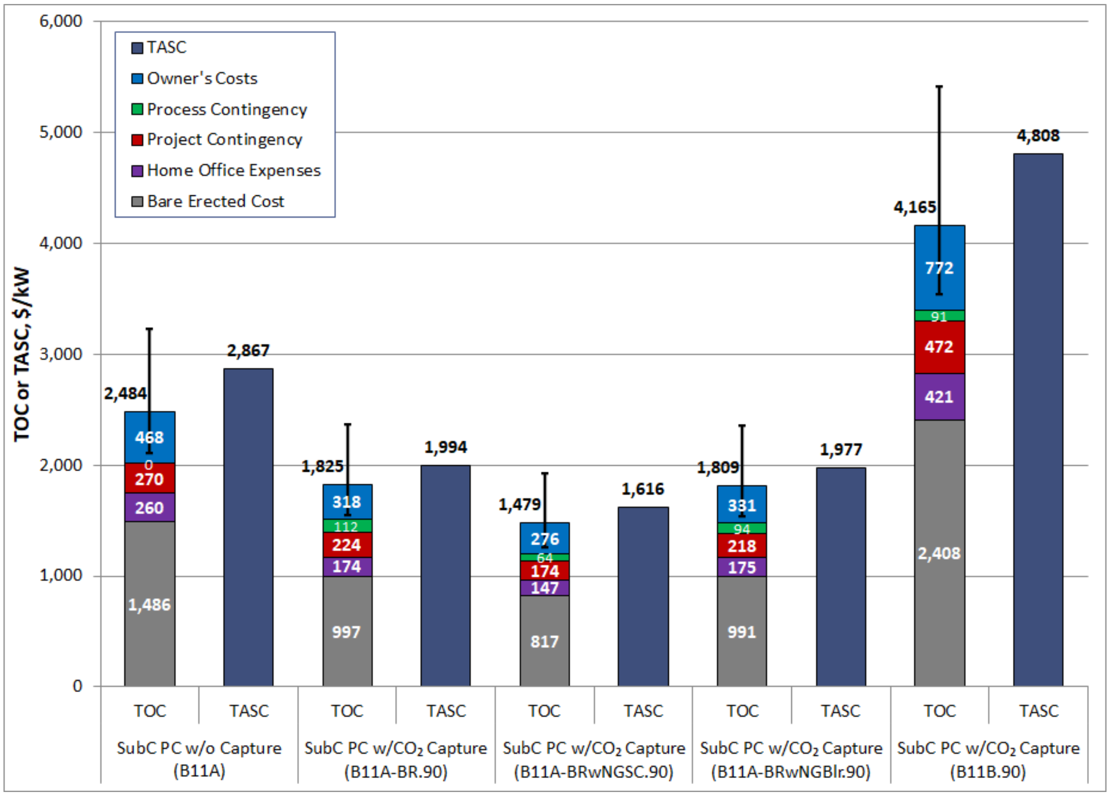


Exhibit 4-26. TOC and TASC comparison for 95% capture rate

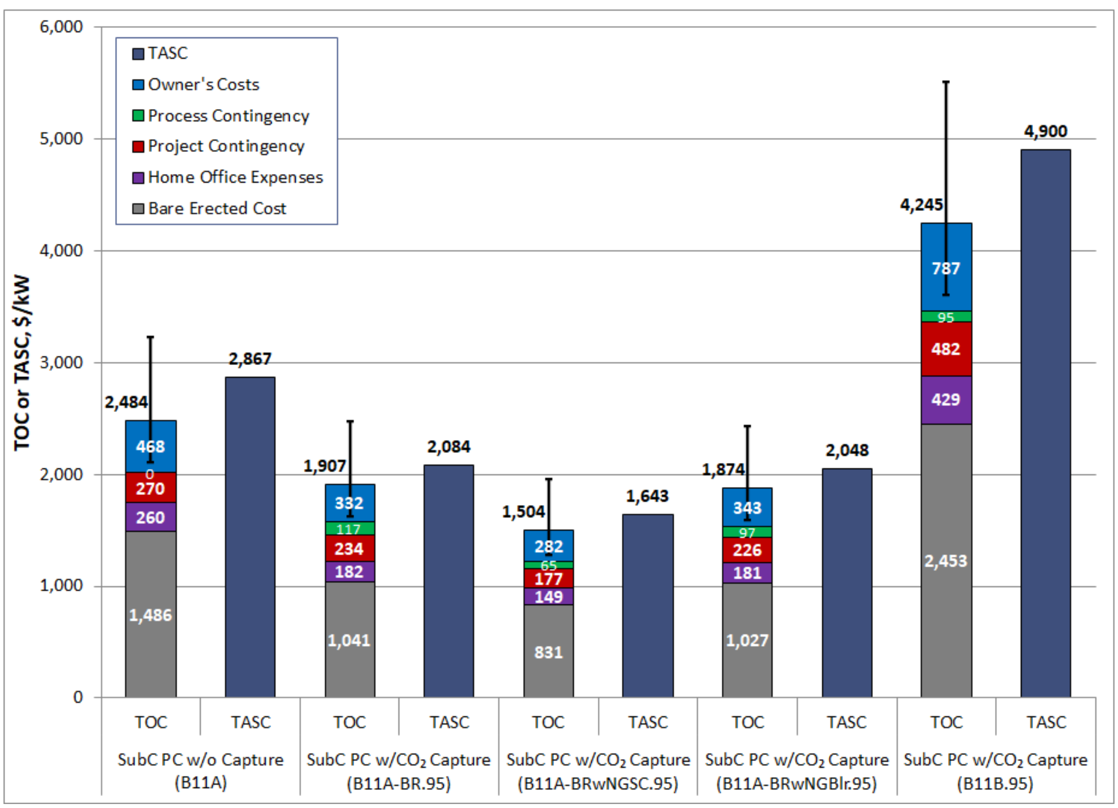


Exhibit 4-27. LCOE comparison for 90% capture rate

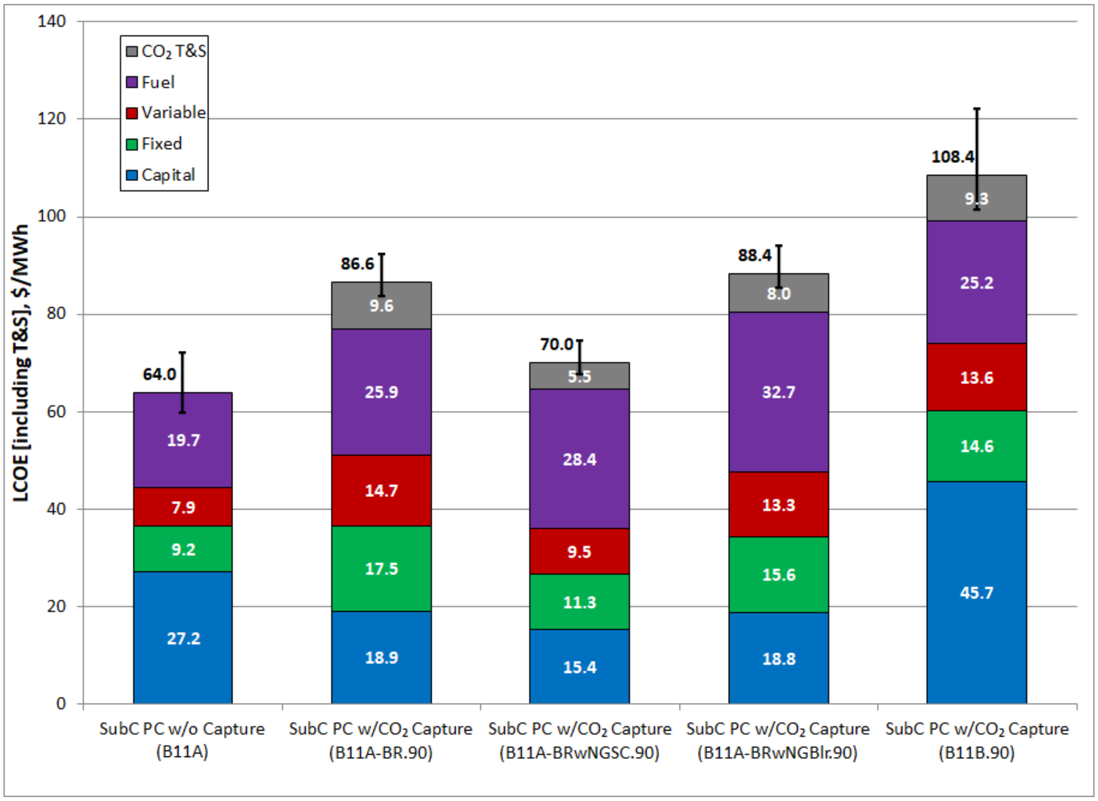
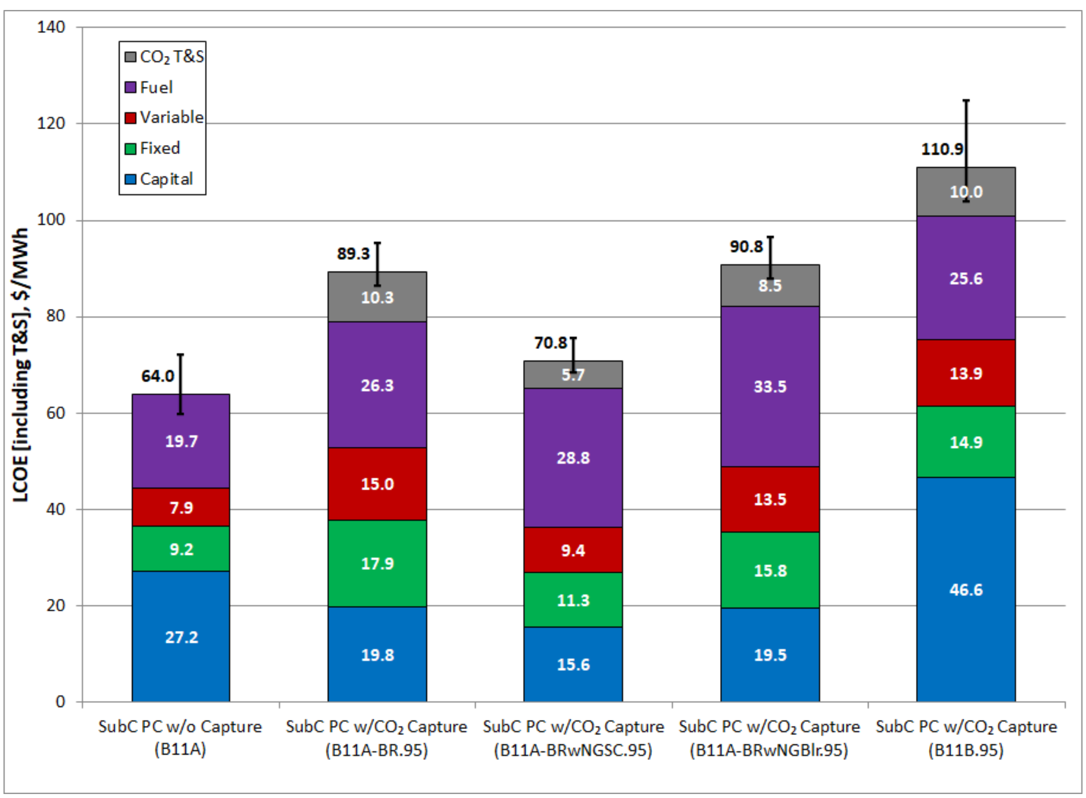


Exhibit 4-28. LCOE comparison for 95% capture rate



Even though the total TOC for the retrofit with an NGSC sized for the capture steam requirement is the highest dollar value, the excess power generated by the NGSC reduces the TOC per MWh value to the lowest by increasing the denominator. Minimizing the derate by generating steam in a natural gas-fired boiler reduces the TOC per MWh value but not as much as the NGSC.

The LCOE for the retrofit cases includes the ongoing O&M costs associated with fully depreciated existing plant. The excess power generated by the NGSC sized for the capture steam requirement reduces the LCOE by increasing the denominator. Minimizing the derate by generating steam in a natural gas-fired boiler almost compensates for the additional auxiliary power requirement of the capture system.

Summary graphs of levelized cost of CO_2 captured and CO_2 avoided are shown in Exhibit 4-29 and Exhibit 4-30. These values are calculated using annual costs as described in the retrofitting studies QGESS. [3] Firing natural gas in the non-capture auxiliary plants reduces the overall capture rate in the denominator, thus increasing the levelized values per tonne. Since less natural gas is fired in the natural gas-fired boiler than in the NGSC, the overall capture percentage is higher for the boiler cases then the NGSC cases but still lower than the derate cases.

Exhibit 4-29. Cost of CO_2 captured, and CO_2 avoided comparison for 90% capture rate

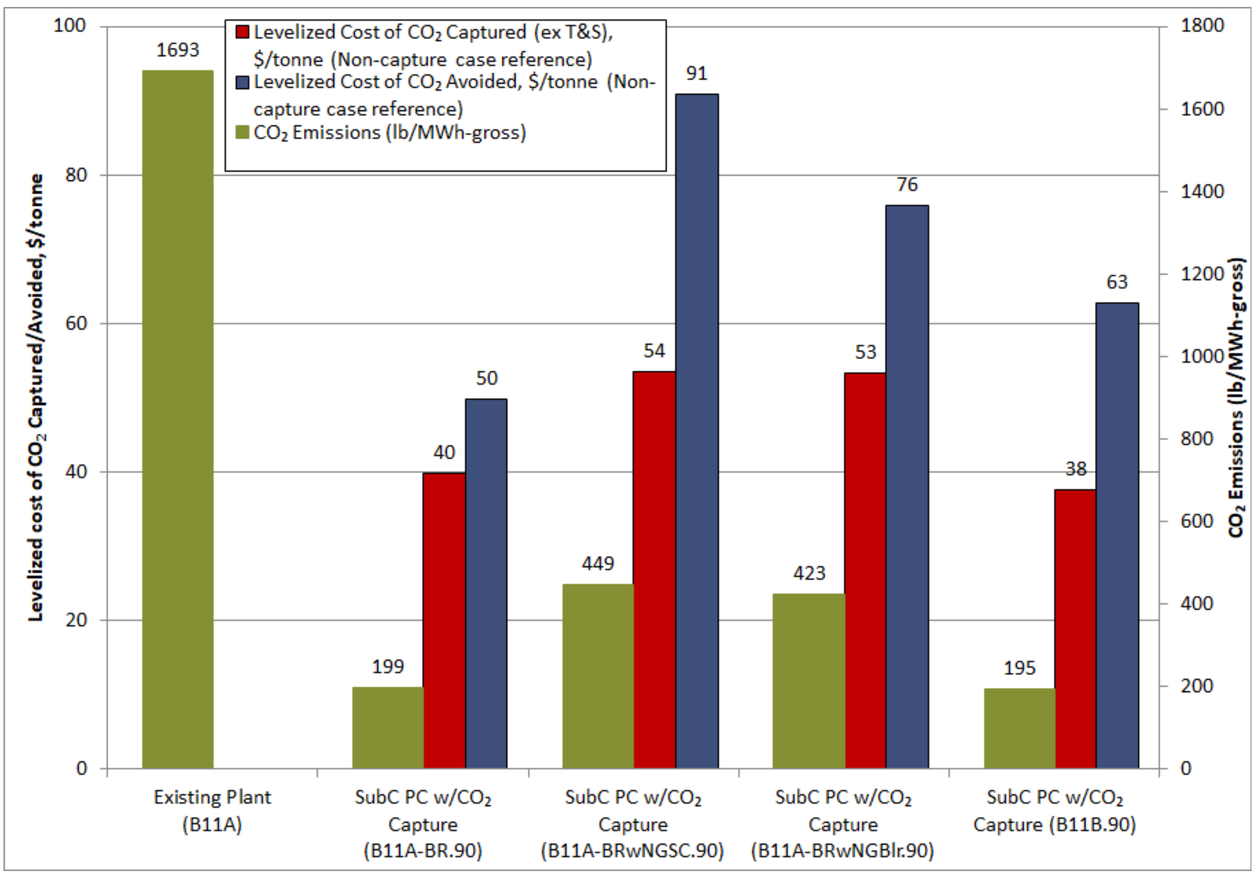
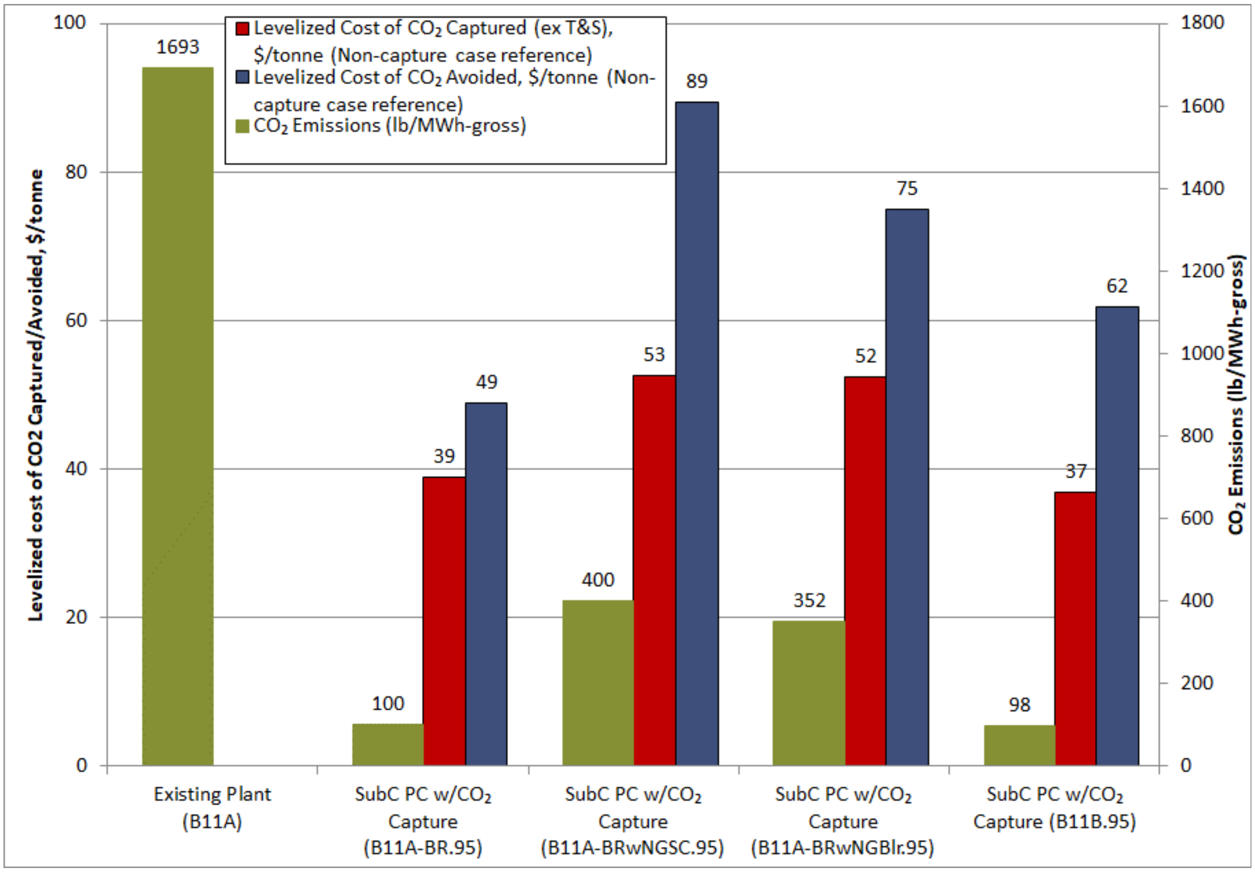


Exhibit 4-30. Cost of CO_2 captured, and CO_2 avoided comparison for 95% capture rate



4.5 SENSITIVITIES

Retrofit difficulty factors for the sub-account level vary between 1.0 and 1.3 as defined in the QGESS for carbon capture retrofits. [8] Graphs of the sensitivity of the LCOE to these factors are shown in Exhibit 4-31 and Exhibit 4-32. The values shown were calculated based on the simplified method of multiplying the factor times the TPC, so they illustrate the impact of variations in the weighted average of individual account factors. Increasing retrofit difficulty factors to 2.0 increases the LCOEs by 10 percent.

Exhibit 4-31. Retrofit difficulty factor sensitivity for 90% capture rate

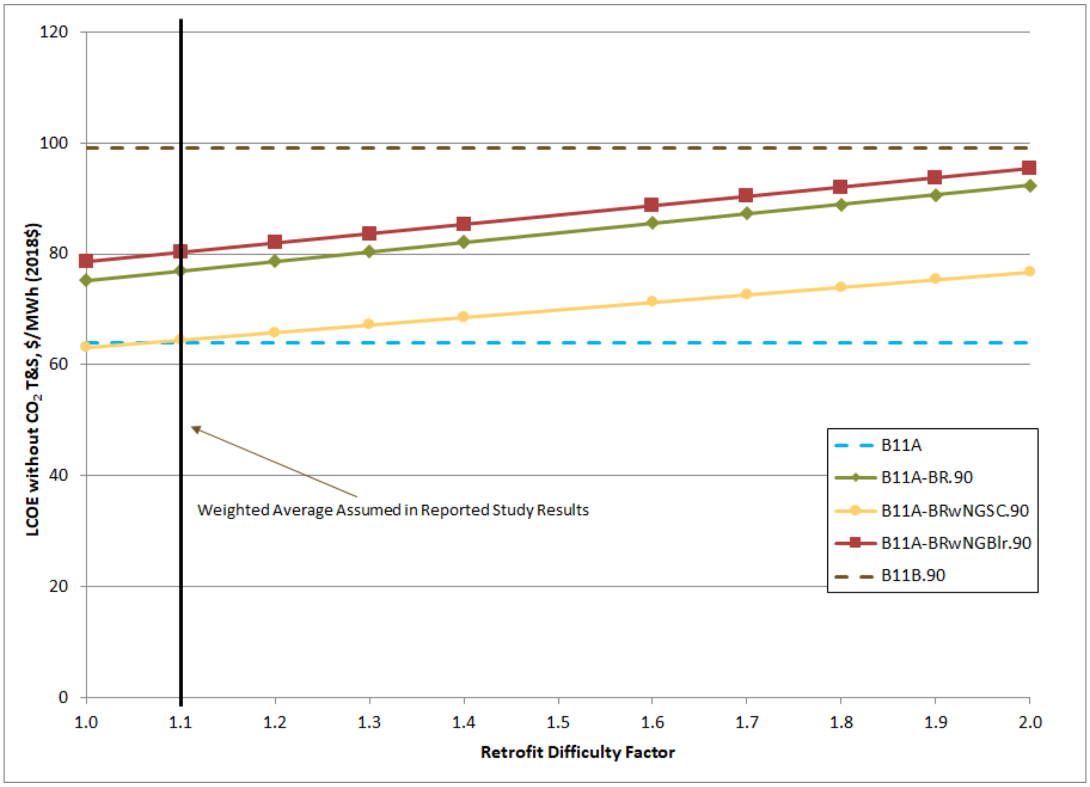
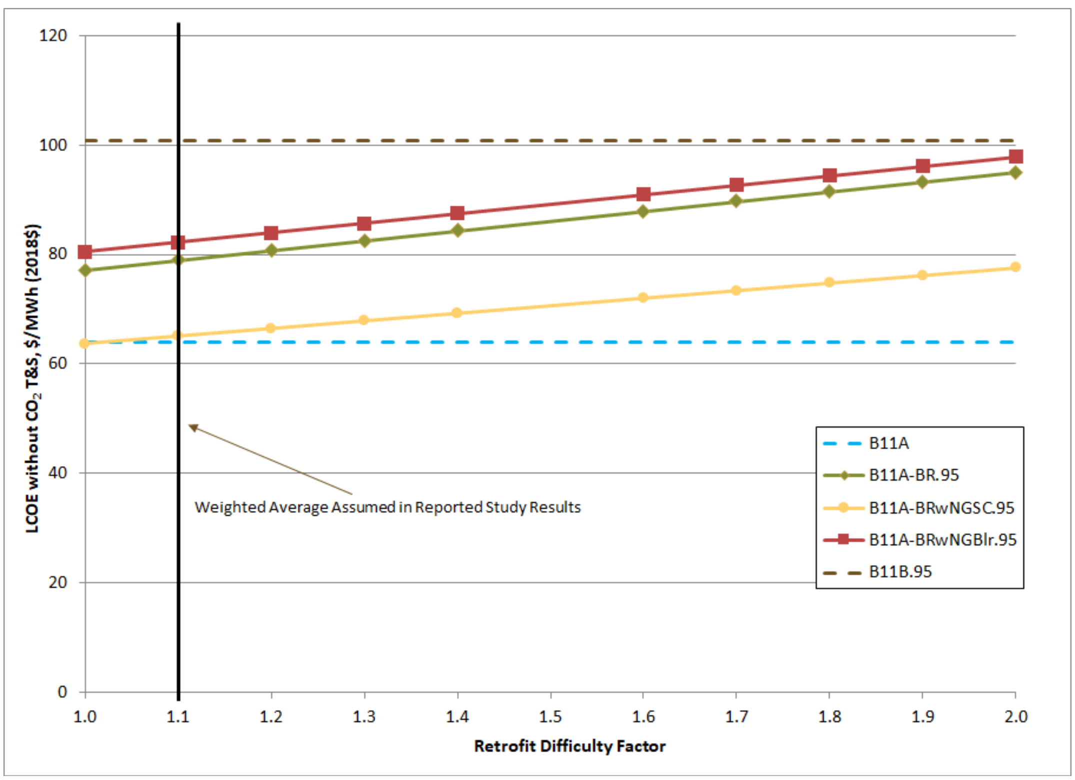


Exhibit 4-32. Retrofit difficulty factor sensitivity for 95% capture rate



Graphs of the sensitivity of the LCOE to the capacity factor are shown in Exhibit 4-33 and Exhibit 4-34. The LCOE for the cases with natural gas-fired auxiliary plants vary slightly less with capacity factor because the variable fuel costs per MWh are a larger portion of the LCOE and not impacted by capacity factor.

Exhibit 4-33. Capacity factor sensitivity for 90% capture rate

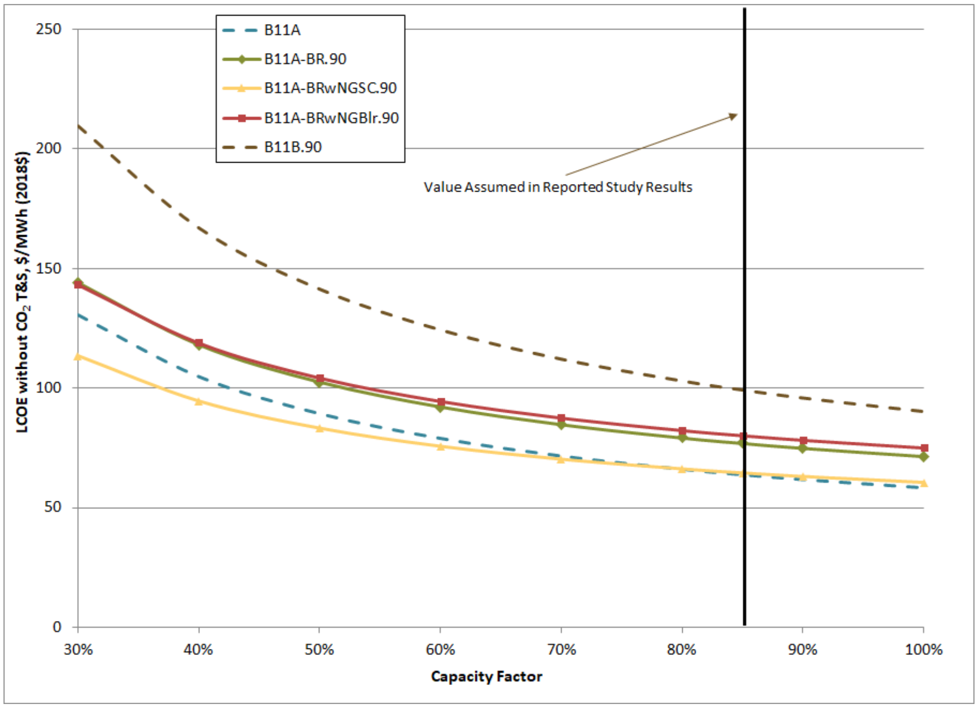
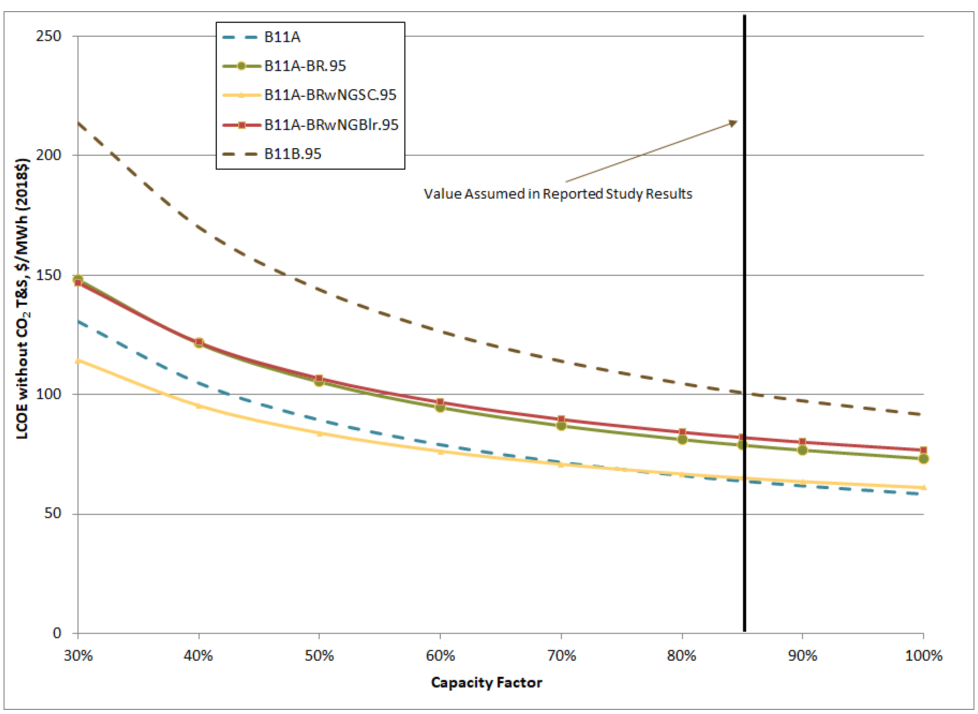


Exhibit 4-34. Capacity factor sensitivity for 95% capture rate



Graphs of the sensitivity of the LCOE to the prices of coal and natural gas are shown in Exhibit 4-35 and Exhibit 4-36. An increase of $1/MMBtu in coal price increases the LCOE by $5/MWh to $10/MWh depending on the case. An increase of $1/MMBtu in natural gas price increases the LCOE by about $3/MWh for the auxiliary plant cases.

Exhibit 4-35. Fuel price sensitivity for 90% capture rate

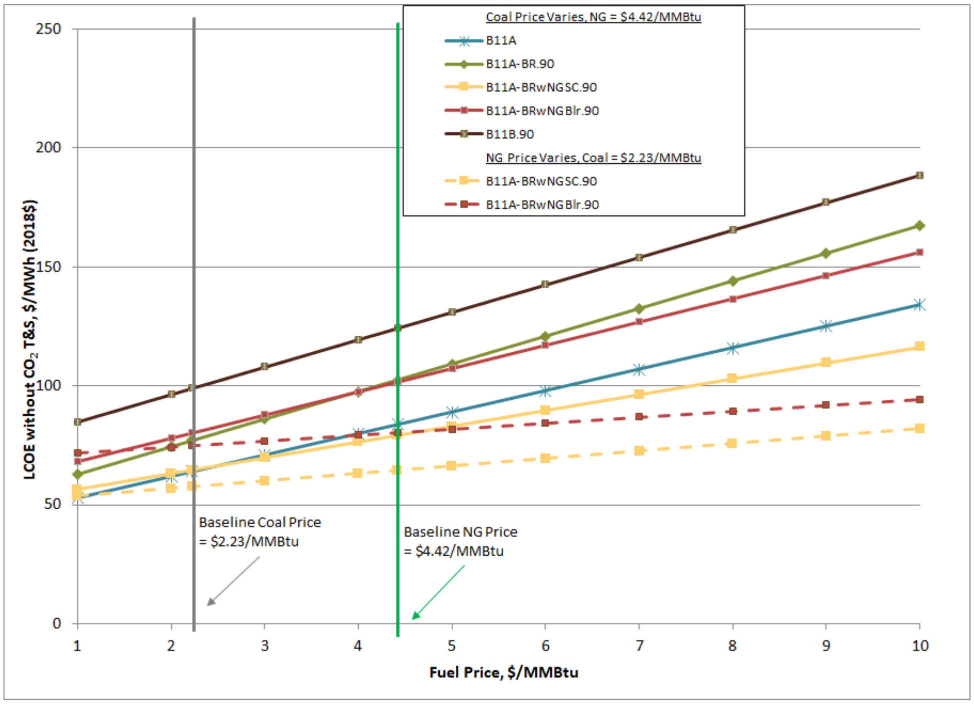
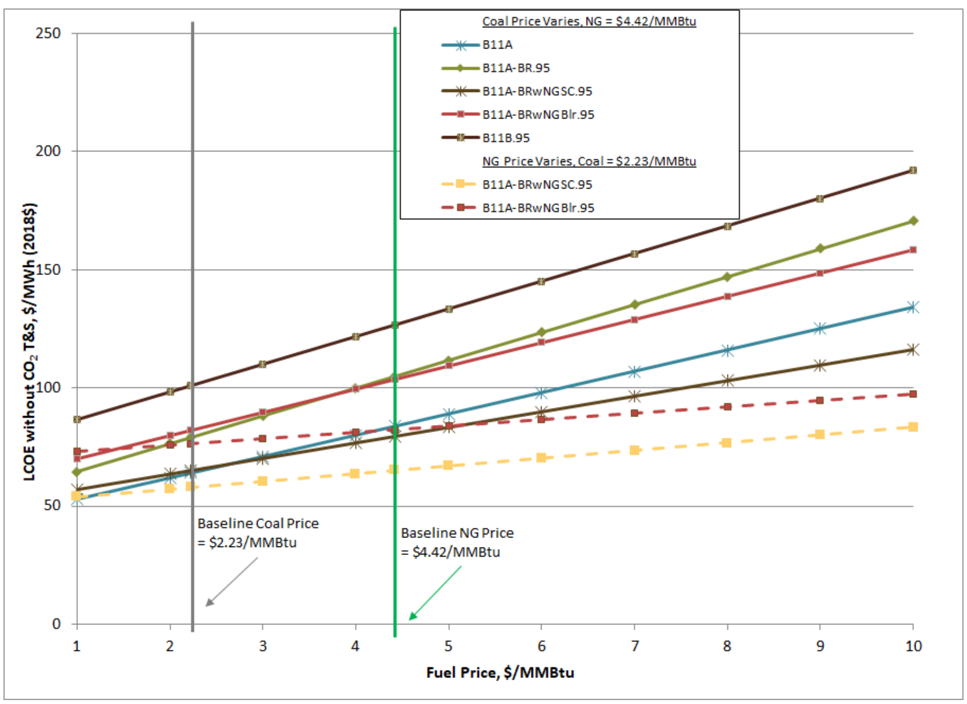


Exhibit 4-36. Fuel price sensitivity for 95% capture rate



5 Conclusions

The cases presented in this report demonstrate viable opportunities to improve the attractiveness of a CO_2 retrofit by using various alternatives to significantly derating an existing plant while adding carbon capture.

Specific observations and conclusions from these results include the following:

- Adding an NGSC auxiliary plant to supply steam for the capture system can make up the lost power due to retrofitting an existing subcritical pulverized coal plant with capture while reducing the LCOE relative to a capture-only retrofit at the expense of higher up-front total capital costs on a dollar basis.
- The capture-only retrofit case that includes extracting steam and power from the existing plant steam cycle has the lowest annual emissions due to the addition of un-captured natural gas combustion emissions in the auxiliary plant cases.
- The capture-only retrofit case with derate also results in the lowest total capital costs on a dollar basis.
- For very low natural gas prices (i.e., less than $2/MMBtu) supplying steam via a natural gas fired boiler can be a lower cost alternative to derating the existing plant.
- Implementing 95 percent capture from the PC plant reduces overall emissions with negligible impact on LCOE, cost of CO_2 captured, or cost of CO_2 avoided.

The discrete nature of the choices available for eliminating the derate of carbon capture retrofits requires examination of multiple strategies for each technology option before an optimal configuration can be identified. Recognizing the potential for future optimization of this approach, the results here suggest that small, on-site, low-carbon auxiliary plants to produce steam and power lost to CO_2 retrofits are a viable complement to amine-based CCS retrofits.

Additional studies could be conducted to improve the understanding of the impact of retrofitting carbon capture to pulverized coal power plants and ways to eliminate or minimize the derate. Some items to examine include the following:

- Examine the impact of including capture on the natural gas fired auxiliary NGSC and boiler.
- Examine the impact of part load operation and design on the retrofitted capture system performance and cost.
- Examine the impact of an extended outage for retrofitting on the costs.
- Examine the impact of the capture system design on the emissions in more detail including modeling components throughout the processes.

6 REFERENCES

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APPENDIX A: PC WITH 99 PERCENT CO_2 CAPTURE

Exhibit A-1. Performance summary and environmental profile for 99% capture rate

Parameter	Combined Plant Performance				
	Existing Plant	Retrofit Baseline	With Auxiliary Plants		Greenfield capture
	Baseline B11A [1]	B11A-BR.99	B11A-BR wNGSC.99	B11A-BR wNGBlr.99	B11B.99 [1]
Gross Steam Turbine Power (MWe)	688	578	688	688	780
Gross Combustion Turbine Power (MWe)	N/A	N/A	307	N/A	N/A
Auxiliary Power Requirement (MWe)	38	99	104	103	130
Net Power Output (MWe)	650	479	891	585	650
Coal Flow Rate (lb/hr)	493,115	493,115	493,110	493,110	651,832
Natural Gas Flow Rate (MMBtu/hr)	N/A	N/A	2,975	1,650	N/A
HHV Thermal Input (kWt)	1,685,945	1,685,944	2,557,914	2,169,481	2,228,591
Net Plant HHV Efficiency (%)	38.6%	28.4%	34.8%	26.9%	29.2%
Net Plant HHV Heat Rate (Btu/kWh)	8,849	11,999	9,800	12,663	11,691
Steam Load to Capture System (MMBtu/hr)	N/A	1,268	1,268	1,268	1,676
CO_2 Capture Flow Rate (lb/hr)	N/A	1,152,028	1,152,018	1,152,018	1,522,826
CO_2 Emissions Flow Rate (lb/hr)	1,163,905	11,988	364,939	206,879	15,847
Overall Plant CO_2 Capture (%)	**N/A**	**99%**	**76%**	**85%**	**99%**
Raw Water Withdrawal (gpm)	6,504	7,974	10,448	10,519	10,472
Process Water Discharge (gpm)	1,336	2,057	2,560	2,632	2,704
Raw Water Consumption (gpm)	5,169	5,917	7,888	7,888	7,769
CO_2 Emissions (lb/MMBtu)	202	2	42	28	2
CO_2 Emissions (lb/MWh-gross)	1,693	21	367	301	20
CO_2 Emissions (lb/MWh-net)	1,790	25	410	354	24
SO_2 Emissions (lb/MMBtu)	0.081	0.000	0.000	0.000	0.000
SO_2 Emissions (lb/MWh-gross)	0.675	0.000	0.003	0.002	0.000
NO_X Emissions (lb/MMBtu)	0.084	0.070	0.056	0.065	0.072
NO_X Emissions (lb/MWh-gross)	0.700	0.700	0.494	0.700	0.700
PM Emissions (lb/MMBtu)	0.011	0.009	0.008	0.009	0.009
PM Emissions (lb/MWh-gross)	0.090	0.090	0.068	0.092	0.090
Hg Emissions (lb/TBtu)	0.359	0.302	0.342	0.279	0.308
Hg Emissions (lb/MWh-gross)	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06

Exhibit A-2. Case cost estimation results summary for 99% capture rate

Parameter	Combined Plant Costs[A]					
	Greenfield	Existing Plant	Retrofit Baseline	With Auxiliary Plants		Greenfield capture
	Baseline B11A [1]	B11A	B11A-BR.99	B11A-BR wNGSC.99	B11A-BR wNGBlr.99	Baseline B11B.99 [1]
Total Plant Cost (2018$/kW)	2,015	N/A	1,517	1,138	1,458	3,543
Bare Erected Cost	1,486	N/A	1,002	773	977	2,510
Home Office Expenses	260	N/A	175	139	173	439
Process Contingency	0	N/A	113	61	93	100
Project Contingency	270	N/A	226	165	215	494
Retrofit Difficulty Contingency	N/A	N/A	152	114	146	N/A
Total Plant Cost with RDF	2,015	N/A	1,668	1,252	1,603	3,543
Total Overnight Cost (2018$MM)	1,615	N/A	968	1,372	1,147	2,829
Total Overnight Cost (2018$/kW)	2,484	N/A	2,020	1,540	1,963	4,349
***Owner's Costs* (2018$/kW)**	468	N/A	352	289	359	805
Total As-Spent Cost (2018$/kW)	2,867	N/A	2,207	1,683	2,144	5,020
LCOE ($/MWh) (excluding T&S)	64.0	36.8	81.6	65.8	84.6	103.1
Capital Costs	27.2	0.0	21.0	16.0	20.4	47.7
Fixed Costs	9.2	9.2	18.5	11.2	16.1	15.2
Variable Costs	7.9	7.9	15.4	9.4	13.8	14.2
Fuel Costs	19.7	19.7	26.7	29.1	34.4	26.0
LCOE ($/MWh) (including T&S)	64.0	36.8	92.5	71.7	93.6	113.8
CO_2 T&S Costs	N/A	N/A	10.9	5.9	8.9	10.6

[A]All costs are on a net output basis ($/kW, $/MWh) representing the costs spread over the combined plant (retrofitted existing plant plus CHP plant if applicable)

Exhibit A-3. Capital costs for 99% capture rate

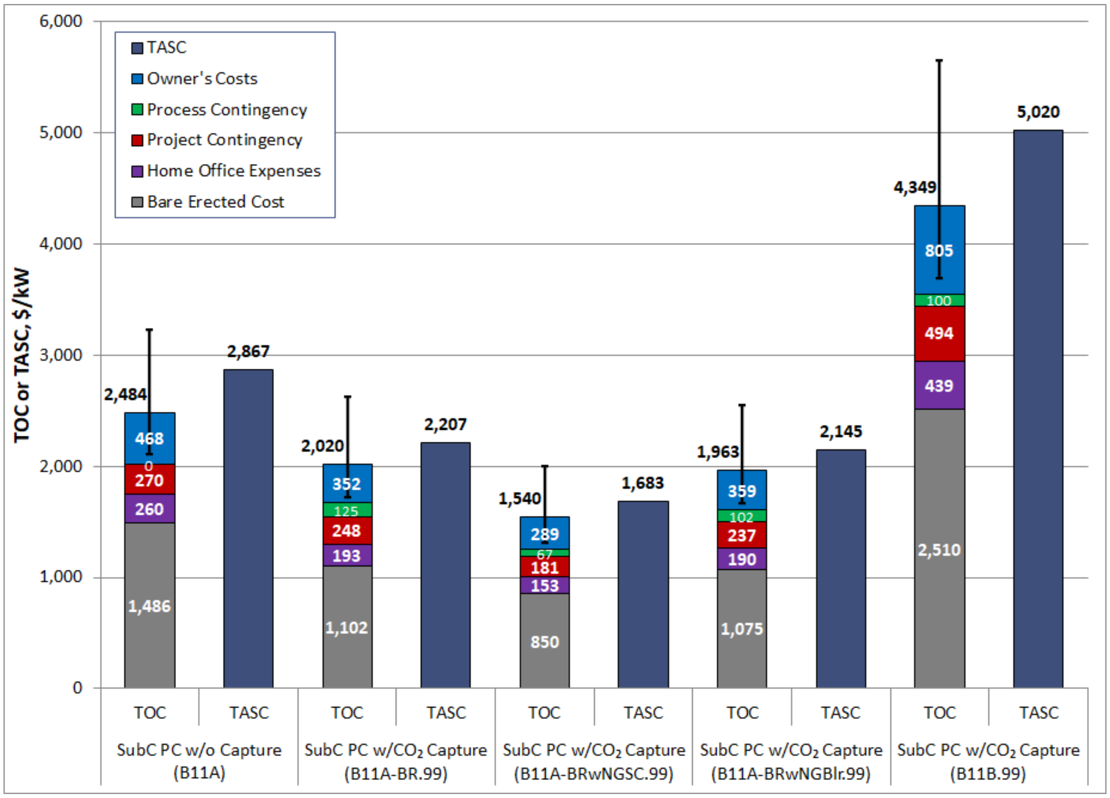


Exhibit A-4. LCOE breakdown for 99% capture rate

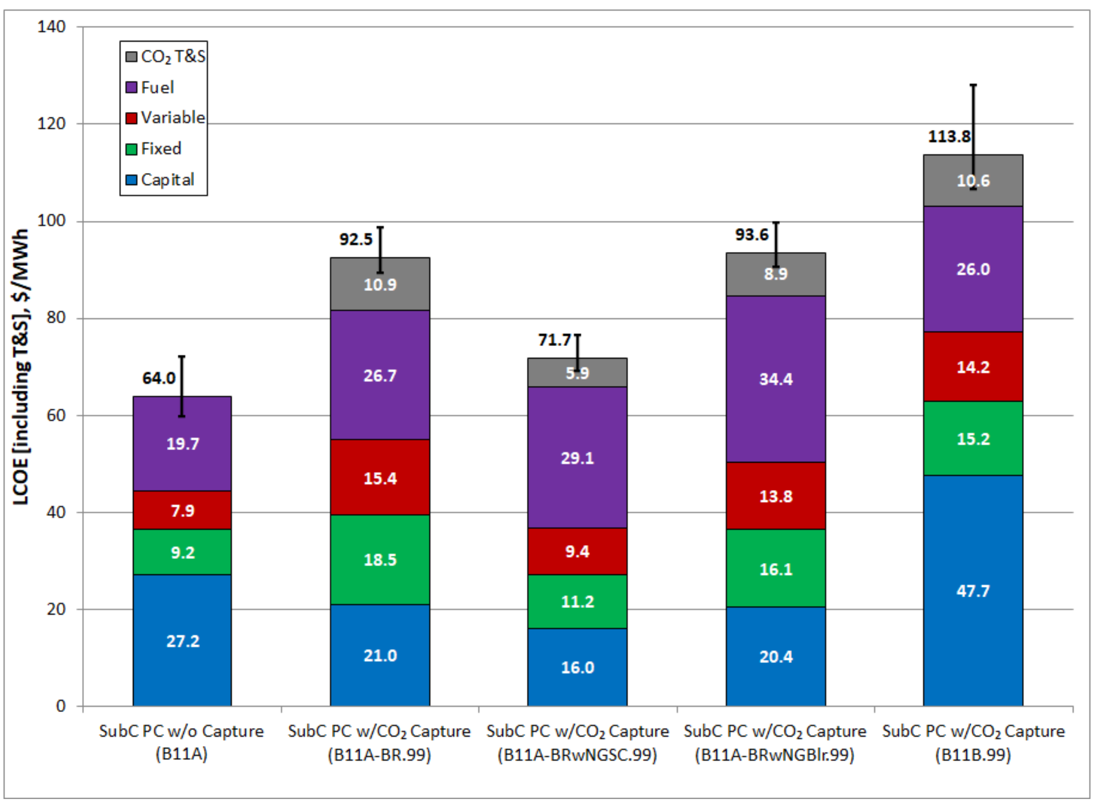


Exhibit A-5. LCOE sensitivity to retrofit difficulty factors for 99% capture rate

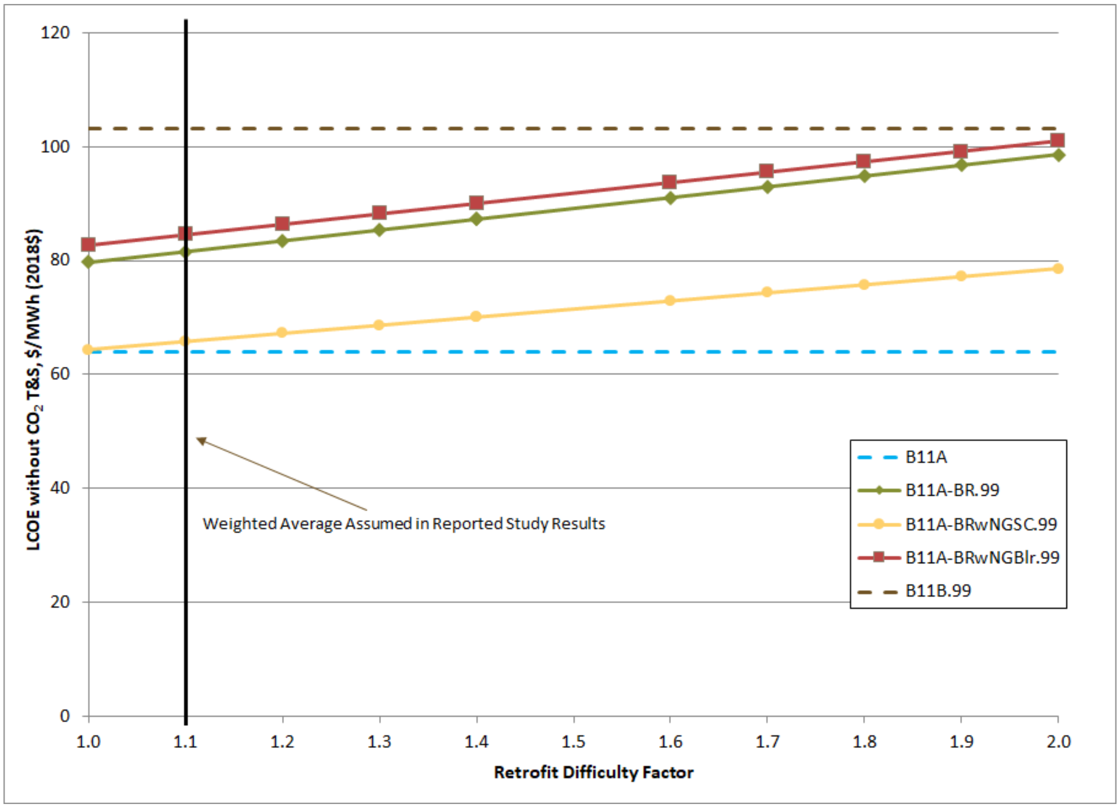
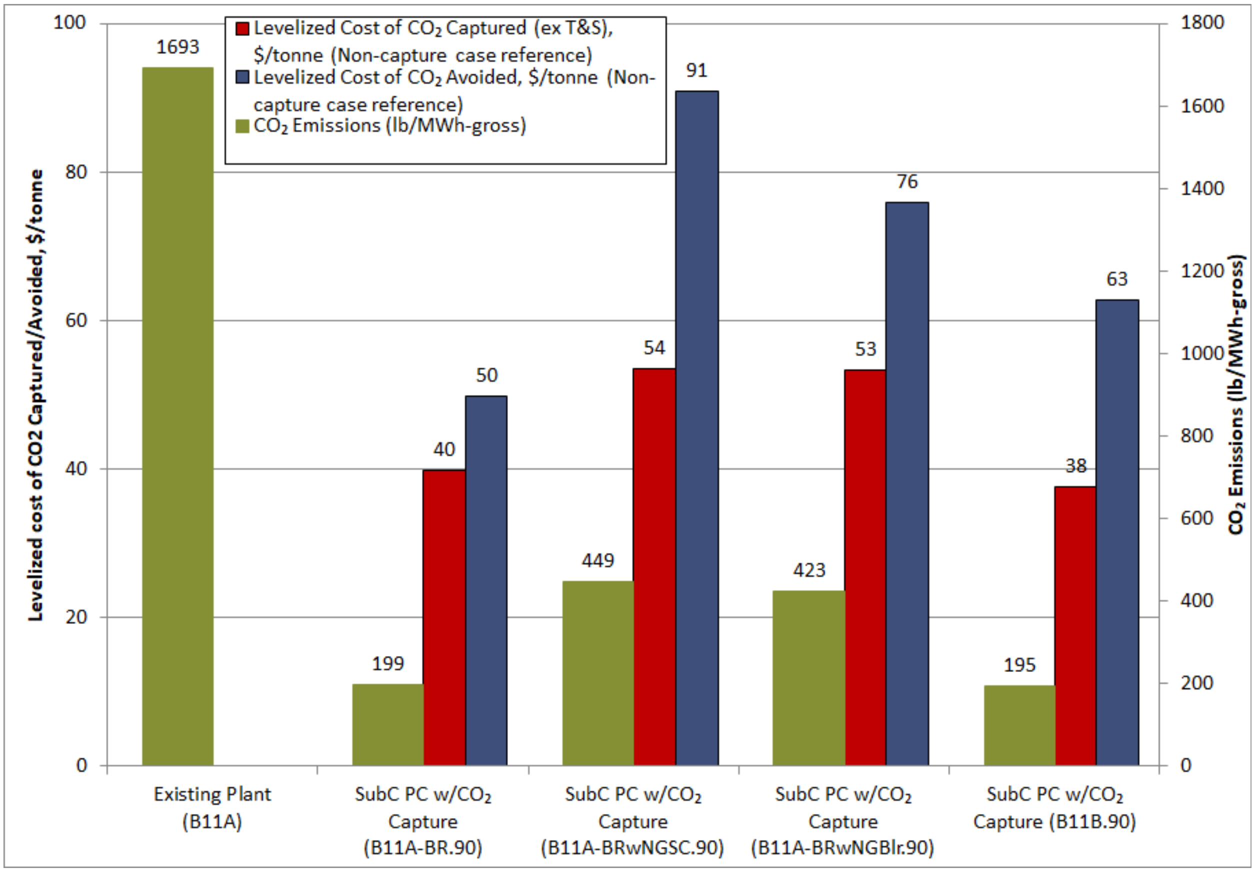


Exhibit A-6. Cost of CO_2 captured, and CO_2 avoided for 99% capture rate



A.1 Performance Results – B11A-BR.99

Exhibit A-7. Case B11A-BR.99 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	0.0000
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	60,980	60,980	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,515	0	86,214	5
V-L Flowrate (kg/hr)	1,759,697	1,759,697	52,120	540,561	540,561	74,394	38,896	0	0	12	119,513	2,420,543	0	2,552,647	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,673	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)[B]	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,065.93
Density (kg/m³)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.898
V-L Flowrate (lb_{mol}/hr)	134,438	134,438	3,982	41,298	41,298	5,684	2,972	0	0	2	8,859	179,711	0	190,070	12
V-L Flowrate (lb/hr)	3,879,468	3,879,468	114,905	1,191,732	1,191,732	164,011	85,750	0	0	27	263,480	5,336,383	0	5,627,622	1,216
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,115	9,940	2,687	2,128	40,847	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)[A]	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)[B]	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.3
Density (lb/ft³)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-7. Case B11A-BR.99 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0103	0.0000	0.0000	0.0000	0.0000
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0807	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8614	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0460	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,209	86,209	5,036	3,609	96,375	203	681	2,805	31,087	28,473	76,111	310	310	12,136	11,902
V-L Flowrate (kg/hr)	2,552,082	2,552,082	90,749	104,139	2,769,827	3,656	12,591	50,543	560,045	512,942	2,095,999	5,586	5,586	527,247	523,033
Solids Flowrate (kg/hr)	0	0	0	0	0	32,888	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	266	105	45	355	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.12	0.10	4.28	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.58	302.09	-47.80	30.23	297.00	---	---	---	2,994.07	439.34	179.65	3,098.44	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,496.21	-14,994.25	-12,986.23	-15,540.95	-710.95	-12,881.86	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.4	1,003.7	2.0	954.9	1.1	16.0	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.494	18.019	18.015	18.015	27.539	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,059	190,059	11,103	7,956	212,470	447	1,501	6,184	68,536	62,771	167,796	684	684	26,755	26,239
V-L Flowrate (lb/hr)	5,626,377	5,626,377	200,068	229,587	6,106,423	8,060	27,759	111,429	1,234,688	1,130,844	4,620,886	12,314	12,314	1,162,381	1,153,091
Solids Flowrate (lb/hr)	0	0	0	0	0	72,505	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	511	221	113	671	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	17.4	14.8	620.5	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,287.2	188.9	77.2	1,332.1	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.2	-6,446.4	-5,583.1	-6,681.4	-305.7	-5,538.2	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.145	62.658	0.123	59.612	0.066	1.000	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-7. Case B11A-BR.99 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41
V-L Mole Fraction											
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	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
H_2O	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
HCl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	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	0.0000
SO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NaCl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	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
V-L Flowrate (kg_{mol}/hr)	25	15	15	11,877	11,877	103,949	96,714	96,714	81,145	37,527	53,935
V-L Flowrate (kg/hr)	482	275	275	522,551	522,551	1,872,678	1,742,326	1,742,326	1,461,844	676,050	971,658
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	476	29	30	566	355	566	267	38	39
Pressure (MPa, abs)	2.81	1.64	2.42	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32
Steam Table Enthalpy (kJ/kg)[A]	137.94	863.65	3,408.95	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43
AspenPlus Enthalpy (kJ/kg)[B]	-15,225.22	-15,116.65	-12,571.34	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	-12,986.23	-13,640.29	-15,817.87
Density (kg/m³)	351.5	861.8	7.1	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015
V-L Flowrate (lb_{mol}/hr)	55	34	34	26,184	26,184	229,169	213,217	213,217	178,893	82,732	118,907
V-L Flowrate (lb/hr)	1,063	605	605	1,152,028	1,152,028	4,128,548	3,841,172	3,841,172	3,222,814	1,490,436	2,142,140
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	888	85	86	1,050	671	1,050	512	101	101
Pressure (psia)	407.6	237.4	350.5	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7
Steam Table Enthalpy (Btu/lb)[A]	59.3	371.3	1,465.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8
AspenPlus Enthalpy (Btu/lb)[B]	-6,545.7	-6,499.0	-5,404.7	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5
Density (lb/ft³)	21.943	53.801	0.446	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-8. Case B11A-BR.99 plant performance summary for 99% capture rate

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BR.99)
Steam Turbine Power, MWe	688	578
Total Gross Power, MWe	**688**	**578**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	16,500
CO_2 Compression, kWe	N/A	41,840
Balance of Plant, kWe	37,520	40,430
Total Auxiliaries, MWe	**38**	**99**
Net Power, MWe	**650**	**479**
HHV Net Plant Efficiency, %	38.6%	28.4%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	12,660 (11,999)
LHV Net Plant Efficiency, %	40.0%	29.5%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	12,210 (11,573)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	55.5%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	6,489 (6,150)
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	1,688 (1,600)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,848 (1,752)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,673 (493,115)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,944
Coal LHV Thermal Input, kWt	1,626,114	1,626,114
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.063 (16.6)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.047 (12.3)

Exhibit A-9. Case B11A-BR.99 plant power summary for 99% capture rate

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BR.99)
Steam Turbine Power, MWe	688	578
Total Gross Power, MWe	**688**	**578**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	730
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	7,730
CO_2 Capture/Removal Auxiliaries, kWe	N/A	16,500
CO_2 Compression, kWe	N/A	41,840
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	540
Cooling Tower Fans, kWe	2,950	4,000
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	720
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	40
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
Transformer Losses, kWe	2,160	2,040
Total Auxiliaries, MWe	**38**	**99**
Net Power, MWe	**650**	**479**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

Exhibit A-10. Case B11A-BR.99 air emissions

	kg/GJ (lb/MMBtu)	tonne/year (ton/year)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	0 (0)	0.000 (0.000)
NO_X	0.030 (0.070)	1,367 (1,507)	0.318 (0.700)
Particulate	0.004 (0.009)	176 (194)	0.041 (0.090)
Hg	1.30E-7 (3.02E-7)	0.006 (0.006)	1.36E-6 (3.00E-6)
CO_2	1 (2)	40,490 (44,632)	9 (21)
CO_2[C]	-	-	11 (25)
	mg/Nm^3		
Particulate Concentration[D,E]	12.22		

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

Exhibit A-11. Case B11A-BR.99 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	142,580 (314,335)	Stack Gas	1,484 (3,272)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
		CO_2 Product	142,584 (314,343)
		CO_2 Dryer Vent	15 (33)
		CO_2 Knockout	0.4 (0.9)
Total	**145,157 (320,016)**	**Total**	**145,157 (320,016)**

Exhibit A-12. Case B11A-BR.99 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,360)	FGD Product	5,271 (11,620)
		Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
Total	**5,606 (12,360)**	**Total**	**5,606 (12,360)**

Exhibit A-13. Case B11A-BR.99 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (2.1)	0.0 (-2.1)
CO_2 Capture Recovery	–	–	–	0.9 (230)	-0.9 (-230)
CO_2 Compression KO	–	–	–	0.1 (19)	-0.1 (-19)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**30 (7,958)**	**0.3 (84)**	**30 (7,874)**	**6.8 (1,790)**	**23 (6,084)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**33 (8,681)**	**2.7 (707)**	**30 (7,974)**	**7.8 (2,057)**	**22 (5,917)**

Exhibit A-14. Case B11A-BR.99 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Raw Water Makeup	–	114 (108)	–	114 (108)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	356 (337)	356 (337)
TOTAL	**6,069 (5,753)**	**190 (180)**	**356 (337)**	**6,615 (6,270)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	377 (357)	–	377 (357)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	39 (37)	39 (37)
Cooling Tower Load[A]	–	3,934 (3,728)	–	3,934 (3,728)
CO_2 Product Stream	–	-121 (-114)	–	-121 (-114)

	HHV	Sensible + Latent	Power	Total
AGR Effluent	–	45 (43)	–	45 (43)
Blowdown Streams and Deaerator Vent	–	14 (14)	–	14 (14)
Ambient Losses[B]	–	144 (137)	–	144 (137)
Power	–	–	2,082 (1,973)	2,082 (1,973)
TOTAL	**2.0 (1.9)**	**4,403 (4,173)**	**2,120 (2,010)**	**6,525 (6,185)**
Unaccounted Energy[C]	–	*89 (85)*	–	*89 (85)*

[A]Includes condenser, AGR, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

Exhibit A-15. Case B11A-BR.99 energy and mass balance, subcritical PC boiler with CO_2 capture

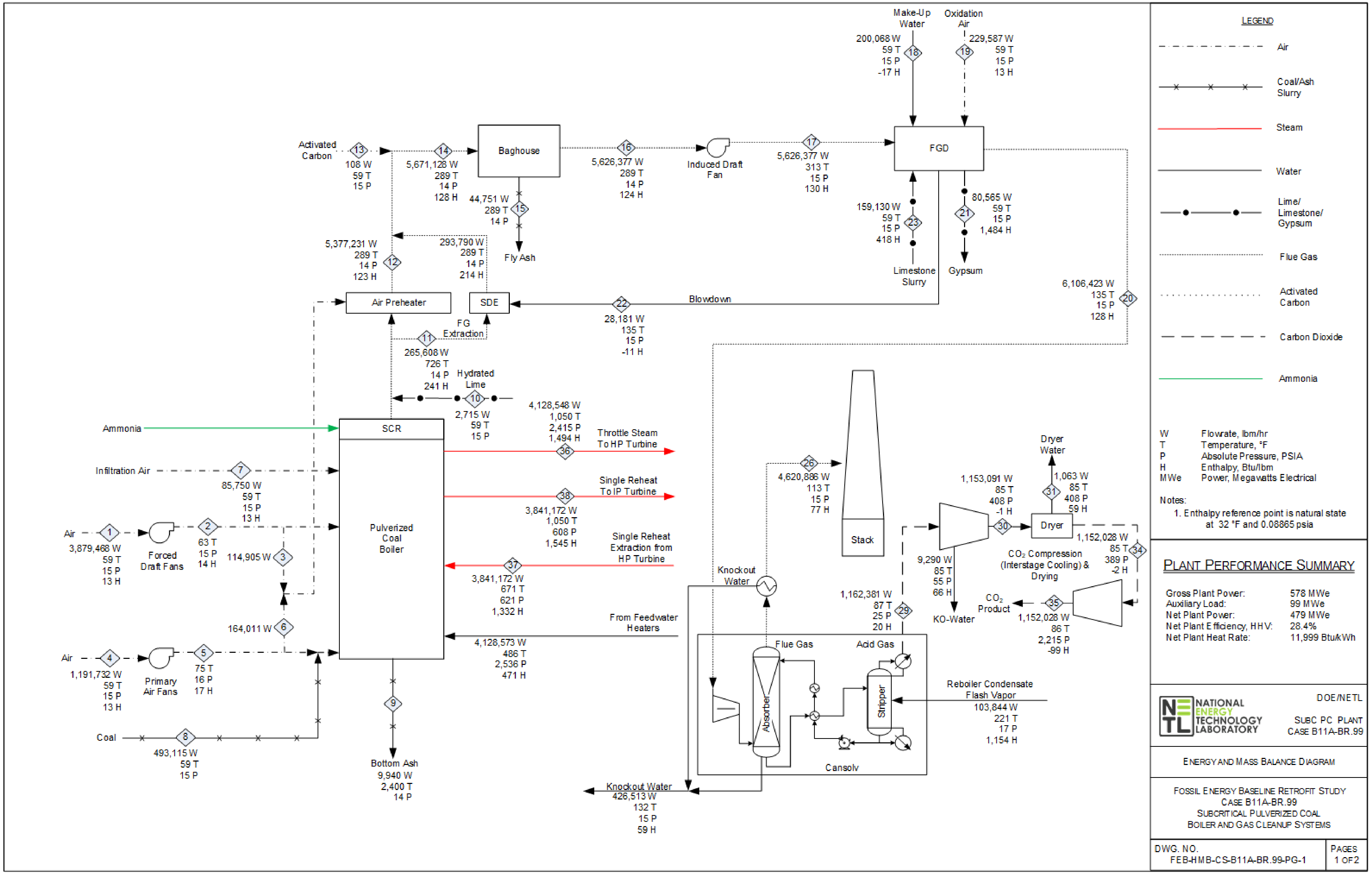
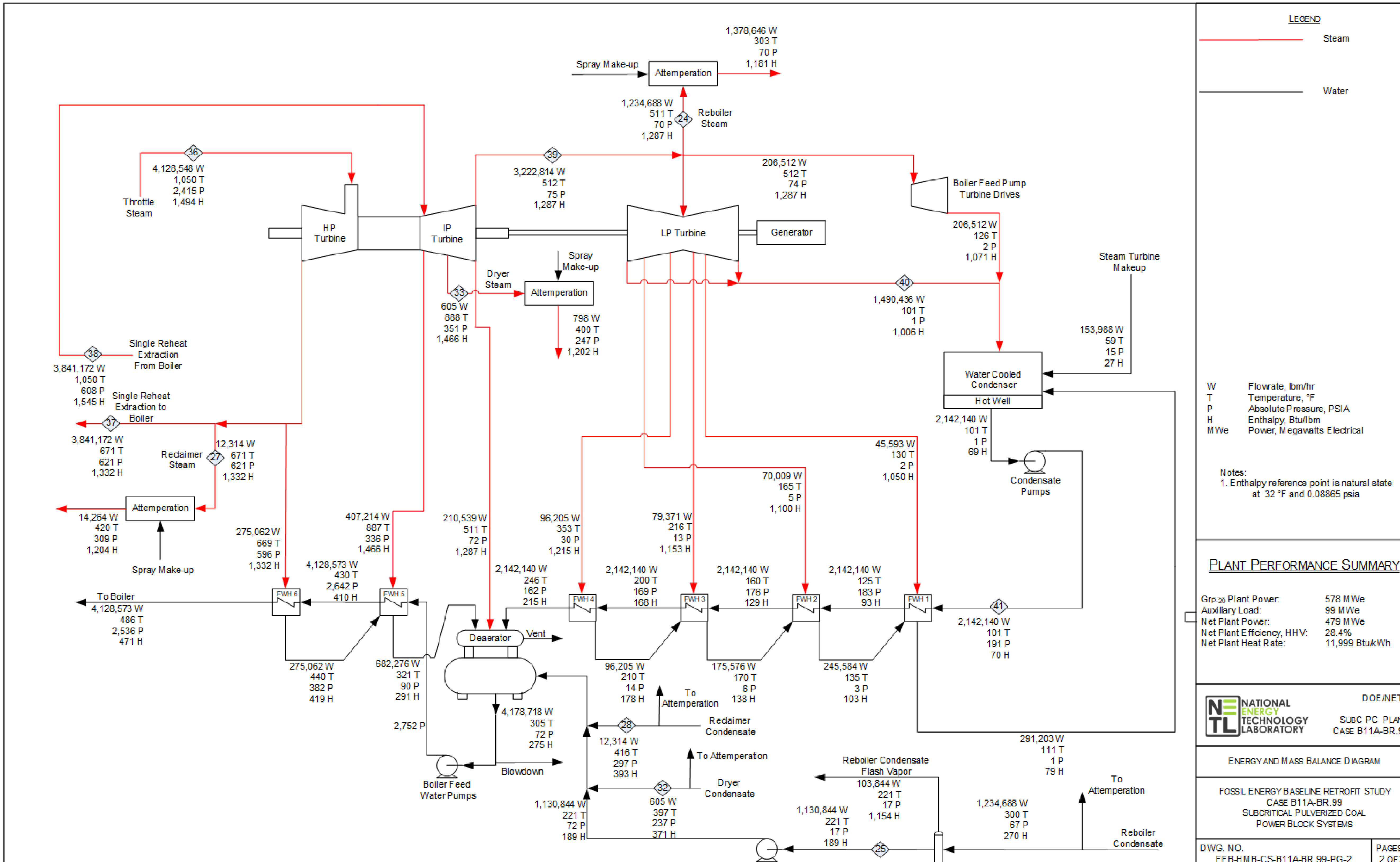


Exhibit A-16. Case B11A-BR.99 energy and mass balance, subcritical steam cycle



A.2 Performance Results – B11A-BRwNGSC.99

Exhibit A-17. Case B11A-BRwNGSC.99 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	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
CH_4S	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
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
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
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	60,979	60,979	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,515	0	86,214	5
V-L Flowrate (kg/hr)	1,759,681	1,759,681	52,119	540,556	540,556	74,394	38,895	0	0	12	119,510	2,420,522	0	2,552,623	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,671	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)[B]	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,066.03
Density (kg/m^3)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.899
V-L Flowrate (lb_{mol}/hr)	134,437	134,437	3,982	41,298	41,298	5,684	2,972	0	0	2	8,859	179,709	0	190,069	12
V-L Flowrate (lb/hr)	3,879,432	3,879,432	114,904	1,191,721	1,191,721	164,010	85,749	0	0	27	263,473	5,336,338	0	5,627,570	1,217
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,110	9,940	2,687	2,128	40,847	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)[A]	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)[B]	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.3
Density (lb/ft^3)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-17. Case B11A-BRwNGSC.99 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0102	0.0000	0.0000	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
CH_4S	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
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
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
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0851	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8573	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0458	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,208	86,208	5,036	3,609	96,374	203	681	2,805	34,713	34,713	76,477	359	359	12,136	11,902
V-L Flowrate (kg/hr)	2,552,058	2,552,058	90,749	104,138	2,769,801	3,656	12,591	50,543	625,357	625,357	2,102,586	6,470	6,470	527,242	523,029
Solids Flowrate (kg/hr)	0	0	0	0	0	32,887	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	151	149	46	216	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.46	0.10	2.13	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.59	302.09	-47.80	30.23	297.00	---	---	---	2,747.01	628.07	188.27	2,799.90	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,496.04	-14,994.25	-13,233.28	-15,352.23	-749.71	-13,180.40	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.5	1,003.7	2.6	918.0	1.1	10.7	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.495	18.019	18.015	18.015	27.493	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,057	190,057	11,103	7,956	212,468	447	1,501	6,184	76,528	76,528	168,603	792	792	26,755	26,239
V-L Flowrate (lb/hr)	5,626,324	5,626,324	200,067	229,584	6,106,367	8,060	27,759	111,428	1,378,676	1,378,676	4,635,409	14,264	14,264	1,162,370	1,153,081
Solids Flowrate (lb/hr)	0	0	0	0	0	72,504	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	303	300	115	420	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	67.2	14.8	308.9	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,181.0	270.0	80.9	1,203.7	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.1	-6,446.4	-5,689.3	-6,600.3	-322.3	-5,666.6	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.146	62.658	0.161	57.307	0.066	0.667	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-17. Case B11A-BRwNGSC.99 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
V-L Mole Fraction															
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0000	0.0089	0.0089
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	0.9310	0.0000	0.0000
CH_4S	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	0.0320	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	0.0070	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	0.0040	0.0000	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0100	0.0408	0.0408
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	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0099	0.0000	0.0874	0.0874
HCl	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
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7732	0.0160	0.7429	0.7429
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2074	0.0000	0.1200	0.1200
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	0.0000	0.0000
SO_3	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
NaCl	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
$CaCl_2$	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
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 Flowrate (kg_{mol}/hr)	25	20	20	11,877	11,877	103,895	96,973	96,973	82,051	65,522	83,313	85,568	3,464	89,133	89,133
V-L Flowrate (kg/hr)	482	362	362	522,546	522,546	1,871,696	1,746,997	1,746,997	1,478,180	1,180,395	1,500,904	2,469,232	60,028	2,529,260	2,529,260
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	204	29	30	566	355	566	267	38	39	15	27	625	104
Pressure (MPa, abs)	2.81	1.64	1.71	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32	0.10	2.96	0.11	0.11
Steam Table Enthalpy (kJ/kg)[A]	137.94	863.65	2,795.02	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43	30.23	22.04	832.54	248.19
AspenPlus Enthalpy (kJ/kg)[B]	-15,225.22	-15,116.65	-13,185.27	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	- 12,986.23	- 13,640.29	- 15,817.87	-97.58	-4,487.18	-643.70	-1,228.04
Density (kg/m³)	351.5	861.8	8.6	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3	1.2	22.1	0.4	1.0
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015	28.857	17.328	28.376	28.376
V-L Flowrate (lb_{mol}/hr)	55	44	44	26,184	26,184	229,049	213,789	213,789	180,893	144,451	183,673	188,645	7,637	196,504	196,504
V-L Flowrate (lb/hr)	1,063	799	799	1,152,018	1,152,018	4,126,384	3,851,468	3,851,468	3,258,830	2,602,326	3,308,928	5,443,726	132,339	5,576,064	5,576,064
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	400	85	86	1,050	671	1,050	512	101	101	59	80	1,156	219
Pressure (psia)	407.6	237.4	247.3	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7	14.7	430.0	15.5	15.5
Steam Table Enthalpy (Btu/lb)[A]	59.3	371.3	1,201.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8	13.0	9.5	357.9	106.7
AspenPlus Enthalpy (Btu/lb)[B]	-6,545.7	-6,499.0	-5,668.6	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5	-42.0	-1,929.1	-276.7	-528.0
Density (lb/ft³)	21.943	53.801	0.537	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010	0.076	1.380	0.025	0.060

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-18. Case B11A-BRwNGSC.99 plant performance summary

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGSC.99)
Combustion Turbine Power, MWe	N/A	307
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**995**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	16,500
CO_2 Compression, kWe	N/A	41,840
Balance of Plant, kWe	37,520	46,010
Total Auxiliaries, MWe	**38**	**104**
Net Power, MWe	**650**	**891**
HHV Net Plant Efficiency, %	38.6%	34.8%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	10,339 (9,800)
LHV Net Plant Efficiency, %	40.0%	36.9%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	9,754 (9,245)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	46.3%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	7,770 (7,364)
HHV Combustion Turbine Cycle Efficiency, %	N/A	35.3%
LHV Steam Turbine Cycle Efficiency, %	N/A	39.1%
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	2,793 (2,648)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,848 (1,752)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,671 (493,110)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,928
Coal LHV Thermal Input, kWt	1,626,114	1,626,099
Natural Gas Feed, kg/hr (lb/hr)	N/A	60,028 (132,339)
NG HHV Thermal Input, kWt	N/A	871,985
NG LHV Thermal Input, kWt	N/A	787,053
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.044 (11.7)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.034 (8.9)

Exhibit A-19. Case B11A-BRwNGSC.99 plant power summary

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGSC.99)
Combustion Turbine Power, MWe	N/A	307
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**995**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	720
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	9,910
CO_2 Capture/Removal Auxiliaries, kWe	N/A	16,500
CO_2 Compression, kWe	N/A	41,840
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	720
NGSC Condensate Pumps, kWe	N/A	90
Cooling Tower Fans, kWe	2,950	5,120
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	950
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	60
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
Combustion Turbine Auxiliaries, kWe	N/A	510
Transformer Losses, kWe	2,160	3,300
Total Auxiliaries, MWe	**38**	**104**
Net Power, MWe	**650**	**891**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

Exhibit A-20. Case B11A-BRwNGSC.99 air emissions

	kg/GJ (lb/MMBtu)	tonne/year (ton/year)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	9 (10)	0.001 (0.003)
NO_X	0.024 (0.056)	1,661 (1,831)	0.224 (0.494)
Particulate	0.003 (0.008)	228 (251)	0.031 (0.068)
Hg	1.02E-7 (2.36E-7)	0.007 (0.008)	1.36E-6 (3.00E-6)
CO	0.000 (0.001)	19 (20)	0.003 (0.006)
CO_2	18 (42)	1,232,563 (1,358,668)	166 (367)
CO_2[C]	-	-	186 (410)
	mg/Nm^3		
Particulate Concentration[D,E]	15.84		

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

Exhibit A-21. Case B11A-BRwNGSC.99 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	142,579 (314,332)	Stack Gas	1,484 (3,272)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
Natural Gas	43,357 (95,586)	CO_2 Product	142,582 (314,340)
NGSC Air (CO_2)	336 (740)	CO_2 Dryer Vent	15 (33)
		CO_2 Knockout	0.4 (0.9)
		NGSC Stack Gas	43,693 (96,326)
Total	**188,848 (416,339)**	**Total**	**188,848 (416,339)**

Exhibit A-22. Case B11A-BRwNGSC.99 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,359)	FGD Product	5,271 (11,620)
Natural Gas	0.6 (1.3)	Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
		NGSC Stack Gas	0.6 (1.3)
Total	**5,607 (12,361)**	**Total**	**5,607 (12,361)**

Exhibit A-23. Case B11A-BRwNGSC.99 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)	m^3/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (2.1)	0.0 (-2.1)
CO_2 Capture Recovery	–	–	–	0.9 (225)	-0.9 (-225)
CO_2 Compression KO	–	–	–	0.1 (19)	-0.1 (-19)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
NGSC HRSG	11 (2,787)	9.7 (2,556)	0.9 (237)	0.0 (5.1)	0.9 (232)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**39 (10,194)**	**0.3 (84)**	**38 (10,111)**	**8.7 (2,293)**	**30 (7,818)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**52 (13,705)**	**12 (3,262)**	**40 (10,448)**	**9.7 (2,560)**	**30 (7,888)**

Exhibit A-24. Case B11A-BRwNGSC.99 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Natural Gas	3,139 (2,975)	2.1 (2.0)	–	3,141 (2,977)
CT Air	–	75 (71)	–	75 (71)
Raw Water Makeup	–	149 (141)	–	149 (141)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	376 (356)	376 (356)
TOTAL	**9,208 (8,728)**	**302 (286)**	**376 (356)**	**9,886 (9,370)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	396 (375)	–	396 (375)
CT Stack Gas	–	628 (595)	–	628 (595)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	71 (67)	71 (67)
Cooling Tower Load[A]	–	5,039 (4,776)	–	5,039 (4,776)
CO_2 Product Stream	–	-121 (-114)	–	-121 (-114)
AGR Effluent	–	45 (43)	–	45 (43)
Blowdown Streams and Deaerator Vent	–	15 (14)	–	15 (14)
Ambient Losses[B]	–	163 (154)	–	163 (154)
Power	–	–	3,582 (3,395)	3,582 (3,395)
TOTAL	**2.0 (1.9)**	**6,175 (5,853)**	**3,653 (3,462)**	**9,830 (9,317)**
Unaccounted Energy[C]	–	*56 (53)*	–	*56 (53)*

[A]Includes condenser, capture system, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

Exhibit A-25. Case B11A-BRwNGSC.99 energy and mass balance, subcritical PC boiler with CO_2 capture and NGSC

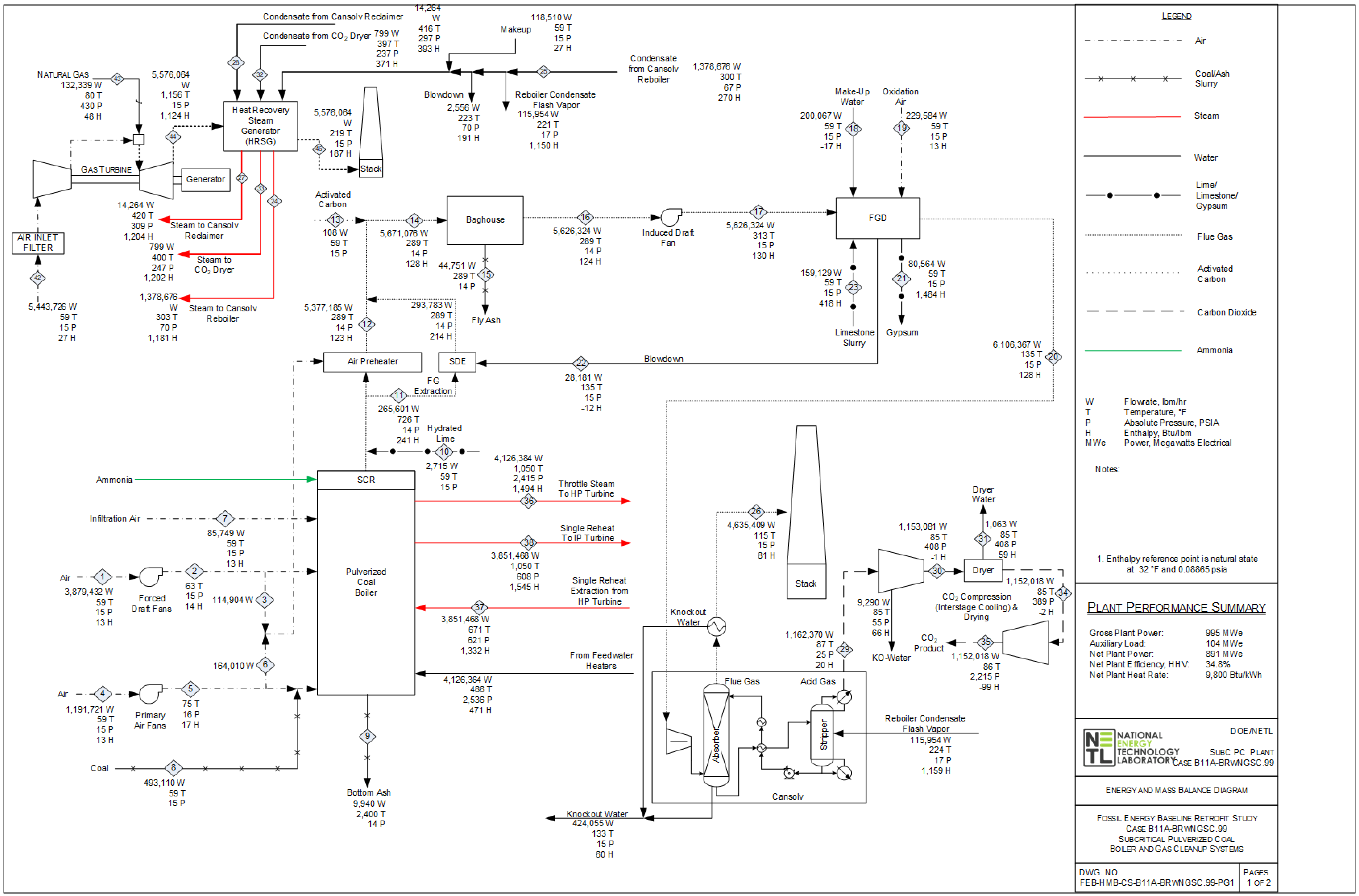
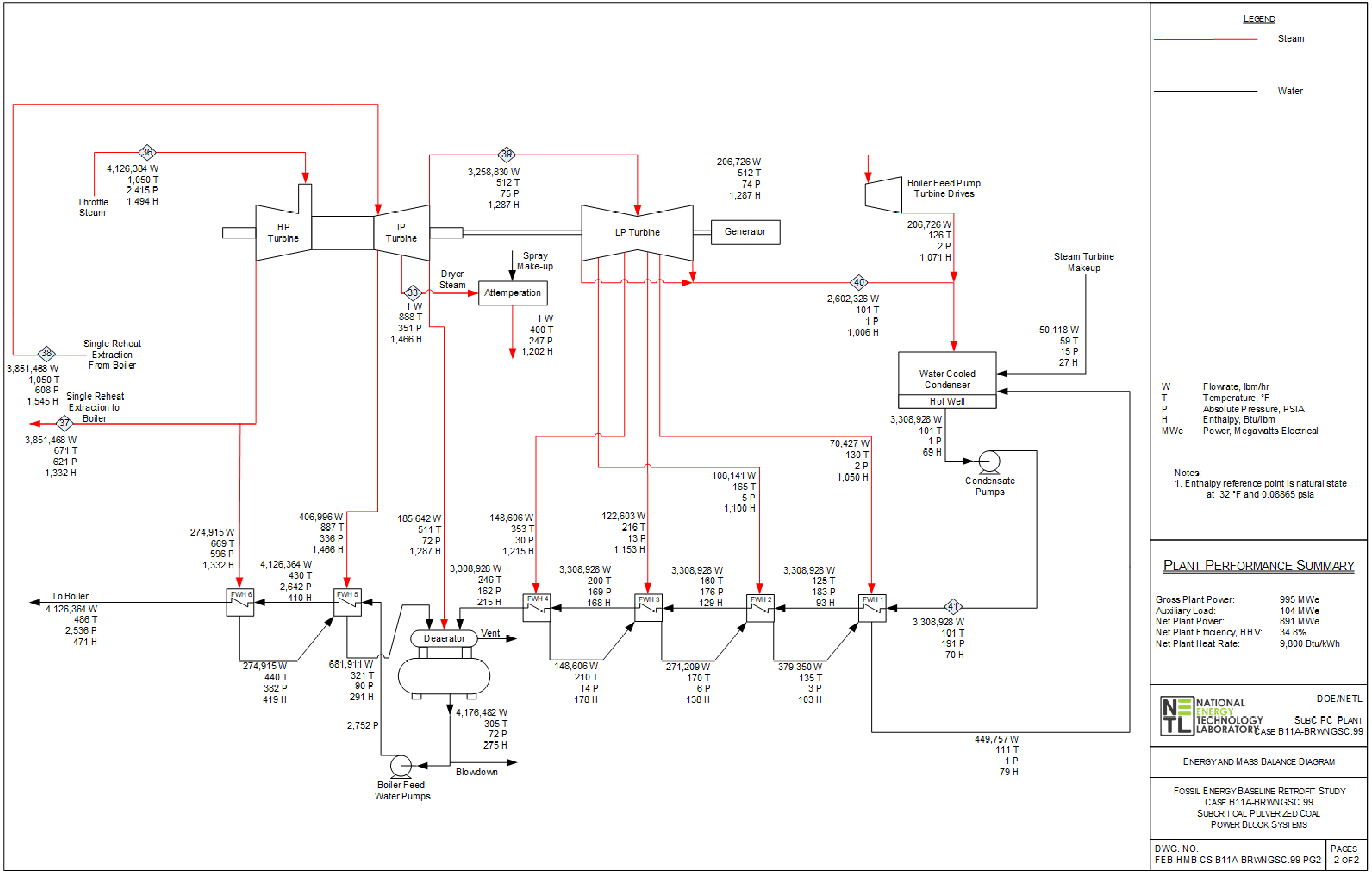


Exhibit A-26. Case B11A-BRwNGSC.99 energy and mass balance, subcritical steam cycle



A.3 Performance Results – B11A-BRwNGBlr.99

Exhibit A-27. Case B11A-BRwNGBlr.99 stream table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V-L Mole Fraction															
Ar	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0092	0.0000	0.0000	0.0000	0.0087	0.0088	0.0000	0.0087	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
CH_4S	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
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
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
CO_2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0000	0.0000	0.0000	0.1457	0.1379	0.0000	0.1372	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
H_2O	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0000	0.0000	1.0000	0.0879	0.0837	0.0000	0.0911	0.0000
HCl	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	0.0001	0.0000
N_2	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.7732	0.0000	0.0000	0.0000	0.7318	0.7340	0.0000	0.7281	0.0000
O_2	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.2074	0.0000	0.0000	0.0000	0.0237	0.0336	0.0000	0.0329	0.0000
SO_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0020	0.0000	0.0020	0.0000
SO_3	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
NaCl	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	0.1158
$CaCl_2$	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	0.8842
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	60,979	60,979	1,806	18,732	18,732	2,578	1,348	0	0	1	4,018	81,515	0	86,214	5
V-L Flowrate (kg/hr)	1,759,681	1,759,681	52,119	540,556	540,556	74,394	38,895	0	0	12	119,510	2,420,522	0	2,552,623	552
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	223,671	4,509	1,219	965	18,528	49	19,734	19,747
Temperature (°C)	15	17	17	15	24	24	15	15	1,316	15	385	143	15	143	143
Pressure (MPa, abs)	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	30.23	32.49	32.49	30.23	38.98	38.98	30.23	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (kJ/kg)[B]	-97.58	-95.31	-95.31	-97.58	-88.83	-88.83	-97.58	-2,119.02	1,267.06	-13,402.95	-2,261.17	-2,394.31	-6.79	-2,453.14	-1,066.03
Density (kg/m³)	1.2	1.2	1.2	1.2	1.3	1.3	1.2	---	---	1,003.6	0.5	0.8	---	0.8	2,150.2
V-L Molecular Weight	28.857	28.857	28.857	28.857	28.857	28.857	28.857	---	---	18.015	29.742	29.694	---	29.608	104.899
V-L Flowrate (lb_{mol}/hr)	134,437	134,437	3,982	41,298	41,298	5,684	2,972	0	0	2	8,859	179,709	0	190,069	12
V-L Flowrate (lb/hr)	3,879,432	3,879,432	114,904	1,191,721	1,191,721	164,010	85,749	0	0	27	263,473	5,336,338	0	5,627,570	1,217
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	493,110	9,940	2,687	2,128	40,847	108	43,506	43,535
Temperature (°F)	59	63	63	59	75	75	59	59	2,400	59	726	289	59	289	289
Pressure (psia)	14.7	15.0	15.0	14.7	15.9	15.9	14.7	14.7	14.3	14.7	14.3	14.1	14.7	14.1	14.1
Steam Table Enthalpy (Btu/lb)[A]	13.0	14.0	14.0	13.0	16.8	16.8	13.0	---	---	---	---	---	---	---	---
AspenPlus Enthalpy (Btu/lb)[B]	-42.0	-41.0	-41.0	-42.0	-38.2	-38.2	-42.0	-911.0	544.7	-5,762.2	-972.1	-1,029.4	-2.9	-1,054.7	-458.3
Density (lb/ft³)	0.076	0.077	0.077	0.076	0.080	0.080	0.076	---	---	62.650	0.033	0.052	---	0.052	134.232

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-27. Case B11A-BRwNGBlr.99 stream table (cont'd)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
V-L Mole Fraction															
Ar	0.0087	0.0087	0.0000	0.0092	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0101	0.0000	0.0000	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
CH_4S	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
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
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
CO_2	0.1372	0.1372	0.0000	0.0003	0.1245	0.0001	0.0000	0.0000	0.0000	0.0000	0.0156	0.0000	0.0000	0.9783	0.9975
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	0.0911	0.0911	0.9999	0.0099	0.1508	0.9998	0.9943	0.9999	1.0000	1.0000	0.0807	1.0000	1.0000	0.0217	0.0025
HCl	0.0001	0.0001	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
N_2	0.7281	0.7281	0.0000	0.7732	0.6803	0.0000	0.0000	0.0000	0.0000	0.0000	0.8483	0.0000	0.0000	0.0000	0.0000
O_2	0.0329	0.0329	0.0000	0.2074	0.0363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0453	0.0000	0.0000	0.0000	0.0000
SO_2	0.0020	0.0020	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
SO_3	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
NaCl	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$CaCl_2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	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
V-L Flowrate (kg_{mol}/hr)	86,208	86,208	5,036	3,609	96,374	203	681	2,805	30,950	30,950	77,286	359	359	11,031	10,818
V-L Flowrate (kg/hr)	2,552,058	2,552,058	90,749	104,138	2,769,801	3,656	12,591	50,543	557,573	557,573	2,145,261	6,469	6,469	479,243	475,413
Solids Flowrate (kg/hr)	0	0	0	0	0	32,887	192	21,637	0	0	0	0	0	0	0
Temperature (°C)	143	156	15	15	57	15	57	15	151	149	45	216	214	31	29
Pressure (MPa, abs)	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.48	0.46	0.10	2.13	2.04	0.17	2.81
Steam Table Enthalpy (kJ/kg)[A]	287.59	302.09	-47.80	30.23	297.00	---	---	---	2,747.01	628.07	178.41	2,799.89	913.81	46.68	-3.05
AspenPlus Enthalpy (kJ/kg)[B]	-2,464.16	-2,449.65	-16,015.01	-97.58	-2,939.24	-12,513.34	-15,496.04	-14,994.25	-13,233.28	-15,352.23	-903.21	-13,180.40	-15,066.49	-8,978.62	-8,972.51
Density (kg/m³)	0.8	0.9	1,003.7	1.2	1.1	878.3	979.5	1,003.7	2.6	918.0	1.1	10.7	848.5	3.0	57.8
V-L Molecular Weight	29.603	29.603	18.019	28.857	28.740	18.021	18.495	18.019	18.015	18.015	27.757	18.015	18.015	43.445	43.945
V-L Flowrate (lb_{mol}/hr)	190,057	190,057	11,103	7,956	212,468	447	1,501	6,184	68,233	68,233	170,387	792	792	24,319	23,850
V-L Flowrate (lb/hr)	5,626,324	5,626,324	200,067	229,584	6,106,367	8,060	27,759	111,428	1,229,238	1,229,238	4,729,491	14,263	14,263	1,056,551	1,048,107
Solids Flowrate (lb/hr)	0	0	0	0	0	72,504	423	47,701	0	0	0	0	0	0	0
Temperature (°F)	289	313	59	59	135	59	135	59	303	300	113	420	416	87	85
Pressure (psia)	13.9	15.3	14.7	14.7	14.8	14.7	14.7	14.7	70.0	67.2	14.8	308.9	296.6	24.7	407.6
Steam Table Enthalpy (Btu/lb)[A]	123.6	129.9	-20.5	13.0	127.7	---	---	---	1,181.0	270.0	76.7	1,203.7	392.9	20.1	-1.3
AspenPlus Enthalpy (Btu/lb)[B]	-1,059.4	-1,053.2	-6,885.2	-42.0	-1,263.6	-5,379.8	-6,662.1	-6,446.4	-5,689.3	-6,600.3	-388.3	-5,666.6	-6,477.4	-3,860.1	-3,857.5
Density (lb/ft³)	0.051	0.055	62.658	0.076	0.067	54.829	61.146	62.658	0.161	57.307	0.067	0.667	52.968	0.184	3.609

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-27. Case B11A-BRwNGBlr.99 stream table (cont'd)

	31	32	33	34	35	36	37	38	39	40	41	42	43	44
V-L Mole Fraction														
Ar	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0000	0.0085
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	0.9310	0.0000
CH_4S	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	0.0320	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	0.0070	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	0.0040	0.0000
CO_2	0.0500	0.0000	0.0000	0.9995	0.9995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0100	0.0869
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
H_2O	0.9500	1.0000	1.0000	0.0005	0.0005	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0099	0.0000	0.1758
HCl	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
N_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7732	0.0160	0.7083
O_2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2074	0.0000	0.0205
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	0.0000
SO_3	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
NaCl	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
$CaCl_2$	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
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
V-L Flowrate (kg_{mol}/hr)	23	18	18	10,796	10,796	103,895	96,973	96,973	82,051	65,522	83,313	18,858	1,715	20,623
V-L Flowrate (kg/hr)	438	330	330	474,975	474,975	1,871,696	1,746,997	1,746,997	1,478,180	1,180,395	1,500,904	544,194	29,712	573,906
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°C)	29	203	204	29	30	566	355	566	267	38	39	15	27	102
Pressure (MPa, abs)	2.81	1.64	1.71	2.68	15.27	16.65	4.28	4.19	0.52	0.01	1.32	0.10	0.10	0.10
Steam Table Enthalpy (kJ/kg)[A]	137.94	863.65	2,795.02	-3.59	-231.09	3,473.89	3,098.44	3,593.58	2,994.07	2,340.01	162.43	30.23	54.60	396.64
AspenPlus Enthalpy (kJ/kg)[B]	-15,225.22	-15,116.65	-13,185.27	-8,967.15	-9,194.65	-12,506.41	-12,881.86	-12,386.71	-12,986.23	-13,640.29	-15,817.87	-97.58	-4,454.63	-2,672.62
Density (kg/m³)	351.5	861.8	8.6	54.7	630.1	47.7	16.0	11.1	2.1	0.1	993.3	1.2	0.7	0.9
V-L Molecular Weight	19.315	18.015	18.015	43.997	43.997	18.015	18.015	18.015	18.015	18.015	18.015	28.857	17.328	27.829
V-L Flowrate (lb_{mol}/hr)	50	40	40	23,800	23,800	229,049	213,789	213,789	180,893	144,451	183,673	41,576	3,780	45,465
V-L Flowrate (lb/hr)	966	727	727	1,047,141	1,047,141	4,126,384	3,851,468	3,851,468	3,258,830	2,602,326	3,308,928	1,199,742	65,504	1,265,247
Solids Flowrate (lb/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (°F)	85	397	400	85	86	1,050	671	1,050	512	101	101	59	80	215
Pressure (psia)	407.6	237.4	247.3	389.1	2,214.7	2,414.7	620.5	608.1	75.0	1.0	190.7	14.7	14.7	14.7
Steam Table Enthalpy (Btu/lb)[A]	59.3	371.3	1,201.6	-1.5	-99.4	1,493.5	1,332.1	1,545.0	1,287.2	1,006.0	69.8	13.0	23.5	170.5
AspenPlus Enthalpy (Btu/lb)[B]	-6,545.7	-6,499.0	-5,668.6	-3,855.2	-3,953.0	-5,376.8	-5,538.2	-5,325.3	-5,583.1	-5,864.3	-6,800.5	-42.0	-1,915.1	-1,149.0
Density (lb/ft³)	21.943	53.801	0.537	3.416	39.338	2.975	1.000	0.692	0.132	0.003	62.010	0.076	0.044	0.057

[A]Steam table reference conditions are 32.02°F & 0.089 psia

[B]Aspen thermodynamic reference state is the component's constituent elements in an ideal gas state at 25°C and 1 atm

Exhibit A-28. Case B11A-BRwNGBlr.99 plant performance summary

Performance Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwNGBlr.99)
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**688**
CO_2 Capture/Removal Auxiliaries, kWe	N/A	16,500
CO_2 Compression, kWe	N/A	41,840
Balance of Plant, kWe	37,520	44,670
Total Auxiliaries, MWe	**38**	**103**
Net Power, MWe	**650**	**585**
HHV Net Plant Efficiency, %	38.6%	26.9%
HHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,336 (8,849)	13,360 (12,663)
LHV Net Plant Efficiency, %	40.0%	28.3%
LHV Net Plant Heat Rate, kJ/kWh (Btu/kWh)	9,005 (8,535)	12,702 (12,039)
HHV Boiler Efficiency, %	88.0%	88.0%
LHV Boiler Efficiency, %	91.3%	91.3%
Steam Turbine Cycle Efficiency, %	46.3%	46.3%
Steam Turbine Heat Rate, kJ/kWh (Btu/kWh)	7,770 (7,365)	7,770 (7,364)
HHV NG Boiler Efficiency, %	N/A	77.6%
LHV NG Boiler Efficiency, %	N/A	86.0%
Condenser Duty, GJ/hr (MMBtu/hr)	2,793 (2,648)	2,793 (2,648)
AGR Cooling Duty, GJ/hr (MMBtu/hr)	N/A	1,848 (1,752)
As-Received Coal Feed, kg/hr (lb/hr)	223,673 (493,115)	223,671 (493,110)
Limestone Sorbent Feed, kg/hr (lb/hr)	21,637 (47,701)	21,637 (47,701)
Coal HHV Thermal Input, kWt	1,685,945	1,685,928
Coal LHV Thermal Input, kWt	1,626,114	1,626,099
Natural Gas Feed, kg/hr (lb/hr)	N/A	33,288 (73,387)
NG HHV Thermal Input, kWt	N/A	483,552
NG LHV Thermal Input, kWt	N/A	436,454
Raw Water Withdrawal, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.038 (10.0)	0.068 (18.0)
Raw Water Consumption, $(m^3/min)/MW_{net}$ (gpm/MW_{net})	0.030 (8.0)	0.051 (13.5)

Exhibit A-29. Case B11A-BRwNGBlr.99 plant power summary

Power Summary	Existing Plant (B11A)	Retrofitted Plant (B11A-BRwBlr.99)
Steam Turbine Power, MWe	688	688
Total Gross Power, MWe	**688**	**688**
Auxiliary Load Summary		
Activated Carbon Injection, kWe	30	30
Ash Handling, kWe	730	720
Baghouse, kWe	100	100
Circulating Water Pumps, kWe	5,700	9,910
CO_2 Capture/Removal Auxiliaries, kWe	N/A	16,500
CO_2 Compression, kWe	N/A	41,840
Coal Handling and Conveying, kWe	480	480
Condensate Pumps, kWe	720	720
NG Boiler Condensate Pumps, kWe	N/A	90
Cooling Tower Fans, kWe	2,950	5,120
Dry Sorbent Injection, kWe	60	60
Flue Gas Desulfurizer, kWe	3,460	3,460
Forced Draft Fans, kWe	1,150	1,150
Ground Water Pumps, kWe	590	950
Induced Draft Fans, kWe	10,600	10,600
Miscellaneous Balance of Plant[A,B], kWe	2,250	2,250
Primary Air Fans, kWe	1,360	1,360
Pulverizers, kWe	3,350	3,350
SCR, kWe	40	50
Sorbent Handling & Reagent Preparation, kWe	1,040	1,040
Spray Dryer Evaporator, kWe	250	250
Steam Turbine Auxiliaries, kWe	500	500
NG Boiler Auxiliaries, kWe	N/A	100
Transformer Losses, kWe	2,160	2,380
Total Auxiliaries, MWe	**38**	**103**
Net Power, MWe	**650**	**585**

[A]Boiler feed pumps are turbine driven
[B]Includes plant control systems, lighting, HVAC, and miscellaneous low voltage loads

Exhibit A-30. Case B11A-BRwNGBlr.99 air emissions

	kg/GJ (lb/MMBtu)	tonne/year (ton/year)[A]	kg/MWh (lb/MWh)[B]
SO_2	0.000 (0.000)	5 (6)	0.001 (0.002)
NO_X	0.028 (0.065)	1,626 (1,792)	0.318 (0.700)
Particulate	0.004 (0.009)	214 (236)	0.042 (0.092)
Hg	1.20E-7 (2.79E-7)	0.007 (0.008)	1.36E-6 (3.00E-6)
CO_2	12 (28)	698,723 (770,210)	136 (301)
CO_2[C]	-	-	161 (354)
	mg/Nm^3		
Particulate Concentration[D,E]	14.86		

[A]Calculations based on an 85 percent capacity factor
[B]Emissions based on gross power except where otherwise noted
[C]CO_2 emissions based on net power instead of gross power
[D]Concentration of particles in the flue gas after the baghouse
[E]Normal conditions given at 32°F and 14.696 psia

Exhibit A-31. Case B11A-BRwNGBlr.99 carbon balance

Carbon In		Carbon Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	142,579 (314,332)	Stack Gas	1,484 (3,272)
Air (CO_2)	332 (733)	FGD Product	169 (373)
PAC	49 (108)	Baghouse	733 (1,617)
FGD Reagent	2,195 (4,840)	Bottom Ash	171 (377)
Natural Gas	24,043 (53,006)	CO_2 Product	142,582 (314,340)
NG Boiler Air (CO_2)	83 (183)	CO_2 Dryer Vent	15 (33)
		CO_2 Knockout	0.4 (0.9)
		NG Boiler Stack Gas	24,126 (53,189)
Total	**169,281 (373,202)**	**Total**	**169,281 (373,202)**

Exhibit A-32. Case B11A-BRwNGBlr.99 sulfur balance

Sulfur In		Sulfur Out	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Coal	5,606 (12,359)	FGD Product	5,271 (11,620)
Natural Gas	0.3 (0.7)	Stack Gas	0.0 (0.0)
		Polishing Scrubber and Solvent Reclaiming	110 (241)
		Baghouse	226 (498)
		NG Boiler Stack Gas	0.3 (0.7)
Total	**5,606 (12,360)**	**Total**	**5,606 (12,360)**

Exhibit A-33. Case B11A-BRwNGBlr.99 water balance

Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	m³/min (gpm)	m³/min (gpm)	m³/min (gpm)	m³/min (gpm)	m³/min (gpm)
FGD Process Makeup	1.5 (400)	1.5 (400)	–	–	–
FGD Slurry Water	0.8 (223)	0.8 (223)	–	–	–
CO_2 Drying	–	–	–	0.0 (2.1)	0.0 (-2.1)
CO_2 Capture Recovery	–	–	–	0.9 (225)	-0.9 (-225)
CO_2 Compression KO	–	–	–	0.1 (19)	-0.1 (-19)
Deaerator Vent	–	–	–	0.1 (17)	-0.1 (-17)
Natural Gas Boiler	11 (2,787)	9.7 (2,556)	1.2 (309)	0.3 (77)	0.9 (232)
Condenser Makeup	**0.4 (100)**	**–**	**0.4 (100)**	**–**	**0.4 (100)**
BFW Makeup	0.4 (100)	–	0.4 (100)	–	0.4 (100)
Cooling Tower	**39 (10,194)**	**0.3 (84)**	**38 (10,111)**	**8.7 (2,293)**	**30 (7,818)**
BFW Blowdown	–	0.3 (84)	-0.3 (-84)	–	-0.3 (-84)
Total	**52 (13,705)**	**12 (3,262)**	**40 (10,519)**	**10.0 (2,632)**	**30 (7,888)**

Exhibit A-34. Case B11A-BRwNGBlr.99 overall energy balance (0°C [32°F] reference)

	HHV	Sensible + Latent	Power	Total
Heat In GJ/hr (MMBtu/hr)				
Coal	6,069 (5,753)	5.1 (4.8)	–	6,074 (5,757)
Air	–	71 (67)	–	71 (67)
Natural Gas	1,741 (1,650)	1.2 (1.1)	–	1,742 (1,651)
NG Boiler Air	–	18 (17)	–	18 (17)
Raw Water Makeup	–	150 (142)	–	150 (142)
Limestone	–	0.5 (0.4)	–	0.5 (0.4)
Auxiliary Power	–	–	371 (351)	371 (351)
TOTAL	**7,810 (7,403)**	**246 (233)**	**371 (351)**	**8,427 (7,987)**
Heat Out GJ/hr (MMBtu/hr)				
Bottom Ash	–	5.7 (5.4)	–	5.7 (5.4)
Fly Ash	–	2.1 (2.0)	–	2.1 (2.0)
Stack Gas	–	396 (375)	–	396 (375)
NG Boiler Stack Gas	–	255 (242)	–	255 (242)
Sulfur	2.0 (1.9)	0.0 (0.0)	–	2.1 (1.9)
Gypsum	–	2.1 (2.0)	–	2.1 (2.0)
Motor Losses and Design Allowances	–	–	45 (43)	45 (43)

	HHV	Sensible + Latent	Power	Total
Cooling Tower Load[A]	–	5,039 (4,776)	–	5,039 (4,776)
CO_2 Product Stream	–	-121 (-114)	–	-121 (-114)
AGR Effluent	–	45 (43)	–	45 (43)
Blowdown Streams and Deaerator Vent	–	25 (24)	–	25 (24)
Ambient Losses[B]	–	179 (169)	–	179 (169)
Power	–	–	2,475 (2,346)	2,475 (2,346)
TOTAL	**2.0 (1.9)**	**5,828 (5,524)**	**2,521 (2,389)**	**8,351 (7,915)**
Unaccounted Energy[C]	–	*76 (72)*	–	*76 (72)*

[A]Includes condenser, capture system, and miscellaneous cooling loads
[B]Ambient losses include all losses to the environment through radiation, convection, etc. Sources of these losses include the boiler, reheater, superheater, and transformers
[C]By difference

Exhibit A-35. Efficiency comparison for 99% capture rate

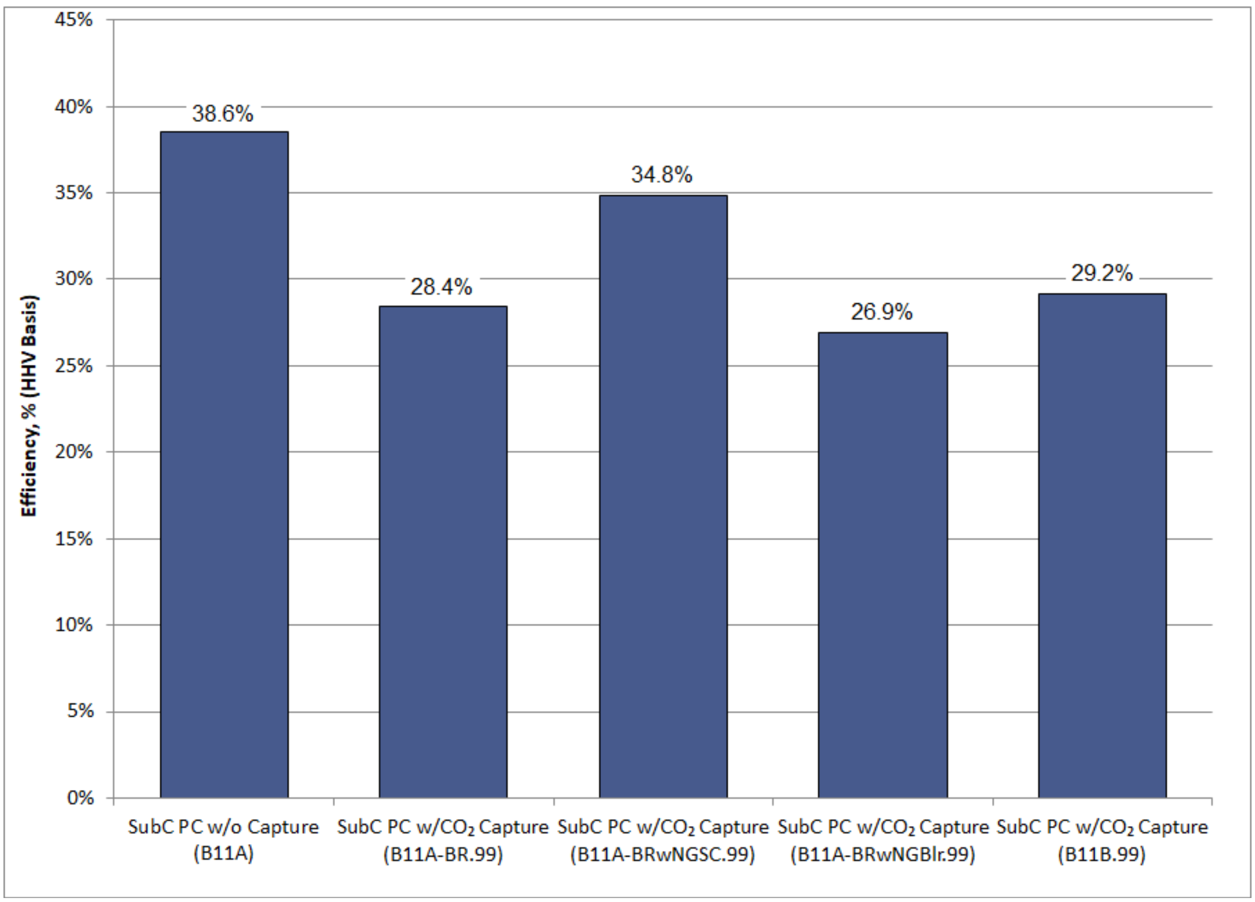


Exhibit A-36. SO_2, NO_X, and PM emissions comparison for 90% capture rate

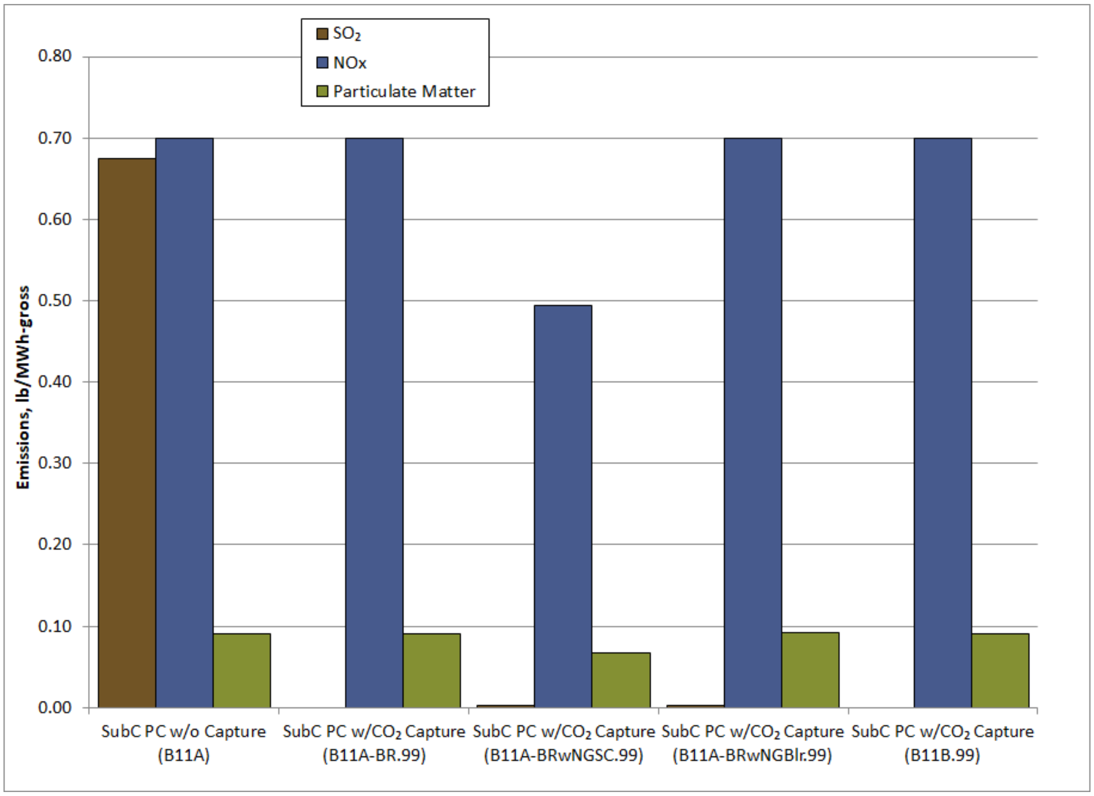


Exhibit A-37. CO_2 emissions comparison for 99% capture rate

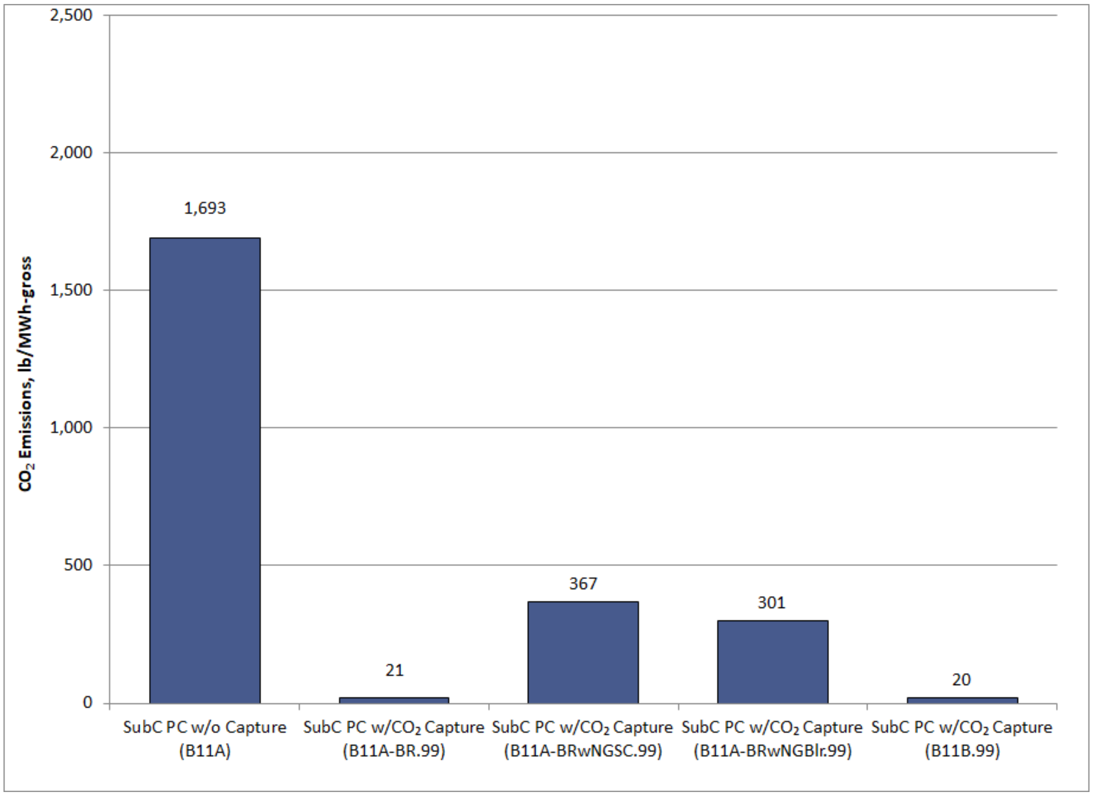


Exhibit A-38. Water metric comparison for 95% capture rate

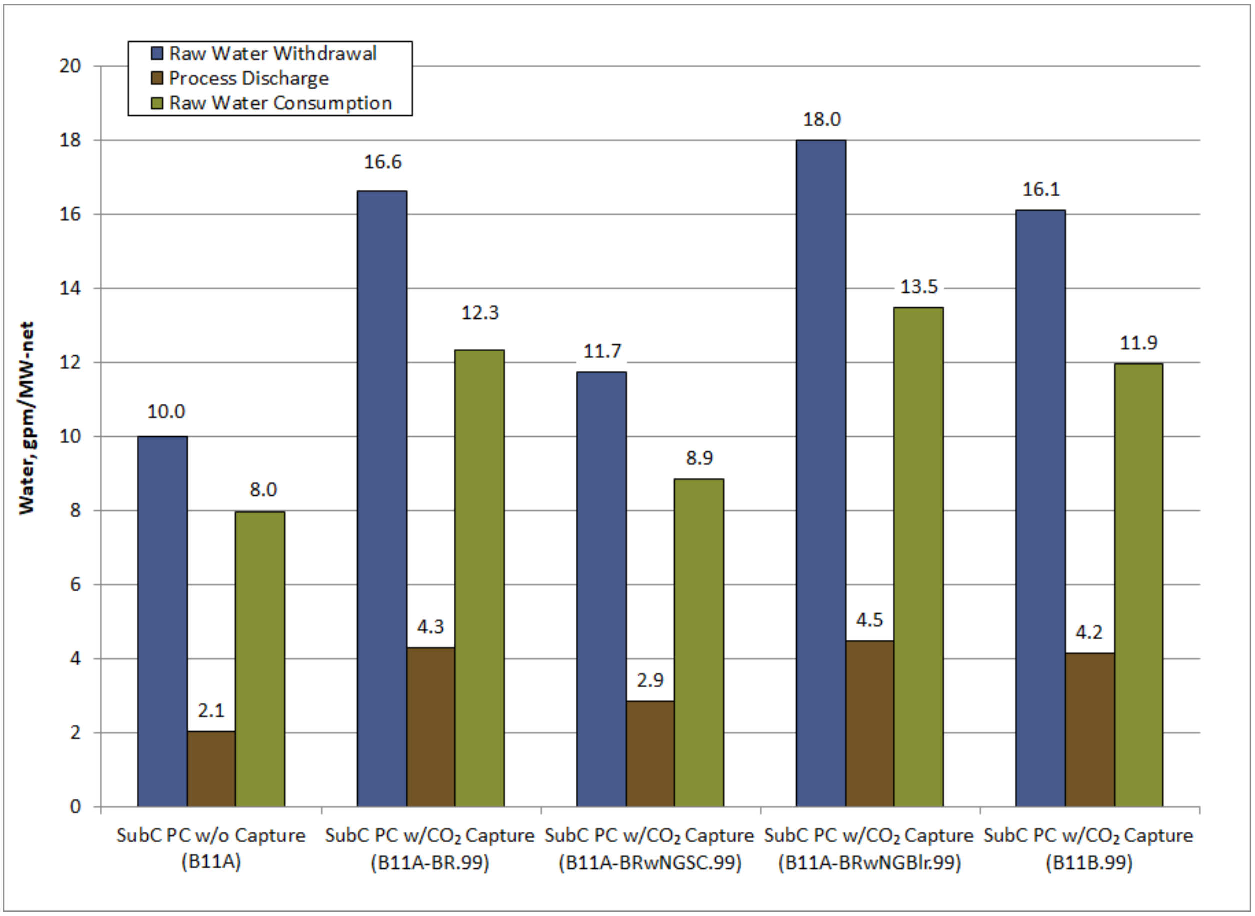


Exhibit A-39. Retrofit energy penalty comparison for 99% capture rate

Parameter	Case B11A	Case B11A-BR.99	Case B11A-BR wNGSC.99	Case B11A-BR wNGBlr.99	Case B11B.99
Overall HHV Heat Rate, Btu/kWh	8,849	11,999	9,800	12,663	11,691
Overall CO_2 Emissions Factor, lb CO_2/MMBtu of Fuel	204	204	175	185	204
Overall CO_2 Capture Rate, %	N/A	99.0%	75.9%	84.8%	99.0%
Energy Penalty, kWh/lb CO_2	N/A	0.147	0.083	0.217	0.136

Exhibit A-40. Case B11A-BRwNGBlr.99 energy and mass balance, subcritical PC boiler with CO_2 capture and NG boiler

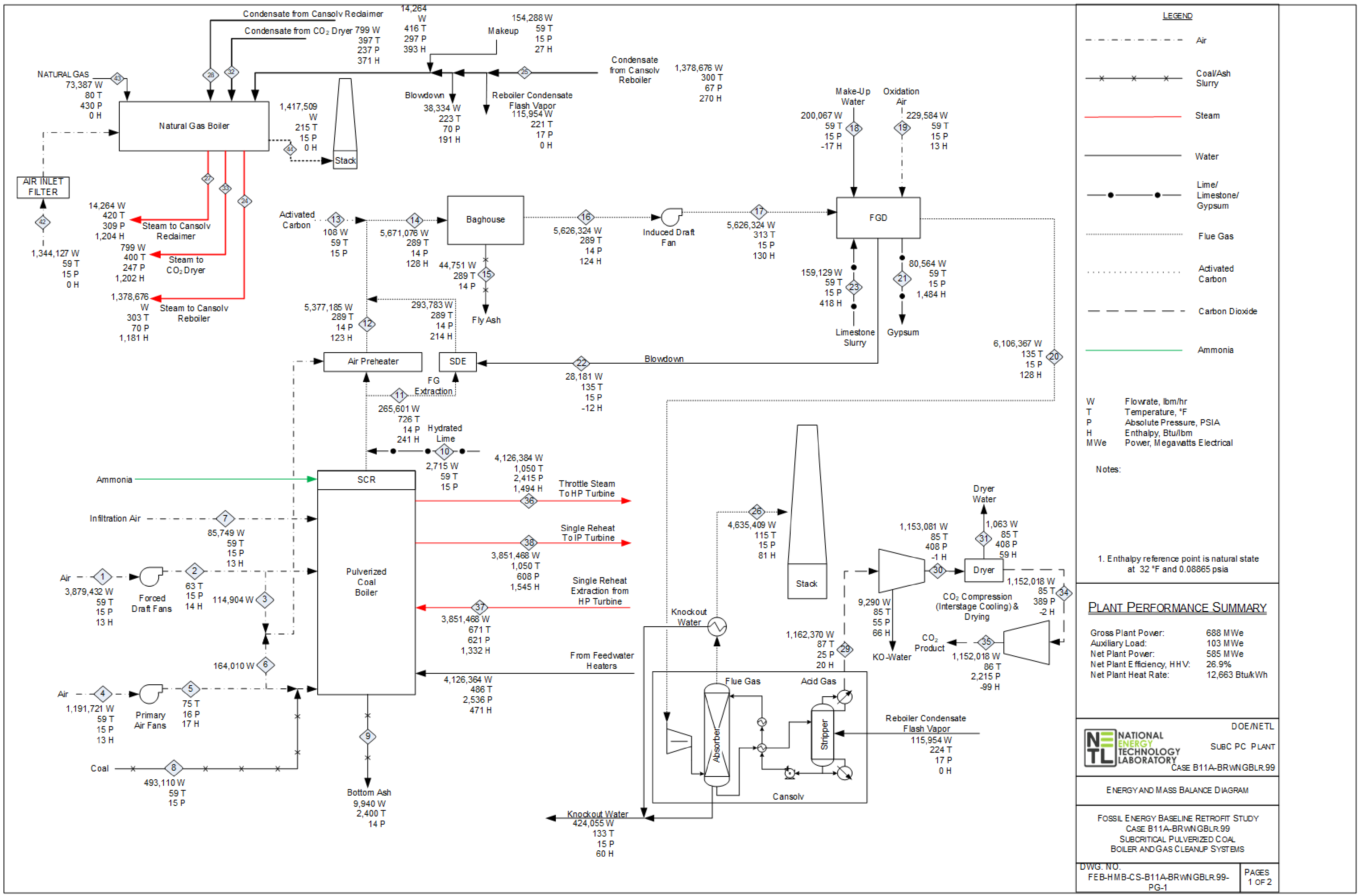
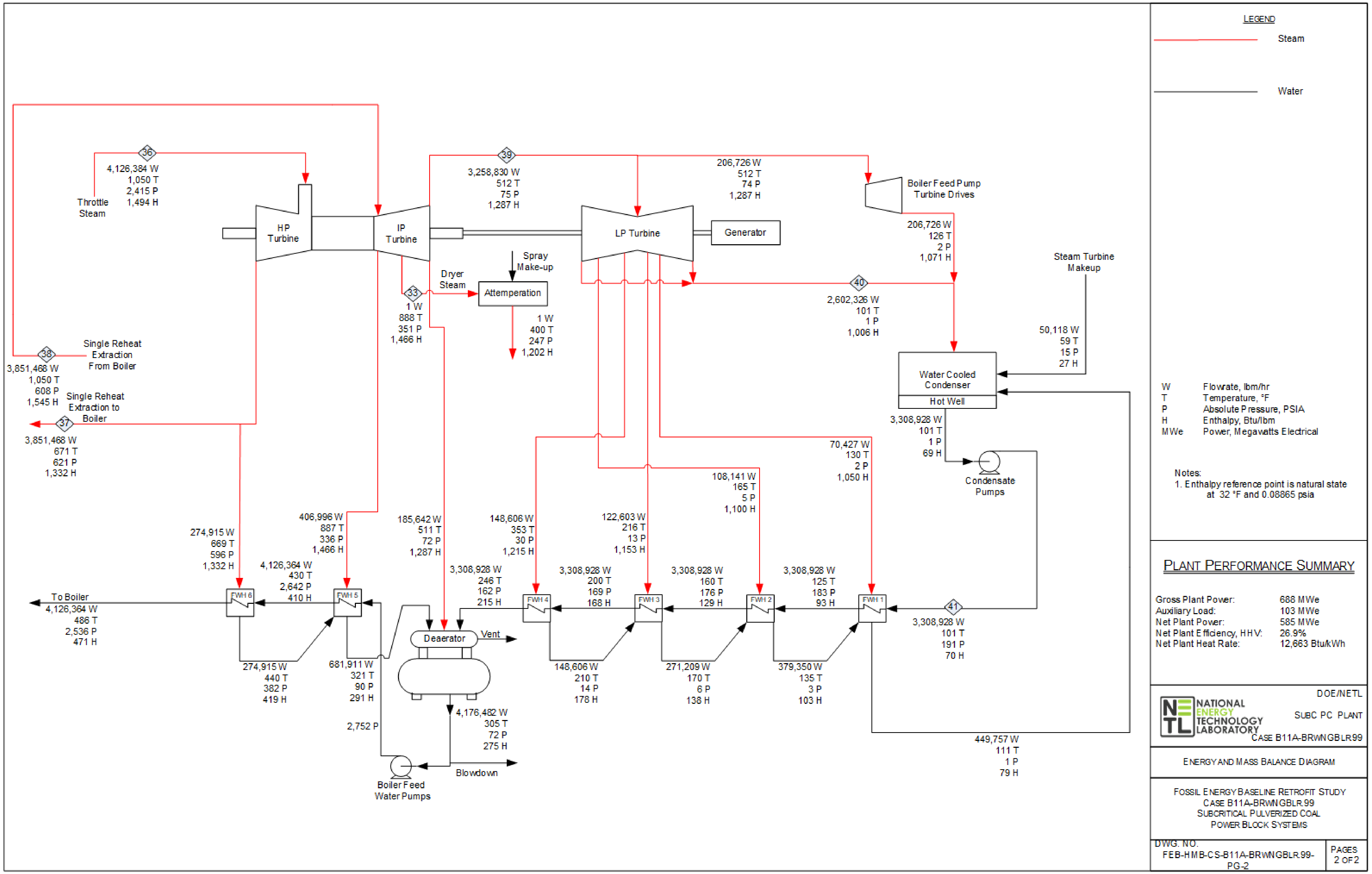


Exhibit A-41. Case B11A-BRwNGBlr.99 energy and mass balance, subcritical steam cycle



A.4 Cost Results – B11A-BR.99

Exhibit A-42. Case B11A-BR.99 retrofit plant cost details

	Case:	B11A-BR.99	– Retrofit Subcritical PC w/ CO_2					Estimate Type:		Conceptual	
	Plant Size (MW, net):	479						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
1	Coal & Sorbent Handling										
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
2	Coal & Sorbent Preparation & Feed										
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
3	Feedwater & Miscellaneous BOP Systems										
3.1	Feedwater System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.2	Water Makeup & Pretreating	$1,973	$197	$1,118	$0	$3,288	$575	$0	$773	$4,636	$10
3.3	Other Feedwater Subsystems	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.4	Service Water Systems	$570	$1,089	$3,526	$0	$5,185	$907	$0	$1,219	$7,311	$15
3.5	Other Boiler Plant Systems	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.6	Natural Gas Pipeline and Start-Up System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.7	Wastewater Treatment Equipment	$5,467	$0	$3,351	$0	$8,817	$1,543	$0	$2,072	$12,432	$26
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$8,010**	**$1,286**	**$7,995**	**$0**	**$17,291**	**$3,026**	**$0**	**$4,063**	**$24,380**	**$51**
4	Pulverized Coal Boiler & Accessories										
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
5	Flue Gas Cleanup										
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$134,562	$59,269	$124,465	$0	$318,296	$55,702	$54,110	$74,919	$503,027	$1,049
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$40,084	$6,013	$13,198	$0	$59,295	$10,377	$0	$13,934	$83,606	$174
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$428	$68	$183	$0	$679	$119	$0	$159	$957	$2
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Case:		B11A-BR.99	– Retrofit Subcritical PC w/ CO_2					Estimate Type:		Conceptual	
Plant Size (MW, net):		479						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
5.12	Gas Cleanup Foundations	$0	$135	$118	$0	$253	$44	$0	$45	$343	$1
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$175,074**	**$65,485**	**$137,965**	**$0**	**$378,523**	**$66,242**	**$54,110**	**$89,057**	**$587,932**	**$1,226**
7	Ductwork & Stack										
7.3	Ductwork	$0	$751	$522	$0	$1,273	$223	$0	$224	$1,720	$4
7.4	Stack	$885	$0	$514	$0	$1,399	$245	$0	$246	$1,890	$4
7.5	Duct & Stack Foundations	$0	$207	$246	$0	$454	$79	$0	$107	$640	$1
	Subtotal	**$885**	**$959**	**$1,282**	**$0**	**$3,125**	**$547**	**$0**	**$577**	**$4,250**	**$9**
8	$885										
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$370	$0	$786	$0	$1,156	$202	$0	$204	$1,562	$3
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$13,861	$0	$5,618	$0	$19,480	$3,409	$0	$3,433	$26,322	$55
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,231**	**$0**	**$6,404**	**$0**	**$20,636**	**$3,611**	**$0**	**$3,637**	**$27,884**	**$58**
9	Cooling Water System										
9.1	Cooling Towers	$6,162	$0	$1,906	$0	$8,067	$1,412	$0	$1,422	$10,901	$23
9.2	Circulating Water Pumps	$751	$0	$53	$0	$804	$141	$0	$142	$1,087	$2
9.3	Circulating Water System Auxiliaries	$6,268	$0	$829	$0	$7,098	$1,242	$0	$1,251	$9,591	$20
9.4	Circulating Water Piping	$0	$2,899	$2,625	$0	$5,524	$967	$0	$974	$7,464	$16
9.5	Makeup Water System	$508	$0	$653	$0	$1,161	$203	$0	$205	$1,569	$3
9.6	Component Cooling Water System	$452	$0	$347	$0	$798	$140	$0	$141	$1,079	$2
9.7	Circulating Water System Foundations	$0	$291	$484	$0	$775	$136	$0	$182	$1,093	$2
	Subtotal	**$14,141**	**$3,190**	**$6,896**	**$0**	**$24,227**	**$4,240**	**$0**	**$4,316**	**$32,782**	**$68**
10	Ash & Spent Sorbent Handling Systems										
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
11	Accessory Electric Plant										
11.1	Generator Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.2	Station Service Equipment	$5,778	$0	$496	$0	$6,273	$1,098	$0	$1,106	$8,477	$18
11.3	Switchgear & Motor Control	$8,969	$0	$1,556	$0	$10,525	$1,842	$0	$1,855	$14,223	$30
11.4	Conduit & Cable Tray	$0	$1,166	$3,360	$0	$4,526	$792	$0	$798	$6,116	$13
11.5	Wire & Cable	$0	$3,088	$5,519	$0	$8,607	$1,506	$0	$1,517	$11,630	$24
11.6	Protective Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.7	Standby Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	Case:	B11A-BR.99	– Retrofit Subcritical PC w/ CO_2					Estimate Type:		Conceptual	
	Plant Size (MW, net):	479						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
11.8	Main Power Transformers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.9	Electrical Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,747**	**$4,254**	**$10,931**	**$0**	**$29,932**	**$5,238**	**$0**	**$5,276**	**$40,446**	**$84**
	12					**Instrumentation & Control**					
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.3	Steam Turbine Control Equipment	$566	$0	$65	$0	$631	$110	$0	$111	$852	$2
12.5	Signal Processing Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.6	Control Boards, Panels & Racks	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.7	Distributed Control System Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.8	Instrument Wiring & Tubing	$509	$407	$1,628	$0	$2,544	$445	$127	$467	$3,584	$7
12.9	Other Instrumentation & Controls Equipment	$625	$0	$1,448	$0	$2,074	$363	$104	$381	$2,921	$6
	Subtotal	**$1,700**	**$407**	**$3,141**	**$0**	**$5,248**	**$918**	**$231**	**$960**	**$7,357**	**$15**
	13					**Improvements to Site**					
13.1	Site Preparation	$0	$32	$641	$0	$673	$118	$0	$158	$950	$2
13.2	Site Improvements	$0	$149	$198	$0	$348	$61	$0	$82	$490	$1
13.3	Site Facilities	$171	$0	$180	$0	$351	$61	$0	$82	$494	$1
	Subtotal	**$171**	**$182**	**$1,019**	**$0**	**$1,372**	**$240**	**$0**	**$322**	**$1,934**	**$4**
	14					**Buildings & Structures**					
14.2.	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$28	$22	$0	$50	$9	$0	$9	$68	$0
14.6	Water Treatment Buildings	$0	$41	$38	$0	$80	$14	$0	$14	$108	$0
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$8	$24	$0	$32	$6	$0	$6	$43	$0
	Subtotal	**$0**	**$77**	**$85**	**$0**	**$162**	**$28**	**$0**	**$29**	**$219**	**$0**
	Total	**$228,959**	**$75,839**	**$175,718**	**$0**	**$480,516**	**$84,090**	**$54,341**	**$108,237**	**$727,184**	**$1,517**
	Retrofit Difficulty Allowance	**$22,896**	**$7,584**	**$17,572**	**$0**	**$48,052**	**$8,409**	**$5,434**	**$10,824**	**$72,718**	**$152**
	Total (Including Retrofit Difficulty Factor)	**$251,854**	**$83,423**	**$193,290**	**$0**	**$528,567**	**$92,499**	**$59,775**	**$119,061**	**$799,903**	**$1,668**

Exhibit A-43. Case B11A-BR.99 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$3,548	$7
1 Month Maintenance Materials	$684	$1
1 Month Non-Fuel Consumables	$960	$2
1 Month Waste Disposal	$13	$0
25% of 1 Months Fuel Cost at 100% CF	$0	$0
2% of TPC	$15,998	$33
Total	**$21,204**	**$44**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$1,798	$4
0.5% of TPC (spare parts)	$4,000	$8
Total	**$5,797**	**$12**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$0	$0
Other Owner's Costs	$119,985	$250
Financing Costs	$21,597	$45
Total Overnight Costs (TOC)	**$968,486**	**$2,020**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$1,058,214**	**$2,207**

Exhibit A-44. Case B11A-BR.99 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	21.0	23%
Fixed	18.5	20%
Variable	15.4	17%
Fuel	26.7	29%
Total (Excluding T&S)	**81.6**	88%
CO_2 T&S	10.9	12%
Total (Including T&S)	**92.5**	100%

Exhibit A-45. Case B11A-BR.99 initial and annual operating and maintenance costs

Case:	B11A-BR.99	– Retrofit Subcritical PC w/ CO_2			Cost Base:	Dec 2018
Plant Size (MW, net):	**479**	**Heat Rate-net (Btu/kWh):**		**11,793**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:		2.0
Operating Labor Burden:		30.00	**% of base**	Operator:		11.3
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:		1.0
				Lab Techs, etc.:		2.0
				Total:		**16.3**
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,161,008	$14.94
Maintenance Labor:					$13,038,858	$27.20
Administrative & Support Labor:					$5,049,967	$10.53
Property Taxes and Insurance:					$40,746,433	$84.99
Total:					**$65,996,266**	**$137.66**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$19,558,288	$5.48
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	5,741	$1.90	$0	$3,384,453	$0.95
Makeup and Wastewater Treatment Chemicals (ton):	0	17.1	$550.00	$0	$2,918,418	$0.82
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,680	$0.18
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,548	$0.68
Limestone (ton):	0	572	$22.00	$0	$3,906,998	$1.09
Ammonia (19 wt%, ton):	0	57.7	$300.00	$0	$5,367,284	$1.50
SCR Catalyst (ft^3):	14,235	13.0	$150.00	$2,135,241	$604,985	$0.17
CO_2 Capture System Chemicals[A]	Proprietary				$7,237,887	$2.03
Triethylene Glycol (gal):	w/equip.	539	$6.80	$0	$1,136,080	$0.32
Subtotal:				**$2,135,241**	**$27,624,332**	**$7.74**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,135	$1.77
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,320	$0.39
SCR Catalyst (ft^3):	0	13.0	$2.50	$0	$10,083	$0.00
Triethylene Glycol (gal):	0	539	$0.35	$0	$58,475	$0.02
Thermal Reclaimer Unit Waste (ton)	0	6.64	$38.00	$0	$78,247	$0.02
Subtotal:				**$0**	**$7,884,260**	**$2.21**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,135,241**	**$55,066,880**	**$15.43**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,388,046	$26.72
Total:				**$0**	**$95,388,046**	**$26.72**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

A.5 Cost Results – B11A-BRwNGSC.99

Exhibit A-46. Case B11A-BRwNGSC.99 retrofit plant cost details

	Case:	B11A-BR wNGSC.99	– Retrofit Subcritical PC w/ CO_2 with NGSC					Estimate Type:		Conceptual	
	Plant Size (MW, net):	891						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
	1	Coal & Sorbent Handling									
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	2	Coal & Sorbent Preparation & Feed									
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	3	Feedwater & Miscellaneous BOP Systems									
3.1	Feedwater System	$2,051	$3,515	$1,758	$0	$7,324	$1,465	$0	$1,318	$10,107	$11
3.2	Water Makeup & Pretreating	$4,135	$414	$2,343	$0	$6,892	$1,206	$0	$1,620	$9,718	$11
3.3	Other Feedwater Subsystems	$1,167	$382	$363	$0	$1,912	$382	$0	$344	$2,639	$3
3.4	Service Water Systems	$1,256	$2,398	$7,765	$0	$11,419	$1,998	$0	$2,683	$16,101	$18
3.5	Other Boiler Plant Systems	$291	$106	$265	$0	$662	$132	$0	$119	$914	$1
3.6	Natural Gas Pipeline and Start-Up System	$5,988	$258	$193	$0	$6,439	$1,288	$0	$1,159	$8,886	$10
3.7	Wastewater Treatment Equipment	$8,044	$0	$4,930	$0	$12,974	$2,271	$0	$3,049	$18,294	$21
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$183	$24	$93	$0	$300	$52	$0	$70	$422	$0
	Subtotal	**$23,115**	**$7,097**	**$17,711**	**$0**	**$47,923**	**$8,795**	**$0**	**$10,363**	**$67,081**	**$75**
	4	Pulverized Coal Boiler & Accessories									
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	5	Flue Gas Cleanup									
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$134,561	$59,269	$124,464	$0	$318,294	$55,702	$54,110	$74,919	$503,024	$565
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$40,084	$6,013	$13,198	$0	$59,295	$10,377	$0	$13,934	$83,606	$94
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$428	$68	$183	$0	$679	$119	$0	$159	$957	$1
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

	Case:	B11A-BR wNGSC.99	– Retrofit Subcritical PC w/ CO_2 with NGSC					Estimate Type:			Conceptual
	Plant Size (MW, net):	891						Cost Base:			Dec 2018
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.12	Gas Cleanup Foundations	$0	$135	$118	$0	$253	$44	$0	$45	$343	$0
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$175,073**	**$65,484**	**$137,964**	**$0**	**$378,521**	**$66,241**	**$54,110**	**$89,057**	**$587,929**	**$660**
	6	Combustion Turbine & Accessories									
6.1	Combustion Turbine Generator	$50,794	$0	$3,091	$0	$53,885	$10,777	$0	$9,699	$74,361	$83
6.2	Emergency / Startup / Dump Condenser	$4,384	$0	$1,766	$0	$6,150	$1,230	$0	$1,107	$8,487	$10
6.3	Combustion Turbine Accessories	$2,017	$0	$123	$0	$2,140	$428	$0	$385	$2,953	$3
6.4	Compressed Air Piping	$0	$666	$151	$0	$817	$163	$0	$147	$1,127	$1
6.5	Combustion Turbine Foundations	$0	$696	$752	$0	$1,447	$289	$0	$347	$2,084	$2
	Subtotal	**$57,195**	**$1,361**	**$5,882**	**$0**	**$64,438**	**$12,888**	**$0**	**$11,686**	**$89,012**	**$100**
	7	Ductwork & Stack									
7.1	Heat Recovery Steam Generator	$27,396	$0	$6,849	$0	$34,245	$6,849	$0	$6,164	$47,259	$53
7.2	Heat Recovery Steam Generator Accessories + Foundations	$11,872	$440	$2,617	$0	$14,929	$2,565	$0	$2,254	$19,749	$22
7.3	Ductwork	$0	$1,757	$1,006	$0	$2,763	$484	$0	$487	$3,734	$4
7.4	Stack(s)	$8,107	$0	$1,851	$0	$9,958	$1,743	$0	$1,755	$13,455	$15
7.5	Duct & Stack Foundations	$0	$1,310	$770	$0	$2,081	$364	$0	$489	$2,934	$3
7.6	Selective Catalytic Reduction System	$1,082	$454	$634	$0	$2,170	$434	$0	$391	$2,995	$3
	Subtotal	**$48,457**	**$3,962**	**$13,727**	**$0**	**$66,146**	**$12,439**	**$0**	**$11,540**	**$90,125**	**$101**
	8	Steam Turbine & Accessories									
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$14,979	$0	$6,071	$0	$21,050	$3,684	$0	$3,710	$28,444	$32
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,979**	**$0**	**$6,071**	**$0**	**$21,050**	**$3,684**	**$0**	**$3,710**	**$28,444**	**$32**
	9	Cooling Water System									
9.1	Cooling Towers	$10,706	$0	$3,311	$0	$14,016	$2,453	$0	$2,470	$18,940	$21
9.2	Circulating Water Pumps	$1,403	$0	$99	$0	$1,502	$263	$0	$265	$2,030	$2
9.3	Circulating Water System Auxiliaries	$9,909	$0	$1,311	$0	$11,220	$1,963	$0	$1,977	$15,161	$17
9.4	Circulating Water Piping	$0	$4,582	$4,150	$0	$8,732	$1,528	$0	$1,539	$11,799	$13
9.5	Makeup Water System	$824	$0	$1,059	$0	$1,883	$329	$0	$332	$2,544	$3

	Case:	B11A-BR wNGSC.99	– Retrofit Subcritical PC w/ CO_2 with NGSC					Estimate Type:		Conceptual	
	Plant Size (MW, net):	891						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
9.6	Component Cooling Water System	$714	$0	$548	$0	$1,262	$221	$0	$222	$1,705	$2
9.7	Circulating Water System Foundations	$0	$444	$737	$0	$1,181	$207	$0	$278	$1,666	$2
	Subtotal	**$23,556**	**$5,026**	**$11,214**	**$0**	**$39,796**	**$6,964**	**$0**	**$7,083**	**$53,844**	**$60**
	10					**Ash & Spent Sorbent Handling Systems**					
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	11					**Accessory Electric Plant**					
11.1	Generator Equipment	$1,989	$0	$1,500	$0	$3,489	$698	$0	$628	$4,815	$5
11.2	Station Service Equipment	$5,998	$0	$515	$0	$6,513	$1,140	$0	$1,148	$8,801	$10
11.3	Switchgear & Motor Control	$9,312	$0	$1,616	$0	$10,928	$1,912	$0	$1,926	$14,766	$17
11.4	Conduit & Cable Tray	$0	$1,210	$3,489	$0	$4,699	$822	$0	$828	$6,350	$7
11.5	Wire & Cable	$0	$3,206	$5,730	$0	$8,936	$1,564	$0	$1,575	$12,075	$14
11.6	Protective Equipment	$35	$0	$123	$0	$158	$28	$0	$28	$214	$0
11.7	Standby Equipment	$526	$0	$486	$0	$1,012	$177	$0	$178	$1,367	$2
11.8	Main Power Transformers	$2,203	$0	$45	$0	$2,248	$393	$0	$396	$3,037	$3
11.9	Electrical Foundations	$0	$113	$288	$0	$401	$70	$0	$94	$565	$1
	Subtotal	**$20,064**	**$4,529**	**$13,791**	**$0**	**$38,384**	**$6,804**	**$0**	**$6,802**	**$51,990**	**$58**
	12					**Instrumentation & Control**					
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.2	NGSC Control + Combustion Turbine Equipment	$567	$0	$361	$0	$928	$186	$0	$167	$1,281	$1
12.3	Steam Turbine Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control Equipment	$608	$0	$387	$0	$995	$199	$0	$179	$1,373	$2
12.5	Signal Processing Equipment	$423	$0	$13	$0	$436	$87	$0	$78	$602	$1
12.6	Control Boards, Panels & Racks	$112	$0	$68	$0	$180	$36	$0	$32	$249	$0
12.7	Distributed Control System Equipment	$6,220	$0	$189	$0	$6,409	$1,282	$0	$1,154	$8,845	$10
12.8	Instrument Wiring & Tubing	$515	$412	$1,647	$0	$2,573	$450	$129	$473	$3,625	$4
12.9	Other Instrumentation & Controls Equipment	$633	$0	$1,465	$0	$2,097	$367	$105	$385	$2,954	$3
	Subtotal	**$9,077**	**$412**	**$4,130**	**$0**	**$13,619**	**$2,607**	**$234**	**$2,469**	**$18,929**	**$21**
	13					**Improvements to Site**					
13.1	Site Preparation	$0	$410	$8,656	$0	$9,066	$1,586	$0	$2,130	$12,783	$14
13.2	Site Improvements	$0	$1,364	$1,802	$0	$3,166	$554	$0	$744	$4,464	$5

	Case:	B11A-BR wNGSC.99	– Retrofit Subcritical PC w/ CO_2 with NGSC					Estimate Type:		Conceptual	
	Plant Size (MW, net):	891						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
13.3	Site Facilities	$1,336	$0	$1,402	$0	$2,738	$479	$0	$644	$3,861	$4
	Subtotal	**$1,336**	**$1,774**	**$11,860**	**$0**	**$14,970**	**$2,620**	**$0**	**$3,518**	**$21,108**	**$24**
	14	**Buildings & Structures**									
14.1	Combustion Turbine Building	$0	$223	$118	$0	$340	$68	$0	$61	$470	$1
14.2	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$117	$93	$0	$210	$37	$0	$37	$284	$0
14.6	Water Treatment Buildings	$0	$303	$277	$0	$580	$101	$0	$102	$783	$1
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$615	$1,867	$0	$2,482	$434	$0	$437	$3,354	$4
	Subtotal	**$0**	**$1,258**	**$2,354**	**$0**	**$3,613**	**$641**	**$0**	**$638**	**$4,891**	**$5**
	Total	**$372,851**	**$90,904**	**$224,704**	**$0**	**$688,460**	**$123,682**	**$54,344**	**$146,866**	**$1,013,352**	**$1,138**
	Retrofit Difficulty Allowance	**$37,285**	**$9,090**	**$22,470**	**$0**	**$68,846**	**$12,368**	**$5,434**	**$14,687**	**$101,335**	**$114**
	Total (Including Retrofit Difficulty Factor)	**$410,137**	**$99,995**	**$247,175**	**$0**	**$757,306**	**$136,051**	**$59,778**	**$161,553**	**$1,114,687**	**$1,252**

Exhibit A-47. Case B11A-BRwNGSC.99 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$4,967	$6
1 Month Maintenance Materials	$954	$1
1 Month Non-Fuel Consumables	$1,426	$2
1 Month Waste Disposal	$14	$0
25% of 1 Months Fuel Cost at 100% CF	$2,400	$3
2% of TPC	$22,294	$25
Total	**$32,054**	**$36**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$21,725	$24
0.5% of TPC (spare parts)	$5,573	$6
Total	**$27,299**	**$31**
Other Costs		
Initial Cost for Catalyst and Chemicals	$546	$1
Land	$0	$0
Other Owner's Costs	$167,203	$188
Financing Costs	$30,097	$34
Total Overnight Costs (TOC)	**$1,371,885**	**$1,540**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$1,498,987**	**$1,683**

Exhibit A-48. Case B11A-BRwNGSC.99 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	16.0	22%
Fixed	11.2	16%
Variable	9.4	13%
Fuel	29.1	41%
Total (Excluding T&S)	**65.8**	92%
CO_2 T&S	5.9	8%
Total (Including T&S)	**71.7**	100%

Exhibit A-49. Case B11A-BRwNGSC.99 initial and annual operating and maintenance costs

Case:	B11A-BR wNGSC.99	– Retrofit Subcritical PC w/ CO_2 with NGSC			Cost Base:	Dec 2018
Plant Size (MW, net):	**891**	**Heat Rate-net (Btu/kWh):**		**9,800**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:	2.0	
Operating Labor Burden:		30.00	**% of base**	Operator:	12.3	
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:	1.0	
				Lab Techs, etc.:	2.0	
				Total:	**17.3**	
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,599,446	$8.53
Maintenance Labor:					$14,870,333	$16.70
Administrative & Support Labor:					$5,617,445	$6.31
Property Taxes and Insurance:					$46,469,791	$52.18
Total:					**$74,557,015**	**$83.71**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$22,305,500	$3.36
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	7,522	$1.90	$0	$4,434,304	$0.67
Makeup and Wastewater Treatment Chemicals (ton):	0	22.4	$550.00	$0	$3,823,706	$0.58
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,674	$0.10
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,525	$0.37
Limestone (ton):	0	572	$22.00	$0	$3,906,961	$0.59
Ammonia (19 wt%, ton):	0	86.8	$300.00	$0	$8,074,761	$1.22
SCR Catalyst (ft^3):	17,873	15.0	$150.00	$2,680,879	$697,741	$0.11
CO_2 Capture System Chemicals[A]		Proprietary			$7,237,820	$1.09
Triethylene Glycol (gal):	w/equip.	538	$6.80	$0	$1,136,069	$0.17
Subtotal:				**$2,680,879**	**$32,379,563**	**$4.88**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,167	$0.95
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,307	$0.21
SCR Catalyst (ft^3):	0	15.0	$2.50	$0	$11,629	$0.00
Triethylene Glycol (gal):	0	538	$0.35	$0	$58,474	$0.01
Thermal Reclaimer Unit Waste (ton)	0	6.64	$38.00	$0	$78,247	$0.01
Subtotal:				**$0**	**$7,885,824**	**$1.19**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,680,879**	**$62,570,887**	**$9.44**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,387,161	$14.38
Natural Gas (MMBtu):	0	71,408	$4.42	$0	$97,926,721	$14.77
Total:				**$0**	**$193,313,881**	**$29.15**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

A.6 Cost Results – B11A-BRwNGBlr.99

Exhibit A-50. Case B11A-BRwNGBlr.99 retrofit plant cost details

	Case:	B11A-BR wNGBlr.99	– Retrofit Subcritical PC w/ CO_2 with NG Boiler					Estimate Type:		Conceptual	
	Plant Size (MW, net):	585						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
	1	Coal & Sorbent Handling									
1.1 – 1.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	2	Coal & Sorbent Preparation & Feed									
2.1 – 2.9	Coal & Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	3	Feedwater & Miscellaneous BOP Systems									
3.1	Feedwater System	$2,051	$3,515	$1,758	$0	$7,324	$1,465	$0	$1,318	$10,107	$17
3.2	Water Makeup & Pretreating	$4,191	$419	$2,375	$0	$6,986	$1,223	$0	$1,642	$9,850	$17
3.3	Other Feedwater Subsystems	$1,167	$382	$363	$0	$1,912	$382	$0	$344	$2,639	$5
3.4	Service Water Systems	$1,274	$2,433	$7,877	$0	$11,584	$2,027	$0	$2,722	$16,334	$28
3.5	Other Boiler Plant Systems	$291	$106	$265	$0	$662	$132	$0	$119	$914	$2
3.6	Natural Gas Pipeline and Start-Up System	$3,321	$143	$107	$0	$3,571	$714	$0	$643	$4,927	$8
3.7	Wastewater Treatment Equipment	$8,385	$0	$5,139	$0	$13,524	$2,367	$0	$3,178	$19,068	$33
3.8	Spray Dryer Evaporator	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3.9	Miscellaneous Plant Equipment	$158	$21	$80	$0	$258	$45	$0	$61	$364	$1
	Subtotal	**$20,837**	**$7,019**	**$17,965**	**$0**	**$45,822**	**$8,356**	**$0**	**$10,027**	**$64,205**	**$110**
	4	Pulverized Coal Boiler & Accessories									
4.9 – 4.16	Pulverized Coal Boiler & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	5	Flue Gas Cleanup									
5.1	CANSOLV Carbon Dioxide (CO_2) Removal System	$134,561	$59,269	$124,464	$0	$318,294	$55,702	$54,110	$74,919	$503,024	$860
5.2	WFGD Vessels & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.3	Other FGD	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4	Carbon Dioxide (CO_2) Compression & Drying	$40,084	$6,013	$13,198	$0	$59,295	$10,377	$0	$13,934	$83,606	$143
5.5	Carbon Dioxide (CO_2) Compressor Aftercooler	$428	$68	$183	$0	$679	$119	$0	$159	$957	$2
5.6	Mercury Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	Particulate Removal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.12	Gas Cleanup Foundations	$0	$135	$118	$0	$253	$44	$0	$45	$343	$1

	Case:	B11A-BR wNGBlr.99	– Retrofit Subcritical PC w/ CO_2 with NG Boiler						Estimate Type:	Conceptual	
	Plant Size (MW, net):	585							Cost Base:	Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
5.13	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$175,073**	**$65,484**	**$137,964**	**$0**	**$378,521**	**$66,241**	**$54,110**	**$89,057**	**$587,929**	**$1,006**
6	Combustion Turbine & Accessories										
6.1 – 6.5	Combustion Turbine & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	Ductwork & Stack										
7.1	NG Package Boiler w Stack	$13,106	$0	$8,559	$0	$21,665	$4,333	$0	$3,900	$29,898	$51
7.2	NG Steam Boiler Accessories + Foundations	$5,679	$211	$1,252	$0	$7,142	$1,227	$0	$1,079	$9,448	$16
7.3	Ductwork	$0	$751	$522	$0	$1,273	$223	$0	$224	$1,720	$3
7.4	Stack	$885	$0	$514	$0	$1,399	$245	$0	$246	$1,890	$3
7.5	Duct & Stack Foundations	$0	$207	$246	$0	$454	$79	$0	$107	$640	$1
	Subtotal	**$19,670**	**$1,169**	**$11,093**	**$0**	**$31,933**	**$6,107**	**$0**	**$5,556**	**$43,596**	**$75**
8	Steam Turbine & Accessories										
8.1	Steam Turbine Generator & Accessories	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Steam Turbine Plant Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.3	Condenser & Auxiliaries	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.4	Steam Piping	$14,979	$0	$6,071	$0	$21,050	$3,684	$0	$3,710	$28,444	$49
8.5	Turbine Generator Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$14,979**	**$0**	**$6,071**	**$0**	**$21,050**	**$3,684**	**$0**	**$3,710**	**$28,444**	**$49**
9	Cooling Water System										
9.1	Cooling Towers	$10,706	$0	$3,311	$0	$14,016	$2,453	$0	$2,470	$18,940	$32
9.2	Circulating Water Pumps	$1,403	$0	$99	$0	$1,502	$263	$0	$265	$2,030	$3
9.3	Circulating Water System Auxiliaries	$9,909	$0	$1,311	$0	$11,220	$1,963	$0	$1,977	$15,161	$26
9.4	Circulating Water Piping	$0	$4,582	$4,150	$0	$8,732	$1,528	$0	$1,539	$11,799	$20
9.5	Makeup Water System	$831	$0	$1,068	$0	$1,899	$332	$0	$335	$2,567	$4
9.6	Component Cooling Water System	$714	$0	$548	$0	$1,262	$221	$0	$222	$1,705	$3
9.7	Circulating Water System Foundations	$0	$444	$737	$0	$1,181	$207	$0	$278	$1,666	$3
	Subtotal	**$23,563**	**$5,026**	**$11,224**	**$0**	**$39,813**	**$6,967**	**$0**	**$7,086**	**$53,866**	**$92**
10	Ash & Spent Sorbent Handling Systems										
10.6 -10.9	Ash/Spent Sorbent Handling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
11	Accessory Electric Plant										
11.1	Generator Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.2	Station Service Equipment	$5,946	$0	$510	$0	$6,457	$1,130	$0	$1,138	$8,724	$15
11.3	Switchgear & Motor Control	$9,231	$0	$1,602	$0	$10,833	$1,896	$0	$1,909	$14,638	$25
11.4	Conduit & Cable Tray	$0	$1,200	$3,458	$0	$4,658	$815	$0	$821	$6,294	$11
11.5	Wire & Cable	$0	$3,178	$5,681	$0	$8,859	$1,550	$0	$1,561	$11,970	$20
11.6	Protective Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Case:		B11A-BR wNGBlr.99	– Retrofit Subcritical PC w/ CO_2 with NG Boiler						Estimate Type:	Conceptual	
Plant Size (MW, net):		585							Cost Base:	Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	$/1,000	$/kW
11.7	Standby Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.8	Main Power Transformers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11.9	Electrical Foundations	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Subtotal	**$15,178**	**$4,378**	**$11,251**	**$0**	**$30,806**	**$5,391**	**$0**	**$5,430**	**$41,627**	**$71**
12	**Instrumentation & Control**										
12.1	Pulverized Coal Boiler Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.2	NG Boiler Control Equipment	$361	$0	$230	$0	$591	$118	$0	$106	$816	$1
12.3	Steam Turbine Control Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.4	Other Major Component Control Equipment	$506	$0	$322	$0	$829	$166	$0	$149	$1,143	$2
12.5	Signal Processing Equipment	$422	$0	$13	$0	$435	$87	$0	$78	$600	$1
12.6	Control Boards, Panels & Racks	$112	$0	$68	$0	$180	$36	$0	$32	$248	$0
12.7	Distributed Control System Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
12.8	Instrument Wiring & Tubing	$513	$411	$1,642	$0	$2,566	$449	$128	$472	$3,615	$6
12.9	Other Instrumentation & Controls Equipment	$631	$0	$1,461	$0	$2,092	$366	$105	$384	$2,947	$5
	Subtotal	**$2,546**	**$411**	**$3,737**	**$0**	**$6,693**	**$1,222**	**$233**	**$1,222**	**$9,370**	**$16**
13	**Improvements to Site**										
13.1	Site Preparation	$0	$354	$7,464	$0	$7,818	$1,368	$0	$1,837	$11,023	$19
13.2	Site Improvements	$0	$1,183	$1,564	$0	$2,747	$481	$0	$646	$3,873	$7
13.3	Site Facilities	$1,163	$0	$1,220	$0	$2,383	$417	$0	$560	$3,360	$6
	Subtotal	**$1,163**	**$1,537**	**$10,248**	**$0**	**$12,948**	**$2,266**	**$0**	**$3,043**	**$18,256**	**$31**
14	**Buildings & Structures**										
14.1	NG Boiler Building	$0	$196	$103	$0	$299	$60	$0	$54	$413	$1
14.2	Boiler Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Steam Turbine Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.4	Administration Building	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.5	Circulation Water Pumphouse	$0	$117	$93	$0	$210	$37	$0	$37	$284	$0
14.6	Water Treatment Buildings	$0	$306	$279	$0	$585	$102	$0	$103	$791	$1
14.7	Machine Shop	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.8	Warehouse	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.9	Other Buildings & Structures	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
14.10	Waste Treating Building & Structures	$0	$616	$1,869	$0	$2,484	$435	$0	$438	$3,357	$6
	Subtotal	**$0**	**$1,235**	**$2,344**	**$0**	**$3,579**	**$634**	**$0**	**$632**	**$4,845**	**$8**
	Total	**$273,009**	**$86,259**	**$211,896**	**$0**	**$571,164**	**$100,868**	**$54,343**	**$125,763**	**$852,137**	**$1,458**
	Retrofit Difficulty Allowance	**$27,301**	**$8,626**	**$21,190**	**$0**	**$57,116**	**$10,087**	**$5,434**	**$12,576**	**$85,214**	**$146**
	Total (Including Retrofit Difficulty Factor)	**$300,309**	**$94,885**	**$233,085**	**$0**	**$628,280**	**$110,954**	**$59,777**	**$138,339**	**$937,351**	**$1,603**

Exhibit A-51. Case B11A-BRwNGBlr.99 owner's costs

Description	$/1,000	$/kW
Pre-Production Costs		
6 Months All Labor	$4,322	$7
1 Month Maintenance Materials	$802	$1
1 Month Non-Fuel Consumables	$1,321	$2
1 Month Waste Disposal	$13	$0
25% of 1 Months Fuel Cost at 100% CF	$1,331	$2
2% of TPC	$18,747	$32
Total	**$26,536**	**$45**
Inventory Capital		
60-day supply of fuel and consumables at 100% CF	$12,956	$22
0.5% of TPC (spare parts)	$4,687	$8
Total	**$17,642**	**$30**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$0	$0
Other Owner's Costs	$140,603	$241
Financing Costs	$25,308	$43
Total Overnight Costs (TOC)	**$1,147,441**	**$1,963**
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	**$1,253,748**	**$2,145**

Exhibit A-52. Case B11A-BRwNGBlr.99 initial and annual operating and maintenance costs

Case:	**B11A-BR wNGBlr.99**	**– Retrofit Subcritical PC w/ CO_2 with NG Boiler**			**Cost Base:**	**Dec 2018**
Plant Size (MW, net):	**585**	**Heat Rate-net (Btu/kWh):**		**12,663**	**Capacity Factor (%):**	**85**
Operating & Maintenance Labor						
Operating Labor				**Operating Labor Requirements per Shift**		
Operating Labor Rate (base):		38.50	**$/hour**	Skilled Operator:	2.0	
Operating Labor Burden:		30.00	**% of base**	Operator:	12.3	
Labor O-H Charge Rate:		25.00	**% of labor**	Foreman:	1.0	
				Lab Techs, etc.:	2.0	
				Total:	**17.3**	
Fixed Operating Costs						
					Annual Cost	
					($)	**($/kW-net)**
Annual Operating Labor:					$7,599,446	$13.00
Maintenance Labor:					$13,838,558	$23.67
Administrative & Support Labor:					$5,359,501	$9.17
Property Taxes and Insurance:					$43,245,494	$73.98
Total:					**$70,042,999**	**$119.82**
Variable Operating Costs						
					($)	**($/MWh-net)**
Maintenance Material:					$20,757,837	$4.77
Consumables						
	Initial Fill	**Per Day**	**Per Unit**	**Initial Fill**		
Water (/1000 gallons):	0	7,574	$1.90	$0	$4,464,674	$1.03
Makeup and Wastewater Treatment Chemicals (ton):	0	22.6	$550.00	$0	$3,849,895	$0.88
Brominated Activated Carbon (ton):	0	1.29	$1,600.00	$0	$642,674	$0.15
Enhanced Hydrated Lime (ton):	0	32.6	$240.00	$0	$2,425,525	$0.56
Limestone (ton):	0	572	$22.00	$0	$3,906,961	$0.90
Ammonia (19 wt%, ton):	0	75.6	$300.00	$0	$7,038,439	$1.62
SCR Catalyst (ft^3):	14,235	13.0	$150.00	$2,135,221	$604,979	$0.14
CO_2 Capture System Chemicals[A]	Proprietary				$7,237,820	$1.66
Triethylene Glycol (gal):	w/equip.	538	$6.80	$0	$1,136,069	$0.26
Subtotal:				**$2,135,221**	**$31,307,036**	**$7.19**
Waste Disposal						
Fly Ash (ton)	0	537	$38.00	$0	$6,331,167	$1.45
Bottom Ash (ton)	0	119	$38.00	$0	$1,406,307	$0.32
SCR Catalyst (ft^3):	0	13.0	$2.50	$0	$10,083	$0.00
Triethylene Glycol (gal):	0	538	$0.35	$0	$58,474	$0.01
Thermal Reclaimer Unit Waste (ton)	0	6.64	$38.00	$0	$78,247	$0.02
Subtotal:				**$0**	**$7,884,278**	**$1.81**
By-Products						
Gypsum (ton)	0	870	$0.00	$0	$0	$0.00
Subtotal:				**$0**	**$0**	**$0.00**
Variable Operating Costs Total:				**$2,135,221**	**$59,949,152**	**$13.77**
Fuel Cost						
Illinois Number 6 (ton):	0	5,917	$51.96	$0	$95,387,161	$21.91
Natural Gas (MMBtu):	0	39,599	$4.42	$0	$54,304,445	$12.48
Total:				**$0**	**$149,691,606**	**$34.39**

[A]CO_2 Capture System Chemicals includes NaOH and CANSOLV Solvent

Exhibit A-53. Case B11A-BRwNGBlr.99 LCOE breakdown

Component	Value, $/MWh	Percentage
Capital	20.4	22%
Fixed	16.1	17%
Variable	13.8	15%
Fuel	34.4	37%
Total (Excluding T&S)	**84.6**	90%
CO_2 T&S	8.9	10%
Total (Including T&S)	**93.6**	100%

Exhibit A-54. Capacity factor sensitivity for 99% capture rate

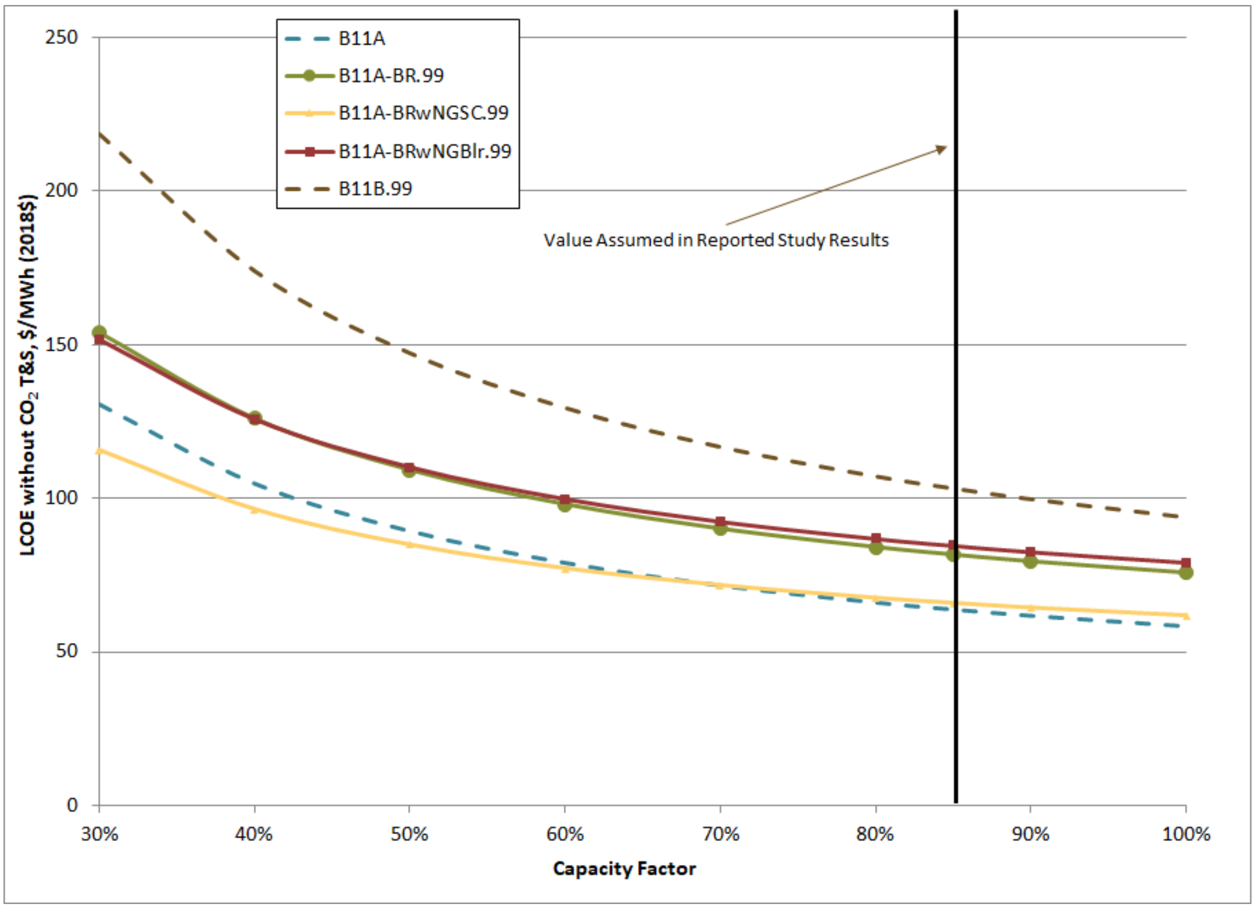
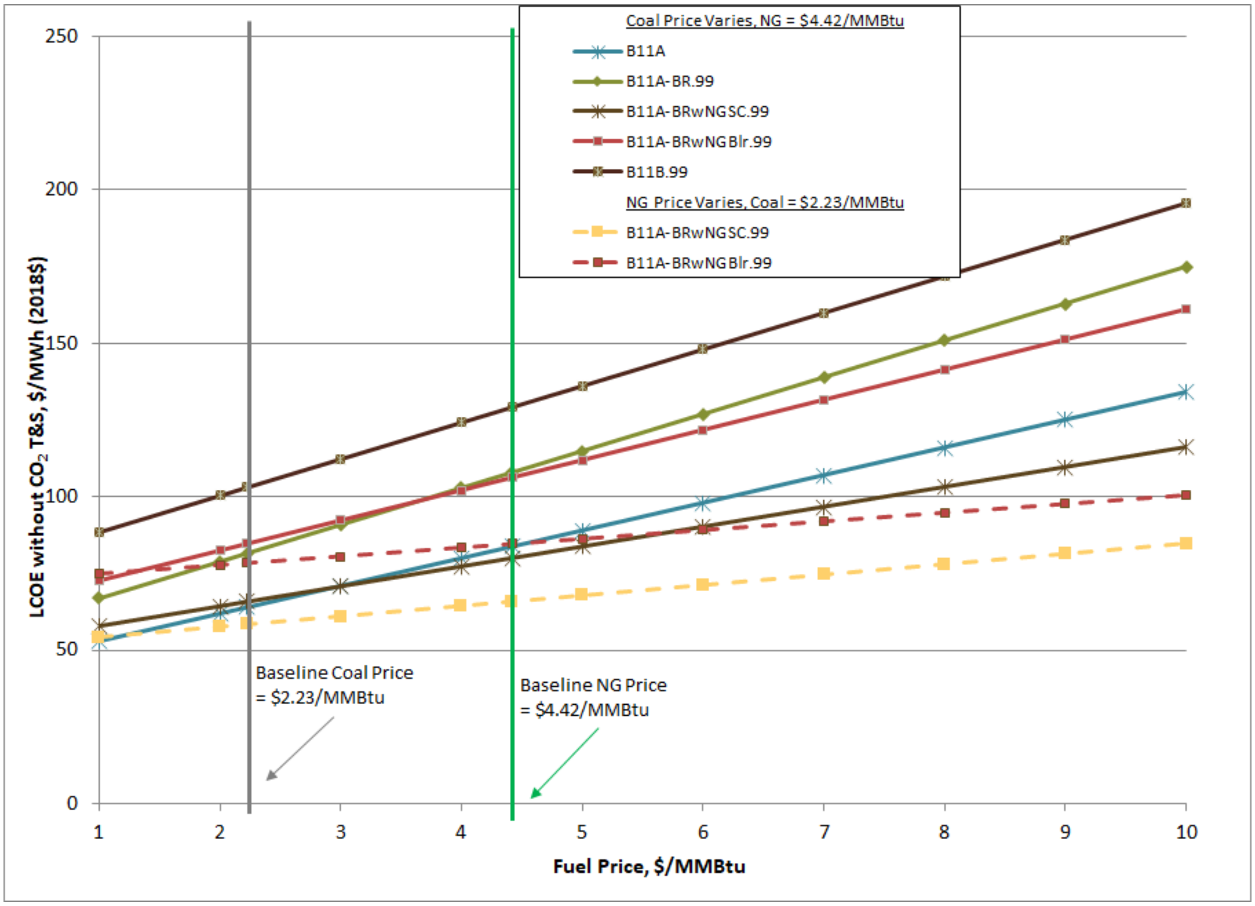


Exhibit A-55. Fuel price sensitivity for 99% capture rate



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